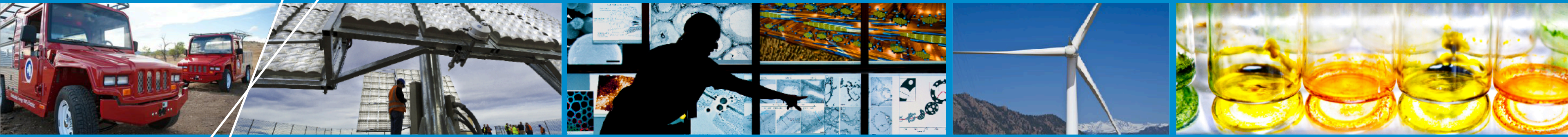
# Infrastructure Analysis Tools: A Focus on Cash Flow Analysis

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**Presented at the Hydrogen Infrastructure Meeting**

**International Council for Clean Transportation (ICCT)**
**Breakthrough Technologies Institute (BTI)**

**Toronto, 5 June 2012**

# 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**

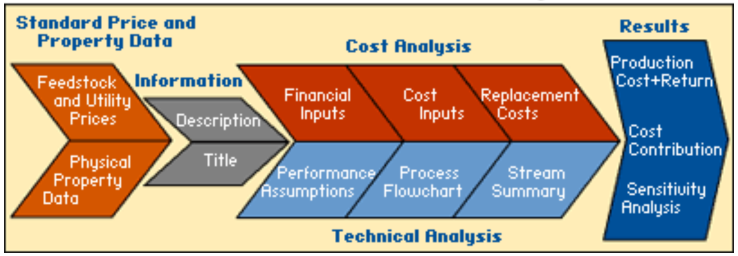
- NREL has been developing multiple analysis tools to address each of these topics for the U.S. Department of Energy for more than 10 years
- Business case analysis is the most recent addition to this tool set, which started with stationary fuel cells
- Major analysis topics are vehicle-infrastructure interactions and the integration of renewable hydrogen

# Main models supporting cash flow analysis

## Hydrogen Analysis (H2A) models

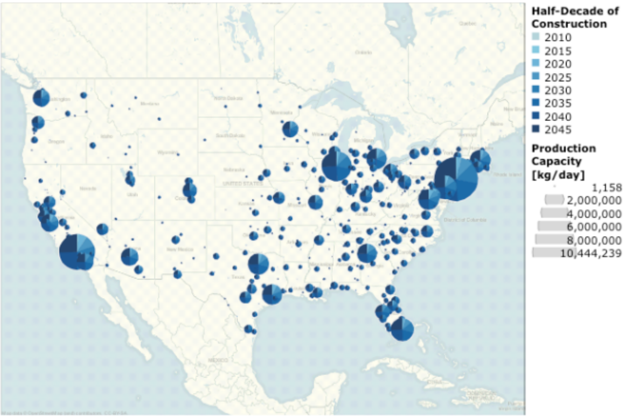
- Production, Delivery, and Fuel Cells
- Discounted cash flow framework
- Models are transparent and public
  http://www.hydrogen.energy.gov/h2a_analysis.html

H2A Production Cash Flow Analysis Tool




## 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)

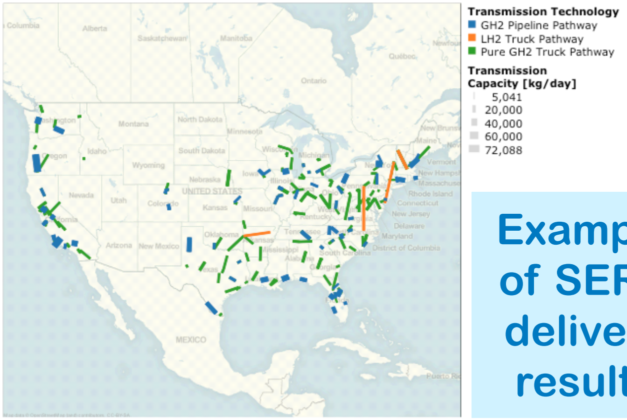
**Discounted cash flow framework (H2A-SERA)**

- 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 Truck-Tube | | | | T+D | T+D | D | D | | |
| | Distribution Pipeline | | | | | | | | D | D |
| | Gaseous Refueling Station | | | | D+S | D+S | D+S | D+S | D+S | D+S |
| | Geologic Storage | | S | | S | | S | | S | |
| | Gaseous 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 | T |
| | Transmission Pipeline | | T | T | | | T | T | T | T |

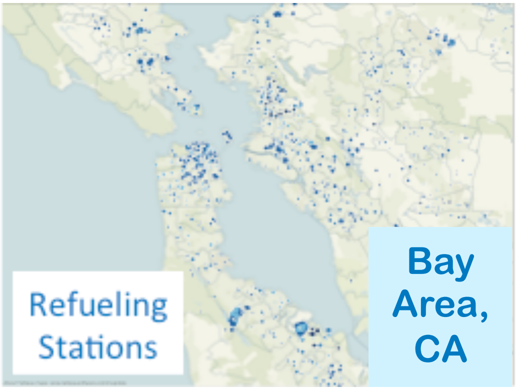
*G* = gas trucks; *L* = liquid trucks; *P* = pipelines; D = distribution; S = storage; T = transmission.

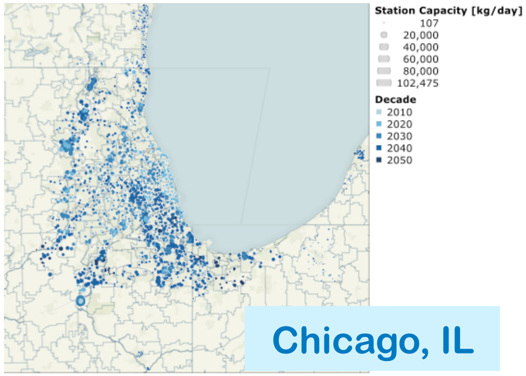


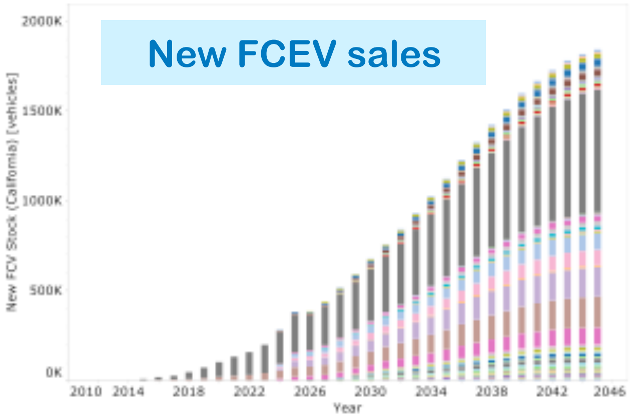

**Example of SERA delivery results**

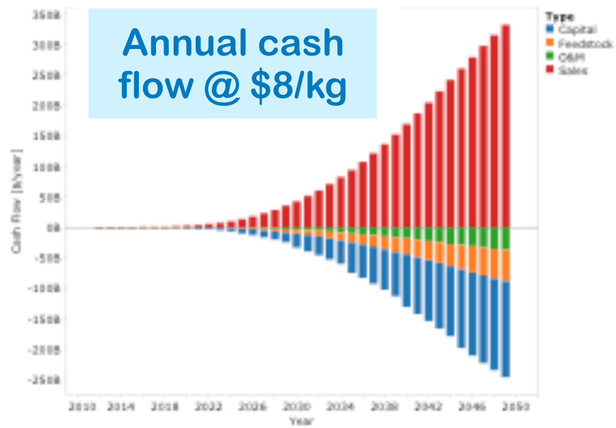
# 2. Realistic market growth scenarios

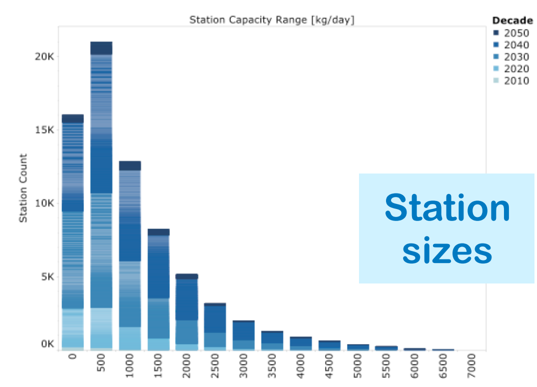
- Steady-state infrastructure costs are relatively simple to analyze; rollout dynamics are much more complex
- For early market growth dynamics and interactions, NREL analysts have incorporated guidance from:
  - Stakeholder workshops (Greene et al. 2008)
  - Early market coordination activities such 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



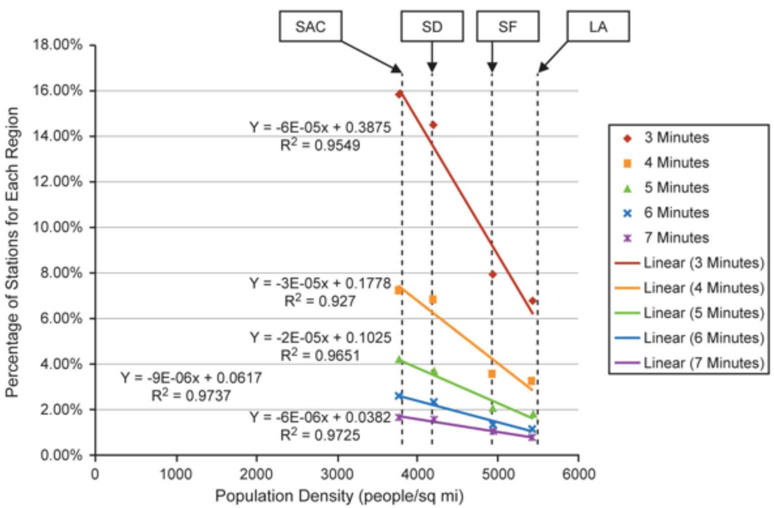



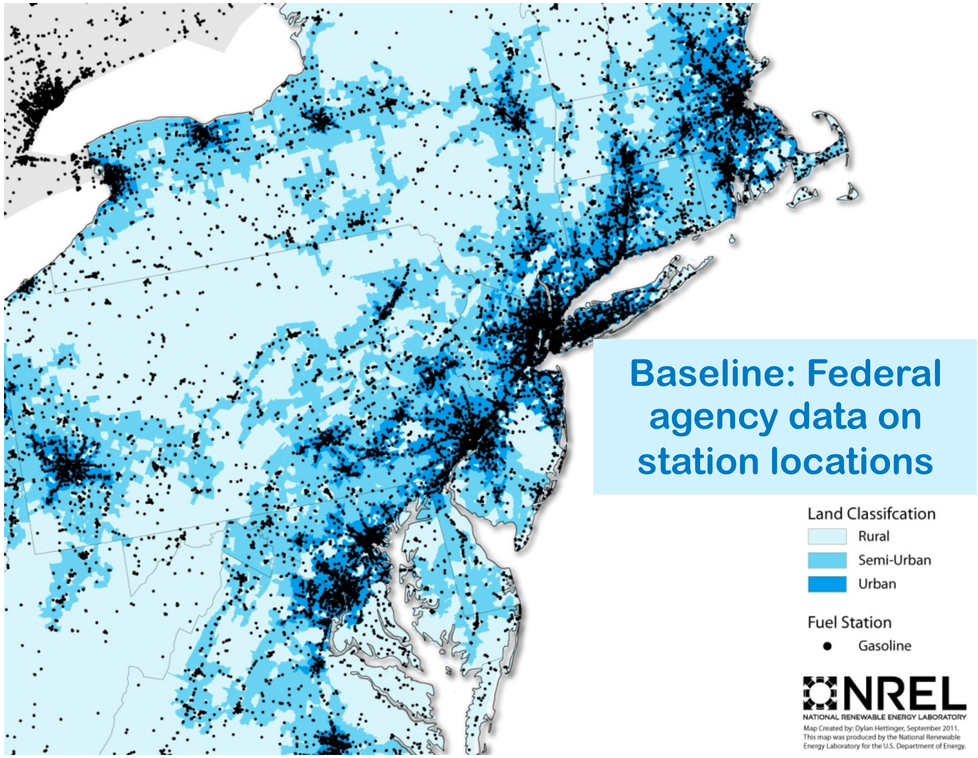



# 2. Realistic market growth scenarios (cont.)

- 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



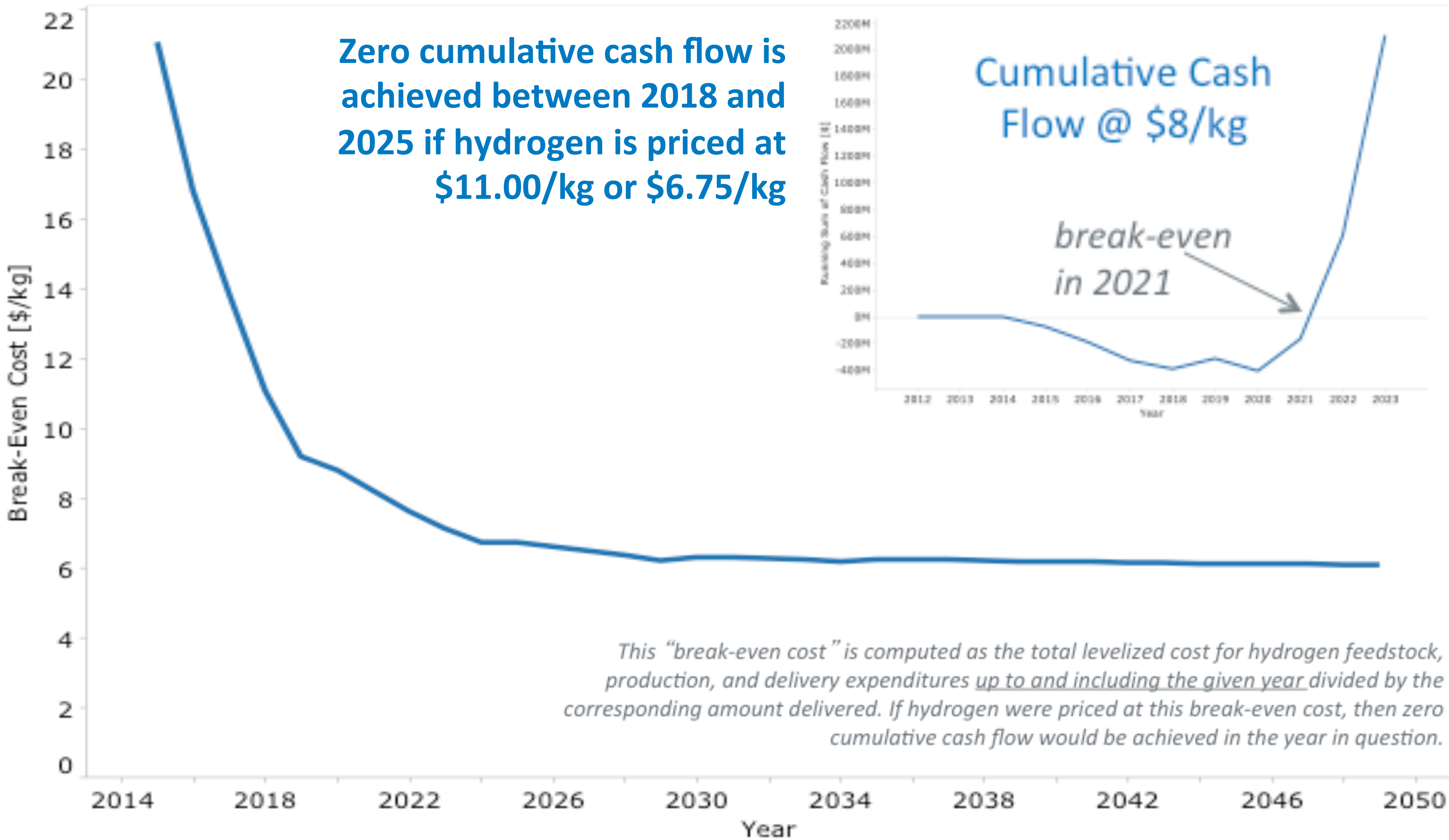

Correlation of traffic model results to urban area metrics (such as population density) allows for extrapolations to all U.S. urban areas




Baseline: Federal agency data on station locations

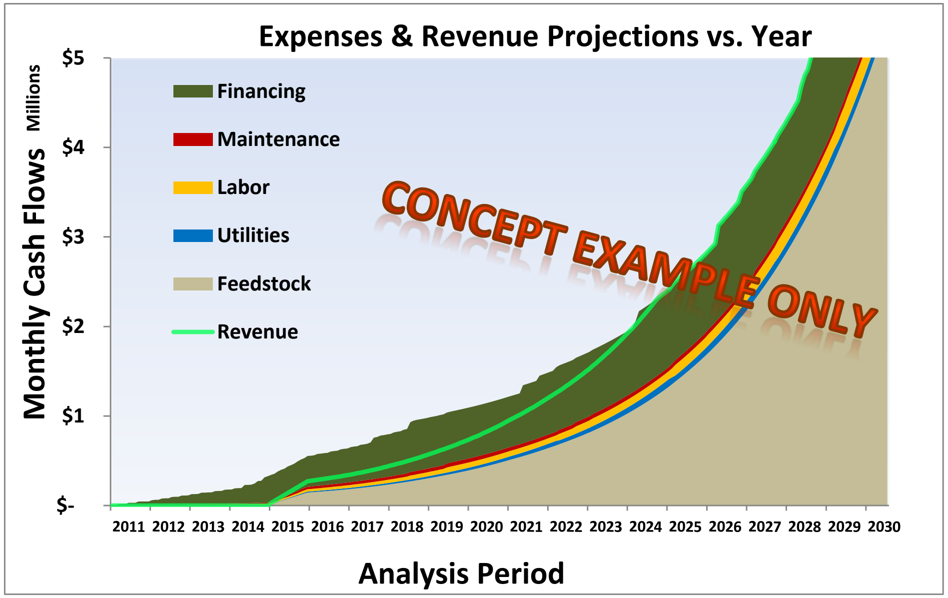
# Basic national cash flow results from SERA

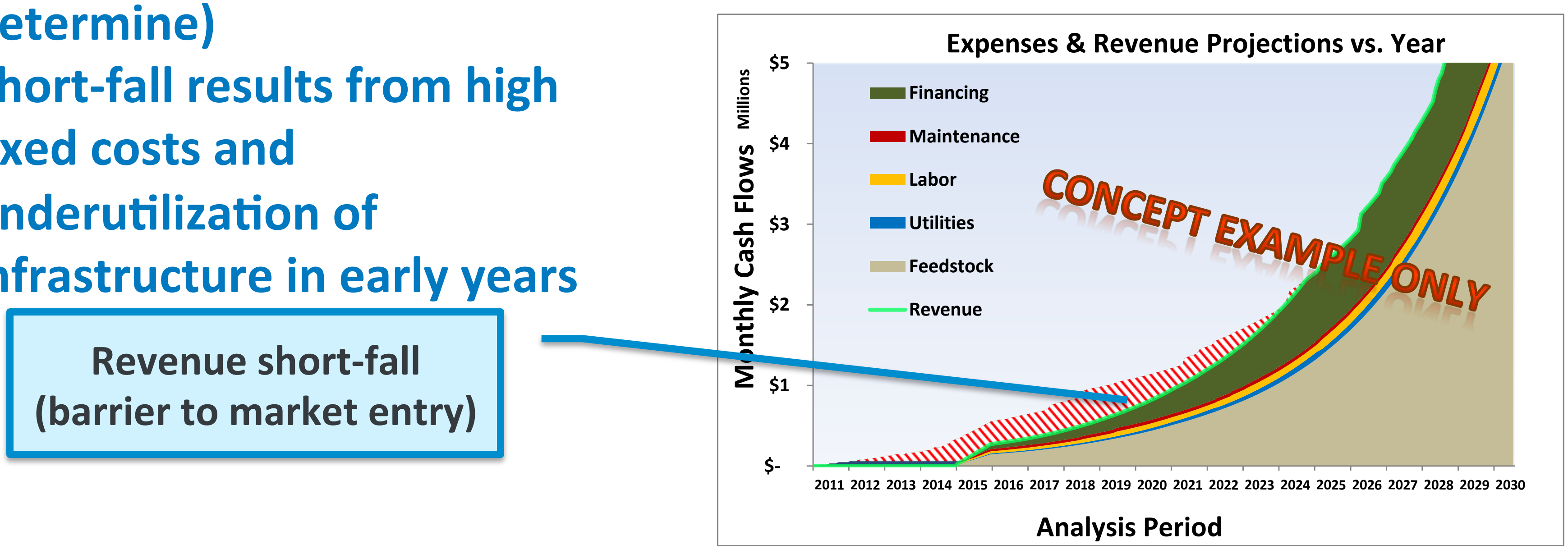
- **Break-even year is a function of assumed market price ($/kg)**
- **Cash flows determined nationally, by state, by city, or per station**



# More elaborate and detailed cash flows

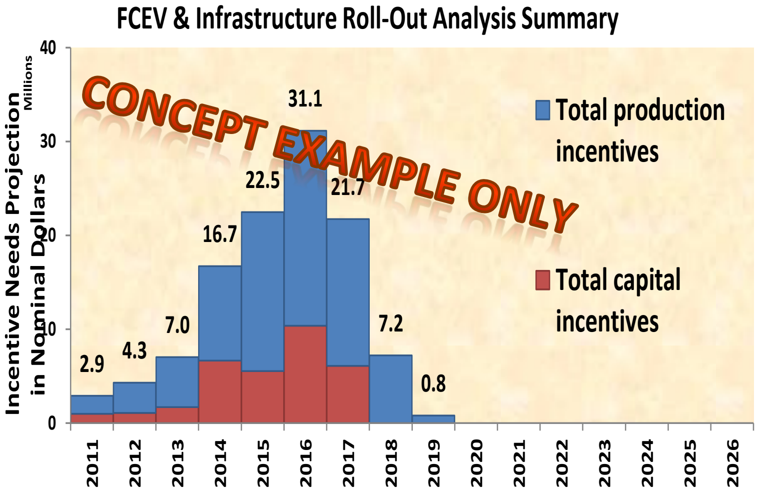
- Developed in response to partner/stakeholder requirements in H2I and discussions with EIN/CaFCP
- Hydrogen price assumed to be equal to gasoline price on a per-mile-driven basis (need mpg assumptions to determine)
- Short-fall results from high fixed costs and underutilization of infrastructure in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

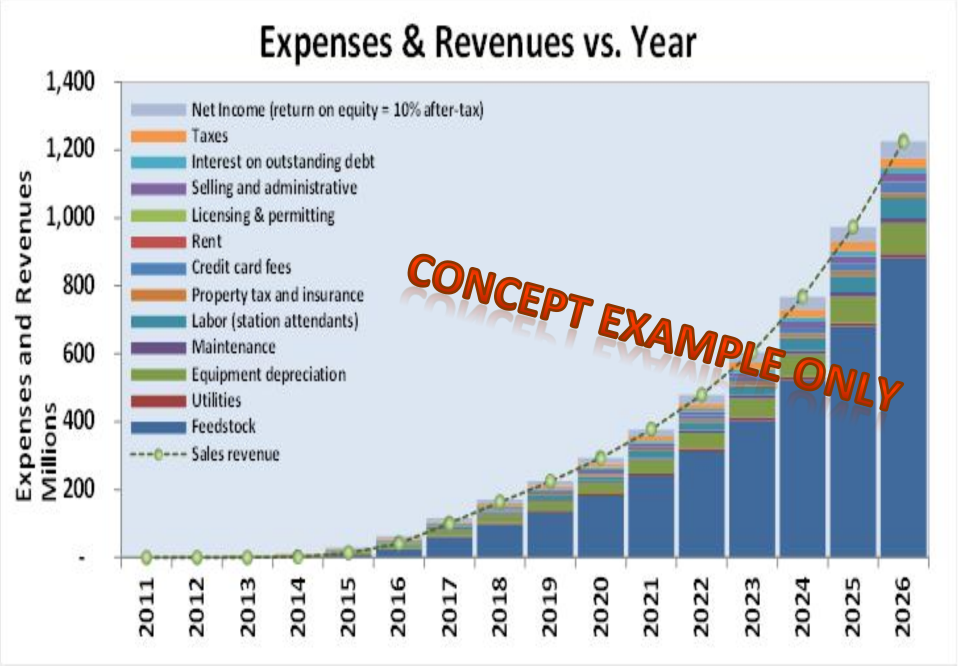


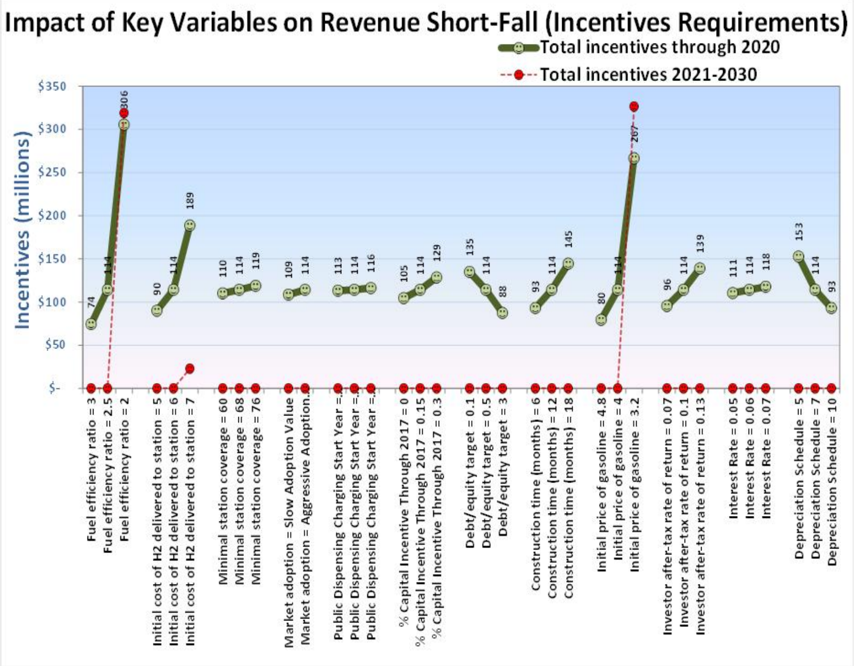



# Cash flow can be resolved with high level of detail and for various financing/incentive options

- 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



# 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**

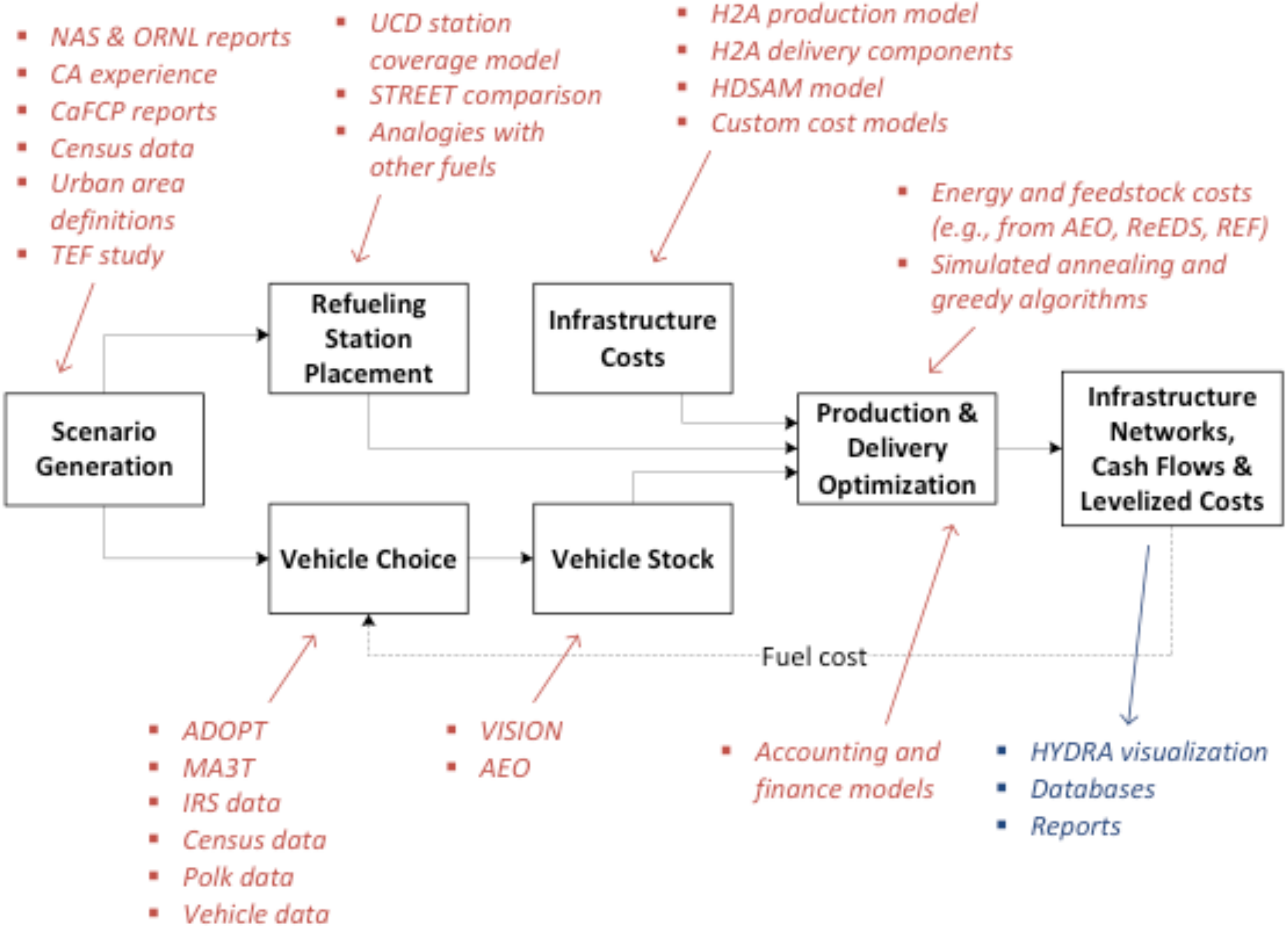
# Additional Slides

# SERA overview

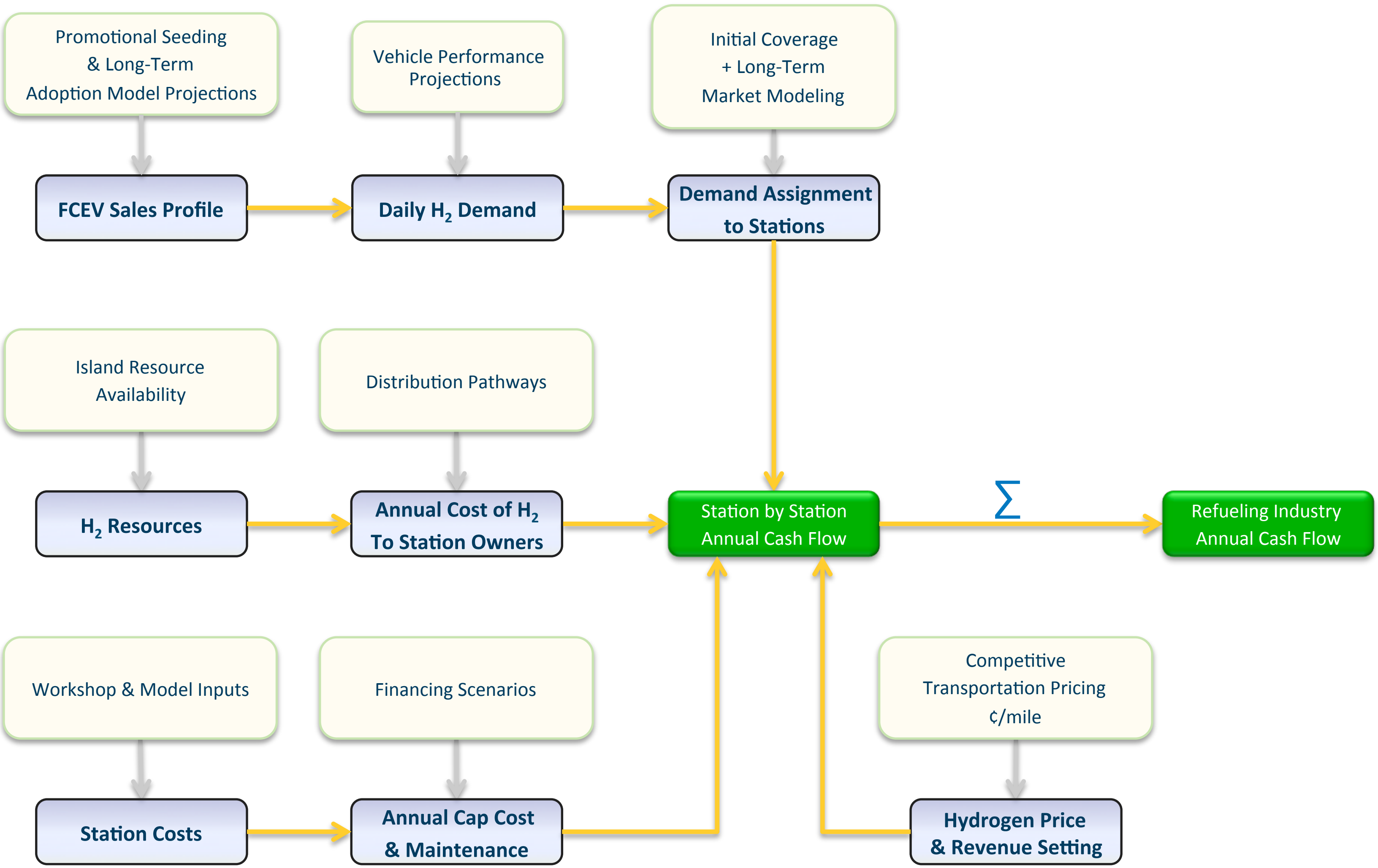
**The SERA Model integrates assumptions and data from multiple sources and related modeling efforts**

<u>General Features</u>

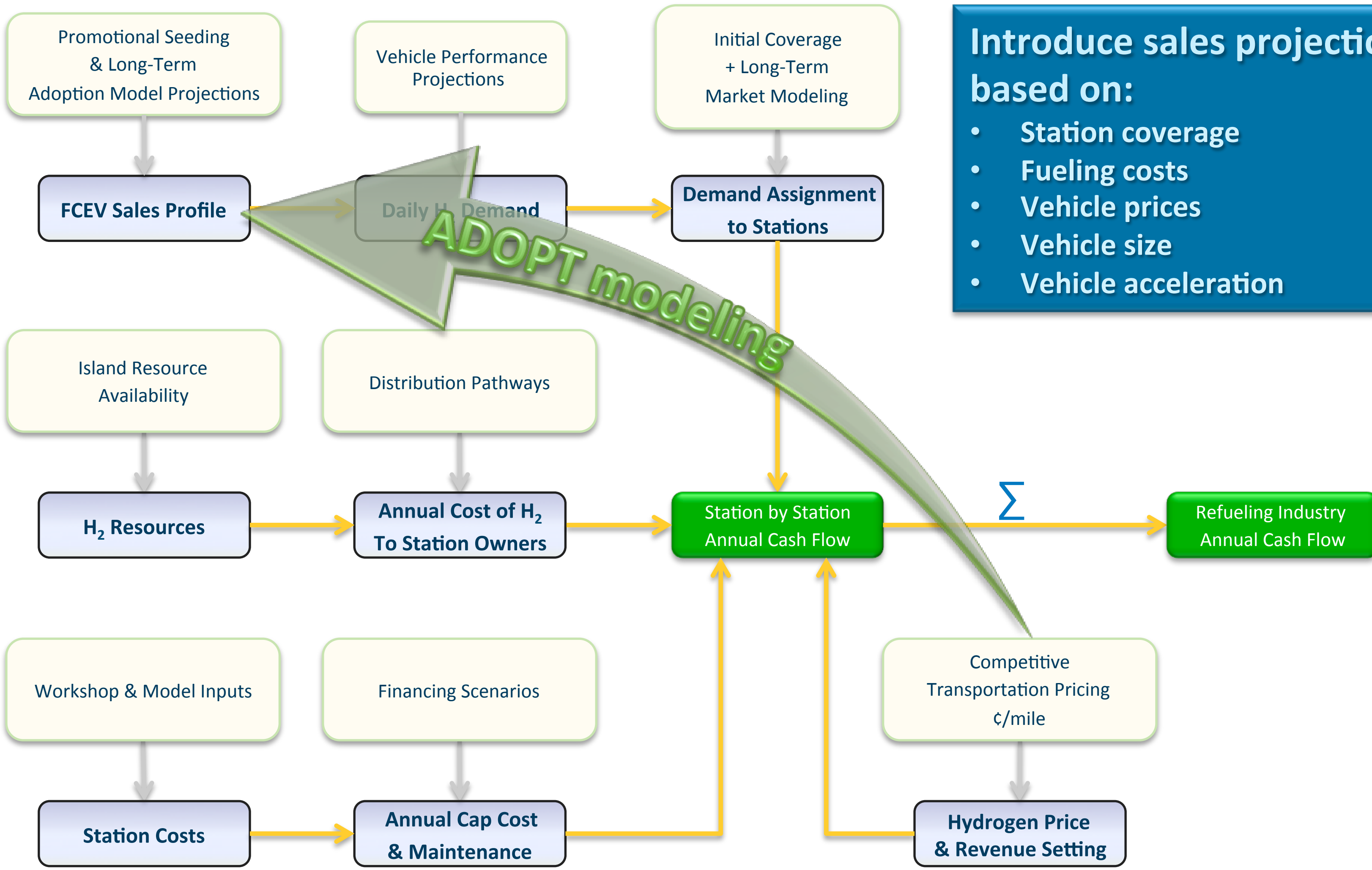
- High level of customizability
- User-defined geographic detail
- User-defined vehicle types, classes, and characteristics
- Disaggregated computations
- Agnostic about sources of cost data
- Choice of algorithms
- Interoperable with other models
- Easy to add new submodels for special-purpose studies



# Current modeling approach



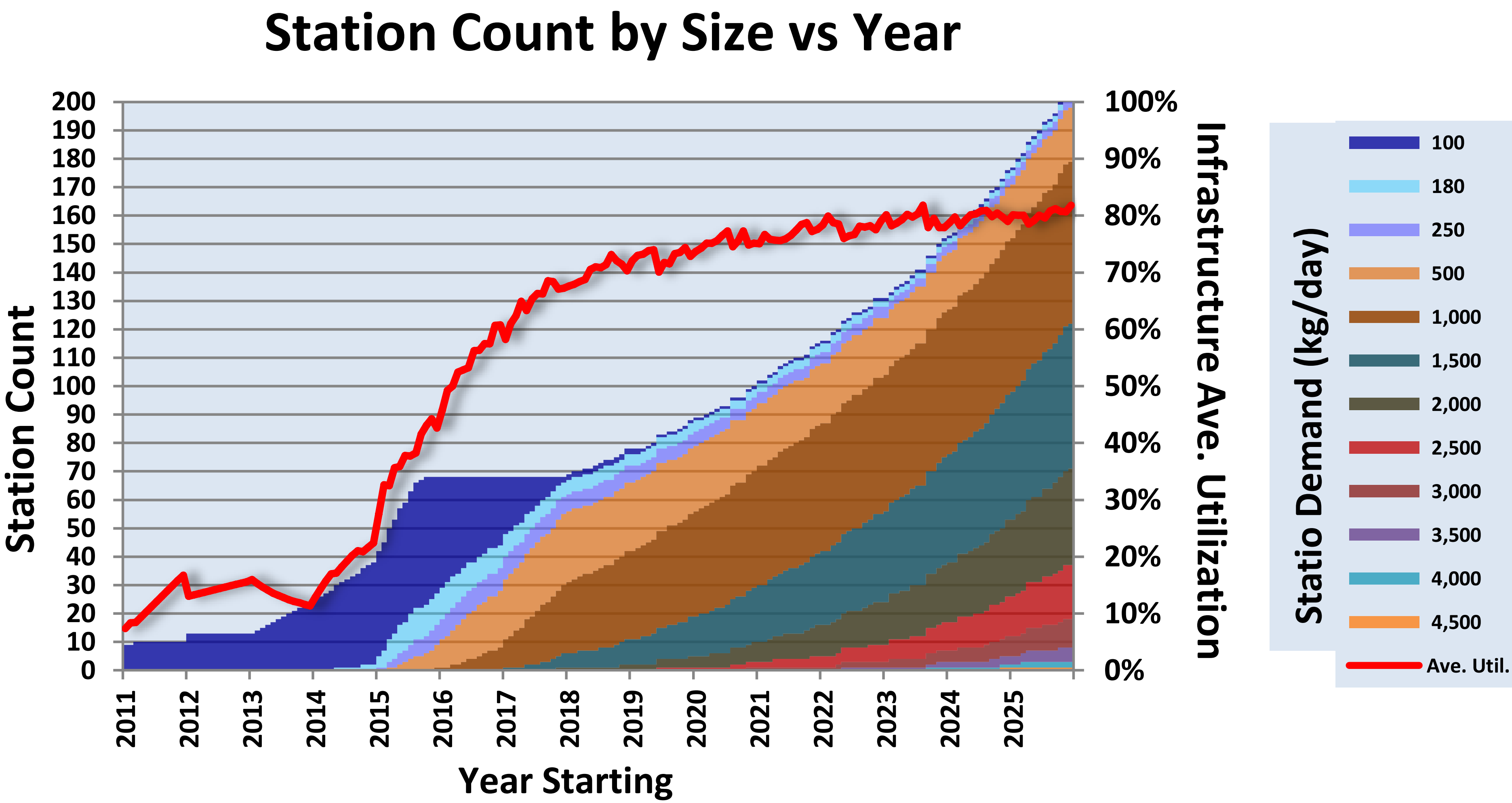
# On-going effort




**Introduce sales projections based on:**

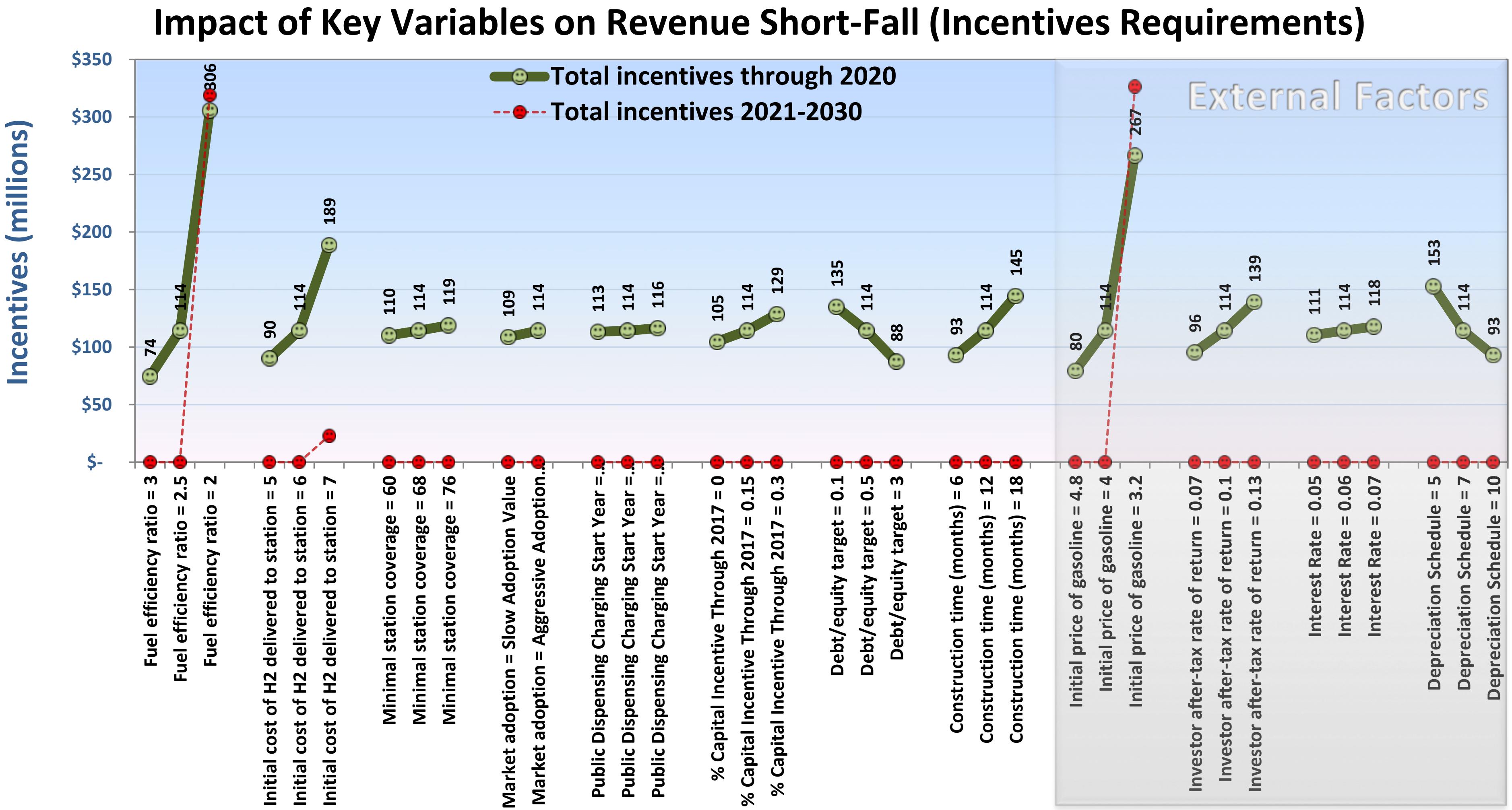
- Station coverage
- Fueling costs
- Vehicle prices
- Vehicle size
- Vehicle acceleration

# Station roll-out in support of FCEV




Station 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

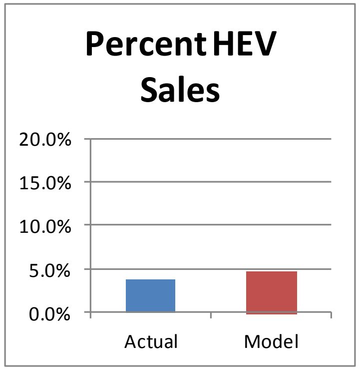
# Sensitivity analysis

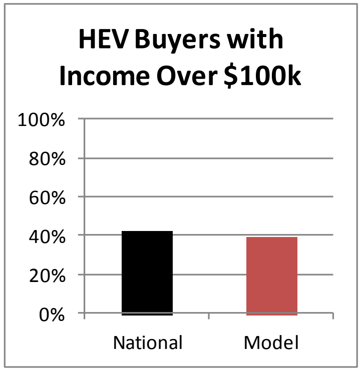


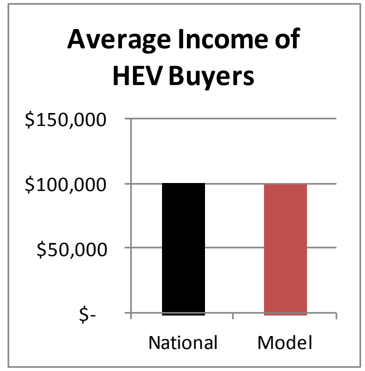

## Most important controllable variable: vehicle fuel economy

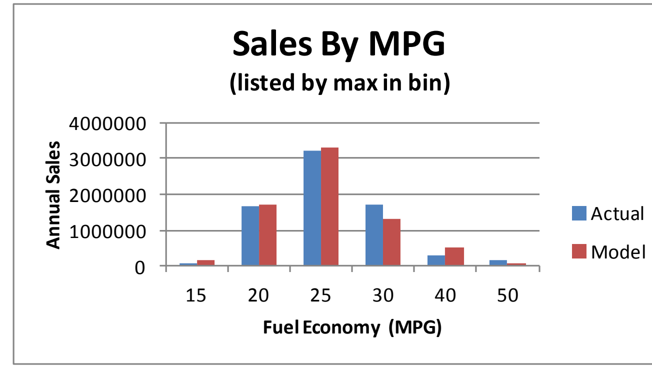
- High fuel economy = lower infrastructure investment
- High fuel economy = higher revenue per kg $H_2$
- High fuel economy = effective production resource utilization

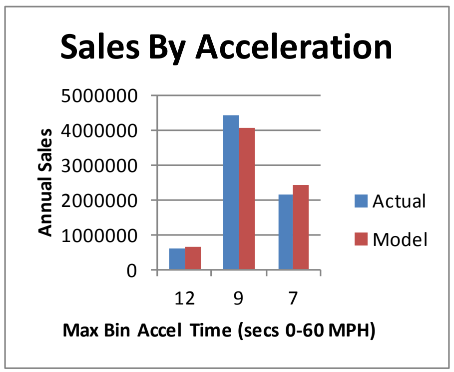
# ADOPT matches historical sales

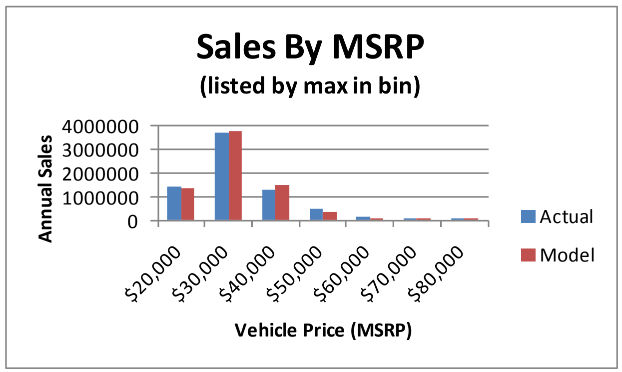


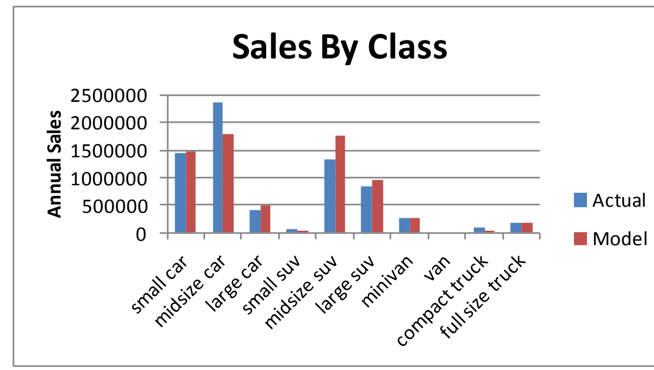



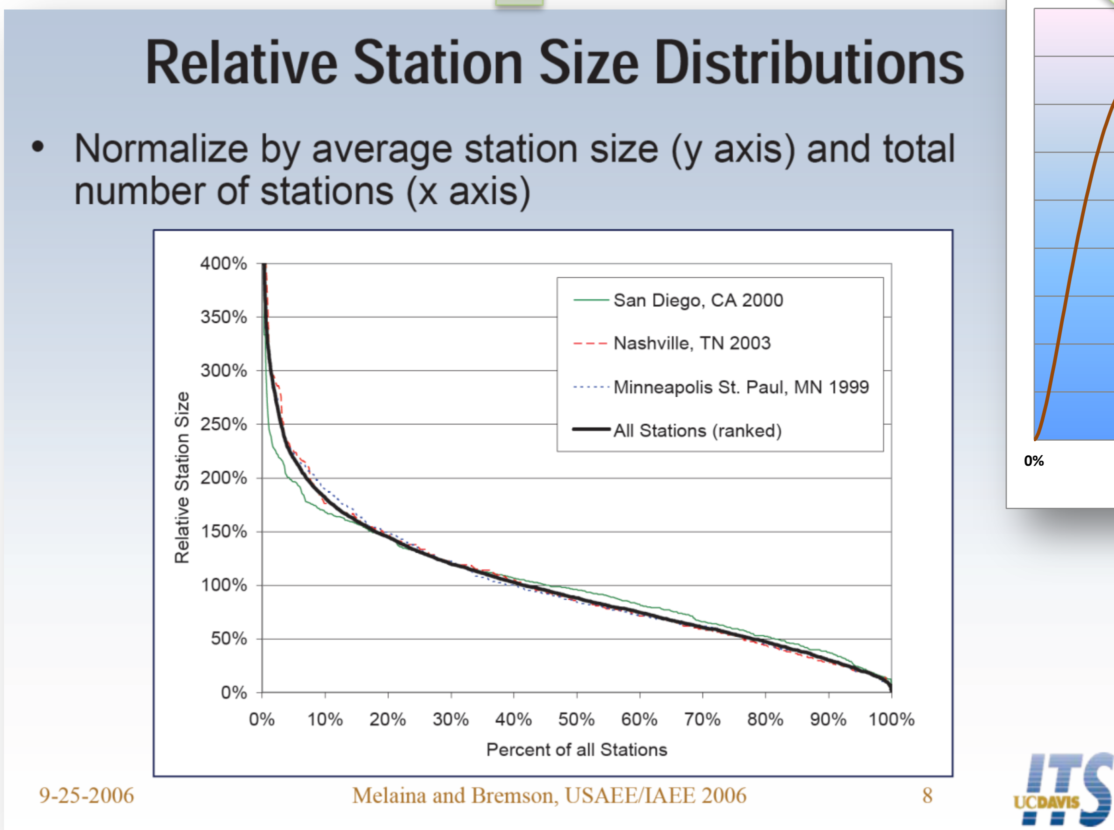



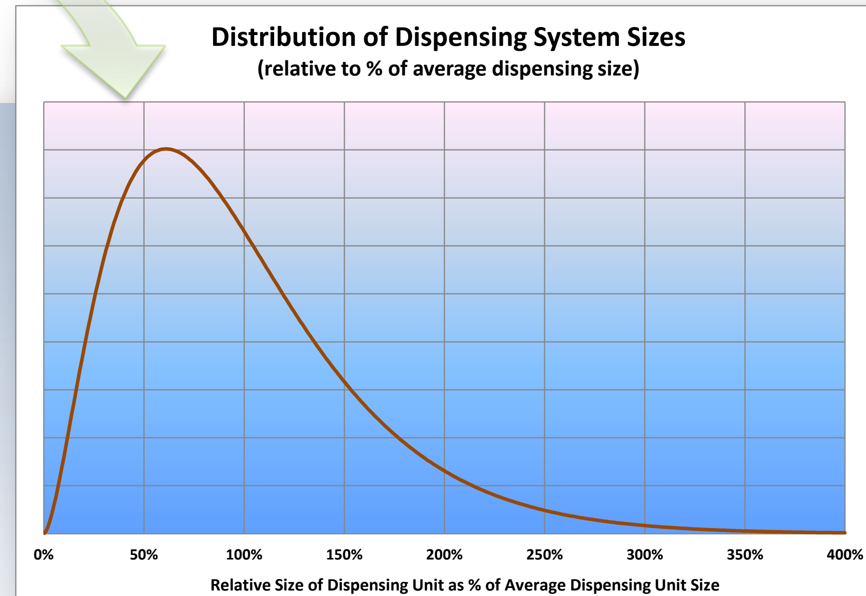




- **ADOPT has been calibrated for U.S. markets**
- Model predicts historical sales with a relatively high degree of accuracy
- Range of FCEV sizes and performances will be modeled to provide wide variety of market choices

# Gasoline demand distribution applied to hydrogen




**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*