Blue Hydrogen and CO_2 Enhanced Geothermal Energy - A CCUS Concept for The Transformation of Hydrocarbon Based Economies

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Abstract

Following the Paris Accord carbon neutrality is targeted for 2050 by most nations. Emission from fossil energy sources must be reduced despite abundant hydrocarbon reserves. Yet, the world requires energy beyond what can be provided in that time frame by alternative energies. Furthermore, societies depending on the production of fossil energy sources can ill afford losing revenue from its sale. In view of this contradiction the objective of this paper is to provide a CCUS concept for Arabian hydrocarbon producers aiming for a transformation of energy production towards achieving carbon neutrality without stranding energy assets.

The concept is based on a circular economy approach. The loop starts with CO2 capture at industrial point sources. The captured CO2 is injected into geological reservoirs at depth. The combination of world-class reservoirs and seals (e.g. Sudair Fm., Hith Anhydrite, Nahr Umr Shale, etc.) found over vast areas of the Arabian Peninsula indicates that potential storage sites with minimum leakage risks are abundant. Known temperature/depth gradients over the Arabian Peninsula (>32-35°C) are sufficient for low-enthalpy geothermal exploitation starting from 2.5 km depth. Stored CO2 utilized as a medium for geothermal energy extraction offers a factor two efficiency increase compared to water with potential additional benefits in minimizing operational issues associated with brine circulation. CO2-based geothermal energy extraction can provide electricity for domestic use and heat energy for desalination and district cooling. The final key component is the generation of blue hydrogen/ammonia fuels from hydrocarbons for export and domestic consumptions. This step ensures continued income from hydrocarbon sources through the export of blue hydrogen to energy consumers. The capture of the CO2 generated by this process and its storage for geothermal energy utilization closes the loop. At a later stage, when hydrocarbon reservoirs are nearing depletion, CO2 from storage reservoirs can be used for large scale EOR to further improve recovery.

A techno-economic evaluation of this concept has been conducted based on a large carbonate reservoir in a typical Middle Eastern 4-way anticlinal dip structure of 10km by 20km size with a crestal depth of 3200m. Our simulation results show that CO2 captured from converting ~600,000 bbl/d of hydrocarbons to an equivalent of ~4 Mt/year production of blue H2 can be injected by a total of 216 injectors, resulting in cumulative sequestration of ~1.1 gigatons (Gt) of CO2 over 11 years. To manage critical pore pressures at the injection well region and ensure sufficient CO2 saturation at the production well region to avoid water coning, phased and pressure-controlled injection and production wells are essential, necessitating careful drilling and production schedule. Utilizing horizontal production wells (n=64) results in an average geothermal net electricity generation of 164 MW. The base-case economic analysis reveals a Levelized Cost of Electricity (LCOE) of 77 $/MWh and a Net Present Value (NPV) of 480 million USD over 50 years at a high-capacity factor.

The results demonstrate that this CCUS concept is promising to provide a way for energy production from hydrocarbons without CO2 emission, continued revenue for HC asset holders through electricity production and blue hydrogen sales and energy security for consumers.