Integrated Assessment of Advanced Energy Technology Options

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Outline

- Philosophy of Assessment Framework
- Structure of Assessment Framework
- A Couple of Key Design Issues
- Initial Applications of Assessment Framework
- Initial Insights From Assessment Framework
- Future Directions
Recommendations On Global Energy-Economic Modeling in General

• Don’t Take It Too Seriously

• Don’t Ignore It Either
Revolutionary Energy Technologies and “Other” Climate Policies
Difficulties In Using Existing General Purpose E-E Models Directly to Assess Long-Run Energy R&D

• Models With Enough Technical Detail Are Too Cumbersome For Uncertainty Analyses

• Models Set Up for Uncertainty Analyses Don’t Have Enough Technical Detail
Design Criteria for Assessment Framework

• Reflect Uncertainties in:
  – Future Energy Demands
  – Future Energy-Environment Policies
  – Future Energy Prices\Resource Availabilities
  – Target Technology Performance
  – Competing Technology Performance

• Focus on Critical Features of GCEP Portfolio:
  – Value New Technologies Contingent on Availability of Other New Technologies
  – Value New Technology Contingent on a Broad Range of Possible Market Futures
Structure of Assessment Framework

- **4 Sectors**
  - (1) Electricity
  - (2) Transportation
  - (3) Industrial Heat
  - (4) Resid. & Comm. Heat

- **8 Regions**
  - US(4)/West Europe/Japan/Other OECD
  - China(2)/India/Other Developing
  - Eastern Europe & Former Soviet Union

- **4 Time Periods**
  - 2000-2025
  - 2026-2050
  - 2051-2075
  - 2076-2100
Structure of Assessment Framework (continued)

• Technology Areas – Approx. 250 Technologies
  – Solar/Wind/Biomass/Sequestration
  – Advanced Combustion/Hydrogen/Nuclear
  – Advanced Electric/ Advanced Coal

• Output Metrics
  – Carbon Emission Reductions/Fuel Use
  – Total Benefits
  – Public & Private Benefits
  – By Technology and Portfolio (Inc. Option Values)
  – Water/Land/Platinum Use/Price Feedbacks
Schematic Diagram of Technology Evaluation Process

- SAGE/TIMES/IEO
  - Tech Detail
  - Public
  - Annual Updates

- GCEP
  - Thermo
  - Step Out
  - Integrated

Technology Cost & Performance Probability Distributions

Technology/Portfolio Evaluation

Desirable Technologies/Portfolios

Scenario/Scenario Variable Probability Distributions

Valuation Model

Scenarios

Models/Results

Expert Assessments
Levelized Cost Comparison Concept

Levelized Cost Comparison for Electric Power Generation
With $100 per Ton Tax on Carbon (2004-5 Fuel Prices)
GCEP Technology Assessment: Conceptual Overview

Price Of Energy

Demand

Supply

Supply With Carbon Constraints

Supply With Carbon Constraints and GCEP

Net Benefits

Quantity of Energy
Alternative Global Carbon Emission Projections

Billion Metric Tons

Year

2005 Technologies
High Baseline
Reference Baseline
Low Baseline
550 ppmv Stabilization
Key Uncertainties Considered in Integrated Technology Assessment Framework

• Specific to Advanced Technologies
  – Cost
  – Performance
  – Public Acceptability

• Market Uncertainties
  – Energy Demand Levels
  – Oil & Gas Prices
  – Government Policies (Esp. Related to Climate Change)
GCEP Technology Assessment: Conceptual Overview

- Supply With Carbon Constraints
- Supply With Carbon Constraints and GCEP
- Large Uncertainties

[Diagram showing supply, demand, and price of energy with net benefits highlighted]

Price Of Energy

Net Benefits

Quantity of Energy
Information, Foresight & Uncertainty: Three Alternative Sets of Assumptions

(1) Static, Myopic, or Recursive Dynamic
(2) Perfect Foresight (Rationale Expectations)
(3) Decision Making Under Uncertainty
Information, Foresight & Uncertainty: Three Alternative Sets of Assumptions

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Interplay Between R&D and Investment Decisions

R&D Decision

Investment Decision

Cost

Time

C₁ C₀

∞

C₁ C₂

GCEP
Projected Range of Impacts of GCEP Program on Global Carbon Emissions
Carbon Emission Reductions Resulting From GCEP Renewables R&D

Cumulative Carbon Emission Reductions Through 2100 (GT)
Integrated Assessment of Carbon Capture, Separation and Sequestration

• **Inputs Required** (Oscar Mascarenhas Project)
  - Energy Penalty for Separation
  - Capital, O&M Costs for Separation
  - CO₂ Transport Costs
  - Sequestration Costs/Capacities by Region & Category
  - PRA of Leakage Potentials
  - Public Acceptability Assessment

• **Outputs Produced**
  - Market Share/Carbon Emission Reductions
  - Impact on Energy System Costs/Energy Markets
  - Under Broad Range of Energy Market/Technology Futures
Carbon Emission Reductions Resulting From GCEP Sequestration R&D

Cumulative Carbon Emission Reductions Through 2100 (GT)

Frequency

Cumulative Carbon Emission Reductions Through 2100 (GT)
Carbon Emission Reductions Resulting From GCEP R&D Portfolio

Cumulative Carbon Emission Reductions Through 2100 (GT)

Frequency
Contributions of GCEP Technologies to Carbon Emission Reductions

- Hydrogen
- Renewables
- Sequestration
- Advanced Combustion
Incremental Value of Renewables Program
Preliminary Insights From Assessment Framework

• All Areas Have High Option Values
  – Can Identify Plausible Cases Leading to 5-10 Times Expected Values
  – Nuclear & End-Use Efficiency Wildcards
  – Choice of Policy Instruments Can Affect Substitutability and Complementarity of Technologies

• Advanced Combustion
  – Large Benefits Robust Over Many Uncertainties

• Carbon Capture and Sequestration
  – Potentially Large Benefits
  – Public Acceptability & Economic Incentive Issues

• Renewables
  – Large Potential Benefits Possible, But Timing Uncertain
  – Economic Incentives And/Or Failures Elsewhere Can Accelerate
  – Key Potential Roles for Niche Markets

• Hydrogen
  – Large Benefits Possible, But They Depend on Success in A Number Complementary Areas
  – Need Careful Internal Co-ordination and External Monitoring
Blanford Dynamic Programming Model
Initial Results

Optimal First Period Investment
U.S. Electric Generation Sector
No Budget Constraint

Cost-Effectiveness Criterion

Cost-Benefit Criterion
Thank You!

The End
Many Technologies Can Contribute

But What is the Optimal R&D Investment Portfolio?

R&D Investment  R&D Outcomes  Market Outcomes

- Nuclear
- Hydrogen
- Carbon Sequestration
- Renewables
- Combustion Efficiency
GCEP Approach for Assessment Activities

Initial Technical Area Assessment
- Selection of Technical Area for Study

Rigorous Energy System Efficiency Analysis
- Thermodynamic Framework
  - Review of current state of energy systems and research directions
    - Literature Studies
    - Workshops
  - Exergy Analysis of Systems
    - Report on potential for significant improvement over current energy systems based on fundamental thermodynamics of systems

System Components and Structure
- System Components Integration
- Performance Limits and Expectations
  - Second Law Analysis of Selected Components
  - System Integration of Components
- Exergy Analysis of Systems
  - Report on potential market penetration and projected overall impact on global greenhouse gas emissions

Integrated Cost and Environmental Analysis
- Scenario Probabilities
- Cost Modeling

Global Impact on GHGs