SCALED-UP USAGE OF SOLID-OXIDE ELECTROLYSIS CELL (SOEC) TECHNOLOGY FOR PRODUCTION OF ROCKET FUEL ON THE MOON BASED ON EXPERIMENTALLY BENCHMARKED MODELS. D. C. Dickson[1], G. F. Sowers[1], C. B. Dreyer[1], G. Jackson[1], J.J. Hartvigsen[2], M. Hollist[2], [1]Colorado School of Mines (1500 W Illinois St, Golden, CO 80401, ddickson@mines.edu), [2]OxEon Energy LLC, 257 River Bend Way, Suite 300, North Salt Lake, UT, 84054.

Introduction: Solid-oxide electrolysis cell technology, as developed by OxEon LLC for lunar application in partnership with the Colorado School of Mines, stands to stands to surpass incumbent space-based water electrolysis technologies such as alkaline and proton-electrolyte membrane (PEM). [1] As shown in recent experimental work, the process stands to be potentially more efficient in energy expended per kilogram of hydrogen produced, due to the higher levels of voltage allowed for driving current and heating water inputs. Additionally, due to the absence of phase change in the electrolysis process itself, in addition to the production of dry O2 and humid H2, energy requirements for liquefaction are lower than in the previous two processes. Previous experimental and modeling work funded by NASA on SOEC lunar water-based fuel production systems has demonstrated the potential for achieving this low specific energy consumption, with the technology readiness level (TRL) of this technology advanced to 5.

To this end, this poster shows the results of a high-fidelity thermophysical model of a scaled-up, industrial SOEC fuel production system, based on benchmarking performed by previous experimental and modeling work. [2,3] Although rough preliminary modeling work has been completed to verify the economic concept of lunar fuel production at the scale of over 250 times the scale of production achieved in the lab4, it has not been performed on a high-fidelity thermophysical level. Moreover, although high-fidelity thermophysical modeling has been performed to benchmark lab-scale production of H2, at a rate of ~2 kgH2/day, it has not been performed to support industrial-scale ISRU of this type. We expect this work to be a major support for the ISRU of lunar water in the coming years.

The team has undergone redesign of the stack and balance-of-plant and used our updated/benchmarked simulation models to perform advance work for this upcoming technology development push, as well as detailed architecture studies for scaled-up demonstration of this technology on the Moon.

Figures 1 thru 4 show system operation using the simulation models for SOEC stack operation for scaled-up, compressor-less operation based on experimental-data benchmarking. It is evident that in scaled-up operation for a SOEC stack and balance of plant simply using the same size OxEon stack used in the previous experiments, assuming thermoneutral stack performance, specific energy consumption is less efficient as system H_2 production increases. This indicates steam generators, recuperators, O_2 coolers, and H_2 dryers in Fig. 1 above will have to be optimized, and their architecture in a 160-ton-per-year-plus H_2 production system redesigned, in order to achieve both the H_2 production values desired, and the energy efficiency levels of 50 kWh/kg_{H2} required.

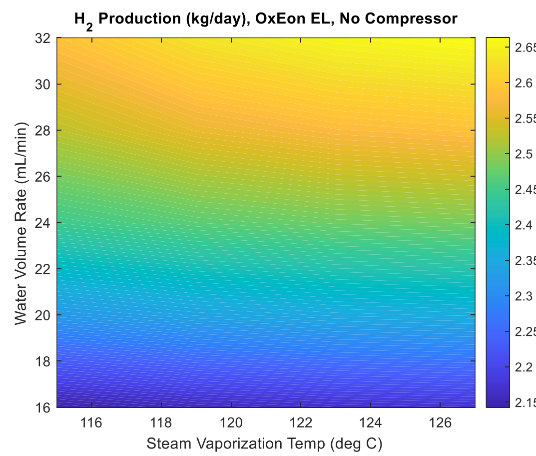

Figure 1. Benchmarked model showing H_2 production, assuming thermoneutral SOEC stack operation.

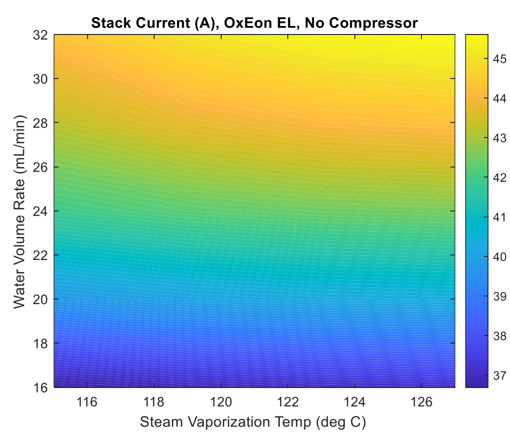

Figure 2. Benchmarked model showing stack current, assuming thermoneutral SOEC stack operation.

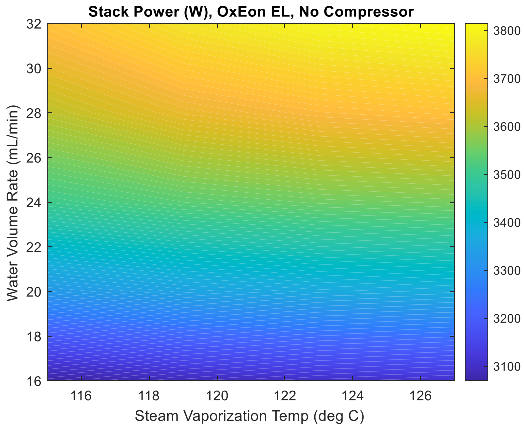

Figure 3. Benchmarked model showing stack power, assuming thermoneutral SOEC stack operation.

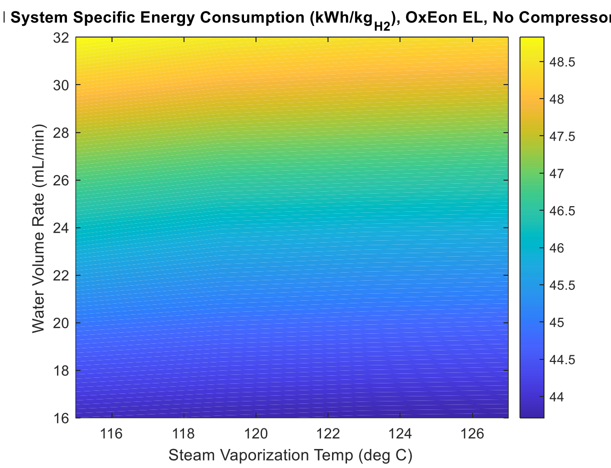

Figure 4. Benchmarked model showing system specific energy per kg H_2 produced, assuming thermoneutral SOEC stack operation.

As such, ongoing work is underway to redesign and optimize that balance-of-plant architecture. The team is accordingly cycling through a set of architectures for said balance of plant, sizing and numbering said balance-of-plant components to that end.

References: [1] Schmidt O. et al. (2017), *IJHE*, 42(52), 30470-92. [2] Dickson D. et al. (2021), *IEEE Aerospace.* [3] Dickson D. et al. (2023) *ECS Transactions, 111(6), 925.*