COLLEGE OF ENGINEERING

Chemical, Biological, and Environmental Engineering

A Techno-Economic Comparison of OER Catalysts for PEM Electrolysis

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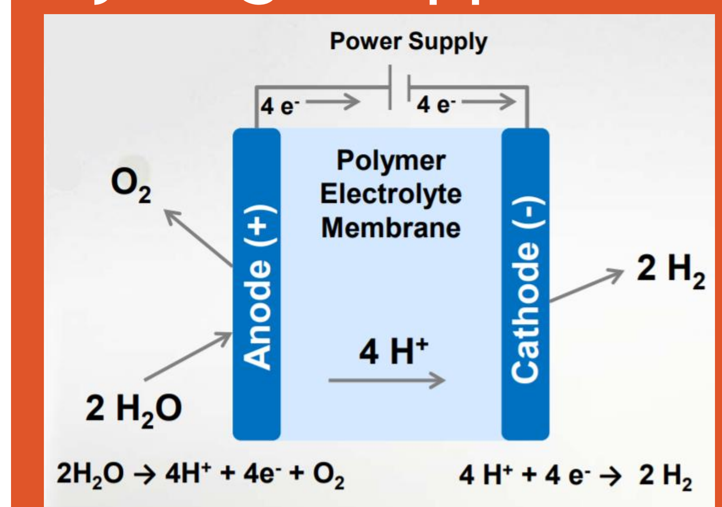
Purpose of Techno-Economic Model

- To assess the state of PEM electrolysis as a H_2 production method
- To find bottlenecks to hydrogen costs where research should be concentrated
- To provide performance targets to meet the 2025 and 2030 DOE renewable hydrogen costs of \$2/kg H_2 and \$1/kg H_2

Hydrogen Applications



Water splitting:
$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

Hydrogen forming:
$4H^+ + 4e^- \rightarrow 2H_2$

The electrolyzer splits water to produce hydrogen, which can be used in transportation, heating, portable energy, and many other applications.

Challenges

PEM electrolysis is a promising zero-carbon H_2 production method, but there are many challenges:

1. The OER is sluggish and requires a high-performance catalyst for low feedstock costs
2. Most catalysts do not function or degrade rapidly in the acidic electrolyte
3. Current OER catalysts contain precious metal elements (Iridium, Ruthenium), which are expensive and low in supply

High-performance, economic, corrosion-resistant catalysts are required.

Questions: What catalysts for PEM electrolyzers are most economically and environmentally feasible for commercial use?

Methods: Modeling & review of hydrogen production costs with an emphasis on catalyst-related parameters

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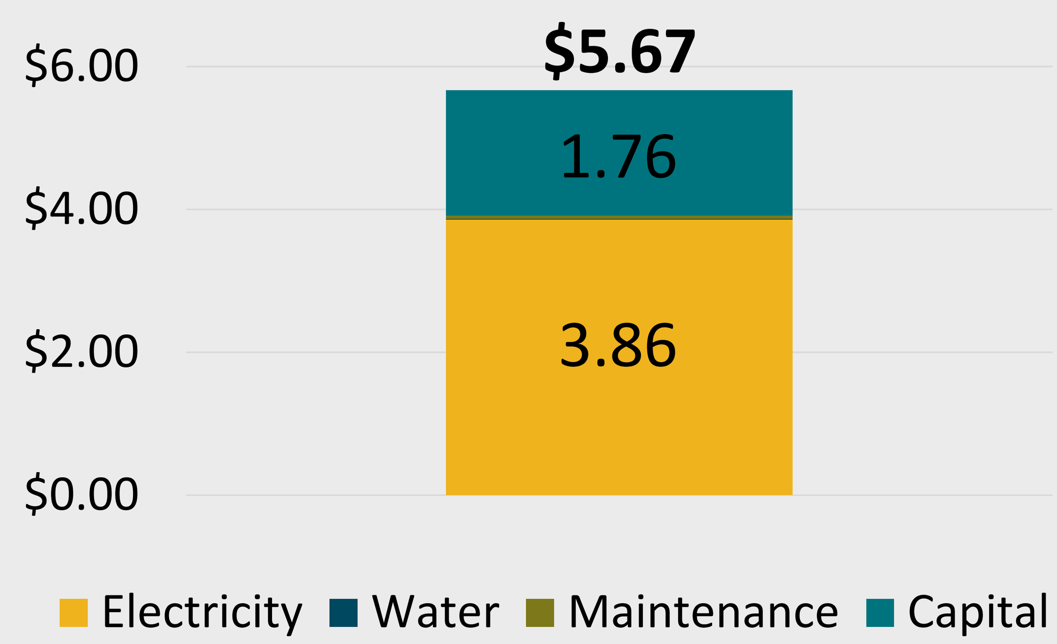
Techno Economic Model

Parameter	Value Used	
Operating Capacity	97%	
Nafion Membrane Cost (\$/m²)	0.05	
Balance of Plant (% of Capital+BoP Cost)	60%	
CCM Cost (% of Capital Cost)	40%	
Maintenance Cost (% of Capital Cost)	2.5%	
BoP Electrical Usage (kWh/kg)	5	
Input Water Cost (\$/kL)	1.44	
Production Rate (kg H_2/day)	1500	
Installation Factor	15%	
Cell Active Area (cm²)	450	
Cathode Catalyst	Pt	
Electricity Price (\$/kWh)	0.03	0.073

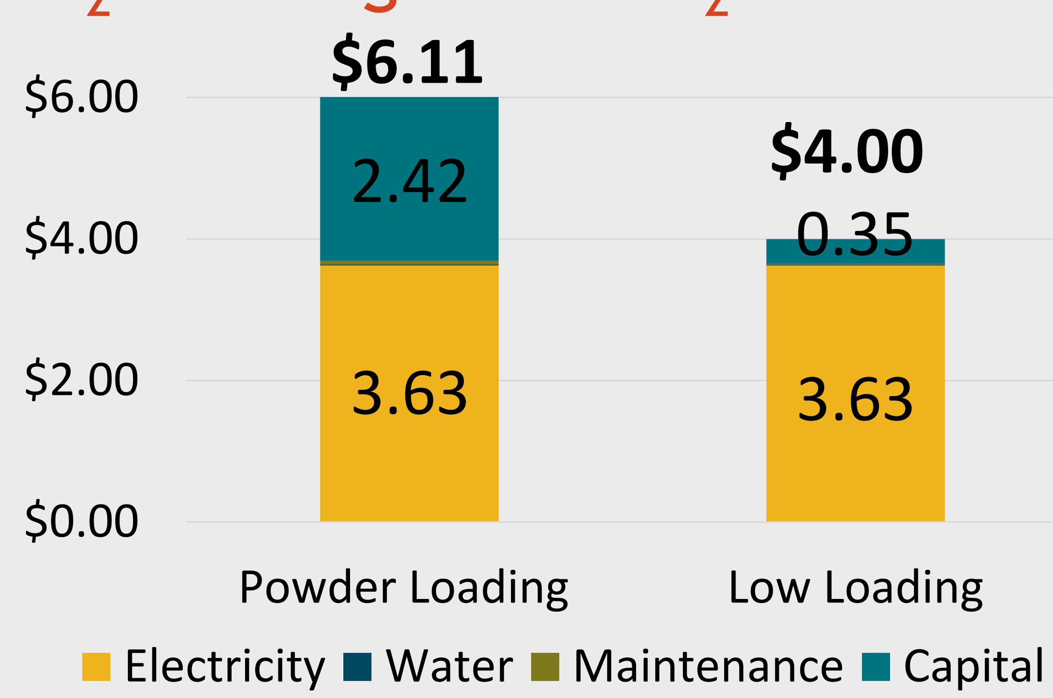
- Conducted review of state-of-the-art electrolyzers using articles from 2019 to 2021
- Balance-of-plant and catalyst coated membrane costs assumed to be a function of catalyst cost
- Balance-of-plant assumed to consume constant amount of energy per kilogram of hydrogen
- Scenarios for grid (\$0.07/kWh) & renewable (\$0.03/kWh) energy sources were analyzed; grid energy was used unless otherwise specified

H_2 Cost/kg With RuO_2



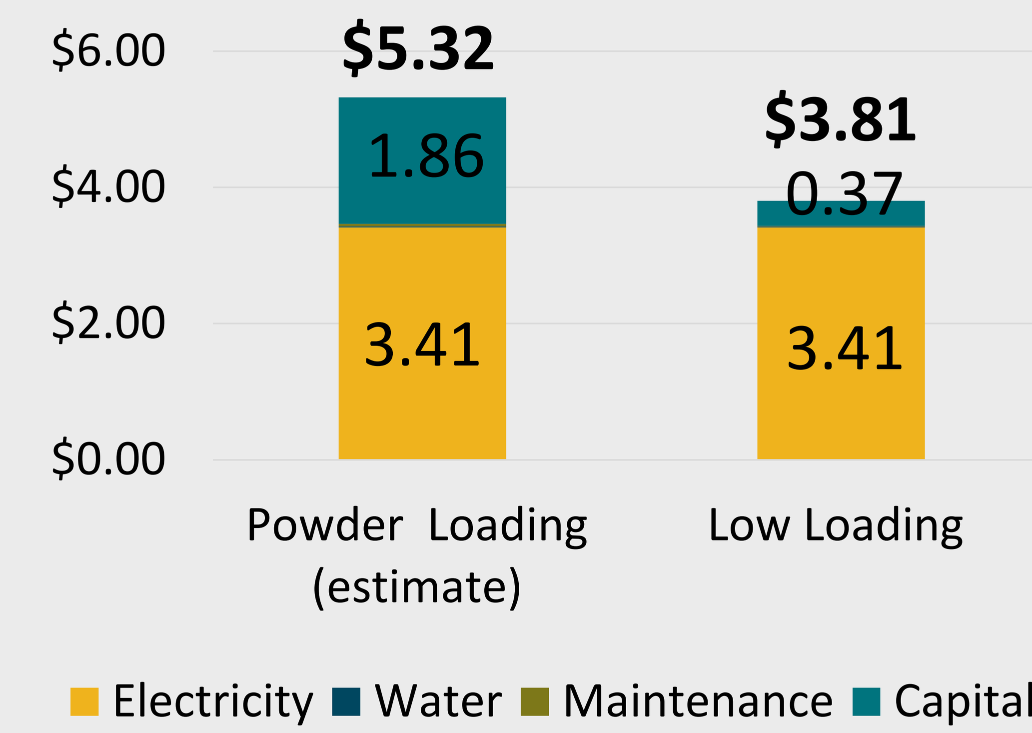
- Poor catalyst performance (~400-770mV overpotential @ 1A/cm²)
- Consistently high loading ~25g/m² yields high capital costs, also environmentally unsustainable
- Greatest overpotential increases at high current densities → incompatible with energy surge from renewable sources

H_2 Cost/kg With IrO_2



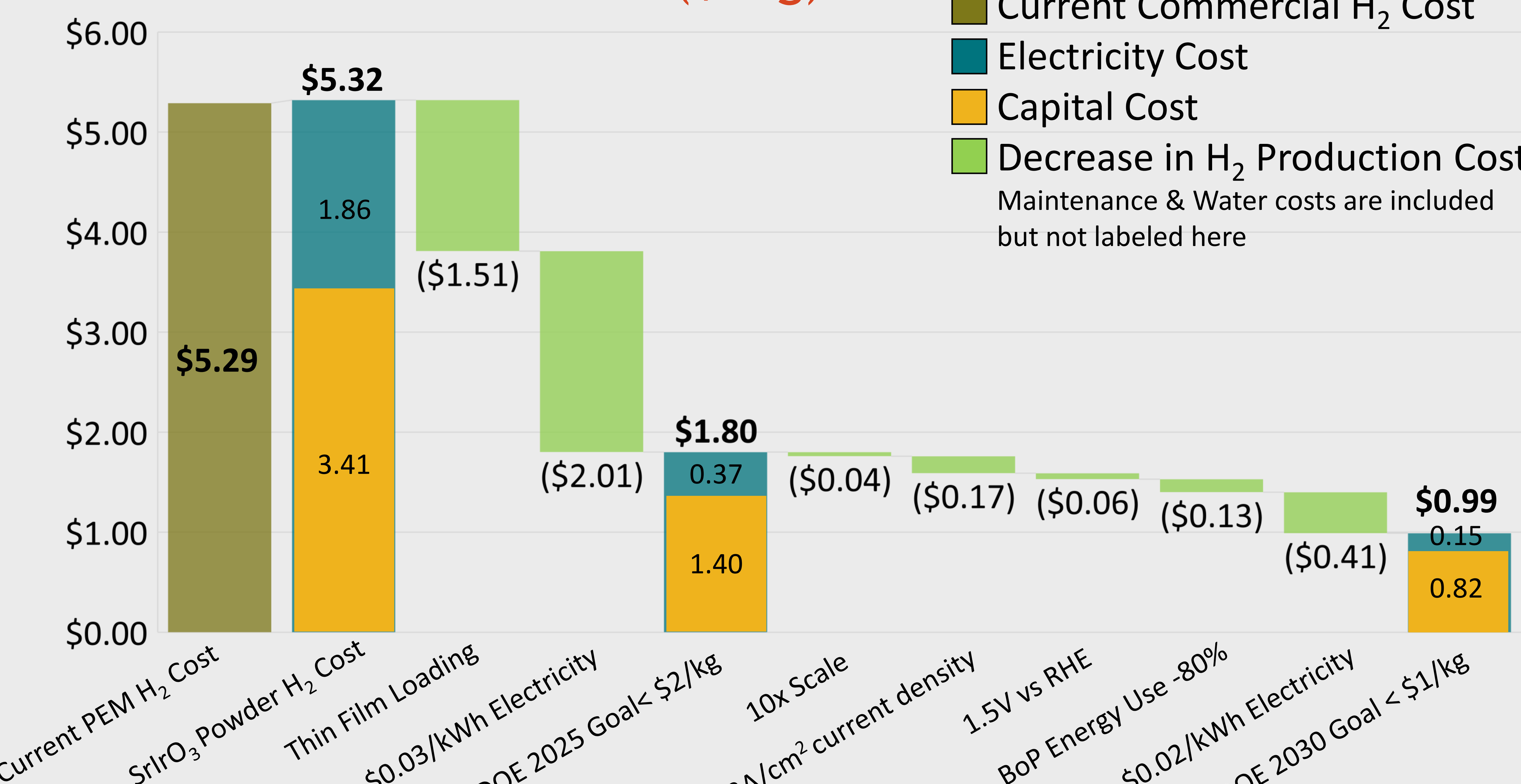
- Low overpotential (~330-570mV @ 1A/cm²) → low energy cost
- Higher median cost than RuO_2, but better average & best case scenario
- High catalyst cost (~\$200/g) and loading (~18g/m²); capital cost can be reduced by use of low loading thin films (~40nm used here)

H_2 Cost/kg With $SrIrO_3$



- Highest performing catalyst (~350-370mV overpotential @ 1A/cm²)
- Lower Ir content → more environmentally sustainable
- Powder loading assumed to be same as IrO_2 (18g/m²)
- Greatly reduce capital costs with low loading; estimated ~100nm thin films from prior research at OSU

Potential Cost Reductions (\$/kg)



- Achieving both DOE goals is most feasible with $SrIrO_3$ catalyst
- As loading & non-CCM capital and energy costs decrease, electricity cost plays a greater role in total production cost → decrease electricity cost & increase efficiency

Conclusion

- PEM electrolysis with the $SrIrO_3$ catalyst can supersede current commercial electrolyzers for cheaper & more sustainable H_2 production
- The main improvement needed for the $SrIrO_2$ catalyst is its loading density
- Past \$2/kg, electricity cost will be by far the largest cost factor, and must be decreased to allow PEM electrolysis meet the DOE goal of \$1/kg H_2 within a decade

Acknowledgements

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