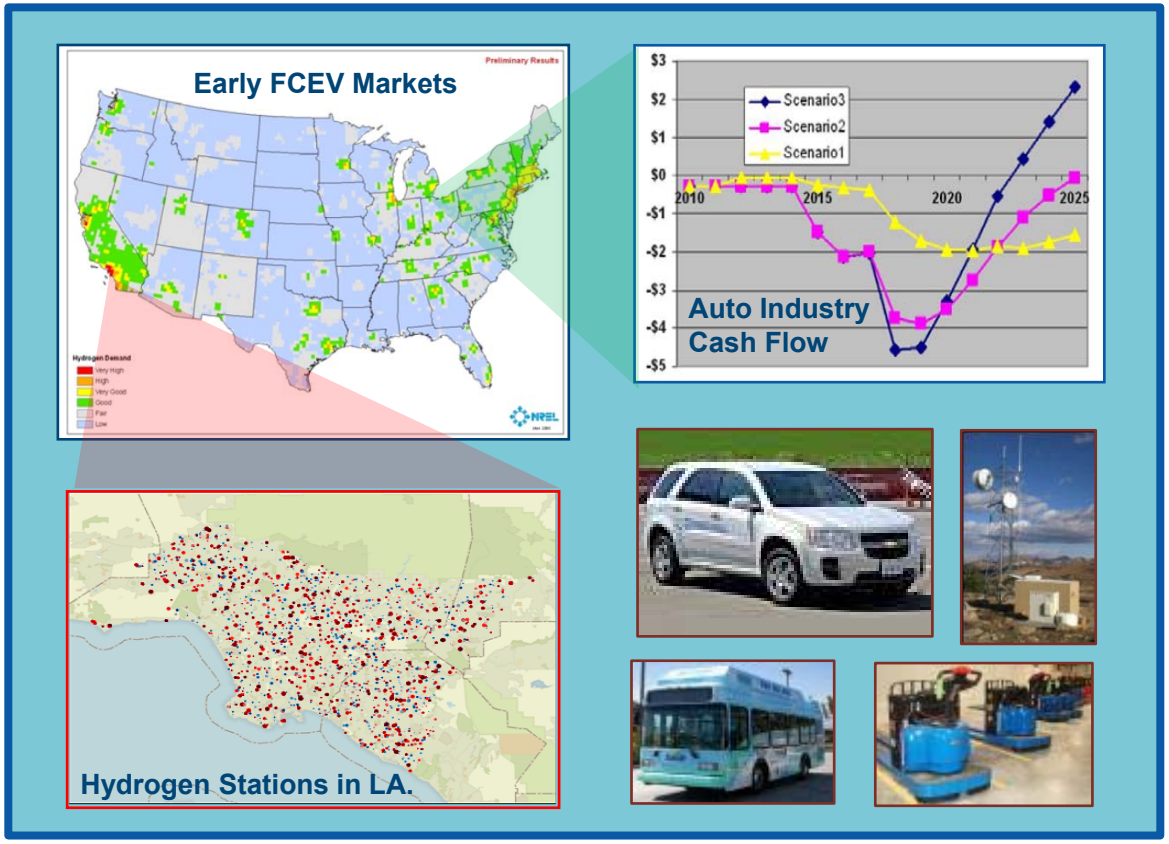
RETHINKING U.S. HYDROGEN INFRASTRUCTURE TRANSITION SCENARIOS: WHAT COMES NEXT?



Marc Melaina

National Renewable Energy Laboratory

David Greene

Oak Ridge National Laboratory

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Project ID # AN019

NREL NATIONAL RENEWABLE ENERGY LABORATORY

OAK RIDGE National Laboratory

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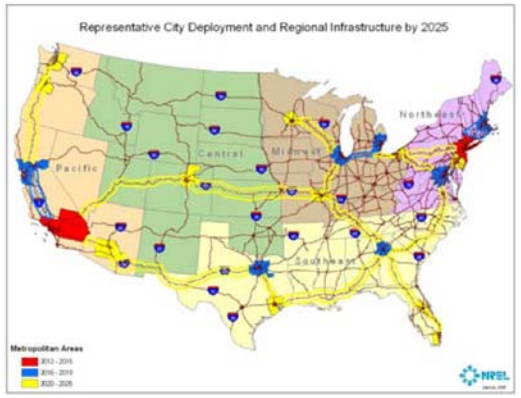
Overview

Timeline	Barriers
• Start: January 2011 • Finish: September 2012 • Complete: 5% *(initial planning only)*	• Future Market Behavior [4.5.A] • Stove-piped, Siloed Analytical Capability [4.5.B] • Inconsistent Data, Assumptions and Guidelines [4.5.C]
Budget	**Partners**
Total Project Funding: $200k • 100% DOE-funded • FY11 funding: $200k	• To be determined

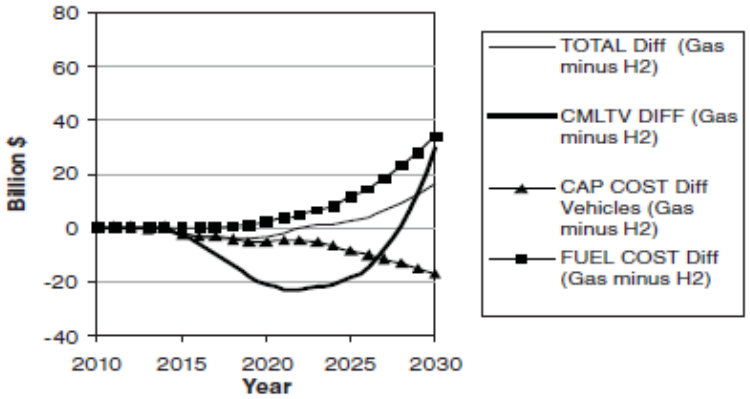
Relevance: Scenario Studies Provide Insight Into Cost Barriers and Technology Potential

Past studies have estimated transition costs for early market barriers

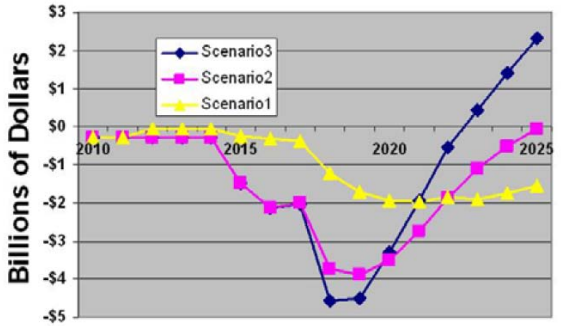
- National Research Council (NRC) and Oak Ridge National Laboratory (ORNL) studies estimated transition costs in the 10s of billions of dollars. Vehicle costs dominated transition costs.



Representative City Deployment and Regional Infrastructure (Melendez and Milbrandt, 2007)



Cash flow for Case 1: Hydrogen Success (NRC 2008)



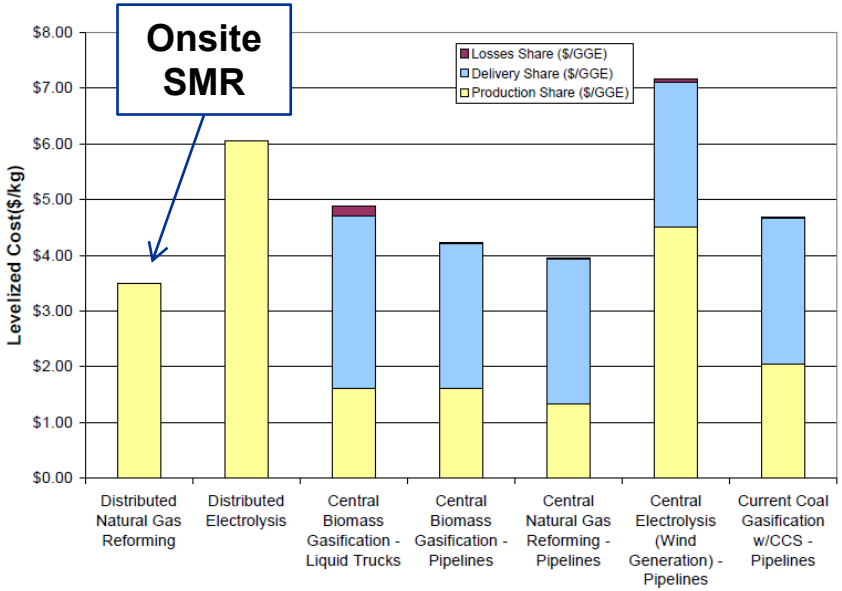
Simulated Auto Industry Cash Flow from Sale of FCVs (Greene and Leiby, 2007)

Previous analyses provided rough estimates of cost barriers and "market takeoff" on a national level

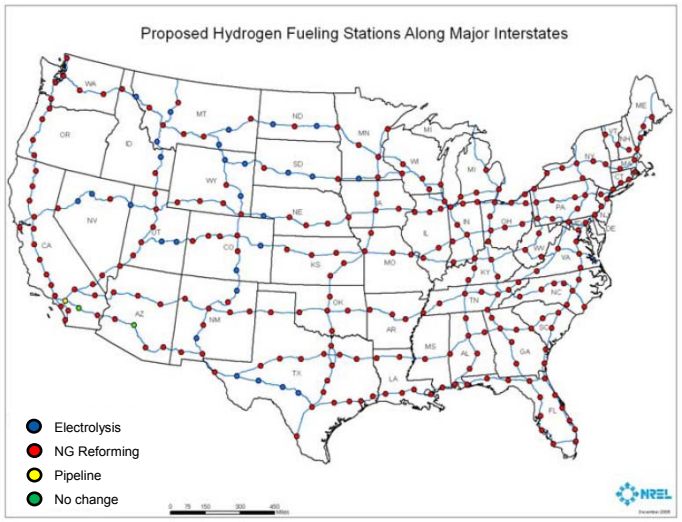
Relevance: Past Studies Relied Upon Key Technologies and Rollout Strategies

Common assumptions and findings

- For the technology suites considered, onsite SMR was often found to be the dominant hydrogen pathway
- It was assumed that retail stations would be 1500 kg/day, even during the rise of early markets
- Infrastructure rollout dynamics followed on a city-by-city "lighthouse" strategy, accompanied by stations along interstates



Levelized cost of hydrogen for 7 pathways (Ruth et al., 2009)



Proposed Hydrogen Fueling Stations Along Major Interstates (Melendez and Milbrandt, 2006)

Relevance: Understanding the Impact of Cost Reductions and Synergies with Growth in Emerging Early Markets

The study will incorporate recent technology cost, market and performance data from stakeholder outreach activities

Emerging early Markets

- Significant advances and experience have been achieved and collected by supporting early markets (e.g. forklifts, buses and telecom) with hydrogen fueling
- In addition to spillover, some synergies may be achieved with LDVs as markets expand

Station Cost Reductions Workshop

- A recent DOE/NREL workshop was held (Feb 16-17, 2011) to better understand early station cost reductions priorities
- Follow-up activities are underway

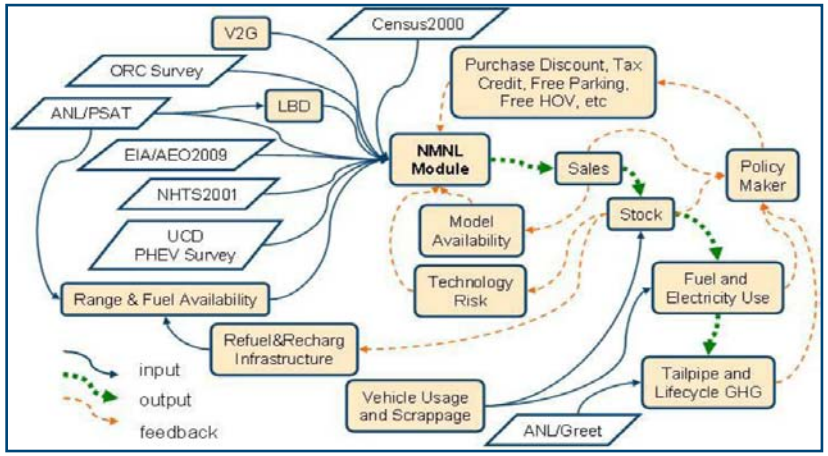
Relevance: Impact on Barriers

Barrier	***Impact***
Future Market Behavior [4.5.A]	• Characterization of early market (forklifts, telecom, etc.) adoption impacts on LDV markets. • Identification of LDV segments for FCEVs.
Stove-piped, Siloed Analytical Capability [4.5.B]	• Combination of detailed geographic analysis data, technology cost and performance data, and market estimation methods.
Inconsistent Data, Assumptions and Guidelines [4.5.C]	• Comparative assessment of multiple hydrogen fuel and advanced vehicle markets, using consistent data and modeling assumptions.

Approach: Combine Results From Multiple Scenario Analysis Models

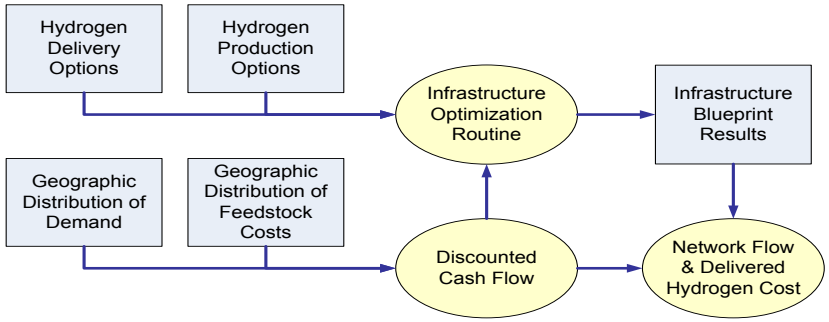
HyTrans and MA3T Models (ORNL)

- Incorporates data from bottom-up cost studies into a LDV and fuels market model.
- Estimates fuel demand in response to consumer behavior and policy assumptions.



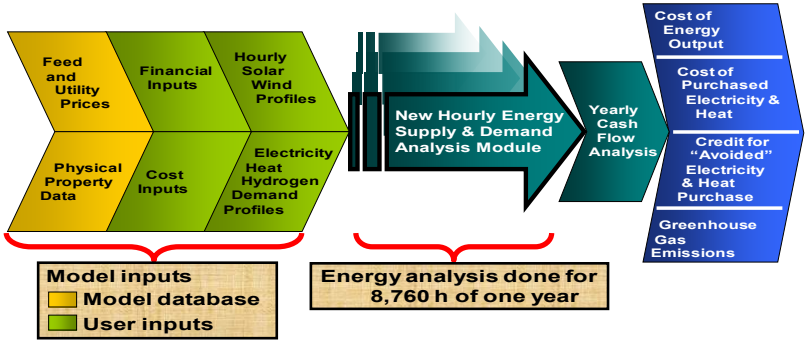
SERA Model (NREL)

- Optimizes infrastructure rollout on the cost of hydrogen spatially and temporally based upon exogenous demand



FCPower model (NREL)

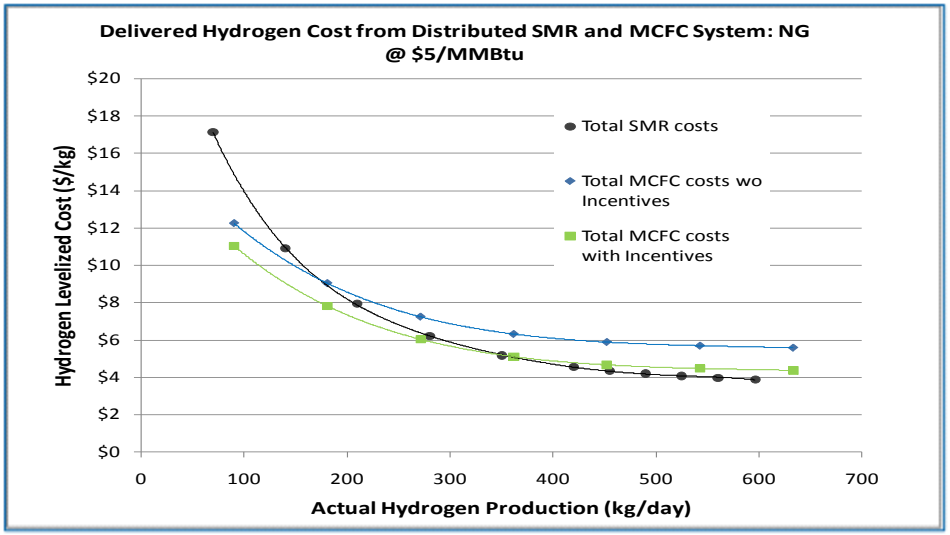
- Estimates the cost of hydrogen from combined heat, hydrogen and power fuel cells using specific input costs



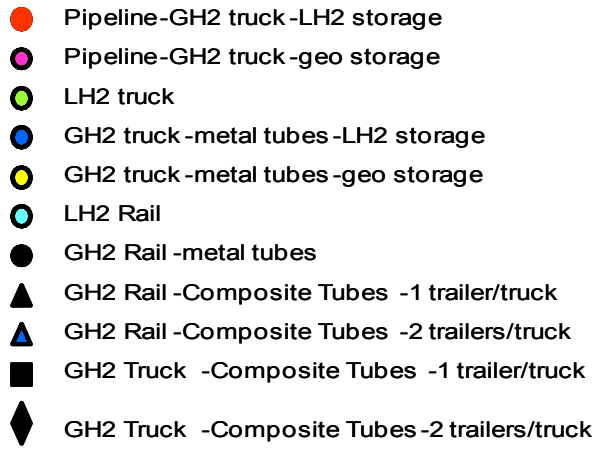
Approach: Scenarios Must be Updated with Recent Analyses of Low-cost, Early Market Technology Options

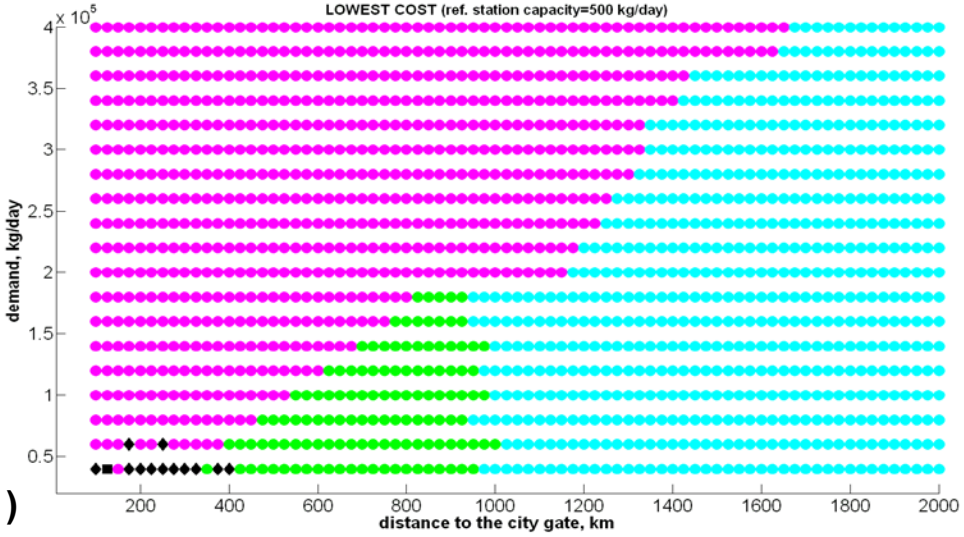
Examples of potentially low-cost options for early markets

- Combined heat, hydrogen and power stationary fuel cells
- Stranded industrial sources
- High pressure/capacity delivery trucks
- Some wind farms can provide hydrogen at relatively low cost



SMR and CHHP Cost Comparisons (Steward, Penev 2010)





Least-cost delivery pathways (Sozinova 2011)

Approach: Collect Input and Guidance on Scenarios and Assumptions Through Stakeholder Workshops

Scenario work will build upon past studies and stakeholder engagements, rather than starting from scratch

Continuity with past and recent workshop results

- Workshops supporting the 2008 ORNL report (Greene et all)
- Industry Workshops conducted at UC Davis for California scenarios
- Recent Market Readiness workshop, NREL/DOE

Collect input from ongoing activities

- Follow-up activities from the Market Readiness workshop
- Update to the CaFCP early market and rollout analysis

Hold new workshops to enhance scenario development

(CaFCP 2011)

(Greene et al 2008)

(Ogden e t al 2009)

Approach: Milestones

One milestone specific to the project in FY11

Milestone	***Date***	***Status***
Scope of work	September 2011	In progress

Technical Accomplishments: Identification of Scenario Components and Scope

The Project Team will be actively pursuing input on Scenario Components and Scope through FY11

Include market analysis of multiple electric drive vehicles

- Indentify early niche markets and long-term potential of FCEVs and other electric drive vehicles
- Include cost synergies for shared vehicle components

Include diversity of hydrogen production sources

- Combined, heat hydrogen and power fuel cells
- Stranded sources of industrial hydrogen
- Wind hydrogen systems (curtailed or dedicated)

Expand analysis to international markets via sensitivities

- Costs may be reduced further due to demand in overseas markets, including Germany, Japan and China

Technical Accomplishments: Identification of Novel Hydrogen Supply Pathways

Combined heat, hydrogen and power stationary fuel cells

- Potential for low-cost hydrogen at low volumes

High pressure tube trailer delivery

- Low volumes for early market stations

Rail delivery

- Appears competitive as low volumes and long distances

Modular station expansion designs

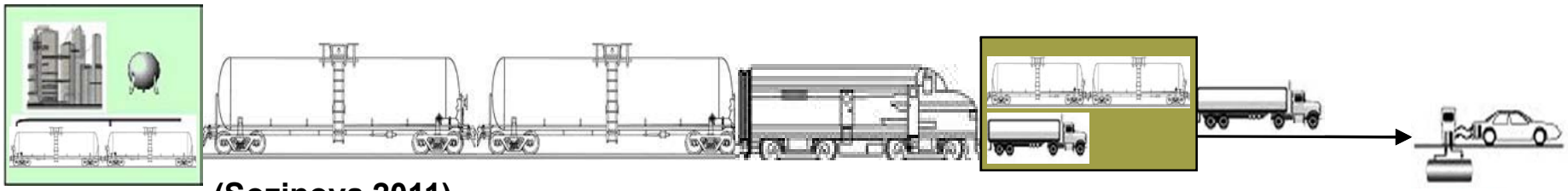
- Evaluate potential cost savings or risk mitigation

Stranded industrial sources of hydrogen

- Marginal cost of purification and delivery

Wind production at the wind site

- Balance hydrogen and electricity transmission costs



(Sozinova 2011)

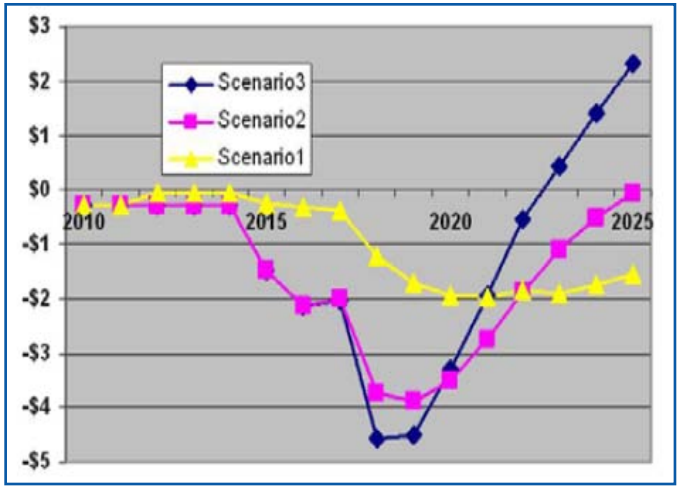
Technical Accomplishments: Expected Outcomes

Some outcomes will be updates to results from previous scenario analyses

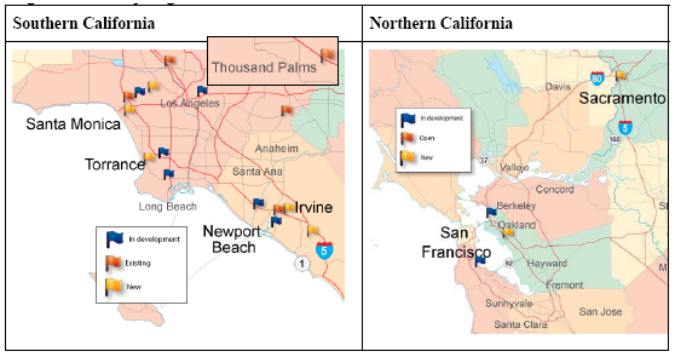
- Vehicle and infrastructure costs will be updated
- Updated costs, new pathways and revised rollout strategies will result in new cash flow and policy analysis results

Other outcomes will be new

- Market segmentation among advanced electric drive vehicles (FCEVs & EV/PHEVs)
- Influence of more diverse sources of hydrogen production
- Influence of international markets on global automotive costs (e.g., learning curves)
- Influence of cost reductions or synergies with FCEVs and emerging hydrogen markets (forklifts, buses, telecom, etc.)



Updated cash flow and policy results will be generated
(image from Greene et al., 2008)



More detailed rollout strategies will be incorporated
(image from CaFCP 2010)

Collaborations and Future Work

Collaborations

- Input from multiple stakeholder types will be collected and integrated based upon results from future scenario workshops

Future Work

- Continue scoping of scenario components
- Identify data and model modification needs

Summary

Relevance	• Scenario studies provide insight into cost barriers and technology potential • Earlier scenario did not account for emerging markets and have assumptions that need to be updated
Approach	• Combine results from multiple scenario models • Incorporate feedback from stakeholder workshops
Accomplishments	• Study scope and focus includes electric drive vehicle market segmentation, diverse hydrogen production sources, and influence of international markets • Identification of expected study outcomes
Collaborations	• Input will be collected from stakeholder workshops
Proposed Future Work	• Continue scoping of scenario components • Identify data and model modification needs