RICE UNIVERSITY

# Energy Market Consequences of an Emerging U.S. Carbon Management Policy

**Kenneth B Medlock III**
Fellow in Energy Studies, Baker Institute
Adjunct Assistant Professor, Department of Economics

**Peter R Hartley**
George and Cynthia Mitchell Chair, Department of Economics
Rice Scholar, Baker Institute

**Debra Pyle**
Energy Forum Graduate Student Fellow, Baker Institute

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**James A Baker III Institute for Public Policy**
**Rice University**

# Study Scope

- The Baker Institute will adjust its World Gas Trade Model to investigate the effects of different CO2 management schemes.
- A scenario approach will be used to examine and compare various outcomes under different sets of assumptions.
  - Scenarios will focus on the CO2 abatement policies currently being considered at the state and federal level in the U.S., holding policies elsewhere fixed.
  - We will also consider a “harmonized” policy in which allowances are traded internationally.
  - We anticipate development of the CO2 pricing element of the global energy model will take 6 about months once techniques and assumptions are finalized.
- Various degrees of CO2 constraint and the associated implications for CO2 pricing will be investigated.
- We will also investigate the effects of changes to operating and capital costs of backstop technologies and other key assumptions.

# Previous work

# MIT (Report 150)

- Apply both forward-looking and recursive versions of the MIT Emissions Prediction and Policy Analysis (EPPA) model to consider the impact of GHG cap-and-trade legislation.
- Effort focuses on the U.S., and aggregates the Rest of the World.
- Model features
  - Constant intertemporal elasticity of substitution utility function dictates household consumption decisions
  - Representative households engage in consumption smoothing
  - Economic growth varies across regions. Convergence is a feature of the model.
  - Macro balance is maintained. Represents international trade and capital flows.
  - "Carbon-free" backstop is assumed at a price of $50/ton. This is chosen via trial and error – anything more is above the 203bmt case so is irrelevant.
    - "Backstop tech" case allows investment in a known abatement technology to occur endogenously. This is different than assuming availability at constant price.
  - Assumes future supply curves in each period for fossil fuels and alternatives

# Other Studies

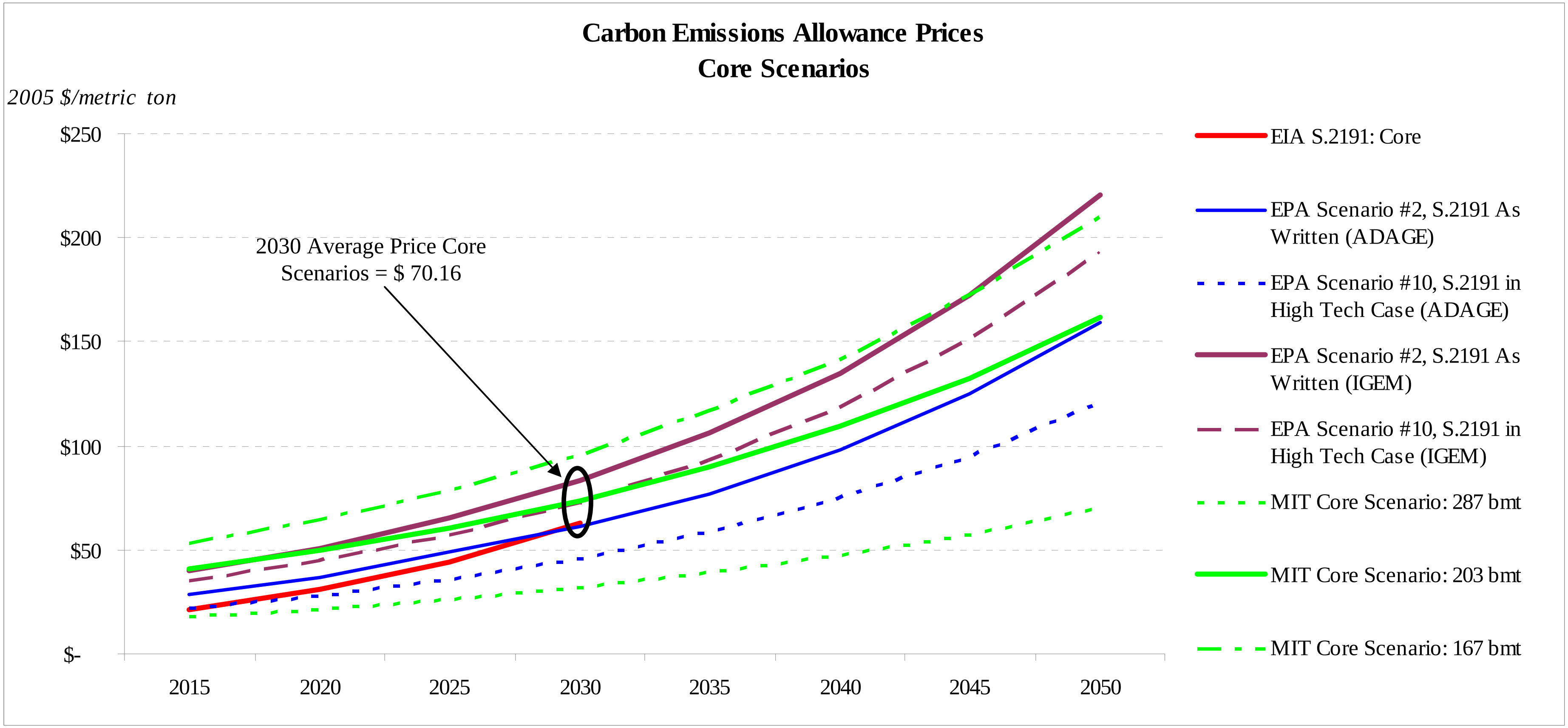
- EIA
  - Source: www.eia.doe.gov/oiaf/service_rpts.htm
  - Specific NEMS runs given S.2191, the Lieberman-Warner Climate Security Act of 2007 legislation. Aggressive adoption of nuclear.
  - Long run carbon price (2030) = $61; $P_{NG}$(2030) = $5.65 (2006$)
- EPA
  - Source: www.epa.gov/climatechange/economics/economicanalyses.html
  - Two exercises using different models: ADAGE and IGEM
  - Carbon price = ADAGE: $61 ($81 with constraints on nukes), IGEM: $82
  - Natural gas price = $5.76 (2005$)
- NGC
  - Used NEMS to dispute EIA on basis of nuclear power assessment
    - "… the EIA analysis incorrectly assumes 145 new nuclear power plants will be built by 2030. Another study by the Natural Gas Council (NGC) assumes that only 25 nuclear power plants will be built in that same time period. This figure is likely more accurate since only one nuclear power plant has been ordered in the last 30 years…"
    - Natural gas demand up by 14 percent (3.6 trillion cubic feet (TCF)) per year from 2020-2030 on average
    - Natural gas wellhead prices $1/mcf or more higher

# Other Studies (cont.)

- Stern Review
  - Received much attention as an authoritative source on the economics of dealing with climate change.
  - Key result: $85/metric ton CO2 equivalent for business as usual case
  - Critics point to various flaws, the most disputed of which centers on a lack of appropriate discounting.
- McKinsey Report
  - Highly cited, especially on Capital Hill.
  - Constructs a marginal cost curve for CO2 abatement measures
  - Identifies a cost of $50/ton.
  - Critics point to low discount rate. McKinsey acknowledges using a "social rate of discount".
- EPRINC
  - Notes cost of cap-and-trade, but argues opportunities will be created as well.

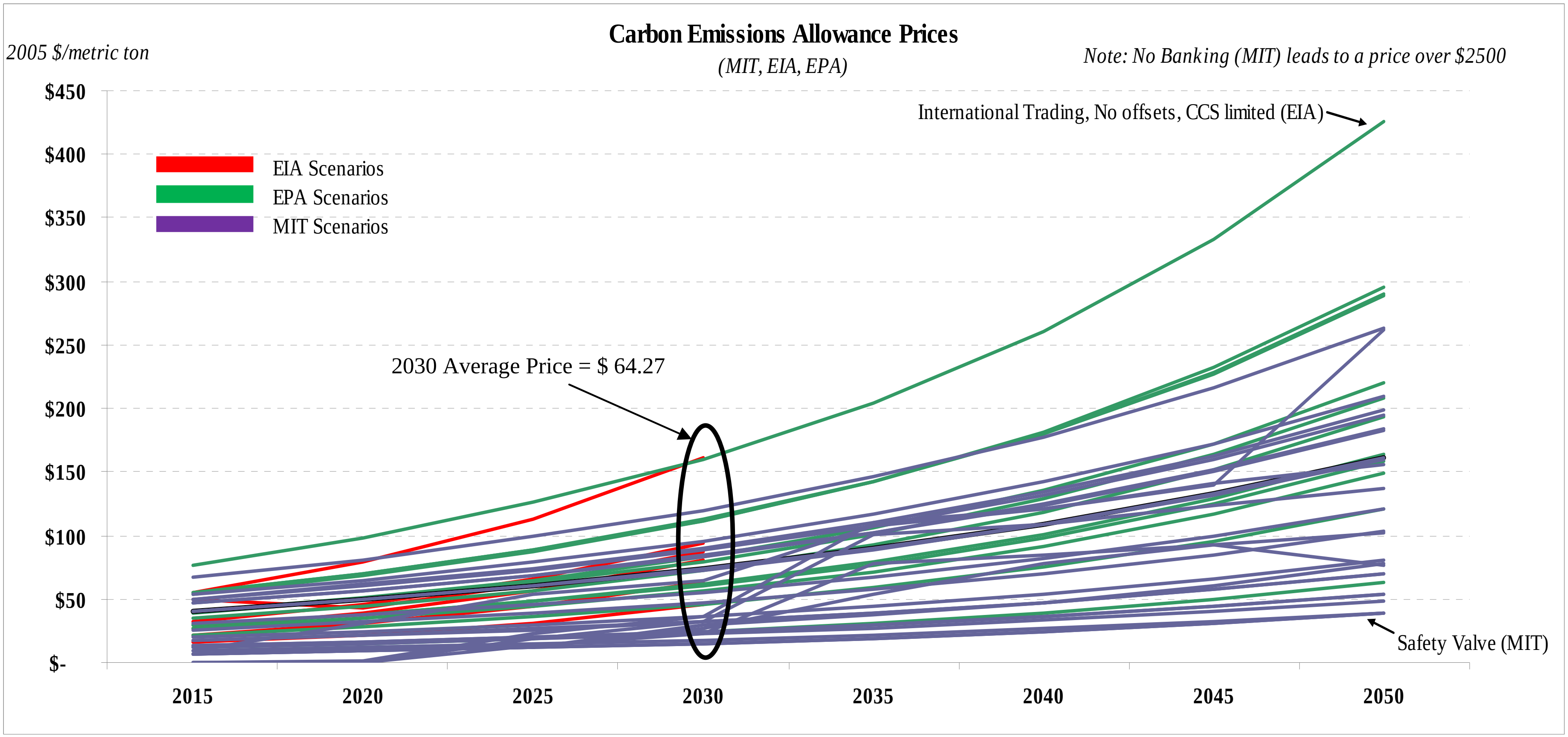
# Carbon Prices

- Carbon prices in core scenarios range across models.
  - Generally prices increase with restrictions
  - Technology assumptions are crucial



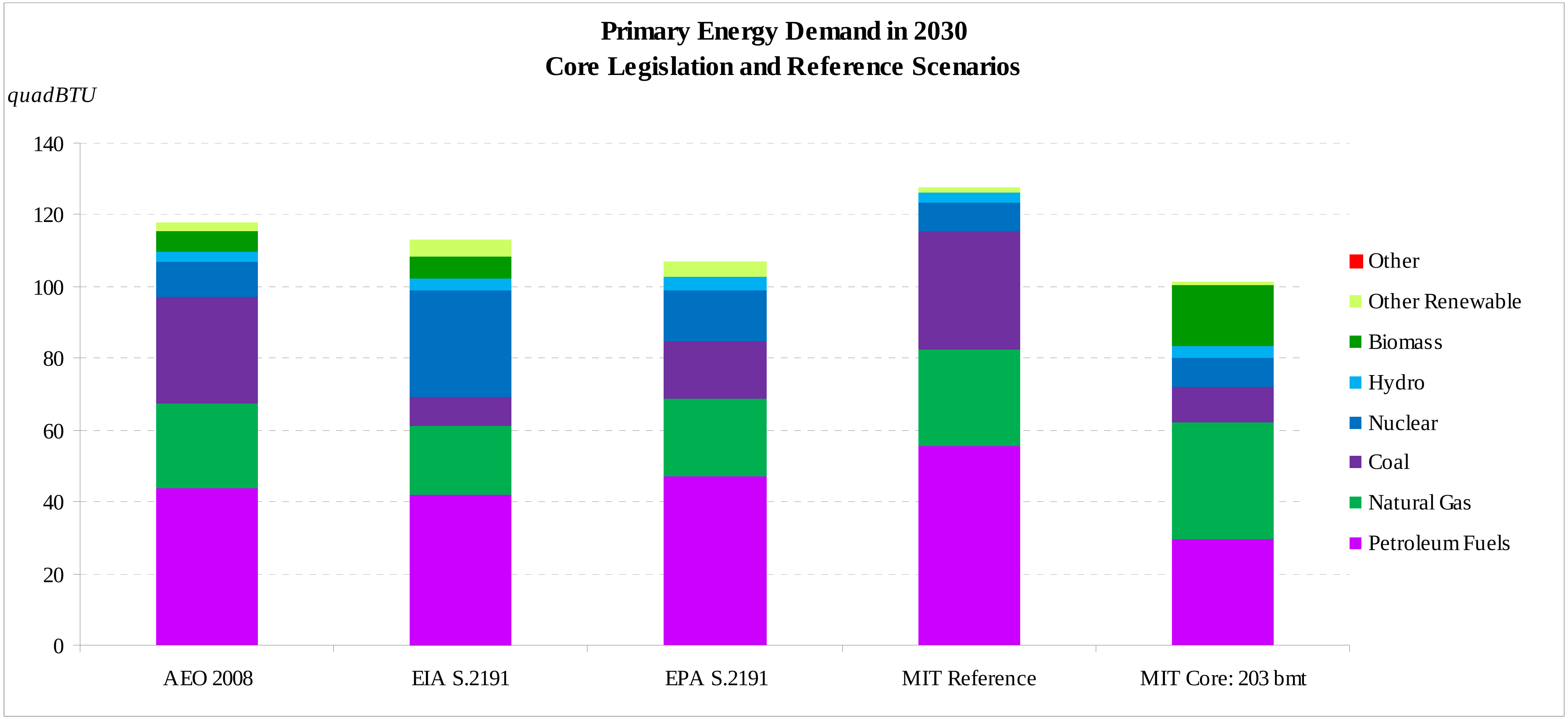
# Carbon Prices (all cases)

- Carbon prices range significantly across scenarios.
  - Generally prices increase with restrictions
  - Technology assumptions are crucial



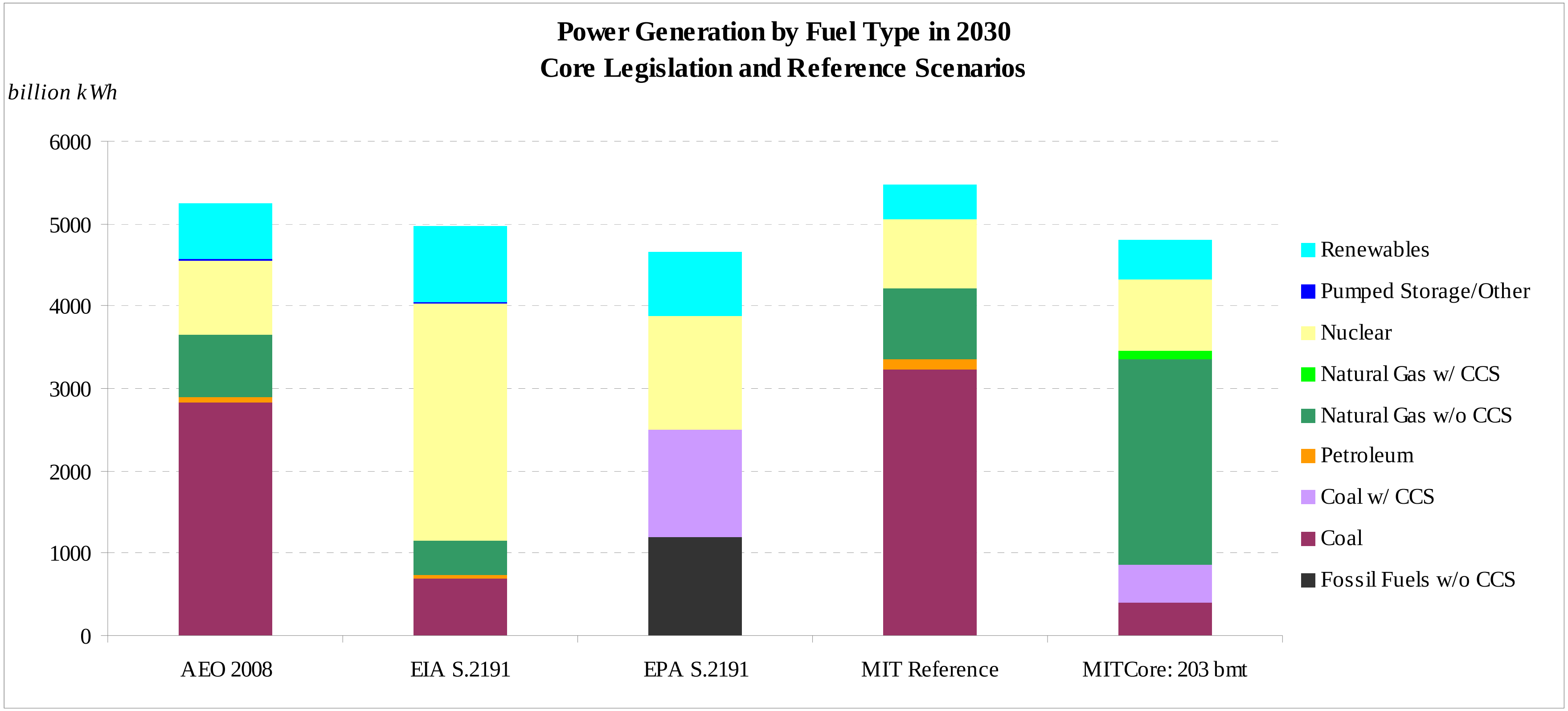
# Energy Demand

- Models vary substantially
  - MIT reference growth and effects of legislation are strong; MIT response strong in biofuels and natural gas, with biofuels partially replacing oil in transport
  - EIA responds with strong growth in nuclear
  - EPA gains largely due to altered use of the same fuels



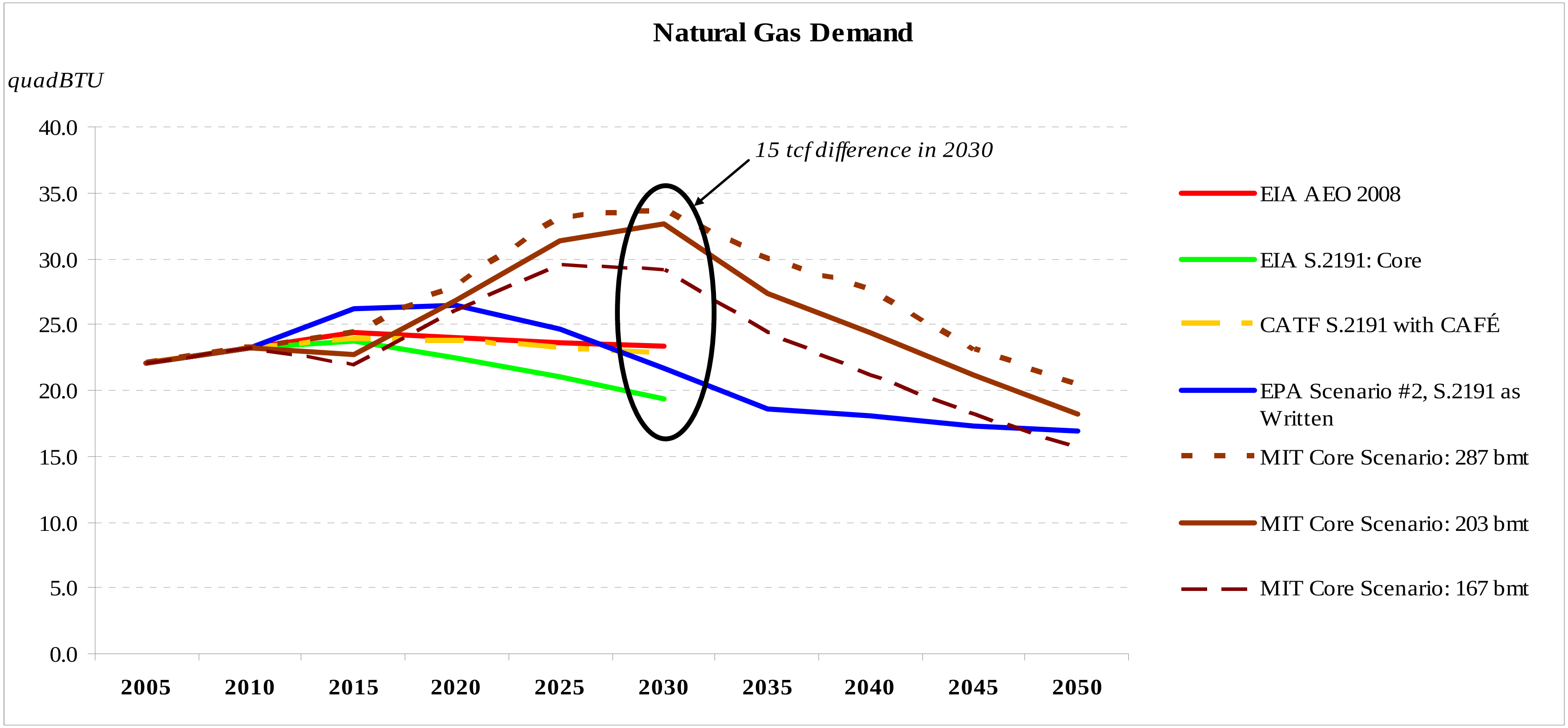
# Power Generation by Source

- Significant differences across models.
  - All models see strong growth in renewables in all cases
  - MIT sees strong growth in natural gas to displace coal
  - EIA strong in nuclear
  - EPA only distinguishes “Coal w/ CCS” from “Fossil Fuels w/o CCS”



# Natural Gas Demand

- Trends vary significantly, as does timing.
  - Strong relationship between natural gas demand, CCS technology availability and assumptions regarding nuclear power.



# BIPP Study

# Differentiation

- We use a global model
- Fossil fuel supply is based in geology
  - Development of supply is based on capital recovery. Thus, anything that alters the profitability of supply within any period will alter the intertemporal investment decision of the project developer.
- Consider risk-adjusted discount rates that may be capital specific, technology specific, etc.
  - Firms will not invest in frontier technologies with uncertain payoffs at low rates of return.
  - Other studies "discount" discounting. BUT, we discount not only because there are various risks that influence investment choices, but because we want to account for *opportunity costs*.
- We will also consider least cost approaches to dealing with climate change
  - Abatement is not the only option. Mitigation of consequences is also part of the conceptual framework.

# The research plan

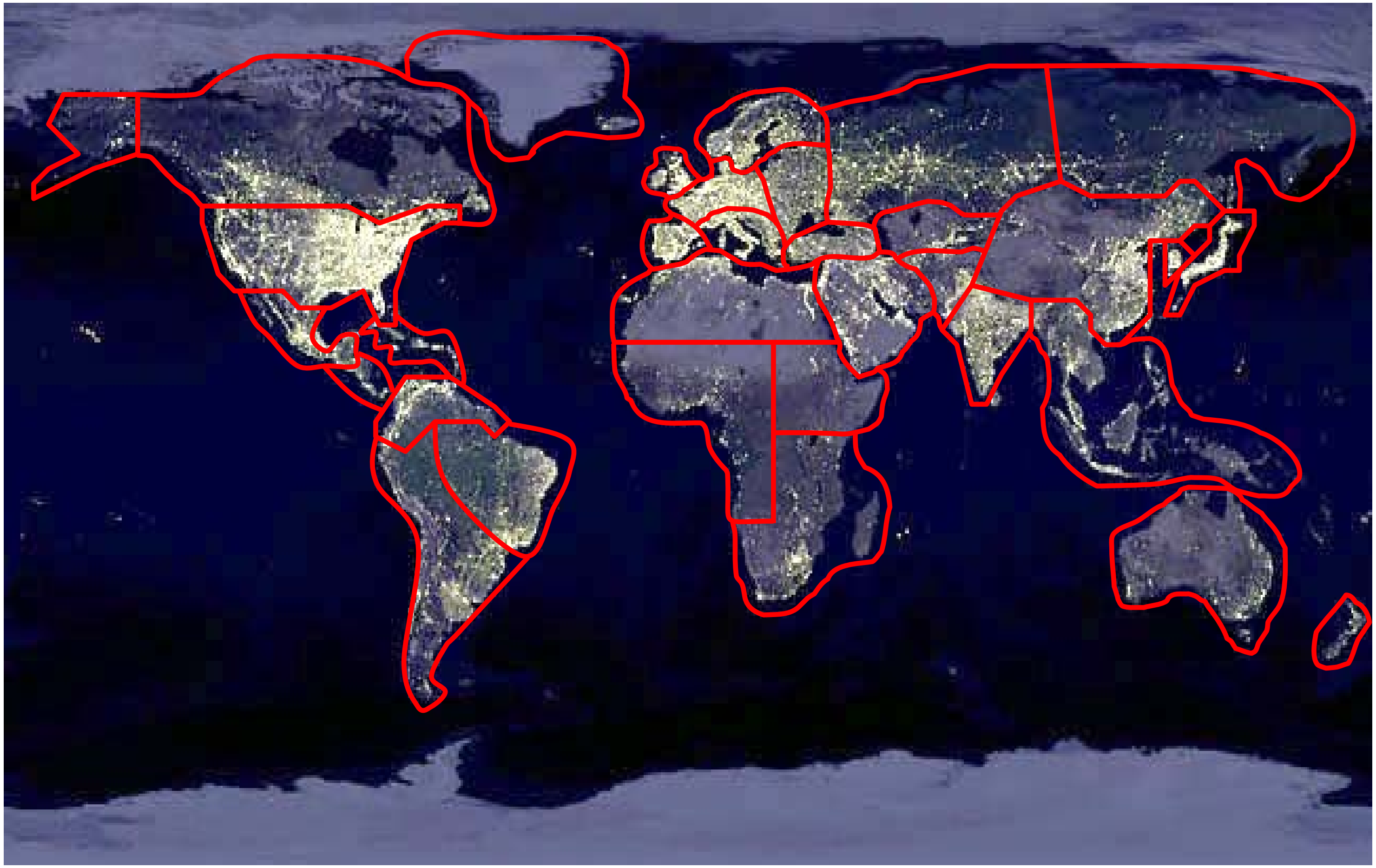
- Already completed some simple work focusing only on the global natural gas market
  - Scenarios regarding cost of alternatives can be analyzed
- Developing other energy sources/sectors to capture fixed costs of investment under different types of CO2 regulatory schemes
  - Allows for more complete consideration of substitution possibilities.
- Compile sources of data and implement
  - Includes fixed and variable costs and returns to investment
- Consider the effect of taxes versus quotas
  - Environmental economics literature implies that the elasticity of marginal damage and marginal cost of control and uncertainty are the key determinants of the desirability of taxes versus quotas
  - What will future policy be?
    - Taxes or quotas that respond to the perceived marginal damage and marginal costs of control *versus*
    - Taxes or quotas that are set in advance and are unresponsive to new information

# The model

- Build on global gas model. Develop a global *energy* model.
- Greater aggregation than RWGTM
- Three demand sectors
  - Transportation, Power Generation, Other Sectors
  - The initial primary energy demand econometric analysis is complete. Work is based upon the relationship between sector-specific energy demand and economic development. Some variations will be introduced by assumptions regarding policy induced technological change.
  - The fuel choice in power is based on the competitiveness of various generation types. The costs of future generation types based on DOE Office of Fossil Energy capital costs. Power production from fossil fuels produces CO2.
- Supply data grounded in geologic assessments.
  - The NPV of the marginal project must be equal to zero.
  - Supply can be modeled as a joint production activity (CO2 and fossil fuel). This can be a full "well-to-wheel" type CO2 accounting.
- Non-stochastic framework is conducive to scenario analysis.

# The model: regional detail

- Model is characterized into super-regions.
  - The US is state level, Canada is provincial, Europe is country level. All other regions are aggregated, except China, India, and Pacific OECD.



# The model: future generation costs

- New Power Plant Capital Costs (source: DOE Office of Fossil Energy)

| Technology | Total Overnight Cost in 2007 (2006 $/kW) | Variable O&M[5] (million 2006 $/kW) | Fixed O&M[5] (2006 $/kW) | Heat Rate in 2007[6] (BTU/kWh) | Heat Rate nth-of-a-kind (BTU/kWh) |
|---|---|---|---|---|---|
| Scrubbed Coal New[7] | 1,534 | 4.46 | 26.79 | 9,200 | 8,740 |
| Integrated Gasification Combined Cycle (IGCC)[7] | 1,773 | 2.84 | 37.62 | 8,765 | 7,450 |
| IGCC with CCS | 2,537 | 4.32 | 44.27 | 10,781 | 8,307 |
| Conventional Gas/Oil Combined Cycle | 717 | 2.01 | 12.14 | 7,196 | 6,800 |
| Advanced Gas/Oil Combined Cycle (CC) | 706 | 1.95 | 11.38 | 6,752 | 6,333 |
| Advanced CC with CCS | 1,409 | 2.86 | 19.36 | 8,613 | 7,493 |
| Conventional Combustion Turbine[8] | 500 | 3.47 | 11.78 | 10,833 | 10,450 |
| Advanced Combustion Turbine | 473 | 3.08 | 10.24 | 9,289 | 8,550 |
| Fuel Cells | 5,374 | 46.62 | 5.50 | 7,930 | 6,960 |
| Advanced Nuclear | 2,475 | 0.48 | 66.05 | 10,400 | 10,400 |
| Distributed Generation - Base | 1,021 | 6.93 | 15.59 | 9,200 | 8,900 |
| Distributed Generation - Peak | 1,227 | 6.93 | 15.59 | 10,257 | 9,880 |
| Biomass | 2,798 | 6.53 | 62.70 | 8,911 | 8,911 |
| MSW - Landfill Gas | 1,897 | 0.01 | 111.15 | 13,648 | 13,648 |
| Geothermal[7, 9] | 1,110 | 0.00 | 160.18 | 35,376 | 33,729 |
| Conventional Hydropower[9] | 1,551 | 3.41 | 13.59 | 10,022 | 10,022 |
| Wind | 1,434 | 0.00 | 29.48 | 10,022 | 10,022 |
| Wind Offshore | 2,886 | 0.00 | 87.05 | 10,022 | 10,022 |
| Solar Thermal[7] | 3,744 | 0.00 | 55.24 | 10,022 | 10,022 |
| Solar Photovoltaic[7] | 5,649 | 0.00 | 11.37 | 10,022 | 10,022 |

# The model: broad scenarios

- State-level controls, disconnected at both federal and international level
- Federal controls
  - Disconnected from EU system
  - Integrated international system
  - Various forms of legislation
- Federal energy tax
  - Discuss merits versus $CO_2$ tax or quota
- Varying discount rates and rates of technological change

# Comments/Discussion