Tri-Generation Fuel Cell Technologies for Location-Specific Applications

Project ID: SA047

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June 9, 2015

2015 U.S. DOE Hydrogen and Fuel Cells Program and Vehicle Technologies Office Annual Merit Review and Peer Evaluation Meeting

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Overview

Timeline

- State date – January 2014
- End date – April 2015
- Percent complete – 98%

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

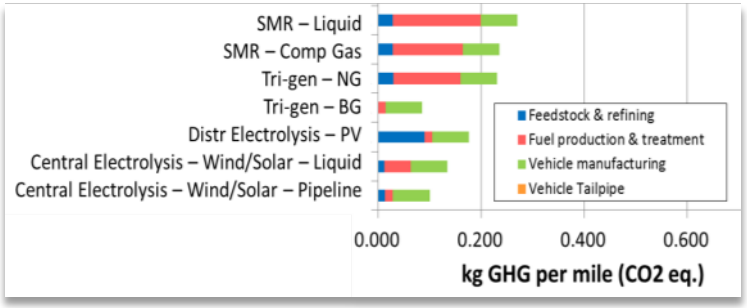
- Total funding spent as of 3/30/15: $139,840
- Total DOE Project Value: $149,967

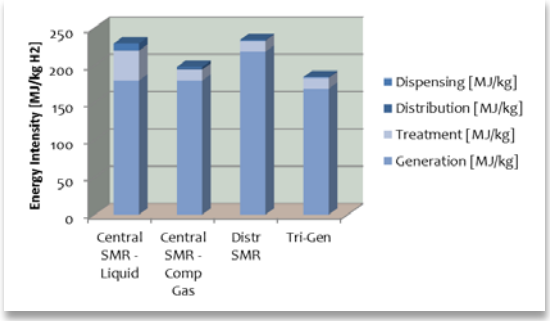
Partners/Collaborators

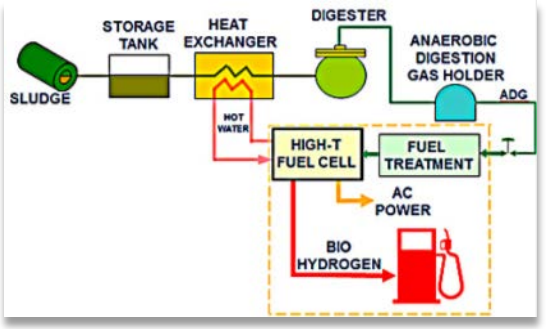
- National Renewable Energy Laboratory (NREL)
- Toyota
  - Market Data / Perspective

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

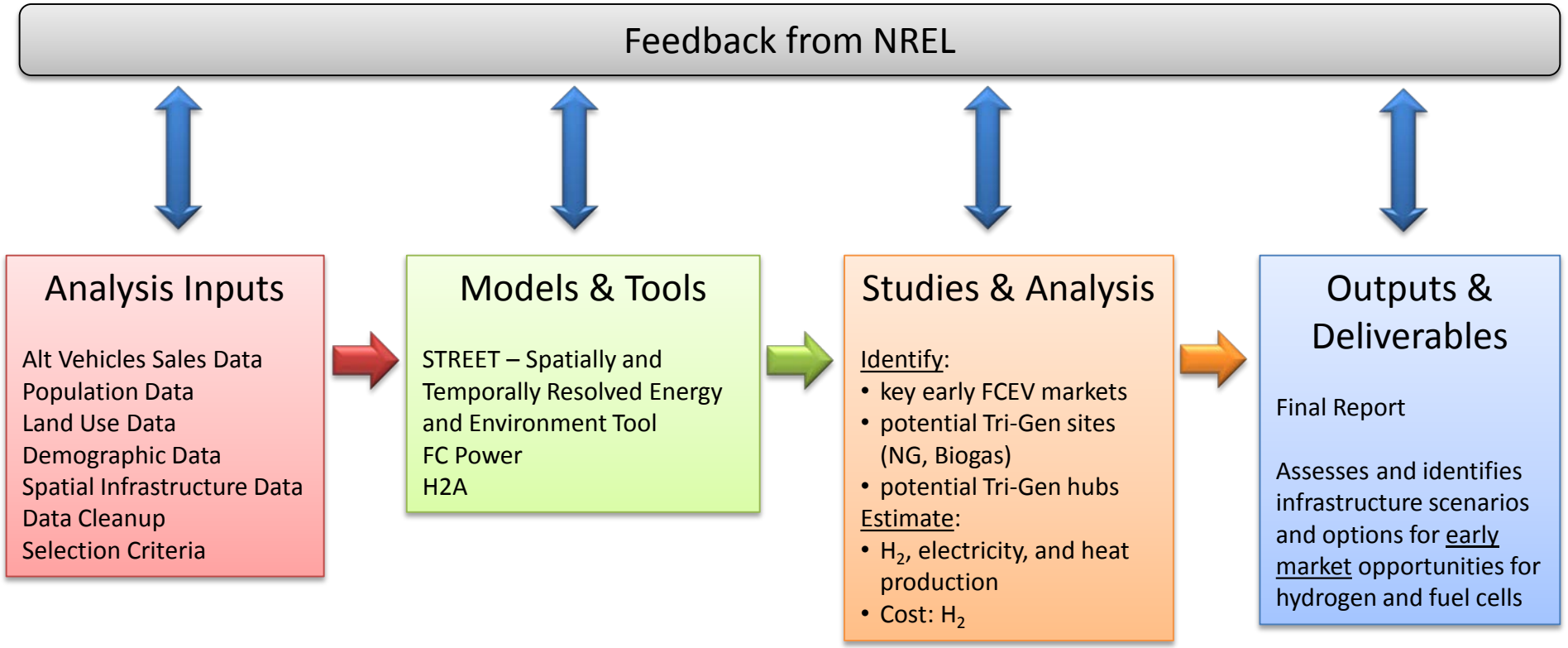
- **February 2014**
  - Kickoff meeting with National Renewable Energy Laboratory (NREL)

- **Draft Final Report**
  - **Jan 2015**

- **Final Report**
  - **Apr 2015**

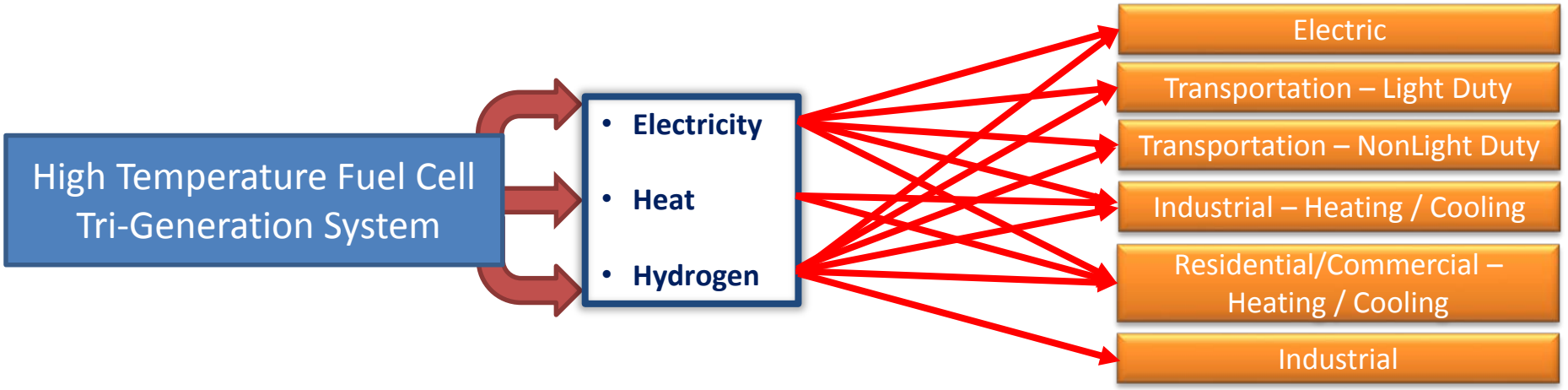
Approach

- Project Overview

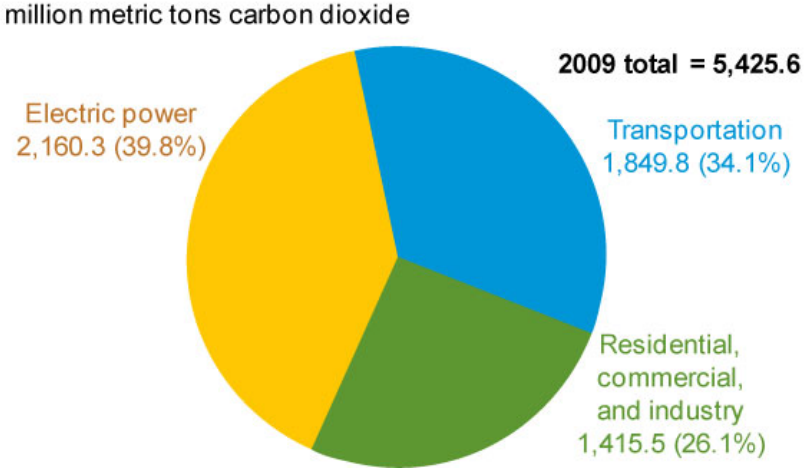


Approach

- How to site with multiple products (i.e., markets)?



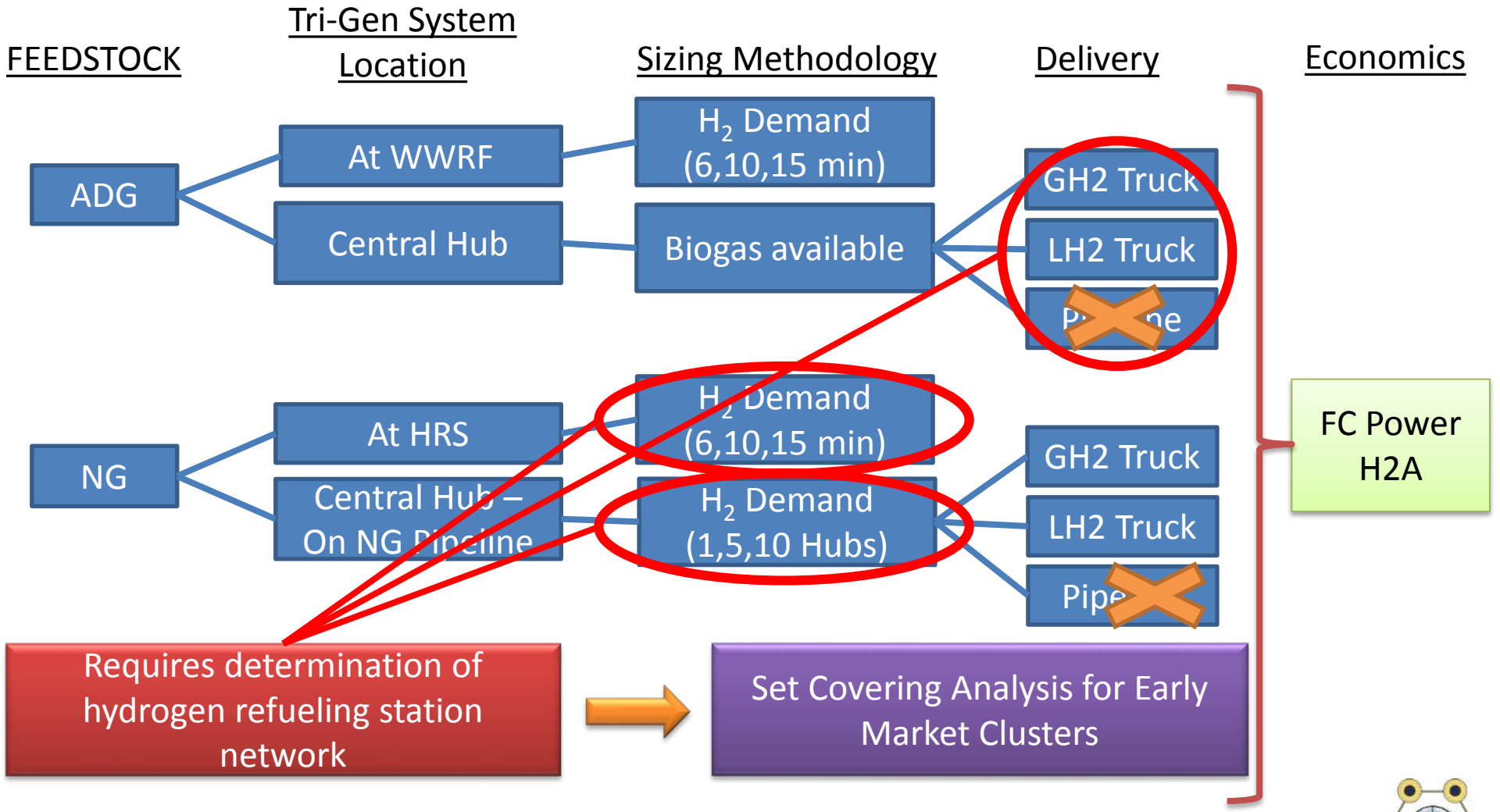
GHG Emission Inventory by Sector in US



US Energy Information Administration

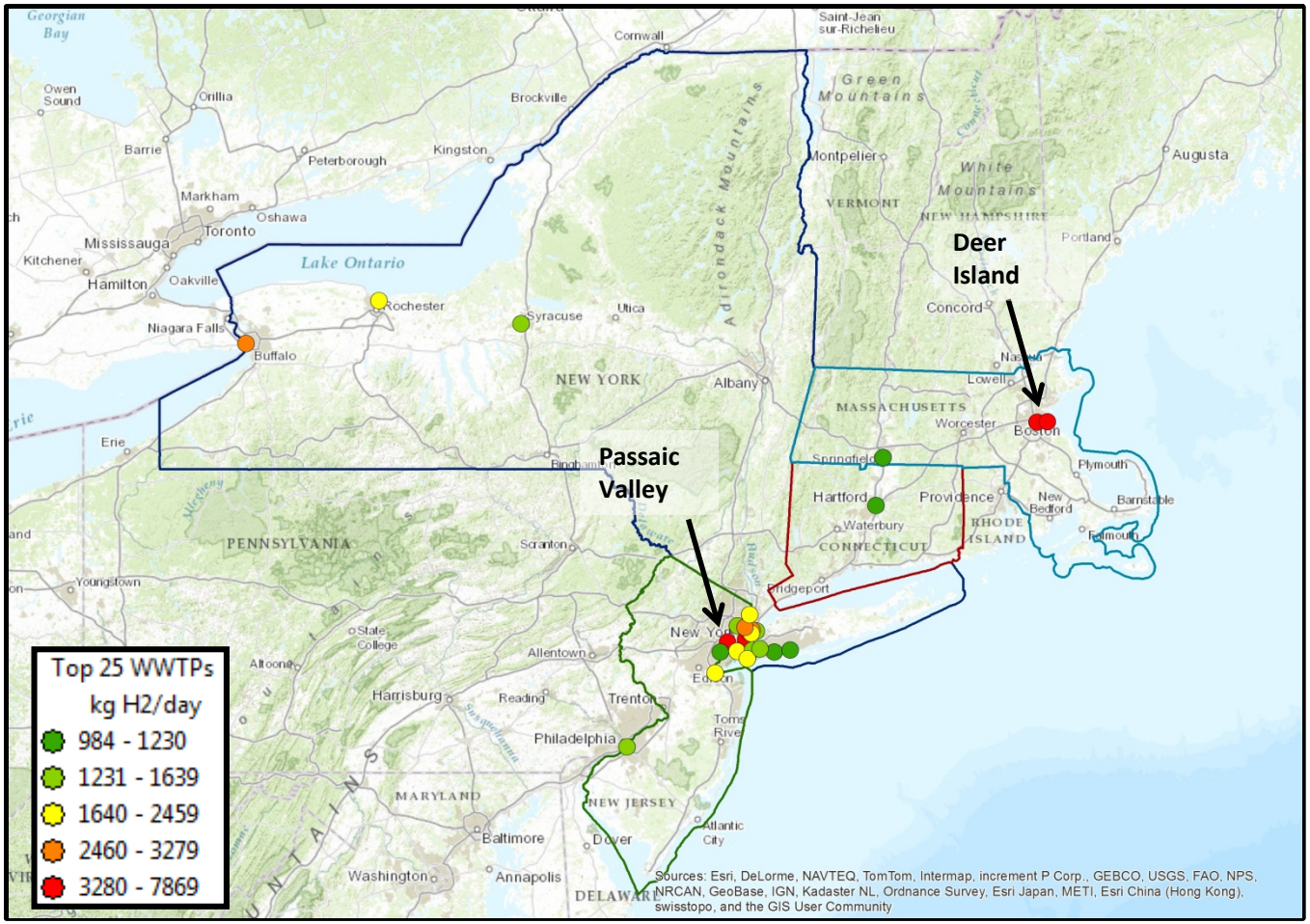
→ Used hydrogen demand to site and size Tri-Gen systems

Approach

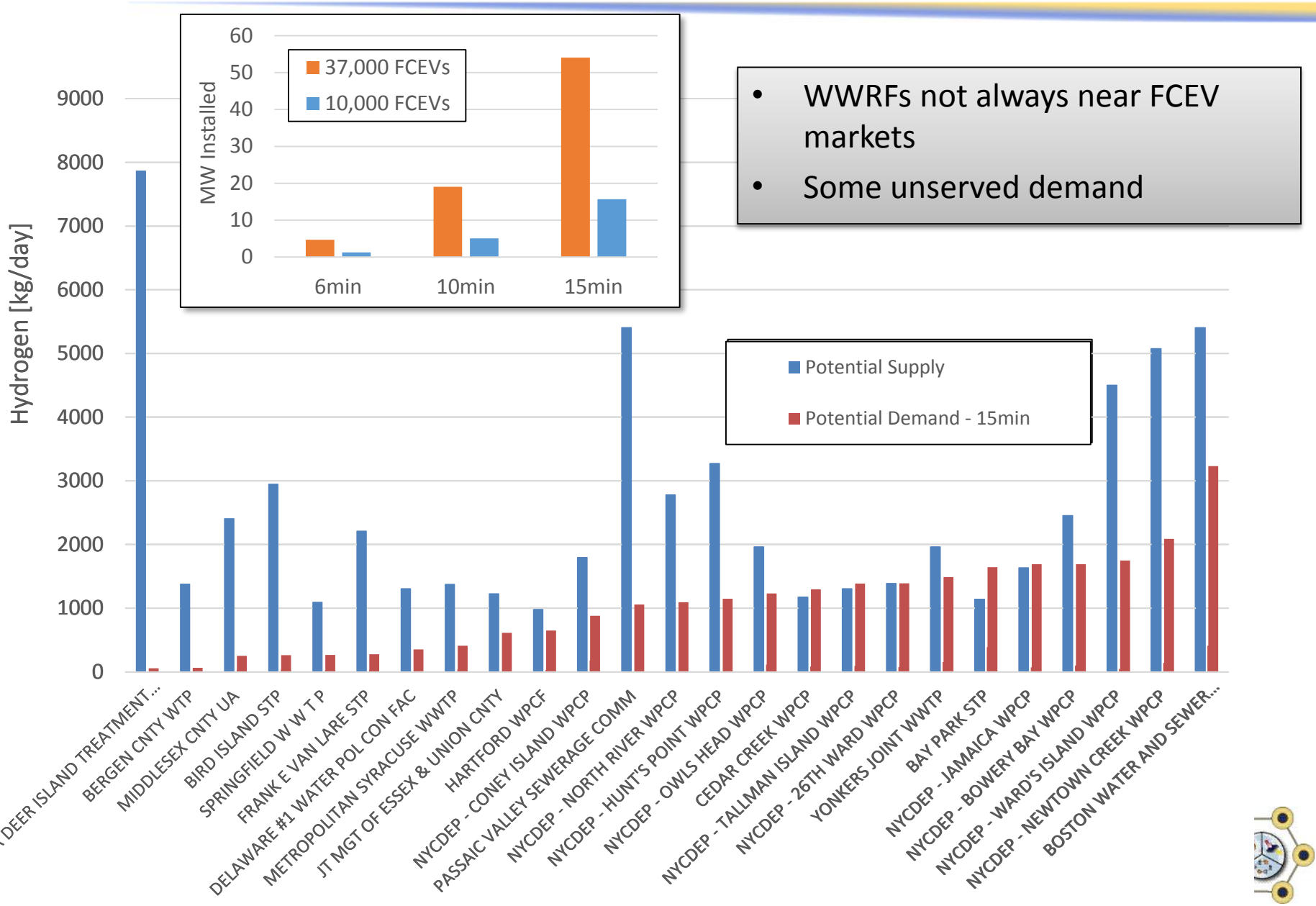

FEEDSTOCK
Tri-Gen System Location
Sizing Methodology
Delivery
Economics
ADG
NG
At WWRF
Central Hub
At HRS
Central Hub – On NG Pipeline
H_2 Demand (6,10,15 min)
Biogas available
H_2 Demand (6,10,15 min)
H_2 Demand (1,5,10 Hubs)
GH2 Truck
LH2 Truck
Pipeline
GH2 Truck
LH2 Truck
Pipe
FC Power H2A
Requires determination of hydrogen refueling station network
Set Covering Analysis for Early Market Clusters

Results: Top 25 WWRFs & H_2 Production Potential

- **Several WWRFs with large potential (>8 MW)**

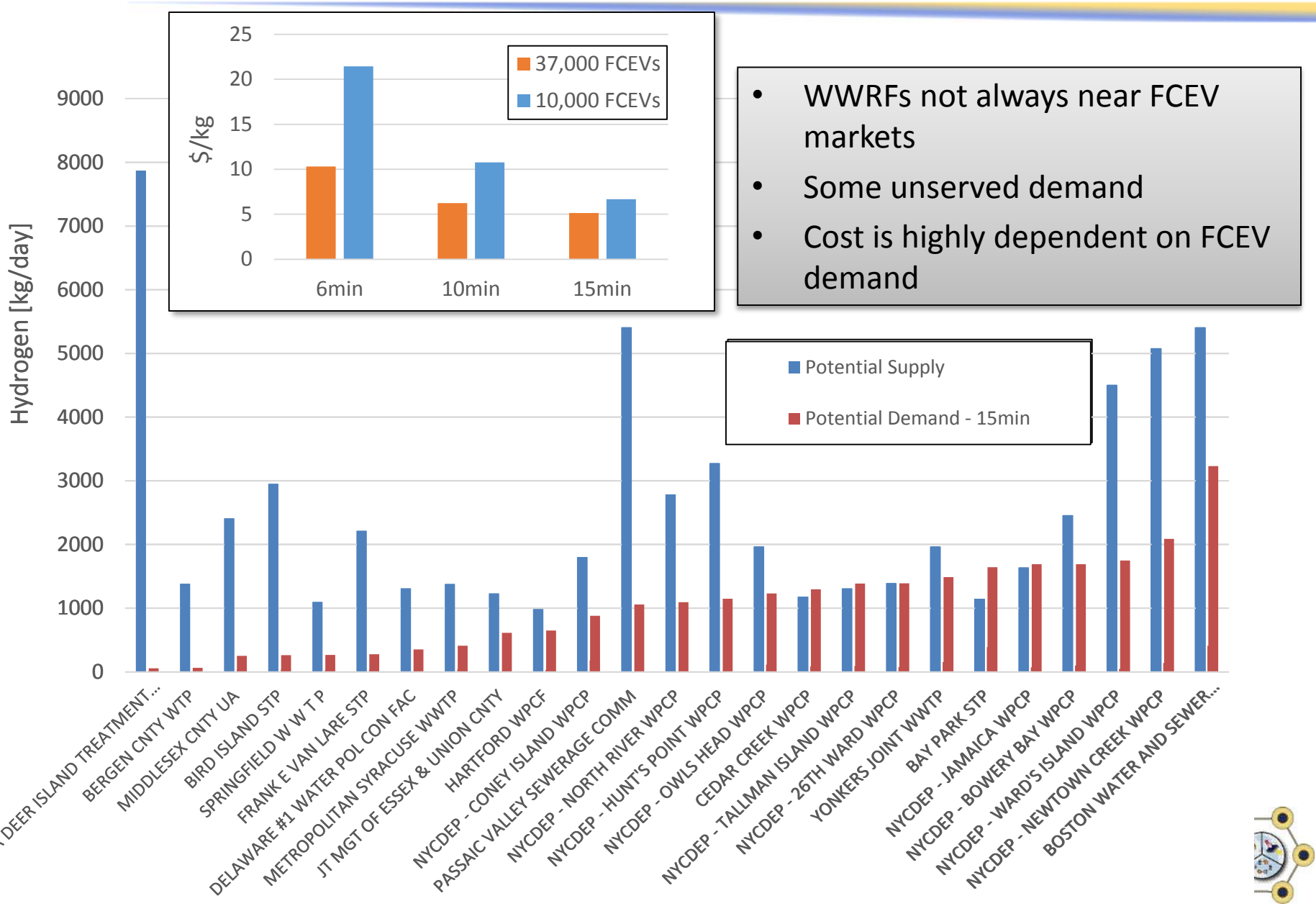


Results: ADG, at WWRF



- WWRFs not always near FCEV markets
- Some unserved demand

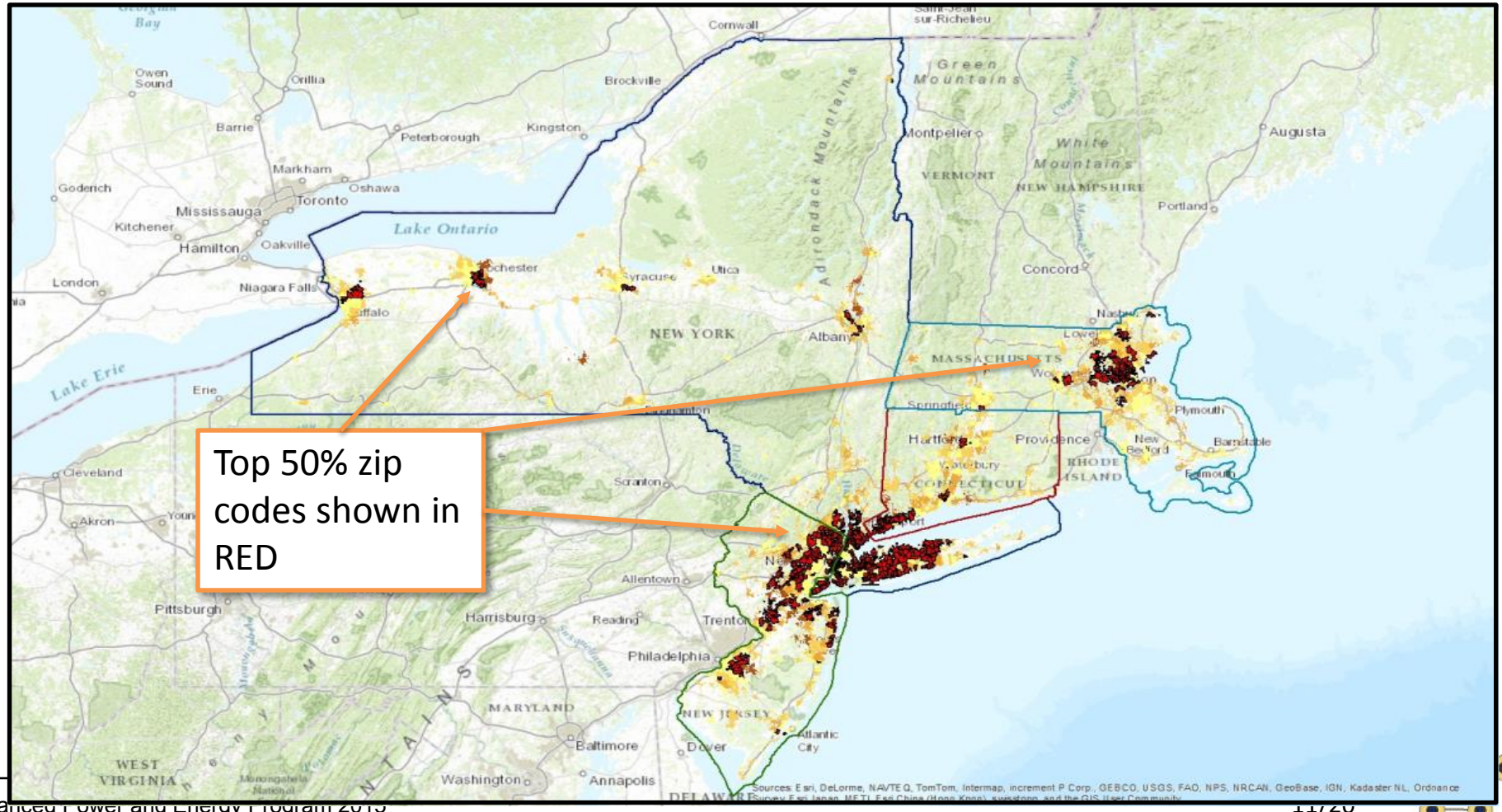
Results: ADG, at WWRF



- WWRFs not always near FCEV markets
- Some unserved demand
- Cost is highly dependent on FCEV demand

Results: Hydrogen Refueling Station Network

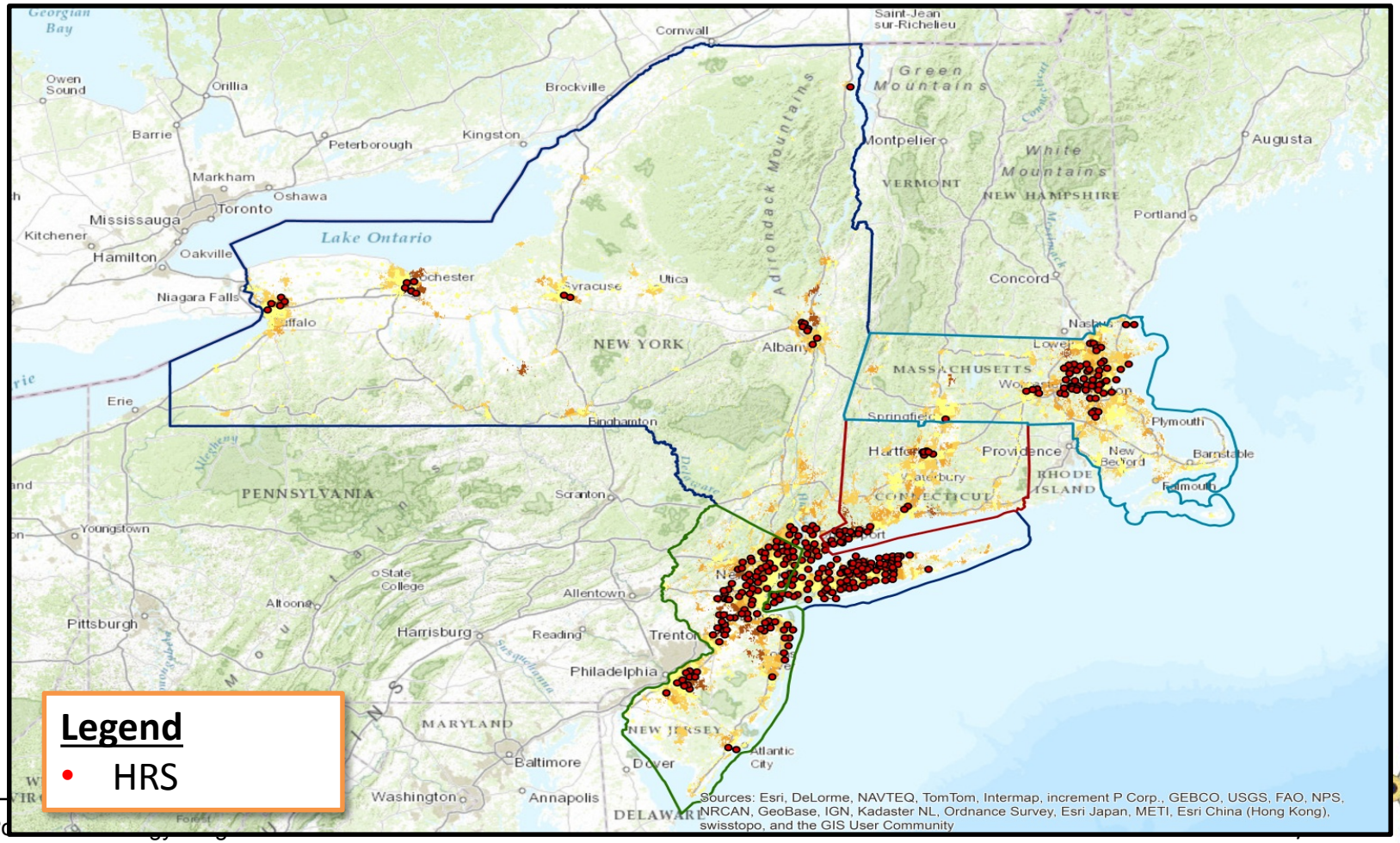
- FCEV Cluster Identification
  - Top 50% of zip codes in alt. vehicle sales (also used 25%, 75% but not presented here)



Results: Hydrogen Refueling Station Network

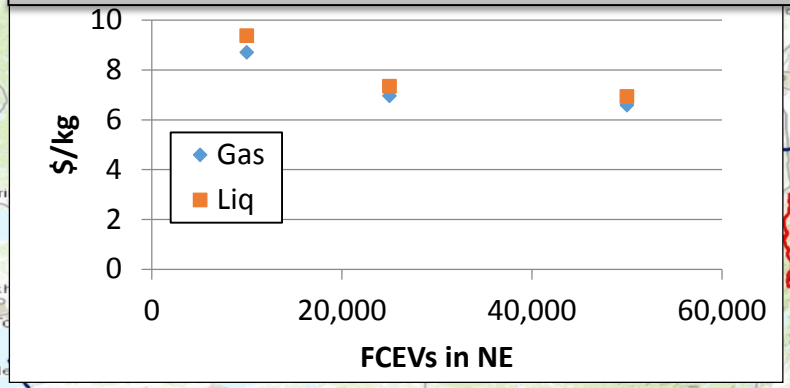
- Hydrogen Refueling Station (HRS) Network
  - Set covering analysis (6 minute service coverage)

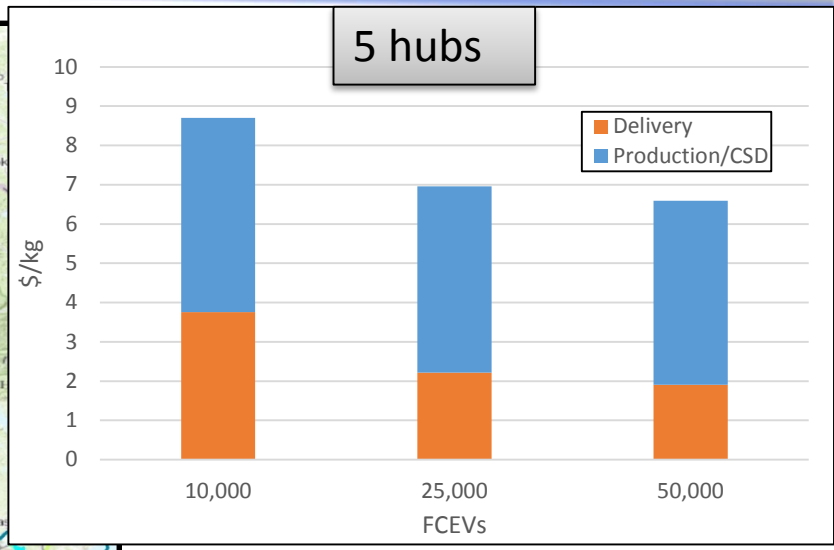
    → **313 stations**

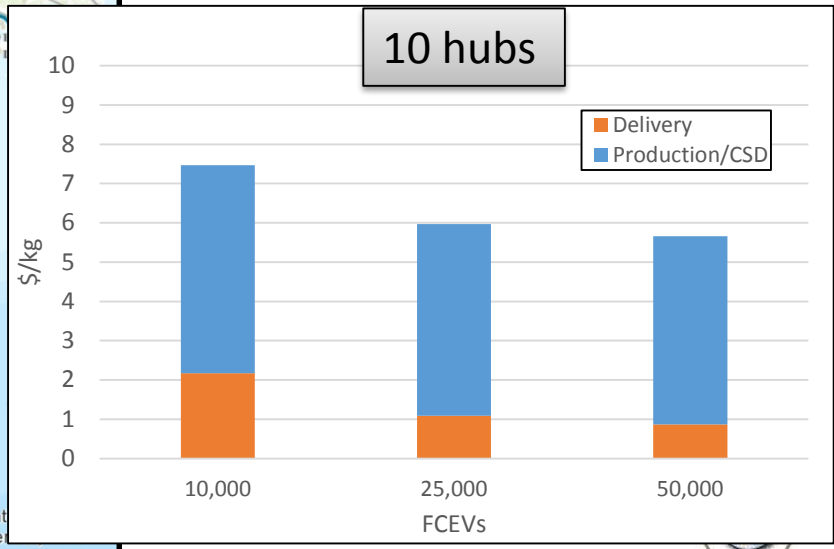


Results: ADG, Central Hub

Gaseous truck lower cost than liquid



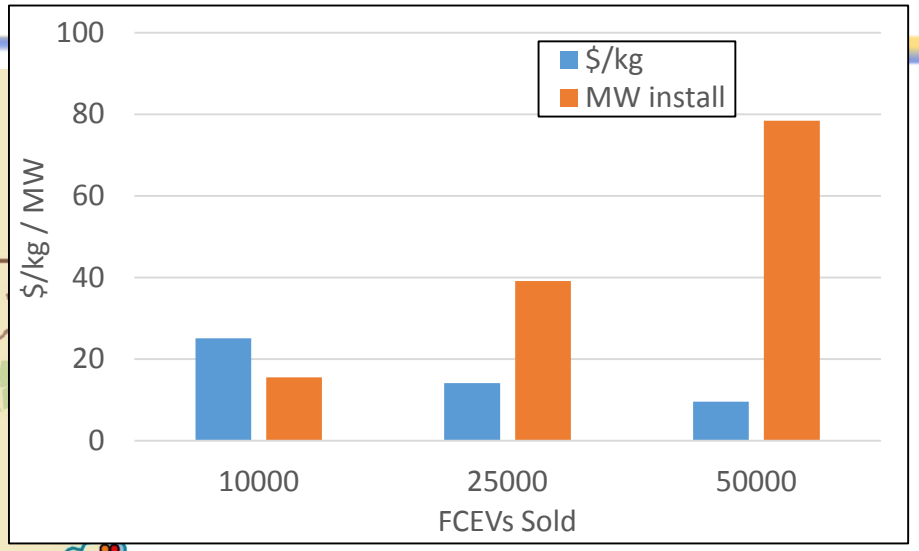


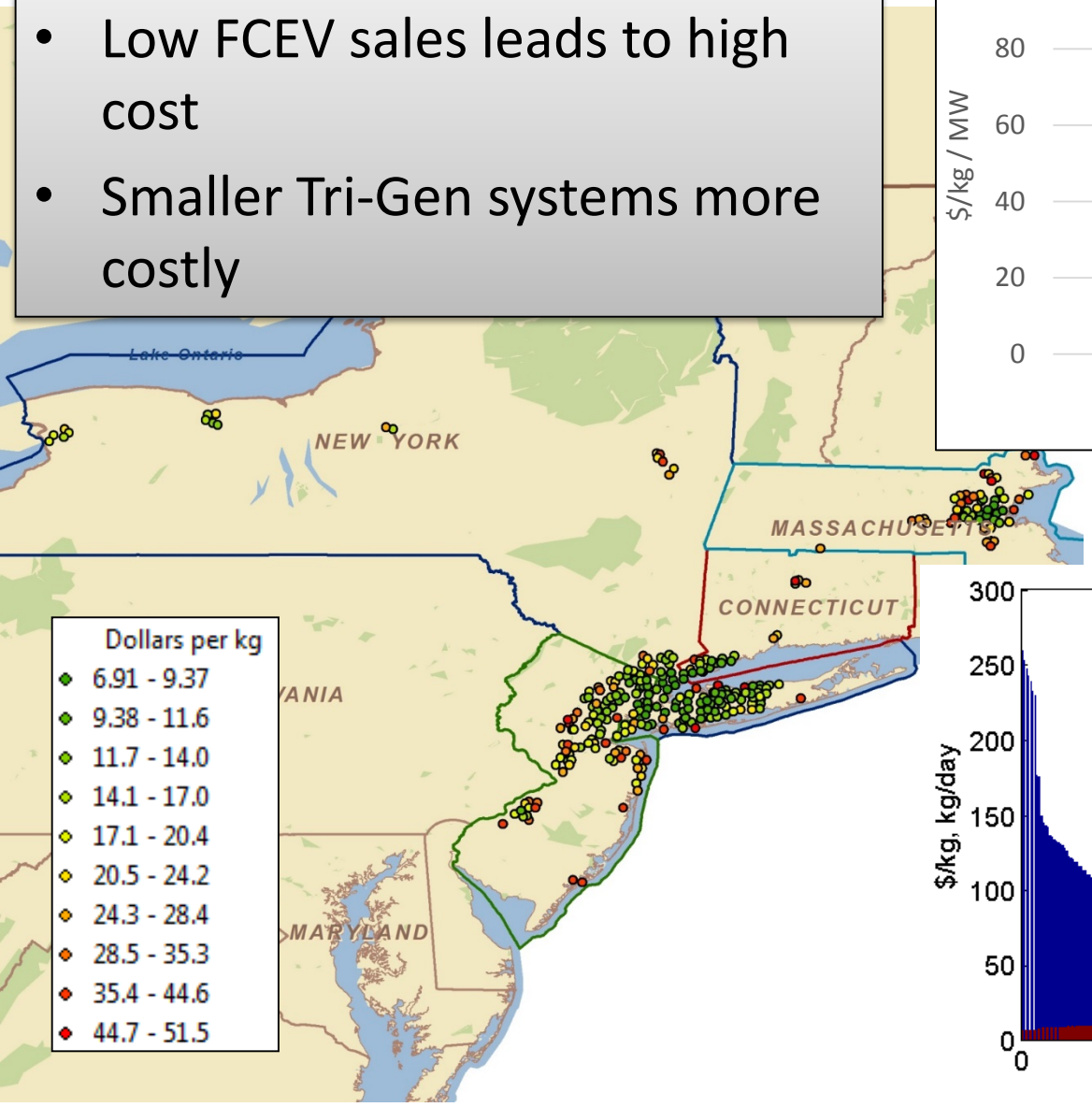


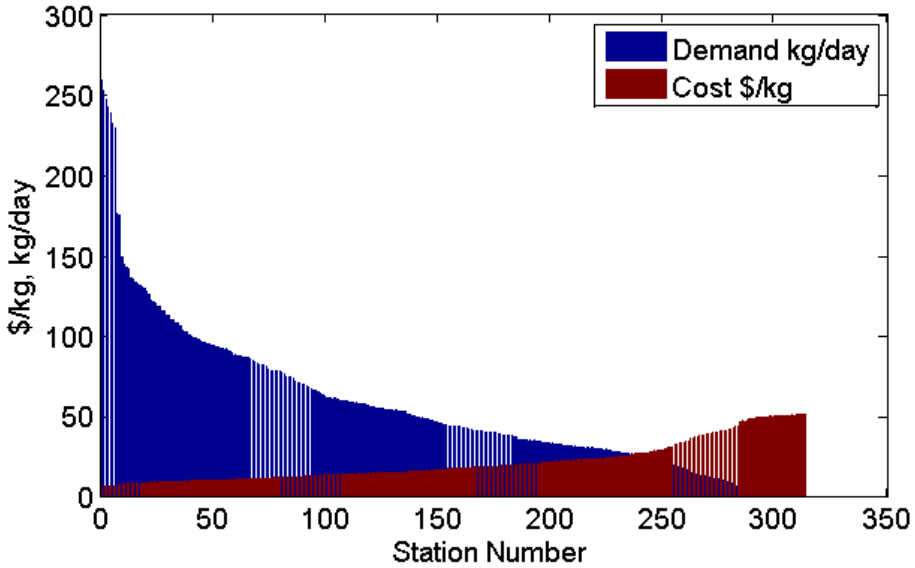
- Low FCEV sales leads to high cost
- More hubs → lower delivery costs and lower overall cost

Results: NG, at HRS

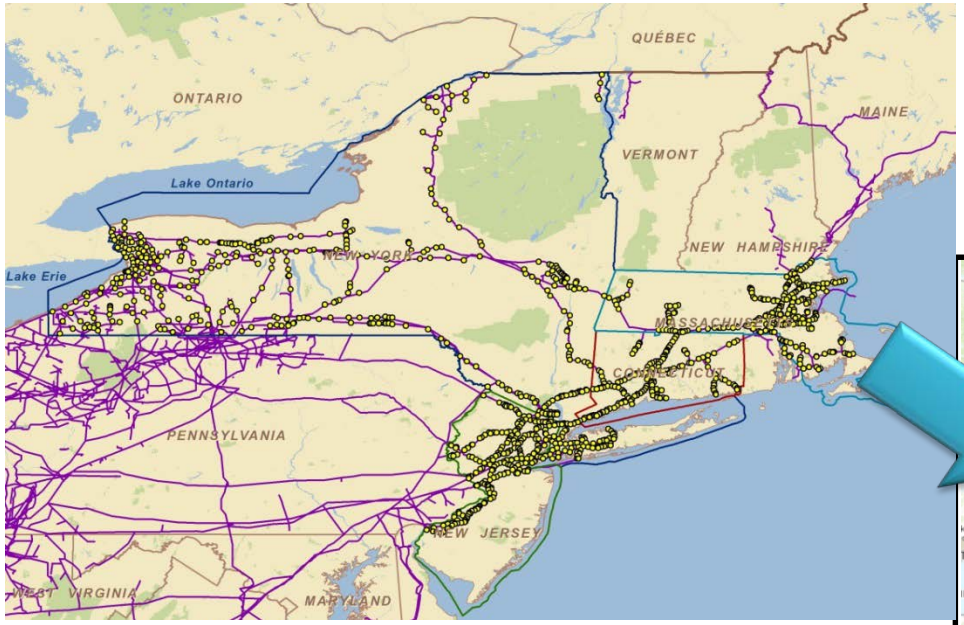
- Low FCEV sales leads to high cost
- Smaller Tri-Gen systems more costly

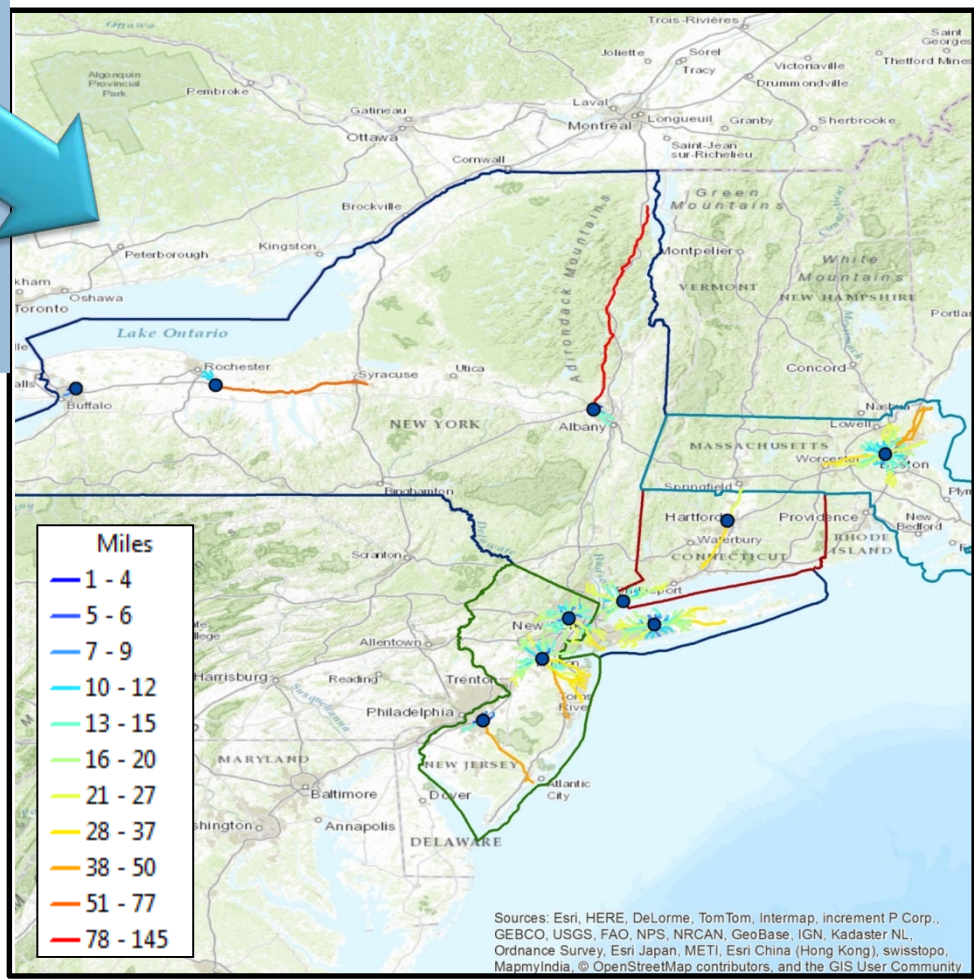






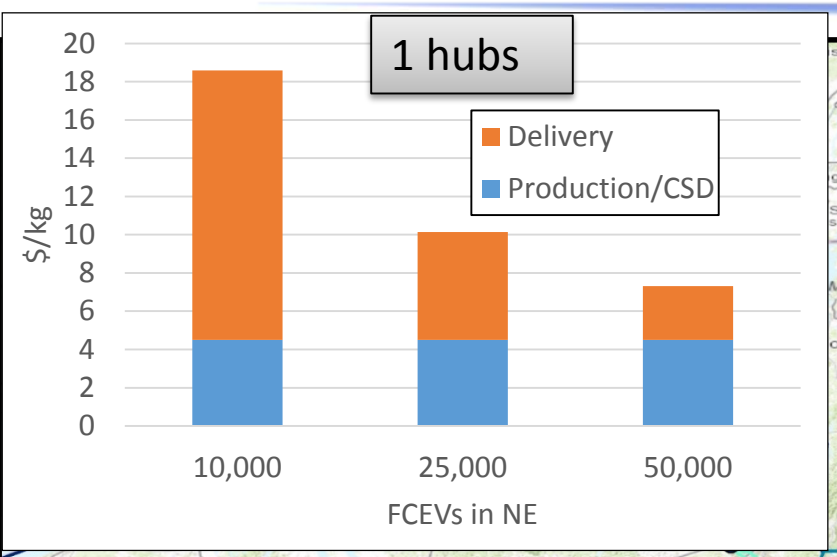
Results: NG, Central Hub

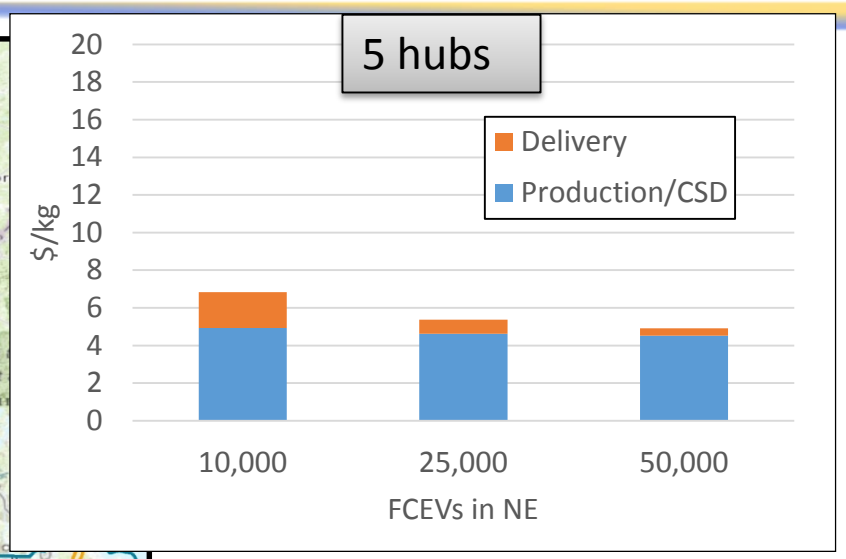


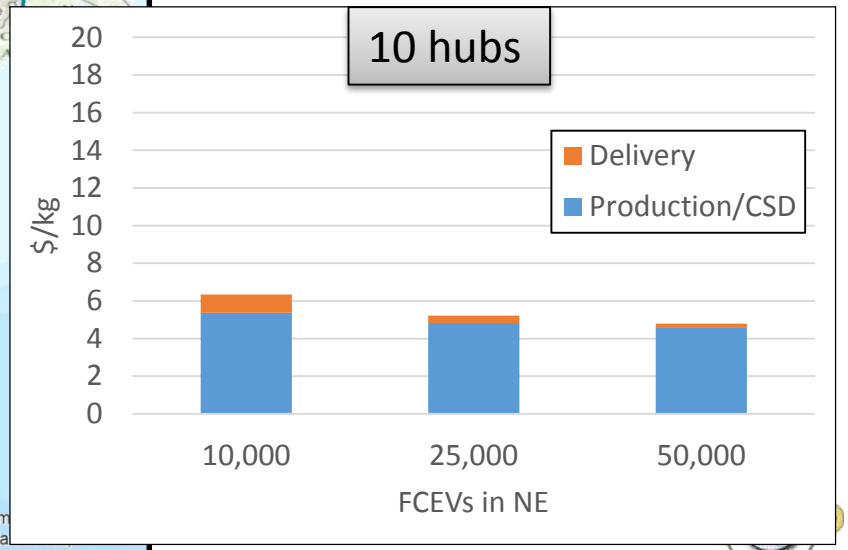


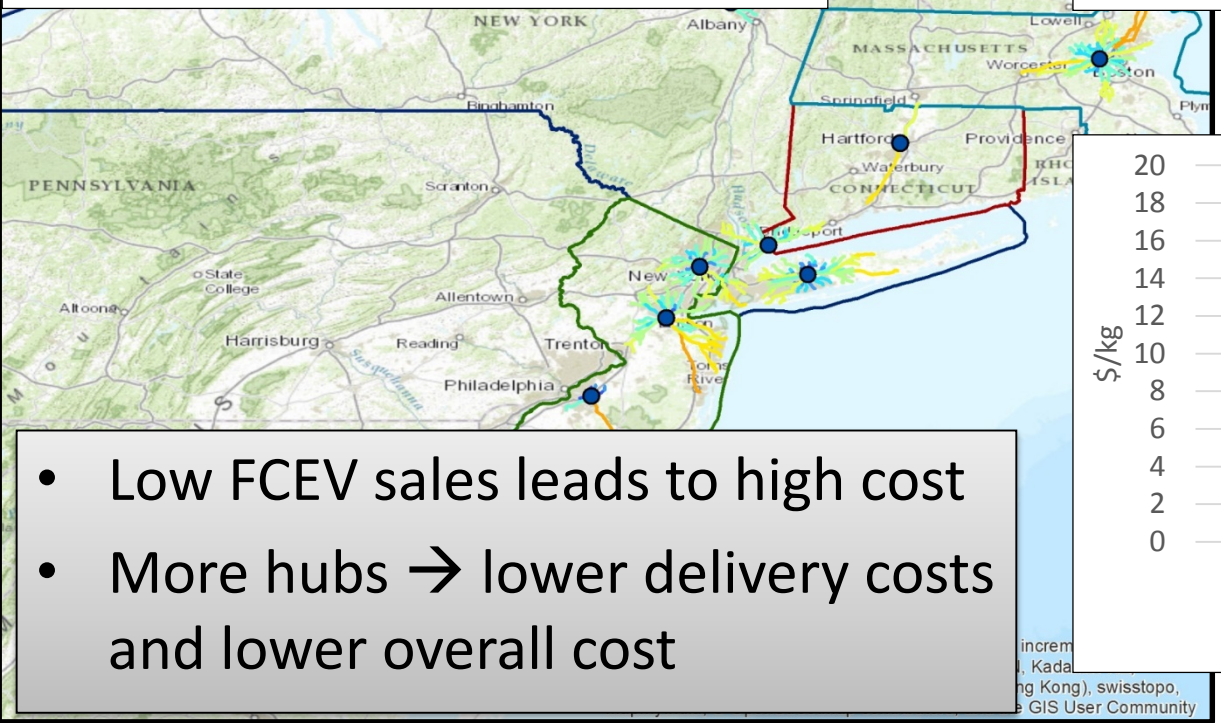
- Ranking candidate sites along Natural Gas Pipeline based on alt vehicles covered

Results: NG, Central Hub





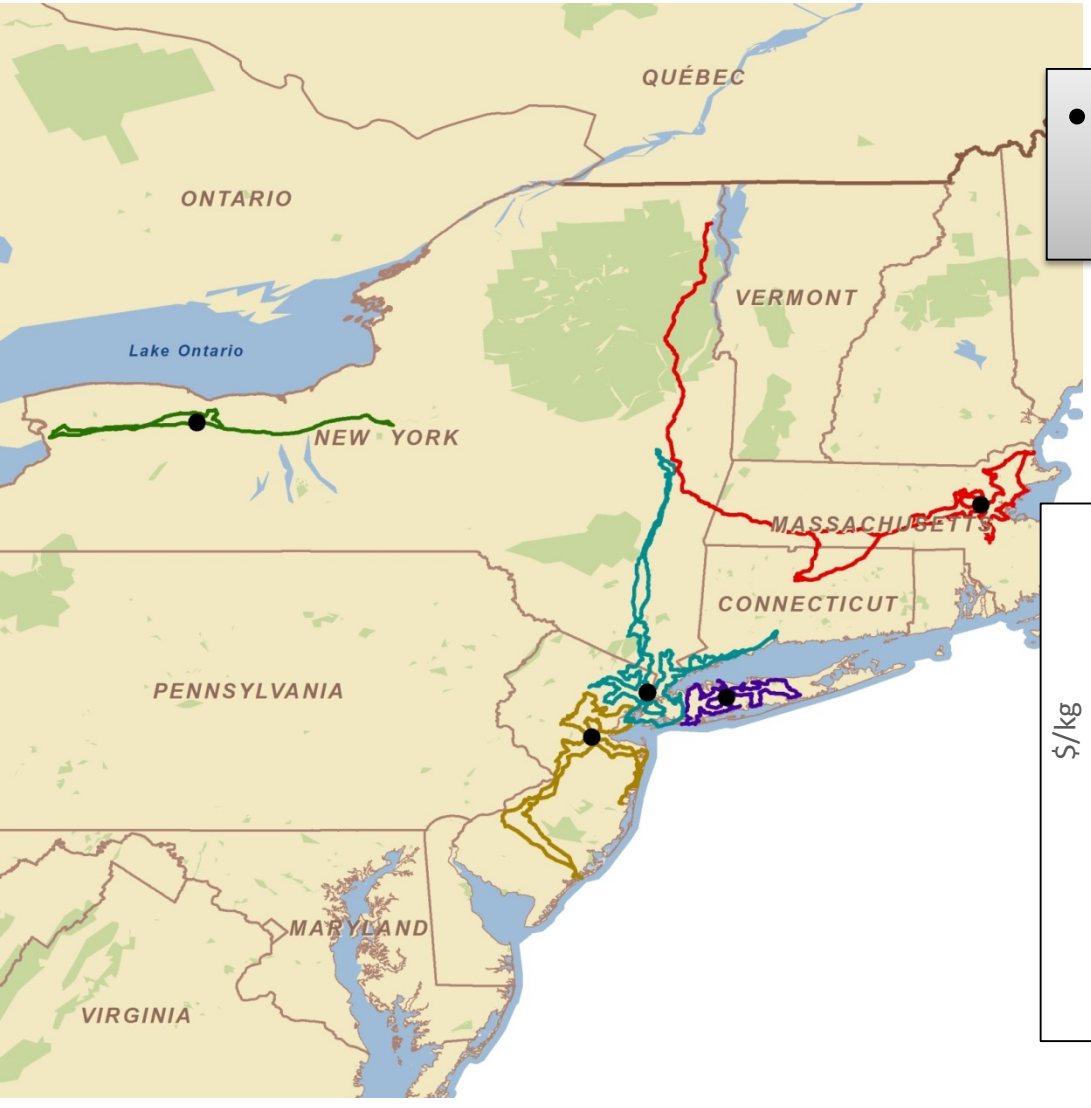




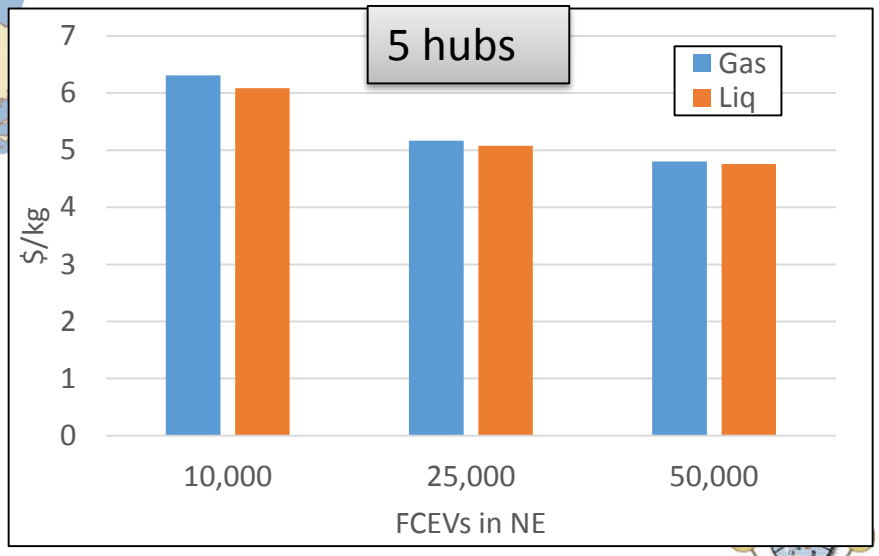
- Low FCEV sales leads to high cost
- More hubs → lower delivery costs and lower overall cost

Results: NG, Central Hub

- Traveling Salesman algorithm to determine chained trips

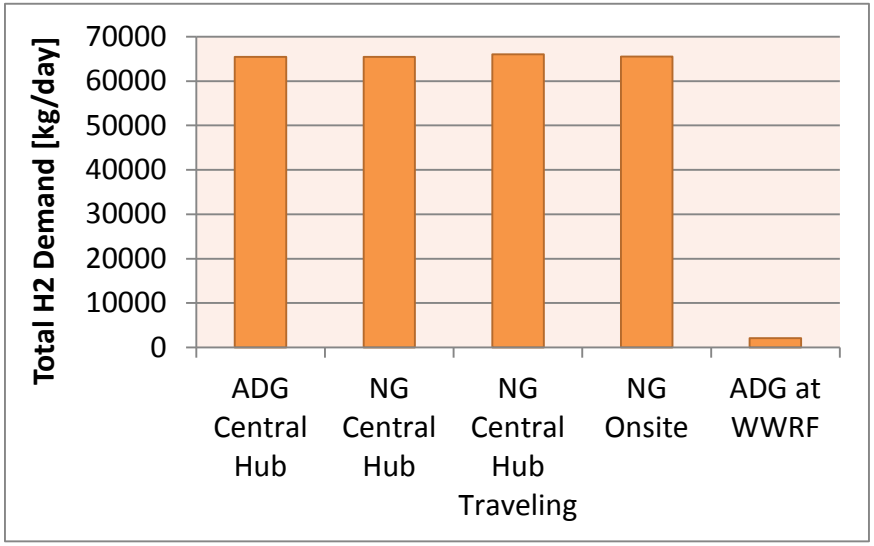


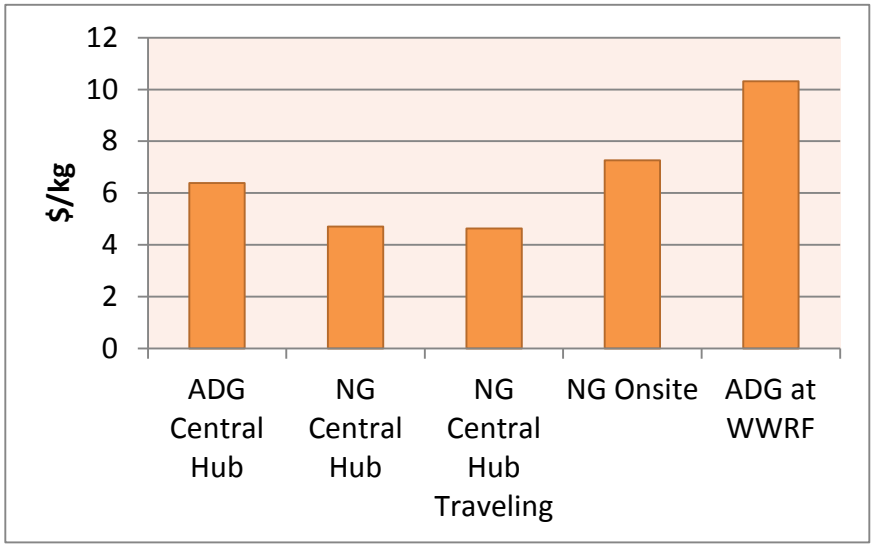
- Results in longer trips → liquid trucks less costly

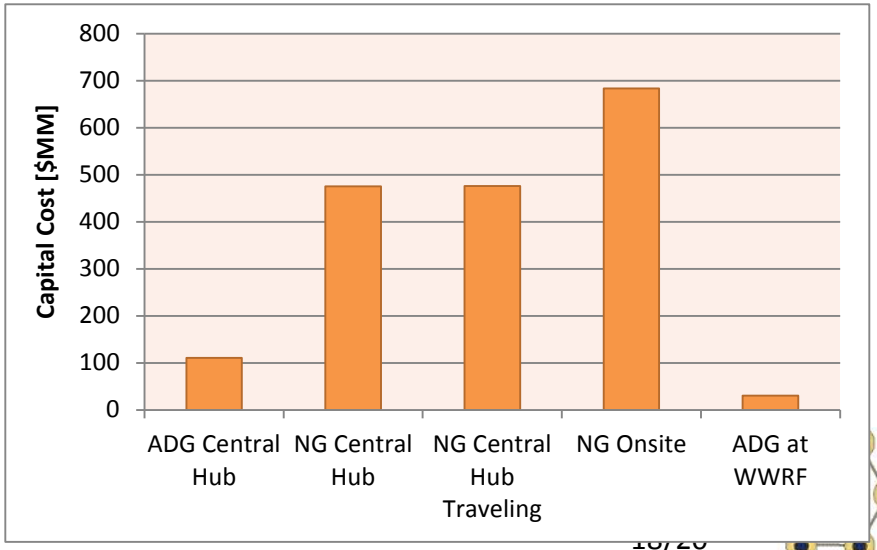


Results: Scenario Comparison

- 6 min coverage for station demand estimation
- Central Hub cases: 5 hubs







- Central hub → lower cost
- NG Central hub → lowest cost

Collaborations

Primary Collaborator

- National Renewable Energy Laboratory

Secondary Collaborator

- Toyota (market data and perspective)
- Massachusetts Clean Energy Center
- New York State: Dept. of Conservation

MASSACHUSETTS CLEAN ENERGY CENTER

New York State ☰ State Agencies
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Leveraging past and current collaborators

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

Summary

- ADG, at WWRF
  - WWRF not always near FCEV markets
  - Some WWRF do not have enough biogas to serve demand

- ADG, Central Hub
  - More hubs → lower cost
  - High sales scenarios → cost < $7/kg

- NG, Central Hub
  - More hubs → lower cost
  - Chained trips decrease delivery cost
  - High sales scenario → cost < $5/kg

- NG, at HRS
  - Some Tri-Gen systems in lower demand areas very small → expensive with cost > $20/kg

Lowest cost scenario → NG, Central Hub

Acronyms

- Dept. of Energy (DOE)
- Fuel Cell Electric Vehicle (FCEV)
- Wastewater Recovery Facility (WWRF)
- Anaerobic Digester Gas (ADG)
- Natural Gas (NG)
- Northeast (NE)
- National Renewable Energy Laboratory (NREL)
- Spatially and Temporally Resolved Energy and Environment Tool (STREET)
- United States Geological Survey (USGS)
- Wastewater Treatment Plant (WWTP)