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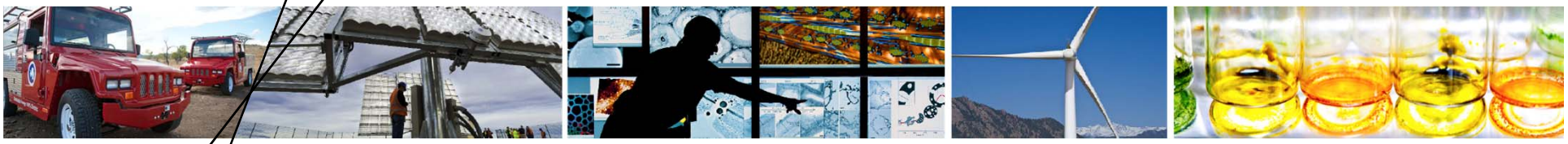
SERA Scenarios of Early Market Fuel Cell Electric Vehicle Introductions: Modeling Framework, Regional Markets, and Station Clustering



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Presentation Overview

1. **SERA model overview**
2. **Methodology**
   Scenarios for hydrogen infrastructure development
3. **Scenario example**
   A “Hydrogen Success” scenario
4. **Detailed scenario metrics**
   For a particular region: Northeast Corridor states

Scenario Evaluation and Regionalization Analysis (SERA)

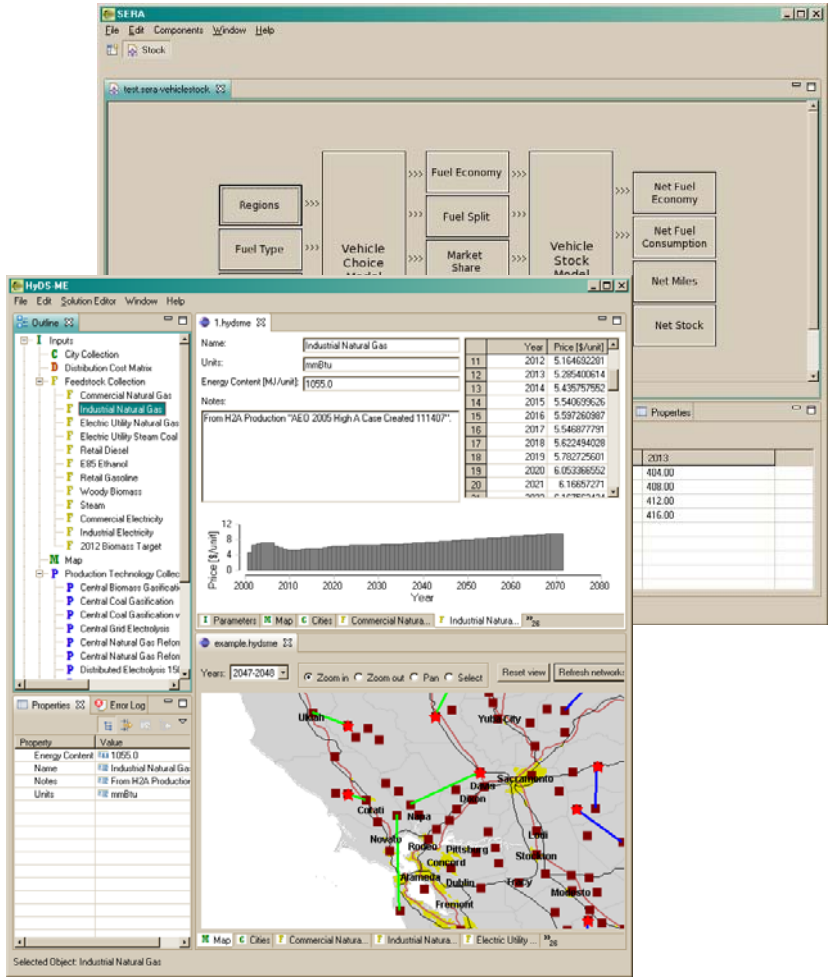
SERA is a suite of tools for studying the cost implications of regional build-outs of renewable energy infrastructures.

Goals

- Generate self-consistent vehicle adoption and fuel demand scenarios relevant to early market transition of alternative fuel vehicles.
- Determine optimal regional infrastructure development patterns for alternative fuels, given resource availability and technology cost.
- Geospatially and temporally resolve the expansion of production, transmission, and distribution infrastructure components.
- Identify niches and synergies related to refueling station placement and early adoption areas.

Key analysis questions

- Which technological pathways will provide least-cost fuels for a specified demand?
- What network economies can be achieved by linking production facilities to multiple demand centers?



Methodology

Scenarios for Hydrogen Infrastructure Development

Scenario Analysis Capabilities

1. Optimization of the physical build-out of hydrogen infrastructure
2. Unified treatment of production, delivery, and dispensing
3. Ease with which new technologies can be added to an analysis
4. Consistent physical and economic computations
5. Ability to estimate costs, cash flows, financing, and incentives
6. Spatial and temporal resolution of hydrogen infrastructure networks, including refueling stations
7. Regional specificity
8. Allowance for exogenously specified urban hydrogen demands.

How are Scenarios Developed?

Construct local scenarios for *early market* infrastructure clustering and vehicle rollout.

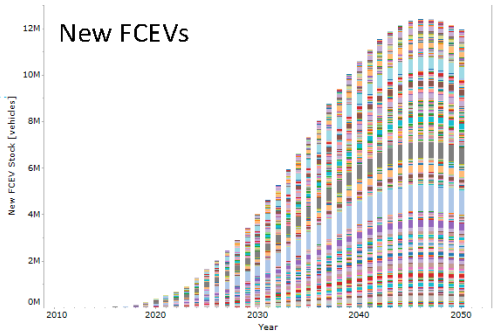
Tune nationwide scenarios to observations and lessons learned in local early market evolution and planning.

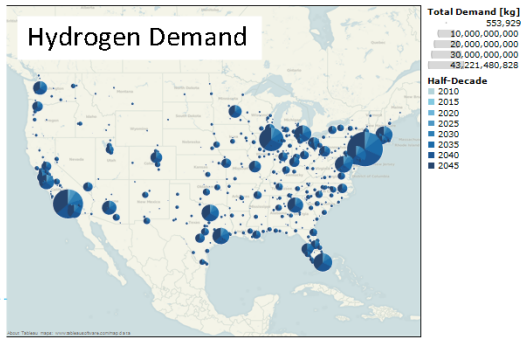
Refine methodology for locating and sizing stations within urban areas.

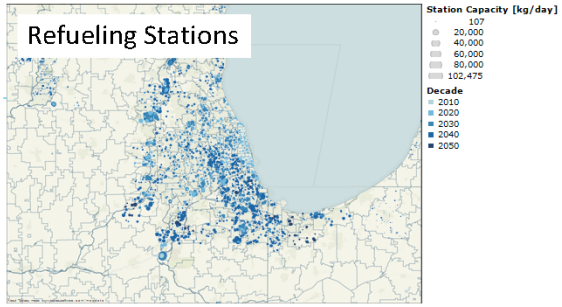
Develop methodology for locating FCEVs at households within urban areas.

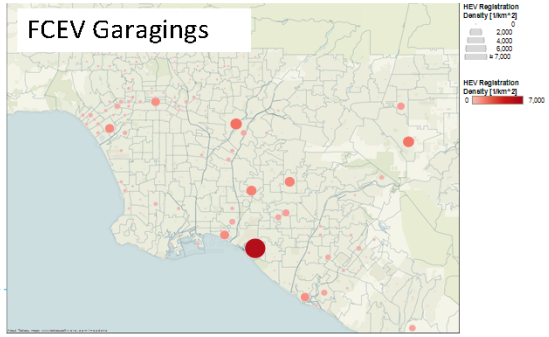
Refine methodology for optimizing the choice of hydrogen production and delivery infrastructure.

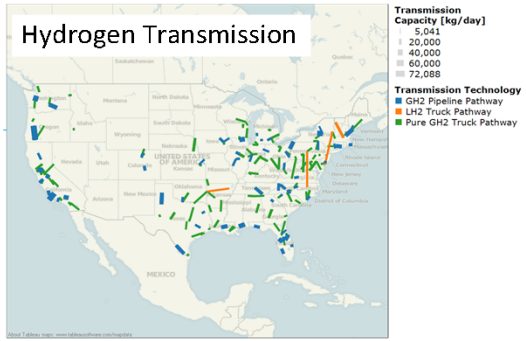
Compute cash flows and delivered costs for hydrogen.

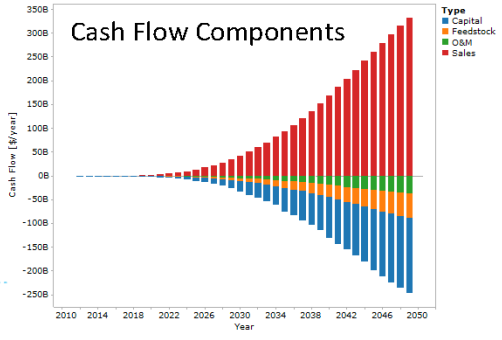




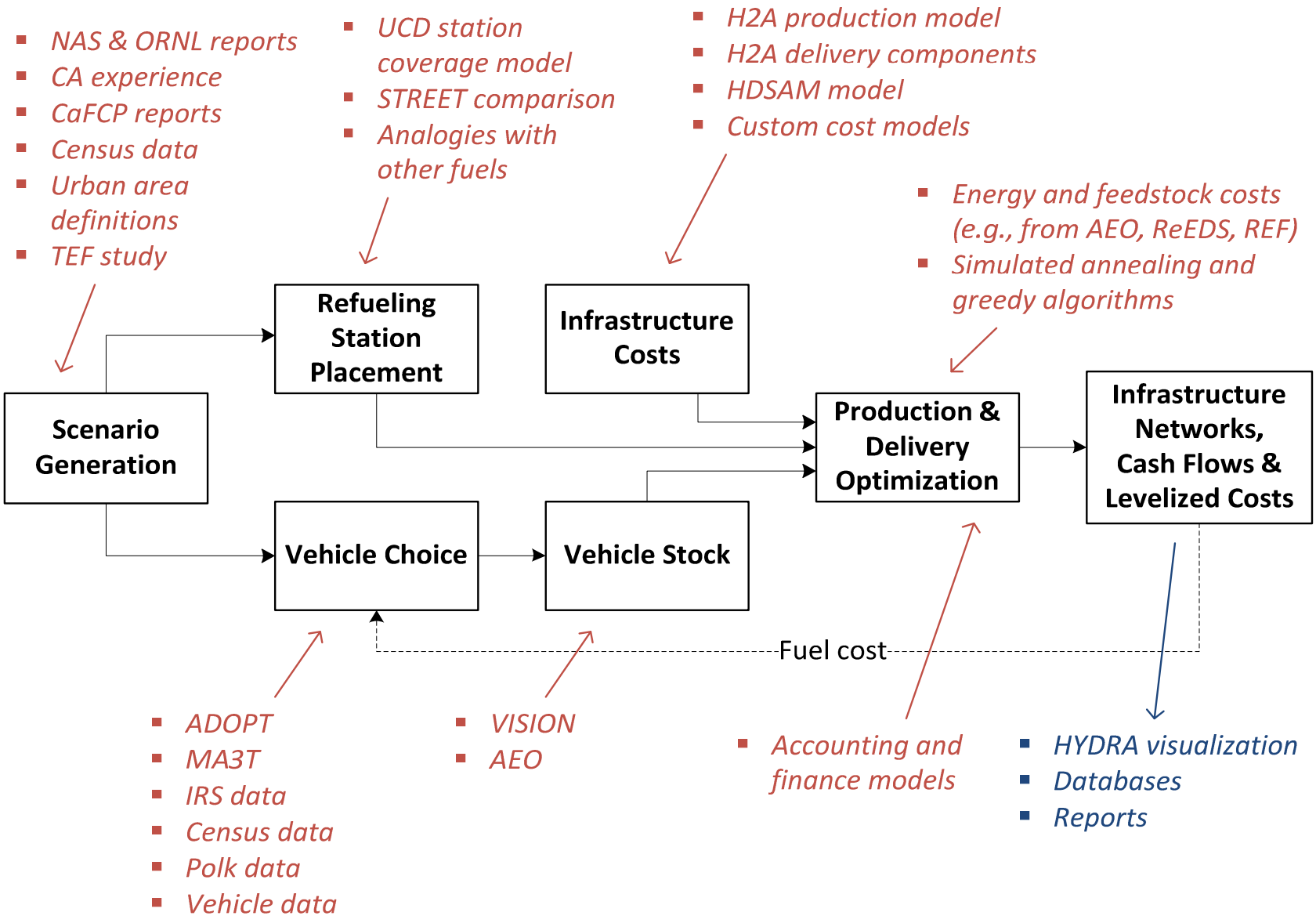






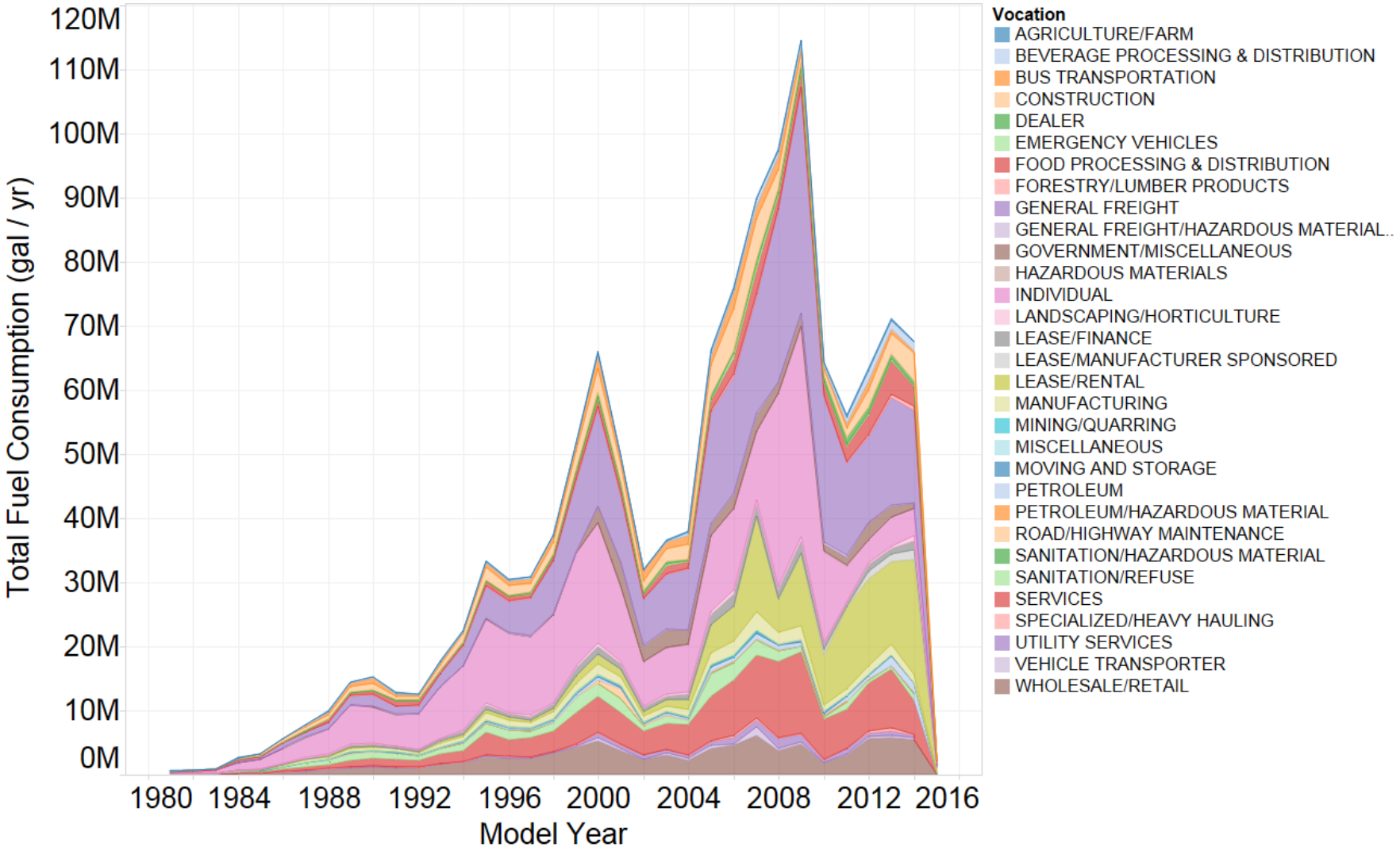


SERA Modules and Inputs



Scenarios can incorporate study-specific inputs

Detailed Breakdowns of Fuel Consumption based on Vehicle Stock

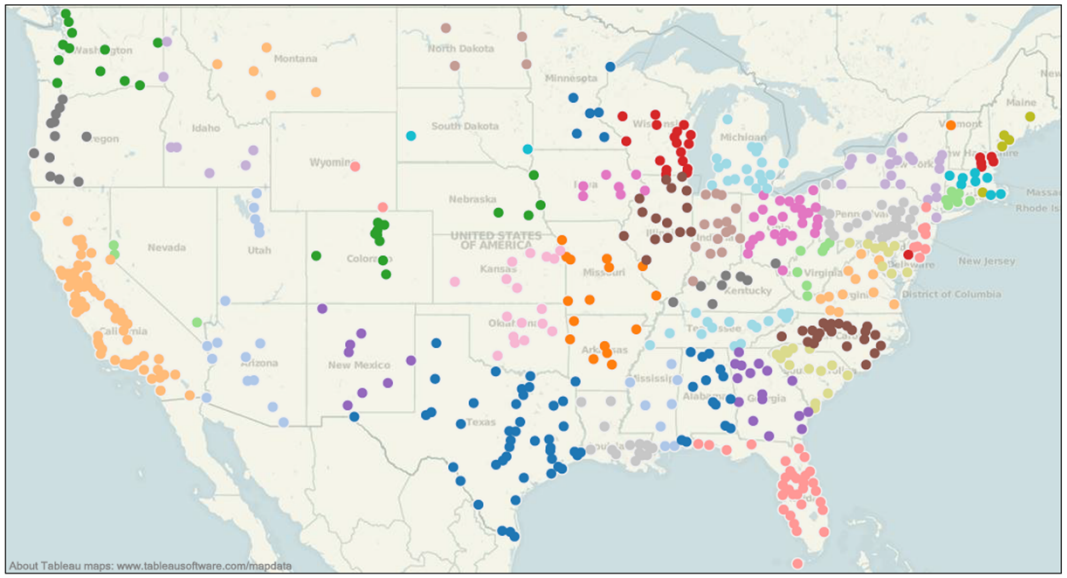


Scenario Example

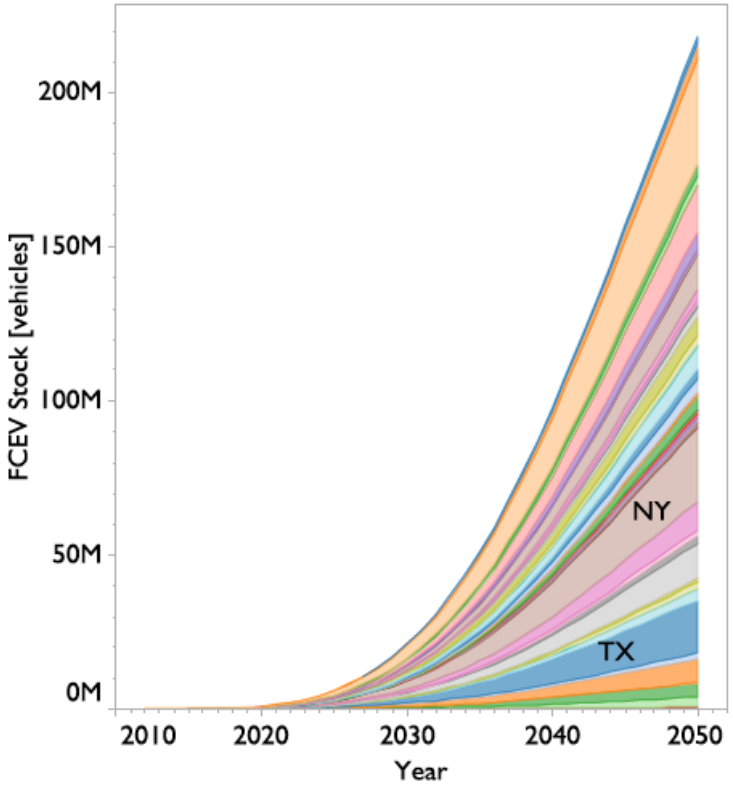
A “Hydrogen Success” Scenario

FCEV sales are disaggregated to city level

- **Urban area FCEV sales growth rates result in an aggregate national market share equivalent to the NAS Hydrogen Success scenario**
- **Disaggregation to largest 600 urban areas**
- **Introduction years are resolved based upon market potential and size**



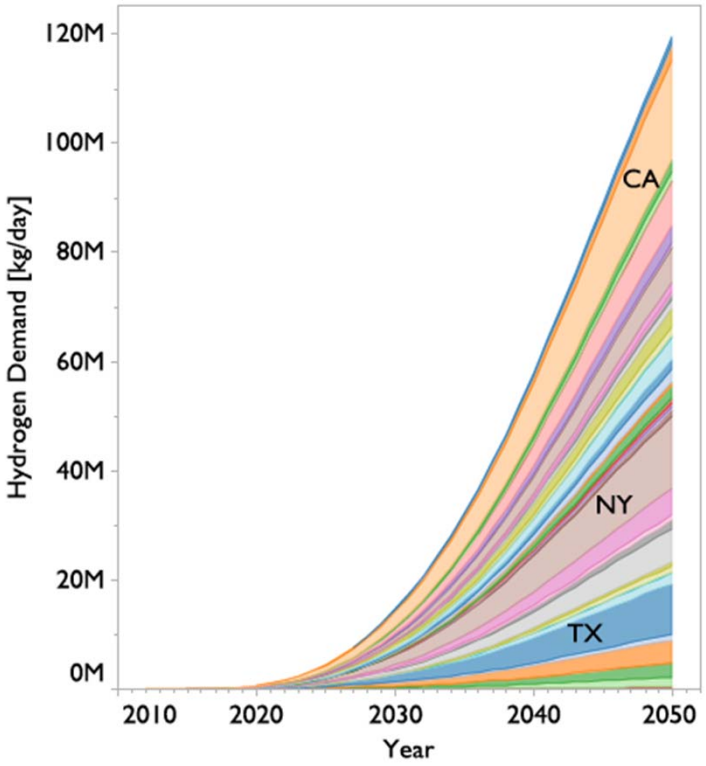
Census urban areas colored by state

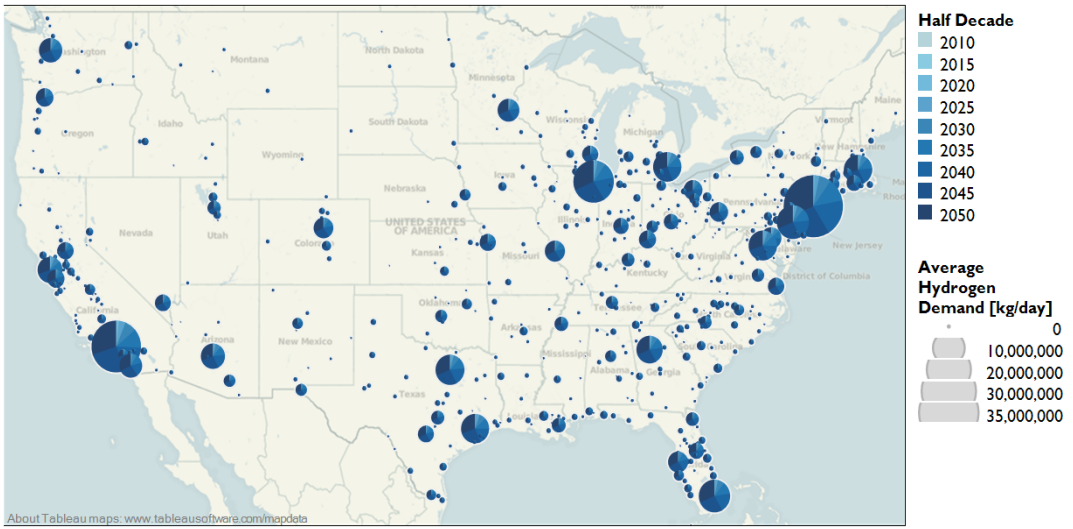


Source for FCEV market share: NAS 2008

LDV stock model resolves resulting hydrogen demand

- VMT and FCEV fuel economy are made equivalent to NAS scenario assumptions, resulting in identical demand growth
- Stock model includes entire LDV and M/HDV fleets, and is based upon ANL's VISION model, which follows AEO projections

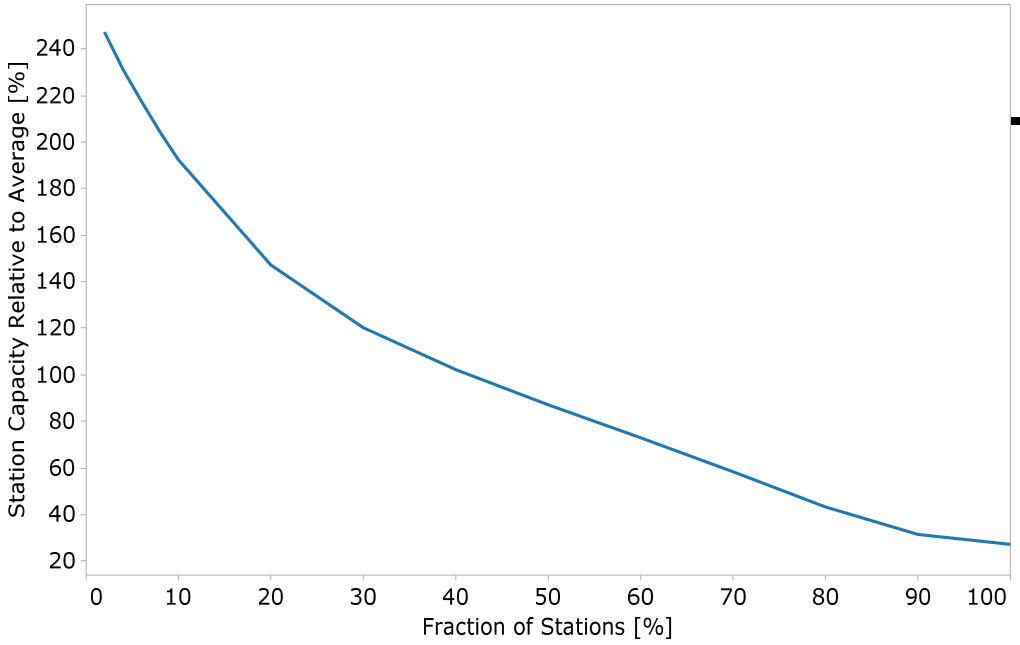


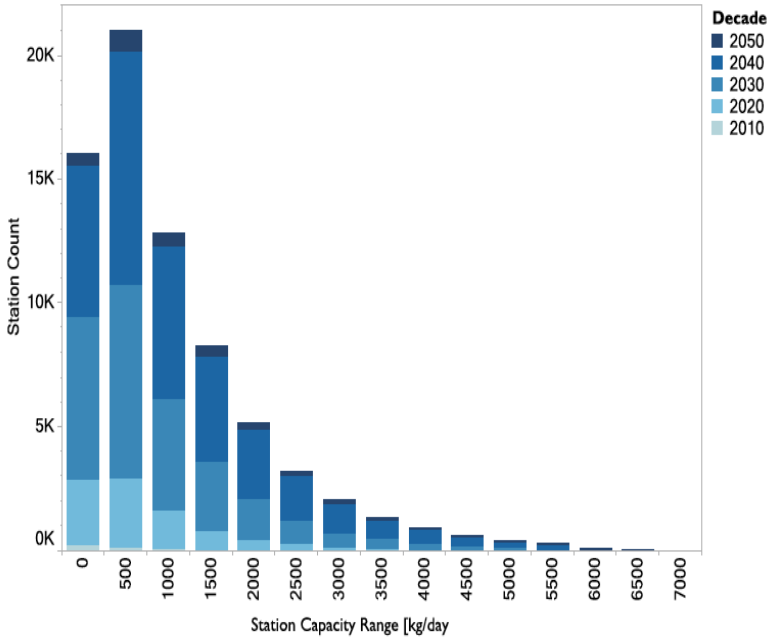


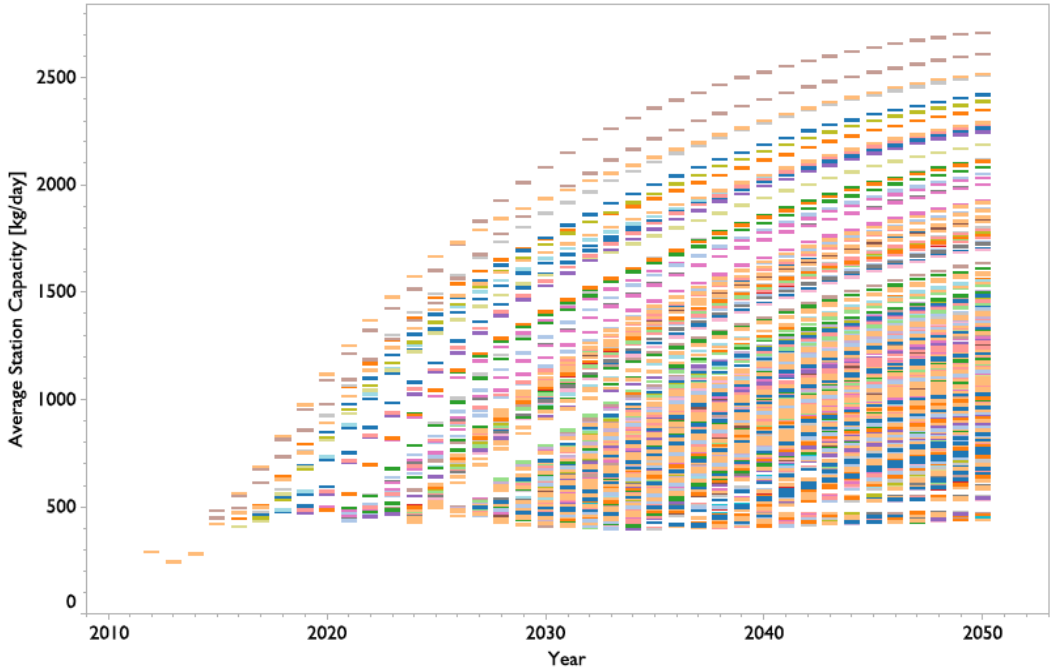
Size is proportional to demand in 2050, and color coding indicates half-decade increases

Station Sizes

- Station sizes follows a uniform relative distribution, following pattern seen in gasoline station networks
- Average sizes increase over time

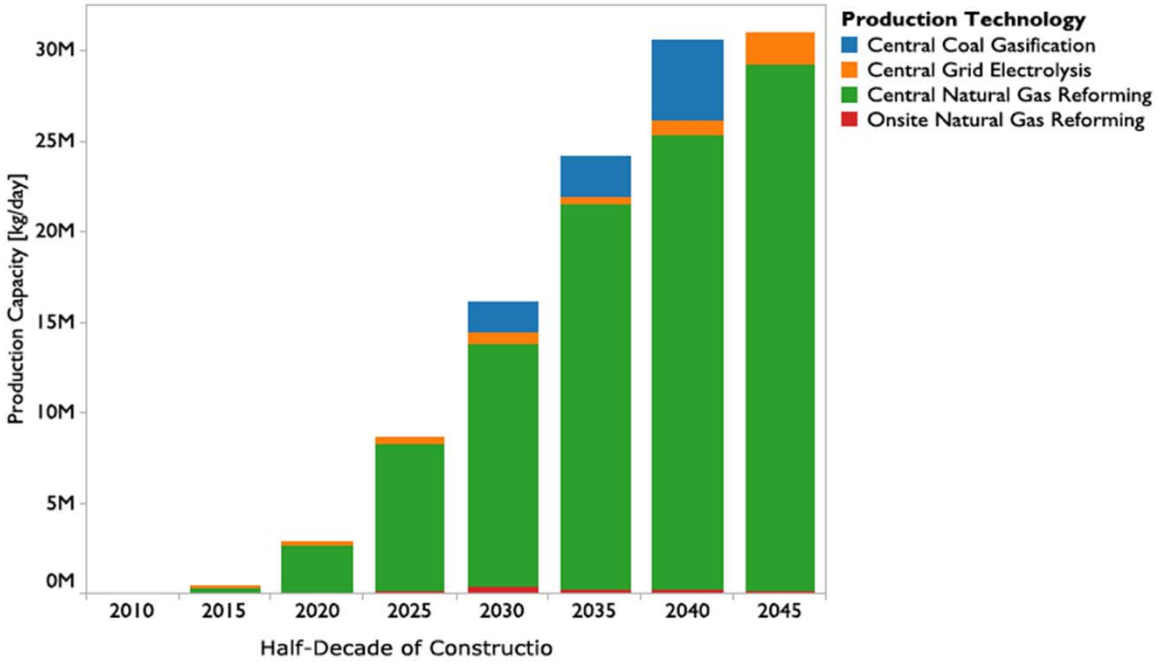


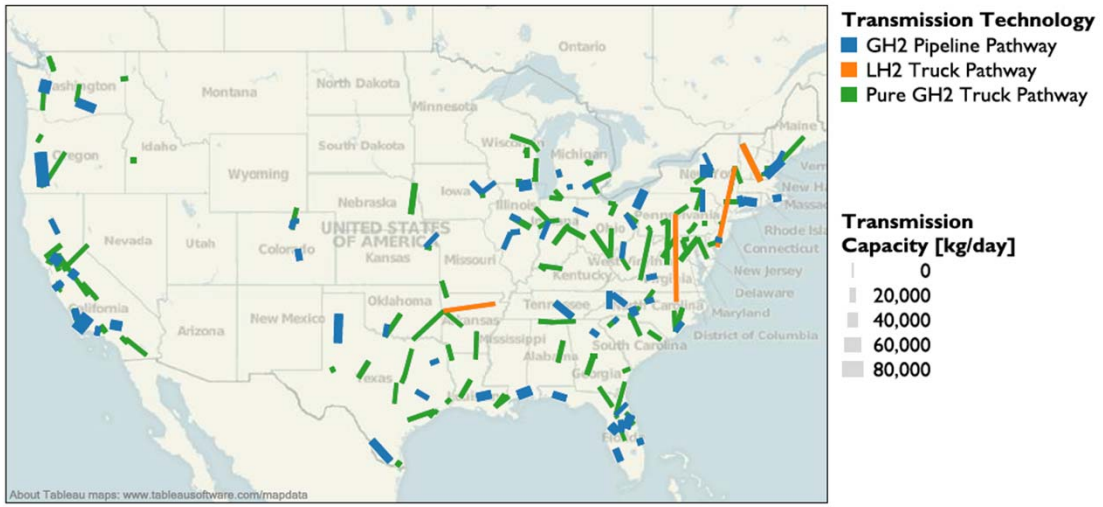




Optimization over all production and delivery pathway combinations

- Full supply chain component characterizations to estimate optimal $/kg of delivered hydrogen
- Incorporates legacy investments, and can be resolved with perfect (long-term) foresight or limited investment horizons
- GH2 truck deliver and central SMR tend to dominate over time





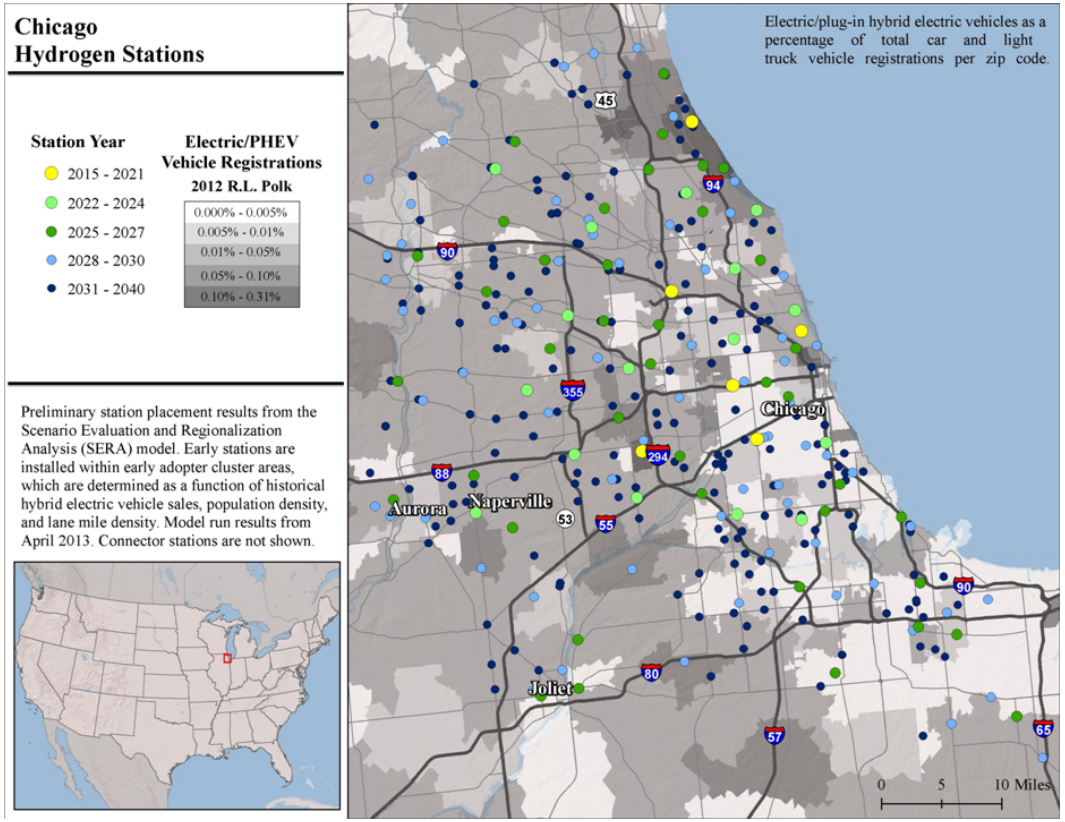
Station size, year of construction, and placement is sensitive of local conditions

Location algorithm incorporates wide range of indicates within a statistical framework

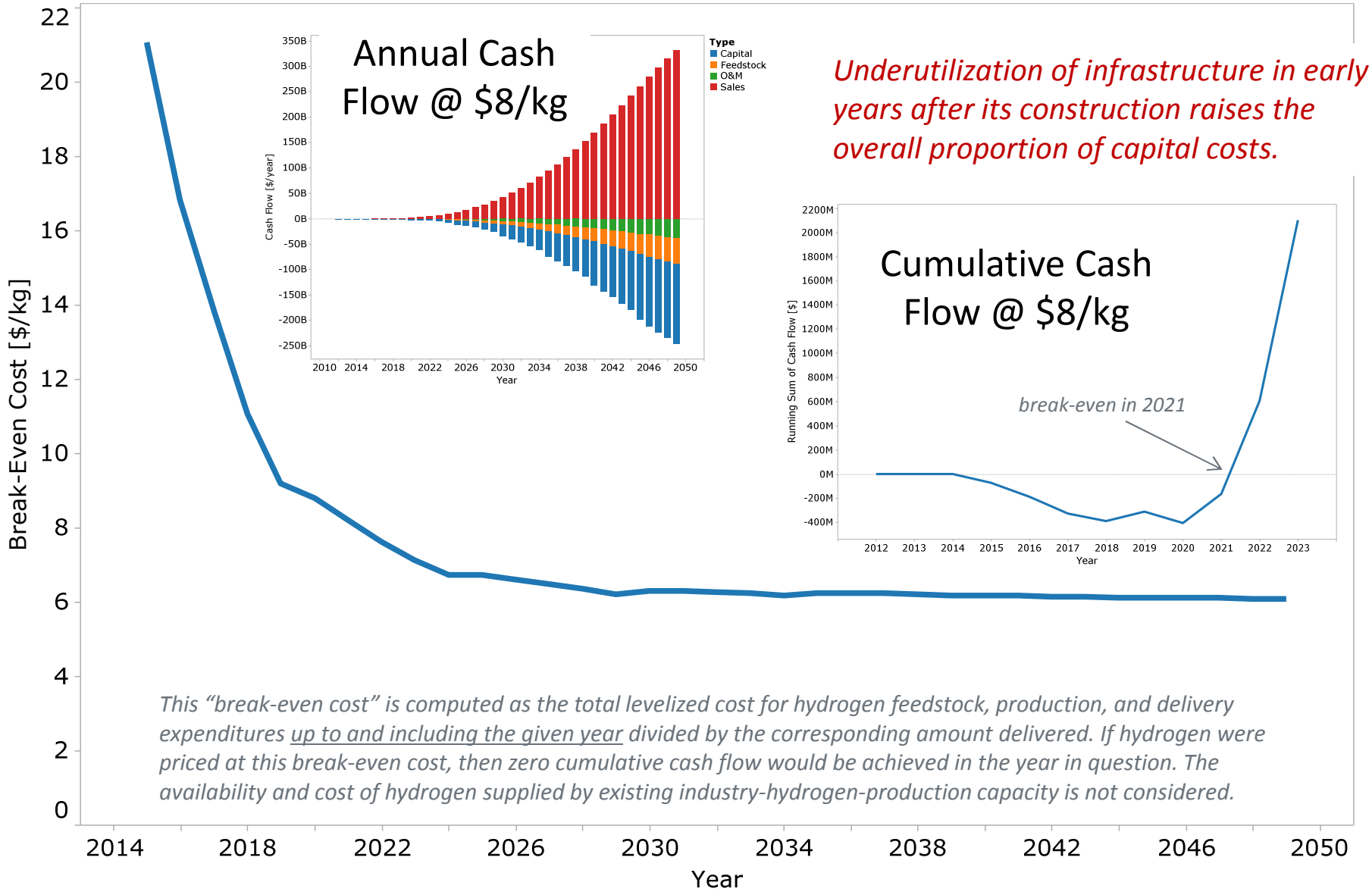
For example:

- Population density
- Early adopter metric
- Highway exits
- Existing gasoline stations

Weights can be developed for other consumer attributes, or for results from a consumer choice model such as ADOPT



Zero cumulative cash flow is achieved between 2018 and 2025 if hydrogen is priced at $11.00/kg or $6.75/kg



Underutilization of infrastructure in early years after its construction raises the overall proportion of capital costs.

This "break-even cost" is computed as the total levelized cost for hydrogen feedstock, production, and delivery expenditures up to and including the given year divided by the corresponding amount delivered. If hydrogen were priced at this break-even cost, then zero cumulative cash flow would be achieved in the year in question. The availability and cost of hydrogen supplied by existing industry-hydrogen-production capacity is not considered.

Detailed Scenario Metrics

For a Particular Region: Northeast Corridor States

PRELIMINARY

Proposed NEC Market Regions: 3 Centers and 3 Corridors

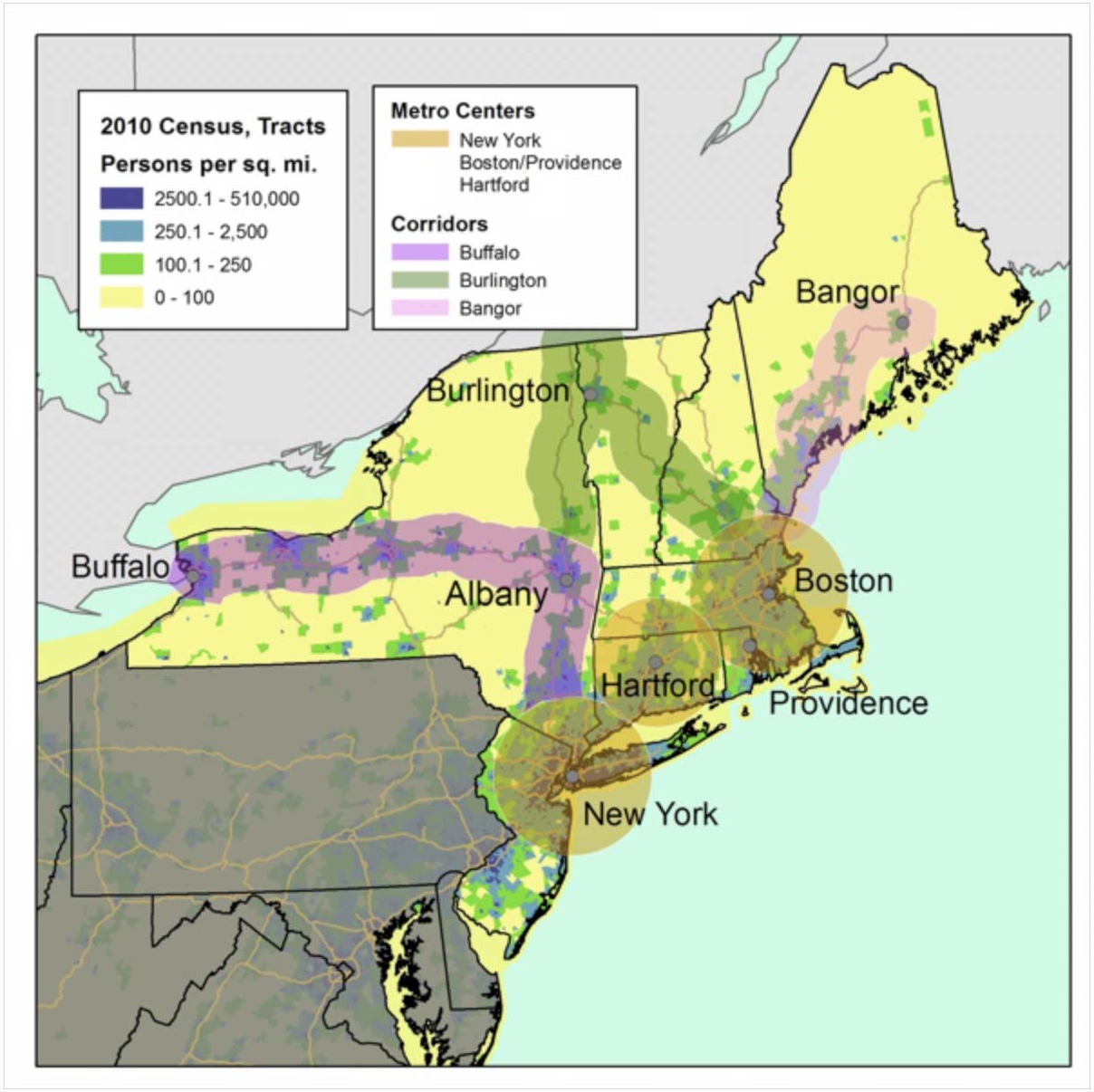
Highest population density metro centers

- New York City
- Boston/Providence
- Hartford

Corridors west to Buffalo and north to Burlington and Bangor

<u>Outside NEC</u>

High density regions extend west to Pittsburgh and south to Philadelphia and Baltimore/ Washington D.C.



Source: Melaina et al. 2012

FCV deployment scenarios meet ZEV mandate

36% ZEV Mandate Scenario

- Meets the ZEV mandate in the Northeast with 36% of credits between 2018 and 2025 derived from FCEV sales

66% ZEV Mandate Scenario

- Meets ZEV mandate with 66% of credits from FCEVs

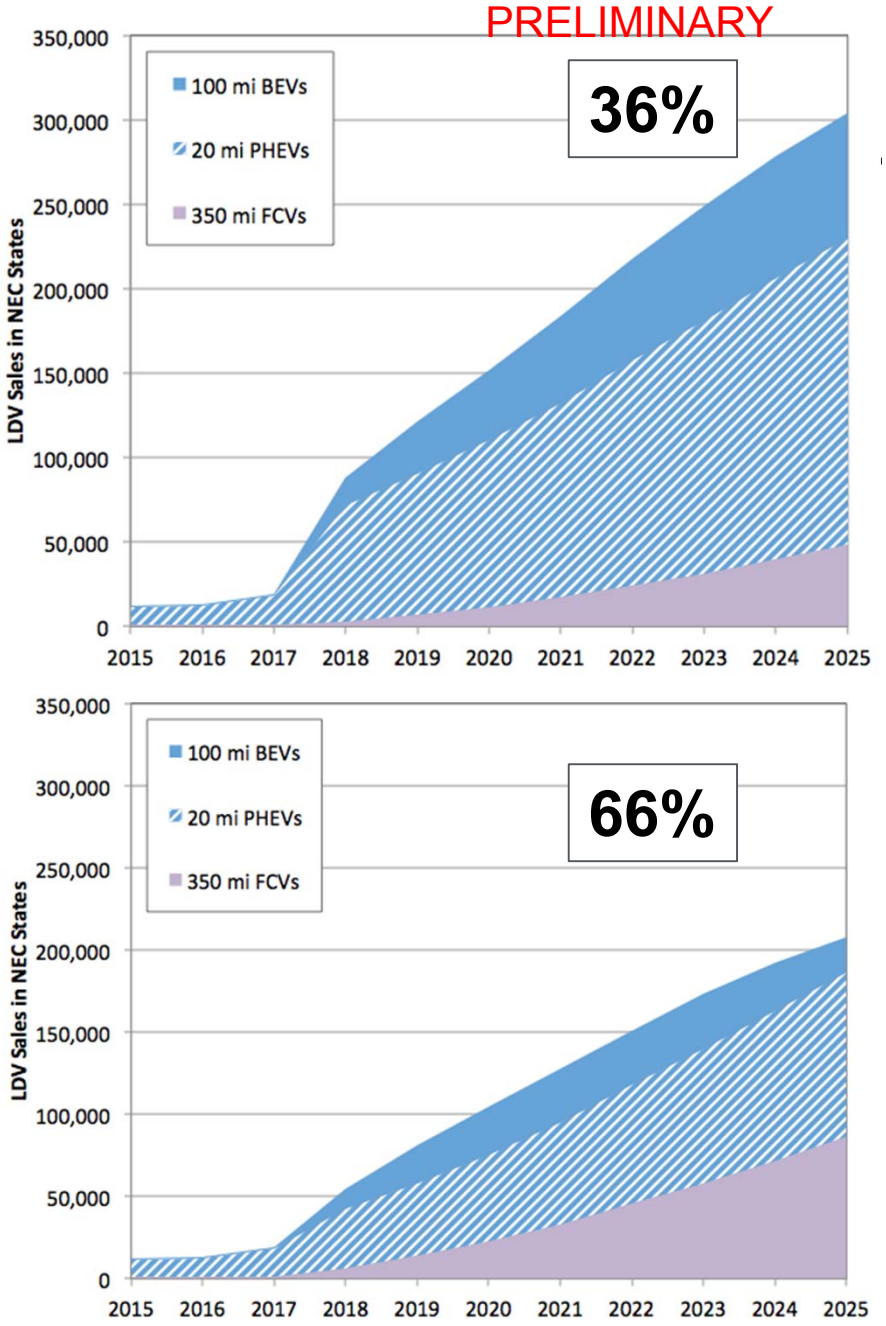
Introduction of FCEVs is staggered similarly in both scenarios, starting with largest and highest density regions and eventually moving to markets along corridors

ZEV Credit Assumptions

- **350 mile FCEVs: 4.0**
- **100 mile BEVs: 1.5**
- **20 mile TZEV/PHEVs: 0.7**

The CARB *ZEV Calculator* is posted here:
http://www.arb.ca.gov/msprog/clean_cars/clean_cars_ab1085/clean_cars_ab1085.htm

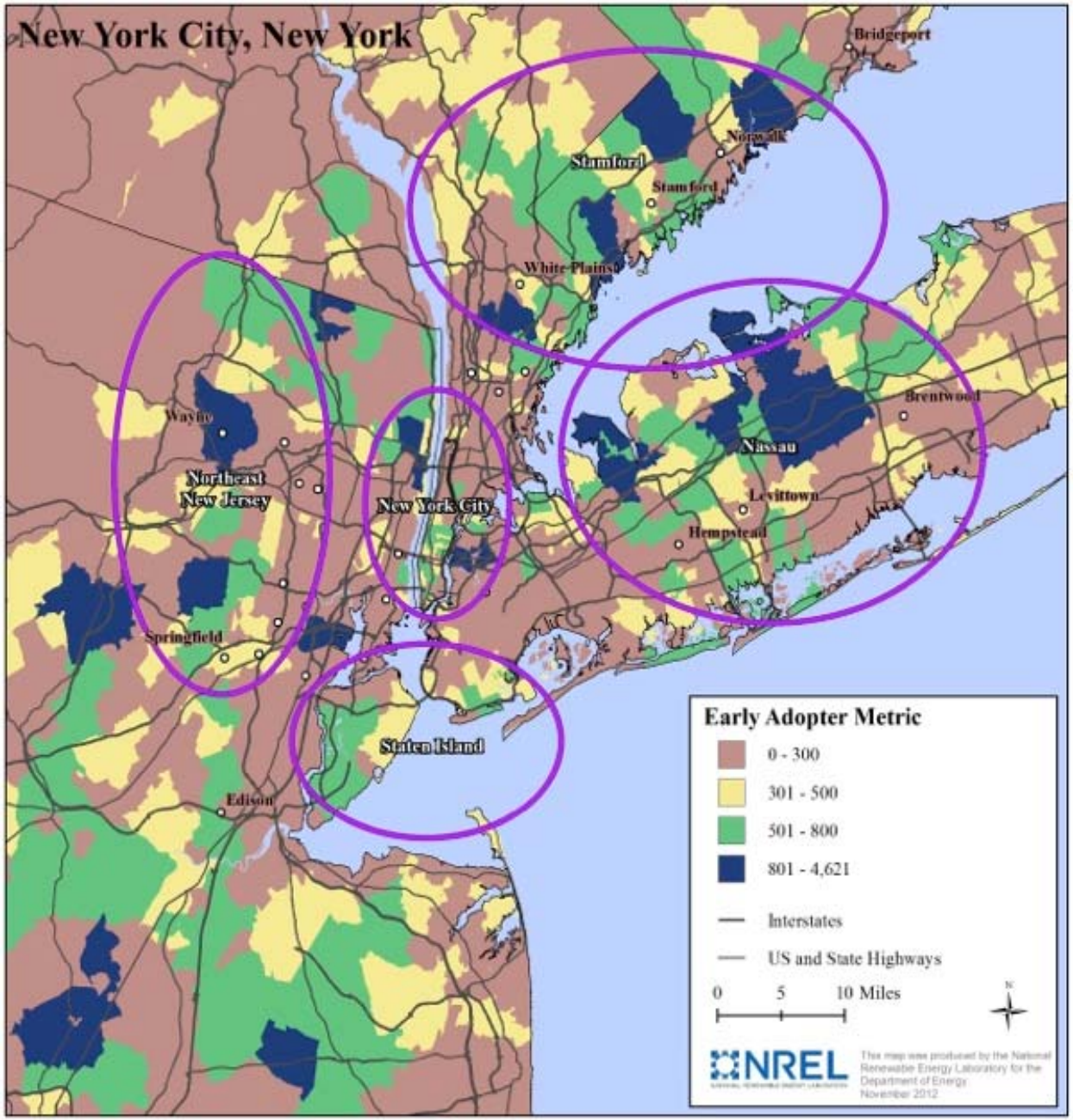
PRELIMINARY



Source: Melaina et al. 2012

PRELIMINARY

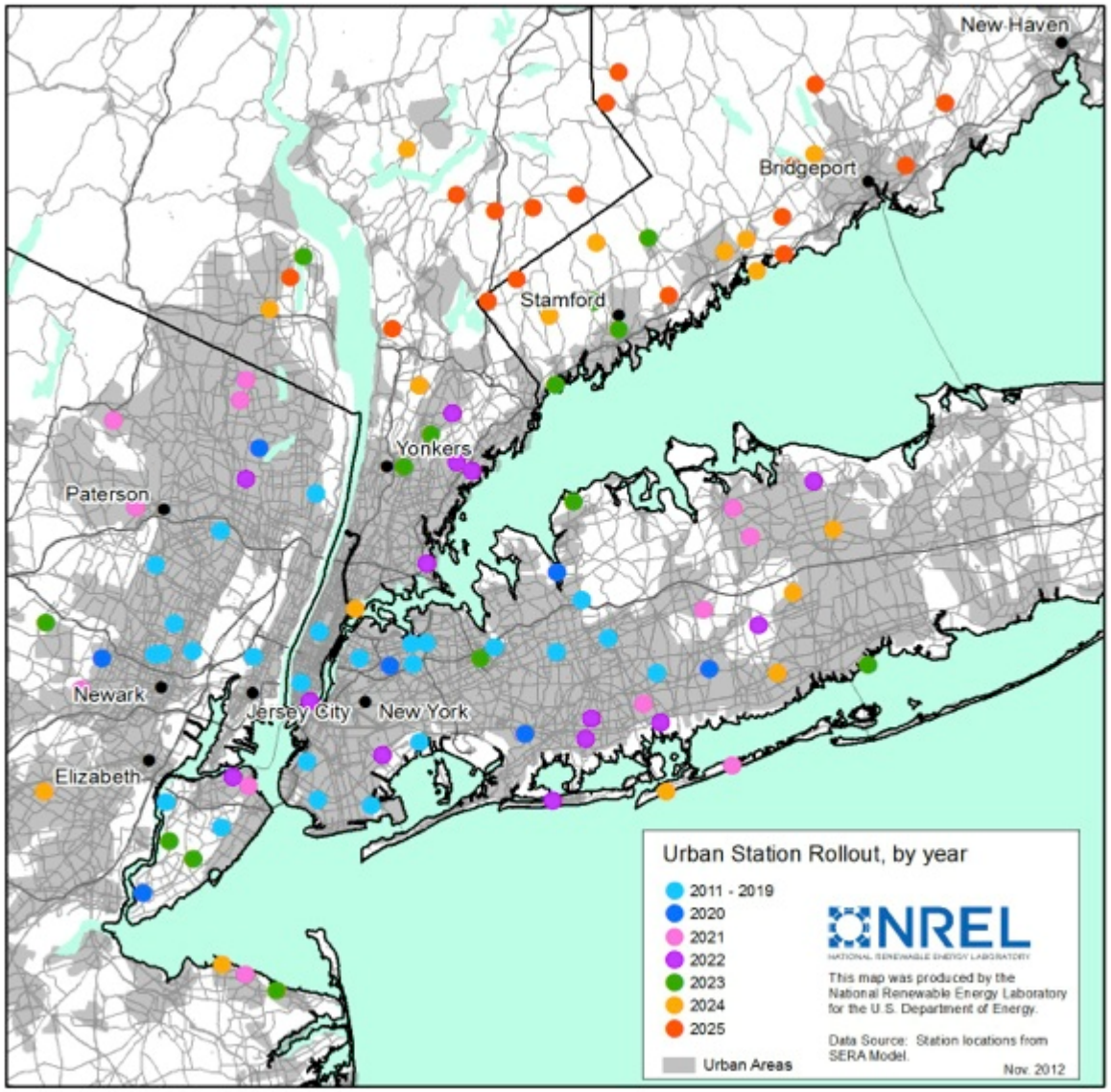
EAM Results and Potential Clusters for the NYC Region



Source: Melaina et al. 2012

PRELIMINARY

Potential NYC region stations out to 2025

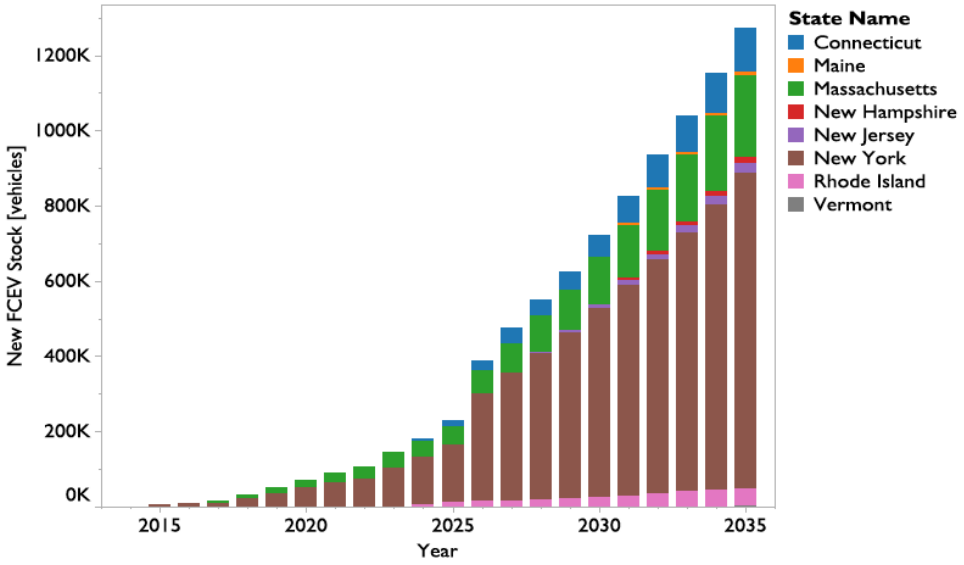


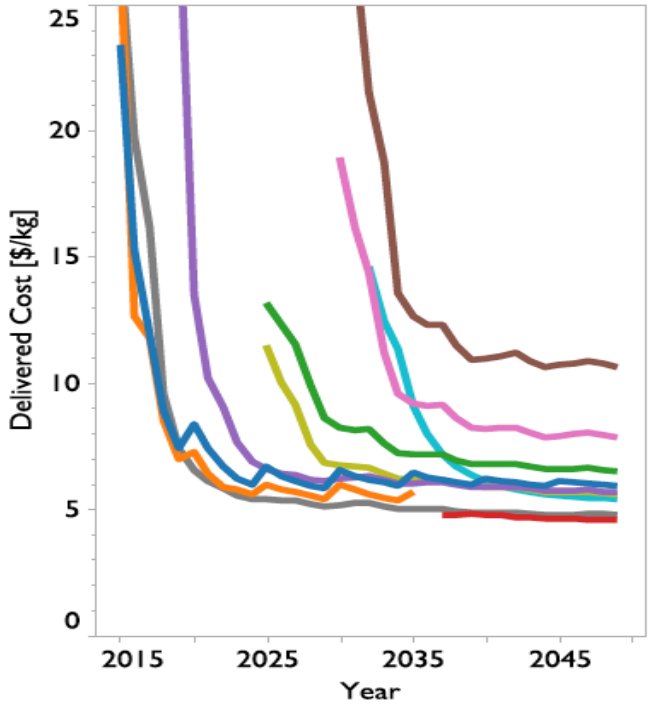
Source: Melaina et al. 2012

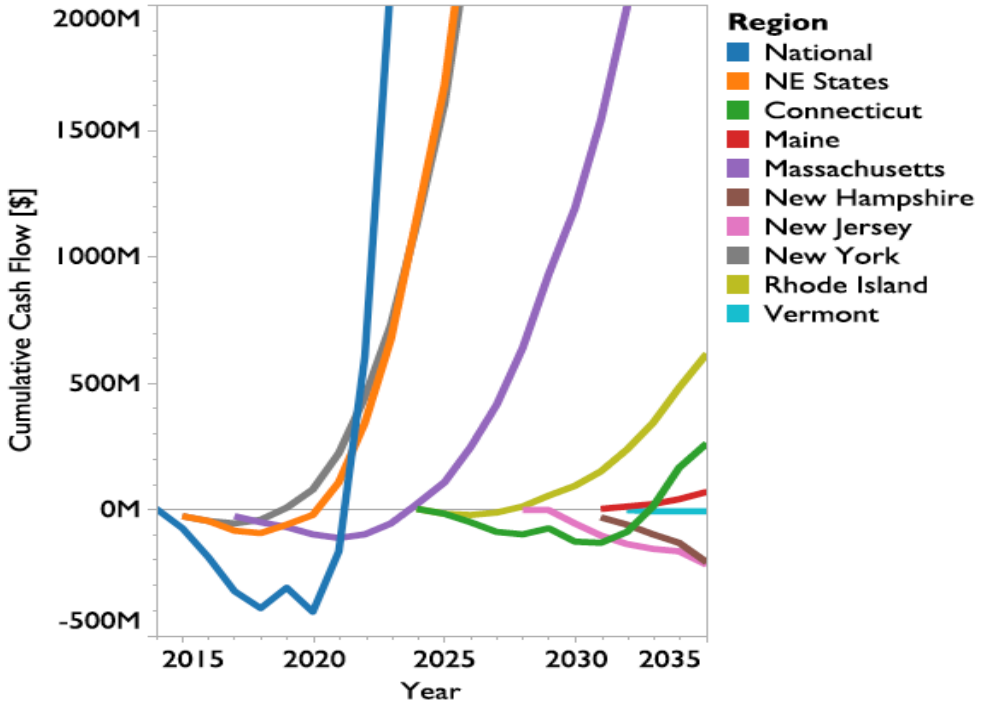
PRELIMINARY

Results by State

- Market share, demand, and cash flows can be broken out by state
- Still optimized across region



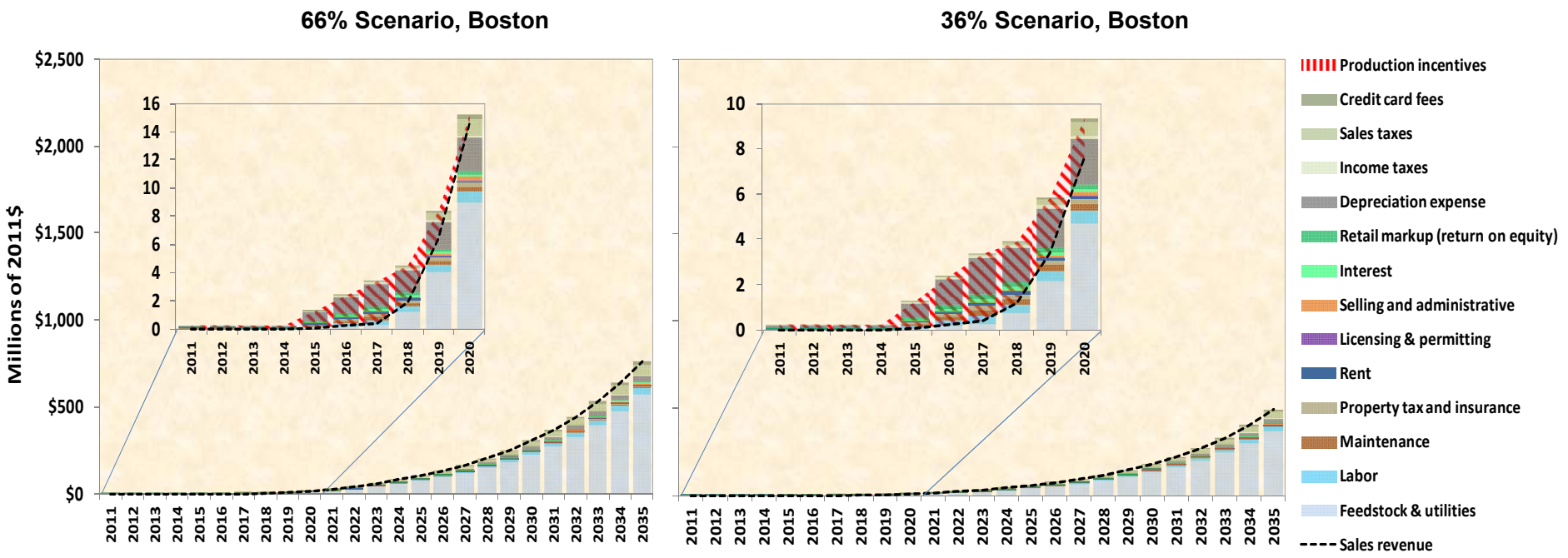




Source: Melaina et al. 2012

PRELIMINARY

Cash flow results with incentives: Boston



Source: Melaina et al. 2012

Summary and Conclusions

- SERA scenario development capabilities can be tailored to a wide range of cases and incorporate data for multiple vehicles, fuels, and optimization metrics.
- The model determines optimal costs for vehicle-fuel pathways over time and space, accounting for competition among pathways and evolving technologies.
- A Northeast Corridor case study demonstrates the ability to resolve technical and financial metrics at the state or urban area scale.
- The national *Hydrogen Success* scenario estimates total cash flows, which can also be disaggregated to any geographic scale.

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Questions?

References

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