2018 Hydrogen and Fuel Cell Development Plan

New York Hydrogen Economy

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

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Cover Photo References
Steve; “20140827=IMG_9655.jpg;”; https://creativecommons.org/licenses/by-sa/2.0/; August 2014.


BMW Manufacturing; “Hydrogen-powered forklift at the BMW Plant in Spartanburg, S.C.”;


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# TABLE OF CONTENTS

**EXECUTIVE SUMMARY** ............................................................................................................................................................... 3

**INTRODUCTION** .......................................................................................................................................................................... 4
  - Technology Description .................................................................................................................................................................... 4
  - Industry/Market Status ...................................................................................................................................................................... 5

**DRIVERS** ................................................................................................................................................................................... 5
  - Energy Resiliency ............................................................................................................................................................................. 5
  - Economic Impact .............................................................................................................................................................................. 6
  - Environmental Benefits..................................................................................................................................................................... 7

**FUEL CELLS FOR STATIONARY POWER** ........................................................................................................................................ 7
  - Distributed Generation/Combined Heat and Power .......................................................................................................................... 7
  - Grid Power ........................................................................................................................................................................................ 8
  - Deployment ....................................................................................................................................................................................... 8

**FUEL CELLS FOR TRANSPORTATION** ............................................................................................................................................ 8
  - Light/Medium Duty Vehicle Fleets ................................................................................................................................................... 9
  - Bus Transit ........................................................................................................................................................................................ 9
  - Specialty Vehicles ............................................................................................................................................................................. 9
  - Hydrogen Infrastructure .................................................................................................................................................................. 10
  - Deployment ..................................................................................................................................................................................... 10
  - Consistency with New York’s Energy Master Plan ........................................................................................................................ 12

**CONCLUSION** ........................................................................................................................................................................... 12

---

## INDEX OF FIGURES

Figure 1 – Hydrogen Production................................................................................................................................................................. 4

## INDEX OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>NEW YORK ECONOMIC DATA – HYDROGEN FUEL CELL INDUSTRY</td>
<td>6</td>
</tr>
<tr>
<td>Table 2</td>
<td>FUEL CELL SYSTEM ADVANTAGES</td>
<td>7</td>
</tr>
<tr>
<td>Table 3</td>
<td>STATIONARY TARGETS</td>
<td>7</td>
</tr>
<tr>
<td>Table 4</td>
<td>FCEV ADVANTAGES</td>
<td>8</td>
</tr>
<tr>
<td>Table 5</td>
<td>TRANSPORTATION TARGETS</td>
<td>9</td>
</tr>
<tr>
<td>Table 6</td>
<td>FC MATERIAL HANDLER ADVANTAGES</td>
<td>10</td>
</tr>
<tr>
<td>Table 7</td>
<td>CRITERIA FOR DEPLOYMENT</td>
<td>10</td>
</tr>
<tr>
<td>Table 8</td>
<td>NEW YORK HYDROGEN FUEL CELL POLICY INCENTIVES</td>
<td>11</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

Existing businesses and institutions in New York have the potential to install 1,131 megawatts (MW) of electric generation using fuel cell technology, which would have an annual output of approximately 9.6 million megawatt hours (MWhs). This amount of fuel cell generation capacity can reduce emissions of nitrogen oxides (NOx) by approximately 2,600 metric tons annually.

Zero emission fuel cell electric vehicles (FCEV) could replace existing conventional vehicles in New York, starting with 2,387 vehicles, which could reduce annual carbon dioxide (CO2) emissions by approximately 40,700 metric tons and NOx emissions by 12 metric tons. Additionally, fuel cells could provide a zero emission alternative for forklifts and other material handling equipment at warehouse facilities, airports, and other emission constrained areas.

While the installation/deployment of fuel cells may be technically viable at many locations, this plan focuses on hydrogen and fuel cell applications that may be both technically and economically viable. The Northeast Electrochemical Energy Storage Cluster (NEESC) recommends development of the following market opportunities for stationary power, vehicles, and supporting hydrogen infrastructure to meet economic, environmental, and energy needs:

- 1,131 MW fuel cell electric generation capacity;
- 2,387 FCEVs (2,038 passenger vehicles and 349 transit/paratransit buses) as zero emission vehicles (ZEV); and
- 18 to 23 hydrogen refueling stations (to support FCEV/FCEB deployment).

Locations where fuel cell installations may be both technically and economically viable include a wide range of private, state, and federal buildings used for offices, manufacturing, data management, warehousing, large retail, education, food sales and services, lodging, in-patient healthcare, and public order and safety. Similarly, fuel cell installations may also be 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 areas of the state where fleets, early market adopters, and hydrogen users co-exist.

Based on a 2017 IMPLAN economic analysis, New York’s hydrogen and fuel cell supply chain contributed to the region’s economy by providing:

- over $353 million in revenue and investment;
- more than 1,764 direct, indirect and induced jobs;
- approximately $26 million in state and local tax revenue; and
- over $158 million in labor income.

The deployment of hydrogen and fuel cell technology will reduce the state’s dependency on oil; improve air and water quality; help 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 assess, plan, and initiate hydrogen and/or fuel cell deployment to help meet the energy, economic, and environmental goals for the state of New York.

Policies and incentives that support hydrogen and fuel cell technology will increase deployment. Increased deployment of hydrogen and fuel cell technology 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 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 Hydrogen and Fuel Cell Development Plan was created for each state in the Northeast region (New York, Vermont, New Hampshire, New Jersey, Rhode Island, Maine, Connecticut, and Massachusetts), 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 made by businesses in the region.

Technology Description

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, and solar. Production technology includes electrolysis of water, steam reforming of natural gas, coal gasification, thermochemical production, and biological gasification (see Figure 1).

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. 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. 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.

Figure 1 – Hydrogen Production

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Industry/Market Status

Demand for hydrogen and fuel cell systems have increased as the cost of the technologies has come down and awareness of their economic and environmental benefits has grown. This in turn has led to steady growth in the hydrogen and fuel cell industry in the U.S., with large and small companies located across the country. States and local governments are also recognizing the advantages of hydrogen and fuel cell technology in providing energy resilience, reduced emissions, improved air quality, and economic growth. Many states have established policies to promote the adoption of hydrogen and fuel cell technologies and/or initiated collaborative efforts to accelerate adoption.

Stationary fuel cells are providing stable power and heat around the world in microgrids and at wastewater treatment plants, food and beverage plants, office buildings, telecommunication hubs, data centers, retail stores, universities, hospitals, hotels, government facilities, and other applications. On the utility side of the meter, large-scale fuel cell systems are being deployed to support the electric grid where transmission is constrained or increased reliability is sought. These fuel cell systems are providing clean 24/7 power generation to complement the increasing deployment of intermittent solar and wind resources and support grid reliability.

Transportation applications include motive power for passenger cars, buses, other fuel cell electric vehicles (FCEVs), specialty vehicles, material handling equipment, and auxiliary power units for off-road vehicles. Early market adopters of these light duty FCEVs may include fleet operators. As hydrogen fueling infrastructure expands, FCEVs will begin to gain greater market acceptance, resulting in faster market penetration. In the year 2032, over 5 million of these vehicles are expected to be sold with projected revenues of over $250 billion.4

Drivers

Economic benefits, environmental quality, and energy reliability are driving the development of hydrogen and fuel cell technologies for regional, national, and global markets. Federal research and tax incentives have been important drivers for deployment of FCEVs, hydrogen infrastructure, and fuel cell stationary power generation.

The age distribution of hydrogen and fuel cell companies in the Northeast states 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. The proximity of the original equipment manufacturers (OEM) and supply chain companies in this cluster has provided a competitive advantage for research, design, development, manufacturing, and export of commercial products to national and international markets.

Energy Resiliency

Extreme weather events in the Northeast, including Hurricane Irene (2011), the Nor’easter snowstorm (2011), Superstorm Sandy (2012), Blizzard Nemo (2013), and the “bomb cyclone” (2018) have emphasized the need for clean and reliable distributed generation located at mission critical facilities to maintain power when grid power is not available due to the impacts of severe weather. According to the New York State Energy Plan, “CHP kept the lights on at multifamily apartment buildings, hospitals, nursing homes, elementary schools, and college campuses in the aftermath of Superstorm Sandy, Hurricane Irene, and Tropical Storm Lee. CHP has been shown to meet the needs of an individual building and can serve as the heart of a community microgrid.” 5

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electrical grid, fuel cells are now being considered as ultra-clean generators for essential services, first responders, refueling stations, and emergency shelters.

More than 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 the energy grid infrastructure.

**Economic Impact**

The Northeast hydrogen and fuel cell supply chain, while still emerging, has contributed:
- Over $1.4 billion in revenue and investment;
- More than 6,620 direct, indirect and induced jobs; and
- Labor income of approximately $615 million.

New York’s hydrogen and fuel cell supply chain companies realized approximately $353 million in revenue and investment in 2016. These companies are involved in manufacturing, parts distributing, fuel processing, supplying of industrial gas, engineering based research and development (R&D), coating applications, and managing of venture capital funds. Furthermore, the hydrogen and fuel cell supply chain is estimated to have contributed approximately $158 million in labor income and over $26 million in state and local tax revenue. Table 1 shows the economic impact of New York’s hydrogen and fuel cell supply chain.

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**Table 1 – New York’s Economic Data – Hydrogen Fuel Cell Industry**

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<th>New York Economic Data</th>
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</thead>
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<tr>
<td>Supply Chain Members</td>
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<tr>
<td>State/Local Tax ($M)</td>
</tr>
<tr>
<td>Direct Revenue and Investment ($M)</td>
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<td>Direct Jobs</td>
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<tr>
<td>Direct Labor Income ($M)</td>
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<tr>
<td>Indirect Revenue and Investment ($M)</td>
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<td>Induced Jobs</td>
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<td>Total Labor Income ($M)</td>
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6 Economic impact derived from an IMPLAN Economic Financial Model, Todd Gabe; NEESC; September 2017.
8 Economic impact derived from an IMPLAN Economic Financial Model, Todd Gabe; NEESC; September 2017. This analysis assessed the direct, indirect, and induced values of the Northeast region’s hydrogen and fuel cell supply chain using 2016 and 2017 data.
Environmental Benefits

The combustion of fossil fuels for electricity production and motor vehicles are significant sources of NOx and CO2 emissions. In the stationary sector, the development of 1,131 MWs of fuel cell generation capacity in New York would reduce NOx emissions by approximately 2,600 metric tons annually. In the transportation sector, zero-emission FCEVs could replace existing conventional vehicles in New York, starting with 2,387 fleet vehicles, reducing annual CO2 emissions by approximately 40,700 metric tons and NOx emissions by 12 metric tons. The reduction of these emissions through the use of fuel cell technology would improve air quality, reduce health problems, reduce carbon emissions that contribute to climate change, and help to meet National Ambient Air Quality Standards.

FUEL CELLS FOR STATIONARY POWER

The combined retail sales of electricity in New York amounted to approximately 148 million megawatt-hours (MWh) for the residential, industrial, transportation and commercial sectors. To meet the current electric demand, New York’s residents rely on both in-state resources and imports of power. Even though New York’s load growth is projected to be nearly flat over the next 10 years, it is expected that approximately 2,300 MW of older, less efficient generation capacity may retire between 2016 and 2018, which may put additional pressure on the electric grid.

Distributed Generation/Combined Heat and Power

Fuel cell technology has high value and opportunity (see Table 2) to help meet the projected increase in demand and need for new generation capacity with clean and high efficiency distributed generation (DG) located directly at the customer’s site. DG and energy storage will increase efficiency, improve end user reliability, and reduce emissions. This technology can also provide opportunities to maximize the efficiency and cost effectiveness of fuel cells with combined heat and power (CHP) applications. The use of CHP helps increase the efficiency of on-site energy use by recycling thermal energy for many end use applications, including hot or chilled water, space conditioning, and process heat. There is also an opportunity for tri-generation to simultaneously produce heat, power, and hydrogen for storage and/or transportation. There are significant market opportunities for fuel cells with CHP, including development at schools, hospitals, energy intensive industries, and other critical facilities (see Table 3).

New York’s proposed Clean Energy Standard will mandate that 50 percent of all electricity consumed in New York by 2030 come from clean and renewable energy sources. According to the New York State Department of Public Service, this goal means increasing energy from renewables by 33,700 gigawatt-hours from current levels. The NYISO estimated that additional renewable energy capacity needed to meet this goal would require the addition of approximately 25,000 MW of solar photovoltaics (PV). Because of a fuel cell’s high availability factor (97%), only approximately 4,000 MW of fuel cell capacity would be required to meet the additional renewable energy goal by 2030.

Table 2 – 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
- Waste heat can be captured and used

Table 3 – Stationary Targets

- Schools/Institutions
- Food Sales
- Inpatient Healthcare
- Lodging
- Public Order & Safety

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9 Assumes passenger car tailpipe emissions of CO2 are reduced by 4.67 metric tons CO2E/vehicle/year; transit bus emissions of CO2 are reduced by 89.27 metric tons CO2E /vehicle/year; NOx emissions for passenger vehicles at .213 g/mile x 11,443 and .59 g/mile x 34,000 for diesel fuel transit buses. https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references.


Grid Power

Fuel cells have a high capacity factor and can be used for grid power with direct ties to transmission and distribution systems. Applications include utility ownership for transmission and distribution reliability via voltage support, frequency regulation, and capacitance.

Deployment

Based on a subset of targets identified within this Plan, there is the potential to develop 1,131 MW of stationary fuel cell generation capacity in New York, which would provide the following benefits (see Appendix V), annually:

- **Production of approximately 9.61 million MWh of electricity.**
- **Production of approximately 9.34 million MMBTUs of thermal energy.**
- **Reduction of NOx emissions by up to approximately 2,600 tons (electric generation only).**

Resources necessary for this deployment may be offset by the following energy products: electricity, thermal energy, and possibly hydrogen. These energy products are of high value to end users for private power; utilities for grid power, voltage support, frequency regulation, and energy storage; and the State of New York for emergency power at critical facilities.

This Plan focuses primarily on applications for 1) small fuel cells that are less than 200 kW, (typically 100 to 200 kW); 2) midsize fuel cells (typically 400 kW to 1,000 kW); and 3) large fuel cells (typically over 1 MW). Midsize and large fuel cells (>400 kW) are potentially viable for large energy users and grid applications, while small fuel cells (< 200 kW) are potentially viable for site-specific applications, such as back-up power for telecommunications sites and grid resilience. Potential stationary targets are illustrated in APPENDIX I – Figure 1, “New York: Market Potential for Hydrogen and Fuel Cell Stationary Applications”.

**FUEL CELLS FOR TRANSPORTATION**

Government and industry are now investigating the use of hydrogen and renewable energy as a replacement of hydrocarbon fuels in the transportation sector, which accounts for 28.9 percent of New York’s total energy consumption. 15 FCEVs have several advantages over conventional vehicles (see Table 4) and can reduce price volatility, decrease dependence on oil, improve environmental performance, and provide greater efficiencies. Targets for FCEV deployment and hydrogen infrastructure development include public/private fleets, bus transit, and specialty vehicles (see Table 5). Zero emission FCEVs could replace existing conventional fleet vehicles in New York, starting with 2,038 passenger vehicles16, providing annual carbon dioxide (CO₂) emission reductions of approximately 9,500 metric tons and NOx emission reductions of approximately five (5) metric tons. Additionally, the introduction of 349 zero emission fuel cell electric buses (FCEBs) in New York would provide further benefits.

13 MMBTU calculations are based on 400 kW PAFC and 1.4 MW MCFC units because SOFC units are non-CHP.
16 Analyses conducted by the Connecticut Center for Advanced Technology (CCAT) based on the ZEV eight-state MOU and HIS Automotive 2016 data for ME, VT, RI, MA, CT, NJ, and MD.

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Table 4 – FCEV Advantages

- Quiet operations
- Zero/Near zero emissions
- Domestic fuel supply
- Price volatility reduction
- Energy security
- Higher efficiency
York could reduce annual CO₂ emissions by approximately 31,200 metric tons and NOx emission by approximately seven (7) metric tons.\textsuperscript{17}

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 “Electric and/or Hydrogen Fuel Cells” with the remainder being plug-in hybrid electric vehicles (PHEV).\textsuperscript{18} As one of the eight states that has signed the MOU, New York has the potential of deploying as many as 68,565 FCEVs by 2025 (See APPENDIX II – Eight (8) State MOU Projections for FCEVs).

**Light/Medium Duty Vehicle Fleets**

There are over 43,600 passenger fleet vehicles classified as non-leasing or company owned vehicles in New York.\textsuperscript{19} Passenger vehicles at transportation hubs for fleets are good candidates for hydrogen fueling and the use of FCEVs because they mostly operate on fixed routes or within fixed districts and can be fueled from a centralized station. As illustrated in Appendix I – Figure 2, “New York: Market Potential for Hydrogen and Fuel Cell Transportation Applications,” clusters of fleet vehicles in New York are located primarily in the Long Island, New York City, Albany, Rochester, and Buffalo areas.

**Bus Transit**

There are approximately 7,458 transit buses that provide public transportation services in New York.\textsuperscript{20} Although the efficiency of conventional diesel buses has increased, these vehicles have the greatest potential for energy savings by using high efficiency fuel cells. FCEBs have an average fuel economy of approximately 7.9 miles per kilogram of hydrogen, which equates to approximately 7 miles per diesel gallon equivalent (DGE).\textsuperscript{21} The average fuel efficiency of conventional diesel transit buses is approximately 3.87 miles per gallon.\textsuperscript{22} The use of hydrogen has the potential to reduce diesel fuel use by approximately 8,800 gallons of diesel fuel per vehicle, per year.\textsuperscript{23} The use of FCEBs may require: 1) fueling infrastructure to be co-located with the FCEB storage facilities, 2) redundancy of fuel supply, 3) generally accepted fuel measurements & certifications, and 4) an established track record for up-time performance.

**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 sales, 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 hours of run time. Fuel cell powered equipment has zero emissions, a lower annual cost of ownership, and almost twice the estimated product life than battery powered equipment. Fuel cell powered lift trucks can be operated indoors, can operate up to eight hours before refueling, can be refueled quickly (2-3 minutes), and eliminate the need for battery storage and charging rooms (see Table 6).

\textsuperscript{17} Passenger car tailpipe emissions of CO₂ are reduced by 4.67 metric tons CO₂E/vehicle/year. Transit bus emissions of CO₂ are reduced by 89.27 metric tons CO₂E/vehicle/year. Assumes NOx emissions for passenger vehicles at .213 g/mile x 11,443 and .59 g/mile x 34,000 for diesel fuel transit buses. https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references.


\textsuperscript{19} Vehicle Fleet data provided by IHS Automotive for CT, ME, MA, RI, NJ, MD (2016).

\textsuperscript{20} National Transit Database; “2014 Annual Database Revenue Vehicle Inventory,” https://www.transit.dot.gov/ntd; October 2016.


\textsuperscript{22} CARB Cost Assumptions and Data Sources (updated on 6/26/2017); https://arb.ca.gov/msprog/ict/meeting/mt170626/170626costdatasources.xlsx.

\textsuperscript{23} Assumes an average transit bus travels approximately 34,000 miles annually and 3.87 miles/gallon.
Fuel cell powered material handling equipment is already in use at dozens of warehouses, distribution centers, and manufacturing plants in North America. For example, FreezPak Logistics has selected Plug Power's full-service GenKey solution for its new cold storage distribution center freezer warehouse under construction in Carteret, New Jersey. This GenKey deployment includes 25 fuel cell powered lift trucks, an outdoor hydrogen storage facility with two indoor dispensers, and total service for both the fuel cell powered lift trucks and hydrogen storage system. For large corporations that are currently using or planning to use fuel cell powered material handling equipment across the country include: Central Grocers, FedEx Freight, Sysco Foods, Amazon, and Walmart.

Hydrogen Infrastructure

Hydrogen refueling infrastructure, consisting of production or delivery, storage, and dispensing equipment, is required to support FCEVs, including light duty passenger vehicles, buses and material handling equipment. While costs for hydrogen refueling infrastructure typically range from $1,000,000 - $3,260,000 per station, it is possible that construction of these stations could be backed by private sector financing or developed publicly in conjunction with deployment of high efficiency ZEV fleets. For example, Air Liquide is currently constructing hydrogen fueling stations in the Northeast, including Hartford, CT, Hempstead, NY, and Brooklyn, NY to support the initial deployment of FCEVs in high population density areas.

Models for hydrogen infrastructure financing have been developed, which support plans for deployment of FCEVs, by OEMs, state stakeholders, H2USA, and Northeast States for Coordinated Air Use Management (NESCAUM). This plan complements those efforts to help coordinate the initial development of hydrogen refueling infrastructure to improve the value of FCEVs to customers that will enable growth and distribution of ZEV technology into the market place. Potential sites for development include existing conventional refueling stations and new sites where hydrogen may be offered with other alternative fuels (see Table 7). Potential locations for hydrogen refueling infrastructure with fleet clusters, early market adopters, and other factors are identified in APPENDIX I – Figure 2, “New York: Market Potential for Hydrogen and Fuel Cell Transportation Applications”.

Deployment

A state investment of $15.58 million to $41.58 million for infrastructure development and FCEV deployment could provide a solid framework to support 2,038 passenger FCEVs and the development of up to 23 hydrogen

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Table 6 – FC Material Handler Advantages

- Lower total cost of ownership
- 80% lower refueling/recharging labor cost
- 75% less space required for refueling
- Improved Net Present Value (NPV)
- Zero Emissions

Table 7 – Criteria for Deployment

- High Population Density
- Areas with Early Market Adopters
- Areas with Hydrogen Production and Use
- Areas with Alternative Refueling Stations
- Non-attainment areas for criteria pollutants

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26 California Air Resources Board; Joint Agency Staff Report on Assembly Bill 8: Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California; December 2015; CEC-600-2015-016.
28 H2USA is a public-private partnership to promote the commercial introduction and widespread adoption of hydrogen fueled fuel cell electric vehicles across America.
refueling stations. An additional $70 million (20 percent of $349 million) would be needed for the acquisition of 349 zero emission transit/paratransit buses.

- 2,038 Fuel Cell Electric Passenger Vehicles (187 FCEVs for NY State fleet) - $4.08 million.\(^29\)
- H₂ Infrastructure (23 stations) - $11.5 million to $37.5 million (50 percent of capital cost).
- 349 Fuel Cell Transit/Paratransit Buses - $70 million (20 percent state cost-share/80 percent federal cost share).\(^30\)

Funding for this investment will come from the private sector, federal and state resources\(^31\), and from other sources, potentially including the VW Partial Consent Decree. The VW Partial Consent Decree has allocated approximately $117.4 million to New York for transportation that includes engine repowering, and alternative fueling with hydrogen.\(^32\)

### POLICY

New York’s proximity to major load centers, cost of electricity, concerns over energy reliability and air quality have resulted in renewed interest in the development of efficient and cost effective renewable energy and energy storage technologies. Specific policies in New York supporting the hydrogen and fuel cell industry are displayed in Table 8 and Appendix IV – State Energy Policy/Incentives for Stationary Fuel Cell and Hydrogen Transportation.

Legislation and policy to support distributed generation and renewable technologies can be cost effective and appropriate for public investment. Since 2004, the New York’s Renewable Portfolio Standard (RPS) program has resulted in the development of 1,900 megawatts (MW) of clean power, which has driven more than $2.6 billion in direct investment in New York’s economy over the lifetime of these facilities and has created more than 650 new jobs each year. In January 2017, NYSEDA made a $360 million investment to support utility-scale clean energy projects, which included hydroelectric, onshore wind, solar, and a fuel cell project. The Long Island Power Authority also recently selected three fuel cell projects totaling 40 megawatts.\(^33\) Fuel cells operating on both renewable and non-renewable fuel are classified as a renewable resource in New York.

Most recently, New York State has a Municipal Zero-Emission Vehicle (ZEV) & ZEV Infrastructure Rebate Program that provides “rebates to cities, towns, villages, and counties (or boroughs of New York City) for costs associated with the purchase or lease (for at least 36 months) of eligible clean vehicles, and installation of eligible infrastructure which supports public use of clean vehicles”, including hydrogen refueling equipment.\(^34\)

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\(^{29}\) New York offers up to a $5,000 rebate per vehicle toward the cost of an eligible clean vehicle based the electric range of the vehicle. State investment assumes 40 percent of FCEVs passenger vehicles are initially adopted by municipal fleets.

\(^{30}\) It is projected that an order for 40 fuel cell buses would reduce the cost to $1 million or less. NREL, Fuel Cell Buses in U.S. Transit Fleets: Current Status 2017; https://www.nrel.gov/docs/fy18osti/70075.pdf.

\(^{31}\) The Federal Transit Administration’s Bus & Bus Facilities Infrastructure Investment Program could provide states and direct recipients 80 percent of the net capital project costs to replace, rehabilitate and purchase buses and related equipment and to construct bus-related facilities including technological changes or innovations to modify low or no emission vehicles or facilities.


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### Table 8 – NY Hydrogen Fuel Cell Policy Incentives

- Mandatory Renewable Portfolio Standards (RPS)
- Interconnection Standards
- Net Metering
- Public Benefits Funds
- Fuel Cell Rebate and Performance Incentive
- New York Green Bank
- ZEV Purchase Targets/Incentives
- Public / Private Infrastructure Partnerships
- ZEV Refueling Infrastructure Program

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\([^\text{source}]{\text{source}}\)
Consistency with New York’s Energy Master Plan

The 2015 New York State Energy Plan builds upon the Draft 2014 New York State Energy Plan (Draft 2014 SEP). The Plan coordinates Governor Andrew M. Cuomo’s major new energy initiative, known as Reforming the Energy Vision (REV), and other energy policies and initiatives. The 2015 State Energy Plan establishes three statewide clean energy targets to be met by 2030:

- Reducing greenhouse gas (GHG) emissions from the energy sector—power generation, industry, buildings, and transportation by 40 percent from 1990 levels;
- Increasing electricity generation from renewable energy sources to 50 percent to reduce electricity price volatility and curb carbon emissions; and
- Increasing statewide energy efficiency by 600 trillion British thermal units (Btu) to reduce energy consumption in buildings by 23 percent from 2012 levels.

The use of hydrogen and fuel cell technology in New York would provide clean, reliable power for transportation and stationary applications, and is consistent with the renewable energy strategies identified in the State Energy Plan, including but not limited to:

- Accelerating the deployment of a broad spectrum of renewable technologies with an emphasis on projects that provide benefits to the grid;
- Enhancing buildings and energy efficiency;
- Supporting clean energy financing;
- Engaging and supporting sustainable and resilient communities;
- Modernizing energy infrastructure;
- Accelerating innovation and R&D; and
- Building a cleaner, more efficient, and sustainable transportation system.

CONCLUSION

Hydrogen and fuel cell technology provides significant opportunities for more efficient use of cleaner energy, job creation and economic development. Realizing approximately $353 million in revenue and investment in 2016, the hydrogen and fuel cell industry supply chain in New York is estimated to have contributed approximately $26 million in state and local tax revenue. 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 New York to more fully utilize its renewable energy industry using hydrogen and fuel cells for transportation, energy storage, and electric generation at consumer sites. Such use could maintain New York’s role as a showcase for regionally manufactured energy storage and renewable energy while reducing NOx and CO2 emissions as new jobs are created. This configuration will also increase local end user reliability which is of high value for businesses and industry. To facilitate the execution of this Plan, New York will need to consider policies and initiatives for funding, financing, a schedule for goal implementation, and work responsibilities (Appendix IV – State Energy Policy/Incentives for Stationary Fuel Cells and Hydrogen Transportation). The near term market opportunities identified by NEESC include:

- 1,131 MW fuel cell electric generation capacity;
- 2,387 FCEVs (2,038 passenger and 349 transit/paratransit buses) as ZEVs; and
- 18 to 23 hydrogen refueling stations (to support FCEV deployment).

These market opportunities represent a short-term investment for long-term US productivity. As such, any provisions for funding/financing and schedule for implementation should recognize the short-term cost to facilitate long-term market opportunities. Development of infrastructure will require planning and investments by public and private entities with an expectation of a payback on those investments.

APPENDIX I – Figure 1, New York: Market Potential for Hydrogen and Fuel Cell Stationary Applications
APPENDIX I – Figure 2, New York: Market Potential for Hydrogen and Fuel Cell Transportation Applications
### APPENDIX II – Eight (8) State MOU Projections for FCEVs

The table below details the projected FCEV deployment by 2025 per Eight (8) State MOU. These projections were derived by applying a 4.675 percent factor to 2011 registered vehicles by state. The projections assume 25 percent of all ZEVs (FCEVs and BEVs) will be 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>
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<tr>
<td>2015</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
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<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>
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<td>2017</td>
<td>192,402</td>
<td>72,168</td>
<td>18,042</td>
<td>7,725</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>
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<tr>
<td>2018</td>
<td>472,806</td>
<td>177,344</td>
<td>44,336</td>
<td>18,984</td>
<td>2,167</td>
<td>5,325</td>
<td>9,824</td>
<td>883</td>
<td>479</td>
<td>2,465</td>
<td>3,497</td>
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<tr>
<td>2019</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>
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<tr>
<td>2020</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>
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<td>2021</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>
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<td>2022</td>
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<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>
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<td>2023</td>
<td>2,404,566</td>
<td>901,925</td>
<td>225,481</td>
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<td>2,436</td>
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<td>2024</td>
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<td>37,165</td>
<td>68,565</td>
<td>6,166</td>
<td>3,344</td>
<td>17,208</td>
<td>24,404</td>
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</table>

**Projected FCEV Deployment by 2025 per Eight (8) State MOU**

The graph above shows the projected FCEV deployment by 2025 per Eight (8) State MOU. The 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.

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36 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.

37 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. These projections for FCEVs assumes 25 percent of all ZEVs (FCEVs and BEVs).

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


40 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 – New York SWOT Analysis

Environment factors internal/external to New York’s existing hydrogen and fuel cell industry are provided below in the form of a SWOT analysis. The SWOT analysis provides information helpful in matching the industry’s resources and capabilities to the competitive environment in which it operates.

**Strengths**
- *Stationary Power* – Strong market drivers (electric cost, environmental factors, critical power); Consistent with the New York State Energy Plan and the Governor’s reforming the energy vision; Fuels cells on any fuel classified as renewable.
- *Transportation Power* – Appeal to market, environmental factors, high gasoline prices, Eight-State MOU signatory, high concentration/density of vehicles.
- *Mobility* – Locally made products for material handling/backup power.

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

**Opportunities**
- *Stationary Power* – Significant opportunities/markets for fuel cell technology, reinforce power grid, support for CHP.
- *Transportation Power* – FCEV/FCEB deployment, supply chain buildup opportunities.

**Threats**
- *Stationary Power* – Other energy generation 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

### 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>
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<th>NY</th>
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<tr>
<td>Mandatory Renewable Portfolio Standard (RPS)</td>
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### State Energy Policy/Incentives for Hydrogen Transportation

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<th>NY</th>
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<td>Purchase Incentives/“Point-of-Purchase” Rebates</td>
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<td>Fuel Efficiency Standard (Private/State Fleets)</td>
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<td>REC Available for Renewable H₂</td>
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<td>Tax Incentives</td>
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<td>HOV Lanes and Parking Incentives</td>
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<tr>
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<td>Identified State “Point” Person</td>
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### NEESC Development Plan Market Potential

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<th>Technology Type</th>
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<tbody>
<tr>
<td>Stationary Fuel Cell (MW, low/high range)</td>
<td>97</td>
<td>74</td>
<td>58</td>
<td>250</td>
<td>82</td>
<td>170</td>
<td>1,133</td>
<td>244</td>
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<td>Transportation FCEV (near-term number of vehicles)</td>
<td>137</td>
<td>20</td>
<td>92</td>
<td>823</td>
<td>171</td>
<td>548</td>
<td>2,058</td>
<td>3,232</td>
<td>560</td>
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<tr>
<td>Transportation Fuel Cell Electric Bus (near-term number of vehicles)</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>84</td>
<td>14</td>
<td>43</td>
<td>349</td>
<td>139</td>
<td>63</td>
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<tr>
<td>Refueling Stations (low/high range)</td>
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<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
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<td>7</td>
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<td>5</td>
<td>2</td>
<td>7</td>
<td>18</td>
<td>35</td>
<td>84</td>
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- **Eligible**
- **Eligible if Renewable**
- **Combined Heat & Power**
### APPENDIX V – Summary of Potential Hydrogen and Fuel Cell Applications

<table>
<thead>
<tr>
<th>Category</th>
<th>Total Sites</th>
<th>Potential Sites</th>
<th>FCs &lt; 400 kW (#)</th>
<th>FCs ≥400 kW (#)</th>
<th>FCs &gt;1,000 kW (#)</th>
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<tr>
<td><strong>Stationary Targets</strong></td>
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<td>Schools and Institutions&lt;sup&gt;43&lt;/sup&gt;</td>
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<td>133</td>
<td>93</td>
<td>27</td>
<td>13</td>
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<tr>
<td>Food Sales/Services&lt;sup&gt;44&lt;/sup&gt;</td>
<td>54,426</td>
<td>4863</td>
<td>4739</td>
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<tr>
<td>Healthcare &amp; Lodging&lt;sup&gt;45&lt;/sup&gt;</td>
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<td>155</td>
<td>29</td>
<td>34</td>
<td>92</td>
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<tr>
<td>Retail&lt;sup&gt;46&lt;/sup&gt;</td>
<td>17,859</td>
<td>88</td>
<td>52</td>
<td>33</td>
<td>3</td>
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<tr>
<td>Public Order &amp; Safety&lt;sup&gt;47&lt;/sup&gt;</td>
<td>4,130</td>
<td>293</td>
<td>159</td>
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<tr>
<td>Energy Intensive Industries&lt;sup&gt;48&lt;/sup&gt;</td>
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<td>97</td>
<td>48</td>
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<tr>
<td>GSA Operated Buildings&lt;sup&gt;49&lt;/sup&gt;</td>
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<td>62</td>
<td>62</td>
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<td>Wireless Telecommunication Towers&lt;sup&gt;50&lt;/sup&gt;</td>
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<td>152</td>
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<td>WWTPs &amp; Landfills&lt;sup&gt;51&lt;/sup&gt;</td>
<td>142</td>
<td>10</td>
<td>7</td>
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<td>2</td>
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<tr>
<td>Commercial Airports, Military, and Ports&lt;sup&gt;52&lt;/sup&gt;</td>
<td>634</td>
<td>51</td>
<td>27</td>
<td>10</td>
<td>14</td>
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<tr>
<td><strong>Total Locations</strong></td>
<td>92,098</td>
<td>5,904</td>
<td>5,368</td>
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<td>220</td>
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<table>
<thead>
<tr>
<th>Category</th>
<th>Total Units</th>
<th>Potential Targets</th>
<th>Emissions (Metric Tons/Year)</th>
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</thead>
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<td></td>
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<td>CO2</td>
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<tr>
<td><strong>Transportation Targets</strong></td>
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<td>FCEVs</td>
<td>43,631</td>
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<td>9,500</td>
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<td>Transit Buses</td>
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<td>31,200</td>
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<tr>
<td>Retail Refueling Stations</td>
<td>4,678</td>
<td>18 – 23</td>
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</table>

The analysis provided in this Plan conservatively estimates that the near term market opportunities for the application of fuel cells (2.5 kW to 1.4 MW) totals approximately 1,131 MW<sup>53</sup> at approximately 5,904 potential locations. These near term market opportunities represent a subset of the “Total Sites” that could be served by commercially available fuel cell technology.<sup>54</sup> FCEV/FCEB replacements for existing fleet vehicles in New York could include the near term deployment of 2,387 vehicles.

---

<sup>42</sup> Potential sites and capacity estimated by NEESC.

<sup>43</sup> Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses.

<sup>44</sup> Buildings used for wholesale of food or for preparation and sale of food and beverages for consumption.

<sup>45</sup> Buildings used as diagnostic and treatment facilities for inpatient care and buildings used to offer multiple accommodations for short-term or long-term residents.

<sup>46</sup> Buildings used for the sale and display of goods other than food.

<sup>47</sup> Buildings used for the preservation of law and order or public safety.

<sup>48</sup> Buildings that are industrial or agricultural.

<sup>49</sup> Buildings actively in use and managed by the General Services Administration.

<sup>50</sup> Off-site telecommunication towers that may require back-up power.

<sup>51</sup> Wastewater treatment plants and landfills.

<sup>52</sup> Commercial airports, military bases, and active ports.

<sup>53</sup> Assumes a 97% availability factor for fuel cell units ranging from 2.5 kW through 1.4 MW.

<sup>54</sup> Many of the targets were identified based on assumptions provided by EIA’s 2012 Commercial Building Energy Consumption Survey (CBECS).