DOE Hydrogen and Fuel Cells Program Record	
Record #: 9010	**Date:** November 3, 2009
Title: Benefits of Fuel Cell APU on Trucks	
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Approved by: Sunita Satyapal	**Date:** November 25, 2009

Item:

Approximately 700 million gallons of diesel can be saved annually through the use of fuel cell auxiliary power units (APUs) in the trucking industry, resulting in a reduction of 8.9 million metric tons of CO_2 per year.

Data and Assumptions

1. **Total number of trucks with sleeper berths is estimated to be 931,000 in 2030**: The total number of heavy-duty freight trucks forecasted in EIA's Annual Energy Outlook 2009 is 5.21 millions in 2010, increasing to 6.93 millions in 2030. In a survey published in 2006, the American Transportation Research Institute (ATRI) received responses from freight truck operators. The operators who participated in the survey reported to ATRI that their companies owned a total of 41,250 sleeper trucks (trucks with sleeper berths). The sleeper trucks are a subset of the 5.21 million freight trucks forecasted by EIA. ATRI stated that 41,250 sleeper trucks constituted 6% of the total number of sleeper trucks. Therefore, the total number of sleeper trucks is estimated as 41,250/0.06 = 687,500 in 2005. Assuming that by 2010 there will be a small increase from 2005, 700,000 is an approximation of the number of sleeper trucks in 2010. In 2030, it is estimated that this number will grow to 931,000 (i.e., approximately 13.4% of the 6.93 million heavy-duty trucks) based on the EIA-projected growth rate for the freight truck population in EIA's Annual Energy Outlook 2009.

   The number of trucks in 2030 that are not sleeper trucks is:

   6.93 million – 0.93 million = 6.0 million trucks with day cabs

2. **In 2030, 625,000 long-haul sleeper trucks will have an average trip length > 500 miles**: Of the 5.21 million freight trucks forecasted by EIA for 2010, 700,000 are sleeper trucks from the previous paragraph. Within the sleeper truck population, approximately 470,000 are long-haul trucks with trip lengths of at least 500 miles (Butcher 2006, Lutsey 2005). In 2030, the 470,000 long-haul sleeper trucks are estimated to grow to 625,000, based on the EIA-projected growth rate for the freight truck population. This is the long-haul subset of the total of 931,000 sleeper trucks estimated in the previous paragraph for 2030. The 625,000 long-haul sleeper trucks are frequently idled overnight at truck stops when power from the truck's main engine is needed for on-board appliances and climate control. A truck within this group idles approximately 1456 hours per year on average (ATRI). Besides sleeper trucks, there are millions of trucks with day cabs (no sleeper berth) because the heavy-duty fleet is estimated at 6.93 million trucks in 2030.

3. **Diesel consumption by idling main engine is 0.64 gallon per hour in 2030**: Today, a typical heavy-duty truck consumes approximately 0.9 gallon of diesel per hour when idling its main engine (Lutsey 2005, Gaines 2009). Truck manufacturers are coming out

with more efficient models that consume less fuel when idling. Gaines shows that a new truck would use 0.6 gallon per hour when idling (Gaines 2009). In 2030, the fleet is assumed to consist primarily of fuel-efficient trucks and a number of trucks introduced in prior years that are less fuel-efficient. For that fleet, the average fuel consumption is estimated at 0.64 gallon per hour.

4. **Diesel consumption by a fuel cell APU is 0.22 gallon per hour in 2030**: A fuel cell APU with an average power of 3.5 kW consumes 0.25 gallon of diesel per hour through the reforming process, based on scaling up the 0.15 gallon-per-hour estimate for a 2.1 kW load in Lutsey 2005. Communications with technology developers indicate that these fuel consumption rates are achievable by 2015. In this analysis, fuel cell APU technology is assumed to improve further with time beyond 2015. Therefore fuel consumption by the APU is assumed to decrease from 0.25 gallon of diesel per hour in 2015 to 0.22 gallon per hour in 2030.

5. **382 million gallons savings associated with fuel cell APUs on long-haul sleeper trucks in 2030**: Annual fuel savings per truck in 2030 with the fuel cell APU:

   (0.64 gallon/hr – 0.22 gallon/hr)(1456 hrs/yr) = 612 gallons of diesel per truck

   Assuming that all the long-haul sleeper trucks are equipped with fuel cell APUs in 2030, the annual savings associated with the 625,000 long-haul trucks in 2030 is:

   612 gallons per truck x 625,000 trucks = 382 million gallons of diesel

6. **131 million gallons savings associated with fuel cell APUs on sleeper trucks with trip length < 500 miles in 2030:** Subtracting the 625,000 long-haul sleeper trucks from the total population of 931,000 sleeper trucks gives 306,000 sleeper trucks whose average trip length is less than 500 miles. From the Department of Commerce's 2002 Vehicle Inventory Use and Survey, the average trip length for this second group of trucks is between 201 and 500 miles. These sleeper trucks combine overnight trips with trips that do not require overnight stops and engine idling. The midpoint between 201 and 500 miles is 350 miles. Assuming 350 miles as the average trip length for this group and 500 miles as the average trip length for the long-haul group, the ratio of the two average trip lengths is: 350/500 = 70%. There is no established methodology to correlate the number of idling hours per year to trip length. Therefore it is assumed that on average, each of the 306,000 sleeper trucks has an annual idling time equal to 70% of the idling time of a truck in the long-haul group. The annual diesel savings for each of the 306,000 trucks is 70% the savings of a truck in the 625,000-truck group:

   612 gallons x 0.70 = 428 gallons per truck.

   The annual savings for 306,000 trucks is:

   428 gallons per truck x 306,000 trucks = 131 million gallons

7. **220 million gallons savings associated with fuel cell APUs on day-cab trucks in 2030:**

   In addition to sleeper trucks, there are day-cab trucks with round trips that last less than a day each and therefore their drivers do not have to idle the engine overnight. However, day-time idling is likely while their drivers wait in a queue for unloading or during a mid-day rest stop when the drivers use air conditioning and some on-board appliances. An average day-cab truck idles approximately 312 hours per year, i.e. approximately 20% of the 1456-hour idling time of a long haul truck (ATRI). Therefore the annual savings per day-cab truck in 2030 is estimated to be equal to 20% of the savings for a long-haul sleeper truck:

612 gallons x 0.2 = 122 gallons per truck

An increasing number of localities and states are requiring or contemplating regulations aimed at the reduction or phase-out of truck engine idling. The annual idling time of a day-cab truck is usually less than that of a sleeper truck. Therefore, day-cab truck operators are assumed to lag sleeper truck operators with respect to investments in idle-reduction equipment. Out of the total 6.0 million day-cab trucks (from Item 1 above), it is assumed that 30% of these, i.e., 1.8 million trucks are equipped with fuel cell APUs in 2030. This is significantly less than the 100% market share assumed for sleeper trucks in the preceding sections. For the 1.8 million day-cab trucks assumed to be equipped with fuel cell APUs, the annual savings is:

1,800,000 trucks x 122 gallons per truck = 220 million gallons.

8. **733 million gallons is the sum of annual savings for fuel cell APUs on trucks**: The total savings in 2030 is obtained by adding 382 million gallons, 131 million gallons and 220 million gallons, i.e. 733 million gallons of diesel per year.

9. **CO_2 Reduction in 2030**:

Table 6-5 in EIA 2008 shows 19.95 million MT C emitted per quad of diesel combusted, or 22.3 lbs CO_2/gallon of diesel combusted.

(22.3 lbs CO_2/gallon)(1 MT CO_2/2200 lbs)(733 million gallons) = 7.4 million MT CO_2

From the GREET Model Version 1.8b, engine CO_2 emissions are 83.6% of lifecycle (well-to-wheels) CO_2 emissions. Lifecycle emissions are:

7.4 million MT CO_2/0.836 = 8.9 million MT CO_2 per year.

References

1. Energy Information Administration, Table 45, Transportation Sector Energy Use by Mode and Type, d041409 for Annual Energy Outlook 2009 with American Recovery and Reinvestment Act, http://www.eia.doe.gov/oiaf/aeo/supplement/

2. American Transportation Research Institute (ATRI), *Idle Reduction Technology: Fleet Preferences Survey*, prepared for New York State Energy Research and Development Authority, February 2006.

3. Jim Butcher (Cummins Power Corporation), *Evolution of the Line Haul Truck APU, from Internal Combustion Engine to Solid Oxide Fuel Cell*, 2005 Fuel Cell Seminar, Palm Springs, California, October 2005.

4. Nicholas Lutsey, Christie-Joy Brodrick & Timothy Lipman, *Analysis of Potential Fuel Consumption and Emissions Reduction from Fuel Cell Auxiliary Power Units (APUs) in Long Haul Trucks*, Elsevier Science Direct, Energy 32 (2005) 2428-2438

5. Linda Gaines (Argonne National Laboratory), *Energy Use and Emissions Comparison of Idling Reduction Options for Heavy-Duty Diesel Trucks*, submitted August 1, 2008 to the Transportation Research Board (TRB, National Research Council) for the 88th TRB meeting held on January 11-15, 2009 in Washington, D.C.

6. U.S. Department of Commerce, 2002 Vehicle Inventory Use and Survey, http://www.census.gov/svsd/www/vius/products.html

7. EIA 2008, *Documentation for Emissions of Greenhouse Gases in the United States 2006,* Energy Information Administration, U.S. Department of Energy, October 2008, DOE/EIA-0638 (2006)

8. Argonne National Laboratory, Greenhouse Gases, Regulated Emissions and Energy use in Transportation (GREET) Model (version 1.8b, September 2008), www.transportation.anl.gov/modeling_simulation/GREET/index.html.