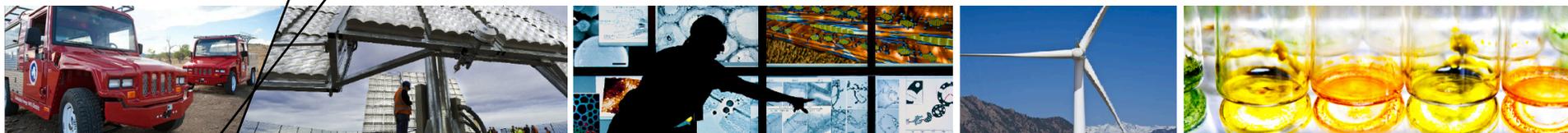


## DOCKETED

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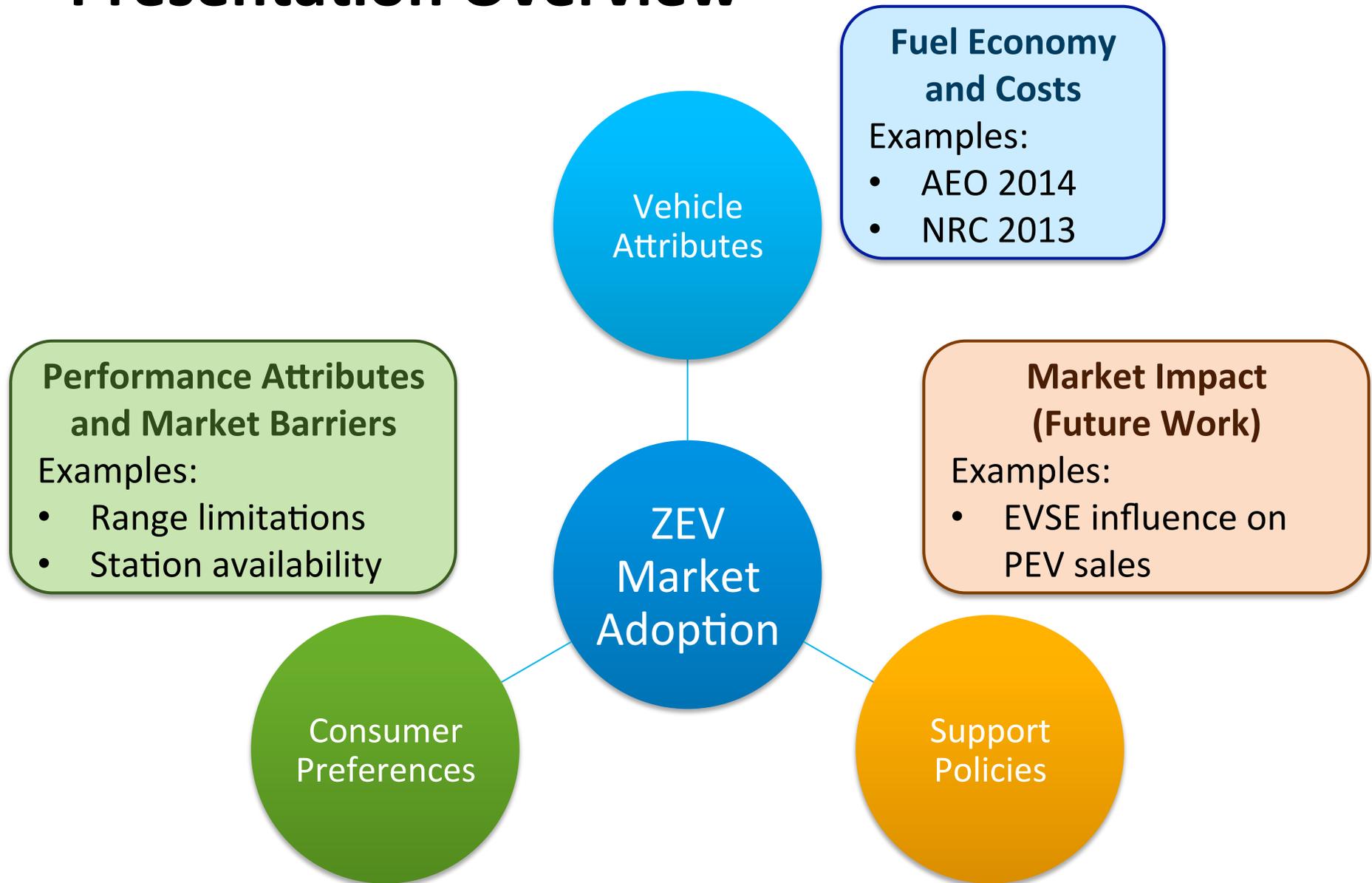
# Vehicle Attributes and Alternative Fuel Station Availability Metrics for Consumer Preference Modeling



***Energy Commission Workshop***  
Sacramento, California  
March 19, 2015

**M. Melaina, Y. Sun and A. Brooker**  
Systems Analysis and Integration  
NREL Transportation Center

# Presentation Overview



# Background: Key Points

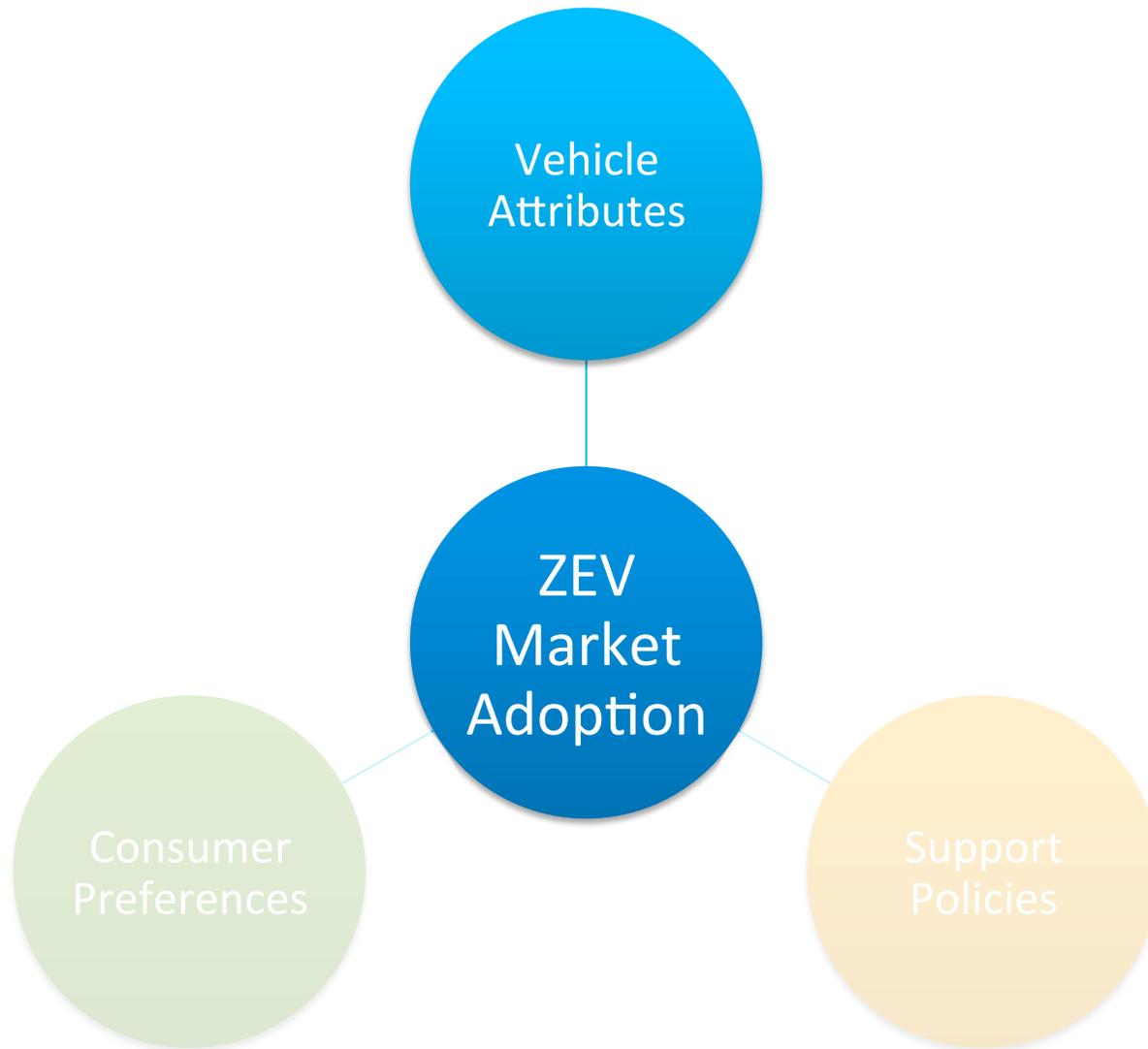
## Vehicle Attributes

- Incumbent vehicles will continue to be competitive
- Alternative fuels and ZEVs (BEVs, PHEVs, FCEVs) have the potential to provide deep carbon reductions over the long term
- Technology innovation trends cannot be considered separately from market transformation policy drivers

## Consumer Preferences

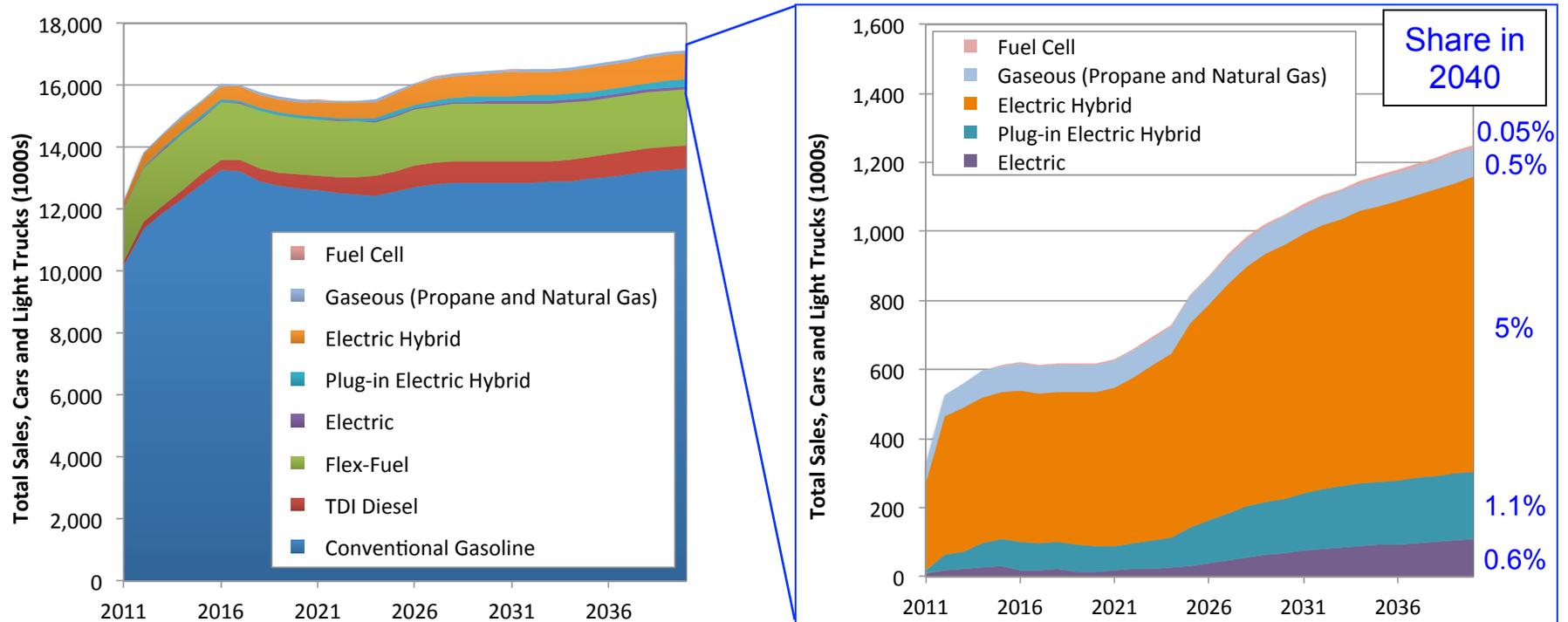
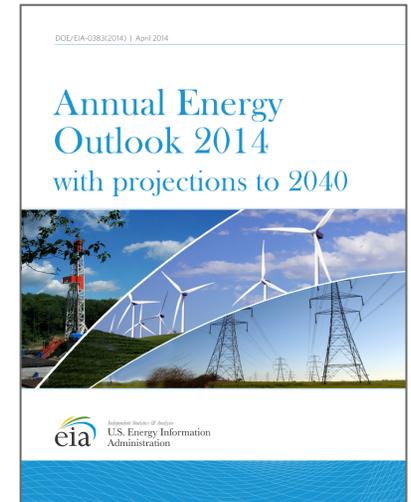
- Range penalties may be significant
- Station availability (EVSE & hydrogen stations)
  - May be an important barrier for BEV adoption, as well as a limiting factor for achieving e-miles in BEVs and PHEVs
  - Critical market barrier for FCEV adoption
  - Major uncertainties around consumer responsiveness

# Vehicle Attributes



# Energy Information Administration's Annual Energy Outlook (AEO 2014)

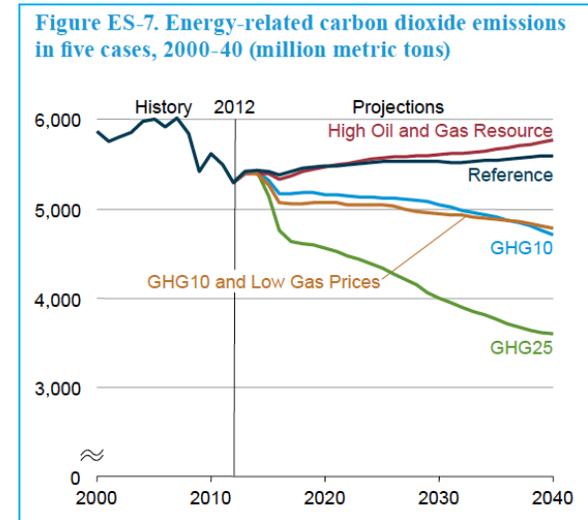
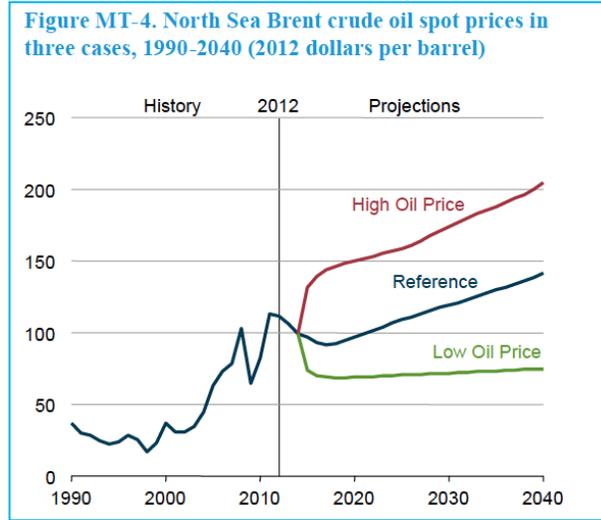
- Independent analysis of energy markets, data, and technology trends
- AEO 2014 suggests very modest market growth for alternative light duty vehicles (LDVs, Cars & L. Trucks)



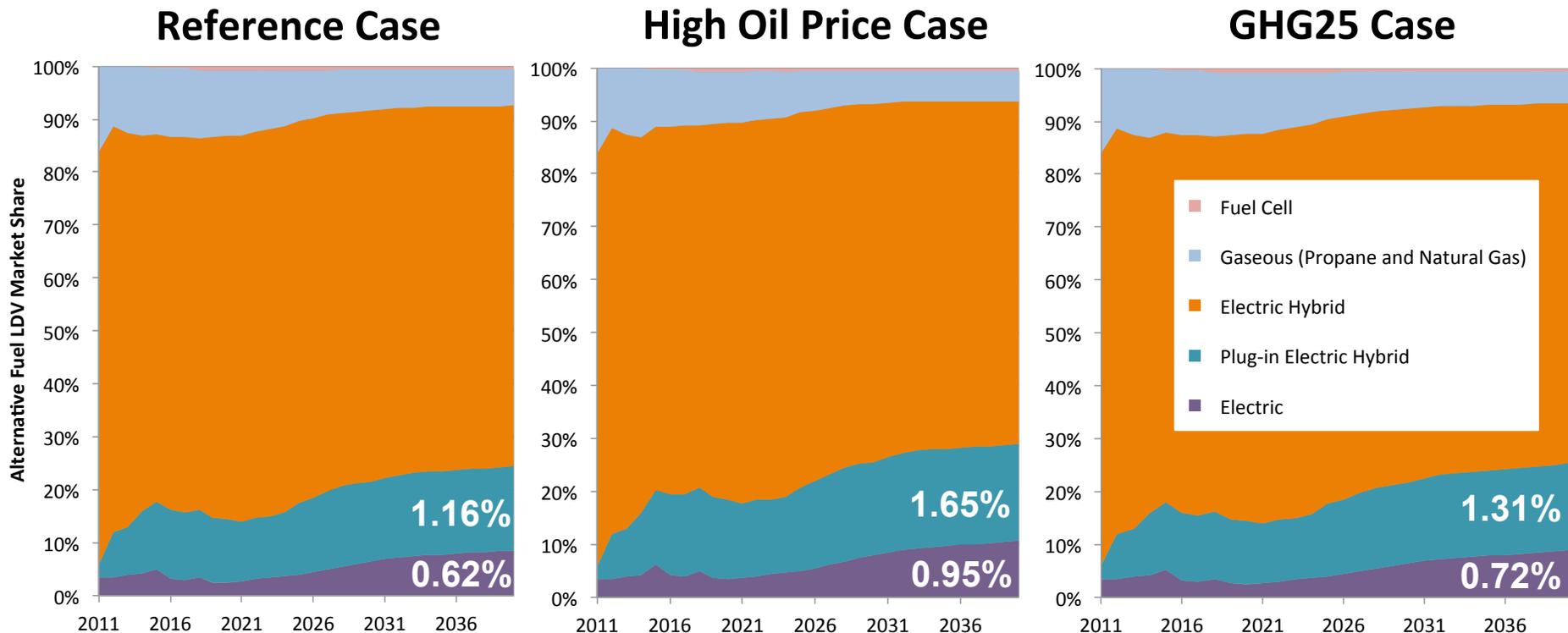
Source: AEO's Interactive Table Viewer: <http://www.eia.gov/oiaf/aeo/tablebrowser/>

# LDV Shares for Alternate AEO 2014 Cases: High Oil Price and GHG25

Very minor differences in Market Share by 2040

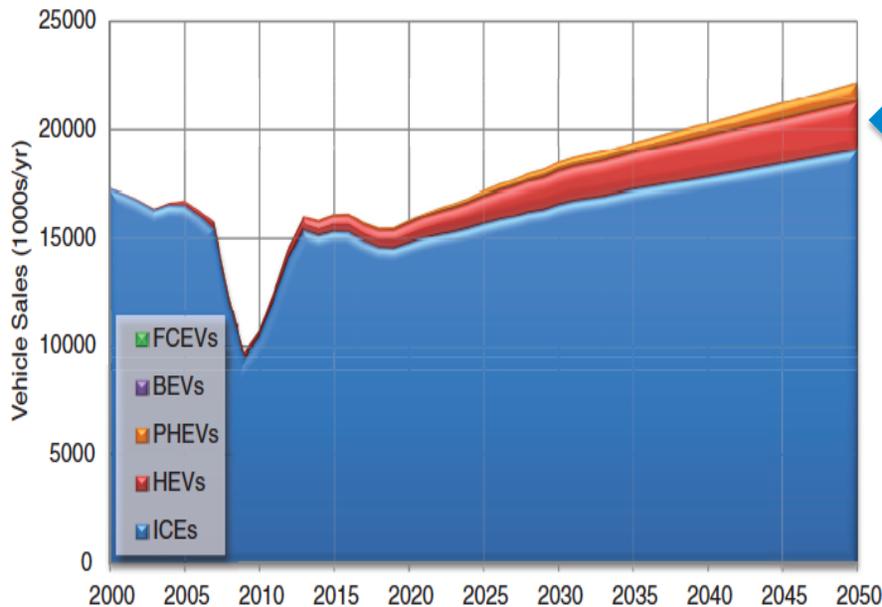
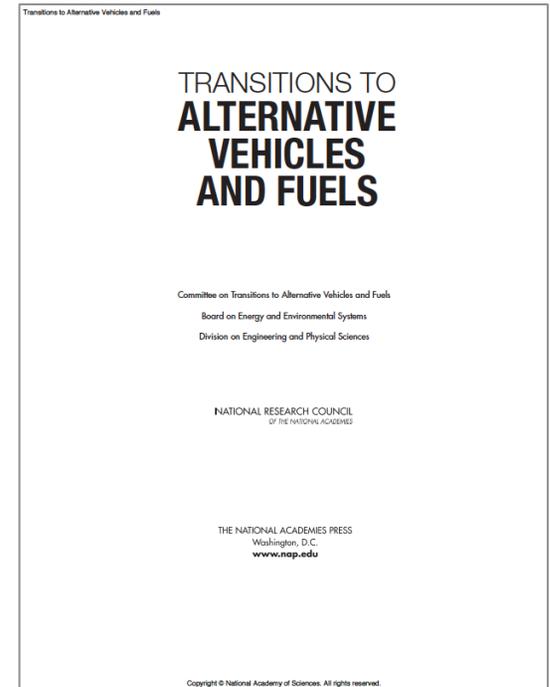


Source: AEO 2014



# National Academy of Sciences 2013 report on reducing LDV GHG emissions 80% by 2050 (NRC 2013)

Report explores multiple options for deep GHG reductions in LDV fleet



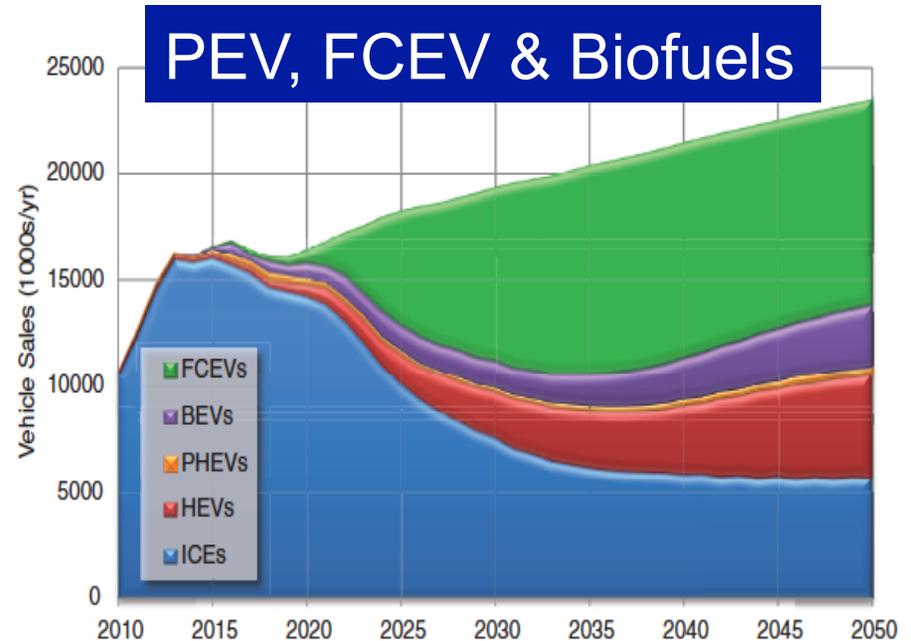
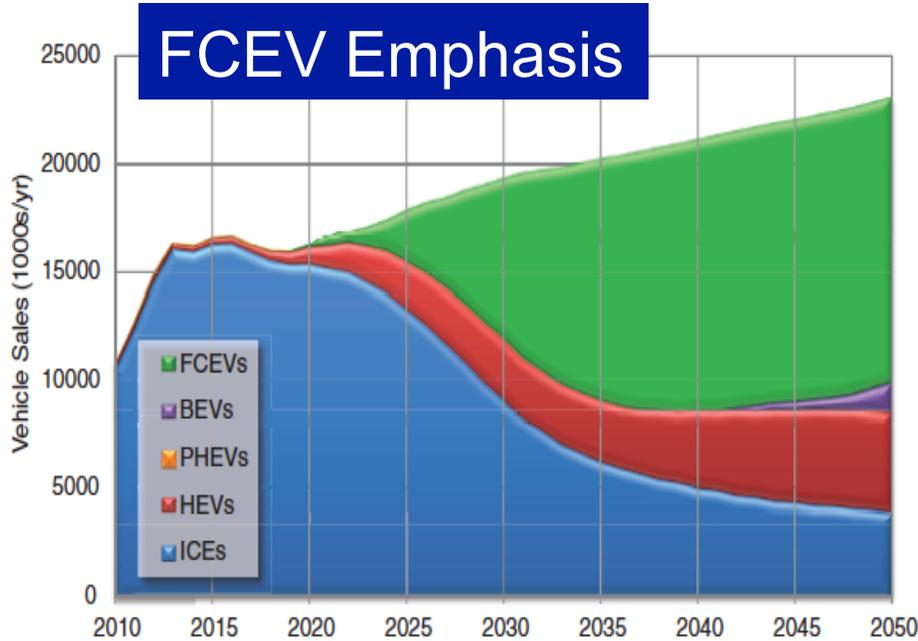
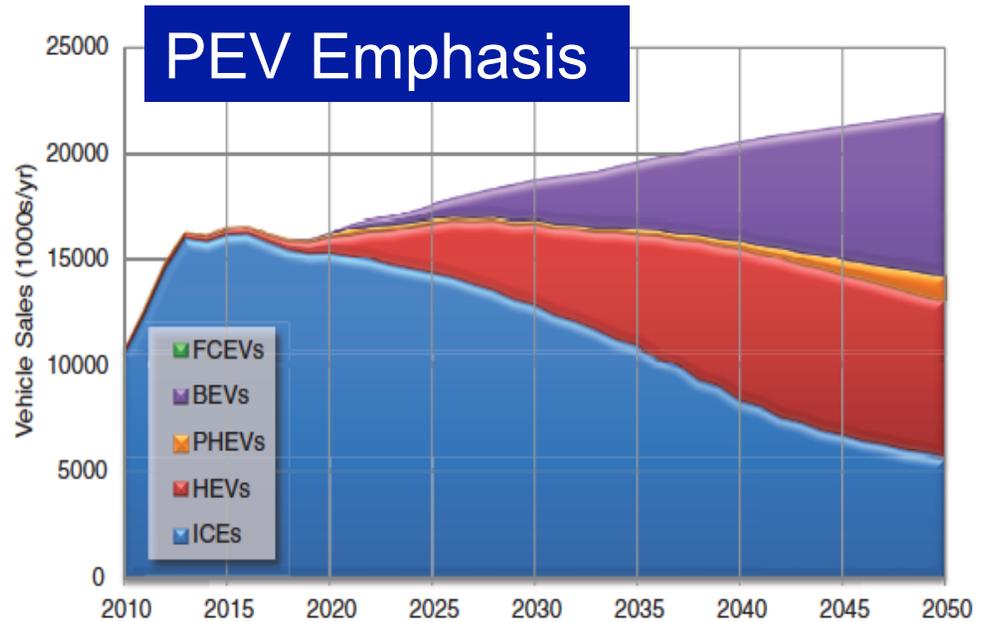
Source: NRC 2014

## Business as Usual Scenario

- BAU scenario is similar to the AEO Reference Case
- Other scenarios include emphasis on: biofuels, PEVs, FCEVs, and CNGVs

# Three Scenarios examine success with electric-drive vehicles

All three require significant vehicle subsidies to achieve market success



Source: NRC 2014

# Only some NRC Scenarios meet 2050 80% Goal

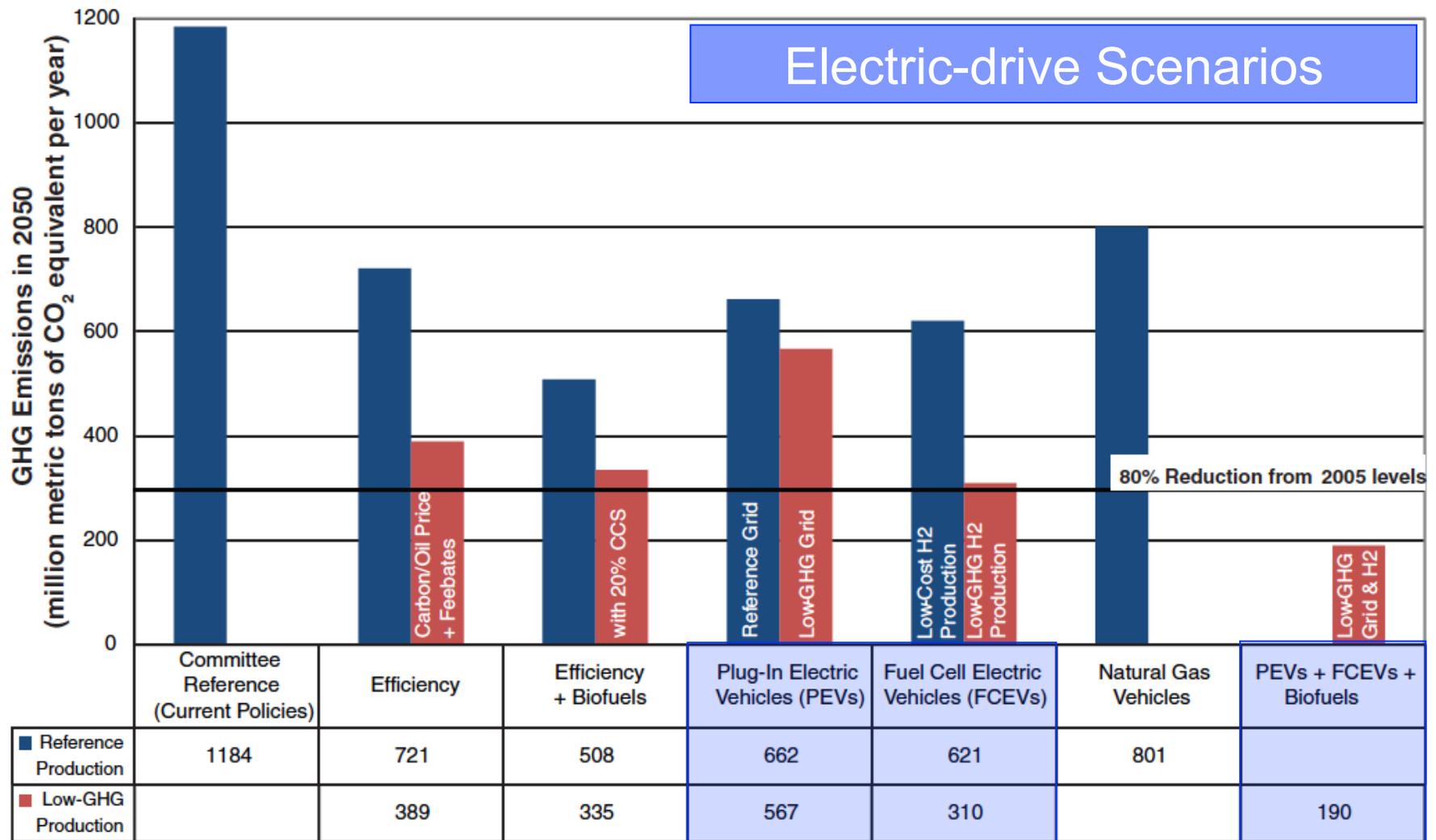


FIGURE S.2 Estimated U.S. LDV GHG emissions in 2050 under policies emphasizing specific technologies. All scenarios except the Committee Reference Case (current policies, including the fuel economy standards for 2025) include midrange efficiency improvements. Fuel production for these scenarios is assumed to be constrained by policies controlling GHG emissions (low GHG production).

Source: NRC 2014

# Major Differences between AEO & NRC Scenarios

## Scenario Goals

- AEO goal is objective projections
- NRC goal is to examine 2050 GHG 80% goal

## Policy Context

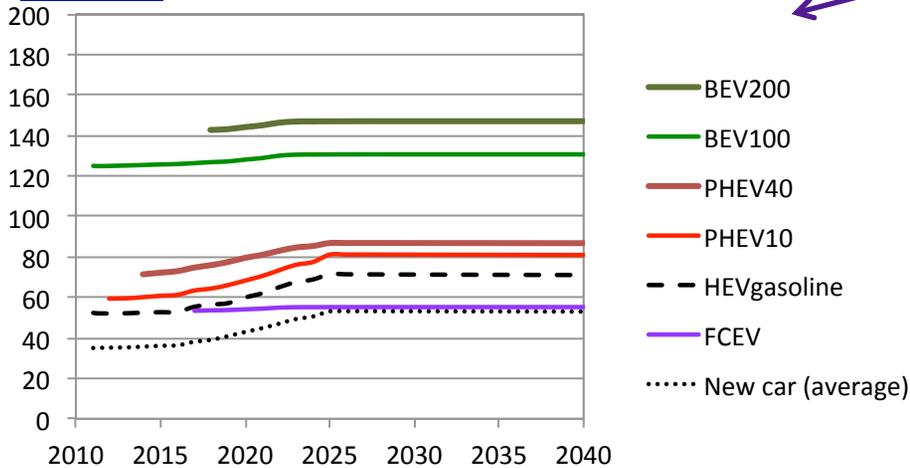
- AEO: primarily existing policies
- NRC articulated and estimated the magnitude of the (very aggressive) policies required to meet the GHG 2050 goal

## Technology Trends

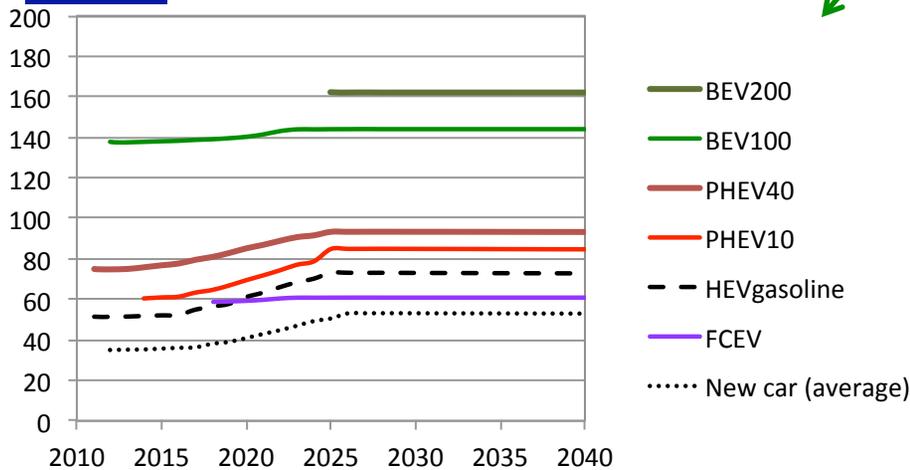
- AEO: Market viability without major transportation policy drivers or major innovation improvements
- NRC: Very aggressive performance and cost improvements for LDVs (midrange and optimistic)

# Comparing Fuel Economy Reference Cases (cars)

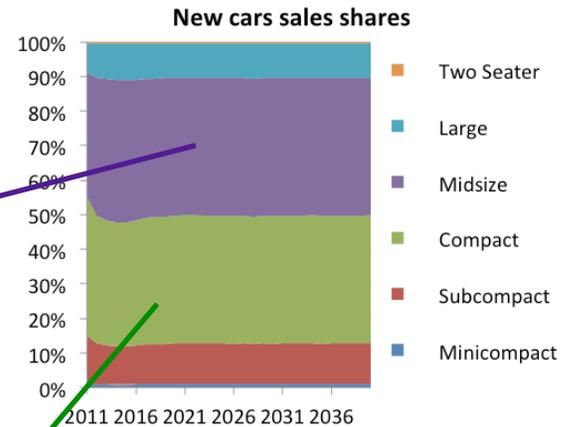
**AEO** Midsize cars fuel efficiencies (MPG)



**AEO** Compact cars fuel efficiencies (MPG)

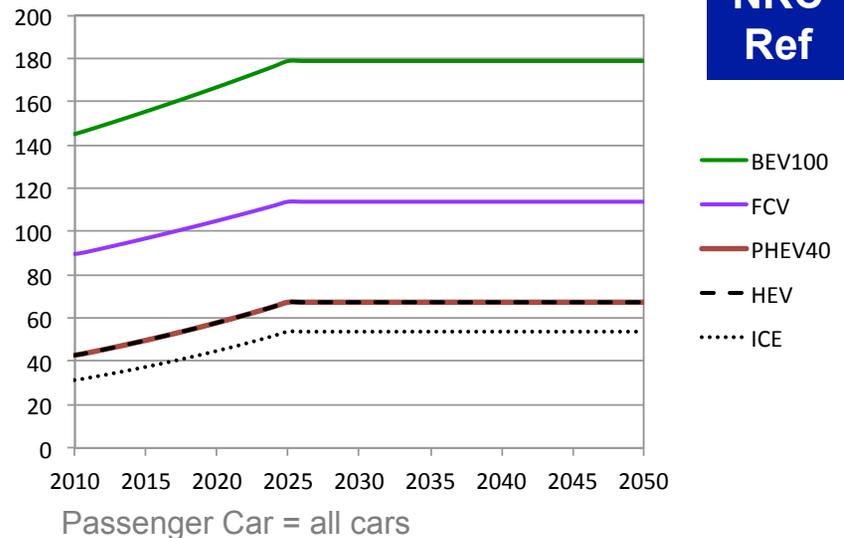


New Car = average across all car sizes



**BEVs are significantly higher in NRC Ref Case. FCEVs do not improve in AEO due to lack of growth.**

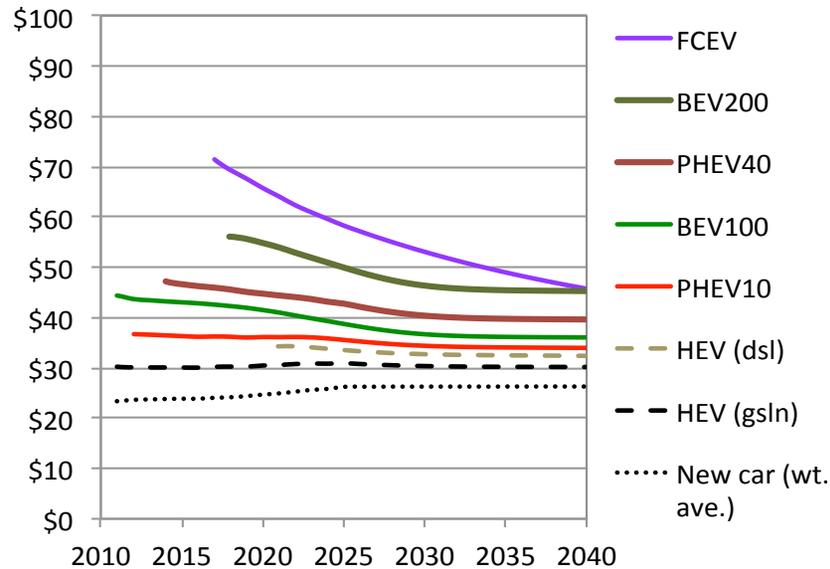
Passenger cars fuel efficiencies (MPG) - Ref



Passenger Car = all cars

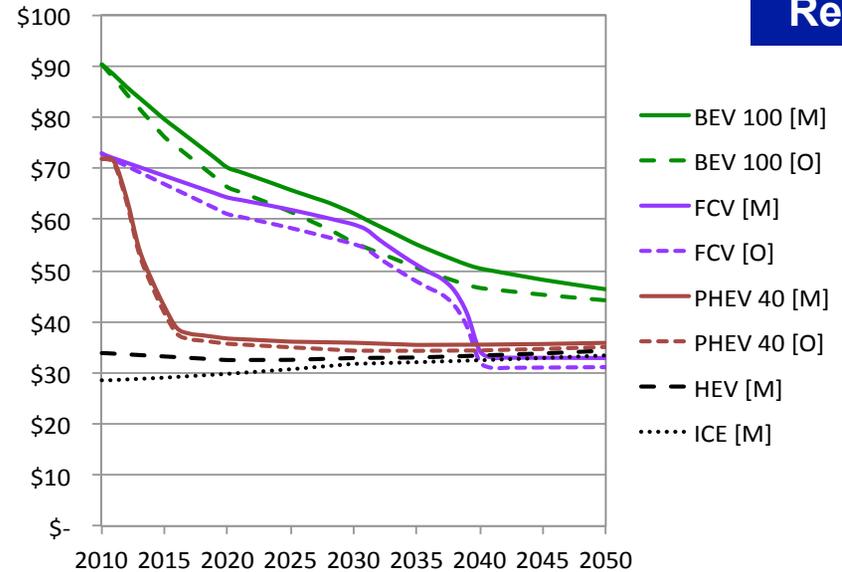
**AEO**

**Midsized cars prices (2012\$,000's)**



**Passenger cars (2012\$,000's): Reference Case - Midrange [M] and Optimistic [O] Costs**

**NRC Ref**

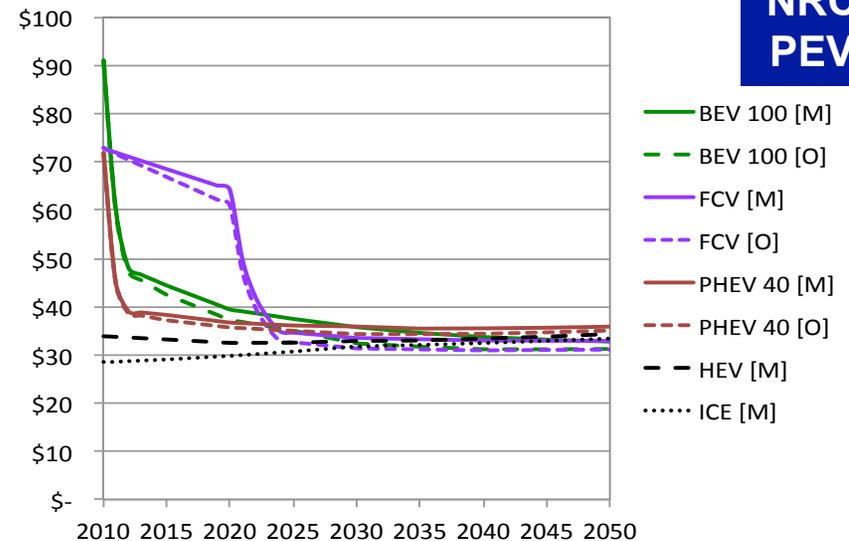


# Car Prices

- Reference cases above have limited market growth in BEVs, FCEVs, PHEVs
- NRC **PEV Emphasis** case at right achieves rapid market growth and correspondingly rapid cost reductions
- Even FCEV costs decline due to some market growth

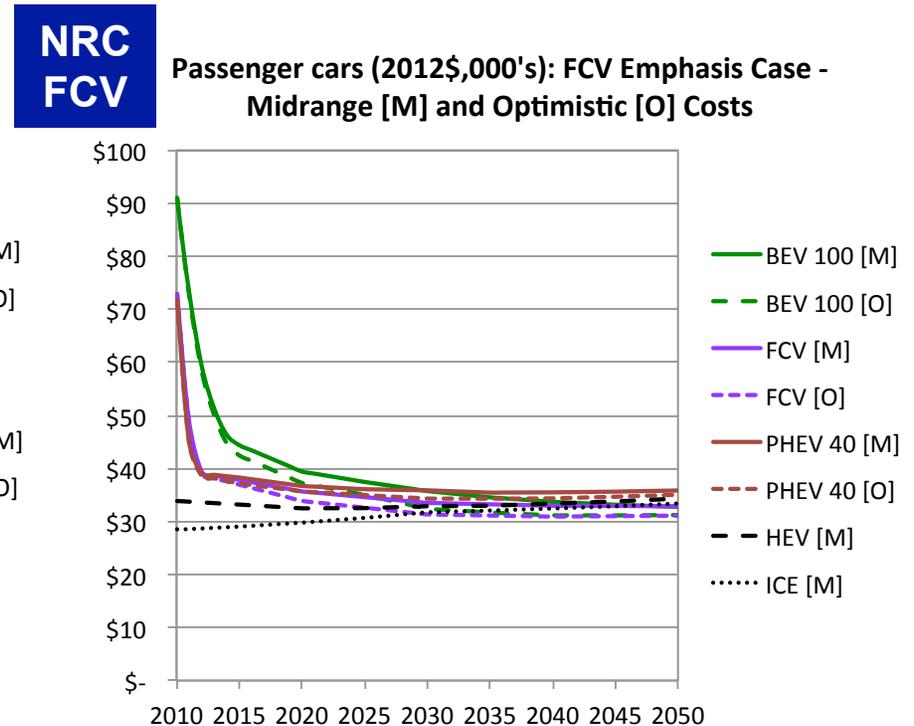
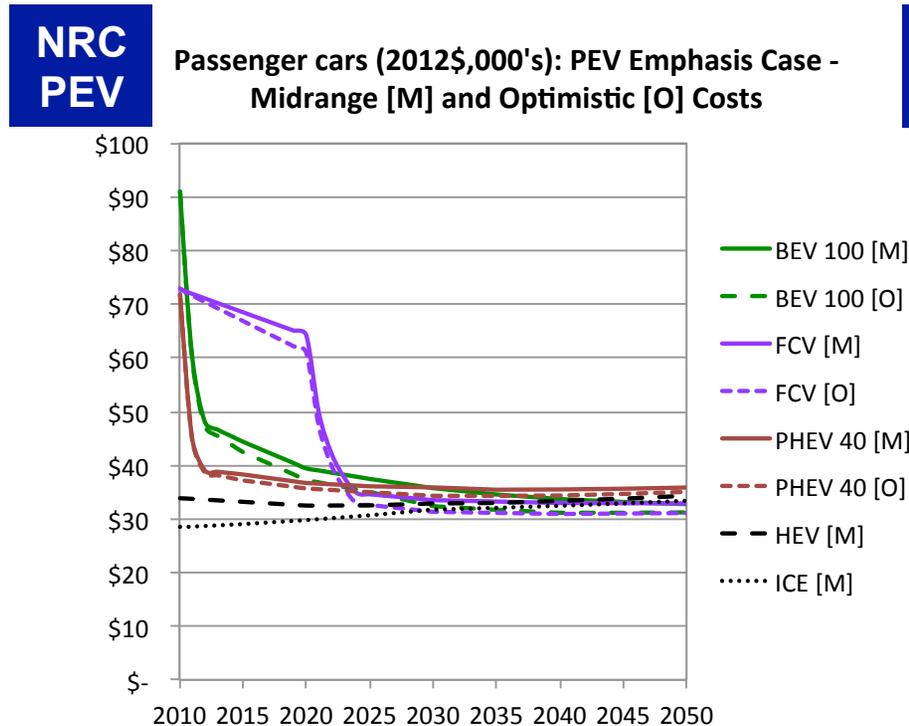
**Passenger cars (2012\$,000's): PEV Emphasis Case - Midrange [M] and Optimistic [O] Costs**

**NRC PEV**



# Vehicle prices vary between scenarios

- Variations are based upon cost multiplier penalties that decline with increasing economies of scale and learning
- Scenarios includes subsidies to accelerate market growth, resulting in movement down cost curves at different rates
- The volume of subsidies required to achieve market success is very sensitive to these multiplier penalties



# “Fully Learned” and “At Scale” costs are achieved only with significant subsidies and policies

- These cost differentials from the baseline ICE vehicle cost occur after all learning and scale reductions have been achieved
- Volume of subsidies depends upon area under learning curves, the effectiveness of market support policies, and consumers preferences

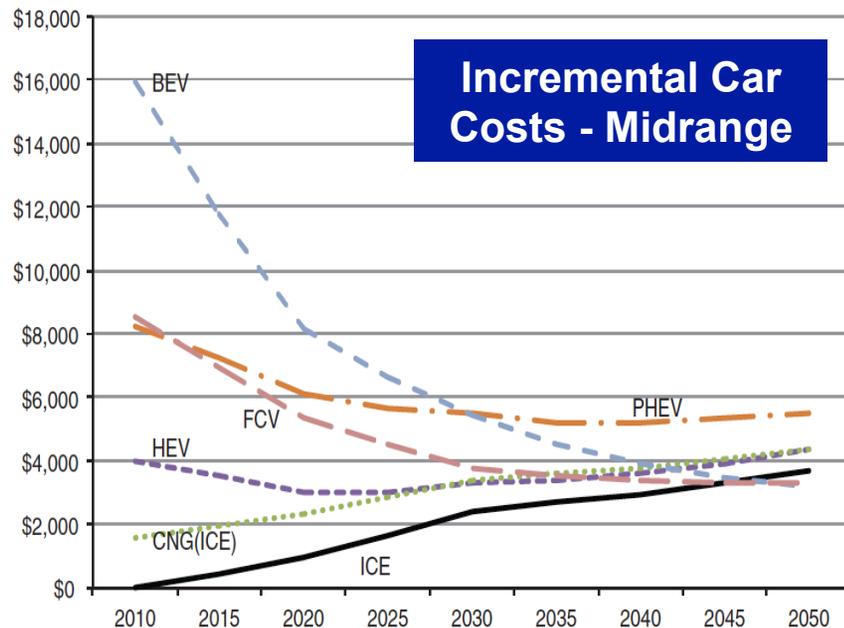


FIGURE 2.8 Car incremental cost versus 2010 baseline (\$26,341 retail price)—Midrange case.

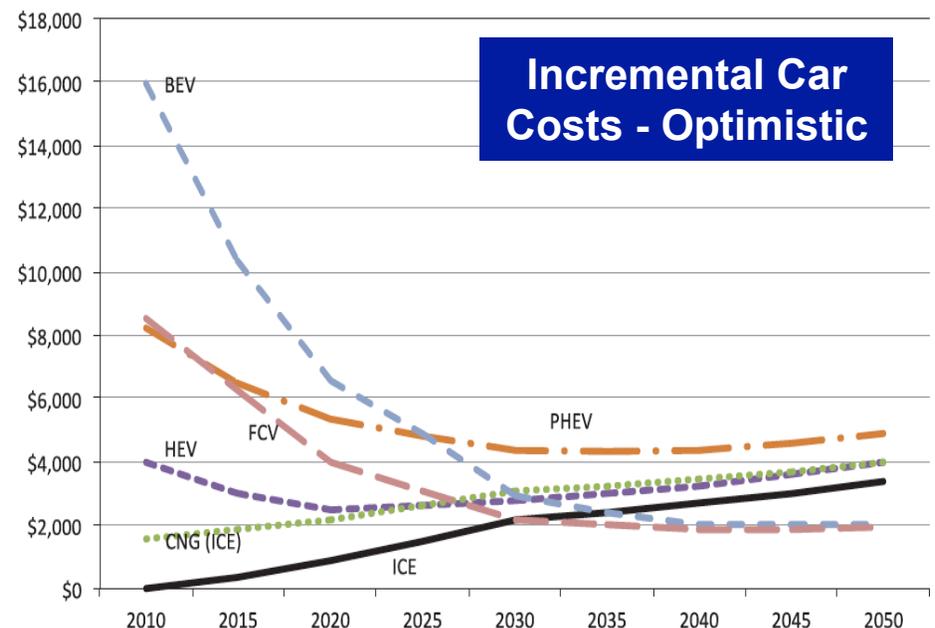
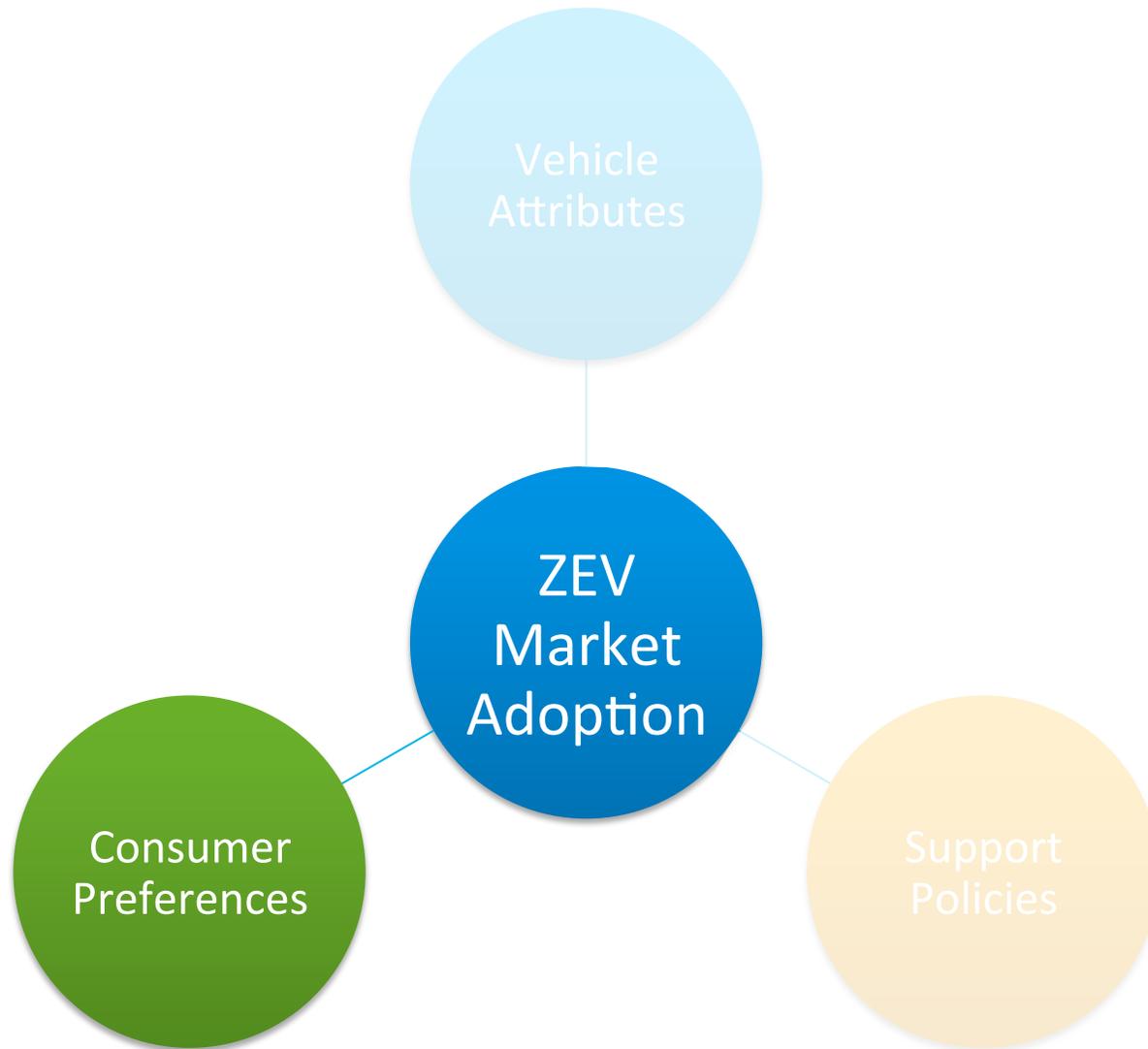


FIGURE 2.10 Car Incremental cost versus 2010 baseline (\$26,341 retail price)—Optimistic case.

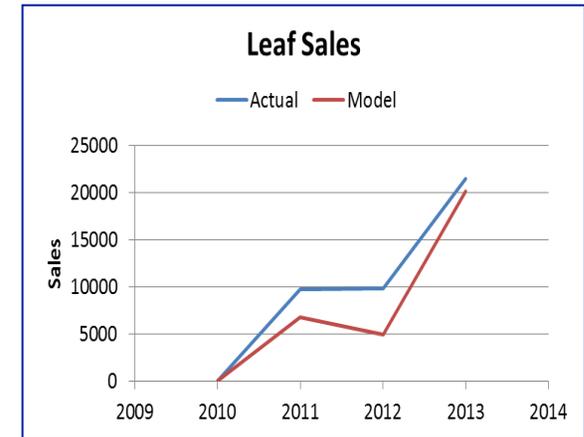
Source: NRC 2014

# Consumer Preferences

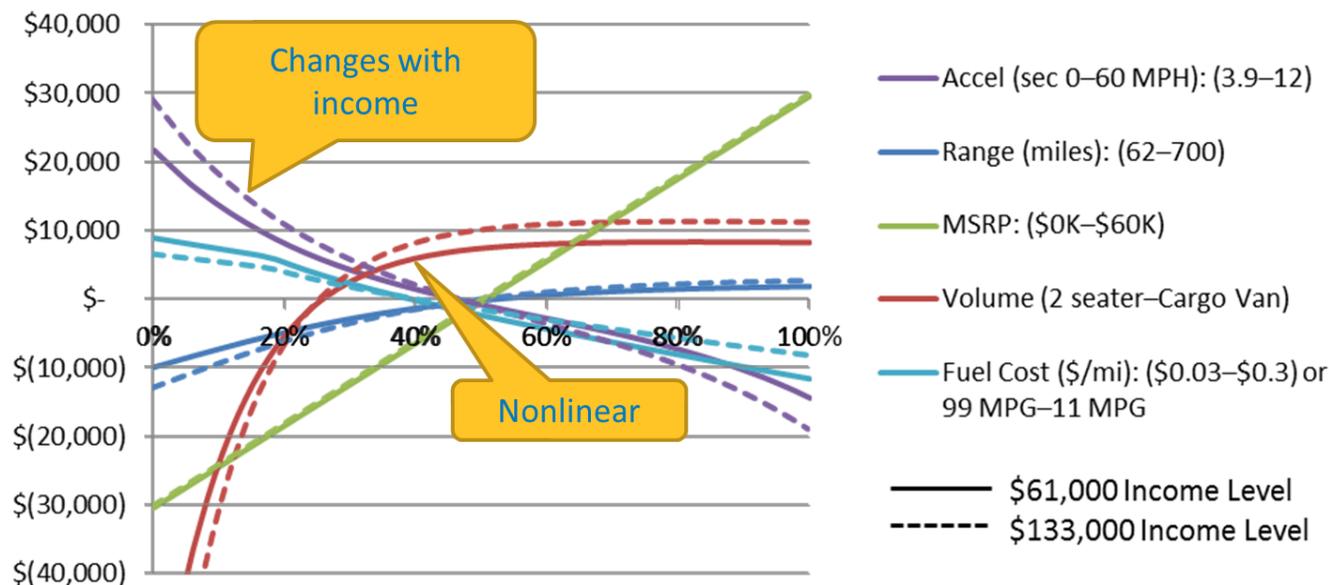


# Example: What is the penalty for limited range from a consumer perspective?

- NREL's ADOPT consumer preference model estimates market share using coefficients derived from empirical sales data
- Range penalty is based upon limited data, but aligns well with Leaf sales



## MSRP Equivalent Value by Characteristic



Source: Brooker, A. (2015) ADOPT: A Historically Validated Light Duty Vehicle Consumer Choice Model, SAE World Congress, 2015 (forthcoming)

# Stated Preference Survey

## NREL and PA Consulting study

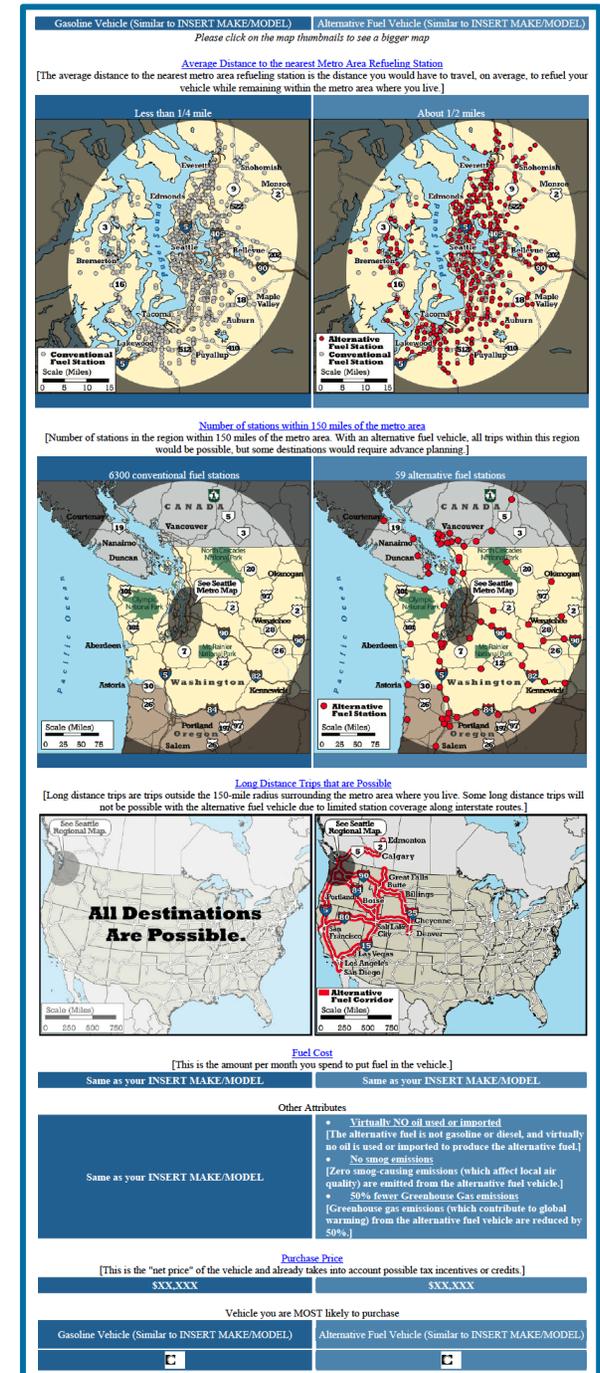
- Developed and fielded 3 discrete choice surveys, each improving on the previous design
- Final survey gave best results
- Relied upon in-house computer survey panels

## Survey Design

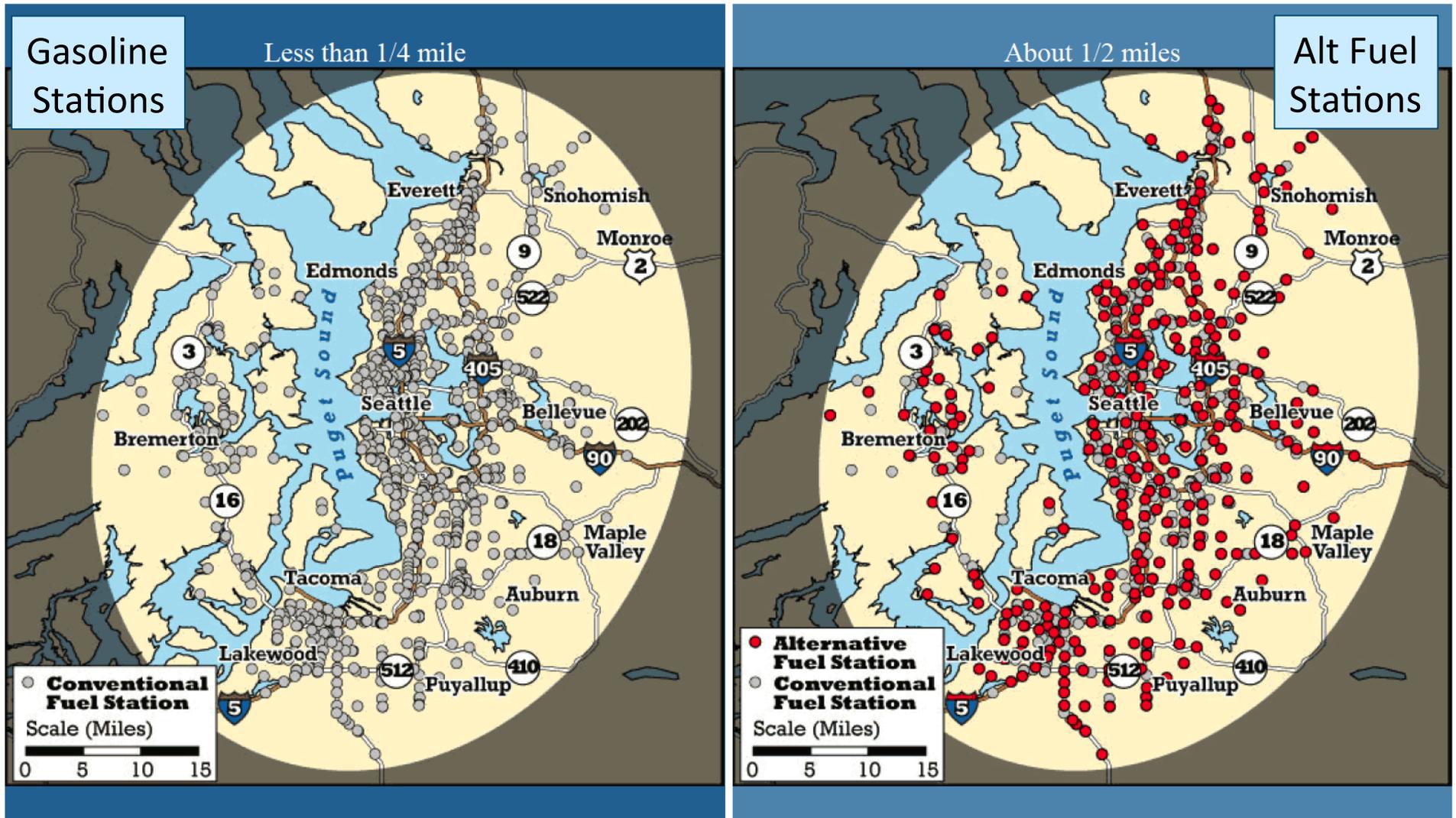
- Sequence of 10 vehicle purchase decisions, with attributes shown side-by-side: Vehicle purchase price, fuel cost, and station coverage at three geographic scales: local, regional, national
- Algorithm varies attribute levels based upon previous responses
- Dedicated vehicle for generic alternative fuel
- ~500 surveys completed in each major city: Los Angeles, Atlanta, Minneapolis and Seattle

Source: Melaina, M., J. Bremson, K. Solo (2012). Consumer Convenience and the Availability of Retail Stations as a Market Barrier for Alternative Fuel Vehicles, Presented at the 31st USAEE/IAEE North American Conference, Austin, Texas, November 4-7, 2012.

Available online: <http://www.nrel.gov/publications/>



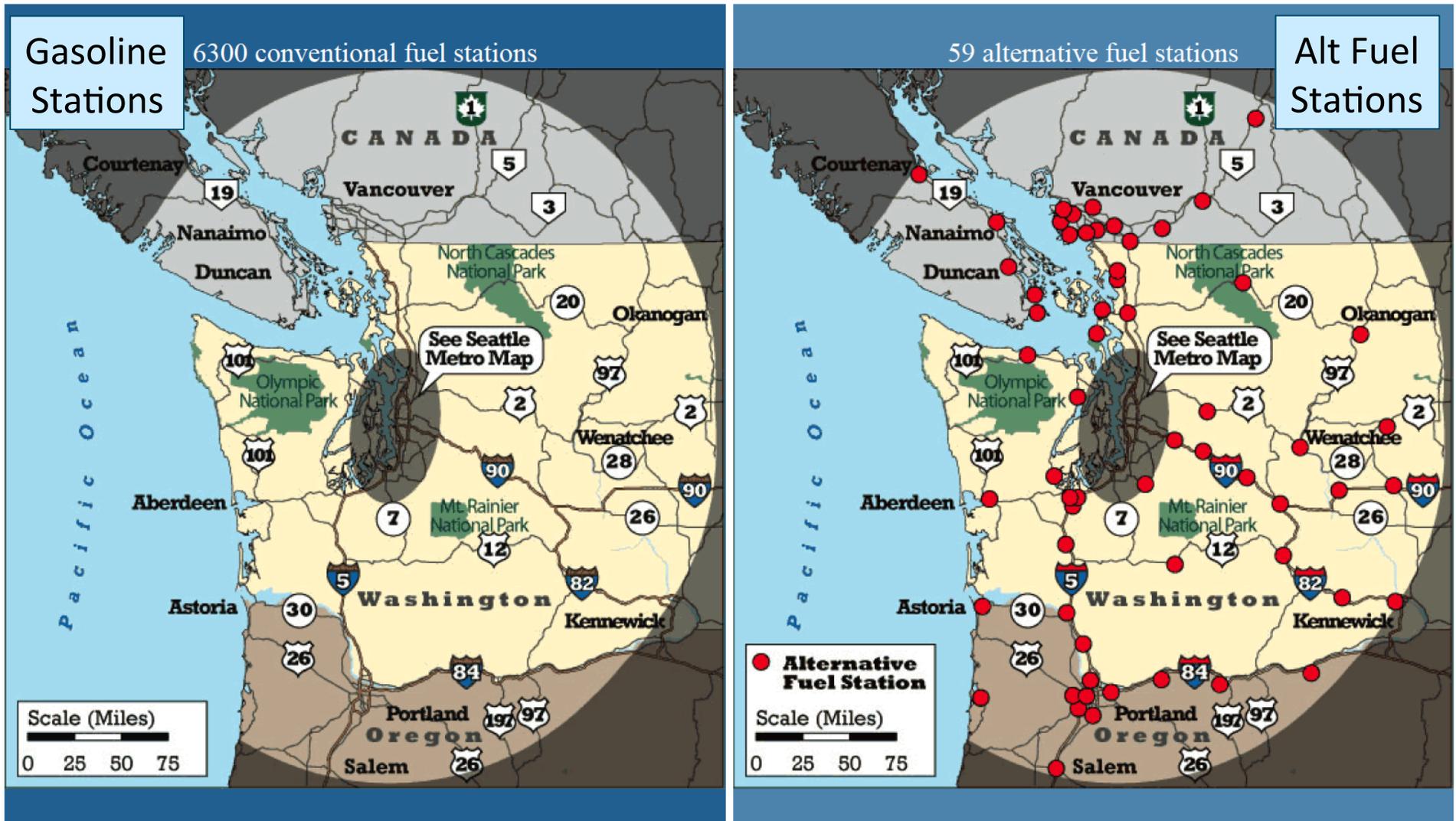
# Example of Local Coverage Maps: Los Angeles



Four Levels: (1) No Alt Fuel Stations, (2) sparse, (3) many, (4) same as gasoline

Source: Melaina, Bremson and Solo (2012).

# Example of Local Coverage Maps: Los Angeles



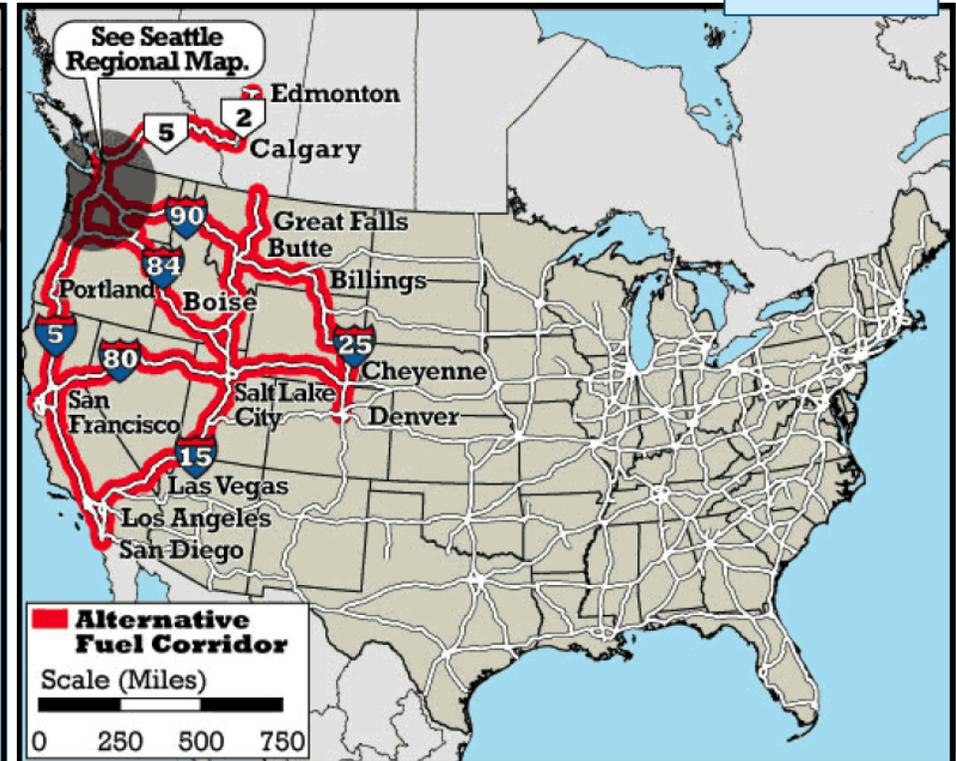
Four Levels: (1) No Alt Fuel Stations, (2) sparse, (3) many, (4) same as gasoline

Source: Melaina, Bremson and Solo (2012).

# Example of Local Coverage Maps: Los Angeles

Gasoline Stations

Alt Fuel Stations



Four Levels: (1) No Alt Fuel Stations, (2) nearby interstates, (3) many interstates, (4) all interstates.

Source: Melaina, Bremson and Solo (2012).

# Study Results: Quantified Stated Preferences for Station Availability and Compared to Rational Behavior Model Results

## Stated Preference Estimates

Survey results suggest that household consumers may perceive the following (cumulative) purchase price penalties:

- **Local: \$750 to \$4,000** for retail station coverage at 1 to 10 percent of existing gasoline stations within metropolitan (urban) areas.
- **Regional: \$1,500 to \$3,000** for limited medium-distance coverage, defined as 5 to 100 stations within 150 miles of the metro area
- **Interstate: \$2,000 to \$9,000** for a lack of long-distance coverage along interstates connecting urban areas

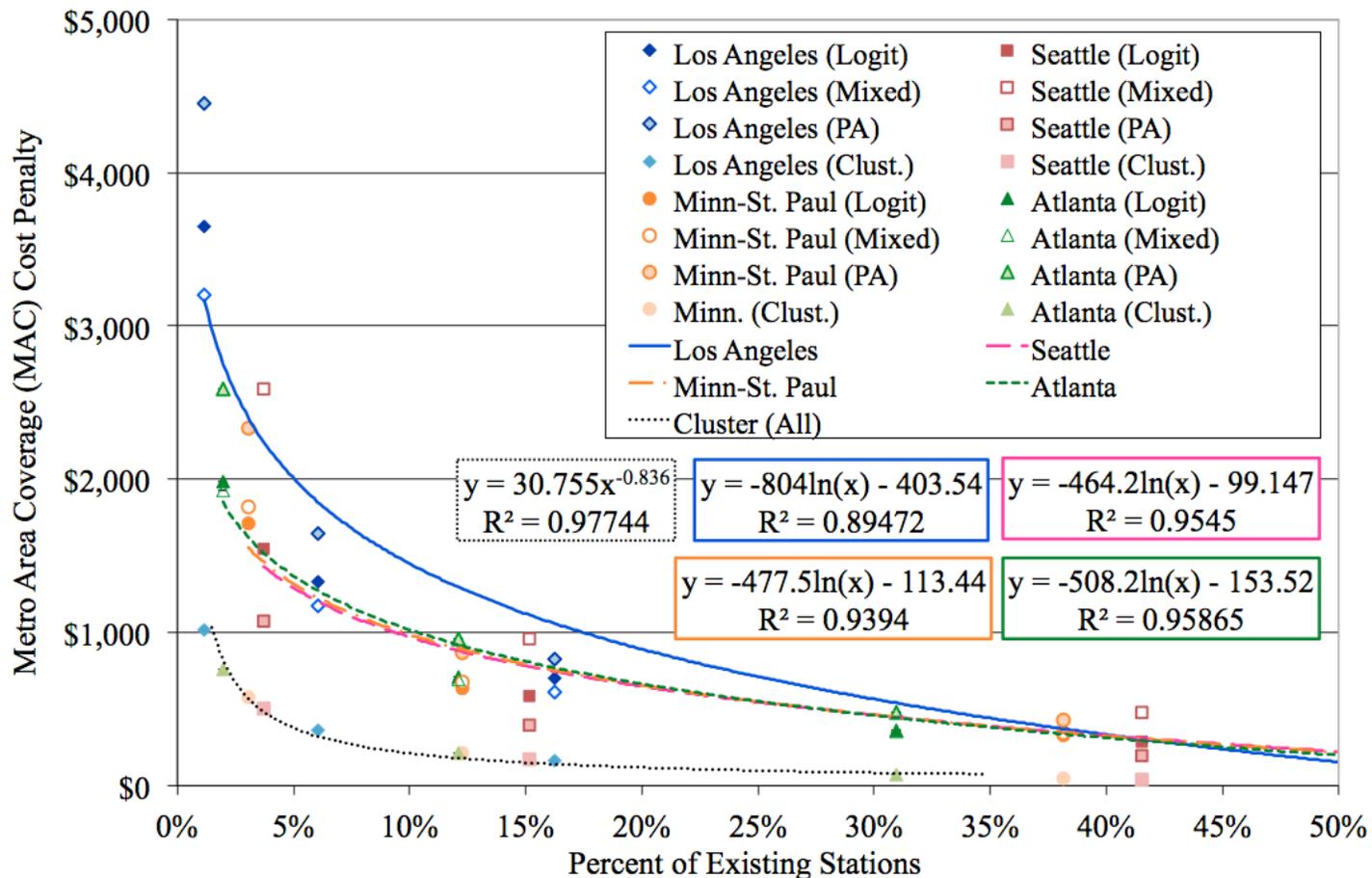
## Rational Actor Estimates

A parallel analysis of urban travel time penalties for a “rational” decision maker (additional time needed to drive to stations in a sparse network):

- The “Rational model” based upon a clustering algorithm and travel times suggests **\$250 to \$1,500** for coverage at 1% to 10% of existing stations.
- This is roughly 3-4 times less than the stated preference penalty for local availability within urban areas.

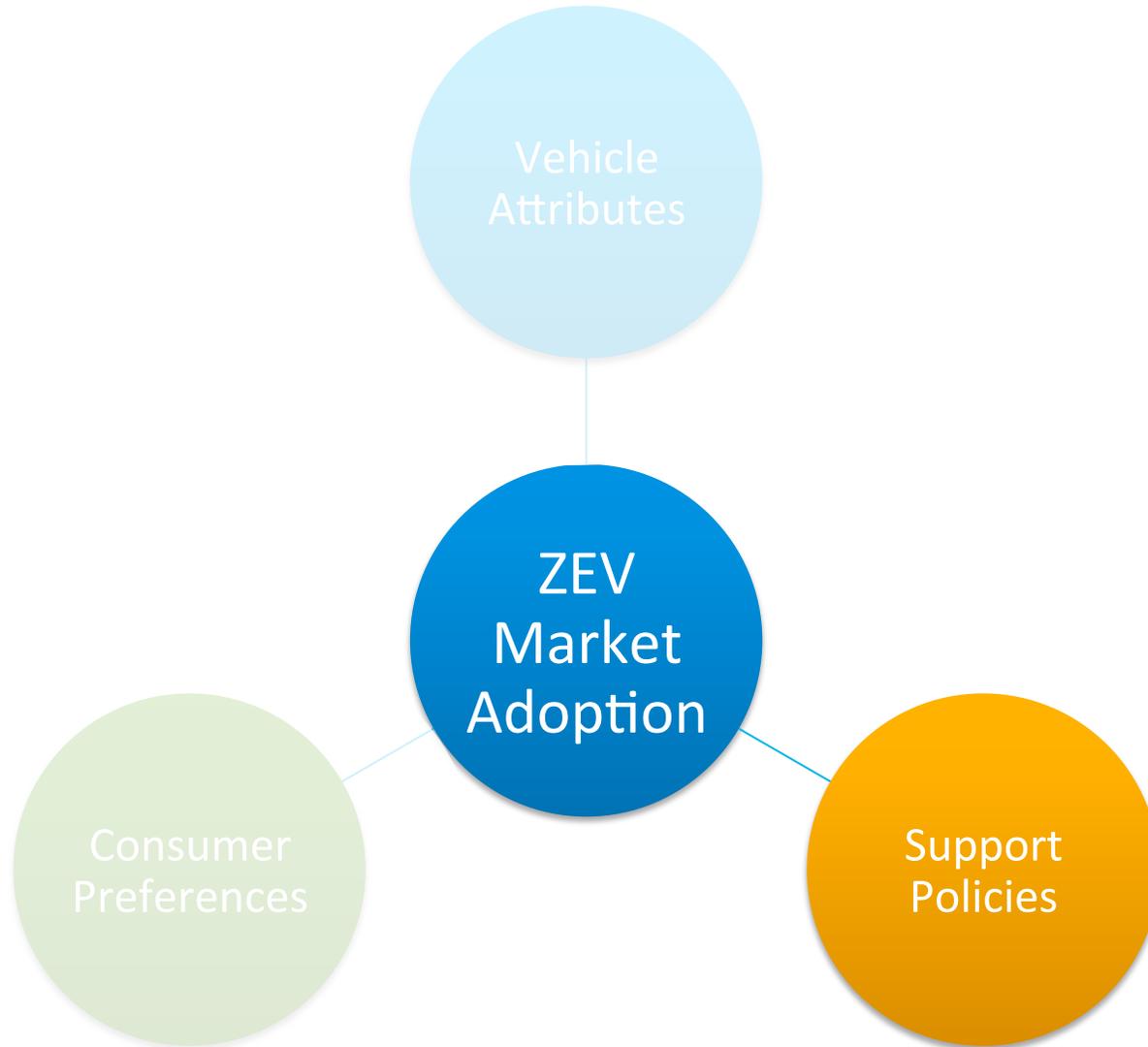
# Local Station Availability Penalties

- Cost Penalty Estimates Against the Purchase Price of a New Dedicated AFV for Limited Urban Area Station Availability.
- Graph shows both Survey Results and Cluster Simulations



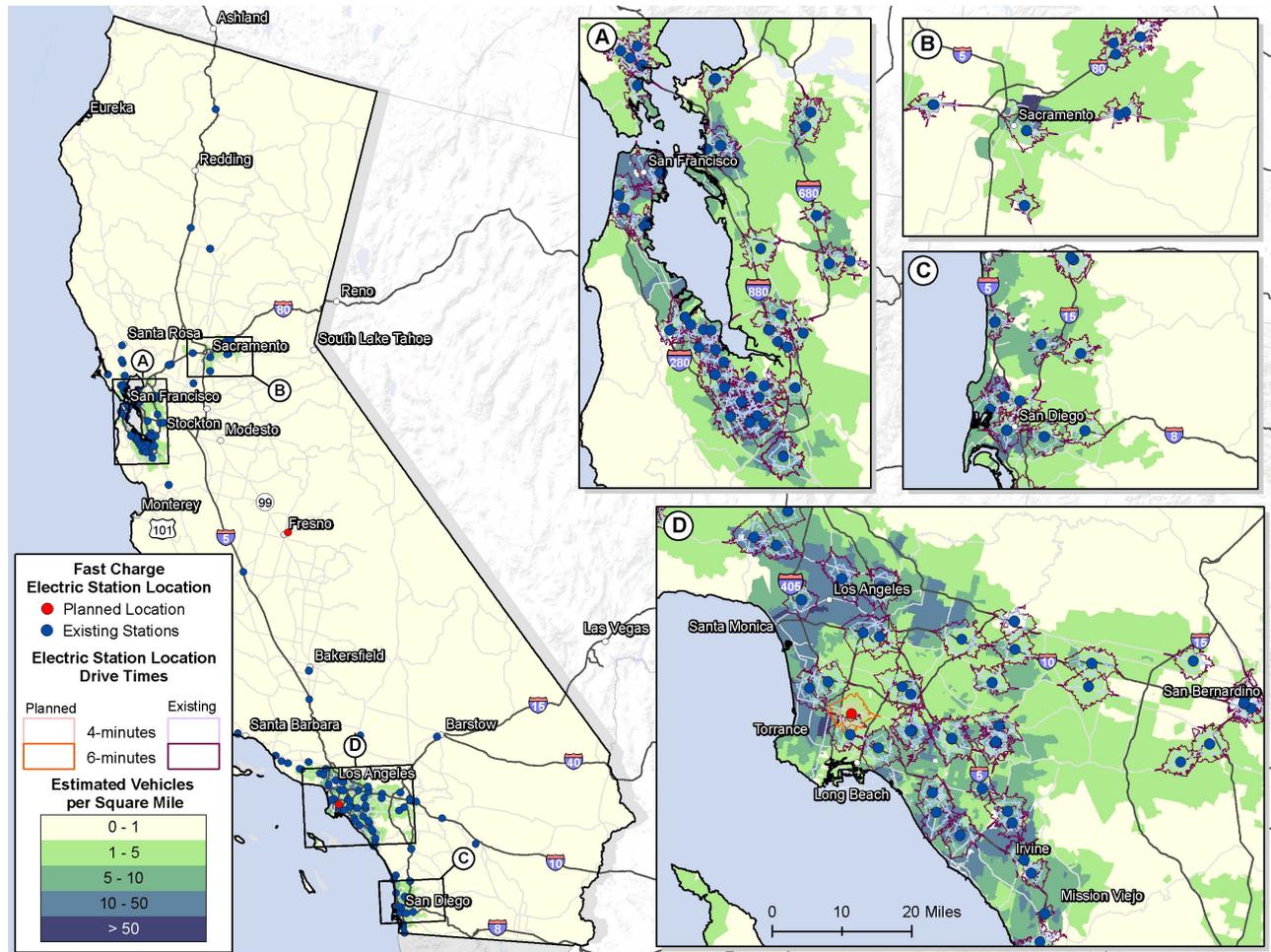
Source: Melaina, Bremson and Solo (2012).

# Support Policies



# Policy Effectiveness: Sufficient Empirical data?

- As new market data become available, statistical correlations between EVSE deployments and vehicle purchases should emerge
- Statistical fits must take into account a variety of factors, including state and local incentives, inherent consumer vehicle preferences, etc.
- Map at right shows DCFC stations with respect to likely early adopter metric (EAM) results



Source: NREL Infrastructure Market Assessment Report for CEC. Forthcoming

# Recommendations for future work

## Future Work on Consumer Preferences

New information on consumer responsiveness may be revealed by:

- (1) Examining market trends associated with EVSE infrastructure
- (2) Developing improved survey methods that take into account station availability as a consumer choice factor

## Future Work on Policy Support Mechanisms

- Explicit representations of fueling infrastructure may improve market projections and inform market support policies
- Interactions or tradeoffs between vehicle range and EVSE type and availability may influence policy effectiveness

# Questions?

