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Underground hydrogen storage in sedimentary and volcanic rock reservoirs: Foundational research and future challenges for New Zealand

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Novel technologies to store hydrogen in geological formations can substantially enhance New Zealand's renewable energy market and help mitigate climate change impacts. New Zealand already supplies about 80% of its electricity demands from renewable sources, mostly geothermal, hydro and wind power. However, over 60% of the country's net energy consumption still comes from fossil fuels. In New Zealand, extensive production and large-volume (>50,000,000 Nm^3) storage of green hydrogen will be essential to buffer diurnal and seasonal shortage of hydro and wind power generation in a future energy mix dominated by renewable sources. Geological storage, technology in use since the 1970's, is currently considered the best large-scale option for hydrogen storage globally.

Here we present preliminary results of an ongoing study into the feasibility of storing hydrogen in sedimentary and volcanic rocks across New Zealand. The country's varied geology and diverse cultural communities provide a unique setting to evaluate the technical capacity, socio-environmental aspirations, and costs-benefits of hydrogen geo-storage for future domestic and export markets. We draw our investigation upon a substantial legacy dataset of petroleum exploration drillholes and seismic reflection surveys coupled with information from sedimentary and volcanic outcrops to determine the most suitable geological formations for hosting large-volumes of hydrogen nationwide. Four possible types of hydrogen geo-storage are considered: (i) construction of artificial rock caves, (ii) injection of hydrogen into sedimentary rocks and aquifers, (iii) utilisation of depleted natural oil and gas reservoirs and infrastructure; and (iv) hydrogen storage in highly porous and permeable volcanic rocks, the last of which would be a world first.

New Zealand has an extensive installed petroleum infrastructure, including 2,500 km of high-pressure gas pipelines and 17,960 km of gas distribution network to support the development of new hydrogen energy enterprises. Multiple depleted or depleting petroleum fields (e.g. Ahuroa, Kapuni and Maui) contain excellent reservoirs and efficient seal rocks confined in large (>25 km^2) geological structures that offer scope for hydrogen storage. Porosity and permeability in

commercial reservoirs vary from 5 to 25% and often up to several thousand millidarcys (mD), respectively, with high values of up to 9900 mD reported in sandstones of the Maui field. Studies in volcanic reservoirs on Banks Peninsula, Oamaru and offshore Taranaki Basin demonstrate that large sections of volcanoes (up to 1 km^3) frequently have porosities of ca 50% and permeabilities above 100 mD, which may provide opportunities for storing hydrogen at relatively shallow (ca 100 m) depths.

Further technical assessment is ongoing to determine microbiological activity, chemical stability of rock targets, and geological modelling in hydrogen-rich reservoirs. This technical assessment will be complemented by community consultation to develop pathways for acceptance of hydrogen geo-storage in the country. Mātauranga Māori (native indigenous knowledge) has real potential to guide renewable energy investments towards a long-term vision that prioritises intergenerational well-being and prosperity for the wider New Zealand society. This convergence of thinking, integrating scientific knowledge, industry aspirations, and societal necessities will provide a novel approach for sustainable growth of the hydrogen industry in New Zealand and abroad.