2015
Hydrogen & Fuel Cell Development Plan

Maine - Hydrogen Economy

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

Collaborative Participants

Hydrogen Energy Center
Kay Mann – President
Gary Higginbottom – Program Director
Richard Smith - Founder

Project Management and Plan Development
Northeast Electrochemical Energy Storage Cluster
Joel M. Rinebold – Program Director
Paul Aresta – Project Manager
Alexander C. Barton – Energy Specialist
Lydia Johnson – GIS Specialist

Supporting Agencies
United States Small Business Administration

Supporting Organizations
Environmental and Energy Technology Council of Maine (E2Tech)

Special thanks to the U.S. Department of Energy for peer reviewing this document

Connecticut Center for Advanced Technology, Inc. © 2015. All Rights Reserved. This document was created with funding from the Small Business Administration under contract number SBAHQ-10-C-0033.

Cover Photo References
Gary Higginbottom; “Portland skyline;” Hydrogen Energy Center (HEC); January 2012.


Brunswick Naval Air Station and airstrips – “Bowdoin in a Changing Brunswick”,

Bill Brine; “Paper Mill at Rumford, ME” no changes made; https://creativecommons.org/licenses/by/2.0; February 2014.

1 This document was produced with support and assistance from the United States Small Business Administration
TABLE OF CONTENTS

EXECUTIVE SUMMARY ............................................................................................... 3
INTRODUCTION ........................................................................................................ 4
DRIVERS ...................................................................................................................... 5
POLICY ....................................................................................................................... 5
ECONOMIC IMPACT .................................................................................................. 5
STATIONARY POWER ............................................................................................... 8
TRANSPORTATION ................................................................................................... 8
CONCLUSION ............................................................................................................ 13

INDEX OF FIGURES

FIGURE 1 – FUEL CELL OPERATION ......................................................................... 4

INDEX OF TABLES

TABLE 1 – MAINE HYDROGEN FUEL CELL POLICY INCENTIVES .............................. 5
TABLE 2 – MAINE ECONOMIC DATA – HYDROGEN FUEL CELL INDUSTRY .......... 6
TABLE 3 – FUEL CELL SYSTEM ADVANTAGES ....................................................... 6
TABLE 4 – STATIONARY TARGETS .......................................................................... 7
TABLE 5 – POLICY/INCENTIVES FOR STATIONARY FUEL CELL DEVELOPMENT ...... 8
TABLE 6 – TRANSPORTATION TARGETS ................................................................ 8
TABLE 7 – FCEV ADVANTAGES ............................................................................... 9
TABLE 8 – FC MATERIAL HANDLER ADVANTAGE ............................................... 10
TABLE 9 – POLICY/INCENTIVES FOR FCEV DEPLOYMENT ................................. 12
EXECUTIVE SUMMARY

Existing Maine businesses and institutions have the potential to install up to 54 to 73 megawatts (MW) of electric generation and combined heat and power (CHP) using fuel cell technology. With an annual output of 440,000 – 590,000 megawatt hours (MWhs), these fuel cell generation facilities can reduce carbon dioxide (CO₂) emissions by between 90,000 – 128,000 tons annually.

Zero emission fuel cell electric vehicles (FCEV) could replace existing conventional vehicles in Maine, starting with 83 vehicles, which would reduce annual CO₂ emissions by approximately 500 to 900 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:

- 54 to 73 MW fuel cell electric generation by 2025
- 83 FCEVs (80 passenger and three (3) transit/paratransit buses) as zero emission vehicles (ZEV)
- 1 to 2 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, Maine has at least 28 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 $3.44 million in revenue and investment, contributed more than $113,000 in state and local tax revenue, and generated approximately $2.9 million in gross state product from their participation in this regional energy cluster 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 Maine.

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 (Maine, Vermont, New Hampshire, Connecticut, Rhode Island, New York, Massachusetts, 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

---

² This plan has coordinated with H2USA and Northeast States for Coordinated Air Use Management (NesCAUM) to advance ZEV development.
**DRIVERS**

The Northeast hydrogen and fuel cell industry, while still emerging, currently has an economic impact exceeding $1 billion in total revenue and investment. Maine benefits from impacts of indirect and induced employment and revenue from this industry. Furthermore, Maine 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. Maine’s 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**

Maine’s relative proximity to renewable energy resources, such as biomass, 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 Maine 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**

Maine is home to at least 28 companies that are part of the growing hydrogen and fuel cell industry cluster in the Northeast region. Realizing approximately $3.44 million in revenue and investment in 2011, these companies include manufacturing, parts distributing, assembly work, supplying of industrial gas, and engineering based research and development (R&D). Furthermore, the hydrogen and fuel cell industry is estimated to have contributed over $113,000 in state and local tax revenue, and generated approximately $2.9 million in gross state product annually (for 2011).

---

14 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.


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

Table 2 – Maine Economic Data – Hydrogen Fuel Cell Industry

<table>
<thead>
<tr>
<th>Supply Chain Members</th>
<th>Maine Economic Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Gross State Product ($M)</td>
<td>2.9</td>
</tr>
<tr>
<td>State Local Tax ($M)</td>
<td>.113</td>
</tr>
<tr>
<td>Indirect Rev ($M)</td>
<td>2.34</td>
</tr>
<tr>
<td>Indirect Jobs</td>
<td>12</td>
</tr>
<tr>
<td>Indirect Labor Income ($M)</td>
<td>0.62</td>
</tr>
<tr>
<td>Induced Revenue ($M)</td>
<td>1.10</td>
</tr>
<tr>
<td>Induced Jobs</td>
<td>9</td>
</tr>
<tr>
<td>Induced Labor Income ($M)</td>
<td>0.34</td>
</tr>
<tr>
<td>Total Revenue ($M)</td>
<td>3.44</td>
</tr>
<tr>
<td>Total Jobs</td>
<td>20</td>
</tr>
<tr>
<td>Total Labor Income ($M)</td>
<td>0.96</td>
</tr>
</tbody>
</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. Maine employment in the hydrogen fuel cell supply chain is predicted to increase by 2020.21

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.22

**Stationary Power**

In 2012, approximately 14 million megawatt-hours (MWh) of electricity was generated in Maine 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.23

This demand represents approximately nine (9) percent of New England total electricity consumption. The State relies on both in-state resources and imports of power, with approximately 3,400 megawatts (MW) of total generation capacity; 11 percent of the total capacity in New England.24 Demand for new electric capacity is expected due in part to the replacement of older less efficient base-load generation facilities.

Table 3 – Fuel Cell System Advantages

- High electric efficiency (> 40 percent)
- Overall efficiency 85 to 93 percent
- Reduction of noise
- Reduction of air pollution
- Siting is not controversial and
- Waste heat can be captured and used

20 Economic data is calculated based on 2011 data.
23 U.S. Energy Information Administration (EIA); “State Electricity Profiles”; http://www.eia.gov/electricity/state/; May 2014.
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).26

Based on the targets identified within this plan, there is the potential to develop up to 54 to 73 MW of stationary fuel cell generation capacity in Maine, which would provide the following benefits (see Appendix V), annually:

- **Production of approximately 443,046 to 590,205 MWhs of electricity**31,32
- **Production of approximately 1.11 to 2.73 million MMBTUs of thermal energy**
- **Reduction of CO₂ emissions by approximately 90,824 to 127,826 tons (electric generation only)**33

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. Potential stationary targets are illustrated in Appendix I – Figure 1, “Maine: Potential Hydrogen and Fuel Cell Applications for Public Facilities” and Figure 2, “Maine: Potential Hydrogen and Fuel Cell Applications for Private Facilities.”

### Tri-generation

A tri-generation station incorporates CHP technology that produces hydrogen in addition to heat and electric power. 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.35

### 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 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.

---

26 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.
31 Calculations incorporate an 87.5% capacity factor when utilizing both electric and thermal loads provided by the system.
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 54 to 73 MW of fuel cell technology in Maine by 2025. Fuel cells are already in use for buildings, data centers, telecommunications applications, power for remote locations, distributed power generation, 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). 38

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 31 percent of Maine’s total energy consumption. 41 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 Maine, starting with 83 vehicles, providing annual carbon dioxide (CO2) emissions reduction of approximately 575 to 869 tons per year. 42 43 FCEVs have advantages (see Table 7) over conventional

<table>
<thead>
<tr>
<th>Table 5 – Policy/Incentives for Stationary Fuel Cell Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Renewable Portfolio Standards</td>
</tr>
<tr>
<td>• Net Metering</td>
</tr>
<tr>
<td>• Public Benefits Funds</td>
</tr>
<tr>
<td>• Performance Power Purchase</td>
</tr>
<tr>
<td>• State Grant Programs</td>
</tr>
<tr>
<td>• State Loan Programs</td>
</tr>
<tr>
<td>• Property Tax Incentive</td>
</tr>
<tr>
<td>• Sales Tax Incentive</td>
</tr>
<tr>
<td>• Property-Assessed Clean Energy (PACE) Financing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 6 – Transportation Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Public/Private Fleets.</td>
</tr>
<tr>
<td>• Bus Transit.</td>
</tr>
<tr>
<td>• Material Handling.</td>
</tr>
<tr>
<td>• Ground Support Equip.</td>
</tr>
<tr>
<td>• Auxiliary Power Units.</td>
</tr>
<tr>
<td>• Ports.</td>
</tr>
</tbody>
</table>

41 U.S. Energy Information Administration (EIA); “Maine Energy Consumption by End-Use Sector, 2012”; http://www.eia.gov/state/?sid=ME#tabs-2; August 2014.
42 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 ZEV’s. Percent calculated was then applied to fleet vehicles as a conservative early projection.
43 CO2 emission reduction = 4.75 metric tons CO2E/vehicle/year*80 (FCEVs) + 65 to 163 metric tons CO2E/vehicle/year*3 (FCEB) = 575 to 869 metric tons CO2E/vehicle/year.
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.\textsuperscript{44}

- FCEVs running on hydrogen produced from renewable resources virtually eliminate all GHG emissions compared to conventional fossil fuel powered vehicles. Passenger car emissions of CO\textsubscript{2} are reduced by 4.75 metric tons CO\textsubscript{2}E/vehicle/year.\textsuperscript{45, 46, 47}

- Fuel cells offer significant GHG reduction opportunities for heavy duty transit buses.\textsuperscript{48, 49} A bus powered by hydrogen fuel cell technology run completely on hydrogen from renewable resources could displace 65 to 163 metric tons CO\textsubscript{2}E/vehicle/year of diesel bus emissions.\textsuperscript{50}

Autors are now making plans to comply with a ZEV program, which is modeled after the California ZEV Action Plan.\textsuperscript{53, 54} Eight (8) states have committed and signed a Memorandum of Understanding (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)”.\textsuperscript{55} 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.\textsuperscript{56} Automakers have indicated that they plan to introduce hydrogen FCEVs by 2015.\textsuperscript{57, 58} If Maine were to adopt similar standards identified by the 8-State MOU, the State has the potential of deploying approximately 25,000


\textsuperscript{45} GHG emissions include carbon dioxide, methane, and nitrous oxide, all expressed as carbon dioxide equivalents.

\textsuperscript{46} 8.89 × 10\textsuperscript{-3} metric tons CO\textsubscript{2}/gallon gasoline × 11,318 VMT car/truck average × 1/21.4 miles per gallon car/truck average × 1 CO\textsubscript{2}, CH\textsubscript{4}, and N\textsubscript{2}O/0.988 CO\textsubscript{2} = 4.75 metric tons CO\textsubscript{2}E/vehicle/year.

\textsuperscript{47} U.S. EPA; “Calculations and References;” http://www.epa.gov/cleanenergy/energy-resources.refs.html; August 9, 2014.

\textsuperscript{48} On average transit buses travel 20,000 to 50,000 miles annually, typical for major metropolitan areas.

\textsuperscript{49} Emissions from conventional urban diesel buses range from 3,000 to 7,000 grams CO\textsubscript{2}E/mi/year (exact figures depend upon traffic conditions and number of bus route stops).


\textsuperscript{53} Only the largest automakers are subject to the mandate: BMW, Daimler AG, Ford, General Motors, Honda, Hyundai, Kia, Mazda, Nissan, Toyota, and Volkswagen.


\textsuperscript{56} Northeast Region includes Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, and New York.


\textsuperscript{58} 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.
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 1,700 passenger fleet vehicles classified as non-leasing or company owned vehicles in Maine. 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, “Maine: Potential Hydrogen and Fuel Cell Applications for Transportation,” the fleet clusters in Maine are located primarily in the Augusta, Auburn, Bangor, and Portland areas.

Bus Transit
There are approximately 61 buses that provide public transportation services in Maine. 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 cell buses are currently in use in several states, with many on public bus routes in California. Fuel economy performance levels for the fuel cell powered buses average 6.8 mi/DGE (diesel gallon equivalent).

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. Large corporations that

Table 8 – FC Material Handler Advantages
- 1.5 times lower maintenance costs
- 8 times lower refueling/recharging costs
- 2 times lower net present value (NPV) and
- Zero emissions

59 Derived from 8-State MOU projected deployment rates calculated for California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont.
60 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.
61 These projections have not been peer reviewed and/or confirmed by NESCAUM.
are currently using or planning to use fuel cell powered material handling equipment include Sysco, CVS, Coca-Cola, BMW, Central Grocers, and Wal-Mart.\(^68\)

**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. H\(_2\)USA and 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.\(^{69, 70, 71, 72, 73}\) For example Proton OnSite is associated with “Lumber Liquidators” and has indicated a willingness to develop hydrogen refueling infrastructure on Lumber Liquidators Sites.\(^74\)

**HYDROGEN TRANSPORTATION GOALS**

NEESC recommends a near-term acquisition of at least 83 FCEVs in the state of Maine. The deployment of 80 passenger fleet vehicles and three (3) transit/paratransit buses would provide an annual CO\(_2\) emissions reduction of approximately 575 to 869 tons per year. NEESC recommends implementation of this goal through the direct acquisition by lease or purchase of 70 FCEVs for the State of Maine fleet.\(^{81, 82}\) Additionally, NEESC has set a goal for the immediate development of 1 to 2 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 payback on that investment (Appendix IV – State Energy Policy/Incentives for Stationary Fuel Cells and Hydrogen Transportation). As summarized below, a state investment for infrastructure development and vehicle deployment could provide a solid framework to support the goal of 80 passenger vehicles, two (2) hydrogen refueling stations. An additional investment for three (3) transit/paratransit buses is also encouraged.

---


\(^69\) There are approximately 1,400 retail fueling stations in Maine; however, only 10 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 17 refueling stations owned and operated by Maine Department of Transportation (MDOT) that could help facilitate the deployment of FCEVs within the state.

\(^70\) “Public retail gasoline stations” www.afdc.energy.gov/afdc/data/docs/gasoline_stations_state.xls, May 5, 2011

\(^71\) Alternative Fuels Data Center, http://www.afdc.energy.gov/afdc/locator/stations/


\(^73\) Currently, there are no publicly or privately accessible transportation fueling stations where hydrogen is provided as an alternative fuel in Maine.

\(^74\) There are currently Lumber Liquidator sites located in Auburn, Scarborough, and Brewer, Maine.

\(^81\) A calculated one percent of 6,960 vehicles operated by the State of Maine.

• 80 Fuel Cell Electric Passenger Vehicles (70 FCEVs for ME State fleet) - $400,000.\(^{83, 84}\)
• H\(_2\) Infrastructure (2 stations) - $2.15 million (50 percent of capital cost).\(^{85}\)
• Three (3) Fuel Cell transit/paratransit Buses - $1.5 million (50 percent cost-share).\(^{86, 87, 88}\)

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>
<thead>
<tr>
<th>Table 9 – Policy/Incentives for FCEV Deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZEV Program</td>
</tr>
<tr>
<td>Purchase of State Passenger Vehicles</td>
</tr>
<tr>
<td>“Point-of-Purchase” Rebates</td>
</tr>
<tr>
<td>Fuel/Infrastructure/FCEV Buy Back</td>
</tr>
<tr>
<td>Tax Incentives</td>
</tr>
<tr>
<td>Infrastructure Partnerships</td>
</tr>
<tr>
<td>HOV Lanes/Parking Incentives</td>
</tr>
</tbody>
</table>

\(^{83}\) California’s Clean Vehicle Rebate Project provides up to $5,000 per ZEV. Adoption of this incentive for the deployment goal of 80 passenger FCEVs would result in the given total.
\(^{84}\) California Air Resources Board; “Clean Vehicle Rebate Projects;” http://www.arb.ca.gov/msprog/aqip/cvrp.htm; August 7, 2014.
\(^{87}\) An order for 100 fuel cell buses would reduce the cost to $1 million or less. Although Maine’s goal is for 3 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 approximately $3.44 million in revenue and investment in 2011, the hydrogen and fuel cell industry in Maine is estimated to have contributed over $113,000 in state and local tax revenue, and approximately $2.9 million in gross state product annually (for 2011). Currently, there are at least 28 Maine 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 Maine 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 Maine 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 Maine 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:

- 54 to 73 MW fuel cell electric generation by 2025
- 83 FCEVs (80 passenger and three (3) transit/paratransit buses) as zero emission vehicles (ZEV)
- 1 to 2 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
APPENDIX I -- Figure 1

Maine: Potential Hydrogen and Fuel Cell Applications for Public Facilities

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

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

Sources:
- U.S. Census Bureau
- U.S. General Services Administration
- U.S. Environmental Protection Agency
- OpenStreetMap
- Maine Office of GIS (Maine.gov)
- ReferenceUSA
- usamilitarybenefits.com
- Federal Aviation Administration
- Northeast Gas Association

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

© OpenStreetMap (and) contributors, CC-BY-SA

January 2015
Maine: Potential Hydrogen and Fuel Cell Applications for Private Facilities

Legend:
- Convalescent Homes (200+ Bed Count)
- Energy Intensive Industry (100+ Employees)
- Commercial Airports
- Food Sales (150+ Employees)
- Interstate
- Area Not Served with Natural Gas
- Area Served by Natural Gas

Sources:
- U.S. Census Bureau
- ReferenceUSA
- AssistedLivingList.com
- altiusdirectory.com
- Federal Aviation Administration
- Northeast Gas Association

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
Maine: Potential Hydrogen and Fuel Cell Applications for Transportation

Legend
- Fleet Owner Locations
- Intertstates
- Fleet Clusters (Passenger Vehicles)

Total Passenger Fleet Vehicles by Census Tract
- No Data
- 20 - 100
- 101 - 200
- 201 - 600

Sources:
- R. L. Polk & Co.
- U.S. Census Bureau

The fleet vehicle counts are based on companies with a total of 20 or more passenger vehicles registered within Maine. 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.

Produced with support provided by the U.S. SBA

APPENDIX I -- Figure 3

© OpenStreetMap (and) contributors, CC-BY-SA
© OpenStreetMap (and) contributors, CC-BY-SA
© OpenStreetMap (and) contributors, CC-BY-SA
© OpenStreetMap (and) contributors, CC-BY-SA

APPENDIX I -- Figure 3

APPENDIX I -- Figure 3
## APPENDIX II – Eight (8) State MOU Projections for FCEVs

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Sale Requirements</th>
<th>Total ZEV Sales Requirements</th>
<th>FCEV</th>
<th>CA</th>
<th>CT</th>
<th>MA</th>
<th>NY</th>
<th>RI</th>
<th>VT</th>
<th>OR</th>
<th>MD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2016</td>
<td>89,543</td>
<td>33,587</td>
<td>8,397</td>
<td>3,595</td>
<td>545</td>
<td>1,008</td>
<td>1,860</td>
<td>167</td>
<td>91</td>
<td>467</td>
<td>662</td>
</tr>
<tr>
<td>2017</td>
<td>192,402</td>
<td>72,168</td>
<td>18,042</td>
<td>7,725</td>
<td>1,172</td>
<td>2,167</td>
<td>3,998</td>
<td>360</td>
<td>195</td>
<td>1,003</td>
<td>1,423</td>
</tr>
<tr>
<td>2018</td>
<td>316,902</td>
<td>118,866</td>
<td>29,717</td>
<td>12,724</td>
<td>1,930</td>
<td>3,569</td>
<td>6,584</td>
<td>592</td>
<td>321</td>
<td>1,652</td>
<td>2,344</td>
</tr>
<tr>
<td>2019</td>
<td>472,806</td>
<td>177,344</td>
<td>44,336</td>
<td>18,984</td>
<td>2,879</td>
<td>5,325</td>
<td>9,824</td>
<td>883</td>
<td>479</td>
<td>2,465</td>
<td>3,497</td>
</tr>
<tr>
<td>2020</td>
<td>673,031</td>
<td>252,446</td>
<td>63,112</td>
<td>27,023</td>
<td>4,099</td>
<td>7,580</td>
<td>13,984</td>
<td>1,258</td>
<td>682</td>
<td>3,509</td>
<td>4,977</td>
</tr>
<tr>
<td>2021</td>
<td>935,407</td>
<td>350,860</td>
<td>87,715</td>
<td>37,558</td>
<td>5,696</td>
<td>10,535</td>
<td>19,435</td>
<td>1,748</td>
<td>948</td>
<td>4,878</td>
<td>6,198</td>
</tr>
<tr>
<td>2022</td>
<td>1,285,032</td>
<td>482,001</td>
<td>120,500</td>
<td>51,596</td>
<td>7,826</td>
<td>14,472</td>
<td>26,699</td>
<td>2,401</td>
<td>1,302</td>
<td>6,701</td>
<td>9,503</td>
</tr>
<tr>
<td>2023</td>
<td>1,757,645</td>
<td>659,272</td>
<td>164,818</td>
<td>70,572</td>
<td>10,704</td>
<td>19,795</td>
<td>36,519</td>
<td>3,284</td>
<td>1,781</td>
<td>9,165</td>
<td>12,998</td>
</tr>
<tr>
<td>2024</td>
<td>2,404,566</td>
<td>901,925</td>
<td>225,481</td>
<td>96,547</td>
<td>14,643</td>
<td>27,081</td>
<td>49,960</td>
<td>4,493</td>
<td>2,436</td>
<td>12,538</td>
<td>17,782</td>
</tr>
<tr>
<td>2025</td>
<td>3,300,000</td>
<td>1,237,792</td>
<td>309,448</td>
<td>132,500</td>
<td>20,096</td>
<td>37,165</td>
<td>68,565</td>
<td>6,166</td>
<td>3,344</td>
<td>17,208</td>
<td>24,404</td>
</tr>
</tbody>
</table>

### 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](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 – Maine SWOT Analysis

Environment factors internal/external to Maine’s 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.95

Strengths

- **Stationary Power** – Energy storage demand to serve the aggressive wind/wave-power industry.
- **Transportation Power** – Receptive and environmentally conscious alternative fuels/transportation market.
- **Economic Development Factors** – Brunswick Renewable Energy Park emphasis on skills development and technology synergies. Potential to coordinate with NEESC, NESCAUM, and H₂USA for added value.

Weaknesses

- **Stationary Power** – No technology/industrial momentum at the OEM level.
- **Transportation Power** – Not one of the adopting “8-State MOU” states. A dispersed population for transportation services.
- **Economic Development Factors** – limited state incentives.

Opportunities

- **Stationary Power** – Linkage between H₂/FC technologies and advanced biofuels R&D.
- **Transportation Power** – Early-stage potential for major roll-out in marine auxiliary power (US Navy).
- **Portable Power** – Little currently-identified opportunity.
- **Economic Development Factors** – Brunswick Renewable Energy Park can be significant seed nucleus for both deployment & development.

Threats

- **Stationary Power** – Competing technologies such as hydro & nuclear, wind, geothermal, direct biomass and power-storage alternatives – batteries, solid state, ammonia etc.
- **Transportation Power** – Absence of a hydrogen infrastructure.
- **Economic Development Factors** – Hesitation of state government to support alternative energy incentives.

---

## APPENDIX IV – State Energy Policy/Incentives for Stationary Fuel Cell and Hydrogen Transportation

### State Energy Policy/Incentives for Stationary Fuel Cells

<table>
<thead>
<tr>
<th>Incentive</th>
<th>ME</th>
<th>NH</th>
<th>VT</th>
<th>MA</th>
<th>RI</th>
<th>CT</th>
<th>NY</th>
<th>NJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandatory Renewable Portfolio Standard (RPS)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Metering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public Benefits Fund</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance-Based Power Purchase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utility Ownership/Investment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>State Grant Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>State Loan Programs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microgrid Reliability Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property Tax Incentive (Commercial)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales Tax Incentive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property-Assessed Clean Energy (PACE) Financing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One Stop Regulatory Approval</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identified State &quot;Point&quot; Person</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### State Energy Policy/Incentives for Hydrogen Transportation

<table>
<thead>
<tr>
<th>Incentive</th>
<th>ME</th>
<th>NH</th>
<th>VT</th>
<th>MA</th>
<th>RI</th>
<th>CT</th>
<th>NY</th>
<th>NJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero Emission Vehicle (ZEV) Program (FCEV/H₂ Infrastructure)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZEV Purchase Target for State Government Fleets (TBD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchase Incentives/&quot;Point-of-Purchase&quot; Rebates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Incentives</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public/Private Infrastructure Partnership</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Efficiency Standard (Private/State Fleets)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refueling Infrastructure Incentives</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REC Available for Renewable H₂</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tax Incentives</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HOV Lanes and Parking Incentives</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One Stop Regulatory Approval</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identified State &quot;Point&quot; Person</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### NEESCI Development Plan Goals

<table>
<thead>
<tr>
<th>Goal</th>
<th>ME</th>
<th>NH</th>
<th>VT</th>
<th>MA</th>
<th>RI</th>
<th>CT</th>
<th>NY</th>
<th>NJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary Fuel Cell (MW, low/high range)</td>
<td>4.6</td>
<td>7.3</td>
<td>6.3</td>
<td>15</td>
<td>23</td>
<td>13.6</td>
<td>24.2</td>
<td>13.6</td>
</tr>
<tr>
<td>Transportation FCEV (near-term number of vehicles)</td>
<td>8.0</td>
<td>23</td>
<td>83</td>
<td>18.3</td>
<td>142</td>
<td>445</td>
<td>5,455</td>
<td></td>
</tr>
<tr>
<td>Transportation Fuel Cell Electric Bus (near-term number of vehicles)</td>
<td>3</td>
<td>9</td>
<td>2</td>
<td>49</td>
<td>11</td>
<td>32</td>
<td>364</td>
<td>1,71</td>
</tr>
<tr>
<td>Refueling Stations (low/high range)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>2</td>
<td>37</td>
<td>32</td>
</tr>
</tbody>
</table>

**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 large electric and thermal loads. Smaller fuel cell units (< 300 kW) may provide back-up power for telecommunication sites, restaurants/fast food outlets, and smaller sized public facilities at this time.

<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>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stationary Targets</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>964</td>
<td>65⁹⁷</td>
<td>46</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Food Sales</td>
<td>1,800+</td>
<td>45⁹⁸</td>
<td></td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Food Services</td>
<td>2,100+</td>
<td>15⁹⁹</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inpatient Healthcare</td>
<td>181</td>
<td>42¹⁰⁰</td>
<td></td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Lodging</td>
<td>837</td>
<td>17¹⁰¹</td>
<td></td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>Public Order &amp; Safety</td>
<td>216</td>
<td>12¹⁰²</td>
<td></td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Energy Intensive Industries</td>
<td>156</td>
<td>32¹⁰³</td>
<td></td>
<td>23</td>
<td>9</td>
</tr>
<tr>
<td>Government Operated Buildings</td>
<td>114</td>
<td>4¹⁰⁴</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wireless Telecommunication Towers</td>
<td>509¹⁰⁵</td>
<td>51¹⁰⁶</td>
<td></td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>WWTPs</td>
<td>111</td>
<td>1¹⁰⁷</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Landfills</td>
<td>25</td>
<td>2¹⁰⁸</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Airports (w/ AASF)</td>
<td>103</td>
<td>5 (1)¹⁰⁹</td>
<td></td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Military</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ports</td>
<td>42</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td><strong>Total Stationary</strong></td>
<td>7,159+</td>
<td>294</td>
<td>112</td>
<td>141</td>
<td>41</td>
</tr>
</tbody>
</table>

⁹⁷ 65 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.

⁹⁸ 45 food sales facilities located in communities serviced by natural gas and have 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.

⁹⁹ Ten percent of the 2,100+ food service facilities located in communities serviced by natural gas. On average, food service facilities consume 20,300 kWh of electricity per work 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.

¹⁰¹ 12 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.

¹⁰² 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.

¹⁰³ Ten percent of the 509 wireless telecommunication sites in Maine targeted for back-up PEM fuel cell deployment.

¹⁰⁴ Maine 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.

¹⁰⁵ Ten percent of the landfills targeted based on LMOP data.

¹⁰⁶ 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.

¹⁰⁷ Four actively owned federal government operated building located in communities serviced by natural gas.

¹⁰⁸ AASF may consider installation of a 1000+ unit.
As shown above, the analysis provided here estimates that there are approximately 294 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 182 fuel cell units, with a capacity at least of 300 – 400 kW, could be deployed for a total fuel cell capacity of 54 to 73 MW.  

<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>1,714</td>
<td>80</td>
<td>380</td>
</tr>
<tr>
<td>Transit Buses</td>
<td>61</td>
<td>3</td>
<td>195 to 489</td>
</tr>
<tr>
<td>Retail Refueling Stations</td>
<td>1,400</td>
<td>2</td>
<td>NA</td>
</tr>
</tbody>
</table>

As shown above, FCEV replacements for existing Maine fleet vehicles could amount to at least 83 vehicles by 2025, providing annual CO₂ emissions reduction of approximately 575 to 869 tons per year.

---

110 At an 87.5 percent capacity, 400 kW units provide a maximum of 590,205 MWhs electric and 2.73 million MMBTUs (equivalent to 800,814.88 MWh) of thermal energy annually, which could reduce CO₂ emissions by at least 127,826 tons per year. 300 kW units provide a minimum of 443,045.76 MWhs electric and 1.11 million MMBTUs annually (equivalent to 326,728.5 MWh) of thermal energy, which could reduce CO₂ emissions by at least 90,824 tons per year.