POLICY
facts

Fuel Cells

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NETL

Impact of Emerging Diesel Regulations on the SECA Fuel Cell Program

Background

As air quality problems persist, there is continued pressure to further reduce emissions from diesel engines, and to further tighten diesel fuel specifications. By 2010, on-road diesel fuel sulfur levels will be reduced to 15 ppm in the U.S. and 10 ppm in the European Union (EU) (1,2). In addition, specifications for aromatics and polycyclic aromatic hydrocarbons (PAH) content in diesel fuel, which is strongly correlated with soot production, will also be tightened in some jurisdictions. By 2010 the EU will limit aromatic content to 14% and PAH content to 2%, while the U.S. federal and California Air Resources Board (CARB) specifications will remain at 35% and 10% respectively for aromatics. PAH specifications will remain at 1.4% in California and won't be regulated under US Federal specifications. Non-road emissions standards and fuel specifications are following these trends (3), albeit with a few years delay (Figure 1).

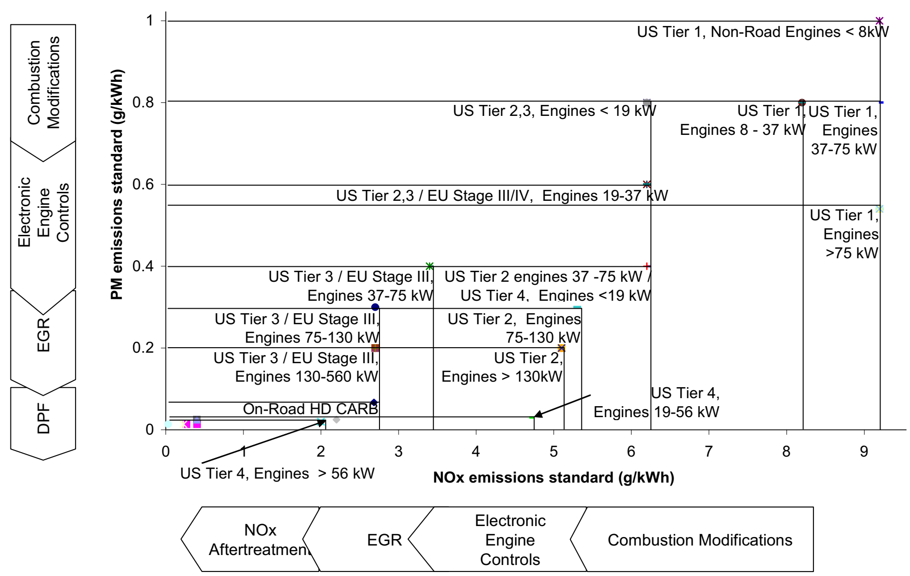

Figure 1. Diesel Engine Emissions Standards are Drastically Reduced by 2010, Requiring Application of New Engine Technologies.

CONTACT POINTS

Heather Quedenfeld
Policy Analyst
304-285-5430
heather.quedenfeld@netl.doe.gov

Mark Williams
Fuel Cells Technology Manager
304-285-4747
mark.williams@netl.doe.gov

Wayne Surdoval
SECA Program Coordinator
412-386-6002
wayne.surdoval@netl.doe.gov

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www.netl.doe.gov/dgfuelcells

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www.seca.doe.gov

Introduction

For many of the potential applications of Solid Oxide Fuel Cell (SOFC) technology being developed under the NETL Solid State Energy Conversion Alliance (SECA), it is highly desirable that the technology can operate on diesel fuel. The transportation market is a large market for SECA fuel cells. Heavy duty trucks, limousines, and recreational vehicles could all use SECA fuel cell auxiliary power units (APUs) to provide non-propulsion power needs. Many of them use diesel as the primary engine fuel and carrying two fuels would be unattractive. In other markets too, such as remote stationary power generation, diesel is the fuel of choice.

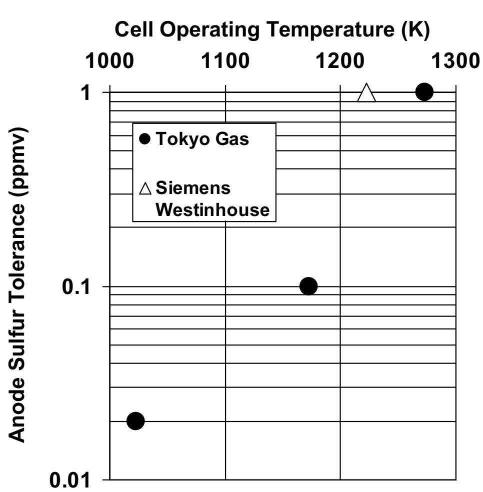
Drastic improvements in diesel fuel quality could impact SOFC's competitiveness *vis a vis* diesel engines in three important ways: it would make diesel-fueled SOFC technically easier to develop, it would strengthen the cost-competitiveness of diesel SOFC, and it would reduce the environmental benefit of SOFC as the engines become much cleaner.

Impact of New Diesel Regulations on Solid Oxide Fuel Cells

Technical Impact

The changes in diesel fuel specifications can be expected to lower some of the hurdles in the development of diesel SOFC. The biggest technical impact on system development results from the reduction in sulfur content. The reduction of diesel fuel sulfur to about 15 ppm will dramatically reduce the level of sulfur-tolerance required for reformer catalysts, and reduce the anode-feed gas-phase sulfur concentration to the roughly the same level as that experienced when using raw pipeline natural gas as a fuel. Experimental data detailing the impact of sulfur content and other fuel properties on SOFC system or stack performance is scarce. Nevertheless, based on existing studies (4,5), the specific effects expected are:

- Chances of development of advanced anodes with sufficient sulfur-tolerance are significantly improved;
- If sulfur removal systems are still required, cartridge or bed replacement intervals will likely be stretched to more than the targeted stack life (more than 40,000 hours);
- Reformer sulfur tolerance requirements will be reduced, improving the chances that sulfur-tolerant reformer catalysts will be successful;
- Especially if the stack is operated at lower temperatures, desulfurization will still be necessary for operation for conventional anodes.



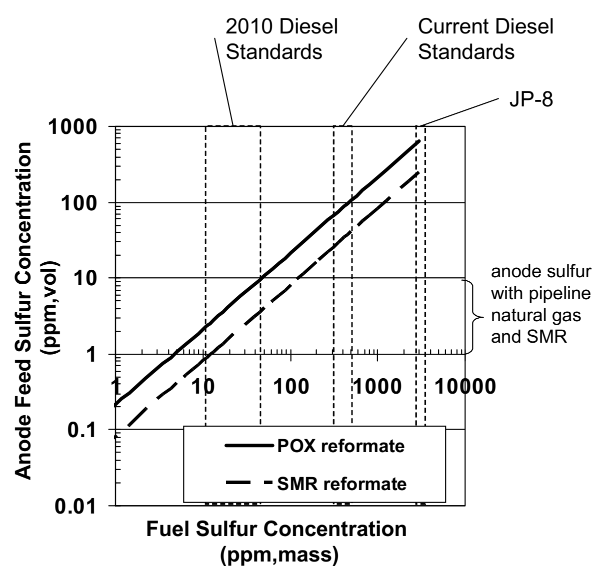


Figure 2. Sulfur Tolerance of State-of-the-Art SOFC Anodes and Sulfur Concentration in Anode Feed as a Function of Fuel Concentration

Lower aromatics content in the fuel would provide greater flexibility in design and operating conditions, especially of the reformer (6). The main impacts of this will likely be slight increases in system efficiency, and a significantly improved reliability. However, given the modest changes in aromatics and PAH content resulting from the move to ULSD, the overall impact of lower aromatics on SOFC system performance and cost is most likely trivial when compared to the cost and performance impacts resulting from the reduction in sulfur content.

Cost Impact

Based on a 2001 study by Arthur D. Little (ADL) (6) estimates were made of the likely impact of the introduction of the new on-road diesel standards on the manufactured cost of an SOFC truck APU. These were then compared with the impact of new engine emissions standards on the cost of competing diesel engines. The analysis indicated that the changes will have several positive impacts on the cost-competitiveness of diesel SOFC:

- The direct manufactured cost of diesel SOFC equipment is expected to be reduced by up to $100 per kW, while the cost of competing engines in the small capacity range (less than 56kW) is projected to increase about a $20 per kW. This cost increase results from the implementation of engine modifications such as EGR. Only larger engines will require catalytic aftertreatment and particulate filters (7,8). This would move diesel SOFC from a position of cost disadvantage compared with engines to one of cost advantage.
- The impact of new regulations does not appear to significantly change the difference of operating and maintenance cost between diesel SOFC and diesel engines. Operating and maintenance cost for SOFC would be reduced due to the introduction of ULSD, mostly because the sulfur cartridge exchange interval will be stretched by a factor of ten. However, this impact would likely be minor (less than 10%) when compared to the major component of SOFC maintenance: stack replacement.
- If SECA cost targets are met, diesel SOFC may be interchangeable with ULSD. Both from a cost and a functionality perspective this provides a major advantage for SOFC in a number of markets, notably APUs.

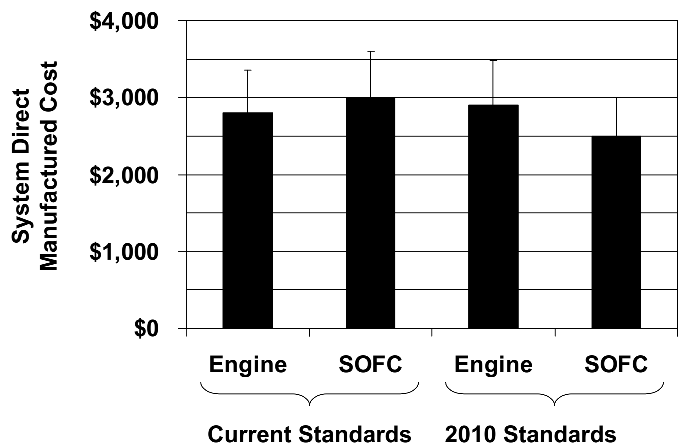


Figure 3. Comparison of Equipment Cost of Engines and SOFC for Truck APU Under Current and 2010 Standards

Impact on National Benefits

The analysis shows that the impacts of the new diesel regulations on both SOFC and engines have several consequences for the national impacts of the use of diesel SOFC in selected small-capacity (less than 56 kW) SOFC applications (including APUs, mobile generators, remote telecoms and industrial power, and small non-road vehicles):

- The criteria pollutant emission benefits from SOFC are reduced as the engines that they replace become substantially cleaner. Still, SOFC will be substantially cleaner than the competing engine technologies;
- The reductions in energy use and greenhouse gas emissions that result from the use of diesel SOFC are maintained and in most cases increased;
- The cost comparison between diesel engines and diesel SOFC will change in SOFC's favor due to the new regulations, thus favoring a faster market penetration.

Conclusions

The changes in diesel fuel specifications will facilitate the development of diesel SOFC technology, but even with the new technologies, the need for more sulfur-tolerant reformers and anodes persists, especially at lower temperatures. Nevertheless, the introduction of ULSD makes it much more likely that functional and competitive diesel SOFC technology will be developed in the next ten years. To foster this development, a more systematic characterization of the effect of sulfur and hydrocarbon species on the performance of SOFC stacks and other system components is needed.

The analysis indicated that the lower sulfur content in diesel will virtually eliminate the cost-penalty for diesel-SOFC over diesel engines (which may be about $100/kW if CARB diesel were to be used.) In addition, a diesel SOFC designed for ULSD will likely be substantially the same as one designed for operation with gasoline. This could substantially broaden the appeal of SOFC compared with diesel engines.

ADDRESS

National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4469 fax

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4604 fax

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