A Study of the Feasibility of Utilizing Fuel Cells to Generate Power for the New Haven Rail Line

August 2007

A Report By

The Connecticut Academy of Science and Engineering

For

The Connecticut Department of Transportation

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Richard H. Strauss
Executive Director

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16. Abstract

Stationary fuel cell power plants have been deployed in commercial operation since the early 1990's. The Connecticut General Assembly seeks to determine the feasibility of using fuel cells for the New Haven commuter rail line. Ongoing rail infrastructure improvements provide a window of opportunity to use fuel cel products manufactured in Connecticut as a clean and efficient power source while simultaneously growing the Connecticut economy. Two Connecticut companies, FuelCell Energy and UTC Power, are currently the only companies that offer commercial products with ratings above 100 kilowatts, a level deemed appropriate for most rail line applications.

This report defines New Haven rail line candidate applications; determines technical feasibility of utilizing fuel cell power plants to meet these requirements; identifies economic consequences of using fuel cells; recommends appropriate utilization of fuel cells, and; identifies additional effort require to prepare and issue a request for fuel cell bids.

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Fuel cells, rail car traction power, catenary system power, rail station power, rail maintenance yard power, emergency power.

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EXECUTIVE SUMMARY

STATEMENT OF INQUIRY

Background

The New Haven Rail Line, operated by Metro-North Commuter Railroad (MNR) for the Connecticut Department of Transportation (ConnDOT), is a key element of Connecticut's transportation infrastructure. The line involves over 100 miles of track in the main and branch lines, nearly 35 million passengers per year and over 300 trains daily, including 282 operated by MNR and 37 operated by Amtrak.

Significant improvements to this component of Connecticut's transportation system are occurring over the next decade in accordance with recommendations made by the Connecticut Transportation Strategy Board ("Moving Forward, Connecticut's Transportation Strategy, Report and Recommendations of the Transportation Strategy Board," January, 2007). When these upgrades are completed, the line will be responsible for electricity consumption equal to 0.7% of the total electric energy consumption of the state. Since this consumption is concentrated in the southwestern region of the state, where transmission congestion is a problem, alternative approaches to providing power for the New Haven Line could be constructive.

Stationary fuel cell power plants have been deployed in commercial operation since the early 1990s, and two Connecticut companies—FuelCell Energy and UTC Power—are currently the only companies to offer commercial products with ratings in excess of 100 kilowatts (kW) appropriate to use in New Haven Line applications. The New Haven Line infrastructure improvements provide a valuable window of opportunity to use fuel cell products manufactured in Connecticut to provide clean, efficient power to serve the increasing electricity needs of the New Haven Line, while at the same time accelerating deployment of fuel cell power plants with the attendant growth in the Connecticut economy.

In 2006, the Connecticut General Assembly, in Public Act No. 06-136, mandated a study of "the feasibility of building a fuel cell power station to generate power for the New Haven Line."

Study Description

This study was conducted for ConnDOT by the Connecticut Academy of Science and Engineering (CASE), with ConnDOT required to report the study's findings and recommendations to the General Assembly on or before January 1, 2008.

The objectives of the study are to define the applications for electric power on the New Haven Line; to determine the technical feasibility of fuel cell power plants to meet these requirements; to identify the economic consequences of using fuel cells; to recommend the best applications for use of fuel cells; and to identify additional effort required preparatory to issuing a request for bids on the most promising fuel cell applications.

The scope of applications considered included the following:

- Primary power from natural gas-fueled fuel cell power plants operating in parallel with power from the utility network in which one parallel source maintains power to critical loads if an outage occurs in the other source. This concept was applied to traction power, maintenance yard power and large passenger stations.
- Back-up power for emergency power needs of small passenger stations using hydrogen-fueled fuel cell power plants.

SUMMARY OF FINDINGS

Electric Power Requirements

With completion of expansion of the New Haven maintenance yard in 2015 and addition of passenger stations in West Haven, Milford and Fairfield, the total electric power demand of the New Haven Line is estimated to be nearly 50,000 kW and annual electric energy consumption is estimated to be over 200 million kilowatt hours (kWh).

Table ES-1 summarizes the characteristics of the different power applications on the New Haven Line and summarizes the current cost of power and the potential cost of power from fuel cells meeting manufacturer cost goals. Traction power for the trains is responsible for 61% of the total demand, with maintenance yard power, station power and control and signal power accounting for 33%, 6% and less than 1%, respectively.

	Traction	**Maintenance Yards**	**Passenger Stations**	**Control and Signaling**
Power Demand (kW)	>30,300	Growing to 16,000	>3,000	100
Power Form (Frequency/Number Phases/voltage)	60/ 1/12,500	60/3/480	60/3/480	100/1/12,500
Load Factor (%)	35 - 45	35 - 55	50 - 70	Not Available
Use for Heat	No	Yes	Yes	No
Critical Power Needs	No	Yes	Yes	Yes
Power Demand Increasing?	Yes	Yes (New construction)	Yes (New Construction)	No
Current Cost of Electricity (cents per kWh)	11.3	14.7 - 15.7	12.5 - 13	Not Available
Cost of Electricity from Fuel Cell (cents per kWh)*	13 - 27	13 - 16	13 - 16	Not Available
Availability of space for fuel cell	Limited	Will probably require roof mounting	Constrained	Available

*At cost goal of $2,000/kW installed. Will be reduced with environmental and congestion incentives, which depend on specific situation, market factors and which in some cases require application and evaluation

TABLE ES-1: NEW HAVEN LINE ELECTRIC POWER REQUIREMENTS

Commercial fuel cell power plants produce three-phase power at a frequency of 60 Hz (cycles per second) for use in the United States and at a frequency of 50 Hz to serve electric applications in Europe and many other portions of the world. This form of power is consistent with power used in maintenance yard and passenger station facilities. The single-phase, high-voltage power used in the traction power system will require modification to the electrical output of the fuel cell power plant. This modification will not involve new technology, but rather a design change which could be as simple as use of two inverter systems instead of one. In summary, there are no issues with technical feasibility of fuel cells in New Haven Line applications.

Fuel cell power plants produce both power and heat. Applications which operate the fuel cell at full electrical capacity and which utilize a high percentage of available fuel cell heat improve the prospects for fuel cell power plant economics. Another factor improving the prospects is the ability of the fuel cell, combined with the electric network, to provide critical power at lower cost than by adding emergency generators or uninterruptible power systems. Table ES-1 shows that passenger stations and maintenance yards have characteristics which are favorable to fuel cell power economics, but that traction power has characteristics which are less favorable to the cost of fuel cell power.

Installation of fuel cells during construction of new facilities will reduce installation cost and time, so the fact that power demand is increasing is favorable in most of the applications. Power requirements in the New Haven yard are expected to increase by a factor of ten, from 1,270 kW to 15,000 kW, with many new buildings being constructed between 2008 and 2015. An expansion of the parking garage facilities at the New Haven station is another situation where the construction may facilitate fuel cell installation.

Traction power is expected to increase to accommodate increasing passenger loads and design of the cars to provide better access for passengers with disabilities. However, this need for increased power will be accommodated by an already planned additional supply point. Installation of fuel cells distributed along the line between supply points would provide more uniform voltage levels along the line and improved power security. If improved power security becomes a key issue with regard to traction power, fuel cells distributed along the line could provide a more robust electrical system. Another factor which could enhance the suitability of fuel cells for the traction application is the development of Energy Improvement Districts along the line, which would provide a use for and an economic benefit from the product heat produced by fuel cell power plants.

Another important application factor is availability of space to install fuel cell power plants. Traction power fuel cells would have to be installed adjacent to the utility line, and this area is very congested. This could lead to significant cost and approval issues in this application. Passenger station and yard applications involve land already owned by the state for rail purposes, so this presents somewhat lesser concerns regarding land acquisition costs and approval issues. For new maintenance buildings in the rail yard at New Haven, rooftop installation would present fewer siting issues.

Fuel cell power plants are in early stages of commercial deployment and cost is high, in part, because production volume is still low. At historic fuel cell costs of \$4,000 to \$5,000 per kW, fuel cells are not competitive in New Haven Line applications. Fuel cell manufacturers have cost goals of \$2,000/kW which they expect to achieve with higher production rates and further technology advances. Table ES-1 shows that power plants meeting these cost goals are competitive for some New Haven Line applications without benefit of incentives, but will require incentives to be competitive for the traction power application. Fuel cell electricity costs in Table ES-1 do not include the benefit of substantial incentives for the environmental features of fuel cells or their ability to defer transmission line investment in congested areas. Capturing these incentives, coupled with avoidance of investment in back-up power in situations where it is required, could make fuel cells at the cost goal competitive in all applications. Capturing the incentives would also make fuel cell power plants costing more than the $2,000/kW goal competitive in some New Haven Line applications.

Fuel Cell Characteristics

The two Connecticut manufacturers, who are the only producers of commercial stationary fuel cell power plants with ratings in excess of 100 kW, made presentations on the characteristics of their power plants to the CASE Study Committee and also provided additional information. In addition, information was developed on fuel cells in the development stage by other manufacturers. Table ES-2 compares characteristics of molten carbonate fuel cells from FuelCell Energy and phosphoric acid fuel cells from UTC Power.

	FuelCell Energy	**UTC Power**
Fuel Cell Technology	Molten Carbonate	Phosphoric Acid
Power Plant Ratings (kW)	300, 1,200, 2,400	200, 400
Electrical Generation Efficiency (%-Lower Heating Value)	47	40 to 42
Total Heat Available (BTU/kWh electricity delivered)*	2,670	4,000+
High Grade Heat Available* (BTU/kWh electricity delivered)	1,580 - 1,920	2,580 - 2,700
High Grade Heat Temperature (Degrees F)	Heat exchange with a gas stream ranging from 250 - 700	250
Footprint (ft^2/kW)	2.2 - 4.2	2.3 - 3.5
Start Time (hours)	72	5
Response to Load Change	8 hours, instantaneous with load absorber	Instantaneous
Water required (gallons/kWh)	0.18	None
Stack Life in years Current/Projected	3/5	5/10

* Total heat available includes high-grade heat, which is at temperatures of 250° F or above, as well as low-grade heat available at lower temperatures.

TABLE ES-2: SUMMARY OF FUEL CELL CHARACTERISTICS

The value of the differences in fuel cell characteristics shown in summary form in this table and in more detail in the body of this report depends on the specifics of the situation. Results of bids to detailed specifications will be required to determine which power plant is best suited to a specific application.

Because this study may lead to a procurement action, the fuel cell companies were not asked to provide cost information. However, other sources indicate that current fuel cell costs are in the range of $4,000 to $5,000 per kW and the manufacturers have cost goals of $2,000/kW which they expect to reach with higher production rates and continued improvement in designs and technology.

Significant experience with fuel cell power plants in applications similar to yard power and station power applications on the New Haven Line has been accumulated since the early 1990s, and unattended fuel cell power plants have availability of 95%, which is equal to or greater than central station power plants with a three-shift operating and maintenance staff. Multi-Megawatt installations of fuel cell power plants have been used in other applications. However, the single-phase, high-voltage requirements of the traction power application would require a straightforward design modification to current fuel cell power plant products.

Economic Incentives

Because the fuel cell operates efficiently and cleanly in ratings consistent with individual loads, it contributes to a cleaner environment and more dependable power. Consequently, a number of incentives are available which improve the economics of fuel cell power plants installed in Connecticut. These incentives include sale of Renewable Energy Certificates to meet Connecticut Renewable Portfolio standards, capacity credits from ISO New England, incentives from the Connecticut Clean Energy Fund for On-Site Renewable Distributed Generation and a Federal Income Tax Credit. These incentives could reduce cost of fuel cell electricity significantly.

Federal Support

The federal government has significant programs in support of fuel cell power plants for stationary and vehicle power. However, an initial review of programs of the US Department of Energy, Department of Homeland Security and Department of Transportation did not identify any programs which have funds specifically available for stationary fuel cell power plants which have been deployed on a commercial basis. While allocation from grants to Connecticut from the Department of Homeland Security or Department of Transportation is possible, this would be at the expense of allocations to other projects where these funds are historically applied, and stationary fuel cell power plant projects may not meet criteria for use of these funds. The Department of Homeland Security has not made power reliability for transportation infrastructure a high priority objective and consequently, no funds from that source are expected.

Suggested Fuel Cell Applications

The best application of fuel cells to New Haven Line electrical power appears to be for new maintenance buildings in the New Haven yard. These buildings provide good use for the power plant heat, and use of fuel cells would reduce or eliminate the cost of back-up power.

Because the yard involves only one meter, excess power from one building will be used in other buildings in the complex and no export to the utility will occur. New construction will minimize the cost of fuel cell installation. A number of buildings appear to be good candidates and multiple installations at this site are possible over the next decade. The best use of fuel cells in the New Haven yard would be as a source of critical power for new buildings. A total of 2,200 kW of fuel cell capacity would be required to serve this application, which would require a number of fuel cell power plants to be located at individual buildings. The economics of these fuel cells would be enhanced by recovery of a significant portion of their product heat.

Fuel cell power plant installation at the new parking garage at the New Haven passenger station should also be considered. This application also involves new construction and the possibility of avoiding the cost of a standby generator.

A recent study of the adequacy of the traction power supply resulted in plans to add a fourth supply point where power is provided from the utility network. With this change, electric power will not be a constraint even with increased traffic on the Line through 2020. Consequently, other than economics, the only benefit of using fuel cells for traction power would be a reduction in line losses and improved voltage control along the line. The economics of fuel cell power for traction are less favorable than the economics for yard power or passenger station power because there is no need for heat or for critical power and no need for additional electric power facilities. Integrating the electrical load of the traction power system with thermal loads of facilities adjacent to the New Haven Rail Line would improve economics of fuel cells in traction power applications, and implementation of Energy Improvement Districts facilitated by action of the General Assembly in 2007 could achieve this result.

If fuel cell power plants are applied to traction power, they could be used in combination with the utility network to provide greater power reliability in emergency situations. Depending on the amount of fuel cell power installed, this would permit partial to full passenger service in the event of a utility power outage.

If emergency power for smaller passenger stations becomes a requirement, hydrogen- fueled fuel cell power plants for this application should be considered.

Fuel cell power plants are still in the early stages of commercialization and historic costs of fuel cell power plants do not yield competitive economics unless a significant portion of the incentives for environmental characteristics and avoidance of transmission congestion described above are captured. Experience with fuel cell production is increasing, and further technology improvements which could make fuel cell economics more competitive in the future are expected. A firm understanding of fuel cell economics will require analysis of bids for a specific application.

Use of fuel cells in maintenance yard and passenger station facilities is consistent with actions in Public Act 07-242 to establish a strategic plan to improve energy management in state buildings and to provide bonding in accordance with implementation of that strategic plan.

Alternative forms of ownership including state ownership and ownership by third parties should be considered in order to establish the best economic approach for providing fuel cell power on the New Haven Line.

Suggested Action

This report provides an initial assessment of the technical and economic feasibility of stationary fuel cell power for the New Haven Line, and indicates the most attractive applications. However, more information is needed to assess specific applications. Some of this information will be developed as design of the new buildings in the New Haven yard and the new parking garage at the New Haven Station proceeds. Other information will require a study of line losses on the catenary system. Section 6 of this report provides detail on the additional information and action required prior to issuing a request for bids, and suggests information which should be requested from the bidders as well as suggestions for evaluating the bids.