Membrane-Based Electrolysis: Overview

• Many cost and efficiency advancements still feasible for PEM electrolysis
  – >50% reduction in membrane thickness
  – >90% reduction in catalyst loading
  – Improved O₂ evolution activity
  – Part integration and high speed manufacturing
  – Balance of plant improvements: drying, electronics

• AEM electrolysis can enable new cost curve
  – Will need to balance with potential efficiency loss based on OH⁻ conduction
  – Durability still needs significant work
Cost and Efficiency Comparison

- Advanced PEM can reach projected AEM introduction on cost
- AEM approaches current PEM efficiency at low current density but PEM has potential for additional improvement
- Need to balance technology with application (OpEx vs. CapEx)
AEM Challenges

• Materials are not at same scale or maturity yet
• Membrane and ionomer are far less stable than PEM especially to temperature
  – Need alternate electrode manufacturing methods
  – Air sensitivity requires special electrode conditioning
  – Proton OnSite has become standard test bed
• Non-PGM catalysts have had complications translating from liquid systems
  – Need optimization of 3-phase boundary layer at GDL
• Water management is more difficult
  – Combined with lower OH- conductivity likely limits operating current range
Membrane/Ionomer Durability Status

LANL/Sandia Durability Test, ~27°C

Have demonstrated >2000 hours of operation but need to improve voltage stability.
Alternate Approach to Stability

- Carbonate electrolyte can stabilize ionomer but need to balance with balance of plant complexity
Non-PGM Catalyst and Cost Validation

Cost estimates and validation

<table>
<thead>
<tr>
<th></th>
<th>PEM baseline</th>
<th>Alkaline equivalent</th>
<th>Alkaline + improvements</th>
<th>% Original component</th>
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<tbody>
<tr>
<td>O₂ flowfield</td>
<td>100%</td>
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<tr>
<td>H₂ flowfield</td>
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<td>8%</td>
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Needed Activities and DOE Assistance

• Need cohesive team efforts to make progress
  – Material interactions need to be understood
  – Multi-phase boundaries require strong analytical tools
• Use of consistent device testing under practical conditions for valid comparisons
• Integrators have the knowledge of the pieces and need to drive the effort
• Many parallels with the status of PEM electrolysis and integration of advanced materials