Addressing Climate Change with Fuel Cell Technology

CLIMATE CHANGE AND OUR RESPONSIBILITY

Climate change poses one of the most critical challenges of our lifetime. It is the responsibility of governments, industry and end-users alike to fund, develop and utilize solutions that will contribute to greenhouse gas (GHG) emission reductions.

GHG REDUCTIONS THROUGH USE OF FUEL CELLS

Today, fuel cells are being rigorously tested and commercially deployed in residential cogeneration, distributed generation, backup power, materials handling, and transit bus applications. Each of these applications are expected to have a positive impact on the environment, to varying degrees, through reduction in harmful GHG emissions. In order to understand these impacts better, we have made assumptions regarding global market penetration of each of these fuel cell applications through the year 2025, and combined these with range estimates of environmental impacts based on information available from public data sources. Key estimates - together with predicted global environmental impacts - are outlined on the reverse side of this document. Note that CEERT provided independent verification of all results.

BENEFITS OF FUEL CELL TECHNOLOGY

Fuel cells powered by hydrogen generate clean power, reduce GHG emissions, and have demonstrated a wide range of tangible environmental, economic and operational benefits.

Clean Energy with Environmental Benefits

Fuel cells produce only heat and water as by-products. Today, most hydrogen is produced using fossil fuels, which allows for a 30% reduction in GHG emissions compared with conventional technologies. It is expected that as the hydrogen economy grows, hydrogen will be generated using renewable energy and resources.

Efficient

Fuel cells extract more power from the same quantity of fuel than traditional combustion. The direct electrochemical process reduces the amount of fuel consumed and leads to a 30% - 90% efficiency depending on the fuel cell system and whether the heat by-product is utilized.

Energy Security and Independence

Hydrogen can be produced practically anywhere by developed as well as developing countries in order to meet their respective energy requirements. Domestic leaders in the development and early commercialization of fuel cell technology and the hydrogen economy will be best positioned to take full advantage of the associated market-based and environmental benefits.

Complementary Technologies

Fuel cells work in conjunction with other technologies to offer a best-in-class solution and deliver a significant environmental advantage. Perfectly suited for hydbridization, fuel cells help deliver a mosaic approach to address the needs of our energy and transportation systems.

Economic Business Case

Most businesses publicly support environmental protection and GHG reductions. But it is the economic values demonstrated through direct customer experience that will drive adoption of green technologies. Fuel cells have been shown to deliver strong value propositions and compelling economic business cases for a variety of applications across vertical markets.

CLIMATE CHALLENGES

- Increased threats of flooding, severe storms and coastline erosion.
- Increased heat waves and more intense hurricanes.
- Possible water shortages, and increased risk of hunger and disease.
- Possible arctic temperature increases of 10°C in next 100 years.
- Arctic sea ice expected to almost disappear in late 21st century.
- Up to 30% of Earth's species face increased risk of extinction.
- Increased acidification of oceans.

CBC News - Climate Change: The Heat Is On, April 10, 2007.

ABOUT CEERT

The Center for Energy Efficiency and Renewable Technologies (CEERT) is a nonprofit public-benefit organization located in Sacramento, California. CEERT consists of scientists, environmentalists, public interest advocates and innovative energy technology companies working to promote sustainable resources and nonpolluting technologies to meet the world's appetite for energy. Mr. John Shears, Research Coordinator at CEERT, would be pleased to discuss any questions regarding the estimates referenced in this document.

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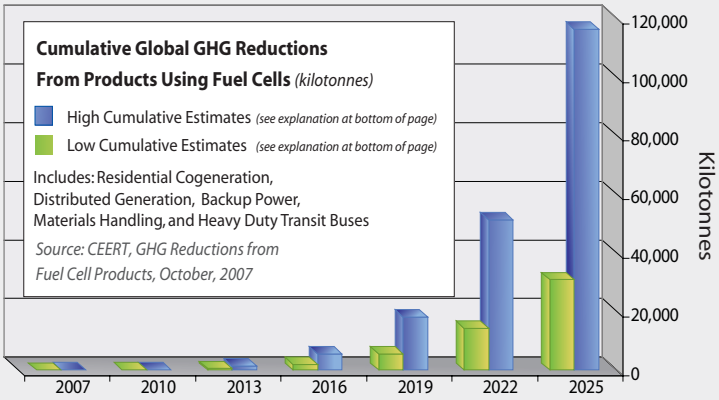
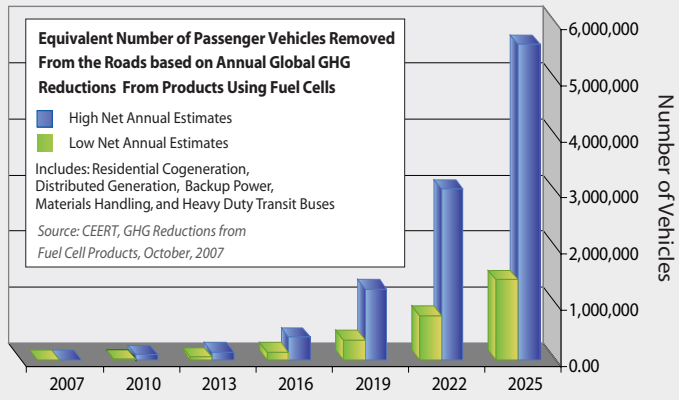
Key Fuel Cell Estimates (by application) and Environmental Impacts

ENVIRONMENTAL IMPACTS





The estimated cumulative global greenhouse gas (GHG) emission reductions attributable to fuel cell applications identified within this report, through the year 2025 cover a range from 31,000 to 116,000 kilotonnes....

WHICH IS EQUIVALENT TO

....removing 1.4 to 5.6 million passenger vehicles from the world's roads in 2025.

KEY ESTIMATES

RESIDENTIAL COGENERATION UNITS & DISTRIBUTED GENERATION

In a demonstration project launched through the Japanese Ministry of Economy, Trade and Industry (METI)[1], 1,257 fuel cell units from 15 utilities/fuel suppliers currently provide hot water and additional energy for homes in Japan. Ranging in power from 0.7kW to 1kW, the units run for nine hours a day and provide GHG emission reductions on average of 85.1 kg/month or 1.021 tonnes/year.[2]

Looking at distributed generation (DG) applications in which electric generation occurs at or near the point of end use, the Houston Advanced Research Center (HARC) as part of a feasibility study for the Texas State Energy Conservation Fuel Cell Initiative analyzed the potential benefits of using 5kW fuel cells[3] fueled by hydrogen derived from natural gas. HARC found these systems could provide GHG reductions of one tonneCO_2/year for each kilowatt of power (ie. 5kW = five tonnes/year). Based on the data in HARC's analysis, if the same 5kW units were similarly run on renewable hydrogen, they could displace roughly 30 to 40 tonnes CO_2/year.[4]

BACKUP POWER SYSTEMS

HARC further examined the benefits of using 2.5kW, 5kW and 10kW fuel cells using hydrogen derived from natural gas for backup power. The resulting analysis indicated emissions reductions are proportional to the duration of equipment operation, approximately 0.3 tonnes per 1000 hours of operation, if the 2.5kW, 5kW and 10kW backup power units were similarly run on renewable hydrogen, they could displace roughly 2, 4 and 8 tonnes of emissions, respectively.[5]

MATERIALS HANDLING

Fuel cell powered lift trucks run on hydrogen produced from natural gas provide emissions reductions over battery powered electric lift trucks in 26 states and four provinces[6] where average grid emissions exceed 550g CO_2e (carbon dioxide equivalent)/kWh. Independent analysis conducted by HARC and for the state of California [7] determined that lift trucks using fuel cells and hydrogen reformed from natural gas demonstrate a 25 to 50% reduction in emissions relative to lift trucks run on propane and diesel. Based on data submitted to the Canadian Government's System of Measurement and Reporting of Technologies (SMART) program, this would reduce GHG emissions by 4.3 tonnes/year on only a 6hr/260 workday schedule.[8]

HEAVY DUTY TRANSIT BUSES

Fuel cells offer significant GHG reduction opportunities for heavy duty transit buses. Emissions from a conventional urban diesel bus range from 3,000 to 7,000gCO_2e/mi/year (exact figures depend upon traffic conditions and number of bus route stops).[9] Combined with an annual trip range of 20,000 to 50,000 mi. (typical for major metropolitan areas)[10]; diesel buses emit between 140 to 150 tonnesCO_2e/year.[11] A bus powered by fuel cells using renewable hydrogen would displace all (100%) of these GHG emissions. Hybridizing diesel buses would yield a 20 to 40% reduction in GHG emissions.[12]

Analysis conducted for the State of California indicates that a fuel cell bus running on hydrogen either reformed at a central station and pipelined, or reformed on-site, would reduce GHGs by 23% (emitting ~2500gCO_2e/mi) when compared with a diesel bus running on California low sulfur (<15ppm) diesel (modeled @3250gCO_2e/mi).[13] On this basis a hydrogen fuel cell bus run completely on hydrogen from renewable resources would displace 65 to 163 tonnes/CO_2e/year of diesel bus emissions.

High Estimate:
Residential cogeneration and distributed generation using hydrogen derived from natural gas or kerosene, and materials handling using hydrogen derived from natural gas when compared to ICE lift trucks powered using propane, and heavy duty transit buses using hydrogen derived from renewable resources. Backup Power operating 400 hrs/year and using hydrogen derived from natural gas.

Low Estimate:
Residential cogeneration and distributed generation using hydrogen derived from natural gas or kerosene, and materials handling using hydrogen derived from natural gas when compared to battery electric lift trucks powered from the North American grid, and heavy duty transit buses using hydrogen derived from natural gas. Backup Power operating 200 hrs/year and using hydrogen derived from natural gas.

All footnotes can be found at http://www.ballard.com/About_Ballard/Resources/Links.htm