System for the Analysis of Global Energy Markets

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Purpose of SAGE

- Produce International Energy Projections
  - Publish the *International Energy Outlook 2005*
    - Generate Reference Case Projection
    - Generate Alternative Projections
      - Kyoto implementation strategies
        - » Percent of Reduction to be done domestically
      - High and Low Economic Growth

SAGE Purposes, Cont.

- Establish resource, technology and emission baselines.
- Assess the attractiveness of competing technologies.
- Evaluate the costs and benefits of environmental regulations.
- Provide an indication of the implications for economic development under various energy/environmental futures.
- In the context of Climate Change:
  - Establish emission inventories and baselines.
  - Evaluate the criteria (e.g., additionality) and implications (value of carbon rights) of individual mitigation reduction projects (e.g., CDM, AIJ).
  - Link countries to examine the role of trade (energy, materials and emission permits).

SAGE Country/Region Models

USA

Canada

Mexico

Central & South America

Western Europe

Eastern Europe

Former Soviet Union

China

India

Other Developing Asia

South Korea

Japan

Africa

Middle East

Australia & New Zealand

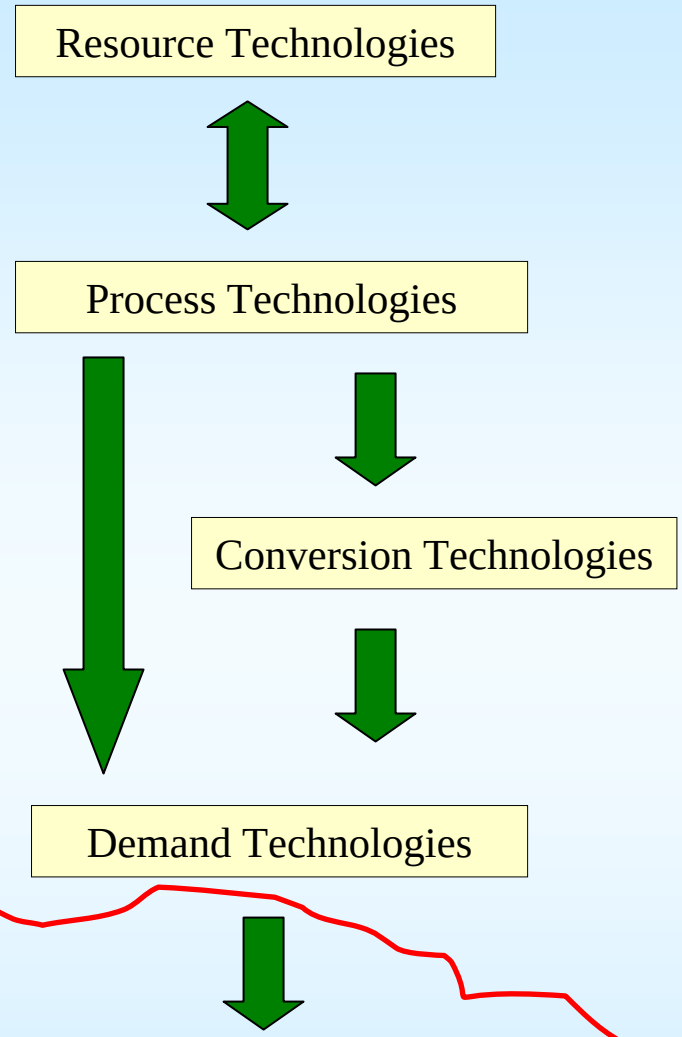
Reference Energy System

Building Blocks

1. **Energy Carriers**
   e.g. crude oil
   liquefied petroleum gas
   gasoline
   distillate
   jet fuel

2. **Technologies**
   e.g. extraction
   import
   refining
   electricity generation
   light duty vehicles
   airplanes
   cookstoves

3. **End-Use Energy Service Demands categorized by sector**



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End-Use Energy Service Categories Represented in SAGE

Residential Sector (11)

Space Heating
Space Cooling
Refrigeration
Water Heating
Cooking
Lighting
Clothes Washing
Clothes Drying
Dishwashing
Residential Electric Appliances
Other Residential Energy Services

Commercial Sector (8)

Space Heating
Space Cooling
Refrigeration
Water Heating
Cooking
Lighting
Electric Office Equipment
Other Commercial Energy Services

Industrial Sector (6)

Iron & Steel
Non-Ferrous Metals
Chemicals
Non-Metallic Minerals
Pulp & Paper
Other Industries

Steam
Process Heat
Motors
Electrolytic
Feedstock
Other

Transportation Sector (13)

Personal Automobiles
Personal Light Duty Trucks
Buses
Commercial Heavy Trucks
Commercial Medium Trucks
Commercial Light Trucks
Two & Three Wheeled Vehicles
Domestic Aviation
International Aviation
Passenger Rail
Freight Rail
Internal Navigation
International Water Shipping

Agriculture Sector (1)

Total Agriculture Energy Demand

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Implications of Simulating Energy Projections with LPs

- LPs are good at simulating cost minimizing or profit maximizing behavior (i.e., dispatching electric power plants)

- LP's do well at indicating how consumers and policy makers *should* act to minimize cost in a world where all future events are known

- However, consumers satisfy complex utility functions and the impact of energy and environmental policies on markets evolve over time without full knowledge of the future.
- we must 'endogenize' mechanisms that represent non-economic aspects of energy markets.
  - Imperfect foresight, hurdle rates, market shares, etc.

Features of LPs, cont.

- Most energy LPs solve ‘dynamically’
  - Solution represents the least cost of providing energy services over the entire forecast horizon with full knowledge of all relevant future events
- But energy and environmental policies work one time period to the next—you’re stuck with past investment decisions that seem misguided in the light of an unforeseen future.
- SAGE is a time-stepped LP approach. Decisions made in each period are conditional on decisions made in all previous periods

SAGE - Demand

- Defines Reference Energy System (RES) – region specific
  - Technologies - existing and potential future with operating and cost characteristics.
  - Energy carriers (e.g., crude oil and gasoline) - flow between technologies that extract, import, refine and consume the carriers.
  - End-use Service Demand - .
    - > Forecast as function of exogenous macro-economic “drivers” (e.g. GDP, Population, GDP/capita)
    - > Main Sectors: Residential, Commercial, Industrial, Transportation and Agriculture
    - > Sectors have service demand categories (e.g. space heating)
    - > Service demands categories met by one or more technologies (e.g. electric resistance heating, heat pumps, natural gas furnaces, etc.)

SAGE "Supply"

(i.e. technologies to meet demand & resulting fuel use)

Approach Overview

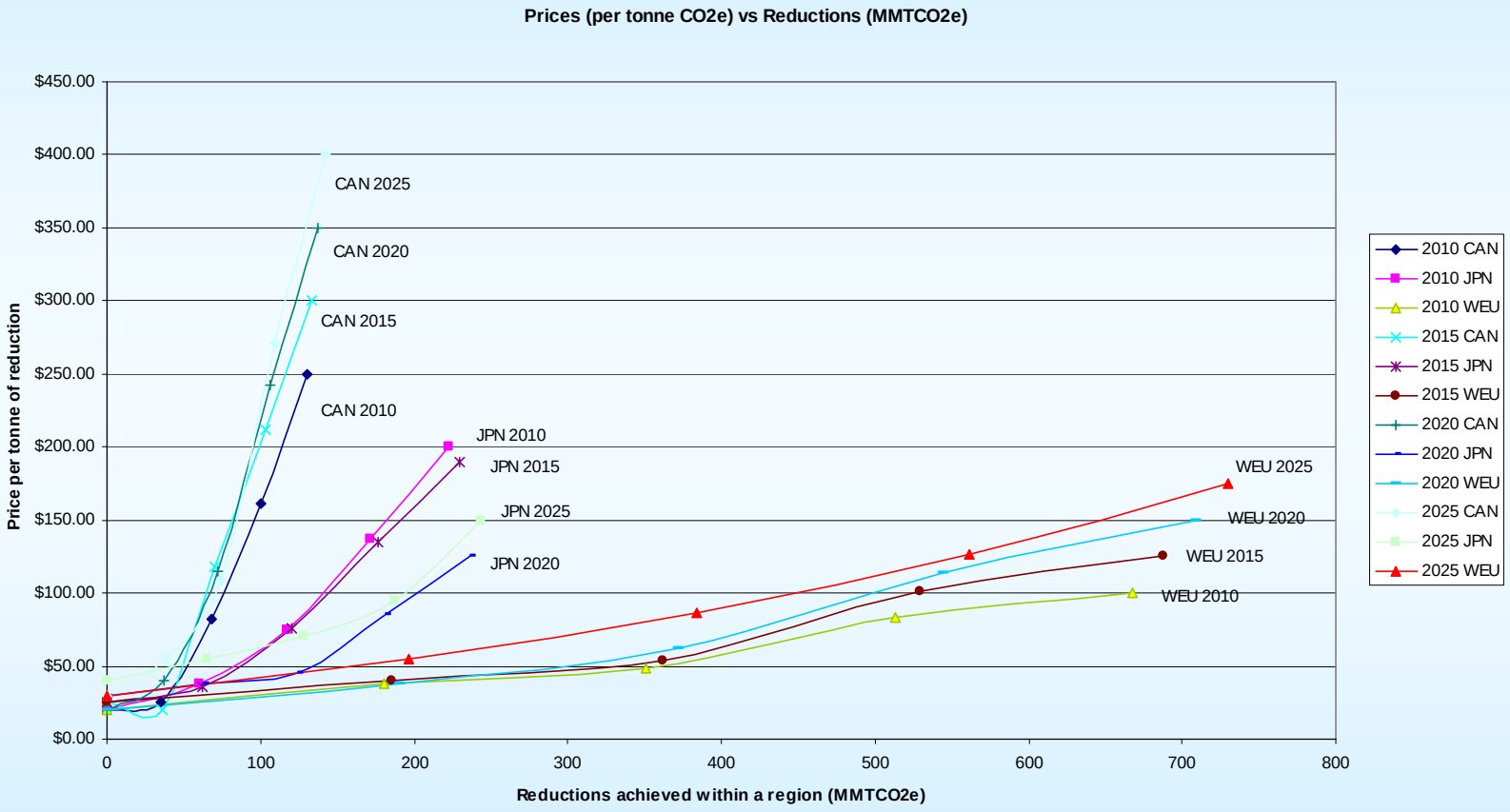
- Establish baseline (period 0) technology stock from historical data.
- Apply SAGE (LP) to find least cost technology mix that satisfies forecasted service demands.
- Solve for 5 year time blocks to 2025 for each of the 15 regions.

LP General Characteristics of Interest

- Starts with existing stock of technology derived from historical sources (principally EIA, IEA, UDI for electricity generation capacity.);
- Technology characteristics define fuel type and quantity to produce 1 "unit" of service. Costs include fuel (extraction, production, etc.), technology construction, and O&M.
- Fossil resources (coal, natural gas, petroleum) defined for reserves, reserves growth, and new discovery; Three price and quantity points for each category yield 9 step supply curves.
- Generally selects existing stock before building new capacity (existing technology don't have new construction costs);
- For technologies with use substantially driven by non-economic factors, analysts apply "constraints" as dictated by exogenous data and expert judgment.

Environmental Analysis Focus

- How do particular technologies and economic policies (e.g., taxes, subsidies) affect GHG and emissions of other pollutants?
- What are the costs of meeting mitigation targets and/or other environmental policies?
- How do demand-side actions affect the supply-side, and vice versa?
- How do technology and fuel mix changes affect energy prices?



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