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Requirements Document For Demonstration of Fuel Cell-Based Auxiliary Power Unit for Refrigerated Trucks

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Pacific Northwest NATIONAL LABORATORY

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1.0 Introduction

1.1 Background

Fuel cells can provide clean, efficient auxiliary power for trucks, recreational vehicles, marine vessels, airplanes, locomotives, and similar applications that have significant auxiliary power demands. Currently, primary motive-power engines are often kept running solely to provide electrical power for those auxiliary loads, an inefficient practice that both wastes fuel, increases emissions, and results in increased engine wear. Fuel cell-based Auxiliary Power Units (APUs) represent a possible solution to meet such demands, and are being considered for terrestrial, aviation, and maritime applications.

APUs for medium duty refrigerated trucks is a potential early market opportunity for fuel cell deployment. Significant fuel savings and lowered engine wear, as well as reduction in CO_2 and criteria pollutant emissions, may be achieved through more efficient fuel conversion and reduction in engine idling time. The American Trucking Association has determined that 30,000 refrigerated trucks are being produced each year in the US for the fleet total of approximately 300,000 refrigerated trucks. The Fuel Cell Technologies Program in the Office of Energy Efficiency and Renewable Energy (EERE) performed a preliminary market penetration study and found that if 30,000 refrigerated trucks used fuel cell-based APUs, the consumption of diesel fuel could be reduced by more than 300,000 gallons per day while avoiding up to 500 kg of particulate matter and more than 1.4 MT of NO_x per day.

Unique challenges for APUs on medium-duty refrigerated trucks include its need for durability in spite of its transient operation over a range of temperatures and the shock and vibrations inherent on a vehicle. The APU unit must fit in the limited space available on the vehicle and not add unnecessary weight, but also be accessible for maintenance. The fuel cell-based APUs must also become cost-competitive with alternate approaches, including small combustion engines and battery packs.

1.2 Scope

To aid in enabling successful market penetration of fuel cell technologies, auxiliary power for medium-duty trucks was identified as a potential early market opportunity. This project targets the demonstration of fuel cell-based APUs to provide power for Truck Refrigeration Units (TRU) for short - haul trucks. The fuel cell-based APU to be developed is intended to serve as a retrofit to existing TRU on Class 4-6 medium duty trucks.

Accelerating fuel cell use in this key early market segment is expected to create jobs in the sustainable energy systems sector, increase fuel cell production volumes, decrease fuel cell manufacturing costs, and catalyze a stronger domestic supplier base for these strategically important distributed power generators. This investment is expected to result in growth in employment opportunities in the areas of manufacturing fuel cell-based APUs and related technologies; maintaining and supporting fuel cell-based APUs; and producing, delivering and storing related fuels upstream of the Fuel Cell Systems (FCS) in their energy supply chain. This investment is expected to help the fuel cell industry overcome a number of non-technical barriers to market entry, such as the need to educate users and to overcome inherent resistance to new technologies and approaches. These kinds of barriers will be addressed by enabling users to gain confidence with the technology through hands-on operating experience.

This project is open to nonprofit and for-profit entities, institutions of higher education, and state and local governments, however industry participation is required to assure there is a potential for commercial market entry. Federally Funded Research and Development Centers, including U.S. national laboratories, are not eligible for this project. This award is available to U.S. based original equipment manufacturers (OEM) . Foreign entities, if participating as a supplier or subcontractor, are required to conduct work through their U.S. subsidiary and the units must be demonstrated in the U.S. A minimum cost sharing of 50% of non-federal funds for demonstration and market transformation will be required for all awards issued under this project. Cost share applies to all allowable costs associated with the project including, but not limited to, capital, installation, operating, maintenance, and decommissioning costs. All systems must be installed in the U.S. and its territories. State and other fuel cell subsidies and tax incentives cannot be used for the cost share.

It is anticipated that this project would be conducted over a period of 12 to 24 months. The first phase of the project will perform a cost benefit analysis comparing the benefits of fuel cell APUs to conventional APUs. The later phases of the project will deploy and demonstrate the fuel cell based APU operation in commercial use on the vehicle. Offerors must ensure the safe installation and operation of APUs and any related ancillary technologies or needs. This includes, but is not limited to, safety applied to all system components, refueling and other ancillary systems, and monitoring equipment. Project deliverables include a final report that provides performance data plus a refined comparative life cycle cost analysis. The cost analysis should compare the APU to currently-used technologies and assess its potential for market penetration.

1.3 Objectives

This project aims to increase the number of commercially available fuel cell-powered systems, expand practical user operating experiences, lower the cost of fuel cell manufacture, generate volume for the fuel cell supply chain, validate fuel cell performance using real-world operations data, increase private equity confidence, and increase market pull for existing and new-generation fuel cell-powered APUs. It aims to provide independently-verified, measured data and analyses on the engineering, financial, and environmental performance of these fuel cell systems to the DOE and Pacific Northwest National Laboratory. For this program, PNNL is acting in the capacity as an unbiased, third party, independent evaluator of these systems in operation. PNNL will objectively assess the projects' engineering, financial, and environmental performance.

To achieve eventual commercial success, a fuel cell-based APU must provide operating advantages when compared to competing technologies, which include internal combustion engines and battery packs. The APU to be demonstrated is expected to be consistent with technical targets (2011 status) established by the U.S. Department of Energy for energy efficiency, power density, specific power, cost, cold startup time, transient response, degradation with cycling, operating lifetime, and system availability.

2.0 Requirements

2.1 Technical Requirements

Over a period of 12-24 months, this project shall develop and demonstrate a fuel cell-based APU for a TRU on a short-haul truck used in regular commerce (e.g. making actual deliveries). Minimum requirements that must be met for consideration include:

- Shall be able to deliver and deploy a fuel cell-based APU on a commercial TRU in the range of approximately 3-6 kW net cooling capacity. The APU shall employ commercially available fuel cell technology as opposed to lab-scale experimental technologies.
- The APU shall be a drop-in replacement for the original power unit powering the TRU on a Class 4 to 6 short-haul truck without any additional power from the vehicles main drive engine. The APU may consist of a fuel cell/battery hybrid, which may lower fuel cell stack size requirements. The design may include modification or adaption of a TRU, to enable fuel cell integration.
- On-board reformation to produce hydrogen fuel from transportation fuels or other means of fuel production on board the vehicle is not allowable.
- Demonstrate operation of each fuel-cell based APU on board the vehicle during commercial-scale deliveries of cargo for a minimum 400 APU operating hours. Durability testing should include, at minimum, daily cycles to stand-by conditions and weekly cycles to full off conditions. Demonstrations should be performed over a range of ambient temperatures.

The technical portion of the proposals will be evaluated in regards to the following evaluation criteria categories:

1. Technical System Requirements
2. Project Management and Deployment and Demonstration Plans
3. Past Performance of the Proposing Team
4. Project Deliverables and Schedule

2.1.1 Technical System Requirements

For the Technical Systems requirements, applications should describe at a minimum:

- Number of units to be demonstrated. A minimum of one must be demonstrated, but multiple units would be preferred. Demonstration of multiple units can be performed after the go/no-go decision point involving DOE and Battelle PNNL based on the initial performance of the first unit.
- A description of the fuel cell power system to be utilized on this project, which may include controllers, inverters, dc-dc converters, and batteries in addition to the stack. An estimate of the size and mass of APU components should be included.
- A description of the commercial TRU to be retrofit with a fuel cell-based APU, and any anticipated modifications/adaptions required.

- A description of the short-haul trucks to be used and their required refrigeration temperatures and anticipated daily cooling duty cycles for a range of ambient temperatures.
- A description of the proposed location of the deployments and opportunities for leveraging the hydrogen infrastructure developed for this project for future applications (in particular, lift trucks in the short term and fuel cell vehicles in the long term).
- A refueling plan that includes a description of the fuel to be used, where and how refueling will occur, and how safety aspects of refueling will be addressed.
- Anticipated system operational profile, including APU hours per day for operating, standby, and frequency of cold start-ups.
- Anticipated truck usage including expected number of miles travelled and operating hours per week
- Anticipated maintenance schedule.
- Estimates of anticipated average and peak power, electrical efficiency at rated power, system mass and volume, lifetime, start-up time, mean time to stack failure, and system availability as compared to relevant information in the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan[1] and the DOE Revised APU Targets.[2]
- The time-frequency of performance data, and the lag time between the APU's output and data provision to PNNL.

2.1.2 Project Management and Deployment and Demonstration Plans

The Project Management and Deployment and Demonstration Plans need to detail how objectives of this project will be met. The plans should include the following:

- Program management plan. This plan should describe how the Offeror will manage the program including description of phases, key milestones, go/no-go decisions, critical path and timeline. It should also include a brief summary of capabilities of commercial partners and a brief summary of facilities that would be available to this project.
- Deployment and Demonstration Plan. This plan should describe the data monitoring and control plan including what data would be collected and how and at what frequency it would be shared with DOE and Battelle PNNL. It should also include the commercial viability of the fuel cell powered APU demonstrated for this project and the potential for continued evaluation, follow-on deployments, or future infrastructure availability without DOE funding at the conclusion of the project.

2.1.3 Past Performance of the Proposing Team

Proposals shall include detailed documentation of past performance similar to the requirements of this document. Preference will be given to proposal teams who have demonstrated the successful deployment of fuel cell systems.

[1] http://www1.eere.energy.gov/hydrogenandfuelcells/mypp/pdfs/fuel_cells.pdf
[2] http://hydrogen.energy.gov/pdfs/11001_apu_targets.pdf

2.1.4 Project Deliverables and Schedule

Project Deliverables

- Attend all project meetings via webinar, phone, or in-person. These include an in-person kick-off meeting and site visit, an in-person DOE Annual Merit and Peer Review Evaluation held once per year and attended annually for the proposed period of performance of the project, and webinar-based monthly planning and monitoring meetings. Host periodic visits for technical and project management review. Other required meetings will be negotiated in the final contract.
- Provide a work plan for the deployment and demonstration of an approximately 3-6 kW net cooling capacity TRU retrofitted with a fuel cell-based APU on a Class 4-6 truck. The work plan will include a Phase I for system cost benefit analysis, a go/no-go decision point with its criteria, and a Phase II for system integration and demonstration. One unit would be demonstrated in Phase II and deployment and demonstration of any additional units would be performed in Phase III based on a go/no-go decision point. Applicant should provide the go/no-go decision criteria.
- Provide a safety plan to address all safety risks. This includes addressing the safe installation, operation, and monitoring of FCS over the entire spectrum of the FCSs design space and cooperating with the appropriate regulators. Hydrogen safety should be explicitly addressed in this plan, in accordance with: http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/safety_guidance.pdf.
- Install, operate, and monitor a fuel cell-powered TRU on a Class 4-6 truck in a safe manner and consistent with program goals.
- Provide calibration reports for all measuring and testing equipment used for data collection. These reports should include traceability to National Institute of Standards and Technology (NIST).
- For the duration of the demonstration effort, continuously report performance data as close to real-time as possible. Where applicable and available, the following performance data shall be provided to PNNL biweekly during the demonstration.
    - Number of units deployed
    - Miles the trucks travelled
    - Truck operating hours
    - Fuel cell operating hours
    - Number of fuel cell start-ups and shut-downs
    - Ambient temperature (max, min, and at start-up)
    - Average refrigeration temperature during use
    - Fuel cell power provided (kW-hrs between fills)
    - Fuel cell efficiency (kW-hrs/kg fuel)
    - Fuel cell operation time between fills
    - Number of fueling events (how many times its filled)
    - Amount of fuel dispensed during refueling
    - Filling station type (compressed hydrogen, liquid hydrogen, methanol, etc.)
    - Refueling rate
    - Duration and number of maintenance shut downs
- Provide quarterly progress reports to PNNL
- Provide a final report that includes the following:
    - Summary of operational data

- A comparison to the DOE technical targets for fuel cells as discussed in the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan
- Comparative life cycle cost analysis to currently-used technologies
- An assessment of the potential for the technology market penetration.

Schedule

Offerors shall provide a detailed schedule, work breakdown, and project structure as part of the proposal. These plans must include, at a minimum, a kick-off meeting, a work plan, a management plan, and a safety plan. Schedules should delineate key milestones, performance periods, and at least two go/no-go decision points with their evaluation criteria. The phases of the project shall be included in the schedule. The go/no-go decision points shall involve PNNL and DOE. Deliverables will include the cost-benefit analysis, quarterly progress reports, participation in the Annual Merit Review Meetings, participation in monthly progress update meetings (on-site at Offerer's facilities or via teleconference), and a final report. Offerors can expect periodic on-site visits from PNNL and DOE.

2.2 Price/Cost Requirements

Proposal cost will be a significant factor in the proposal evaluation. The Offeror shall provide the following information:

- Level of non-federal contribution above the minimum required for non-federal cost share. A minimum cost share of 50% is required. If foreign partners are involved, they must provide at least 50% cost share for their portion of work scope; the U.S. partner cannot cover their cost share for the project.
- All life cycle costs including: capital and development costs; ancillary equipment costs (if applicable); installation, commissioning, operation, maintenance, decommissioning, and recycling costs for the specified system.
    - Acceptable costs include capital costs for fuel cell system components, fuel cell system development and optimization, purchase of the TRU, its modification/adaption for fuel cell integration, and fuel for the APU.
    - Unacceptable costs include development of a H_2 refueling station (note: some components specific to this project may be allowable e.g. fuel dispenser), and purchase of a medium-duty truck and diesel fuel for its operation.

3.0 Additional Information

Information on Cost Share

- Costs charged to Federal funds and those counted as the recipient's cost share or match are to be consistent with requirements for cost reasonableness, allowability, and allocability in the applicable cost principles and in the terms and conditions of the award.
- Costs are not paid by the Federal Government under another award unless authorized by Federal statute to be used for cost sharing or matching.

Information on U.S. fuel cell companies is available at these websites:

- Fuel Cells 2000: http://www.fuelcells.org/

- U.S. Fuel Cell Council: http://www.fchea.org/

Information on developing a safety plan for the FCS is available at the DOE website:

http://www1.eere.energy.gov/hydrogenandfuelcells/codes/oversight.html

Information on financial incentives for fuel cell projects is available at this website:

- U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy (EERE), Fuel Cell Technologies Program, Market Transformation: Program:https://www1.eere.energy.gov/hydrogenandfuelcells/incentives.html

4.0 List of Acronyms

APU	Auxiliary Power Unit
DOE	Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
FCS	Fuel Cell System
kW	kilowatt
NIST	National Institute of Standards and Technology
OEM	original equipment manufacturers
TRU	Truck Refrigeration Unit
U.S.	United States
$	U.S. dollars