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Techno-economic Feasibility of Underground Storage of Hydrogen Energy Produced from Bruce Nuclear Generating Station, Ontario

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Summary

With the growing concerns about climate change and security of supply worldwide, many countries including Canada are trying to develop green energy to reduce their carbon footprint and meet the international agreements on climate protection. The development of hydrogen energy has emerged as a promising solution due to its abundance, high energy density, non-toxicity, and zero greenhouse gas emissions when used. Aside from the production of hydrogen energy, hydrogen storage plays a crucial role in energy supply and demand in order to provide a stable source of energy during periods of peak demand. In this study, we are looking at the case study of the proposed plan to produce hydrogen energy from the Bruce Nuclear Power Station in Bruce County, Ontario. The southwestern Ontario, where Bruce County is located, has abundant subsurface geological formation for underground hydrogen storage. We are assessing the techno-economic feasibility for the underground hydrogen storage in the vicinity of the Bruce Nuclear Station. Although there is a promising future for producing and storing hydrogen energy from the Bruce Nuclear Generating Station, clarifying jurisdiction and safety standards has to be done to complement the feasibility study.

Nuclear-generated hydrogen energy or pink hydrogen

Hydrogen is not a naturally occurring source of energy in its pure form. Therefore, in order to use hydrogen as a source of energy, hydrogen needs to be produced beforehand. There are many ways to produce hydrogen, and color codes have been used to differentiate the types of hydrogen according to the production methods, such as gray, blue, green and pink. Pink hydrogen is a new term to describe the production of hydrogen through electrolysis or thermochemical cycle using electricity generated from nuclear power.

Bruce Nuclear Generating Station is one of the largest nuclear power plants in the world (Natural Resources Canada, 2022). The nuclear power plant is managed by Bruce Power and is located in Bruce County, Ontario, on the eastern shore of Lake Huron. Bruce Power is conducting a feasibility to produce hydrogen using the electricity generated by its nuclear power plant (Nuclear Innovation Institute, 2021). Bruce Power is planning a feasibility study for using excess electricity generated by the nuclear power plant to produce hydrogen.

A joint initiative between the Bruce County and the Saugeen First Nations was established in 2020. The initiative, titled “The Bruce Innovates: Foundational Hydrogen Infrastructure Project”, aims to promote clean technology development and innovation in the region. One of the objectives of this project is to support the Saugeen First Nations in building capacity towards energy self-sufficiency by developing hydrogen energy systems. The proposed plan of generating pink hydrogen from the Bruce Nuclear Generating Station is aligned with the initiative.

Potential underground hydrogen storage (UHS) in southwestern Ontario

Hydrogen could be stored to balance the gap between supply and demand. There are many ways to store hydrogen; such as above ground in the form of compressed hydrogen tanks; or in the underground geological subsurface. Underground hydrogen storage (UHS) is considered the cheapest method for storing a large amount of hydrogen energy (Tarkowski, 2019). There are three major types of geologic formation suitable for UHS; depleted gas/oil reservoirs, saline aquifers, and salt caverns (Zivar et al., 2021).

Bruce County in southwestern Ontario, is home to the Bruce Nuclear Generating Station. Southwestern Ontario is known for its subsurface geological formation capable of storing hydrogen energy (Lemieux et al., 2019). Southwestern Ontario has an extensive salt formation, named the Salina formation in the form of bedded rock salt. There are also several oil and gas reservoirs and deep saline aquifers that can potentially store a large amount of hydrogen energy (Armstrong & Carter, 2006). The proximity of the Bruce Nuclear Generating Station and the underlying geological formations provides an opportunity for the region to build a UHS facility. Figure 1 shows the extent of each potential UHS type and the location of the Bruce Nuclear Generating Station.

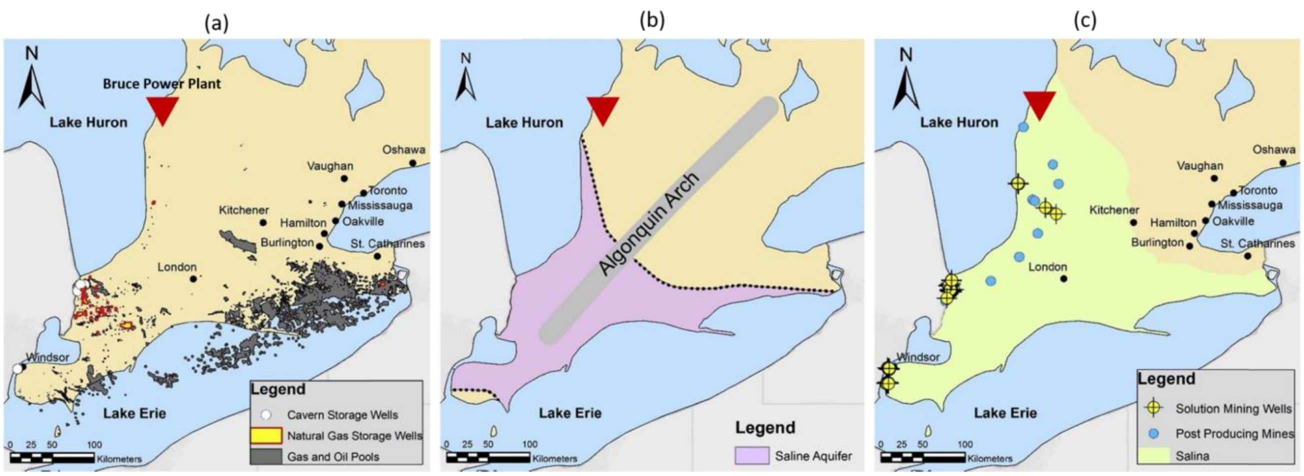

Figure 1. The extent of each potential UHS formation in southwestern Ontario and the location of Bruce Nuclear Generating Station. a) depleted oil/gas reservoirs, b) saline aquifer, c) salina formation and the salt mine locations. (Modified from Lemieux et al., 2019)

UHS storage capacity and costs

The storage capacity is an important factor in the techno-economic feasibility study. UHS capacity depends on a number of factors; including the porosity and the permeability of the geologic formation, and the temperature and the pressure at which the hydrogen is stored. Taking those factors into consideration, we estimated the storage capacity for each potential UHS type (salt caverns, saline aquifers, and depleted oil/gas reservoirs).

The cost of the storage facility is also an important factor. The cost estimation for the UHS facility includes the capital cost and the levelized cost. The capital cost is a one-time expenditure, which includes construction, equipment purchase, cushion gas, and potential site preparation. The levelized cost is the average net present cost over its lifetime (Chen et al., 2022). We estimated the storage cost for each potential UHS type (salt caverns, saline aquifers, and depleted oil/gas reservoirs).

Jurisdiction and safety issues regarding nuclear-generated hydrogen energy

In Canada, the Constitution Act (1867) explicitly recognized provinces and territories constitutional rights to manage their own non-renewable natural resources, forestry resources, and electrical energy which includes the power to levy mining taxes and royalties. The Federal Government on the other hand, derives their legislative authority from Section 91 of the Constitution Act (1867), with parliament having the exclusive authority to make laws with respect to regulating trade and commerce, raising money by any mode or system of taxation, etc. Jurisdiction over nuclear power, or any other aspect of nuclear regulation, is not spelled out in the Canadian Constitution. Instead, federal jurisdiction over various aspects of nuclear power has been found to reside in other powers set out in sections 91 and 92 of the Constitution Act (Constitution, 1867: Supra note 24). Aside from jurisdiction, the decision about whether or not to generate hydrogen from Bruce Nuclear Generation Station could also fall under provincial authority through the operation of s.92A of the Constitution Act (1867), which gives the provinces authority to manage its non-renewable natural resources. An activity like nuclear power development may have many aspects, some of which are federally regulated and some of which are provincially regulated (Law Society of British Columbia, 2001; Hodge v. The Queen, 1883).

In respect to safety issues, the Canadian Hydrogen Installation Code sets the installation requirement for hydrogen-generating equipment for non-process end use, hydrogen utilization equipment, hydrogen-dispensing equipment, hydrogen storage containers, hydrogen piping systems, and their related accessories all over Canada. In Ontario, where the storage of hydrogen produced from the Bruce Nuclear Generating Station will be carried out, the Technical Standards and Safety Act (2000) is responsible for enhancing public safety by providing the efficient and flexible administration of technical standards with respect to amusement devices, boilers and pressure vessels, elevating devices, fuels, and operating engineers. Although the codes and safety standards for hydrogen are well established by both federal and provincial governments, there is a policy gap of insufficient familiarity with the codes and safety standards among the regulatory agencies and jurisdictions. The fire code inspections, for instance, tend to vary dramatically across the province which can be addressed by having more workshops that invite participation from the fire protection industry and fire chiefs. This in the long run will establish a common framework for such inspections and approvals.

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