



INFRASTRUCTURE, SAFETY,
AND ENVIRONMENT

Managing Risks of Aggressive Policies to Promote Technology Transitions: Case of Renewable Energy Requirements

Robert Lempert

The Economics of Technologies to Combat Global Warming

Snowmass, August 4-5, 2008

Based on: [Impacts on U.S. Energy Expenditures and Greenhouse-Gas Emissions of Increasing Renewable-Energy Use](#), Michael Toman, James Griffin, Robert J. Lempert, TR-384-1-EFC 2008

Collaborators

- **Michael Toman, RAND**
- **James Griffin, Pardee RAND Graduate Schools**

What Are Impacts of Renewable Energy Requirements?

- **Renewable requirements**
 - Aim to reduce dependence on foreign oil, reduce greenhouse emissions, create markets for new technology, but
 - May have unintended consequences
- **Consider one aggressive proposal**
 - 25% renewables in U.S. electricity and fuels markets by 2025
- **Meeting this 25x25 goal would require significant deployment of new technologies**
 - Any estimate of the costs and other impacts of this requirement thus very sensitive to a wide range of technology and market uncertainties.

How can we gain the benefits and reduce the risks of such policies?

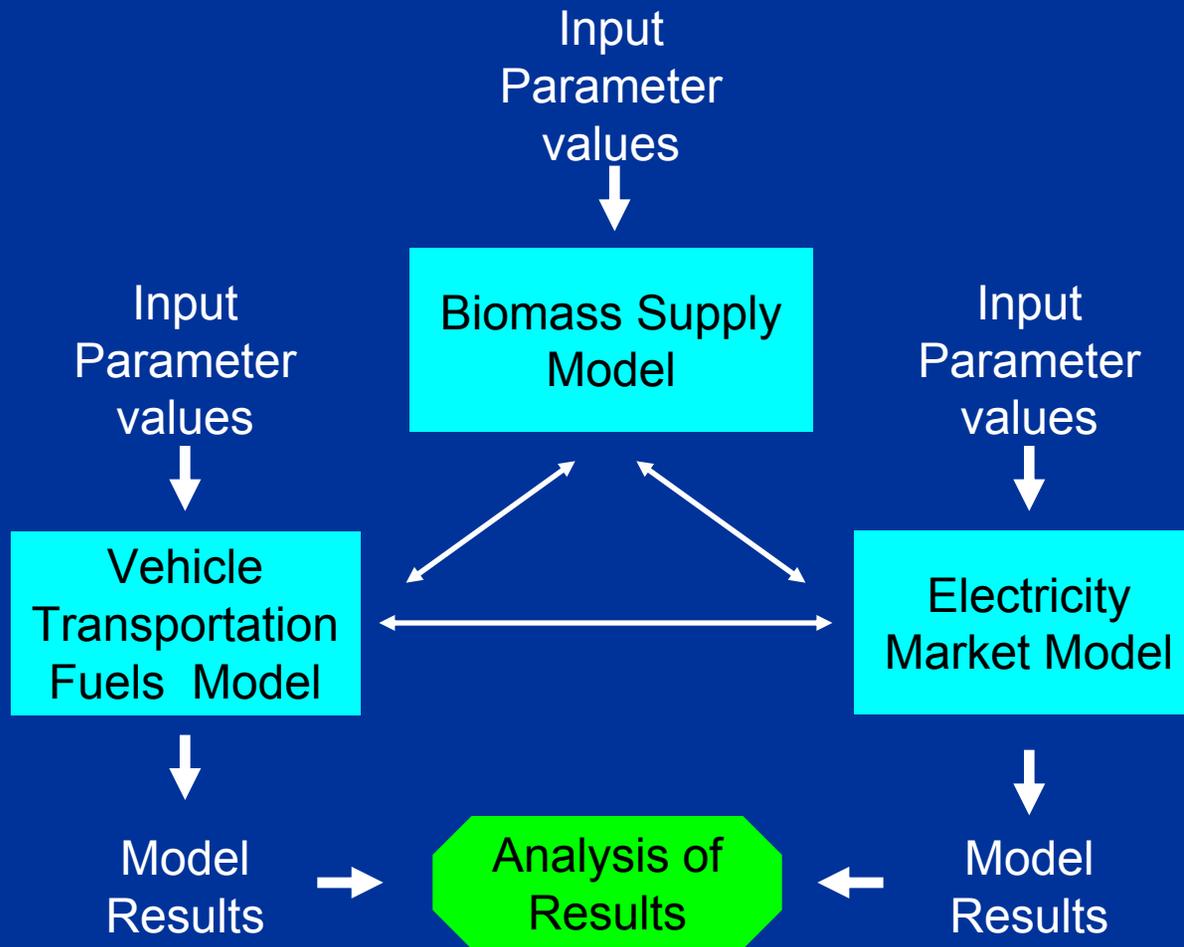
Outline

- **Impacts of 25x25 renewable energy requirement**
- **Policy designs to reduce risks of 25x25 proposal**

Analysis of 25x25 Policy Must Address Large Uncertainties

- **Simple simulation balances supply and demand in electricity and transportation fuels markets in 2025**
 - Links sectors via biomass feedstocks
 - Tracks prices, quantities, and expenditures
 - Considers impacts of renewable energy requirements
- **Simulation allows exploration of implications of a wide range of assumptions about technology and market characteristics**
 - Based on EIA 2006 projections
 - Reflects observation that
 - Future commercial costs of currently pre-commercial technologies are very difficult to estimate
 - Speed of technological innovation is quite uncertain
- **Use exploratory modeling approach to examine the**
 - Range of possible outcomes
 - Key assumptions that drive these outcomes
 - Means to make the policy more robust

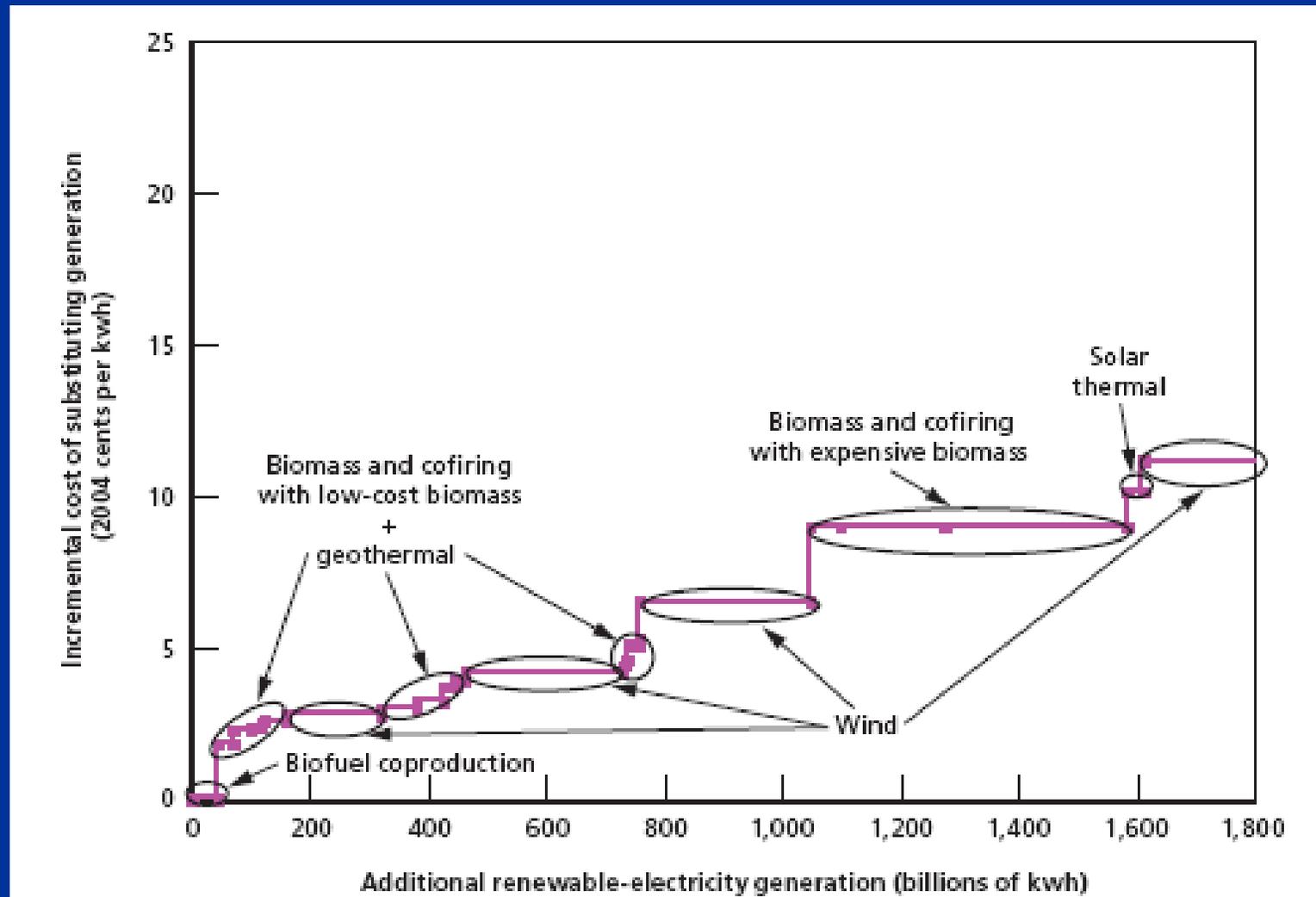
Simulation Links Fuels and Electricity Markets Via Biofuels



APPROACH

1. Construct cost curve for renewable energy technologies
2. Calculate expenditure impacts of requirements
3. Substitute renewable for fossil fuels
4. Calculate new prices
5. Calculate new demand

Technology Assumptions Suggest Incremental Costs of Renewables Substitution in Electricity Market



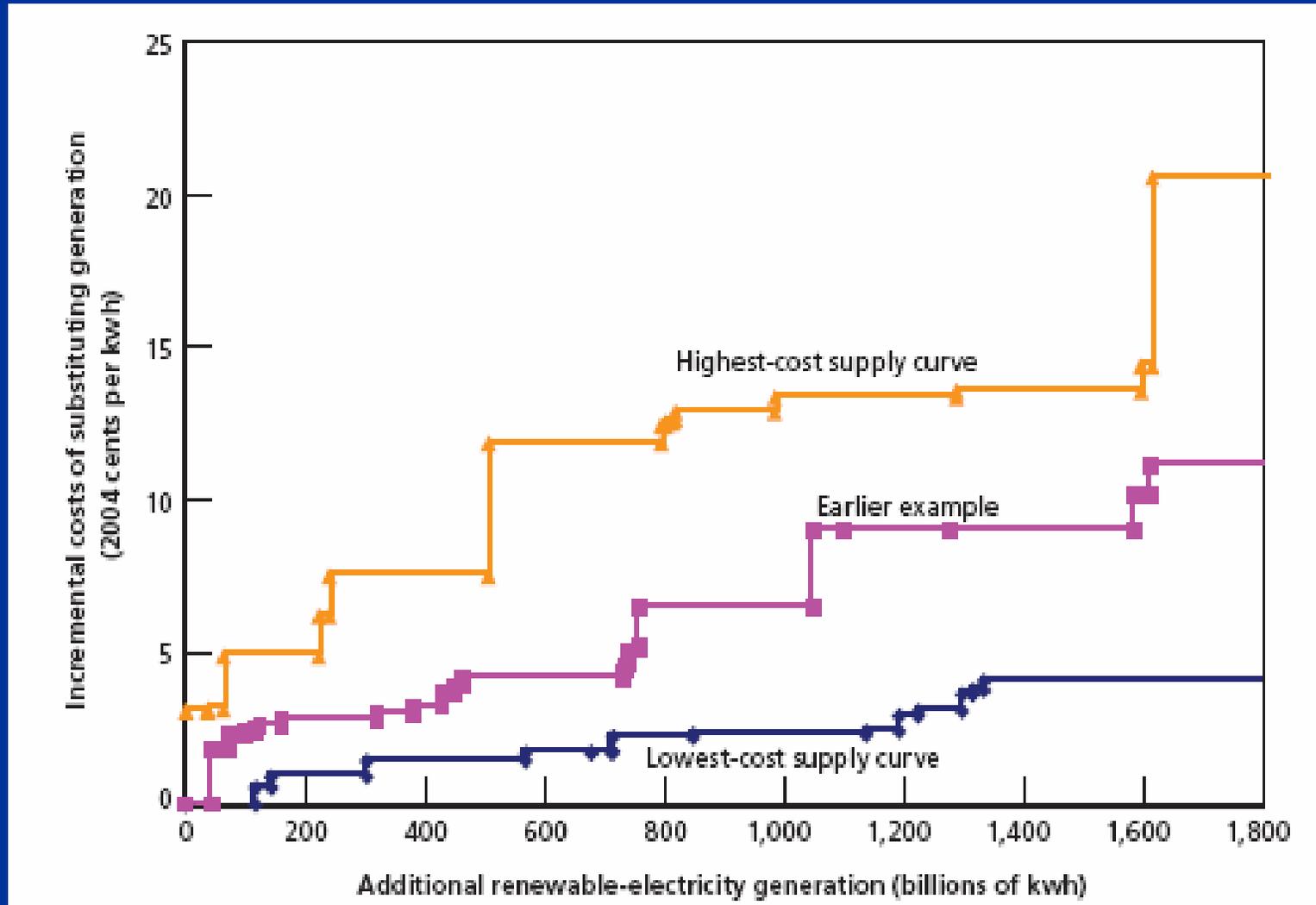
Analysis Considers a Wide Range of Assumptions

ELECTRICITY	Low	High
Wind capital cost	\$0.035	\$0.058
Wind cost escalation (0,20,50,100,200)	-50%	+50%
Biomass cost	\$0.033	\$0.049
Geothermal escalation (5,7.5,10,15,20,25,35 ¢/kWh)	-25%	+25%
Natural gas supply elasticity	0.2	0.6
Coal supply elasticity	0.7	1.3
Electricity demand elasticity	-0.2	-0.6
Wind capacity credit	0	0.4
Solar-thermal cost	\$0.0945	\$0.1755
Solar thermal quantity	-30%	30%

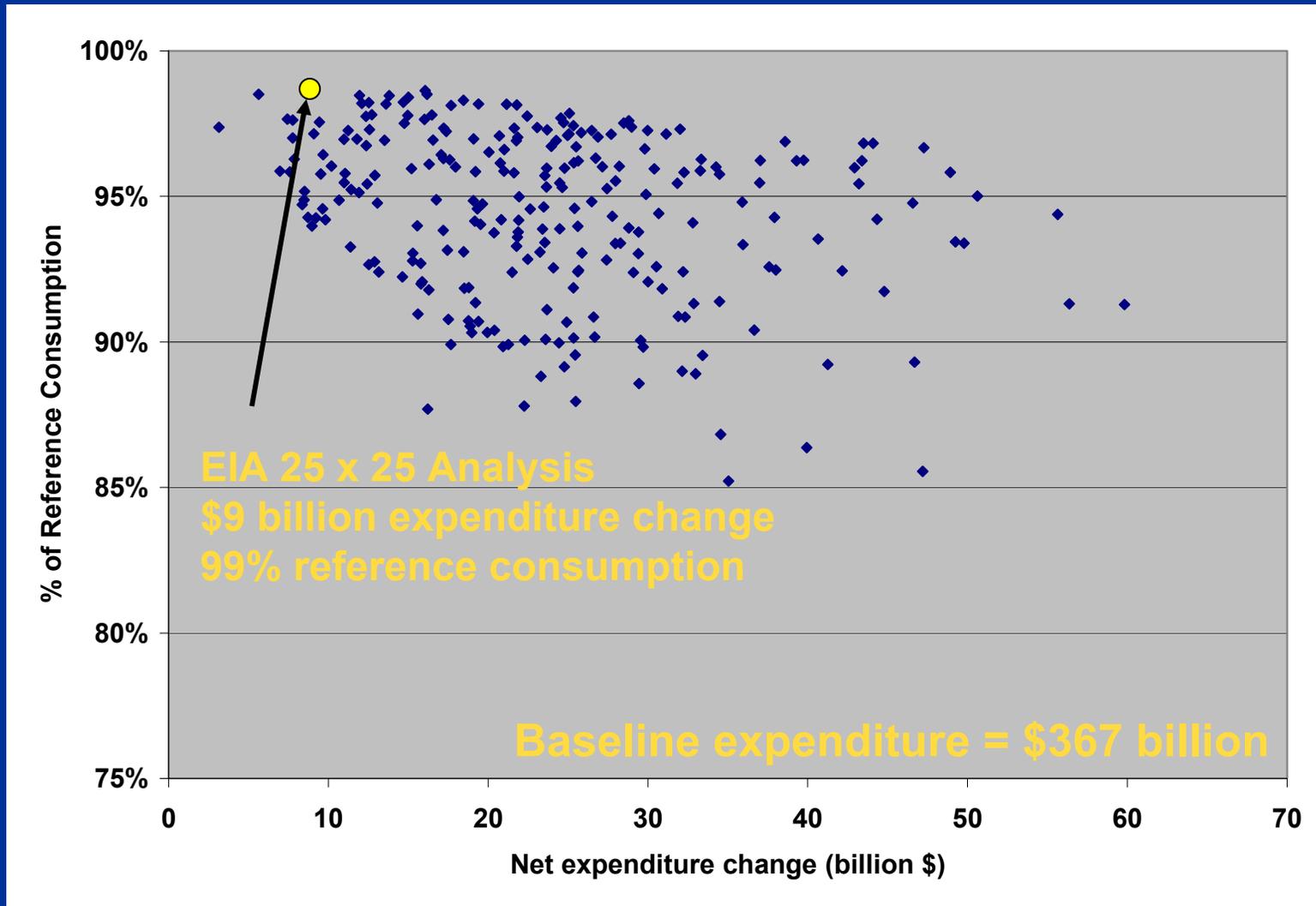
FUELS	Low	High
Bio fuel production cost (per unit input)	\$67	\$134
Low cost biomass supply (million tons)	450	1,000
Feedstock supply distribution	EIA	UT
Biomass-backstop price (\$/ton)	\$90	\$200
Biofuel yield (gal/ton)	80	100
Oil supply elasticity	0.2	0.6
Transportation demand elasticity	-0.2	-0.8
Shift in oil supply curve	\$43/bl	\$53/bl
Electricity co-product (kWh/gal)	0	2

Use Latin Hypercube design with 2,582 points to sample the combinations of these uncertain input parameters

Uncertainties Give a Range of Incremental Cost Curves for Electricity Sector

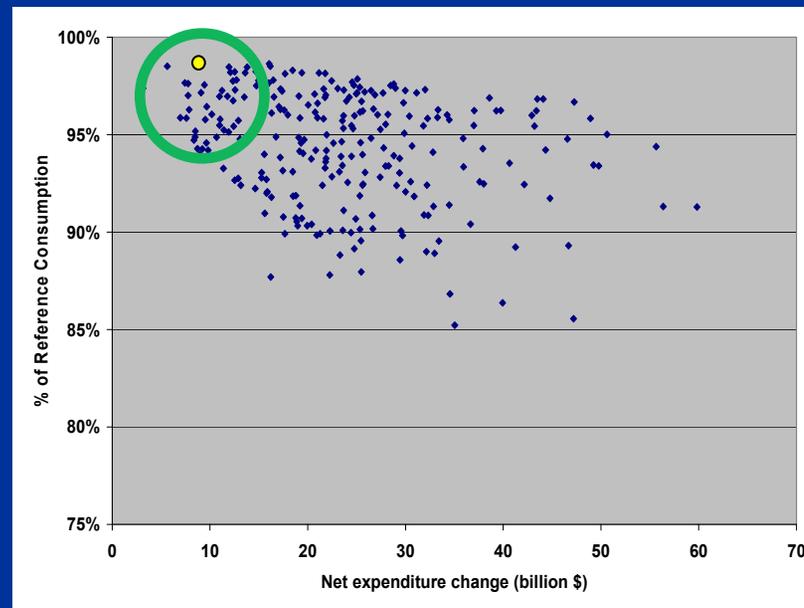


Expenditure Changes in Electricity Market Span Wide Range



Small Number of Key Uncertainties Drive Most Expenditure Variation in Electricity Markets

- Create database of 2,582 cases sampling all plausible combinations of uncertain input parameter values
- Identify cases of interest in this database
- Use statistical algorithms to identify range of values for a small number of parameters most strongly predictive of cases of interest
- Measure quality of resulting “scenarios” via
 - Density: fraction of points in scenario that are of interest
 - Coverage: fraction of all points of interest in scenario

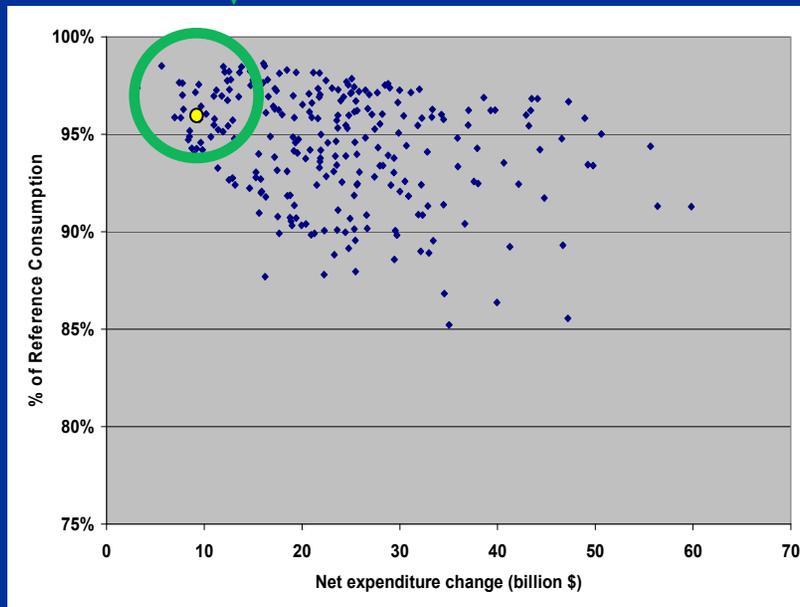


Small Number of Key Uncertainties Drive Most Expenditure Variation in Electricity Markets



- Create database of simulation runs
- Identify cases of interest
- Identify parameters that best predict these cases
- Measure quality of resulting “scenarios” via
 - Density
 - Coverage

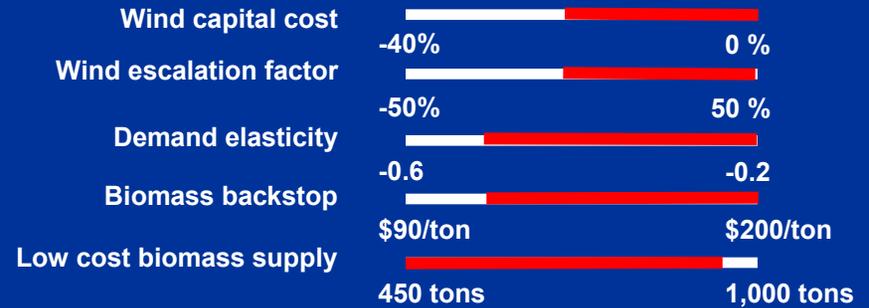
Density = 70%, Coverage = 67%



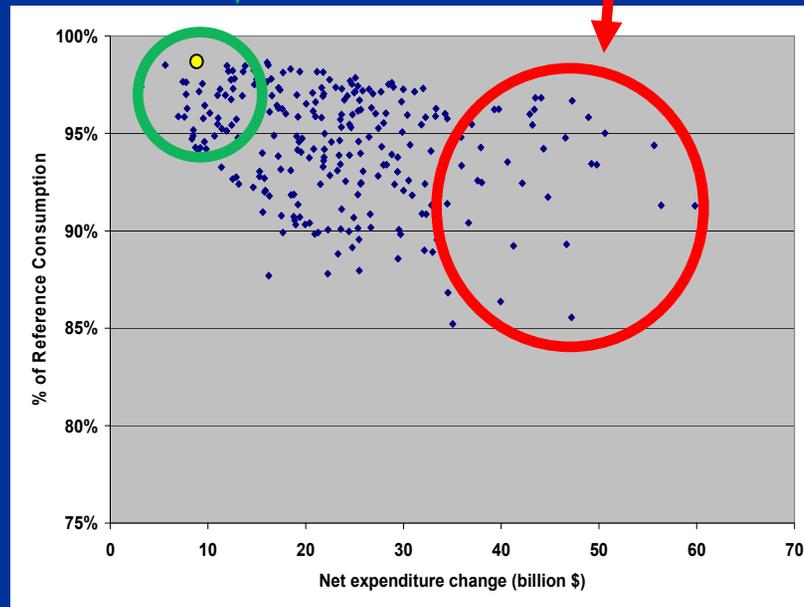
Small Number of Key Uncertainties Drive Most Expenditure Variation in Electricity Markets



Density = 70%, Coverage = 67%



Density = 57%, Coverage = 79%

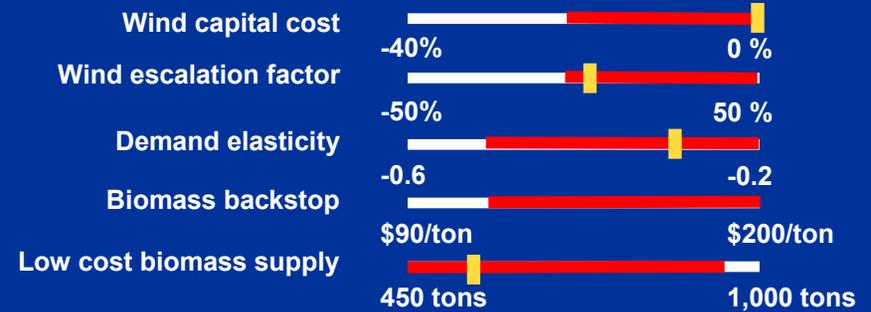


Toman, Griffin, Lempert (2008)

Small Number of Key Uncertainties Drive Most Expenditure Variation in Electricity Markets

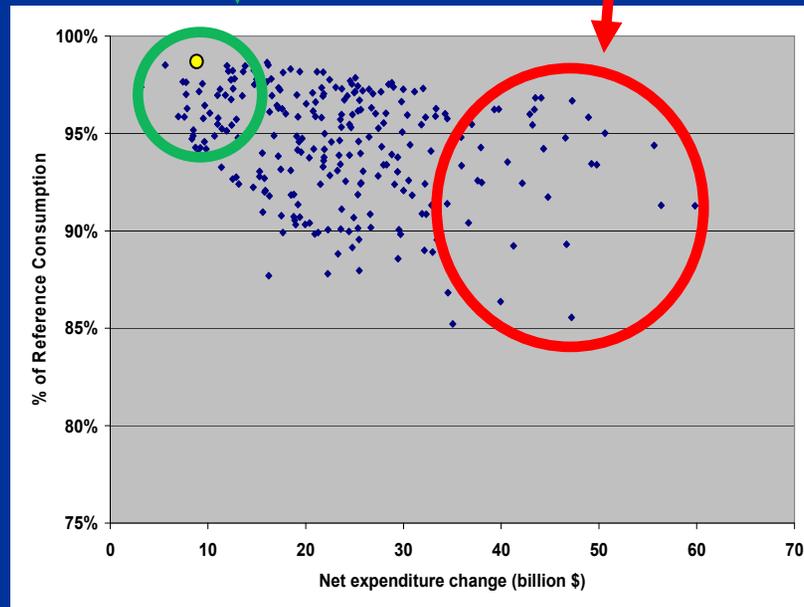


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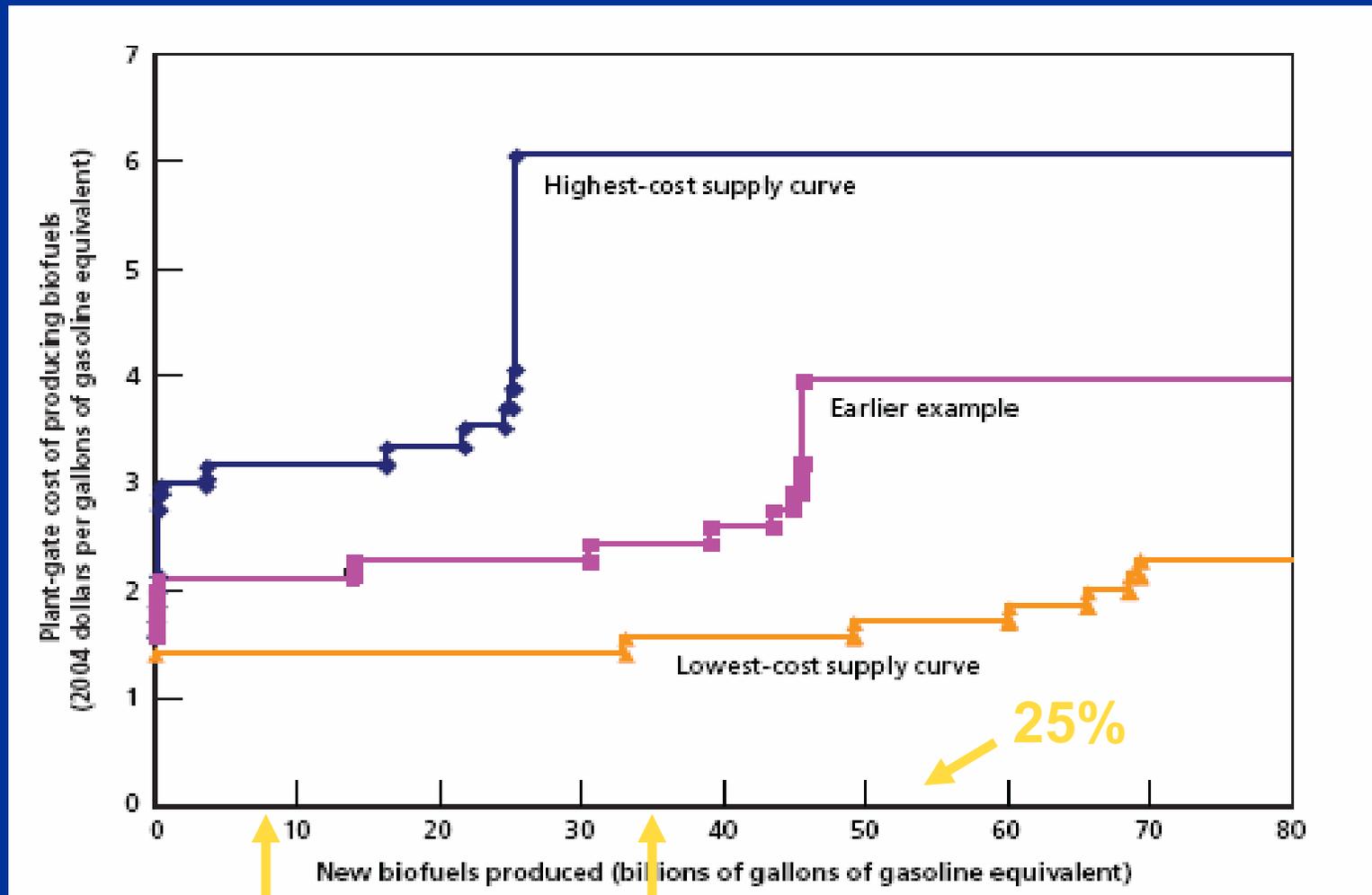
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■ EIA assumptions

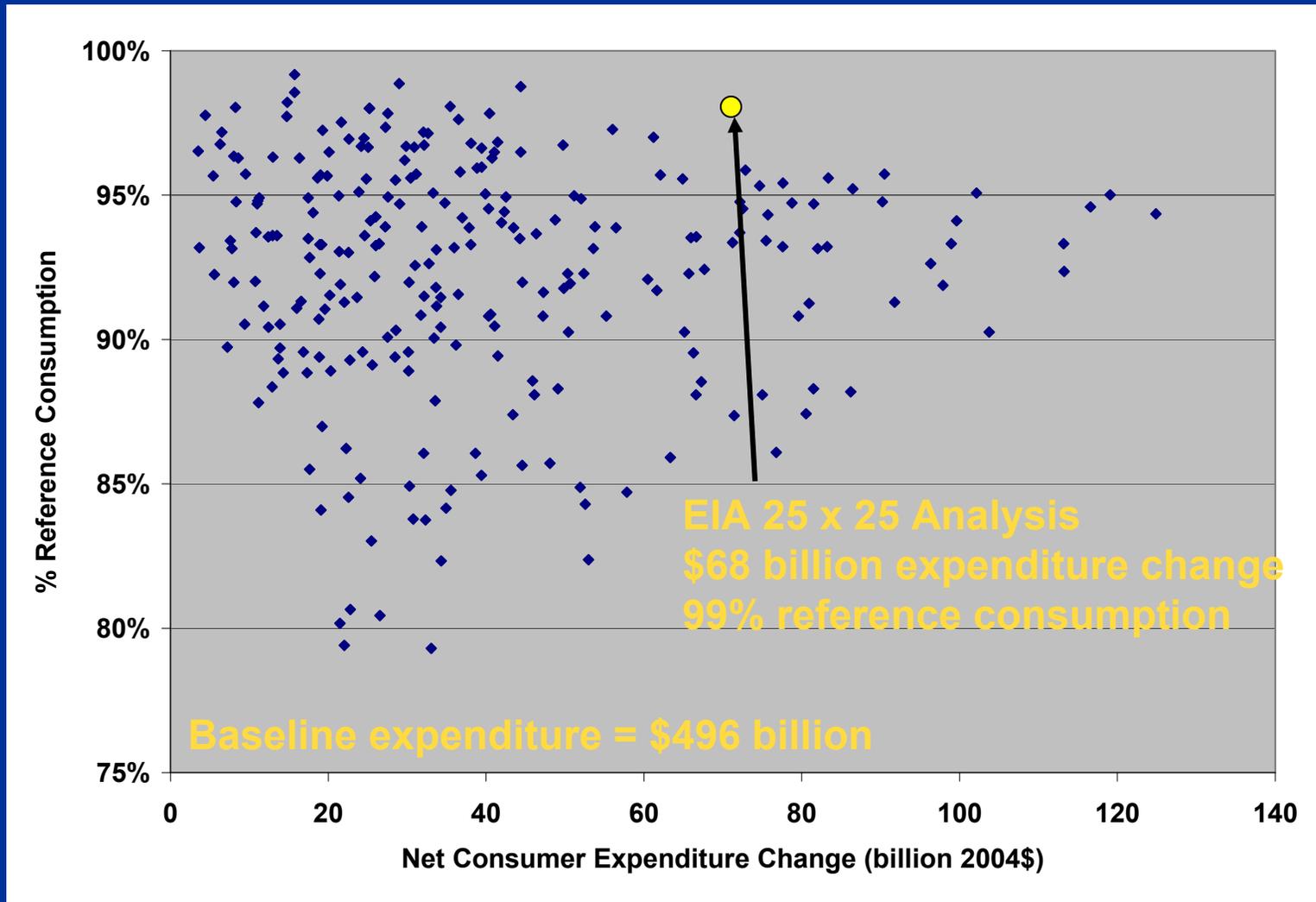


Toman, Griffin, Lempert (2008)

Biofuels Supply Curves Have Greatest Uncertainties



Expenditure Changes in Motor Vehicle Fuels Market Span Even Wider Range



Small Number of Key Uncertainties Drive Most Expenditure Variation in Fuels Market

Biofuel conversion cost



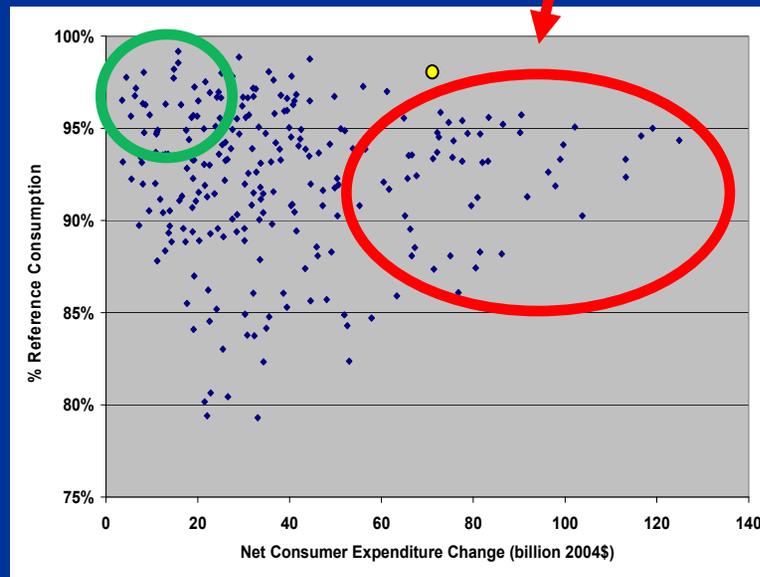
Biofuel conversion cost



Density = 83%, Coverage = 84%

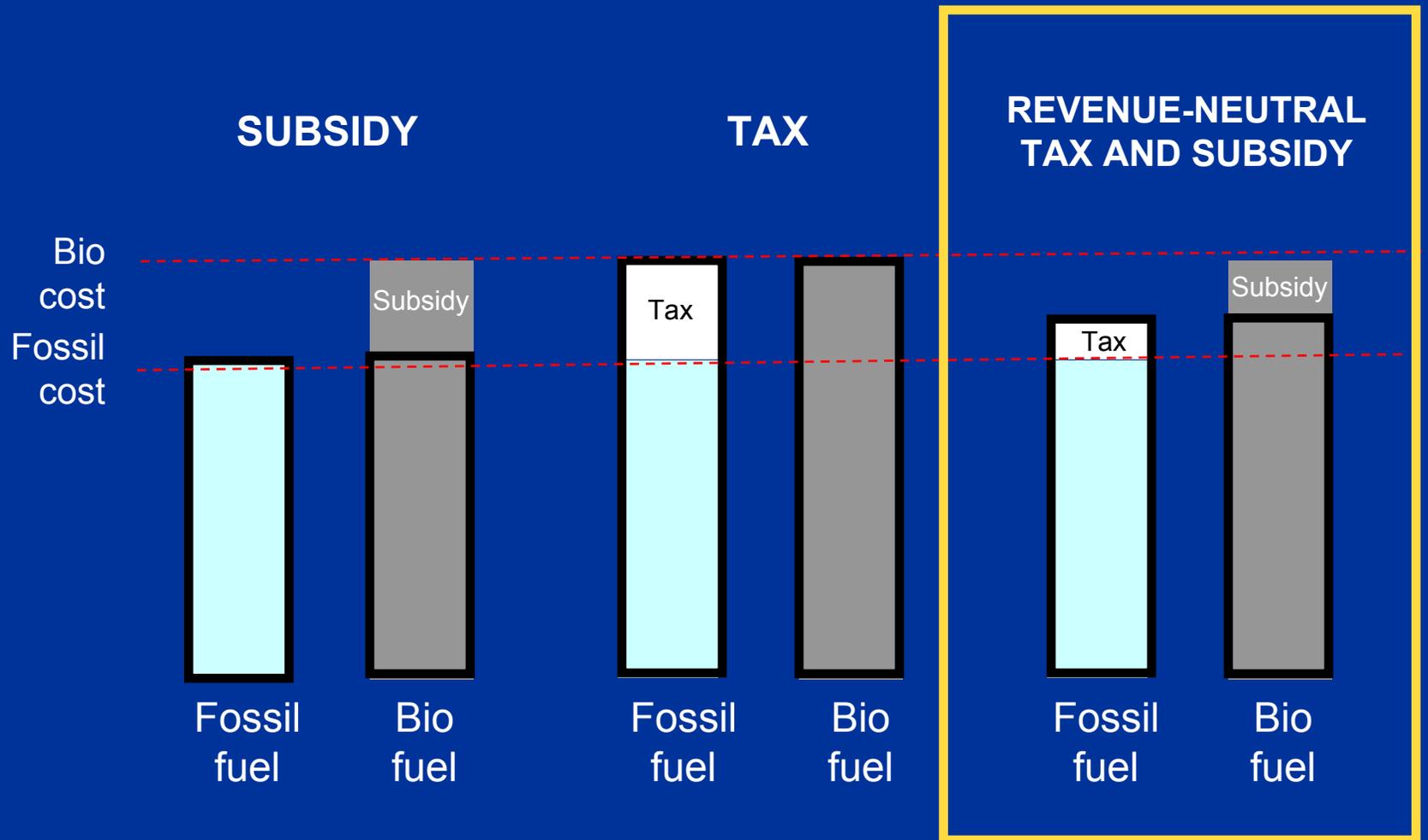
Density = 57%, Coverage = 79%

■ EIA assumptions

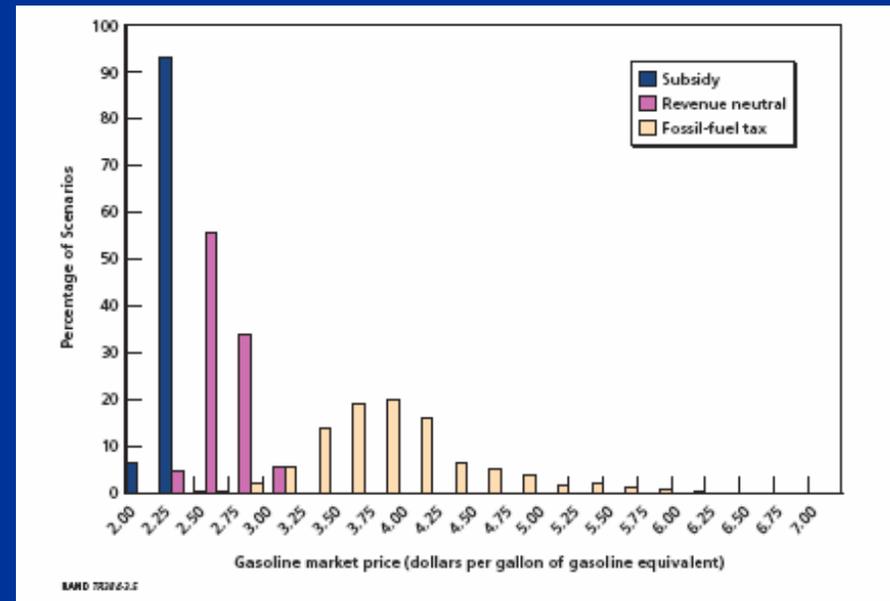
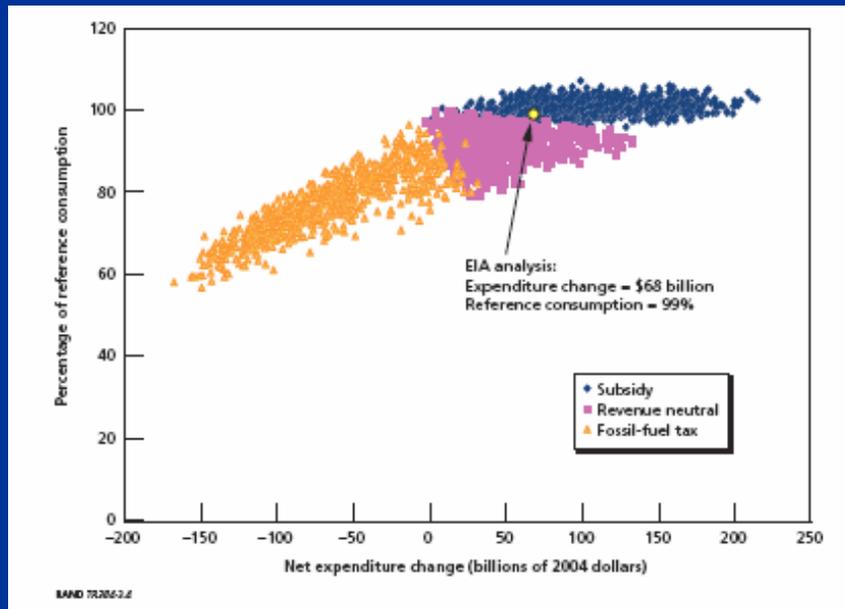


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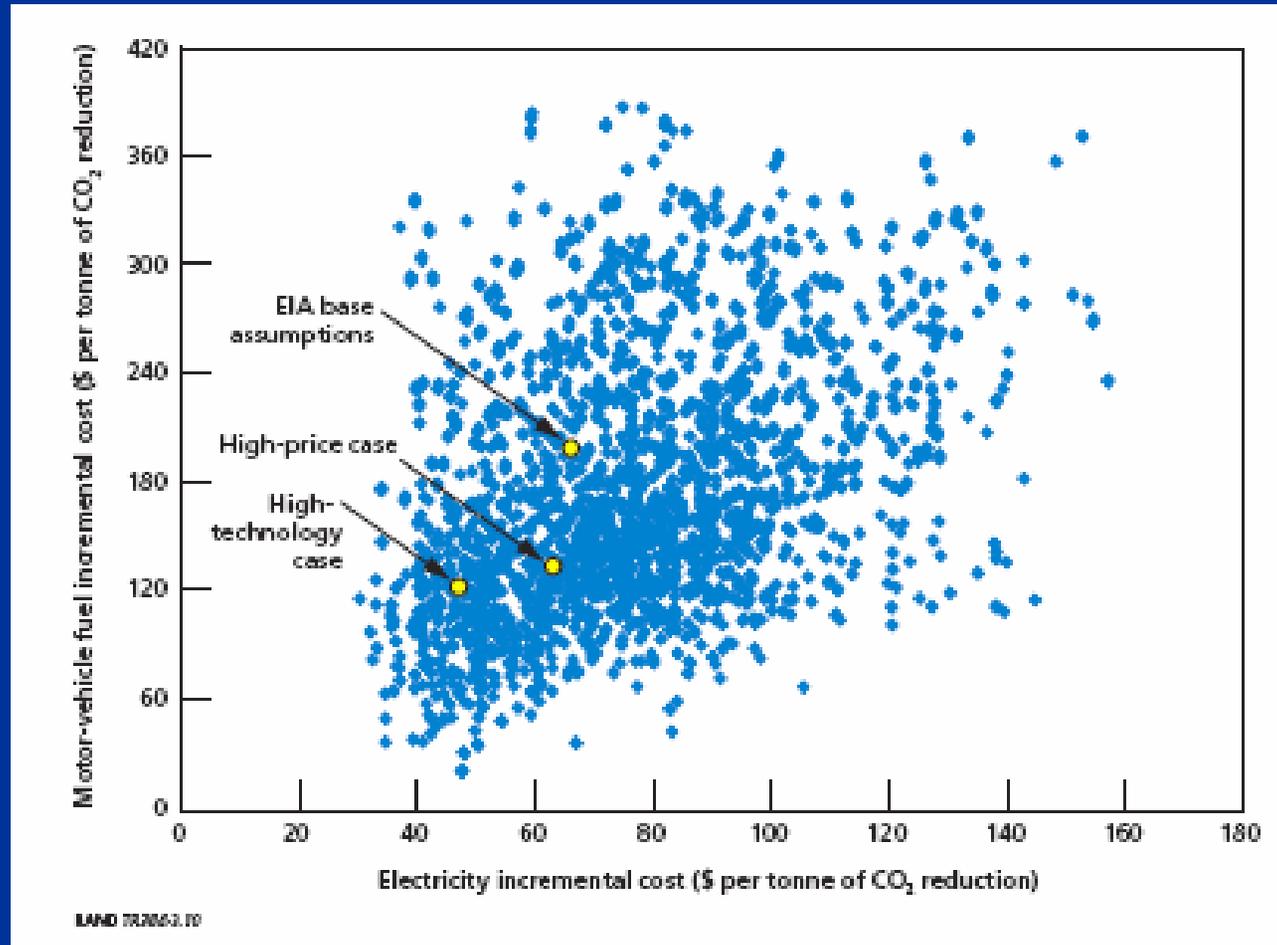
Analysis Considered Three Ways To Implement Fuels Requirement



Choice of Policy Affects Distribution of Costs



Incremental CO₂ Reduction Costs Can Be Higher Than Other Policy Options



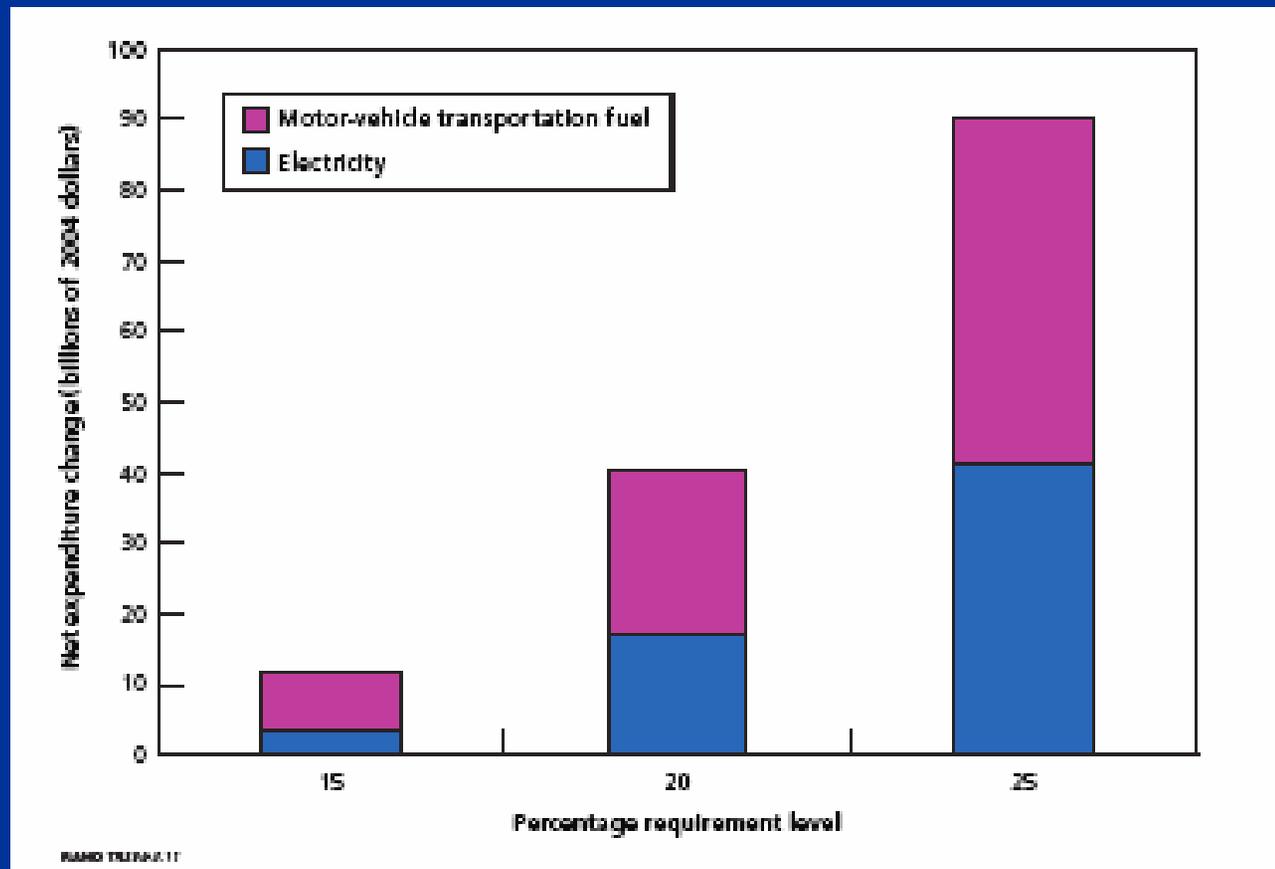
Projected 25x25 Impacts Depend Strongly on Uncertain Technology Assumptions

- 25x25 renewable energy requirement could have significant impact on U.S. greenhouse gas reductions
- Projected expenditures depend strongly on a small number of cost and performance assumptions about new technologies
 - Lowest cost projections driven by low estimates for:
 - Wind costs, biomass supply, biomass yields, and demand elasticities
 - Highest cost projections driven by high estimates for:
 - High estimates for wind costs, biomass backstop costs, and demand elasticities
 - Low estimates for biomass supply
- Policy design influences distribution of costs

Outline

- **Impacts of 25x25 renewable energy requirement**
- **Policy designs to reduce risks of 25x25 proposal**

Reductions in Target Can Give Large Expenditure Reductions



But can also reduce the benefits

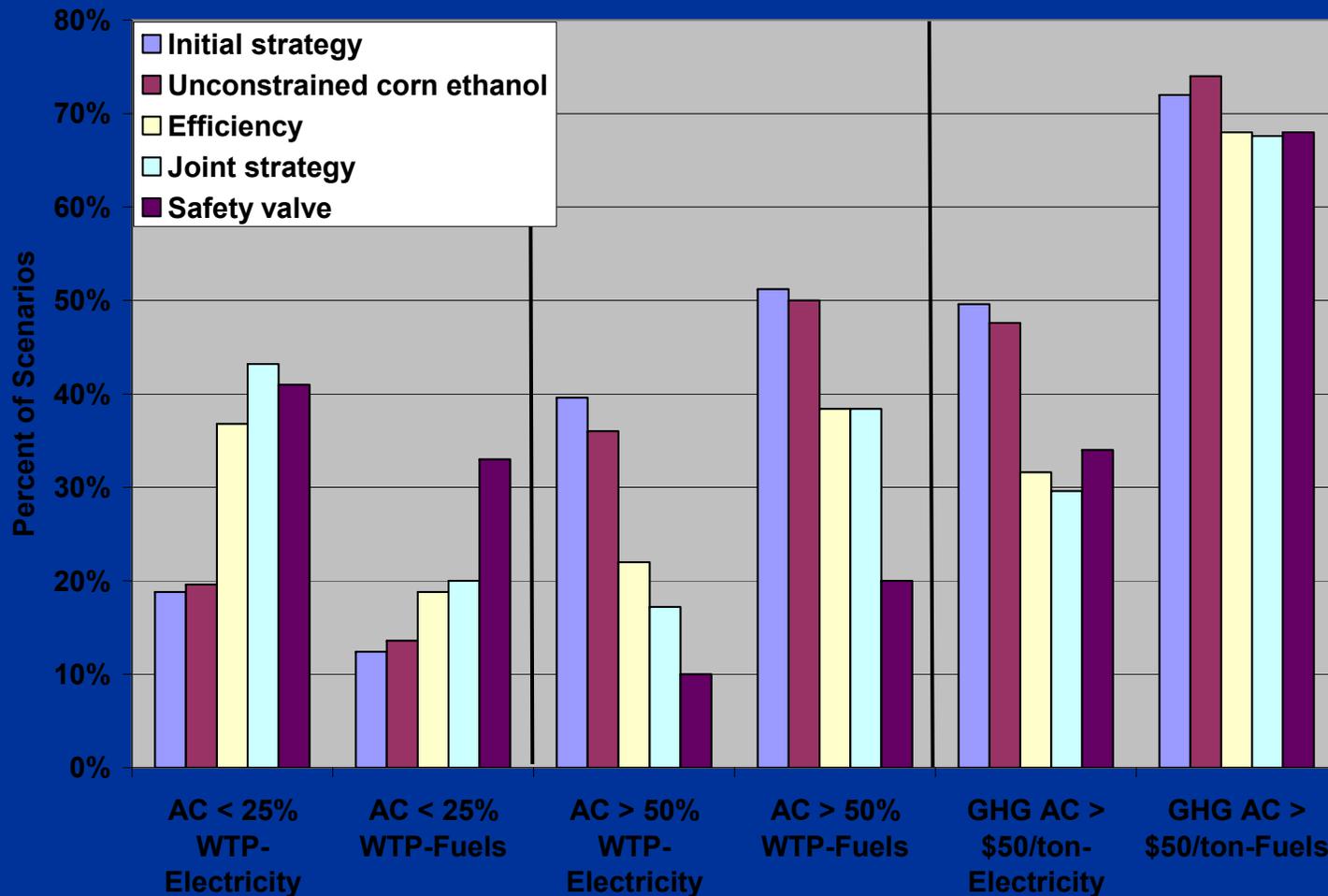
Analysis Compares Alternative Policies with Multiple Performance Measures

- **Examine policies that seek to manage risk of 25x25 proposal with combinations of**
 - Unconstrained corn based ethanol
 - Count efficiency as renewables
 - Safety valve
- **Use a variety of performance measures for policies**
 - Net energy expenditures
 - Change in social welfare
 - Incremental costs of policy requirement and land conservation
 - Land use change
 - Greenhouse gas emissions
 - Oil consumption
 - New benefits from policy requirement
- **Compare measures to data on willingness to pay**

Consider Five Alternative Policy Designs

	Unconstrained Corn Ethanol	Count Efficiency as Renewable	Safety Valve
Base Policy			
Ethanol unconstrained	X		
Efficiency		X	
Joint	X	X	
Safety value	X	X	X

Policy Design Can Decrease Number of Scenarios with High Cost Outcomes



Some Observations on Design of Robust Policies

- **Thoughtful design may capture benefits and manage risks of aggressive policies to promote technology transitions**
 - **Uncertainty analysis aims to characterize key vulnerabilities of policies and help identify responses**
- **Some unaddressed factors may provide important caveats to these results**
 - **Model provides only a 2025 snapshot; does not address time dependence**
 - **Model does not address incentives to develop new technologies**

New Work Examines Market Creation as Policy Tool for Transformational Change

- **Policy analysts have well-developed tools to consider the efficiency-enhancing potential of markets**
 - But more importantly, new markets often induce profound technical, institutional, political and social change
- **Long-term climate policy may require**
 - Political and social transformations that generate positive feedbacks as emissions go towards zero
- **Given the many uncertainties, RDM analysis may help suggest near-term policy designs robust over the long-term**

Collaborators:

Steven Popper, RAND; Barry Ickes, Penn State; Ted Parson, Univ Mich

References

Impacts on U.S. Energy Expenditures and Greenhouse-Gas Emissions of Increasing Renewable-Energy Use, Michael Toman, James Griffin, Robert J. Lempert, TR-384-1-EFC 2008

http://www.rand.org/pubs/technical_reports/TR384-1/

Thank You

Rob Lempert

lempert@rand.org