National Renewable Energy Laboratory
Innovation for Our Energy Future

Discrete Choice Analysis of Consumer Preferences for Refueling Availability

Dr. Marc W. Melaina

National Renewable Energy Laboratory

May 19, 2009

Project ID #
AN_05_Melaina

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Timeline

Project start date

September 2007

Project end date

May 2009

Percent complete

100%

Budget

Total project funding

$510 K (DOE)

Funding received in FY08

$320 K (DOE)

Funding for FY09

None

Barriers

Systems Analysis

- Future Market Behavior: "…hydrogen supply, vehicle supply, and the demand for vehicles and hydrogen are all dependent and linked."

Hydrogen Production

- Reduce the cost of hydrogen to $2.00-$3.00/gge (delivered) at the pump.
- Depends upon size and number of early stations required.

Partners

Subcontractor: PA Consulting (with Knowledge Networks)

Project lead: Marc Melaina, NREL

Relevance: Refueling Availability is Fundamental to Commercializing FCVs

Consumers must feel comfortable with the availability of refueling (i.e., number and location of stations) before purchasing a hydrogen fuel cell vehicle (FCV)

During early market adoption the number of stations will be limited, resulting in suppressed FCV sales

Capital Cost Barrier

~160,000 gas stations in U.S.

·

5%-15% supplying hydrogen

·

Average of $2-$3 million/station

~

$20-$70 billion in capital

We need a more strategic understanding of effective approaches to overcoming this upfront capital cost barrier, which may range from ~$20-$70 billion in upfront capital

A quantitative estimate of the value of refueling availability to consumers is key element of any analytic approach to this problem

Relevance: Project Objectives

Objectives

1. Quantify consumer reluctance to purchase an alternative fuel vehicle due to a lack of refueling availability
   - Based upon survey results
   - Reluctance is expressed as a cost penalty against the purchase price of a vehicle
2. Compare survey results to comparable results derived from analytic models
3. Develop a general discrete choice model for major urban areas

Relevance: To Hydrogen Program and Barriers, Targets, and Milestones

System Analysis

"Systems analysis supports decision-making by providing greater understanding of the contribution of individual components to the hydrogen energy system as a whole, and the interaction of the components and their effects on the systems." (p. 4-1)

Barrier A: Future Market Behavior

"Understanding the behavior and drivers of the fuel and vehicle markets…"

Barrier B: Stove-piped/Siloed Analytical Capability

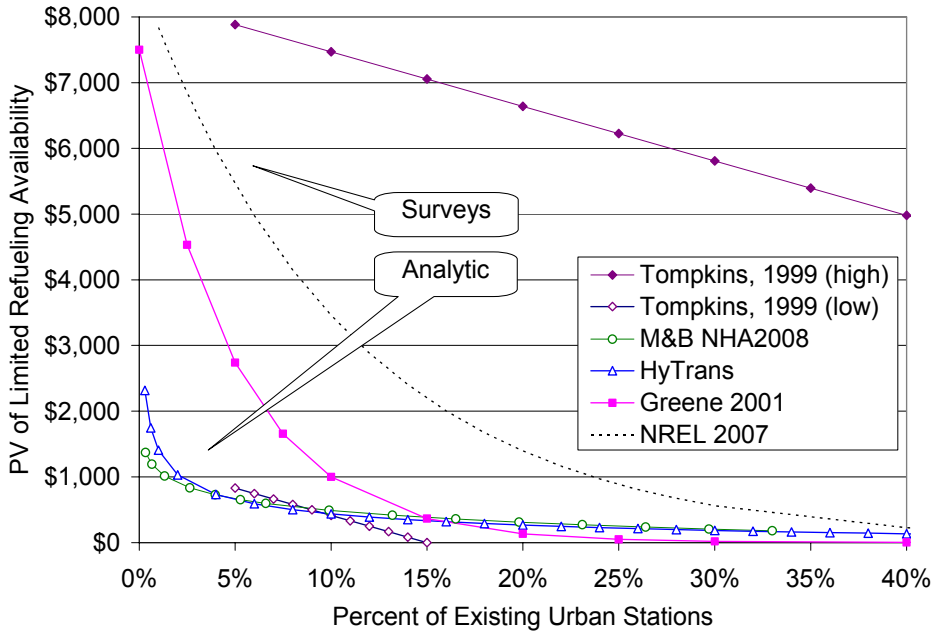
"…coordination and integration of analysis resources across all facets of the analytical domain."

Milestone 3

"Begin a coordinated study of market transformation analysis with H2A and Delivery models"

Approach: Building Upon Previous Studies

- Several discrete choice studies have included questions on refueling availability (e.g. Tompkins 1999, Greene 2001)
- Analytic studies have tended to result in much lower cost penalties (HyTrans, M&B NHA08)
- Few studies have focused on specific regions, or variations among regions
- No studies have systematically examined refueling availability on multiple geographic scales



Comparison of Metro Area Costs
(Analytic models predict much lower penalties than survey results suggest)

- NREL 2007 study estimated penalties for: L.A., Houston, and New York
- NREL 2008 study includes 3 additional metro areas and an improved survey structure

Approach: Discrete Choice Methodology

- Discrete choice methods are commonly applied in decision analysis of preferences for products with similar attributes

Hypothetical Example:

Attribute	Product A	Product B
A - Color	A1	B1
B - Speed	A2	B2
C - Cost	A3	B3
Choice:	☐	☑

- Respondents weigh their relative preferences for each attribute
- The choice algorithm alters attributes level between choices to elicit statistically relevant preference data from respondents
- Attributes included in the 2007 survey:
  - Vehicle Purchase Price
  - Fuel Costs ($/mo)
  - Vehicle Range (miles)
  - Refueling Availability
    - Metropolitan, Regional and National/Interstate

Approach: Vehicle Choice Survey

Hypothetical New Vehicle Purchase:

- Respondents were asked to choose between two vehicles:
  - Conventional Vehicle
  - Alternative Fuel Vehicle
- Both vehicles were described as being identical to the respondent's most recently purchased vehicle

The Alternative Fuel Vehicle (AFV)

Described as identical to the Conventional Vehicle (CV) in all respects, except two:

1) Social and Environmental Benefits
   - Virtually no oil use, no smog-forming pollutants, and reduction in greenhouse gas emissions by 50%
2) Limited refueling availability
   - **Metropolitan**, **Regional**, and **National** geographic scales

Approach: Ensuring Clarity of Interpretation and Consistent Responses

A series of preliminary questions are used to familiarize the respondents with:

- Concepts used in the survey (e.g., AFV; regional stations)
- Maps used for each geographic scale
  - e.g., asked them if they could locate their homes on map
- Types of choices they would be making in the discrete choice portion of the survey

After a beta test, follow-up questions and one-on-one interviews inquired about the difficulty of the survey

- Only a small fraction of respondents found the survey very difficult
- Minor survey adjustments were made in response to beta test feedback

Approach: 2008 Survey Modifications

Removed vehicle range attribute and made fuel costs equivalent

- These attributes were not directly related to the issue of refueling availability, and tended to distract respondents
- Other studies have estimated value of vehicle range

Increased range and number of vehicle purchase price levels

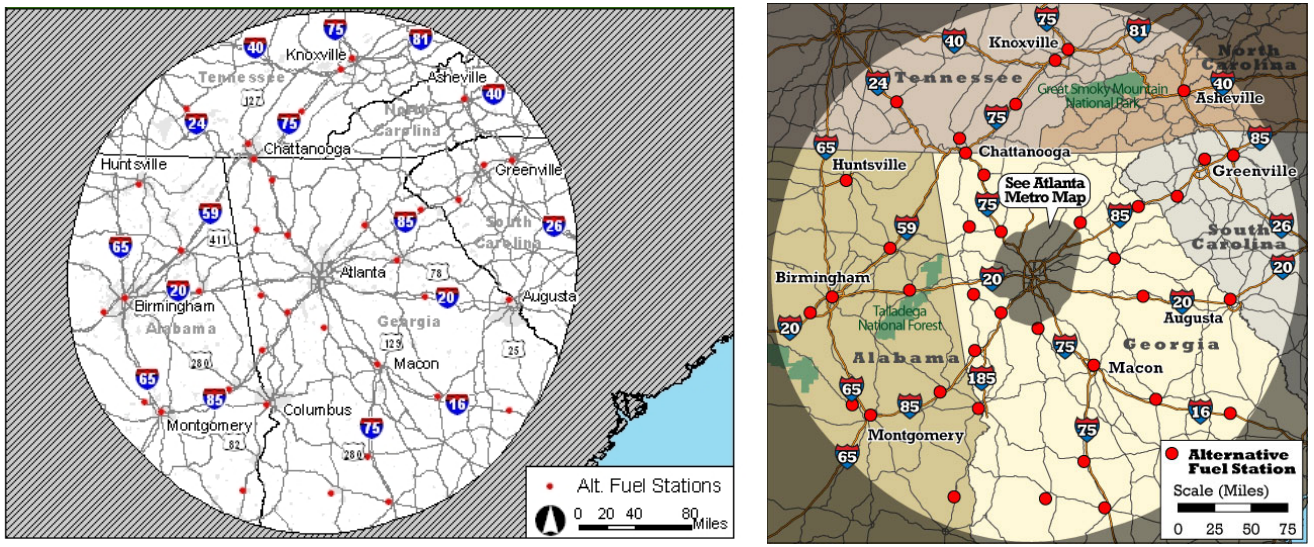
- From 3 levels (equal, +/-15%) to 5 levels (equal, +/-15%, +/-35%)

Improved clarity and readability of maps and survey screen layout

- New maps are larger and more closely resemble commercial maps

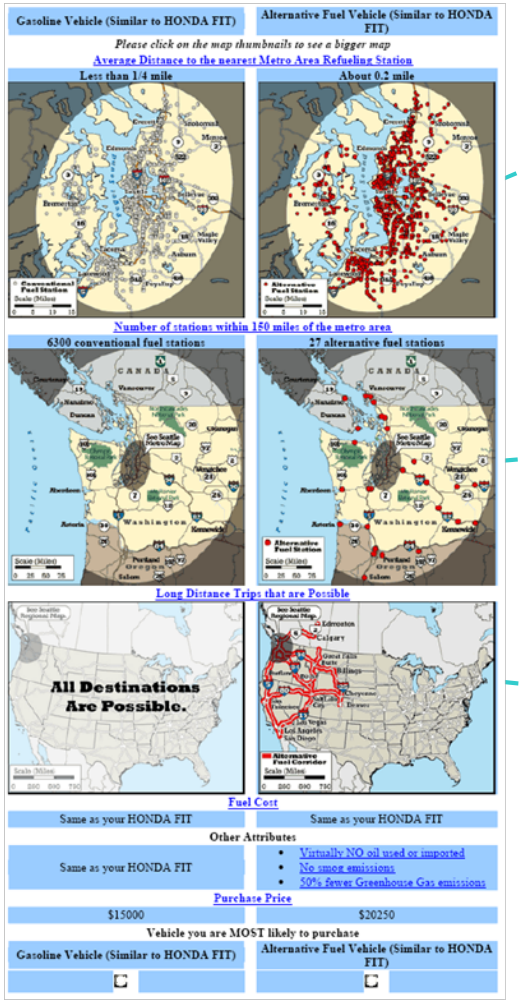
Atlanta Region

Previous format (left) and new format (right)

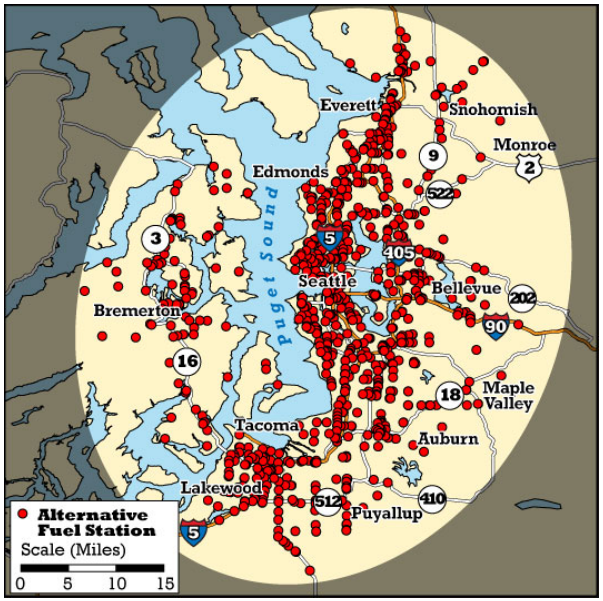


Approach: Survey Format

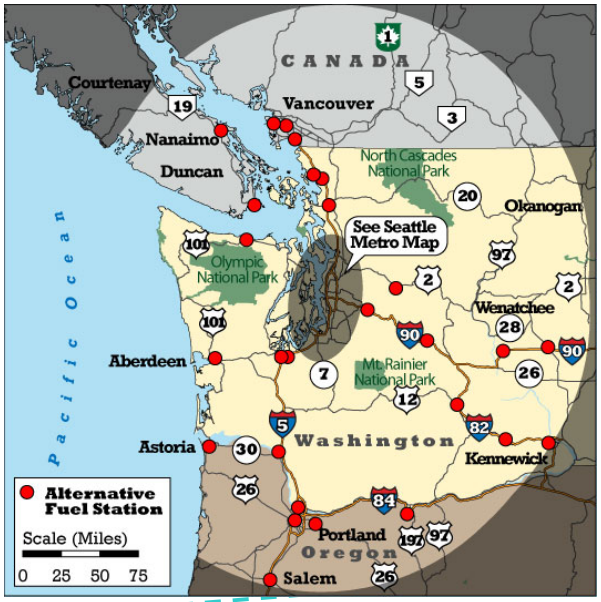
Choice Screen



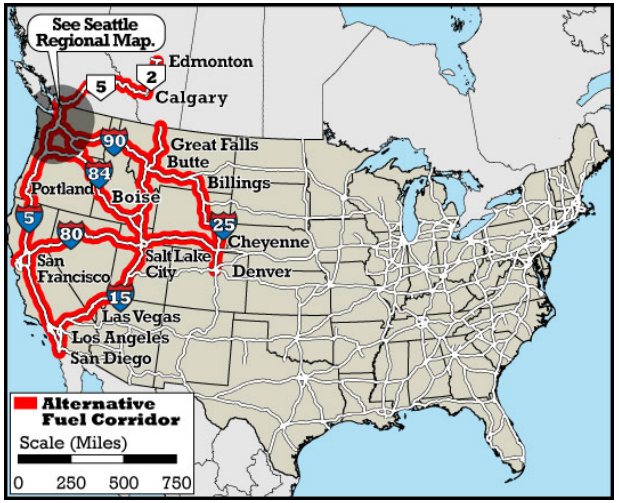
Metropolitan Coverage



Regional Coverage



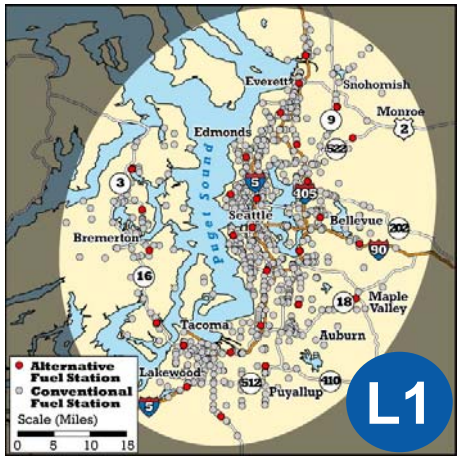
National Coverage

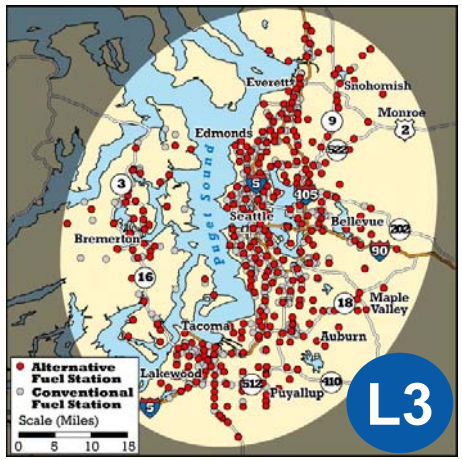


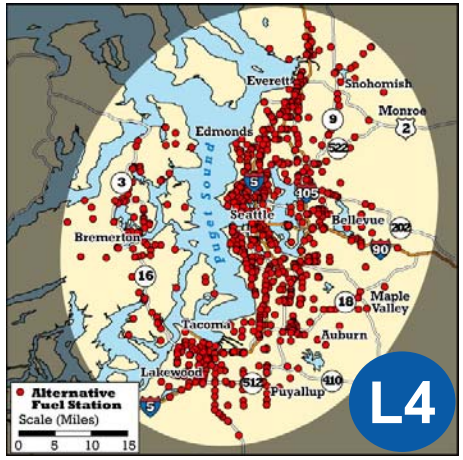
Fuel Costs, Other Attributes, and Vehicle Purchase Price

Approach: Geographic Levels (1-4) in 2008 Survey are More Distinct from One Another

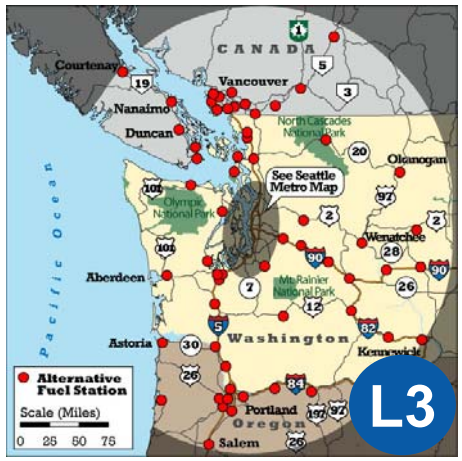
Metropolitan Levels – Seattle Example







Regional Levels – Seattle Example



Technical Accomplishments and Progress: Characterization of Discrete Choice Model

General Utility Function:

CA = Consumer attributes
VA = Vehicle attributes
RA = Refueling availability attributes

$$U_{General} = U_{CA} + U_{VA} + U_{RA}$$

Consumer Attributes:

Close = Home location close to map station
Warm = Climate Change is major concern
Early = Self-identified early adopter

$$U_{CA} = \alpha_{Close} X_{Close} + \alpha_{Warm} X_{Warm} + \alpha_{Early} X_{Early}$$

Vehicle Attributes:

ASC = Alternative specific constant
VPP = Vehicle purchase price

$$U_{VA} = \beta_{VPP} X_{VPP} + \beta_{ASC} X_{ASC}$$

Refueling Attributes:

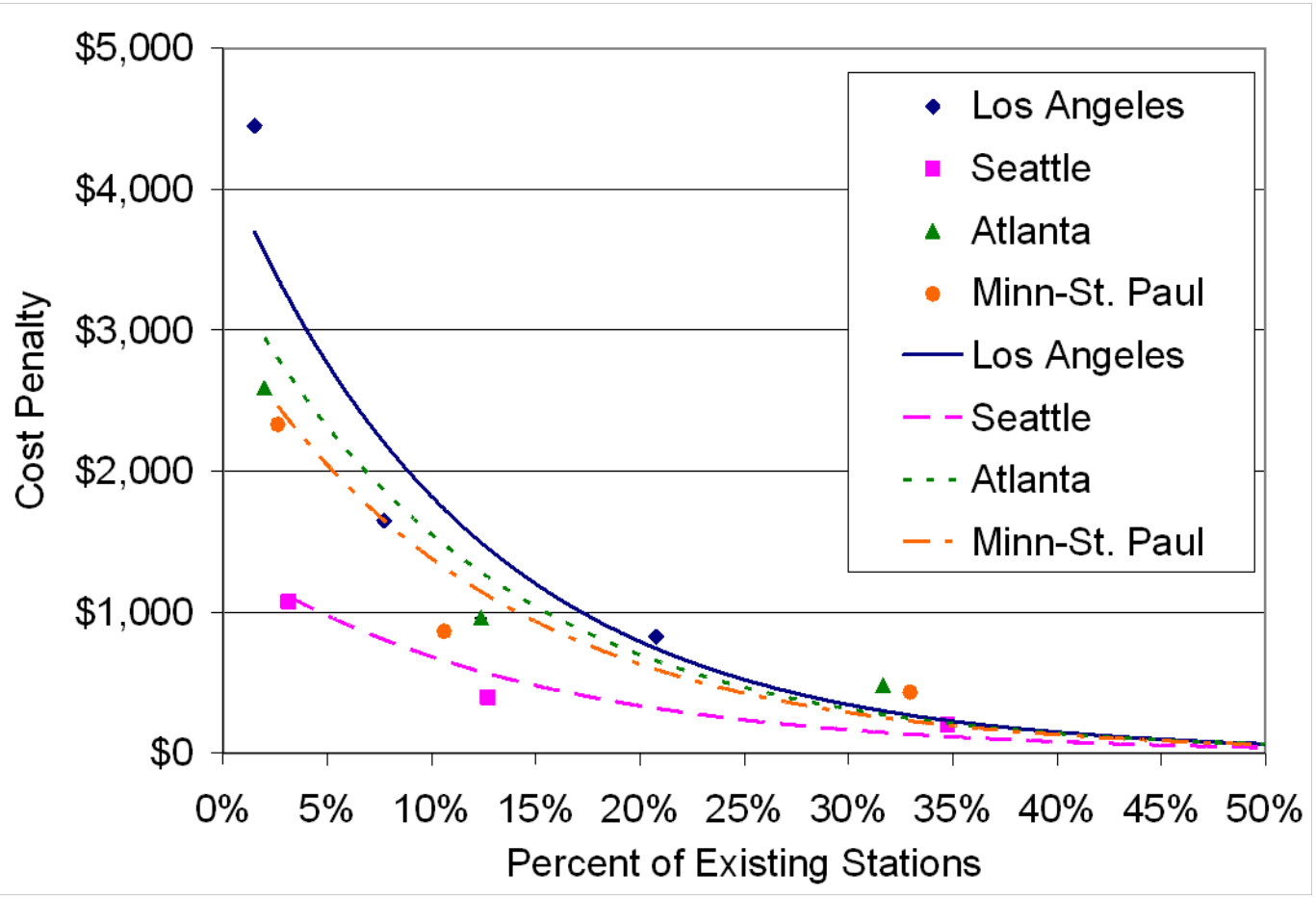
(See below. MAC & MRC are continuous)

$$U_{RA} = \beta_{MAC} X_{MAC-C} + \beta_{MRC} X_{MRC-C} + \beta_{LDC,i} X_{LDC,i}$$

Coefficients were significant for 19 of 20 refueling availability parameters

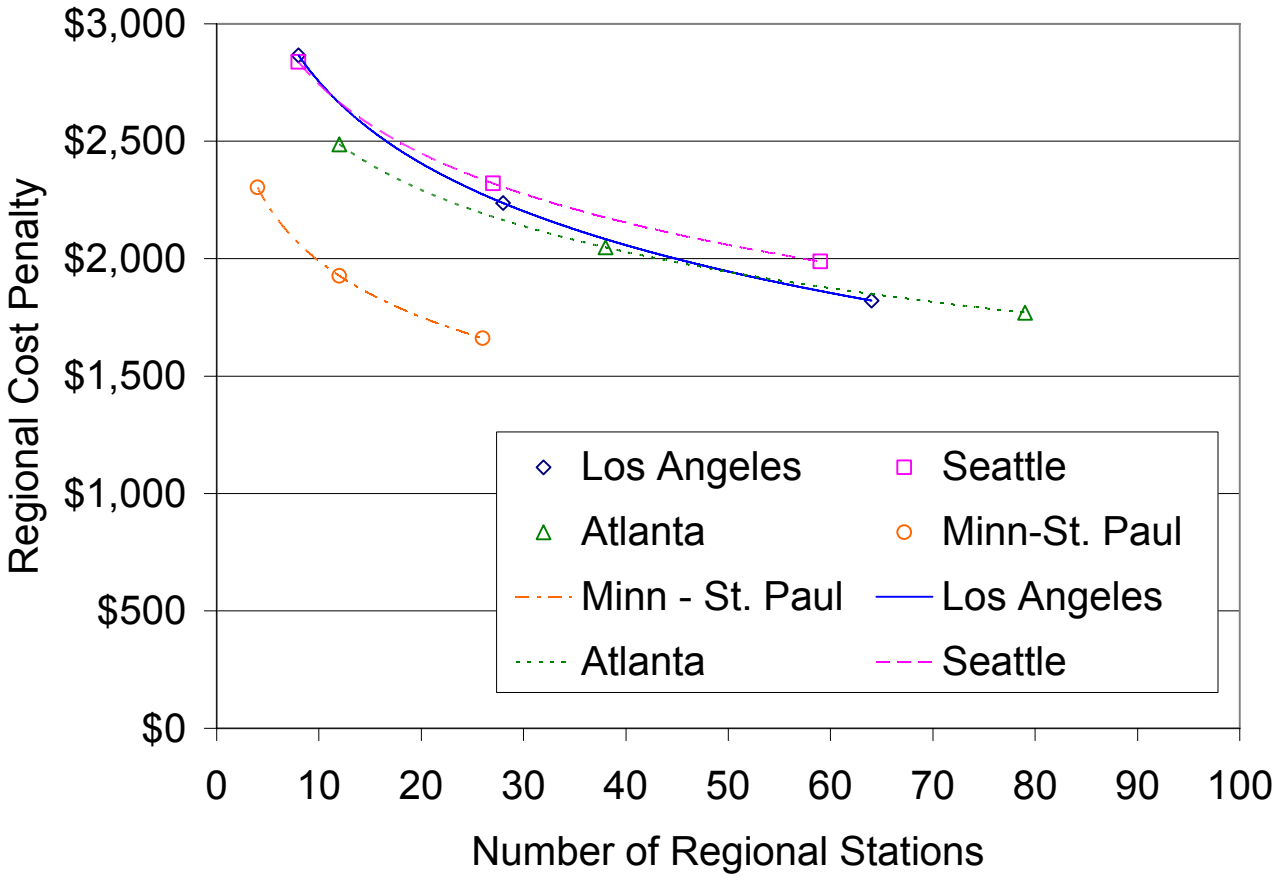
Scale	Parameter	Acronym	Units
Metropolitan	Metropolitan Area Coverage	MAC	Percent of existing stations
Regional	Metropolitan Regional Coverage	MRC	Percent of existing stations
National	Long Distance Coverage	LDC	Percent of long-distance trips along interstate highways

Technical Accomplishments and Progress: Metropolitan Scale Cost Penalties



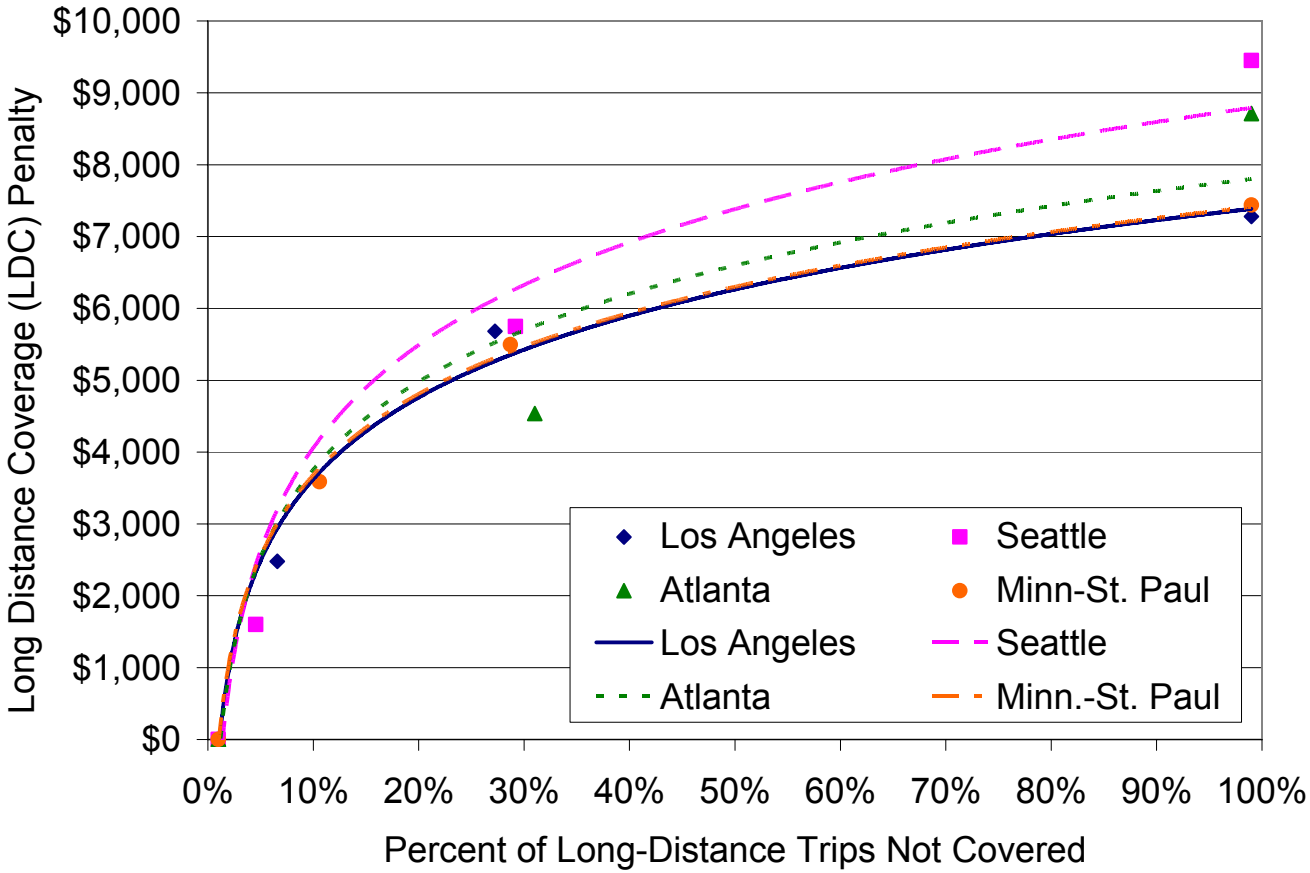
- Coefficients have higher statistical relevance than those from 2007
- In general, Metro Area penalties are about half those from 2007 study

Technical Accomplishments and Progress: Regional Scale Cost Penalties



- All data points significant and consistent for regional scale availability
- Logarithmic function fits to survey data result in X-axis intercepts that approximate actual number of stations in each region (addl. validation)

Technical Accomplishments and Progress: National/Interstate Scale Cost Penalties



- Note: units on horizontal axis are for long-distance trips not covered
- Penalties for a lack of interstate coverage are higher than 2007

Collaborations and Critical Feedback

Collaborations

- **PA Consulting** is primary subcontractor on project
- **Knowledge Networks** fielded the in-house survey
- **NREL GIS Staff** (B. Roberts) developed survey maps
- **MIT researchers** collaborated with NREL staff to developed the initial version of the HyDIVE model (2006)

Critical Feedback

- **Merit Review feedback** in 2007 resulted in a refocusing of project to examine refueling availability
- **Two external reviewers** provided feedback for a draft of report of 2007 survey results
  - This feedback was used to improve the 2008 survey

Proposed Future Work

Integrate Results into Existing Discrete Choice Models

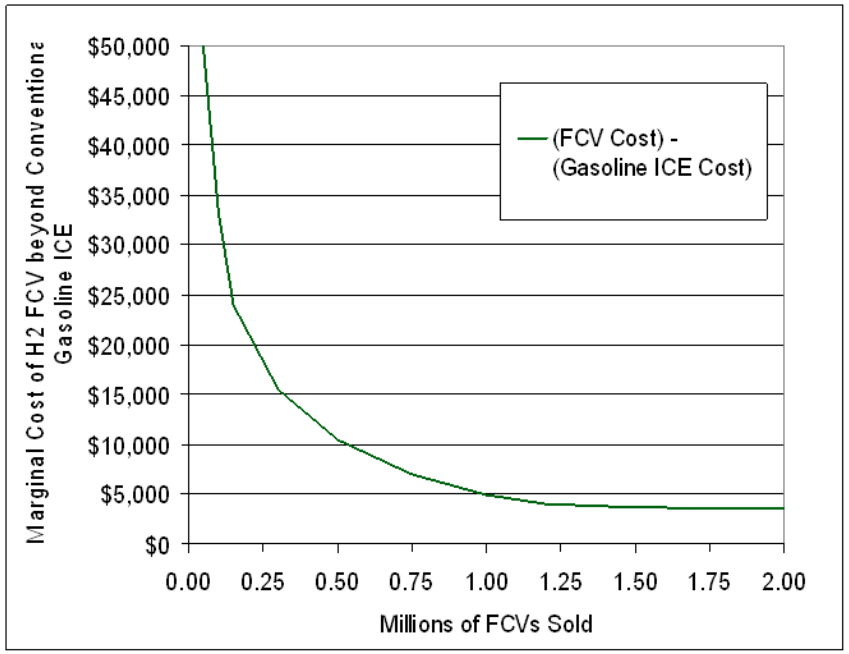
- Cost penalties can be integrated into existing discrete choice models to improve the geographic detail of feedback between infrastructure expansion and vehicle market adoption
  - Could improve realism of models such as NEMS or HyTrans
  - Could provide basis for policy runs that compare interactions between vehicle incentives and infrastructure incentives

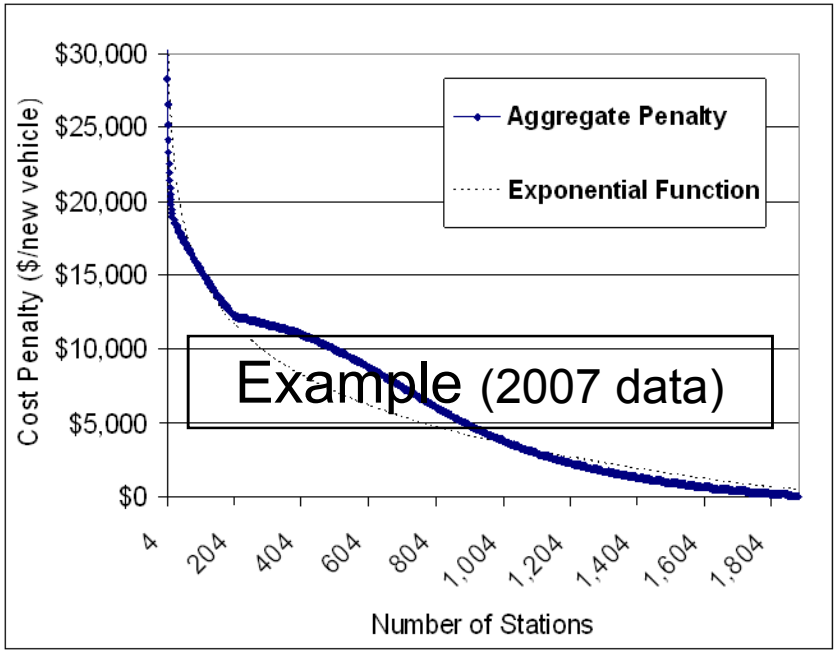
Use Results to Enhance Existing Rollout Modeling Efforts

- Bottom-up infrastructure rollout simulations can be pursued using a least-cost algorithm that minimizes fuel costs and the number and size of stations installed
  - This approach will contribute to an ongoing NREL study of L.A. infrastructure rollout
  - General methodology is discussed in the following two slides

Proposed Future Work: Use Results to Examine Tradeoffs between Station Sizes and Numbers

The additional cost of FCVs beyond conventional gasoline vehicles is shown in left figure (NRC 2008). An example of availability costs per vehicle is shown as a function of the number of stations installed in L.A. (right figure)

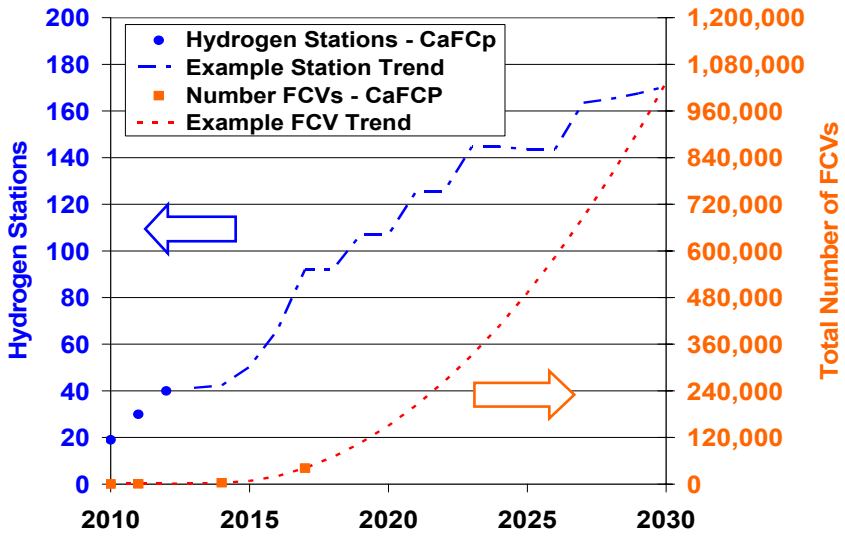




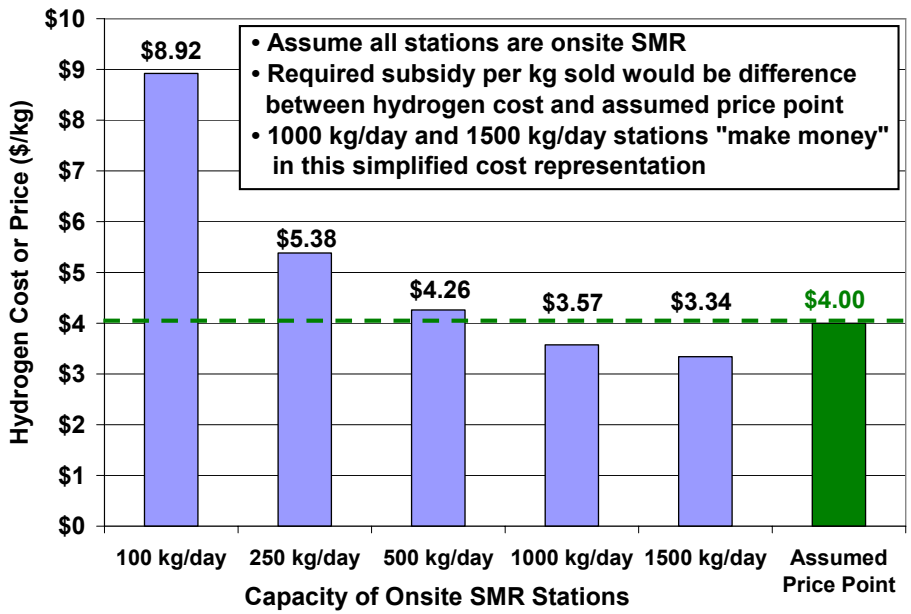
Cost penalties for each geographic level are ranked here from highest to lowest, resulting in an "effective" spatial allocation of stations

Proposed Future Work: Contribute to L.A. Infrastructure Rollout Study

- A small number of large stations would produce low-cost hydrogen by taking advantage of economies of scale
  - But would this result in rapid adoption of fuel cell vehicles?
  - Would more smaller stations decrease required vehicle subsidies?
- Minimize two costs: [refueling availability + underutilizing stations]
- Determines the number and size of stations installed in a given year



Demand is Exogenous



Summary

Relevance	Better understanding of upfront capital costs for early stations. Market Behavior and Coordinated Analysis barriers.
Approach	Developed an improved quantitative representation of the cost penalty for limited refueling availability using discrete choice survey and modeling methodology.
Results	Penalties have been estimated for limited coverage at three geographic scales (metropolitan, regional and national) and for four distinct metropolitan areas (L.A., Seattle, Atlanta, Minn-St. Paul). The results are consistent across each metro area, and have been compared to comparable results from other studies (Results satisfy each of the project objectives)
Collaborations	PA Consulting, Knowledge Networks
Future Work	Potential to integrate results into existing discrete choice models, or to use results to enhance existing bottom-up infrastructure rollouts simulation models