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Analysis of Electroless Coupled Exchange Reduction Oxidation Technology

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Building and Transportation Sciences Division

VERIFICATION OF THERMODYNAMIC CONSERVATION IN THE EXERO: H2GEN REACTOR

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SUMMARY

Utility Global Inc. (UG) is leading the development of a novel 'electroless X: coupled exchange reduction oxidation' (eXERO) technology towards enabling a circular carbon economy. Feedstock for eXERO technology includes renewable natural gas, effluent gases from production streams of steel, refineries or biogas, and carbon-rich solid waste such as biomass. Operated in H2Gen™ (h2G) mode, enriched carbon dioxide (CO_2) and high-purity hydrogen (H_2) can be produced without added electric power. Product CO_2 can be used to operate eXERO in CO-Gen™ (COGen) mode to execute the water gas shift reaction across a ceramic membrane to produce green carbon monoxide (CO) and water vapor (H_2O) as a harmless by-product. The electrochemical equivalence in COGen mode provides 1:1 molar conversion of excess H_2 in feedstock to green CO without added electric power. Low-cost ammonia (NH_3) can be cracked by steam without added electric power to convert NH_3 to nitrogen (N_2), H_2O, and high-purity H_2 as a product stream by running eXERO in Am2H2 mode. Experimental runs of eXERO in H2Gen mode have been conducted over the past four years. In this study, ORNL examined recently conducted experiments in the year 2023 and large-scale pilot runs conducted in the year 2022.

Oak Ridge National Laboratory (ORNL) and Utility Global Inc. (UG) agreed to enter into a strategic partnership under contract NFE-23-09559. A document with summarized measurements and predictions was provided to Oak Ridge National Laboratory (ORNL) for independent verification of first- and second-law conservation.

The key objective of this project is to conduct an independent analysis of UG's eXERO technology. Additionally, ORNL will perform 3D multiphysics modelling of the cell to understand and optimize the key operating parameters in generating 99.9+% pure hydrogen. The first objective of this work is to conduct first and second law analysis of the eXERO technology and independently verify the measured performance data, provided by UG.

Based on ORNL's analysis, we conclude the following. Detail justification and analysis is provided in the Report (ORNL/SPR-2023/3012):

- ORNL's first and second law analysis are in line with UG's calculations, leading to the conclusion that the eXERO technology is viable.
- Based on estimated energy balances and measured mass balances, the eXERO process demonstrates theoretical sustainability when process waste heat and valuable products are re-utilized within the H2Gen™ process boundary.
- Independent assessments align with UG's scientific approach including assumptions, general physics, fundamental equations, and models, etc.
- Pilot demonstrations of the eXERO technology have presented themselves as successful at being technologically viable.
- ORNL further concludes that the core technology within eXERO utilizes current reliable ceramic fuel cell developments and the eXERO technology has the capability to positively impact the hydrogen economy.

All ORNL predictions of H_2 yield were within 7% of the values reported by UG, as can be inferred from Figure 1. Red error bars indicate a range of $\pm$5% of the UG value. Similarly, an independent estimate of the volumetric proportions of H2 at the cathode outlet determined the volume percentage of hydrogen for run 14-11 as 36.81%. This is in excellent agreement with the reported value of 36.9% calculated based on UG's 'water-weight test'.

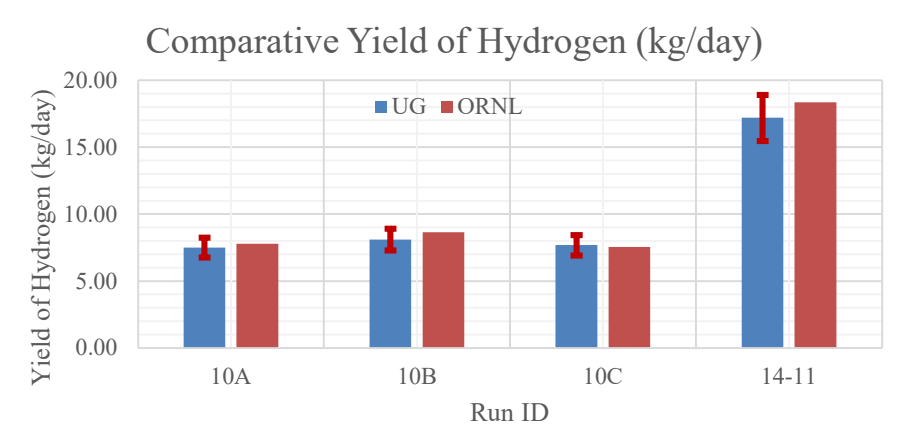

Figure 1. Comparative yield predictions of H_2 at the cathode outlet.