Deep Dive into the RECYCLE Technology

In the search for sustainable energy solutions, the RECYCLE (REthinking low Carbon hYdrogen production by Chemical Looping rEforming) project aims to contribute by producing low carbon hydrogen through chemical looping reforming. This innovative technology aims to help reduce greenhouse gas emissions across various industries, including refineries, chemical production, and iron and steel manufacturing. This article aims to explain the science behind the unique RECYCLE technology, exploring the challenges and opportunities encountered, and provide an overview of its future potential. The RECYCLE project is part of the Low Carbon Hydrogen Supply 2 competition, funded by the Department for Energy Security and Net Zero under the Net Zero Innovation Portfolio.

RECYCLE uses a three-step chemical looping reforming process with fixed bed reactors. This approach enables the efficient generation of syngas while providing the energy for the reforming with near zero emissions. At the core of this technology is a specially designed metal oxide, known as an oxygen carrier material. When exposed to air, this material oxidises, producing pure nitrogen. The metal oxide then undergoes a reduction process with fuel, resulting in an unmixed combustion reaction that naturally concentrates and produces high-purity carbon dioxide.

The RECYCLE technology is both modular and adaptable, capable of functioning on various scales with different feedstocks. Syngas, a vital chemical used in numerous energy applications – including hydrogen, ammonia, methanol, and liquid fuels – can be generated with minimal greenhouse gas emissions. The technology can also operate at different pressures and can feature intermittent operation thus resulting in an alternative energy storage device.

Figure 1: First skids of the rig have been manufactured

Unlike other processes, the RECYCLE technology does not require additional carbon dioxide capture processes based on solvents, which are often expensive in terms of both capital and operational expenditures. The oxygen carrier materials also function as an oxygen separator, eliminating the need for a cryogenic air separation unit. Additionally, the reactors used for syngas generation do not rely on external energy sources like fired heaters or furnaces, despite being exposed to cyclic operations and high temperature switching valves. These innovations result in a more cost-effective, efficient technology with ultra-low carbon dioxide emissions, made possible by the innovative materials developed by Johnson Matthey.

Figure 2: Chemical looping reactors manufactured by Helical Energy

The RECYCLE technology has successfully been demonstrated under simulated conditions at laboratory scale at the University of Manchester. Currently, a new demonstration plant is being constructed by Helical Energy, with the goal of achieving a consolidated Technology Readiness Level 6 (TRL6) by the project's end. This plant will continuously produce 0.8 kg/h of hydrogen and 7 kg/h of pure carbon dioxide from natural gas. The demonstration plant includes not only the syngas generation unit but also a Water Gas Shift Reactor (WGSR) and a Pressure Swing Adsorption (PSA) system. Additionally, the project is expanding research into industrial applications, exploring potential market opportunities, and conducting large-scale reactor design and techno-economic analysis in collaboration with TotalEnergies and KENT plc.

The RECYCLE project has encountered several challenges, primarily related to the complexity of the demonstration plant. Sourcing the necessary instrumentation and process components proved difficult, as the plant's scale is too large for typical lab equipment but too small for the industrial-sized units that would mitigate these supply chain issues. However, by collaborating with multiple suppliers and leveraging the expertise of teams at Manchester and Helical Energy, the project successfully overcame these obstacles.

The immediate goal of the RECYCLE project is to complete the demonstration plant and commission all its modules. Once this is achieved, the project will enter the demonstration phase, where high performance is anticipated. If successful, the next step will involve pre-commercial scale testing in industrial settings, in partnership with end-users who require hydrogen or low-carbon syngas to decarbonise their processes. The technology has potential applications in various industries, including chemical production and the generation of high-temperature heat for glass, ceramic, and metal industries. Looking ahead, the continued development and potential integration of RECYCLE technology into these sectors could play a critical role in advancing global decarbonisation efforts.