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## Maritime ports may be the next deployment for hydrogen fuel cells

Hydrogen fuel cells may be heading out to sea in the not-too-distant future. Hydrogen fuel cells are being used in a variety of ways to provide efficient, pollution-free power—mobile lighting systems, forklifts, emergency backup systems, and light duty trucks, to name a few. Providing auxiliary power to ships in berth may be added to that list soon.

Joe Pratt (8366) and Aaron Harris (8367) recently completed a [study](#) for the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy that found hydrogen fuel cells may be both technically feasible and commercially attractive as a strategy for providing power to ships at berth and replacing on-board diesel generators.

Auxiliary power to stationary ships in port, usually provided by on-board diesel engines, is a significant contributor to greenhouse gas emissions and air pollution, accounting for one-third to one-half of the in-port emissions attributed to ocean-going vessels. For a busy place like the Port of Los Angeles, those average daily emissions could exceed that of nearly 200,000 vehicles<sup>1</sup>.

The fuel cell strategy is simple—a hydrogen-fueled proton exchange membrane (PEM) fuel cell mounted on a floating barge. Supplying a container ship with average power and run times (1.4 MW over 48 hours) requires four 40-ft containers, two for the fuel cell and two for the hydrogen storage, which could readily fit on a typical flat-top barge. For ships requiring less power, like a tugboat, a single container housing both the fuel cell and hydrogen will suffice.

To evaluate the feasibility of this strategy and analyze potential deployment options, Joe visited ports up and down the west coast and in Hawaii. He gathered data from two Department of Transportation Maritime Administration MARAD facilities and the Ports of Long Beach, Los Angeles, Oakland, Portland, Tacoma, Honolulu, and Seattle.

“While Sandia has previously examined the potential for hydrogen and fuel cells in aircraft, construction equipment, electrical generators, telecom backup, man-portable power, and mobile lighting systems, this is the first study of a maritime environment,” he says. “During the course of this study I learned what complex and amazing places ports are, with so much activity and so much variety between the individual ports.”

An alternative to auxiliary diesel engines is a practice called “cold-ironing,” in which a vessel at berth connects to a source of electricity on the shore. The engine, made of steel or iron, literally becomes cold, hence the name. Electricity supplied by a hydrogen fuel cell can be another form of cold-ironing.

The Navy has been employing grid-based cold-ironing for many years to save fuel. California is now turning to the practice to meet the state's tough environmental regulations. While only a few berths have grid-based cold-ironing, infrastructure is being installed at ports across the state to meet California Air Resources Board regulations that take effect in 2014.

Grid-based cold-ironing is complex and costly to implement, as most ports lack the necessary infrastructure to meet the power needs of multiple ships at berth. Those costs can run to \$5-10 million or more per berth. The Port of Oakland is installing 11 berths on six terminals at an estimated cost of approximately \$70 million.

In addition, switching to grid-based power doesn't eliminate emissions. Instead, this approach shifts the emissions to the source of electricity. Depending on the electricity source, the overall reduction in emissions can be quite small.

The hydrogen fuel cell barge bypasses the need for electrical infrastructure. The barge also has the potential for higher usage because it can be moved from berth to berth as needed and to anchorage points to power vessels waiting for berths.

"In California, ports are already installing the necessary infrastructure for cold-ironing because of the regulations introduced a few years ago," says Joe. "So the need for hydrogen fuel cell auxiliary power isn't there. While this was an unexpected finding, we discovered other locations and applications for hydrogen fuel cell power."

At ports in Oregon and Washington, grid-based cold ironing infrastructure is limited or nonexistent. Using a hydrogen fuel cell for powering container ships at berth has attracted interest for the potential economic and environmental benefits. Joe continues to work with those ports on quantifying the benefits and deployment options.

In Hawaii's Honolulu Harbor in Oahu, a different need was found. Much of the cargo is unloaded and then reloaded onto barges for distribution to the other islands. As the barges have no power, they carry diesel generators to provide power to shipping containers that require refrigeration, known as "reefers."

"You can replace the diesel generator with a hydrogen fuel cell without changing the operations. It's just a power source in a box, a shipping container in this case," says Joe. Hawaii ports aren't facing the same strict regulation of emissions as California ports, but the potential savings in fuel cost is attractive for the company operating the inter-island transportation service, along with anyone else suffering from high fuel expenses.

The study's basic fuel cost analysis showed that hydrogen at about \$4 per kilogram with a fuel cell can break even with maritime fuels at today's prices with a combustion engine. Subsequent analysis has shown that when generators are frequently producing less than maximum power (part load operation), such as in the Hawaii application, the efficiency difference between the fuel cell and combustion engine is widened. Even hydrogen at \$5 per kilogram can potentially save tens of thousands of dollars per year for each generator.

"Fuel cost is only part of the total economic picture, but discovering that the cost-effective hydrogen price matches that which is expected to be available is an important finding," says Joe.

He is now developing a detailed plan for the Hawaiian inter-island transport barge application. "A successful deployment of the containerized fuel cell on a floating platform in a typical marine environment will be useful not only in this particular service, but also because it validates the concept for the larger, container-ship sized application," he says. "It's challenging on many levels, but technically feasible with potential commercial and worldwide impact."



Auxiliary power through a hydrogen fuel cell may soon be piloted on the intra-island transport barge system in Hawaii. The fuel cell will replace the diesel generators used to supply power to containers on the barge.

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<sup>i</sup> D. Bailey, T. Plenys, G. M. Solomon, T. R. Campbell, G. R. Feuer, J. Masters, and B. Tonkonogy, "Harboring Pollution - Strategies to Clean Up U.S. Ports," National Resources Defense Council, NY, August, 2004.