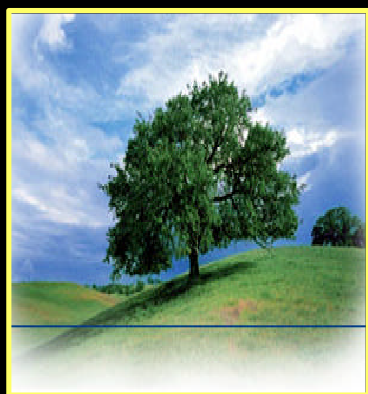
APPENDIX B - Presentation by Seung-Jin Kang, KEEI

Experiences of KEEI's Bottom-Up Modeling



March 2, 2000

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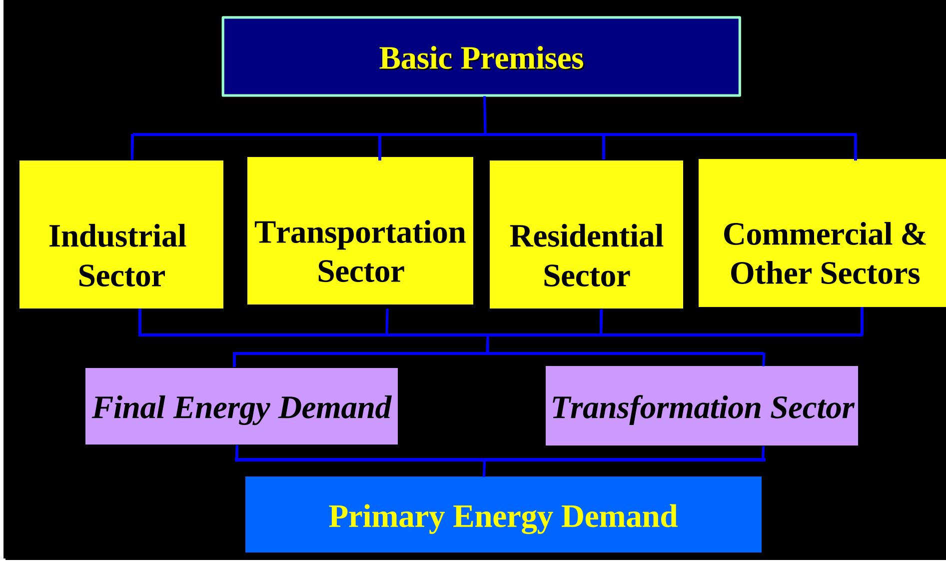
Overview

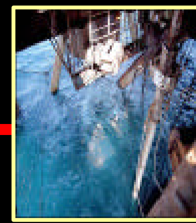
- **KEEI Model**
  - Long-term energy demand and GHG emission forecasting
- **EFOM-ENV Model**
  - Optimization of energy system with respect to constraints

Use of KEEI Model

Structure of KEEI Model

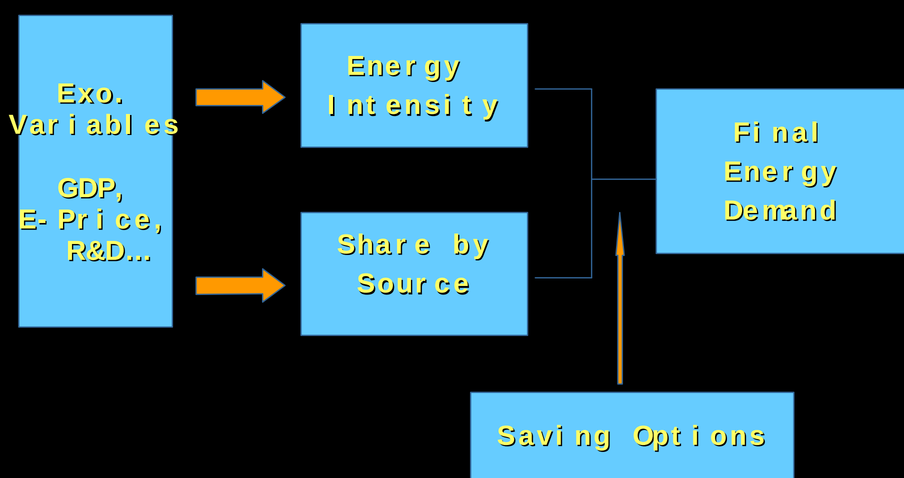


Framework of Model



- Origin of Model : MEDEE, LEAP
- Disaggregate approaches
  - Each sector divided into several subsectors or activities
  - Estimate final energy, not useful energy
  - Energy demand = Activity X Energy Intensity
  - Energy transformation : electricity, district heating & Towngas distribution

Industrial Sector (1)



Industrial Sector (2)

$$Int = f[\ VA\ (GDP)\ ,\ EPI\ (Electricity\ PI),\ Int_{-1}\ ]$$

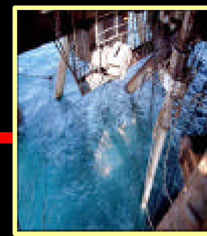
- Electricity, non-electricity
- 3 Energy-intensive industries : Intensity per product
  (Petrochemical, Iron & Steel, Cement)
- Other industries : Intensity per value Added

Industrial Sector (3)

$$E.\ Share_{t+1,i} = \frac{Q_{t,i}(1 + a_i\ Pgr_{t+1,i})}{\Sigma\{\ Q_{t,i}\ (1 + a_i\ Pgr_{t+1,i})\ \}}$$

- a_i : Energy price elasticity
- Pgr_i : Changing rate of energy price
- i : coal, oil, gas

Transportation Sector(1)



- Basic Equation

  $D_{tr} = ??_{i\,j}(V_i \ \mathrm{x}\ I_i \ \mathrm{x}\ \beta_{ij})$

  D_{tr} = Energy demand in transportation sector

  V_i = Transportation volume

  I_i = Energy Intensity

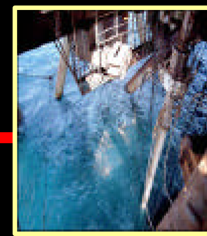
  β_{ij} = Fuel share ($? \beta_{ij} = 1$)

- Estimation
  - Traffic volume : GDP elasticity, past trend
  - Energy intensity : past trend, other countries' case
  - Fuel mix : survey results, new fuels

Transportation Sector (2)

- Passenger transportation (10 subsectors)
  - Unit : pass.-km, energy/pass.-km
  - Road : 5 subsectors by mode
    - Vehicle stock, pass./vehicle, mileage
  - Non-road : 5 subsectors by mode
- Freight transportation (6 subsectors)
  - Unit : ton-km, energy/ton-km
  - Road : 2 subsectors by ownership
  - Non-road : 4 subsectors by mode

Residential Sector (1)



- Basic equation

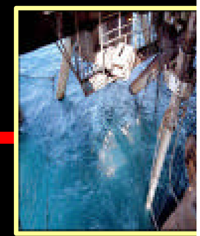
$$R = \sum_i \sum_j (N \times U_i \times \beta_{ij})$$

  - R : residential energy demand
  - N : number of households
  - i : use (heating & hot water, cooling, cooking, lighting, electric appliances)
  - j : energy type
  - U_i : energy per household for use i
  - β_{ij} : energy share for use i ($\sum_j \beta_{ij} = 1$)

Residential Sector (2)

- Electric appliances : 9 types
  - Stock : estimation using Compertz curve
- Energy intensity (per household)
  - Heating/cooking : estimate by regression using household income, number of persons
  - Electricity : related to house space
- Fuel share
  - Heating : towngas, district heating, solar estimated; heating oil as residual
  - cooking : towngas, LPG as residual

Commercial Sector (1)



- Basic Equation

$$D_c = \sum_k \sum_l \sum_m (S_k \times I_{kl} \times \beta_{klm})$$

– D_c: energy demand in residential & other sector
– S_k : building space of subsector k
– I_{kl} : energy intensity of use l
– β_{klm}: fuel share ($\Sigma_m \beta_{klm} = 1$)

Commercial Sector (2)

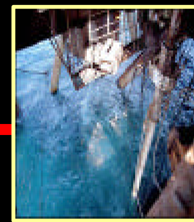
- Building Space
  – Estimate by GDP elasticity, refer to Japan case
- Energy intensity

$$I_i = I_{95} \times (1 - e_i) \times (1 + g_i)$$

– I_i : energy intensity per m²
– e_i : energy efficiency improvement factor
– g_i : income effect

- Fuel share : supply plan, past trend

Basic Premise



- GDP & Population

	1995	2000	2010	2020
GDP	377.3	461.1	783.9	1,160.3
AAGR		6.4%	5.4%	4.0%
Population	45.1	47.3	50.6	52.4
AAGR		0.9%	0.5%	0.2%

- Unit
  - GDP : trillion won in 1995 price
  - Population : thousand persons

Energy Demand Indicators

	Unit	1995	2000	2010	2020
GDP	T won	377.3	461.1	783.9	1,160.3
Primary Energy	M TOE	150.9	191.1	271.2	332.2
Per capita Energy	TOE	3.35	4.04	5.36	6.35
Energy/GDP	TOE/M won	0.40	0.41	0.35	0.29
Final Energy	MTOE	121.8	152.4	213.9	257.9
Industry		51.7%	54.6%	50.9%	49.8%
Transport		22.3%	20.9%	23.3%	22.8%
Residential		17.7%	15.6%	16.1%	16.8%
Commercial		8.4%	8.9%	9.8%	10.6%

GHG Emission Indicators

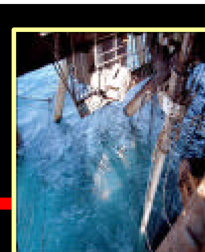
	Unit	1995	2000	2010	2020
GHG Emission	M TC	102.4	121.2	174.0	205.4
Per capita GHG	TC	2.27	2.56	3.44	3.92
GHG/GDP	TC/Mwon	0.27	0.26	0.22	0.18
GHG/energy	TC/TOE	0.68	0.63	0.64	0.62
By sector					
Industry		48.8%	49.5%	46.5%	45.4%
Transport		21.9%	21.6%	23.6%	23.5%
Residential		18.7%	16.9%	16.9%	17.3%
Commercial		10.6%	12.0%	13.0%	13.7%

Major Issues

- Uncertainties
  - Economic growth, industrial structure
  - Energy market situation
  - Energy technology development
  - Develop several scenarios ?
- Trade-off disaggregation & data availability
- Effect of policies and measures

Use of EFOM-ENV

Basic Framework of EFOM-ENV

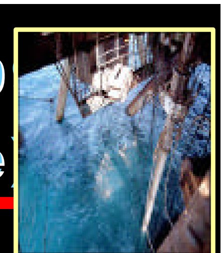


- Minimize total energy system costs with respect to primary energy requirements and energy transformation technologies
- Given constraints such as useful (or final) demand for energy, available technologies, and environmental restrictions

Structure of EFOM-ENV

- Total energy system costs of OBJ: variable costs, and capital costs, 1995 - 2020
- Four subsystems for energy use
- Nine subsystems for primary energy supply, and energy transformation

Use of EFOM-ENV, 199
(Presentation Scheme



- Main purpose: least-cost GHG abatement strategies, and their potentials
- Two scenarios: BAU, and 10% GHG Abatement
- Preliminary results
- Issues and discussion

Two Scenarios

- **BAU**
  - Useful energy demand predicted on the basis of the KEEI Bottom-up model
  - Autonomous efficiency improvement of energy appliances assumed
- **10% GHG Abatement**
  - 10% GHG reduction with BAU assumptions

Major Abatement Strategies Available

- **High efficient energy appliances**
- **Use of low GHG fuels**

< Promising options not considered >

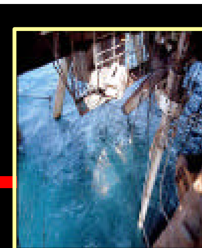
- Encouraged improvement of energy efficiency, and promoted use of high-efficient appliances
- Energy pricing (tax) policy
- Strengthened dissemination of information for the efficient use of energy

Preliminary Results
Major Least Cost GHG Mitigation Sectors

	Average Cost (US$/TC)	Abatement Potentia (1,000 TC)
■ Residential heating and transportation	-	5,827
■ Industrial motor power	413.3	5,196
■ Industrial direct heating	416.0	4,191
■ Total average cost	403.0	

f.n., estimation for 2020 at 1995 price

Issue 1: Model Limitations and Potential Solutions



- Linearity of OBJ in terms of costs and GHG mitigation options, which requires that scenarios be specified very carefully
- EFOM-ENV cannot be a stand-alone model, and it needs to be assisted by and assist other models such as top-down and microscopic economic and technical models

Issue 2
Implementability of Model Solutions

- EFOM-ENV solutions can represent only policy targets where we may arrive, but not policy vehicles by which we may get there

- Research attention needs to be given to
  - What policy variables can be considered
  - To what extent they can be used separately or altogethe

Issue 3
Preparedness for Data Requirements

- EFOM-ENV needs quite a large data and information base

- Current issues for a data base
  - Data specificity: how bottom is bottom?
  - Physical data base management: centralized or decentralized?
  - Data quality management

Issue 4
Resource Costs for Model Improvement and Maintenance

- Building, polishing, and maintaining models and relevant data bases are time-consuming, and in need of lots of resources
- Orderly provision of necessary resources
  - research manpower
  - research fund with reasonable time frame
  - research cooperation domestically and internationally

Issue 5
Future Research Areas

- Developing policy tools in order to translate least cost options into markets
- Refining model structures of EFOM-ENV
  - Building capacity to integrate EFOM-ENV with other models and micro studies on energy and its relevant markets
- Establishing energy DBMS