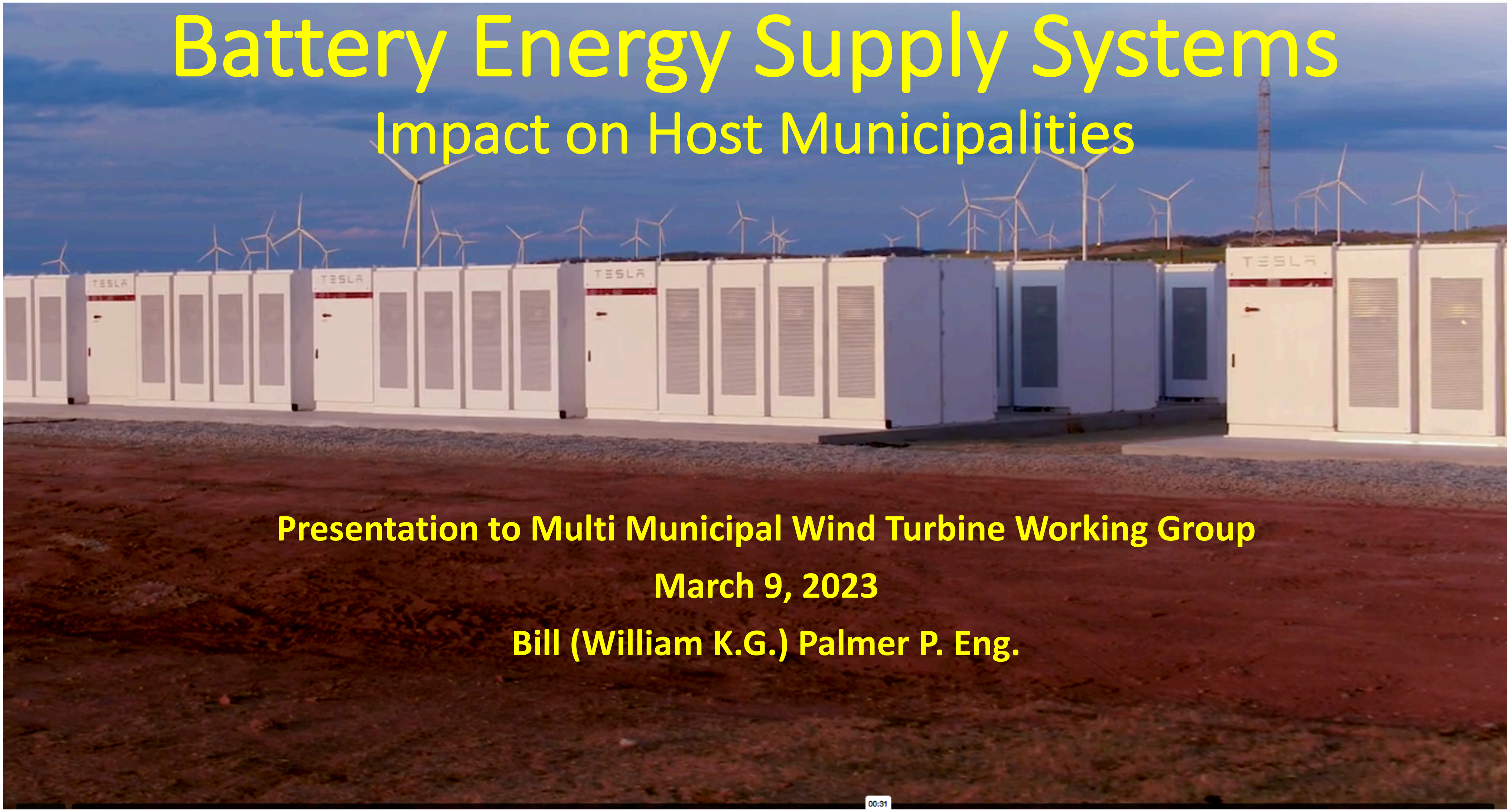
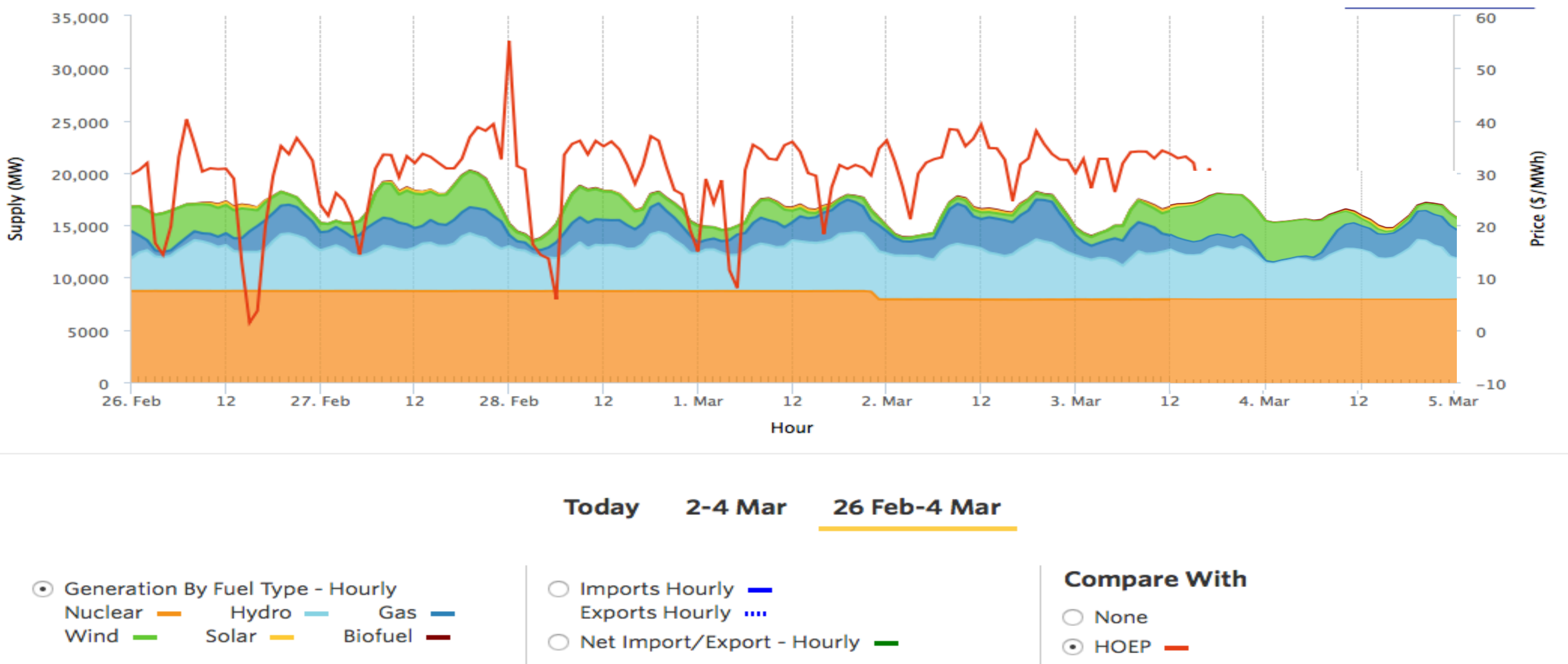
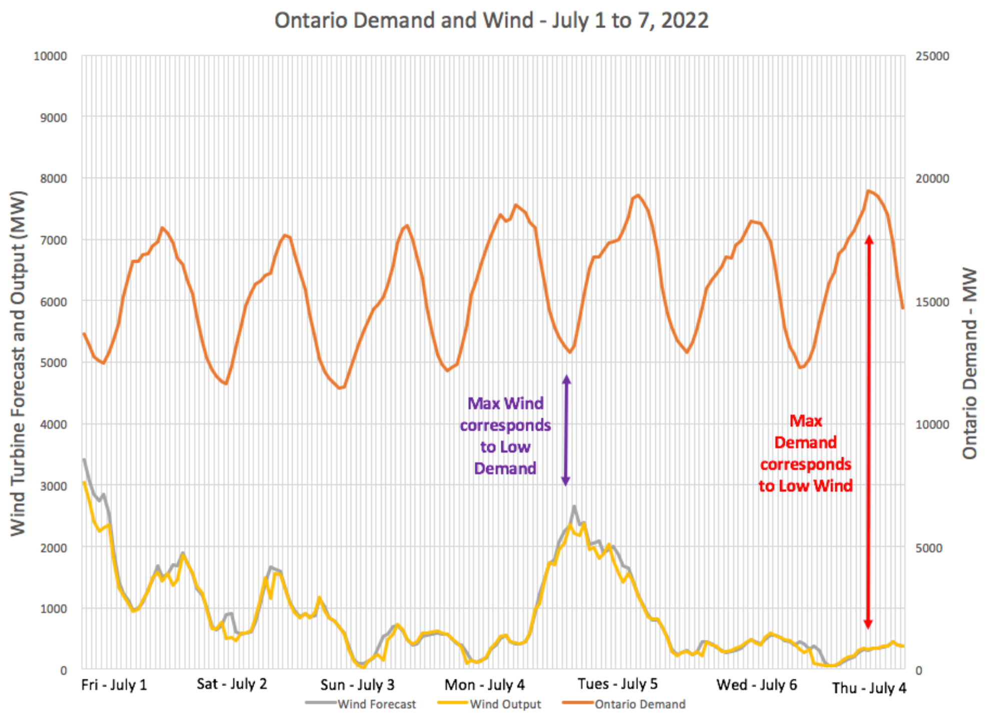

Battery Energy Supply Systems
Impact on Host Municipalities
Presentation to Multi Municipal Wind Turbine Working Group
March 9, 2023
Bill (William K.G.) Palmer P. Eng.
00:31

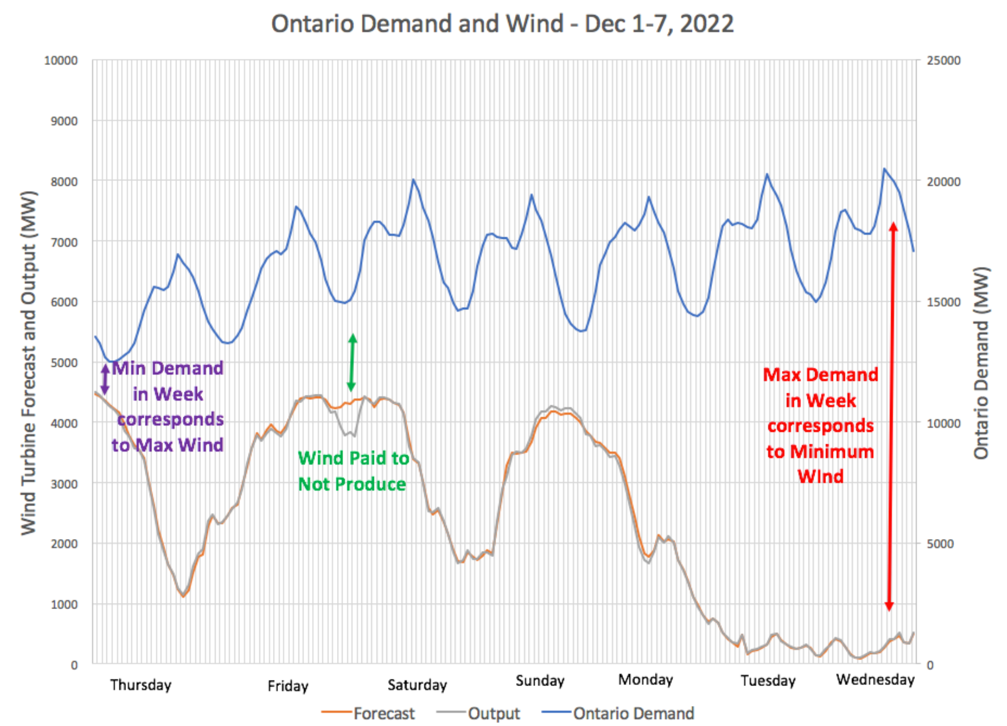
What’s the Issue?

Supply does not match Demand – Here’s Last Week

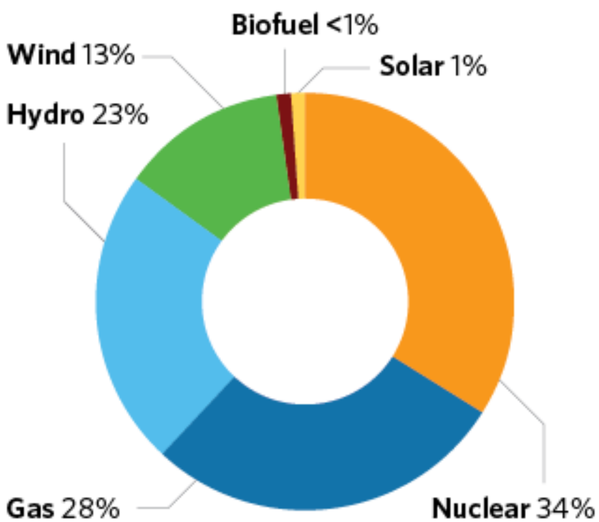


Two more examples of why adding more wind will make the need for storage more apparent

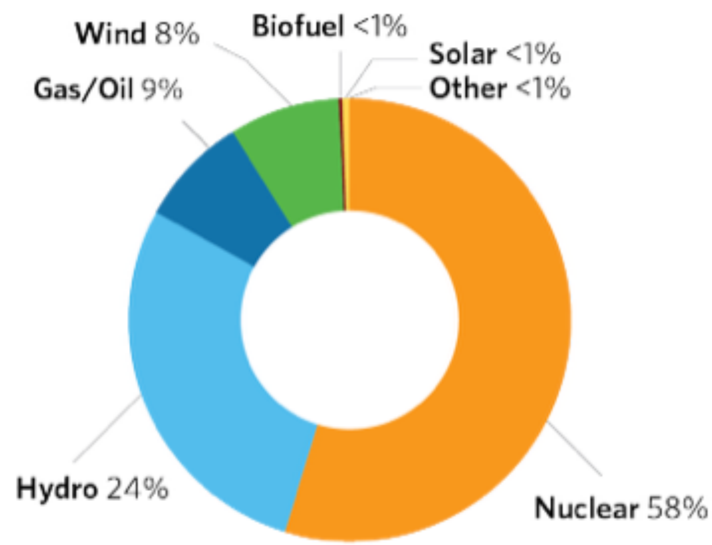




The Supply – Demand Mismatch is Growing



Nuclear	13,089 MW (
Gas/Oil	10,482 MW
Hydro	8,868 MW
Wind	4,883 MW
Biofuel	296 MW
Solar	478 MV



Nuclear	83.0 TWh o
Hydro	34.2 TWh o
Gas/Oil	12.2 TWh
Wind	12 TWh
Biofuel	0.4 TWh (
Solar	0.75 TWh (
Other	0.01 TWh (

Total 142.6 TWh

Here's today's Ontario Supply
Wind capacity > 38% of Nuclear

Here's What they Generated in 2021
Wind Generated < 15% of Nuclear

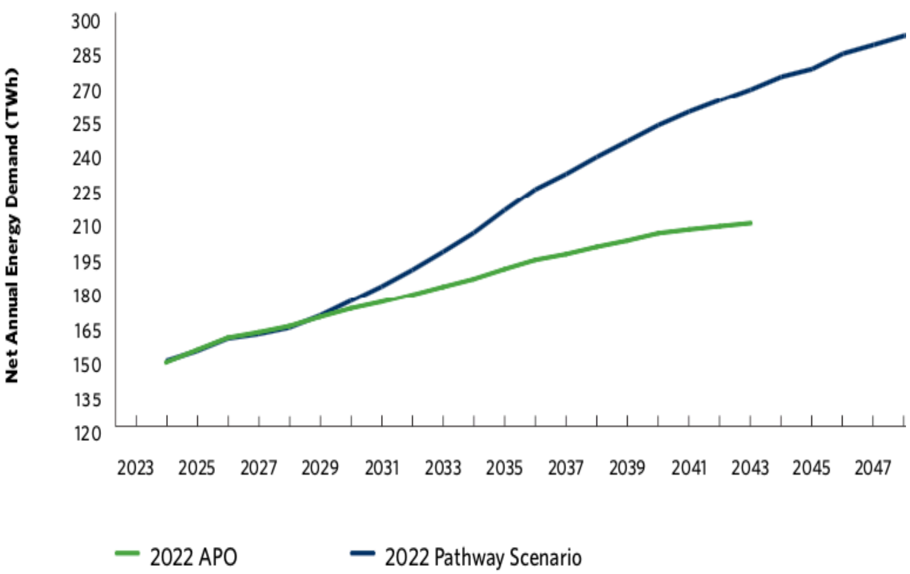
As the Proportion of Unreliable Generation Grows – There will be a Need for Batteries to Smooth the Valleys

- IESO ”Pathways to Decarbonization” forsees the need by 2050 as:
  - 2,500 MW of battery storage – (by 2027- in 4 years!) \ (Perhaps not enough)
  - 6,000 MW of new solar (compared to 488 MW grid connected today)
  - 17,600 MW of new wind (compared to 4,883 MW grid connected today)
  - 657 MW new hydro
  - 17,800 MW of new nuclear (with only 300 MW committed today)
  - 15,000 MW of hydrogen equivalent (from … somewhere else ???)

- BUT – the “Pathways” Document only *mentions* the transportation shift from petroleum to electricity in passing – sourced from who knows where?

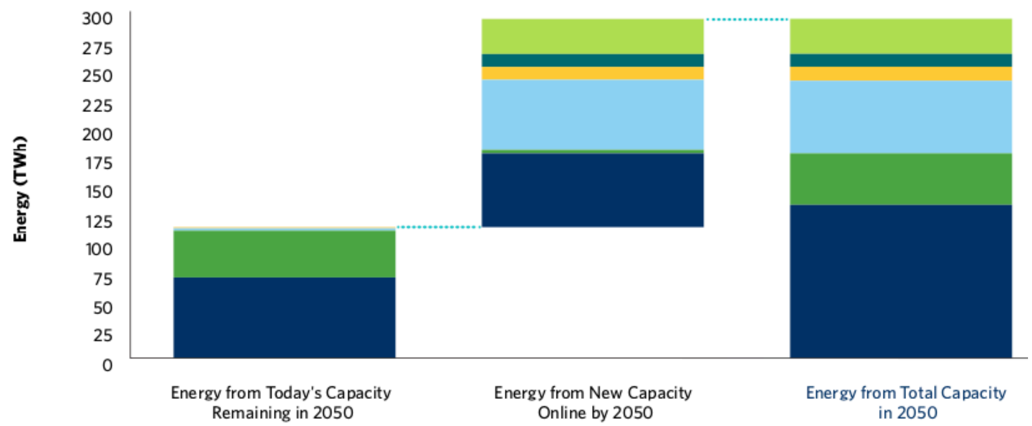
Here’s What IESO Expects by 2050

Figure 7 | Energy Demand



IESO expects demand to double, and the increase in wind turbines to supply 22% of energy by 2050.

Figure 13 | Pathway Scenario – Energy in 2050



	Energy from Today's Capacity Remaining in 2050	Energy from New Capacity Online by 2050	Energy from Total Capacity in 2050
Storage	0	0	0
Imports	0	30	30
Demand Response	0	0	0
Hydrogen	0	12	12
Bioenergy	0	0	0
Solar	1	11	12
Wind	2	62	63
Hydroelectric	41	3	44
Nuclear	70	63	133
Total TWh	**113**	**181**	**294**

What was Ontario's Energy Demand (in 2019)

Figure 5: End-Use Demand by Sector (2019)

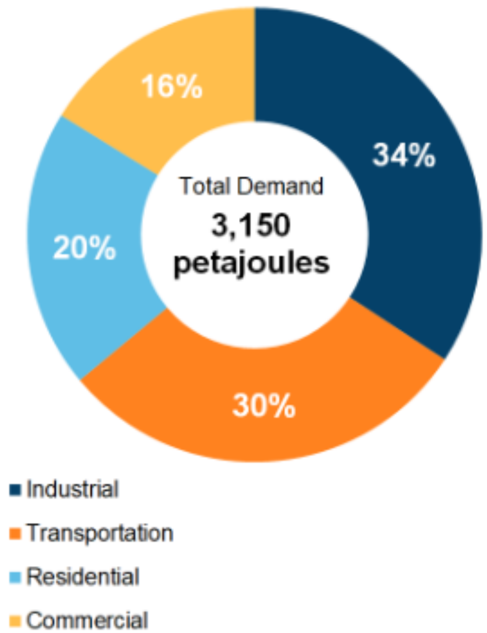
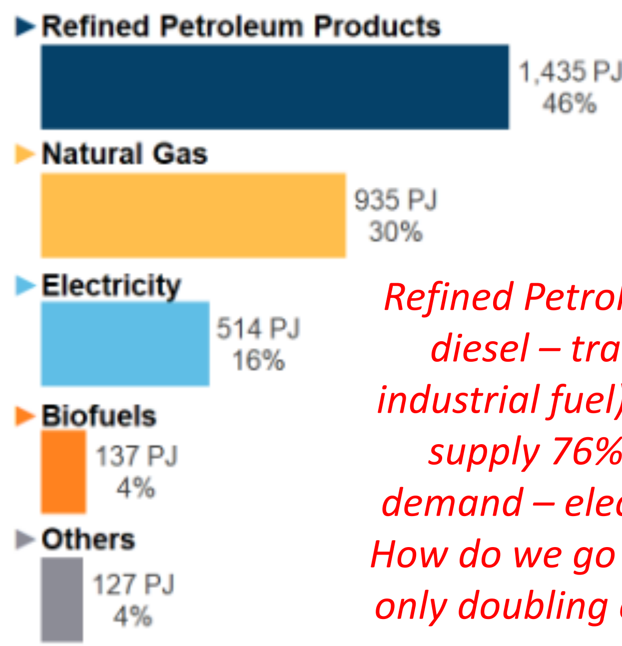


Figure 6: End-Use Demand by Fuel (2019)



Refined Petroleum (gasoline & diesel – transportation & industrial fuel) plus natural gas supply 76% of the energy demand – electricity only 16%. How do we go off oil and gas by only doubling electrical supply?

Battery Options

- Lithium Ion is the present champion (some 90% of industrial/electrical supply storage batteries)
  - has mostly replaced lead – acid as storage battery of choice except for motor vehicle starting duty
- Li-ion generally good for fast response, up to 4 hour discharge time. Barely adequate for shifting night supply to daytime usage of energy, a poor choice for storage needing days or weeks, vs, hours of storage, due to Li-Ion self-discharge over time. Expensive ~ 135 to 250 US$ per MWh, lithium scarce, fire hazard.
- Alternatives under development
  - Flow Batteries (charge stored in liquid electrolyte tanks, outside battery cell) e.g.
    - "Primus" zinc-bromide battery, said to be non-toxic, long term storage, good for 100 hour discharge
    - "ESS" iron-flow battery, said to be non-toxic, reduced need for fire protection than Li-ion.
  - Metal/Air Batteries
    - "Form Energy" iron-air batteries, cheaper than Li-Ion, said good for 100 hour discharge
    - "Zinc8" zinc-air battery, a Canadian start-up, designing for 8 hour + discharge cycle, cheaper than Li-Ion
    - "Aluminum-Air" battery, still in development, perhaps for long range motor vehicles. Replaceable not rechargeable.
  - Gravity storage
    - Pumped hydro (as at Meaford)
    - Energy-vault (crane storing blocks in tower, recover energy lowering blocks) aka "Gravity Storage"
  - Thermal storage, "thermo photo voltaic" cells sensitive to heat energy stored in carbon blocks for days
  - "HydroStor" compressed air storage - pilot plant now at Goderich, ON
  - Hydrogen extraction from water by electricity (electrolysis) – Later generation of electricity from fuel cells or as a heating fuel – BUT, mind the expense, as each step costs $$$.

Li-Ion Grid Backup (BESS) Risks (1st example)

Lithium ion battery energy storage systems (BESS) hazards (published Feb, 2023)

- Over 30 large-scale (1 MW +) Li-Ion BESS experienced failures resulting in destructive fires in the past 4 years
- contain flammable electrolytes, can create unique hazards when the battery cell enters thermal runaway.
- paper focusses primarily on small containerized BESS are often installed in standard shipping containers ranging from 8 feet to 53 feet in length, with a width and height of approximately 8 feet each.
- typically equipped with smoke detection, fire alarm panel, and some form of fire control and suppression system
- initiating event frequently a short circuit which may be a result of overcharging, overheating, or mechanical abuse. During thermal runaway, large amounts of flammable and potentially toxic battery gas will be generated.
- Journal of Loss Prevention in the Process Industries, Vol 81, Feb. 2023, 104932
- https://doi.org/10.1016/j.jlp.2022.104932

Li-Ion Grid Backup (BESS) Risks (2nd example)

Battery Hazards for Large Energy Storage Systems (Published 2022)

- Li-ion batteries have become popular in new grid-level installations due to rapidly decreasing prices and wide availability
- variety chemistries, from lithium iron phosphate (LFP) cathode to those with a nickel manganese cobalt oxide (NMC) cathode and with graphite, silicon composite, or lithium titanate (LTO) anodes. (Different Chemical Risks – Must Know the Specifics)
- The reactive and hazardous nature of Li-ion batteries under off-nominal conditions can lead to safety incidents and may cause extensive damage to the BESS. 42 reported failure incidents from 2011 to 2021.
- Li-ion batteries are prone to overheating, swelling, electrolyte leakage venting, fires, smoke, and explosions.
- gases produced as a result of a fire, smoke, and/or thermal runaway can accumulate to a combustible level and cause explosion.
- High and low temperatures lead to different unsafe conditions. High temperatures lead to … violent venting, fire, and thermal runaway. Low temperatures increase the viscosity of the electrolyte … leads to increased internal cell temperatures … thermal runaway and fire. *Heaters installed, to heat batteries before charging, but if heaters fail "off" – or "on" can lead to same destructive result.*
- combustible gases such as hydrogen, carbon monoxide, methane, ethylene, and propylene can be produced in concentrations above the TLV.
- *doi: 10.1021/acsenergylett.2c01400*

Li-Ion Grid Backup (BESS) Risks (3rd example)

What are the fire safety risks of lithium-ion batteries? (Published Aug 2022)

- Dr Amer Magrabi, principal fire engineer at Lote Consulting, gave a talk on battery fire safety at the Australasian Fire and Emergency Services Council (AFAC) conference in Adelaide.
- “It’s an emerging risk, we’re still coming to grips with it.”
- “Once alight, lithium-ion battery fires are very hard to extinguish. Common fire suppressants don’t work and the fire can burn very fiercely. In some circumstances, the battery can explode.”
- “If you have a problem with one cell, it’s going to start spreading.” This unstoppable fire is called “thermal runaway.”
- Water may assist with absorbing heat from some small fires, but it reacts dramatically with lithium – making it a bad decision to go directly on fires.
- Lithium-ion fires don’t burn cleanly: batteries can vent toxic gases. It’s not always clear what these gases will be, as battery chemistry is a closely guarded commercial secret.”
- Some fire services have a code of not intervening in lithium-ion battery fires: they’re unlikely to suppress them because the risk to firefighters is too high.
- Instead, they wait for the reaction to finish, and protect the surrounding environment.
- 26 August 2022 / COSMOS Magazine

Li-Ion Grid Backup (BESS) Risks (4th example)

- **A comprehensive investigation on the thermal and toxic hazards of large format lithium-ion batteries with $LiFePO_4$ cathode (Published 2020)**
- Toxic gases released from lithium-ion battery fires pose a ***very large threat*** to human health.
- Li-Ion Batteries with higher state of charge (SOC) are found to have greater fire risks in terms of their burning behavior, normalized heat release rate, and fire radiation, as well as the concentration of toxic gases.
- The major toxic gases detected from the online analysis are CO, HF, SO_2, NO_2, NO and HCl.
- Results show that the effects of irritant gases are much more significant than those of asphyxiant gases. HF and SO_2 have much greater toxicity than the other fire gases. The maximum FEC value *(fractional effective concentration – a measure of toxicity impact)* is approaching the critical threshold in such fire scenarios.
- https://doi.org/10.1016/j.jhazmat.2019.120916.

Li-Ion Grid Backup (BESS) Risks (5th example)

- **Toxic fluoride gas emissions from lithium-ion battery fires (published 2017)**
- Lithium-ion battery fires generate intense heat and considerable amounts of gas and smoke.
- the emission of toxic gases can be a larger threat than the heat.
- large amounts of hydrogen fluoride (HF) may be generated - HF can pose a serious toxic threat
- The amounts of HF released from a large burning Li-ion battery packs could be 200 kg for a 1 MWh battery. The immediate dangerous to life or health (IDLH) level for HF is 0.025 g/m^3 (30 ppm) and the lethal 10 minutes HF toxicity value is 0.0139 g/m^3 (170 ppm). The release of hydrogen fluoride from a Li-ion battery fire can therefore be a severe risk and an even greater risk in confined or semi-confined spaces.
- 15–22 mg/Wh of another potentially toxic gas, phosphoryl fluoride (POF_3), was measured in some of the fire tests
- Using water mist resulted in a temporarily ***increased*** production rate of HF but the application of water mist had no significant effect on the total amount of released HF.
- https://doi.org/10.1038/s41598-017-09784-z

Now – You Have the "Big Picture"
- so what can you do? (Other than reject BESS?)

- **6 practical steps to improve community safety near lithium-ion energy storage systems (Published Sept. 2021)**
- By Steve Kerber *Vice President of Research at UL Firefighter Safety Research Institute.*
- most first responders have limited experience with Li-Ion battery fires - behave differently than typical fires
  - Lithium-ion batteries have flammable chemical electrolytes and are susceptible to thermal runaway
  - lithium-ion batteries can spontaneously reignite hours or even days later after a fire event
  - safety requirements for ESS sites are still evolving as more information about the technology becomes available
- what can be done right now to improve safety?
  - Lithium-ion battery ESS should incorporate gas monitoring that can be accessed remotely.
  - Lithium-ion battery ESS should incorporate robust communications systems to help ensure remote access to the battery management system, sensors and fire alarm control panel remains uninterrupted.
  - Owners and operators of ESS should develop an emergency operations plan in conjunction with local fire service personnel and the authority having jurisdiction and hold a comprehensive understanding of the hazards associated with lithium-ion battery technology.
  - Signage that identifies the contents of an ESS should be required on all ESS installations to alert first responders to the potential hazards associated with the installation.
  - Lithium-ion battery ESS should incorporate adequate explosion prevention protection as required in National Fire Protection Association (NFPA) 855 or International Fire Code Chapter 12, where applicable, in coordination with the emergency operations plan.
  - New lithium-ion battery ESS should be built in accordance with NFPA 855, the most current standards available for safety, and we are calling on local governments to mandate adoption within their cities and municipalities.
- https://www.utilitydive.com/news/6-practical-steps-to-improve-community-safety-near-lithium-ion-energy-stora/585938/

The “Other” Current Hype - Hydrogen

- Invest 20 minutes to watch, “The Trouble With Hydrogen” It’s easy watching, and very informative.
- https://www.youtube.com/watch?v=Zklo4Z1SqkE
- Briefly:
    - Most (>90%) hydrogen produced today is from fossil fuels. To produce “green hydrogen” from renewable electricity (solar or wind) will be “cost prohibitive” (3 or 4 times greater)
    - Hydrogen for vehicle fuel cells is stored under very high pressure of about 10,000 PSI
        - Needs heavy cylinders, with carbon fibre reinforced barriers
        - Hydrogen under pressure tends to react with metal, forming brittle hydrides, degrading the storage vessel.
    - Fuel cells to make electricity from hydrogen for vehicle propulsion need platinum or irridium – neither are cheap nor plentiful.
- Not mentioned in video:
    - Adding hydrogen above about 7% in concentration to natural gas supply network requires modifying ALL combustion equipment (furnaces, etc.) connected to the gas line for safety reasons, so that’s not an easy option.
    - Batteries can typically reuse between 80–90% of the chemical energy stored, but fuel cells generally transform only 40% to 60% of their energy to produce electrical power. (There are more losses, hence less efficiency.)
    - Overall, “Green Hydrogen” supply/usage efficiency is about 30%. 70% of the energy is wasted. That’s economically undesirable.
    - However, there are Big government subsidies for Green Hydrogen (big-hype) Too Good to be True … usually is.
- An internet search for “Green Hydrogen Hype” returns over 6,000 results.