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

## Project ID: AN047

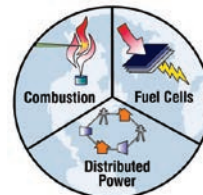**Kersey Manliclic**

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**June 17, 2014**

# Overview

## Timeline

- State date – January 2014

- End date – January 2015

- Percent complete – 35%

## 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

## Budget

- Total funding spent as of 3/31/14: $4,267

- Total DOE Project Value: $149,967

## 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**
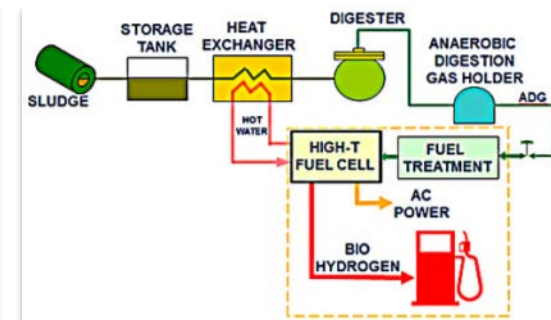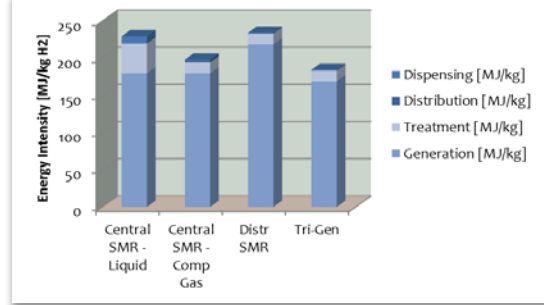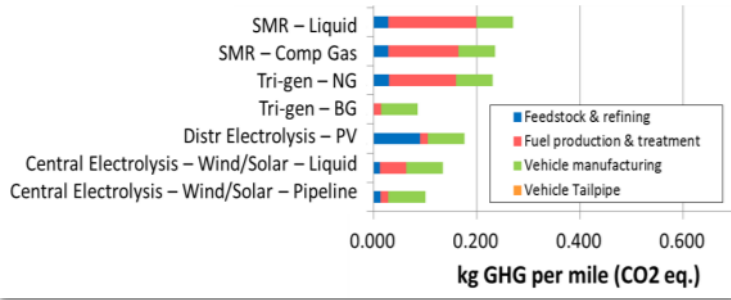


## Objectives

- **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

- **February 2014**
    - Kickoff meeting with National Renewable Energy Laboratory (NREL)
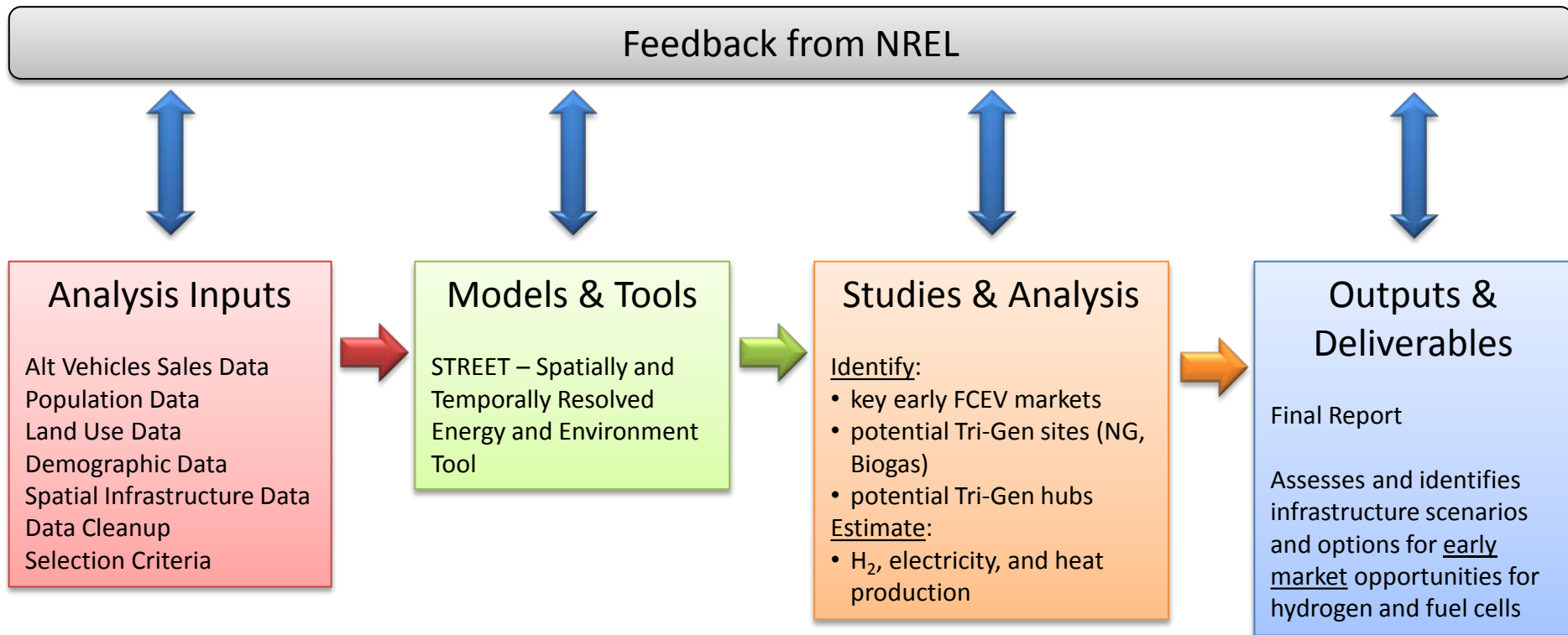
- **Intermediate Briefing**
    - **July 2014**

- **Draft Final Report**
    - **Oct 2014**

- **Final Report and Briefing**
    - **Jan 2015**

# Approach

- Project Overview

| Feedback from NREL |
|---|

## Analysis Inputs

Alt Vehicles Sales Data
Population Data
Land Use Data
Demographic Data
Spatial Infrastructure Data
Data Cleanup
Selection Criteria

## Models & Tools

STREET – Spatially and Temporally Resolved Energy and Environment Tool

## Studies & Analysis

Identify:
- key early FCEV markets
- potential Tri-Gen sites (NG, Biogas)
- potential Tri-Gen hubs

Estimate:
- $H_2$, electricity, and heat production

## Outputs & Deliverables

Final Report

Assesses and identifies infrastructure scenarios and options for early market opportunities for hydrogen and fuel cells

# Approach: *Alternative Vehicle Sales*



Vehicles
- 0 - 28
- 29 - 87
- 88 - 177
- 178 - 346
- 347 - 613

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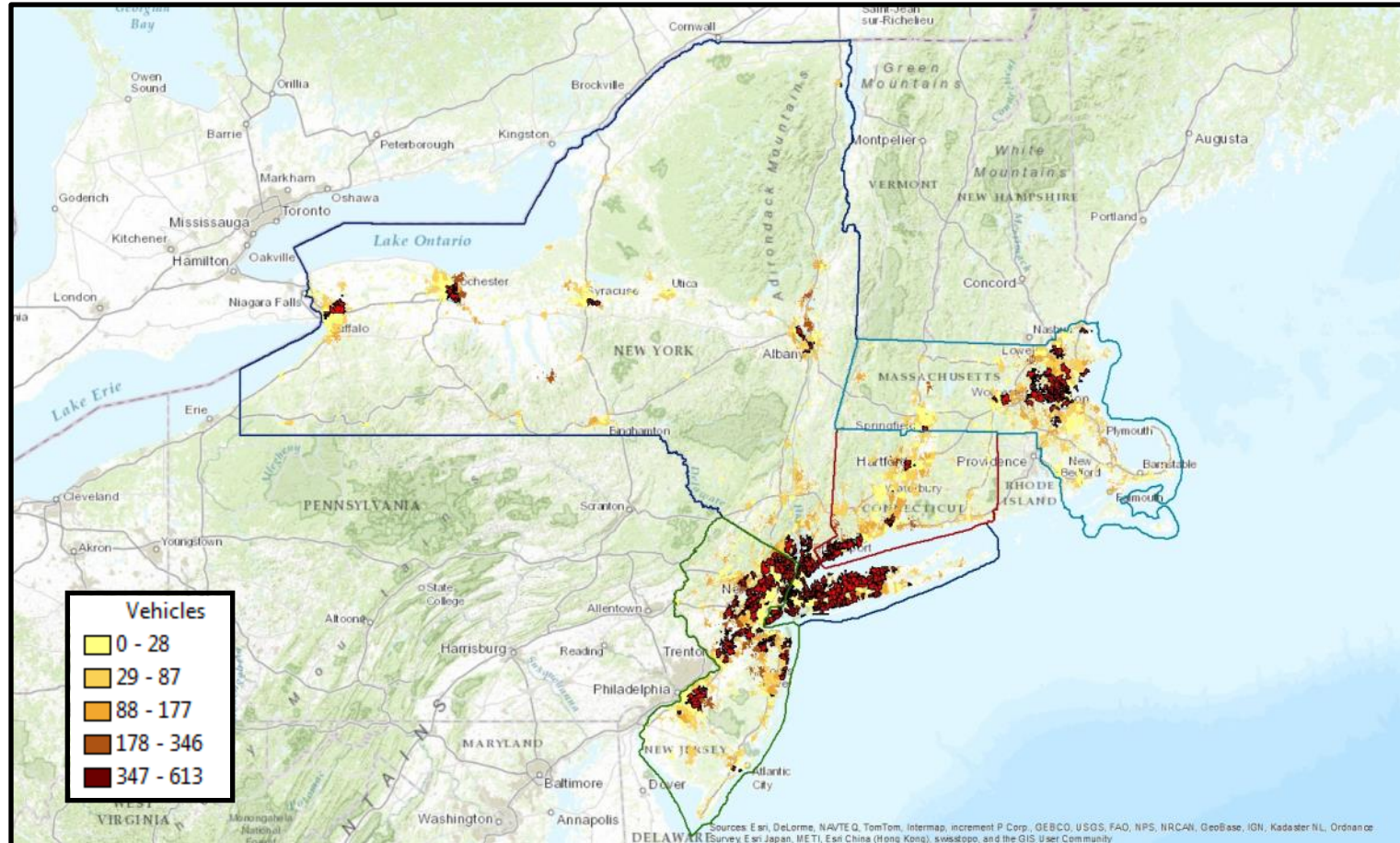- • **Hybrids, Electric Vehicles, and Natural Gas Vehicles (Household Income > $75,000)**
- • **95,048 vehicles**

**+**

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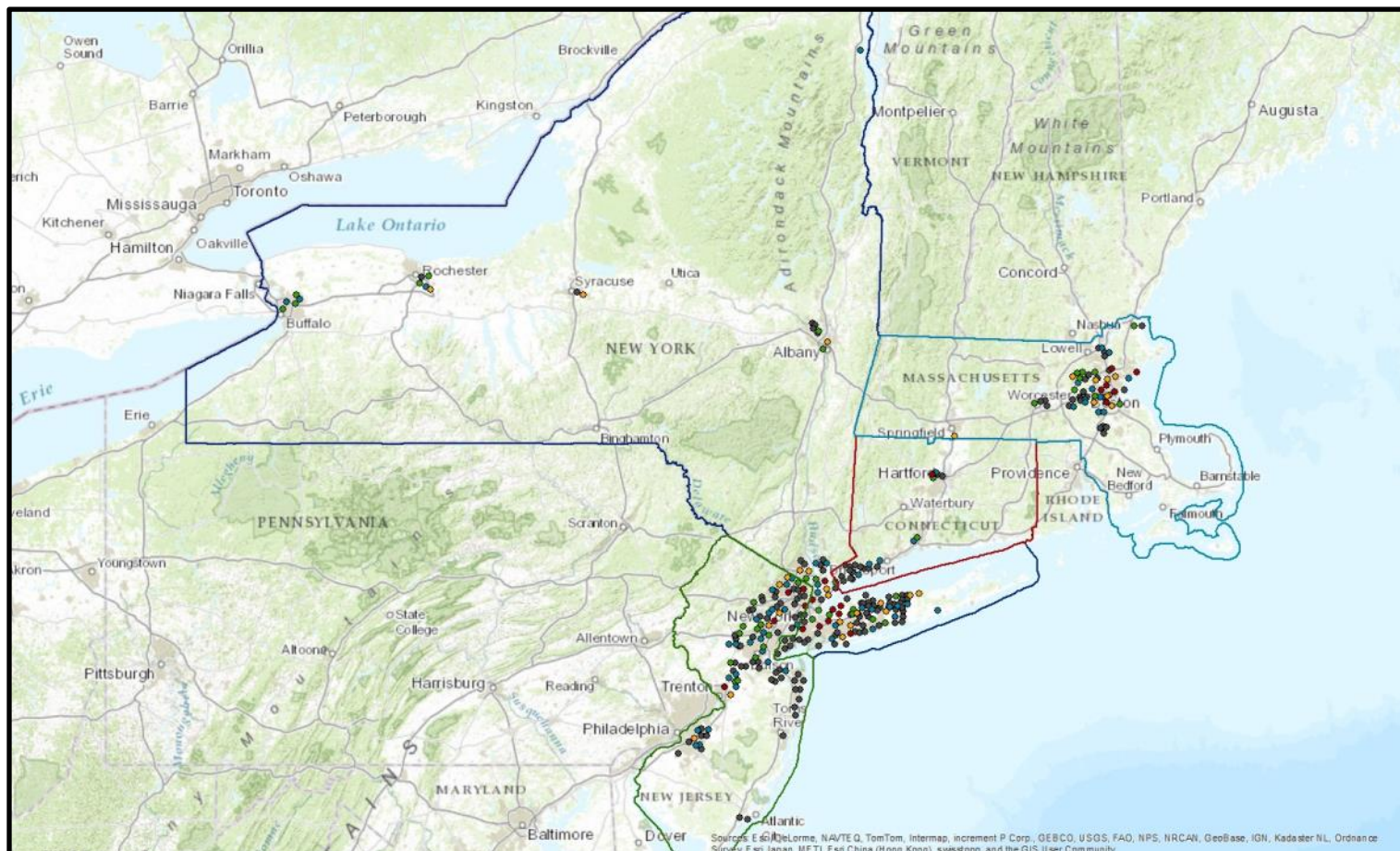  - • **Omit rural areas**

# 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$_2$ stations covers 11,368 vehicles (20% of goal)**
- **51 H$_2$ stations covers 20,558 vehicles (40% of goal)**
- **92 H$_2$ stations covers 29,150 vehicles (60% of goal)**
- **150 H$_2$ stations covers 38,517 vehicles (80% of goal)**
- 313 H$_2$ stations covers 53,114 vehicles (+100% of goal)

# Approach: *WWTPs & Landfills as candidate locations*
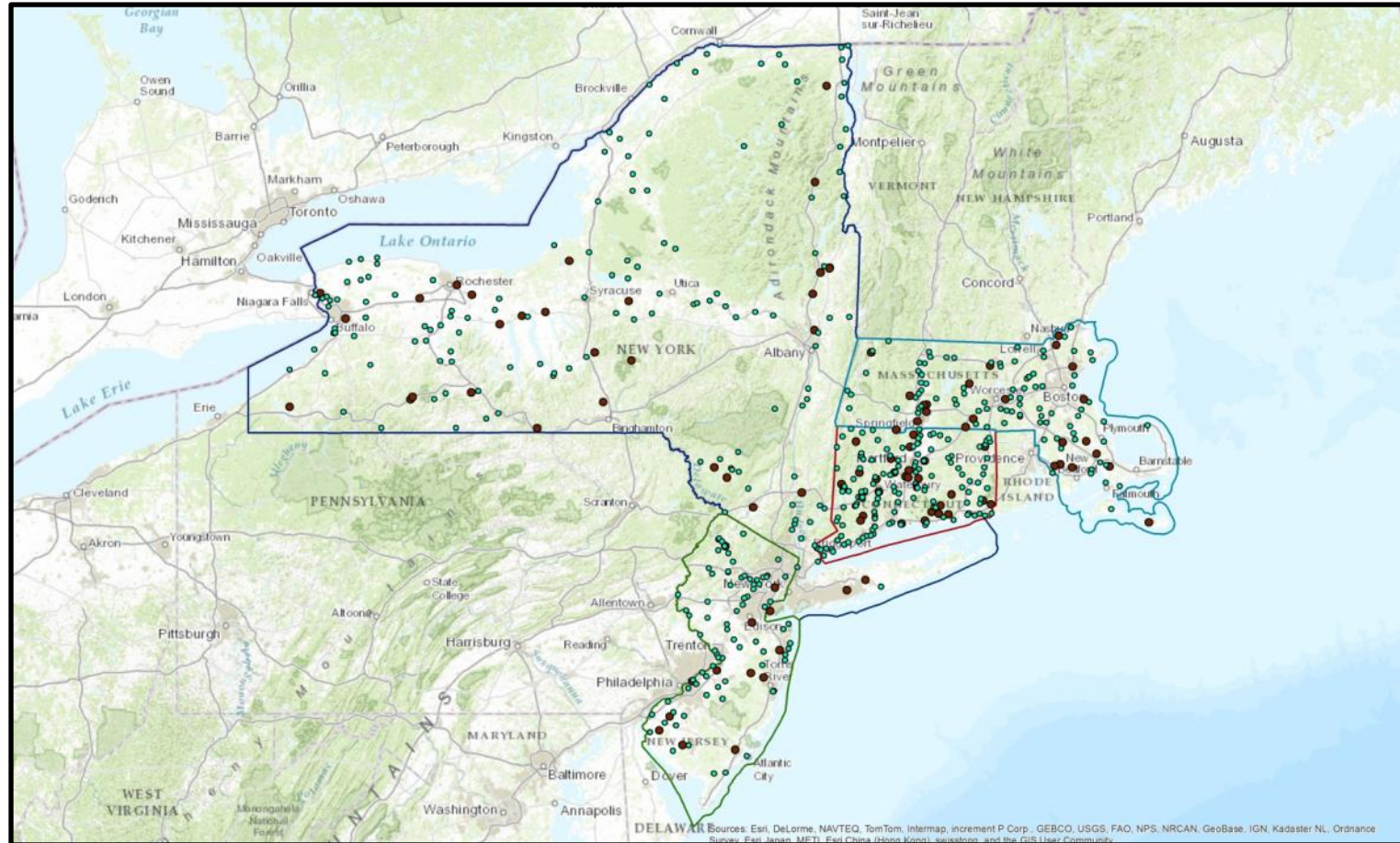


- **451 Wastewater Treatment Plants (WWTPs): NY (135), MA (91), NJ (86), and CT (139)**
- **96 Landfills: NY (32), MA (23), NJ (13), and CT (28)**

# 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)**



Legend:
- Airport
- Building
- Church
- Civil
- Hospital
- Locale
- Military
- Populated Place
- School
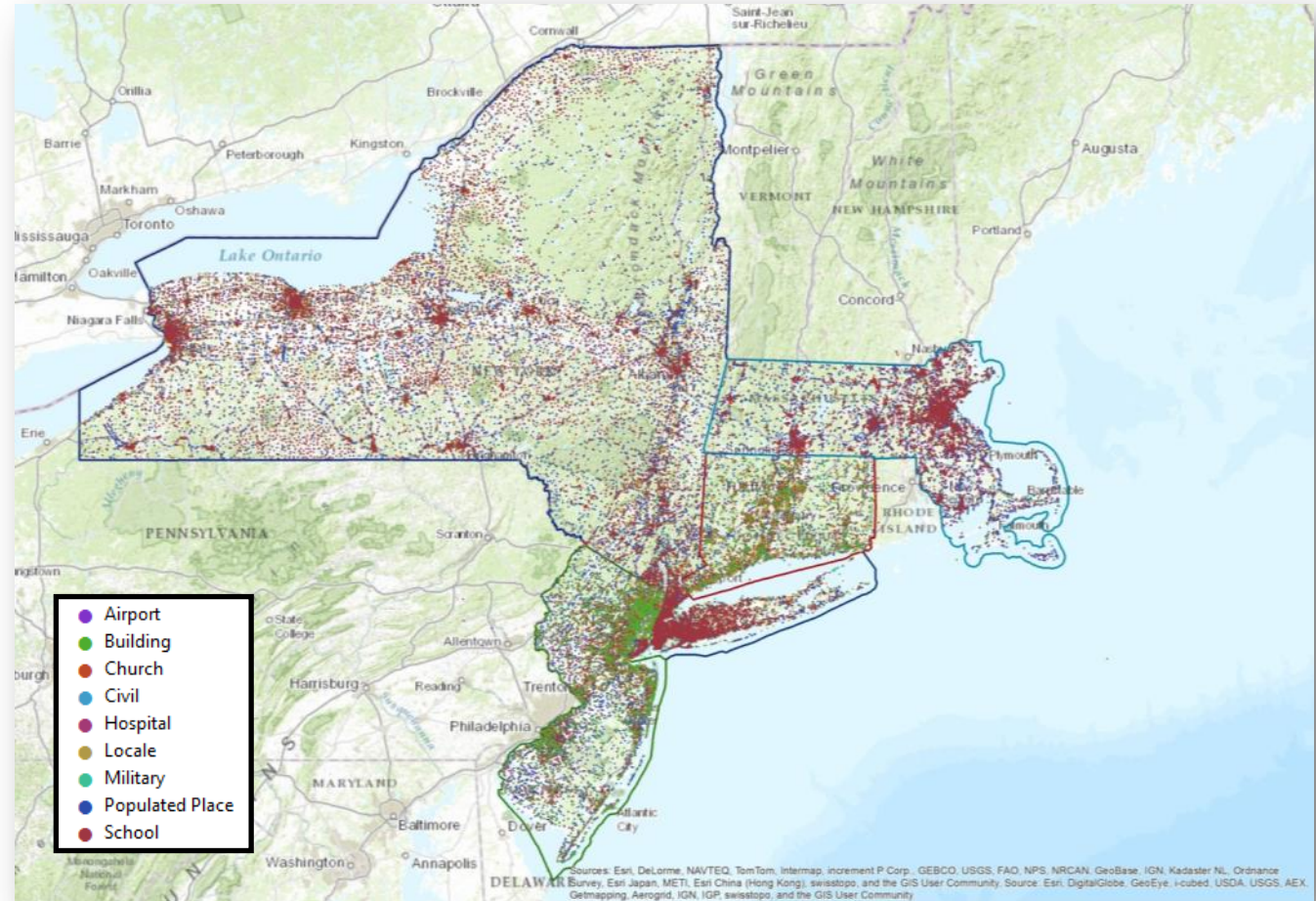
**Identifying heating and electrical loads for Tri-Gen systems seems encouraging & promising**

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



**10 Landfills: 1634 vehicles (<1.7% Sales)**

**10 WWTPs: 3671 vehicles (<4% Sales)**

**\*Potential FCHV drivers and people generally don't live near WWTPs and Landfills**

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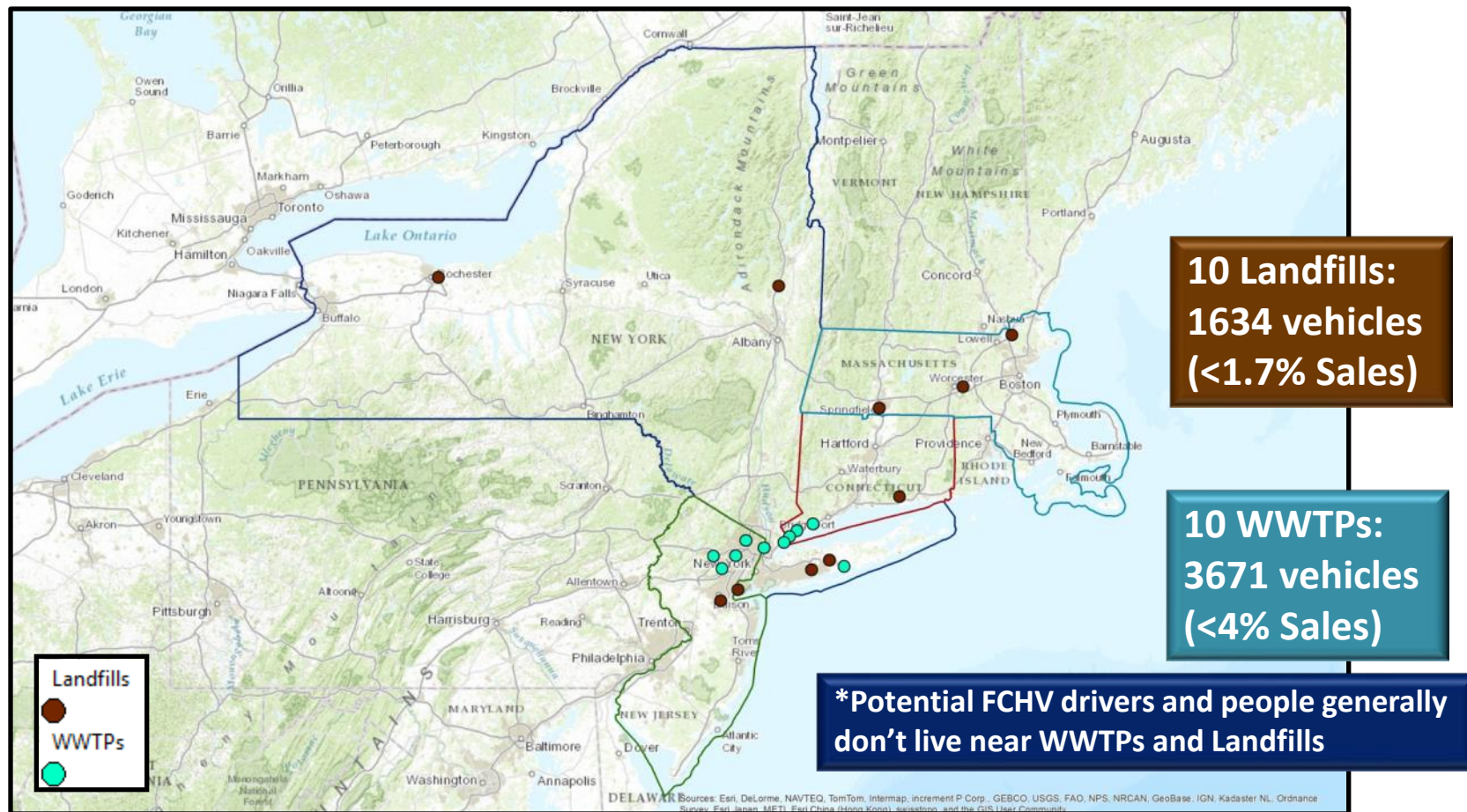
- For the 451 wastewater treatment plants and 96 landfills, respectively, we determined the 6 minute drive time service coverage .
- Based on the # of alternative vehicles covered, we ranked and obtained the Top 10 WWTPs and Landfills

# Results and Progress: *Landfills as Central Hubs Supplying H$_2$*

**Sites that are favorable from both:**
1) **Consumer Standpoint**
2) **Central Hub**

| Name | # of Stations |
|------|---------------|
| Blydenburgh Road Landfill Complex | 18 |
| Babylon North U Bypass Landfill | 13 |
| Keegan Landfill (NJMC) | 11 |
| Middlesex County Sanitary landfill | 7 |
| Monmouth County Reclamation Center | 7 |
| Pennsauken Sanitary Landfill | 7 |
| Schultz Landfill | 5 |
| WHEELABRATOR SAUGUS INC ASH LANDFILL | 5 |
| Fresh Kills Landfill | 5 |
| Total | 78 |

- **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**
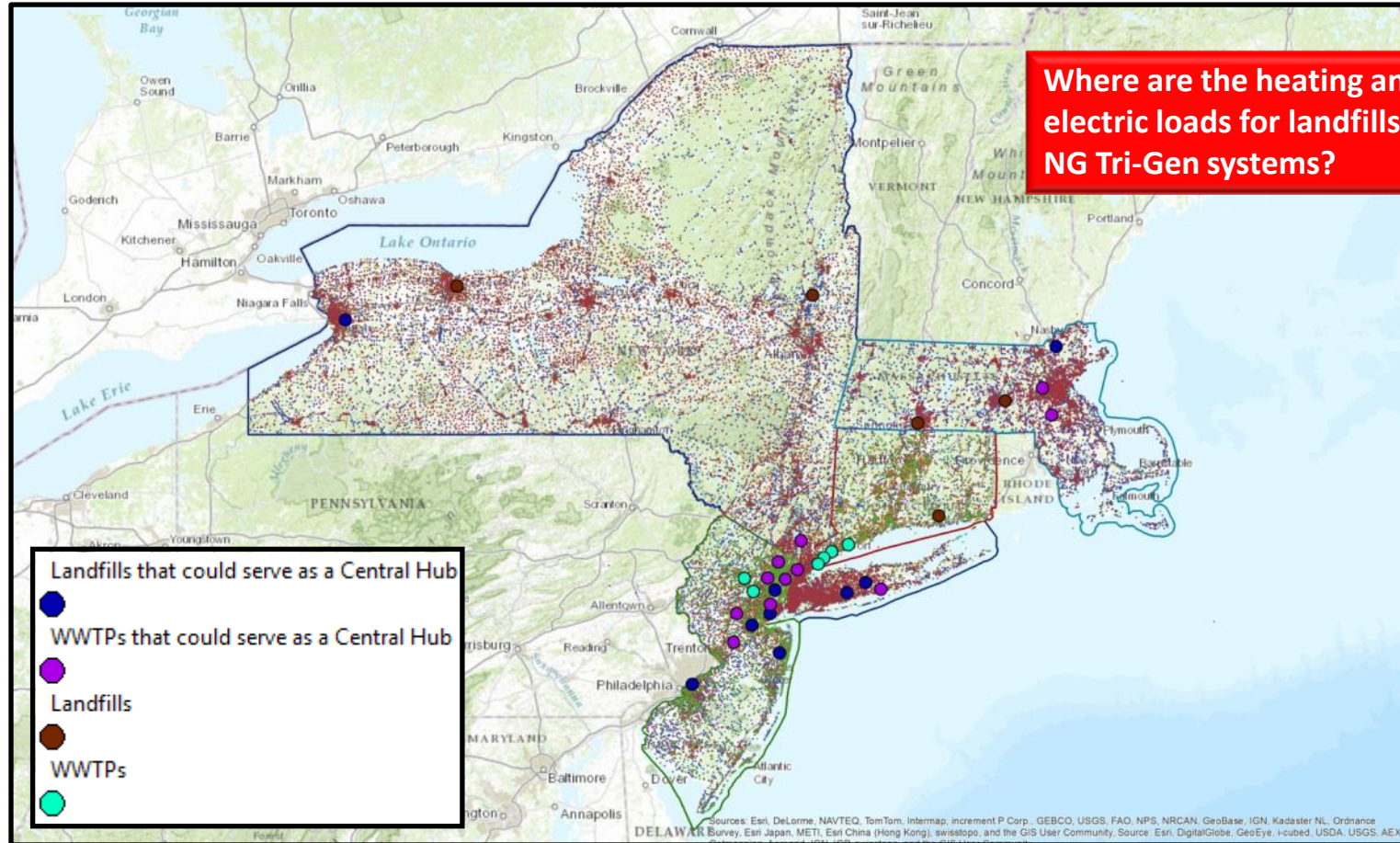- **9 Landfills that could serve 5 or more stations**

# Results and Progress: *WWTPs as Central Hubs Supplying H$_2$*



Sites that are favorable from both:
1) **Consumer Standpoint**
2) **Central Hub**

| Name | # of Stations |
|---|---|
| RIDGEWOOD VILLAGE WPC FACILITY | 9 |
| Patchogue Village Wastewater Treatment Plant | 9 |
| Center Street Solar Aquatics System WWTF | 9 |
| BERGEN CNTY UTILITIES AUTHORITY (BCUA) | 7 |
| CEDAR GROVE STP | 7 |
| CROSSROADS AT OLDWICK | 6 |
| Ossining Wastewater Treatment Plant | 6 |
| Yonkers Joint Wastewater Treatment Plant | 6 |
| Ciba Corning Diagnostics Corp.-Mfg WWT | 6 |
| JOINT MEETING OF ESSEX & UNION COUNTIES | 5 |
| UNITED WATER PRINCETON MEADOWS | 5 |
| **Total** | **75** |

- **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*



Where are the heating and electric loads for landfills and NG Tri-Gen systems?

Legend:
- Landfills that could serve as a Central Hub
- WWTPs that could serve as a Central Hub
- Landfills
- WWTPs

- **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**

**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**

**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

Pennsauken Sanitary Landfill (NJ)
- Pennsauken High School

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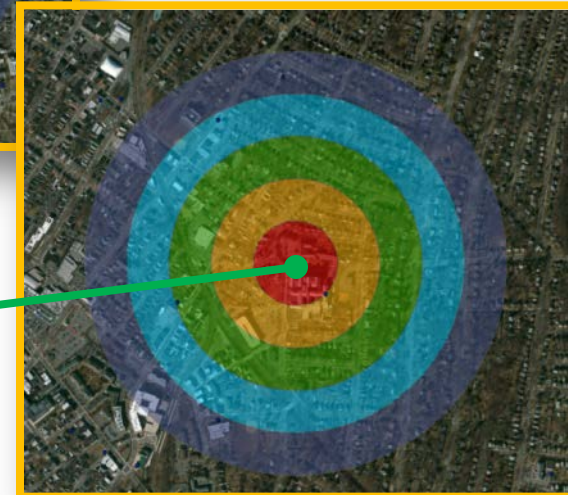
# Collaborations

**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 <u>acquisition</u> and <u>cleanup</u> 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

- **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

- 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)