Massachusetts - Hydrogen Economy

- Economic Development
- Environmental Performance
- Energy Reliability
Hydrogen and Fuel Cell Development Plan – “Roadmap”

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Cover Photo References


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1 This document was produced with support and assistance from the United States Small Business Administration
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**EXECUTIVE SUMMARY**

Existing Massachusetts businesses and institutions have the potential to install up to **234 to 312 megawatts (MW)** of electric generation and combined heat and power (CHP) using fuel cell technology. With an annual output of **2,307,000 – 3,100,000 megawatt hours (MWhs)**, these fuel cell generation facilities can reduce carbon dioxide (CO₂) emissions by between **842,000 – 1.2 million tons** annually.

Zero emission fuel cell electric vehicles (FCEV) could replace existing conventional vehicles in Massachusetts, starting with **1,867 vehicles**, which can reduce annual CO₂ emissions by approximately **11,800 to 16,600 tons** per year. Additionally, fuel cells could provide a zero emission alternative for fork lifts and other material handling equipment necessary for prolonged work in enclosed warehouse space.

While fuel cell installation/deployment may be technically viable at many locations, this plan focuses on hydrogen and fuel cell applications that are both technically and economically viable. The Northeast Electrochemical Energy Storage Cluster (NEESC) has recommended the following goals for stationary and transportation hydrogen fuel cell deployment to meet economic, environmental, and energy needs:

- **234 to 312 MW fuel cell electric generation by 2025**
- **1,867 FCEVs (1,818 [101 FCEVs for MA State fleet] passenger and 49 transit/paratransit buses) as zero emission vehicles (ZEV)**
- **18 to 19 hydrogen refueling stations (to support FCEV deployment)**

Locations where fuel cell installations are both technically and economically viable include a wide range of private, state, and federal buildings used for offices, manufacturing, data management, warehousing, education, food sales and services, lodging, in-patient healthcare, and public order and safety. Similarly, fuel cell installations are viable at wastewater treatment plants, landfills, telecommunications sites, seaports, high-traffic airports, and for electric grid service. Locations for FCEVs and hydrogen refueling would be technically and economically viable in urban regions of the state where fleets, early market adopters, and hydrogen users exist.

Currently, Massachusetts has at least **300 companies** that are part of the growing hydrogen and fuel cell industry supply chain in the Northeast region. The age distribution of hydrogen and fuel cell companies in the Northeast suggests a substantial expansion in the sector, with several small businesses exhibiting recent growth. Growth of hydrogen and fuel cell patents in the Northeast far exceeds the growth of all types of clean energy patents in the region. Based on an IMPLAN economic analysis, these companies are estimated to have realized approximately **$184 million in revenue and investment**, contributed more than **$11 million in state and local tax revenue**, and generated approximately **$147 million in gross state product** from their participation in this regional energy cluster in 2011. Additionally, eight (8) of these companies are original equipment manufacturers (OEMs) of hydrogen and/or fuel cell systems, and were responsible for supplying **406 direct jobs** and **$56.8 million in direct revenue and investment** in 2011.

The deployment of hydrogen and fuel cell technology will reduce the state’s dependency on oil, improve air and water quality, meet carbon and ZEV requirements, utilize renewable energy from indigenous sources such as biomass, wind, and photovoltaic (PV) power, and increase the number of energy sector jobs within the state. This plan provides links to relevant information to help assess, plan, and initiate hydrogen and/or fuel cell deployment to help meet the energy, economic, and environmental goals of the State of Massachusetts.

Policies and incentives that support hydrogen and fuel cell technology will increase deployment. Increased demand for hydrogen and fuel cell deployment will increase production and create jobs throughout the supply chain. As deployment increases, manufacturing costs will decline and hydrogen and fuel cell technology will be in a position to compete more effectively in a global market without support on incentives. Policies and incentives can be coordinated regionally to maintain the regional cluster as a global exporter for long-term growth and economic development.
INTRODUCTION

A 2015 *Hydrogen and Fuel Cell Development Plan* was created for each state in the Northeast region (Massachusetts, Vermont, New Hampshire, Connecticut, Rhode Island, Maine, New York, and New Jersey), with support from the United States (U.S.) Small Business Administration (SBA), to increase awareness and facilitate the deployment of hydrogen and fuel cell technology. The intent of this guidance document is to make available information regarding the economic value and deployment opportunities to increase environmental performance and energy reliability using hydrogen and fuel cell technologies.²

A fuel cell is a device that uses, but does not burn, hydrogen (or a hydrogen-rich fuel such as domestic natural gas) and oxygen to create an electric current. Fuel cells occupy a technology platform that when coupled with electric drivetrains have the potential to replace the internal combustion engine (ICE) in vehicles and provide power for stationary and portable power applications. Fuel cells are in commercial service throughout the world, providing thermal energy and electricity to power the grid, homes, and businesses. Fuel cells are also used in vehicles, such as forklifts, automobiles, trucks, buses, and other land, marine, air, and space equipment. Fuel cells for portable applications currently in development will provide power for video cameras, military electronics, laptop computers, and cell phones.

Hydrogen can be produced using a wide variety of resources found here in the U.S. Hydrogen can be renewable and produced by waste, biomass, wind, solar, tidal, wave, and geothermal. Production technology includes electrolysis of water, steam reforming of natural gas, coal gasification, thermochemical production, and biological gasification.³

Natural gas, which is composed of four (4) hydrogen atoms and one (1) carbon atom (CH₄), has the highest hydrogen-to-carbon ratio of any energy source.⁴ Furthermore, natural gas is widely available throughout the Northeast region, is relatively inexpensive, and is primarily a domestic energy supply. Consequently, natural gas shows potential to serve as a transitional fuel for the near future hydrogen economy.⁵ Over the long term, hydrogen production from natural gas may be augmented with renewable energy, nuclear, coal (with carbon capture and storage), and other low-carbon domestic energy resources.⁶

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² This plan was developed in coordination with H₂USA and Northeast States for Coordinated Air Use Management (NESCAUM) to advance ZEV development.
The Northeast hydrogen and fuel cell industry, while still emerging, currently has an economic impact exceeding $1 billion in total revenue and investment. Massachusetts benefits from impacts of direct, indirect, and induced employment and revenue from this industry.  

Furthermore, Massachusetts has a definitive and attractive economic development opportunity to greatly increase its participation in the hydrogen and fuel cell industry as this collective industry strives to meet global demand for clean, low carbon heat, and power. Massachusetts’ biomass, wind, and photovoltaic (PV) power production initiatives could be further enhanced with energy storage provided by hydrogen. These drivers will become more important as users turn to sustainable energy sources in place of fossil fuels.

### Policy

Massachusetts’ relative proximity to major load centers, the high cost of electricity, concerns over regional air quality, available federal tax incentives, and legislative policy have resulted in renewed interest in the development of efficient and cost effective renewable energy. Specific policies in Massachusetts supporting the hydrogen and fuel cell industry are displayed in Table 1.

Legislation and policy to support hydrogen and fuel cell technologies can be cost effective and appropriate for public investment. The public value of the hydrogen and fuel cell industry in the Northeast region includes jobs, environmental quality, and economic development.

### Economic Impact

Massachusetts is home to at least 300 companies that are part of the growing hydrogen and fuel cell industry cluster in the Northeast region. Realizing approximately $184 million in revenue and investment in 2011, these companies include manufacturing, parts distributing, fuel processing, supplying of industrial gas, engineering based research and development (R&D), coating applications, and managing of venture capital funds.

Furthermore, the hydrogen and fuel cell industry is estimated to have contributed over $11 million in state and local tax revenue, and approximately $147 million in gross state product annually (for 2011). Additionally, eight (8) of these companies are original equipment manufacturers (OEMs) of hydrogen and/or fuel cell systems, and were responsible for supplying 406 direct jobs and $57 million in direct revenue and investment in 2011. Table 2 shows Massachusetts’ impact in the Northeast region’s hydrogen and fuel cell industry as of August 2011.

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**Table 1 - MA Hydrogen Fuel Cell Policy Incentives**

- Mandatory Renewable Portfolio Standards (RPS)
- Interconnection Standards
- Net Metering
- Public Benefits Funds
- ZEV Purchase Incentives
- Renewable Fuel Incentive Rebates
- Refueling Infrastructure Incentives

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Indirect impacts are the estimated output (i.e., revenue), employment and labor income in other business (i.e., not-OEMs) that are associated with the purchases made by hydrogen and fuel cell OEMs, as well as other companies in the sector’s supply chain. Induced impacts are the estimated output, employment and labor income in other businesses (i.e., non-OEMs) that are associated with the purchases by workers related to the hydrogen and fuel cell industry.

7 Indirect impacts are the estimated output (i.e., revenue), employment and labor income in other business (i.e., not-OEMs) that are associated with the purchases made by hydrogen and fuel cell OEMs, as well as other companies in the sector’s supply chain. Induced impacts are the estimated output, employment and labor income in other businesses (i.e., non-OEMs) that are associated with the purchases by workers related to the hydrogen and fuel cell industry.


9 Economic Impact derived from an IMPLAN Economic Financial Model, Todd Gabe, August 2012.

<table>
<thead>
<tr>
<th>Massachusetts Economic Data</th>
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<tr>
<td>Supply Chain Members</td>
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<tr>
<td>Gross State Product ($M)</td>
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<td>State Local Tax ($M)</td>
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<td>Induced Revenue ($M)</td>
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<td>Induced Jobs</td>
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<tr>
<td>Induced Labor Income ($M)</td>
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<tr>
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<tr>
<td>Total Jobs</td>
<td>1,103</td>
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<tr>
<td>Total Labor Income ($M)</td>
<td>91.79</td>
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</table>

The growth of jobs in the production of hydrogen vehicles and other hydrogen equipment may produce some job declines in traditional activities; however, there will be a net increase in job creation. Massachusetts employment in the hydrogen fuel cell supply chain is predicted to increase by 1,319 to 4,285 jobs by 2020.\(^{12}\)

Information on the age distribution of hydrogen and fuel cell companies in the Northeast is suggestive of a substantial expansion in the sector, with recent growth of several small businesses. Growth of hydrogen and fuel cell patents in the Northeast far exceeds the growth of all types of clean energy patents in the region. Analysis of the 2010 to 2013 employment growth in the region shows that a greater percentage of incumbent businesses grew than declined, and that companies experienced an average growth rate of nine (9) percent.\(^{13}\)

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\(^{11}\) Economic data is calculated based on 2011 data.


**STATIONARY POWER**

In 2012, approximately 36 million megawatt-hours (MWh) of electricity was generated in Massachusetts to serve the electric demand for the residential, industrial, and commercial sectors. Overall electricity demand is forecasted to grow at a rate of 1.1 percent annually over the next decade.\(^{14}\)

This demand represents approximately 46 percent of New England total electricity consumption. The State relies on both in-state resources and imports of power, with approximately 13,150 megawatts (MW) of total generation capacity; 41 percent of the total capacity in New England.\(^{15}\) Demand for new electric capacity is expected due in part to the replacement of older less efficient base-load generation facilities.\(^{16}\) Fuel cell technology has high value and opportunity (see Table 3) to meet grid needs and to replace older generation facilities with high efficiency generation located directly at the customer’s site. Distributed generation will increase efficiency, improve end user reliability, provide opportunity for combined heat and power (CHP), and reduce emissions. Targets for CHP distributed generation (DG) include schools, hospitals and other mission critical facilities (see Table 4).\(^{17}\)

Based on the targets identified within this plan, there is the potential to develop up to 234 to 312 MW of stationary fuel cell generation capacity in Massachusetts, which would provide the following benefits (see Appendix V), annually:

- **Production of approximately 2,307,113 to 3,073,665 MWh of electricity**\(^{18,19}\)
- **Production of approximately 5.51 to 13.7 million MMBTUs of thermal energy**
- **Reduction of CO\(_2\) emissions by approximately 842,445 to 1.2 million tons (electric generation only)**\(^{20}\)

This plan focuses on applications for fuel cells in the 300 kilowatt (kW) to 400 kW range. However, larger fuel cells are potentially viable for grid applications and small fuel cells are potentially viable for site-specific applications such as back-up power for telecoms and grid resilience. Potential stationary targets are illustrated in Appendix I – Figure 1, “Massachusetts: Potential Hydrogen and Fuel Cell Applications for Public Facilities” and Figure 2, “Massachusetts: Potential Hydrogen and Fuel Cell Applications for Private Facilities.”

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14 U.S. Energy Information Administration (EIA); “State Electricity Profiles”; http://www.eia.gov/electricity/state/; May 2014.
17 As defined by CBECs, Public Order & Safety facilities are buildings used for the preservation of law and order or public safety. Although these sites are usually described as government facilities they are referred to as commercial buildings because their similarities in energy usage with the other building sites making up the CBECs data.
18 Calculations incorporate an 87.5% capacity factor when utilizing both electric and thermal loads provided by the system.
Tri-generation

A tri-generation station incorporates CHP technology that produces hydrogen in addition to heat and electricity. Hydrogen produced by the fuel cell system can be used to support a fueling station for FCEVs or for industrial purposes. FuelCell Energy is currently involved in the manufacture of tri-generation technology and operation of a tri-generation facility that runs on natural gas and biogas. This facility produces heat and power for a wastewater treatment facility and hydrogen for vehicles.\textsuperscript{21}

Emergency Preparedness

Recent weather events in the Northeast including Hurricane Irene (2011), the Nor’easter snowstorm (2011), Superstorm Sandy (2012), and Blizzard Nemo (2013) have emphasized the need for clean, reliable, baseload distributed generation located at mission critical facilities to maintain power when grid power is not available due to storm damage. Over 25 fuel cells, located in the Northeast region affected by Hurricane Sandy, performed as expected and provided electricity, heat, and hot water during and after the storm passed. Several states are considering initiatives that include increased use of performance and engineering standards, improved planning, hardening of the infrastructure, increased communications and collaboration, additional response training, and the use of microgrids and other emerging technologies to mitigate impact(s) on energy grid infrastructure. Fuel cells are now being considered as ultra clean generators for microgrids to reliably provide heat and electricity at base load and to operate in island mode to serve essential needs during extended power outages.

STATIONARY FUEL CELL GOALS

NEESC recommends a goal to develop 234 to 312 MW of fuel cell technology in Massachusetts by 2025. This goal coupled with the existing 800 kW of fuel cells currently operating in Massachusetts would result in a total of 234.8 to 312.8 MW of high efficiency fuel cell capacity by 2025 (See Appendix VI for installed fuel cell locations in Massachusetts).

Table 5 – Policy/Incentives for Stationary Fuel Cell Development

\begin{itemize}
  \item Renewable Portfolio Standards
  \item Net Metering
  \item Public Benefits Funds
  \item Performance Power Purchase
  \item State Grant Programs
  \item State Loan Programs
  \item Property Tax Incentive
  \item Sales Tax Incentive
  \item Property-Assessed Clean Energy (PACE) Financing
\end{itemize}

Fuel cells are already in use for buildings, data centers, telecommunications applications, power for remote locations, distributed power generation, grid resilience, and cogeneration (in which excess heat released during electricity generation is used for other applications).

Transformation requires vision, commitment, and action to overcome challenges associated with the deployment of stationary fuel cells. Continued advancement of hydrogen and fuel cell technology to advance economic, energy, and environmental policy will require the continuation of existing incentives such as, mandatory renewable portfolio standards (RPS), interconnection standards, net metering and virtual net metering, public benefits funds, cooperation and/or ownership from electric utilities, and performance based power purchase agreements (see Table 5 and Appendix IV – State Energy Policy/Incentives for Stationary Fuel Cells and Hydrogen Transportation).\textsuperscript{22}


\textsuperscript{22} NEESC; “Renewable Energy Incentives;” http://neesc.org/opportunities/incentives; September 2014.
TRANSPORTATION

As oil and other non-sustainable hydrocarbon energy resources become scarce, energy prices will increase and the reliability of supply will be reduced. Government and industry are now investigating the use of hydrogen and renewable energy as a replacement of hydrocarbon fuels in the transportation section, which accounts for 32.5 percent of Massachusetts’ total energy consumption. 23 As these system sizes and applications increase efficiency will increase resulting in more favorable economics and increased reliability. Targets for FCEV deployment and hydrogen infrastructure development include public/private fleets, bus transit, and specialty vehicles (see Table 6). Zero emission FCEVs could replace existing conventional fleet vehicles in Massachusetts, starting with 1,867 vehicles, providing annual carbon dioxide (CO₂) emissions reduction of approximately 13,728 tons per year. 24, 25 FCEVs have advantages (see Table 7) over conventional technology and can reduce price volatility, decrease dependence on oil, improve environmental performance, and provide greater efficiencies, as follows:

- Fuel cells can achieve 40 to 70 percent efficiency, which is substantially greater than the 30 percent efficiency of the most efficient internal combustion engines. 26

- FCEVs running on hydrogen produced from renewable resources virtually eliminate all GHG emissions compared to conventional fossil fuel powered vehicles. Passenger car emissions of CO₂ are reduced by 4.75 metric tons CO₂E/vehicle/year. 27, 28, 29

- Fuel cells offer significant GHG reduction opportunities for heavy duty transit buses. 30, 31 A bus powered by hydrogen fuel cell technology run completely on hydrogen from renewable resources could displace 65 to 163 metric tons CO₂E/vehicle/year of diesel bus emissions. 32

Automakers are now making plans to comply with a ZEV program, which is modeled after the California ZEV Action Plan. 35, 36 Eight (8) states have committed and signed a Memorandum of Understanding

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24 Analyses conducted by the Connecticut Center for Advanced Technology (CCAT) based on the ZEV eight-state MOU and R. L. Polk vehicle data. Eight (8) State MOU projection of 3.3 million and total 2011 registered vehicles were used to derive 4.675 percent of registered vehicles that may be registered as ZEVs. Percent calculated was then applied to fleet vehicles as a conservative early projection.
25 CO₂ emission reduction = 4.75 metric tons CO₂E/vehicle/year*1,818 (FCEVs) + 65 to 163 metric tons CO₂E/vehicle/year*49 (FCEB) = 11,820.5 to 16,622.5 metric tons CO₂E/vehicle/year.
27 GHG emissions include carbon dioxide, methane, and nitrous oxide, all expressed as carbon dioxide equivalents.
28 8.89 × 10⁷ metric tons CO₂/gallon gasoline × 11,318 VMT car/truck average × 1/21.4 miles per gallon car/truck average × 1 CO₂, CH₄, and N₂O/0.988 CO₂ = 4.75 metric tons CO₂E/vehicle/year.
30 On average transit buses travel 20,000 to 50,000 miles annually, typical for major metropolitan areas.
31 Emissions from conventional urban diesel buses range from 3,000 to 7,000 grams CO₂E/mi/year (exact figures depend upon traffic conditions and number of bus route stops).
33 Only the largest automakers are subject to the mandate: BMW, Daimler AG, Ford, General Motors, Honda, Hyundai, Kia, Mazda, Nissan, Toyota, and Volkswagen.
(MOU) requiring large-volume automakers to sell approximately 3.3 million ZEVs between 2018 and 2025, 1.24 million of which are defined as “ZEVs (Electric and/or Hydrogen Fuel Cells)”. Additionally, a 2012 Preliminary Study conducted by the National Renewable Energy Laboratory (NREL) projects deployment of approximately 117,000 to 205,000 FCEVs in the Northeast region by 2025. Automakers have indicated that they plan to introduce hydrogen FCEVs by 2015. As one of the eight states that has signed this MOU, Massachusetts has the potential of deploying approximately 148,000 FCEVs by 2025. The expected result of this deployment will be high efficiency vehicles that require less fuel and produce very low or zero tailpipe emissions.

Potential deployment appears very large based on the Eight (8) State MOU projection of 3.3 million ZEVs by 2025. NEESC took a more conservative approach by applying the NESCAUM projections to the total registered vehicles to derive 4.675 percent of registered vehicles that may be registered as ZEV, and then applied this percentage to fleet vehicles as a conservative early projection.

### Fleets

There are over 38,800 passenger fleet vehicles classified as non-leasing or company owned vehicles in Massachusetts. Passenger vehicles at transportation hubs are good candidates for hydrogen fueling and conversion to FCEVs because they mostly operate on fixed routes or within fixed districts and are fueled from a centralized station. As illustrated in Appendix I – Figure 3, “Massachusetts: Potential Hydrogen and Fuel Cell Applications for Transportation,” the fleet clusters in Massachusetts are located primarily in the Lowell, Boston, Springfield, and Worcester metropolitan areas.

### Bus Transit

There are approximately 1,030 buses that provide public transportation services in Massachusetts. Although the efficiency of conventional diesel buses has increased, these buses, which typically achieve fuel economy performance levels of 3.9 miles per gallon, have the greatest potential for energy savings by using high efficiency fuel cells. Fuel economy performance levels for the fuel cell powered buses average 6.8 mi/DGE (diesel gallon equivalent). Fuel cell buses are currently in use in several states, with many on public bus routes in California. A fuel cell transit bus funded by the Federal Transit Authority’s (FTA) National Fuel Cell Bus Program (NFCBP) is going into service at the Massachusetts

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40 Auto blog green; “2015 Toyota hydrogen fuel cell car will have 300-mile range;” http://gas2.org/2013/07/02/toyotas-2015-fuel-cell-car-aims-for-300-mile-range/; July 2, 2013.
41 Derived from 8-State MOU projected deployment rates calculated for California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhodes Island, and Vermont.
42 The existing hydrogen and fuel cell industry in the Northeast is comprised of almost 1,200 supply chain companies, $1.1 billion in revenue and investment, and over 5,600 full- and part-time jobs. This data does not include full contribution from the hydrogen and fuel cell transportation industry, which would increase with market deployment of FCEVs.
43 These projections have not been peer reviewed and/or confirmed by NESCAUM.
44 Fleet vehicle data provided by R. L. Polk & Co., 2013.
45 NTD Date, “TS2.2 - Service Data and Operating Expenses Time-Series by System;” http://www.ntdprogram.gov/ntdprogram/data.htm; December 2011.
Specialty Vehicles
Specialty vehicles, such as material handling equipment, airport tugs, street sweepers and wheel loaders, are used by a variety of industries, including manufacturing, construction, mining, agriculture, food, retailers, and wholesalers. Batteries that currently power some equipment for indoor use are heavy and take up significant storage space while only providing up to six (6) hours of run time. Fuel cell powered equipment has zero emissions, can be operated indoors, may last more than twice as long (12-14 hours) before refueling, can be refueled quickly, and eliminates the need for battery storage and charging rooms (see Table 8). Fuel cell powered material handling equipment is already in use at dozens of warehouses, distribution centers, and manufacturing plants in North America.48 Large corporations that are currently using or planning to use fuel cell powered material handling equipment include Sysco, CVS, Coca-Cola, BMW, Central Grocers, and Wal-Mart. Sysco Boston LLC operates hydrogen fueled forklifts at its Plympton, Massachusetts.49

Hydrogen Infrastructure
Hydrogen refueling stations will be required to support FCEVs including FCEV fleets, buses, material handling equipment, etc. Hydrogen refueling can be developed privately or publically depending on usage. While costs for hydrogen refueling infrastructure could range from $1,000,000 - $3,000,000 per station, it is possible that construction of these stations could be backed by private sector financing or developed publically in conjunction with high efficiency ZEV fleets. NESCAUM are currently developing hydrogen infrastructure models for financing and development to serve projected FCEV fleets (See Appendix II – Eight (8) State MOU Projections for FCEVs). Potential sites for development include existing refueling stations, but new potential sites are also possible.50, 51, 52, 53, 54 For example Proton OnSite is associated with Lumber Liquidators and has indicated a willingness to develop hydrogen refueling infrastructure on Lumber Liquidators sites.55

HYDROGEN TRANSPORTATION GOALS
NEESCS recommends a near-term acquisition of at least 1,867 FCEVs in the state of Massachusetts. The deployment of 1,818 passenger fleet vehicles and 49 transit/paratransit buses would provide an annual CO₂ emissions reduction of approximately 11,821 to 16,623 tons per year. The direct acquisition by lease or purchase of 101 FCEVs for the state of Massachusetts fleet is also recommended.56, 57

Table 8 – FC Material Handler Advantages

<table>
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<tr>
<td>1.5 times lower maintenance costs</td>
</tr>
<tr>
<td>8 times lower refueling/recharging costs</td>
</tr>
<tr>
<td>2 times lower net present value (NPV) and</td>
</tr>
<tr>
<td>Zero emissions</td>
</tr>
</tbody>
</table>

50 There are approximately 2,700 retail fueling stations in Massachusetts; however, only 56 public and/or private stations within the state provide alternative fuels, such as biodiesel, compressed natural gas, propane, and/or electricity for alternative-fueled vehicles. There are also at least 27 refueling stations owned and operated by Massachusetts’ Department of Transportation (MassDOT) that could help facilitate the deployment of FCEVs within the State.
54 Currently, there are four (4) existing/planned fueling stations where hydrogen is provided as an alternative fuel in Massachusetts.
55 There are currently 10 different Lumber Liquidator sites located in the Massachusetts.
56 A calculated one percent of 10,072 vehicles operated but the state of Massachusetts.
Additionally, NEESC has set a goal for the immediate development of 18-19 hydrogen refueling stations, to support FCEV deployment.

Transformation requires vision, commitment, and action to overcome challenges associated with the deployment of FCEVs and the construction of supporting hydrogen infrastructure. Consumer incentives to mitigate costs and enhance the FCEV ownership experience may include purchasing of state passenger vehicles, “point-of-purchase” rebates, hydrogen fuel rebates, incentives for refueling infrastructure, FCEV buy back incentives, tax incentives, infrastructure partnerships, and high occupancy vehicle (HOV) lanes/parking (see Table 9). Alternative vehicle infrastructure to support ZEVs will require planning and investment by public and private entities with an explanation of a payoff on that investment (Appendix IV – State Energy Policy/Incentives for Stationary Fuel Cells and Hydrogen Transportation). As summarized below, a state investment of at least $29.47 million for infrastructure development and vehicle deployment could provide a solid framework to support the goal of 1.818 passenger vehicles, 19 hydrogen refueling stations. An additional $24.5 million (50 percent of $49 million) for 49 transit/paratransit buses is also encouraged.

- **1,818 Fuel Cell Electric Passenger Vehicles (101 FCEVs for MA State fleet) - $9.09 million**\(^{58, 59}\)
- **H\(_2\) Infrastructure (19 stations) - $20.378 million (50 percent of capital cost)**\(^{60}\)
- **49 Fuel Cell transit/paratransit Buses - $24.5 million (50 percent cost-share)**\(^{61, 62, 63}\)

Coordination of hydrogen and fuel cell related plans underway in the Northeast states will lead to market and economic development opportunities. Partnerships between the U.S. DOE, H\(_2\)USA, industry OEMs, and the hydrogen industry will increase opportunities for phased infrastructure development with deployment of FCEVs. Supporting DOE and national efforts to develop uniform codes and standards will further strengthen deployment opportunities.

Table 9 – Policy/Incentives for FCEV Deployment

<table>
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<th>Policy/Incentives</th>
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<tr>
<td>ZEV Program</td>
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<tr>
<td>Purchase of State Passenger Vehicles</td>
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<tr>
<td>“Point-of-Purchase” Rebates</td>
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<td>Fuel/Infrastructure/FCEV Buy Back</td>
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<td>Tax Incentives</td>
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<td>Infrastructure Partnerships</td>
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<td>HOV Lanes/Parking Incentives</td>
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\(^{58}\) California’s Clean Vehicle Rebate Project provides up to $5,000 per ZEV. Adoption of this incentive for the deployment goal of 1,818 passenger FCEVs would result in the given total.


\(^{62}\) An order for 100 fuel cell buses would reduce the cost to $1 million or less. Although Massachusetts’ goal is for 49 buses, the regional goal of 638 buses by 2025 would create an order well over 100 units and would drive each units cost for each bus down to the $1 million target price.

CONCLUSION

Hydrogen and fuel cell technology provides significant opportunities for more efficient use of cleaner energy, job creation and economic development. Realizing over $184 million in revenue and investment in 2011, the hydrogen and fuel cell industry in Massachusetts is estimated to have contributed over $11 million in state and local tax revenue, and approximately $147 million in gross state product annually (for 2011). Additionally, eight (8) of these companies are OEMs of hydrogen and/or fuel cell systems, and were responsible for supplying 406 direct jobs and $56.8 million in direct revenue and investment in 2011. Currently, there are at least 300 Massachusetts companies that are part of the growing hydrogen and fuel cell industry supply chain in the Northeast region. If newer/emerging hydrogen and fuel cell technology were to gain momentum, the number of companies and employment for the industry could grow substantially. Hydrogen and fuel cell technology provides an opportunity for Massachusetts to more fully utilize its renewable energy industry using hydrogen and fuel cells for transportation, energy storage, and use at consumer sites. Such use could make Massachusetts a showcase for renewable energy while reducing GHG emissions as new jobs are created. This configuration will also increase local end user reliability which is of high value for businesses and industry, and will be cleaner with less GHG emissions. To facilitate the execution of this plan Massachusetts will need to develop an “Action Plan,” providing provisions for funding and financing and a schedule for goal implementation and work responsibilities. The goals recommended by NEESC include:

- **234 to 312 MW fuel cell electric generation by 2025**
- **1,867 FCEVs (1,818 [101 FCEVs for MA State fleet] passenger and 49 transit/paratransit buses) as zero emission vehicles (ZEV)**
- **18 to 19 hydrogen refueling stations (to support FCEV deployment)**

These goals represent a short-term investment for long-term productivity. As such, the Action Plan and schedule should recognize the short-term impact of public support, provide expectation(s) for long-term productivity, and assist with the development of public/private partnership(s) necessary to share risk and facilitate long-term market opportunities.
APPENDICES
Massachusetts: Potential Hydrogen and Fuel Cell Applications for Public Facilities

Legend
- Landfills
- Correctional Facility
- Federally Owned Building
- Military Airports
- Military Base
- Wastewater Treatment Plants (ADF<10 mgd)
- Public Schools (With CHP Potential)!
- Universities
- Hospitals

Area Served with Natural Gas
Area Not Served by Natural Gas
Interstate

Sources:
- Mass. Office of Geographic Information
- U.S. Census Bureau
- U.S. General Services Administration
- U.S. Environmental Protection Agency
- OpenStreetMap
- HighSchools.com
- ReferenceUSA
- Massachusetts Office of Geographic Information
- Northeast Gas Association
- Federal Aviation Administration
- U.S. Environmental Protection Agency
- U.S. General Services Administration
- U.S. Census Bureau

Footnotes:
1) Public schools with combined heat and power potential indicate public schools that house swimming pools.

Disclaimer:
Information presented in this map is for planning purposes only. Verification of potential sites and their energy consumption has not been undertaken on a site-specific basis. No representation as to the accuracy of the data depicted is implied.

Produced with support provided by the U.S. SBA
APPENDIX I – Figure 2

Massachusetts: Potential Hydrogen and Fuel Cell Applications for Private Facilities

Legend
- Convalescent Homes (200+ Bed Count)
- Commercial Airports
- Energy Intensive Industry (100+ Employees)
- Food Sales (150+ Employees)

Disclaimer:
Information presented in this map is for planning purposes only. Verification of potential sites and their energy consumption has not been undertaken on a site.

Sources:
Mass. Office of Geographic Information
U.S. Census Bureau
ReferenceUSA
AssistedLivingList.com
altusdirectory.com
Federal Aviation Administration
Northeast Gas Association

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Produced with support provided by the U.S. SBA
Massachusetts: Potential Hydrogen and Fuel Cell Applications for Transportation

Legend

H2 Refueling Stations
- Existing
- Planned
- Fleet Owner Locations

Interstates

Fleet Clusters (Passenger Vehicles)

30% or more of Households with income > $200,000

Total Passenger Fleet Vehicles by Census Tract
- No Data
- 20 - 2000
- 2001 - 5000
- 5001 - 20000

Sources:
R. L. Polk & Co.
U.S. Census Bureau
Alternative Fuels Data Center

The fleet vehicle counts are based on companies with a total of 20 or more passenger vehicles registered within Massachusetts. Consequently, companies with less than 20 vehicles are not depicted. Most rental and leased vehicles have been omitted. This map was produced with the cooperation of H2USA and SBA.

Disclaimer:
Information presented in this map is for planning purposes only. Verification of potential sites and their energy consumption has not been undertaken on a site-specific basis. No representation as to the accuracy of the data depicted is implied.

APPENDIX I - Figure 3

Produced with support provided by the U.S. SBA

April, 2015
### APPENDIX II – Eight (8) State MOU Projections for FCEVs

**Eight (8) State MOU Projections for FCEVs per each MOU State**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Sale Requirements</th>
<th>Total ZEV Sales Requirements</th>
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<th>CT</th>
<th>MA</th>
<th>NY</th>
<th>RI</th>
<th>VT</th>
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<td>2015</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>33,587</td>
<td>3,595</td>
<td>545</td>
<td>1,008</td>
<td>1,860</td>
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<td>72,168</td>
<td>7,725</td>
<td>1,172</td>
<td>2,167</td>
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<td>12,724</td>
<td>1,930</td>
<td>3,569</td>
<td>6,584</td>
<td>592</td>
<td>321</td>
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<td>2019</td>
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<td>177,344</td>
<td>18,984</td>
<td>2,879</td>
<td>5,325</td>
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<td>883</td>
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<td>252,446</td>
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<td>4,099</td>
<td>7,580</td>
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<td>10,535</td>
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### Projected FCEV Deployment by 2025 per Eight (8) State MOU

**Data provided is an averaged projection that does not account for different market drivers and/or incentives/barriers that could substantially change the deployment ratios between state and the delivery of different ZEV/hybrid vehicles.**

**Derived from applying 4.675 percent to FCEVs. The 4.675 percent was calculated by comparing 8-State MOU data to 2011 registered vehicles by state. This data assumes 25 percent of all ZEVs (FCEVs and BEVs) will be FCEVs.**

**This data assumes 25 percent of all ZEVs (FCEVs and BEVs) will be FCEVs.**

**California Environmental Protection Agency Air Resources Board; http://www.arb.ca.gov/newsrel/newsrelease.php?id=620; October 24, 2013.**

**Derived from a DOE projection of California ZEV (FCEV and BEV), California transitional ZEV (plug-in hybrids), and California total sales (ZEV and transitional). These projections were applied to the other seven (7) states’ 2011 registered vehicle data to estimate potential ZEV vehicle requirements.**

APPENDIX III – Massachusetts SWOT Analysis

Environment factors internal/external to Massachusetts’ existing hydrogen and fuel cell industry are provided below in the form of an economic strengths, weaknesses, opportunities and threats (SWOT) assessment. The SWOT analysis provides information helpful in matching the industry’s resources and capabilities to the competitive environment in which it operates.72

**Strengths**
- *Stationary Power* – Strong market drivers (electric cost, environmental factors, critical power).
- *Transportation Power* – Strong indigenous technology and industrial base in PEMFC/H2 generation.
- *Portable Power* – Strong technology/industrial base.
- *Economic Development Factors* – Supportive state policies.

**Weaknesses**
- *Stationary Power* – Cost/Performance improvement required.
- *Transportation Power* – Hydrogen infrastructure build out needed.

**Opportunities**
- *Transportation Power* – Potential to benefit with general H2/transportation growth.
- *Portable Power* – Opportunities to bridge from military to broader industrial/consumer markets.

**Threats**
- *Stationary Power* – Other renewable energy technologies.
- *Transportation Power* – Lack of consumer education/Lower fuel prices.
- *Economic Development Factors* – Losing industry to foreign companies.

---

72 QuickMBA; “SWOT Analysis;” http://www.quickmba.com/strategy/swot/; February 2014
### APPENDIX IV – State Energy Policy/Incentives for Stationary Fuel Cell and Hydrogen Transportation

<table>
<thead>
<tr>
<th>State Energy Policy/Incentives for Stationary Fuel Cells</th>
<th>ME</th>
<th>NH</th>
<th>VT</th>
<th>MA</th>
<th>RI</th>
<th>CT</th>
<th>NY</th>
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<th>RI</th>
<th>CT</th>
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<td>Public/Private Infrastructure Partnership</td>
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<th>NJ</th>
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<td>45</td>
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<td>Transportation FCEV (near-term number of vehicles)</td>
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<td>10</td>
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- **Eligible**
- **Eligible if Renewable**
APPENDIX V – Summary of Potential Fuel Cell Applications

Hydrogen and fuel cell technologies offer significant opportunities for improved energy reliability, energy efficiency, and emission reductions. Large fuel cell units (>300 kW) may be appropriate for applications that serve the grid and large electric and thermal loads at consumer sites. Smaller fuel cell units (< 300 kW) may provide back-up power for telecommunication sites, restaurants/fast food outlets, and smaller sized public facilities.

<table>
<thead>
<tr>
<th>Category</th>
<th>Total Sites</th>
<th>Potential Sites</th>
<th>FCs &lt; 299 kW (#)</th>
<th>FCs 299 - 999 kW (#)</th>
<th>FCs &gt;/=1,000 kW (#)</th>
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<td>Lodging</td>
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<td>223</td>
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<td><strong>Total</strong></td>
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<td>1,572</td>
<td>611</td>
<td>168</td>
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73 594 high schools and/or college and universities located in communities serviced by natural gas with 10+ buildings may satisfy a 300+ kW unit and locations with 33+ buildings may satisfy a 1000+ kW unit. On average, educational facilities consume 283,000 kWh of electricity per building on an annual basis.

74 237 food sales facilities located in communities serviced by natural gas and more 60+ employees may satisfy a 300+ kW unit and locations with 200+ employees may satisfy a 1000+ kW unit. On average, food sales facilities consume 43,000 kWh of electricity per employee on an annual basis.

75 Ten percent of the 10,000 food service facilities located in communities serviced by natural gas. On average, food services facilities consume 20,300 kWh of electricity per employee on an annual basis, which results in more than 130 workers required to satisfy a 300+ kW unit and locations with 390+ employees may satisfy a 1000 kW unit. A smaller fuel cell may be more appropriate to meet hot water and space heating requirements.

76 79% of the 10,000 food service facilities located in communities serviced by natural gas and more 60+ employees may satisfy a 300+ kW unit and locations with 200+ employees may satisfy a 1000+ kW unit. On average, food sales facilities consume 43,000 kWh of electricity per employee on an annual basis.

77 Hospitals located in communities serviced by natural gas and manage 100+ beds may satisfy a 300+ kW unit or 350+ beds may satisfy a 1000+ kW unit.

78 136 hotel facilities with 94+ employees and 87 convalescent homes with 150+ beds onsite, which are located in communities serviced by natural gas. 15 of these hotels/convalescent homes employ 329+ employees or occupy 525+ beds and therefore are not large enough to satisfy a 1000+ kW unit. On average, lodging facilities consume 28,000 kWh of electricity per worker on an annual basis.

79 Correctional facilities and/or other public order and safety facilities with 212 workers or more. On average, public order and safety facilities consume 12,400 kWh of electricity per worker on an annual basis.

80 On average, energy intensive industry facilities consume 21,500 kWh of electricity per employee on an annual basis. Locations located in areas serviced by natural gas with 122 employees may satisfy a 300+ kW unit and 427+ employees may satisfy a 1000+ kW unit.

81 16 actively owned federal government operated building located in communities serviced by natural gas.

82 The Federal Communications Commission regulates interstate and international communications by radio, television, wire, satellite and cable in all 50 states, the District of Columbia and U.S. territories.

83 Ten percent of the 583 wireless telecommunication sites in Massachusetts’ targeted for back-up PEM fuel cell deployment.

84 Massachusetts WWTP with average flows of 3.0+ MGD may satisfy a 300+ kW unit. Locations with 10.5+ MGD flows may satisfy a 1000+ kW unit. A conservative 10 percent were used as potential targets.

85 Ten percent of the landfills targeted based on LMOP data.

86 Airport facilities with 2,500+ annual Enplanement Counts, located in areas serviced by natural gas. Locations supporting AASF may consider installation of a 1000+ kW unit.
As shown above, the analysis provided here estimates that there are approximately 2,352 potential locations, which may be favorable candidates for the application of a fuel cell to provide heat and power. Assuming the demand for electricity was uniform throughout the year, approximately 779 fuel cell units, with a capacity of at least 300 – 400 kW, could be deployed for a total fuel cell capacity of 234 to 312 MW.86

<table>
<thead>
<tr>
<th>Category</th>
<th>Total Units</th>
<th>Potential Targets</th>
<th>CO₂ Emissions (Tons/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation Targets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCEVs</td>
<td>38,889</td>
<td>1,818</td>
<td>8,635.5</td>
</tr>
<tr>
<td>Transit Buses</td>
<td>1,030</td>
<td>49</td>
<td>3,185 to 7,987</td>
</tr>
<tr>
<td>Retail Refueling Stations</td>
<td>2,700</td>
<td>19</td>
<td>NA</td>
</tr>
</tbody>
</table>

As shown above, FCEV replacements for existing Massachusetts fleet vehicles could start with at least 1,867 vehicles, providing annual CO₂ emissions reduction of approximately 11,821 to 16,623 tons per year.

86 At an 87.5 percent capacity, 400 kW units provide a maximum of 3,073,665 MWhs electric and 13.7 million MMBTUs (equivalent to 4.02 million MWh) of thermal energy annually, which could reduce CO₂ emissions by at least 1.2 million tons per year. 300 kW units provide a minimum of 2,307,112.5 MWhs electric and 5.513 million MMBTUs annually (equivalent to 1.636 million MWh) of thermal energy, which could reduce CO₂ emissions by at least 842,445 tons per year.
## APPENDIX VI – Installed Stationary Fuel Cells in Massachusetts

<table>
<thead>
<tr>
<th>Title</th>
<th>Number of Units</th>
<th>Total Size</th>
<th>City</th>
<th>State</th>
<th>Year</th>
<th>Operational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Star Market (Shaw’s Market)</td>
<td>1</td>
<td>400 kW</td>
<td>Chestnut Hill</td>
<td>MA</td>
<td>2009</td>
<td>Yes</td>
</tr>
<tr>
<td>Whole Foods Market</td>
<td>1</td>
<td>400 kW</td>
<td>Dedham</td>
<td>MA</td>
<td>2009</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>800 kW</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>