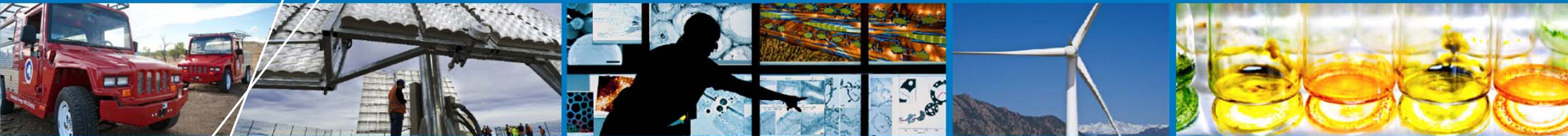


Infrastructure Analysis Tools: A Focus on Cash Flow Analysis



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Introduction: Cash flow and related models

Inputs needed to analyze a business case for hydrogen infrastructure:

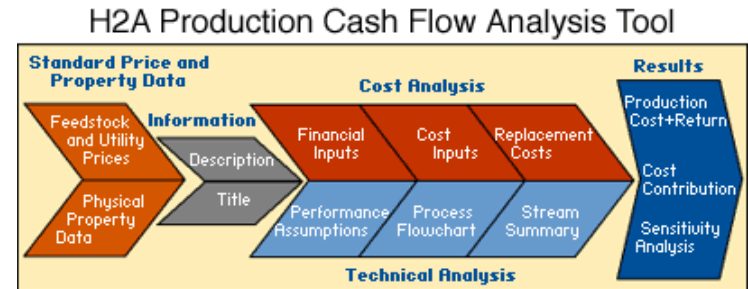
1. Infrastructure costs
 2. Realistic market growth scenarios
 3. Return on investment expectations
 4. Policy support options
- NREL has been developing multiple analysis tools to address each of these topics for the U.S. Department of Energy for more than 10 years
 - Business case analysis is the most recent addition to this tool set, which started with stationary fuel cells
 - Major analysis topics are vehicle-infrastructure interactions and the integration of renewable hydrogen



Main models supporting cash flow analysis

Hydrogen Analysis (H2A) models

- Production, Delivery, and Fuel Cells
- Discounted cash flow framework
- Models are transparent and public
http://www.hydrogen.energy.gov/h2a_analysis.html



Scenario Evaluation and Regionalization Analysis (SERA) Model

- Optimizes spatial-temporal infrastructure in response to hydrogen demand
- Runs have optimized on least cost \$/kg
- H2A cost models “plug in” to SERA
- Optimization across all pathway options
- Developed over ~7 years
- Sub-models explore finance options



Fuel cell vehicle market projections (ADOPT, MA3T, other models)

- Based upon consumer preferences and vehicle attributes
- Market share models haven't been integral to SERA runs

1. Determining infrastructure costs

Combining unit costs with detailed geographic constraints improves the realism of infrastructure cost estimates

- Methodologically, this is done by ingesting H2A unit costs into the spatial-temporal optimization routine within SERA

KEY MODELING FACTORS TO CONSIDER

Full supply chain costs

- Multiple production, storage and delivery options (H2A)
- Resource availability and cost (wind, biomass, etc.) (based upon multiple data sources)
- Natural gas pathways tend to dominate (H2A-SERA)

Station costs

- Station types are coupled to delivery options (H2A)
- Coverage is based upon station numbers and size distribution (SERA)
- Coverage evolves on a city-by-city basis, requiring a detailed geographic cost model (SERA)

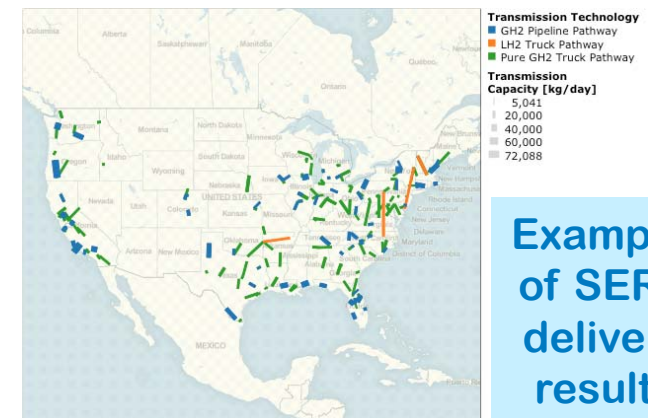
Discounted cash flow framework (H2A-SERA)

- H2A framework assumes 10% IRR to calculate a “profited cost” (H2A)
- SERA financial analysis is more flexible and business-oriented (SERA)

Pathway combinations in SERA

		Pathway								
		1	2	3	4	5	6	7	8	9
Scenario	Transmission	L	P	P	G	G	P	P	P	P
	Delivery	L	L	L	G	G	G	G	P	P
	Storage	L	G	L	G	L	G	L	G	L
Component	Compressed H2				T+D	T+D	D	D		
	Truck-Tube								D	D
	Distribution Pipeline								D	D
	Gasose Refueling Station				D+S	D+S	D+S	D+S	D+S	D+S
	Geologic Storage		S		S		S		S	
	Gasose H2 Terminal				T+S	T+S	S	S		
	Liquid Refueling Station	D+S	D+S	D+S						
	Liquefier	S	S	S		S		S		S
	Liquid Terminal	T+S	S	S		S		S		S
	Liquid Tractor-Trailer	T+D	D	D						
Pipeline Compressor		T	T				T	T	T	
Transmission Pipeline		T	T				T	T	T	

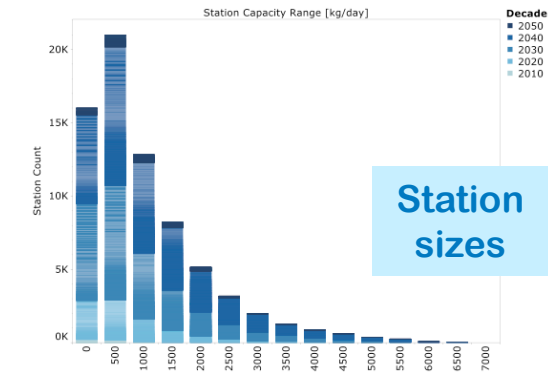
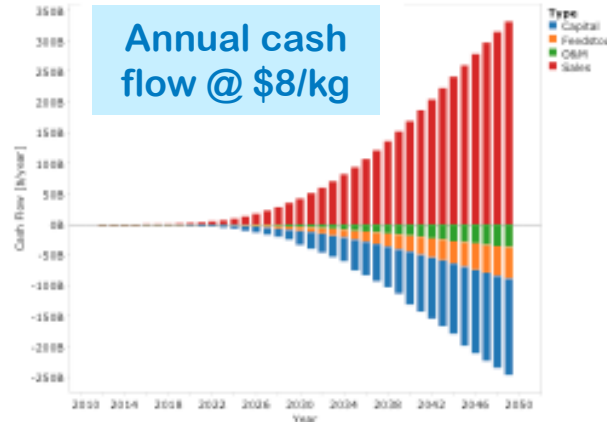
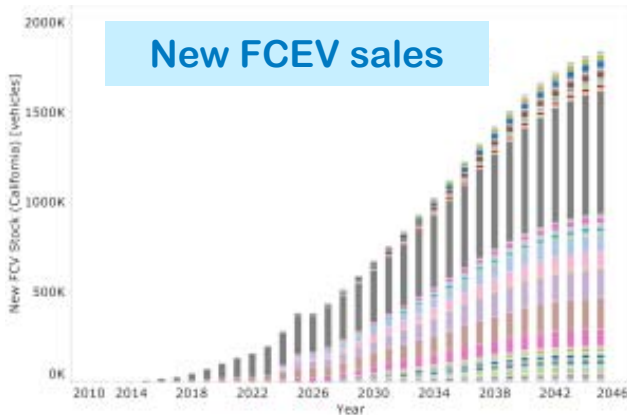
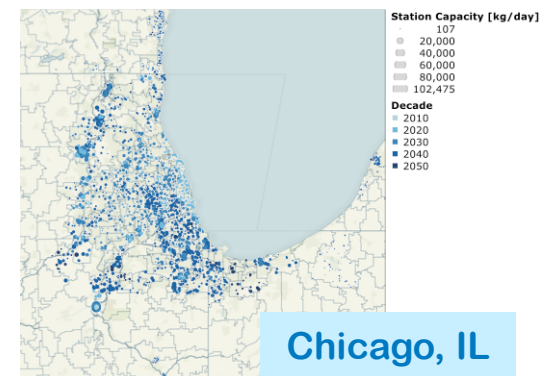
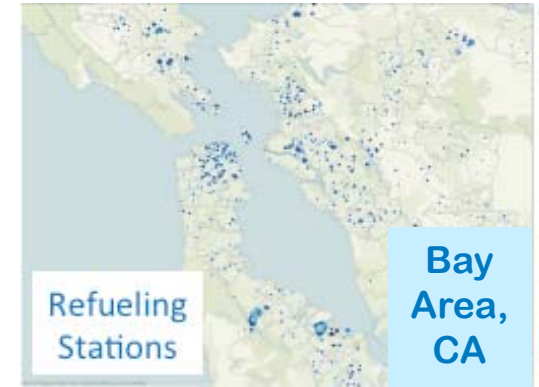
G = gas trucks; L = liquid trucks; P = pipelines; D = distribution; S = storage; T = transmission.



Example of SERA delivery results

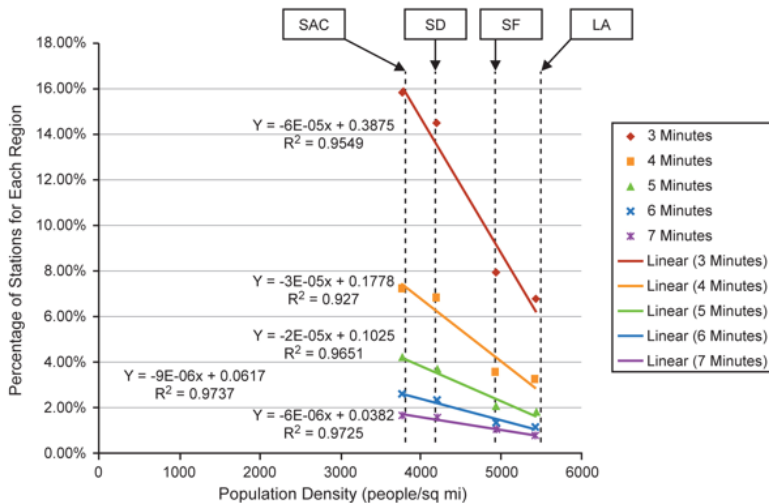
2. Realistic market growth scenarios

- Steady-state infrastructure costs are relatively simple to analyze; rollout dynamics are much more complex
- For early market growth dynamics and interactions, NREL analysts have incorporated guidance from:
 - Stakeholder workshops (Greene et al. 2008)
 - Early market coordination activities such as the Hawaii Hydrogen Initiative (H2I), EIN, and CaFCP
 - Initial discussions with CCAT
- Station rollout is explicit at any level of detail
- SERA offers a consistent framework to incorporate regional infrastructure rollout scenarios

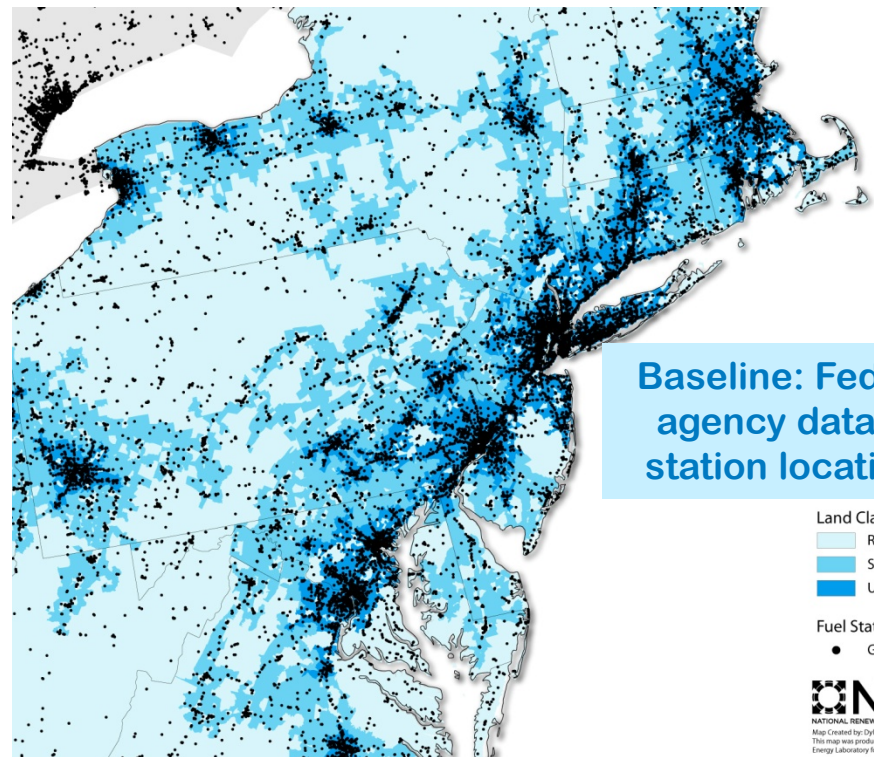


2. Realistic market growth scenarios (cont.)

- Station coverage results are extrapolated from detailed results of individual urban areas
- Traffic models from UC Davis and UC Irvine (STREET) characterize coverage requirements, which are generalized as an input to SERA
- Coverage will eventually be included (endogenized) as a vehicle attribute in consumer choice sub-models within SERA

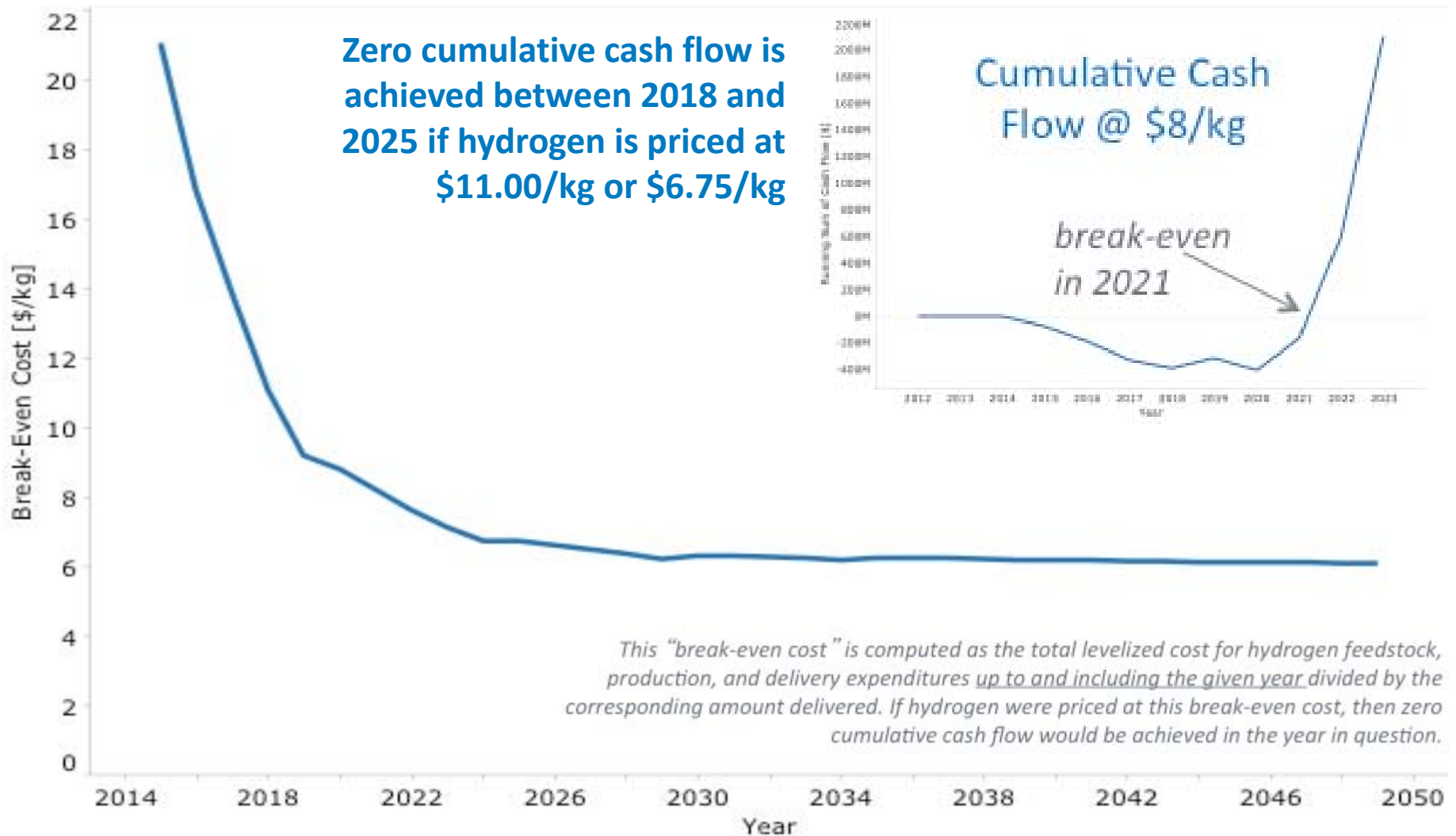


Correlation of traffic model results to urban area metrics (such as population density) allows for extrapolations to all U.S. urban areas



Basic national cash flow results from SERA

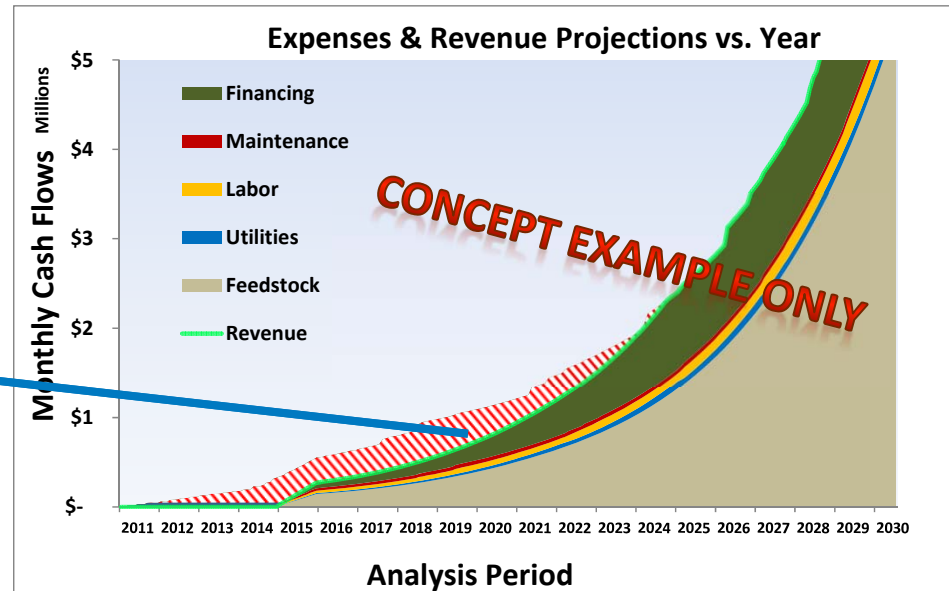
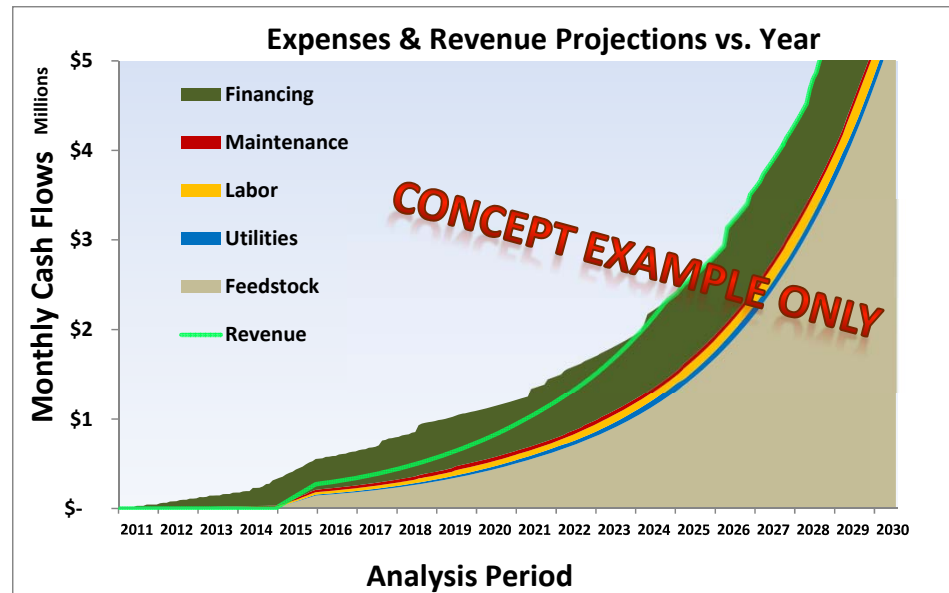
- Break-even year is a function of assumed market price (\$/kg)
- Cash flows determined nationally, by state, by city, or per station



More elaborate and detailed cash flows

- Developed in response to partner/stakeholder requirements in H2I and discussions with EIN/CaFCP
- Hydrogen price assumed to be equal to gasoline price on a per-mile-driven basis (need mpg assumptions to determine)
- Short-fall results from high fixed costs and underutilization of infrastructure in early years

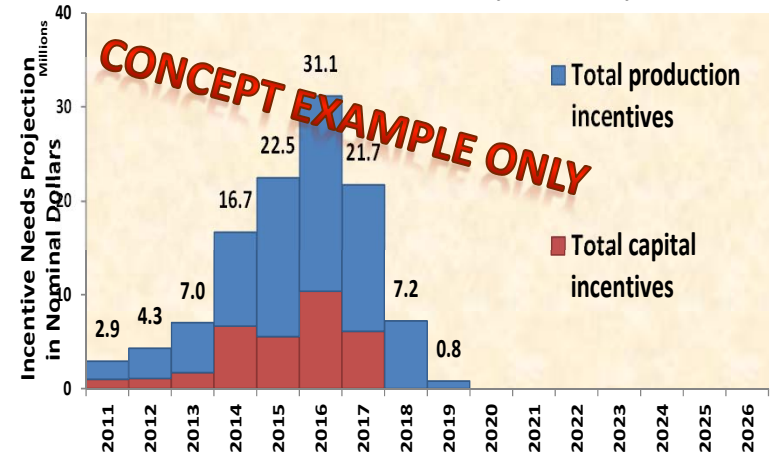
Revenue short-fall
(barrier to market entry)



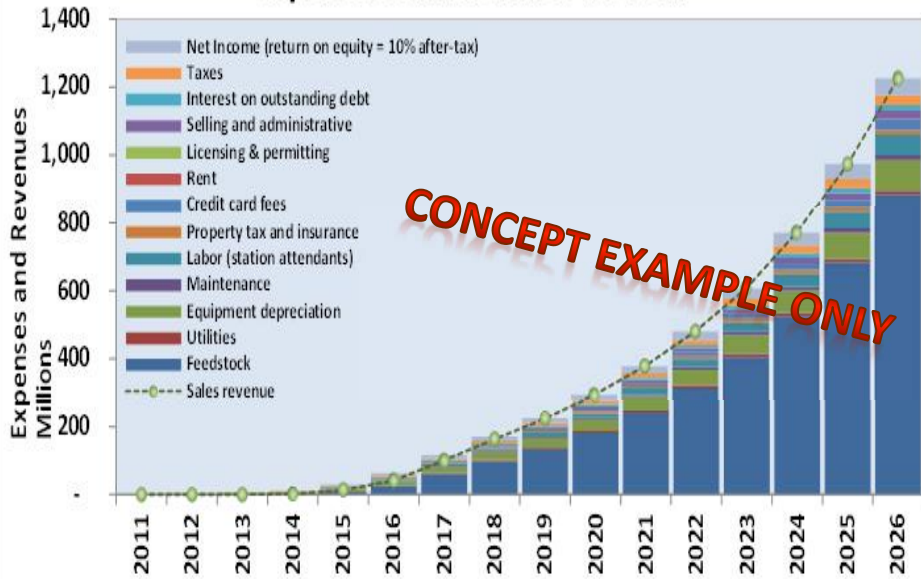
Cash flow can be resolved with high level of detail and for various financing/incentive options

- Finances can be analyzed for multiple funding sources and debt-equity ratios
- Per-station cash flow is possible
- Capability to compare various incentives (e.g., production or capital incentives)
- Sensitivities on key input parameters

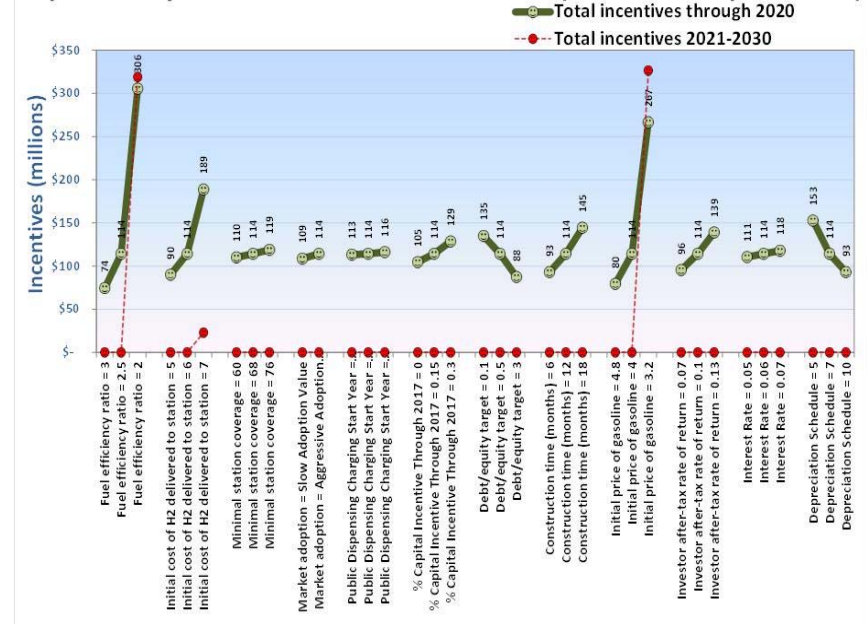
FCEV & Infrastructure Roll-Out Analysis Summary



Expenses & Revenues vs. Year



Impact of Key Variables on Revenue Short-Fall (Incentives Requirements)



Summary

NREL models

- NREL has developed and maintains a variety of infrastructure analysis models for the U.S. Department of Energy
- Business case analysis has recently been added to this tool set

Cash flow analysis

- Cash flows depend upon infrastructure costs, optimized spatially and temporally, and assumptions about financing and revenue
- Detailed metrics have been incorporated on financing/incentives

Next steps in modeling

- Continue to collect feedback on regional/local infrastructure development activities and “roadmap” dynamics
- Incorporate consumer preference assumptions on infrastructure to provide direct feedback between vehicles and station rollout

Questions?

Contact: marc.melaina@nrel.gov

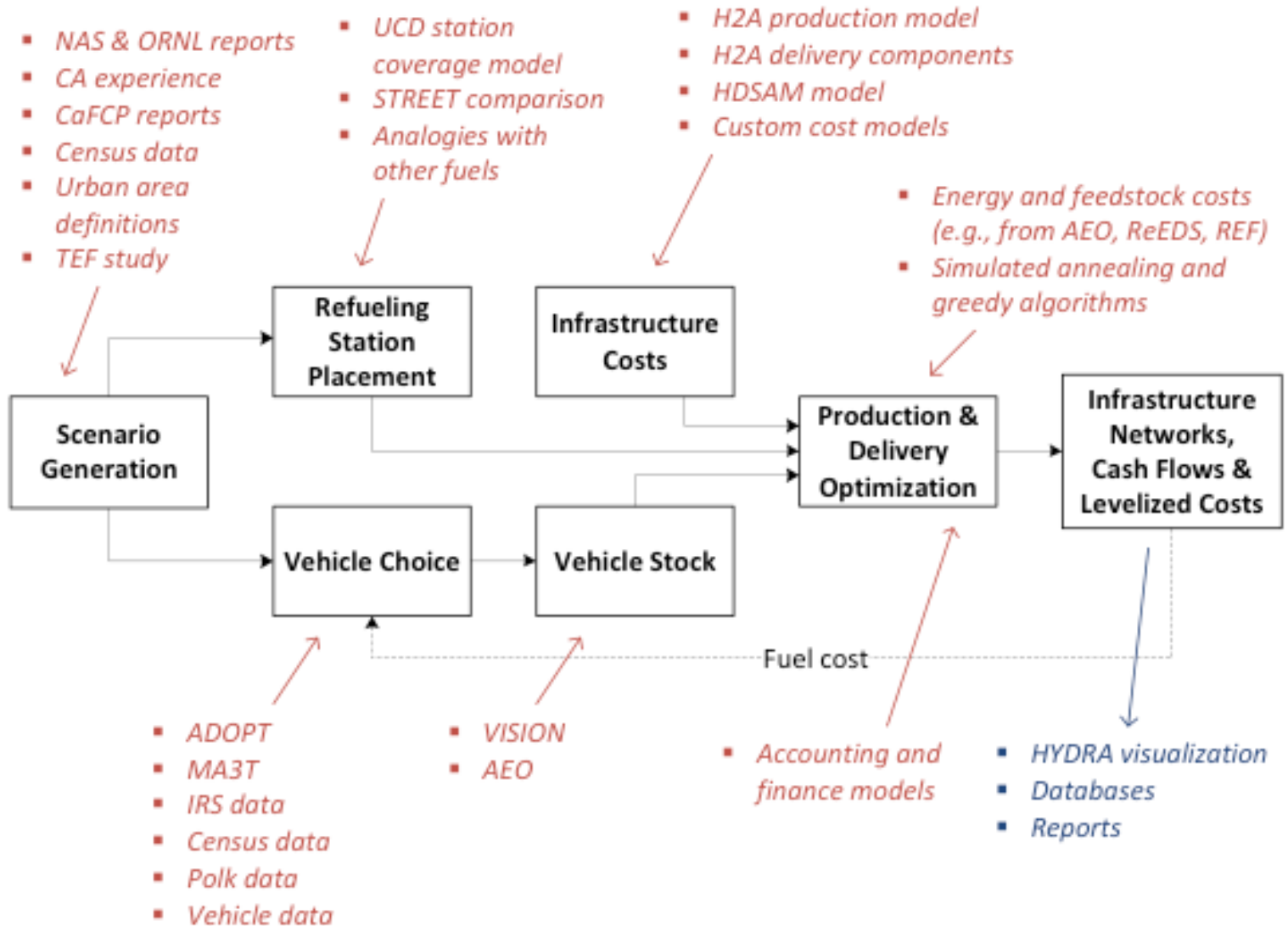
Additional Slides

SERA overview

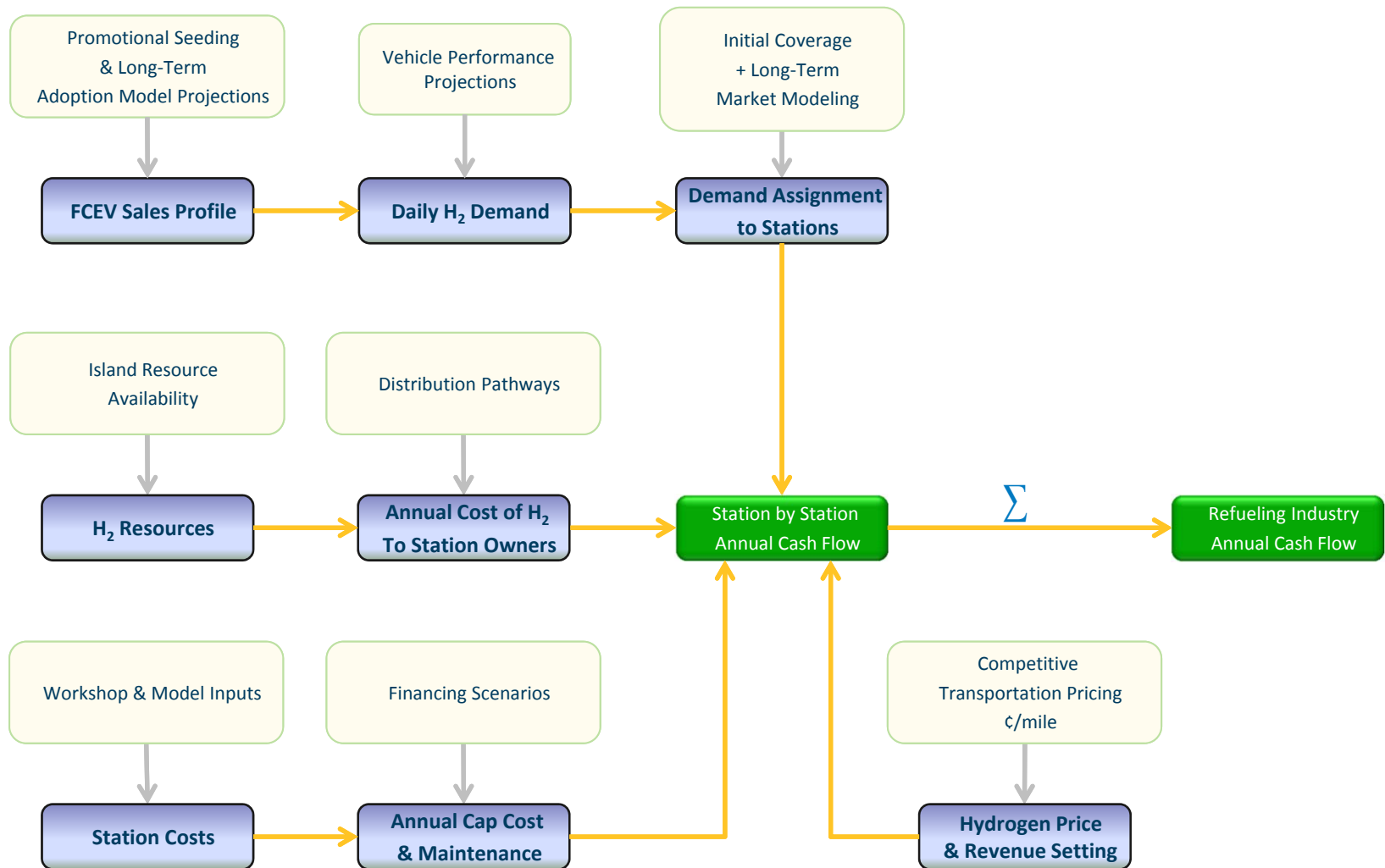
The SERA Model integrates assumptions and data from multiple sources and related modeling efforts

General Features

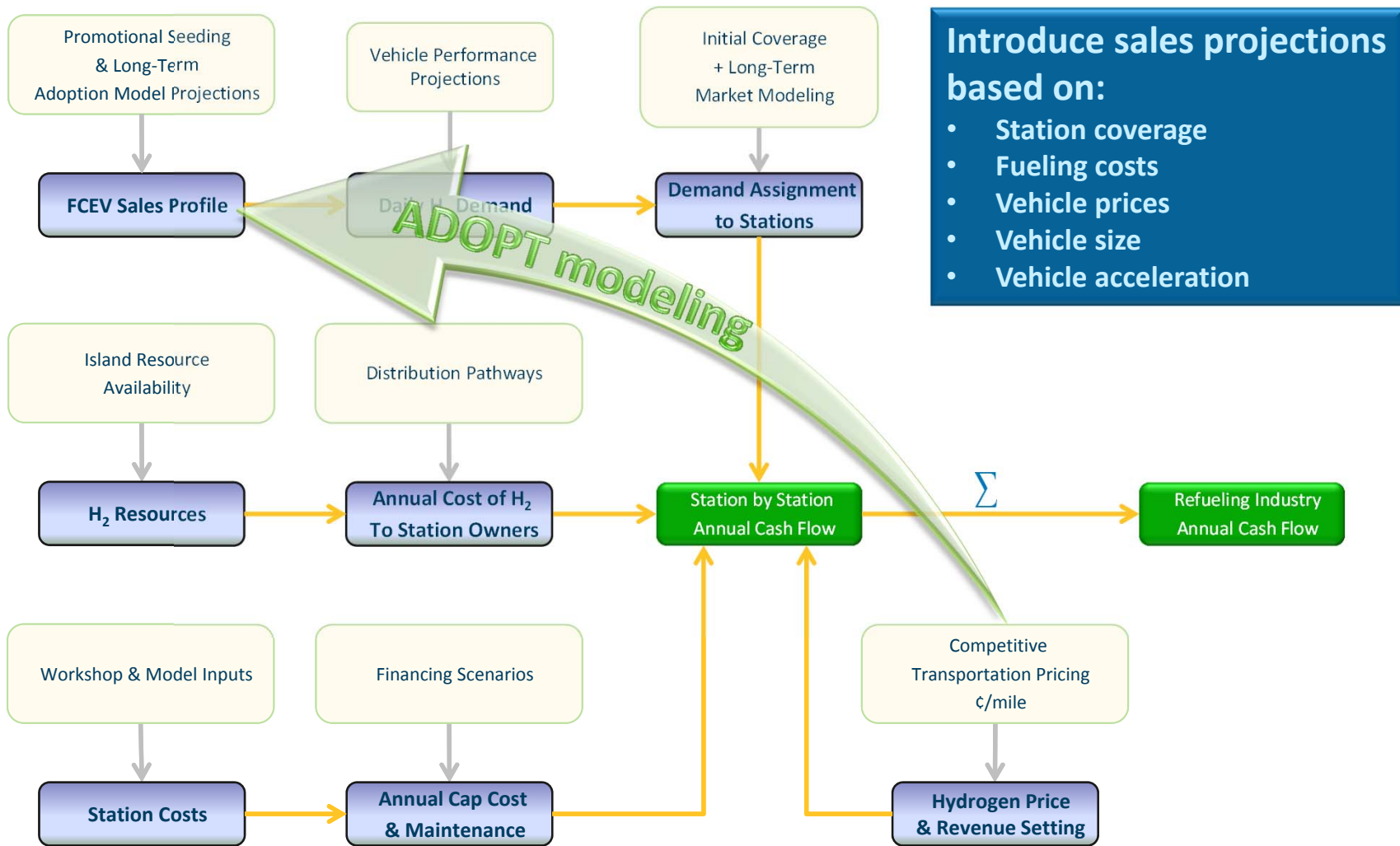
- High level of customizability
- User-defined geographic detail
- User-defined vehicle types, classes, and characteristics
- Disaggregated computations
- Agnostic about sources of cost data
- Choice of algorithms
- Interoperable with other models
- Easy to add new submodels for special-purpose studies



Current modeling approach



On-going effort

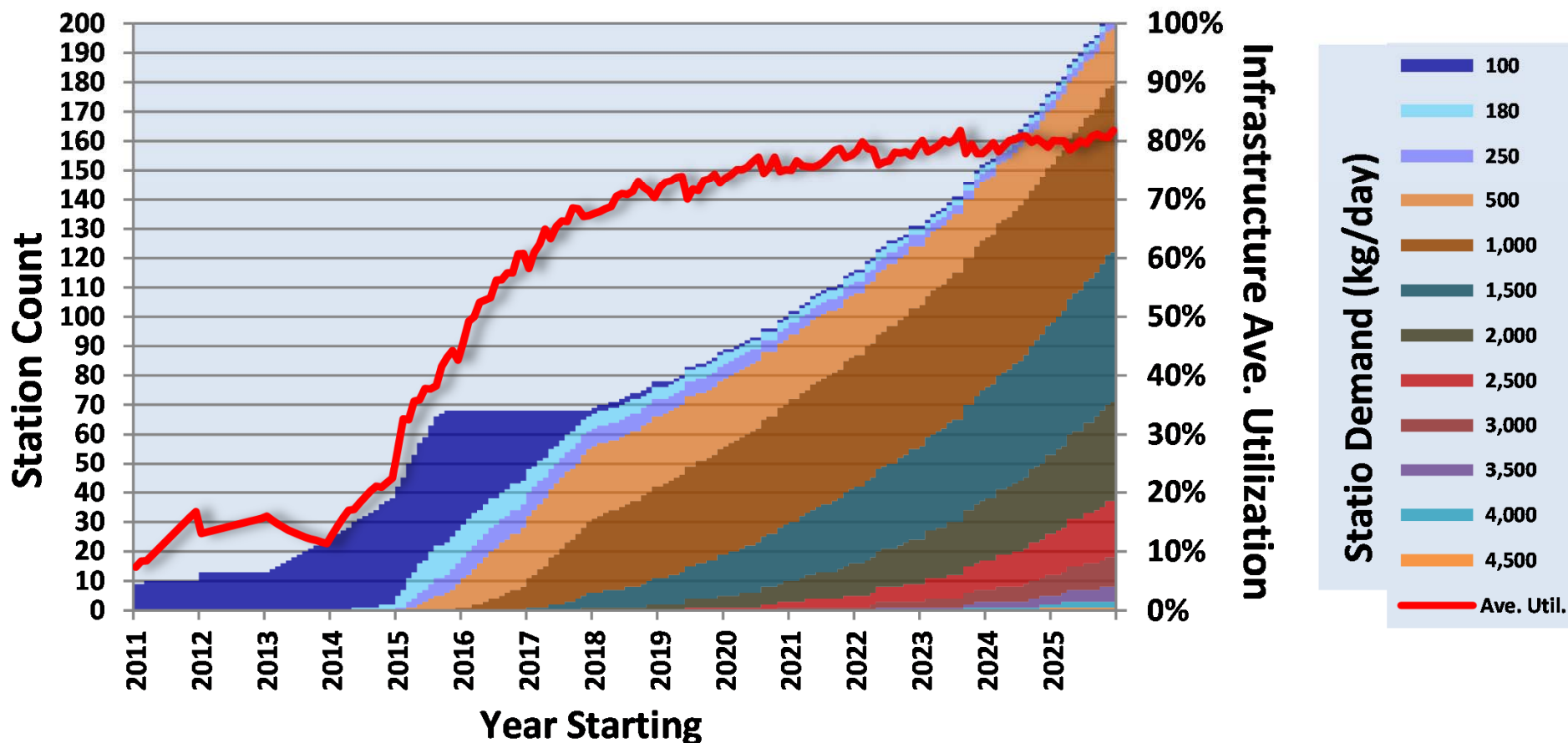


Introduce sales projections based on:

- Station coverage
- Fueling costs
- Vehicle prices
- Vehicle size
- Vehicle acceleration

Station roll-out in support of FCEV

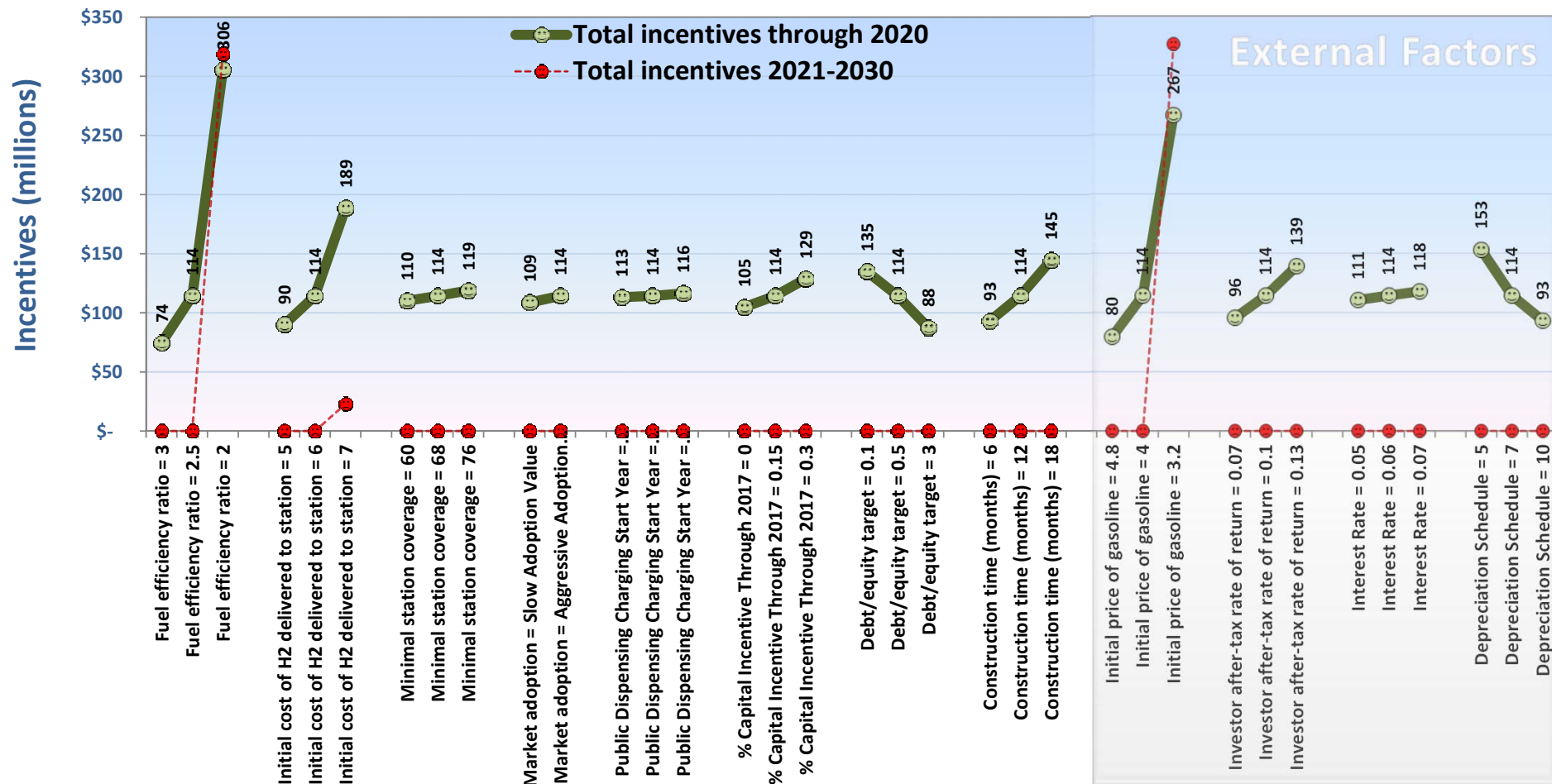
Station Count by Size vs Year



Station size and distribution modeled statistically to comply to gasoline demand distribution
Large stations as much 4,500 kg/day will be needed by 2025 as demand density grows

Sensitivity analysis

Impact of Key Variables on Revenue Short-Fall (Incentives Requirements)

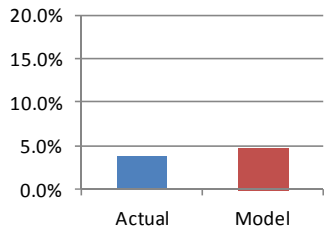


Most important controllable variable: vehicle fuel economy

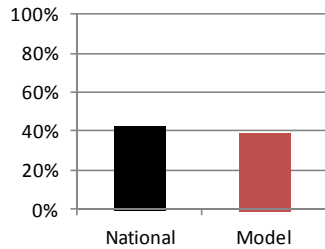
- High fuel economy = lower infrastructure investment
- High fuel economy = higher revenue per kg H₂
- High fuel economy = effective production resource utilization

ADOPT matches historical sales

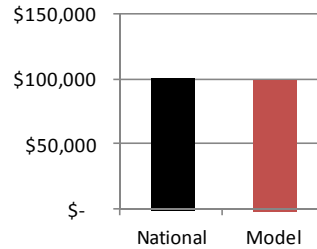
Percent HEV Sales



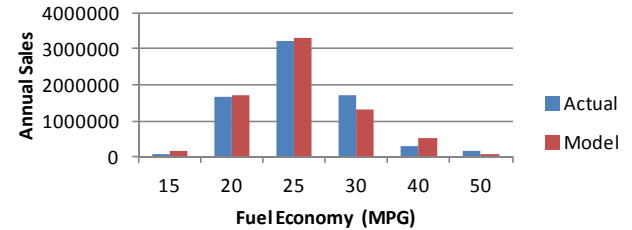
HEV Buyers with Income Over \$100k



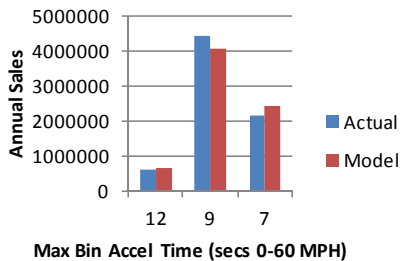
Average Income of HEV Buyers



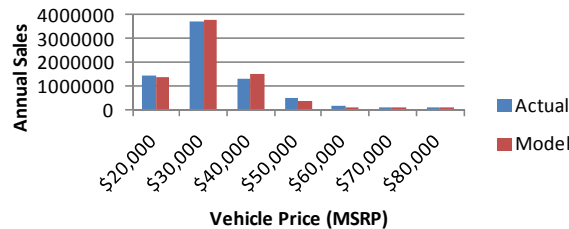
Sales By MPG (listed by max in bin)



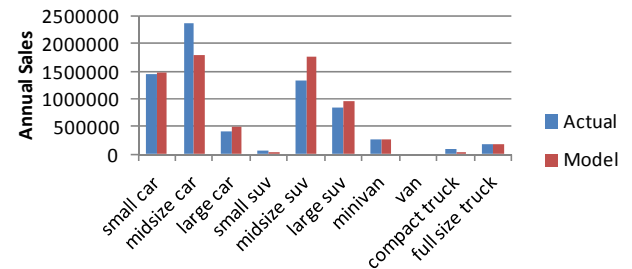
Sales By Acceleration



Sales By MSRP (listed by max in bin)



Sales By Class

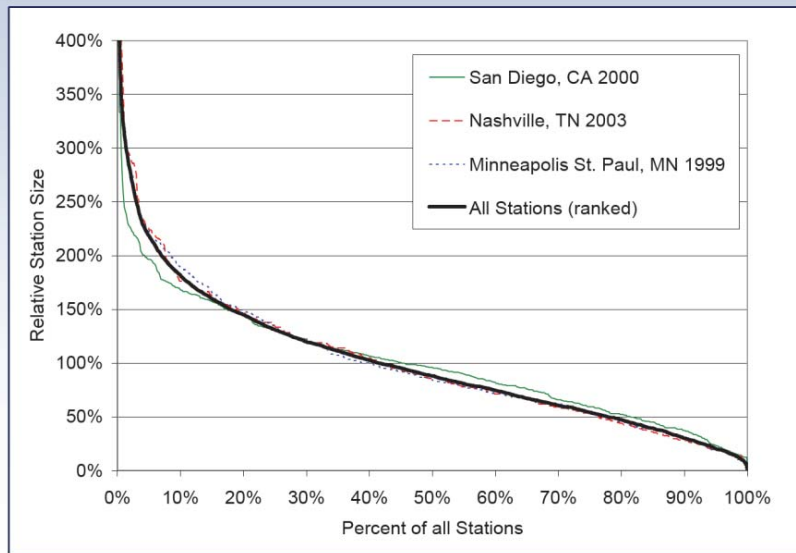


- ADOPT has been calibrated for U.S. markets
- Model predicts historical sales with a relatively high degree of accuracy
- Range of FCEV sizes and performances will be modeled to provide wide variety of market choices

Gasoline demand distribution applied to hydrogen

Relative Station Size Distributions

- Normalize by average station size (y axis) and total number of stations (x axis)



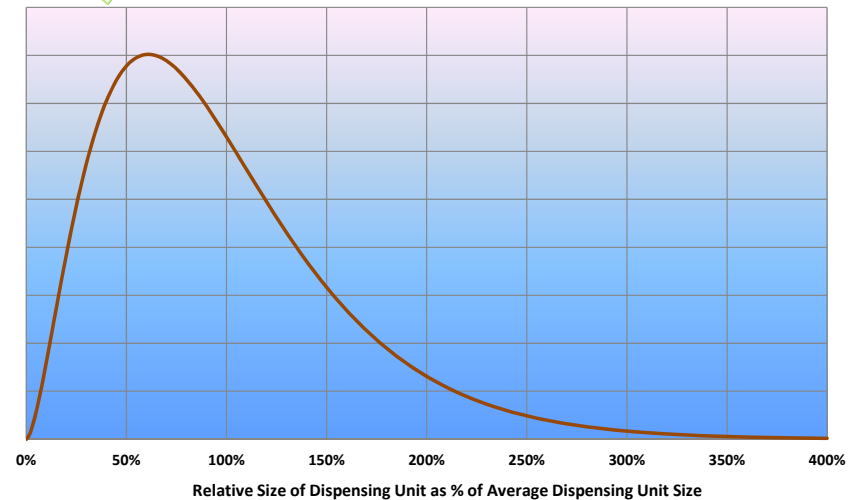
9-25-2006

Melaina and Bremson, USAEE/IAEE 2006

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Distribution of Dispensing System Sizes
(relative to % of average dispensing size)



Hydrogen demand is distributed to stations statistically, to conform to gasoline demand distribution

*Regularities in Early Hydrogen Station Size Distributions, Marc W. Melaina and Joel Bremson
Hydrogen Pathways Program Institute of Transportation Studies, UC Davis
26th USAEE / IAEE North American Conference, September 24-27, 2006 • Ann Arbor, Michigan*