

# Analysis of Electroless Coupled Exchange Reduction Oxidation Technology

Praveen K Cheekatamarla  
Vivek M Rao  
Nathan D See

**August 2023**



## DOCUMENT AVAILABILITY

Reports produced after January 1, 1996, are generally available free via OSTI.GOV.

**Website** [www.osti.gov](http://www.osti.gov)

Reports produced before January 1, 1996, may be purchased by members of the public from the following source:

National Technical Information Service  
5285 Port Royal Road  
Springfield, VA 22161  
**Telephone** 703-605-6000 (1-800-553-6847)  
**TDD** 703-487-4639  
**Fax** 703-605-6900  
**E-mail** [info@ntis.gov](mailto:info@ntis.gov)  
**Website** <http://classic.ntis.gov/>

Reports are available to US Department of Energy (DOE) employees, DOE contractors, Energy Technology Data Exchange representatives, and International Nuclear Information System representatives from the following source:

Office of Scientific and Technical Information  
PO Box 62  
Oak Ridge, TN 37831  
**Telephone** 865-576-8401  
**Fax** 865-576-5728  
**E-mail** [reports@osti.gov](mailto:reports@osti.gov)  
**Website** <https://www.osti.gov/>

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Building and Transportation Sciences Division

**VERIFICATION OF THERMODYNAMIC CONSERVATION IN THE EXERO: H2GEN  
REACTOR**

Praveen K Cheekatamarla  
Vivek M Rao  
Nathan D See

August 2023

Prepared by  
OAK RIDGE NATIONAL LABORATORY  
Oak Ridge, TN 37831  
managed by  
UT-BATTELLE LLC  
for the  
US DEPARTMENT OF ENERGY  
under contract DE-AC05-00OR22725

## 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<sub>2</sub>) and high-purity hydrogen (H<sub>2</sub>) can be produced without added electric power. Product CO<sub>2</sub> 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<sub>2</sub>O) as a harmless by-product. The electrochemical equivalence in COGen mode provides 1:1 molar conversion of excess H<sub>2</sub> in feedstock to green CO without added electric power. Low-cost ammonia (NH<sub>3</sub>) can be cracked by steam without added electric power to convert NH<sub>3</sub> to nitrogen (N<sub>2</sub>), H<sub>2</sub>O, and high-purity H<sub>2</sub> 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<sub>2</sub> 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 H<sub>2</sub> 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’.

---

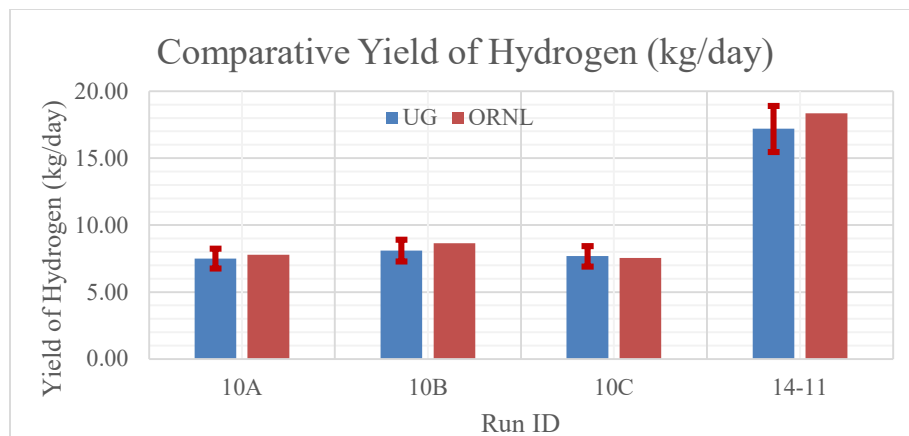


Figure 1. Comparative yield predictions of  $H_2$  at the cathode outlet.