DE-FOA-0002372: Request for Information on Office of Energy Efficiency & Renewable Energy's Medium- and Heavy-Duty Truck Research and Development Activities & SuperTruck Initiative

DATE: October 9, 2020
SUBJECT: Request for Information (RFI)

Description

The Vehicle Technologies Office (VTO), within the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE), seeks feedback from industry, academia, research laboratories, government agencies, and other stakeholders on research needs and opportunities related to medium and heavy-duty freight trucking. The information requested is intended to inform EERE's medium and heavy-duty freight energy and operational efficiency R&D planning. EERE plans to support a future public workshop following this RFI to discuss the feedback received.

Background

How freight moves is changing dramatically due to a number of factors including new technologies, business models, and consumer demands. Although Class 7/8 trucks are still the most significant consumer of fuel, the average length-of-haul for dry van (box trailer) truckloads has decreased by 37% since 2000[1]. Driver shortages are influencing vehicle design and operating patterns as a new hub and spoke freight system has developed. Package delivery is up 50% due to "real time" delivery expectations, creating potential opportunities in short hauls and last-mile delivery. There are new opportunities in all commercial vehicle classes to increase efficiency and to more broadly introduce new energy sources such as electricity, natural gas, biofuels, and hydrogen.

Affordable truck freight movement is essential for the nation's economy. Trucks carry 72% of the nation's freight on a tonnage basis and 73% of freight on a value basis.[2] Virtually all goods consumed in the United States are shipped by truck for at least part of the trip to the

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[1] American Trucking Association, 2018. *Trucking Activity Report (TRAC) 2018,* September 2018.
[2] U.S. Department of Transportation, 2020. "2017 Commodity Flow Survey Preliminary Data," Table 1, https://www.bts.gov/sites/bts.dot.gov/files/Table%201_Mode%20of%20Transportation.xlsx.

This is a Request for Information (RFI) only. EERE will not pay for information provided under this RFI and no project will be supported as a result of this RFI. This RFI is not accepting applications for financial assistance or financial incentives. EERE may or may not issue a Funding Opportunity Announcement (FOA) based on consideration of the input received from this RFI.

consumer. In 2016, the trucking industry collected around 80 cents of every dollar spent on freight transportation.[3] The trucking industry paid over $17 billion in annual federal highway user taxes in 2016[4].

Trucking is also an important source of U.S. employment. The trucking sector is a $700 billion industry.[5] About 90% of the regulated carriers in the United States are relatively small businesses, operating fewer than 10 trucks.[6] The truck and engine manufacturing industry represent almost a million U.S. manufacturing jobs.[7]

Trucks are a major energy consumer in the U.S. and globally. Commercial trucks in classes 3 through 8 used a total of approximately 44 billion gallons of fuel in 2015.[8] Class 3-8 trucks are only 4% of the total number of U.S. on-road vehicles but represent a quarter of the annual vehicle fuel use.[9]

Economic growth and commercial truck transportation energy demand are closely aligned. Expansion in the global economy will lead to a similar growth in truck fuel use unless technology advances in efficiency are made to improve the energy productivity in moving freight. U.S. Energy Information Administration (EIA) projections, illustrated in Figure 1. U.S. Freight Transportation Energy Use Projected to Rise (U.S. Energy Information Administration) show that the freight truck sector's annual vehicle miles traveled (VMT) is projected to

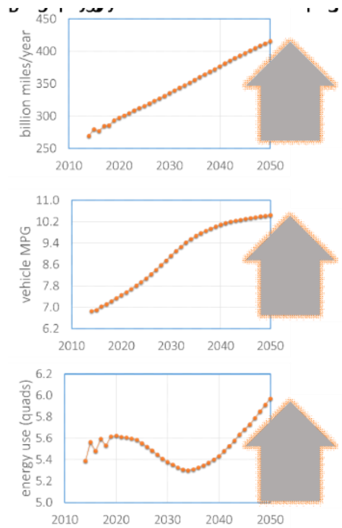

Figure 1. U.S. Freight Transportation Energy Use Projected to Rise (U.S. Energy Information Administration)

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[3] American Trucking Associations, 2018. *American Trucking Trends 2018*.

[4] American Trucking Associations, 2018. *American Trucking Trends 2018.*

[5] American Trucking Associations, 2018. *American Trucking Trends 2018.*

[6] U.S. Department of Transportation, 2018. Pocket Guide to Large Truck and Bus Statistics, table 1-11, https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/safety/data-and-statistics/413361/fmcsa-pocket-guide-2018-final-508-compliant-1.pdf

[7] American Trucking Associations, 2018. *American Trucking Trends 2018.*

[8] Oak Ridge National Laboratory, 2017. *Transportation Energy Data Book 36*, tables 5.1, and 5.2.

[9] Oak Ridge National Laboratory, 2017. *Transportation Energy Data Book 36*, tables 4.1, 4.2, 5.1, and 5.2.

increase by 54% through 2050[10] relative to 2014.[11] The fuel economy of these trucks is expected to rise as well, but the efficiency increase does not completely offset the rise in annual miles traveled. This leads to an estimated 11% increase in freight truck energy use by 2050[12] relative to 2014.[13]

Fuel costs are a significant fraction of freight movement costs, but cost-effective improvements in freight fuel efficiency through technology advancements and applied research have the potential to reduce the fuel used per ton-mile of freight shipped, and improve energy productivity and affordability of shipping goods.

While heavy-duty vehicles have considerably improved their fuel efficiency, they continue to be one of the largest contributors to nitrogen oxides (NOx) emissions from mobile sources.[14] Heavy-duty vehicles are also a major contributor to mobile source particulate matter (PM) pollution. NOx emissions from these vehicles, specifically at low load operations, i.e. during engine warm-up, idling, and stop-and-go traffic have become a concern for cities and areas of high traffic as well as for the regulators. The Environmental Protection Agency in January 2020 released an 'Advanced Notice of Proposed Rulemaking' soliciting comments on its Cleaner Truck Initiative – 'Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine Standards' and intended to release the proposed rulemaking at the end of this year.[15] In the meantime, the California Air Resources Board has adopted a NOx Omnibus rulemaking that would reduce engine-out NOx emissions from heavy-duty vehicles by 90% from present level in

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[10] U.S. Energy Information Administration, 2018. *Annual Energy Outlook 2018,* Table 7, "Transportation Sector Key Indicators and Delivered Energy Consumption," Travel Indicators (billion vehicle miles traveled) – Freight Trucks, https://www.eia.gov/outlooks/aeo/data/browser/#/?id=7-AEO2018&cases=ref2018&sourcekey=0, accessed September 15, 2020.

[11] U.S. Energy Information Administration, 2016. *Annual Energy Outlook 2016,* Table 7, "Transportation Sector Key Indicators and Delivered Energy Consumption," Travel Indicators (billion vehicle miles traveled) – Freight Trucks, https://www.eia.gov/outlooks/aeo/data/browser/#/?id=7-AEO2016&sourcekey=0, accessed September 15, 2020.

[12] U.S. Energy Information Administration. *Annual Energy Outlook 2018,* Table 7, "Transportation Sector Key Indicators and Delivered Energy Consumption," Energy Use by Mode – Freight Trucks, https://www.eia.gov/outlooks/aeo/data/browser/#/?id=7-AEO2018&cases=ref2018&sourcekey=0, accessed September 15, 2020.

[13] U.S. Energy Information Administration. *Annual Energy Outlook 2016,* Table 7, "Transportation Sector Key Indicators and Delivered Energy Consumption," Energy Use by Mode – Freight Trucks, https://www.eia.gov/outlooks/aeo/data/browser/#/?id=7-AEO2016&sourcekey=0, accessed September 15, 2020.

[14] U.S. Environmental Protection Agency. ''Air Emissions Modeling: 2016v1 Platform,'' https://www.epa.gov/air-emissions-modeling/2016v1-platform, accessed September 15, 2020.

[15] U.S. Environmental Protection Agency. "Advanced Notice of Proposed Rule: Control of Air Pollution from New Motor Vehicles Heavy-Duty Engine Standards," https://www.epa.gov/regulations-emissions-vehicles-and-engines/advance-notice-proposed-rule-control-air-pollution-new, accessed September 15, 2020.

2027 as well as significantly increase the warranty and full useful life requirements and reduce the low-load emissions of these vehicles.[16]

As the five SuperTruck 2 teams begin to assemble their prototype Class-8 tractor trailer prototypes for on-road testing in 2021, it is projected that they will far exceed the goal of a 100% increase in freight efficiency over a 2009 production vehicle baseline. This breakthrough is due to high-risk, cost-shared industry/government research in the areas of engine and transmission systems, electrification, aerodynamics, lightweighting, low-rolling resistance tires and hundreds of other individual hardware and software developments. This technology is transitioning to production, enabling model year 2020 Class-8 tractor trailers with the highest-level efficiency packages to demonstrate fuel economies of over 10 mpg.

Future freight transportation solutions will need to be affordable, efficient, clean, and safe to meet customer needs and broader societal demands. Several technology and fuel options, including petroleum, natural gas, propane, electricity, diesel, biofuels and hydrogen, may all play a role in future commercial truck markets. Innovations in areas such as high efficiency engines, advanced domestically-sourced fuels, connected and automated vehicle systems, electrified drivetrains, fuel cells, and intelligent freight and passenger routing also may provide future transportation solutions.

Addressing the considerable challenges facing the commercial truck market in the future may require new thinking and new technologies. Feedback from industry, academia, research laboratories, government agencies, and other stakeholders on research needs and opportunities related to medium and heavy-duty freight trucking is an essential part of EERE's medium and heavy-duty freight operational efficiency R&D planning.

Collaborating Offices

This RFI is being issued by DOE's Vehicle Technologies Office (VTO), Bioenergy Technologies Office (BETO), and the Hydrogen and Fuel Cell Technologies Office (HFTO).

The mission of VTO is to fund research to develop new, affordable, efficient and clean transportation options that increase domestic economic opportunity. This research enables industry to accelerate the development and widespread use of a variety of promising sustainable technologies to support affordable, secure, reliable, and efficient transportation systems across America. VTO leverages a comprehensive portfolio of research to develop new

[16] California Air Resources Board, 2020. "California adopts strong new regulation to further reduce smog-forming pollution from heavy-duty diesel trucks," https://ww2.arb.ca.gov/news/california-adopts-strong-new-regulation-further-reduce-smog-forming-pollution-heavy-duty, accessed September 15, 2020.

innovations including: advanced battery technologies; advanced combustion engines and fuels (including co-optimized systems); advanced materials for lighter-weight vehicle structures and better powertrains; and energy efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement).

VTO's high-level R&D goals target new technology options to be more efficient and at least as affordable compared to this baseline, while also accounting for consumer payback period expectations. Key technology goals relevant to the MD/HD sector include:

- Advanced Battery R&D in support of new battery chemistry and cell technologies with the potential to reduce the cost of electric vehicle battery packs by more than half, to less than $100/kWh. (The long term goal is to decrease battery cell cost to $60/kWh while reducing the critical material content, utilizing recycled material feedstocks and, decreasing charge time to 15 minutes or less).

- Advanced Electric Drive Technologies R&D Electric Drive Technology goals for vehicle electrification include increasing the power density of the traction drive while reducing cost by half in 2025 compared to the 2015 baseline numbers while reducing the critical material content.

- Advanced Engines and Fuels supports R&D of combustion processes, fuels property, and catalyst formulation R&D and innovations to enable the development of the next generation of heavy-duty engine capable of increasing efficiency by 35%in 2025 (vs. 2009 baseline of 42% BTE). Additional focus is to reduce the cost of natural gas medium and heavy-duty trucks, as well as reduce gaseous fuel storage cost.

- Advanced Materials Research supporting novel approaches to build lightweight, multi-material structures with the potential to significantly reduce vehicle glider (i.e., chassis, body structure, and interior) weight.

- Energy Efficient Mobility Systems R&D to create breakthrough modeling, simulations, and high performance computing-enabled data analytics to support the development of new transportation-system technologies, which have the potential to improve energy productivity through new mobility solutions including connected, shared, and automated vehicles.

The Hydrogen and Fuel Cell Technologies Office (HFTO) supports R&D to facilitate wide-spread adoption of hydrogen and fuel cells across sectors by reducing the cost and improving the performance/durability of fuel cells, as well as developing affordable and efficient technologies for hydrogen production, delivery, and storage. The scope is technology neutral and feedstock-flexible, emphasizing diverse end uses including energy storage, transportation (e.g., trucks, marine, rail, aviation), chemicals (e.g., ammonia, synthetic fuels), backup power (e.g., emergency power, data centers), industry (e.g., iron and steel making) and others. The program has established application-specific targets relevant to the affordability of these emerging options, taking into account consumer expectations regarding pay back periods. As one example for medium/heavy-duty truck applications, the ultimate targets are 30,000 hours for fuel cell durability; $60/kW for fuel cell cost and $8/kWh for onboard hydrogen storage costs. Achieving these targets, in conjunction with the program's hydrogen production target of <$2/kg, can allow hydrogen fuel cell powered vehicles to be competitive in terms of cost and performance with incumbent technologies.

The Bioenergy Technologies Office (BETO)[17] focuses on research, development, demonstration, and commercial application for bioenergy, including biopower energy systems; biofuels; bioproducts; integrated biorefineries that may produce biopower, biofuels, and bioproducts; cross-cutting research and development in feedstocks; and economic analysis. DOE is investing in cutting-edge technologies designed to produce biofuels from biomass such as wastes and agricultural residues, and from energy crops like switchgrass and algae. The program's primary focus is on R&D to produce "drop-in" biofuels that are compatible with existing fueling infrastructure and vehicles across a range of transportation modes, including renewable-gasoline, -diesel, -jet, and -marine fuels.

Purpose

The purpose of this RFI is to solicit feedback from industry, academia, research laboratories, government agencies, and other stakeholders on issues related to medium and heavy-duty freight trucking. EERE is specifically interested in information on safe, efficient, affordable solutions that reduce energy use, emissions and total cost of ownership (purchase, fuel, maintenance and operational cost) for medium and heavy-duty trucking.

This is solely a request for information and not a Funding Opportunity Announcement (FOA). EERE is not accepting applications.

Medium- and Heavy-Duty Freight Trucking Workshop

DOE is planning a public workshop in the December 2020 timeframe to share the key findings of the request for information with outside stakeholders. The request for information and

[17] As defined in 42 USC 16232.

workshop discussions will help identify gaps and barriers to commercializing new technologies, and help inform DOE's R&D and competitive funding strategy into the next ten years.

Request for Information Categories and Questions

Category 1: **Freight Operational Efficiency and Systems –** DOE has research interest in improving freight efficiency at the vehicle and freight transportation system levels. This includes the vehicle and how the vehicle is used within the context of the overall freight management system. It covers the role of connectivity, automation, last mile delivery options and new operating patterns. It recognizes that freight moves through multiple vehicles and processes to go from manufacturing to its end destination at a business or home. For this RFI, the following questions are posed to help understand the freight operational efficiency space and focus areas for research.

1a.) <u>Understanding the trends and defining metrics</u>: Data and analysis identified by VTO highlights several trends: (1) Average length of haul for dry van freight has decreased in recent years by 38% (to around 300 miles); (2) 75% of freight by mass moves less than 250 miles; (3) freight shippers are making more use of hub and spoke distribution systems; and (4) day cab tractors are becoming increasingly popular as an option to meet freight needs as a result of items 1-3.

1.a.1.) What are the most critical data gaps in understanding current freight operation and developing scenarios for future freight trends? What data sources might fill these gaps? Are there gaps that cannot currently be filled with existing data sources, so new data collection would be needed?

1b.) How will the trends for long-haul and regional-haul change in the coming years and what are the implications for the types of trucks and propulsion systems that will be used.

1.b.1.) In the past, DOE focused on freight efficiency as a metric (ton-miles/gallon), looking at the benefit of changes to a single truck, operated over a prescribed duty cycle. In the future, are there better ways to measure system level efficiency? How could these metrics cover different technologies whose benefits may vary in different types of operational environments?

1.b.2.) If DOE retained a freight efficiency metric, should it change from ton-miles/gallon? Should energy metrics be weight-based, volume-based, or both? Are cost metrics valuable to include, and if so, should they be total-cost-of-ownership based or cost of shipment based? Are time-based metrics valuable to include, and why or why not? Should Total Cost of Ownership (TCO) or CO_2-eq emissions metrics be included?

1.b.3.) With these trends, are there additional opportunities to increase efficiency and decrease emissions across a broad range of trucks? What classes provide the largest potential from technological advancements?

1b.) What are the major benefits, research opportunities, and barriers for developing system-level freight efficiency technologies (i.e., technologies with an effect beyond the efficiency of individual vehicles)? What are the research needs and barriers to connectivity and automation technologies to improving freight efficiency?

1c.) What opportunities do these trends open up for alternative fuels such as electricity, natural gas, biofuels, and hydrogen? Will the use cases change to fit the technology or will aggressive technology changes be needed to make them fit the current use cases? What impact will infrastructure have on the uptake of these fuels, and what opportunities and barriers exist in the area of infrastructure?

1d.) <u>Understanding system constraints:</u> To utilize the efficiencies of today's system and improve them, building off existing assets is necessary. These constraints may help identify the key needs and make incremental changes in efficiency while breakthroughs that disrupt the system are also developed in the longer term.

1.d.1.) Do trucks typically operate at maximum payload capacity (by weight or volume)? In the coming decade, are there any anticipated any changes to the typical weight of payloads on board trucks? In what truck vocations/class and/or regions of the country is there anticipated market growth in the coming years, and why?

1.d.2.) Are commercial fueling stations for trucks commonly co-located with light-duty vehicle fueling stations? Are commercial fueling stations for trucks commonly located in regions where land area is a constraint (e.g., urban locations)?

1.d.3.) What is the typical payback period for capital equipment (e.g., fueling stations) for trucks? What is the associated discount rate?

1.d.4.) What are the major benefits, opportunities, and barriers in this space and is this worthwhile to pursue?

1.d.5.) Is there data available that shows distribution of distance traveled versus payload? Is there data sufficient to validate baseline truck models? This includes drive cycle data with grade as well as fuel consumption measurements and vehicle characteristics (tire rolling resistance, aero drag coefficient, frontal area, gross weight (including payload data).

Category 2: Internal Combustion Engine, Powertrain, Fuels, and Emissions Control - Internal combustion engine powertrains are projected to dominate the commercial truck market for several more decades, but the challenges of achieving higher efficiency with lower criteria and CO2 emissions at an acceptable cost continue to drive DOE research. New combustion strategies coupled with advanced fuels and cost-effective emissions solutions may find customer acceptance.

2a.) Understanding fuel choice: Fuel choice has a significant impact on total cost of ownership and represents a significant and long-term commitment by fleets when options are available. Please consider whether the following issues qualify as research topics relevant to industry – i.e., precompetitive work from fundamental to applied research, excluding deployment or technology implementation issues applied exclusively to existing technology (e.g., subsidies for vehicle purchases or infrastructure installation, etc.).

2.a.1.) Are Spark Ignition (SI) fuels, such as gasoline, attractive for stand-alone ICE-powered vehicles in MD and HD vehicle classes? If so, in what specific applications and vehicle classes?

2.a.2.) Is there interest in using market gasoline for advanced compression ignition combustion strategies in MD or HD engines? Is there consideration to use of technologies such as an intake heater or additive injection to enable such a combustion strategy?

2.a.3.) Are dual-fuel engines/vehicles of interest to industry and consumers? (These would include any system requiring two fuels to be available at all times, e.g., pilot-ignited gaseous fuels as well as systems that rely on advanced combustion such as reactivity controlled compression ignition. Please exclude bi-fuel systems which can provide full utility on either of two fuels.) If dual fuel systems are of interest, please specify applications, fuel pairs, and type of system of interest.

2.a.4.) To what extent are gaseous alternative fuels, such as natural gas or LPG, of interest in the MD and HD vehicle classes - i.e., Class 3-8? If gaseous alternative fuels are of interest to industry and consumers, what specific fuel types are of interest for what engines/vehicle platforms and applications?

2.a.5.) To what extent are biofuels of interest in the MD and HD vehicle classes - i.e., Class 3-8? If biofuels are of interest to industry and consumers, what specific fuel types are of interest for what engines/vehicle platforms and applications?

2b.) Renewable and Biofuels for Trucking: Trucks OEMs, large truck fleet operators and large commercial customers have indicated a need to target low carbon dioxide equivalent (CO2-eq) emissions for future trucks. Given the ubiquity of liquid fuels, this has led to increased industry and commercial customer interest in drop-in renewable fuels such as biofuels that can deliver large reductions in CO2-eq emissions from conventional powertrains. DOE R&D has shown that CO2-eq reductions of 80% or more relative to incumbent fuels (gasoline or diesel fuel) are possible from renewable fuels.

2.b.1.) Is there an interest from industry or consumers in research into low lifecycle CO_2-eq liquid fuels? How much CO_2-eq reduction is sufficient to qualify as "low-carbon" and compete with other advance technologies? Is there value in expending additional R&D effort to reduce lifecycle CO_2-eq emissions by greater than 80%?

2.b.2.) Low lifecycle CO_2-eq liquid fuels have the potential advantage of not requiring vehicle, infrastructure or operational changes that could come with other options such as battery electrification, hydrogen fuels, or natural gas. How important are these benefits? If these fuels cost more per mile than today's fuels, how much does the benefit of less disruption offset that higher cost?

2.b.3.) How important to industry and your customer's is the lifecycle CO2-eq emissions of medium/heavy-duty trucks? Is CO2-eq emissions accounting, if any, conducted on a tank-to-wheels or well-to-wheels basis? And is any accounting down looking at the total movement of freight from manufacture to customer? Are customer/market/investor interests in CO2-eq emissions reduction a major factors in industry's interest in CO_2-eq emissions reduction, or is it driven primarily by regulations? What is the relative importance of domestic markets vs. international markets for determining current and planned CO_2-eq posture?

2c.) The capacity for high performance computing continues to increase at a rapid rate. Large, high-fidelity computer simulations of engine processes create massive datasets that can be coupled with emerging artificial intelligence methods, creating the potential for powerful tools to design engines. How interested is industry in creating engine design tools that can leverage advancements in computer science and artificial intelligence?

2d.) Manufacturers are actively considering gasoline fueled engines for commercial vehicles, specifically for class 3-6 vehicles. They also offer potential savings from low gasoline price compared to diesel and lower complexity emissions control requirements. How important is it to industry to conduct research focused on large-bore gasoline engines?

2e.) Waste heat recovery ("WHR") systems have demonstrated the ability to increase overall engine efficiency and are included in the EPA Phase 2 Rule as contributing to fuel economy improvements for future trucks. How interested is industry in further developing WHR systems or specific components for WHR?

2f.) Heavy-duty diesel and gasoline vehicles are under increasing pressure from regulators to further reduce their criteria emissions, specifically NOx and PM while minimizing efficiency losses. Regulators are also considering significantly increasing the warranty and full useful life requirements for these vehicles. While DOE has active research on low temperature NOx emissions and on technologies for low NOx and PM with the national laboratories, universities and industry, what additional research can DOE undertake to help further reduce NOx and PM emissions? What technical challenges are you envisioning with extended warranty and full useful life requirements and what are the research needs? Should DOE Metrics in initiatives like SuperTruck target current emissions or future

2g.) CARB's low NOx project with Southwest Research Institute recently revealed an aftertreatment system for ultra-low NOx emissions that consisted of multiple SCR, dual DEF dosing, multiple NOx, NH3, and temperature sensors as well as catalytic converter for ultra-low PM emissions. What technical challenges and system requirements are you envisioning for this type of aftertreatment system and what research would be useful for DOE undertake in order to improve system efficiency and help commercialization?

2h.) At the engine systems level, what specific additional development is required in technologies such as air handling and boosting, combustion and aftertreatment sensors, fuel injection systems, and thermal management (including temperature-following thermal barrier coatings)?

Category 3: **Batteries, Electrification, and Charging of MD/HD Trucks:** DOE has ongoing early-stage R&D efforts for batteries, electric drive systems, and charging technologies that are broadly pre-competitive and could be applied to many different forms of transportation electrification. For this RFI the following questions are posed as to how R&D for these technologies, or resulting innovations, could be best applied for medium- and heavy-duty vehicles.

3a.) What factors are most important in motivating the choice to pursue powertrain systems for MD/HD trucks that are all-battery vs. battery dominant vs. fuel cell- or internal combustion-dominant?

3b.) Please list three most ideal applications for battery electric heavy-duty trucks. What is the most probable entry-point for battery electric vehicle architectures in medium- and heavy-duty vehicles? What are the most attractive features of electrification across these applications? What range should be targeted for these applications?

3c.) The mission of VTO is to fund early-stage, high risk R&D. What would be the most impactful R&D areas and/or results for industry or consumers in this area of batteries, electrification, and charging of MD/HD trucks?

3d.) Batteries for MD/HD trucks

3.d.1.) Cost: at what cost ($/kWh) do batteries attract interest for the MD/HD industry? How does this change across different truck classes?

3.d.2.) Please comment on what production volume for any given medium- or heavy-duty application would be necessary to shift from battery cells designed for the light-duty market to seeking a tailored battery design for trucks.

3.d.3.) Are there aspects of presently commercial battery systems for light-duty vehicles that cause concern or could not be suitably adapted to medium- and heavy-duty applications? If so, what are those inherent features that will complicate that scale-up?

3.d.4.) Discuss the benefits and drawbacks of purpose-built battery-electric truck chassis. In the near-term, are purpose-built or conventional chassis likely to be the preferred architecture? If accommodating battery systems to conventional chassis is initially preferred, is this likely to change in the next decade?

3.d.5.) Would a modular battery module that scales with truck size/vocation needs be preferable and possible across hybridization schemes and truck classes, or are customized battery designs preferable and required?

3.d.6.) Please comment on the trade-offs between designing for battery replacement, or modular repair, or requiring a single pack last the entire truck lifetime.

3.d.7.) What are the expected volumetric and gravimetric penalties are expected for the pack design of the most attractive medium- and heavy-duty vehicles?

3.d.8.) Are there any areas in the space of medium- and heavy-duty electrification for batteries that we are not considering in this RFI that would be useful to consider?

3e.) Electric drive technologies:

3.e.1.) Considering the traction inverter, traction motor, high voltage to low voltage dc-dc converter, and the electrified accessories, what are the greatest barrier(s) to the electrification of MD and HD vehicles? What are the primary R&D needs to overcome barriers?

3.e.2.) To what extent can commercially available, off-the-shelf products for inverters, converters, and motors can be used in current MH and HD vehicles? What are the gaps and challenges?

3.e.3.) Considering the roadmap for passenger vehicle electric drive technologies targets, are there any activities missing that would be needed for MD/HD Electrification? Any targets or requirements to add? Are there additional technology challenges or gaps that should be addressed?

3.e.4.) All the power electronics components, power electronics systems, and electric motors require many iterations and lab testing of each iteration due to modeling accuracy problems of the commercial software. Are available high fidelity modeling tools sufficient to reduce the design cycle time or are additional design tools needed that are tailored to MD/HD applications?

3f.) Recovering the braking energy a.k.a. regeneration through electric braking is an important aspect of electrified transportation. Are the current technologies sufficient to recover all or sufficient amount of the energy generated without wasting it? Are other technologies required not to waste any recoverable energy?

3g.) Charging for Electrified Trucks:

3.g.1.) How much down time do trucks typically have at stops (during which they can be charged)? If possible, please provide the vocation/class of the truck corresponding to a given amount of down time.

3.g.2.) What charging rate(s) are you currently considering for electrified trucks? What information would help (e.g., validation, analysis, etc.) in determining future decisions to electrify further?

3.g.3.) How is industry envisioning the future of charging infrastructure? Who would or should own charging infrastructure? Will they leverage publicly funded, publicly available stations? Will a minimum cluster or corridor of stations be required to support an initial rollout of technology? What is the minimum number?

3.g.4.) Are there Electric Vehicle Supply Equipment (EVSE) capabilities or technologies that are not currently being addressed in the market?

Category 4: **Hydrogen and Fuel Cell Trucking:** DOE is shifting its R&D focus on hydrogen fuel cell powertrains to medium- and heavy-duty vehicle applications. Among the challenges to be addressed are achieving a Total Cost of Ownership (TCO) that is comparable to current production vehicles and the expansion of the hydrogen fueling infrastructure.

4a.) At what vehicle range (for each class/vocation), does hydrogen become a more cost effective solution than other technology options such as diesel, biofuel, or battery vehicles (today, and in the future)?

4b.) DOE is considering reference truck designs that do not need to meet the 6% grade for 11 miles (40 mph for single drive axle trucks and 30 mph for trucks with two drive axles). Is this appropriate for representing the requirements of the majority of trucks. What percentage of trucks experience 11 miles, 6% grade? DOE is considering a continuous-speed grade requirement of 1.25% at max cruising speed (65 mph for primarily highway vehicles, 55 mph for others) for truck modeling purposes.

4c.) HFTO is considering the following target combining durability, performance, efficiency, and cost for membrane electrode assemblies (MEAs) for heavy-duty fuel cell trucks: 2.5 kW/gPGM power (total PGM loading 0.3 mg/cm2; equivalent to 1.07

A/cm2 current density) at 0.7 V measured after a 25,000 hour-equivalent accelerated durability test (MEA test conditions: 88°C, 2.5 atm, stoichiometric ratio: 1.5 cathode/2 anode, 40% RH). Is this combined target appropriate and reasonable?

4d.) Are there available data required for optimizing vehicle design around a specific use case for a vehicle class? This includes 1 hertz (Hz) drive cycle data (speed and grade vs. time) including payload, for a variety of regional geographical conditions, including urban, suburban, and rural; flat, mountainous conditions with hot and cold weather. Are there data available to map a distribution the number of trucks over regional conditions? What other data is needed?

4e.) Fueling for Hydrogen and Fuel Cell Trucks:

4.e.1.) How much down time do trucks typically have in between shifts (during which they can be refueled)? If possible, please provide the vocation/class of the truck corresponding to a given amount of down time.

4.e.2.) Are trucks commonly fueled at fueling stations in the middle of routes/during shifts? If so, approximately how long does the fueling process currently take?

4.e.3.) Approximately what percentage of the market requires fuel fill time of less than 15 minutes?

4.e.4.) What fueling pressure will be considered? Is liquid hydrogen considered to be a viable fuel system choice? What information is still needed (e.g., validation, analysis, etc.) to determine the decision?

4.e.5.) How is industry envisioning the future of fueling infrastructure? Will stations be owned by hydrogen vehicle fleet owners? Will they leverage publicly funded, publicly available stations? Will a minimum cluster or corridor of stations be required to support initial rollout of technology? What is the minimum number?

4.e.6.) Will Truck manufacturers develop their own fuel dispenser technology? What specific bottlenecks in the supply chain would industry be interested in addressing (e.g., nozzles, hoses, chillers, modular station designs, etc.)?

Category 5: Other important considerations?

5a.) How important is non-powertrain vehicle-level efficiency technology improvements (e.g., aerodynamics for certain trucks/duty cycles, tire rolling resistance, idling reduction, lightweighting).

5b.) What are best opportunities and mechanisms to validate, test and integrate advanced technologies into trucks? How important is it to demonstrate technologies in real world applications?

5c.) What kind of collaborations and partnerships need to occur in order to ensure systems-wide efficiency gains are met? What role should trucking fleets play in these collaborations and partnerships?

5d.) Artificial intelligence techniques are currently being used for design and control optimization. Would new tools and technologies using artificial intelligence help with industry technology challenges? Please specify

Disclaimer and Important Notes

This RFI is not a Funding Opportunity Announcement (FOA); therefore, EERE is not accepting applications at this time. EERE may issue a FOA in the future based on or related to the content and responses to this RFI; however, EERE may also elect not to issue a FOA. There is no guarantee that a FOA will be issued as a result of this RFI. Responding to this RFI does not provide any advantage or disadvantage to potential applicants if EERE chooses to issue a FOA regarding the subject matter. Final details, including the anticipated award size, quantity, and timing of EERE funded awards, will be subject to Congressional appropriations and direction.

Any information obtained as a result of this RFI is intended to be used by the Government on a non-attribution basis for planning and strategy development; this RFI does not constitute a formal solicitation for proposals or abstracts. Your response to this notice will be treated as information only. EERE will review and consider all responses in its formulation of program strategies for the identified materials of interest that are the subject of this request. EERE will not provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that EERE is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind EERE to any further actions related to this topic.

Proprietary Information

Because information received in response to this RFI may be used to structure future programs and FOAs and/or otherwise be made available to the public, **respondents are strongly advised**

to NOT include any information in their responses that might be considered business sensitive, proprietary, or otherwise confidential. If, however, a respondent chooses to submit business sensitive, proprietary, or otherwise confidential information, it must be clearly and conspicuously marked as such in the response.

Responses containing confidential, proprietary, or privileged information must be conspicuously marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Federal Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

If your response contains confidential, proprietary, or privileged information, you must include a cover sheet marked as follows identifying the specific pages containing confidential, proprietary, or privileged information:

> **Notice of Restriction on Disclosure and Use of Data:**
> Pages [List Applicable Pages] of this response may contain confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for the purposes described in this RFI DE-FOA-0002372. The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

In addition, (1) the header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: "Contains Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure" and (2) every line and paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets or highlighting.

Administration by Federal and Non-Federal Personnel

Federal employees are subject to the non-disclosure requirements of a criminal statute, the Trade Secrets Act, 18 USC 1905. The Government may use non-Federal personnel to conduct routine, nondiscretionary administrative activities. The respondents, by submitting their response, consent to EERE providing their response to non-Federal parties. Non-Federal parties given access to responses must be subject to an appropriate obligation of confidentiality prior to being given the access. Submissions may be viewed by support contractors and private consultants.

Request for Information Response Guidelines

Responses to this RFI must be submitted electronically to VTO@ee.doe.gov no later than 5:00pm (ET) on November 9, 2020. Include "Medium and Heavy Duty Truck R&D Activities and SuperTruck Initiative RFI" in the subject line of the email. Responses must be provided as attachments to an email. It is recommended that attachments with file sizes exceeding 25MB be compressed (i.e., zipped) to ensure message delivery. Responses must be provided as a Microsoft Word (.docx) or pdf attachment to the email, and no more than 10 pages in length, 12-point font, 1-inch margins. Only electronic responses will be accepted.

Please provide your answers by responding to a specific question(s) and reference the Number (for example 1.a.1) for each question and answer. Please follow the question numbering convention provided in the RFI to identify the answer. Respondents may answer as many or as few questions as they wish.

EERE will not respond to individual submissions or publish publicly a compendium of responses. A response to this RFI will not be viewed as a binding commitment to develop or pursue the project or ideas discussed.

Respondents are requested to provide the following information at the start of their response to this RFI:

- Company / institution name;
- Company / institution contact;
- Contact's address, phone number, and e-mail address.