DOE Hydrogen Program

2021 Annual Merit Review and Peer Evaluation Meeting

Cummins PEM Fuel Cell System for Heavy Duty Applications

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AMR Project ID # FC337

6/9/2021 2:00:00 PM

Cummins New Power Background

Recent **acquisitions and partnerships**

- GE Fuel Cells (US)
- Hydrogenics* (Belgium, Germany, Canada)
- Loop Energy (Canada)
- JV with NPROXX (Germany)

**Air Liquide has an ownership stake of 19% of Hydrogenics*

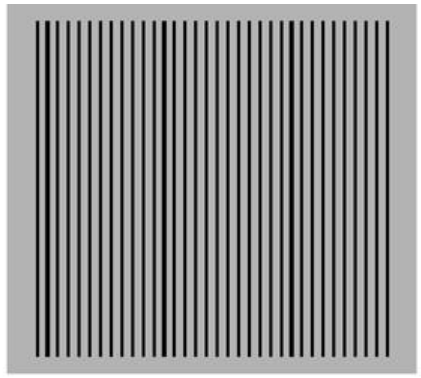
HD30

Type IV Tank

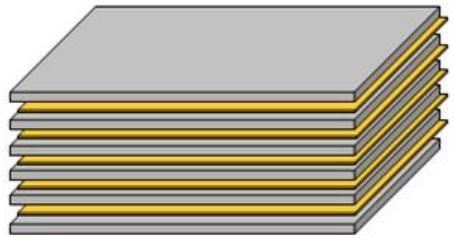
Europe	**China**	**Scandinavia**
Passenger Trains	Bus Commercialization	MD Delivery Truck
10 year agreement	200 in operation	4 Demonstration Trucks

Project Goal

- To develop a high pressure PEMFC stack & system for Heavy Duty applications, designed for mass manufacture with high efficiency, 25,000 hours life and able to operate at temperatures ≥100°C.
- This will be done by using an advanced graphite bipolar plate design with high temperature capable membranes and a specially developed e-Turbo for high efficiency at low cost.



Micro-channel bipolar plate
Design for high pressure operation & manufacturability



Modular stack
MEA developed for high temperature and durability

Air Compressor/e-Turbo
Designed for high efficiency and low cost

Overview

Timeline and Budget

- Project Start Date: TBD
- Project Duration: 36 months
- Total Project Budget: $3,750,000
  - Total DOE Share: $3,000,000
  - Total Cost Share: $750,000
  - Total DOE Funds Spent*: $0
  - Total Cost Share Funds Spent*: $0

* As of 04/12/2021

Barriers

- Barriers addressed:
  - Operation ≥100°C
  - 68% peak efficiency
  - 25,000 hour life
  - $80/kW system cost in mass manufacture

Partners

- Cummins – Project Lead
- FCHT (Hydrogenics) – Sub-recipient
- ANL - FFRDC
- W.L. Gore – Key Membrane Supplier
- Dana – Key Bipolar Plate Supplier
- CTT (Cummins Turbo Technologies) - Supplier

Relevance/Potential Impact

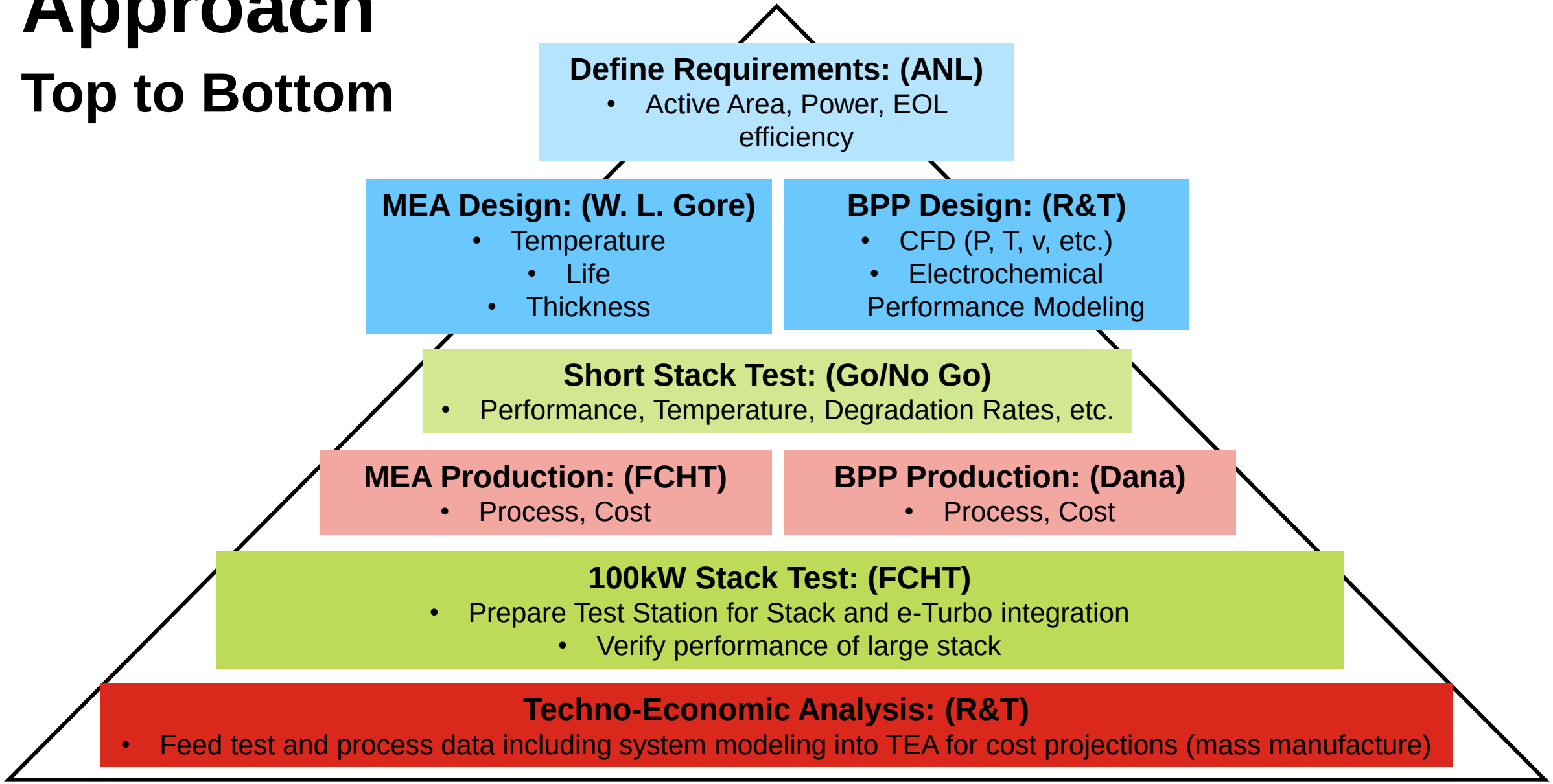
Barriers addressed

- **Operation ≥100°C**
  - To reduce the size and cost of the cooling system
  - Higher efficiency (lower activation losses)
  - Lower fuel grade (less CO adsorption)
- **68% peak efficiency**
  - Leading to lower fuel consumption for longer range, smaller tanks, less heat rejected and lower operating costs
- **25,000 hour life**
  - Durability target to minimize down time and stack replacement costs
- **$80/kW system cost in mass manufacture**
  - Enable widespread adoption of hydrogen PEM FC technology

Performance Summary	
	GOAL: HD-FC 100 kW
Description	DOE Class 8 HD Targets
Volume/yr	100,000
Durability (hrs)	>25,000
Peak System Efficiency	>68%
System Cost ($/kW)	$80
Operating Temperature (°C)	>100
PGM Total Loading (mg/cm^2)	0.2 - 0.3

Approach

Top to Bottom



Approach

Main Tasks

- **Phase 1**
  - **1.0 HD Stack Development**
    - 1.1 Stack and System Requirements
      - *ANL, FCHT*
    - 1.2 BPP Development
      - Analysis Led Design (CFD, stack performance modeling)
      - *R&T, FCHT*
    - 1.3 Membrane and MEA Development
      - 100°C capability
      - *W. L. Gore, FCHT, ANL*
  - **2.0 Short Stack Test**
    - Go/No Go Decision Point
    - R&T, FCHT

- **Phase 2**
  - **4.0 HD System Development**
    - System Modeling - *R&T*
    - Air Compressor (e-Turbo) - *CTT*
  - **5.0 Production Development**
    - BPP - *Dana*
    - *MEA - FCHT*
  - **6.0 100 kW Stack Test (inc. e-Turbo)**
    - Verify Performance
    - *FCHT*
  - **7.0 Final Report & TEA**
    - Projecting costs for mass manufacture
    - *R&T*

Milestones – Phase 1

#	Milestone	Description	Quarter
	HD Stack Development		
1	Cell active area	Defined based on analysis of expected product requirements.	1
2	System requirements	System power, EOL efficiency, etc.	2
3	BPP design released	Based on non-electrochemical coupon tests.	3
4	Stack model	Stack model to meet stack requirements	4
5	BPP prototypes delivered	Meets all aspects of the design requirements	5
6	MEA prototypes delivered	Meets all aspects of the design requirements	5
	HD Short Stack Test (1 kW)		
Go/ No Go	1 kW Stack Test Review	1. Performance data 2. High temperature (>100°C) and pressure (>250 kPa) 3. Short term degradation (<10 mV/1000 hr at 0.4 A/cm^2) 4. Cost review	6

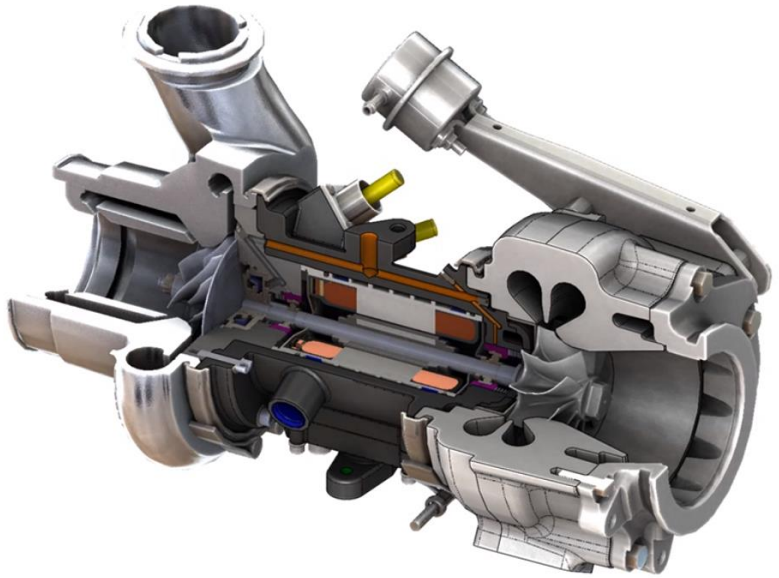
Milestones – Phase 2

#	Milestone	Description	Quarter
	HD System Development		
7	System Specifications	Compressor, humidifier, cooling system, etc.	7
8	Air compressor	Meets pressure, flow rate, and power requirements	8
	High Volume Stack Production Development		
9	Manufacturing cost targets	For volumes of 100,000 units/yr,	9
	HD Full Stack Test (100 kW)		
10	5,000 hours MEA test	Short stack using a relevant drive cycle	10
11	Validation of 100 kW stack prototype	At rated and peak power conditions, temperature, pressure, humidity conditions, stoic, and cooling requirements.	11
	End of Project Goal		
	Prototype 100 kW HD Stack Validation Test.	1. Demonstration of a 100 kW, HD PEM fuel cell stack 2. Procurement of stack components 3. Advanced manufacturing techniques 4. Detailed cost analysis up to 100,000 units per year 5. Validation of prototype air compressor	12

Accomplishments and Progress

Note: Project has not yet started (4/12/2021)

- CTT (Cummins Turbo Technologies) has received external funding and is defining the specifications of the e-Turbo with FCHT. Following tasks have started:
  - Material Selection
  - Turbine Wheel Design
  - E-Turbo Concept Design



Collaboration and Coordination

Partner	Type	Project Roles
Cummins R&T	Prime	Project Management CFD and Performance Modeling System Modeling CAD support Short stack & Component Testing
FCHT (Hydrogenics)	Sub-recipient	PEM FC Expertise Stack Design Lead MEA production Full Stack Testing
ANL	FFRDC	Supply TCO Requirements based on existing modeling tools
W.L Gore	Key Supplier	Selection, test and supply high temperature membranes
Dana	Key Supplier	Develop manufacturing process and supply graphite bipolar plates
CTT	Internal Supplier	Supply prototype e-Turbo

Remaining Challenges and Barriers

- **Barrier:** Negotiating advanced patent waiver provisions due to FCHT (Hydrogenics) being located in Canada. This has caused a delay to the start of the program.
- **Barrier:** Receiving Foreign Worker approvals for new team members
- **Challenge:** High temperature operation over 100°C will require test station upgrades and coolant challenges

Proposed Future Work

Remainder of FY 2021

- Milestone 1: Define Active Area
  - Work with ANL to define the stack requirements
- Membrane Selection for high temperature operation
  - Working with W.L. Gore to define membrane requirements
  - Start membrane testing
- Bipolar Plate Modeling and Design
  - R&T and HFCT collaborating to optimize BPP and channel geometry for high pressure operation
- Milestone 2: System Requirements Defined
  - Collaboration between HFCT, ANL and R&T to define the system requirements

FY 2022

- Deliver MEAs and BPPs for short stack test
- Short Stack Test: Go/No Go decision point
- System Specifications released

Summary

- Cummins is developing a high power HD PEM fuel cell stack capable of operating above 100°C for peak load cases
- Stack will be built using graphite based bipolar plates targeting 25,000 hours life
- A custom e-Turbo is being developed at CTT for optimal efficiency and low cost
- Manufacturing process development for reduced component costs
- 100 kW stack test data will be used for TEA study (cost at 100,000 units/yr.)

Q+A


Cummins

Technology Transfer Activities

- Nothing to report.
- Project delayed due to petition for advanced patent waivers