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Hydrogen: The Revival

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Summary

Alberta has provided Canada and the US with a cheap and convenient energy source since before the completion of the transcontinental railway in 1885. This energy varied over time, but the one constant was the fact that it came from western Canada. Coal resources provided the fuel for CPR trains bringing in immigrants enabling the settlement of western Canada. Subsequently, in 1947, the Leduc #1 discovery transformed Alberta into the richest province in the country. Alberta crude production enabled Canada to become energy self-sufficient with a decade. In 1957 in Ft. St. John, a gas plant bigger than all 11 existing plants combined, opened the natural gas energy industry in BC and Alberta. Is there another energy shift in the making…?

Hydrogen is an energy carrier just like hydrocarbons, except, unlike hydrocarbons, when hydrogen energy is captured using a polymer electrolyte membrane (PEM) fuel cell, only water vapour is released, not CO_2. This of course, is the appeal to society and a tool to abate the global warming dilemma that we are currently experiencing. And Alberta can, yet again, be the provider of this fuel to the continent, and abroad, if we act now.

Hydrogen can be created through several processes (see Table 1), the most common is through Steam Methane Reforming (SMR). In this process, natural gas is heated in the presence of a nickel catalyst that yields pure hydrogen and CO2. If the CO2 is emitted into the atmospehere, the hydrogen is classified as grey hydrogen. If the hydrogen is captured and sequestered (either in subsurface reservoirs and through carbonization) it is classified as blue hydrogen. The second most common method to produce hydrogen is from coal, known as gasification. At high temperature and pressure, coal is mixed with water vapour and oxygen yielding synthetic gas (syngas) which can then be separated into hydrogen, carbon monoxide, carbon dioxide, and methane. Finally, hydrogen can be produced via electrolysis (running an electric current through water) which breaks water molecules into hydrogen and oxygen. This hydrogen is classified as green hydrogen.

Table 1 – Hydrogen Production Methods			
Method	Process	Advantages	Disadvantages
Steam Methane Reforming (SMR)	In presence of nickel catalyst & at 700 – 1100 °C: $CH_{4(g)} + H_2O_{(g)} \rightarrow CO_{(g)} + 3H_{2(g)}$ Next reaction at lower temperature: $CO_{(g)} + H_2O_{(g)} \rightarrow CO_{2(g)} + H_{2(g)}$	75+% efficiency, inexpensive, proven reliability, CO2 can be captured and sequestered, scalable	Geography specific, non-renewable
Gasification (hydrogen from coal)	At high temperature and pressure: Coal + $H_2O_{(g)} + O_{2(g)} \rightarrow$ syngas Syngas = $H_2 + CO + CO_2 + CH_4$	Large supplies of coal	Produces CO2 where capture costs are uneconomic, environmental implications associated with mining operations
Electrolysis	Electric current passed through water: $2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)}$	No direct emissions, scalable	Energy input exceeds energy output, expensive, unpredictable when created using renewable energy, indirect emissions

Uses and Timing

Hydrogen is currently primarily used in the petrochemical and fertilizer industry. Over 95% of this hydrogen is grey hydrogen (CO2 is released into the atmosphere). Given the current and anticipating increasing carbon emissions costs (carbon credit system, Clean Fuel Standard, and carbon tax) we anticipate a dramatic switch to blue hydrogen.

Additionally, hydrogen is currently used in the transportation sector. California has over 80 hydrogen fueling station available for hydrogen fuel cell electric vehicles (HFCEV) to refuel. In HFEV, The PEM allows only the hydrogen ions to pass through to the cathode where these ions react with oxygen to produce water. The electrons travel down a circuit creating an electrical current. The fuel cells are arranged in stacks in order to provide enough electricity to power a vehicle. The use of a fuel cell eliminates the nitrous oxide emissions. Furthermore, the fuel cell is 45-60% efficient (compared to up to 40% for internal combustion engines (ICE).