Potential Cost and GHG Impacts of Increased Renewable Energy Use

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Policy Interest in Renewable Energy Comes from Several Sources

- **Potential contributions of renewable energy to:**
  - **mitigate CO_2 emissions (global warming)**
  - **reduce oil consumption (energy security)**
- **Status of renewable technologies relevant for:**
  - **Evaluating potential contributions of RE to CO_2 emissions control**
  - **Impacts of requirements for renewable energy use**
  - **Tradeoffs between GHG mitigation and alternative fossil energy for enhancing energy security**
  - **Priority setting in energy R&D programs**

RAND Study Assessed Impacts of Requiring 25% US Renewables by 2025

- **Focused on electricity and motor fuels**
  - **Represent about 65% of total energy consumption**
- **Examined effects on**
  - **total consumer expenditures for energy**
    - **including impacts on world oil prices**
    - **did not address overall economic impacts**
  - **government expenditures or revenues generated in achieving increased renewables use**
    - **Renewable fuel subsidies and/or fossil fuel taxes**
  - **CO_2 emissions**
  - **final energy demands**
- **James Griffin and Rob Lempert, co-authors**

Study Strengths and Limitations

- **Strengths**
  - **Explored wide range of technology and cost assumptions**
  - **Captured several important market interactions**
  - **Identified greatest influences on outcomes**
- **Limitations**
  - **Not an economic welfare analysis**
  - **Looked only at separate renewable standards for fuels and power**
    - **Extensions and robustness discussed below**

Key Findings

- **Expenditure impacts of meeting 25% requirements are uncertain but potentially quite large**
  - **Substantial technical progress on several fronts (biomass, wind) is key to mitigating higher energy outlays**
  - **Biomass supply and conversion cost are especially critical uncertainties**
  - **Expenditure impacts depend on baseline energy prices (especially oil), *and* effects of policy on oil prices**
    - **Higher baseline prices means lower *relative* impact, but also less need for a policy target**
    - **Depending on renewable fuel pricing policy, significant economic rents in oil market can be gained -- or lost**
- **While the 25% requirements will reduce CO_2 emissions considerably, other measures could achieve this more cost-effectively**

Presentation Outline

- **Analytical approach**
- **Effects of RE targets**
- **Conclusions**

Each Renewable Energy Source Faces Uncertainties

Source	Uncertainties
Wind	• Progress in utilizing lower-quality sites • Costs of developing remote sites • Offshore wind development
Solar	• Progress in new materials • Improvements in energy storage
Geothermal	• Availability of high-quality sites • Progress in new drilling techniques
Biomass	• Availability of lower-cost feedstock supply • Conversion costs to fuels or electricity

Study scope did not include hydropower; in simulations, limited use of solar

Analyzing Future Costs of Renewables Means Addressing Several Uncertainties

- **Future costs of pre-commercial technologies are very difficult to estimate**
  - **Early estimates tend to be optimistic**
- **Speed of technological improvement is uncertain**
  - **Need to account for scale economies and learning by doing over time**
- **Relative cost of increasing renewables also depends on trends in conventional energy costs**
- **Availability of biomass feedstock a key uncertainty**
  - **Critical option for biofuels, and important for renewable power**

Study Modeled Supply and Demand for Renewable and Fossil Energy

- **Built simple models for motor fuels and electricity sectors, and biomass feedstock**
  - **Models included competition for feedstock use in the two sectors**
  - **Modeling framework also tracked changes in demand and price for oil, natural gas and coal**
- **Models used to calculate change in unit costs and expenditures under a 25% renewable requirement in each sector**
  - **Calculations reflect a wide range of possible future costs for renewables**

Findings reflect only a snapshot in 2025 and do not incorporate costs of getting from here to there

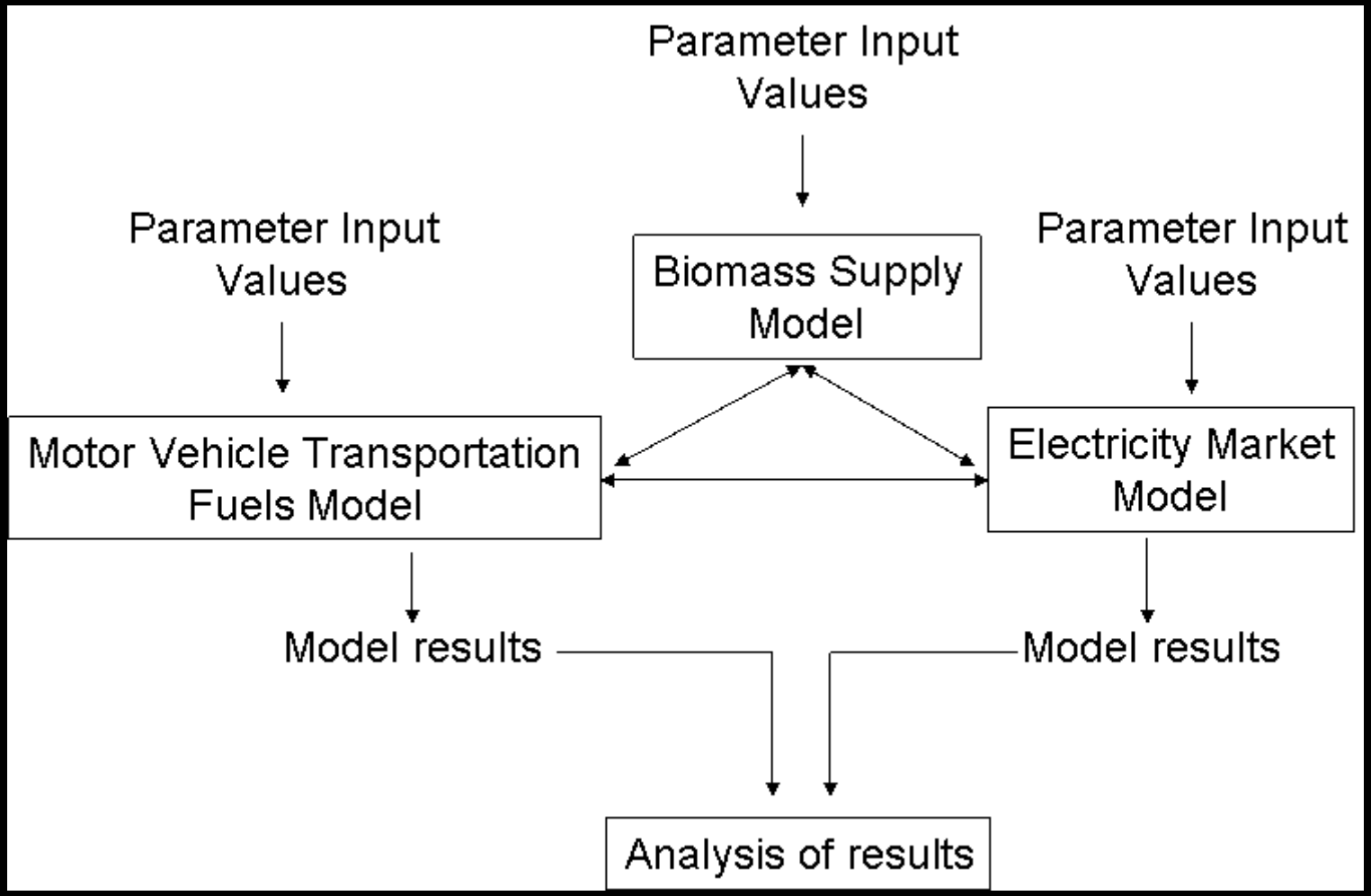
Study Modeled Supply and Demand for Renewable and Fossil Energy

- **Government can use different policies to induce 25% renewable fuel use when renewable fuels are costlier**
  - **Different combinations of fossil fuel taxes and renewable fuel subsidies**
  - **Analysis assumes that costs of renewable electricity sources are averaged into electricity prices**
- **Benchmark projections of energy demands, costs, and capacity investment come from 2006 Energy Information Administration Outlook**
  - **Also considered implications of significantly higher baseline oil prices in 2025**
- **Changed energy mix used to calculate CO_2 impacts**

Study Modeled Supply and Demand for Renewable and Fossil Energy

- **Constraints on biomass availability**
  - **Supply curve initially constructed assuming no conversion of high-value crop or pasture land**
  - **In many scenarios total biomass demand exceeds total quantity of such "lower cost" biomass**
  - **Rather than just have feedstock price bid up, we assumed a higher-cost "backstop" supply**
    - **Backstop also can be interpreted as biofuels imports at some higher price**
    - **Price at which this increased supply is available also is part of uncertainty analysis**

Schematic of the Model



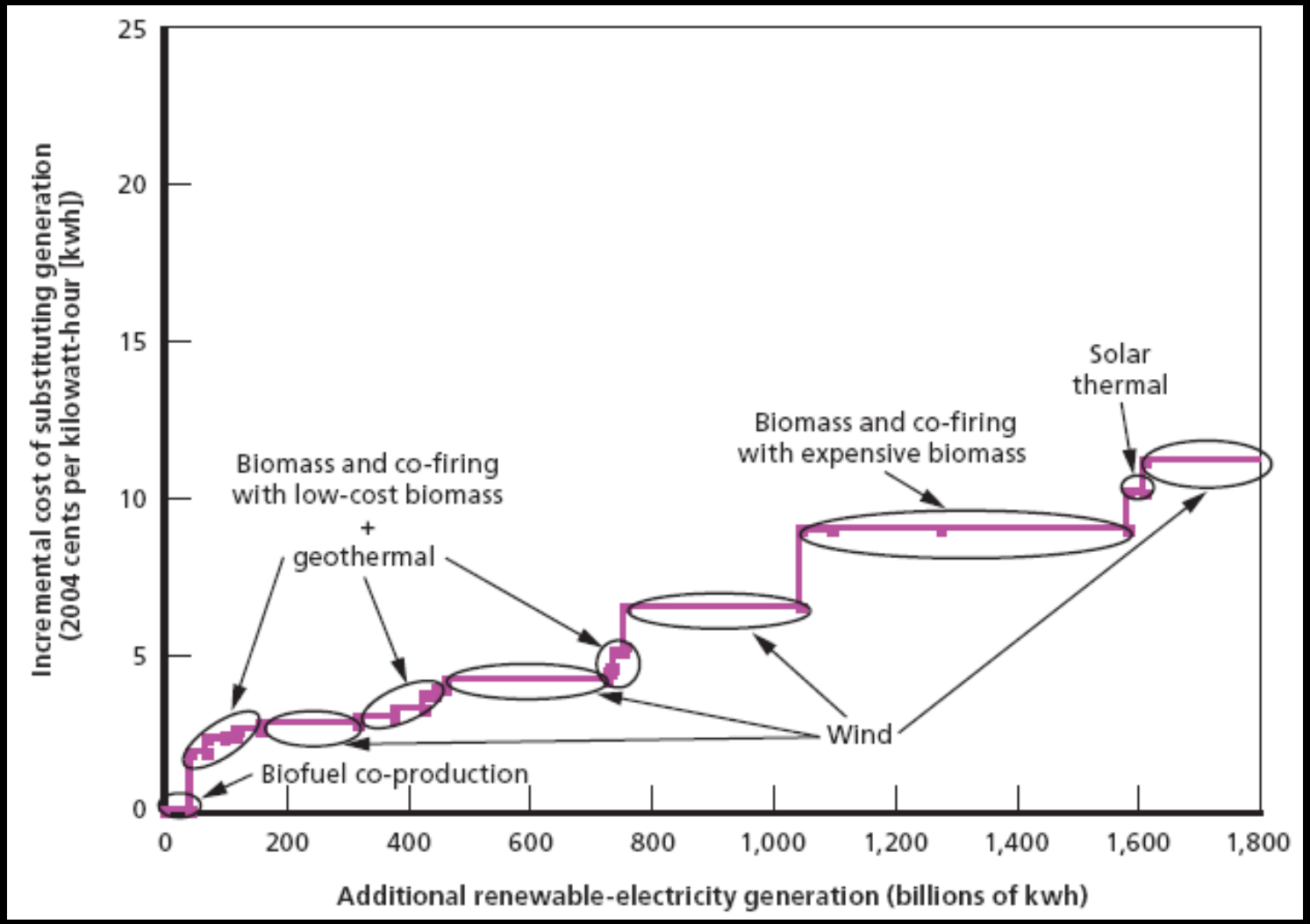
Analysis of Uncertainties

- **Bottom-up approach: Ranges for key cost parameters constructed by reviewing energy market and technology literatures**
  - **Additional levelized capital and/or operating costs from substituting different renewable electricity sources, relative to baseline supplies**
  - **Biomass cost**
    - **Feedstock availability and cost**
    - **Cost of backstop resource**
  - **Biomass conversion efficiency and cost for liquid fuels**
    - **Ethanol or biomass liquefaction**
- **Parameter ranges span more and less optimistic projections found in literatures**
  - **Largely heuristic estimates or program goals given uncertainties**

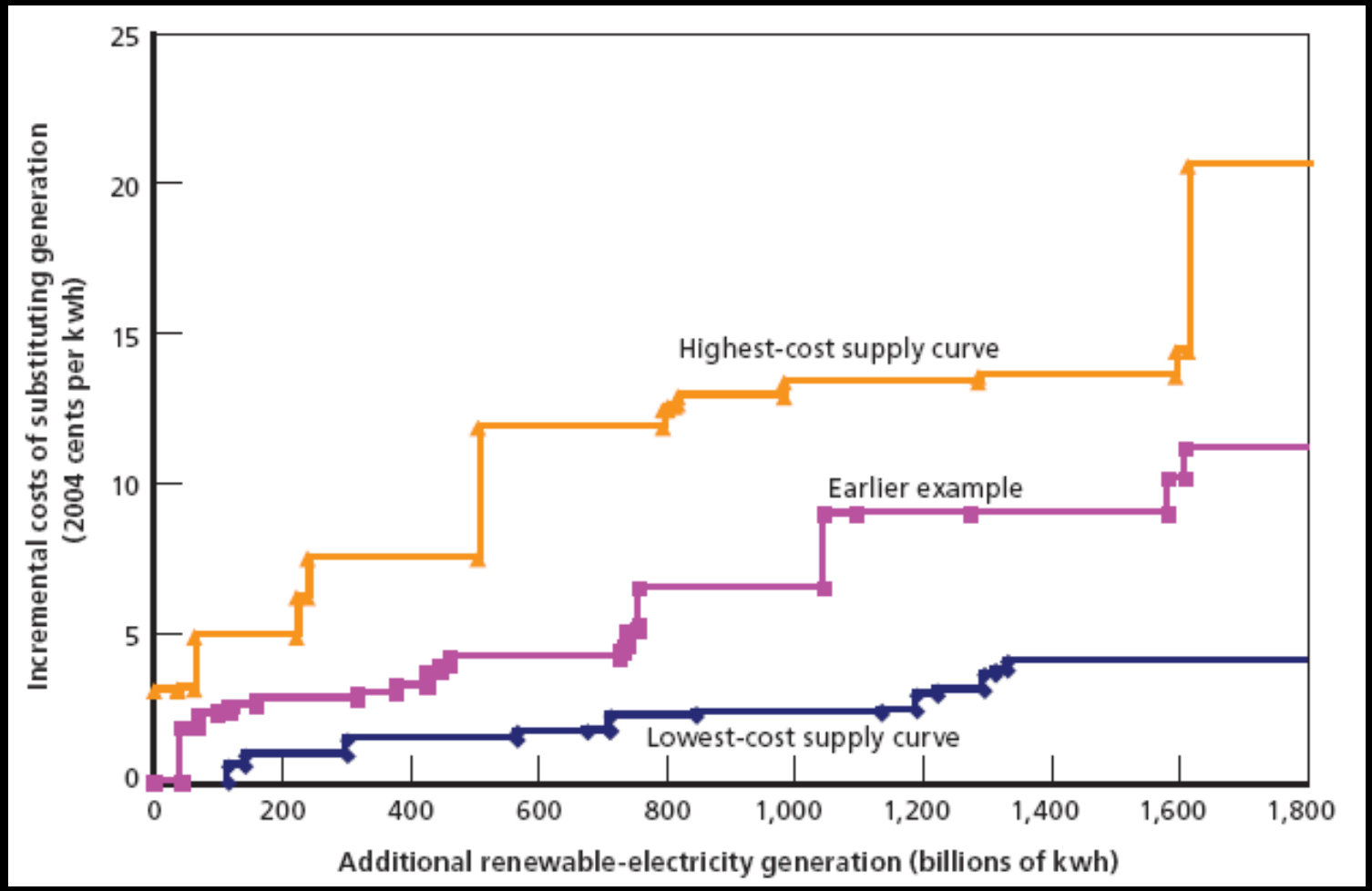
Analysis of Uncertainties

- **Other energy market influences likewise modeled via assuming a range of possible parameter values**
  - **Baseline world oil price (EIA reference or high)**
  - **Supply elasticities for domestic coal and natural gas, end-use natural gas demand**
    - **Adjustments in these fuel markets from changed energy mix are included in energy expenditure impacts**
  - **Oil "price reaction curve" to determine how world oil price might change relative to baseline from renewable fuels requirement in US**
    - **Includes elasticity assumptions for non-US petroleum demands and non-OPEC supplies**
    - **Reduced payment for inframarginal oil imports a major influence on expenditures under renewables requirement**

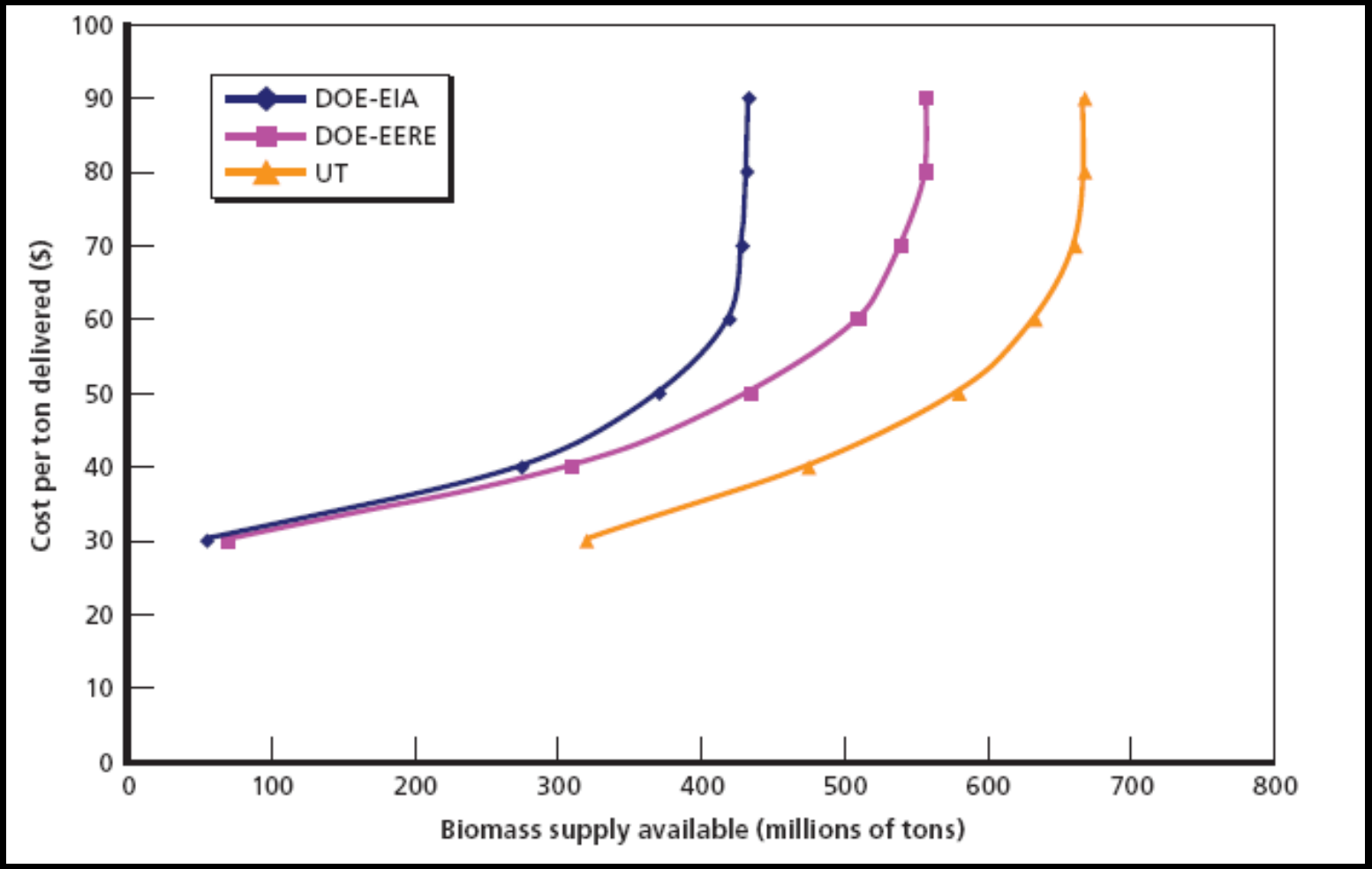
Additional Cost of Renewable Electricity Resource Substitution – "Central Case"



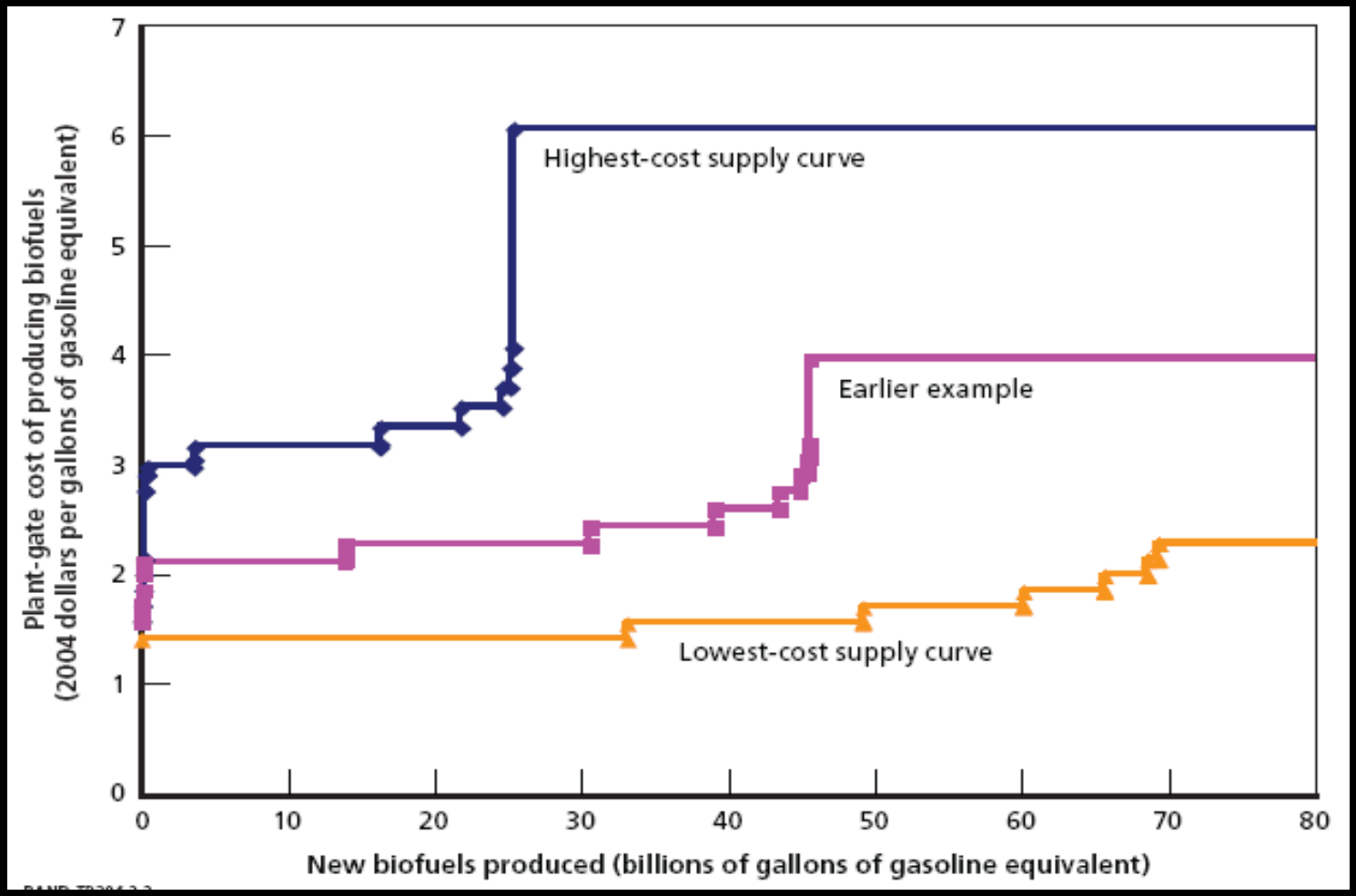
Range of Renewable Electricity Substitution Additional-Cost Curves



Range of Biomass Supply Curves Found in the Literature



Range of Biofuel Marginal Cost Curves



Includes ranges of biomass costs and conversion costs

Analysis of Uncertainties

- **Because uncertainty about many parameters is so high, we used methods of "robust decision analysis" to explore sensitivity of findings to assumptions**
  - **Sample parameter values to "fill up" the parameter space**
    - **Avoid leaving "holes" in parameter space that could omit unrepresentative but policy-relevant scenarios**
  - **Apply non-parametric methods to resulting model outputs to identify most influential input uncertainties**

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Achieving Targets With Modest Expenditure Impacts Would Require Several Major Technical Advances

- **Significant improvement in use of costlier, less-productive locations for wind power**
- **Significant progress in biomass conversion technology**
- **Ability to produce a very large and inexpensive biomass supply on less-productive land**
  - **Greater use of biomass for fuels limits options for increasing renewable electricity**

Higher elasticities of energy demands imply smaller expenditure impacts

Targets Increase Average and Total Electricity Expenditures

	Baseline	Level Under Targets	% Change
Average Expenditure (cents per kwh)	7.4	7.7 to 10.2	4% to 38%
Total Expenditure change (billion 2004 $)	$368	-$0.1 to $62	0% to 17%

Expenditure changes reflect the net effect of using higher-cost renewables and lower prices for coal and natural gas power, and changes in demand. Wide range of changes reflects different assumptions about technology costs and demand adjustments.

Economic Impacts of Renewable Fuels Requirement Depends on Government Policy for Fuel Pricing

- **Renewable fuels are more expensive than fossil alternatives in many scenarios**
- **Various policy options for overriding fuel price differences have different impacts on fuel demand, consumer cost, total (public and private) expenditure**
  - **fossil fuel tax: large consumer price change, more demand reduction**
  - **renewable energy subsidy: no consumer price jump, significant government outlay**
  - **revenue-neutral combination of taxes and subsidies falls in between**

These different impacts increase the range of potential outcomes

Targets With Revenue-Neutral Tax/Subsidy: Increased Fuel Prices and Expenditures

	Baseline	Level Under Targets	% Change
Motor fuels market prices ($ per gallon)	$2.13	$2.13 to $2.96	0% to 39%
Expenditure change (billion 2004 $)	$491	-$3.1 to $132	-1% to 27%

Price and expenditure change reflects net effect of higher-cost renewables, lower crude oil prices, and changes in demand as well as government policy toward renewable fuel pricing.

Renewable Price Subsidy: Little Impact on Motor Fuels Prices but Larger Expenditure Increase

	Baseline	Absolute Range	% Change
Motor fuels market prices ($ per gallon)	$2.13	$1.95 to $2.27	-8% to 7%
Expenditure Change (billion 2004 $)	$491	$1.5 to $214	0.3% to 44%

Expenditure change reflects net effect of using higher-cost renewables, lower oil prices, and changes in demand.

Expenditure increases are higher than with tax/subsidy policy because renewables requirement lowers world oil price, so subsidy stimulates demand.

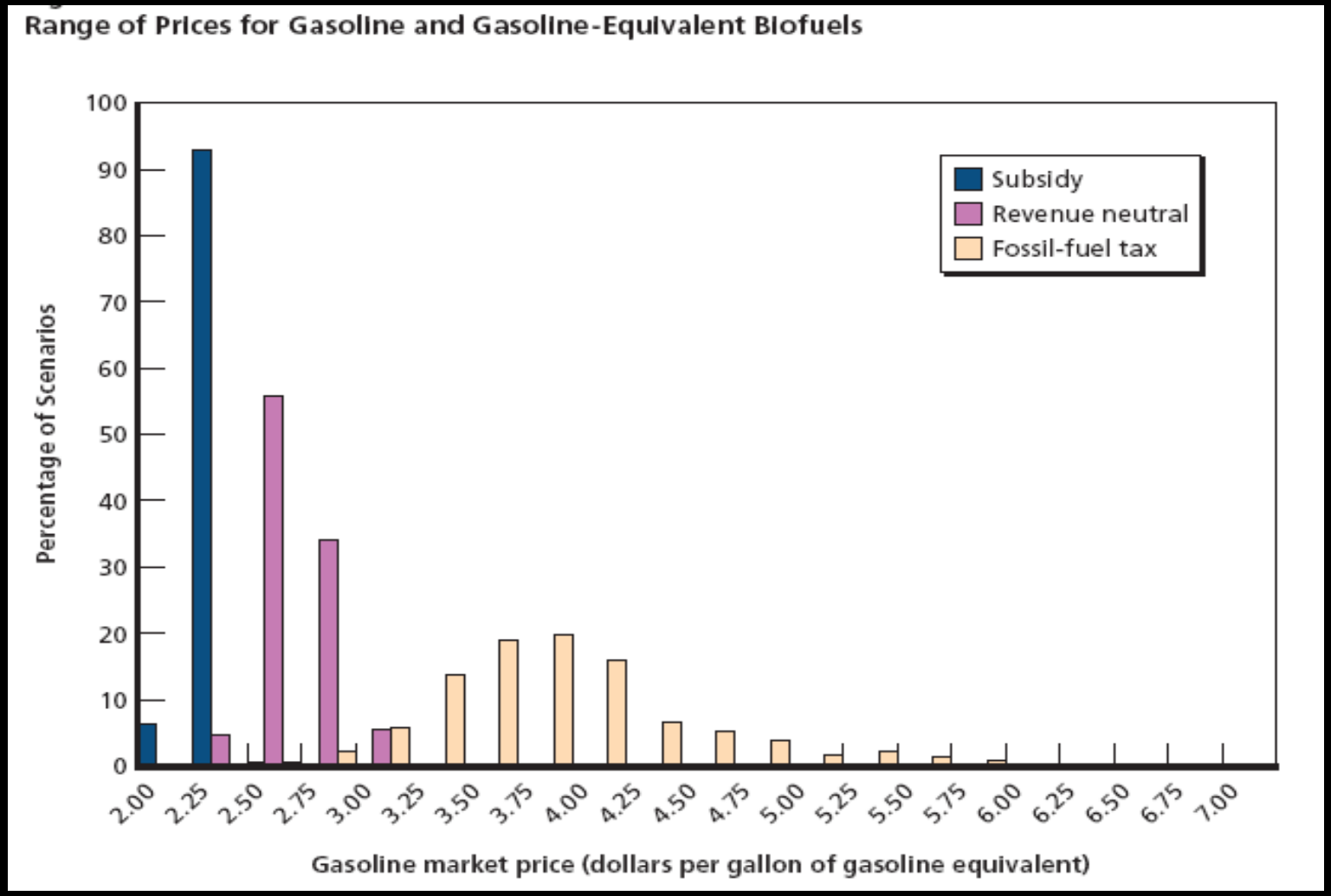
Fossil Fuel Tax: Targets Increase Motor Fuels Prices, Decrease Oil Prices and Fuel Demand

	Baseline	Absolute Range	% Change
Motor fuels market prices ($ per gallon)	$2.13	$2.45 to $6.39	15% to 200%
Expenditure Change (billion 2004 $)	$491	$-168 to $31	-134% to -94%

Expenditure change reflects net effect of using higher-cost renewables, lower oil prices, and changes in demand.

Significant net expenditure decreases relative to tax/subsidy policy because renewables requirement lowers world oil price, but fuel tax curbs fuel demand.

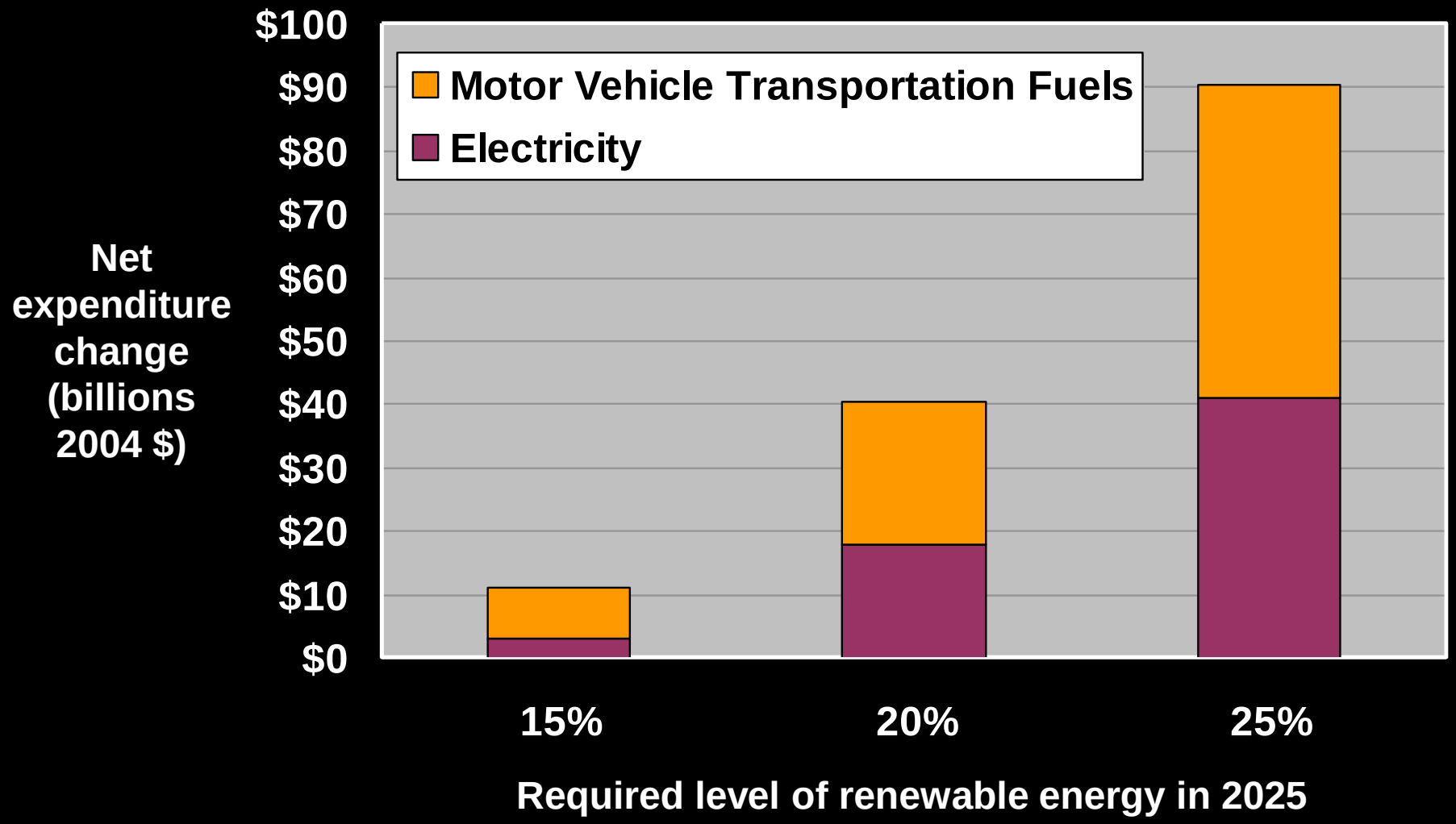
Long "Tail" in Fuel Prices With Tax Shows the Potentially High Cost of Biofuels



What If Baseline Future Oil Prices Are High?

- **We considered the impact of $85/bbl versus $50/bbl long-term (2025) crude oil price**
- **Baseline energy consumption will be lower, but baseline energy expenditures will be higher**
- **Thus *relative* expenditure impacts from costlier renewables will be lower**
  - **Smaller technology cost differences**
  - **Lower demand baseline, more renewables in baseline**
  - **Thus less rationale for renewables requirements**

Relaxing the Renewables Requirements Can Reduce Overall Expenditures Disproportionately



Targets Reduce CO_2 Emissions Significantly, But Other Measures More Cost-Effective

Targets reduce total CO_2 emissions about 13-26% nationally (20-40% in the 2 sectors)

	Cost per CO_2 reduction ($/metric ton CO_2 equiv)
Electricity Market	**$30 to $157**
Motor Fuels Market	**$22 to $382**

Higher ends of ranges represent high unit cost relative to other CO_2 mitigation options

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Structuring Renewable Energy Requirements Requires Careful Consideration

- **Meeting a requirement up to 25% by 2025 could be costly unless technologies advance considerably**
  - **RAND analysis did not consider transition costs or aggregate economic impacts**
  - **Fiscal implications of policies for inducing greater biofuels use could be substantial**
  - **Findings emphasize the need for expanded and well-targeted public-private RD&D for renewables**

Cost And Effectiveness

- **Significant CO_2 emissions possible, but cost is potentially high**
  - **A more cost-effective approach is desirable for larger-scale emission reductions**
    - **Market-based approach to CO_2 pricing can incorporate range of options including energy efficiency**
  - **Improved target designs can improve cost-effectiveness of RE requirements**
    - **Target flexibility (renewable credit trading, "safety valve" provisions for credit pricing)**
    - **Phasing in renewables targets to better balance objectives with implementation costs**
    - **Credits for energy efficiency?**

Energy Markets and Energy Security

- **Drop in crude oil demand, prices and oil import payments significantly offset costs of targets**
  - **Stronger impact if accompanied by increased end-use fuel prices to enhance fuel economy**
  - **Benefits occur regardless of where increased RE production takes place**
- **Little or even negative impact on vulnerability to market disruptions**
  - **Lower fuel supply elasticities would increase vulnerability**
  - **Without CO_2 constraints, higher conventional energy prices would stimulate higher-GHG alternative fossil resources (tar sands, coal liquefaction)**

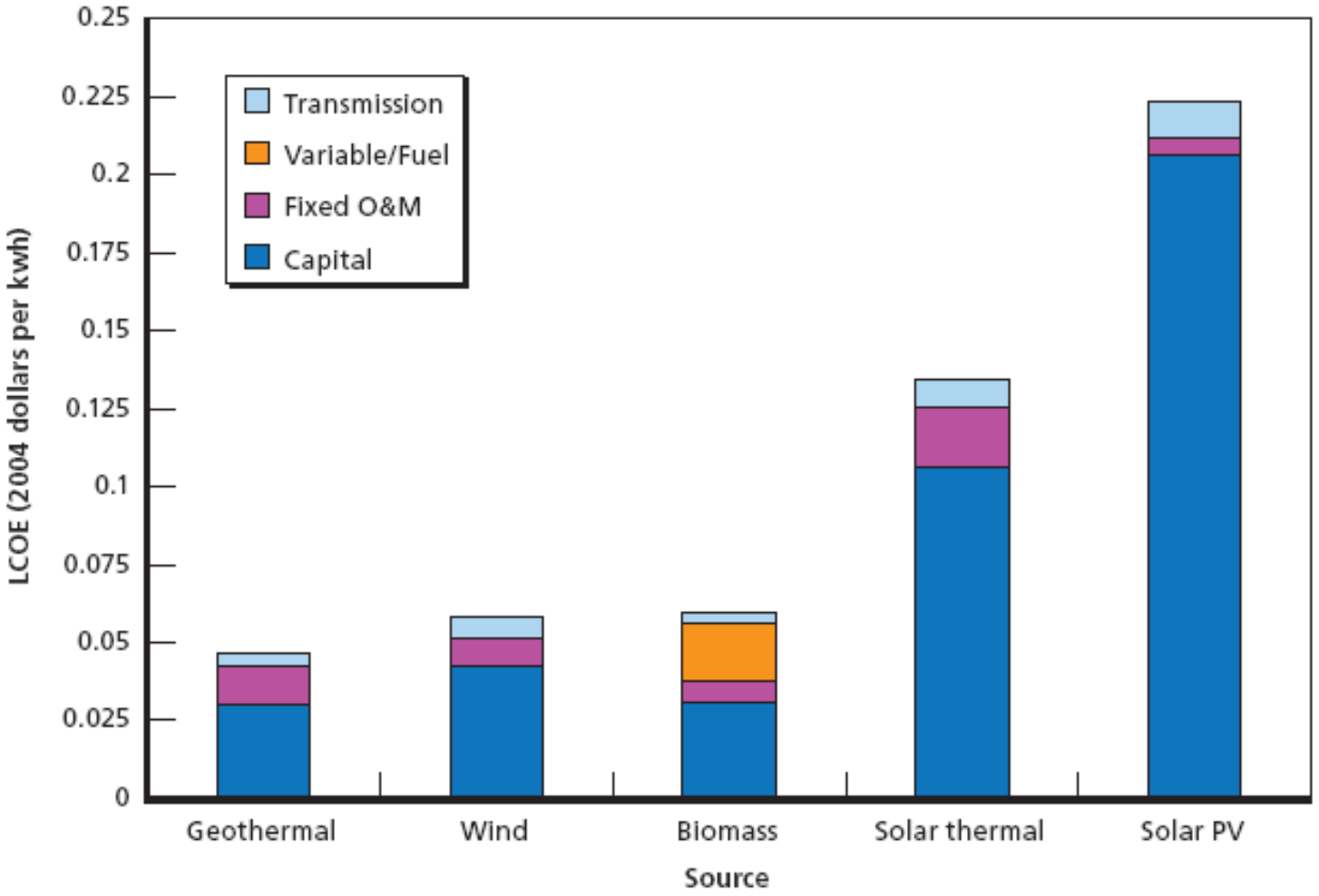
Further Reading….

- **Impacts on U.S. Energy Expenditures and Greenhouse-Gas Emissions of Increasing Renewable-Energy Use**
  - **http://www.rand.org/pubs/technical_reports/TR384-1/**
- **Improving Cost-Effectiveness and Mitigating Risks of Renewable Energy Requirements (J. Griffin)**
  - **http://www.rand.org/pubs/rgs_dissertations/RGSD236/**
- **Unconventional Fossil-Based Fuels: Economic and Environmental Trade-Offs (M. Toman et al)**
  - **http://www.rand.org/pubs/technical_reports/TR580/**

Thank You

Additional Slides: Information on Input Assumptions, Sample Model Outputs

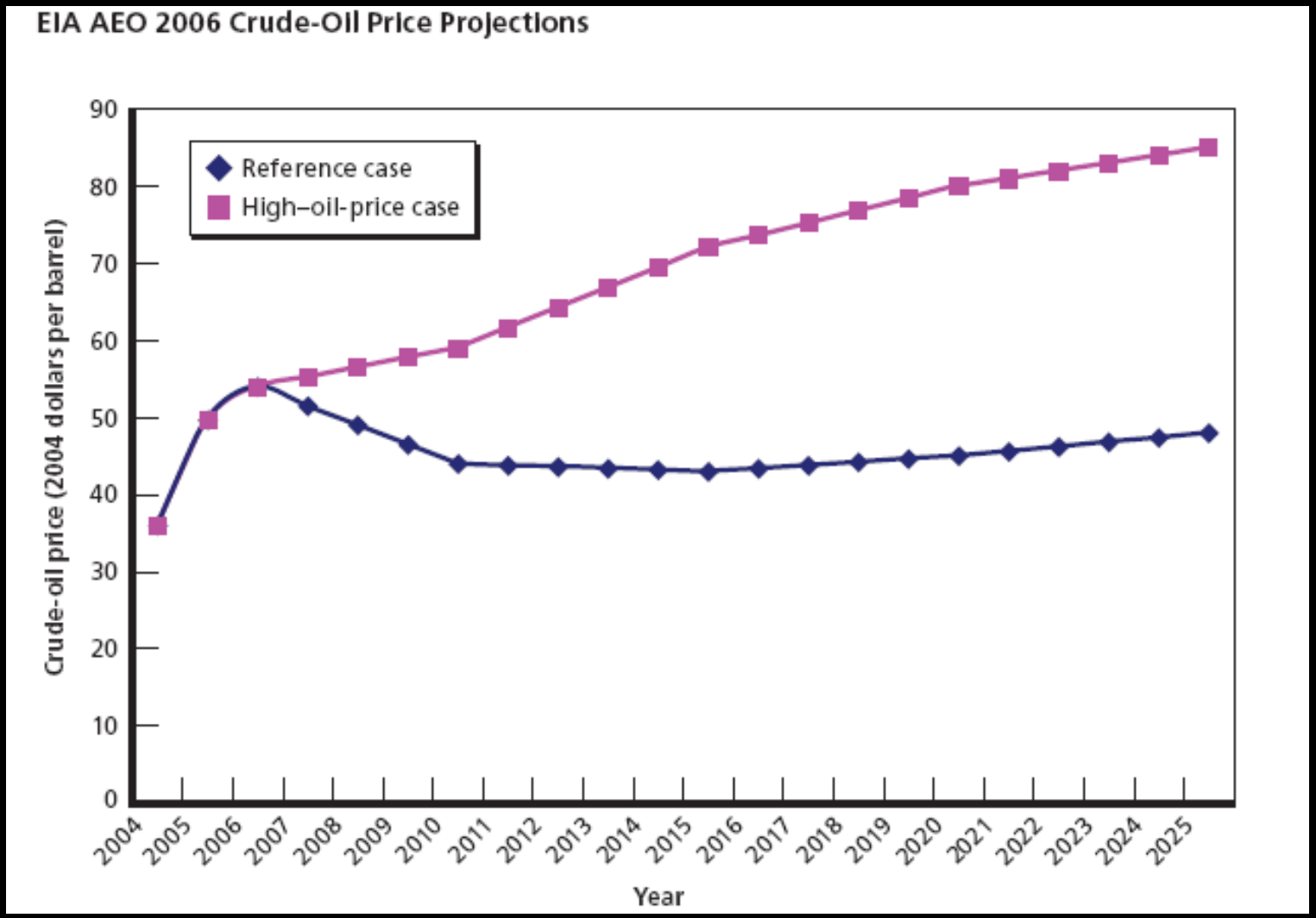
AEO 2006 Renewable-Electricity Cost Projections for 2020



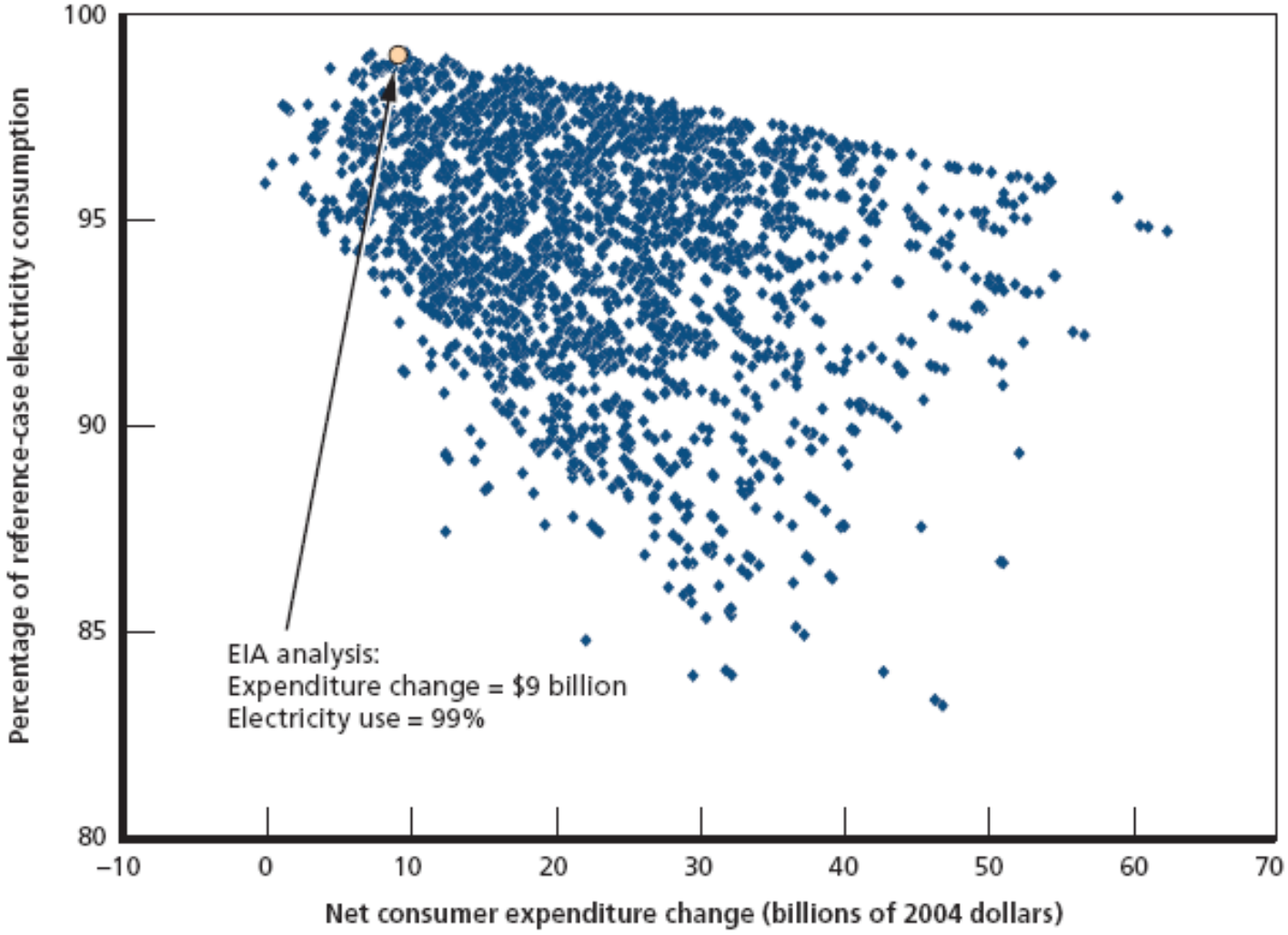
Assumed Price-Elasticity Values

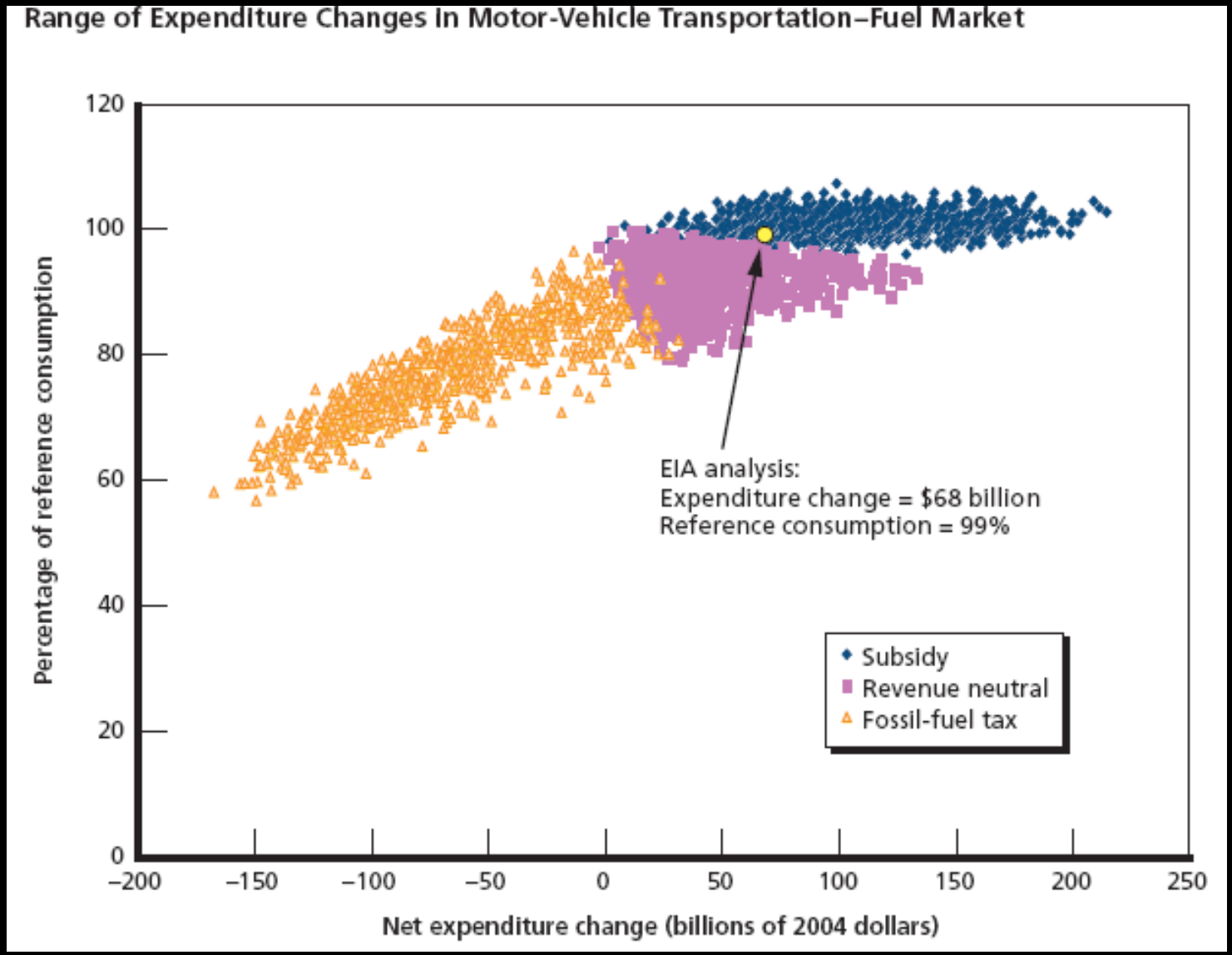
Energy Supply or Demand Type	Elasticity Value		
	Low	Nominal	High
Transportation-fuel demand	–0.2	–0.5	–0.8
Oil supply	0.2	0.4	0.6
Electricity demand	–0.2	–0.4	–0.6
Natural gas supply	0.2	0.4	0.6
Coal supply	0.7	1	1.3

EIA AEO 2006 Crude-Oil Price Projections

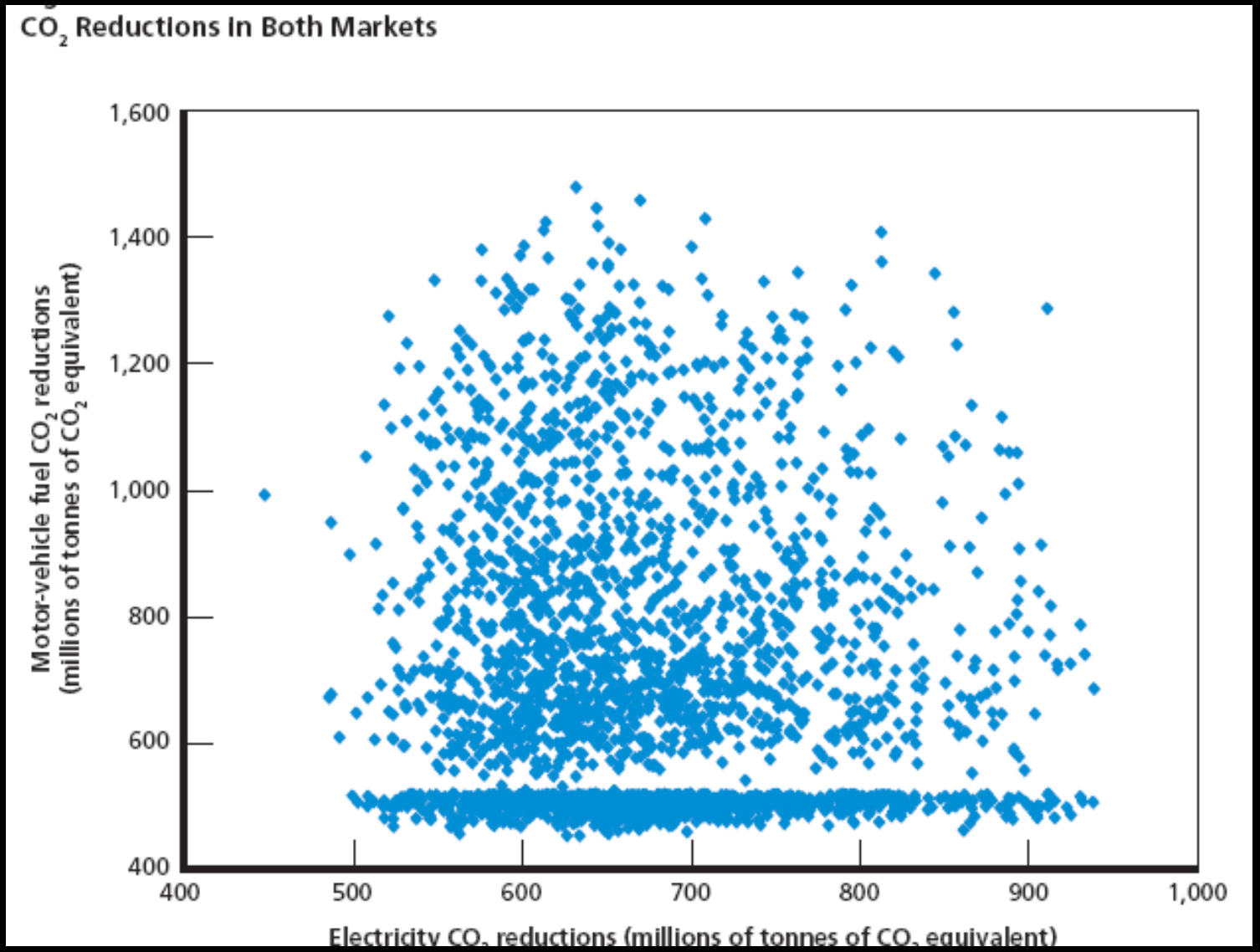


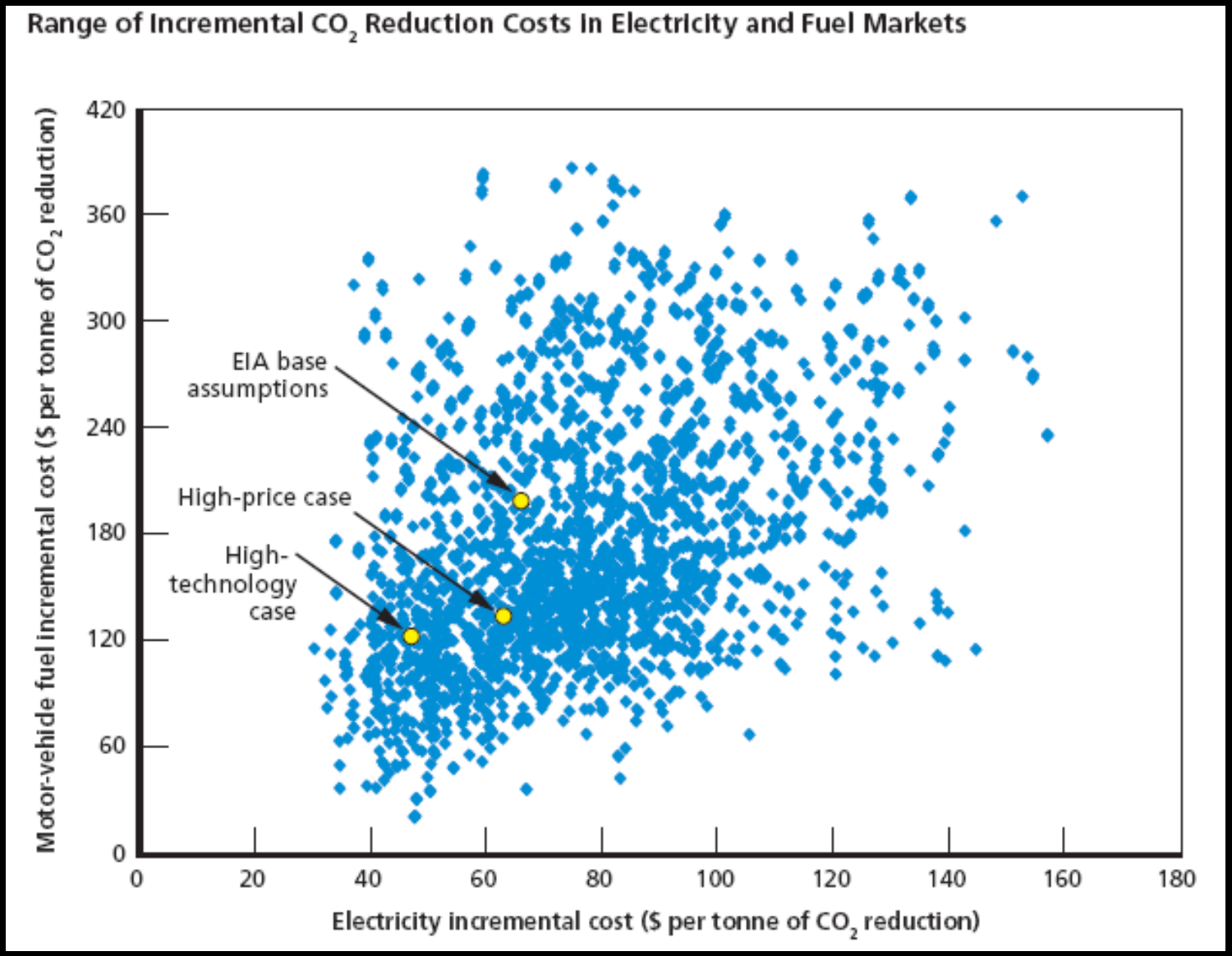
Range of Expenditure and Consumption Changes in the Electricity Market




Range of Expenditure Changes in Motor-Vehicle Transportation–Fuel Market
Percentage of reference consumption
120
100
80
60
40
20
0
–200
–150
–100
–50
0
50
100
150
200
250
Net expenditure change (billions of 2004 dollars)
EIA analysis:
Expenditure change = $68 billion
Reference consumption = 99%
Subsidy
Revenue neutral
Fossil-fuel tax

CO_2 Reductions In Both Markets




Range of Incremental CO_2 Reduction Costs in Electricity and Fuel Markets
Motor-vehide fuel incremental cost ($ per tonne of CO_2 reduction)
420
360
300
240
180
120
60
0
EIA base assumptions
High-price case
High-technology case
0
20
40
60
80
100
120
140
160
180
Electricity incremental cost ($ per tonne of CO_2 reduction)