Hybrid Energy Geostorage Systems in Eastern Canada

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Contents

Energy Transition

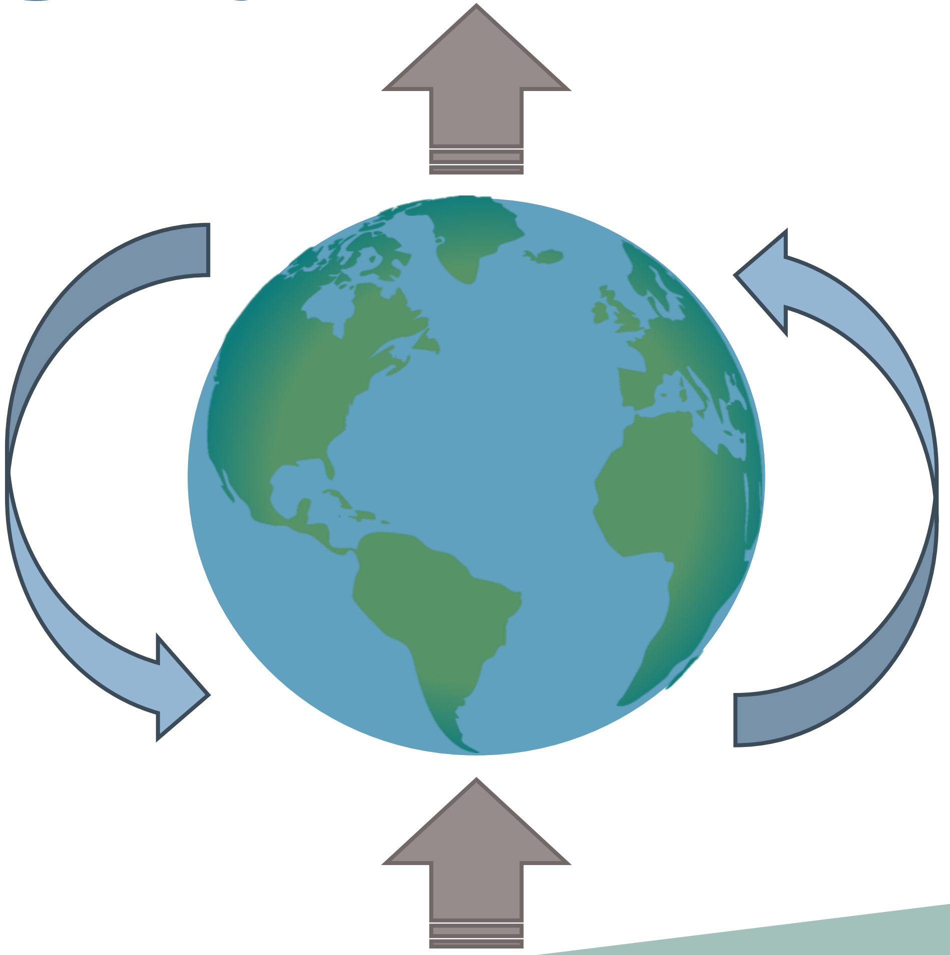
- Through the Paris Agreement and associated federal and global moves towards a sustainable future, comes the idea of the energy transition
- As our main route to reducing global emissions and combatting climate change, the energy transition marks the shift from fossil fuel-based energy systems to renewable and low to zero carbon fuels
- This transition is driven by economics, public environmental support, and government and institutional policy

Energy Transition

- While simple in theory, the energy transition cannot happen overnight
  - Difficult to change established industries and infrastructure
  - Lack of incentives or penalties
  - Leniency for existing relationships
  - Need for storage
- Hence why creative solutions are needed to support the move to clean energy and eventual net zero
  - This is where hybrid energy systems come in…

Hybrid Energy Geostorage Systems

- Hybrid energy systems refers to primary energy production (preferably from renewable sources) in tandem with the ability to store that energy both in the long and short term
- Because renewable sources are often intermittent (solar, wind, tidal), storage solutions are necessary to capture excess energy and access it again when resources are low



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Global Energy Needs & UN SDGs

The UN Sustainable Development Goals outline 17 areas to improve the ultimate sustainability of our planet

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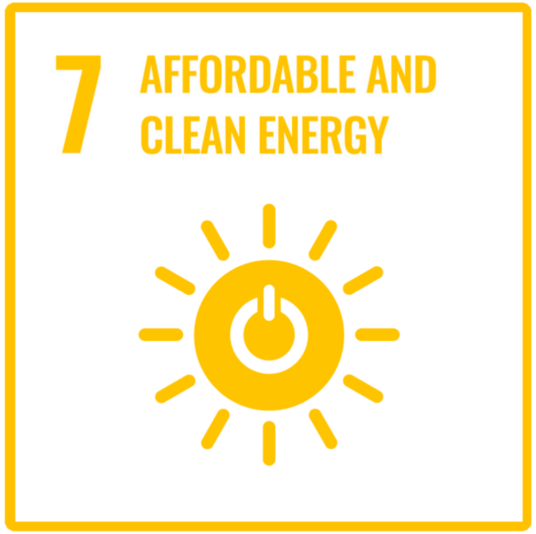
Global Energy Needs & UN SDGs

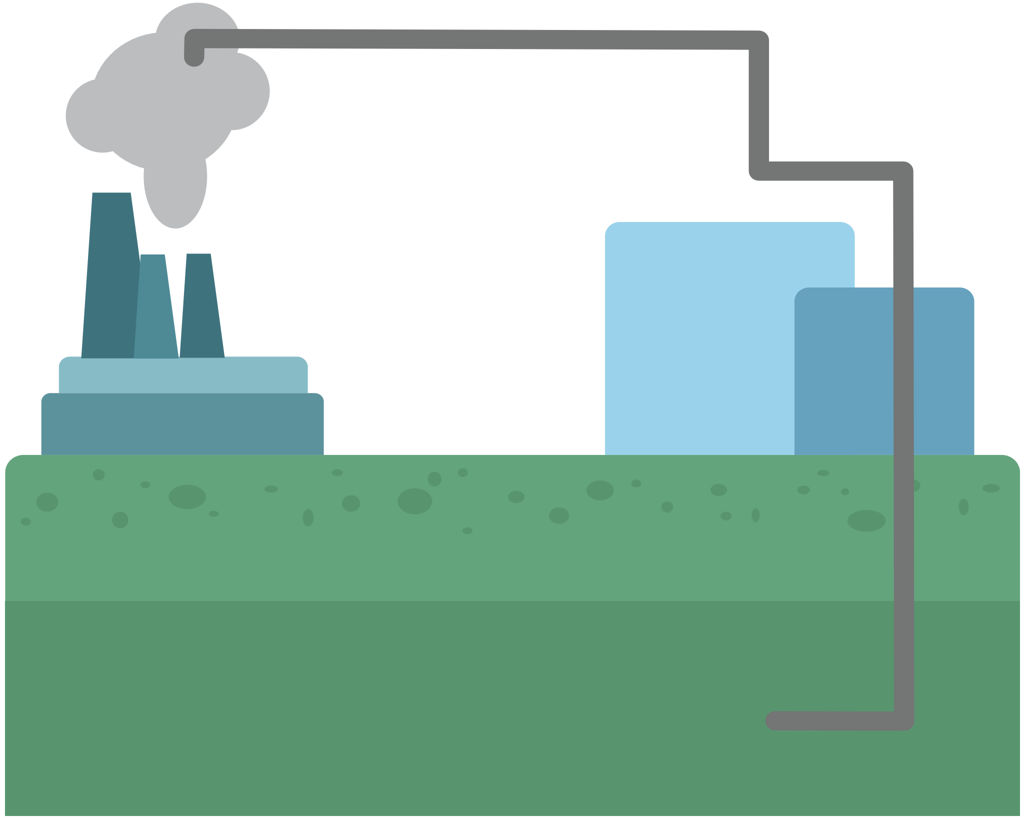


These goals in particular align with work being done in the energy sector, directly relating to the development of hybrid energy geostorage systems for Atlantic Canada and beyond.

Global Energy Needs & UN SDGs

- To align with Goal 7 of affordable and clean energy, we must transition away from fossil fuels towards renewable energy sources – and to make the most out of our clean energy, we need reliable storage solutions
- To contend with global energy needs and available renewable energy, required storage volumes are estimated to be 580-650 billion cubic meters to fit global demand

Storage Systems



- Storage approaches are classified by response time, power output, energy capacity, and duration
- The proper choices for the ongoing energy transition require careful planning and creative solutions

Battery Energy Storage Systems (BESS)

- The most known storage solution today is in batteries, particularly in battery farms
- Battery energy storage systems (BESS) have their benefits, along with constraints, that must be considered for our future needs
- Benefits include:
  - Excellent short-term response
  - Farm capability to store energy at the +GWh scale
  - Power output can be designed over a huge range – from sub-MW to hundreds of MW
  - Well known, already implemented globally

Battery Energy Storage Systems (BESS)

With the pros there must be cons...

- Need for Critical Raw Materials (CRMs)
- Relatively short lifespan
- Vulnerability to sabotage and vandalism
- Chemical Recycling

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Battery Energy Storage Systems (BESS)

With the pros there must be cons...

- Need for Critical Raw Materials (CRMs)
- Relatively short lifespan
- Considerations on Placement
- Chemical Recycling

Requiring minerals & metals in quantities that will soon strain global supplies as electrification continues.

Many of these materials are considered strategic resources to their respective governments, making them prone to global politics and conflicts.

Strain on supply will increase storage costs and generate greater environmental and political concerns relating to resource exploitation in challenging sociopolitical conditions.

Political manipulations of rare earth metal supply chains have already impacted industry.

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Battery Energy Storage Systems (BESS)

With the pros there must be cons…

Need for Critical Raw Materials (CRMs)	Relatively short lifespan	Considerations on Placement	Chemical Recycling

Typical battery lifespans, in best case scenario, last 8-10 years.

Replacement costs must be considered of long-term plans and budgets.

BESS must be designed to accommodate battery replacement.

Slow decay of rechargeability, must be monitored for changes in efficiency.

Battery Energy Storage Systems (BESS)

With the pros there must be cons…

Need for Critical Raw Materials (CRMs)	Relatively short lifespan	Considerations on Placement	Chemical Recycling

Need to find a site that fulfills all the necessary requirements while avoiding potential risks.

Vulnerable to sabotage and vandalism, especially in regions of conflict.

Fire hazards related to manufacturing defects and essential components.

Land use issues, public concerns and existing industrial infrastructure.

Climatic concerns, particularly in colder regions.

Battery Energy Storage Systems (BESS)

With the pros there must be cons…

- Need for Critical Raw Materials (CRMs)
- Relatively short lifespan
- Considerations on Placement
- Chemical Recycling

Massive battery use means massive chemical recycling to recover metals.

Requires large infrastructure investments and environmental care.

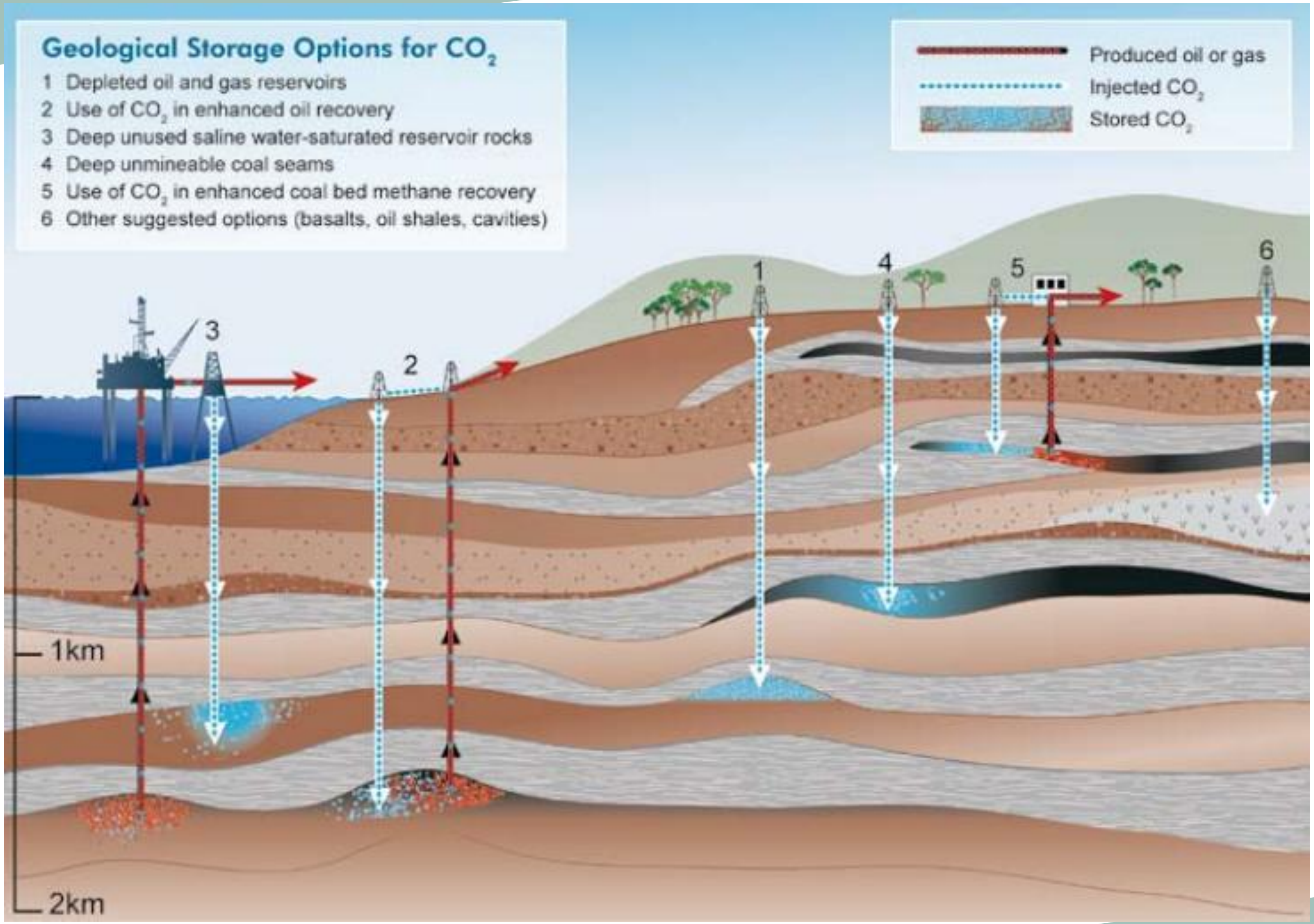
Battery Energy Storage Systems (BESS)

Although BESS are a vital part of our current grid system, meeting our short-term needs, their use as long-duration energy storage (LDES) systems is already problematic based on costs per MWh along with the other issues described.

So, what are the options?

Geological Storage

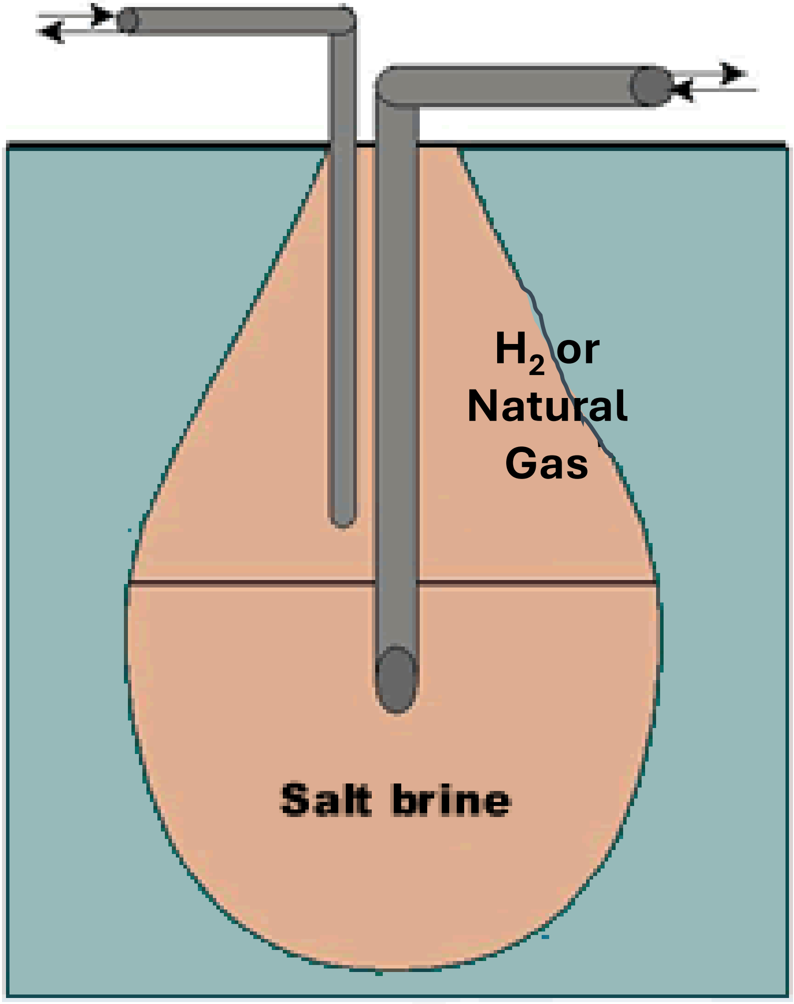
- Storage in subsurface geological formations is the most practical solution to achieve grid-scale energy storage
- Numerous types of formations can in theory be used for storage, with salt structures currently boasting the most potential for these purposes
- Through hydrogen (H_2) or compressed air energy storage (CAES), energy can be stored in underground salt caverns, enabling grid growth with sustained stability while servicing an emerging international-scale green H_2 industry



Geological Storage Options for CO_2
1 Depleted oil and gas reservoirs
2 Use of CO_2 in enhanced oil recovery
3 Deep unused saline water-saturated reservoir rocks
4 Deep unmineable coal seams
5 Use of CO_2 in enhanced coal bed methane recovery
6 Other suggested options (basalts, oil shales, cavities)
Produced oil or gas
Injected CO_2
Stored CO_2
1
2
3
4
5
6
1km
2km

Geological Storage

- By solution mining, caverns are created in suitable subsurface salt structures
- Many parameters to consider including maximum probable cavern diameter, optimum roof shape, sustained indefinite stability with minimal sloughing, rate of filling, and most importantly the estimated pressure



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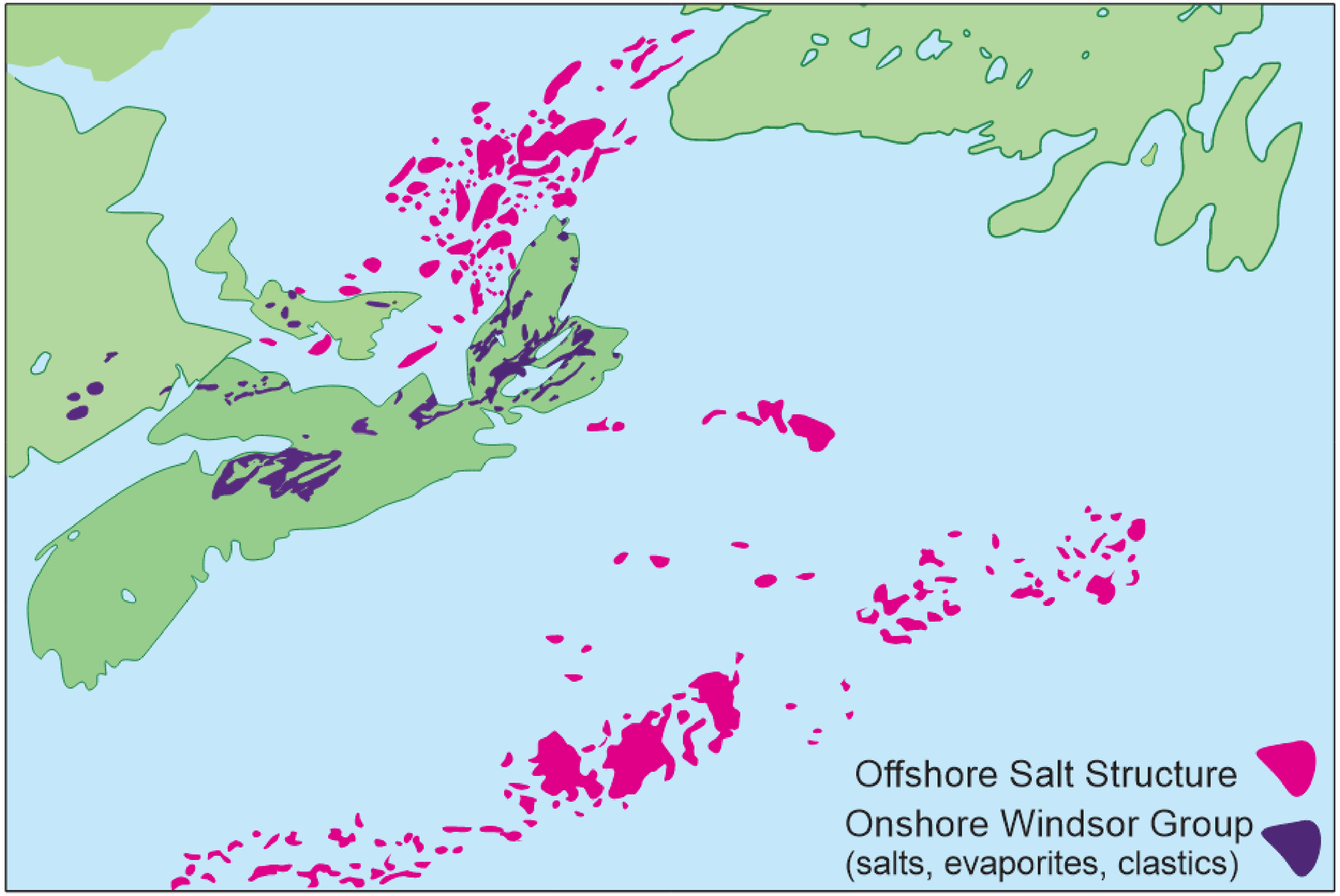
Geological Storage



Salt structures offshore Atlantic provinces provide significant potential for storage, in areas already developed with transport routes and energy infrastructure

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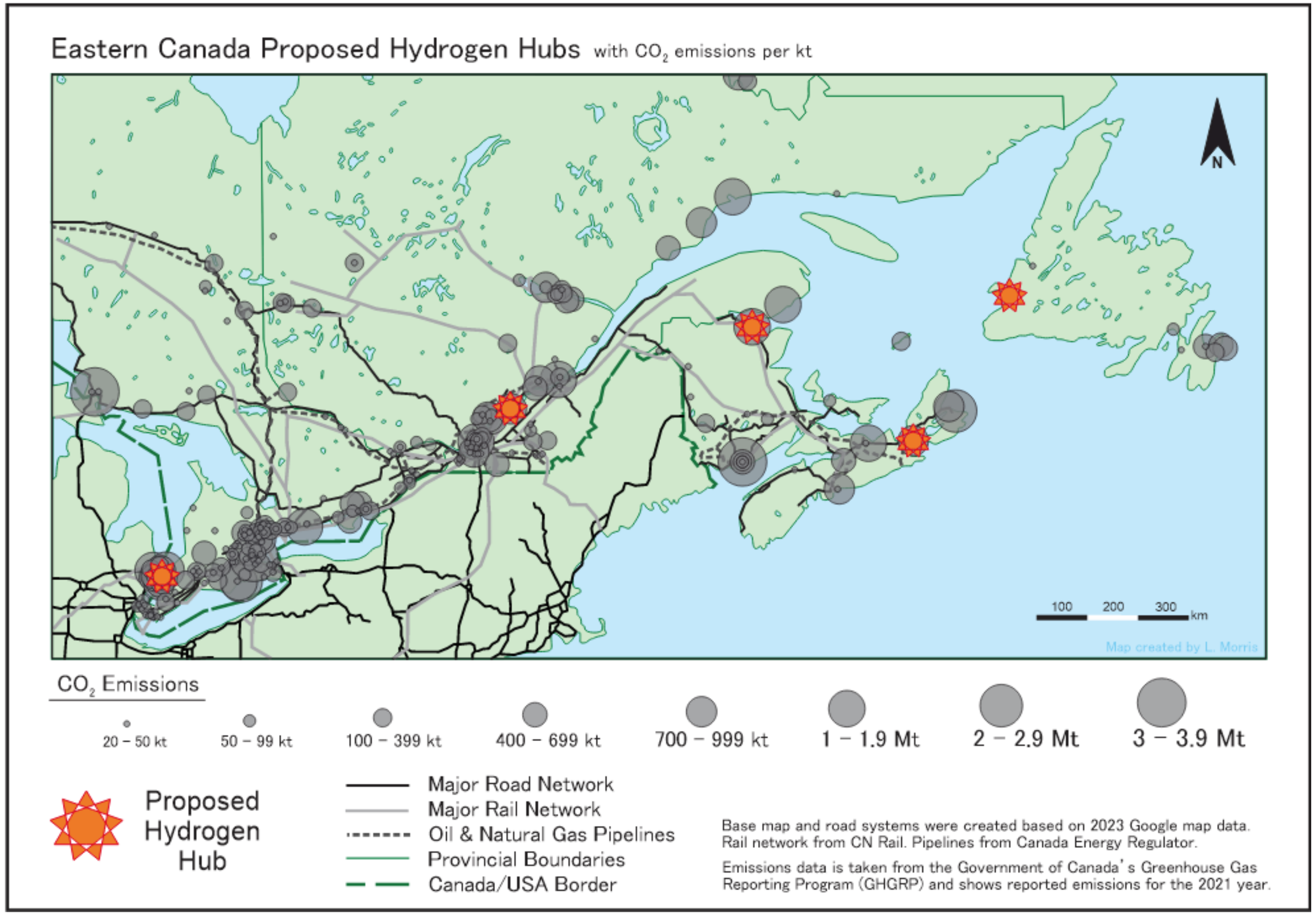
Wind Energy

Offshore windfarms would have several requirements to be met, making the Gulf of St. Lawrence an attractive option

- Best average wind profile in southern Canada
- Moderate wave height (compared to open Atlantic littoral)
- No iceberg risk (although risk for surface drift ice)
- Diapiric salt structures for product and energy storage available both onshore and offshore
- Direct marine access for international transshipment
- Highly skilled marine infrastructure companies, technologists, and engineers in the Atlantic Provinces
- High connectivity to the North American Eastern Connection regionally integrated grid
- Supportive LDES exists in the hydro dams in the QC and NL regions, increasing stability and assurance of green energy supply to the grid and to industry

Wind Energy



While multiple renewable energy approaches have potential, in Atlantic Canada, development of wind power to produce storable H_2 remains our most viable option

Wind Energy -> H_2

- Energy cannot just be stored immediately, but transformed into a storable substance, such as H_2
- This is done through electrolysis. This process breaks up $2H_2O$ into the storable H_2, and lost energy in the form of low-grade heat as O_2
  - If the electrolysis facilities are positioned strategically near urban centers or industrial sites, the low-grade heat could be used for other purposes, reducing the amount of lost energy from the electrolysis process
- In order for H_2 to be stored and shipped, it must also be compressed or liquified

Wind Energy Storage

- Electrolysis requires steady direct current, but wind power provision is irregular and variable
- Two factors are essential: large-scale grid connections and large-scale energy storage

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Wind Energy Storage

Large-Scale Grid Connections

Large-Scale Energy Storage

- Allows wind power beyond stable electrolyser needs to be dispatched to other clients
- Allows grid to provide power to make up for shortfalls in wind power when needed
- Larger the connection capacity, the better the stabilizing effects on the wind power provision

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Wind Energy Storage

Large-Scale Grid Connections

Large-Scale Energy Storage

- Needed to achieve long-term stable electrolysis power supply if the demand is a significant amount of the grid provision capacity (>10%) and if the degree of entry of wind power into the grid is large (>30-40%)
- Options are using some produced H_2 as fuel in turbines or fuel cells, pumped hydro storage, batteries, or CAES

Wind Energy Storage

- Consumption of some of the generated H_2 for use in the grid is an option, but because H_2 is likely to be of substantial value, it seems inappropriate to use it to generate energy to stabilize the grid due to the electrolyser needs for a stable current
- More direct storage of the renewable energy is more efficient
- Storage allows the irregular portion of the wind energy provision to be stripped and stored to be emitted later as stable, well-conditioned electrical power

CAES

- Installation of caverns for CAES when wind power is in excess is the best way to approach the massive storage capacity needed
- Not only serves the H_2 industry, also smooths the renewable energy's variability and stabilizes long duration supply
  - Decarbonization can be more readily achieved
- Will allow for the unhindered closure of coal-fire plants and reduce the need for natural gas power generation for meeting demand-supply management needs

CAES & BESS

- Estimated costs per MWh for CAES energy storage in dissolved salt caverns is less than for batteries, but some batteries will be needed in an integrated grid system to address short term response
- Large-scale energy storage not only atablizes power provision to the electrolysers, but also provides rotational inertia for grid frequency management
  - Allos a substantially larger amount of renewable energy to enter the grid, aiding in the final stages of electricity decarbonization in the Maritimes and in the electricity markets to which the stabilized renewable power will be dispatched

Conclusions

- The energy transition will benefit from the stability and services that large-capacity energy storage technologies bring
- Massive storage is becoming an essential component of grid design
- H_2 manufacture and distribution as a means of storing and distributing green energy and fuels continue to be viewed as an important part of the energy transition
- Location of H_2 production near urban centers provides great potential for use of waste heat from electrolysis

Conclusions

- Salt cavern storage of compressed air can provide grid stability, leading to grid decarbonization
- The four Atlantic provinces and Quebec are ideally located for H_2 production at an international scale
- Excellent grid interconnections, an educated populace with broad experience in marine technology, deep-sea access, and port facilities exist throughout the region
- Interprovincial planning and federal government coordination is needed to fully develop these proposals

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