



Fuel Cell Economic Development Plan Hydrogen Roadmap

Connecticut Center for Advanced Technology, Inc.

In Partnership With

The Connecticut Department of Economic and Community Development



CCAT Energy Initiatives: Joel M. Rinebold



Project Management and Plan Development
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Project Consultants

Connecticut Academy of Science and Engineering – Third Party Review

Connecticut Economic Resource Center – Communications Plan

GZA GeoEnvironmental Inc. – Emissions Analysis

Barr Group, Inc. – Economics

Connecticut Center for Manufacturing Supply Chain Integration – Supply Chain

Joe King – Transportation

Trent M. Molter – Research & Development

Mark A. Thompson – Economic Multipliers

State Agencies

Connecticut Department of Economic and Community Development

Renewable Energy Investment Fund (Connecticut Clean Energy Fund)

Connecticut Department of Environmental Protection

Connecticut Department of Transportation

Connecticut Siting Council

Education

University of Connecticut Global Fuel Cell Center

Gateway Community College

Goodwin College

Connecticut Hydrogen - Fuel Cell Coalition

Manufacturers and Supply Chain

Legal and Finance

Labor

Government

Education



Public Act 06-187, Section 64

Statutory Goals and Objectives

- Facilitate commercialization
- Enhance energy reliability and security
- Reduce emissions, greenhouse gases with efficient use of nonrenewable and renewable fuels
- Installation of infrastructure
- Dissemination of information
- Develop strategies for Connecticut industry
- Identify targets within the state transportation system
- Consult with electric and natural gas service providers regarding distributed generation targets



Plan Objectives

Preliminary Plan - January 1, 2007

Final Plan - January 1, 2008

- Identify and assess market conditions for fuel cell and hydrogen technology.
- Analyze Connecticut's hydrogen and fuel cell industry.
- Examine Issues and identify proposed solutions.
- Identify and assess strategies to enhance Connecticut's hydrogen and fuel cell industry for increased employment, revenues, and economic development.



Connecticut Opportunities

Connecticut is a world leader in the research, design, and manufacture of hydrogen and fuel cell related technologies. The State is uniquely positioned to help develop the fuel cell/hydrogen market and facilitate a smooth transition from hydrocarbon fuels using conventional combustion technology to the use of efficient electrochemical technology.



Functional Focus Areas

- Stationary
- Transportation
- Research & Development
- Workforce Development



Reasons for Market Growth

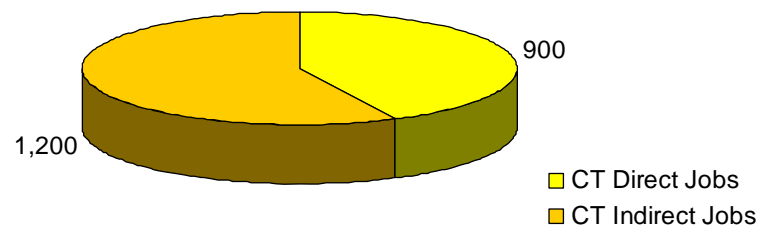
- World electric consumption to double between 2003 and 2030.
- Transportation demands for petroleum exceed domestic supply.
- Increased energy efficiency required (oil cost/\$bbl).
- Reduced emissions of greenhouse gases and primary air pollutants.
- Growth of peak electric demand.
- New generation capacity to meet additional demands.



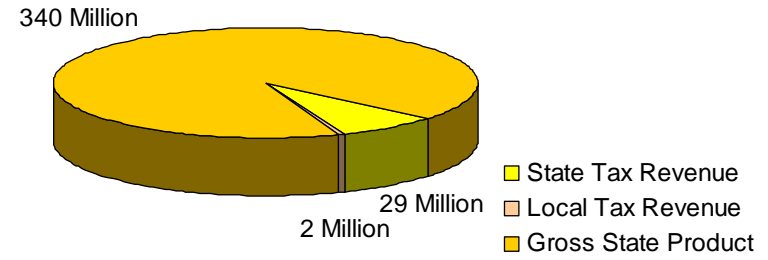
Connecticut Market Growth

- In 2006, there were over 900 jobs associated with research and development and manufacture of equipment (1,156 in 2007).
- Over 1,200 indirect jobs in 2006 (over 1,500 in 2007).
- The industry contributed \$29 million in local tax revenue, and over \$340 million in gross state product in 2006.

Current Connecticut Direct/Indirect Job Summary
Total 2,100 Jobs



Current Connecticut Tax Revenue and Gross State Product
(Millions of Dollars)





Economic Multipliers

Economic Multipliers			
	Employment	Industry Revenues	Employee Compensation
Multiplier	2.31	1.84	1.72

- For each job the hydrogen and fuel cell industry directly supports, an additional 1.31 jobs are indirectly supported elsewhere in Connecticut.
- For every \$1.00 of revenue generated by industry, an additional 84 cents of revenue is received by the state of Connecticut.
- For every \$1.00 paid to industry employees, an additional 72 cents is paid by other employers in the supply chain.

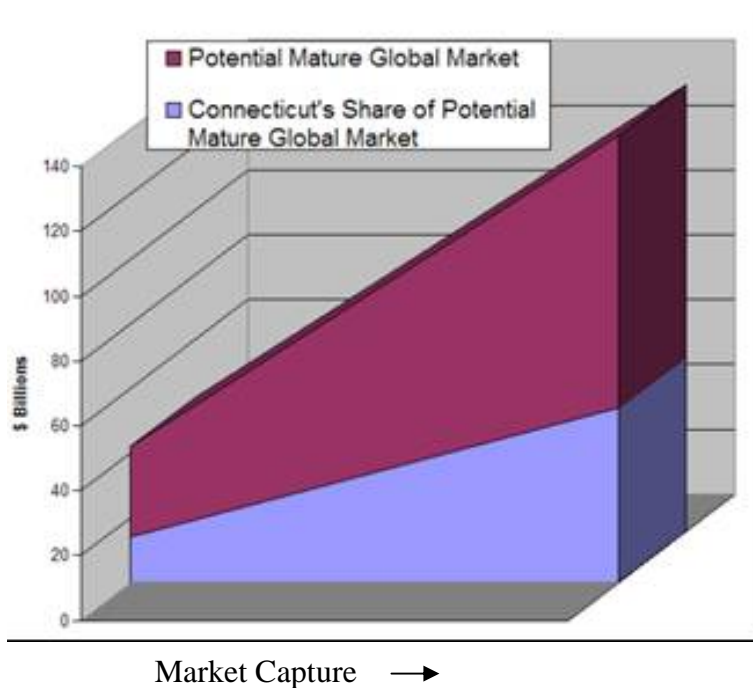


Industry Employment

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

- Job growth directly associated with the industry is estimated to grow by over 700 jobs between 2006 and 2010, however such growth would be modest compared to potential applications of a mature market.
- Connecticut's hydrogen and fuel cell industry presently employs 1,156 employees, an increase of 229 jobs since early 2006.

Potential Mature Global Market



- A mature global market could generate between \$43 and \$139 billion annually.
- If Connecticut captures a significant share of the distributed generation and transportation markets, revenues could be between \$14 and \$54 billion annually.
- A mature market would require a Connecticut employment base of tens of thousands.



Roadmap Environmental Value

Emissions Reduction and Energy Savings

- Fuel cell generation facilities can substantially reduce emissions, greenhouse gases, and energy use.

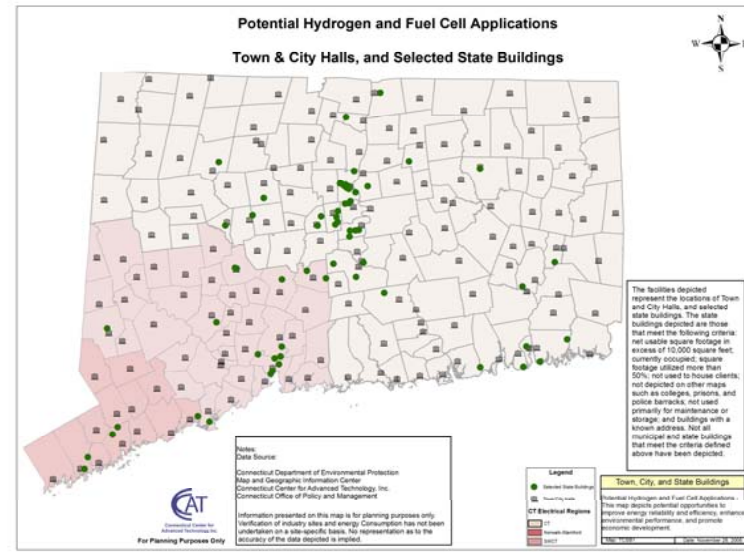
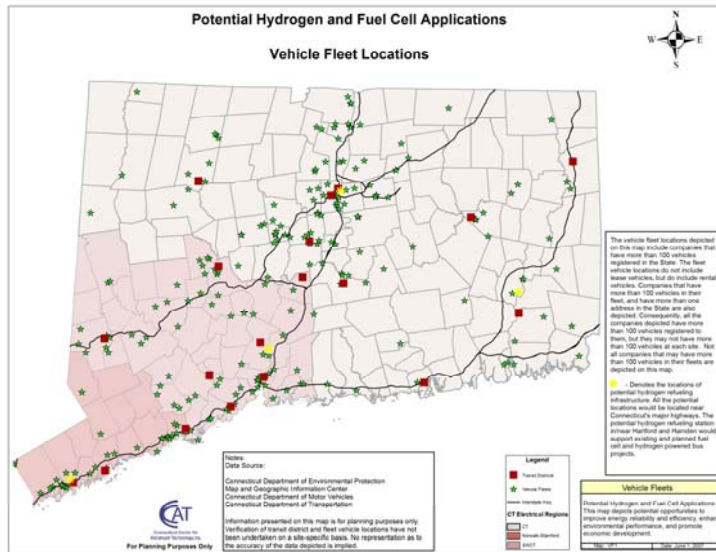
Potential Average Annual Emissions Reduction and Energy Savings Associated with the Displacement of 40 MW of Conventional Fossil Fuel Generation			
Air Emissions		Energy Savings	
NO _x	224 tons	Btu	1.4 – 1.6 Trillion
SO ₂	187 tons	No. 2 Oil Equivalent	10 - 12 Million Gallons
CO ₂	144,365 tons		

- Fuel cells would increase transportation efficiency by two to three times.

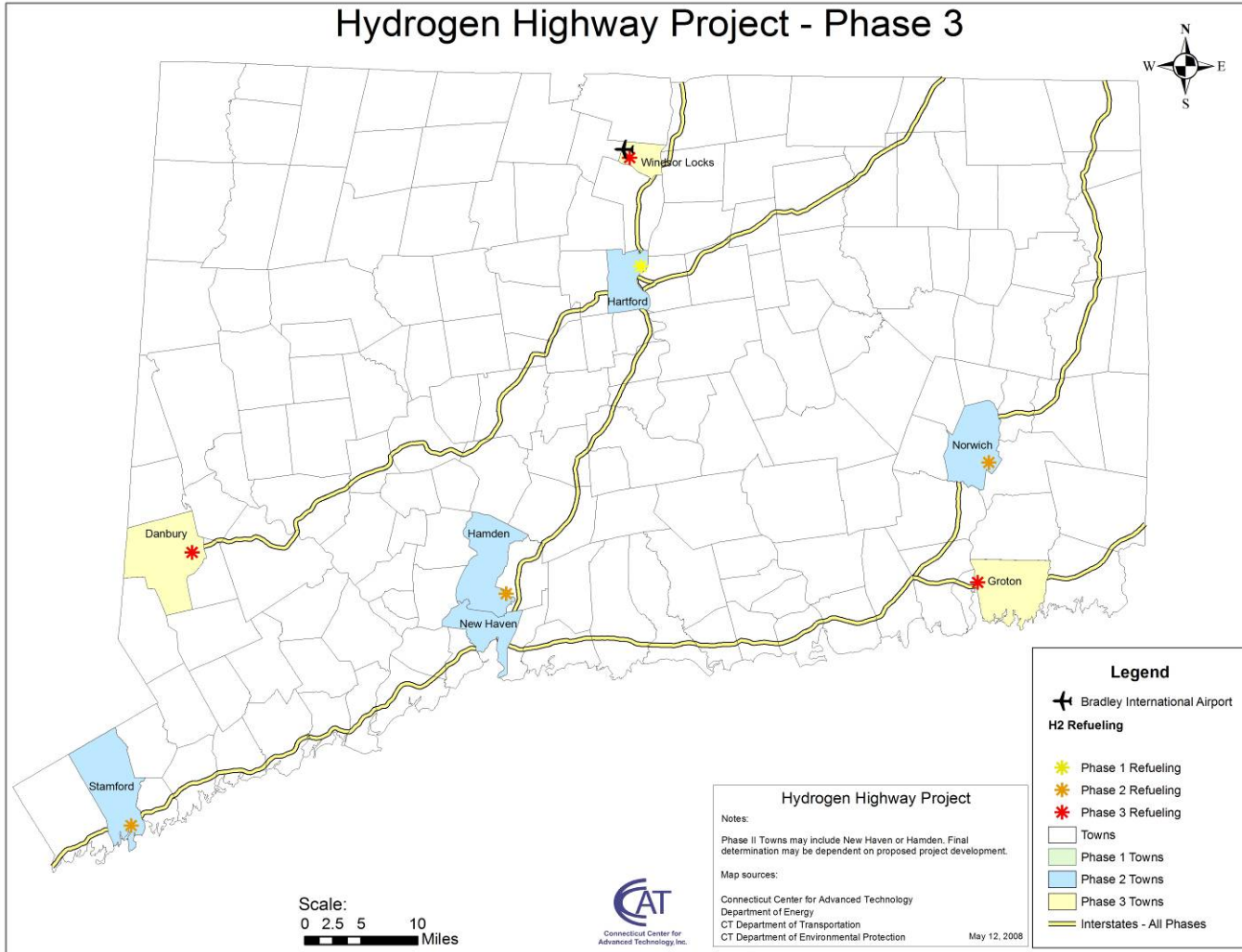
Average Expected Energy Use (mpge)					
Passenger Car		Light Truck		Transit Bus	
Hydrogen Fuel Cell	Gasoline Powered Car	Hydrogen Fuel Cell	Gasoline Powered Light Truck	Hydrogen Fuel Cell	Diesel Powered Transit Bus
81.2	29.3	49.2	21.5	12.4	3.9

Roadmap Geographic Targeting

- Targeted deployment of hydrogen and fuel cell technology could effectively meet electric power, thermal and transportation needs, reduce emissions, increase energy efficiency, and reduce costs.
- Examples of targets include state public buildings, prisons, universities, hospitals, transit fleets, delivery fleets, major highway fueling stations, etc.

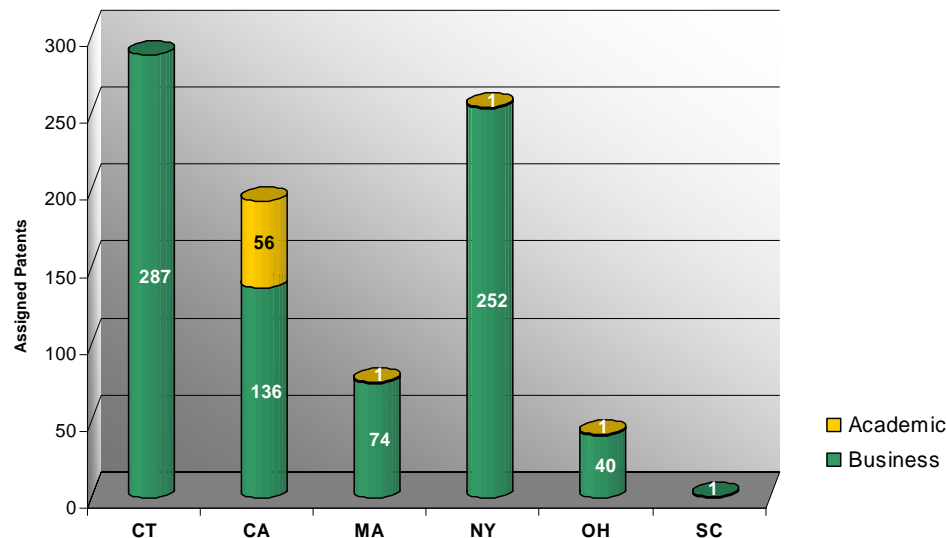


Phase III Deployment



Connecticut Capabilities

- Connecticut is a leader in stationary and spacecraft power plants, with additional capability in vehicle, portable, and submarine applications.
- Connecticut hydrogen companies are involved with hydrogen production, hydrocarbon processing, storage, and distribution.
- Connecticut leads all benchmark states in fuel cell patents and all patents are business driven.



Fuel Cell Patents, across Benchmark States, Business vs. Academic, Total 2000 – 2006

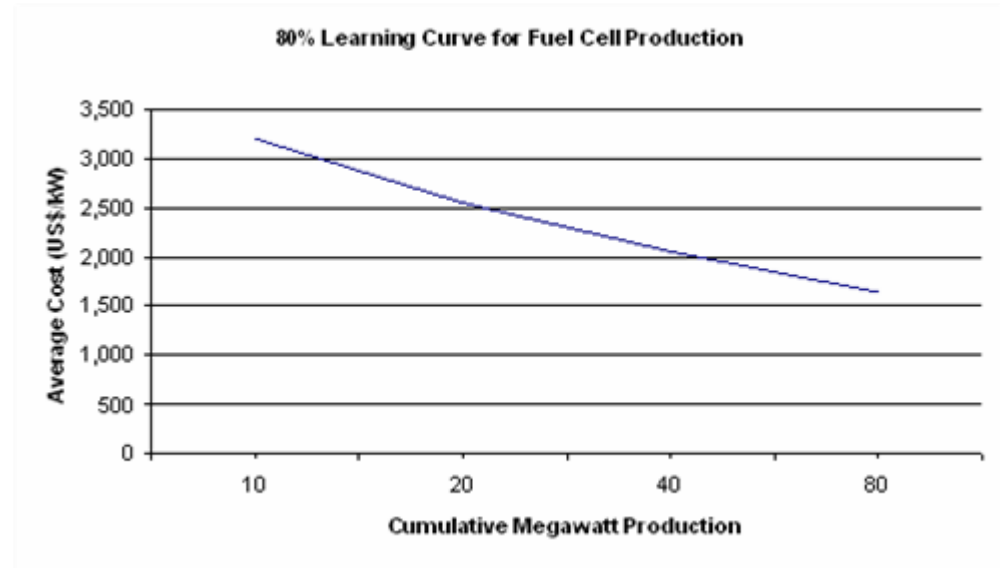
Connecticut Supply Chain

- There are opportunities for further supply chain development for fuel cell manufacturing in Connecticut.
- There are over 150 Connecticut companies that have the capability to be part of the fuel cell supply chain to provide materials for the manufacture of fuel cells and hydrogen equipment.
- The future state of a Connecticut supply chain can conceivably consist of hundreds of suppliers and tens of thousands of employees.

Connecticut OEM Activities	
<u>What do Connecticut OEMs currently do?</u>	<u>What do Connecticut OEMs currently make?</u>
<ul style="list-style-type: none"> • Manufacture • Repair • Refurbish • Test • Assemble • Install 	<ul style="list-style-type: none"> • Turn-key fuel cell systems • Fuel cell stacks • Fuel cell plates • BOP equipment • Hydrogen production equipment

Reducing Production Cost

- Increased production rates and improved design and technology will reduce unit costs.
- 10 MW per year to 40 MW per year production increase could drop unit costs from \$3,200 per kW to ~\$2,000 per kW
- Connecticut industries can reduce unit costs and capture a larger market share of the global market with an investment to produce 40 MW of fuel cell capacity, annually.





Roadmap Market Findings

- A mature global market could generate between \$43 and \$139 billion annually.
- Connecticut can potentially capture a significant share of the world distributed generation and transportation markets generating revenues between \$14 and \$54 billion annually.
- An employment base of tens of thousands would be required if Connecticut realizes a mature market compared to the 2010 estimated 1,635 jobs.



Roadmap Summary

- This Hydrogen Roadmap suggests that there are favorable market conditions for the expansion of the hydrogen and fuel cell industry in Connecticut.
- Public investment is appropriate and justified.
- Investment in hydrogen and fuel cell technology would provide a favorable return for the State.
- 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.



Investment Strategy

- State investment in the industry could provide a return on investment that may exceed \$4 for every \$1 of state investment, with the potential to increase significantly with a maturing global market.
- Without significant action Connecticut may face loss of sales, missed opportunities to capture R&D funding, and emigration of employment to other competing states and countries.
- Connecticut has the opportunity to create and sustain a synergistic critical mass of jobs and technology, potentially overflowing to the general energy sector, an outcome analogous to Silicon Valley and Boston/Route 128.

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



Recommended Strategies

Strategic Investment

- 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 for 10 years. This investment strategy would earn a favorable return on investment for state economic development.
- Provide long-term and predictable grant and grant matching resources to support public and private research and development (R&D) efforts in Connecticut.
- Provide long-term support for bus, automobile, auxiliary power, service/off-road vehicle, fueling station and infrastructure development and demonstration in Connecticut.



Recommended Strategies

Supply Chain Support

- Provide general support to the industry through the Connecticut Hydrogen-Fuel Cell Cluster to:
 - Monitor jobs, electric capacity, and environmental performance;
 - Disseminate information; and
 - Support supply chain development and in-state lean manufacturing.
- Implement a Communications Plan.

Targeted Deployment

- Target the installation of fuel cells at sites that provide high public benefit.



Recommended Strategies

Market Expansion

- Dedication of a portion of Connecticut's Renewable Portfolio Standard (RPS).
- Provide utility customer choice.
- Expand local property tax and state sales tax exemptions.
- Support utility ownership of fuel cells.



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