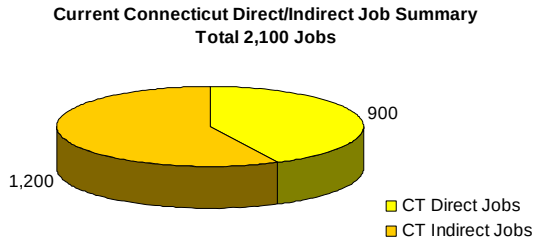
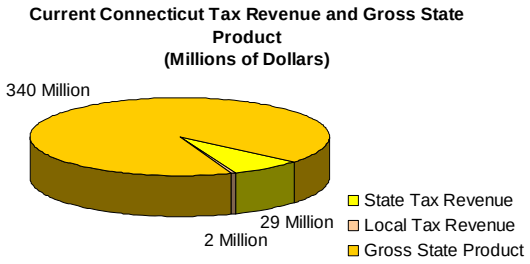
EXECUTIVE SUMMARY

Connecticut's industry has been the leader and innovator of fuel cell and electrolysis technologies since the 1950s, and pioneered applications for spacecraft, submarines, and stationary power. More recently, Connecticut industry has joined the effort to apply these technologies to transportation. Connecticut manufacturers and researchers have developed expertise in all fuel cell technologies and hydrogen generation. Consequently, Connecticut is well positioned to maintain or expand its share of the stationary power and transportation markets for increased employment, increased sales, and increased research and development (R&D) expenditures.

In 2006, Connecticut's hydrogen and fuel cell industry contributed to the State's economy by providing 927 direct jobs associated with research and development, the manufacture of equipment, and over 1,200 indirect jobs for a total of over 2,100 jobs statewide. The industry contributed approximately $29 million in state tax revenue, approximately $2 million in local tax revenue, and over $340 million in gross state product.

Figures ES.1 and ES.2 - 2006 Connecticut Hydrogen and Fuel Cell Industry Employment and Economic Summary





Connecticut's hydrogen and fuel cell industry also provides widespread economic value to the State's economy as identified through favorable multipliers for employment, industrial revenues, and employee compensation.

Table ES.1 - Economic Multipliers for Connecticut's Hydrogen and Fuel Cell Industry

Economic Multipliers			
	Employment	**Industry Revenues**	**Employee Compensation**
Multiplier	2.31	1.84	1.72

The employment multiplier of 2.31 indicates that for each job the hydrogen and fuel cell industry directly supports, an additional 1.31 jobs are indirectly supported elsewhere in Connecticut's economy. Likewise, the revenue multiplier of 1.84 suggests that for each dollar of revenue generated by the hydrogen and fuel cell industry, an additional 84 cents of revenue is received by Connecticut businesses. The compensation multiplier of 1.72 indicates that for every $1.00 paid to employees within the hydrogen and fuel cell industry, an additional 72 cents is paid by other employers in the supply chain.

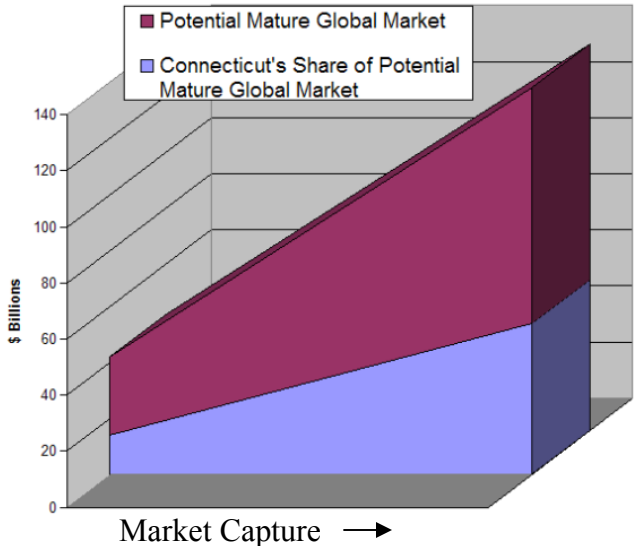
Presently, Connecticut's hydrogen and fuel cell industry employs 1,156 employees; an increase of 229 jobs since early 2006. Under existing trends, it is projected that by the year 2010, Connecticut would be positioned to increase direct employment to over 1,600 jobs.

Table ES.2 - Connecticut's Hydrogen and Fuel Cell Industry Jobs

Industry Employment			
	2006	2007	2010 (Estimated)
Direct Employment	927 Jobs	1,156 Jobs	1,635 Jobs

These near-term projections of industry growth are encouraging; however, this growth is modest compared to the potential opportunities of a mature global market. It has been estimated that the global fuel cell/hydrogen market, when mature, could generate between $43 and $139 billion annually. If fuel cells are deployed as distributed

Figures ES.3 - Potential Mature Global Market



generation and if Connecticut's fuel cell and hydrogen industry captures a significant share of the transportation market, revenues to Connecticut companies in a mature global market could be between approximately $14 and $54 billion annually, which would require an employment base of tens of thousands.

The market for hydrogen and fuel cell technology is expected to grow for the following reasons:

- World electric consumption is projected to more than double between 2003 and 2030. This growth will place a high demand on distributed generation for use in many regions that lack transmission infrastructure.
- Transportation demands for petroleum currently exceed domestic supply. To ensure energy security and reduce price volatility, alternative fuels such as hydrogen, and alternative technologies such as fuel cells will be required.
- Increased energy efficiency for transportation and electric generation will be required by all global consumers as traditional fuel prices increase. For example, oil prices have risen steeply from nearly $30 per barrel in 2003 to nearly $100 per barrel in late 2007; arriving much sooner than the U.S Energy Information Administration's (EIA) prediction of $100 per barrel in 2030.
- Reduced emissions of greenhouse gases (GHG) and primary air pollutants from mobile and stationary sources will become mandated by most if not all countries.
- Connecticut's summer peak electric demand is projected to increase by approximately 1,200 MW by 2016. This projected growth in peak electric

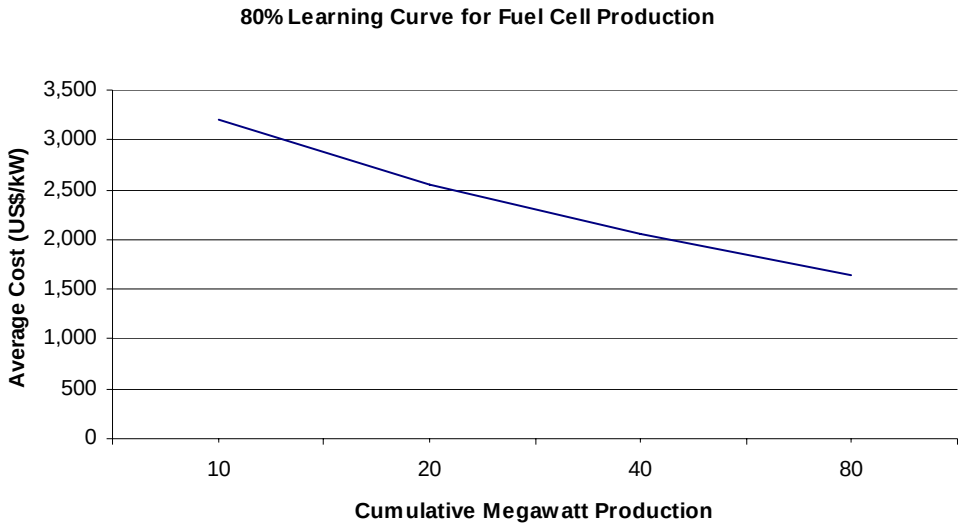
demand will require new generation resources in addition to conservation measures.

- Connecticut will require new generation capacity to replace 942 MW of existing generation capacity that will be at least 40 years old by 2008, and 2,461 MW of existing generation capacity that will be at least 40 years old by 2016.

While hydrogen and fuel cell technology offers significant opportunities for improved energy reliability, energy efficiency, and emission reductions, barriers have slowed market penetration. These barriers include: high costs, lack of understanding and recognition of fuel cell reliability and durability, unappreciated environmental values, lack of investment needed to undertake research and development, insufficient infrastructure, and strong competition from rate-base supported conventional grid generation.

The most significant barrier to increased market penetration is cost. However, increased production rates and improved design and technology will reduce unit costs. Models suggest that if production were to increase for stationary power applications from a level of approximately 10 MW per year to a level of 40 MW per year, unit costs would drop to approximately $2,000 per kW; a level closer to parity with conventional distributed generation, as depicted in Figure ES.3.

Figure ES.3 - Cost Reduction Gains and Fuel Cell Production



With investment to produce 40 MW of fuel cell capacity in the state per year, Connecticut industries will be able to reduce unit costs and potentially capture a larger share of the global market. A long term investment of 40 MW per year will also help to address Connecticut's renewable portfolio standard requirements (RPS), GHG reduction goals, and projected capacity deficiency of electric generation.

The potential annual energy savings, and reductions in the emission of GHG and primary air pollutants associated with the displacement of 40 MW of conventional electric generation, would be as shown below:

Table ES.3 - Potential Average Annual Emissions Reduction and Energy Savings Using Fuel Cells

Potential Average Annual Emissions Reduction and Energy Savings Associated with the Displacement of 40 MW of Conventional Fossil Fuel Generation			
Air Emissions		Energy Savings	
NO_X	224 tons	Btu	1.4 – 1.6 Trillion
SO_2	187 tons	No. 2 Oil Equivalent	10 - 12 Million Gallons
CO_2	144,365 tons		

In addition, fuel cells would increase transportation efficiency by two to three times, as shown below:

Table ES.4 - Average Energy Efficiency of Conventional and Fuel Cell Vehicles

Average Expected Energy Use (mpge)					
Passenger Car		Light Truck		Transit Bus	
Hydrogen Fuel Cell	Gasoline Powered Car	Hydrogen Fuel Cell	Gasoline Powered Light Truck	Hydrogen Fuel Cell	Diesel Powered Transit Bus
81.2	29.3	49.2	21.5	12.4	3.9

The targeted deployment of hydrogen and fuel cell technology in Connecticut would effectively meet electric power and transportation needs. For stationary power applications, there are many buildings in the state that have characteristics favorable for the operation of stationary fuel cell power plants, including state public buildings, state prisons, universities, hospitals, and many other sites. In transportation applications, state and private fleets are excellent applications for initial hydrogen-fueled and fuel cell-powered vehicles. These include: transit buses, delivery fleets, service vehicles for utilities and industry, postal vehicles, and waste collection vehicles. Existing or planned refueling stations, as well as fleet garages along Connecticut's major highways, are attractive locations for hydrogen fueling stations that could be used for both fleet vehicles as well as vehicles traveling long distances through the northeast states.

In order for hydrogen and fuel cell technology to meet performance goals, and capture a significant share of the mature global market, a significant amount of research and development must be conducted. It is estimated that U.S. federally-sponsored research and development expenditures for fuel cell and hydrogen in FY 2010 will exceed $1.1 billion, including almost $649 million in Department of Energy funds. With Connecticut's deep heritage in hydrogen and fuel cell technologies, presence of a talented pool of human capital, patent position, facilities, product focus, and the proposed research and development investment program, Connecticut entities could capture at least 15% of the projected Department of Energy R&D funds, which could be approximately $97

million. Consequently, the state is poised to benefit from innovation and business creation opportunities associated with research and development activities.

The challenge for Connecticut is to support a strategic plan that will enhance the development of the fuel cell/hydrogen market, counter market obstacles which are impeding growth, and ensure that Connecticut maintains and increases its position as a world leader in the industry. State investment in Connecticut's hydrogen and fuel cell industry could provide an attractive return on investment that may exceed $4 for every $1 of state investment. As the global market matures, the potential return on investment for Connecticut could also increase significantly.

Table ES.5 - Summary of Investment Strategy and Potential Annual Return on Investment

Investment Strategy and Potential Annual Return on Investment		
	Annual Investment	**Potential Return on Investment**
Stationary Power*	$32 Million	$129.3 Million
Transportation**	$2 Million	$5.5 Million
Research and Development***	$15 Million	$97 Million
Total	**$49 Million**	**$231.8 Million**

* State employment is projected to increase by 1,280 direct and indirect jobs.
** Assumes implementation of the proposed transportation plan.
*** Assumes 15 percent capture of projected DOE R&D expenditures in 2010.

Without such state action, Connecticut may face loss of sales, missed opportunities to capture R&D funding, and emigration of employment as other states and countries compete for fuel cell and hydrogen development activities. Currently, Connecticut is host to an industry that commands a global market as does no other industry in the state. With a well established workforce, patents for advanced technology, and a large share of the existing stationary power market, Connecticut has the opportunity to create and sustain a synergistic critical mass of jobs and technology in the fuel cell industry, potentially overflowing to the general energy sector, an outcome analogous to what has occurred in and around Silicon Valley and Boston/Route 128.

In summary, data in this Final Report suggests that there are favorable market conditions for the expansion of the hydrogen and fuel cell industry in Connecticut, that public investment is appropriate and justified, that investment in hydrogen and fuel cell technology would provide a favorable return for the state, and that there are favorable sites for deployment of hydrogen and fuel cell technology in Connecticut to meet our pressing energy needs, improve environmental performance, increase economic development, and create new jobs.

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Summary of Recommended Strategies

The following recommendations are intended as a menu of options to consider in support of Connecticut's hydrogen and fuel cell industry:

- Provide long-term and predictable tax advantage incentives to reduce early development production costs for local manufacturers of fuel cells, fuel cell components, and hydrogen equipment at $32 million per year for 10 years. This investment strategy could earn a favorable return on investment for state economic development, including federal tax credits of $40 million, and an estimated $56 million in private investment from the manufacturers for a cumulative value equivalent of over $128 million per year. In addition, the state would gain 554 new jobs with an estimated value of nearly $33.28 million, for an estimated total of 1,280 new jobs that would be added to the supply chain.

- Provide long-term and predictable grant and grant matching resources to support public and private research and development (R&D) efforts in Connecticut at $15 million per year for ten years, to capture approximately $100 million in federal R&D funding annually.

- Provide long-term support for bus, automobile, auxiliary power, service/off-road vehicle, fueling station and infrastructure development and demonstration in Connecticut at approximately $2 million per year to earn a favorable return on investment for state economic development, including approximately $38.6 million from federal funding through 2015.

- Provide general support to the industry through the Connecticut Hydrogen-Fuel Cell Cluster at $250,000 per year to:
    - Monitor the implementation of the hydrogen roadmap for measurable results in terms of jobs, electric capacity, and environmental performance;
    - facilitate the development of hydrogen and fuel cell technology;

- disseminate information, and facilitate industry, academic and government interaction; and
- assist and support manufacturing innovation, supply chain development, and in-state lean manufacturing.

- Implement a Communications Plan to increase awareness and the level of knowledge amongst potential customers, stakeholders, and investors

- Leverage all existing and proposed funding and/or state purchase to target the installation of 40 MW of fuel cells per year at sites that provide high public benefit, including but not limited to state and municipal public buildings including schools, hospitals, and emergency shelters; Energy Improvement Districts; and other identified priority sites.

- Dedicate a portion of Connecticut's Renewable Portfolio Standard (RPS) for combined heat and power (CHP) fuel cell and other performance equivalent hydrogen fueled facilities and hydrogen (equivalent) production for dedicated use with a fuel cell.

- Provide electric utility customer choice on utility bills for selection of hydrogen and fuel cell technology as a Class I Renewable Energy manufactured in Connecticut.

- Expand local property tax and state sales tax exemptions for hydrogen and fuel cell technology, manufactured or partially manufactured (with proportional benefit), in Connecticut.

- Support utility ownership of any fuel cell and other performance equivalent hydrogen fueled facilities, including hydrogen (equivalent) production for dedicated use with a fuel cell, up to 5 MW, at sites needed for voltage control, grid security, and/or system reliability.