Report

HIGHLIGHTS

April 2017

Review of the Research Program of the U.S. DRIVE Partnership - Fifth Report

The development of new light-duty vehicle (LDV) technologies affects a range of policy issues from energy security and transportation to the economy and the environment. Vehicles with better fuel economy, including those that use alternative sources of energy such as electricity or hydrogen, can play an important role in reducing the nation's petroleum consumption and the environmental impact of greenhouse gas emissions. The United States has formed government-industry partnerships in order to encourage research and development (R&D) for LDVs since the early 1990s. From 1993 to 2001, the Partnership for a New Generation of Vehicles (PNGV) sought to improve the nation's competitiveness in manufacturing future generations of vehicles, to implement commercially viable innovations from ongoing research on conventional vehicles, and to develop vehicles with up to three times the fuel efficiency of comparable 1994 family sedans. The PNGV was transformed into the FreedomCAR and Fuel Partnership, which operated from about 2003 to 2011, and increased the focus on the development of hydrogen fuel and fuel cell technologies with the aim of advancing these technologies to the point that a private sector decision on the commercial viability of hydrogen fuel cell vehicles (HFCVs) could be made by 2015.

In 2011 the U.S. DRIVE (Driving Research and Innovation for Vehicle Efficiency and Energy Sustainability) Partnership replaced the FreedomCAR and Fuel Partnership. In this new partnership, more emphasis is placed on electric drive technologies for plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) compared to HFCV technologies. However, much of the work on electric drive technologies is also applicable to HFCVs because the latter are inherently electric vehicles. The U.S. DRIVE Partnership provides federal leadership for a group of automotive, energy, and electric power companies and research institutes with the goal of accelerating the development of innovative and clean LDVs. The Partnership provides a forum to discuss precompetitive, technology-specific needs, identify possible solutions, and evaluate progress toward jointly developed technical goals. The Partnership does not itself have a budget or conduct R&D, with each partner making its own decisions regarding the funding and management of its projects. The vast majority of the precompetitive research projects within the Partnership are funded by DOE's Vehicle Technologies Office, a government partner of U.S. DRIVE. The leadership for the Partnership is provided by the Executive Steering Group (ESG) composed of the U.S. Department of Energy's (DOE's) Assistant Secretary for Energy Efficiency and Renewable Energy (EERE) and a vice-presidential-level executive from each of the Partnership companies.

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VEHICLE AND FUEL TECHNOLOGIES: PROGRESS AND BARRIERS

The technologies for advanced vehicles and the DOE R&D projects that are associated with U.S. DRIVE goals range across a broad set of activities, which include advanced combustion; fuels; emissions control; fuel cells; hydrogen storage; hydrogen production, distribution and fueling; electric drive components (motors and power electronics); and advanced materials for vehicle weight reduction. The Partnership has established a number of technical teams involving government, industry and national laboratory members to address the research needed to advance the various technologies. This structure has been demonstrated to be an effective means for identifying high-priority, long-term precompetitive research needs. Furthermore, the Partnership also addresses cross-cutting integration challenges, such as vehicle systems and analysis, hydrogen fuel pathways, hydrogen codes and standards, integration of plug-in electric vehicles with the electric grid, and life-cycle analysis of different vehicle/fuel options.

Significant progress has clearly been made since the prior review conducted by the National Academies in 2012 in many of the technical areas including advanced combustion, hydrogen fuel cell durability and cost, and electric drive systems and cost. At the same time, market introduction of improved hybrid electric vehicles, PHEVs, and BEVs both by automotive manufacturers represented in U.S. DRIVE as well as others indicates that much of the technology is migrating out of the precompetitive realm and into the marketplace. HFCVs are being introduced in limited numbers by foreign automotive manufacturers, and General Motors, a Partnership member, anticipates releasing an HFCV by 2020. However, while some of the remaining challenges are purely technical, cost remains a formidable barrier for all the technologies under development. With these technology advances, the Partnership needs to ensure that its technical targets are sufficiently long-term in order to ensure a focus on high-risk technologies. The other notable barrier for the deployment of HFCVs is the lack of a hydrogen distribution and refueling infrastructure, which is outside the precompetitive scope of the Partnership.

MANAGEMENT, STRATEGY, AND PRIORITY SETTING

The Partnership has made several welcome improvements in response to prior National Academies' reviews including the adoption of a portfolio-based strategy and the creation of both the target-setting task force (TSTF) and the cradle-to-grave (C2G) working group. The C2G lifecycle analysis model provides a major step forward in the ability of the Partnership to advise the industry and the DOE on program and policy choices. However, the ESG needs to meet more frequently in order to provide the necessary program coordination.

RECOMMENDATION: The ESG should meet more regularly than annually, perhaps at least quarterly, and participate directly in the portfolio analysis and target-setting process for revised 2020 and new 2025 goals. Furthermore, the recently published C2G study on vehicle-fuel pathways and follow-on work by the TSTF and C2G working group should be used proactively and specifically to help shape the overall EERE portfolio, and the C2G working group should be transitioned from temporary to permanent status. The C2G model should be continuously updated and, where possible, tailored to improve its ability to support senior policy makers.

The past few years have heralded a dramatic increase in domestic oil production, the introduction of many new options for consumers who wish to purchase zero emission vehicles, the rapid development of technologies for autonomous vehicles, and a growing trend towards alternative personal mobility models such as car-sharing and ride-sharing. These factors could have strategic implications for the Partnership in the future.

RECOMMENDATION: The ESG should identify appropriate changes in Partnership focus to reflect the impact of new personal mobility models, shrinking opportunities to achieve the aggressive greenhouse gas goals, the transition of many candidate technologies into the competitive domain, and the significant infrastructure challenges in providing hydrogen at fueling stations at a competitive cost, in particular, while retaining the focus on pre-competitive technology enablers.

INTERNAL COMBUSTION ENGINES AND FUELS

Advanced combustion and emission controls for internal combustion engines (ICEs) are important because they are going to be the dominant automotive technology for decades, whether in conventional, hybrid, biofuel, or natural gas vehicles. There is still much opportunity to reduce the fuel consumption and environmental impact of ICE-powered vehicles. The Partnership is primarily focused on conventional four stroke engine architectures for both near- and longer-term research. However, work on alternate engine architectures is taking place and should be assessed for potential improvements in efficiency and environmental impact. The DOE has set an aggressive timeline for developing an “optimized reaction-controlled” engine/fuel system. The DOE has established the Co-Optima program to help collect the data necessary to establish such an optimized system, but it has not yet addressed how such a system would be implemented in the LDV fleet. Engine manufacturers

will not introduce vehicles that utilize advanced combustion systems without the assurance that suitable fuels are available for the new combustion technology.

RECOMMENDATION: The advanced combustion and emissions control technical team should be proactive in seeking out and assessing data on the performance of alternate engine architectures that will allow benchmarking against those within their current research portfolio.

RECOMMENDATION: The DOE should further explain how the Co-Optima program will lead to the introduction of an optimum engine/fuel system in commercial practice. Reaching consensus between the DOE's Co-Optima program and U.S. DRIVE on the concept of an optimum engine and fuel is necessary, but not sufficient. A plan for introduction of advanced combustion systems and fuels designed to increase transportation energy efficiency and reduce carbon dioxide (CO2) emissions is required.

HFCVS AND HYDROGEN

Recent activities by both foreign and domestic automotive companies demonstrate that HFCVs are in the late stages of development and are now ready for customer engagement, albeit at a modest level owing to limited production volume and refueling infrastructure issues. With U.S. companies in different states of fuel cell vehicle development, there appears to be a fine line between what might be considered near- and long-term projects.

RECOMMENDATION: The Partnership should evaluate projects for their near-term or long-term potential impact and assign technology readiness levels to them. The Partnership should continually assess its process for prioritizing projects and should continue to address the longer-term, precompetitive (lower technology readiness level) objectives.

All the goals for on-board hydrogen storage including vehicle driving range and fueling time for HFCVs have not been met to date. As the technologies continue to mature, progress towards these goals may be achieved by merging activities and introducing a wider range of options other than gravimetric and volumetric hydrogen storage density alone.

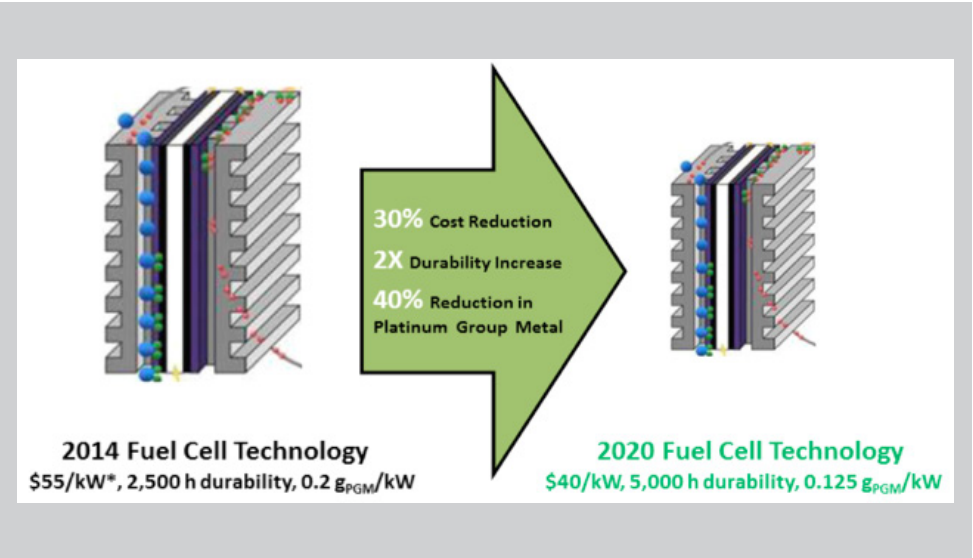
RECOMMENDATION: The hydrogen storage technical team should increasingly work with the other technical teams even beyond those areas where overlap currently exists.

Regardless of the source of hydrogen, it is clear that any widespread penetration of HFCVs into the LDV fleet is dependent on hydrogen being available for refueling. Delivery and dispensing of hydrogen is still prohibitively expensive, and hydrogen infrastructure is practically non-existent, making market introduction of HFCVs a daunting challenge.

RECOMMENDATION: The ESG should address issues (e.g., how will fueling stations be installed and by whom, who will produce hydrogen, how will investments occur in fueling infrastructure without sufficient fuel cell vehicles on the road and vice versa, etc.) related to hydrogen infrastructure and assess U.S. DRIVE's role to formulate an action plan to address the issues and barriers.

ELECTRIC VEHICLES AND INFRASTRUCTURE

The electric drive system is a critical part of electrified powertrains for LDVs, and several motor configurations are under investigation to address the high cost of rare earth magnets. The Partnership has explored the use of wide bandgap materials for power electronics. While the majority of these projects focus on silicon carbide, gallium nitride is significantly less costly and will likely be the preferred choice for automotive applications.



RECOMMENDATION: The U.S DRIVE Partnership should increase the focus on the advancement of gallium nitride technology in order to accelerate its readiness for commercial implementation.

Improving electrochemical energy storage technologies, such as batteries, is needed for all electric drive vehicles. While high cost remains the main impediment to market penetration of plug-in electric vehicles, there are battery performance characteristics that must be improved and safety issues that also need to be addressed. A new set of energy storage goals for

various types of electric vehicles was established in 2012, but these targets are not presented consistently and in one place.

RECOMMENDATION: U.S. DRIVE should establish a single, authoritative website for energy storage targets and goals for the various electric vehicle applications that is prominently and easily accessible to all. It should provide a roadmap of energy storage needs for several (rolling) decades into the future for use by research organizations and investigators for various applications and differing time frames.

The convenience, affordability, and environmental impacts of electricity are important for the future of both plug-in electric vehicles (for re-charging) and HFCVs (for electrolysis). Rapid advances in technology coupled with a growing global need to reduce carbon emissions are bringing disruptive and unpredictable changes to the electric grid. State regulatory authorities will shape the pace and direction of this transition to a greater extent than the federal government.

RECOMMENDATION: The U.S. DRIVE partners should closely monitor the evolution of the electric grid to understand how (or whether) vehicle design can enable effective participation in the emerging electric marketplace in a way that increases the market share of non-petroleum vehicles such as HFCVs and (possibly) BEVs.

STRUCTURAL MATERIALS

A major approach for improving vehicle efficiency, and thus fuel economy, is reducing vehicle mass. While some of the mid-term targets for weight reduction and cost set by the U.S. DRIVE materials technical team are reasonable, the long-term goals and baselines proposed are unrealistic.

RECOMMENDATION: U.S. DRIVE should set the long-term target for the cost of weight reduction to be consistent with the long-term cost targets for the other technical teams. The practice of setting mid-term targets should also be continued. In doing so, it is important for all DOE and U.S. DRIVE sources to reference a consistent set of targets.

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