Attachment – Additional Questions for the Record

The Honorable John Shimkus

1. Dr. Farrell, in your view, what are the benefits for future spark ignition engines of high octane fuels?

   The fuel property with the greatest impact on efficiency of spark ignition (SI) engines is the octane level. Numerous studies have shown that higher-octane fuels can deliver dramatically improved engine efficiency and performance. Determining the optimal octane level requires consideration of additional factors, such as cost and emissions.

2. Compared to other octanes which NREL has studied and researched through Co-Optima efforts, how does ethanol compare?

   The Co-Optimization of Fuels and Engines (Co-Optima) initiative has conducted a detailed and comprehensive assessment of different fuel blendstocks' potential performance in high-efficiency SI engines. This characterization factored in a wide range of fuel properties that impact efficiency, including octane levels. Co-Optima researchers are exploring blendstocks that can be produced from a wide spectrum of domestic resources, including natural gas and petroleum—as well as from domestic biomass such as forestry and agricultural feedstocks.

   Representative blendstocks from five chemical families identified by researchers as demonstrating the greatest promise of delivering fuel properties that meet performance and production requirements include small alcohols, such as ethanol. For conditions relevant to smaller, advanced turbocharged engines, small alcohols such as ethanol work well, and ethanol is typically the current market's incremental octane source of choice.

The Honorable Joe Barton

1. While we work to create new, energy efficient technologies to fuel our transportation system, are we also taking steps to make current energy sources more sustainable? For example, natural gas is one of this country's most practical energy sources and a proven fuel with many opportunities that could be explored to upgrade with new technologies. With the rapid growth in energy demand, I believe that more needs to be done to explore novel developments of this major untapped natural resource.

   NREL and DOE are pursuing a full spectrum of transportation solutions to improve the efficiency, performance, affordability, and sustainability of transportation options for consumers and businesses, including electric vehicles that are charged using renewable solar and wind power sources. At the same time, researchers are working to optimize the more conventional fuel and propulsion technologies that will continue to play an important role in transportation solutions for decades to come. Vehicles powered using plentiful, affordable domestic resources—including the United States' wealth of natural gas reserves—are important components of a broad and inclusive transportation portfolio designed to improve energy efficiency, national security, and air quality.

At the same time, numerous technical and marketplace barriers must be overcome before wider adoption of natural gas vehicles can be realized. Significant research is still needed to cost-effectively achieve diesel-like efficiency in natural gas engines for medium- and heavy-duty vehicles, while meeting current and future emissions standards.

In early March 2018, to further exploration in this area, DOE announced $4 million to support three new cost-shared research projects focused on medium- and heavy-duty, on-road natural gas engines. NREL is collaborating with three other national labs on this early-stage research, focusing on innovations to push to the next level pre-chamber spark-ignition (PCSI) technology that has demonstrated efficiency improvements up to 20% in light-duty gasoline engine.

2. What steps is the Department of Energy taking to encourage natural gas-related energy research and development for biological and catalytic technologies, methods and tools to convert natural gas into fuels, chemicals and other products? Moving forward to upgrade this vital resource in our nation not only offers alternative sources of fuel but also provides opportunities for economic growth in regions of our country where methane gas is prevalent.

   DOE continues to encourage natural gas-related R&D through recent projects including one focused on biogas biocatalysis. Researchers are developing a biocatalyst (microbe) with the capability to co-utilize carbon dioxide (CO2) and methane (CH4) to produce fuels and chemicals. Through non-photosynthetic CO2 utilization in novel hosts, the research aims to enhance CH4/CO2 uptake via targeted metabolic engineering.

   Other NREL research is already addressing a critical gap in the 11- to 13-liter engine category needed to power vocational vehicles ranging from garbage trucks and transit buses to Class 8 long-haul freight trucks. Two projects have focused on certification and commercial production of natural gas engines, utilizing both compressed natural gas and liquefied natural gas. This led to Cummins Westport's development and eventual commercial production of the 11.9-liter ISX12 G engine.

3. What types of financial incentives currently exist through the federal government and private sector, to encourage this type of innovation?

   Given that NREL does not have authority in the area of federal and private financial incentives, the Department of Energy has agreed to submit an answer to this question.

4. How would such a company present these types of ideas to the federal government for consideration?

   Given that NREL does not have authority beyond that within a National Laboratory's limited purview in how a company would present ideas to the federal government, the Department of Energy has agreed to submit an answer to this question.

The Honorable Bill Flores

1. In your testimony, you discuss the wave of innovation dramatically reshaping the concept of transportation as we know it. Often, when alternative fueling stations, such as hydrogen, are first introduced to a community, the local governments are challenged in how best to permit the stations.

   a. How could the federal government facilitate the development of these fueling stations?

      As consumer adoption of fuel cell vehicles gains momentum, the federal government could consider supporting research to overcome technical challenges faced by industry in scaling up from today's ~200 kg/day stations to the >1000 kg/day high-throughput hydrogen fueling stations needed to achieve full commercial success. In addition, national infrastructure strategy could improve reliability, decrease cost, and optimize use of domestic energy sources while supporting successful deployment of advanced transportation technologies to move people and goods using light-duty passenger vehicles, heavy-duty commercial trucks, and other vocational vehicles and equipment. These efforts are aligned with DOE's H2@Scale initiative, which focuses on R&D to generate low-cost hydrogen from diverse domestic resources for multiple applications, including transportation, energy storage, and industrial uses.

   b. Could the federal government provide some sort of consistency in permitting alternative fueling infrastructure, for hydrogen or others, to facilitate the development of fueling stations?

      Permitting for any type of fueling station is currently led by local jurisdictions, which rely on a mix of ordinances and procedures. Because of this, the primary focus of federal efforts in supporting permitting are:

      - Conducting research to evaluate the safety and performance of new technologies
      - Providing access to the latest research via publications, tools, and training
      - Developing standardized tools and permits
      - Making technical experts available.

      While permitting at a federal level may encourage more steady growth and adherence to relevant codes, it could also result in a more confusing patchwork between federal and local regulations and possibly have a detrimental effect on project quality and timelines. Instead, DOE has provided local governments with a range of tools and information to assist in the permitting and development of fueling stations. In a related effort driven by the hydrogen industry, NREL is working on standardized permits that local jurisdictions can use for hydrogen stations.

      Ongoing dialogue with local jurisdictions also points to the need for technical assistance in many areas, including understanding the market and the potential barriers to success for new technology, educating local jurisdictions and first responders as new stations are established, and partnering among cities to build fueling corridors.

2. The availability of fueling infrastructure is critical to the widespread adoption of alternative fuel vehicles. In what manner is NREL examining challenges that new technologies face, such as cost and fueling infrastructure barriers?

   NREL research and development optimizes fueling infrastructure technologies to increase station reliability and decrease consumer fuel costs through improving safety, nozzle and dispenser technology, metering, material compatibility, resilience, and systems integration. NREL also provides analysis and analytic tools to support decisions on infrastructure placement and costs. Finally, NREL collaborates closely with industry partners on applied infrastructure research to ensure that the most challenging technical issues are being addressed in ways that will lead to better, more affordable fueling options for U.S. consumers as hydrogen production is scaled up. As mentioned above, these efforts are aligned with DOE's H2@Scale initiative.

   The following provide more detailed information on NREL's work that addresses infrastructure issues:

   - Transportation Big Data – Unbiased Analysis and Tools to Inform Sustainable Transportation Decisions
     https://www.nrel.gov/docs/fy16osti/66285.pdf
   - Scenarios of Early Market Fuel Cell Electric Vehicle Introductions
     https://www.nrel.gov/docs/fy13osti/56588.pdf
   - California Power-to-Gas and Power-to-Hydrogen Near-Term Business Case Evaluation
     https://www.nrel.gov/docs/fy17osti/67384.pdf
   - Performance of Existing Hydrogen Stations
     https://www.nrel.gov/docs/fy18osti/70527.pdf
   - CNG VICE Model evaluates return on investment and payback period for new infrastructure
     www.afdc.energy.gov/vice_model
   - E85 Handling and Use Guidelines
     www.afdc.energy.gov/uploads/publication/ethanol_handbook.pdf
   - Biodiesel Handling and Use Guidelines
     www.afdc.energy.gov/uploads/publication/biodiesel_handling_use_guide.pdf
   - Costs Associated with Propane Infrastructure
     www.afdc.energy.gov/uploads/publication/propane_costs.pdf
   - Costs Associated with Natural Gas Infrastructure
     www.afdc.energy.gov/uploads/publication/cng_infrastructure_costs.pdf
   - CNG and Fleets: Building your Business Case
     www.afdc.energy.gov/uploads/publication/cng_fleets_business_case.pdf.