Demonstrating E-fuel production in a Power-to-X plant via the rWGS-FT Pathway

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Highlights

- Bench-scale rWGS process coupled to FT with recycle has been developed
- rWGS showed good stability at high CO productivity of 300 $mmol/cm^3_{cat}$*h at close to equilibrium gas composition
- Successful operation of a Power-to-X demonstration plant involving CO_2 capture, solid oxide electrolysis and synthesis

1. Introduction

EU has implemented a sustainable aviation fuel (SAF) blending mandate specifying minimum synthetic fuels share of 1.2% by 2030, which increases to 35% by 2050 [1]. Achieving such ambitious targets necessitates the high-volume production of electrofuels. The catalytic reverse water-gas shift (rWGS) process emerges as a promising approach for high volume carbon dioxide (CO_2) valorization into chemicals and fuels and the integration of rWGS with Fischer-Tropsch (FT) synthesis offers a viable route for sustainable fuel production. In the Business Finland funded E-Fuel project [2], a Power-to-X plant, incorporating high-temperature electrolysis, carbon capture, and two-stage synthesis, has been successfully demonstrated at a pre-commercial scale. This presentation outlines our comprehensive efforts in developing the coupled rWGS-FT process, encompassing standalone tests and reaching culmination in the demonstration plant.

2. Methods

A tubular CPOx (catalytic partial oxidation)/rWGS reactor was constructed, consisting of an in-house prepared noble-metal catalyst coated on FeCrAl monoliths, and was heated through oxygen-fed combustion. The process was coupled to a low temperature FT process, including ability to recirculate FT off-gases to the CPOx/rWGS stage for enhanced process efficiency. One of the main CPOx/rWGS process development milestones involved prolonged testing (300 h), encompassing both once-through and recycle modes in order to assess the stability of the process and catalyst.

The E-Fuel project power-to-X demonstration at VTT Bioruukki, Espoo Finland, consisted of a Convion solid-oxide electrolysis unit with Elcogen stacks providing the hydrogen to synthesis, and a carbon dioxide recovery unit from Carbon Reuse Finland and Andritz providing CO_2 derived from flue gas. The synthesis process was first operated with bottled gases before coupling of all units was complete for extended duration testing and FT crude production.

3. Results and discussion

Standalone CPOx/rWGS tests: The extended duration performance of the CPOx/rWGS process in both once-through and recycle modes (20 % of FT off-gas directed to CPOx/rWGS) was assessed under high throughput conditions of SV 40 000 – 50 000 1/h and reactor temperatures of 800-820 °C. The recycle mode demonstrated enhanced CO productivities of 10 % compared to once-thorugh operation, and increasing the CO productivity to 22 ndm^3/min with a fresh CO_2 feed of 38 ndm^3/min. The FT process yielded off-gas containing hydrocarbons up to C5-C6 and the CPOx/rWGS outlet gas analysis showed high conversion of these C2+ hydrocarbons. The once-through productivity remained stable, although a minor decrease (below 5 %) was observed in the recycle mode. Both tests exhibited an increase in CO selectivity favoring CH_4, signifying a departure from the equilibrium gas composition

Power-to-X demonstration: The demonstration plant comprised six distinct units, encompassing flue gas and steam generation, solid oxide electrolysis, CO_2 capture, gas compression and synthesis. These units were eventually coupled to enable continuous operation. The realized configuration is depicted in Figure 1.

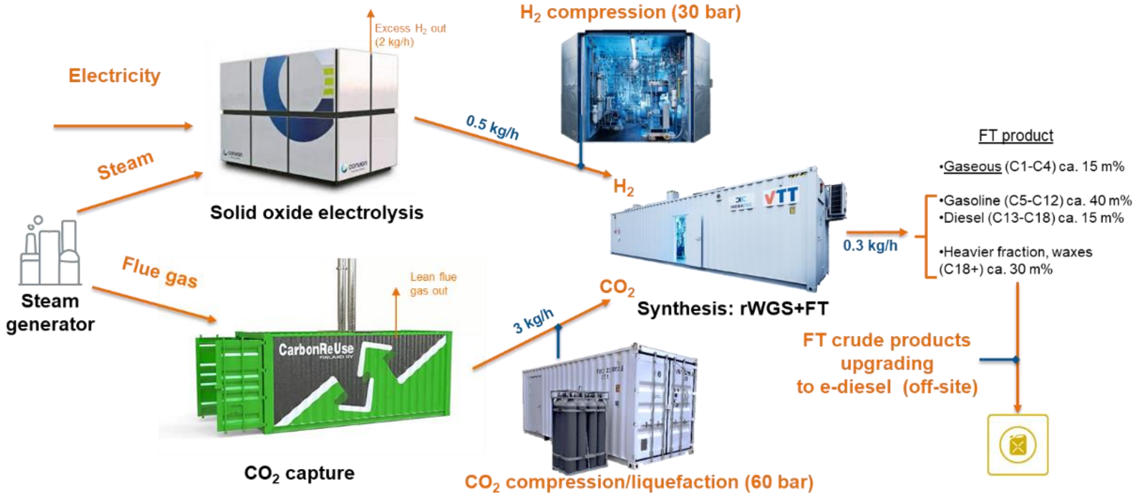

Figure 1. Realized E-Fuel production plant configuration.

Over the entire operational duration of 1100 hours, which includes both bottled gas operation and process gas operation, 300 kilograms of FT crude were produced. The product was collected in the form of an oil phase (45% by mass) and a solid wax phase (55% by mass), maintaining a stable ASF-alfa of 0.87. During the period when the plant operated with process gases (up to 500 hours), both the CPOx/rWGS and FT productivities experienced a slight reduction by a few percentages, attributed to the dilution effect of N_2 in the feed process gases. In a reference test for the CPOx/rWGS conducted before and after the demonstration the specific activity exhibited a minimal < 2% relative difference, underscoring the robustness and reliability of the catalyst.

4. Conclusions

Results from the CPOx/rWGS tests indicated stable operation in once-through mode, achieving high specific productivities of 300 mmolCO/cm^3_{cat}*h, closely aligning with equilibrium gas composition. However, some deactivation was observed in recycle mode, potentially attributed to catalyst/reactor coking. Finally, a complete e-fuel demonstration plant was successfully operated, yielding 300 kg of FT crude. The synthesis process, powered by real electrolysis-derived H_2 and flue gas-derived CO_2, demonstrated comparable productivities and product selectivities to those obtained using bottled gases. This successful demonstration underscores the technical feasibility of the integrated process for sustainable fuel production.

References

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Keywords
rWGS;e-fuel;demonstration;power-to-X