Fully Unitized Fuel Cell Manufactured by a Continuous Process

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DE-EE0009614

DOE Hydrogen Program
2022 Annual Merit Review and Peer Evaluation Meeting

AMR Project ID # FC346

Overview

Timeline

- Project start date: 2/1/2022
- Project end date:1/31/2025

Partners

- Plug Power, project lead
- University of TN, EESC Lab
- ORNL, Materials Processing and Joining Group

Budget

- Total project budget: $2.3M
  - Recipient share: $0.5M
  - Federal share: $1.8M

Relevance

A PEMFC bipolar plate (BPP) architecture for heavy-duty applications using flat foil metal separators with grooves in the diffusion substrates that is manufactured in a continuous roll-to-roll process.

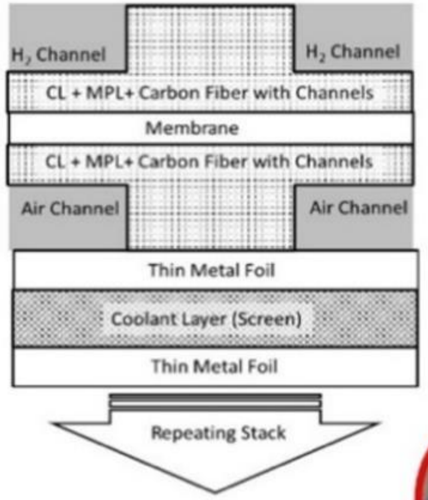
- Evaluate flat aluminum and stainless-steel alloy foils with various conductive corrosion resistant coatings for mechanical and chemical durability using ex-situ experiments
- Develop and predictive model supported by parametric in-situ experiments for porous flow field ribs
- Demonstrate a printable wireless individual cell voltage measurement
- Demonstrate a high throughput production method for creating grooves on one side of a diffusion substrate at research scale
- Scale design to a 400 cm^2 short stack
- Develop manufacturing model and TEA for 10M plates/year (bipolar plate and diffusion substrate)

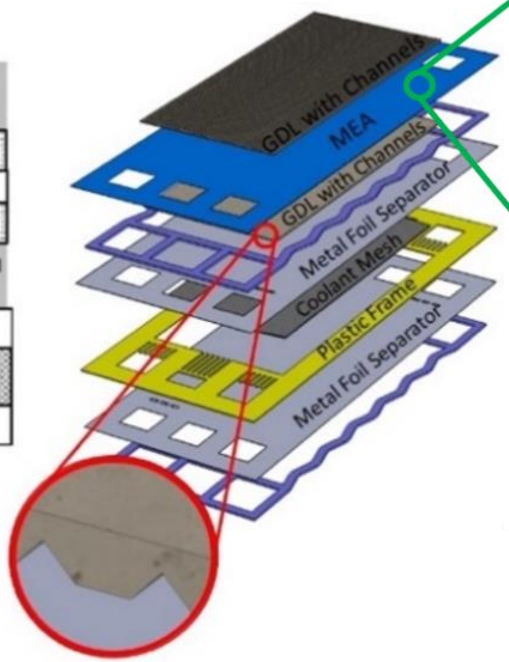
Key outcome - BPP architecture that meets DOE 2030 BPP targets demonstrated with a 400 cm^2 short stack.

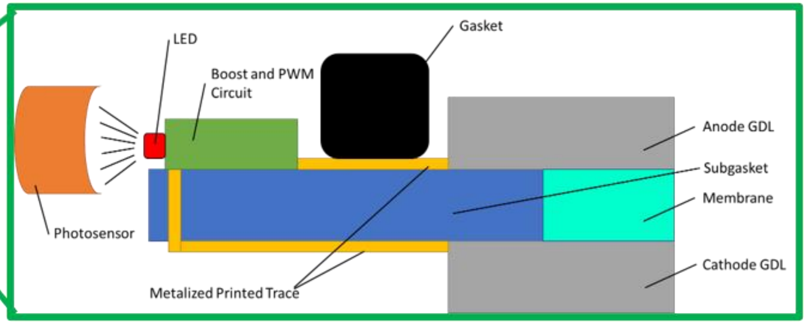
Characteristic	Units	2030 Targets
Cost [a]	$\$/kW_{net}$	5
Durability	hrs	25,000
Plate weight	kg/kW_{net}	<0.18

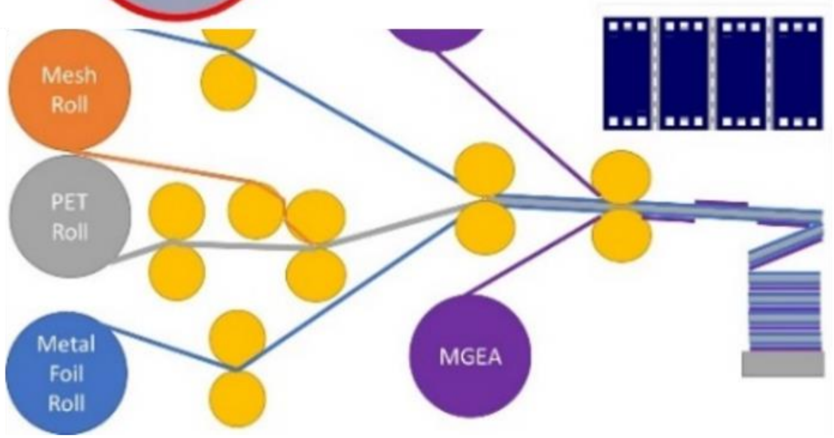
Approach

Cell Architecture for High Volume Production and Stack Assembly







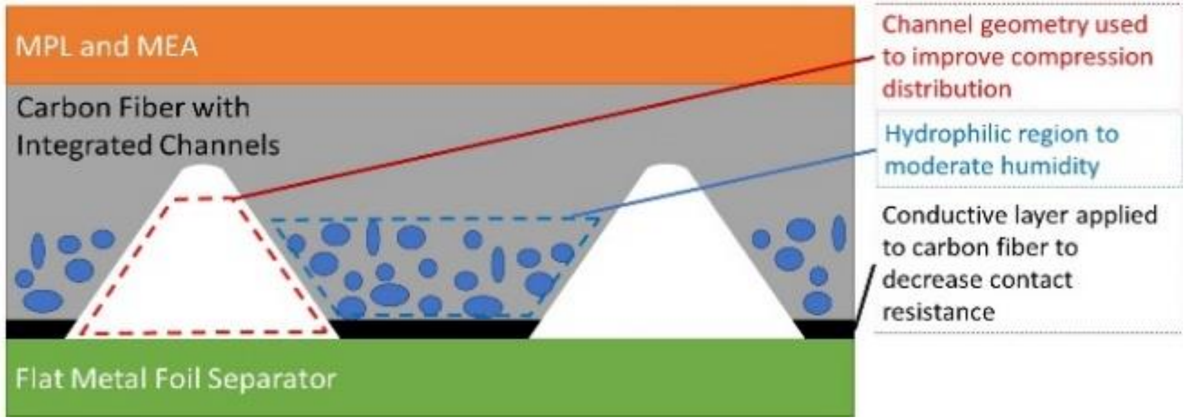


This concept is centered around utilizing flat metal foils for fluid separation in the bipolar plates (BPPs). The flow channels are formed into the gas diffusion layer (GDL) instead of the plate. This allows the use of much thinner metal compared to stamped plates where the formed channels need to maintain shape under compression loads. The use of thinner metal for the separator plates reduces the mass and cost of the bipolar plate. The concept was developed for compatibility with roll-to-roll manufacturing processes. This is accomplished by constraining a symmetric design with only rolled good components and processes such as coating, printing, and roller die cutting that are continuous.

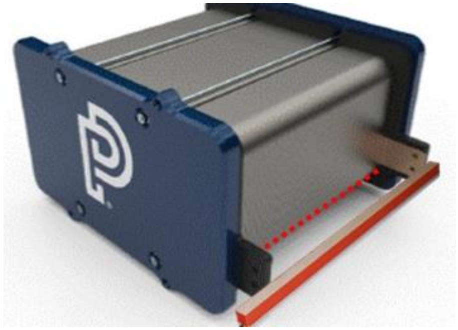
Approach

Research Topics that Enable Cost and Mass Reduction While Improving Performance

Improved GDL compression stiffness, multi-phase transport, and MEA/coolant dT



Wireless cell information



Durability of Al alloys with optimized coating

Perceived Benefits
Utilize Existing Manufacture Methods
Fine Pitch
R2R Manufacturing of Plates
Enables Thin Metal Foil (<2 mil)
Reduced Mass
Reduced Shunt Current
Improved Gas Transport
Reduced Plate Coating Damage
Increased GDL-Plate Contact Area (lower resistance)
Increased Membrane-Plate dT (water transport)
Simplified Stack Assembly
Digital Part Tracking and Data Integration

Approach - Project Timeline and Deliverables

Current Status: Project has not kicked off at the time this presentation was prepared

GNG1:
- Path to 2030 BBP targets validated
- Performance meets solid rib
- Manufacturing methods demonstrated
- Predictive model correlates with experimental data

GNG2:
- Full-scale protype with scalable manufacturing methods
- Full-scale performance and AST meet baseline metrics
- TEA detailing cost < $\$5/kW_{net}$
- Mass < $0.18\ kg/kW_{net}$

Final:
- Stack performance meets baseline
- 1000+ hours of durability
- BPPs delivered to M2FCT
- Finalized predictive model

14 Months: Small-Scale
- Requirements Document
- Select/Evaluate Metal Foil, Coating, Joining
- Additive GDL Rib Demo
- Bench-Scale Wireless CVM Demo
- Porous Rib Model Validation Data
- TEA Framework

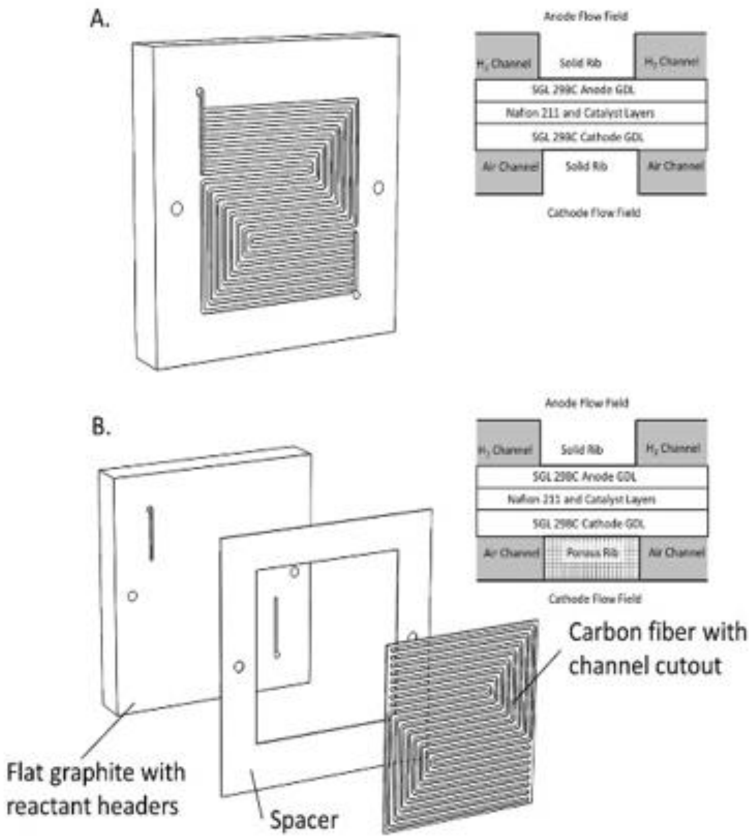
12 Months: Full-Scale Single Cell
- 400 cm^2 design
- Base metal and coating corrosion studies
- 400 cm^2 fabrication
- 400 cm^2 single cell performance and durability
- In-Operando Wireless CVM Demo
- Enhanced multi-dim model and validation
- Postmortem Corrosion Studies, Coating Optimization

10 Months: Stack Validation
- Short Stack Build
- Short Stack Performance
- Optimized multi-dim model and validation
- Short Stack Durability

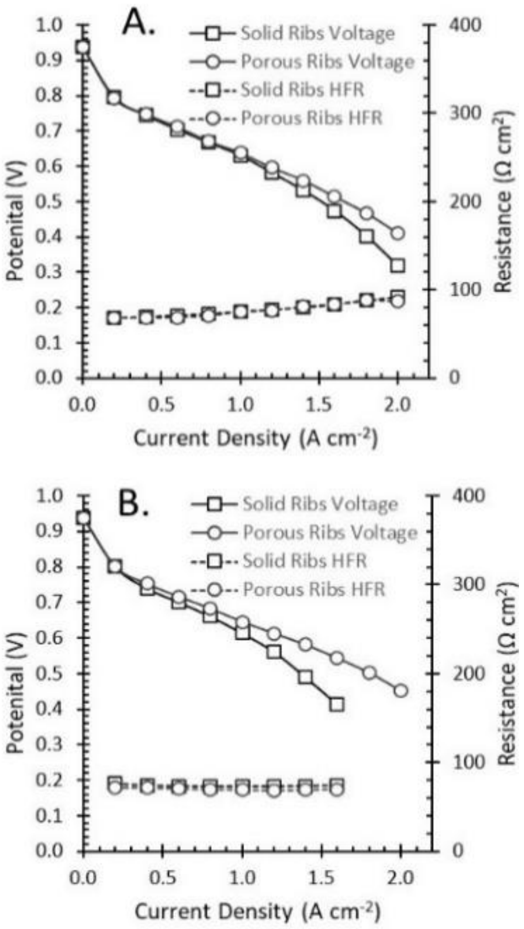
Organizational Leads

Plug Power | UTK | ORNL

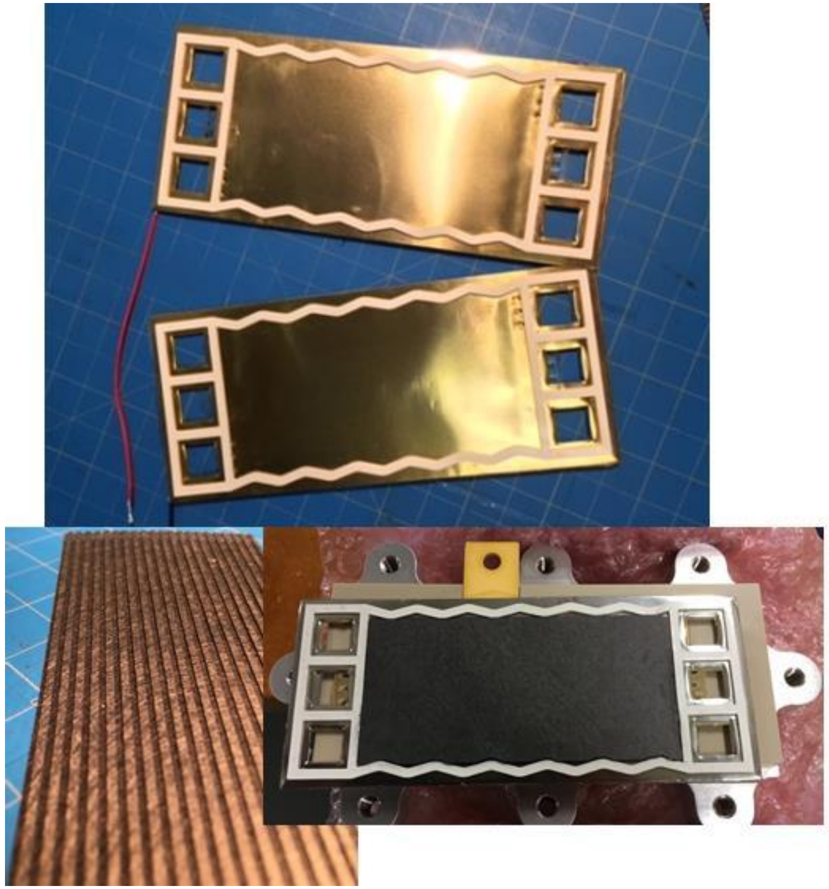
Small-scale hardware developed for diagnostic and performance evaluations of the proposed FC architecture



Diagnostic test hardware to isolate the performance impact of porous cathode ribs.

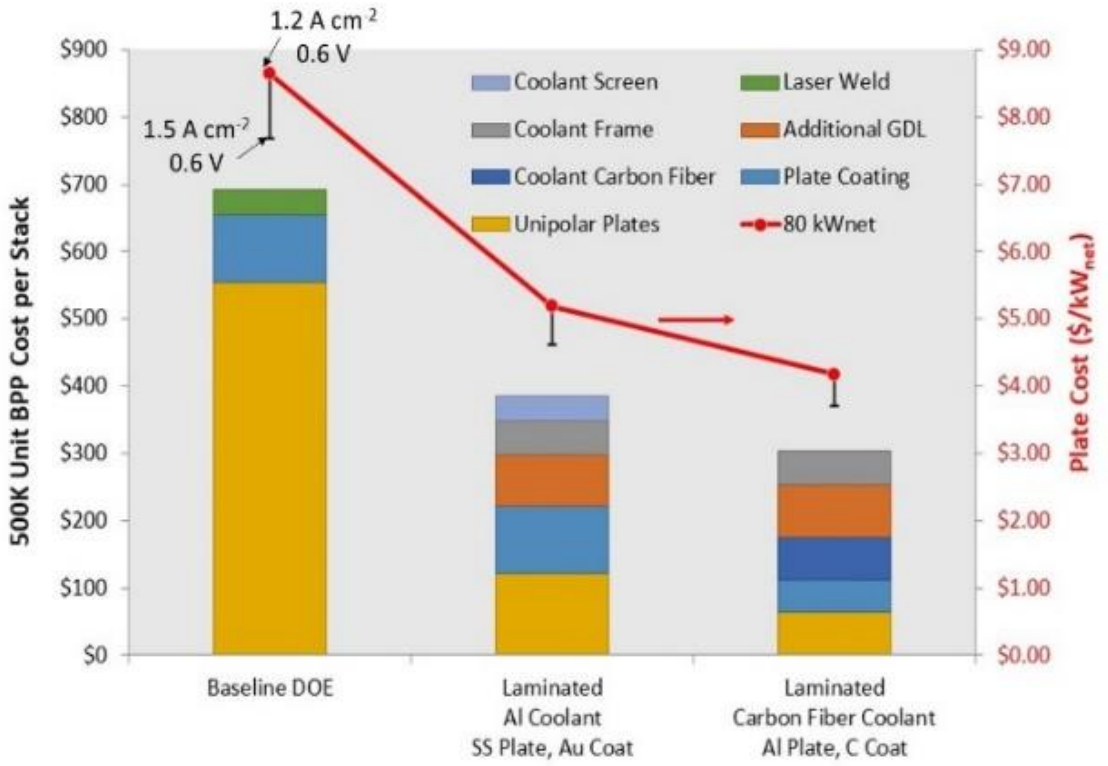


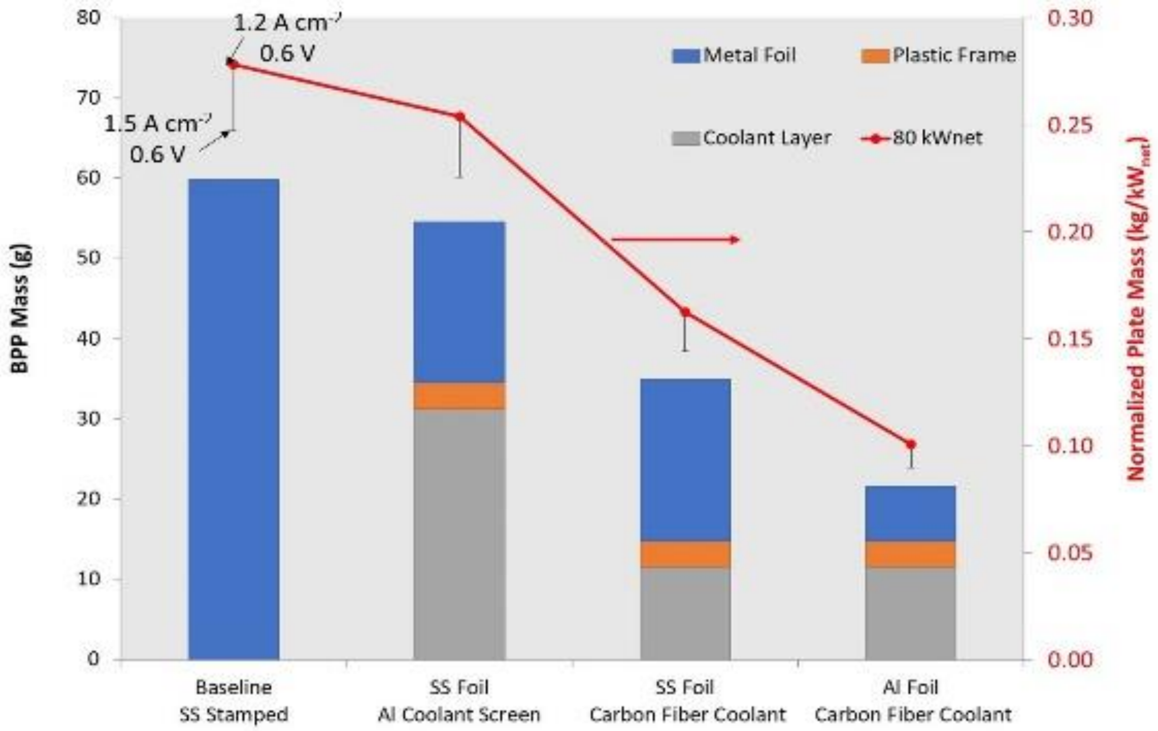
Performance with fully humidified inlets at A.) 80 °C and B.) 60 °C cell temperatures and 100% RH



50 cm^2 hardware that represents the entire fuel cell architecture. This includes anode and cathode flat foils, channel grooves in the GDL, and a mesh coolant layer.

Cost and mass estimates indicate a path to 2030 DOE BPP targets





Results from initial modeling using nonoptimized small-scale performance and 20% system parasitic power. This project will explore several material configurations aimed at reduced cost and mass BPPs. These estimates shown indicate that proven materials will decrease cost and mass in the proposed architecture and alternatives being investigated through this project will further improve these metrics if proven durable. .

Responses to Previous Year Reviews' Comments

- This project was not reviewed last year

Collaborations

Partner	Project Roles
Plug Power	Project lead, management and coordination, design, testing, cost modeling
University of Tennessee	Diagnostics and FC modeling
Oak Ridge National Lab	Plate materials, coatings, joining, corrosion characterization
Lyntec Engineering	Carbon fiber substrate manufacturing methods
Limitless Design	Wireless CVM development

Remaining Barriers and Challenges

- Carbon fiber substrate with uniform grooves to replace stamped flow channels
  - *Subtractive and additive methods are being investigated during the first phase of the project*
- Aluminum alloy foil with conductive coating to resist corrosion
  - *Investigate most promising material sets early, stainless steel alternative path*
- Conductive porous coolant layer supporting compressive load with even coolant distribution
  - *Wire mesh, carbon fiber, and conductive foams will be evaluated*
- Durable separator joining methodologies
  - *Screen printed adhesives will be evaluated with welding as an alternative path*
- Compatibility with high-throughput manufacturing methods
  - *All R&D work with materials and methods will be constrained by manufacturing processes that are currently used in high-volume production*

Proposed Future Work

Subaward agreements are currently near completion, project will be fully operational in May 2022

Task Number	Task or Subtask (if applicable) Title	Milestone Type (Milestone or Go/No-Go Decision Point)	Milestone Number* (Go/No-Go Decision Point Number)	Milestone Description (Go/No-Go Decision Criteria)	Percent Complete
1.0	DESIGN SPECIFICATIONS				
1.0	Requirements Document	Milestone	M1.1	BPP requirements and material selection guide	60
2.0	COMPONENT EVALUATION				
2.1	Coating Characterization	Milestone	M2.1.1	Coating samples and characterization	0
2.1	Coating Characterization	Milestone	M2.1.2	Coupon postmortem characterization	0
2.2	Joining	Milestone	M2.2.1	Joining methodologies	0
2.2	Joining	Milestone	M2.2.2	Pressure cycling of joined foils	0
2.3	Diffusion Layer Channels	Milestone	M2.3.1	Prototype diffusion layer with channels – subtractive	0
2.3	Diffusion Layer Channels	Milestone	M2.3.2	Prototype diffusion layer with channels – additive	0
2.4	Coolant Layer	Milestone	M2.4.1	Coolant layer material recommendation	0
2.5	Wireless CVM	Milestone	M2.5.1	Validation and Circuit Design	0
3.0	MODELING AND VALIDATION				
3.1	Model Framework	Milestone	M3.1.1	2D Model Framework	0
3.2	Small-Scale Experiments	Milestone	M3.2.1	Summary of Porous Rib Experimental Results	0
3.3	Model Evaluation	Milestone	M3.3.1	Model Validation with Porous Rib Parametric Studies	0

Summary

- A fuel cell architecture developed for roll-to-roll manufacturing of all stack components on a continuous web
- Design enabled by flat metal foil separators with gas flow channels in the carbon fiber diffusion layer
- Concept shown to meet or exceed performance of conventional flow distributors in stamped plates
- Clear path to lower cost and mass BPPs than the DOE 2030 targets while meeting all critical BPP performance and material requirements
- Subawards currently being finalized with project kickoff near-term