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ENERGY TRANSITION

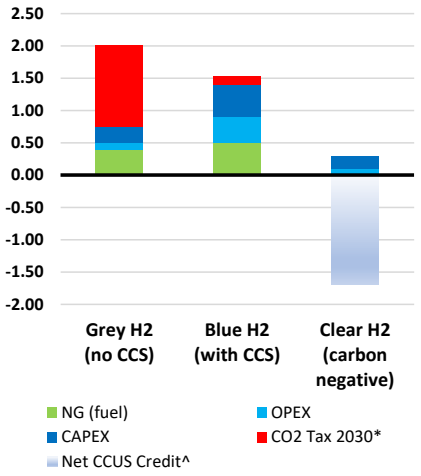
Is In-Situ "Clear H_2" the Ace in the Hole?

Inside every hydrocarbon reservoir is a (super cheap) clean hydrogen resource waiting to get out. Following up on our multi-sector, multi-energy, energy transition thematic note on Hydrogen published in December *Hydrogen (H2) - Energising The Future (2020)*, on April 19, 2021, we hosted private Canadian firm *Proton Technologies* in an insight discussion focused on *next-level* hydrogen opportunities. **Proton is developing in-situ hydrocarbon reservoir clean H_2 production technology that leaves unwanted emissions in the ground, and that can re-use mature / end of life / watered out oil/gas assets to make "*Clear H_2*" (clean H_2 from hydrocarbons)**. At scale, we believe this could be a game-changer in the clean H_2 space over coming decades, using infrastructure already in place (with sunk costs) and well understood oil/gas geology, drilling, production and reservoir engineering capabilities that can be re-focused on clean energy output rather than fossil energy volumes. By implication, most abandonment liabilities could represent a valuable *Clear H_2* opportunity for forward thinking asset owners.

In-situ *Clear H_2* could step-change support for the global push to decarbonise energy systems through electrification and the increasing use of all types of hydrogen as an energy vector across many sectors. In a modularised form, air and oxygen injection units retrofitted to current oil and gas developments, and reservoir driven downhole chemistry akin to surface SMR processes (but with no fuel costs) produce H_2, heat and other valuables. In separate well bores this H_2 can be separated downhole using membranes (currently being tested by Proton) and produced to surface as *Clear H_2*. There are potential synergies with the oxygen by-product of water electrolysis systems, implying that wind and solar supported Green H_2 volumes being developed by the renewable divisions of Integrated Energy companies, Utility names and electrolyser firms could also support the ramp up of Clear H_2 volumes. Moreover, the O_2 injection stream can also co-inject CO_2 volumes, thus providing for a sequestration opportunity, and the CO_2 can also be supportive of the downhole chemistry, further enhancing the *Clear H_2* output potential. Furthermore, applicable carbon credits (to sequester CO_2) could make the production of *Clear H_2* a highly profitable business even before selling or using the clean H_2 itself.

In our view - everyone with current oil/gas assets, and anyone looking at clean H_2 (of all colours) **and MT/LT decarbonised energy systems should be interested in hearing about what Proton is doing**. It is like "wheels on a suitcase" - a truly intelligent solution that seems so simple that we kick ourselves saying '*we should have done this years ago*'. We know that for climate change and clean air targets to be met, the surface combustion of hydrocarbons must cease over time and clean energy systems need to be progressed. The sub-surface, in-situ oxidation of hydrocarbons to produce low-cost, clean energy in the form of *Clear H_2* (via eg Proton IP) has the potential to provide a significant carbon negative support and deserves investigation. **Is this an Ace in the Hole for global clean energy solutions? In our opinion, it could well be.**

Estimated Net Cost of Grey, Blue & scaled up Clear H_2 2030e (US$/kg)*



* Chart shows estimated costs in US$/kg 2030e and assumes C$170/t CO_2 tax (Canada Federal Gov't proposal - tbc) which at 9.3kgCO_2/kgH_2 adds C$1.58/kg tax (+US$1.26/kg) if emitted by industrial processes in Canada (including Grey H_2 production). Blue H2 - CCS assumes 90% CO_2 capture. Clear H2 assumed to have no fuel cost in scaled up process by 2030e (liquid O_2 expansion supports injection stream, and H2 output (small proportion) supports energy to make liquid O_2). Modularised liquid O_2 possible at US$33/t based on COSIA analysis.

^ Assumed carbon credit if Proton paid C$100/t to co-inject & sequester someone else's CO_2 with Proton's oxygen injection stream at 25ktCO_2 per (12ktO_2 used to generate) 1kgH_2 (or -C$2.5/kg, -US$2.0/kg). This assumes no net system capital difference.

Source: Proton Technologies, Canada Federal Gov't and COSIA,

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There are no recommendation or TP changes in this report for our large cap integrated energy coverage

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