A study of the economic and technical viability of a salt cavern Compressed Air Energy Storage facility in Alberta

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Summary

Energy storage will play a vital role in Alberta's future electricity grid as the province transitions away from coal-fired power to meet the country-wide net zero target by 2050. Storage captures surplus electricity during off-peak hours and returns it to the grid during periods of high demand, providing a solution to the intermittency of renewables. Specifically, Compressed Air Energy Storage (CAES) provides long-term and cost-effective storage with low environmental impact. Alberta's geology is suited for CAES because of the existence of halite formations in Cold Lake that could be used as storage reservoirs for compressed air. However, the existing provincial energy legislations and market framework do not consider the unique attributes of energy storage systems. In this project, we examine the economic and technical feasibility of a salt cavern CAES facility in the Cold Lake region in Alberta and evaluate its contribution to Alberta's energy grid demand.

Alberta's Energy Grid

Energy storage is vital to Canada's transition to net-zero greenhouse gas emissions by 2050 (Pembina Institute, 2017) through facilitating the integration of renewable energy sources into the grid (e.g., wind and solar), as well as improving grid efficiency and reliability (Canada Renewable Energy Association, 2022). Net-zero emissions are achieved when the amount of energy consumed by a project or facility is equal to on-site renewable energy provider capacity. Due to the usage of hydroelectric and nuclear power resources, Canada's emission intensities are among the lowest in the world. However, as a fossil fuel-based province, Alberta's emission rate is 620 g/kWh (Ontario's rate, for instance, is 1 g/kWh), the highest in Canada (Shaffer, 2021).

The energy suppliers in Alberta in 2020 were mainly natural gas (59%), coal & coke (30%), wind and solar (6%), and hydro (3%). However, onshore wind, hydro, solar farming, and biomass are existing renewable power potentials that can produce more than 60% of the energy demand of the province (Barrington-Leigh & Ouliaris, 2017). By adding 5000 MW of renewable energy capacity by 2030, the government of Alberta anticipates producing 30% of its energy from renewable sources (Alberta, 2021). Figure 1 shows the electricity generation by fuel type in Alberta, as well as a forecast of electricity generation sources by 2050, with the reliance on solar and wind being the most significant growth.

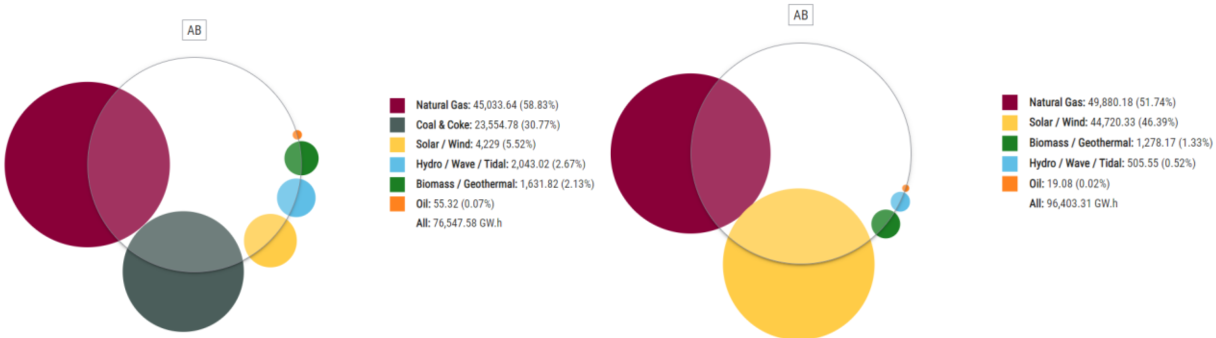

Figure 1: Electricity generation in Alberta by fuel type (a) in 2020 and (b) in 2050, with the prediction being based on evolving policies (Canada Energy Regulator, 2022).

The intermittency of renewables induces disruption on the hourly load-following phase for the grid (Fares, 2015). As a result, there is a need to develop a robust and effective renewable energy system, tackling the intermittency problem by designing appropriate energy storage systems. Each type of energy storage system has advantages and disadvantages, and depending on the power and capacity, has different uses. Nevertheless, a renewable energy-based electrical system should offer both short-term and long-term energy storage options to be flexible and balanced.

Compressed Air Energy Storage (CAES) Technology

Compressed Air Energy Storage (CAES) involves using compression turbines to store the air in reservoirs – viable options are vessels, salt caverns, aquifers, and hard rock formations. To recover the energy stored, the compressed air goes through expansion turbines that generate electricity to the grid. CAES has a high delivery rate that is well suited for peak load hours (Natural Resources Canada, 2022).

In terms of CAES options for reservoirs, salt caverns appear as a less expensive alternative when compared to vessel and hard rock formations, which involve, respectively, costly construction and drilling processes. The choice of aquifers or salt caverns for compressed air storage is limited to the geographical location. In the province of Alberta, for example, the presence of thick halite formations close to the Cold Lake region indicates a favorable geology for building salt caverns for compressed air storage.

The environmental impacts caused by a salt cavern CAES facility must be addressed in the design and operation phases. Brine from cavern mining dissolution can be disposed into sedimentary basins with suitable porosity and permeability (Dusseault, 2021). Brine could also be used for industrial applications and for de-icing roads; in both cases, brine transportation and storage must be previously planned. Other impacts such as noise production, surface tilting, deformation, and seismic events, can be prevented or mitigated by being considered during the design phase and assuring a thorough geological characterization and constant monitoring (Dusseault, 2021).

Geology in Alberta: halite formations and sandstone formations

The Province of Alberta has a favorable geology for CAES given the existence of halite and evaporite formations – Lotsberg formation and prairie formations – where salt caverns can be constructed (Alberta Geological Survey, 2022). Figure 2 depicts a cross section of the mentioned formation, where it can be noted the thickness of the salt layer. In fact, Federation Engineering has a project for the construction of a salt cavern CAES in the Cold Lake region, and the estimative is that the salt cavern will be placed at a region 1100m depth from the surface with approximate thickness of 200m (Federation Engineering, 2022).

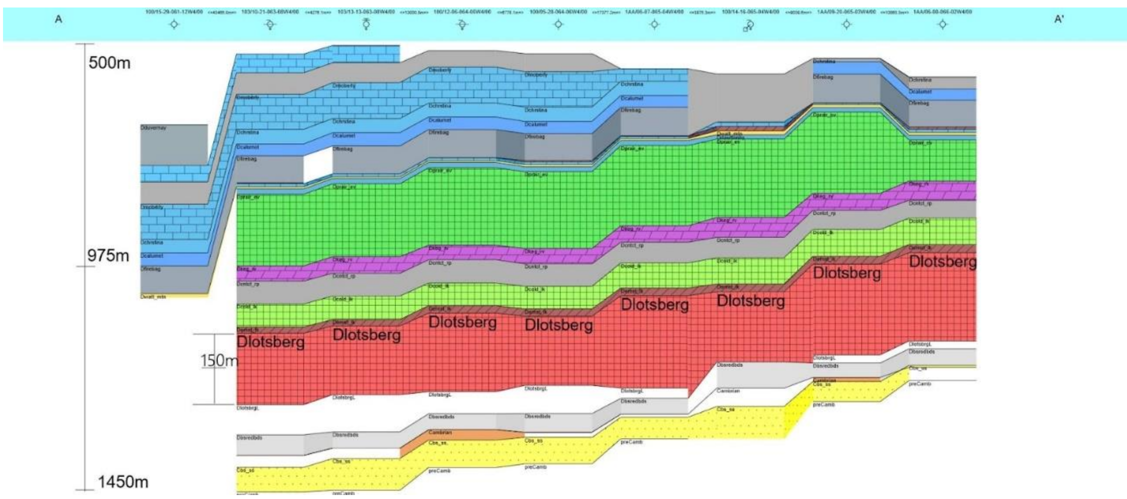

Figure 2: Cross section of the Lotsberg halite (red layer) of the Elk Point Group; graph tools and data are from geoSCOUT (2022). The scaling on the left shows the vertical depth of the wells used during the characterization of the geological layers.

The presence of sandstone formations in Alberta, which were previously used for water disposal in hydraulic fracturing operations, is a valuable indicator that such formation is also suitable for brine disposal. Figure 3 illustrates a possible location for brine disposal, chosen accordingly to the location of active oil and gas infrastructure and aiming to minimize the environmental risk.

CAES and Alberta's Energy Grid

Energy storage is a central element in energy policy debates in Alberta as the province is transitioning away from coal and towards renewables (Alberta Storage Alliance, 2016). However, the regulatory and market frameworks in Alberta lack clarity on their application to energy storage and flexibility to consider the unique attributes of energy storage systems (AESO, 2019; Eeles et al., 2021). Hence, Alberta's grid and market framework should be modernized to provide legislative certainty for investors and encourage the deployment of storage technology in the province (The Conference Board of Canada, 2020). The Alberta Electricity System Operator (AESO) energy storage roadmap details a plan to integrate energy storage systems into the electricity market (Barrington-Leigh & Ouliaris, 2017).

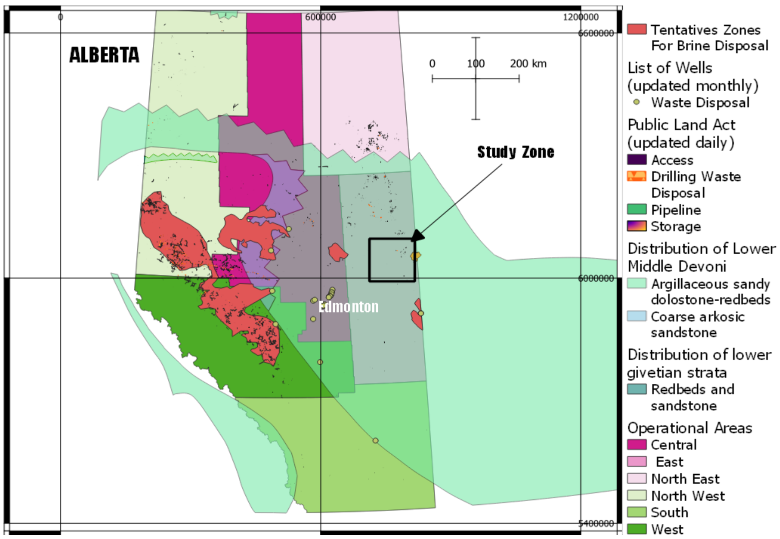

Figure 3: study zone for construction of a salt cavern CAES and suitable regions for brine disposal. The location was chosen based on the closeness to zones where brine can be either disposed or used in oil and gas operations and on the minimization of seismic events in populated areas.

As suggested by the AESO energy storage roadmap, Alberta's legal framework must be redesigned to recognize energy storage as a unique asset type that is neither a load nor a generator to eliminate this cost disincentive and encourage energy storage deployment in the province. Moreover, the legal framework should outline ownership rules of energy storage as there is legislative ambiguity about who can own energy storage facilities (Selim, 2021). This uncertainty stems from Alberta Utilities Commission's classifying energy storage facilities as both generation and distribution assets and excluding a generating unit.

Further, investors are reluctant to invest in Alberta's energy market because of entry barriers, such as lengthy timelines for project review processes, and regulatory uncertainties. It is recommended that the federal and provincial governments facilitate regulatory approval to encourage investments in energy storage technology in Alberta (Drance et al., 2018).

Conclusion

The use of intermittent renewable energy, such as photovoltaics and wind power, is expected to grow in the near future. Fossil fuel plants are the least desirable solution for maintaining system balance by 2050 in order to reach net zero. Due to the increase of renewable sources in the electricity generation scene, energy storage is critical to maintaining grid stability and reliability.

Compressed Air Energy Storage has proven its effectiveness at grid scale. However, existing CAES installations on an industrial scale are restricted in their diffusion by the availability of appropriate salt formations. Alberta has such geology, and it is possible to create a CAES facility that contributes to Alberta's energy supply and to grid stability.

Energy storage at grid scale is, however, still a recent development. Existing legislation does not account for the market necessities, especially in Alberta where the “energy only” wholesale energy market leaves energy storage participation as an unknown variable. Therefore, there is a need for specificity and clarity in Alberta’s policies, legislations, and regulations about energy storage. Guaranteeing adaptations in the legislative framework, investors are encouraged to participate in the energy storage market in Alberta.

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