Innovation in Energy Storage
How Ontario can Attract Investment

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Business Development, Alternative & Emerging Technology

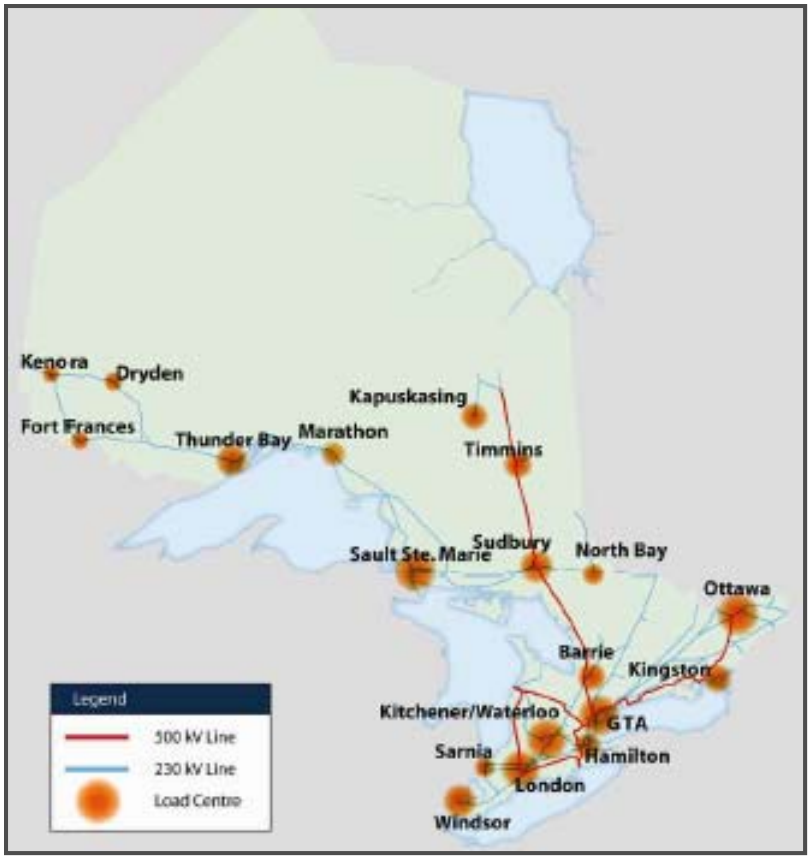
Distributed Energy Storage Workshop – Nov 27, 2012

Enbridge's Conventional & Alternative Energy Footprint

- Employ 10,000 in Canada & U.S.
- Largest liquid pipeline operation
- Natural gas transmission and Canada's largest gas distributor
- Electricity transmission
- ~ $ 3 Billion in Green and Alternative energy
  - Includes fuel cells, geothermal power, run of river hydro, heat to power, etc.
  - More than 1000 MW of wind and solar assets operating or under construction
  - Pathfinding Investments include Hydrogenics for electricity storage & Morgan Solar for next-generation CPV

Storage Integrates Generation and Load

Does Ontario Need Electricity Storage ?



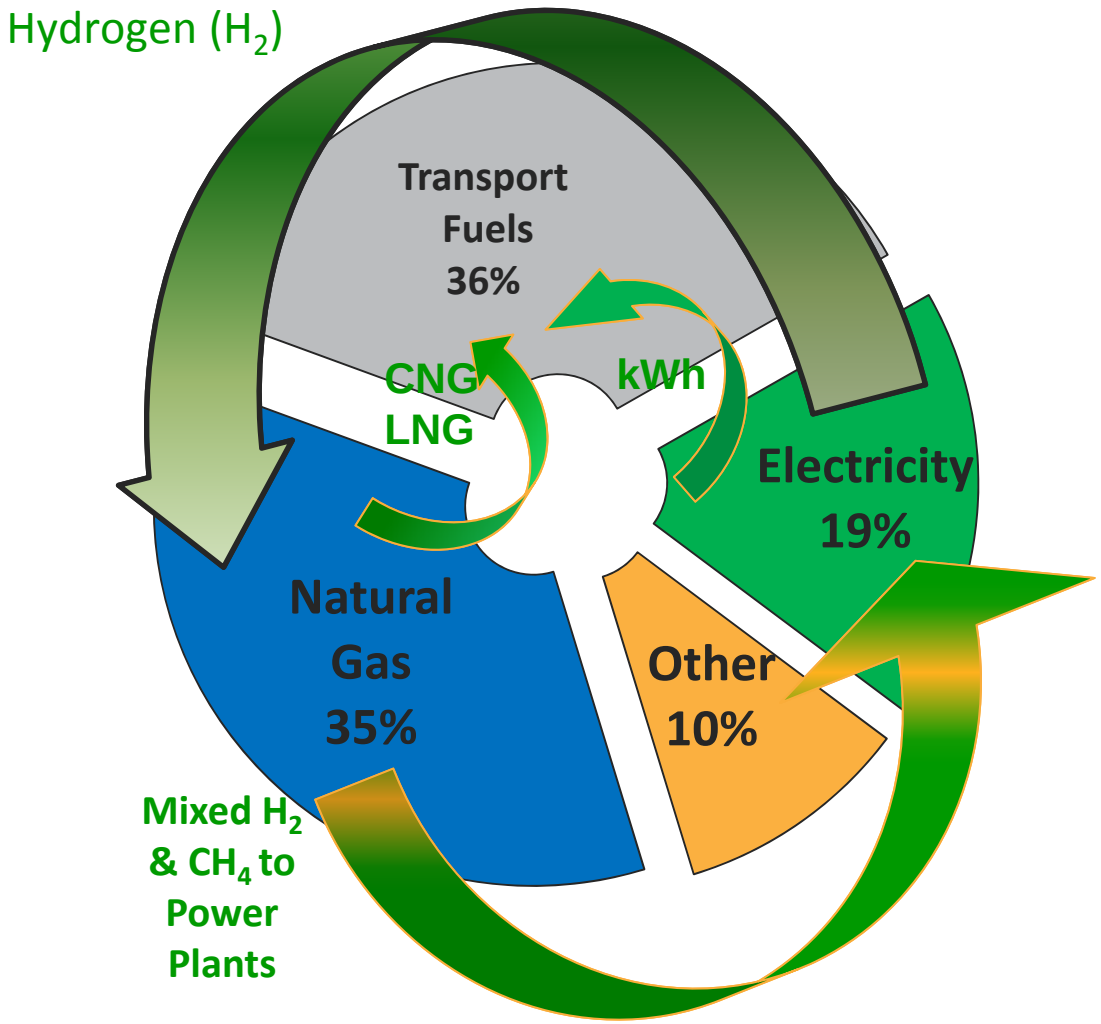
Original Source/Image : OPA / IEOS; Ontario's Integrated Power System Plan, Discussion Paper 5: Transmission, Nov 13, 2006

Need will be derived from "Value"

Value will be influenced by "Policy", "Market Design" and "Contract Structure"

Innovating for Smarter Energy Grids
Energy Exchanges Between Silos

Energy-Use Composition



- Today we think in Silos
- Focus on Smart "electricity" grid limits benefits
- Majority of focus is on small part of energy pie
- "Energy" Storage offers operational, economic & environmental flexibility
- Society and the economy benefit by extracting more value from existing assets
- New energy conversions are key to unlocking value in energy infrastructure

Source Data: Rethinking Energy Conservation in Ontario, May 2010 Report

Storage Potential; Multiple Benefits & Beneficiaries

Technical / Market Benefits

- Time Shift – Arbitrage
- Streamline renewable integration
- Deferred T&D Investment
- Improved capacity factor for all generation = lower costs
- New grid stabilization tools and services (i.e. regulation, etc.)
- Reduced emissions, renewable energy credits, etc.
- Improve social license to renew energy infrastructure

Beneficiaries / Stakeholders

- Renewable Energy Developers
- Base load generation, like nuclear operators
- Energy transmission and distribution companies
- Environmental policy
- Independent electricity system operators
- Consumer, regulatory and community interests

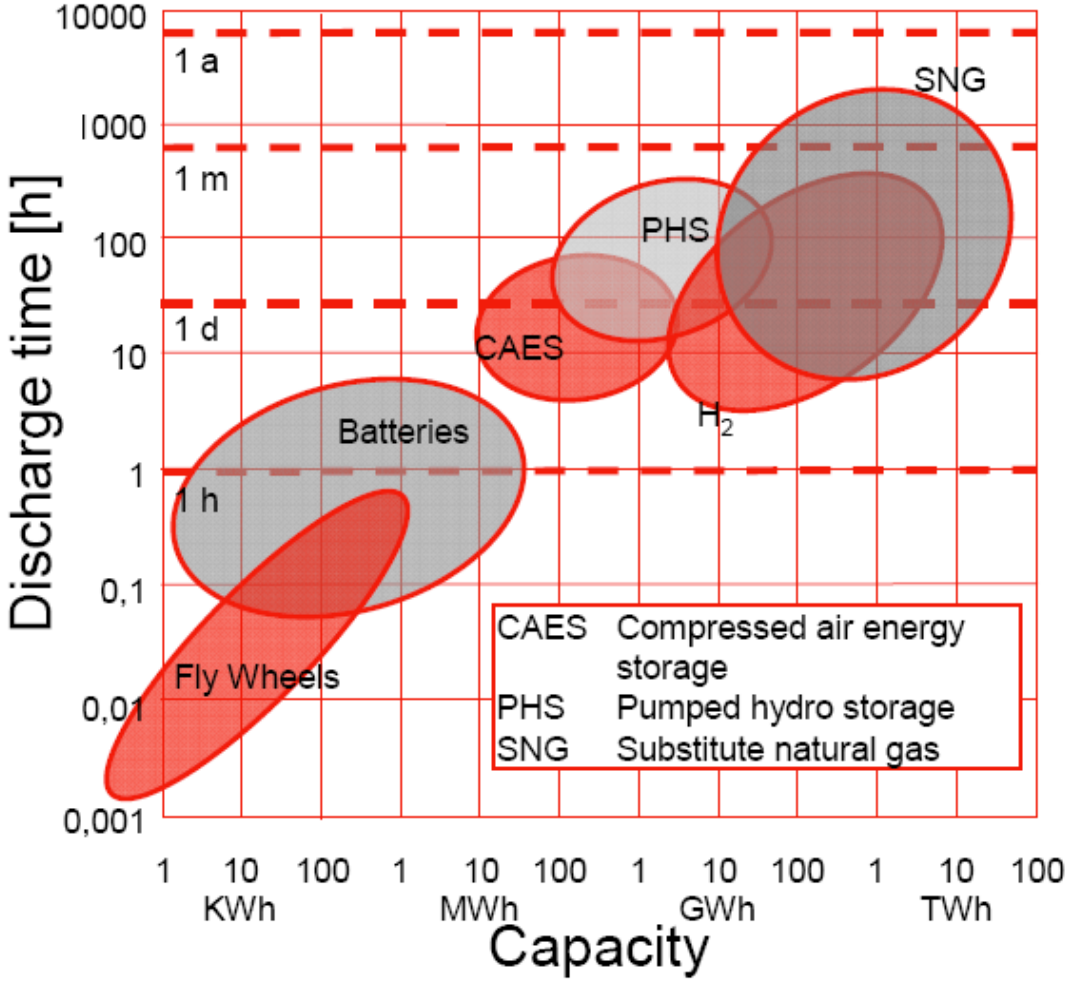
Storage Can be the New Provincial Inter-Tie

- Today, grid management tools include power exports
- Storage, in aggregate, could be considered an new inter-tie option
  - Distributed
  - Scalable
  - Incremental
- Exports to in-province storage assets could:
  - Retain environmental attributes of power
  - Reduce or eliminate curtailment/waste of renewable and non-emitting nuclear

Original Source/Image : OPA / IEOS; Ontario's Integrated Power System Plan, Discussion Paper 5: Transmission, Nov 13, 2006

Diverse - No Single Storage Solution

- **Bulk storage solutions can range from MWh to TWh of energy**
- **Seasonal storage possible with hydrogen or substitute natural gas**



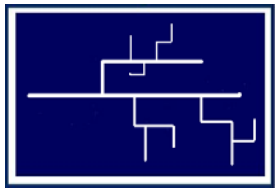
Source: International Gas Union Research Conference 2011, Abstract from Dr. Gerald Linked

Power to Gas; Seasonal Electricity Storage

- Off-Peak electricity to hydrogen with electrolysis of water

PEM Electrolysis

- Blending of hydrogen with methane in gas grid

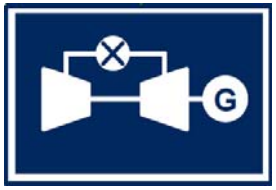


Natural Gas Network

- Blended gas in cavern or pipeline

Cavern Storage

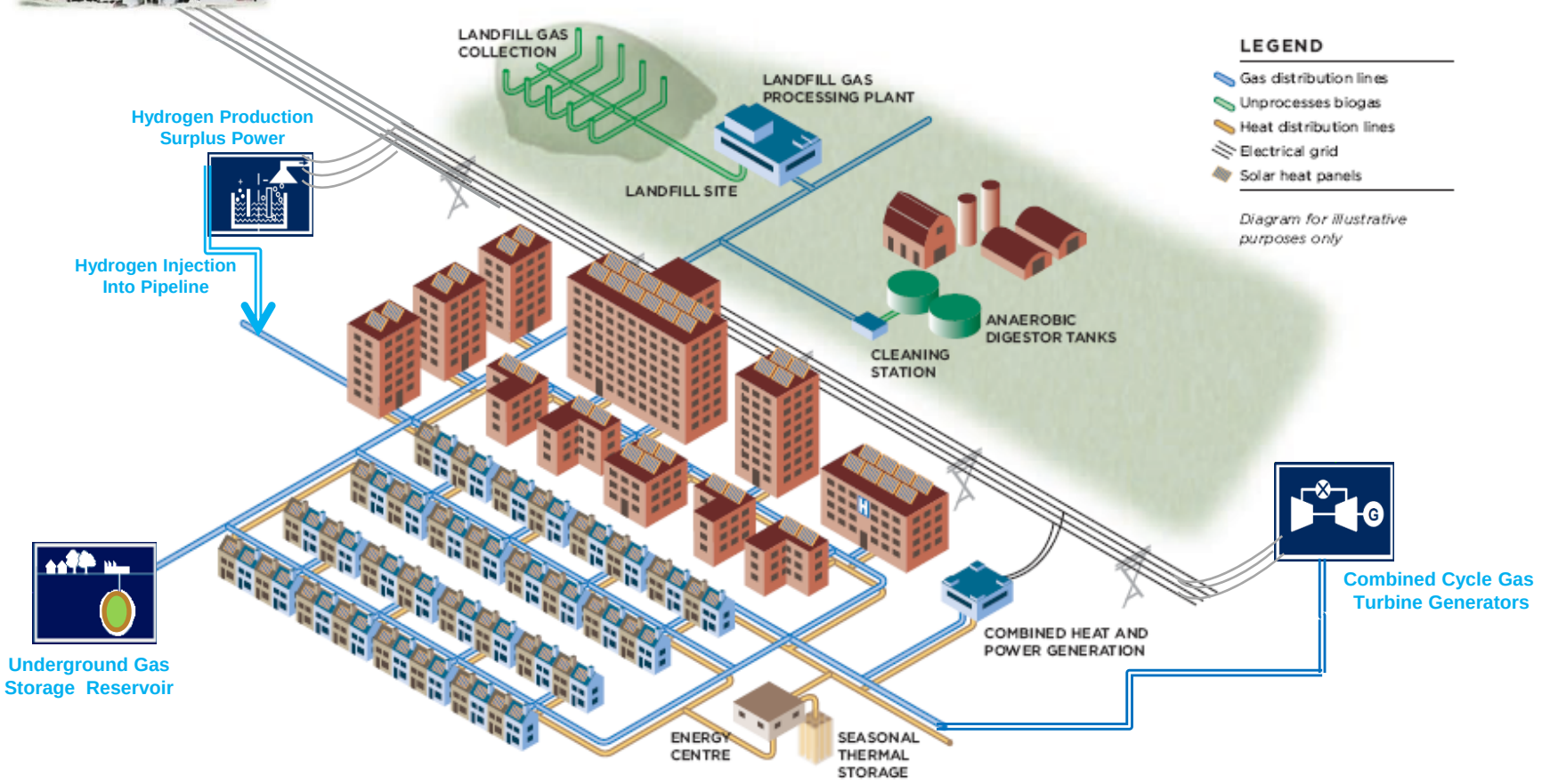
- Blended gas to electricity at peak time / peak season



Renewable Fuel to CCGT & Gas-Fired Distributed Generation

Smart Energy Grids Share Infrastructure

- More flexible planning for energy supply & transmission
- Less NIMBY pressure on energy infrastructure



Original Source Image: CGA, "Natural Gas, our Place in Canada's Sustainable Energy Future

Distributed Storage with Transmission

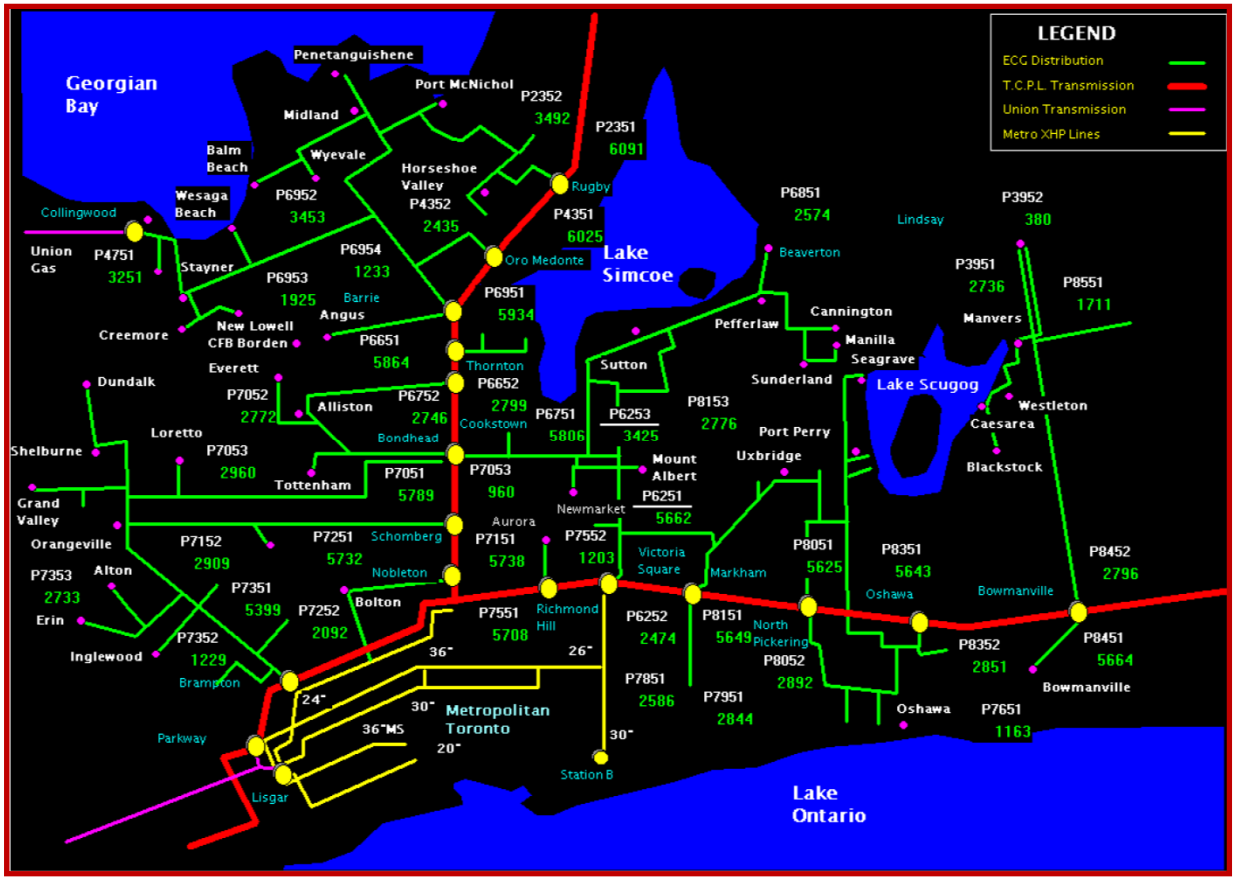


Illustration of Extra-High-Pressure Gas Distribution System in Greater Toronto Area

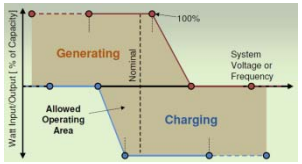
- Pipelines are large distributed storage
  - Power to gas 85% to 90% efficient
  - Electrolysers are incremental, at 1-100 MW per site
- Over 275 bcf of gas storage and > 75,000 kM of gas pipelines
- Distributed inter-tie with electricity system
- On energy equivalency basis, Enbridge peak day exceeds 40,000MW

Storage Contracting Challenges
Single Bill; but Many Influencing Factors

Power-to-Gas illustrates why storage contract design is a challenge; benefits are many, and spread over wide group of stakeholders

Milliseconds to Minutes

Frequency Regulation

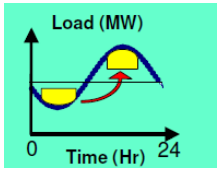


Source: Brian Seal (EPRI)

- Fast Acting Storage
- Alternative Supply via Dispatchable Load Control

Hours

Shift Energy



Gas Dispatch With Renewable Fuel

Daily

Alternative to Exports

Maneuver Nuclear

Congestion Relief

Load-Following Renewables

Weeks to Seasonal

Underground Storage

(> 80 TWh)

Emission Credits

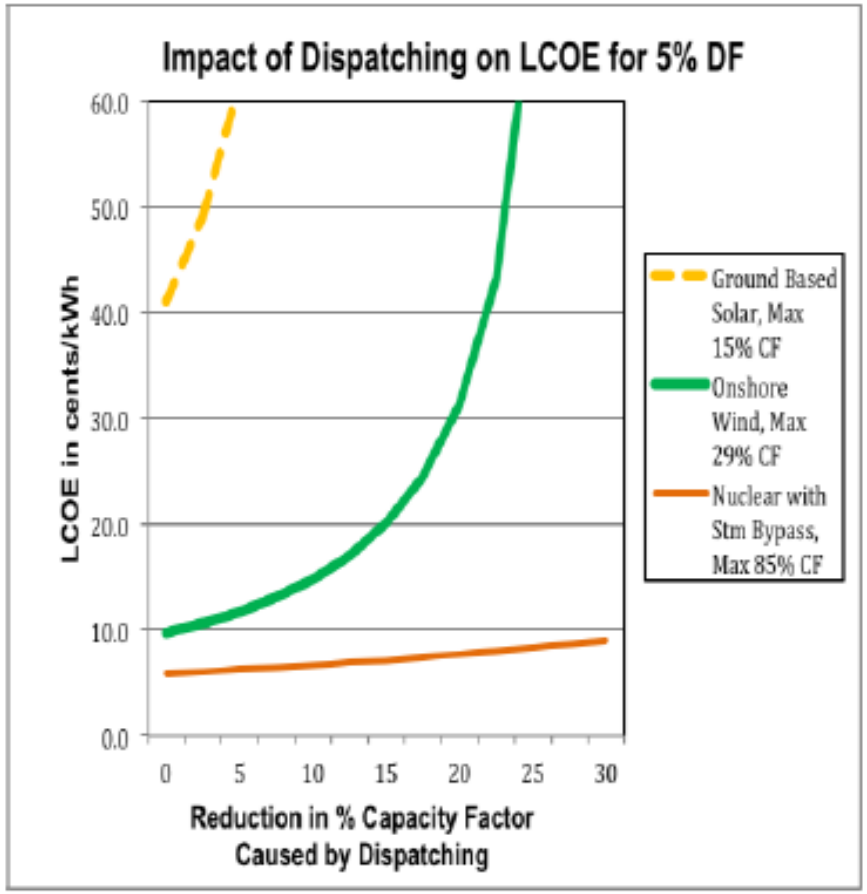
< GHG

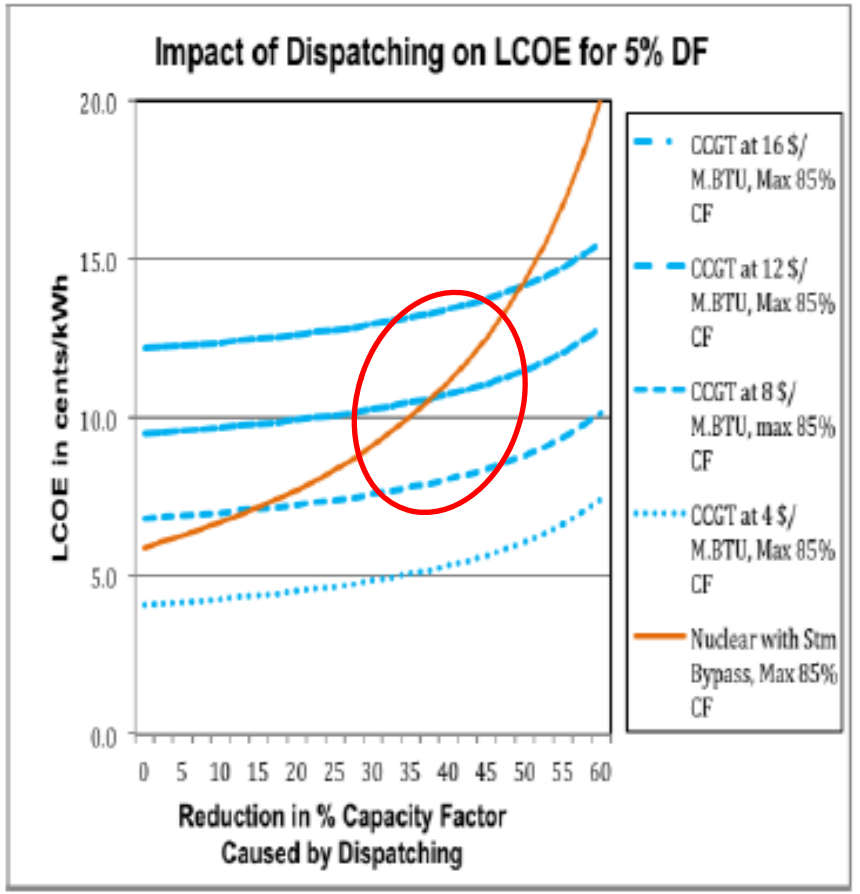
Improving Levelized Cost of Electricity (LCOE)

LCOE > if generation is curtailed for reliability or market conditions

- System storage can have positive effect on Levelized Cost of Electricity (LCOE)
- Additional improvements with gas-fired power plants using Power-to-Gas

Anticipate economics / cost for CCGT using renewable fuel



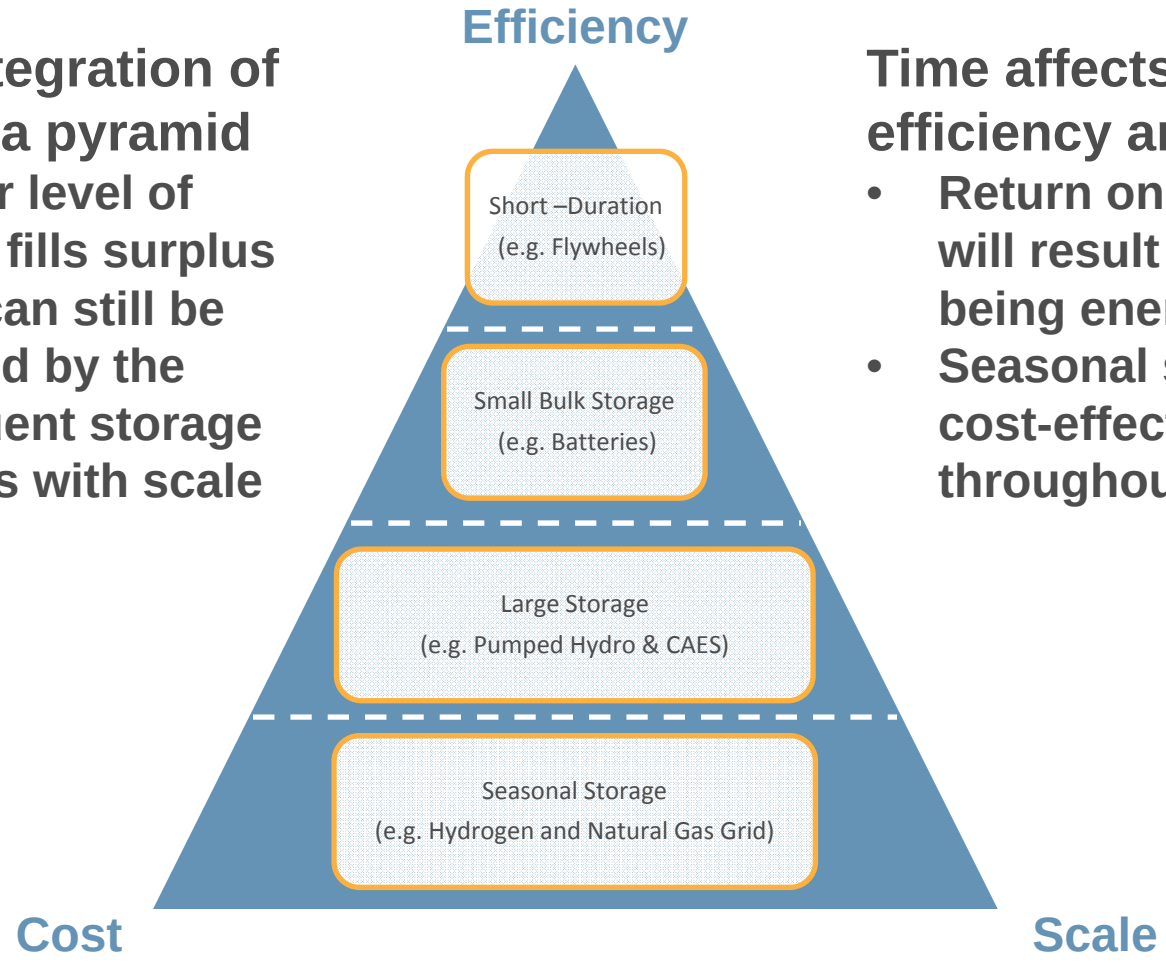


Original Source Images: Wind and the Electrical Grid, Ontario Society of Professional Engineers, March 14, 2012

Define the Job are We Trying To Do

System integration of storage is a pyramid

- As upper level of pyramid fills surplus energy can still be optimized by the subsequent storage solutions with scale



Time affects the value of efficiency and scale

- Return on capital hurdles will result in most storage being energy-limited
- Seasonal storage allows cost-effective harvesting throughout the weekends

Why Scale and Efficiency Matter; But in Different Applications

High efficiency storage is suitable for energy balancing (e.g. integration renewables on distribution feeders, etc.)

Lower cost, distributed, seasonal storage (GWh and TWh) is well-aligned with overall system optimization

Energy must be captured before efficiency matters

Ontario is likely to benefit from seasonal storage that has unlimited scale to store meaningful energy volumes

- IESO reporting for 2011
  - Exports 12.9 TWh
  - Imports 3.9 TWh
  - Net 9.0 TWh Exported
- Example 1 (higher-efficiency storage)
  - 500 MW – with 10 hours of storage
  - 5 day, 50 week profile
  - 75% round trip efficiency
  - 937 GWh /year
- Example 2 (seasonal storage)
  - 500 MW - 10hours of storage
  - 5 day, 50 week profile + 46 incremental hours each weekend
  - 48% round trip efficiency as green power (1,152 GWh / year)
  - 81 % round trip efficiency as green heat (1,944 GWh / year)

Seeking Value - Balance Scale & Efficiency

To understand value we must first define the challenges or objectives – then set policy and market rules

Example – Are we striving for maximum GHG reductions by optimizing Ontario's off-peak electricity exports?

Illustrative Scenario

- **500 MW higher-efficiency storage**
  - **Annual energy harvest ~ 0.94 TWh**
- **500 MW seasonal storage (output as green electricity)**
  - **Annual energy harvest ~ 1.15 TWh**
- **Total of 2.09 TWh of non-emitting energy**

Total harvest has potential to optimize 16.2 % of Ontario's 12.9 TWh of annual energy exports

Establish New Markets for Green Energy

Alternative method for GHG reductions by optimizing Ontario's off-peak electricity exports?

Illustrative Scenario 2

- **500 MW higher-efficiency storage**
  - **Annual energy harvest ~ 0.94 TWh**
- **500 MW seasonal storage (output as green heat)**
  - **Annual energy harvest ~ 1.94 TWh**
- **Total of 2.88 TWh of non-emitting energy**

Total harvest has potential to optimize 22.3 % of Ontario's 12.9 TWh of annual energy exports, and at a lower cost to Ontario energy consumers

Many alternative scenarios exist in which energy storage has potential value; but, policy and market design matters!

A Few Realities

- **Base load supply can exceed off-peak demand**
- **Long-Term Energy Plan with > 6000 MW of new intermittent supply by 2018**
- **Electricity exports only one tool to manage surplus conditions**
- **Nuclear maneuvering, spilling hydro and curtailing wind technically viable - but wasteful**
  - Lost resource / opportunity
- **Inefficiencies with system integration reflected in "Global Adjustment"**

Barriers to Storage Investments

General Market Barriers

- **Investors in storage assets are investing:**
  - Capital $$
  - Operations $$
  - Managed operational / market risk
- **In an mature market, storage revenues include:**
  - Energy sales; Arbitrage $$
  - Some ancillary services (e.g. regulation, etc.)
  - Other??
- **How does one monetize:**
  - T&D deferral, emission credits, etc.

Barriers Unique to Ontario

- **Hybrid market heavily weighted to "Contracted Generation" with CES, RES, FIT and Bruce agreements**
  - How does storage derive value in market with contracted supply?
- **Global Adjustment (GA) and other tariff or uplift costs**
  - GA not levied on exports
  - Ont. Regulation 429/04 and adjustment of GA for consumers > 5 MW (Class A customers)
  - GA on net-operations still an uneven playing field; ***Skews Value***

Setting Ontario's Competitive Advantage

Storage a service provider to system-at-large

- **Ensure storage providers are not penalized**
  1. Acknowledge hybrid market when considering market design for storage
     - Market lacks on-peak/off-peak delta
     - Value of storage supplies measured against contracted generation
       - E.g. costs below FIT pricing might be viewed as offering higher-value
  2. Global Adjustment could have perverse affect on investment decisions
     - Storage and exports require similar treatment, or investment signal will align with out-of-province storage assets

Hurdle

Storage delivers system-wide benefits with the potential for compelling value in totality; however, many of these benefits accrue to multiple stakeholders and consumers without direct financial support to investors in storage assets

Conceptual Contracting Options for Storage

- **Today, Accessible market revenues not sufficient to drive investment in storage**
  - Total life-cycle benefits may meet consumer benefit test
- **When Ontario lacked clean generation capacity it established a Top-Up-Payment**
  - Clean Energy Supply (CES) agreements use a Contract for Differences (CfD)
  - Ontario has expertise with CES agreements
- **CfD Structure one option for stimulating storage investments**
  - Investors negotiate a Net Revenue Requirement (NRR)
  - Monthly Revenue > NRR = Payment to Consumers
  - Monthly Revenue < NRR = Top-Up-Payment to Investor
  - Flexible contract structure fair when future revenues change
    - E.g. market pricing of carbon emissions, etc.

Pilot Projects verses Demonstrations

- **Demonstration Projects:**
  - Short operating window
  - Validate technology works
  - If contract support does not exist - no path forward if successful
  - Usually one-off (pre-commercial)
- **Incremental Pilot Projects:**
  - Pilot projects can include late-stage demonstrations
  - Supported with pilot-contracts to learn about markets and technology
  - If industry makes technology work it has right to long-term operation
  - No promise to build future projects under same contract conditions
  - Incentive for industry to improves technology and reduce costs

Image: Enbridge 2.2 MW Hybrid FuelCell demonstration of cleanest, most efficient gas power plant, Toronto, Ont.

Does Ontario Need Electricity Storage?

“Value” can be identified through early storage pilots – learn by doing

“Policy”, “Market Design” and “Contract Structure” can be tested on pilot projects

To accelerate learning, we need early pilot projects – *Today!*

By learning we will understand what Ontario’s needs are, and how best to meet these needs in the future

Recommendations & Conclusions

Ontario has an immediate opportunity to advance several pilot storage projects

- We should empower Ontario's planning and operating authorities to establish learning pilots (1-10 MW projects)
- Seek to understand how system-wide storage can serve as relief valve for renewable and non-emitting electricity supplies
- Planning and regulatory bodies should adopt a Smart-Energy-Grid approach - breakdown silos that lessen consumer benefits
- Prioritize infrastructure investments to storage if quantifiable benefits can be identified, demonstrated and validated:
  - Use of existing infrastructure where relevant
  - Attainment of renewable / non-emitting energy objectives while improving societal & community engagement
  - Establish contracts that monetize total system benefits

Q&A

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