U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Overview of DOE-Supported Infrastructure Analyses Webinar

July 24, 2013

U.S. Department of Energy
Fuel Cell Technologies Office

Agenda

- Introduction and webinar objectives
- Analyses and Models
  - Examples
    - Component-level Models
    - Market Penetration
    - Transition Scenarios
    - Financial Models
    - Impact of Policies
    - Regional Models
- Model enhancements
- Next steps

Introduction

Webinar Objective: To provide an informational briefing on DOE-funded analysis activities, models and tools, and their relevance to H_2 USA.

H_2 USA is being formed as a public/private partnership among DOE and other Federal Agencies, automakers, hydrogen and industrial gas suppliers, state governments, academic institutions, and additional stakeholders to promote the widespread adoption of fuel cell electric vehicles (FCEVs).

H_2 USA activities will contribute to

- Establishing necessary hydrogen infrastructure and leveraging multiple energy sources, including natural gas and renewables
- Deploying FCEVs across America
- Improving America's energy and economic security
- Significantly reducing greenhouse gas emissions
- Developing domestic sources of clean energy and creating jobs in the United States
- Validating new technologies and creating a strong domestic supply base in the clean energy sector

Examples of Initial Proposed Activities:

- Forming a strategy to coordinate FCEV and H_2 infrastructure rollout
- Identifying synergies and opportunities to leverage other alternative fueling infrastructure—such as natural gas—to enable cost reductions and economies of scale
- Identifying actions to incentivize early adopters
- Evaluating the business cases require for commercialization of FCEVs and hydrogen infrastructure technologies

Slides will be made available on the DOE Fuel Cell Technologies Office website

http://www1.eere.energy.gov/hydrogenandfuelcells/

Preliminary Analysis Meetings among National Labs and Academia

A preliminary meeting with national labs, academia and contractors was held at NREL in March 2013 to understand the information and modeling requirements for assessing a coordinated roll-out plan for FCEVs and hydrogen infrastructure in the United States.

Purpose:

- Assess analytical capabilities to support market launch studies assuming the technological hurdles are resolved.
- Identify and collect feedback on the following:
    - Information and data required to undertake the studies
    - Identify models capable of assessing a coordinated infrastructure roll-out and market launch, with focus on in-depth business cases and implementation plans
    - Identify gaps to performing the analysis and assessment
    - Identify next steps in organizing the team and critical workshops to complete the studies

Potential Issues That Analysis Can Address

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Stakeholder Input

- Hydrogen value and supply chains
  - Where is hydrogen coming from?
  - What are the business cases and drivers for hydrogen suppliers?
- Station analysis
  - How many, where and when?
  - What kind of hydrogen fueling stations?
  - What are the business models and supporting policies?
- Consumer acceptance
  - What are the economic and vehicle performance drivers for early adopters ?
  - What are the social behavior drivers?
- Policy framework to go along with and support the plan
  - What are the social benefits of the transition to hydrogen and fuel cell vehicles?
  - What actions can be taken to incentivize early adopters?
  - What actions can be taken to enable profitability and mitigate risk (financial, technological and policy)?
- Market Transitions
  - How do early deployment efforts lead to a sustainable national market?
- Role of hydrogen in a low carbon future

Specific initial output: A statement of work to provide critical analysis and resource data in partnership with decision makers and stakeholders

Overview

FCEVs and H_2 are part of a portfolio of technologies to increase energy security, and reduce greenhouse gas and criteria pollutants

Hurdles for FCEV sales

- FCEVs will be relatively expensive at market introduction
- FCEVs will be unfamiliar to consumers at market introduction
- The hydrogen refueling experience will be unfamiliar for drivers
- The availability of hydrogen stations will be different than gasoline

Hurdles for hydrogen infrastructure

- Early hydrogen stations may be under-utilized
- Deploying more stations will accelerate FCEV market growth
- A sound business case will balance profitability and expansion of station networks

The array of analysis capabilities:

- Provide market research on location and numbers of potential buyers for near, mid, and long term scenarios
- Optimize refueling infrastructure numbers and locations to match potential customers, maximize coverage, and minimize public investment
- Determine financial scenarios necessary for successful hydrogen infrastructure and FCEV deployment
- Understand uncertainty and risk mitigation

- Increased Energy Security
- Reduced GHG Emissions
- Reduced Criteria Pollutant Emissions

↑

Exciting products accelerate in the market after initial threshold is attained

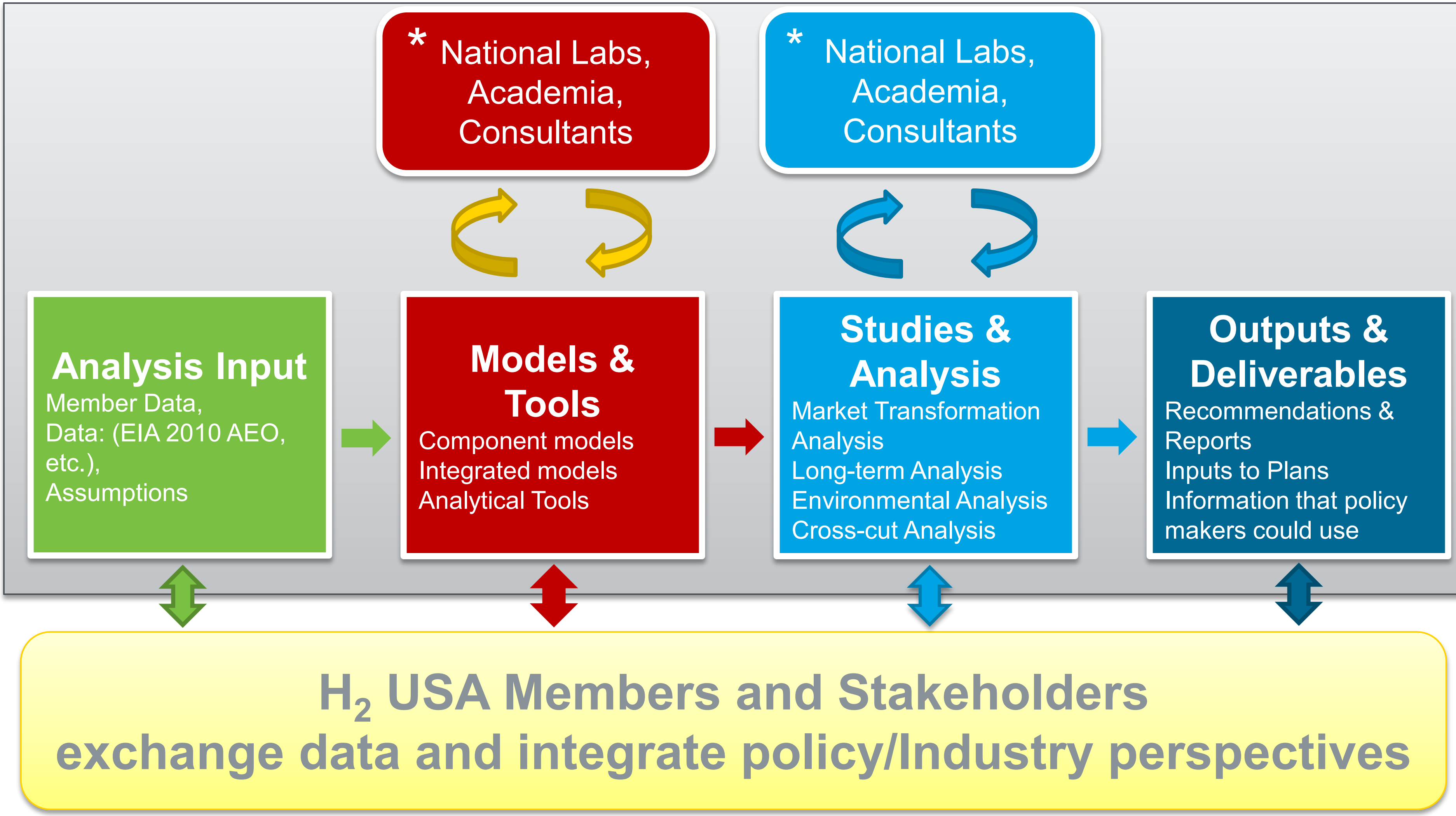
↑

Analysis provides foundation for effective FCEV and H_2 deployment

Analysis Framework

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Integrated Analysis Achieves Consistent and Transparent Results

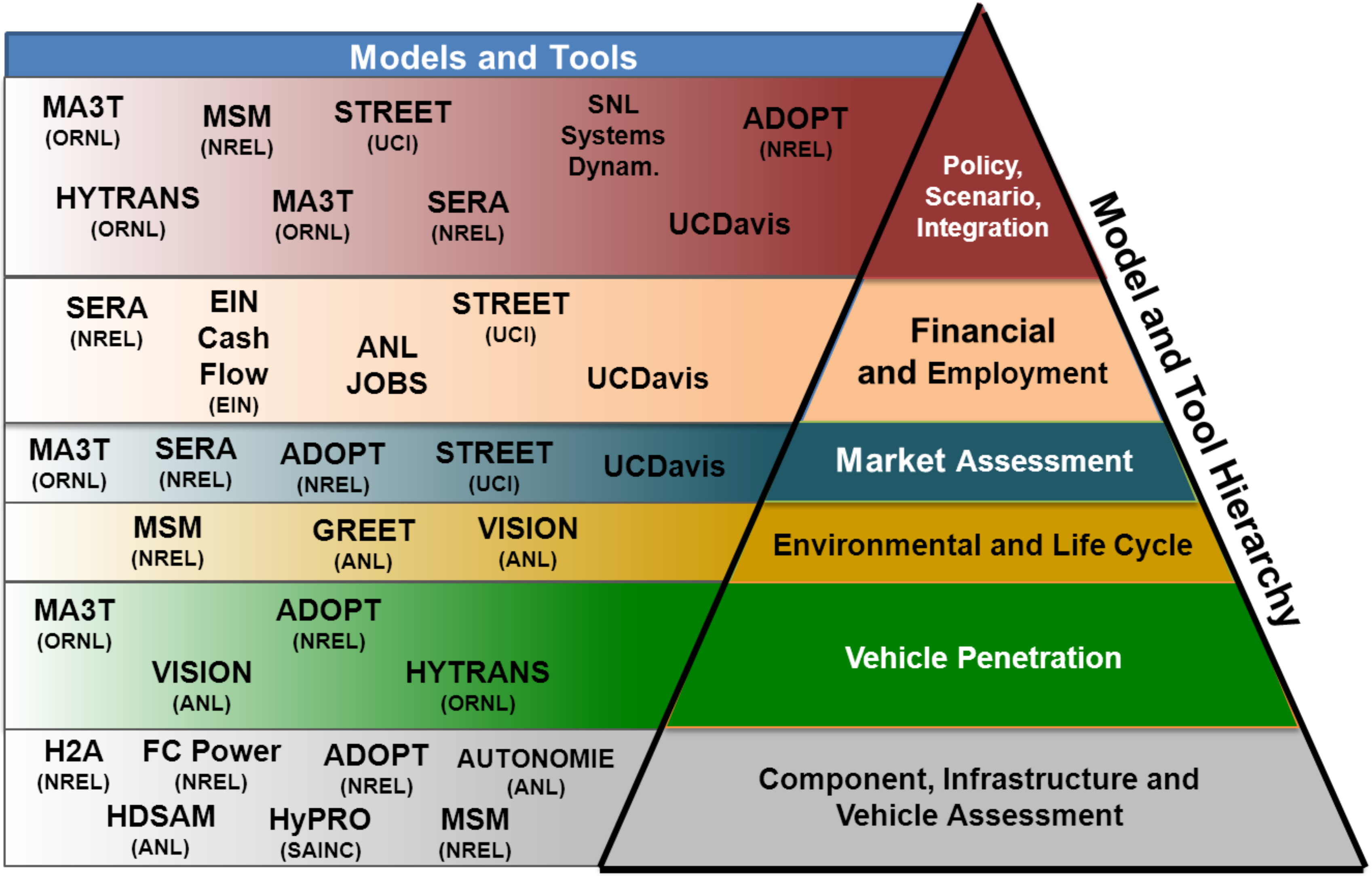


* DOE sponsored analysis

Existing Model Framework

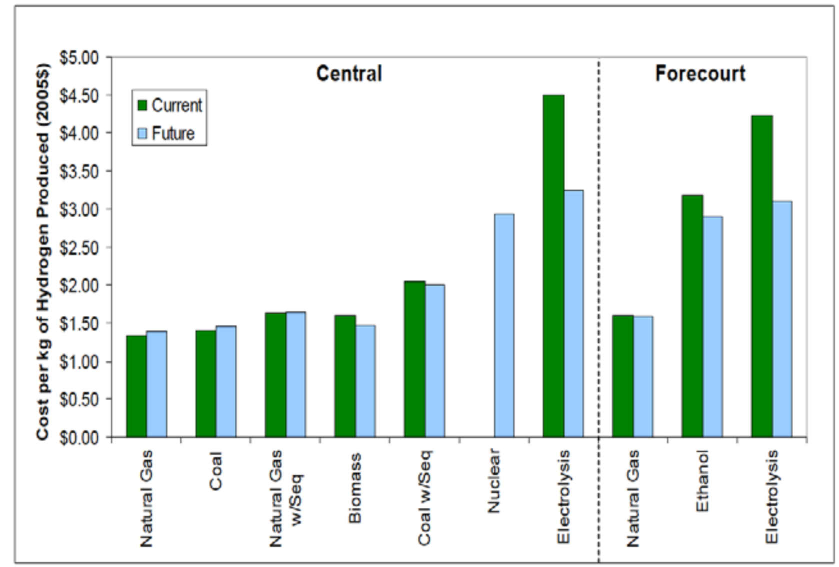
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

DOE Fuel Cell Technologies Office models were designed to address and assess different questions and in combination they function as a versatile and multi-functional toolkit



Overview of H2A

- H2A is a discounted cash flow model that computes the required price of H_2 for a desired after-tax internal rate of return (IRR)
- H2A uses custom macros in Microsoft Excel
- Latest analyses exist in H2A Version 3 (2012)
- Two main types of H2A analyses:
  - production and delivery.
- Objective of H2A Analyses (production):
  - Establish a standard format for reporting the production cost of H_2, so as to compare technologies and case studies
  - Provide transparent analysis
  - Provide consistent approach



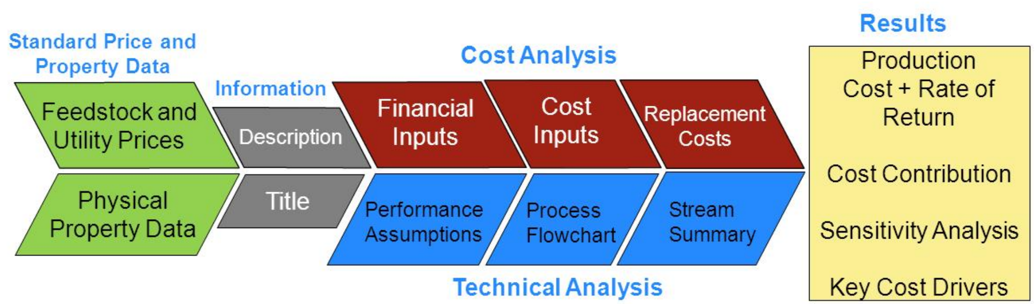
Costs are for hydrogen production and carbon sequestration only; delivery, compression, storage, and dispensing costs are not included.

Figure ES - 1. Levelized Hydrogen Production Cost: All Technology Cases.

Example H2A Production Costs

(Ramsden, Steward, Zuboy 2009)

H2A Process Flow Diagram



Publicly Available

http://www.hydrogen.energy.gov/h2a_analysis.html

H2A Webinar

https://www1.eere.energy.gov/hydrogenandfuelcells/webinar_archives_2013.html#date070913

Hydrogen Cost Analysis from Distributed Natural Gas Reforming

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Natural gas price projections have declined in recent years and the corresponding cost of hydrogen*, also declines**

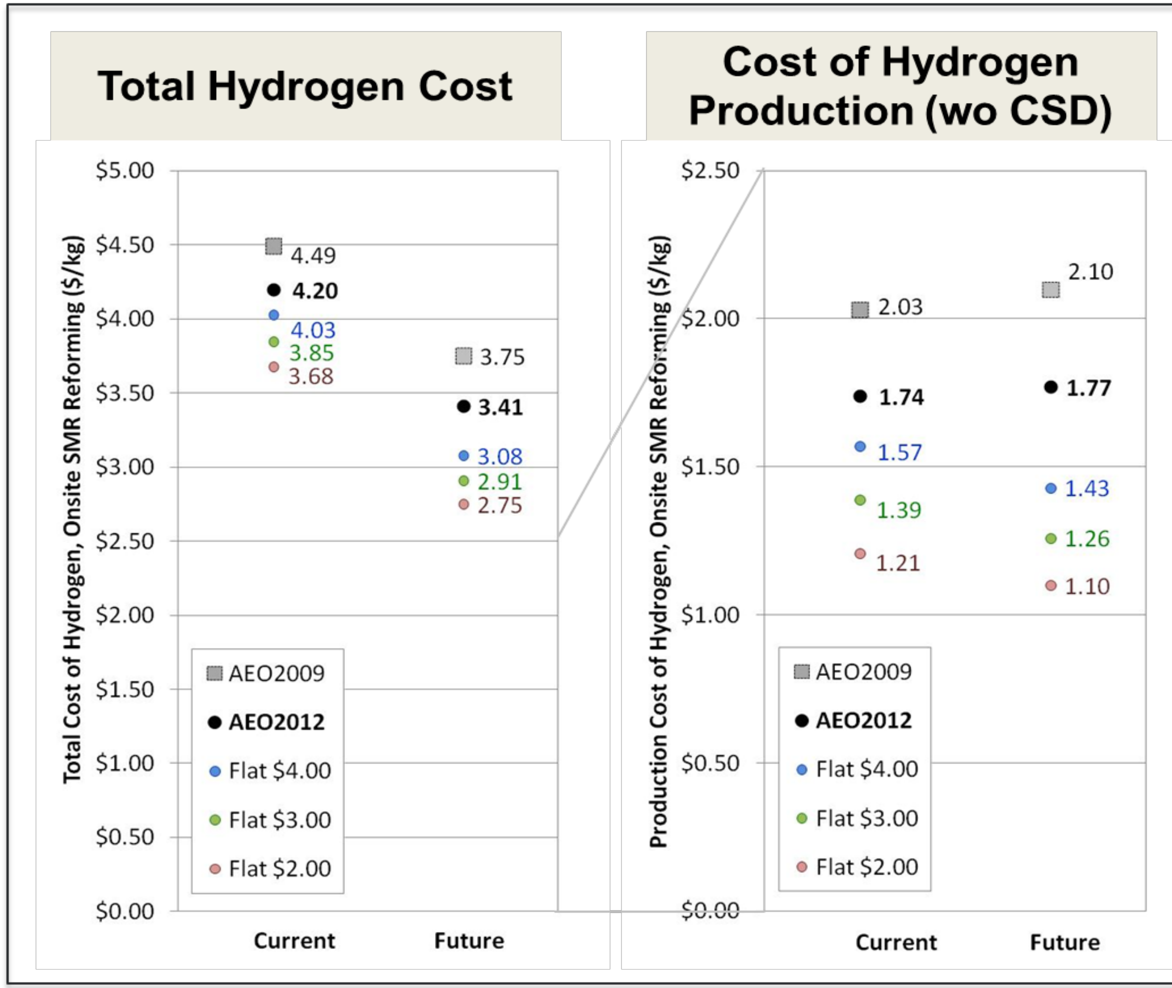
Distributed Hydrogen Production from NG SMR

- Total hydrogen cost (production plus station compression, storage and dispensing [CSD]) and production cost for Current and Future forecourt SMR stations

- Current Case: Startup year is 2010; Station life is 2010-2030
- Future Case: Startup year is 2020; Station life is 2020-2040

- The cost of natural gas ($/MMBtu) is only a fraction of the total cost of hydrogen

- Difference between the two charts is the cost of CSD.



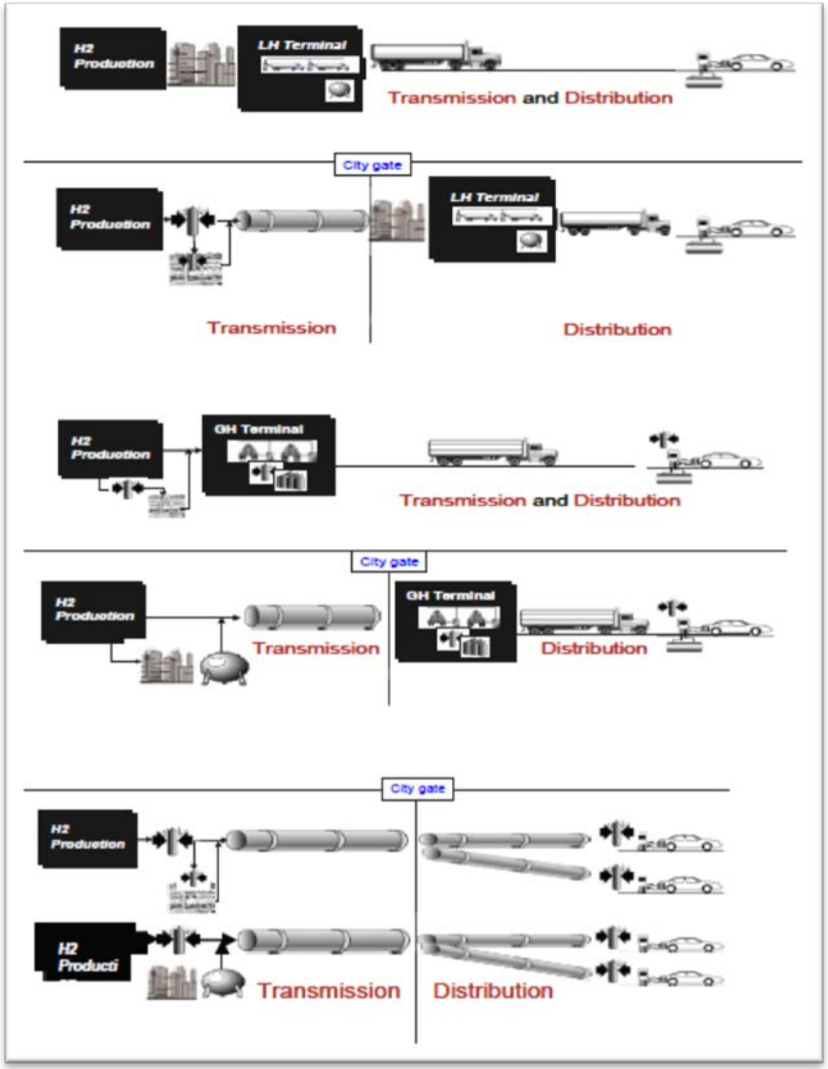
*Based on H2A v3 Case Studies @ http://www.hydrogen.energy.gov/h2a_production.html

**AEO2009 avg NG prices (HHV, $/MMBtu): $7.10 (Current, 2010-2030); $8.44 (Future, 2020-2040)

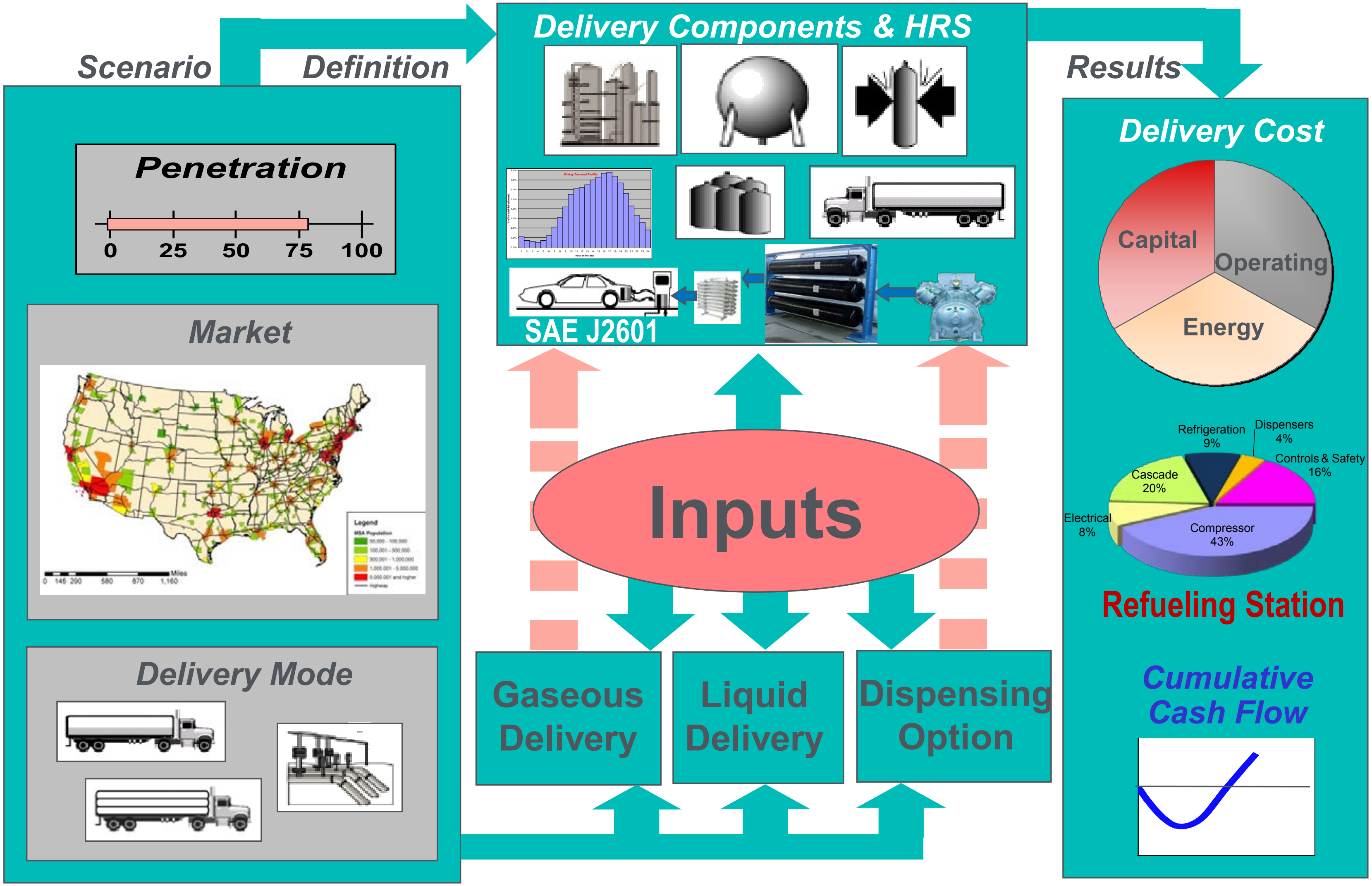
AEO2012 avg NG prices (HHV, $/MMBtu): $5.28 (Current, 2010-2030); $6.48 (Future, 2020-2040)

Hydrogen Delivery Scenario Analysis Model (HDSAM)

- **Model objectives:**
  - Develop database on delivery components costs and performance
  - Develop delivery scenarios that span major markets and demand levels
  - Calculate CAPEX, OPEX, levelized cost and cash flow of hydrogen delivery and refueling
- **Model Attributes:**
  - Capable of sizing and optimizing hydrogen refueling station components (with different configurations and demand profiles) while satisfying the SAE J2601 protocol
  - Tracks pressure, temperature, and mass between refueling components and vehicle's tank
  - All cost assumptions, design and sizing parameters, and calculations are transparent
  - Impact of key delivery components and cost drivers are easily identified
  - Does not model station network buildup
- **Key Assumptions:**
  - Capital cost from vendors and industry, and economic parameters from H2A model system
  - Depreciation and labor rates based on industry input
  - Land requirements based on NFPA codes and standards
  - Cost of energy data from EIA AEO



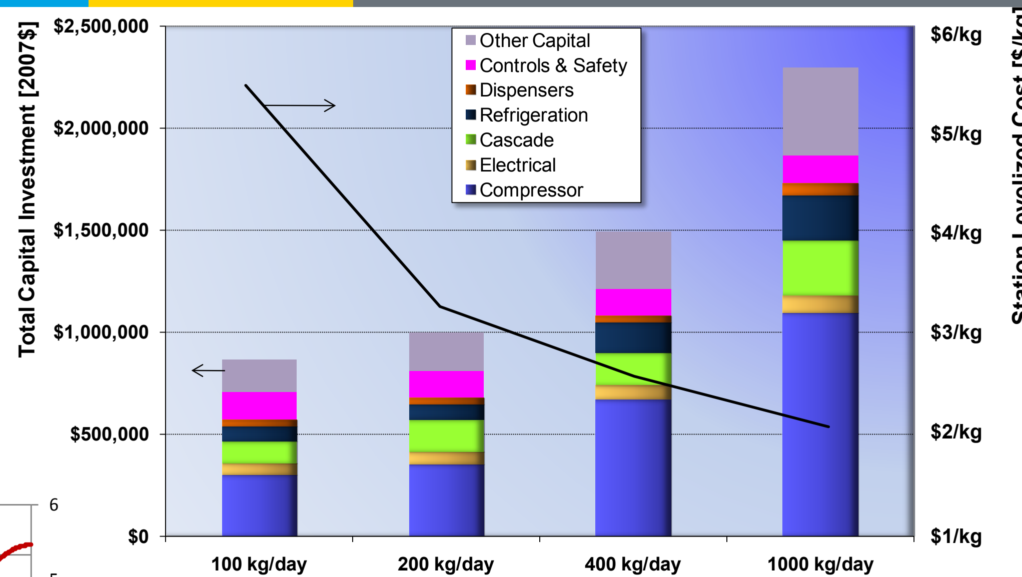
Hydrogen Delivery Scenario Analysis Model (HDSAM)

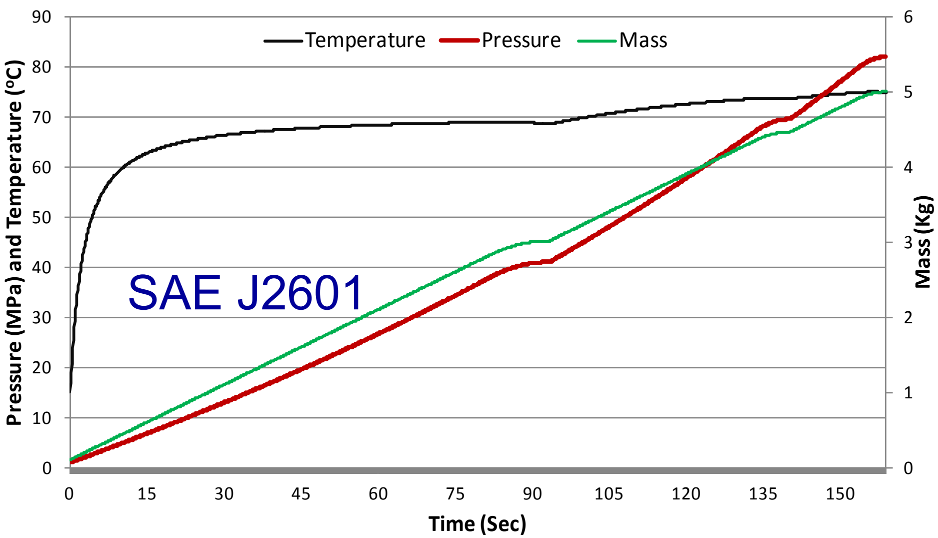


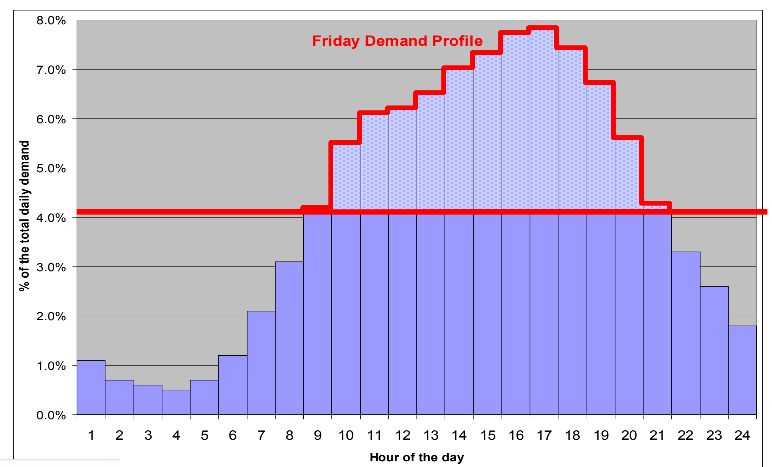
– Developed in Excel and is publicly available for download and use
– Cost data from vendors. Modeling and analysis vetted by experts from industry
– CAPEX, OPEX, levelized cost and cash flow by component and for total H2 delivery

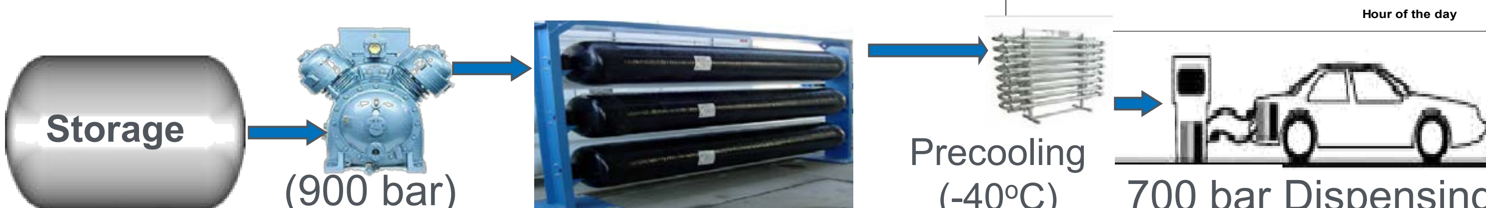
Examples of HDSAM Analysis

HDSAM sizes station components observing SAE J2601 and estimates capital, O&M, and levelized cost of hydrogen







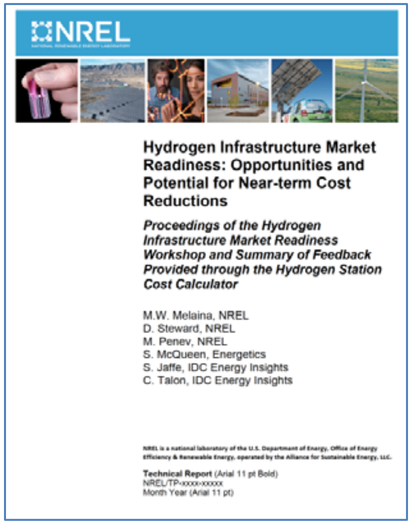


Description of the HSCC

A simplified H2A cost calculator that presents cost inputs side-by-side for four hydrogen station types at different market-ready levels:

- **State-of-the-Art Stations (SOTA).** Hydrogen stations installed and operational within the 2011-2012 timeframe, with the most recent generations of major components; Beyond demonstration phase.
- **Early Commercial Stations (EC).** Installed within the next 5-20 years; financially viable with little government support; supports growing demand in a promising market region; adequate ROI; station design is replicable to allow for further cost reductions.
- **More Stations (MS).** Identical to Early Commercial stations, but deployed in larger numbers; learning by doing.
- **Larger Stations (LS).** Identical to Early Commercial stations, but designed for higher volume output.

- The HSCC was distributed to a select group of expert stakeholders, who provided their inputs for each station types. The calculator then provided a $/kg cost result, giving participants direct feedback on their inputs.
- Results of the HSCC and workshop were summarized in a report.



NREL

Hydrogen Infrastructure Market Readiness: Opportunities and Potential for Near-term Cost Reductions

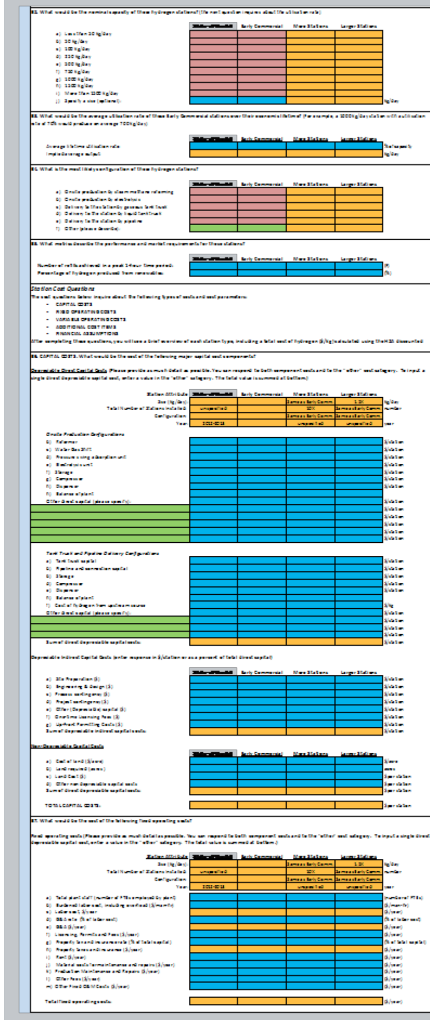
Proceedings of the Hydrogen Infrastructure Market Readiness Workshop and Summary of Feedback Provided through the Hydrogen Station Cost Calculator

M.W. Melaina, NREL
D. Steward, NREL
M. Penev, NREL
S. McQueen, Energetics
S. Jaffe, IDC Energy Insights
C. Talon, IDC Energy Insights

Technical Report (Arial 11 pt Bold)
NREL/TP-xxxx-xxxxx
Month Year (Arial 11 pt)

http://www.nrel.gov/docs/fy12osti/55961.pdf

Screenshot of the HSCC



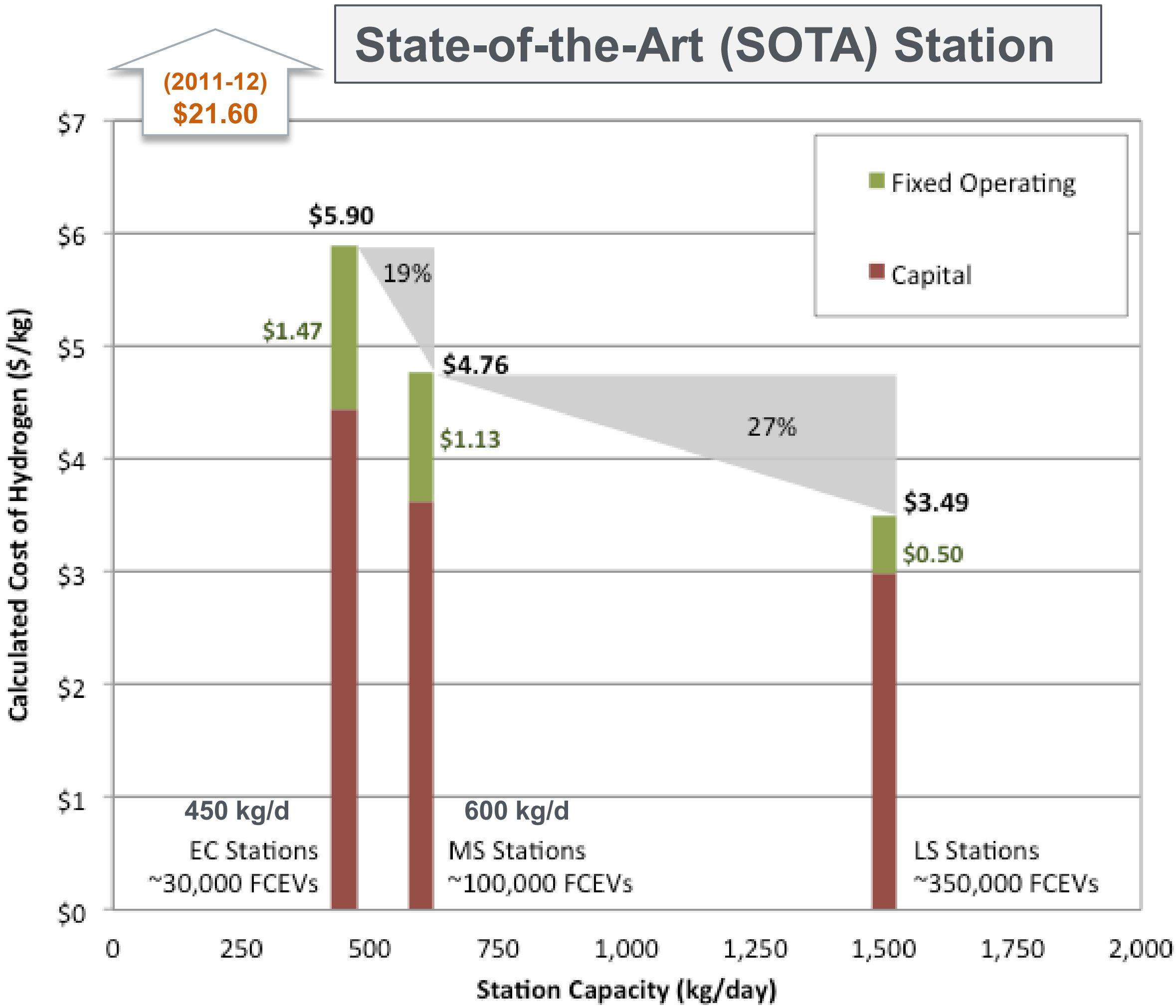
Source: NREL

Hydrogen Fueling Station Capital and Fixed Operating Costs from Stakeholders

Capital and fixed operating costs can decline by 41% between Early Commercial (EC) and Larger (LS) Stations. Variable costs are more station-specific.

- Taking the weighted, aggregated capital and fixed operating costs of stakeholders, gives the $/kg results shown at right
- Variable costs are more station specific, especially with regard to electricity consumption being onsite or upstream
- Future analyses will incorporate variable costs based upon performance

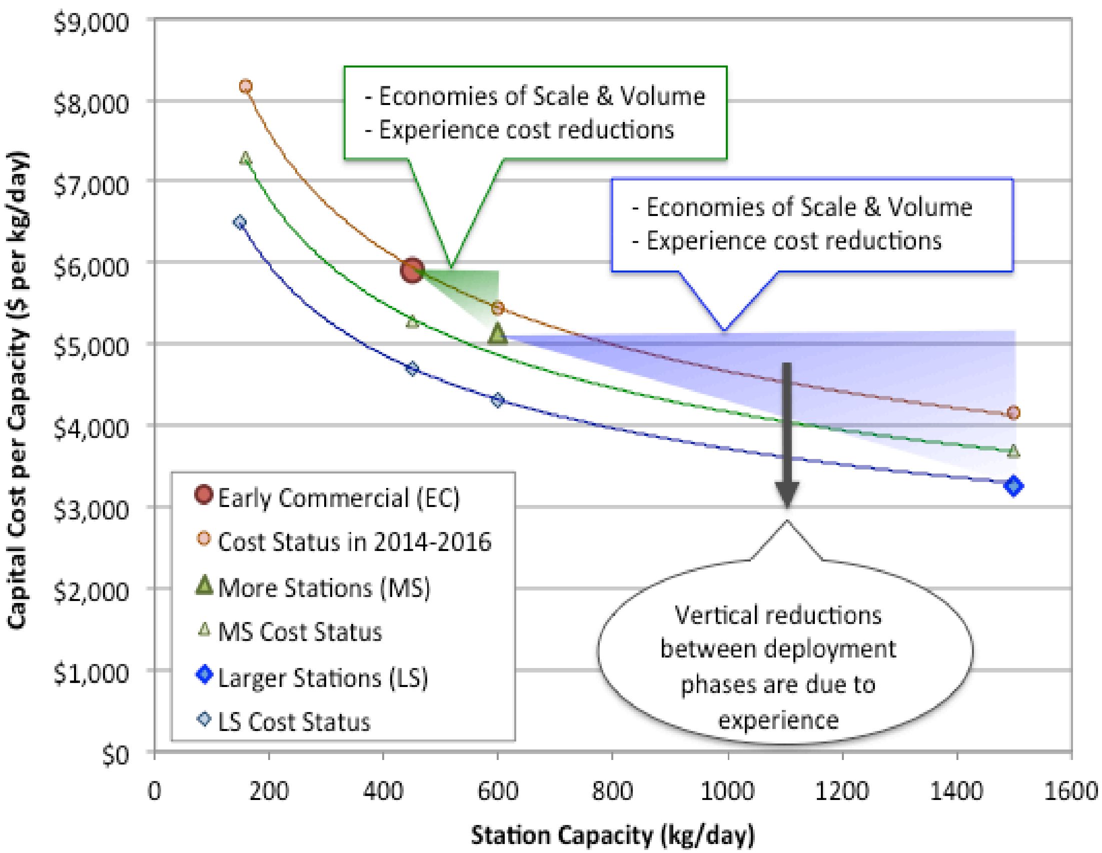
<u>Legend</u>
SOTA (State-of-the-Art)
EC (Early Commercial)
MS (More Stations)
LS (Larger Stations)



Source: NREL

Station Capital Cost Reductions

Longer-term cost reductions are due to economies of scale and volume, as well as increased experience and learning



Source: NREL

A Broader Set of Cost Reduction Opportunities Applies to Early Commercial (EC)-More Stations (MS)-Larger (LS) Stations

- Expand and enhance supply chains for production of high-performing, lower-cost parts
- Reduce cost of hydrogen compression
- Develop high-pressure hydrogen delivery and storage components
- Facilitate development of codes and standards for high pressure equipment

High Capital Utilization Rates

- Develop mechanisms for planning station rollouts and sharing early market information

Energy Independence Now (EIN)* Cash Flow/Incentive Model

California context, but could be adapted to other regions.

Model Purpose:

1. Identify financial challenges (risks) in early H2 infrastructure systems
   → Illustrate hydrogen station cash flows under variety of market scenarios

2. Explore solutions
   → Quantify impact of variety of incentives on these cash flows (IRR, NPV)
   - Quantify cost of incentives

Distinguishing Characteristics:

- Excel Based
- Market segmented into Core, Emerging, Network Support stations
  - Vehicle Fueling, Sales Pattern, and retail price can be varied by market
- Station Build-out differentiated between "coverage" and "capacity" driven phases
- Tests the impact of:
  - Capex & Opex Grants
  - Market Assurance Grants
  - Loans (including guarantees)
  - Tax Incentives

***Funded through California Fuel Cell Partnership (CaFCP)**

EIN Cash Flow/Incentive Model

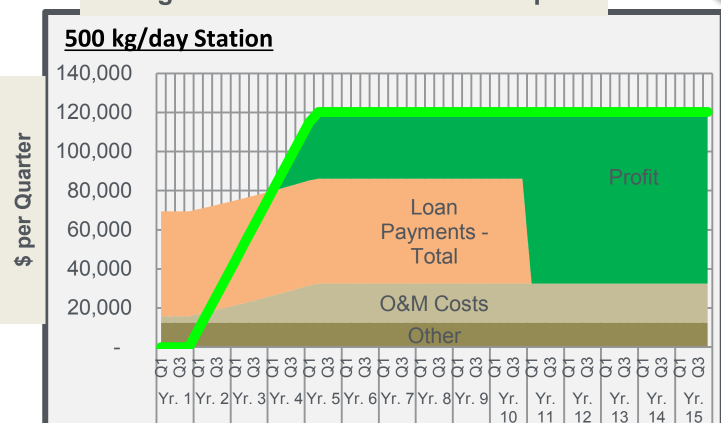
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Inputs:

Market Scenarios
Vehicle Sales + fueling patterns, prices + Infrastructure Build out & Costs

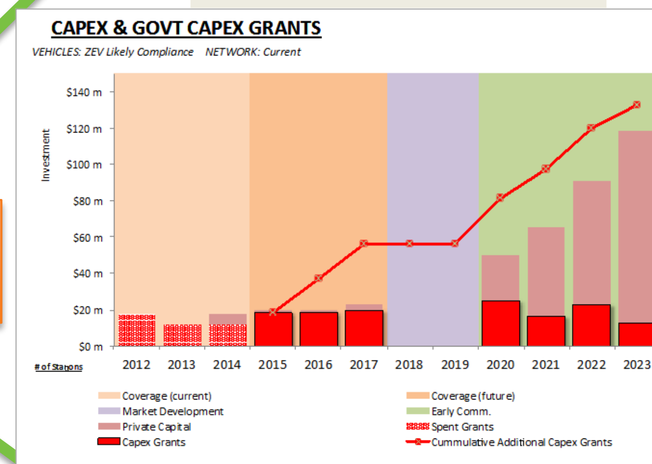
Investment Package Scenarios:
Combos of Grants (CapEx & OpEx), Debt & Tax incentives

Single Station Cash Profile Example



Station & Network Cash flow projections

Network Cost Snapshot



Outputs:

Station-specific:
- Return on investment (IRR)
- Impact of incentives

Network wide
- Funding needs for build-out
- Network support & funding

Market Acceptance of Advanced Automotive Technologies (MA3T) Model

MA3T simulates 1458 U.S. consumer segments choosing among 40 LDV choices

- Nested multinomial logit (NMNL)
- Learning by doing (LBD) and co-learning
- Economy of scale
- Gamma distribution for random daily distance
- Fuel-travel-back: optimal station locations
- Path-dependant charging benefit
- Supply constraint for new technologies
- Conflict: infrastructure availability and utilization
- Policy design, e.g. feebate parameters
- Calibration—learning from history
- Dynamic product design (being implemented)
- Optimal transition (to be implemented)

Additional Features

- U.S. LDV market divided into 1458 segments, 2005-50
- Buy or no buy decision is now endogenous
- 20 powertrain technologies, cars and light trucks, to be expanded into small cars, midsize cars, large cars, SUVs and pickup
- Vehicle attributes: retail price, fuel economies, acceleration, refueling hassle, range limitation cost, etc
- Infrastructure: hydrogen, natural gas, electricity, diesel; home, work, public charging
- Policies: fuel/carbon tax, feebate, parking or HOV incentives, tax credit or rebate

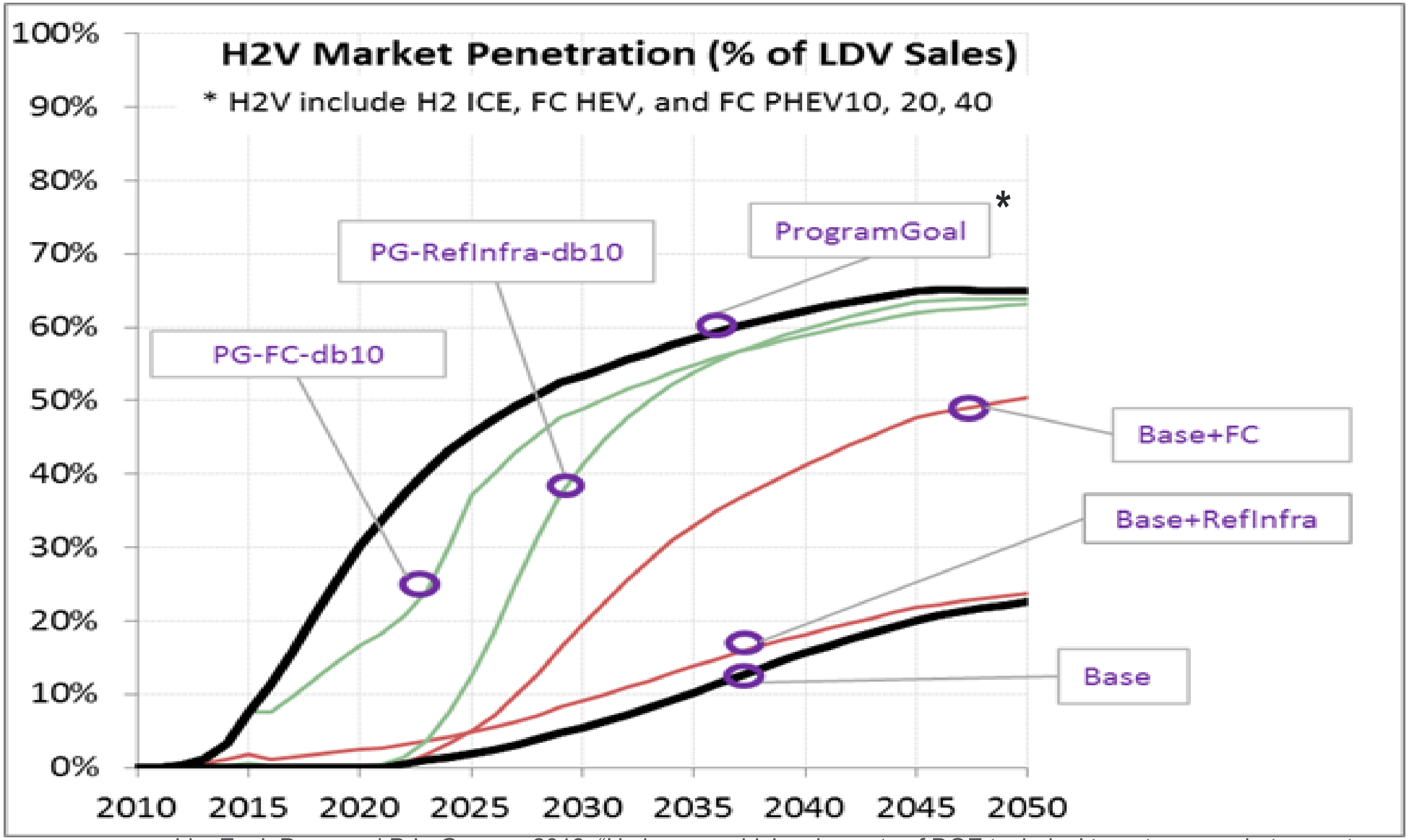
Publicly Available:
http://web.ornl.gov/filedownload?ftp=e;dir=uP212MFV0FrH

Example of MA3T Modeling

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

MA3T was used to analyze impacts of DOE technical targets on market acceptance, social benefits and subsidies of electric drive vehicles

- ~5% hydrogen availability for market onset
- “fast-then-adaptive” infrastructure roll-out strategy?

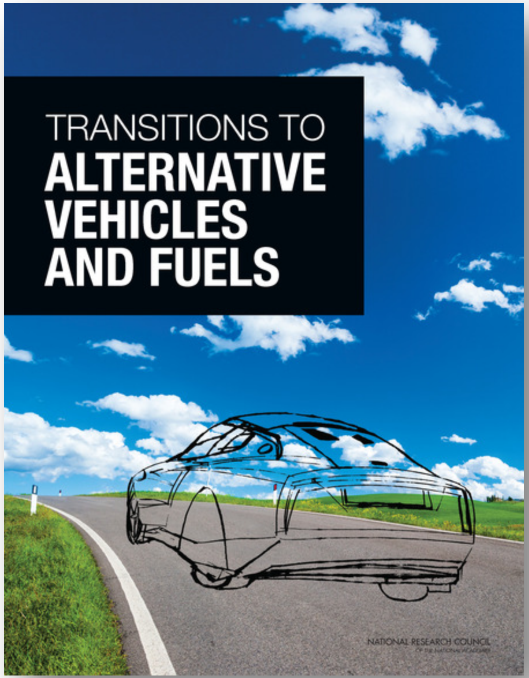


*”Program Goal” refers to meeting technology R&D targets

Lin, Z., J. Dong and D.L. Greene, 2013. “Hydrogen vehicles: impacts of DOE technical targets on market acceptance and societal benefits”, *International Journal of Hydrogen Energy*, vol. 38, no. 19, pp. 7973-7985.

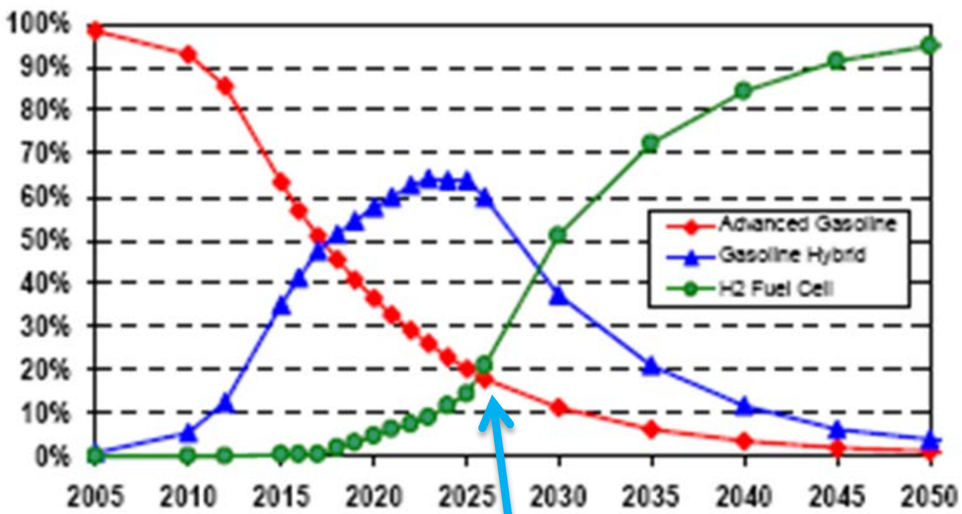
HyTrans Model

- The HyTrans model, used in the 2008 DOE study: "Transition to Hydrogen and Fuel Cell Vehicles" is a dynamic, non-linear optimization, market equilibrium and policy model.
- HyTrans integrates fuel production and delivery, vehicle supply and consumer choice.
- Input data come from H2A, HDSAM, GREET, and PSAT, with calibration to EIA's Annual Energy Outlook.
- Major barriers to novel vehicle technologies and fuels are represented, as are positive feedbacks such as learning by doing and scale economies.
- HyTrans is large for a non-linear optimization model, challenging to solve and not available to the general public.
- Experience and expertise gained in building and operating HyTrans influenced the LAVE-Trans spreadsheet model used by the NRC in its study, *Transitions to Alternative Vehicles and Fuels.*



Policy Analysis with HyTRANS Model

HyTrans illustrated the dynamics of a sustainable transition: with targeted deployment policies during 2012 to 2025 and expected technological progress, FCEV market share grew to 50% by 2030 and 90% by 2050, leading to a sustainable and competitive market for FCEVs beyond 2025, without continued policy support.



Source: Greene and Leiby et al., 2008.
http://www-cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2008_30.pdf

Potential for competitive H_2 FCEV market

Potential Policy Impacts

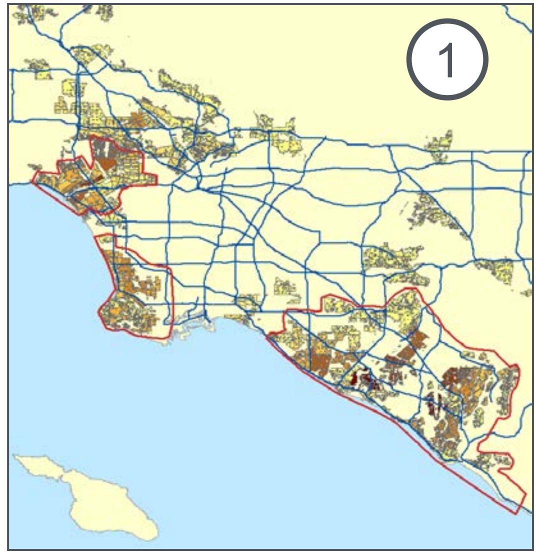
Policy Case	Time Period	Vehicle Policies		Fueling Infrastructure Policies	
		Fuel Cell Vehicle Cost Sharing	Fuel Cell Vehicle Tax Credits	Station Cost Sharing (for Distributed Hydrogen Production)	Hydrogen Fuel Subsidy (Production Tax Credit)
Case 1	2012 - 2017	50% of incremental FCV costs	None	$1.3 Million/Station	$0.50/kg
	2018 - 2021	50% of incremental FCV costs	None	$0.7 Million/Station	Decreases linearly From 2018 to $0.30/kg in 2025
	2022 - 2025	50% of incremental FCV costs	None	$0.3 Million/Station	$0.30/kg in 2025
Case 2	2012 - 2017	50% of total FCV costs	None	$1.3 Million/Station	$0.50/kg
	2018 - 2021	None	100% of incremental cost	$0.7 Million/Station	Decreases linearly From 2018 to $0.30/kg in 2025
	2022 - 2025	None	100% of incremental cost	$0.3 Million/Station	$0.30/kg in 2025
Case 3	2012 - 2017	50% of total FCV costs	None	$1.3 Million/Station	$0.50/kg
	2018 - 2021	None	100% of incremental cost plus $2,000/vehicle	$0.7 Million/Station	Decreases linearly From 2018 to $0.30/kg in 2025
	2022 - 2025	None	100% of incremental cost plus $2,000/vehicle	$0.3 Million/Station	$0.30/kg in 2025

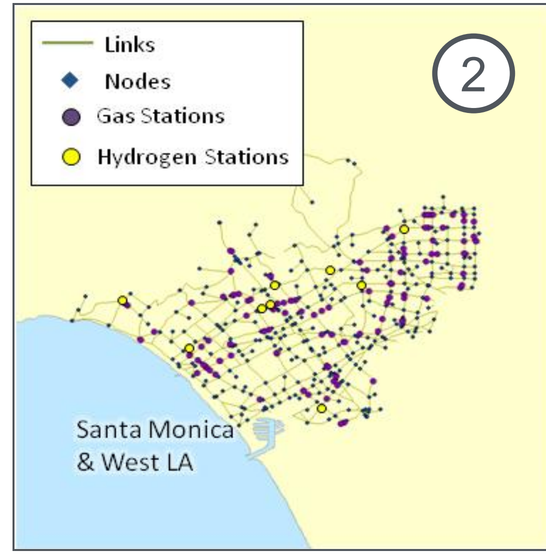
STREET Model

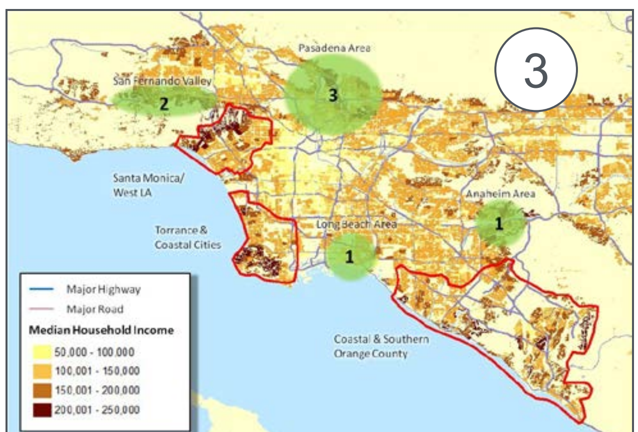
Spatially and Temporally Resolved Energy and Environment Tool (STREET)*

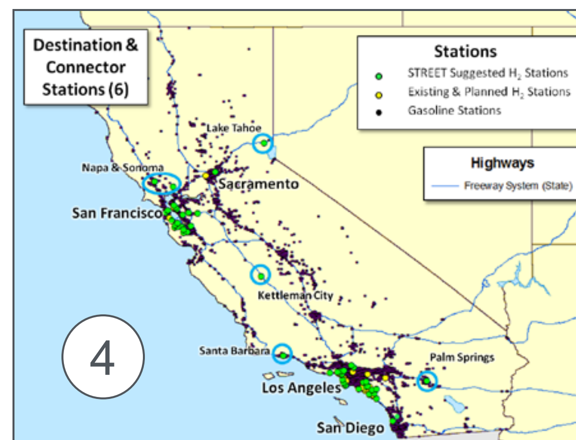
- Developed by the Advanced Power and Energy Program at UC Irvine through extensive collaboration with automakers, energy companies, and other stakeholders

1. Determine clusters
    - Relies on demographic data and OEM FCV market projections
2. Optimize stations within clusters to meet 6 minute coverage
    - Travel time analysis
    - Station land use
    - Vehicle travel density
    - Service coverage
3. Identify secondary markets
    - Demographic data
4. Select destination and connector locations
    - Travel times/distances
    - OEM input
    - Demographic data

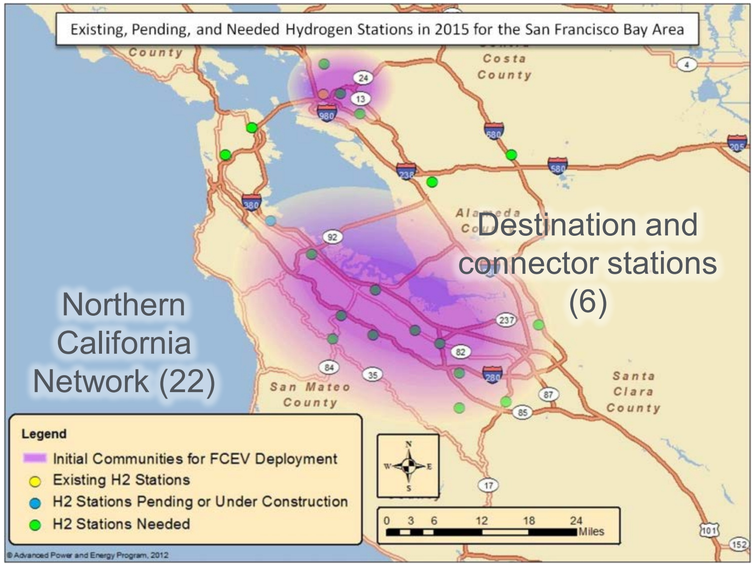


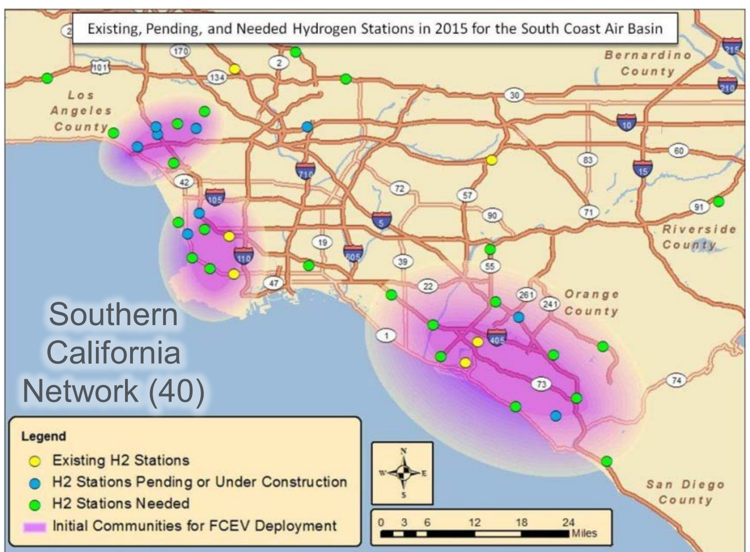






* STREET was initially established in part through funding from the DOE California Hydrogen Infrastructure Project with continued support from automakers and the California Energy Commission





STREET results (68 hydrogen stations) have been adopted by the California Fuel Cell Partnership (CaFCP):

- *A California Road Map: The Commercialization of Hydrogen Fuel Cell Vehicles*
- *A California Road Map: Bringing Hydrogen Fuel Cell Electric Vehicles to the Golden State*

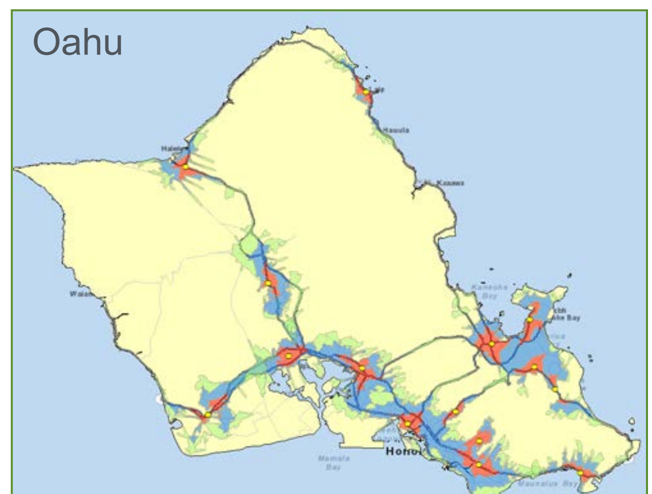
STREET has been used by the California Energy Commission:

- *GRANT SOLICITATION, PON-12-606 (November 2012)*

STREET results have been adopted by the Governor's ZEV initiative:

- *2013 ZEV Action Plan: A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025*

Similar analysis has been completed for the island of Oahu and is underway in 3 other states



UC Davis H_2 FCV Rollout and Transition Models

Goal: Assess alternative strategies for introducing fuel cell vehicles and H2 infrastructure over next decade and beyond.

Station Network Design Tools/Scenarios *(GIS/optimization station placement analysis, based on consumer convenience travel time to stations)*

- Consider station placement, number, size and type of stations
- So. Cal. Case study completed. Model could be extended to other US regions..

Infrastructure Rollout Economic Analysis *(EXCEL-based spreadsheet)*

- Estimate near term H2 station capital & operating costs (coord, w/H2A, CAFCP)
- Consider different infrastructure build-out scenarios over next decade based on "cluster" strategy (co-locate stations and early FCVs)
- Analyze economics from several perspectives: Station Network; Single station owner; Consumer (fuel cost)
- Find Cash flow and Break-even year (When can the station produce H2 competitively?)
- Estimate subsidies that might be needed to support early infrastructure
- Sensitivity studies to better understand uncertainties, risks

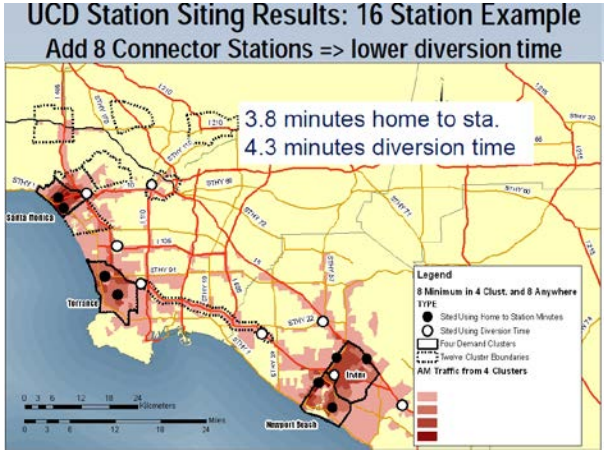
Longer Term H2 Infrastructure, Transition Costs and Benefits: *(EXCEL-based tools, used in NRC 2009 Study;, SSCHISM, H2TIMES)*

UCDavis H_2 Infrastructure Rollout Analysis Tools: Spatial/Economic Analysis to Assess Early Strategies

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Spatial Network Analysis =>H2 Sta. #, Location

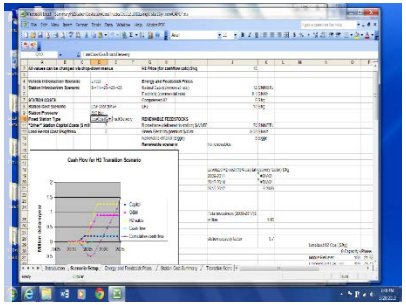
Input GIS data for consumer travel patterns, possible station sites, to find # stations & optimized early network layout to meet growing H2 fuel demands.



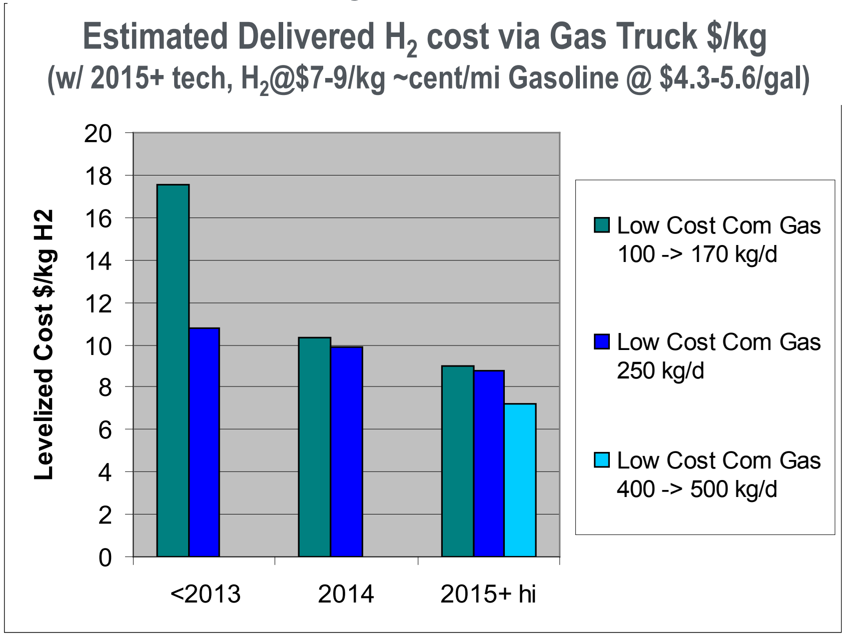
Key Result: Cluster strategy (co-locate early sta, FCVs) enables good fuel access w/ sparse initial network (1-2% of gasoline stations

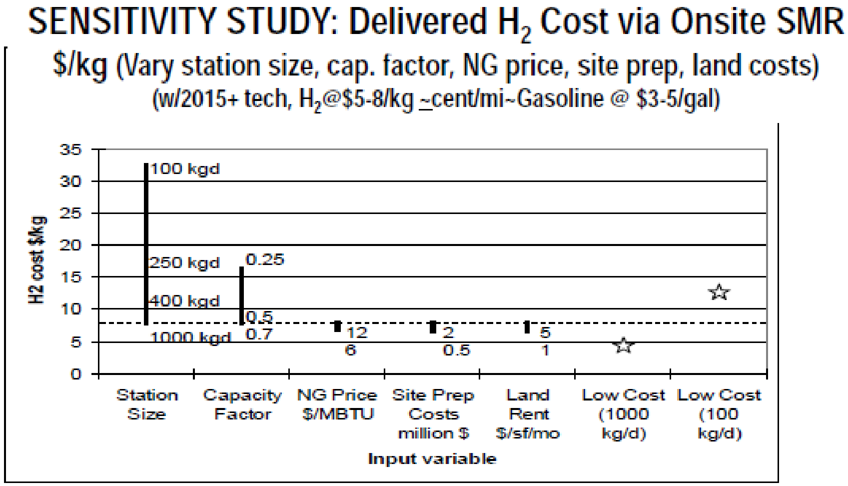
Economic Analysis of Early Rollout

Developed EXCEL based spreadsheet to model economics of different station types and explore costs of rollout strategies.



Economic Analysis : H2 Cost Results





Early Station Cluster Analysis for Early FCEV Rollout

Hydrogen fueling station capacity will increase to meet the increased demand as FCEV fleet expands.

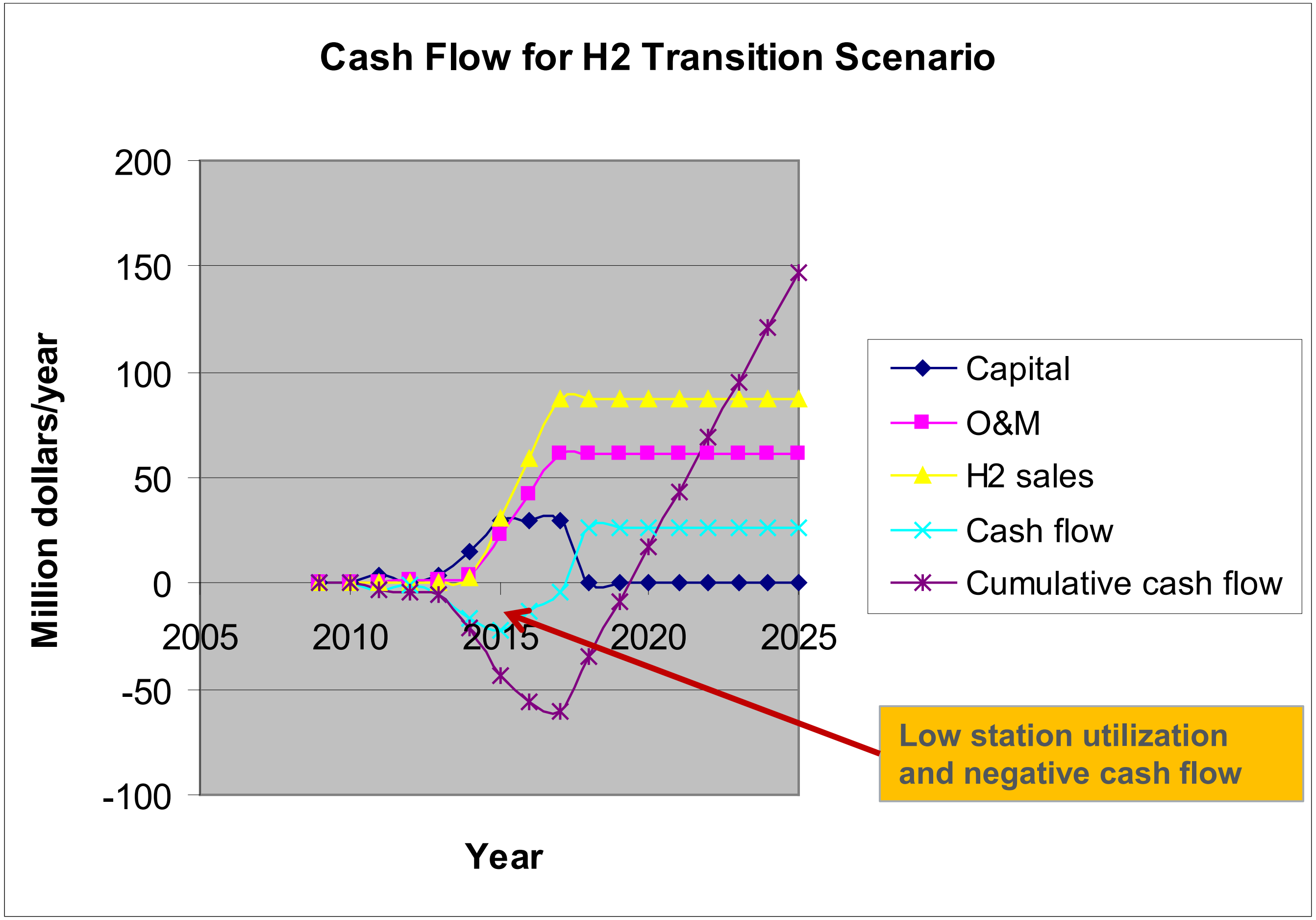
UC Davis examined delivered hydrogen scenario for vehicle rollout in Southern California with 78 stations by 2017

#New Sta	2011	2012	2013	2014	2015	2016	2017
Mobile Refueler	4	0	0	0	0	0	0
Compressed Gas Truck Delivery							
170 kg/d	0	0	4	0	0	0	0
250 kg/d	0	0	0	10	0	0	0
400 kg/d	0	0	0	0	20	20	20
Total sta. capacity (kg/y)	400	400	1080	3580	11580	21580	31580
# FCVs in fleet	197	240	347	1161	12106	23213	34320
H2 demand (kg/y)	137	168	250	800	8500	16000	24000

Source: UCDavis Institute of Transportation Studies

Cluster Cash Flow Analysis for 78 Stations

Hydrogen supply infrastructure will experience a period of negative cash flow during the initial periods of low vehicle penetration and low station utilization



- **78 stations require an approximate capital investment of $110-120 million.**
- **Stations supplied with compressed hydrogen by truck from a central production facility.**
- **California planned vehicle rollout:**

Year	Number of FCEVs in CA
2012	312
2013	430
2014	1389
2015	*5,000-15,000*
2016	*10,000-30,000*
2017	53,000
2018	>53,000

Assumptions:

- Delivered H2 @ $6/gge
- H2 selling price $10/gge
- H2 station cost $1.5 million
- Full station utilization in 4 yrs.

Source: UCDavis Institute of Transportation Studies

- Loan 5.5% for 10 years
- 700 bar dispensing
- O&M: $100,000

H2 Cost in US Cities : UC Davis SSCHISM (Steady-State City H2 Infrastructure System Model)

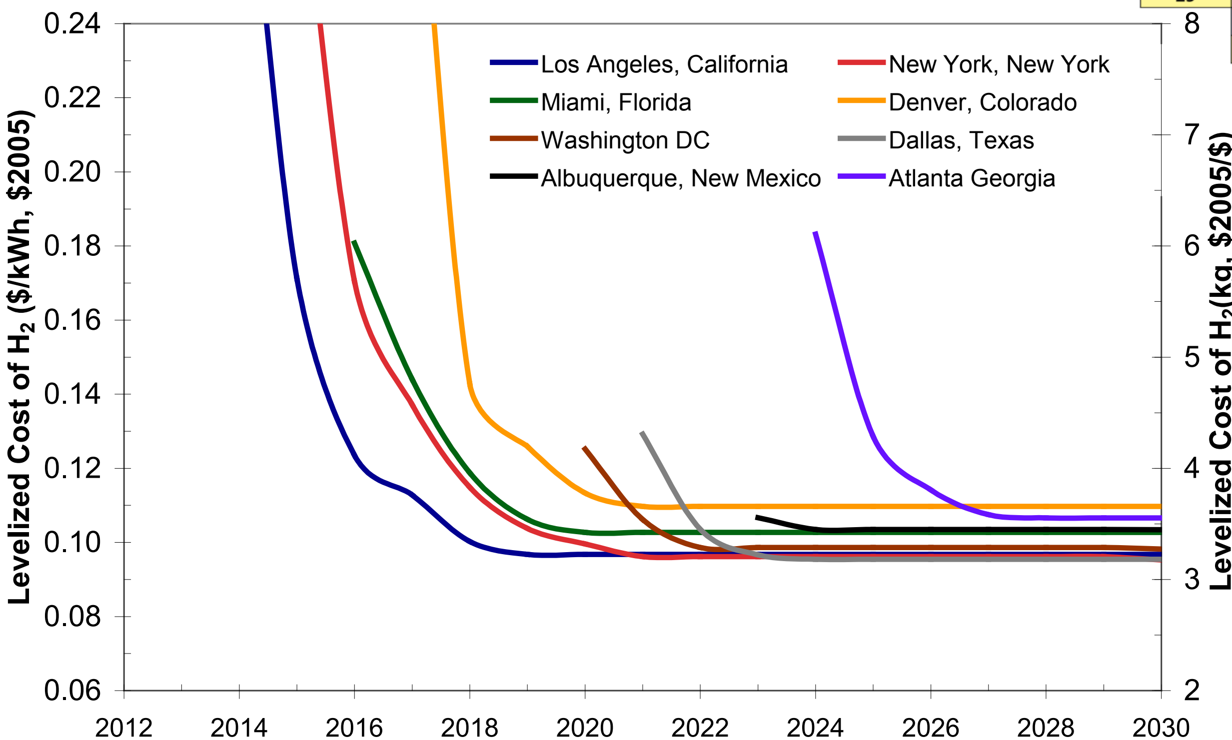
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Early hydrogen costs high, but falls with increasing scale to $3-4/gge.

Clear path forward in reducing cost and hitting targets.

City	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Los Angeles	1	2	2	25	40	50	85	120	160	190	210	250	270	300
New York, Chicago				25	40	50	85	120	150	175	185	225	240	270
San Francisco, Washington/Baltimore					20	30	55	85	120	140	160	190	210	230
Boston, Philadelphia, Dallas						20	50	85	120	145	165	195	210	220
Detroit, Houston							25	50	80	120	140	160	190	210
Atlanta, Minneapolis, Miami								40	75	100	115	130	160	180
Cleveland, Phoenix, Seattle									45	70	90	120	150	170
Denver, Pittsburgh, Portland, St. Louis, Cincinnati, Indianapolis, Kansas City										60	80	110	130	150
Milwaukee, Charlotte, Orlando, Columbus, Salt Lake City											55	80	110	130
Nashville, Buffalo, Raleigh												40	70	90
Nationwide													260	540

Hydrogen Cost in Selected Cities



Source: J. Ogden and C. Yang, "Build-up of a hydrogen infrastructure in the US," Chapter 15, in The Hydrogen Economy: Opportunities and Challenges, edited by Dr Michael Ball and Dr Martin Wietschel, Cambridge University Press, 2009, pp.454-482.

Scenario Evaluation and Regionalization Analysis Model (SERA)

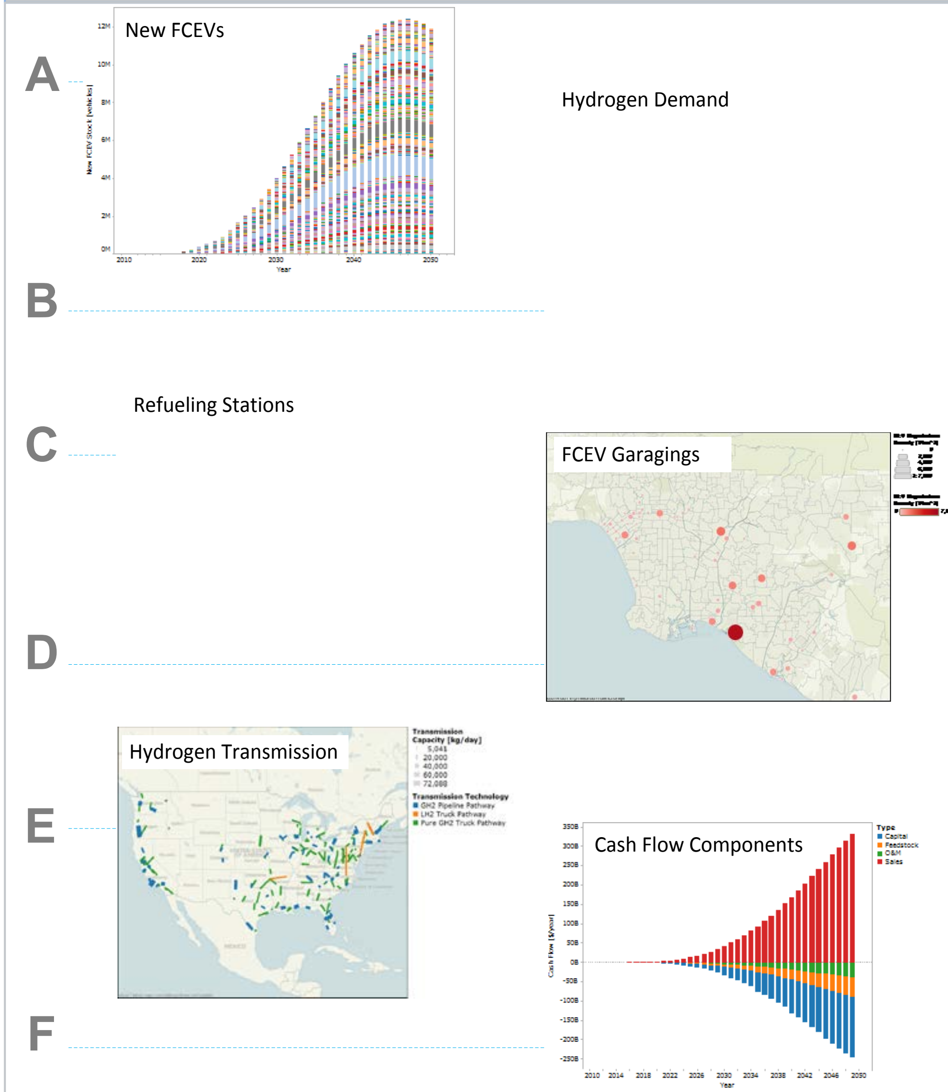
Goals

- Generate self-consistent vehicle adoption and hydrogen demand scenarios relevant to early market transition of FCEVs.
- Determine optimal regional infrastructure development patterns for hydrogen, 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 FCEV adoption areas.

Key analysis questions

- Which pathways will provide least-cost hydrogen for a specified demand?
- What network economies can be achieved by linking production facilities to multiple demand centers?
- How will particular technologies compete with one another?

Workflow for a typical SERA study



SERA is able to assess high-level market adoption scenarios with significant bottom-up detail.

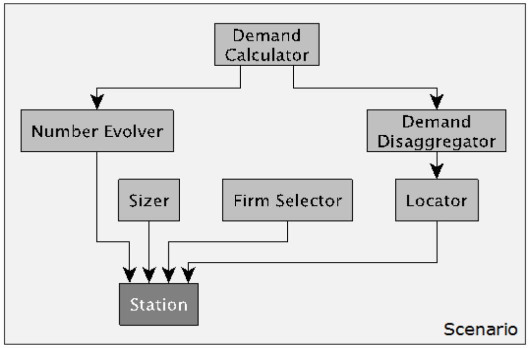
SERA can disaggregate national or regional demand scenarios geographically to the ZIP code level, accounting for likely early adopter clusters.

Optimal hydrogen infrastructure build-outs integrate cost estimates from the H2A suite of models.

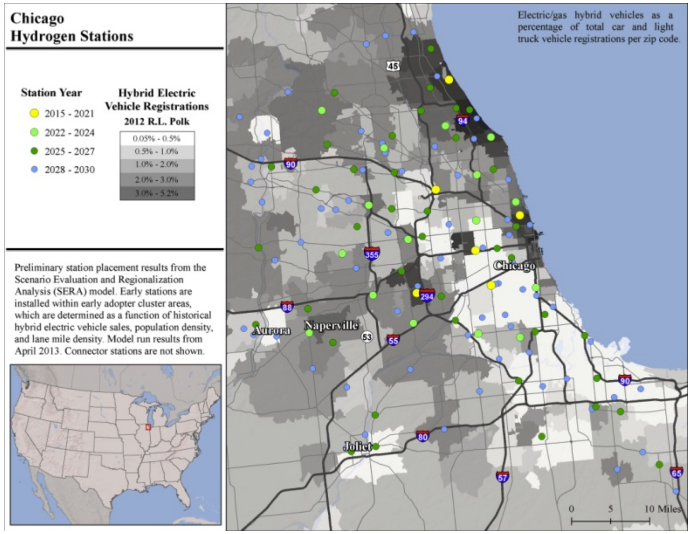
The vehicle stock model resolves demand at the urban area level over time as market share increases.

Cost optimal supply pathways link production types (shown at left without a carbon price) to demand centers.

The top-down station placement algorithm adheres to general trends identified in bottom-up travel time model results from UC Davis and UC Irvine.



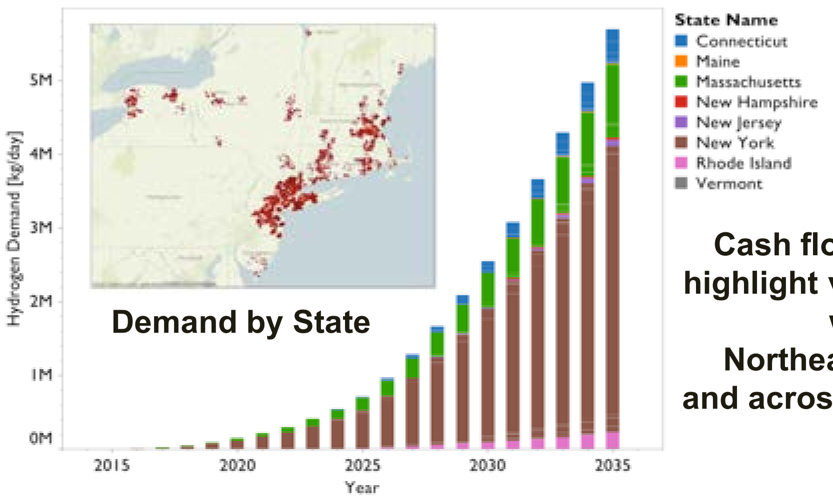
Station size distributions mimic gasoline station networks.



SERA Model results translate to business case metrics

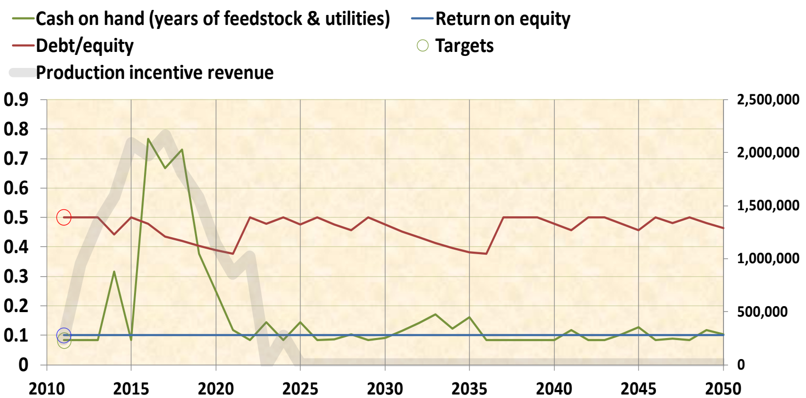
SERA has an open programing framework and can be set up to solve for a wide range of scenario conditions, incorporating data from multiple sources

The Northeast Corridor Case Study examined market growth consistent with ZEV compliance credits

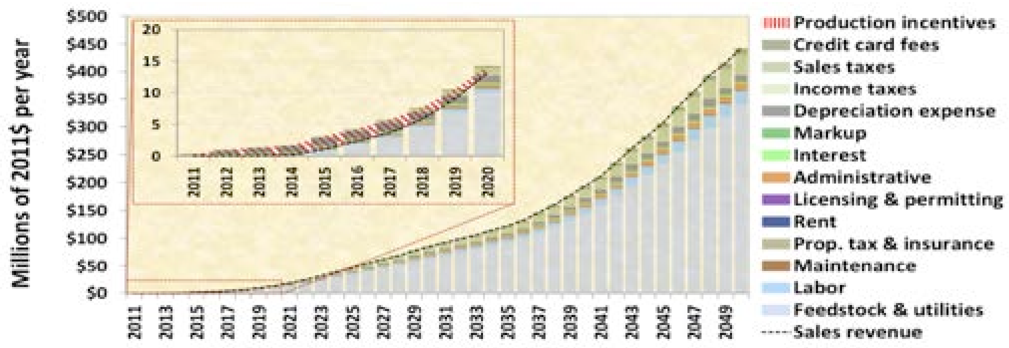


Cash flow results highlight variations within the Northeast region and across the U.S.

Detailed metrics balance equity vs. debt financing and help to assess the potential influence of targeted support mechanisms. Example runs for the Hawaii Hydrogen Initiative Case Study are below.



Estimating production incentives to cover the revenue shortfall



Model Enhancements

Examples of Key Priorities

- Better understanding of consumers
  - Validate and build consensus about how the models represent early adopter willingness to pay for alternative vehicles (EV and hybrid data)
    - How consumers value fuel availability
- Input Data
  - Build consensus on key assumptions and input data from stakeholders to perform analysis and produce necessary analytical products
  - To accurately analyze and model infrastructure development scenarios and strategies, analysts will need the following:
    - Near term cost data for vehicles and infrastructure
    - Vehicle rollout strategies

Next Steps - Continue coordination through H_2 USA

References

Hydrogen Analysis (H2A) Model: http://www.hydrogen.energy.gov/h2a_analysis.html

Hydrogen Delivery Scenario Analysis Model: http://www.hydrogen.energy.gov/h2a_delivery.html

Autonomie Model: www.autonomie.net

GREET Model: http://greet.es.anl.gov/main

Vision Model: http://www.transportation.anl.gov/modeling_simulation/VISION/index.html

JOBS Model: http://JOBSFC.es.anl.gov

FC Power Model: http://www.hydrogen.energy.gov/fc_power_analysis.html

MA3T Model: http://web.ornl.gov/filedownload?ftp=e;dir=uP212MFV0FrH

Analysis Webinar Presenters

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Sunita Satyapal, DOE
- Fred Joseck, DOE
- Marc Melaina, National Renewable Energy Laboratory
- David Greene, Oak Ridge National Laboratory
- Todd West, Sandia National Laboratory
- Amgad Elgowainy, Argonne National Laboratory
- Tyson Eckerle, EIN
- Tim Brown, University of California Irvine
- Joan Ogden, University of California Davis

Thank You

http://www1.eere.energy.gov/hydrogenandfuelcells/