Transportation Energy Transition Modeling and Analysis: the LAVE-Trans Model

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OAK RIDGE NATIONAL LABORATORY
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OVERVIEW

Timeline

- Project start date: Oct. 2013
- Project end date: Continuing

Barriers/Targets*

- Understand the role of DOE VTs in an energy transition
- Costs of advanced powertrains
- Behavior of manufacturers and consumers
- Infrastructure
- Incentives, regulations and other policies

**from 2011-2015 VTP MYPP*

Budget (DOE share)

- FY14 funding: $110k

Partners

- NRC Committee on "Transitions to Alternative Vehicles and Fuels" (2013)
- The International Council on Clean Transportation (ICCT)
- University of Tennessee
- Argonne National Laboratory

Relevance

Objectives of LAVE-Trans Project

- **Understand the transportation energy transition process by modeling the interplay between technologies, consumer market, policies, and infrastructure.**
- **Assess the potential of vehicle technologies in meeting the goal of petroleum and CO2 reduction**
- **Quantify the costs and benefits of the transition**
- **Provide guidance to the transition**

Addressing Barriers

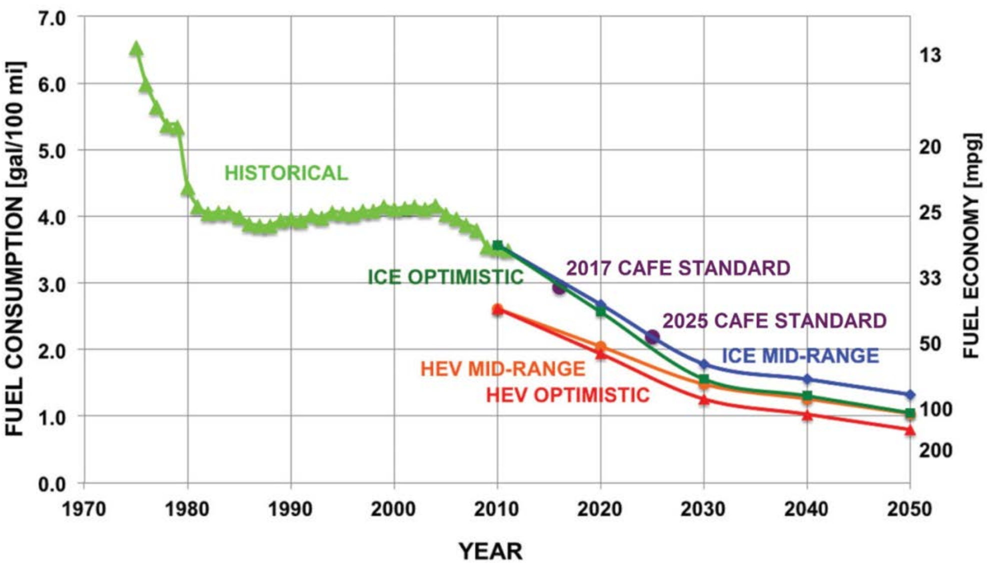
- **Explicitly model transition barriers (e.g. higher technology cost, lack of infrastructure) and evaluate the role of policy strategies in overcoming barriers**

Relevance

Originally developed and used for NRC study (2013)

- **Evaluate the potential of transition scenarios in meeting the 2050 goal of CO2 emissions and petroleum consumption reduction**

Continuously improving energy efficiency appears to be a necessary strategy



Further development under DOE support

- **An alternative consumer choice model for model comparison and cross validation**
- **Understand the role of DOE vehicle technologies in the context of the energy transition and related costs and benefits**

National Research Council (2013). Transitions to Alternative Vehicles and Fuels. Washington, DC: The National Academies Press..

Approach: Built upon discrete choice theory, the LAVE-Trans model represents and quantifies the key processes and barriers to the transition, including many positive feedback loops.

INPUTS:
- Vehicle and fuel attributes
- Infrastructure
- Consumer behavior assumptions
- Policies

Feedback loops

MODEL:
- Consumer choice model based on nested logit
- Model barriers and positive feedbacks in energy transition

OUTPUTS:
- Vehicle market share, sales, energy use and emissions
- Costs & benefits of the transition
- Optimal transition Strategies

Approach: LAVE-Trans models and tracks major market barriers of the transition and network external benefits (positive feedbacks) of overcoming barriers

Market Barriers:

- Lack of Infrastructure
- Higher upfront purchase cost
- Lack of make & model diversity
- Risk aversion
- Current technology limitation (limited range, long charging time)

Positive Feedbacks: Increased vehicle sales will

- Enhance infrastructure viability
- Reduce vehicle production cost via manufacturers' scale economy and learning by doing
- Increase make & model diversity
- Reduce risk aversion of the majority

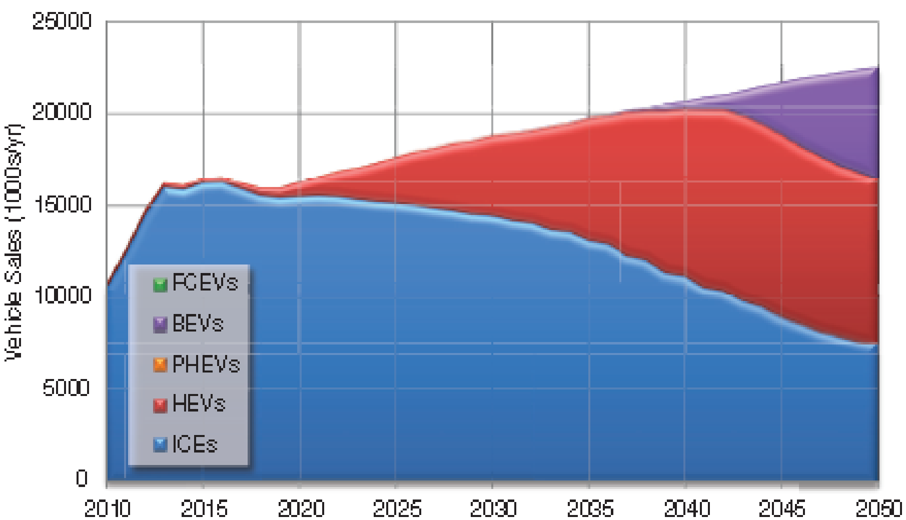
Self-reinforcing positive feedback effect may eventually lead to a self-sustained transition (It needs strong initial push).

Approach: LAVE-Trans recognizes the importance of policies to the success of the transition; strong and temporary subsidies/mandates are needed in the beginning.

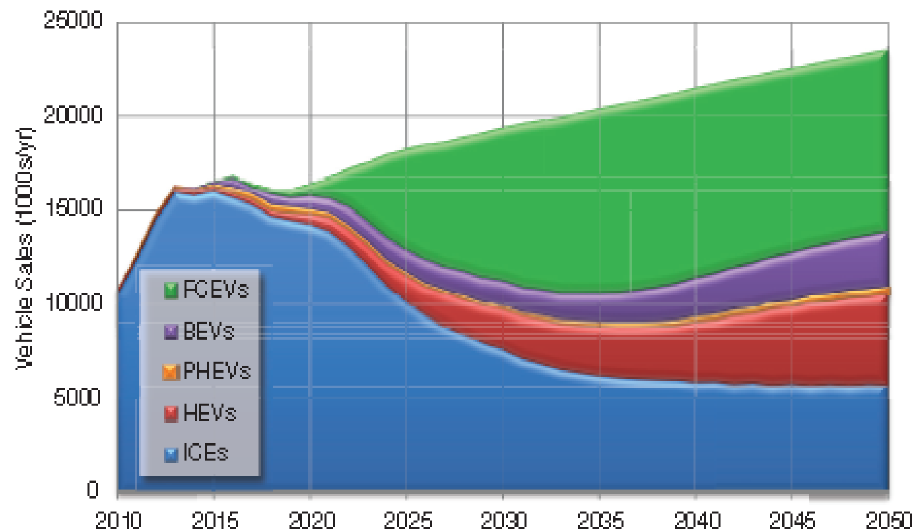
Base case assumptions:
- 2025 CAFE standards plus technological progress beyond 2025.

Policy case assumptions:
- Base case + vehicle subsidies/mandates for a decade or so + early H2 infrastructure.

Base Case Vehicle Sales



Policy Case Vehicle Sales



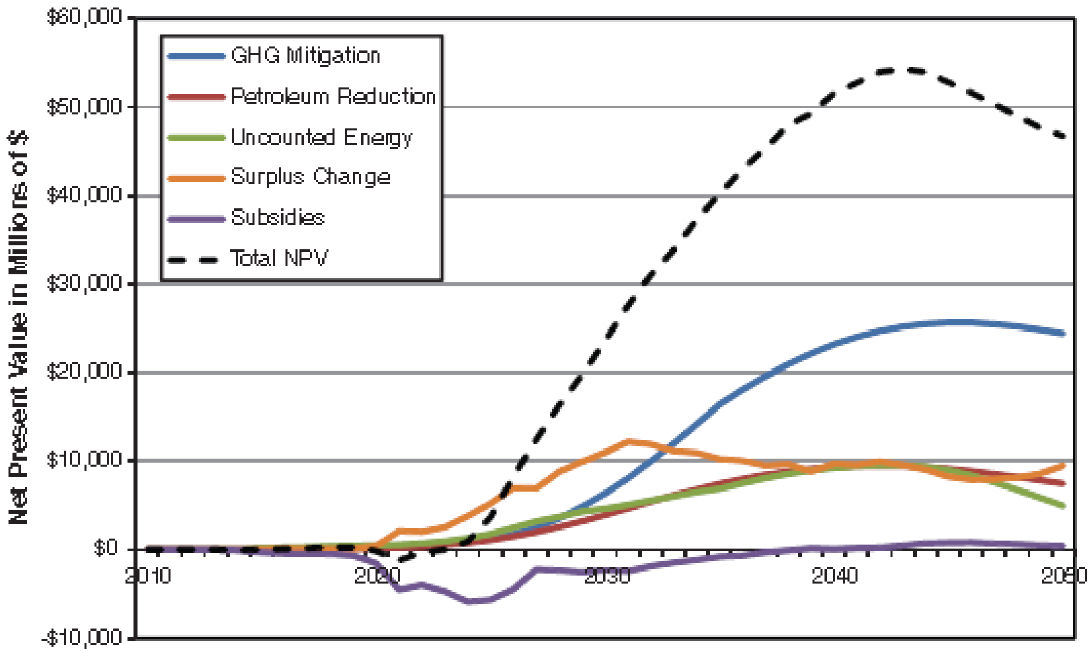
Approach: LAVE-Trans calculates the costs and benefits of the transition (by comparing a policy case with its base case)

Costs & benefits considered:

- **Subsidies**
- **Consumer surplus change**
- **Energy savings**
- **Social value of reductions of emissions and petroleum consumption**

Net Present Value (NPV) is the sum of all costs and benefits

- **The figures illustrates a transition scenario with large positive NPV.**



Technical Accomplishments in FY14

FY14 AOP Milestone	Due Date	Sub-task	Status as of 04/15/2014 (% completed)
Model Update	03/31/2014	Updated with AEO 2013	100%
Model Enhancement	06/30/2014	Revised to allow for alternative technology cost inputs	100%
		Improved representation of hydrogen infrastructure	90%
		Enhanced to conduct Monte Carlo simulation with market and technology uncertainty	100%
Analysis	06/30/2014	Preliminary results on costs and benefits of the transition to electric drive under uncertainty	90%
Reporting	09/30/2014	Update Model Document	0%
		Submit papers for peer-reviewed publication	50%
Additional Achievements	N/A	Add two-region version of model (ZEV states & rest of US) and analyze the role of CA & ZEV states in transition to electric drive	100%

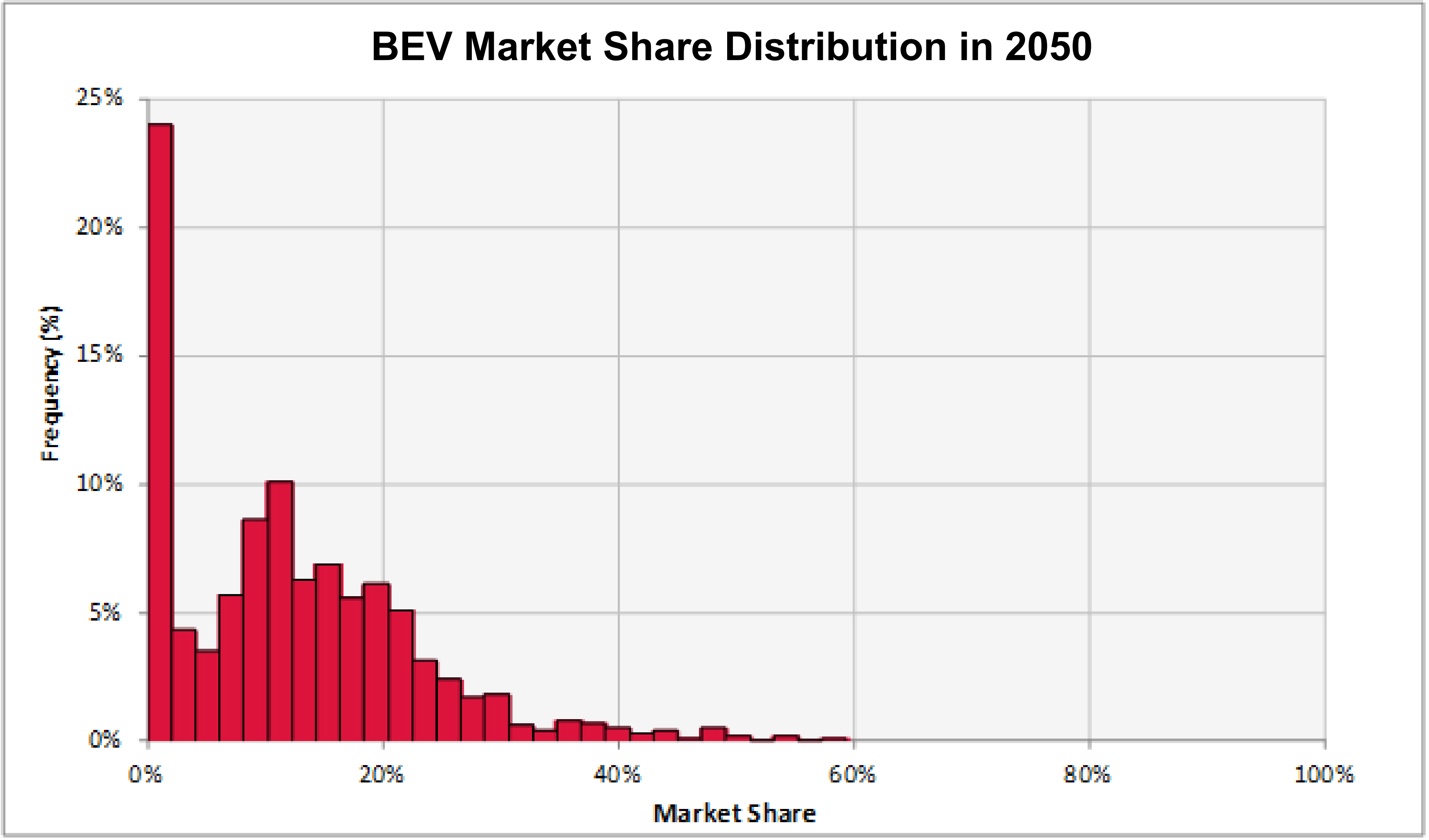
Technical Accomplishments: LAVE-Trans has been enhanced to conduct comprehensive uncertainty analysis of market shares and transition cost & benefits

Model parameters are specified as prob. distributions in Monte Carlo Simulation

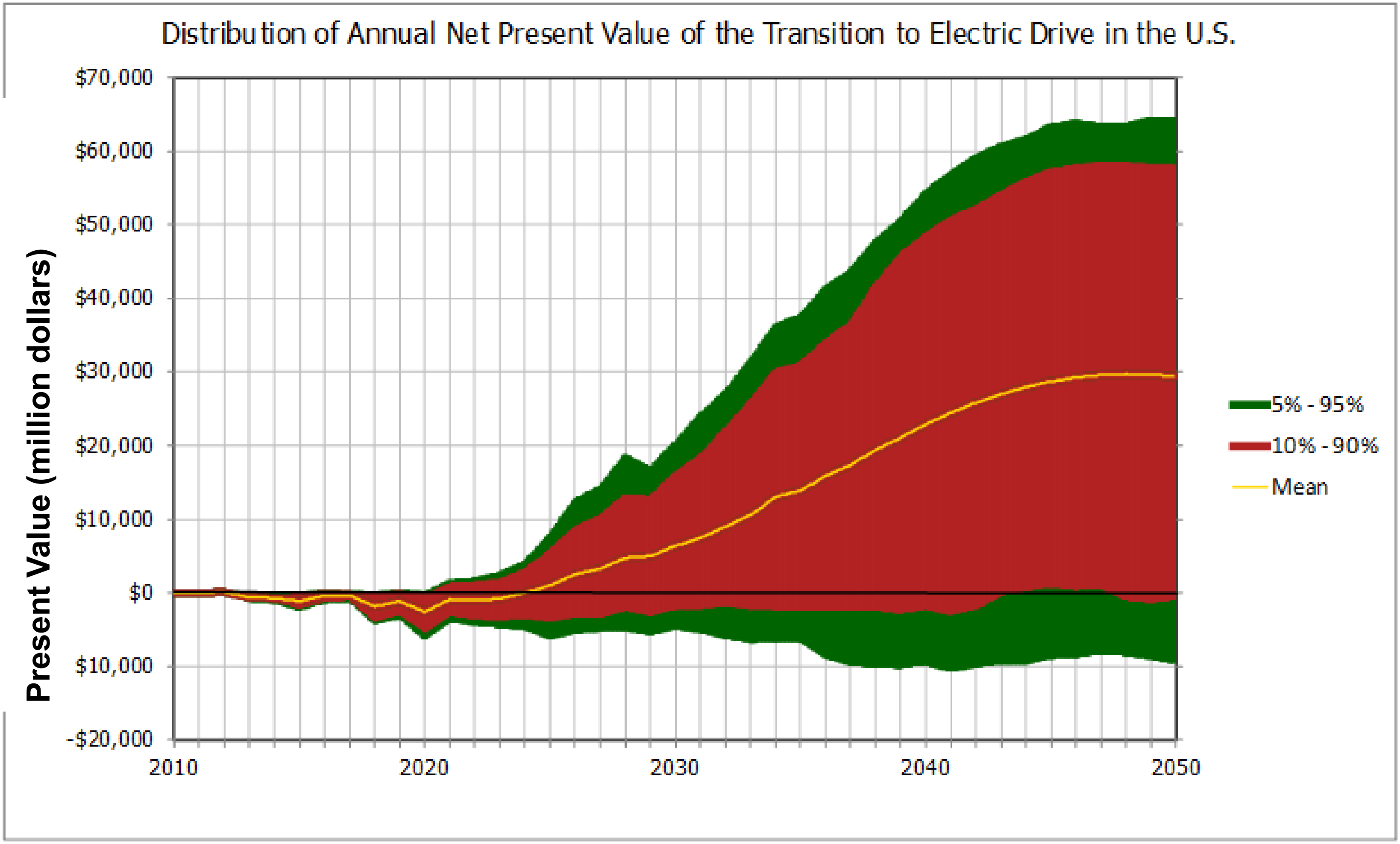
- **Market behavior**
  - **Manufacturers: learning by doing, scale economies**
  - **Consumers: pay back period, risk preference, value of model diversity, price elasticity, range anxiety, etc.**
- **Technology progress**
  - **Vary baseline cost by ±20%**

An algorithm is developed to calculate costs & benefits of each iteration in the simulation and then to derive the distribution of NPV under uncertainty.

Technical Accomplishments: Uncertainty about the market's response is great. There is a risk of having very low market penetration.



<u>Technical Accomplishments :</u> Almost certainly, annual NPV<0 until 2020; the likelihood of net benefits increases to about 90% by 2040.



Responses to Previous Year Reviewer Comments

- **The project has not been reviewed in previous years, but has been extensively reviewed when it was used for NRC study . The model was significantly improve by incorporating the comments.**
- **We look forward to your comments, recommendations and advice.**

COLLABORATION AND COORDINATION

- **National Research Council (NRC) committee on "Transitions to Alternative Vehicles and Fuels"**
  - Providing data and numerous feedbacks on model assumptions and results
- **The International Council on Clean Transportation (ICCT)**
  - Providing data
  - LAVE-Trans is adapted for a project sponsored by ICCT
- **David Greene, University of Tennessee**
  - model development and policy analysis
- **Tom Stephens and Yan Zhou, Argonne National Laboratory**
  - Providing data and assisting in model testing and comparison

PROPOSED FUTURE WORK

- **Remainder of FY2014**
  - **Update model document**
  - **Make the model more user friendly and available to other researchers**
  - **Submit papers for peer-reviewed publication**
- **FY2015**
  - **Data update**
  - **Model Enhancement:**
    - **Improve representation of energy supply infrastructure**
    - **Improve the capability of uncertainty simulation**
  - **Comparison and cross validation with other DOE consumer choice models**
  - **Develop more insights of the transition by mathematical derivation**
    - **E.g., conditions of tipping points, strength of positive feedback**
  - **Decision making under uncertainty: explore robust and adaptive transition strategies by integrating LAVE-Trans and optimization**

Summary

- **Relevance: LAVE-Trans is a consumer choice model and transition costs/benefits analysis tool; the objective is to better understand the role of vehicle technologies in an energy transition.**
- **Technical Accomplishments: LAVE-Trans has been enhanced**
  - **Alternative vehicle data input**
  - **Two-region version of the model**
  - **Monte Carlo simulation capability for comprehensive uncertainty analysis**
- **Future work will further improve the representation of energy supply infrastructure, develop more understanding of the transition process, and integrate the model with optimization.**

Thank you!

Technical Back-Up Slides

Technical Accomplishments: 17 parameters are specified as prob. distributions in Monte Carlo simulation

Parameters	Distribution	Min	Mean	Max
Importance of diversity of makes and models to chose from	Triangle	0.50	0.67	1
Value of time ($/hr.)	Triangle	$10.00	$20.00	$40
Maximum value of public recharging to typical PHEV buyer	Uniform	$500	$1,000	$1,500
Cost of one day on which driving exceeds BEV range	Uniform	$10,002	$20,000	$30000
Maximum value of public recharging to typical BEV buyer	Uniform	$0	$500	$1,000
Importance of fuel availability relative to standard assumption	Triangle	0.67	1.00	1.67
Payback period for fuel costs (yrs.)	Triangle	2.0	3.0	5.0
Volume threshold for introduction of new models rel. to std. assumptions	Uniform	0.80	1.00	1.20
Optimal production scale relative to standard assumptions	Uniform	0.75	1.00	1.25
Scale elasticity relative to standard assumptions	Uniform	0.50	1.00	1.50
Progress Ratio relative to standard assumptions	Uniform	0.96	1.00	1.04
Price elasticities of vehicle choice relative to standard assumptions	Uniform	0.60	1.20	1.80
Percentage of new car buyers who are innovators	Triangle	5.0%	15.0%	20.0%
Willingness of innovators to pay for novel technology ($/mo.)	Uniform	$100	$200	$300
Cumulative production at which innovators WTP is reduced by 1/2	Uniform	1,000,000	2,000,000	3,000,000
Majority's aversion to risk of new technology ($/mo.)	Uniform	-$900	-$600	-$300
Cumulative production at which majority's risk is reduced by 1/2	Uniform	$500,000	$1,000,000	$1,500,000

Technical Accomplishments: LAVE-Trans developed an algorithm to obtain the distribution of NPV under uncertainty of market behavior and technology progress

Complexity

- Each iteration of the simulation has different market behavior and technology progress, which forms a new base case
- For each iteration, iteration-specific subsidies should be automatically applied in order to achieve a transition, which forms a new policy case
- Costs and benefits should be calculated by comparing iteration-specific policy case and base case.

The algorithm

For each iteration,

- Sample uncertain parameters; Form a new base case
- Solve for implied subsidies necessary to achieve the predefined electric drive market shares
- Calculate costs and benefits relative to the new base case