



# ***Tri-Generation Fuel Cell Technologies for Location-Specific Applications***

**Project ID: AN047**

**Kersey Manlicic**

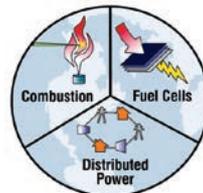
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**Advanced Power and Energy Program**

**University of California, Irvine**

**June 17, 2014**



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# Overview

## Timeline

- State date – January 2014
- End date – January 2015
- Percent complete – 35%

## Budget

- Total funding spent as of 3/31/14:  
\$4,267
- Total DOE Project Value:  
\$149,967

## Barriers & Targets

- Future market behavior
- Siloed analytical capability
- Unplanned studies and analysis
- **Target:** Work with industry and other stakeholders to assess and identify infrastructure scenarios and options for both long term transportation needs and early market opportunities for hydrogen and fuel cells

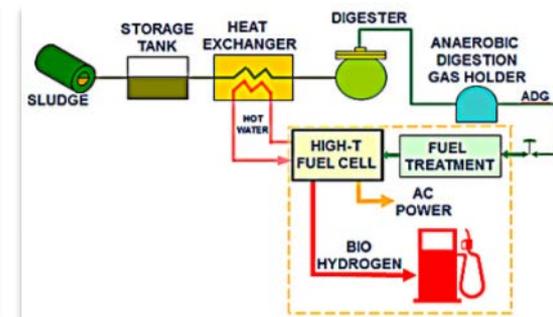
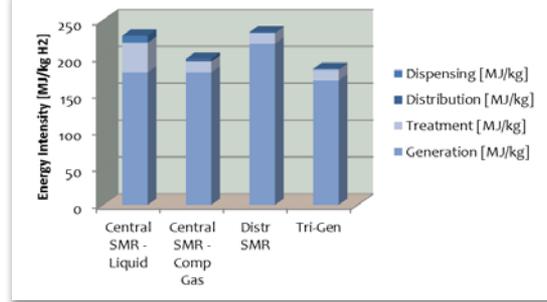
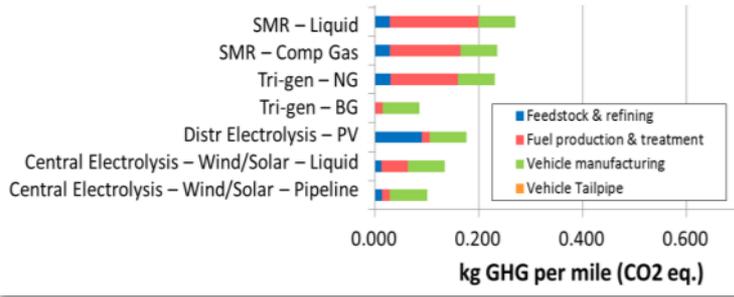
## Partners

- National Renewable Energy Laboratory (NREL)
- Toyota
  - Market Data / Perspective



# Relevance – Objectives

- Limited hydrogen refueling infrastructure remains major barrier to FCEV commercialization
- To achieve significant carbon reductions, hydrogen must be produced renewably
- High temperature tri-generation fuel cell systems → highly effective use of biogas resources



## Objectives

- Assess potential number and location of tri-generation fuel cells, producing electricity, heat, and hydrogen, in an early fuel cell electric vehicle (FCEV) market scenario (circa 2015) in NY, NJ, CT, MA
  - Consider use of natural gas and anaerobic digester gas as feedstock
  - Also consider viability of the Tri-Gen units serving as a local hub for hydrogen production

## Targets Addressed

- Strategic siting of Tri-Gen for effective use of biogas to serve early FCEV markets



# Milestones

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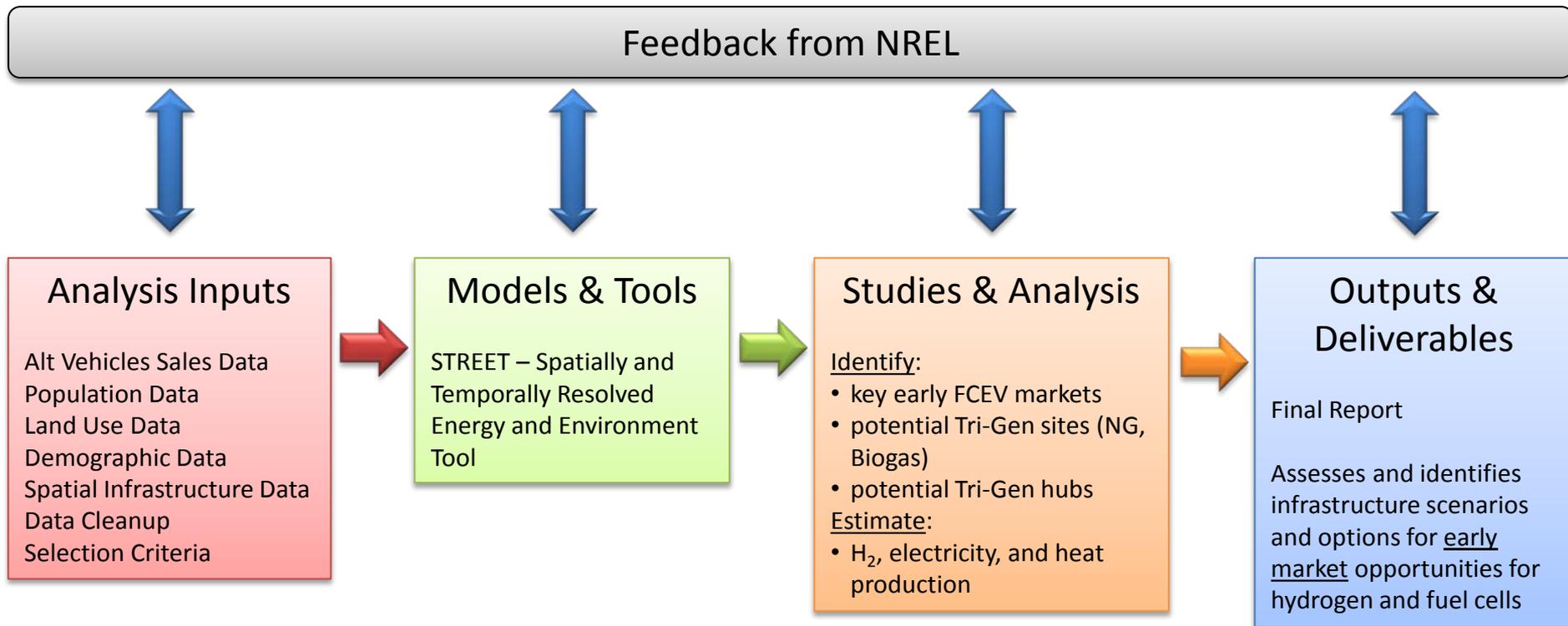


- **February 2014**
  - Kickoff meeting with National Renewable Energy Laboratory (NREL)
  
- **Intermediate Briefing**
  - **July 2014**
  
- **Draft Final Report**
  - **Oct 2014**
  
- **Final Report and Briefing**
  - **Jan 2015**

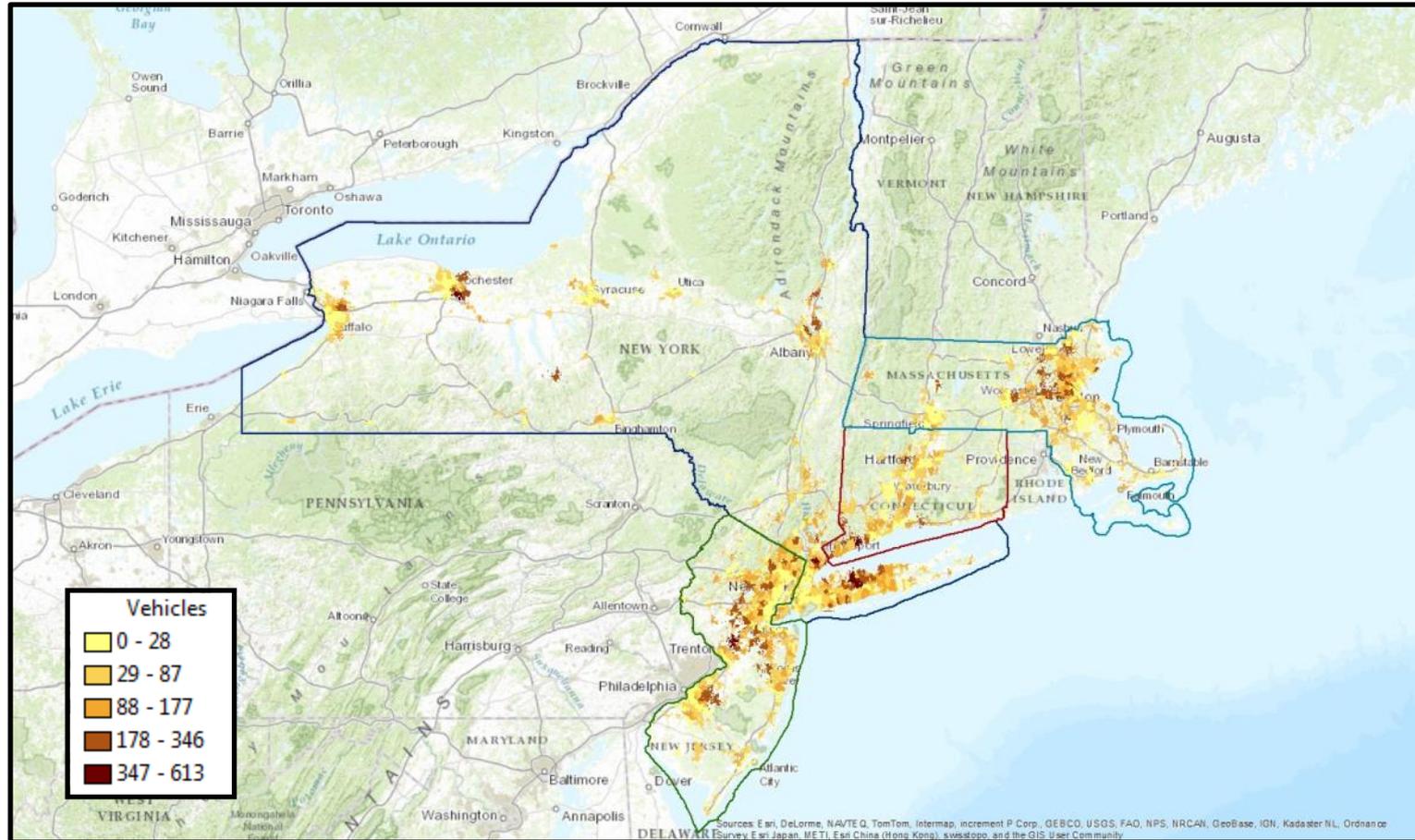


# Approach

- Project Overview



# Approach: *Alternative Vehicle Sales*



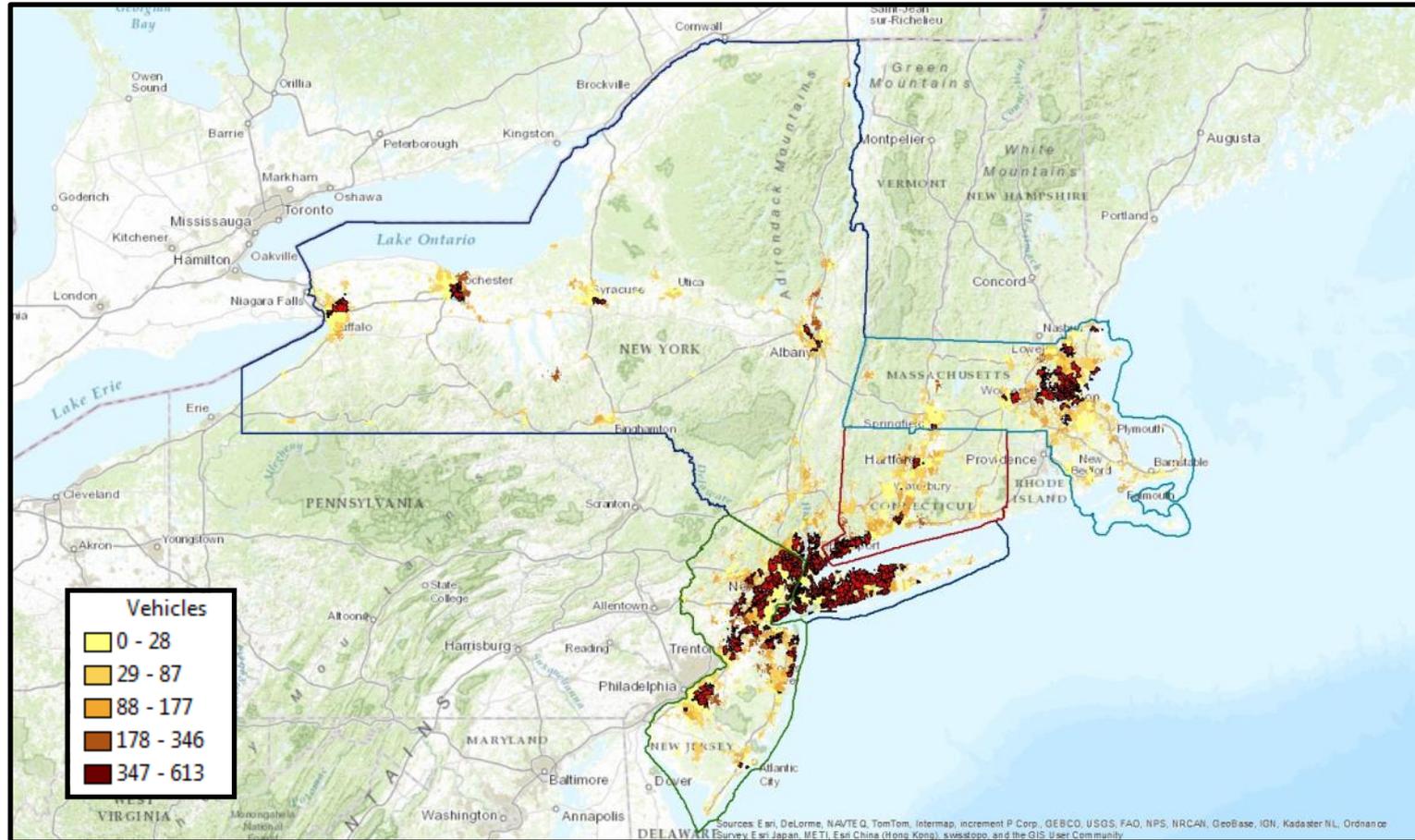
- 4 year sales data (Zip code basis)
- NY, NJ, CT, and MA
- Hybrids, Electric Vehicles, and Natural Gas Vehicles (Household Income > \$75,000)
- 95,048 vehicles



- **High resolution population data**
  - Bring higher resolution and fidelity to the location of sales
  - Omit rural areas



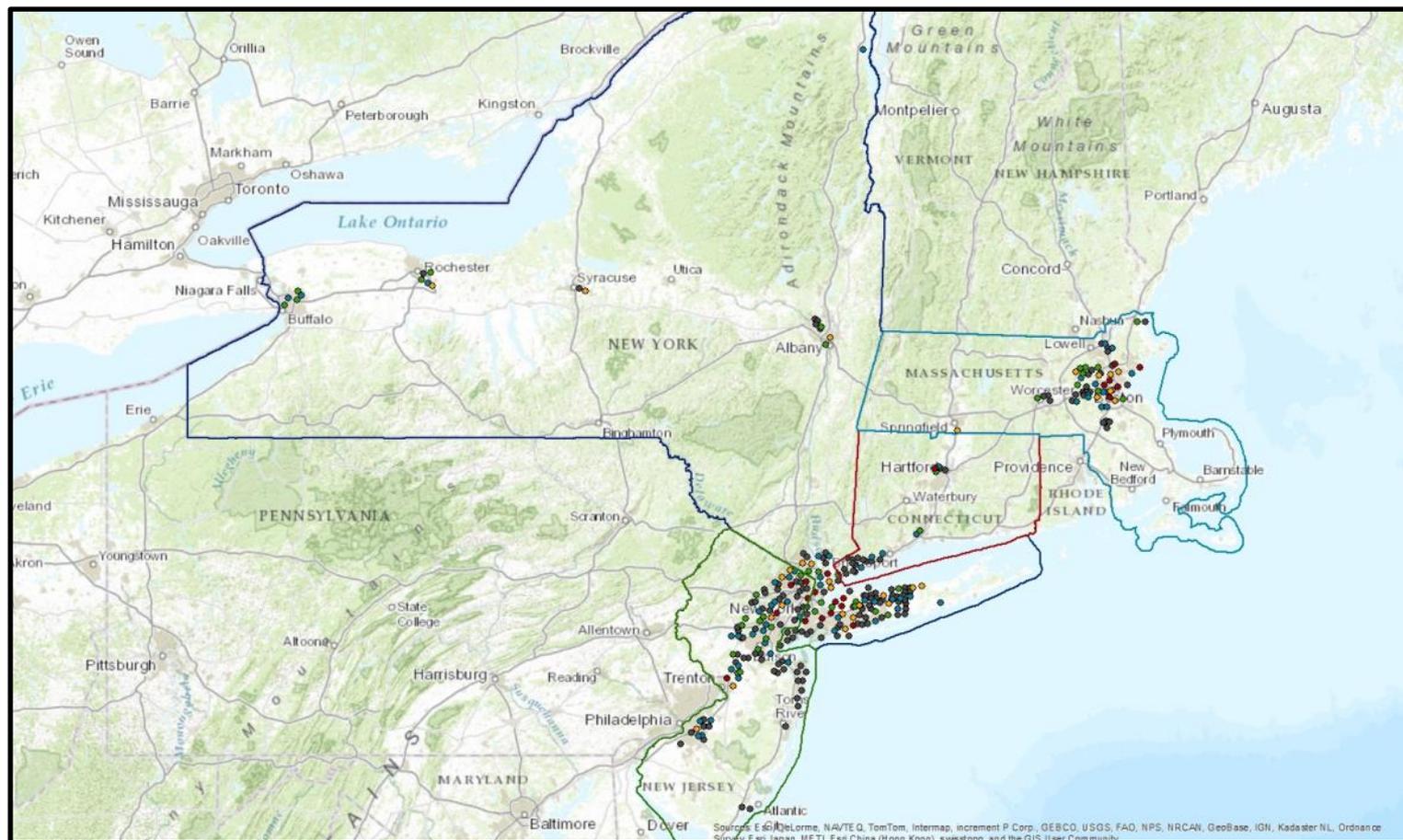
# Approach: *Alternative Vehicle Sales*



- Look at Top-50% of zip codes in terms of sales/density (red)
- 47,542 vehicles
- Determine the # of stations needed to provide 6 minute service coverage and rollout stations most effectively.



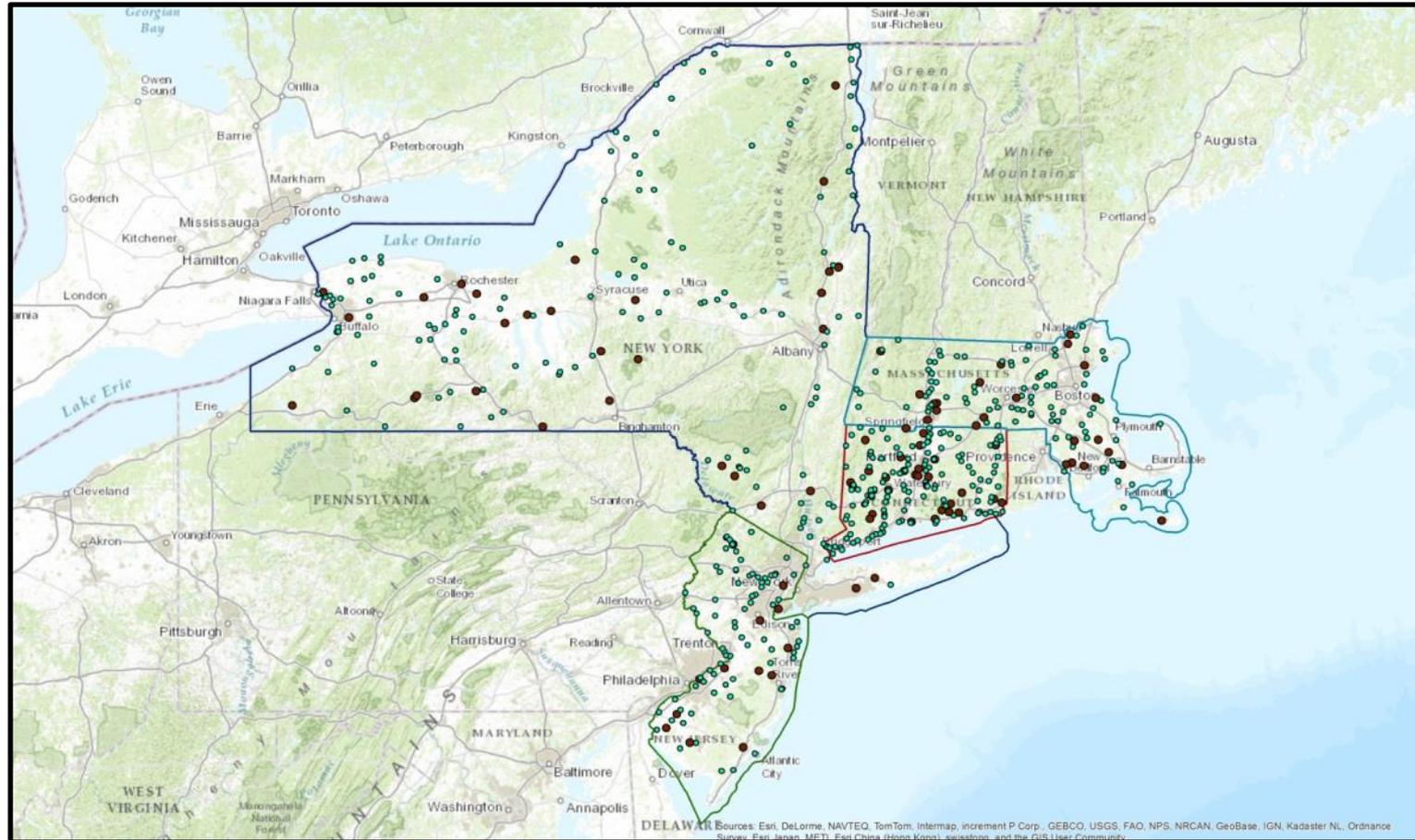
# Approach: *Alternative Vehicle Sales*



- Recall goal is Top-50% of Sales: 47,542 vehicles
- 21 H<sub>2</sub> stations covers 11,368 vehicles (20% of goal)
- 51 H<sub>2</sub> stations covers 20,558 vehicles (40% of goal)
- 92 H<sub>2</sub> stations covers 29,150 vehicles (60% of goal)
- 150 H<sub>2</sub> stations covers 38,517 vehicles (80% of goal)
- 313 H<sub>2</sub> stations covers 53,114 vehicles (+100% of goal)



# Approach: *WWTPs & Landfills as candidate locations*



- **451 Wastewater Treatment Plants (WWTPs): NY (135), MA (91), NJ (86), and CT (139)**
- **96 Landfills: NY (32), MA (23), NJ (13), and CT (28)**



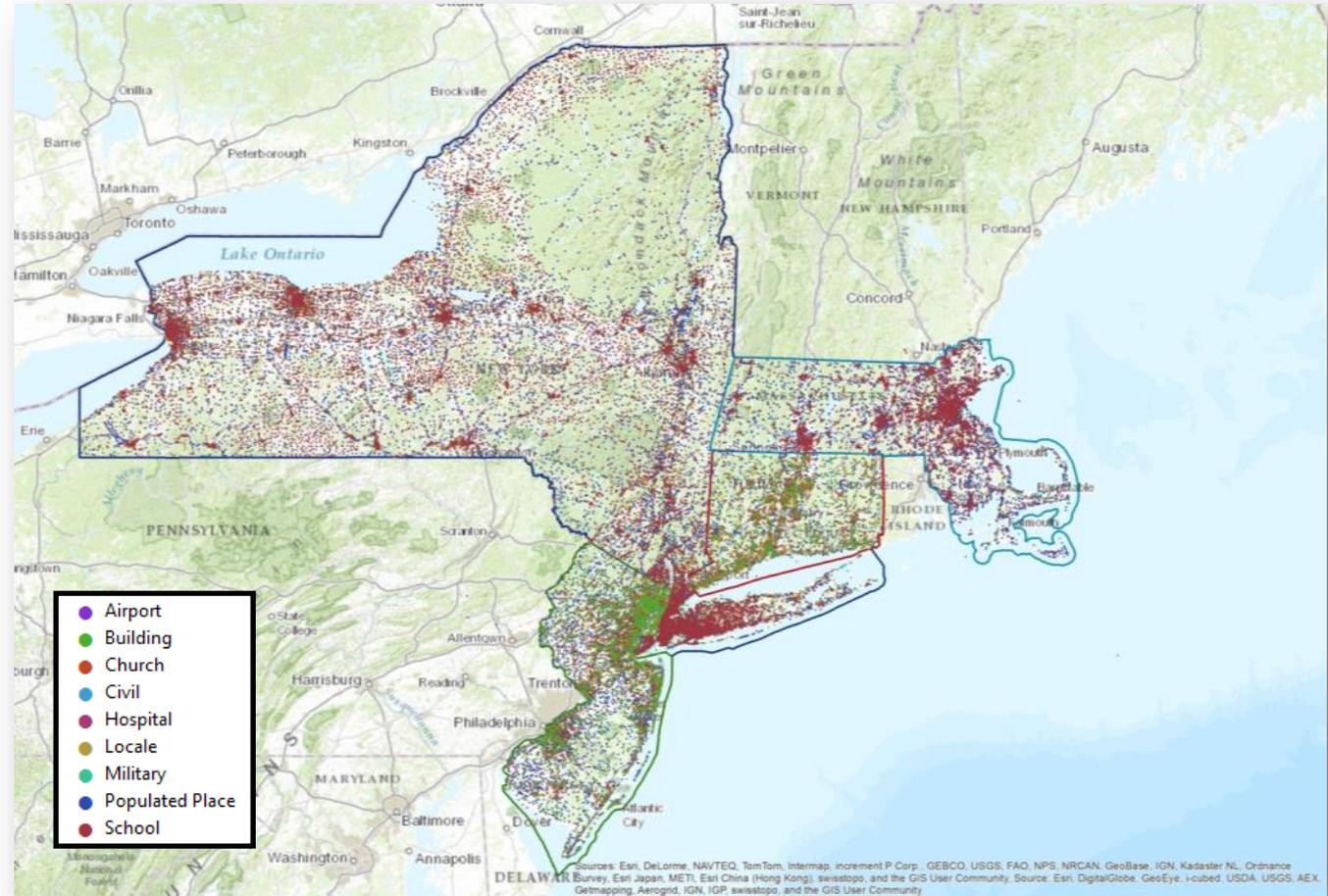
# Approach: *Potential Heating and Electrical Loads*

## Data

- U.S. Dept. of the Interior, USGS, and the United States Board of Geographic Names
- **Locations:**
  - **Airports**
  - **Buildings**
  - **Churches**
  - **Civil**
  - **Hospitals**
  - **Locales**
  - **Military**
  - **Populated Places**
  - **Schools**

## "The #'s"

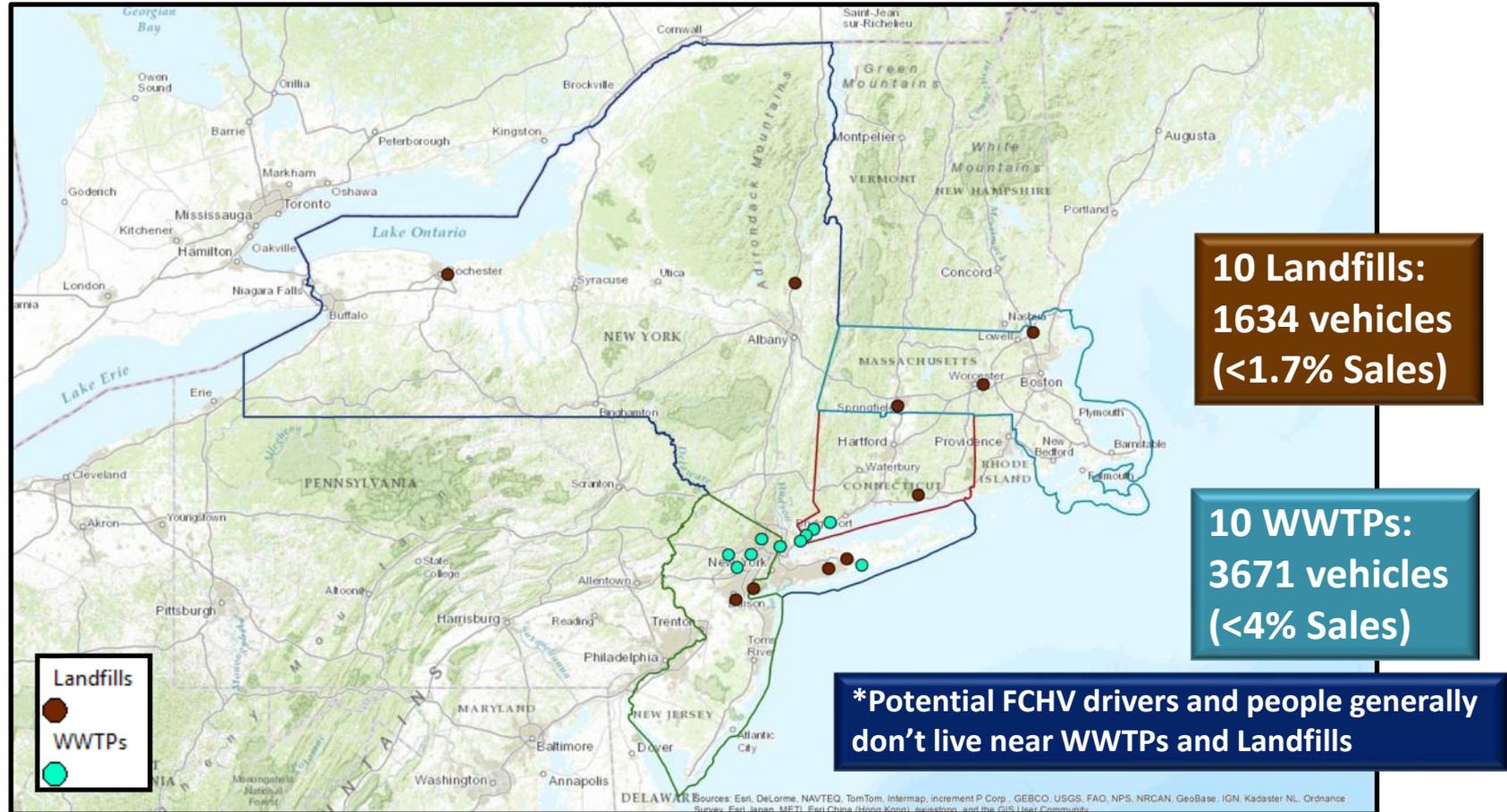
- **NY (45,803)**
- **NJ (14,858)**
- **CT (8,858)**
- **MA (12,931)**



Identifying heating and electrical loads for Tri-Gen systems seems encouraging & promising



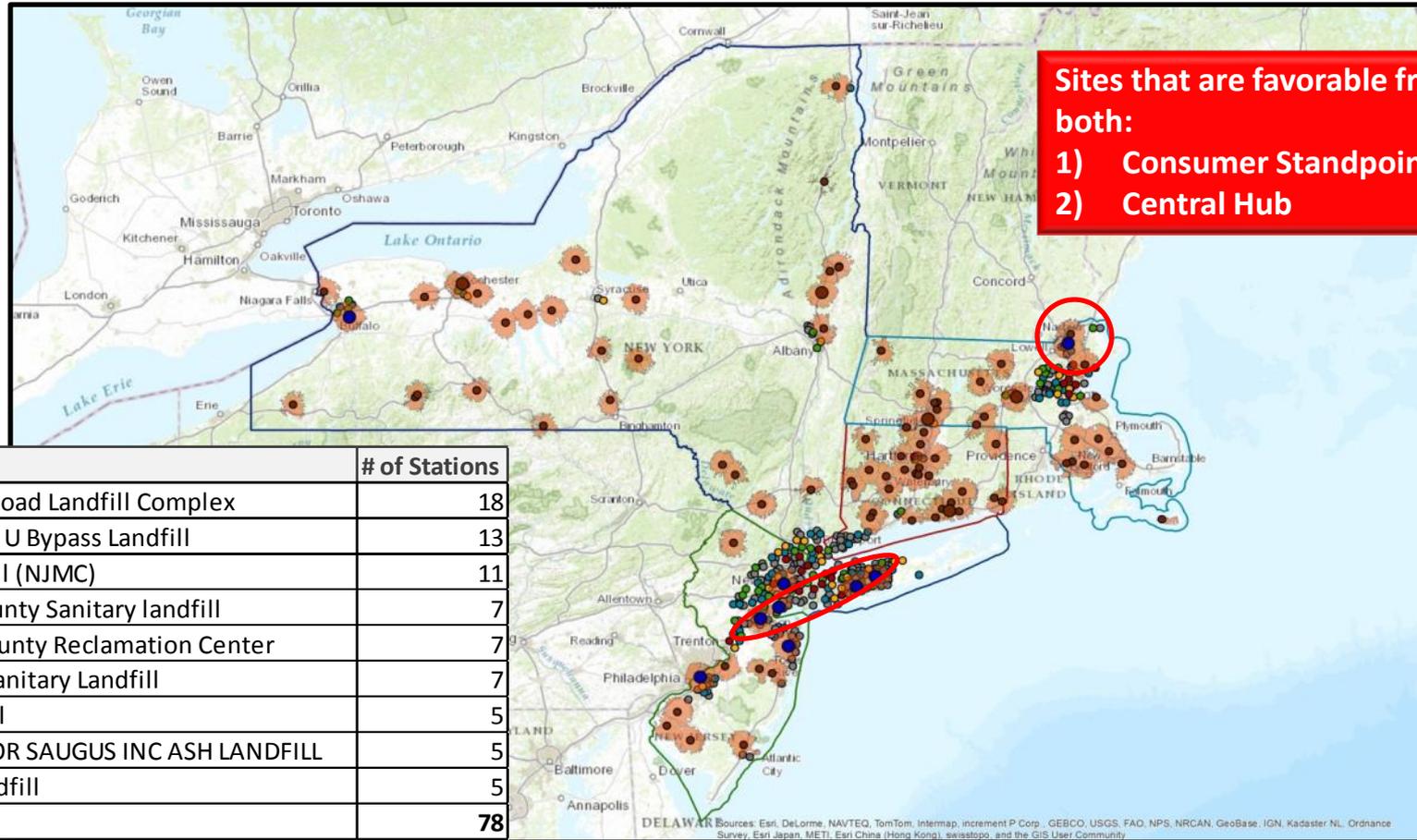
# Results and Progress: *Best sites...market perspective*



- For the 451 wastewater treatment plants and 96 landfills, respectively, we determined the 6 minute drive time service coverage .
- Based on the # of alternative vehicles covered, we ranked and obtained the Top 10 WWTPs and Landfills



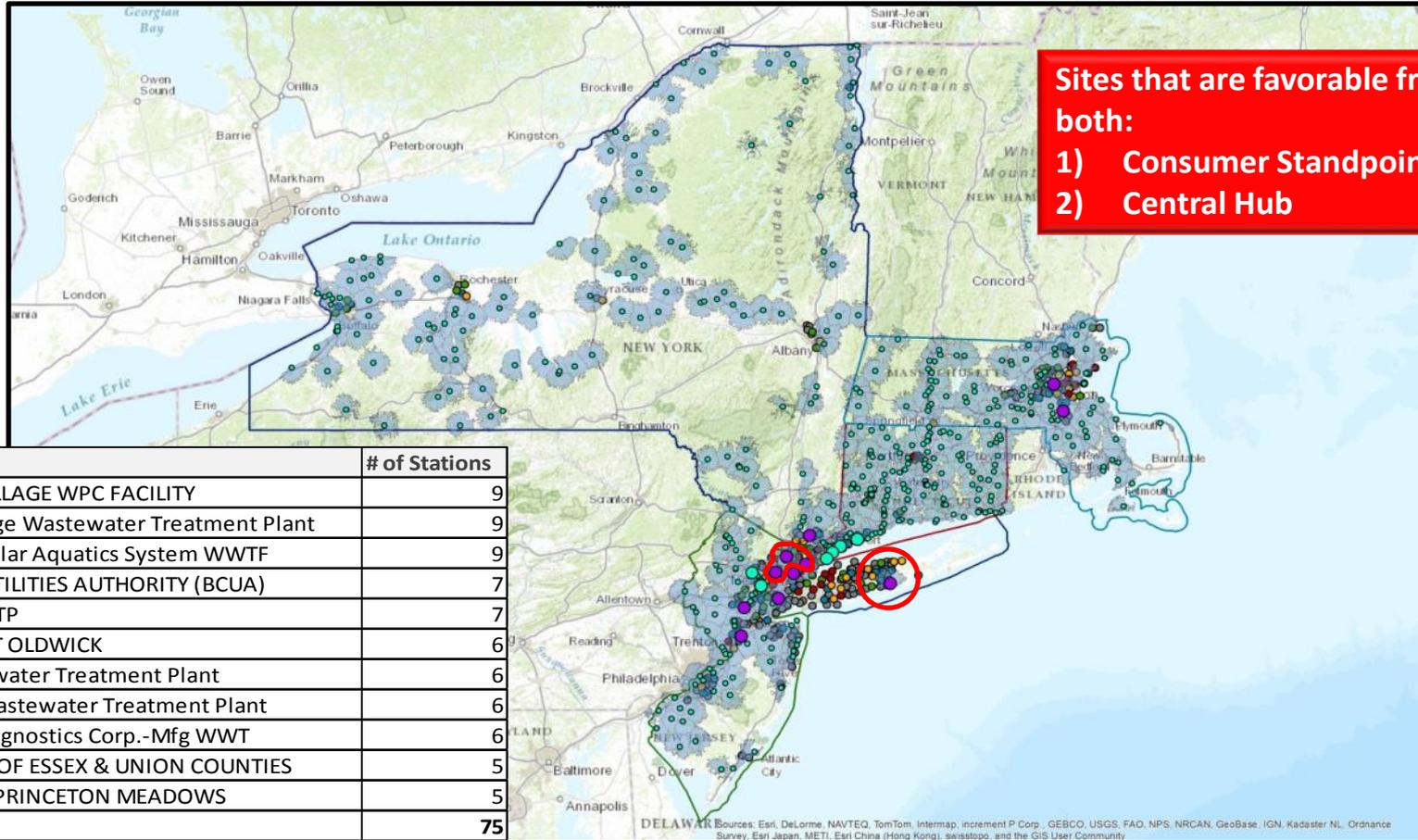
# Results and Progress: *Landfills as Central Hubs Supplying H<sub>2</sub>*



- **96 Landfills (Top 10 from a sales perspective)**
- **Bring back our 313 station solution, serves as our hydrogen station network**
- **10 mile distance coverage from each landfill**
- **9 Landfills that could serve 5 or more stations**



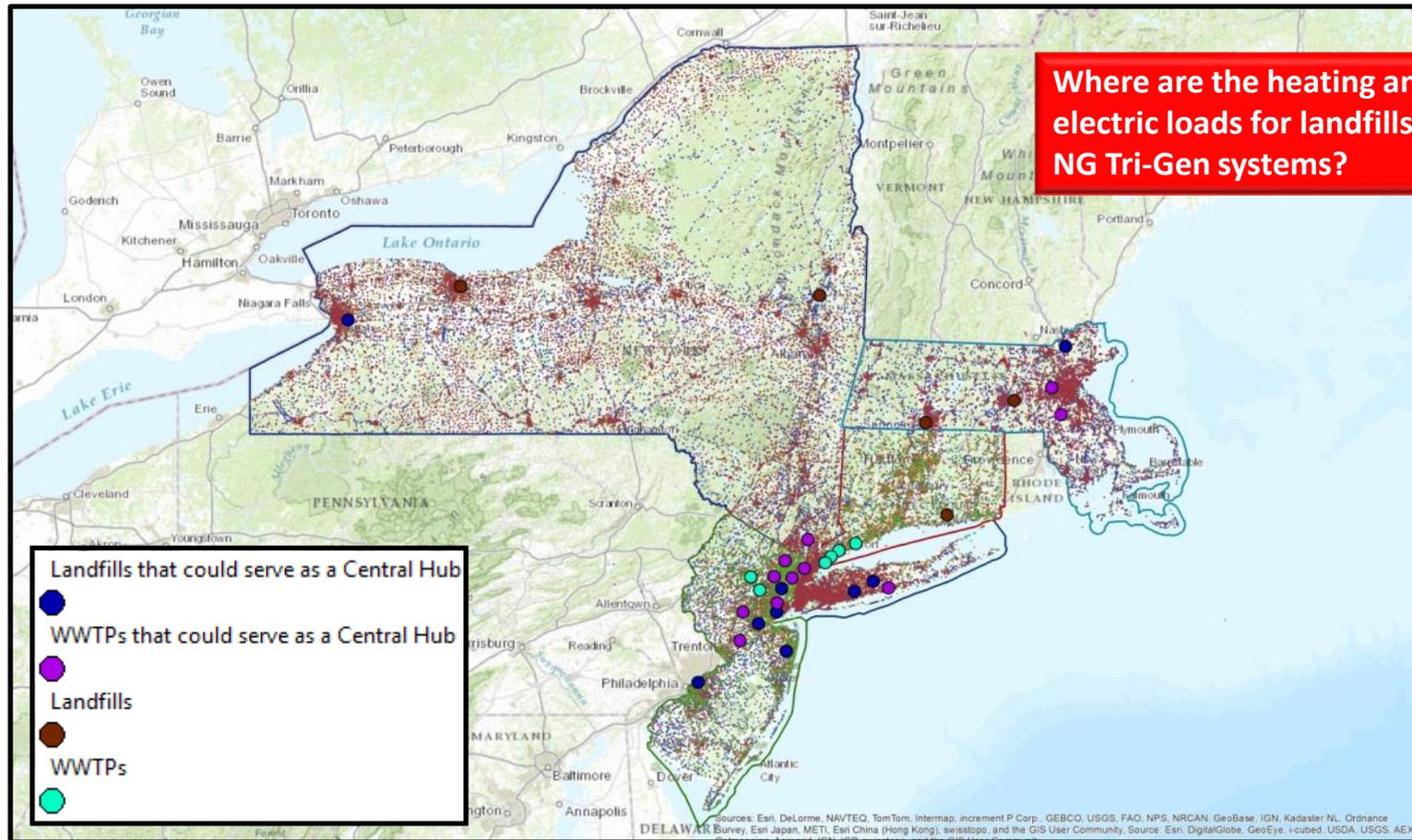
# Results and Progress: *WWTPs as Central Hubs Supplying H<sub>2</sub>*



- 451 WWTPs (Top 10 from a sales perspective)
- Bring back our 313 station solution, serves as our hydrogen station network
- 10 mile distance coverage from each landfill
- 11 WWTPs that could serve 5 or more stations



# Results and Progress: *Potential Heating and Electrical Loads*



- Recall Top Landfills identified (Market Perspective or Central Hub)
- Recall Top 51 H2 refueling stations for Tri-gen using NG
- Recall USGS "locations" data
- **400, 800, 1200, 1600** , and **2000** foot radial buffer for each of the sites



# Results and Progress: *Potential Heating and Electrical Loads Proof of Concept*

## Landfills

Potential heating/elec loads:

- **400 feet = 8 sites**
- **800 feet = 13 sites**
- **1200 feet = 15 sites**
- **1600 feet = 18 sites**
- **2000 feet = 25 sites**

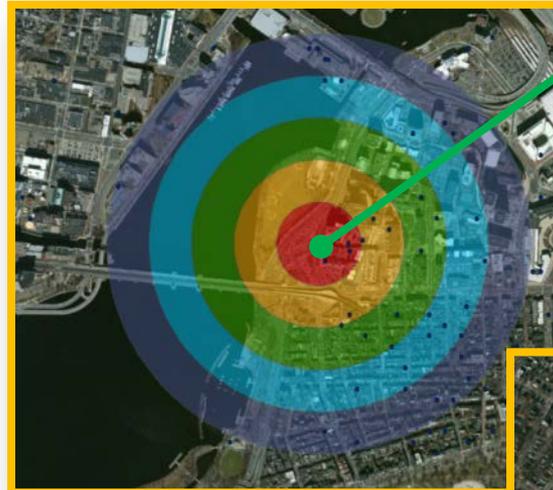


- Pennsauken Sanitary Landfill (NJ)
- Pennsauken High School

## NG Tri-gen

Potential heating/elec loads:

- **400 feet = 21 sites**
- **800 feet = 76 sites**
- **1200 feet = 124 sites**
- **1600 feet = 215 sites**
- **2000 feet = 316 sites**

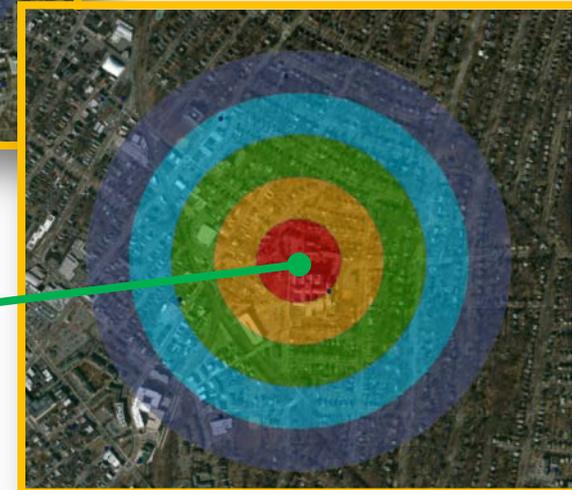


- Glen Ridge, NJ
- Grace Presbyterian Church
  - Grove Street School
  - Mountainside Hospital
  - Washington School
  - Our Lady of Mount Carmel Church

**NG fueled Tri-Gen systems likely to have a greater impact**

Boston, MA

- Museum of Science Heliport
- Hayden Planetarium
- Museum of Science
- Mugar Omni Theater
- Palmer-Davis Library
- West End Branch Boston Public Library
- Boston Fire Department Station 4
- Charles River Park Synagogue
- Saint Josephs Catholic Church
- Massachusetts General Hospital
- Shriners Hospital for Children
- Calvin Coolidge College
- Phillips School



# Collaborations

## Primary Collaborator

- National Renewable Energy Laboratory



## Secondary Collaborator

- Toyota (market data and perspective)



## Leveraging past and current collaborators

- DOE Biogas Tri-Gen Demonstration
  - National Fuel Cell Research Center
  - Orange County Sanitation District
  - FuelCell Energy
  - Air Products



# Future Work

- **Sensitivity studies:**
  - **Effect of vehicle sales data selection on key market distribution**
  - **Selection criteria**
    - **Service coverage**
    - **Proximity to infrastructure / loads**
- **Complete acquisition and cleanup of data**
  - **Will require contacting sites for additional needed information**
- **Complete identification of Tri-gen sites**
- **Complete identification of Tri-gen hubs**
- **Estimate hydrogen, electricity, and heat production from Tri-gen sites**



# Summary

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- **Data collected provides locational information, but lacks other information, e.g., size/capacity, seasonal variation, etc.**
- **Cursory analysis shows:**
  - **wastewater treatment plants and landfills likely not good candidate sites for on-site refueling in early FCEV market**
  - **wastewater treatment plants and landfills likely to be Tri-gen hubs**
- **Proximity to heating loads an issue for Tri-gen units not at WWTPs**
- **Natural gas fueled Tri-gen systems likely to have greatest impact**



# Acronyms

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- Dept. of Energy (DOE)
- Fuel Cell Electric Vehicle (FCEV)
- Landfill (LF)
- Natural Gas (NG)
- National Renewable Energy Laboratory (NREL)
- Spatially and Temporally Resolved Energy and Environment Tool (STREET)
- United States Geological Survey (USGS)
- Wastewater Treatment Plant (WWTP)

