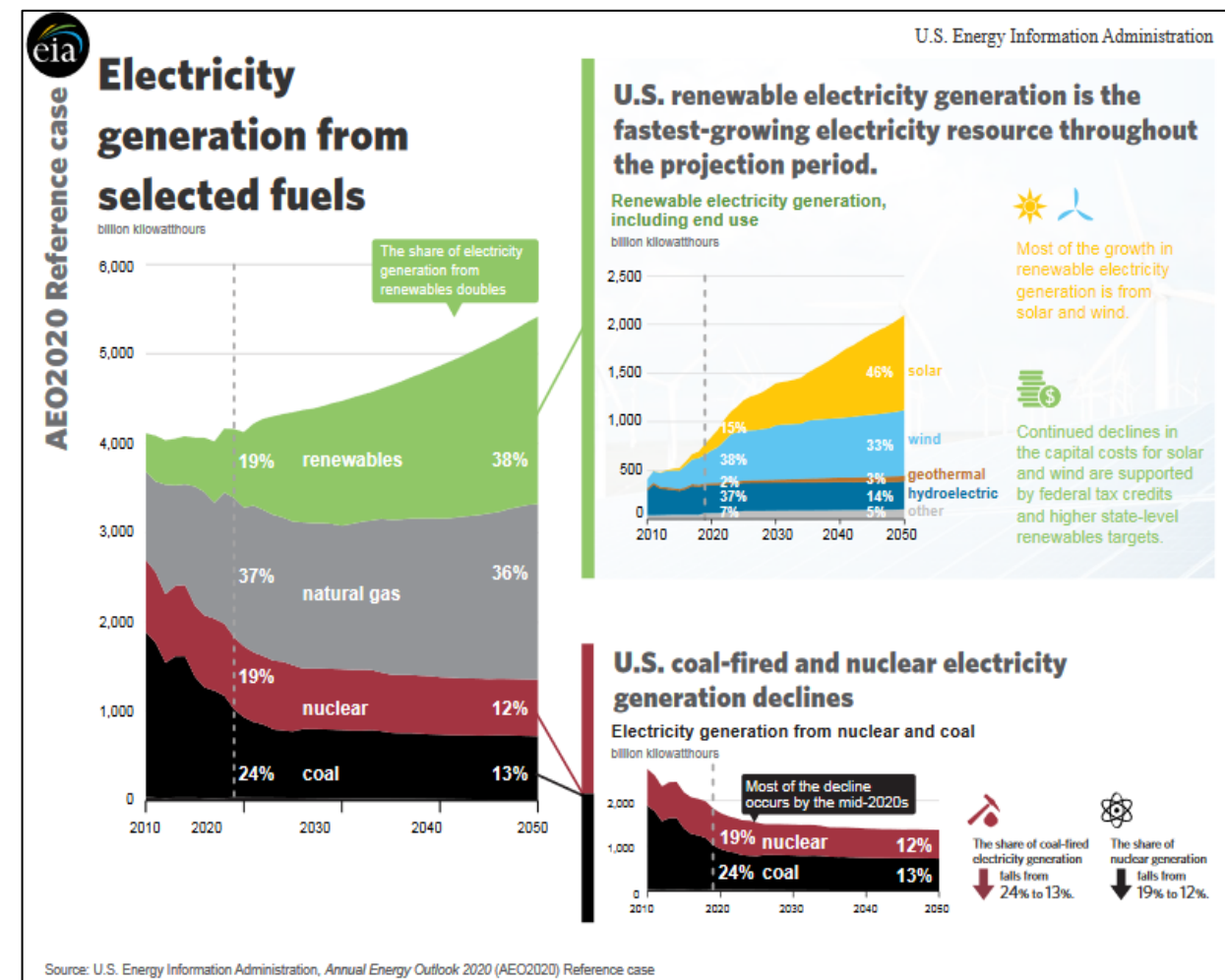


Understanding Efficient Hydrogen Production via Water Electrolysis

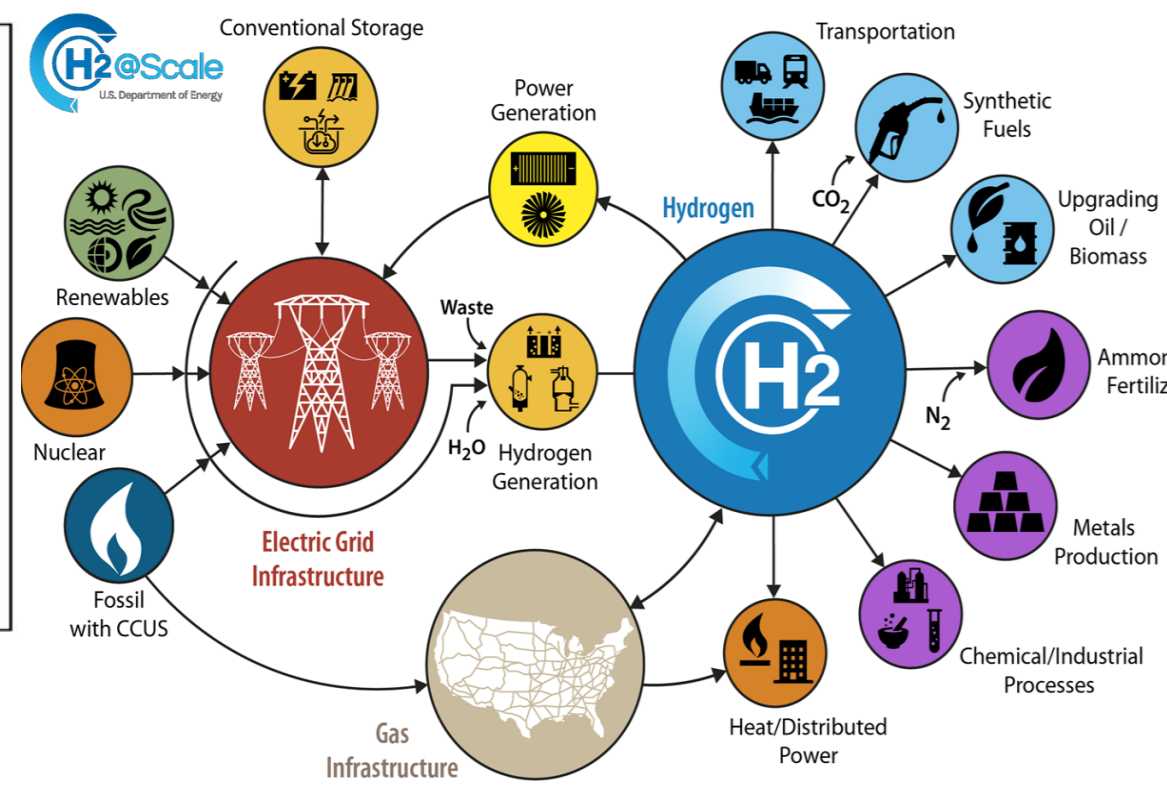
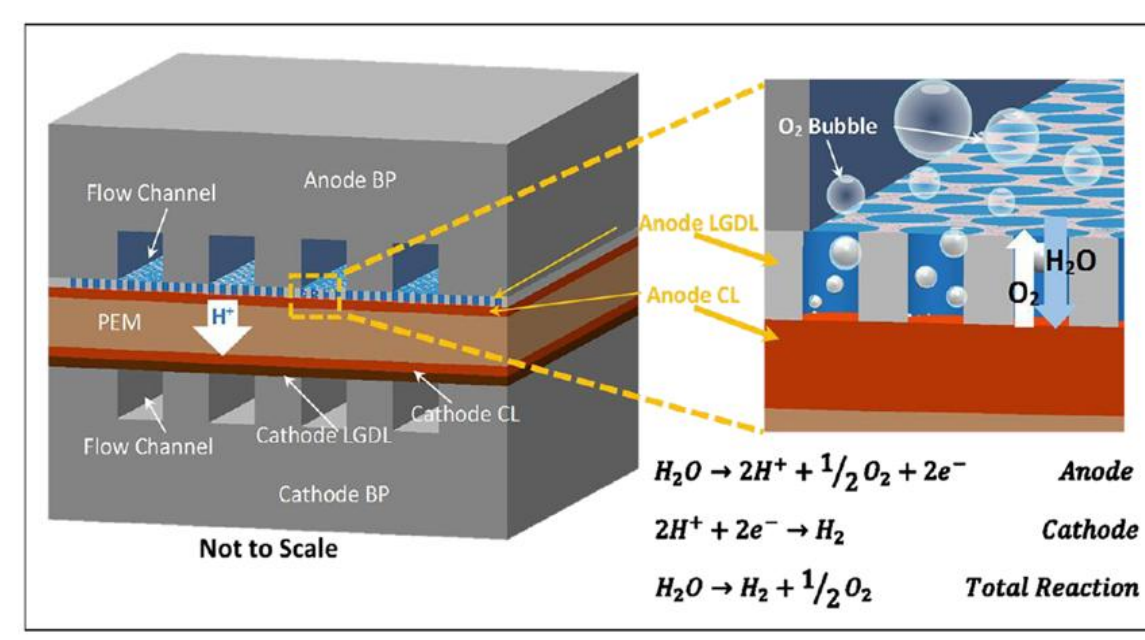
Anirban Roy, Dr. Douglas S. Aaron, Dr. Matthew M. Mench
Department of Mechanical Aerospace & Biomedical Engineering



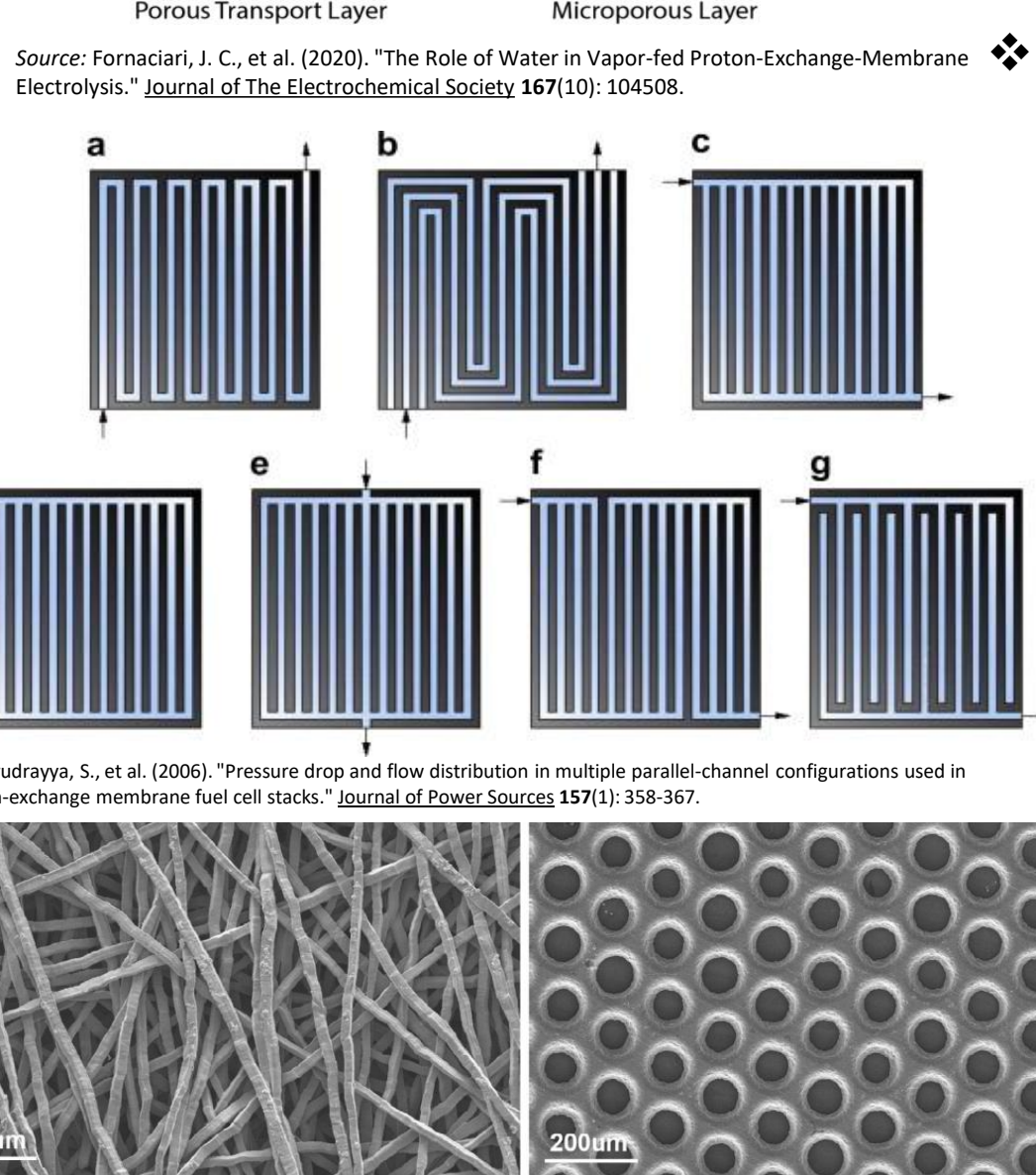
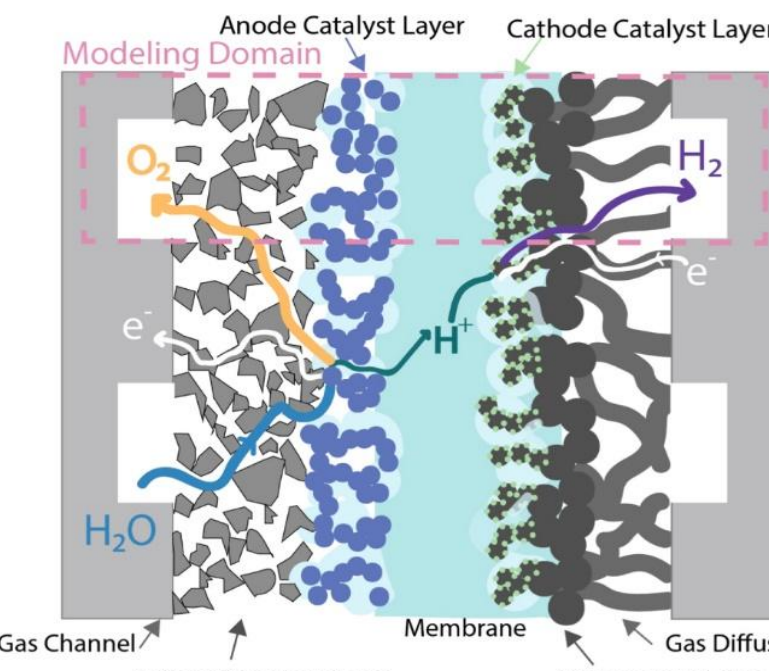
Hydrogen's crucial role in shaping the future of energy utility



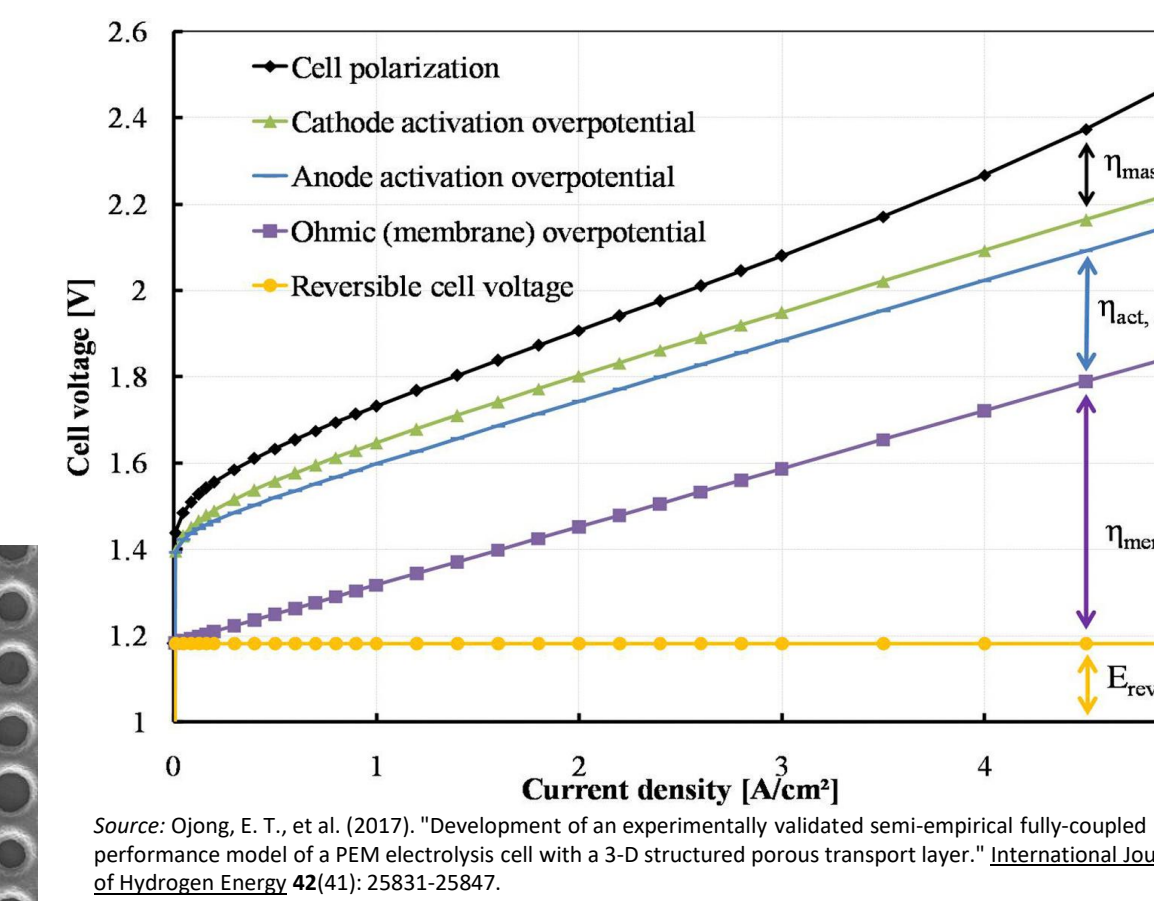
- ❖ U.S. Administration goals to combat climate change:
 - ❖ Net zero emissions economy by 2050
 - ❖ 100% carbon-pollution free electric sector by 2035
- ❖ The U.S. DOE Launched the **Hydrogen Energy Earthshot of "1 1 1"** on June 7, 2021.
 - ❖ "\$1 for 1 kg clean hydrogen in 1 decade"



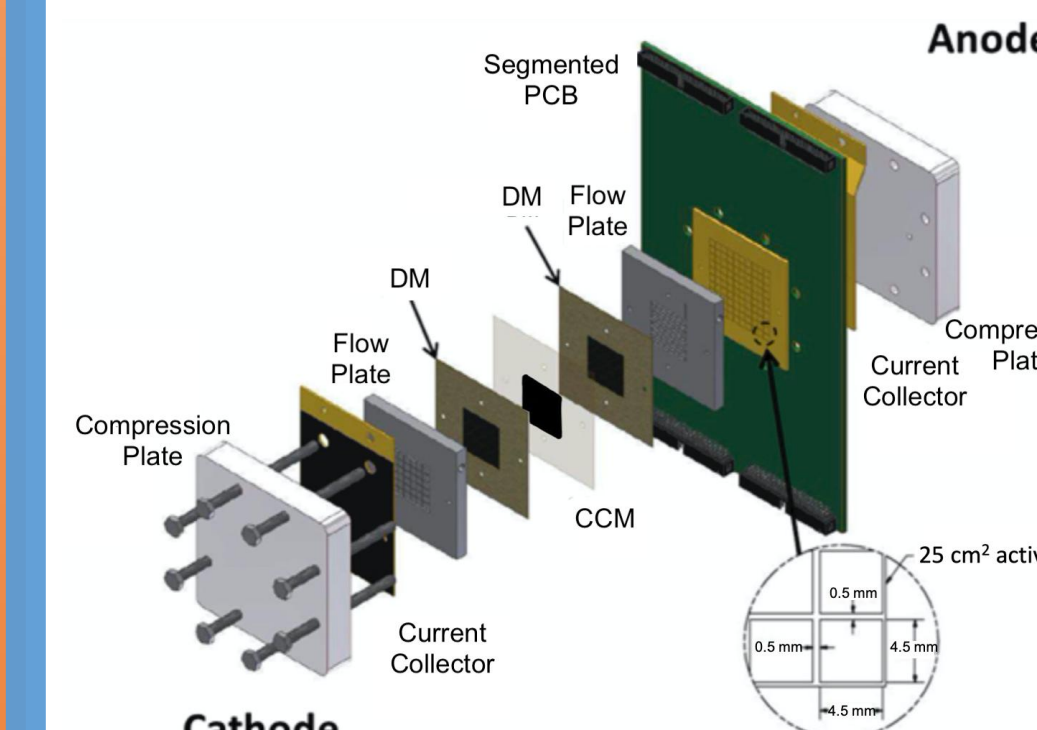
H₂ Production via Water Electrolysis: Exploring the Mechanisms of Transport



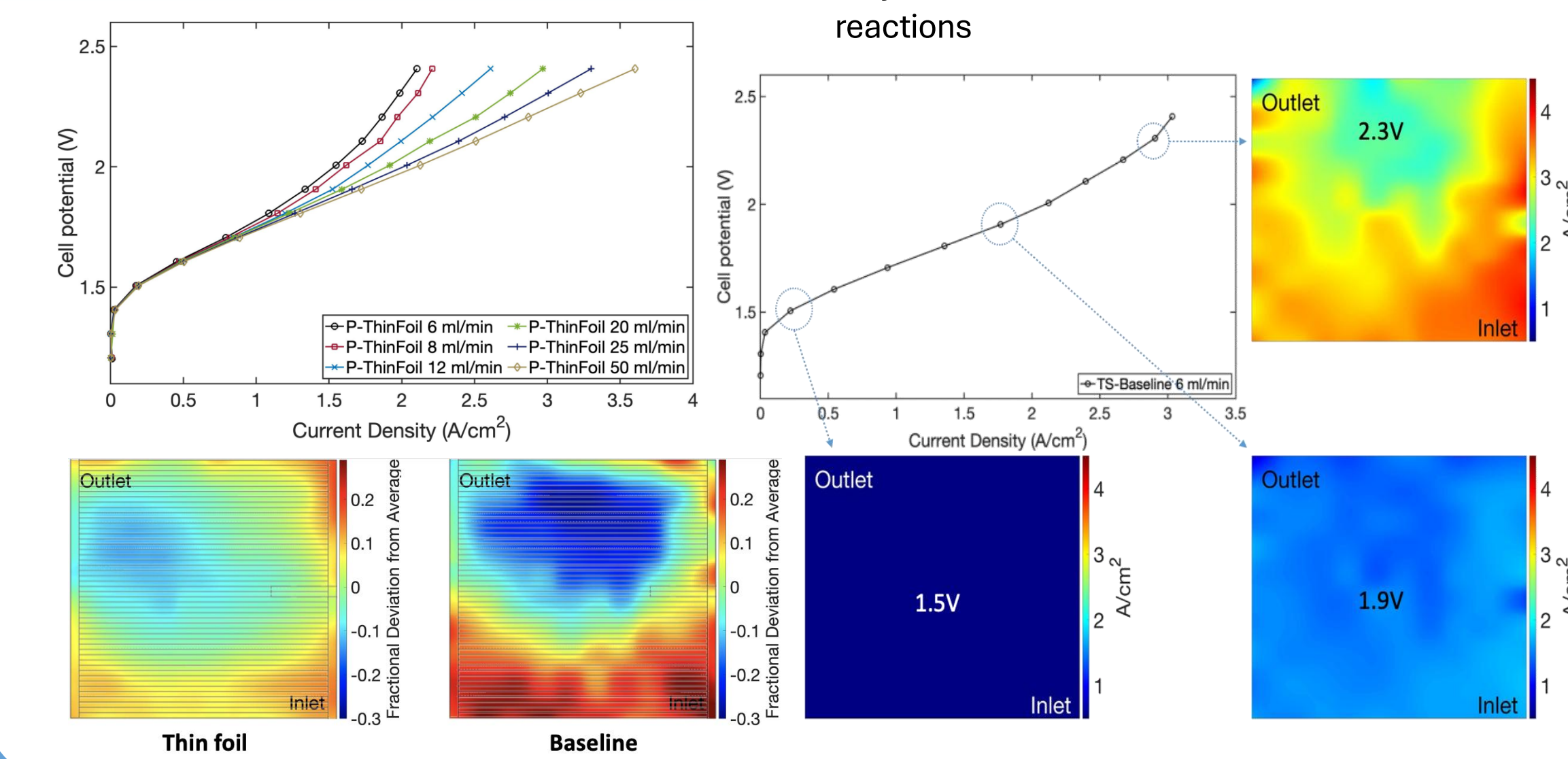
- ❖ Electrolyzers use electrical energy to split water (H₂O) into hydrogen (H₂) and oxygen (O₂) through an electrochemical process at electrodes (containing catalysts)
- ❖ Key performance characteristics:
 - ❖ Current density: Analogous to the rate of electrolysis
 - ❖ Cell Voltage: Analogous to the power required to sustain a given rate of electrolysis
 - ❖ Lower electrolyzer efficiency results in a higher loss of energy as thermal heat
- ❖ Complexities of water electrolysis involve the transport of:
 - ❖ Electrons (related to chemical kinetics)
 - ❖ Mass (involving ions, reactants and products)
 - ❖ Thermal energy (heat and temperature)



Efficient Electrolysis: Minimizing Power, Maximizing Uniformity

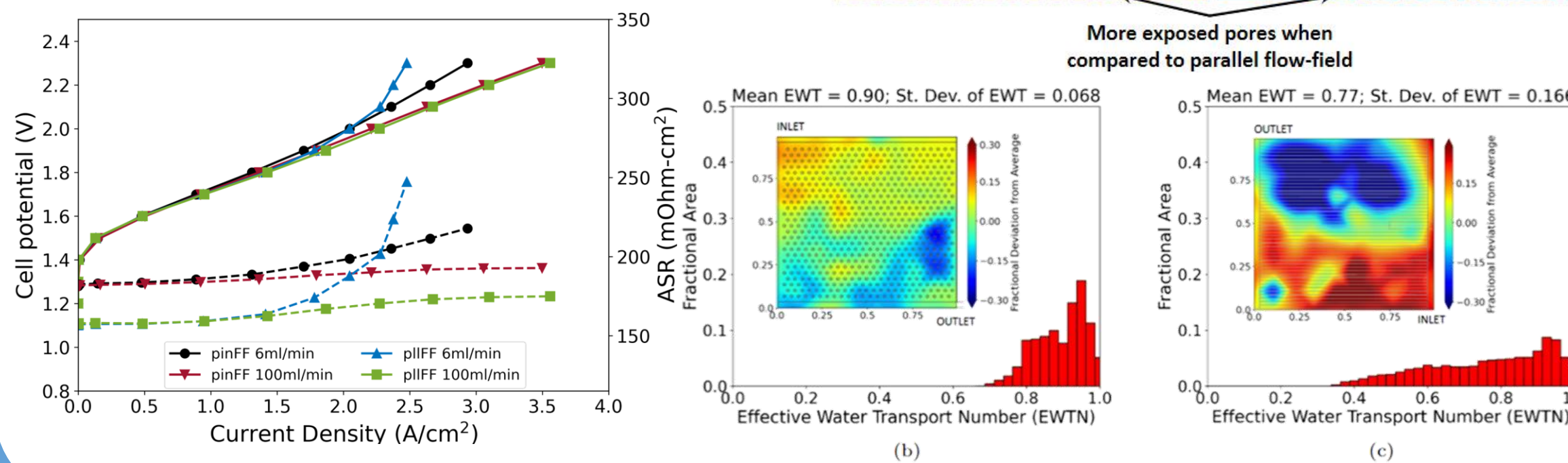
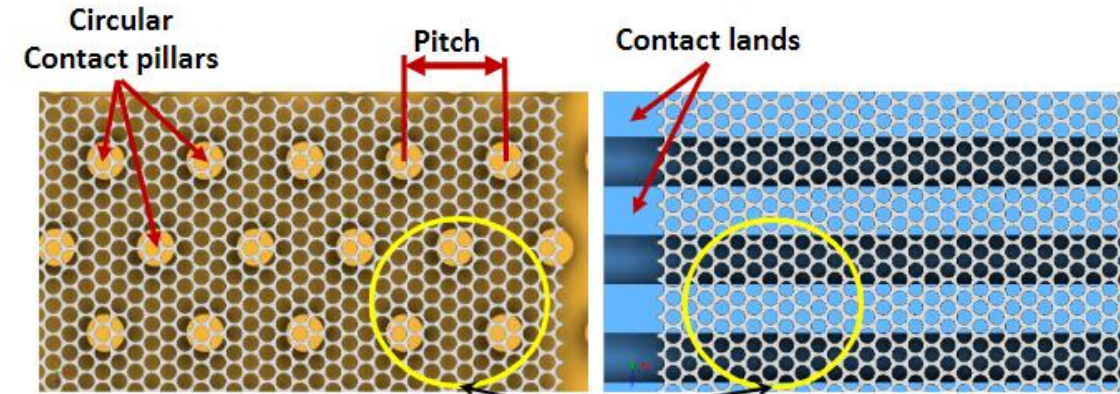
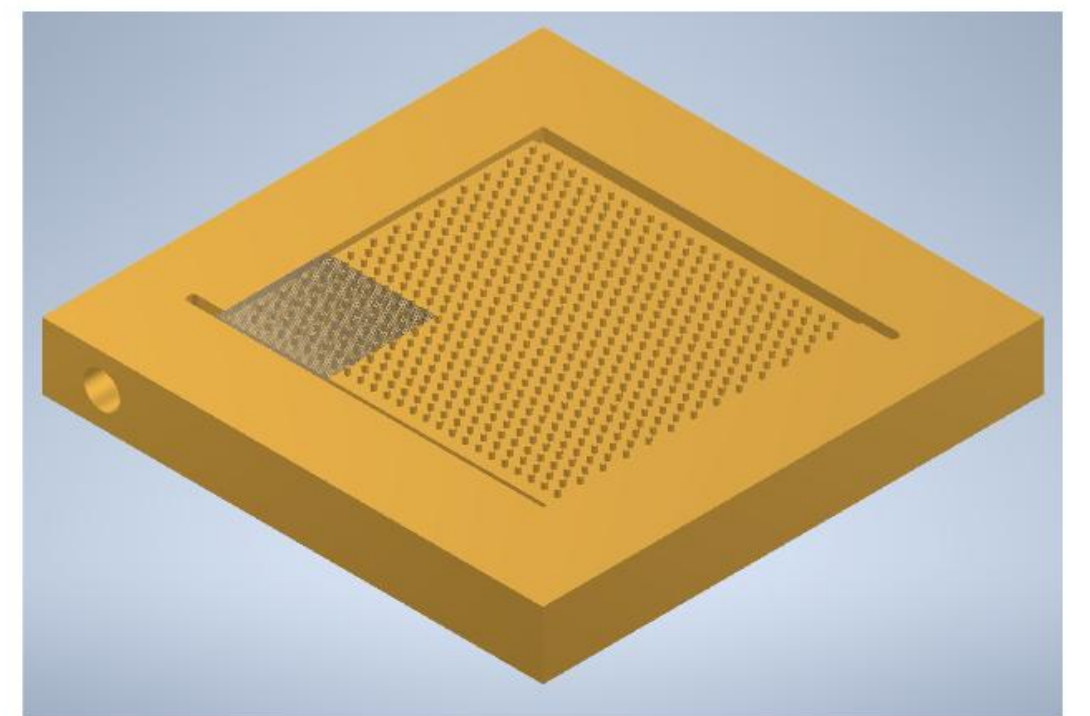


- ❖ Efficient water electrolysis goals:
 - ❖ High reaction rates at lower power consumption
 - ❖ Uniform distribution of sustained reactions for system durability and long-term efficiency
- ❖ Lower catalyst loadings are needed to reduce capital costs associated with hydrogen production
- ❖ Optimized system design considerations:
 - ❖ Lower catalyst loadings can lead to increased losses at higher hydrogen production rates
 - ❖ May also result in non-uniform distribution of reactions



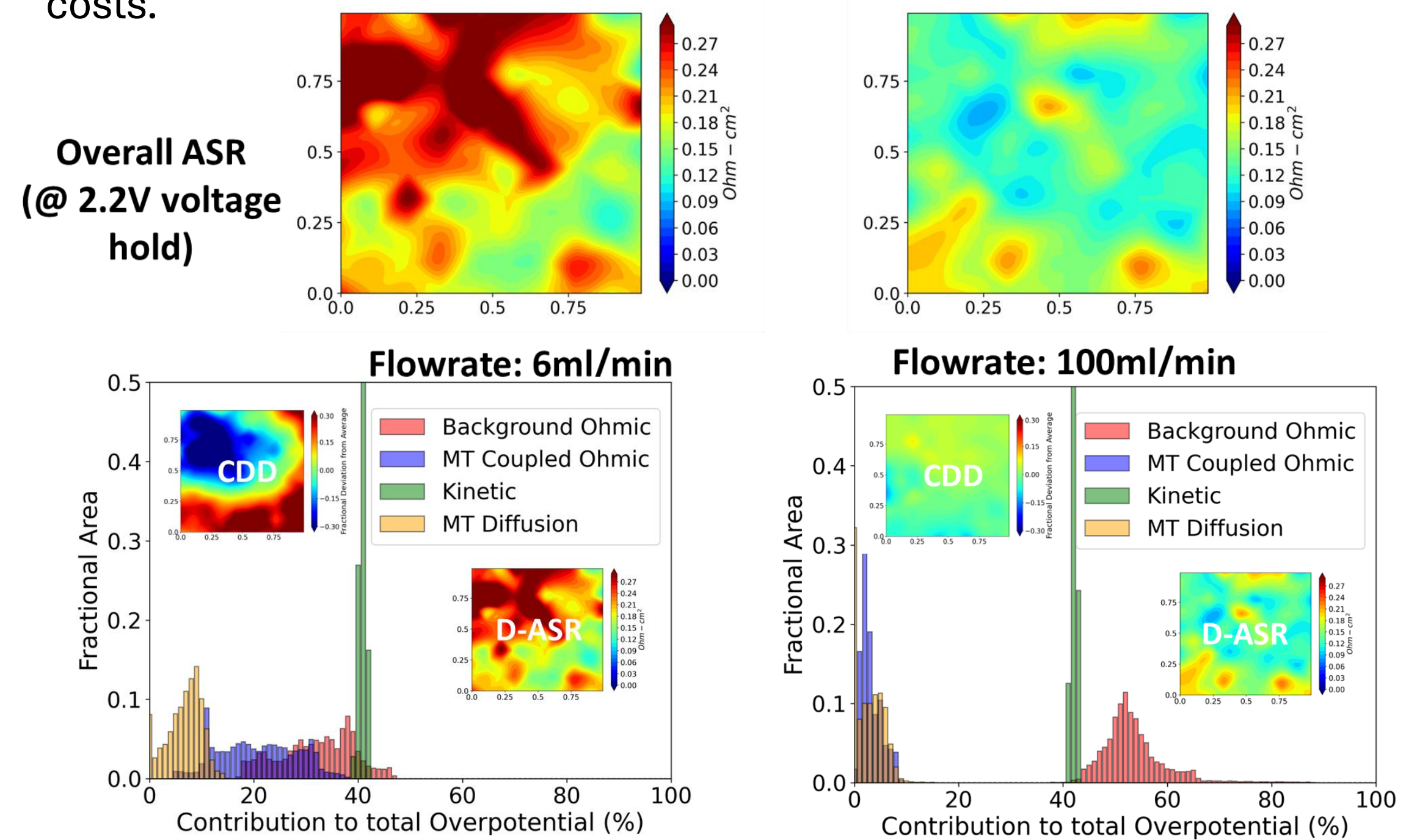
Striving for Efficiency: Optimizing Electrolyzer Design and Operations

- ❖ Benefits of in-situ diagnostic techniques:
 - ✓ Enhanced understanding of system performance
 - ✓ The capability to investigate the impact of different parameters on performance
 - ✓ Facilitate in-depth analysis of system physics
 - ✓ Optimization of the system design and operating conditions



Enhancing Electrolysis Efficiency Utilizing Accessible and In-situ Diagnostics

- ❖ **Real-time Insights:** In-situ diagnostics provide immediate, real-time data, allowing for a deeper understanding of electrolysis processes as they happen.
- ❖ **Accelerated Research:** Distributed measurement diagnostics has the potential to accelerate research and development efforts at very affordable costs.



Key Takeaways

- Why?**
 - The U.S. aims to achieve a net-zero emissions economy by 2050 and a carbon-pollution-free electric sector by 2035, which demands rapid advancement of clean energy technologies like electrolysis.
 - The DOE's "1 1 1" Hydrogen Energy Earthshot initiative, targeting \$1 per kilogram clean hydrogen within a decade, underscores the strategic importance of hydrogen production, driven by technologies such as electrolysis.
- What?**
 - Achieving efficient, low-power water electrolysis with uniform reaction distribution is key for sustainability.
 - Challenges emerge with lower catalyst loadings, which affect losses and reaction distribution.
- How?**
 - Accessible in-situ diagnostics offer a suite of benefits for electrolysis Research and Development
 - Allows in-depth analysis of system physics
 - Design optimization
 - Real-time insights
 - Cost-effective acceleration of research

Sponsors & Collaborators:

