

Overview and Special Features of SAGE

System for the Analysis of Global Energy markets

Pia Hartman & Barry Kapilow-Cohen
Office of Integrated Analysis and Forecasting
Energy Information Administration

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Overview of International Energy Modeling Activity at EIA

Existing Forecasting Tool

World Energy Projection System (WEPS)

- Integrated set of pc-based spreadsheets
- Incorporates projections from independently documented models, and assumptions regarding future energy intensity (E/GDP) trends & the rate of incremental energy requirements met by each fuel type over time
- Used to develop forecasts for the *International Energy Outlook (IEO)*:
 - Total energy consumption, by fuel (oil, natural gas, coal, nuclear, renewables)
 - Net electricity consumption
 - Energy consumption for transportation sector, by fuel
 - Energy-related carbon dioxide emissions, by fuel

Overview of International Energy Modeling Activity at EIA (cont'd)

New Forecasting Tool in Development

System for the Analysis of Global Energy Markets (SAGE)

- 15-region, pc-based, linear programming model of world energy markets
- Developed using MARKAL modeling framework
- User-friendly input structure & output reporting capability
- Projection horizon up to 50 years, in 5-year steps
- Inter-region trade in energy and/or emissions
- Two operational modes: dynamic LP or time-stepped
- Intended use: 1) develop set of *IEO* forecasts, 2) tool for policy/scenario analysis involving international energy markets

15 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

Each SAGE Regional Model...

- Depicts a Reference Energy System (RES) for that region
- Employs common naming conventions & units
- Draws from comparable energy and economic/demographic data to develop the energy service demand estimates

Energy Statistics and Balances (International Energy Agency)

International Energy Annual (Energy Information Administration)

World Economic Outlook, World Industry Monitor (DRI/WEFA)

World Populations, Global Report on Human Settlements (United Nations)

Comprehensive Inputs & Assumptions Templates

RES Building Blocks

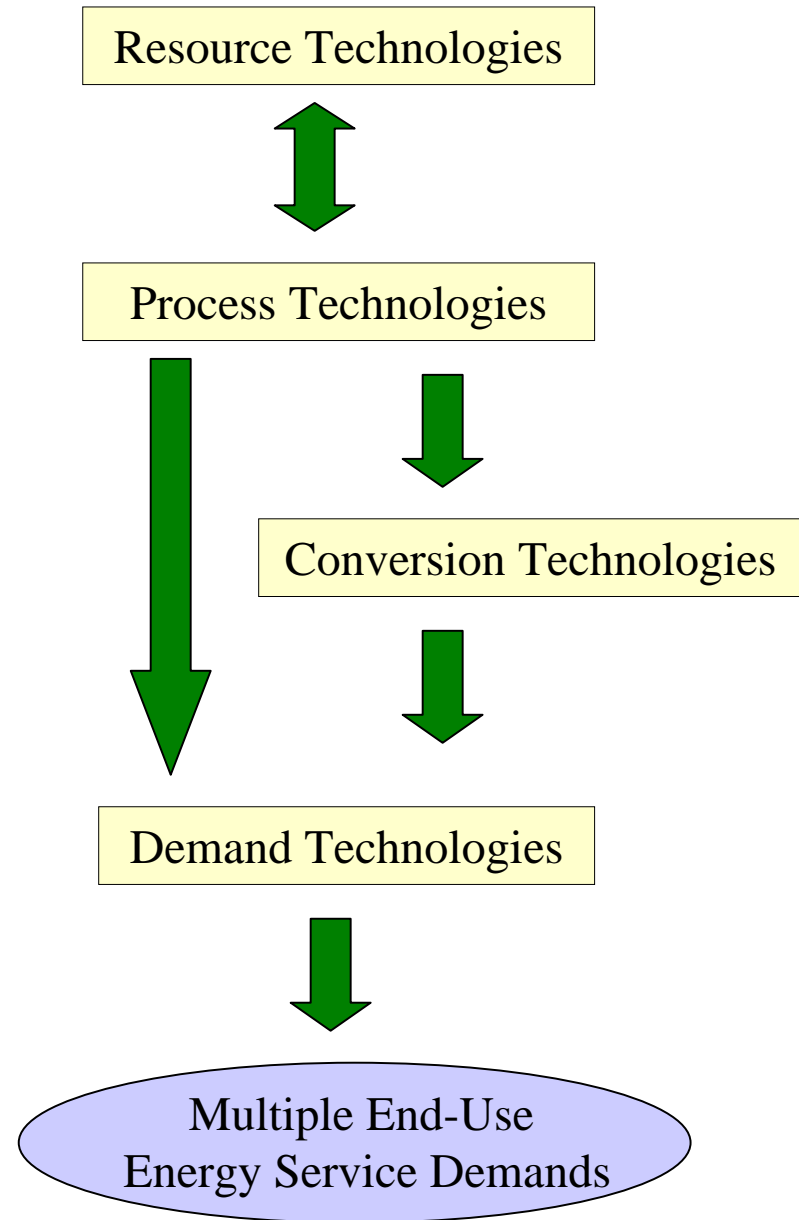
1. Energy Carriers

- 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



End-Use Energy Services 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

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

Technology Representation in SAGE

Each technology is described by a set of parameters, including:

Technical Parameters

Efficiency

Capacity Factor

Physical Lifetime

Energy Carrier Input & Output Mix

Availability Factor

Bound on activity levels or capacity

Economic Parameters

Investment Costs

Fixed O&M Costs

Variable O&M Costs

Discount Rate

Bound on Investment

Environmental Parameters

Emissions factors

Bound on Emissions

SAGE Solutions

- Demand-driven
- Objective function minimizes discounted energy system costs
- Identify least-cost combinations of technologies and fuels for each 5-year solution period, employing either fixed energy service demands, or price-elastic energy service demands*
- Various modes of operation:
 1. Single Region, or Multiple Region* runs
 2. Energy & Emissions Trading*
 3. Dynamic LP (perfect foresight), or Time-Stepped Approach* (imperfect expectations)

*See last slide for status of these features

Learning-By-Doing Returns to Adoption

Background

- Learning-by-doing--well documented since 1930's
- Wright (1936) -- direct labor costs of manufacturing an airframe fell by 20% with every doubling of cumulative output
- Subsequent authors broadened analysis of learning to other costs and showed costs declined with experience

Application in SAGE

- Costs decline as the market accumulates operational and manufacturing experience
- Cumulative capacity built is a surrogate for “market experience”
- Credit for international builds

Learning Curves – Electricity Sector

- Three piece-wise non-linear curves for overnight costs, one for each learning interval
- Overnight Cost (C) is a function of Cumulative Capacity (Q)

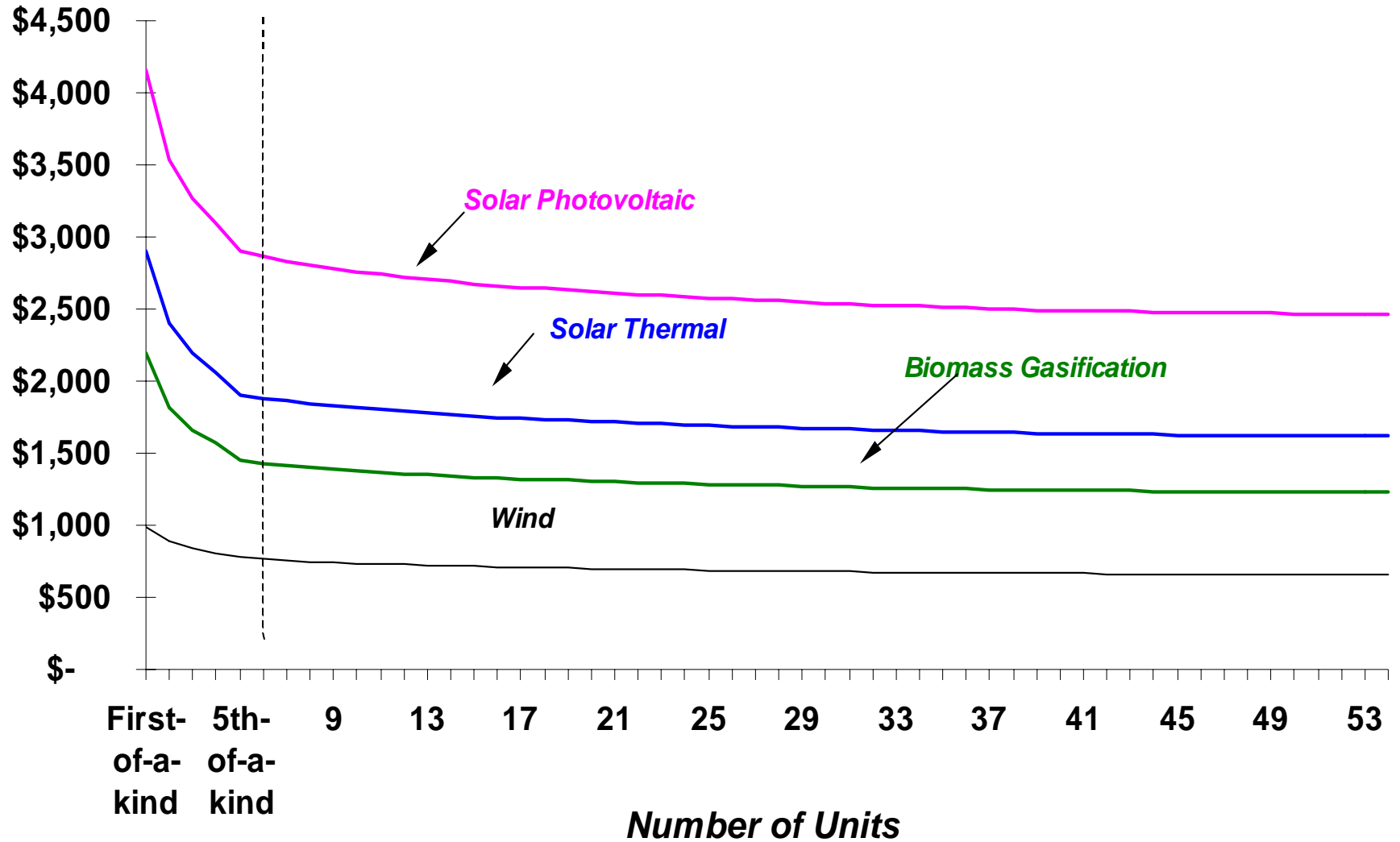
$$C(Q) = a * Q^{-b}$$

- Progress Ratio (pr) defines the speed of learning: $f =$ % cost decline with doubling of cumulative capacity

$$pr = 2^{-b} = (1 - f)$$

$$b = -\ln(1-f)/\ln(2); \quad a = C(Q_0)/Q_0^{-b}$$

Capital Costs for Advanced Renewable Technologies (Illustrative Example)
1997\$/kilowatt



Market Adjustment/Penetration Algorithm

- Select “noise” (“close-enough”) parameter
- Select the fraction of each market segment that should be reallocated to marginally uncompetitive technologies
- Solve SAGE for the “reduced costs”
- Use “reduced costs” and “noise” parameter to determine “close” technologies within each market group
- Recalculate market shares for technologies that were “close enough” based on their relative economics in their markets

Status of SAGE Development

- ✓ Proof of Concept has been completed and tested for 15 regions
- ✓ User interface software for front-end (inputs & assumptions) and back-end (results & analysis) has been developed
- ✓ Internal review and adjustment of inputs and assumptions is underway (transportation sector for all regions is close to final for all 15 regions; other sectors are being enhanced simultaneously) – expected completion by this fall
- ✓ Initial market share algorithm for the time-stepped version has been implemented and will be extensively tested over next few months
- Energy and emissions trading to be implemented and tested over the next few months
- Learning Curve structure to be implemented and tested by this fall
- Anticipate using SAGE for *IEO2003* and policy analysis thereafter