2015
Hydrogen & Fuel Cell Development Plan

Vermont - Hydrogen Economy

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

Clean Energy States Alliance (CESA)
Warren Leon – Executive Director
Valerie Stori – Project Manager

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\(^1\)

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


Tony Hisgett; “Montpelier State Building;” no changes made; https://creativecommons.org/licenses/by/2.0/; September 2011.

\(^1\) 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 – Vermont Hydrogen Fuel Cell Policy Incentives** ............................................................... 5  
**Table 2 – Vermont 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 Vermont businesses and institutions have the potential to install up to **15 to 20 megawatts (MW)** of electric generation and combined heat and power (CHP) using fuel cell technology. With an annual output of **91,900 – 122,600 megawatt hours (MWhs)**, these fuel cell generation facilities can reduce carbon dioxide (CO₂) emissions by between **11,500 – 15,400 tons** annually.

Zero emission fuel cell electric vehicles (FCEV) could replace existing conventional vehicles in Vermont, starting with **82 vehicles**, which can reduce annual CO₂ emissions by approximately **500 to 700 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:

- **15 to 20 MW fuel cell electric generation by 2025**
- **82 FCEVs (80 [8 FCEVs for VT State fleet] passenger and 2 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, Vermont has at least **5 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 over **$4.1 million in revenue and investment**, contributed more than **$183,000 in state and local tax revenue**, and generated approximately **$3.3 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 Vermont.

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 (Vermont, Rhode Island, New Hampshire, Connecticut, Maine, 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 was developed in coordination 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. Vermont benefits from impacts of indirect and induced employment and revenue from this industry. Furthermore, Vermont 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. Vermont’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**

Vermont’s relative proximity to renewable energy resources, such as wind, 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 Vermont 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**

Vermont is home to at least 5 companies that are part of the growing hydrogen and fuel cell industry cluster in the Northeast region. Realizing over $4.1 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 more than $183,000 in state and local tax revenue, and generated approximately $3.3 million in gross state product annually (for 2011).

---

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.

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. Vermont employment in the hydrogen fuel cell supply chain is predicted to increase by 2020.13

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.14

**STATIONARY POWER**

In 2012, approximately 39 million megawatt-hours (MWh) of electricity was generated in Vermont to serve the electric demand for the residential, industrial, and commercial sectors. Overall electricity demand is forecasted to grow at a rate of .7 percent annually over the next decade.15

![Table 2 – Vermont Economic Data – Hydrogen Fuel Cell Industry](image)

<table>
<thead>
<tr>
<th>Supply Chain Members</th>
<th>Vermont Economic Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross State Product (SM)</td>
<td>2.51</td>
</tr>
<tr>
<td>State Local Tax (SM)</td>
<td>.183</td>
</tr>
<tr>
<td>Indirect Revenue (SM)</td>
<td>3.03</td>
</tr>
<tr>
<td>Indirect Jobs</td>
<td>12</td>
</tr>
<tr>
<td>Indirect Labor Income (SM)</td>
<td>.798</td>
</tr>
<tr>
<td>Induced Revenue (SM)</td>
<td>1.08</td>
</tr>
<tr>
<td>Induced Jobs</td>
<td>9</td>
</tr>
<tr>
<td>Induced Labor Income (SM)</td>
<td>.335</td>
</tr>
<tr>
<td>Total Revenue (SM)</td>
<td>4.11</td>
</tr>
<tr>
<td>Total Jobs</td>
<td>21</td>
</tr>
<tr>
<td>Total Labor Income (SM)</td>
<td>1.13</td>
</tr>
</tbody>
</table>

![Table 3 – Fuel Cell System Advantages](image)

- 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

11 Economic data is calculated based on 2011 data.
15 U.S. Energy Information Administration (EIA); “State Electricity Profiles”; http://www.eia.gov/electricity/state/ May 2014.
This demand represents approximately five (5) percent of New England total electricity consumption. The State relies on both in-state resources and imports of power, with approximately 900 megawatts (MW) of total generation capacity; three (3) percent of the total capacity in New England. Demand for new electric capacity is expected due in part to the replacement of older less efficient base-load generation facilities. 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). Based on the targets identified within this plan, there is the potential to develop up to 15 to 20 MW of stationary fuel cell generation capacity in Vermont, which would provide the following benefits (see Appendix V), annually:

- Production of approximately 91,980 to 122,640 MWhs of electricity
- Production of approximately 294,336 to 392,784 MMBTU's of thermal energy
- Reduction of CO₂ emissions by approximately 11,563 to 15,413 tons (electric generation only)

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, “Vermont: Potential Hydrogen and Fuel Cell Applications for Public Facilities” and Figure 2, “Vermont: 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.  

---

**Table 4 – Stationary Targets**

- Education
- Food Sales
- Food Services
- Inpatient Healthcare
- Lodging
- Public Order & Safety

---

18 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.
19 Calculations incorporate an 87.5% capacity factor when utilizing both electric and thermal loads provided by the system.
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 15 to 20 MW of fuel cell technology in Vermont by 2025. 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).

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 38.4 percent of Vermont’s total energy consumption. 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 Vermont, starting

---

with 82 vehicles, providing annual carbon dioxide (CO₂) emissions reduction of approximately 510 to 706 tons per year.  

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

Automakers are now making plans to comply with a ZEV program, which is modeled after the California ZEV Action Plan.  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)”. 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

---

**Table 7 – FCEV Advantages**

- Quiet operations
- Zero/Near zero emissions
- Domestic fuel supply
- Price volatility reduction
- Energy security and
- Higher efficiency

---

25 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.

26 CO₂ emission reduction (per FCEV) is approximately 10,170 for passenger vehicle and 182,984 for transit bus. One pound CO₂ emission reduction = 4.75 metric tons CO₂E /vehicle/year*80 (FCEVs) + 65 to 163 metric tons CO₂E /vehicle/year *2 (FCEB) = 510 to 706 metric tons CO₂E /vehicle/year.


28 GHG emissions include carbon dioxide, methane, and nitrous oxide, all expressed as carbon dioxide equivalents.

29 8.89 × 10⁻³ 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 CO₂-E /vehicle/year.

30 U.S. EPA; “Calculations and References;” http://www.epa.gov/cleanenergy/energy-resources/references.html; August 9, 2014

31 On average transit buses travel 20,000 to 50,000 miles annually, typical for major metropolitan areas.

32 Emissions from conventional urban diesel buses range from 3,000 to 7,000 grams CO₂E/vehicle/year (exact figures depend upon traffic conditions and number of bus route stops).


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


---

For more information, please visit [www.neesec.org](http://www.neesec.org).
has signed this MOU, Vermont has the potential of deploying approximately 13,375 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 1,690 passenger fleet vehicles classified as non-leasing or company owned vehicles in Vermont. 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, “Vermont: Potential Hydrogen and Fuel Cell Applications for Transportation,” the fleet clusters in Vermont are located primarily in the Exeter, Warwick, and Woonsocket/Providence areas.

Bus Transit
There are approximately 42 buses that provide public transportation services in Vermont. 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.

<table>
<thead>
<tr>
<th>Table 8 – FC Material Handler Advantages</th>
</tr>
</thead>
<tbody>
<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>

41 Auto blog green; “2015 Toyota hydrogen fuel cell car will have 300-mile range;” http://gas2.org/2013/07/02/toyotas-2015-
42 Derived from 8-State MOU projected deployment rates calculated for California, Connecticut, Maryland, Massachusetts, New
York, Oregon, Rhode Island, and Vermont.
43 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.
44 These projections have not been peer reviewed and/or confirmed by NESCAUM.
45 Fleet vehicle data provided by R. L. Polk & Co., 2013.
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 are currently using or planning to use fuel cell powered material handling equipment include Sysco, CVS, Coca-Cola, BMW, Central Grocers, and Wal-Mart.

**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. H₂USA and NESCAUM are currently developing hydrogen infrastructure models for financing and development to serve projected FCEV fleets (See Appendix III – Eight (8) State MOU Projections for FCEVs). Potential sites for development include existing refueling stations, but new potential sites are also possible. For example Proton OnSite is associated with “Lumber Liquidators” and has indicated a willingness to develop hydrogen refueling infrastructure on Lumber Liquidators Sites.

**HYDROGEN TRANSPORTATION GOALS**

NEESC recommends a near-term acquisition of at least 82 FCEVs in the state of Vermont. The deployment of 80 passenger fleet vehicles and two (2) transit/paratransit buses would provide an annual CO₂ emissions reduction of approximately 510 to 706 tons per year. NEESC recommends implementation of this goal through the direct acquisition by lease or purchase of eight (8) FCEVs for the State of Vermont fleet. 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 two (2) transit/paratransit buses is also encouraged.

---

51 There are approximately 620 retail fueling stations in Vermont; however, only 11 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 60 refueling stations owned and operated by Vermont Department of Transportation (VDOT) that could help facilitate the deployment of FCEVs within the State.
55 There is currently one (1) Lumber Liquidator located in Williston, Vermont.
56 A calculated one percent of 755 vehicles operated by the State of Vermont. Fleet vehicle data provided by R. L. Polk & Co., 2013.
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, H₂ 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

- ZEV Program
- Purchase of State Passenger Vehicles
- “Point-of-Purchase” Rebates
- Fuel/Infrastructure/FCEV Buy Back
- Tax Incentives
- Infrastructure Partnerships
- HOV Lanes/Parking Incentives

### CONCLUSION

Hydrogen and fuel cell technology provides significant opportunities for more efficient use of cleaner energy, job creation and economic development. Realizing more than $4.1 million in revenue and investment in 2011, the hydrogen and fuel cell industry in Vermont is estimated to have contributed over $184,000 in state and local tax revenue, and approximately $3.3 million in gross state product annually (for 2011). Currently, there are at least 5 Vermont 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 Vermont 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 Vermont 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

---

58 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.


62 An order for 100 fuel cell buses would reduce the cost to $1 million or less. Although Vermont’s goal is for two (2) 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.

execution of this plan Vermont 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:

- 15 to 20 MW fuel cell electric generation by 2025
- 82 FCEVs (80 [8 FCEVs for VT State fleet] passenger and 2 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
Vermont: Potential Hydrogen and Fuel Cell Applications for Public Facilities

Legend
- Landfills
- Correctional Facility
- Federally Owned Building
- Hospitals
- Military Airports
- Colleges
- Wastewater Treatment Plants (ADF<10 mgd)

Sources:
- U.S. Census Bureau
- U.S. General Services Administration
- U.S. Environmental Protection Agency
- OpenStreetMap
- HighSchools.com
- ReferenceUSA
- usamilitarybenefits.com
- Federal Aviation Administration
- www.usamilitarybenefits.com
- 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

January 2015
Legend
- Convalescent Homes (150+ Bed Count)
- Commercial Airports
- Food Sales (150+ Employees)
- Energy Intensive Industry (100+ Employees)

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

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

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

APPENDIX I – Figure 2

Vermont: Potential Hydrogen and Fuel Cell Applications for Private Facilities

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

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

© OpenStreetMap (and) contributors, CC-BY-SA
Legend
- Fleet Owner Locations
- Interstates
- Fleet Clusters (Passenger Vehicles)

Total Passenger Fleet Vehicles by Census Tract
- No Data
- 1 - 50
- 51 - 250
- 251 - 500

North American Energy Storage

Produced with support provided by the U.S. SBA

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 Vermont. 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

Vermont: Potential Hydrogen and Fuel Cell Applications for Transportation

January 2015
### 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(^{68})</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>3,595</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>6,918</td>
</tr>
<tr>
<td>2022</td>
<td>1,285,032</td>
<td>482,001</td>
<td>120,500</td>
<td>51,966</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><strong>3,300,000</strong>(^{69})</td>
<td><strong>1,237,792</strong>(^{69,71})</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

![Graph showing projected FCEV deployment by 2025](image)

---

66 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.

67 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.

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

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

70 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.

71 DOE EERE; *Fact #771 March 18, 2013 California Zero-Emission Vehicle Mandate is Now in Effect; https://www.dropbox.com/s/jrl4gbzw7tsy5p/Fact%20%23771%20March%202013%20California%20Zero-Emission%20Vehicle%20Mandate%20is%20Now%20in%20Effect.pdf?dl=0*
APPENDIX III – Vermont SWOT Analysis

Environment factors internal/external to Vermont’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. 72

Strengths

- **Stationary Power** – Strong market drivers (electric cost, environmental factors, critical power).
- **Transportation Power** – Appeal to market, environmental factors, high gasoline prices, long commuting distance, and lack of public transportation options.

Weaknesses

- **Stationary Power** – FCs only considered statutorily “renewable” if powered by a renewable fuel.
- **Transportation Power** – No fuel cell technology/industrial base at the OEM level.
- **Economic Development Factors** – Limited state incentives.

Opportunities

- **Stationary Power** – More opportunity as an “early adopter market.”
- **Transportation Power** – Some supply chain buildup opportunities.
- **Economic Development Factors** – Job creation.

Threats

- **Stationary Power** – Other renewable energy technologies.
- **Transportation Power** – Lack of consumer education/Lower fuel prices.
- **Economic Development Factors** – Competition from other states/regions.

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>
</tr>
</thead>
<tbody>
<tr>
<td>Mandatory Renewable Portfolio Standard (RPS)</td>
</tr>
<tr>
<td>Net Metering</td>
</tr>
<tr>
<td>Public Benefits Fund</td>
</tr>
<tr>
<td>Performance-Based Power Purchase</td>
</tr>
<tr>
<td>Utility Ownership/Investment</td>
</tr>
<tr>
<td>State Grant Program</td>
</tr>
<tr>
<td>State Loan Programs</td>
</tr>
<tr>
<td>Microgrid Reliability Program</td>
</tr>
<tr>
<td>Property Tax Incentive (Commercial)</td>
</tr>
<tr>
<td>Sales Tax Incentive</td>
</tr>
<tr>
<td>Property-Assessed Clean Energy (PACE) Financing</td>
</tr>
<tr>
<td>One Stop Regulatory Approval</td>
</tr>
<tr>
<td>Identified State “Point” Person</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>State Energy Policy/Incentives for Hydrogen Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero Emission Vehicle (ZEV) Program (FCEV/H₂ Infrastructure)</td>
</tr>
<tr>
<td>ZEV Purchase Target for State Government Fleets (TBD)</td>
</tr>
<tr>
<td>Purchase Incentives “Point-of-Purchase” Rebates</td>
</tr>
<tr>
<td>Fuel Incentives</td>
</tr>
<tr>
<td>Public/Private Infrastructure Partnership</td>
</tr>
<tr>
<td>Fuel Efficiency Standard (Private/State Fleets)</td>
</tr>
<tr>
<td>Refueling Infrastructure Incentives</td>
</tr>
<tr>
<td>REC Available for Renewable H₂</td>
</tr>
<tr>
<td>Tax Incentives</td>
</tr>
<tr>
<td>HOV Lanes and Parking Incentives</td>
</tr>
<tr>
<td>One Stop Regulatory Approval</td>
</tr>
<tr>
<td>Identified State “Point” Person</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NEESCD Development Plan Goals</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>56</td>
<td>65</td>
<td>61</td>
<td>15</td>
<td>24</td>
<td>22</td>
<td>15</td>
<td>33</td>
</tr>
<tr>
<td>Transportation FCEV (near-term number of vehicles)</td>
<td>80</td>
<td>21</td>
<td>83</td>
<td>18</td>
<td>38</td>
<td>14</td>
<td>32</td>
<td>34</td>
</tr>
<tr>
<td>Transportation Fuel Cell Electric Bus (near-term number of vehicles)</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>9</td>
<td>11</td>
<td>32</td>
<td>36</td>
<td>1.7</td>
</tr>
<tr>
<td>Refueling Stations (low/high range)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>26</td>
<td>10</td>
<td>2</td>
<td>3</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 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>
</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>550</td>
<td>21</td>
<td>3</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Food Sales</td>
<td>800+</td>
<td>8</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Food Services</td>
<td>1,000+</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inpatient Healthcare</td>
<td>71</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Lodging</td>
<td>490</td>
<td>9</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Public Order &amp; Safety</td>
<td>91</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Intensive Industries</td>
<td>91</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government Operated Buildings</td>
<td>88</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wireless Telecommunication Towers</td>
<td>83</td>
<td>9</td>
<td>9</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WWTPs</td>
<td>28</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landfills</td>
<td>9</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airports (w/ AASF)</td>
<td>57(1)</td>
<td>1(1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>3,358</td>
<td>62</td>
<td>12</td>
<td>30</td>
<td>20</td>
</tr>
</tbody>
</table>

73 21 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 8 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 approximately 21 food service facility sites in Vermont located in areas serviced by natural gas. On average, food service facilities consume 20,300 kWh of electricity per worker on an annual basis, which results in more than 130 workers required to satisfy a 300+ kW unit. A smaller fuel cell may be more appropriate to meet hot water and space heating requirements.
76 2 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.
77 7 hotel facilities with 94+ employees and 2 convalescent homes with 150+ beds onsite, 33 of which are located in communities serviced by natural gas. None 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.
78 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.
79 On average, energy intensive industry facilities consume 21.500 kWh of electricity per employee on an annual basis. Targets 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.
80 13 actively owned federal government operated building located in communities serviced by natural gas.
81 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.
82 Ten percent of the 83 wireless telecommunication sites in Vermont targeted for back-up PEM fuel cell deployment.
83 Vermont 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.
84 Ten percent of the Landfills targeted based on LMOP data.
85 Airport facilities with 2,500+ annual Enplanement Counts, located in areas serviced by natural gas. Locations supporting AASF may consider installation of a 1000+ unit.
As shown above, the analysis provided here estimates that there are approximately 62 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 50 fuel cell units, with a capacity of at least 300 – 400 kW, could be deployed for a total fuel cell capacity of 15 to 20 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>1,694</td>
<td>80</td>
<td>380</td>
</tr>
<tr>
<td>Transit Buses</td>
<td>42</td>
<td>2</td>
<td>130 to 326</td>
</tr>
<tr>
<td>Retail Refueling Stations</td>
<td>620</td>
<td>2</td>
<td>NA</td>
</tr>
</tbody>
</table>

As shown above, FCEV replacements for existing Vermont fleet vehicles could start with at least 82 vehicles, providing annual CO₂ emissions reduction of approximately 510 to 706 tons per year.

86 At an 87.5 percent capacity, 400 units provide a maximum of 122,640 MWhs electric and 392,784 MMBTUs (equivalent to 115,202.456 MWh) of thermal energy annually, which could reduce CO₂ emissions by at least 15,417.6 tons per year. 300 kW units provide a minimum of 91,980 MWhs electric and 294,336 MMBTUs annually (equivalent to 86,327.5 MWh) of thermal energy, which could reduce CO₂ emissions by at least 11,563 tons per year.