Making Vehicle Technology Deployment Scenarios More Robust

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Center for Transportation Research

Argonne National Laboratory

2013 Vehicle Technologies Annual Merit Review

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Project VAN001

Overview

Timeline

FY12:

- Start Date: Oct 2012 (Funding arrived May 2012)
- End Date: Sep 2013
- Percent Complete: 80%

FY13:

- Start Date: Oct 2012
- End Date: Sep 2013 (24% of funds received)
- Percent Complete: 20%

Barriers

- Vehicle deployment involves complex decision-making and multiple actors
- Lack of data on capital costs of key vehicle deployment infrastructure
- Lack of analysis of vehicle market barriers and trends
- No suitable supply-side model

Budget

Total Project Funding (DOE)

- FY12: $425k
- FY13: $440k

Partners

Interaction/Collaborations

- Oakland Univ., deployment pathways
- NREL, Transportation Energy Futures study
- IPCC transport mitigation chapter team
- NAS Committee on Potential for LDV Technologies, 2010-2050

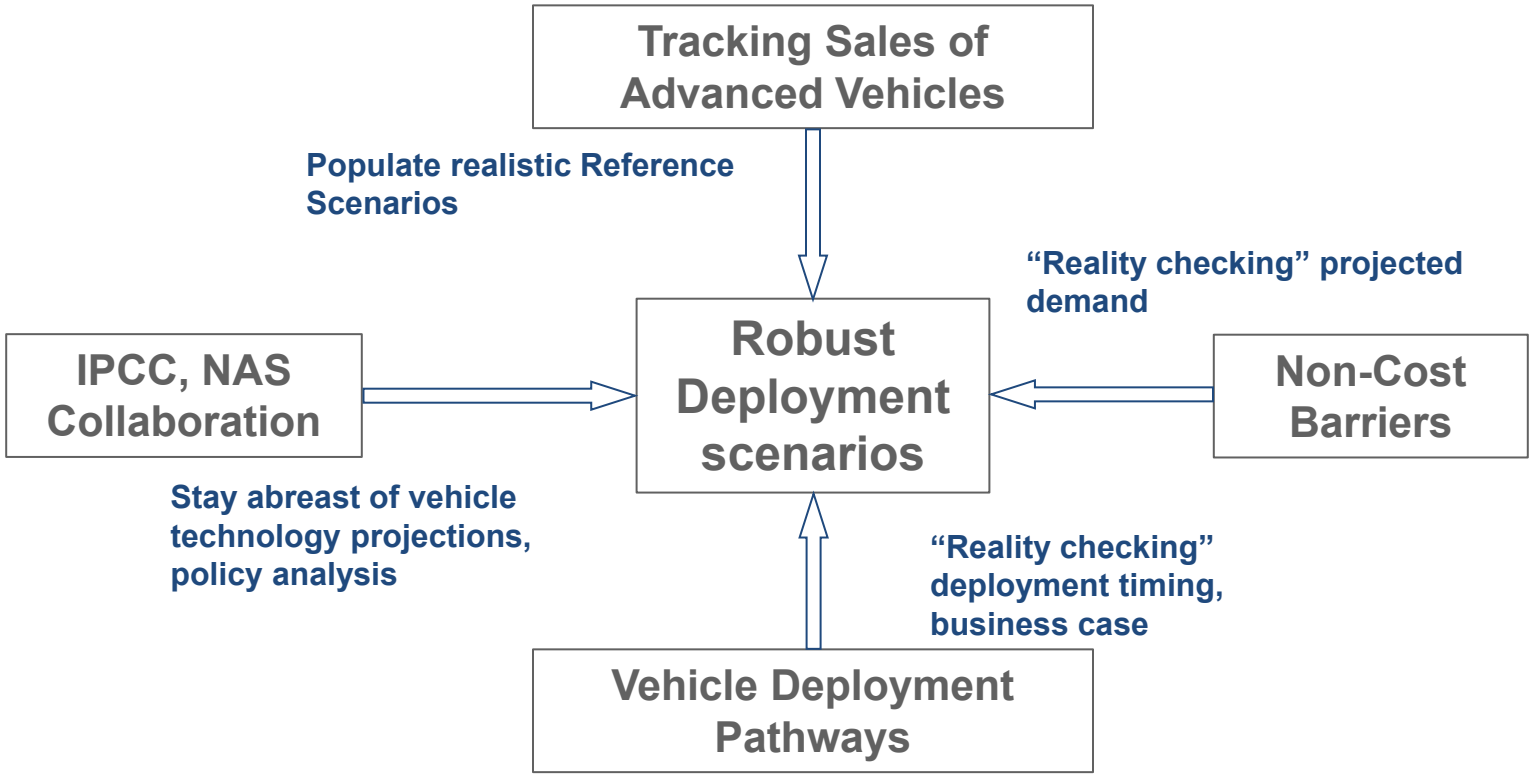
Overview (continued)

Project VAN001 has several tasks

1. Vehicle Deployment Pathways – developing methods to make deployment scenarios more robust (part of the Transportation Energy Futures (TEF) study)
2. Non-cost Barriers to Technology Deployment (part of TEF) – Quantify and rank non-cost barriers to consumer adoption of advanced technology vehicle based on literature review
3. IPCC collaboration – corresponding author on transport chapter, mitigation report, IPCC 5th Assessment Report
4. NAS – consulting on vehicle technology chapter, ongoing report on The Potential for Light-Duty Vehicle Technologies, 2010-2050
5. Trends in advanced vehicle sales – tracking HEV and PHEV sales in U.S.
6. Coordinating development of standardized vehicle simulation results for use in multiple consumer choice models
7. Rapid analysis/review of proposed rules, DOE draft documents, etc.

Relevance

These tasks all support development and analysis of scenarios of reduced petroleum use and GHG emissions from vehicle technologies



Enable EERE-VTP to assess potential impacts of R&D, set priorities and targets, and assess benefits of EERE-VTP technologies

The Vehicle Deployment Pathways task examines methods to make scenarios of penetration of advanced vehicle technologies more robust.

***Examining Hydrogen Transitions*, Plotkin, S.E., Argonne National Laboratory, 2007**

"Most … analyses …..skirt the issue of the transition and look at the "end state' where hydrogen has become a primary vehicle fuel…..most simply postulate a degree of hydrogen penetration ….most do not describe any attempt to conduct a "reality check" on the scenarios….offer little insight about what conditions and/or policies would actually lead to their postulated levels of hydrogen penetration."

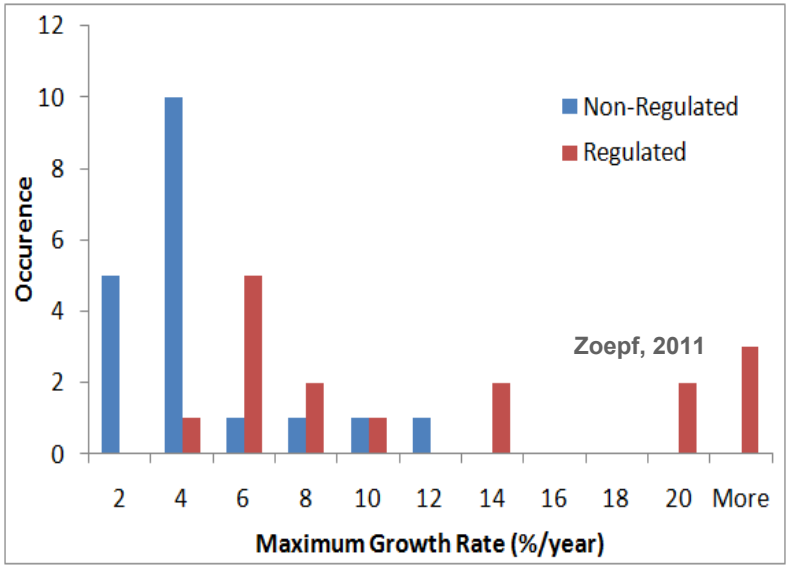
Objectives

1. **Examine recent scenarios of vehicles and fuels deployment, identify examples of "reality checking" scenarios or analytical methods of projecting deployment levels**
2. **Derive a vehicle deployment schedule, identify choke points**
3. **Develop a method to examine the business case for investments demanded by scenarios, explicitly incorporating uncertainty**

Relevance

1. **Help to check realism of VT deployment goals**
2. **Help DOE evaluate vehicle deployment goals/scenarios of other organizations**
3. **Understanding business case allows analysis of proposed economic incentives**

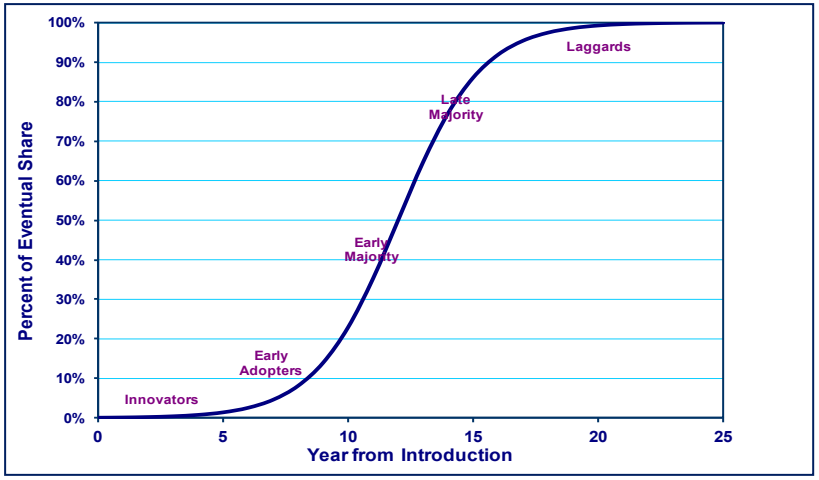
Our approach: Review and synthesize scenario reports, technology timing data, industry reports, economic/business literature on investment strategy



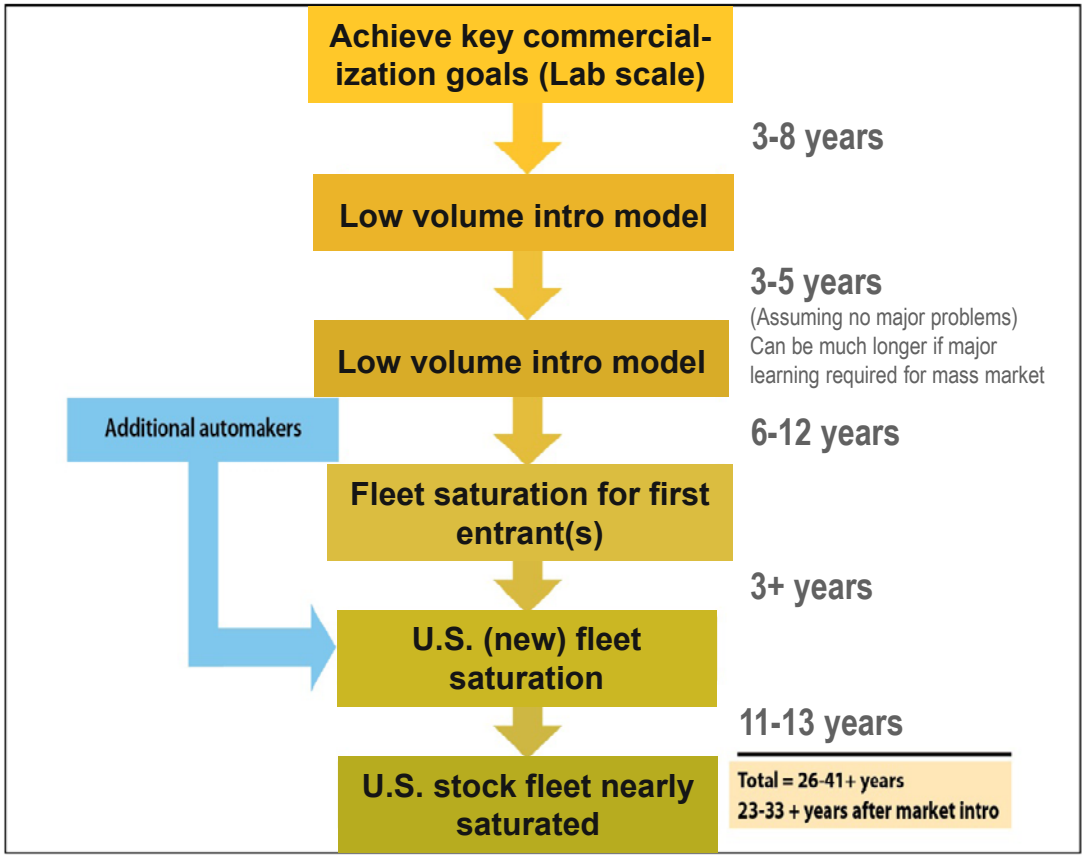
Zoepf, S.E. (2011). Automotive Features: Mass Impact and Deployment Characterization, MIT Master's Thesis, June.

- Analyses of EPA data on technology trends from various sources
- Basic literature on technology penetration, e.g. Rogers
- Literature on investment strategy
- Industry sources, e.g. Center for Automotive Research

- Identify maximum technology penetration rates
- Evaluate methods to represent investor decision behavior



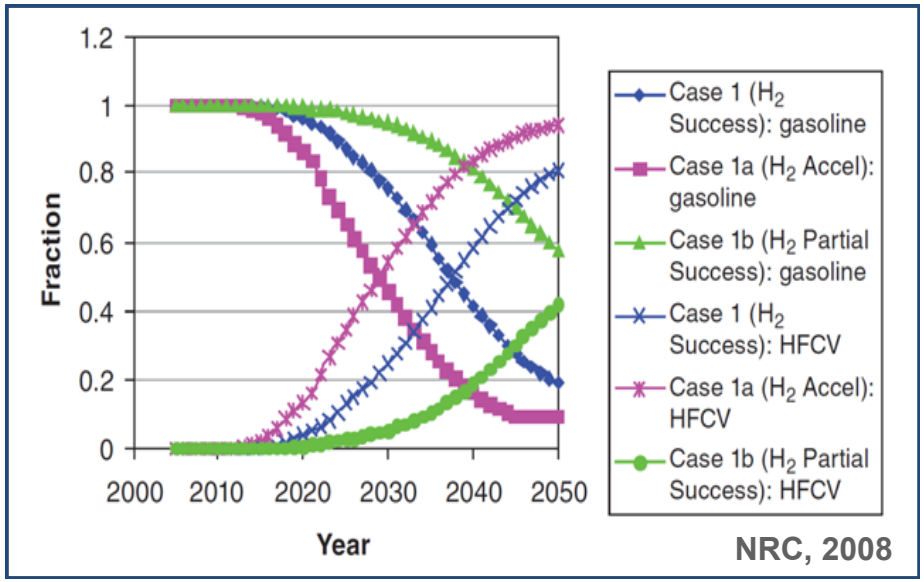
Technical accomplishments: We built a template for vehicle technology deployment timing



- Based on multiple sources
- Note that there is substantial potential for delays, esp. for the transition to the mass market
- Template does *not* incorporate fuel infrastructure deployment… requires additional analysis
- As noted, template was applied to some existing scenarios

A key remaining uncertainty: the significance of recent developments in computer simulation and design, rapid prototyping, modular platforms, and other ways of fast-tracking deployment

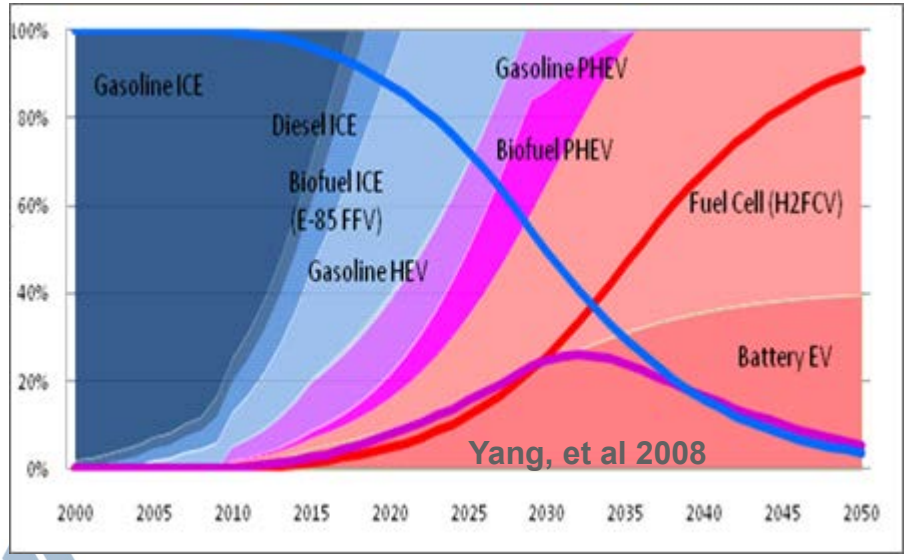
Study results/insights applied to existing scenarios:



NRC H2 Study

- Maximum rate of deployment increase < 4%/yr, OK by historic standards
- Time from market entry to mass market < 10 years despite need for complex infrastructure, unproven technology – **appears unlikely**

National Research Council (2008). *Transitions to Alternative Transportation Technologies: A Focus on Hydrogen*, Committee on Assessment of Resource Needs for Fuel Cell and Hydrogen Technologies, Board on Energy and Environmental Systems.



UCDavis 2050 Study

- Scenario for 80% GHG reduction
- Examine implications for industry
- PHEVs have 50% market share in 2028; *all* ICE drivetrains at zero share by 2035 – implies huge stranded investments

Yang, C., D. McCollum, W. Leighty (2011) Chapter 8: "Scenarios for Deep Reductions in Greenhouse Gas Emissions," Ogden, J. and L. Anderson (eds.), in *Sustainable Transportation Energy Pathways: A Research Summary for Decision Makers*, Institute for Transportation Studies, University of California at Davis.

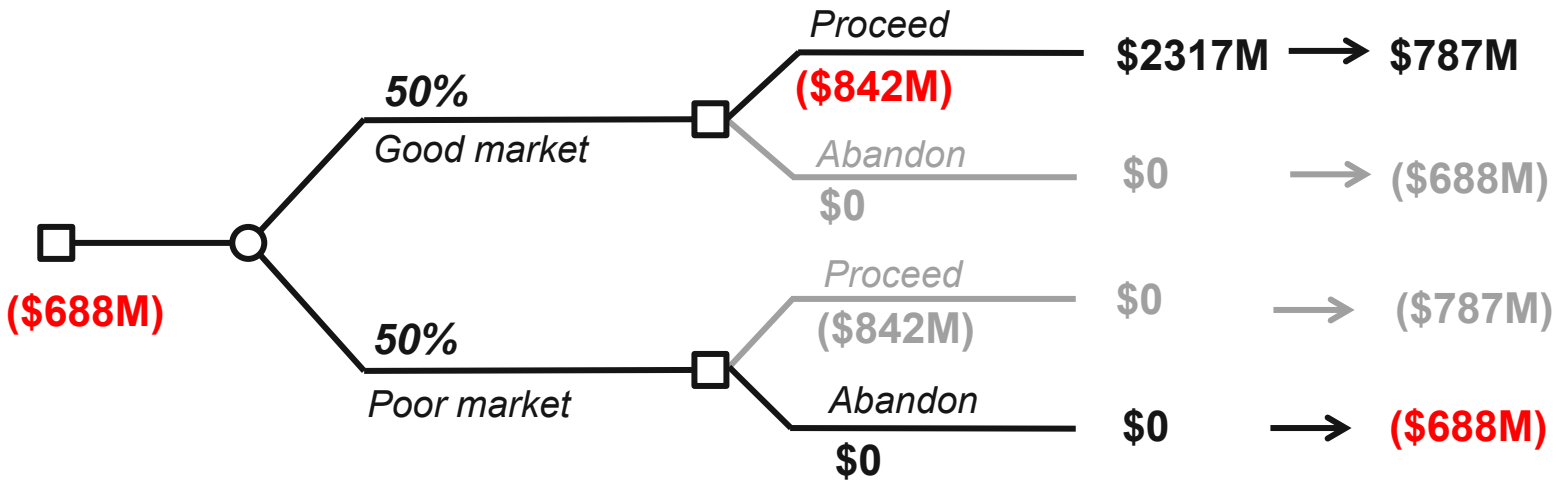
We examined alternative ways of replicating "due diligence" on deployment investments

1. Cash flow analysis
   - Calculate the NPV (net present value) of investments and revenues
   - Use an appropriate discount rate for the required rate of return, RRR
     - Use weighted average cost of capital (WACC)
     - Also take into account risks/uncertainties unique to the proposed project, r_u $\quad RRR = WACC + r_u \leftarrow$ Hard to estimate r_u *a priori*
2. Decision tree analysis
   - Identify one or two major decision points
   - Define two or three possible outcomes of decisions for each
   - Estimate probabilities of uncertain outcomes
   - Estimate cash flows for each branch, discounted at appropriate rate*
   - Use decision tree analysis to evaluate the project

*Discount at industry-relevant WACC if the decision tree captures the risk

Simple example of taking options into account, using a decision tree

Deploying a new technology requires $750M in year 0 and $1000M in year 1 and has a 50% probability of returning $3000M in year 3 and 50% probability of zero return, depending on future market conditions.
(Values shown are present values, at a discount rate of 9%)

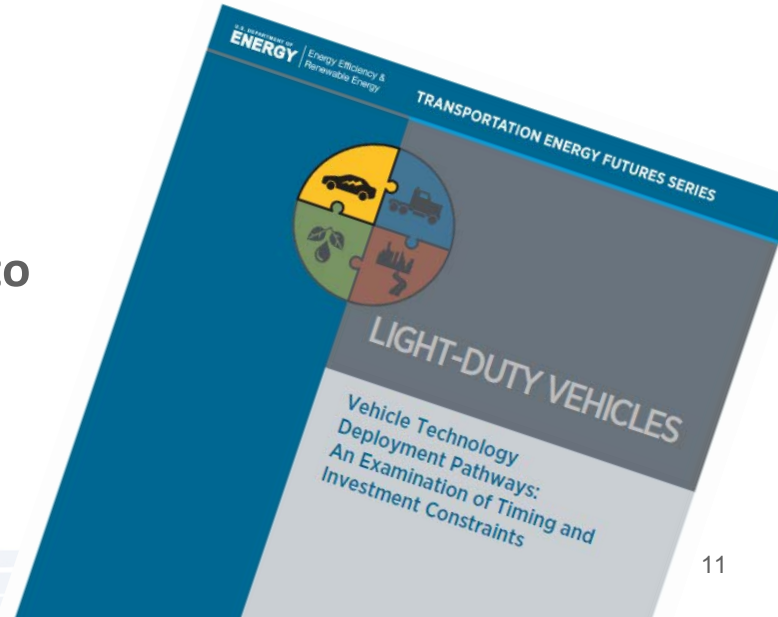


Our simplified tree has a project value of = $(0.50)(\$787M) + (0.50)(-\$688M) = \$49M$

compared to the NPV of –$15 M if we don't account for the option of abandoning after the first investment! The option is worth $34M!

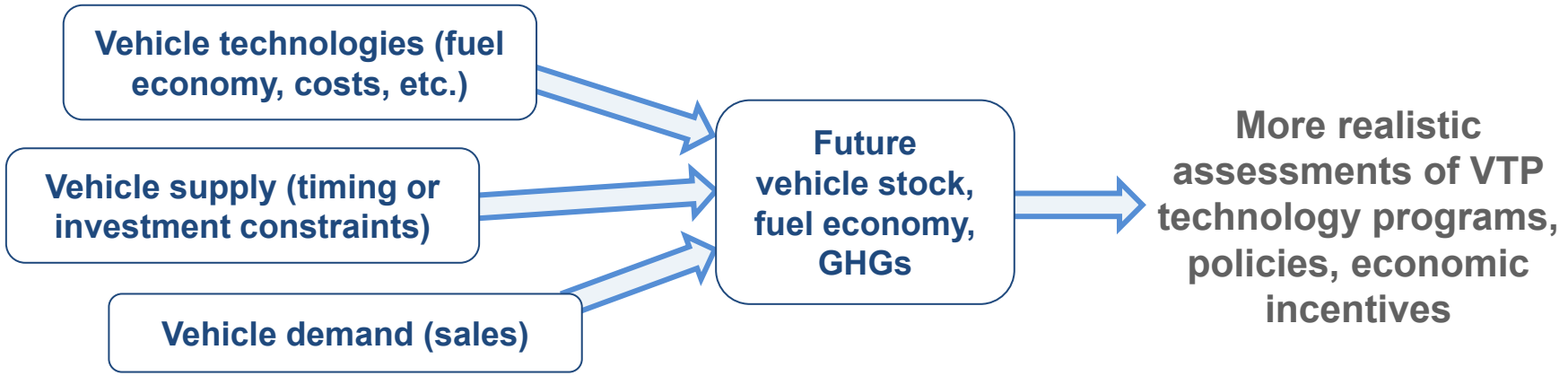
Although scenarios will always be highly uncertain, our results can be used to make them more credible

- Check proposed timing and market penetration rates against historical precedent; especially, be skeptical of rapid shift from niche market to "majority" market
- Do some "reality checking." Examine cash flow and likely returns. Consider whether businesses would be likely to invest
- Construct simple decision trees, with a few major branches and estimates of probabilities for each, e.g.
  - "Best Guess" (60%?)
  - Optimistic, all DOE goals met (10%?)
  - Disappointment (30%?)
- These methods allow scenario developers to take timing, cash flows and uncertainty explicitly into account



Technical accomplishments: Other tasks

- Reviewed and ranked non-cost barriers to adoption of advanced-technology vehicles
  - Ranked barriers by estimated severity and policy effectiveness
  - Non-cost barriers are significant, but policy options exist
- Tracked and analyzed sales trends of HEVs and PHEVs
  - Initial market penetration rates of HEVs and PHEVs are similar
- IPCC 5th Assessment Report – Contributed to Transportation chapter, addressed hundreds of reviewer comments
- Consulted on vehicle technology chapter of National Research Council report on The Potential for Light-Duty Vehicle Technologies, 2010-2050



Technical accomplishments: Other tasks

- **Standardized vehicle simulation results and other data for use in several consumer choice models for predicting vehicle sales shares**
  - **Defined format and data dictionary for vehicle simulation outputs**
  - **Format and data dictionary for non-vehicle parameters under development**
  - **Will permit head-to-head comparison of different models**
- **Rapid analysis/review of proposed rules, DOE draft documents, etc.**
  - **EERE draft report on Prospective Impacts of the EERE Portfolio**
  - **EERE programmatic records**
  - **EPA prosed rulemaking**
  - **National Petroleum Council's Future Transportation Fuels study**

The data and analysis that these tasks provide enable EERE-VTP to

- Assess potential impacts of R&D
- Make informed decisions about priorities and targets
- Communicate to others about the impacts of EERE-VTP

Collaborations & Coordination

Deployment Pathways

- Collaborated with W. McManus, Oakland University (with UMTRI at project start) on methodologies for examining business cases
- Coordinated with A. Brown and L. Vimmerstedt (NREL) on related work under the Transportation Energy Futures study

Other collaborations:

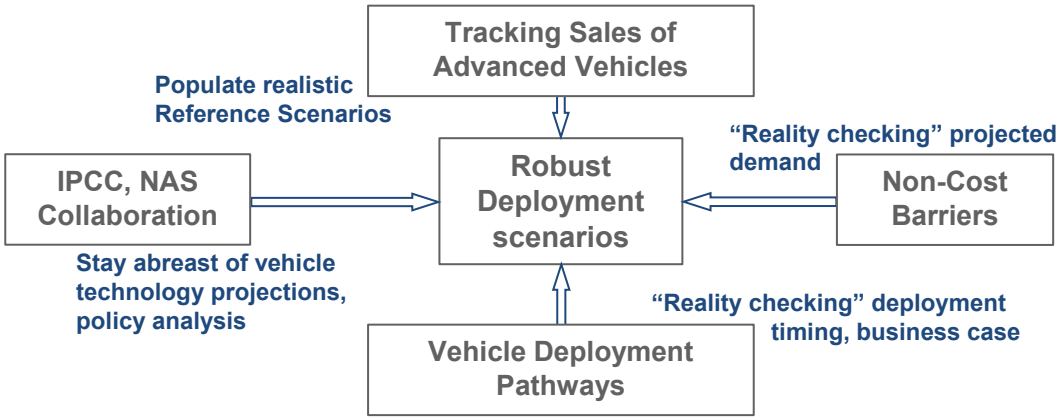
- Consulted for John German, ICCT and other chapter leads for the vehicle technologies chapter, NRC Committee on the Potential for Light Duty Vehicle Technologies 2010-2050
- Extensive consultation (including drafting, review) with lead authors of the transport chapter, Working Group 3, Fifth Assessment Report, Intergovernmental Panel on Climate Change
- Collaborating with Z. Lin (ORNL), A. Birky (TA Engineering, Inc.), A. Brooker (NREL) and A. Vyas (ANL) on standardizing vehicle choice inputs

Proposed future work:

- Deployment Pathways
  - Evaluate recent developments in computer simulation and design, reduced number of platforms, etc. in accelerating technology deployment
  - Extend timing and investment analysis work to fuel infrastructure deployment
  - Develop more realistic decision trees for technology deployment scenarios
  - Develop a data base of capital building blocks for vehicle technology deployment (similar to H2A for hydrogen), to assist developing decision trees
  - Evaluate whether this type of analysis can be applied to complex models such as NEMS, MARKAL
- Tracking trends: track global sales trends
- Analysis methods: improve and integrate models: vehicle simulation, consumer choice, stock energy/emission models
- Interagency collaboration: Support studies, committees, conduct reviews as needed

Summary: Our results can be used to make scenarios of advanced vehicle deployments more credible

- We reviewed historical timing and market penetration rates, recent developments in deployment timing. These can be used to check rates in scenarios
- Methods for examining the business case for supplier investments were reviewed. We conclude:
  - Cash flows and likely returns for a given scenario should be examined
  - Decision tree analysis is proposed for representing major decisions and stages of deployments and to take uncertainties and investor behavior into account
  - These should allow better evaluation of alternative scenarios (e.g. technologies, policies)
- Together with knowledge of trends, projections and barriers from other tasks, we directly support EERE-VTP assessment of advanced vehicle technologies



Separator for Technical Back-up Slides

DOE and others use complex models, and we reviewed how these models examine the business case

- NEMS (National Energy Modeling System)
  - Technologies have a cost timeline
  - Businesses invest in what consumers want, based on costs, other attributes, embodied by the Vehicle Choice Model – "if they buy it, we'll build it"
  - Three year payback in fuel savings seems to be the cutoff point……and industry has stated that it believes this reflects what its customers value
  - But this understanding reflects incremental technologies where we have good knowledge of future costs and strong belief in consumer acceptability
  - *Neither condition exists for the new technologies of most interest!*
  - Timing: incremental improvements have constraints on rate of market penetration (faster if needed for CAFE compliance); new drivetrain technologies do not

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More on models:

- MARKAL Linear Programming Model
  - Perfect foresight model without risk
  - Under given assumptions and constraints, yields least-cost pathways for vehicle types and fuels to meet VMT service demands
  - Constraints can be supplied to limit market penetration rates
  - Doesn't address what business would do with risky investments and uncertain view of the future (in other words, the real world)

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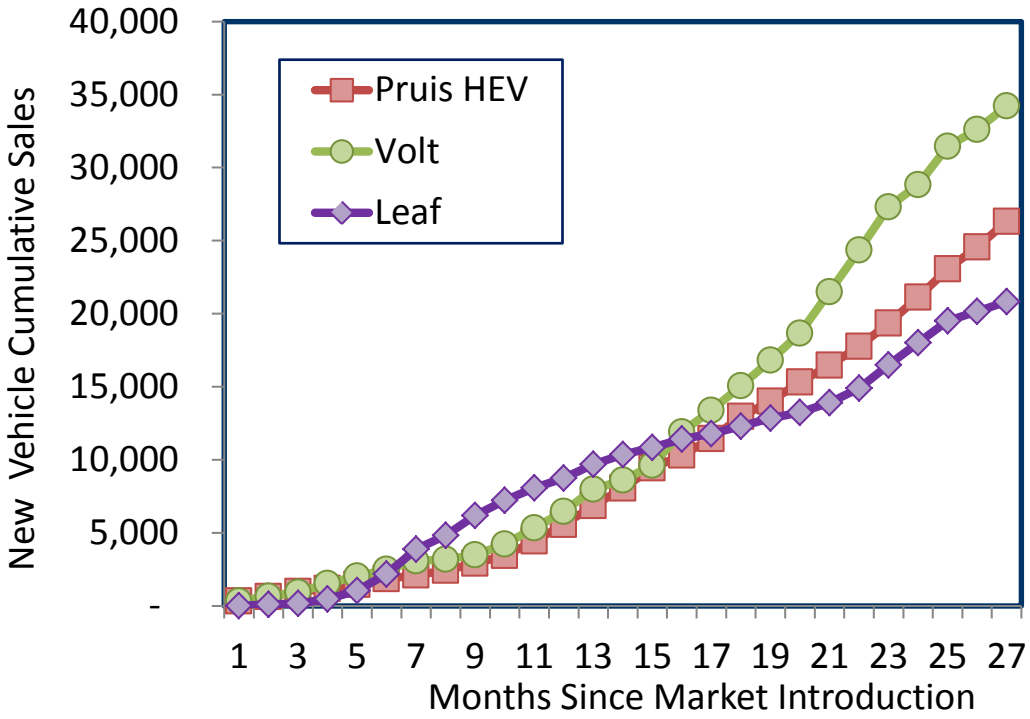
Proposed ranking of non-cost barriers to consumer adoption of advanced-technology vehicles

Non-cost Barrier	Effective Cost	Governing Factors	Possible Policies	Potential Policy Effectiveness	Policy challenges
Limited driving range, fueling/charging stations	$1000 - $10,000	Range, driver mobility needs	Pilot programs, information	Probably somewhat effective	Tailoring policies to consumers
Unfamiliarity, uncertain of benefits	$100 - $10,000	Prevalence, early adopters	Labeling, info, outreach	Effective	Tailoring policies to early adopters, sustainment
Predisposition or perceived differences	$100 - $10,000	Social and behavioral factors	Labeling, info, outreach	Effective	Tailoring policies to early adopters, sustainment
Lack of technology standards	>$1,000	Technology maturity	Testing, standard-ization	Effective	Complexity of future technology and business models
Limited availability of models/makes	$100 - $10,000	Consumer preferences, modularization	R&D	Limited	Limited role

Stephens, T. (2013) "Non-Cost Barriers to Consumer Adoption of New Light-Duty Vehicle Technologies," Transportation Energy Futures Series. Prepared for the U.S. Department of Energy by Argonne National Laboratory, Argonne, IL. DOE/GO-102012-3709. 47 pp.

Tracking sales of HEVs and PHEVs allows comparison of market penetration since market introduction



- U.S. sales of HEVs and PHEVs tracked by model and by month
- Sales data from China, Japan are also tracked

Data summaries available at
http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

Milestones

Month/ Year	Milestone or Go/No-Go Decision	Description	Status
Feb 2012	Milestone	Transportation Energy Futures study reports: Transition Pathways and Non-Cost Barriers	Complete
As requested	Milestone	Report on participation in NAS “Potential for Light Duty Vehicle Technologies 2010-2050” study	Complete
Monthly	Milestone	Reports on trends in sales and other trends	On schedule
As requested	Milestone	Document defining standardized format for vehicle choice model input	50% Complete
May 2013	Milestone	Progress report on vehicle deployment scenarios	On schedule
Jul 2013	Milestone	Report/presentation on IPCC activities	Not started

Performers also provide analyses and review of vehicle- and fuel-related reports, proposed rules, programmatic documents, etc., as requested.