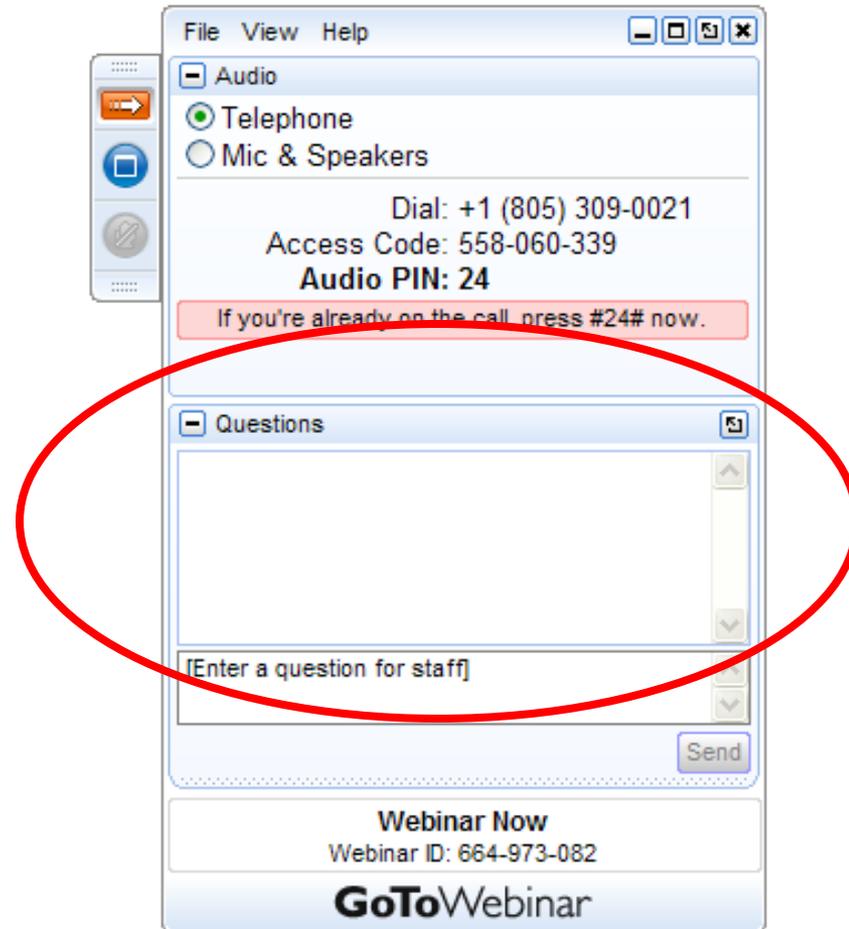


Presenter:
Joel Rinebold – Connecticut Center for Advanced Technology, Inc.

DOE Host:
Peter Devlin– DOE Fuel Cell Technologies Office

U.S. Department of Energy
Fuel Cell Technologies Office
December 1st, 2015

- Please type your questions into the question box





Northeast States' Hydrogen Economy

Economic Development, Environmental Performance, Energy Reliability

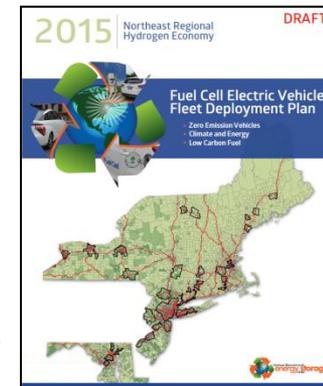
**Joel M. Rinebold
Connecticut Center for
Advanced Technology, Inc.
December 1, 2015**

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

- Clean/Low Carbon Emissions
- Reliability
- Durability
- Lower Costs
- Clean Energy Jobs

2015 Hydrogen and Fuel Cell Development Plans:

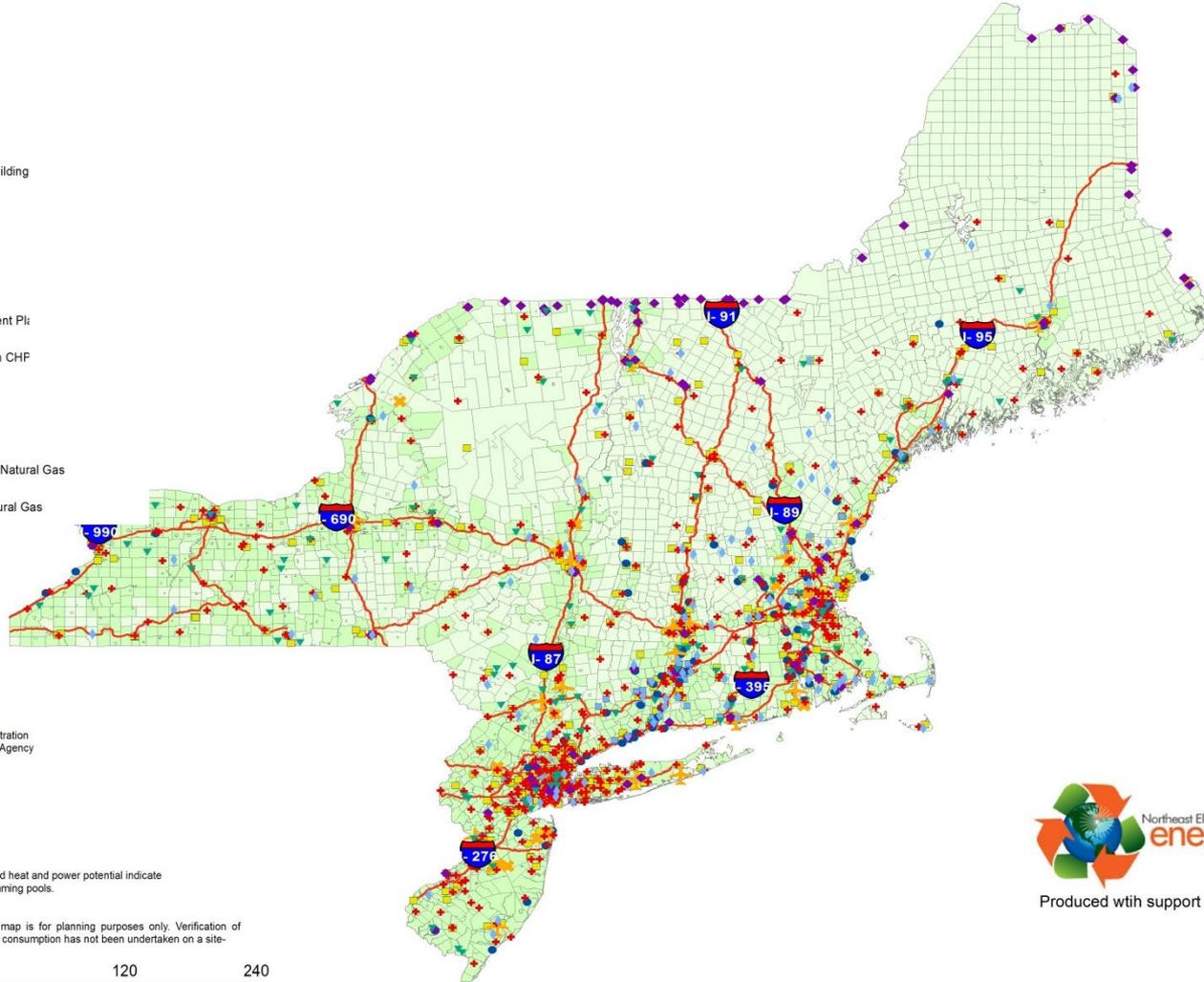
- Economic impacts (jobs, revenue, companies)
- Technology, Applications, and Markets
- Stationary and Transportation Deployment Targets
- Policy and Drivers
 - Job Development
 - Energy Reliability
 - Storm Preparation
 - Environmental/ZEV
 - Carbon Control



- Education
- Food Sales/Services
- Inpatient Healthcare
- Lodging
- Public Order & Safety
- Energy Intensive Industries
- Government Operated Buildings
- Telecommunication Facilities
- Military, Airports, and Ports
- Wastewater Treatment Plants and Landfills
- Fleet Vehicles
- H₂ Refueling

Legend

- Landfills
- Correctional Facility
- Federally Owned Building
- Hospitals
- Military Airports
- Military Bases
- Wastewater Treatment Plr
- Public Schools (With CHP)
- Colleges
- Interstate
- Area Not Served by Natural Gas
- Area Served by Natural Gas



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



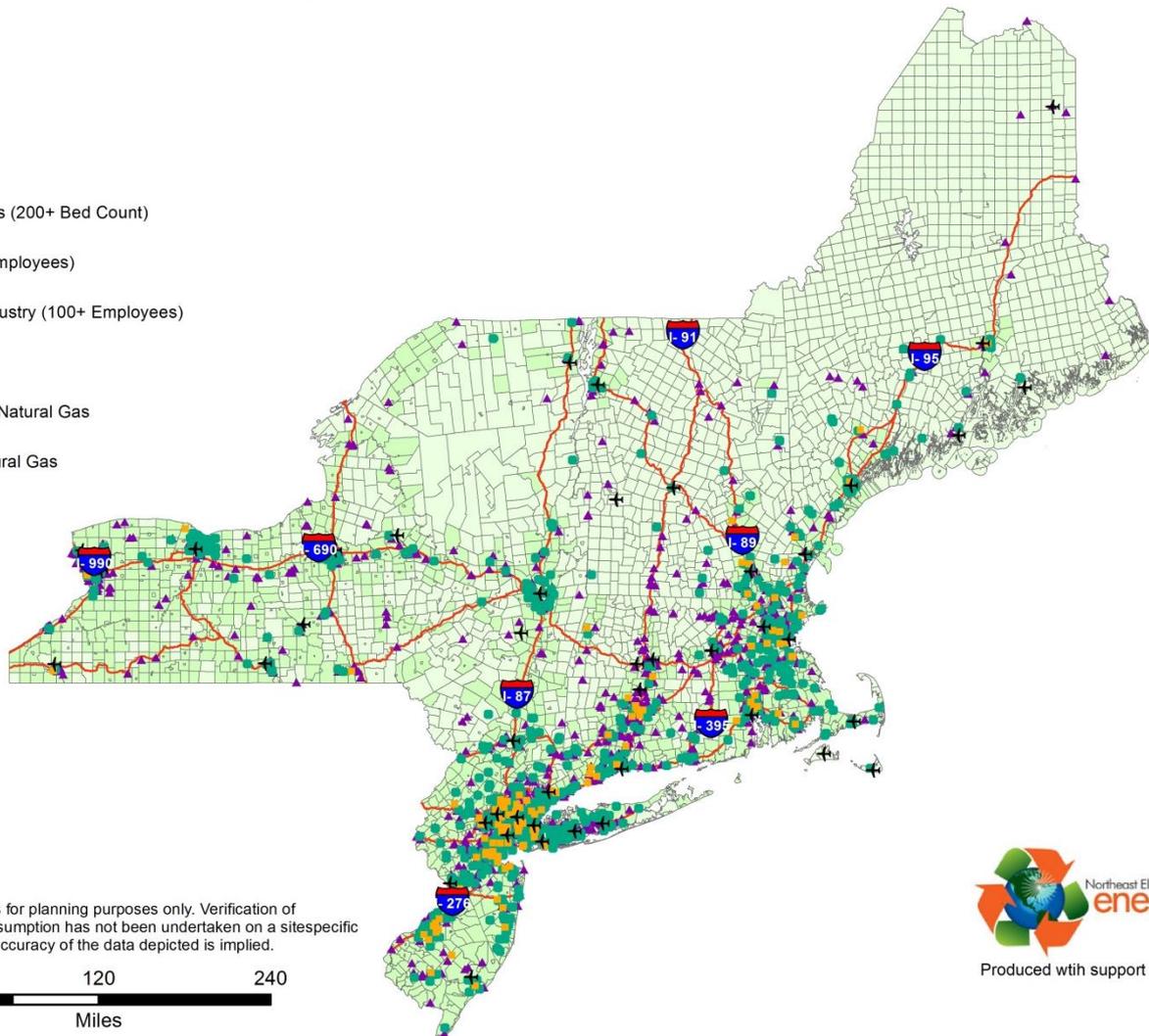
March, 2015



Produced with support provided by the U.S. SBA

Legend

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



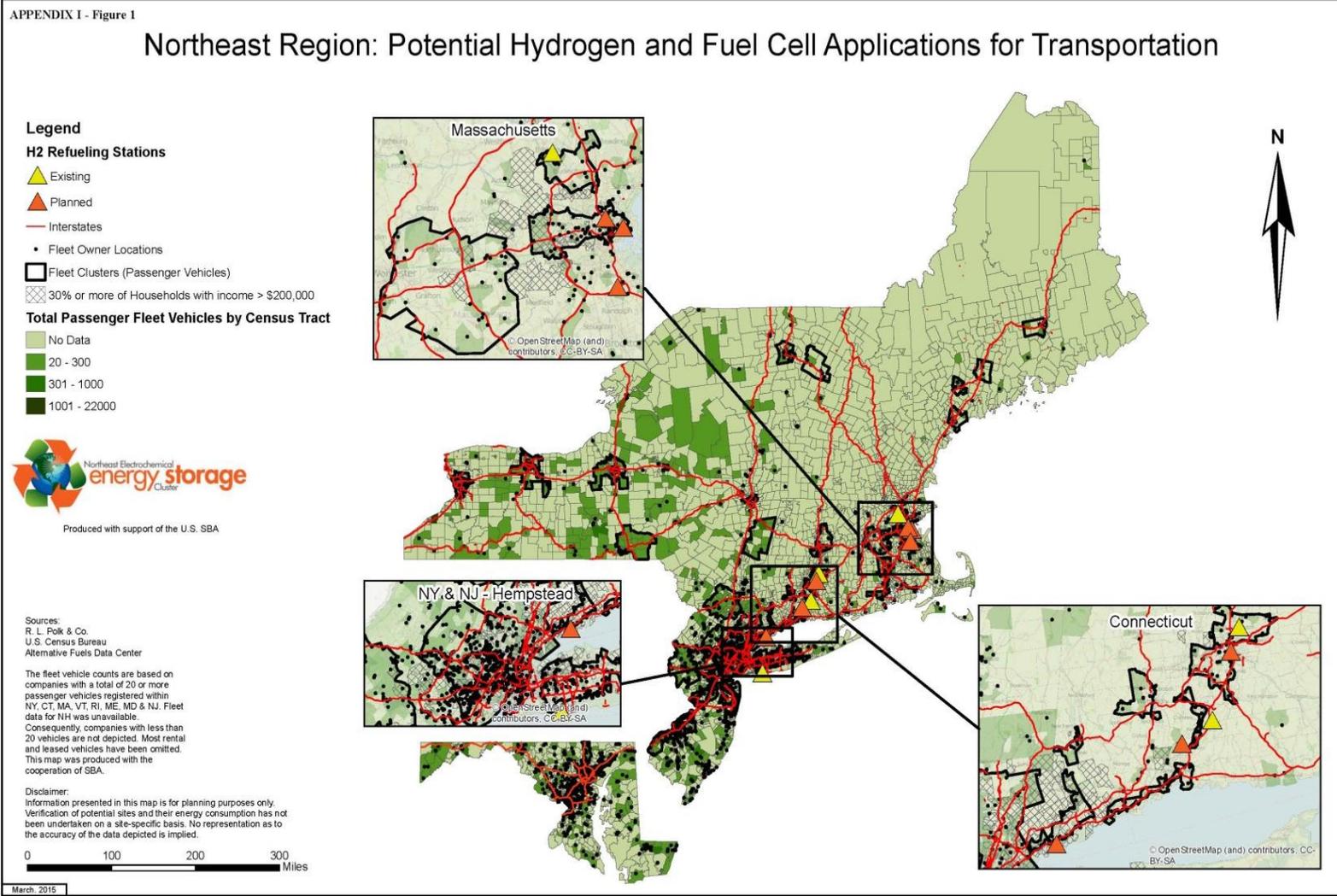
Sources:
 U.S. Census Bureau
 ReferenceUSA
 AssistedLivingList.com
 altiusdirectoy.com
 Federal Aviation Administration
 Northeast Gas Association

Disclaimer:
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March, 2015

Target Priorities: New York City Metro, Boston Metro and Hartford Metro





Stationary (ME, NH, VT, MA, RI, CT, NY, NJ)

- 1,313 to 1,753 MW fuel cell electric generation (2025)

Transportation (ME, NH, VT, MA, RI, CT, NY, NJ, MD)

- 14,380 FCEVs (Projected)
 - 13,684 Passenger Vehicles
 - 680 FCEVs for State fleets
 - 696 transit/paratransit buses(FCEB)
- 135 to 152 hydrogen refueling stations

Next Steps:

- Industry Coordination
- Technical Information Exchange
- Supply Chain Management
- Environmental Performance (GHG Reduction)
- Policy
 - Transportation
 - Stationary
- Financing
- Deployment



- **Supply Chain:**

- Total Employment: 5,770 (60% U.S; 17% global)
- Total Supply Chain Companies : 1,179
- Total OEMs: 30

- **Total Annual Revenue and Investment:**

- \$1.2 Billion (\$508 Million = Direct)
- Awarded over \$540 million over the last 5 years

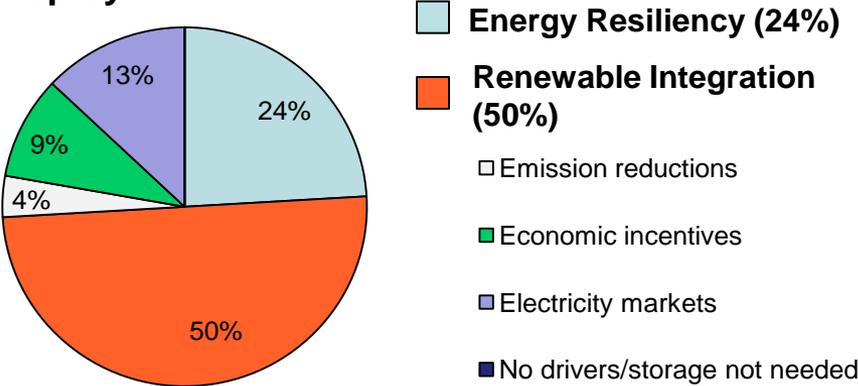
- **Total Jobs (Direct, indirect, and induced):**

- 5,770

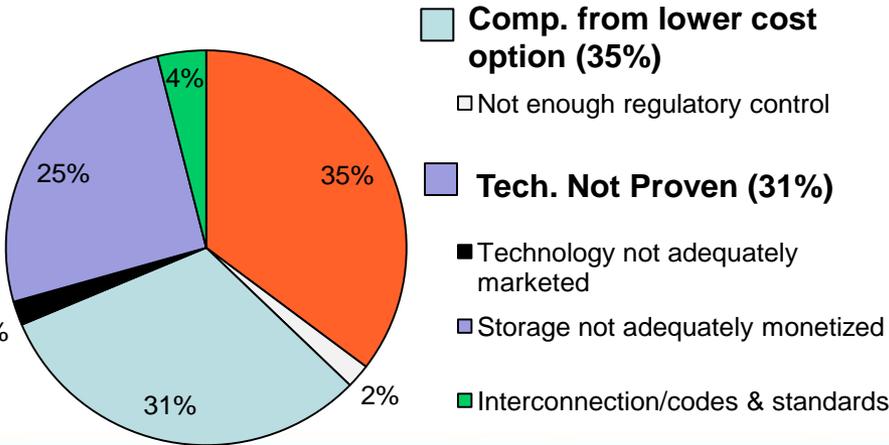
* NEESC regional 2012 baseline data includes ME, MA, VT, RI, CT, NH, NY, NJ

Regional

What are the best drivers/opportunities for deployment?

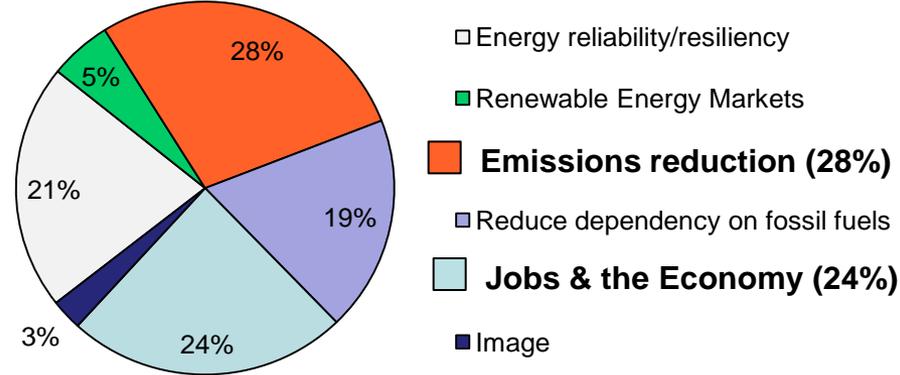


What are the biggest market constraints?

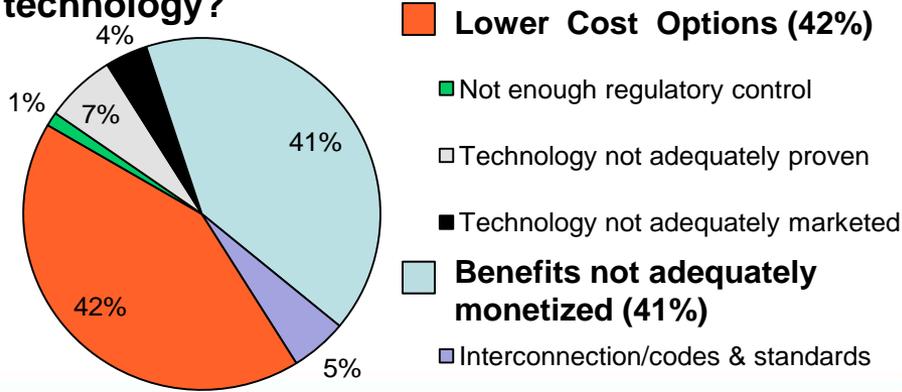


National

What are the best drivers for deployment of hydrogen and fuel cell technology?



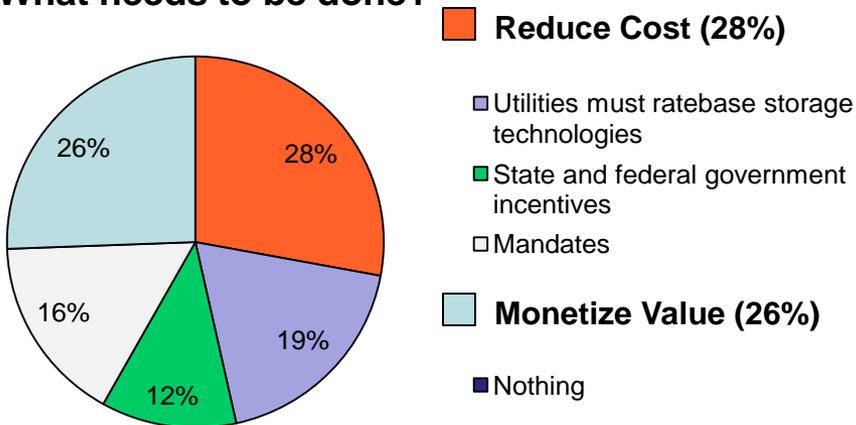
What is the most significant market constraint affecting the use of hydrogen and fuel cell technology?



Action and Government Solutions

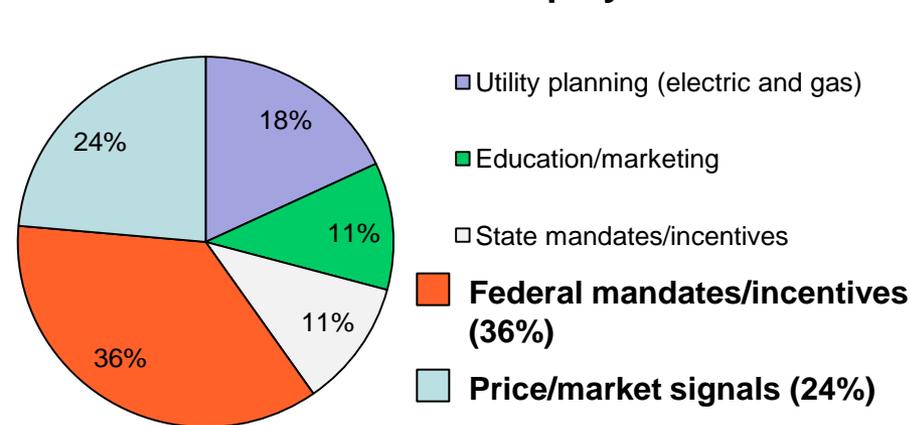
Regional

What needs to be done?

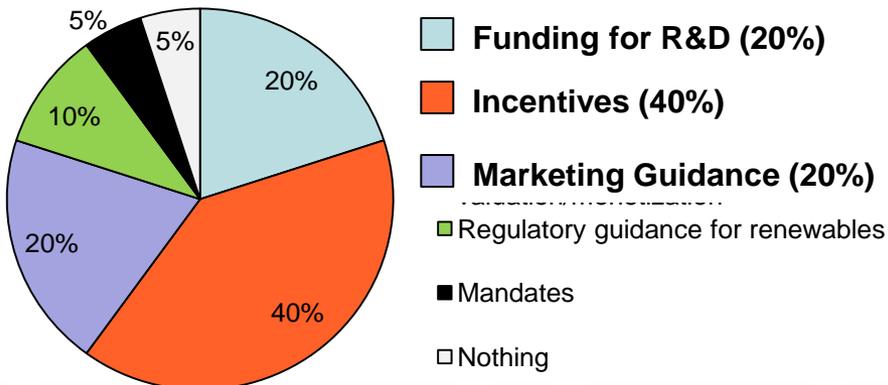


National

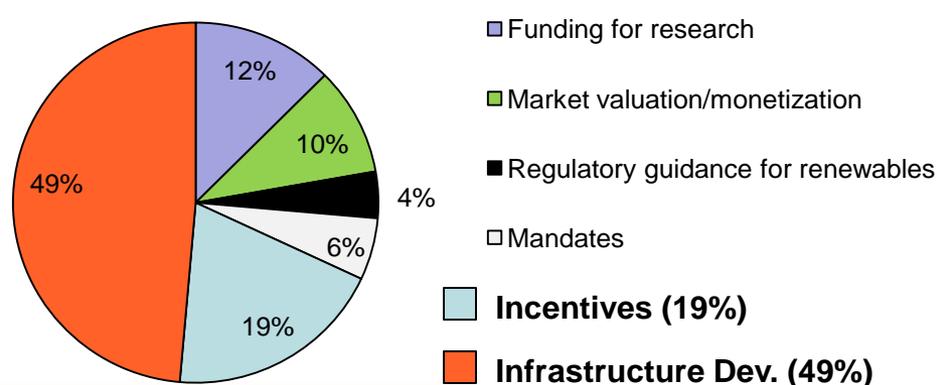
How can more fuel cells be deployed?



What should the Federal and state governments do to facilitate integration?



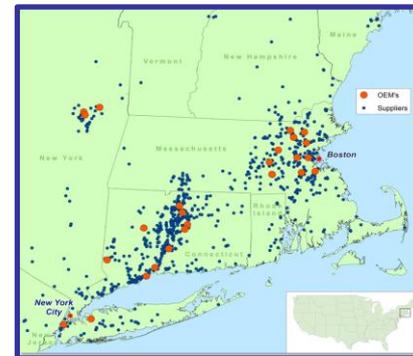
What should the Federal and state governments do to facilitate deployment?



- Tech-Transfer/R&D
- Manufacturing
- OEM/Supply Chain
- Finance
- Government/Policy



Infrastructure Development



Regional Supply Chain



Industry Networking

Batteries	
Components	
Abrasives	
Air	
Batteries	
Cables and wires	
Casters and wheels	
Catalyst	
Ceramic	
Electrical	
Electronic	
Fans and Blowers	
Fasteners	
Hoses and tubes	
HVAC	
Hydraulics	
Industrial	
Miscellaneous	
Plumbing	
Pneumatics	

Online Database

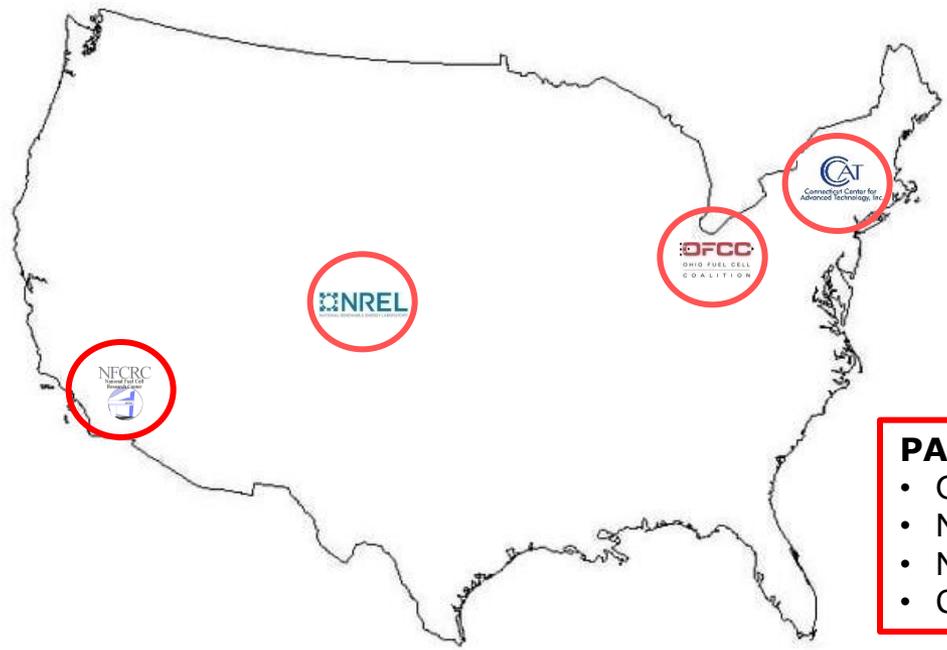


Technical Information Exchange



Next Steps

- DOE Guidance
- National Technical Exchange Centers
- Distribution of Component Specifications
- Global Market Competition



- PARTNERS/COLLABORATORS**
- Ohio Fuel Cell Coalition (OFCC)
 - National Renewable Energy Lab (NREL)
 - National Fuel Cell Research Center (NFCRC) at UC Irvine
 - Connecticut Center for Advanced Technology (CCAT)

Supply Chain Database Search

Supplier Category
 Sub-Category
 Search term

Company Name	Address	City/Town	Zip	State	Website	Map
2 Hopewell	2 Hopewell Road	South Glastonbury	06073	CT	2hopewell.com	show on map
901 D LLC	360 Route 59	Tallman	10982	NY	www.901d.com	show on map
A&P Trucking Co Inc.	106 Pent Hwy	Wallingford	06492	CT		show on map
A.E. Electric L L C	89 N Plains Industrial Road # D	Wallingford	06492	CT		show on map
AA Precision Machine Company, Inc.	300 Curran Road	Fall River	02720	Massachusetts	www.aaprecisionmachine.com	show on map
AAA Aircraft	68 Shaker Road	Enfield	06082	CT	www.aaa-aircraft.com	show on map
Aaron / Andersen Advertising LLC	483 Manchester Rd	East Glastonbury	06025	CT	aaronandersenadv.com	show on map

[next page >>](#)

14 Supply Products/100 Categories

Supplier Category
 Sub-Category

- Components
- Consulting | Legal | Financial Services
- Engineering | Design Services
- Equipment
- FC | H2 System Distr. | Install | Maint Service
- Fuel
- Fuel Cell Stack or System OEM
- Hydrogen System OEM
- Lab or Test Equipment | Services
- Manufacturing Services
- Marketing Products | Services
- Materials
- Other
- Research and Development
- Transportation | Packaging | Shipping Services

Geocoded/Mapped





- Passenger car GHG emissions could be reduced by 4.75 metric tons CO₂E /vehicle/year.
- Transit bus GHG emissions could be displaced 65 to 163 metric tons CO₂E /vehicle/year.

Vehicles Type	Number of Vehicles	Reduction Per Vehicle (MT/yr.)	Potential GHG Reduction (MT/yr.)
Passenger Car	13,684	4.75	64,999
State Fleets	680	4.75	3,230
Transit Bus	696	65 to 163	45,240 to 113,448
All	14,380	N/A	113,469 to 181,677

- If all goals are achieved total regional GHG reductions could amount to **113,469 to 181,677 metric tons CO₂E/year.**



Policy (Stationary)



	ME	NH	VT	MA	RI	CT	NY	NJ
State Energy Policy/Incentives for Stationary Fuel Cells								
Mandatory Renewable Portfolio Standard (RPS)	Eligible	Eligible		Eligible	Eligible if Renewable	Eligible	Eligible	Eligible if Renewable
Net Metering	Eligible	Eligible	Eligible if Renewable	Eligible	Eligible if Renewable	Eligible	Eligible	Eligible if Renewable
Public Benefits Fund	Eligible		Eligible if Renewable	Eligible	Eligible if Renewable	Eligible	Eligible	Eligible if Renewable
Performance-Based Power Purchase	Eligible				Eligible if Renewable	Eligible	Eligible	
Utility Ownership/Investment						Eligible	Eligible	
State Grant Program		Eligible if Renewable	Eligible if Renewable		Eligible	Eligible	Eligible	Eligible
State Loan Programs			Eligible if Renewable		Eligible if Renewable	Eligible	Eligible	
Microgrid Reliability Program						Eligible	Eligible	
Property Tax Incentive (Commercial)			Eligible if Renewable			Eligible		Eligible
Sales Tax Incentive			Eligible if Renewable			Eligible	Eligible	
Property-Assessed Clean Energy (PACE) Financing						Eligible	Eligible	Eligible if Renewable
One Stop Regulatory Approval						Eligible		
Identified State "Point" Person								

Eligible
 Eligible if Renewable



Policy (Transportation)



	ME	NH	VT	MA	RI	CT	NY	NJ	MD
State Energy Policy/Incentives for Hydrogen Transportation									
Zero Emission Vehicle (ZEV) Program (FCEV/H ₂ Infrastructure)			Eligible	Eligible	Eligible	Eligible	Eligible		Eligible
ZEV Purchase Target for State Government Fleets (TBD)			Eligible	Eligible	Eligible	Eligible	Eligible		Eligible
Purchase Incentives/"Point-of-Purchase" Rebates				Eligible if Renewable		Eligible	Eligible		
Fuel Incentives									
Public/Private Infrastructure Partnership						Eligible	Eligible		
Fuel Efficiency Standard (Private/State Fleets)									
Refueling Infrastructure Incentives				Eligible if Renewable		Eligible	Eligible		
REC Available for Renewable H ₂									
Tax Incentives									
HOV Lanes and Parking Incentives									
One Stop Regulatory Approval									
Identified State "Point" Person					Eligible	Eligible			

Eligible
 Eligible if Renewable



Financing & Deployment



Fuel Cell Passenger Vehicle: Hydrogen Vehicle-Refueling Station Business-to-Business Model

Refueling Station Economics		Straight Buy		Lease	
Refueling Station H2 Purchase Price (\$/kg)	\$	Pricing		Customer Buying Assumptions	
Refueling Station H2 Sale Price (\$/kg)	\$	Hydrogen FC Vehicle Cost Plus Dealership - Gross Margin (\$)	Car	Customer Interest Rate	3.00%
Gross Profit (\$/kg)	\$ 3.00	Hydrogen FC Vehicle Grant (\$)		Loan Term (Months)	72
Refueling Station Cost (\$)	\$ 1,000,000	Conventional Vehicle Cost to Dealership + Gross Margin (\$)	25,000	Vehicle Duty Cycle	Car
Number of Years to Payback	4.5	Conventional Vehicle Grant (\$)		Miles Per Year	25,000
Implied Hydrogen Sales Per Year (kg)	74,074	Net Dealership Cost Premium (\$)	5,000	Leasing Assumptions	
kg Per day / Vehicle	1.05	Conventional Vehicle Monthly Costs (\$)		Car Dealer Cost of Capital	3.25%
Miles Per Day	68	Conventional Vehicle Mileage (mpg)	25	Vehicle Life (Miles)	200,000
Annual Revenue Per Vehicle	\$ 2,895	Gallons of Fuel Consumed Annually	1,000	Number of Lease Payments	96.00
Total Revenue for All Vehicles (\$/year)	\$ 518,519	Conventional Vehicle Fuel (\$/gallon)	\$ 4.00	Conventional Vehicle Monthly Lease (\$)	
Total Gross Profit (\$/year)	\$ 222,222	Annual Conventional Fuel Costs (\$)	\$ 4,000	Conventional Monthly Lease Payment (No Fuel)	\$ 290.09
Hydrogen Vehicles Supported Annually	292	Conventional Vehicle Fuel Costs (\$/mile)	\$ 0.16	Conventional Vehicle Monthly Fuel Costs	\$ 333.33
		Fuel Cell Vehicle Monthly Costs (\$)		Conventional Lease Payment With Fuel	\$ 629.42
		Hydrogen FC Vehicle Mileage per kg (MPGE)	65	FCV Monthly Lease (\$)	
		Hydrogen FC Vehicle Energy Consumed (kg)	385	FCV Monthly Lease Payment (No Fuel)	\$ 355.30
		Hydrogen FC Vehicle Fuel (\$/kg)	\$ 7.00	FCV monthly Vehicle Fuel Costs	\$ 224.36
		Annual Hydrogen Fuel Costs (\$)	\$ 2,692	FCV Lease Payment With Fuel	\$ 579.66
		Maintenance Cost Premium (\$/mile)	NA	Net Customer Benefit From FCV Lease	
		Annual Maintenance Cost Premium (\$)	NA	Monthly Savings to Customer (\$)	\$ 49.76
		Hydrogen Vehicle Fuel Costs (\$/mile)	\$ 0.11	Less Than Conventional	
		Summary		Net Customer Benefit From Buying a FCV	
		Annual Savings (\$)	\$ 1,208	Monthly Savings to Customer (\$)	\$ 28
		Sale Price Premium Simple Payback (Years)	8.82	Less Than Conventional	
		Vehicle Life (Miles)	200,000		
		Vehicle Life to Achieve Payback (Miles)	95,500		

Notes for vehicle buy model:
 (1) Costs in excess of the entered refueling station price would be subsidized by government grants or the vehicle refueling would be resized to serve more vehicles with greater sales.
 (2) Based on delivery of approximately 200 kg/day.
 (3) Assumes capability to provide up to 40 kg / hour for peak refueling needs.
 (4) Vehicles supported annually refers to the minimum number of vehicles required to support the refueling station.

H
R
S
A
M

Hydrogen Refueling Station	
Average Daily Dispensing Rate =	50-6000 kg
Station Operating Hours =	6 AM to Midnight
Average Vehicle Fill =	4.6 kg
Average Vehicle Refueling Time =	2.76 minutes
Average Vehicle Lingering Time =	2.24 minutes
Vehicle Refueling Pressure =	5000 psi
Cascade Charging System Maximum Pressure =	6250 psi
Cascade Charging System Minimum Pressure	
high pressure vessel =	6000 psi
medium pressure vessel =	4350 psi
low pressure vessel =	2000 psi
Pipeline Supply Pressure =	300 psi
"Low" Pressure Storage Pressure =	2500 psi

H2FAST

Station Inputs

Installation time [months]

Demand ramp-up [years]

Station type:

Long-term station utilization [%]:

Vehicle refills [refills/day]:

Hydrogen per refill [kg]:

Total capacity [kg/day]:

Hydrogen price [\$/kg]:

Equipment capital cost [\$]:

Total installation cost [\$]:

Planned and unplanned O&M costs [\$/yr]:

Scenario Inputs

Capital incentive [\$/station]:

Initial production incentive [\$/station]:

Annual decrement of production incentive [\$/station]:

Incidental revenue [\$/year]

Cost of delivered hydrogen [\$/kg]

Cost of electricity [\$/kWh]

Cost of natural gas [\$/mmBTU]

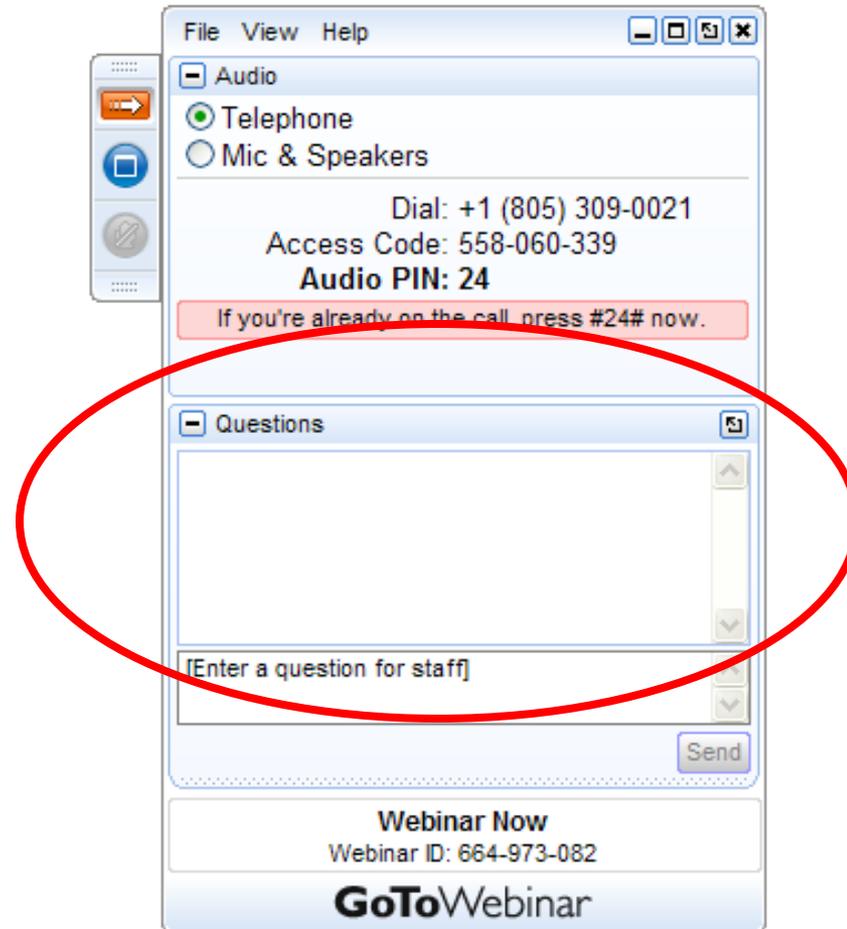
Financing Inputs

Debt interest rate [%]:

Minimum debt to equity ratio:

DOE H2A Delivery Analysis

- Please type your questions into the question box



Thank You

Joel M. Rinebold
Connecticut Center for Advanced Technology
jrinebold@ccat.us
(860) 291- 8832
www.ccat.us

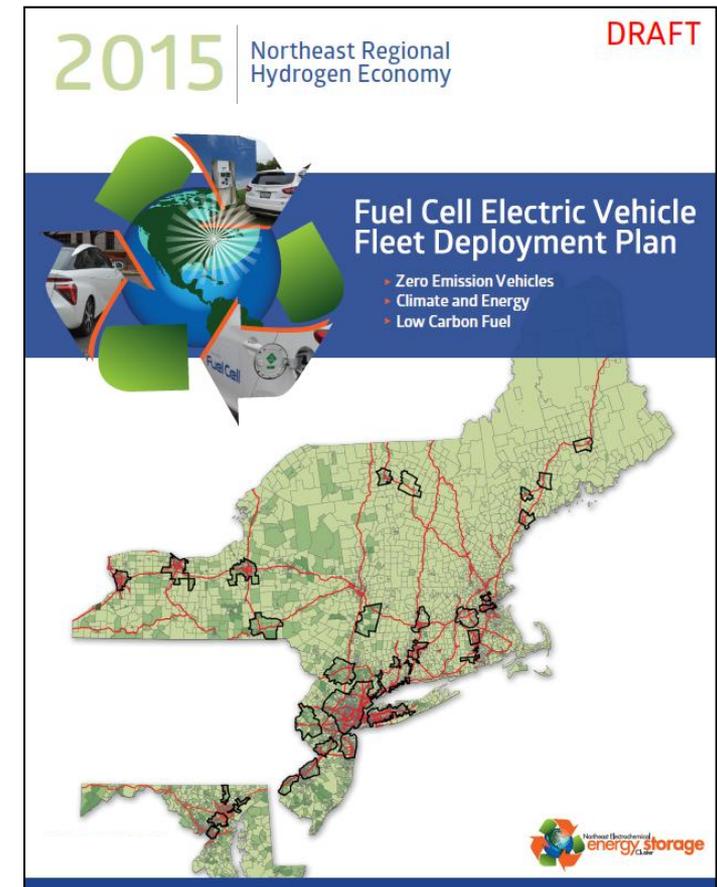
DOE Host: Peter Devlin (Peter.Devlin@ee.doe.gov)

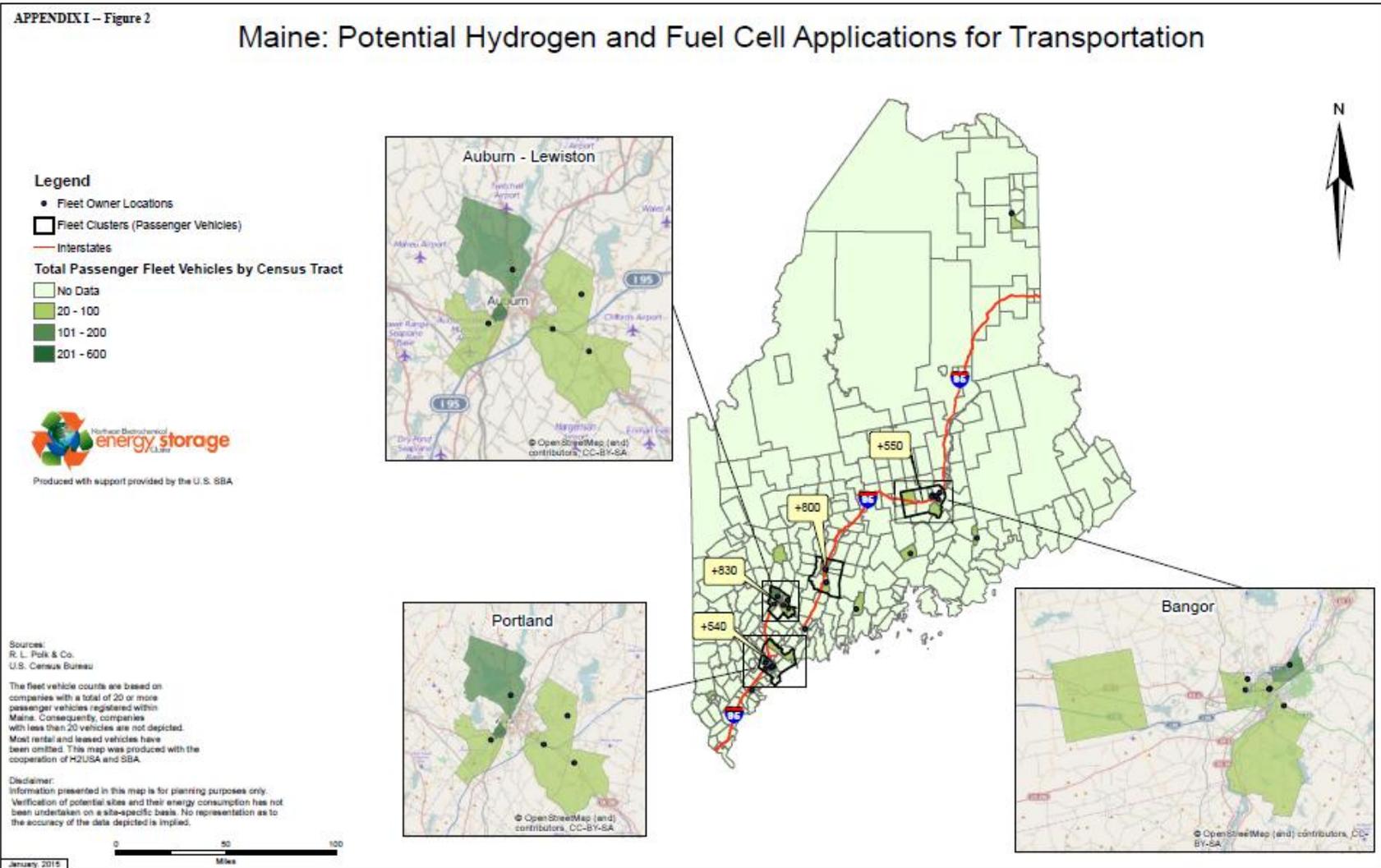
Webinar Recording and Slides:
(<http://energy.gov/eere/fuelcells/webinars>)
Newsletter Signup
(<http://energy.gov/eere/fuelcells/subscribe-news-and-financial-opportunity-updates>)

Extra Slides

Regional Fuel Cell Electric Vehicle Fleet Deployment Plan

- Consistent with goals of H2USA, NESCAUM, and the 8 State MOU Action Plan
- Developed for 9 states
 - Northeast states including Maryland
- ZEV Deployment Targets
 - Early market adopters, fleets, hydrogen users, hydrogen refueling, proximity to highways, etc
- Hydrogen Infrastructure
- Policy and Drivers
- Plan Expandable to Include:
 - OEM survey data
 - NREL modeling
 - Subset of National Roadmap
 - Additional states





APPENDIX I -- Figure 3

Connecticut: Potential Hydrogen and Fuel Cell Applications for Transportation



Legend

H2 Refueling Stations Status

- Existing
- Planned
- Fleet Owner Locations
- Current Hydrogen Users
- Interstates

Fleet Clusters (Passenger Vehicles)

- Fleet Clusters (Passenger Vehicles)
- 30% or more of Households with income > \$200,000

Total Passenger Fleet Vehicles

- No Data
- 20 - 100
- 101 - 500
- 501 - 1000

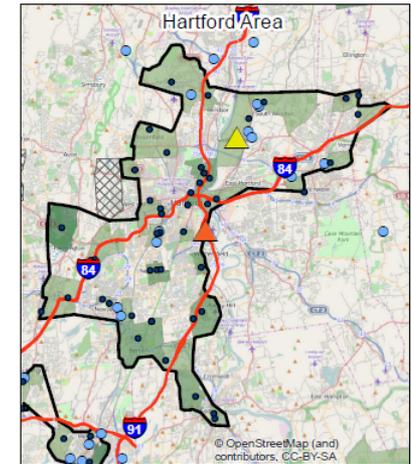
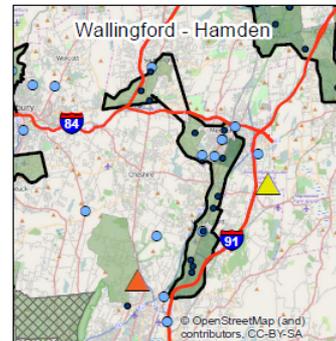
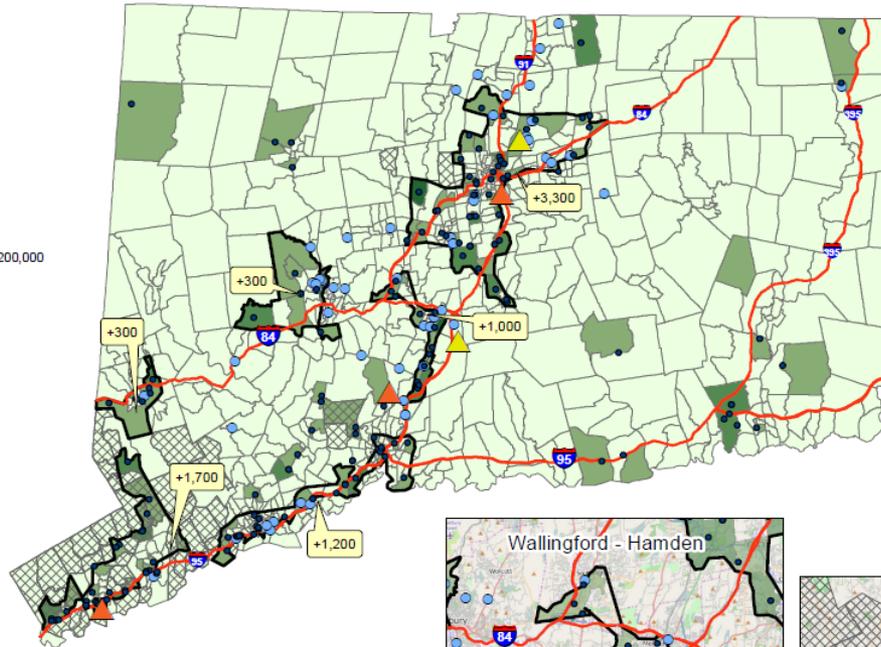


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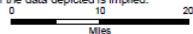
Sources:
 R. L. Polk & Co.
 U.S. Census Bureau
 Alternative Fuels Data Center
 Electrochemical Hydrogen Separator: Opportunities for Commercialization, 2009

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

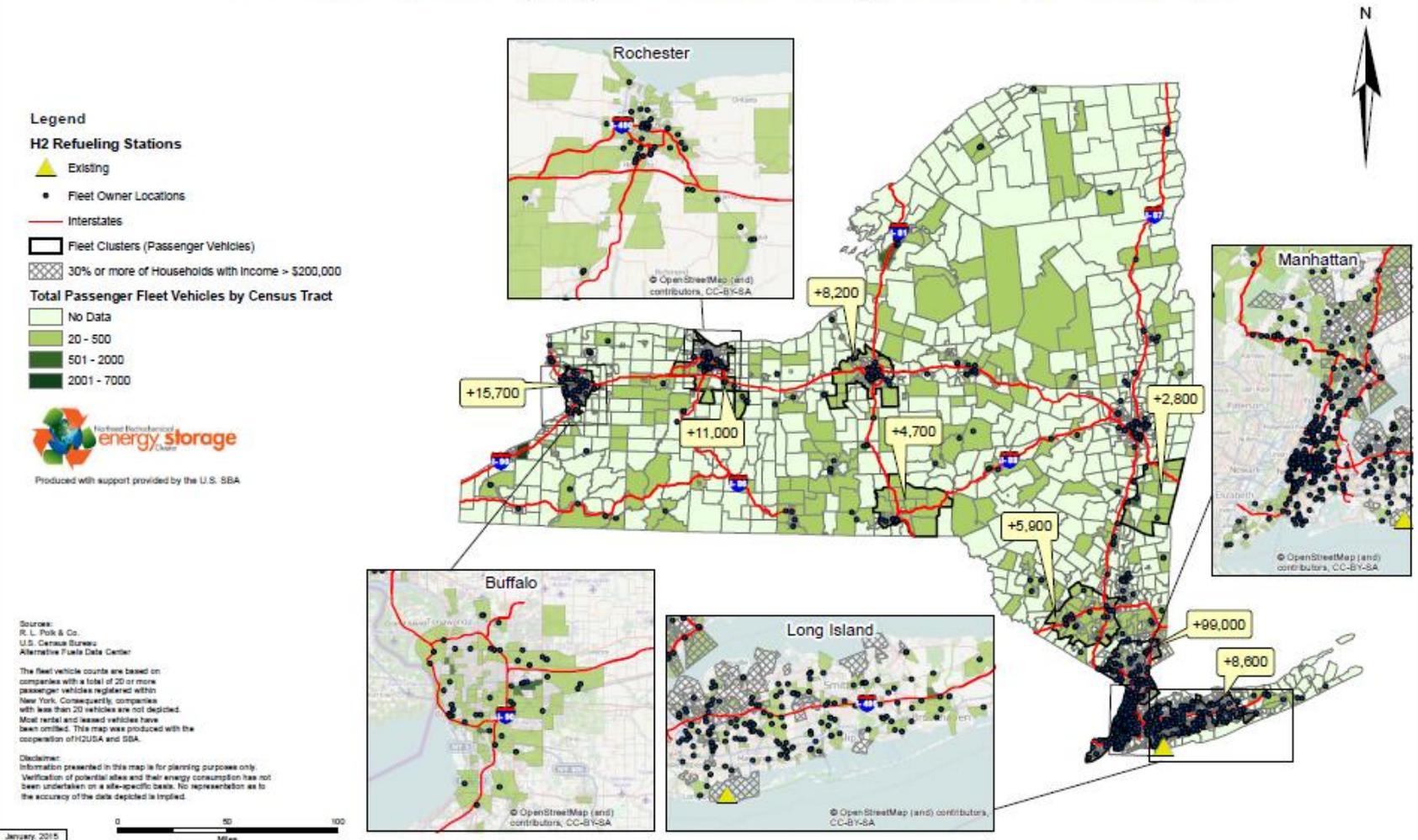


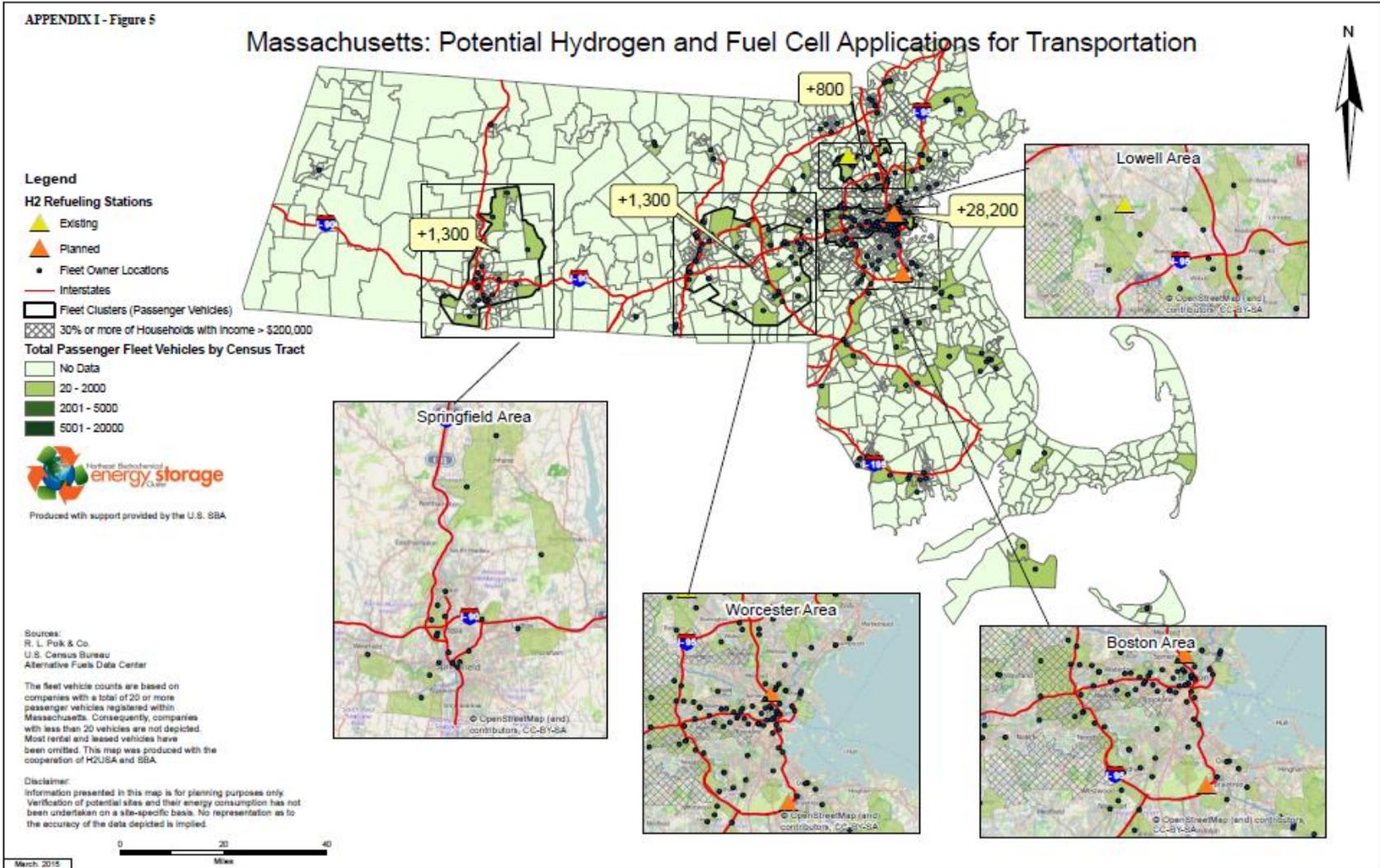
January 2015



APPENDIX I - Figure 4

New York: Potential Hydrogen and Fuel Cell Applications for Transportation





APPENDIX I - Figure 6

Rhode Island: Potential Hydrogen and Fuel Cell Applications for Transportation

Legend

- Fleet Owner Locations
 - Interstates
 - ▭ Fleet Clusters (Passenger Vehicles)
 - ▨ 30% or more of Households with income > \$200,000
- Total Passenger Fleets by Census Tract**
- No Data
 - 1 - 100
 - 101 - 500
 - 501 - 700

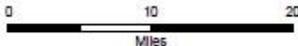


Produced with support provided by the U.S. SBA

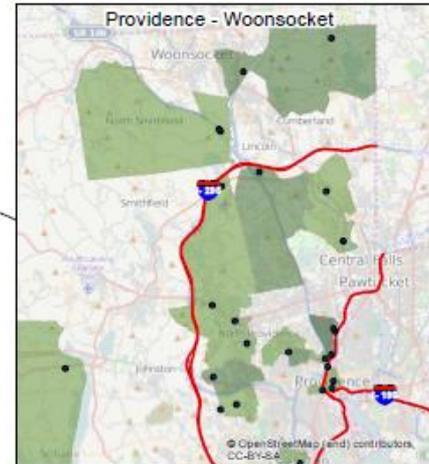
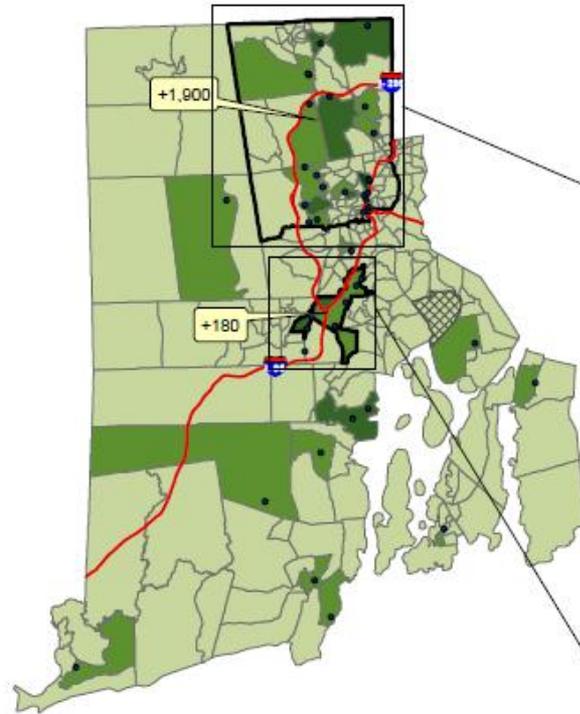
Source:
R. L. Polk & Co.
U.S. Census Bureau

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

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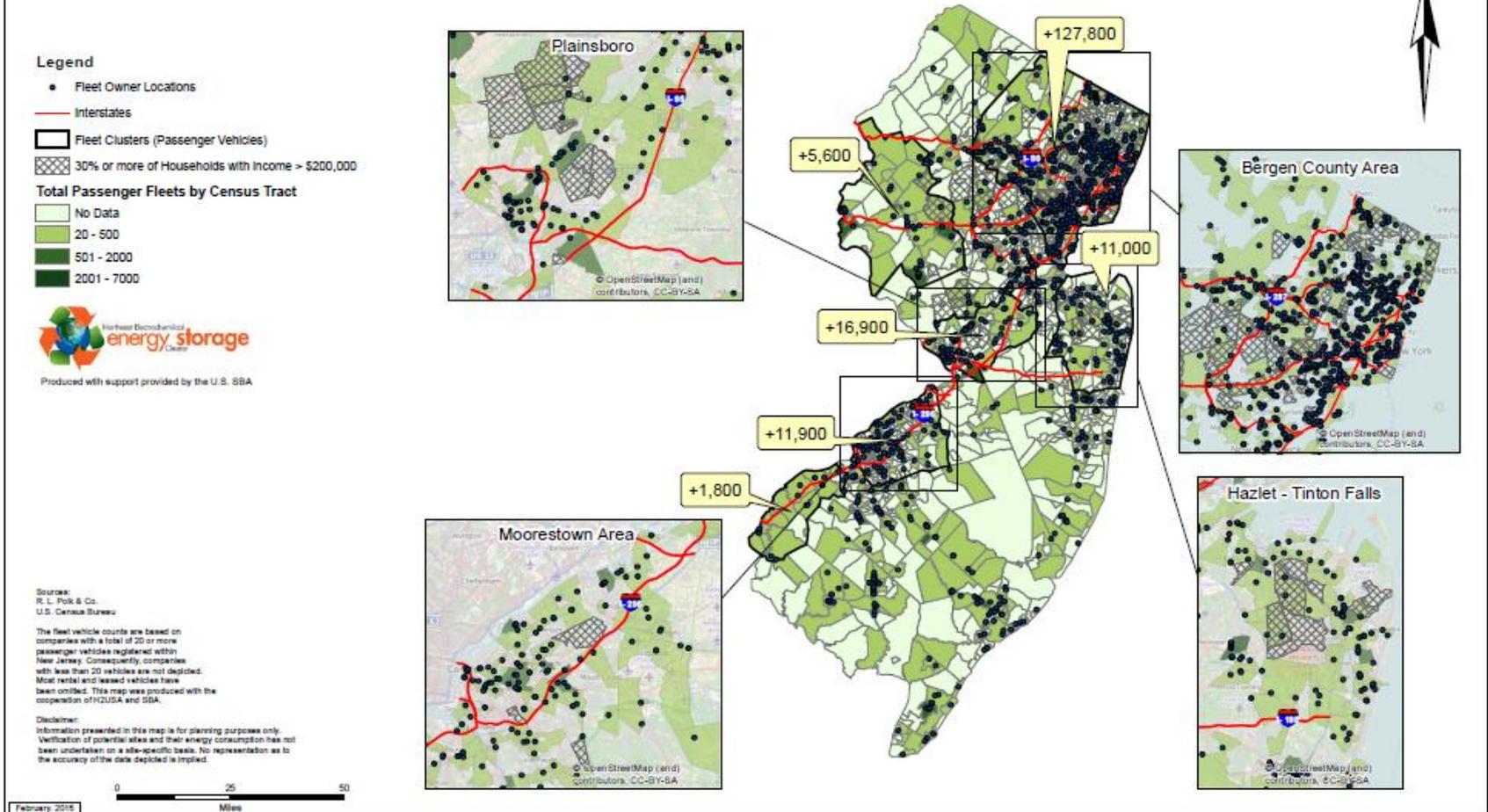


January 2015



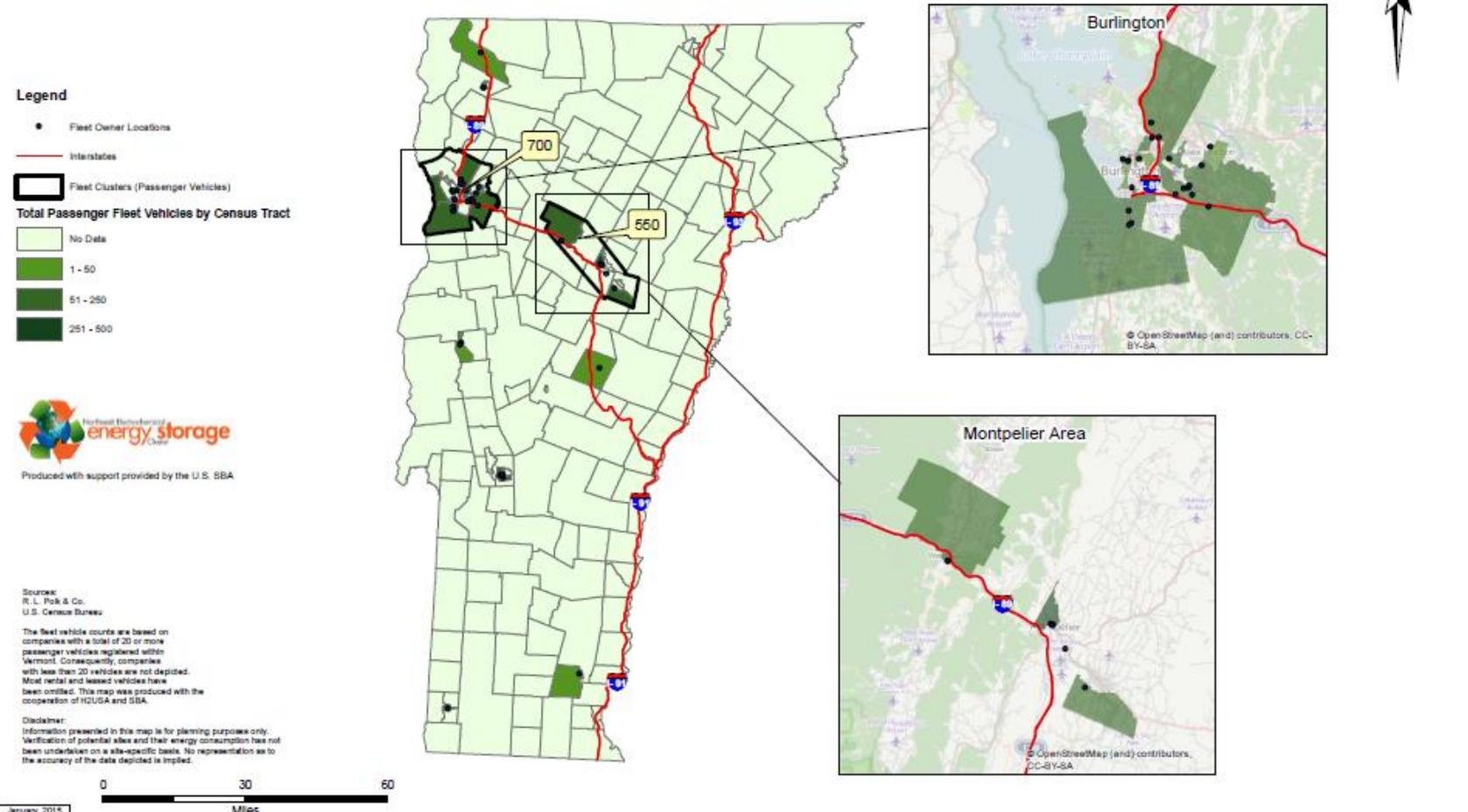
APPENDIX I - Figure 7

New Jersey: Potential Hydrogen and Fuel Cell Applications for Transportation



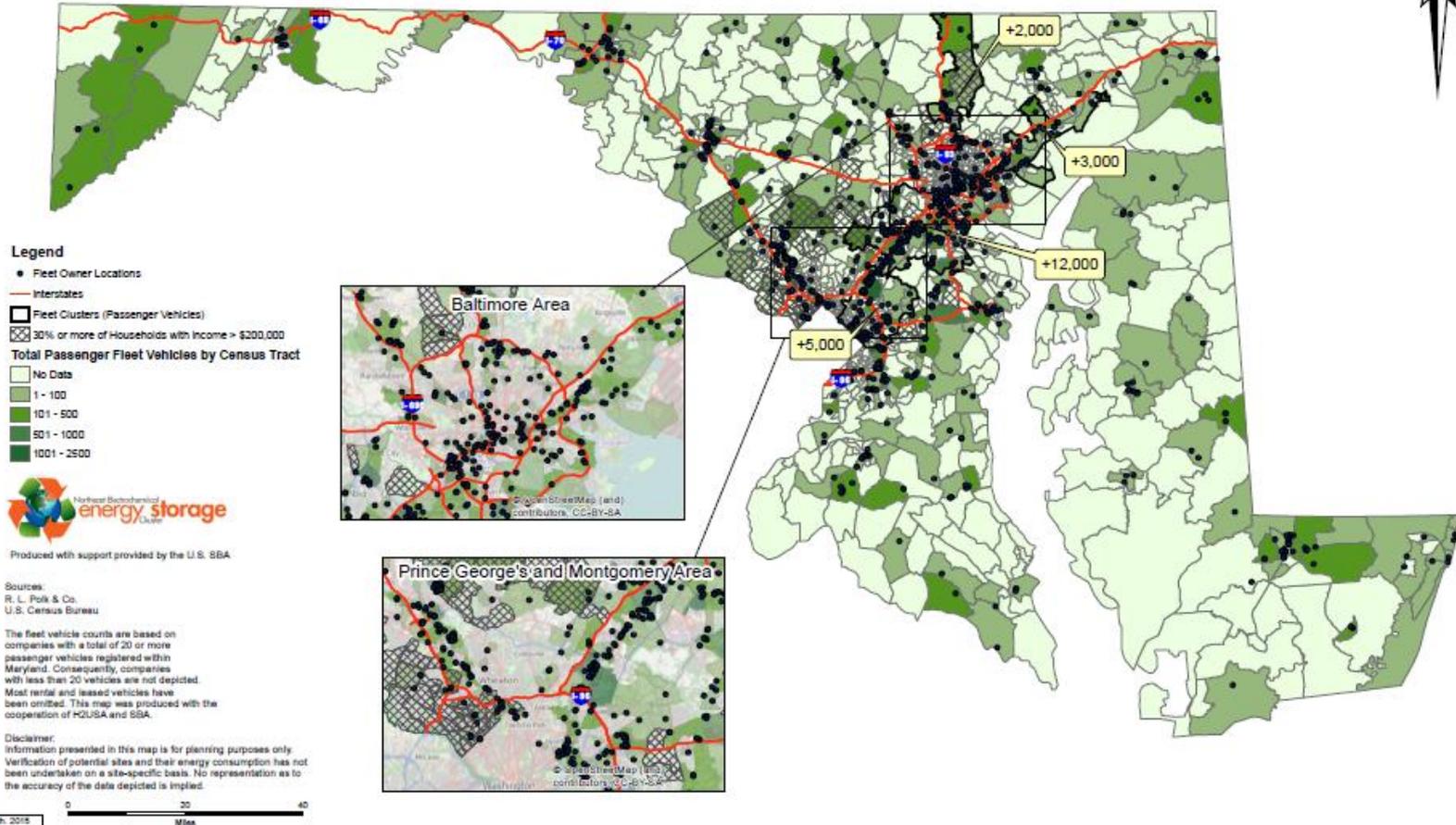
APPENDIX I - Figure 8

Vermont: Potential Hydrogen and Fuel Cell Applications for Transportation



APPENDIX I - Figure 9

Maryland: Potential Hydrogen and Fuel Cell Applications for Transportation



- Electrolysis
 - Solar
 - Wind
- WWTPs
- Anaerobic Digestion
- Steam Reformation
- CHHP
- H₂ Users/Producers



WWTP/Anaerobic Digestion



Steam Reformation



Wind-Powered
Electrolysis



Solar-Powered Electrolysis



CHHP (Tri-generation)