



COORDINATING RESEARCH COUNCIL, INC.

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February 12, 2026

In reply, refer to:

CRC Project No. SM-CR-2024-01

Dear Prospective Bidder:

The Coordinating Research Council (CRC) invites you to submit a written proposal to provide services for “Component-Level Techno-Economic Analysis of Various Hydrogen- and Battery-Powered Light-Commercial- and Heavy-Duty Vehicles” (CRC Project No. SM-CR-2024-01). A description of the project is presented in Exhibit A, “Statement of Work.”

Please indicate your intention to bid at [this link](#) on or before **February 26, 2026** if you or your organization intends to submit a written proposal for this research program. CRC will answer technical questions regarding the Request for Proposal if they are submitted in writing at least one week before the proposal submission deadline here: [Q & A Link](#). CRC will then return written answers to all the bidders, along with a copy of the original questions. Questions submitted within a week of the deadline may not be answered before the proposal submission deadline.

A CRC technical group composed of industry representatives will evaluate your proposal. CRC reserves the right to accept or reject any or all proposals.

The reporting requirements will be monthly progress reports and a summary technical report at the end of the contractual period. The reporting requirements are described in more detail in the attachment entitled “Reports” (Exhibit B).

The proposal must be submitted as two separate documents. The technical approach to the problem will be described in part one, and a cost breakdown that is priced by task will be described in part two. The cost proposal document should include all costs associated with conducting the proposed program. The technical proposal shall not be longer than 10 pages in length.

CRC expects to negotiate a cost-plus fixed fee or cost reimbursement contract for the research program. Contract language for intellectual property and liability clauses is presented in Exhibit C and in Exhibit D, respectively.

Important selection factors to be taken into account are listed in Exhibit E. CRC evaluation procedures require the technical group to complete a thorough technical evaluation before considering costs. After developing a recommendation based on technical considerations, the costs are revealed and the recommendation is modified as needed.

Electronic copies of the technical and cost proposals should be submitted to:

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The deadline for receipt of your proposal is **March 12, 2026**.

Yours truly,

Prem Lehr
Project Manager

EXHIBIT A

SM-CR-2024-01 Statement of Work

“Component-Level Techno-Economic Analysis of Various Hydrogen- and Battery-Powered Light-Commercial- and Heavy-Duty Vehicles”

Research Impact

This research will provide a valuable and detailed overview of the impact of powertrain technologies on efficiency, emissions reduction, and cost. With focus on vehicle segment technology specificity, the results will provide a sound direction on the trade-offs that OEMs face to improve 1) light-commercial and 2) heavy-duty powertrains.

Background

Decarbonization of the transportation sector at a reasonable cost is a critical requirement for achieving net-zero ambitions around the world. Technology innovation and new energy vectors are being explored to supplement efficiency improvements to internal combustion engine technologies with lower carbon fuels. Among them:

- batteries that are capable of fast-charging
- batteries that are capable of swapping
- hydrogen internal combustion engines
- hydrogen fuel cells

Each of these has advantages and drawbacks for efficiency, emissions, and cost, while advances in their various system components continue at differing rates.

Factors such as membrane technology and materials, parts sizing, and balance-of-plant components can influence fuel cell costs. The fuel injection system, special materials, and aftertreatment can influence the cost of internal combustion engines. Battery electric vehicles offer excellent carbon dioxide reduction on a tank-to-wheel basis, but charging times and excessive payload reduction are possible downsides. Battery swapping could address some of these limitations. Recent reports and publications have provided a general assessment of the total cost of ownership of potential lower carbon footprint technologies [1–6]. However, increased variability on cost assumptions and limited technology description are typically found in the literature. Target costs instead of realistic cost evolution and generic hardware performance are common shortcomings of available data. It is possible to conclude that, while literature offers insights into some of the costs for each technology, a detailed assessment considering the different requirements for light-commercial and heavy-duty vehicles is still not available.

Therefore, this project is intended to clarify, through techno-economic analysis at the component level, the cost sensitivity of fuel cells, hydrogen internal combustion engines, and battery electric vehicles. This includes a detailed assessment of the impact of system optimization for each vehicle, as for example, storage system technology, fuel system type for

engines, membrane materials required for each application, battery chemistry and layout, technology readiness levels, etc.

Goals

To evaluate different decarbonization pathways potential in reducing emissions in a cost-effective manner, the goals of this study are:

1. Examine the various component technologies used in powertrains with a) hydrogen proton exchange fuel cells, b) H₂ICE engines, c) plug-in batteries. Evaluate cost and technology readiness compared to a baseline of gasoline ICE (for LCV) and diesel ICE baseline (for HDV).

2. For a) a light-commercial vehicle (LCV) and b) a heavy-duty vehicle (HDV) use-case, model and optimize a representative powertrain for each of the listed powertrain types.

- Assess fuel/energy consumption over homologation/certification and common driving conditions agreed with contractor.
- Assess total vehicle cost compared to that of a conventionally-powered equivalent (baseline)
- Assess GHG emissions compared to that of a conventionally-powered equivalent (baseline) in a well-to-wheel basis agreed on a set of assumptions
- Incorporate effects of payload capacity variation and charging/fueling time to develop a cost of operation.
- Cost of Operation includes:
 - Aggregated assumptions of ‘standard’ vehicle cost assuming industry average markup value for determination of final vehicle cost to the consumer following the approach proposed by [7] Uptime (due to refueling/recharging and fuel use)
 - Payload opportunity
 - Fuel cost (from basic assumptions)
- Cost of Operation does not include:
 - Driver pay, insurance cost, maintenance, tolls, etc.
 - Infrastructure installation cost

3. Examine the effect of changes in cost and efficiency of the various components, and fuel prices, to the Cost of Operation

4. Rank various technologies considering their carbon abatement costs with the different technology packages (I.e., \$/ton of avoided GHG emission, or cost of operation) compared to a baseline of gasoline ICE (for LCV) and diesel ICE baseline (for HDV).

5. Optional goal: develop an interactive analysis tool where the user can define different configurations, fuel/electricity prices and understand the impact on vehicle and operational costs.

6. Optional goal: assess battery powertrains with battery-swapping capability as a 4th powertrain option.

Deliverables

Primary

Database of publicly available aggregated sources, containing the information:

1. Component options for a) fuel cell, b) hydrogen internal combustion engine, and c) battery electric powertrains with key metrics:
 - a. Estimated cost as function of years (2025, 2030 and 2035, when available)
 - b. Technology maturity and adoption
 - c. Current efficiency and improvement potential
 - d. Benefits and downsides
2. For one representative LCV and one HDV, identify an optimized powertrain system configuration for each powertrain type listed in 1, selected among the components identified in 1. For each powertrain system configuration, list:
 - a. Fuel/energy consumption per ton-mile compared to a conventionally-powered equivalent (baseline)
 - b. Emissions per ton-mile compared to a conventionally-powered equivalent (baseline)
 - c. Total system cost compared to a conventionally-powered equivalent (baseline)
 - d. (For the LCV configurations) fuel and vehicle operating cost compared to a conventionally-powered equivalent (baseline)
 - e. (For the HDV configurations) cost of installation and operation of a typical refueling depot, fuel cost, vehicle operating cost compared to a conventionally-powered equivalent (baseline)
3. CRC Final Report explaining the technology, analysis, results, and insights from the Deliverables that fulfills the Goals.

Extended

4. Deliver tool with graphical user interface where the data can be accessed and used to input different assumptions which can allow building different powertrain options and scenarios, allowing calculations for cost of platform and its operation. This tool would be available to SMC members but not the general public.
5. Assess battery powertrains with battery-swapping capability as a 4th powertrain option.

Scope of Work (detailed)

In the proposal, contractor should detail how they intend to collect the data, set up the model calculations, and carry out the analysis described below. Publicly databases should be used, and reviewed with the CRC members.

An initial review is planned to identify the current and future technologies in hydrogen internal combustion engines, fuel cells and battery electric vehicles, incorporating recent advancements in subsystems such as the fuel injection system, air management system, fuel cell membrane, humidifier, storage, battery chemistry and any other representative systems that are deemed relevant from a powertrain perspective for both light duty and heavy-duty powertrains.

Database creation with relevant information on performance, cost and technology maturity, incorporating operational requirements from light duty and heavy-duty transport for selecting the possible technologies to be used in fuel cell, hydrogen internal combustion engines and battery electric vehicles. As an initial result, a ranking of the different relevant technologies for hydrogen, fuel cell and battery electric vehicles powertrains should be provided, considering the key parameters to be identified (e.g. cost, performance benefits).

Powertrain Configurations

Different powertrain configurations for hydrogen internal combustion engines, fuel cell and battery electric trucks will also be identified, with the specifications on cost, performance potential and technology maturity level. Contractor should advise on the powertrain configurations most valuable to consider for Deliverable 2). For example, H₂ ICE could comprise port fuel injection with low pressure storage (350 bar). A second powertrain could consist of a direct injection system with high pressure storage (700bar). Battery electric vehicle powertrains could comprise LFP, versus NMC 811 cathode chemistry, considering the impact on energy density and current limitations. The potential efficiency benefits between these powertrains would be identified, as well as the cost associated with the system and the main technical challenges for implementation. Similarly, for fuel cell trucks, different membrane technologies could dictate specific powertrain configurations. In the light duty space, a perfluorosulfonic acid membrane should be more appropriate. On the heavy-duty side, given the high temperature operational requirements, sulfonated polyaromatic membranes would be a potential candidate, considering the continued high current density demand during operation.

The final benefits of each powertrain layout will be quantified using a driving cycle assessment, which would result in a range of possible fuel consumption values according to the different technologies considered. The driving cycle conditions consider not only homologation cycles but also utilization (duty cycles) for both light commercial and heavy duty powertrains. The fuel consumption/energy cost will be considered in a total-cost-of ownership function, considering the specificities of each powertrain option. Later, a final plot will be presented with the TCO of each technology, whether incremental or substitutive, providing a clear picture of the total cost for achieving the [WTW or life cycle] CO₂ reduction of each technology.

Considering the breadth of the research, a possible tool for evaluating total cost of ownership for the different technologies could be developed, allowing the user to pre-configure powertrain

options according to validity rules and performing total cost of ownership calculations to better understand a vehicle purchase price depending on the technology selected to build the powertrain.

Keywords: Fuel cell, Hydrogen Internal Combustion Engine, Battery Electric Vehicles, Total Cost of Ownership, Technology Innovation, transportation

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- [2] R.K. Ahluwalia, X. Wang, D.D. Papadias, A.G. Star, Performance and Total Cost of Ownership of a Fuel Cell Hybrid Mining Truck, *Energies (Basel)* 16 (2023). <https://doi.org/10.3390/en16010286>.
- [3] H. Basma, A. Saboori, F. Rodríguez, TOTAL COST OF OWNERSHIP FOR TRACTOR-TRAILERS IN EUROPE: BATTERY ELECTRIC VERSUS DIESEL, 2021. www.theicct.orgcommunications@theicct.org.
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- [5] C. Hunter, M. Penev, E. Reznicek, J. Lustbader, A. Birky, C. Zhang, Spatial and Temporal Analysis of the Total Cost of Ownership for Class 8 Tractors and Class 4 Parcel Delivery Trucks, 2021. <https://www.osti.gov/servlets/purl/1821615/%0Ahttps://www.nrel.gov/docs/fy21osti/71796.pdf>.
- [6] C. Rout, H. Li, V. Dupont, Z. Wadud, A comparative total cost of ownership analysis of heavy duty on-road and off-road vehicles powered by hydrogen, electricity, and diesel, *Heliyon* 8 (2022). <https://doi.org/10.1016/j.heliyon.2022.e12417>.
- [7] U. Department of Energy, Analysis Program 2021 Annual Progress Report Vehicle Technologies Office, 2021.

EXHIBIT B

REPORTS

MONTHLY TECHNICAL PROGRESS REPORTS

The contractor shall submit a monthly technical progress report covering work accomplished during each calendar month of the contract performance. An electronic Microsoft® Word compatible file (<1 MB) of the monthly technical progress report shall be distributed by the contractor within ten (10) calendar days after the end of each reporting period. The report shall contain a description of overall progress, plus a separate description for each task or other logical segment of work on which effort was expended during the reporting period.

FINAL REPORT

The contractor shall submit to or distribute for CRC an electronic (Microsoft Word) copy transmittable via email) of a rough draft of a final report within thirty (30) days after completion of the technical effort specified in the contract. The report shall document, in detail, the test program and all of the work performed under the contract. The report shall include tables, graphs, diagrams, curves, sketches, photographs and drawings in sufficient detail to comprehensively explain the test program and results achieved under the contract. The report shall be complete in itself and contain no reference, directly or indirectly, to the monthly report(s).

The draft report must have appropriate editorial review corrections made by the contractor prior to submission to CRC to avoid obvious formatting, grammar, and spelling errors. The report should be written in a formal technical style employing a format that best communicates the work conducted, results observed, and conclusions derived. Standard practice typically calls for a CRC Title Page, Disclaimer Statement, Foreword/Preface, Table of Contents, List of Figures, List of Tables, List of Acronyms and Abbreviations, Executive Summary, Background, Approach (including a full description of all experimental materials and methods), Results, Conclusions, List of References, and Appendices as appropriate for the scope of the study. Reports submitted to CRC shall be written with a degree of skill and care customarily required by professionals engaged in the same trade and /or profession.

Within thirty (30) days after receipt of the approved draft copy of the final report, the contractor shall make the requested changes and deliver to CRC ten (10) hardcopies including a reproducible master copy of the final report. The final report shall also be submitted as electronic copies in a pdf and Microsoft Word file format. The final report may be prepared using the contractor's standard format, acknowledging author and sponsors. An outside CRC cover page will be provided by CRC. The electronic copy will be made available for posting on the CRC website.

EXHIBIT C

INTELLECTUAL PROPERTY RIGHTS

Title to all inventions, improvements, and data, hereinafter, collectively referred to as (“Inventions”), whether or not patentable, resulting from the performance of work under this Agreement shall be assigned to CRC. Contractor X shall promptly disclose to CRC any Invention which is made or conceived by Contractor X, its employees, agents, or representatives, either alone or jointly with others, during the term of this agreement, which result from the performance of work under this agreement, or are a result of confidential information provided to Contractor X by CRC or its Participants. Contractor X agrees to assign to CRC the entire right, title, and interest in and to any and all such Inventions, and to execute and cause its employees or representatives to execute such documents as may be required to file applications and to obtain patents covering such Inventions in CRC’s name or in the name of CRC’s Participants or nominees. At CRC’s expense, Contractor X shall provide reasonable assistance to CRC or its designee in obtaining patents on such Inventions.

To the extent that a CRC member makes available any of its intellectual property (including but not limited to patents, patent applications, copyrighted material, trade secrets, or trademarks) to Contractor X, Contractor X shall have only a limited license to such intellectual property for the sole purpose of performing work pursuant to this Agreement and shall have no other right or license, express or implied, or by estoppel. To the extent a CRC member contributes materials, tangible items, or information for use in the project, Contractor X acknowledges that it obtains only the right to use the materials, items, or information supplied for the purposes of performing the work provided for in this Agreement, and obtains no rights to copy, distribute, disclose, make, use, sell or offer to sell such materials or items outside of the performance of this Agreement.

EXHIBIT D

LIABILITY

It is agreed and understood that _____ is acting as an independent contractor in the performance of any and all work hereunder and, as such, has control over the performance of such work. _____ agrees to indemnify and defend CRC from and against any and all liabilities, claims, and expenses incident thereto (including, for example, reasonable attorneys' fees) which CRC may hereafter incur, become responsible for or pay out as a result of death or bodily injury to any person or destruction or damage to any property, caused, in whole or in part, by _____'s performance of, or failure to perform, the work hereunder or any other act of omission in connection therewith.

EXHIBIT E

PROPOSAL EVALUATION CRITERIA

- 1) Merits of proposed technical approach.
- 2) Previous performance on related research studies.
- 3) Personnel available for proposed study – related experience.
- 4) Timeliness of study completion.
- 5) Cost.