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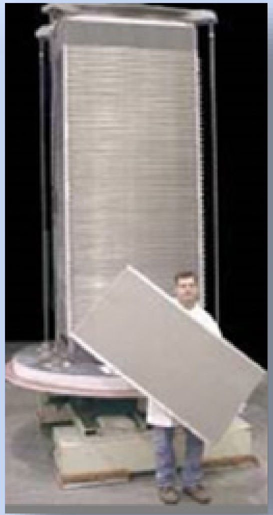
Advancing High-Temperature Steam Electrolysis: Optimizing LCOH at Multi-MW Scale

Industry Reports –Solid Oxide Electrolysis and High Temperature Steam Electrolyzer - Technology Vendor Status

Presentation for the Idaho National Lab
Light Water Reactor Sustainability

Flexible Plant Operation and Generation Pathway
Stakeholder Engagement Meeting

FuelCell Energy Carbonate Technology



400-cell fuel cell stack package

Four-stack module
1.4MW

1.4 MW net power
47% electrical efficiency
up to 90% total efficiency

2.8 MW net power
47% electrical efficiency
up to 90% total efficiency

Tri-generation
2.35 MW net power
1,270 kg/day hydrogen
1,400 gal/day water

Carbon Recovery
1.3-1.8 MW power
20+ Mt/day CO_2

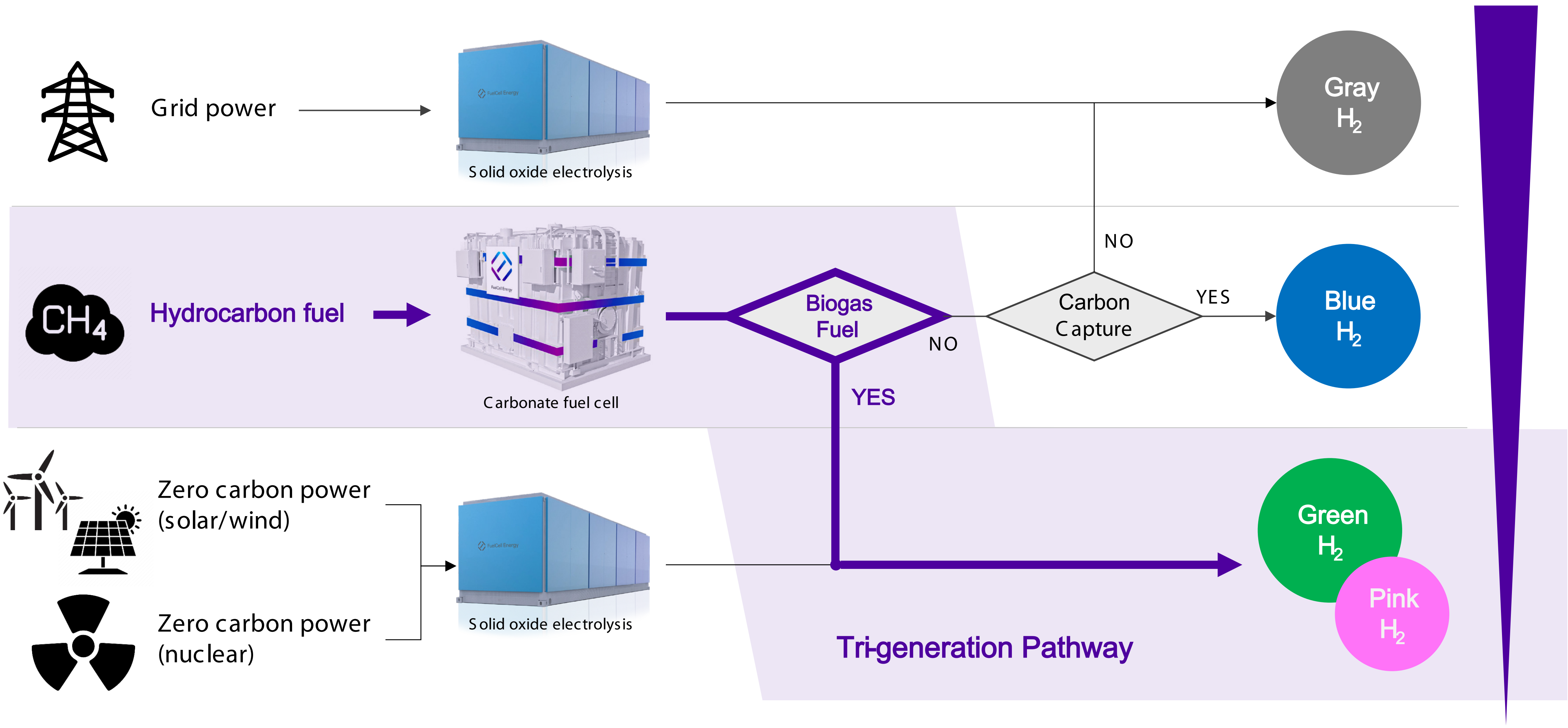
11 MW

15 MW

59 MW

Large-scale fuel cell parks

Potential hydrogen pathways



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INL Demonstration System

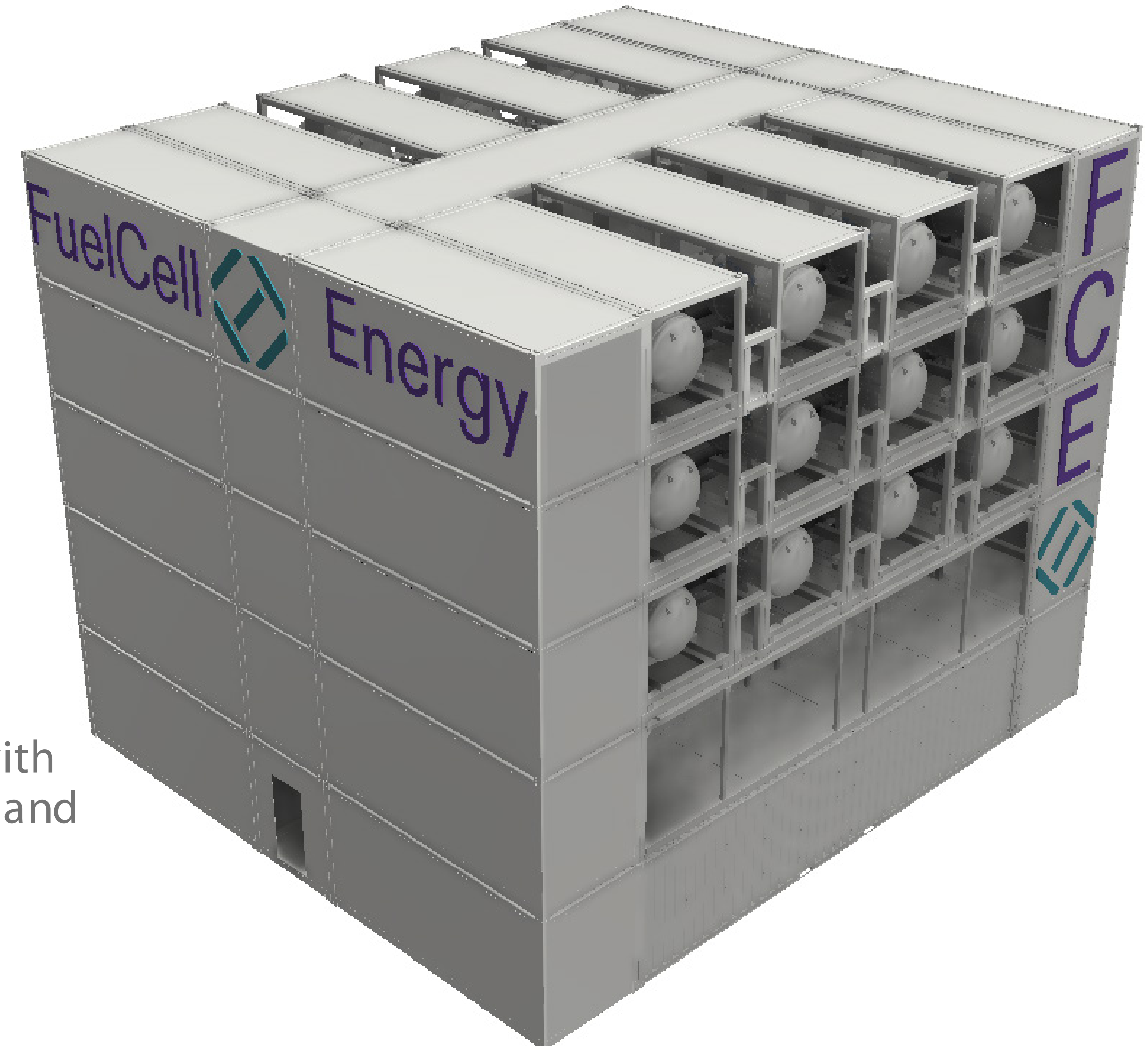
- 250 kW SOEC Demonstration Unit
  - Currently Installed at INL
  - 2000-hour demonstration test
    - Projected Industry Leading Efficiency
      - <45 kWh/kg

- Multi-MW Technology Scaleup
  - 20% reduction in LCOH from PEM
  - Stack Manufacturing Expansion
  - Common Compact Stack Architecture

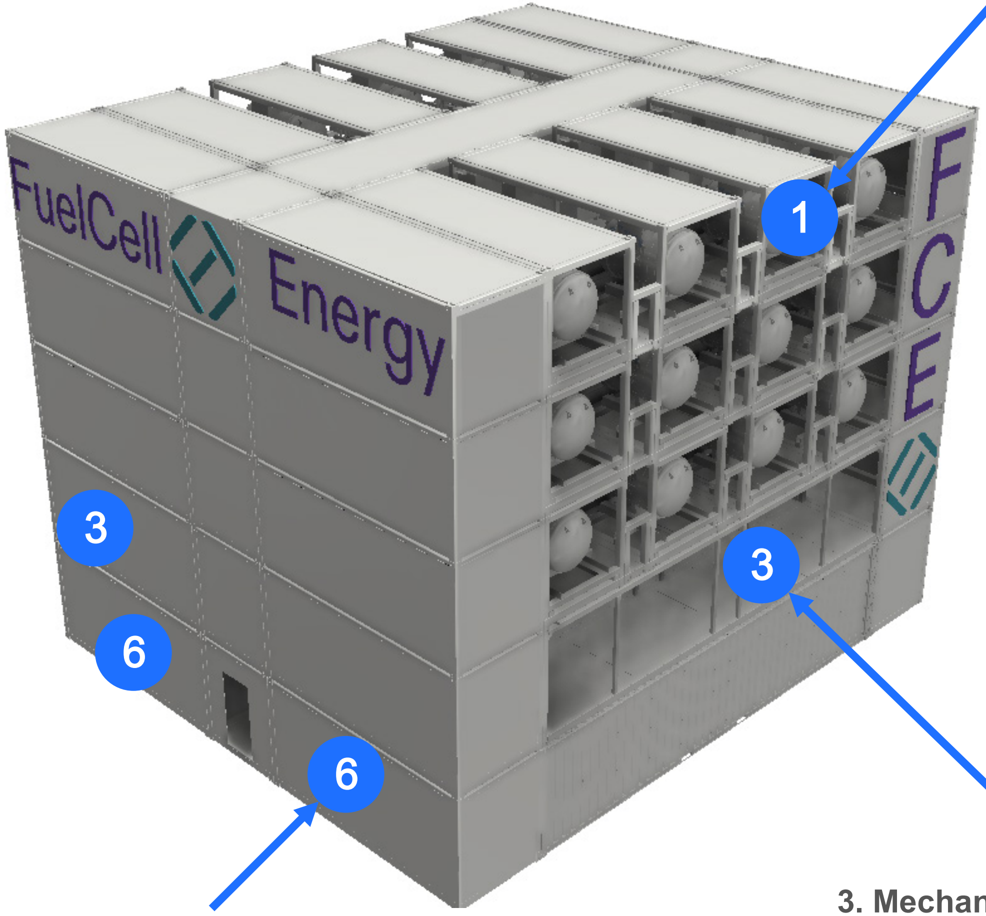
Market Assessment

- Target Markets –Industry Integration
  - Ammonia Production
  - Direct Reduced Iron
  - Sustainable Aviation Fuel
  - Synthetic Diesel Fuel

- Multi-MW Scale Approach
  - Leverage Proven Stack Design
  - Expand to Repeatable Module Units
  - Balance of Plant Design for multi-MW system with hot swapable module design, focusing on LCOH and serviceability from ground up

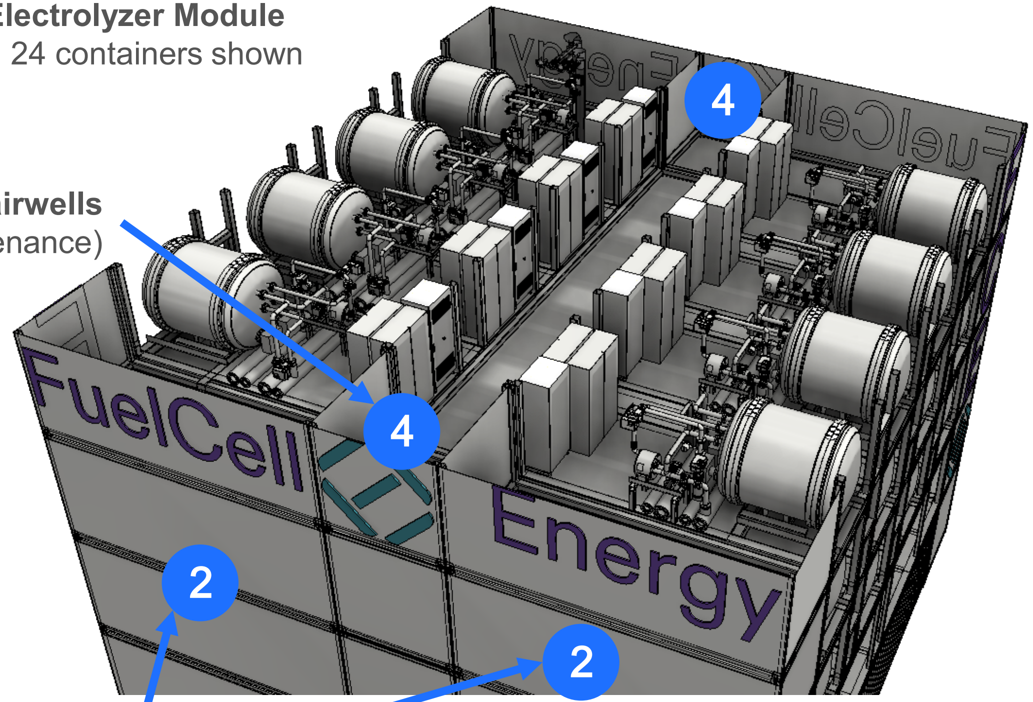


6 Ton/Day SOEC H2 Arrangement (½ "Cluster")



1. SOEC SubMW Electrolyzer Module
1 Per 20' Container, 24 containers shown

4. Access stairwells
(operations & maintenance)



2. Pipe & cable risers

6. Electrical Balance of Plant
(e.g., rectifiers, switchboards)
2 per tower
Each pair feeds 12 MRU's

3. Mechanical Balance of Plant
(e.g., boilers, blowers)
2 per tower
Each pair feeds 12 MRU's

6 TPD hydrogen production

0.5 Bar outlet pressure @ 99% H_2 quality (dry basis)
Note: Compression, purification, water treatment and cooling systems not shown

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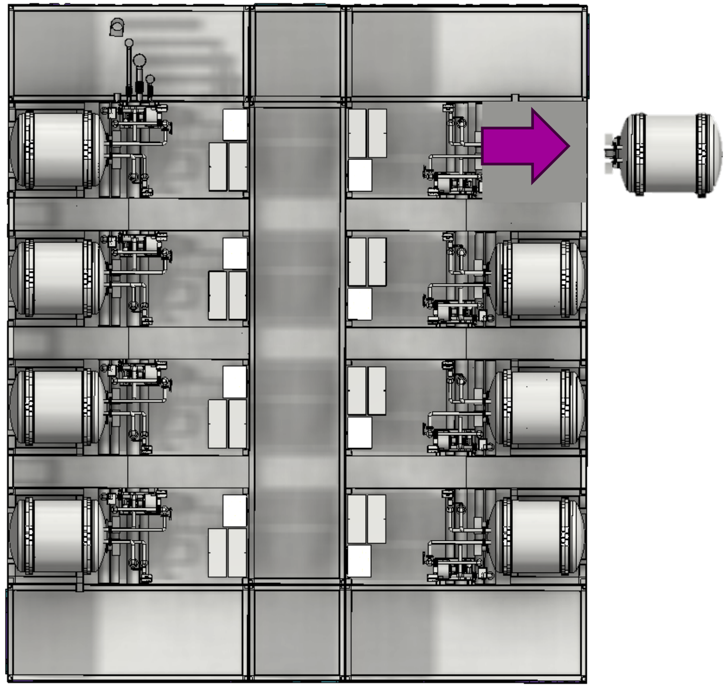
Module Replacement

- All process and electrical connections accessible from the front of the module (inside the MRU)
- All process connections are bolted
- All LV connections to be connector-style (cannon or similar)
- DC cables to be easily disconnected (connector or otherwise)
- Module pulled out of MRU structure
- Aerial bundle extractor to be utilized above 3rd level



Target Price

Objective: 10-20% lower LCOH vs PEM

***Base Project (Plant)** 2030, 25 MW, 30 bar H2, 99.9% H2*

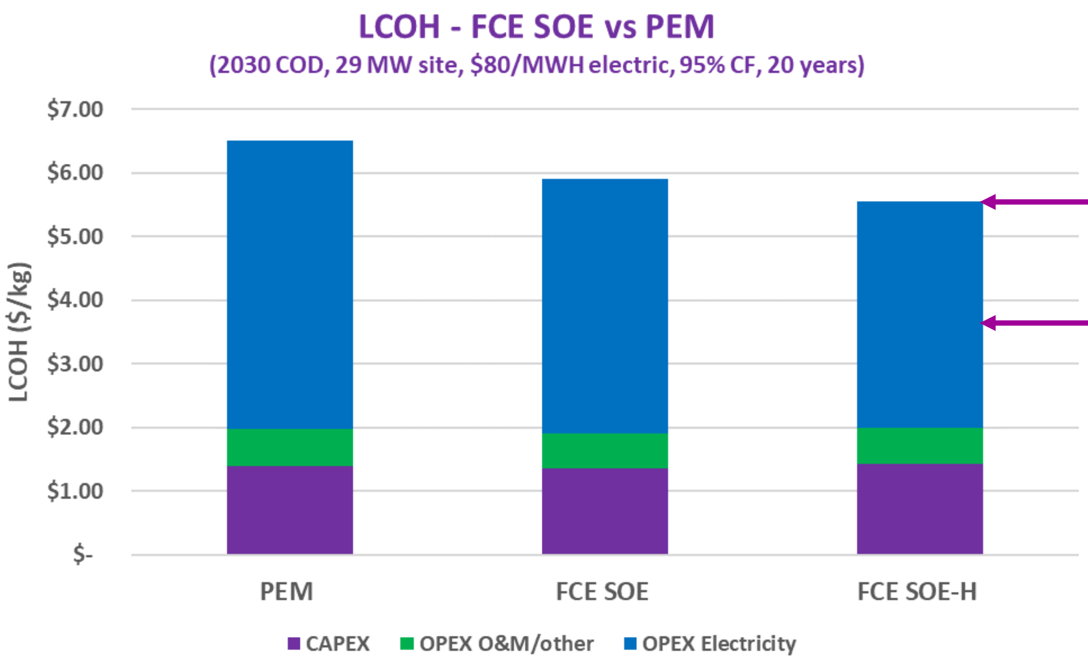
29 MW Site	*Units*	PEM	FCE SOE	FCE SOE-H (heat integrated)
Plant Efficiency, BOL	*kWh/kg*	56.7	50.0	44.5
Net H2 Output, BOL	*kg/day*	12,254	13,680	13,680
Total Plant CAPEX	*$/kW*	$2,000	$2,400	$2,530
Total Plant CAPEX	*$/ kg/day*	$4,724	$4,403	$4,639
LCOH	*$/kg*	$6.52	$5.91	$5.56

FCE SOE Advantage

12-21% better efficiency

12% more H2 production

2-7% lower total CAPEX/kg



12-21% lower total LCOH

9-15% lower cost of electricity

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Plant-level performance comparison

Electrical load by process component, in kWh/kg-H_2

Assumes 99.9% pure hydrogen product at 30 bar pressure and ~25 MW scale

<table>
<tr><th rowspan="2">Technology</th><th rowspan="2">Electrolyzer (avg ±3 kWh/kg)</th><th rowspan="2">Boiler & heaters</th><th rowspan="2">Cooling & HVAC[1]</th><th rowspan="2">Hydrogen compression</th><th rowspan="2">Transformer & rectifier[2]</th><th rowspan="2">Purification (losses)</th><th rowspan="2">Water treatment</th><th colspan="2">Net plant efficiency</th></tr>
<tr><th>kWh/kg</th><th>%HHV</th></tr>
<tr><td>AWE</td><td>47</td><td></td><td rowspan="3">2.8</td><td>2.0</td><td>2.5</td><td rowspan="2">0.8</td><td rowspan="5">0.2</td><td>55.3</td><td>71%</td></tr>
<tr><td>P-AWE</td><td>49</td><td></td><td></td><td>2.6</td><td>55.4</td><td>71%</td></tr>
<tr><td>PEM</td><td>51</td><td></td><td></td><td>2.7</td><td></td><td>56.7</td><td>69%</td></tr>
<tr><td>SOE</td><td rowspan="2">34</td><td>8.0</td><td rowspan="2">1.5</td><td rowspan="2">2.0</td><td rowspan="2">1.8</td><td rowspan="2">2.5</td><td>50.0</td><td>79%</td></tr>
<tr><td>SOE-H</td><td>2.5</td><td>44.5</td><td>89%</td></tr>
</table>

Solid oxide operates at high temperature and requires a steam boiler, but its high efficiency and thermal recycling reduce cooling loads and rectification losses per kilogram of hydrogen production

Solid oxide systems generally require higher hydrogen purification demands

Net of plant loads, solid oxide maintains **highest overall efficiency**

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1) Dry coolers, chillers, and pumps averages as estimated by Wood Mackenzie
2) Assumes 96% efficiency rectification, 99% efficient transformer

Questions?

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