Sensitivity Analysis of H_2-Vehicles Market Prospects, Costs and Benefits

* H_2V = { H_2 ICE, FCV, FC PHEV }

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2012 DOE Fuel Cell Technologies Program

Annual Merit Review

May 15, 2012

Project ID #: AN023

Timeline

- **Start: Oct 1, 2011**
- **End: Sep 30, 2012**
- **50% complete**

Budget

- **Total project funding**
  - DOE share = $130k
  - No cost share
- **FY12 = $130k**

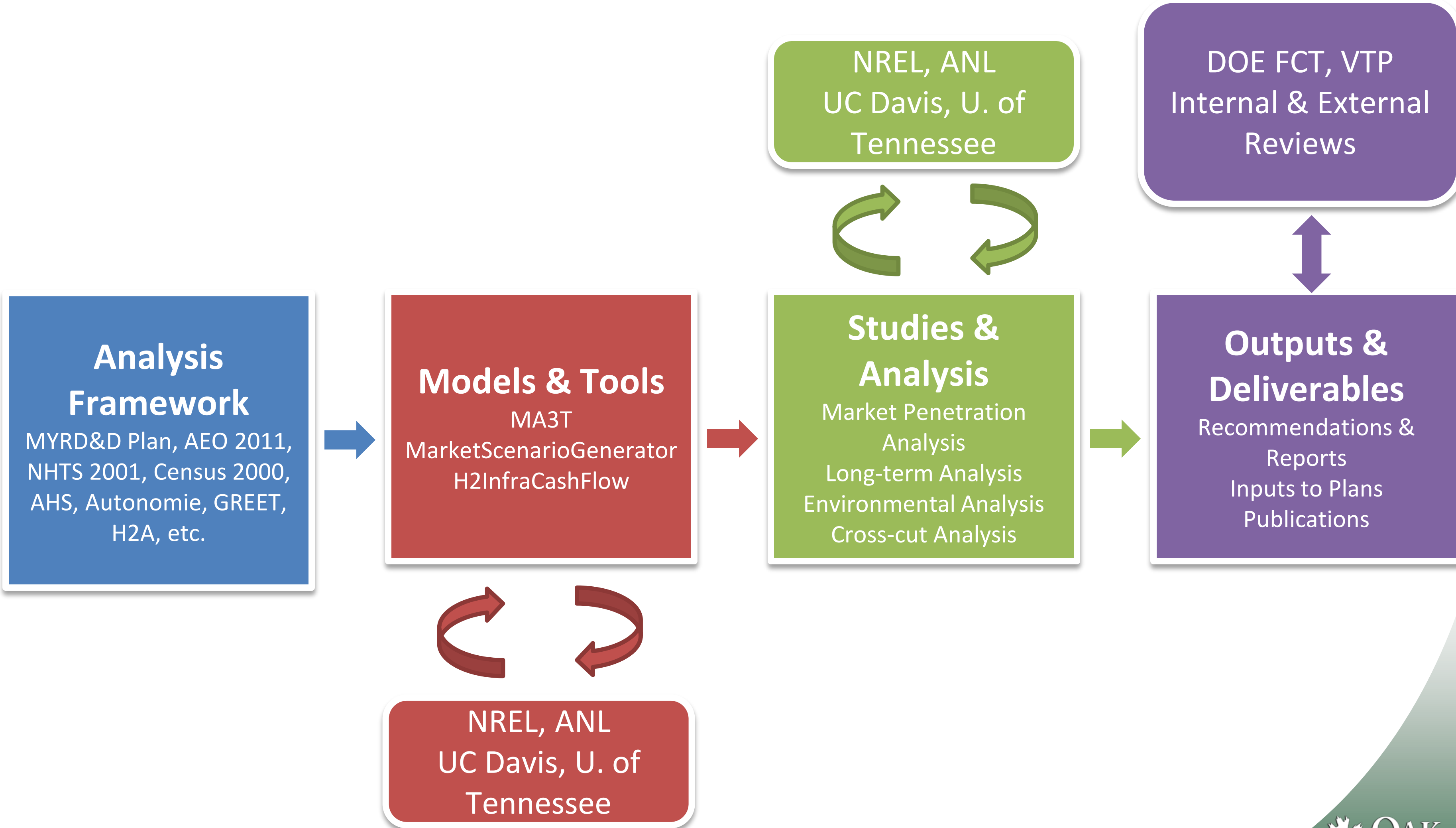
Barriers

- **Barriers addressed**
  - A. Future Market Behavior
  - B. Stove-piped/Siloed Analytical Capability
  - C. Suite of Models and Tools
  - D. Unplanned Studies and Analysis

Partners

- **Interactions / collaborations**
  - NREL
  - ANL
  - UC Davis, U. of Tennessee
  - Industry
- **Project lead**
  - David L. Greene, ORNL

H_2-Vehicles Market Prospect, Cost, and Social Benefit
--Sensitivity to FC/Battery Technology and Infrastructure



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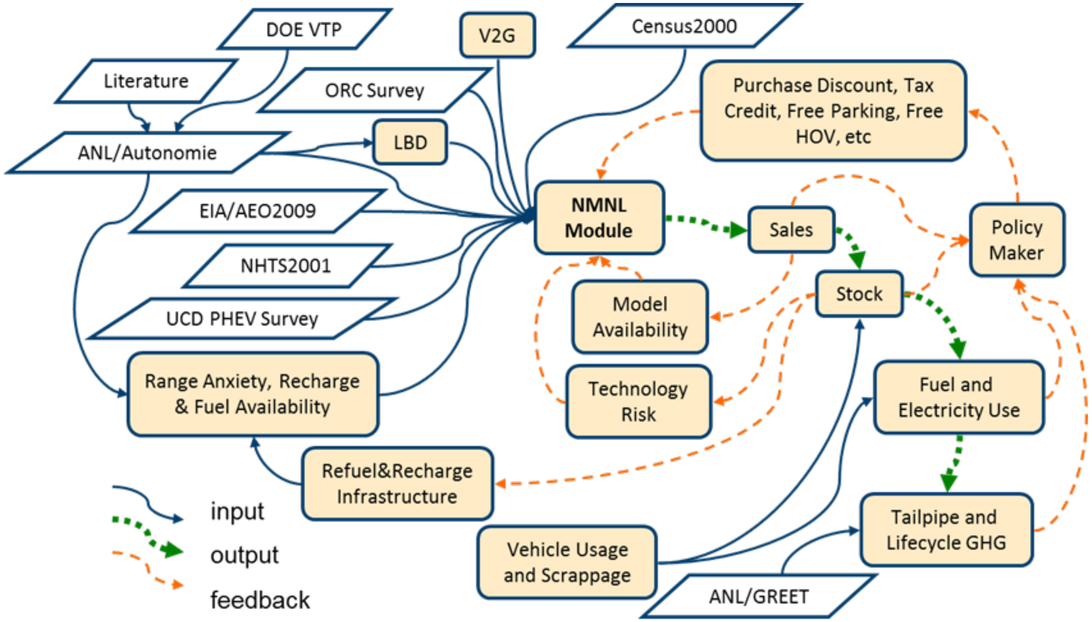
Understand market prospects, costs and benefits of LDV H_2-FC and their sensitivity to fuel cell & battery improvement, and other factors.

DOE Barriers	Project Goals
• Stove-piped/Siloed Analytical Capability • Suite of Models and Tools	• Conduct market analysis by integrating output of various DOE-sponsored and other federal projects
• Future Market Behavior • Unplanned Studies and Analysis	• Project market penetrations of H2 vehicles under varied scenario assumptions • Under different penetration scenarios, estimate social benefits and public costs • Compare cost-effectiveness among scenarios

This study uses ORNL's MA3T model, w/ baseline calibrated to the AEO 2011 reference case



- MA3T = Market Acceptance of Advanced Automotive Technologies
    - A discrete choice model
- Estimates sales of 40 vehicle technologies
    - Conventional and hybrid ICE, PHEV, H_2 ICE, FCV, FC PHEV, NGV, BEV
- 1458 consumer segments: region, area, driver, adopter, home and work charge
- Model calibrated using best available information combined with plausible assumptions rather than statistical inference.

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We used the MA3T model to analyze several factors likely to influence the competitiveness of fuel cell vehicles.

- TECHNOLOGY STATUS
  - Fuel cell vehicles
  - Competitive/synergistic technologies
- ENERGY MARKETS
  - Oil and energy prices
- CONSUMERS' PREFERENCES
  - Sensitivity to price (elasticity)
  - Value of future energy costs
  - Value of range
  - Fuel Availability
- POLICIES
  - H_2 infrastructure deployment
  - H_2 price charged to consumers
  - Charging infrastructure

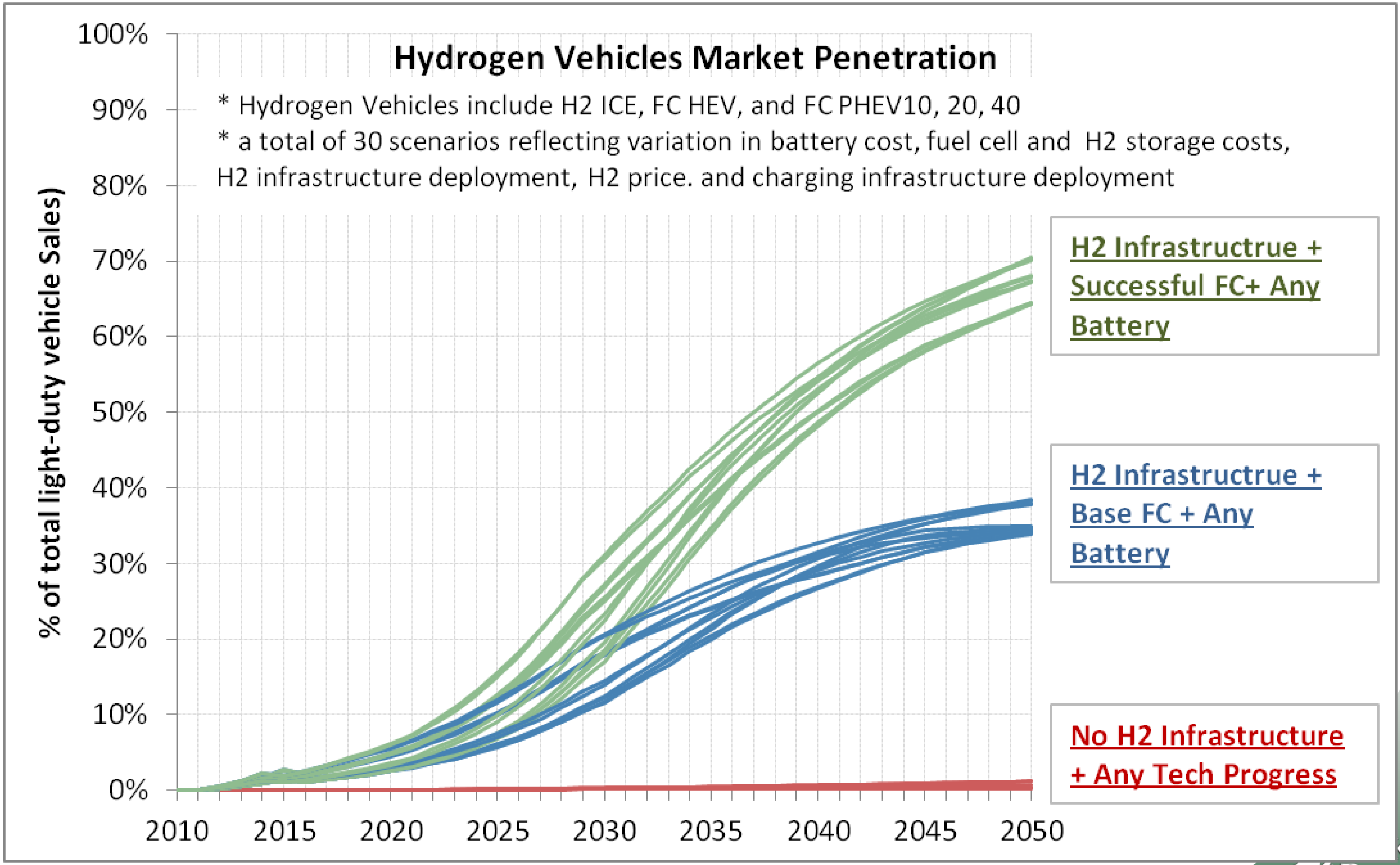
More details on slide #22

The key factors analyzed to date are technology costs, infrastructure deployment and oil prices.

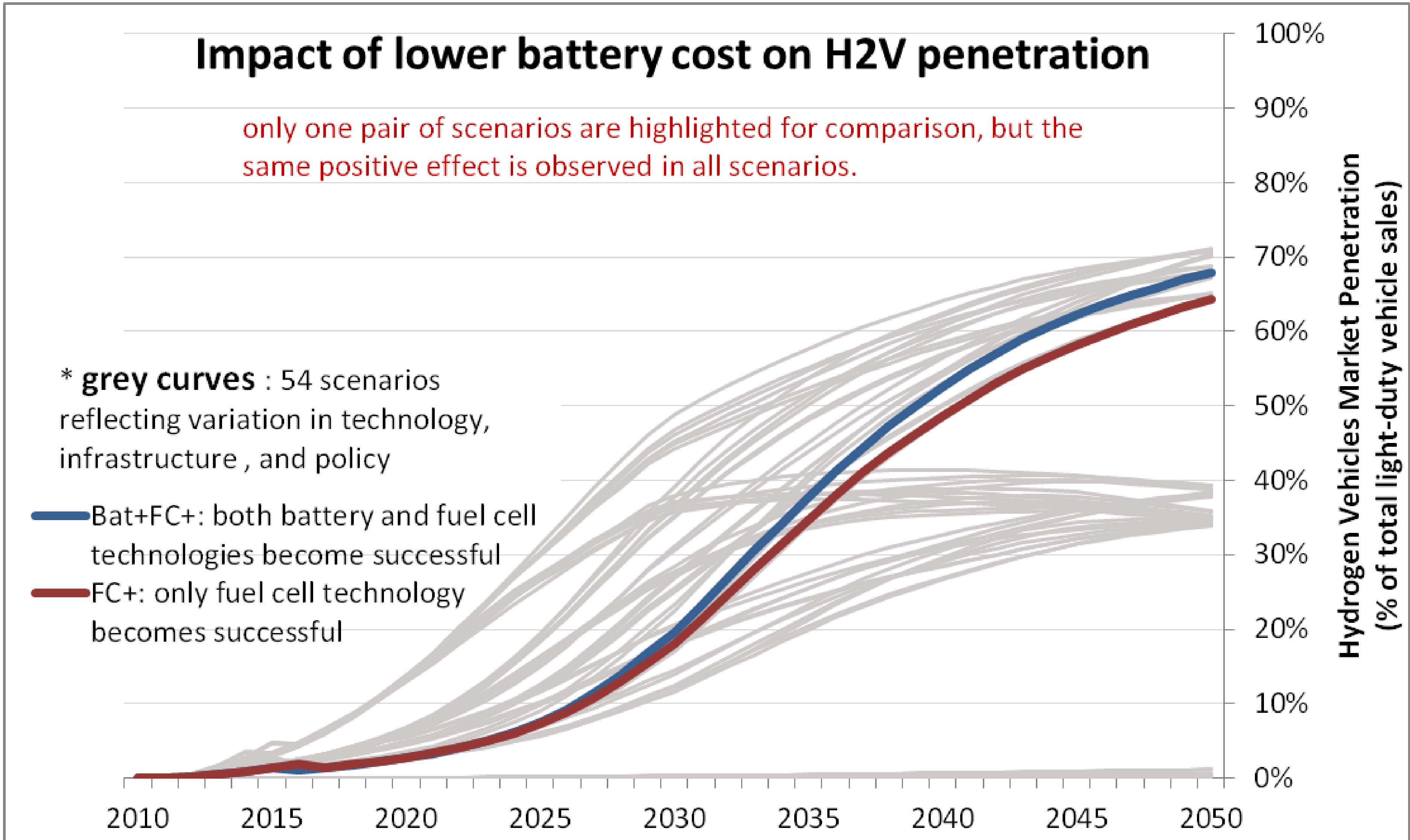
- Fuel Cell Vehicles:
  - Base: $60/kW FC system, $10/kWh storage
  - FC+ : FC $25/kW, on-board storage $5/kWh by 2050
- Plug-in Vehicles
  - Base: $450/kWh through 2050
  - Bat+: $150/kWh by 2050, Bat20yr+ = Bat+ 20 yrs earlier
- Infrastructure:
  - 10% by 2030 to 50% by 2050 vs. 10% by 2020
  - 0 public chargers, 5% work vs. 50% public, 80% work
- Oil Prices: AEO 2011, High, Reference, Low

Technical Accomplishments and Progress---Market Prospect

1. Estimated H_2V market shares range from 30% - 70% in 2050
2. H_2V Technology success doubles estimated market share.
3. Scenarios assume infrastructure & low-priced H2 in early market

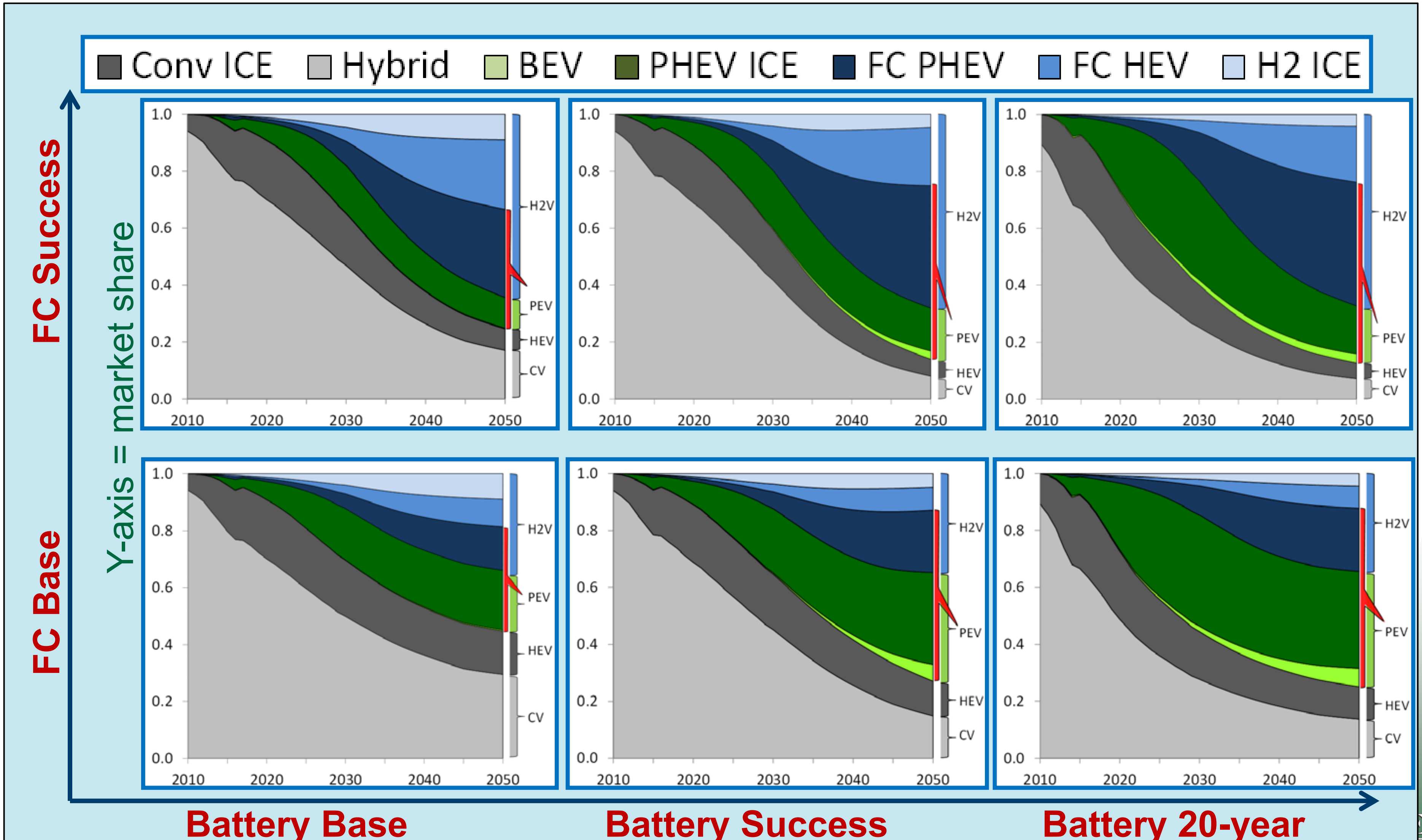


Low-cost batteries (Bat+) help H_2Vs and PEVs as well as BEVs.
LDV market is big enough for both technologies to succeed.

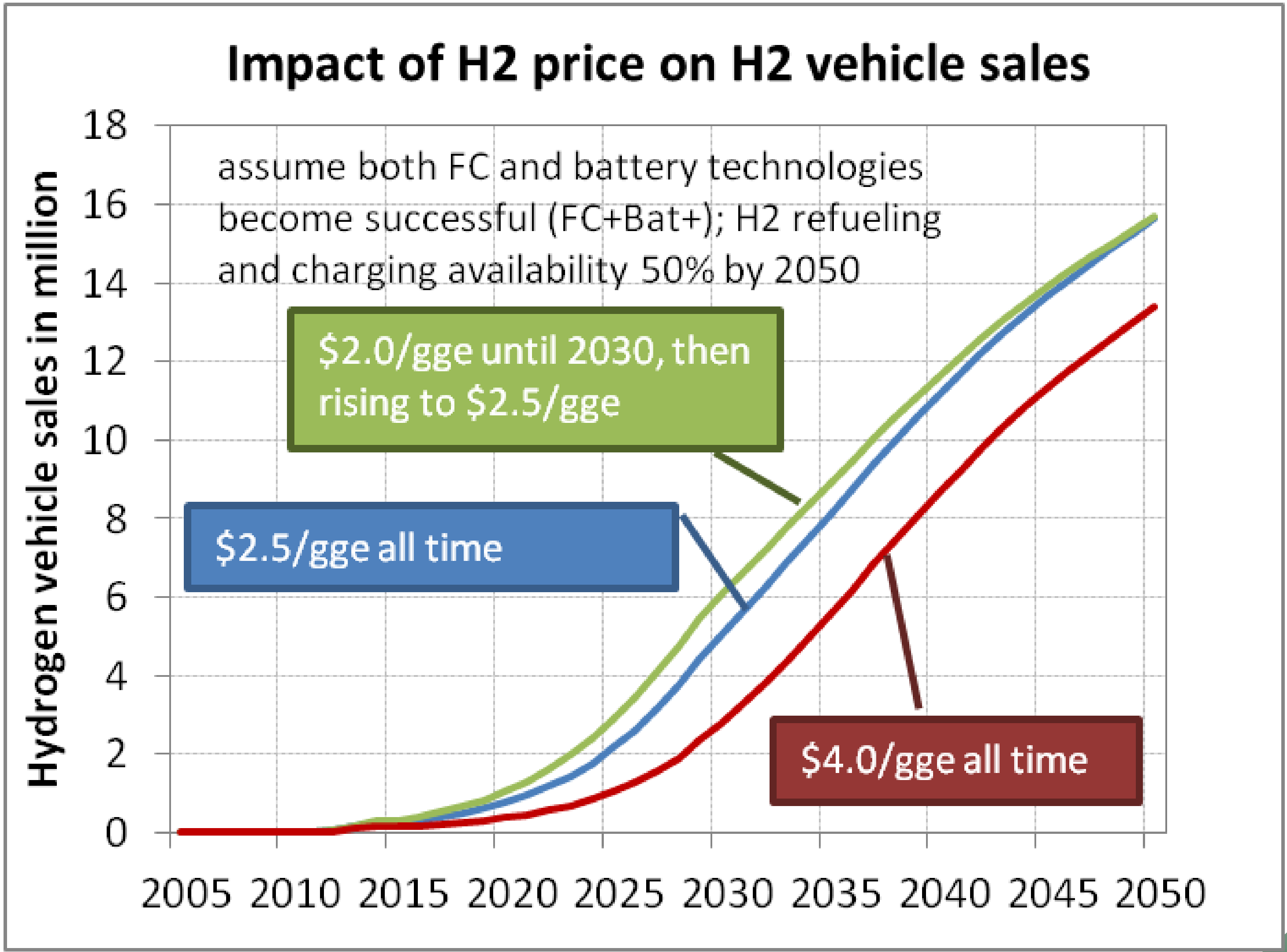


More details on slide #23

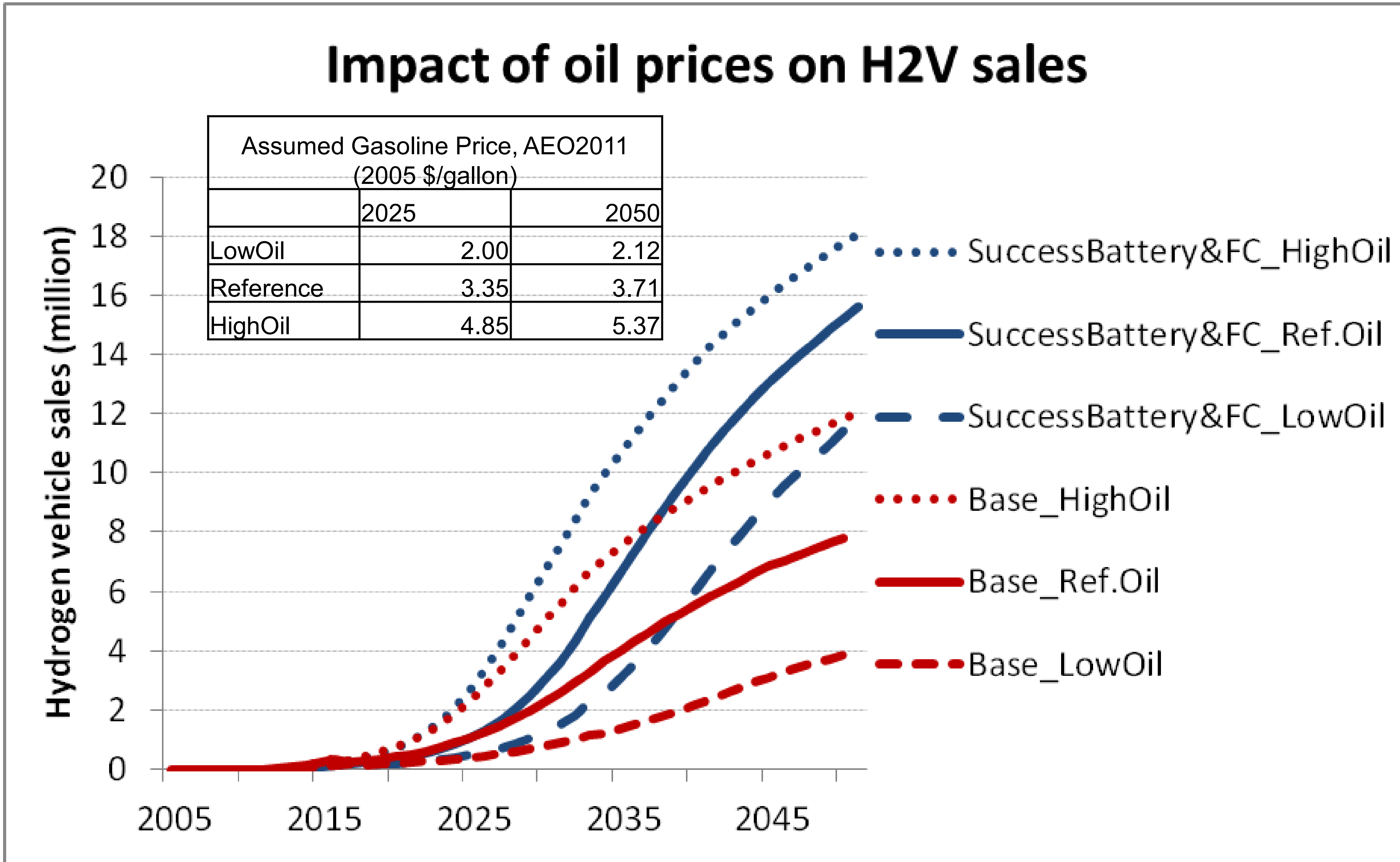
The key factor in H_2V success is fuel cell technology (BLUE). Battery success expands the market for both H_2 and ICE PEVs.



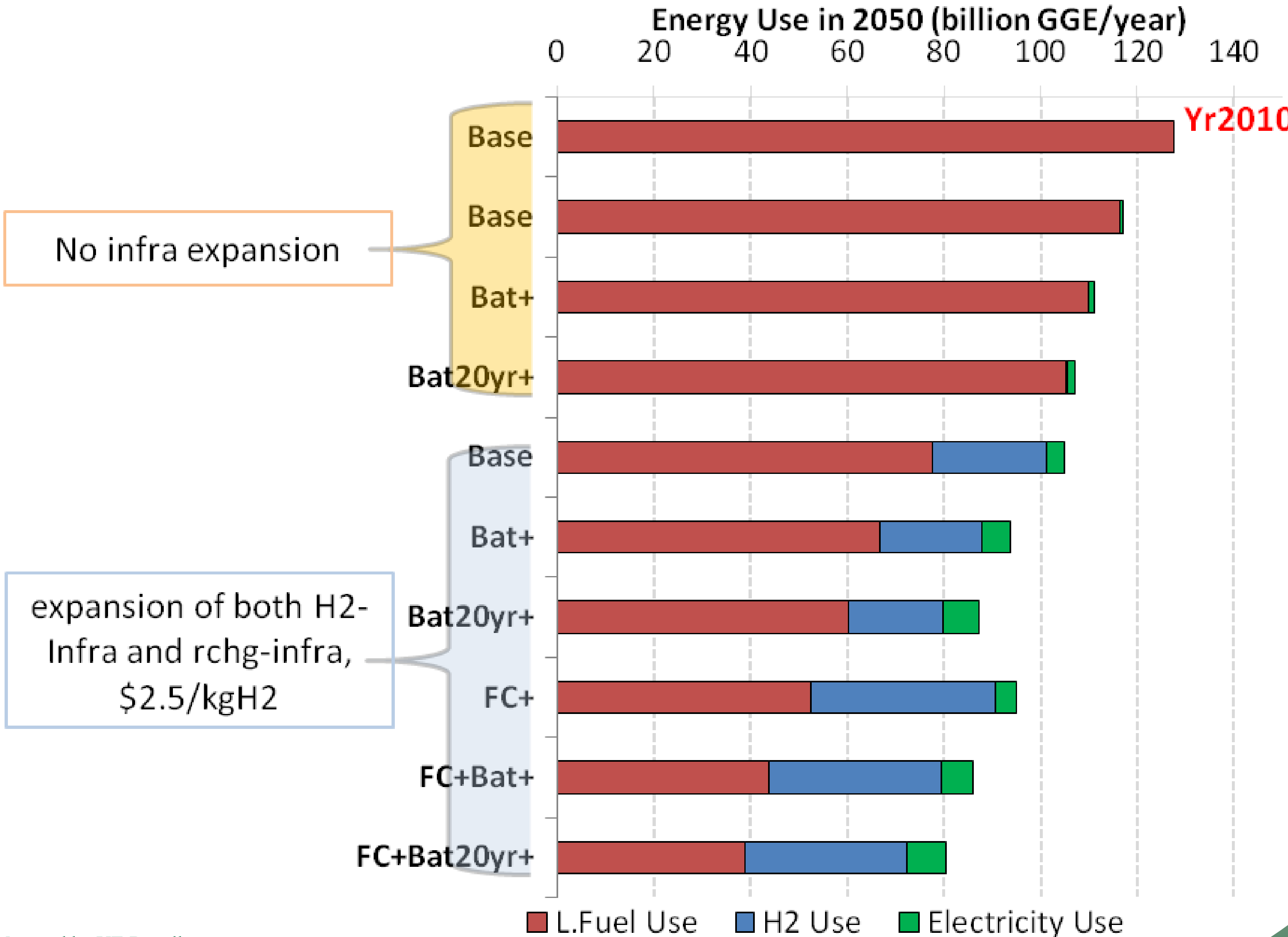
Given technological success, H_2Vs appear to be competitive under a range of hydrogen prices.



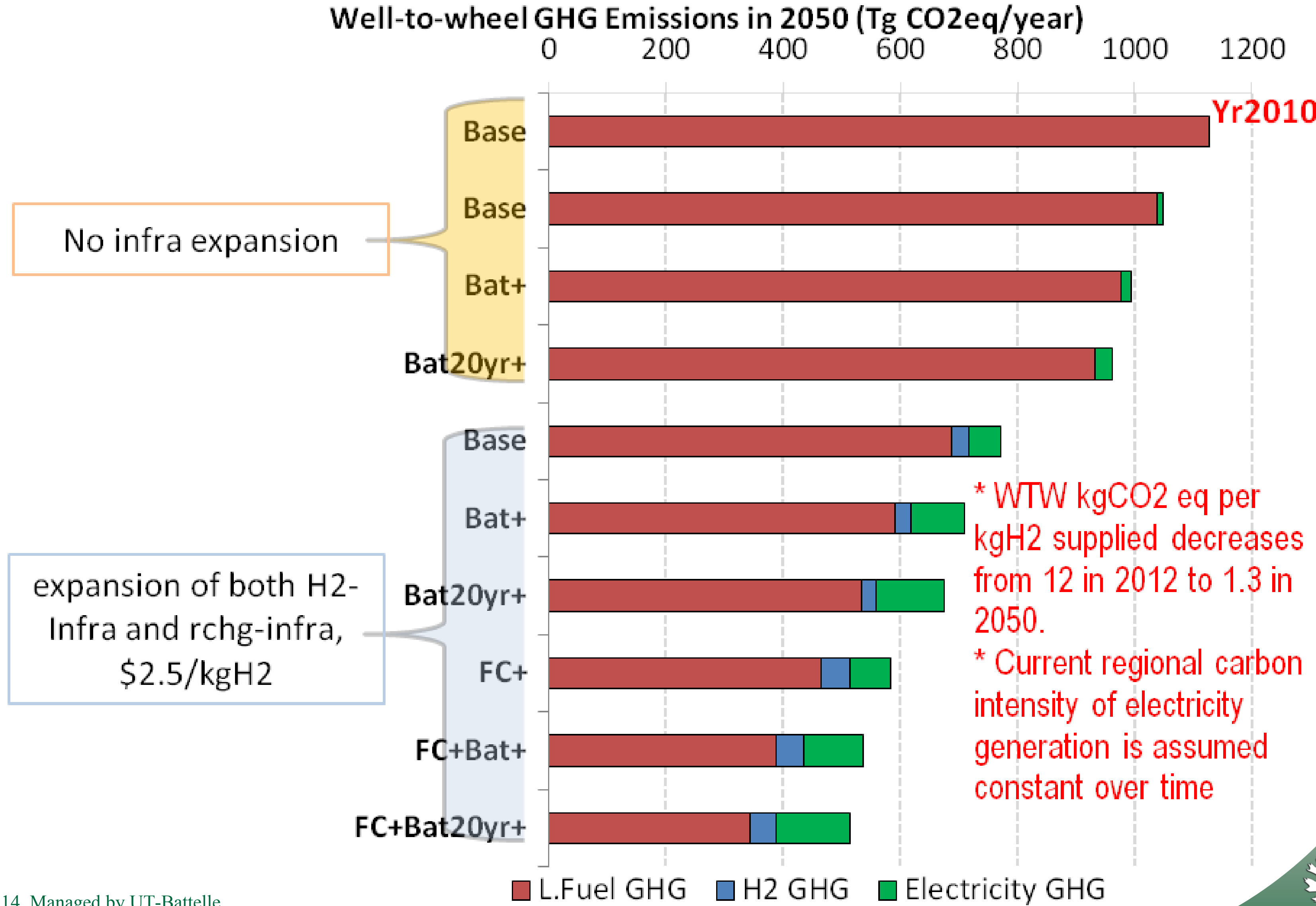
H_2V market success will vary with the price of oil, but technological success is more important.



Technological success + infrastructure deployment → most oil displacement. Cutting liquid fuel use by 70% reduces the amount of biofuel needed.



Battery & FC success reduce LDV GHG by 55% in 2050 vs 2010 before considering low-C biofuel and grid de-carbonation.



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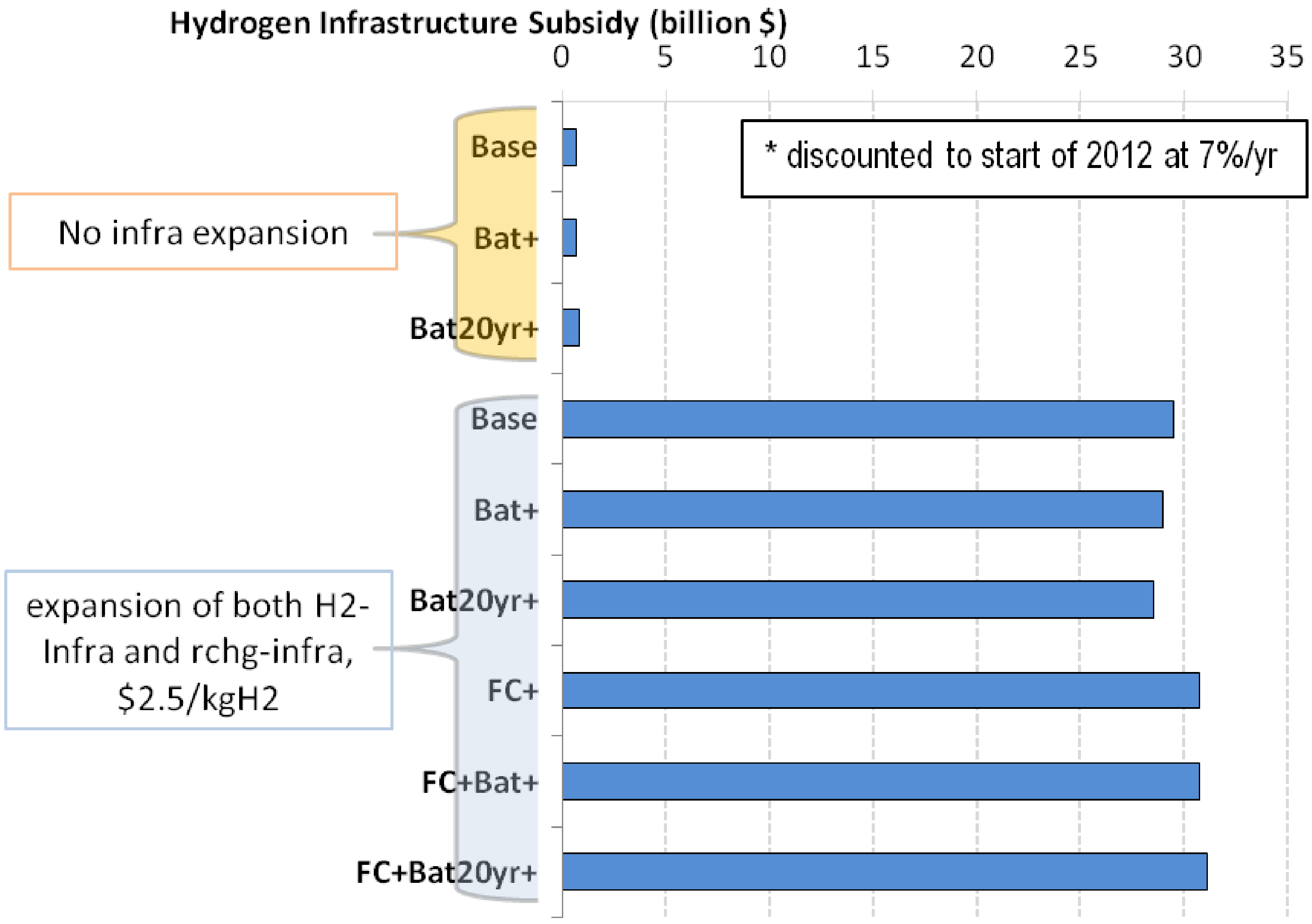
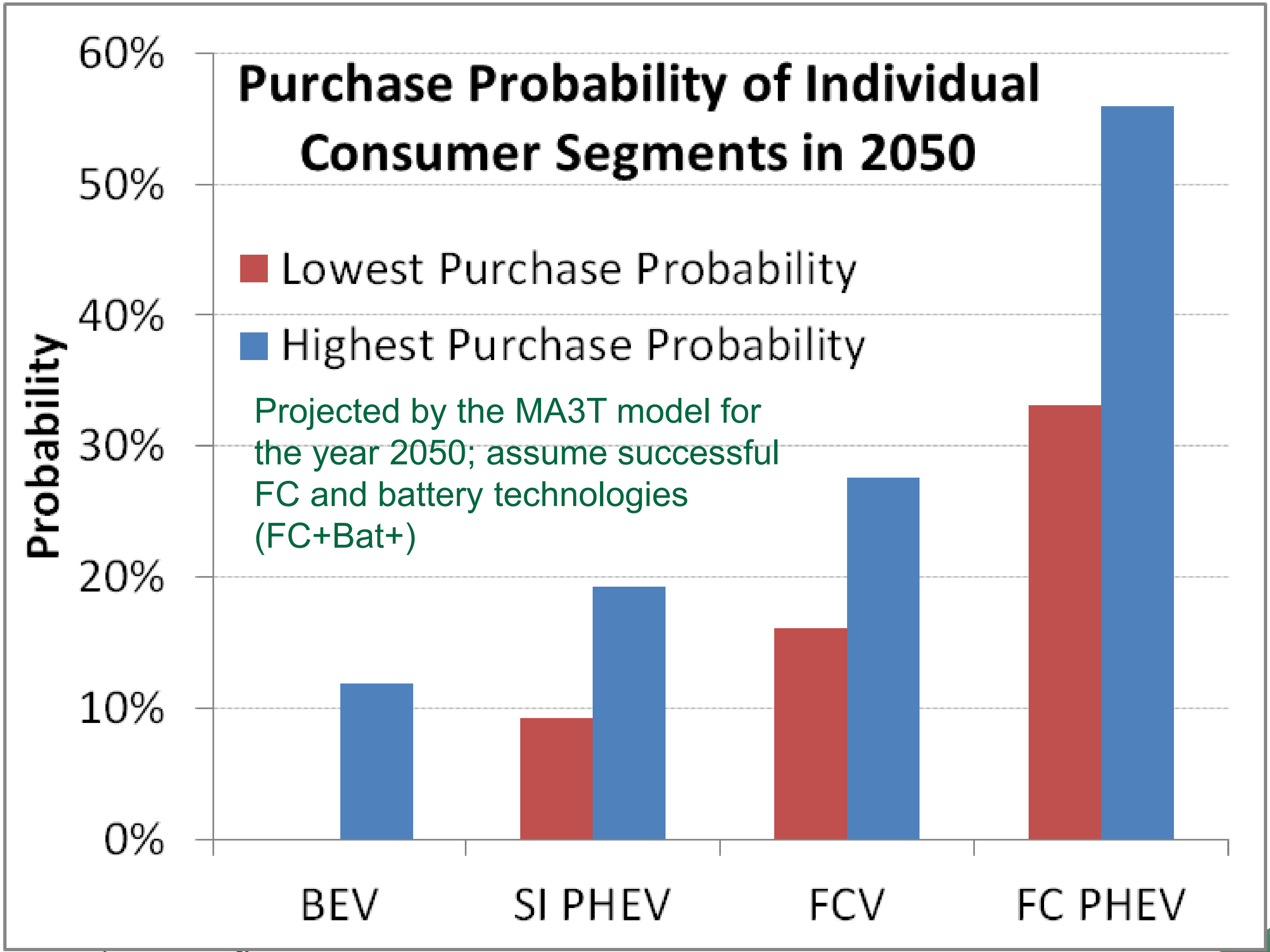
The required H_2 subsidies (fuel+infrastructure) are estimated to be about $30 billion, depending on technology status.



Our next step is to test sensitivity to consumers' preferences, complete the experimental design and analyze the results.



- **Using the MA3T model, we have to date created 30 scenarios for analyzing the sensitivity of hydrogen vehicles' competitiveness and related factors:**
  - technological progress in battery and FC
  - deployment of H2-refueling and recharging infrastructure
  - H2 pricing
  - Oil prices
- **Our goal is to understand the factors that will influence the competitiveness of hydrogen vehicles, and their interaction with technological advances.**
- **Our next steps are:**
  - Analyze the sensitivity to consumers preferences
  - Complete the experimental design and sensitivity analysis

The project depends on the research of collaborators and colleagues from other national labs, industry and universities.

- Collaboration Partners
  - NREL: developed the H2A model, the source of hydrogen cost estimates.
  - NREL and UC Davis: provided key insights on fuel accessibility modeling and consumers' preferences
  - ANL: developed the H2A delivery and Autonomie models and share data
  - Industry (Ford, Nissan, Honda): interaction including exchange on fuel cell vehicle early market strategy and daily VMT variation
  - University of Tennessee: share vehicle data used in model calibration.

THANK YOU

BACKUP SLIDES

Understand market prospect, cost and social benefit of LDV H2-FC and their sensitivity to fuel cell & battery improvement, infrastructure, and H2 price

DOE Barriers	Project Goals

• Stove-piped/Siloed Analytical Capability
• Suite of Models and Tools
	• Conduct market analysis by integrating output of various DOE-sponsored and other federal projects, including:
	  • ORNL's MA3T model
	  • ANL's Autonomie model
	  • NREL's H2A model
	  • EIA's AEO projection
	  • DOT's NHTS database
	  • EPA's technology assessment

• Future Market Behavior
• Unplanned Studies and Analysis
	• Project market penetrations of H2 vehicles under varied assumptions of:
	  • Costs of fuel cell and battery
	  • Deployment of refueling and recharging infrastructure
	  • Hydrogen pricing
	• Under different penetration scenarios, estimate social benefits and public costs, including:
	  • Petroleum use reduction
	  • Greenhouse gas reduction
	  • Zero-emission vehicle population
	  • Grid-connected vehicle population
	  • Public support for infrastructure
	  • Public support for vehicle purchase
	• Compare cost-effectiveness among scenarios

30 scenarios, reflecting different exogenous projections of fuel cell cost, battery cost, H2 and charging infrastructure deployment, and subsidized H2 price

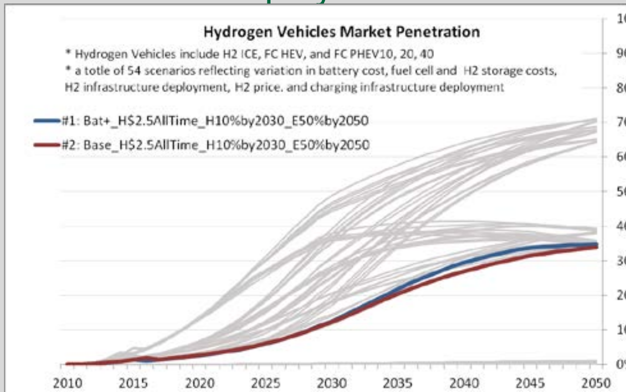
- Fuel cell and storage
  - Base: no significant improvement; $60/kW FC system cost and $10/kWh storage cost by 2050
  - "FC Success" or "FC+": $25/kW FC system cost and $5/kWh storage cost by 2050
- Battery
  - Base: no significant improvement; $450/kWh by 2050 (PHEV40)
  - "Battery Success" or "Bat+": $150/kWh by 2050 (PHEV40)
  - "Bat20yr+": battery cost reduction accelerated by 20 years from the Bat+ scenario; consistent with EPA/CARB technology assessment for the new CAFE analysis
- H2 infrastructure
  - Base: no infrastructure deployment
  - "10%by2030": 10% eq. of gas stations providing H2 by 2030; 50% by 2050
  - "10%by2020"
- H2 price charged to consumers
  - Base: $3.5/kg decreasing to $3.0 by 2050
  - "$2.5AllTime": constant $2.5/kg
  - H2 cost is independent of H2 price; delivered H2 cost assumed to be $3/kg at full utilization and large scale; a 0.85 scaling factor is assumed; actual utilization is endogenous to determine the actual delivered cost; the gap between cost and price is subsidized
- Charging infrastructure
  - Base: no public charger deployment; constant 52%of consumers with home charging and 5% with work charging
  - "Charger": by 2050, 80% with home charging; 80% with work charging; 50% of probability with public charging

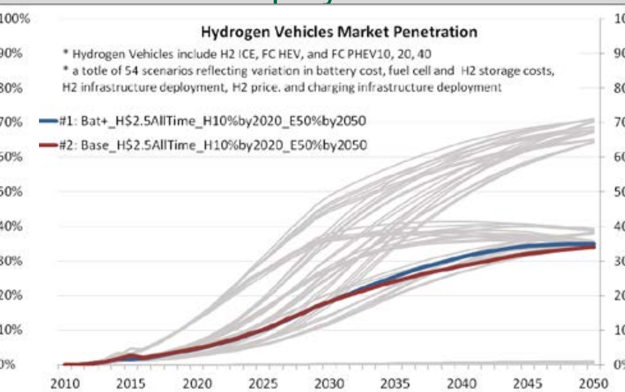
Technical Accomplishments and Progress---Market Prospect

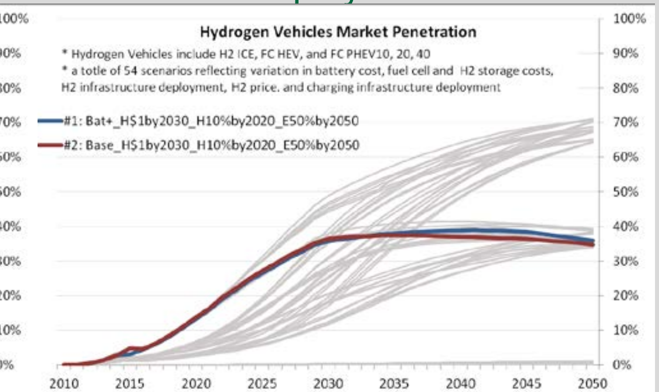
Lower cost battery (Bat+) helps both H2Vs and PEVs
1) battery is a key component of FCV and FCPHEV; 2) LDV market is big enough for both PEV and H2V to grow together, at least by 2050.

Blue Line = Bat + **Red Line = Base technology**

High H2 price, slow infra. deployment | High H2 price, fast infra. deployment | Low H2 price, fast infra. deployment

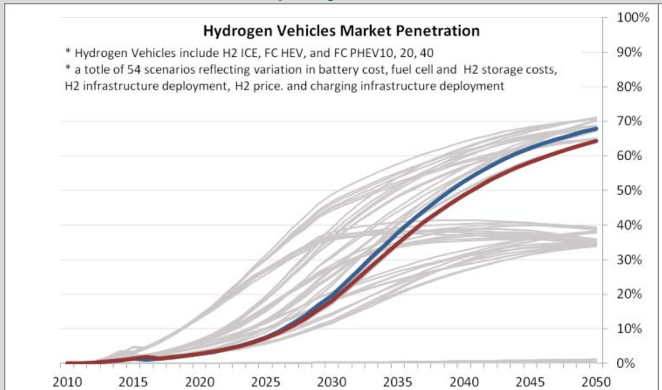


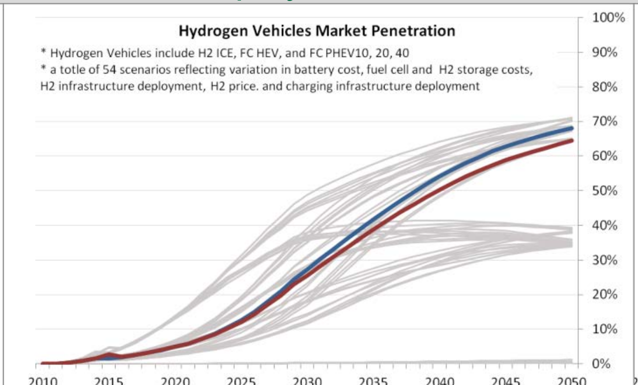


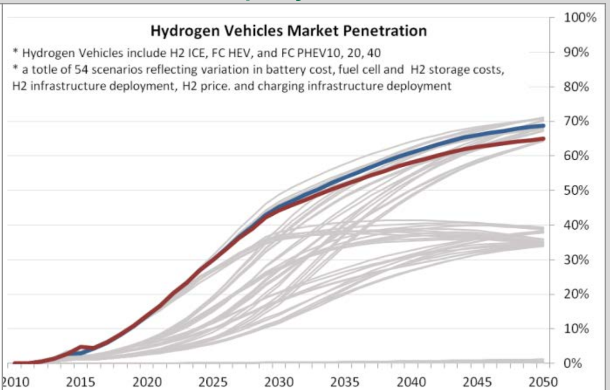


Blue Line = Bat + FC + **Red Line = FC +**

High H2 price, slow infra. deployment | High H2 price, fast infra. deployment | Low H2 price, fast infra. deployment

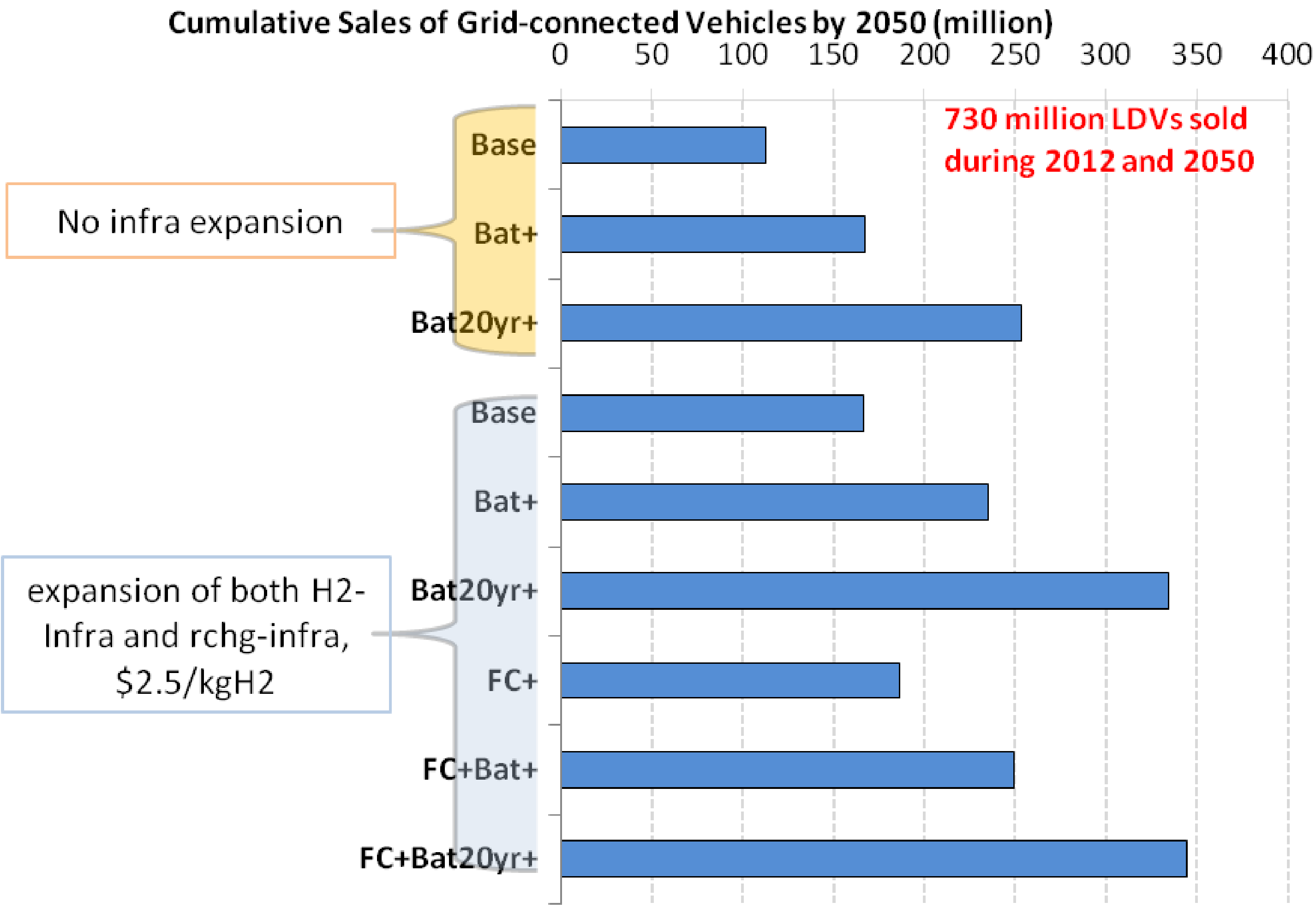






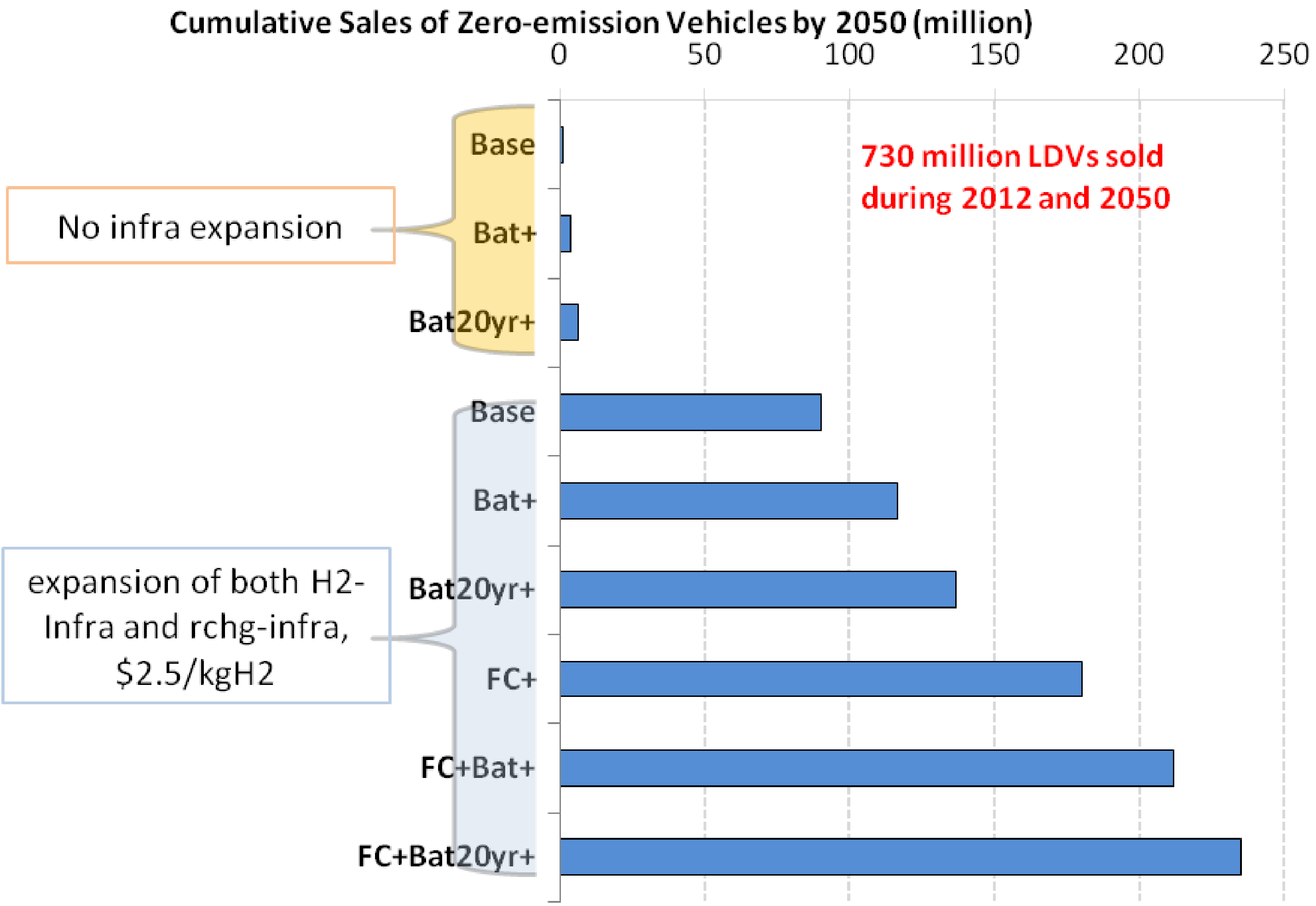
Energy Security

Battery **&** FC success could result in almost 50% grid-connected vehicles on the road in 2050.



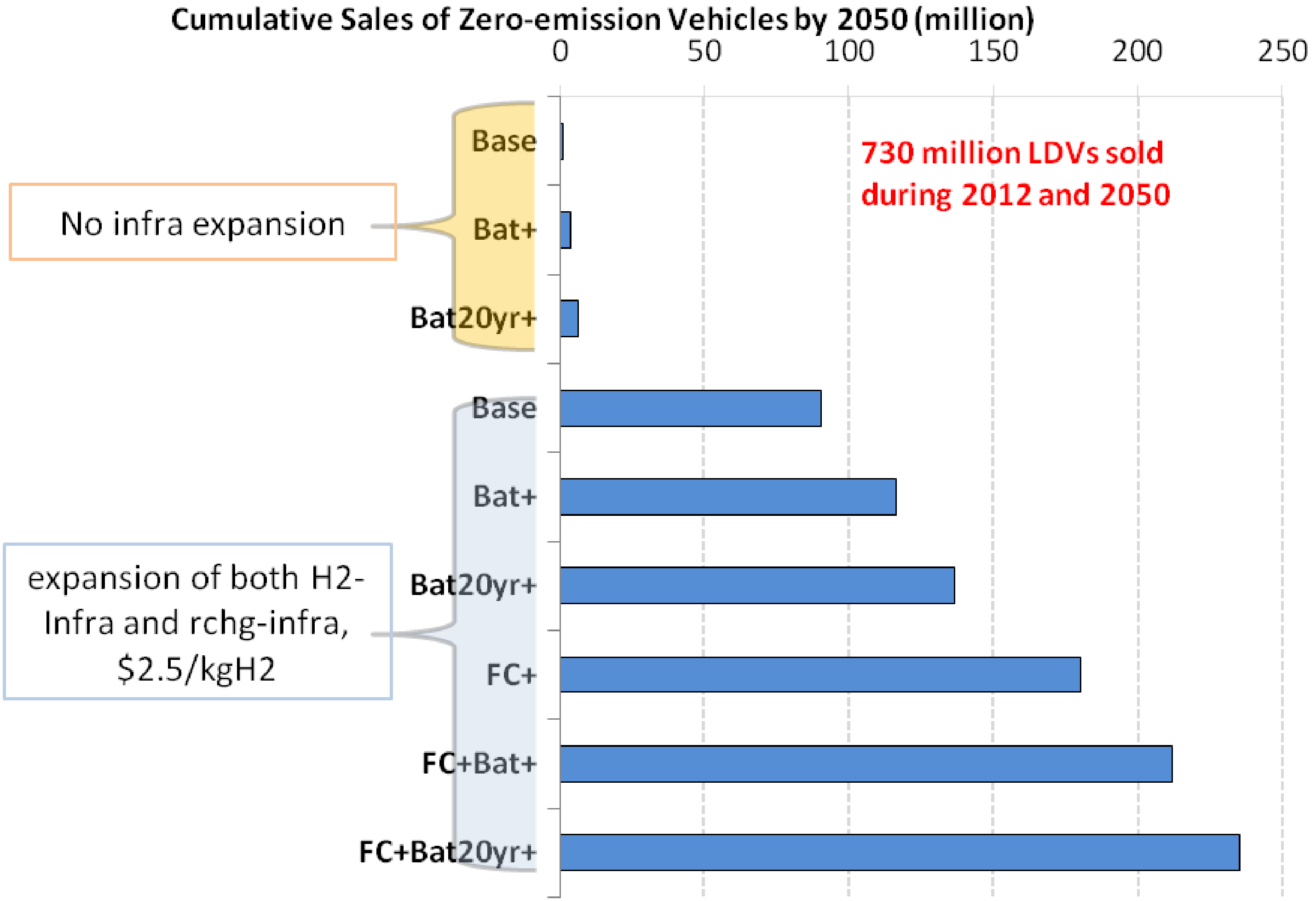
Air Quality

Success of both battery **&** FC technologies could result in 30% to 40% ZEVs on the road in 2050



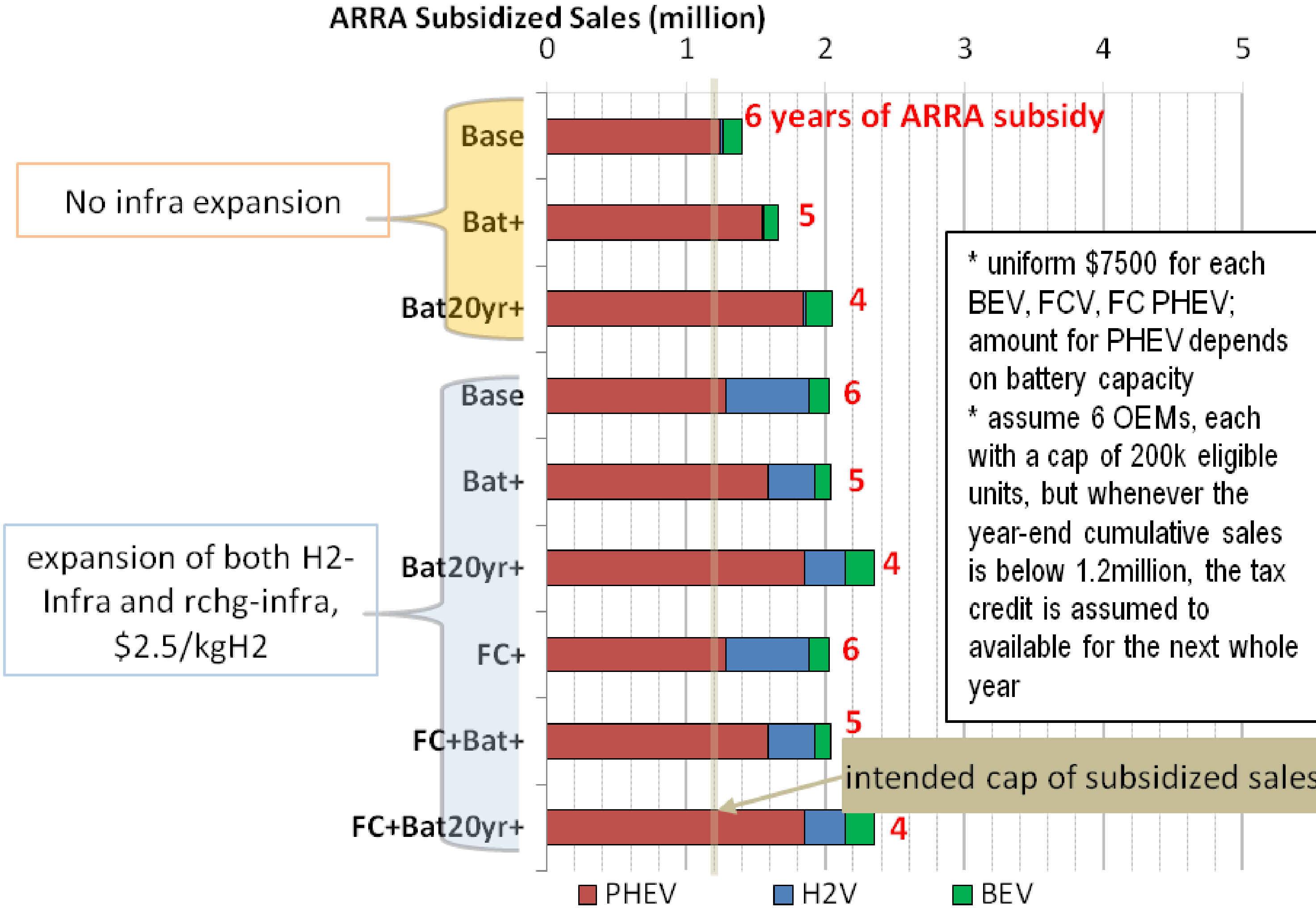
H2-LDV transition

To bring more H2Vs to the road, FC success is the key, and battery success can facilitate.



Competing for ARRA Tax Credit

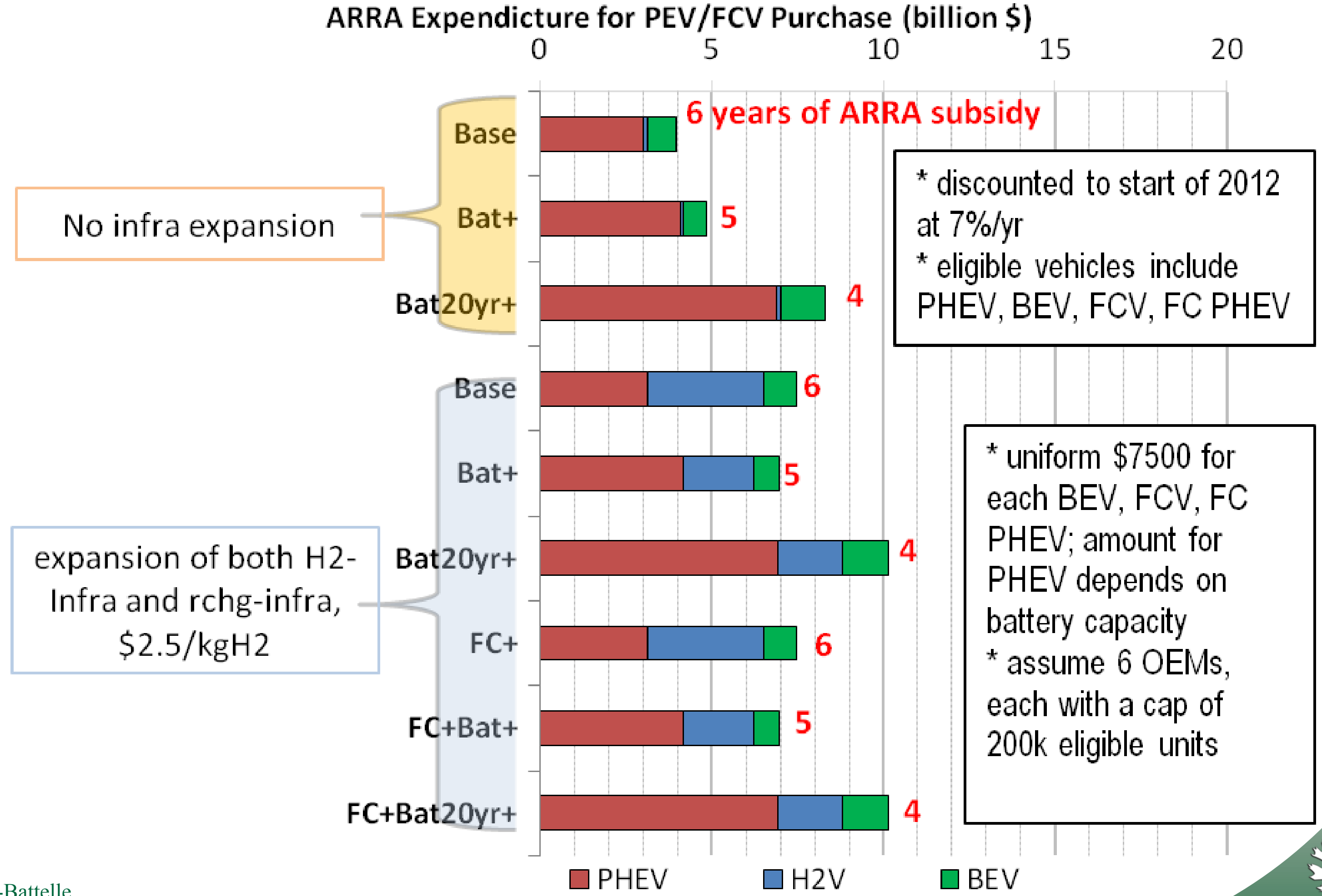
1. In general, faster progress on battery has a bigger impact on number of subsidized PHEVs
2. Faster progress on FC has little impact on number of subsidized H2V



* uniform $7500 for each BEV, FCV, FC PHEV; amount for PHEV depends on battery capacity
* assume 6 OEMs, each with a cap of 200k eligible units, but whenever the year-end cumulative sales is below 1.2million, the tax credit is assumed to available for the next whole year

ARRA subsidy costs depend on technology progress, infrastructure provision, and H2 price.

Effect of technology progress on ARRA vehicle subsidy



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Improvements on fuel cell and storage improves cost-effectiveness of public investment

Effect of technology progress on cost-effectiveness of public investment