Award #: DE-EE0009214

Project Title:
Integrated Fuel Cell Electric Powertrain Demonstration

Project ID: TI141

Principal Investigator: Patrick Kaufman
Cummins Electrified Power NA Inc.

2023 Annual Merit Review & Peer Evaluation Meeting

4/14/23

Overview

Timeline*

- Project Start Date: October 1, 2020
- Project End Date: December 31, 2024
- Percentage Complete: 20%

Budget*

- **Total Project Funding: 7,208,624.00**
  - Department of Energy (DOE) Share: $3,443,063.00
  - Cost Share: $3,765,561.00
- **Funding for FY 2022: $5,377,815**
  - Federal Funds Allocated to BP 1: $2,423,577
  - Recipient Funds Allocated to BP 1: $2,954,238
- **Funding for FY 2023: $1,529,922**
  - Federal Funds Allocated to BP2: $799,360
  - Recipient Funds Allocated to BP2: $730,562

Partners*

- Project Lead- Cummins Electrified Power NA Inc. (CEPNA)
- Partners
  - CALSTART, Inc.
  - Clean Fuels Ohio*
  - Long Beach Clean Cities
  - Navistar Inc.
  - Southern California Gas Company
  - South Coast Air Quality Management District (SCAQMD)
  - Stark Area Regional Transit Authority (SARTA)*
  - Werner Enterprises

Barriers & Targets

- Original Equipment Manufacturer (OEM) commitment at risk
- Prototype components maturity still being evaluated
- Hydrogen (H2) fueling infrastructure availability and capability for heavy duty applications
- Diverging requirements between bus and truck applications leading to architecture differences

Any proposed future work Is subject to change based on funding levels.

Project Objectives

Objectives

Develop and demonstrate a modular and scalable integrated fuel cell electric powertrain for use in heavy-duty trucks and buses.

Parameter	Measure
Range (Component Level)	≥ 300 miles
Fuel Economy (Component Level)	≥8 miles per kg H2 (truck) / ≥10 miles per kg H2 (bus)
Fueling Time	≤10 minutes
Vehicle Availability	≥90%
Component Commonality	≥75% between bus and truck version of powertrain
Vehicle Upfront Cost	$800,000 (bus) / $600,000 (truck) for 1,000 annual sales
Maintenance Cost	$0.40 per mile
Fuel Cost	$5 - $6 per kg H2 at high volumes

Impact

The expected outcome of the project is a market-ready fuel cell electric powertrain whose operational performance and total cost of ownership will support near-term, rapid, and substantial penetration of the truck and bus markets.

If the project is successful, it will have the following impact on advancing the state of the art/technical baseline:

- Help reduce costs of hydrogen fuel cell commercial vehicles
- Advance the commercialization fuel cells in the truck and bus* market
- Drive demand for the proposed technology

Support of VTO Goals

- DOE funding will bring to market a unique and cost-competitive zero-emission powertrain solution that can be scaled to other heavy-duty vehicle markets like marine and industrial applications
- DOE funding will introduce needed competition to the North American fuel cell heavy- duty vehicle market and advance the commercialization of the technology.

Any proposed future work Is subject to change based on funding levels.

Approach*

BP1

Phase 1: Integrated Fuel Cell Powertrain Design & Assembly

Design of a modular and scalable integrated fuel cell electric powertrain by leveraging existing fuel cell powertrains.

The powertrain and its components will be designed and integrated ensuring high level of commonality in components between the truck and bus versions of the powertrain.

The powertrain layouts and integration processes will also be refined to make them highly manufacturable.

A prototype fuel cell class 8 truck and a prototype fuel cell transit bus will both be constructed and commissioned.

BP2

Phase 2: Vehicle Testing, Demonstration & Evaluation

The prototype vehicles will be tested for performance, safety, durability and reliability in operation closely simulating the drive cycles typically taken by the end-user fleets.

Delivered to the end-user fleets and operated in real-world conditions covering both hot and cold climate.

The performance of each vehicle will be thoroughly evaluated and reported throughout the demonstration period.

BP3

Phase 3: Technology Commercialization

Public outreach activities will help establish strong relationships throughout the hydrogen ecosystem to support future commercialization efforts.

An actionable technology deployment plan will be laid out to complete the introduction to market of the Integrated Fuel Cell Electric Powertrain, achieve high production volumes at reduced costs, and identify a viable pathway for commercialization to achieve near-term, rapid, and substantial penetration of the truck and bus market.

Any proposed future work Is subject to change based on funding levels.

FY 2023 & 2024 Milestones*

Budget Period 2: 1/01/2023- 12/31/23

- MS 9 &10- Prototype Tested
- MS11- H2 Fueling Supply Secured
- MS 12 – Field Demonstration Fleets Ready to Operate
- MS 13- Demonstration Period Completed
- MS14- Data Analysis & Performance Evaluation Completed
- MS 15- Successful Completion of Field Demonstration *Go/No-Go decision*

Budget Period 3: 01/01/24- 12/31/24

- MS 16- Voice of the Customer Event
- MS 17- Webinars Completed
- MS 18- Product Development & Manufacturing Plan
- MS 19- Technology Commercialization Roadmap Completed

Go/No-Go Decision- End of Project Goal:
Interest for Integrated Fuel Cell Electric Powertrain Has Been Secured

Any proposed future work Is subject to change based on funding levels.

Project Accomplishments and Progress

- Q3 ‘22 Progress
  - Applied technology improvements with sub-systems/modules wherein improvements are being realized are as follows:
    - Next-generation higher power fuel cell engine, new high-power battery packs better suited to fuel-cell applications, eAxle traction system for Class 8 application & direct drive traction improvement for Transit Bus application, and 700bar H2 Storage system with more H2 capacity for Class 8 applications
  - Fuel Cell Truck
    - Worked with Navistar on an Amendment to the Navistar Agreement to clarify roles and responsibilities, partially based on the improvements listed above
      - Redefined the RASIC and scope of supply for the fuel cell truck components. By September end we were in final reviews and prepping to begin the Amendment to the Navistar contract.
  - Fuel Cell Bus
    - OEM has agreed in principle to partner with Cummins on this project. Both a memorandum of understanding and contract are in continued negotiations.
      - OEM and fleet requirements were reviewed and finalized, received 60% of vehicle information, including computer aided design (CAD) models of stock bus, detailed architecture is frozen, major components confirmed based on the simulation results to meet OEM preferred duty cycle (fleet requirements), 10% of component layout work completed, and Concept BOM defined.
- Q4 ’22 Progress
  - Fuel Cell Truck
    - Began Task 1.1 Integrated Fuel Cell Electric Powertrain Design activities
      - In October, the Cummins team began discussions with Original Equipment Manufacturer (OEM) partner on Powertrain Architecture.
    - Updated and finalized RASIC with OEM partner in November 2022.
    - Executed Amendment 1 to Navistar subcontract agreement on 12/12/2022.
    - Resources secured to kick-off of technical development in January 2023.
  - Fuel Cell Bus
    - In December, it was decided and communicated to DOE that bus OEM is no longer participating in this project.
- Q1 ’23 Progress
  - Progressed design and development of fuel cell powertrain (included in technical backup slides)
  - Engaged battery and H2 storage suppliers
  - Engaged fleet partners to gather voice of customer and better understand their requirements.

Collaboration and Coordination Among Project Team

Lead Organization

- Cummins Electrified Power NA Inc.

Partner Organizations (subrecipients)

- CALSTART, Inc.
- Navistar Inc.
- Stark Area Regional Transit Authority (SARTA)*
- Werner Enterprises

Additional Partners

- Southern California Gas Company
- South Coast Air Quality Management District (SCAQMD)
- Clean Fuels Ohio*
- Long Beach Clean Cities

Cummins Electrified Power NA Inc. (Cummins) is the Recipient and will provide overall project management, task coordination, and administrative functions for the project. Cummins will also manage all the technical tasks, working with Navistar to design the integrated fuel cell electric powertrain. Cummins will build, commission, and test the prototype fuel cell vehicle, providing service and support during the field demonstration Werner Enterprises. CALSTART, with Cummins' guidance, will manage data collection and analysis, develop the product development and manufacturing plan, and the technology commercialization pathway. Long Beach Clean Cities will hold community outreach events. SoCalGas will provide additional funding to the project, and additional funding partners are being sought. Each of the partners listed will participate in regular project meetings and reviews and provide feedback to the Project Team on policies and legislation driving the hydrogen economy and the commercialization of fuel cell and hydrogen technologies.

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Market Impact and Sustainability

- Vertically integrated powertrain: The proposed project will deliver the first fuel cell electric powertrain for commercial vehicles to be made of components from a single provider, CEPNA, eliminating integration, service and support issues.
- Modular and scalable: The proposed powertrain architecture will be designed in several modules that can be easily integrated into truck and bus chassis by vehicle OEMs and scaled to a wide variety of commercial vehicle applications to more quickly achieve scale.
- Highly integrated and manufacturable: The proposed powertrain architecture will be designed in collaboration with 2 major truck and bus OEMs to be easily integrated into existing chassis platforms. In addition, it will be engineered to be highly manufacturable to decrease the module manufacturing and integration costs.
- Increased driving range. The powertrain will be designed to bring a proven range of at least 300 miles, capable of meeting most truck and bus daily range requirements.
- Increased fuel economy. Improved fuel economy of 10 miles per kg of H2 for heavy-duty truck applications and 8 miles per kg of H2 for transit buses will decrease the use of hydrogen fuel and the vehicle operating costs.
- Rapid refueling. The hydrogen fueling system will be designed to be refueled in about 10 minutes, a time comparable with conventional diesel and CNG buses to decrease downtime compared to electric vehicle battery charging.
- 1:1 replacement of conventional vehicles. The system will be designed, engineered and developed with reliability, durability and serviceability in mind and will use proven commercial off the shelf components to reduce downtime and maintenance costs.
- TCO reduction: The system will be capable of achieving scale faster by reaching a high 75% level of component commonality between the truck and bus versions of the powertrain, which in turn will reduce upfront purchase costs. In addition, the increased fuel economy will reduce operating costs and the 1:1 replacement of conventional vehicles will reduce maintenance costs.

Any proposed future work Is subject to change based on funding levels.

Contribution to Energy Equity and Environmental Justice

- An estimated 38,900 gallons of diesel fuel will be displaced annually
  - Bus: 13,900 gallons
  - Truck: 25,000 gallons

- This hydrogen fuel cell emergency relief truck is estimated to reduce GHG emissions by 3,780 metric tonnes CO_2e annually compared to the diesel truck and genset combination.

Any proposed future work Is subject to change based on funding levels.

Summary

Objective

- The objective of the project is to develop and demonstrate a modular and scalable integrated fuel cell electric powertrain for heavy-duty trucks and buses that is highly manufacturable leading to 1:1 replacement of conventional vehicles.

Projected Outcomes

- Vehicles meet or exceed the following key performance parameters that will result in cost savings and improved affordability: proven range of ≥300 miles, increased fuel economy of ≥5.5 miles per kg of H2 for heavy-duty truck applications and ≥7 miles per kg of H2 for transit buses, refueling speeds of ≤ 25 minutes refueling time (at 700 bar) for heavy-duty truck applications and ≤ 20 minutes refueling time (at 350 bar) for transit buses, vehicle availability ≥90%,

Next Steps

- Cummins to work with DOE on an amendment
- Continue design and development towards meeting contract goals.

Technical Backup

02

Accelera

Typical FCEV Architecture

Note: For illustrative purposes only

Final Architecture may vary