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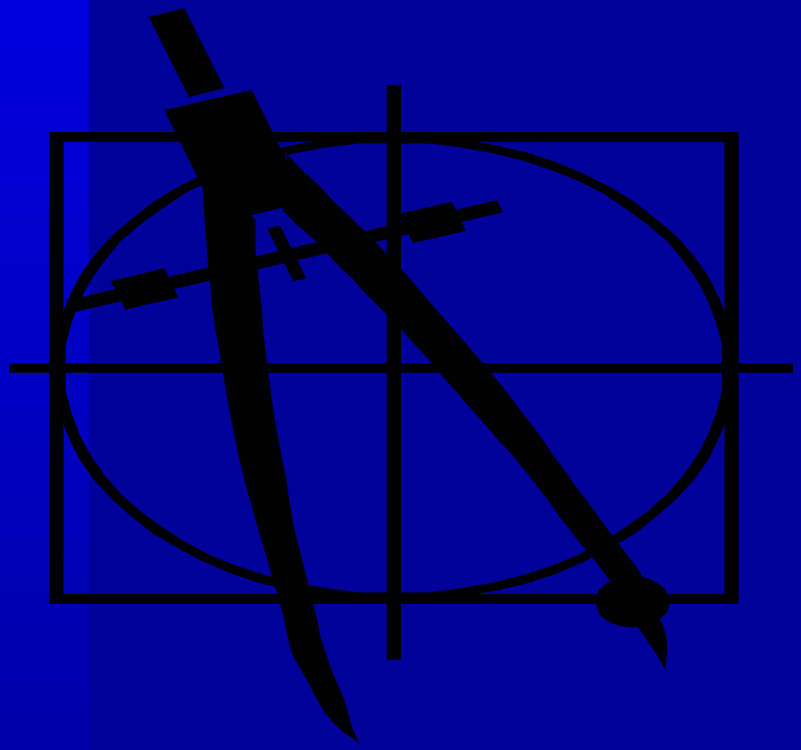
KOREA ENERGY ECONOMICS INSTITUTE

Korea Bottom-up Model for Energy and Carbon Forecasting



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Energy Modeling Experiences in Korea

- Econometric Models
  - Short-term outlook
- Top-down Models
  - National CGE model
  - Global CGE model
- Bottom-up Models
  - Long-term forecasting: energy & carbon dioxide
  - EFOM-ENV

KEEI-Model: Overview

- Bottom-up Accounting Model
  - Energy demand projection at disaggregated level
  - Detailed base year analysis
  - Energy demand = Activity x Intensity
- Long-term Forecasting
  - Energy and carbon forecasting
  - Reflect socio-economic development: economic growth, industrial structure, car ownership, home appliances etc.
  - Take into account technical progress and government plan

Forecasting Model Experiences

- KEEI Model has been used for about 20 Years
  - MEDEE: Introduced early 1980s
  - 1st version: Modifying MEDEE
    - Used for 5 year economic planning(energy sector)
  - 2nd version: Incorporate CO_2 emission module
- LEAP Model
  - Introduced in 1994 for GHG emission forecast
  - Based on useful energy demand
  - Linked to EFOM-ENV for final and primary energy demand

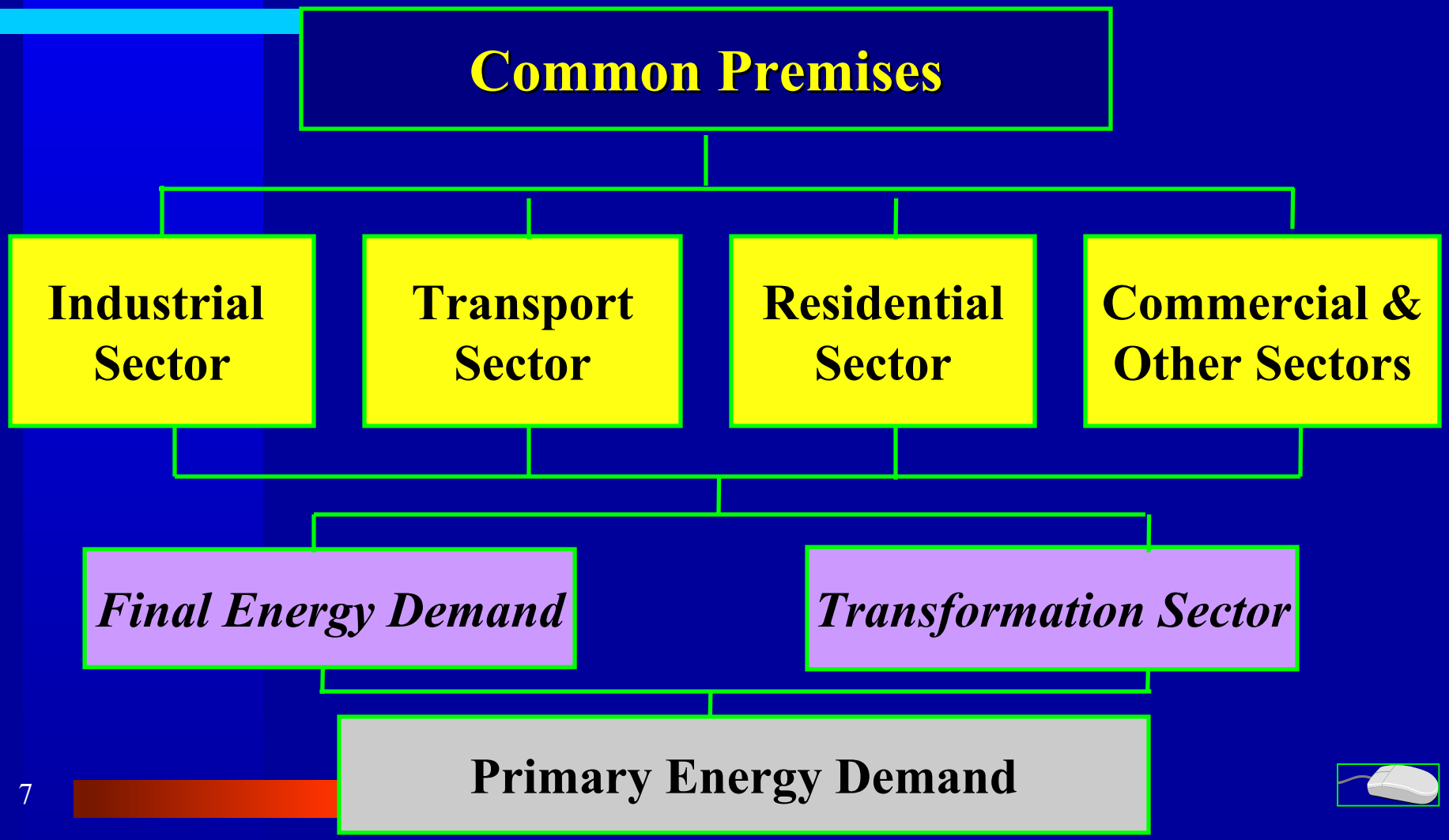
KEEI Model: General Description-1

- Current Model: Revised Version
  - Final demand sectors: Industry, transport, residential, commercial and others
  - Base year: 1999
  - Data sources: Energy Survey 1999, and updated using recent statistics
  - Forecasting years: 2005, 2010, 2015, 2020
  - Start with final energy, estimate primary energy demand
  - Transformation sectors: Electricity generation, district heating, city gas

KEEI Model: General Description-2

- Advantages
  - Easy to understand: overall energy flow in both demand and supply side
  - Flexible: disaggregation according to data availability
  - Possible to incorporate energy saving options
- Weakness
  - No analysis for macro-economic feedback
  - Difficulty in analyzing price effect
    - limited possibility using econometric method

KEEI Model: Structure



Industrial Sector-1

- Disaggregation
  - Agriculture, mining, manufacturing, construction
  - Manufacturing: 8 sub-sectors
    - 3 Energy-intensive industries: chemical, iron & steel, non-metallic mineral(cement)
    - 5 Non energy-intensive industries
- Energy Uses
  - Material for energy-intensive industries
  - non-electricity fuel, electricity for each industry
  - Not useful energy, but final energy

Industrial Sector-2

- Material Use
  - Intensity measured in terms of production quantity
    - Naphatha for ethylene production
    - Coal for pig iron production
    - * coal for (cement) clinker production : (fuel)
- Electricity and Fuel
  - Intensity measured in terms of value-added
  - Estimated by regression method
- Fuel Share
  - Extending past trend, environmental regulation, etc.

Transport Sector-1

- Basic Equation

$$D_{tr} = \sum_i \sum_j (V_i \times I_{ij} \times \beta_{ij})$$

D_{tr} = Energy demand in transportation sector

V_i = Traffic volume of mode i(pass.-km, ton-km)

I_{ij} = Energy intensity of mode i, fuel j

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

- Estimation
  - Traffic volume: Car ownership, GDP elasticity, past trend
  - Energy intensity: past trend, other countries' case
  - Fuel mix: survey results, fuel switch, new fuels(CNG, etc)

Transport Sector-2

- Passenger transport (8 sub-sectors)
  - Unit : pass.-km, energy/pass.-km
  - Road : 4 sub-sectors by mode
    - Vehicle stock, pass./vehicle, mileage
  - Non-road : 4 sub-sectors by mode
- Freight transport (4 modes)
  - Unit : ton-km, energy/ton-km
- International Transport (4 modes)
  - Air, ship (passenger, freight)

Residential Sector-1

- Basic equation

$$D_r = \Sigma\Sigma (H \times I_i \times \beta_{ij}) + \Sigma\Sigma (H \times E_{ik})$$

  - D_r : residential energy demand
  - H : number of households
  - I_i : energy per household for use i
  - E_{ik}: electricity demand per household for use i and appliance k
  - i : use (heating & hot water, cooking; cooling, lighting, electric appliances)
  - j : energy type
  - β_{ij}: fuel share for use i ($\Sigma_j \beta_{ij} = 1$)

Residential Sector-2

- Energy intensity (per household)
  - Heating/cooking : estimate by regression using household income, family size, fuel price, trend
  - Electricity: related to house space, income
- Electric appliances
  - Ownership : estimation using Compertz curve
- Fuel share
  - Heating : city gas, district heating, solar estimated; coal to be phased out, heating oil as residual
  - cooking : city gas, LPG as residual

Commercial Sector

- Equation and Method

$$D_c = \Sigma \Sigma \Sigma (S_i \times I_{ij} \times \beta_{ijk})$$

  - D_c : commercial energy demand
  - S_i : building space of sub-sector i
    - GDP elasticity and the case of Japan
  - I_{ij} : energy intensity for sub-sector i, use j
    - AEEI and income effect considered
  - β_{ijk} : fuel share for sub-sector i, use j
  - i : sub-sector (3 sub-sectors)
  - j : fuel use (heating, cooking, cooling, electric motor, lighting)
  - k : energy type

Public & Other Sector

- Energy Demand
  - GDP
  - Intensity
- Very Simplified

Energy Transformation

- Energy input for transformation to be calculated
- Electricity Generation
  - Based on electricity demand
  - KEPCO's long-term plan considered
    - Hydro, anthracite: existing plan
    - Nuclear & oil: planned capacity, operation rate to be modified
    - Coal and LNG: residual, equal share
- City Gas
  - National pipeline plan, LPG as residual
- District Heating
  - LNG, oil, waste incineration, heat from electricity

Final Energy Demand

MTOE

	1999	2005	2010	2015	2020
Industry	55.8%	52.1%	50.6%	49.6%	49.2%
Transport	20.0%	22.4%	22.9%	23.5%	23.7%
Redential	13.8%	13.7%	14.1%	14.2%	14.3%
Commercial	8.5%	9.8%	10.5%	10.8%	10.8%
Others	1.9%	1.9%	1.9%	1.9%	1.9%
Total	143.1	182.8	209.1	231.7	250.0

Industrial Energy Demand

MTOE

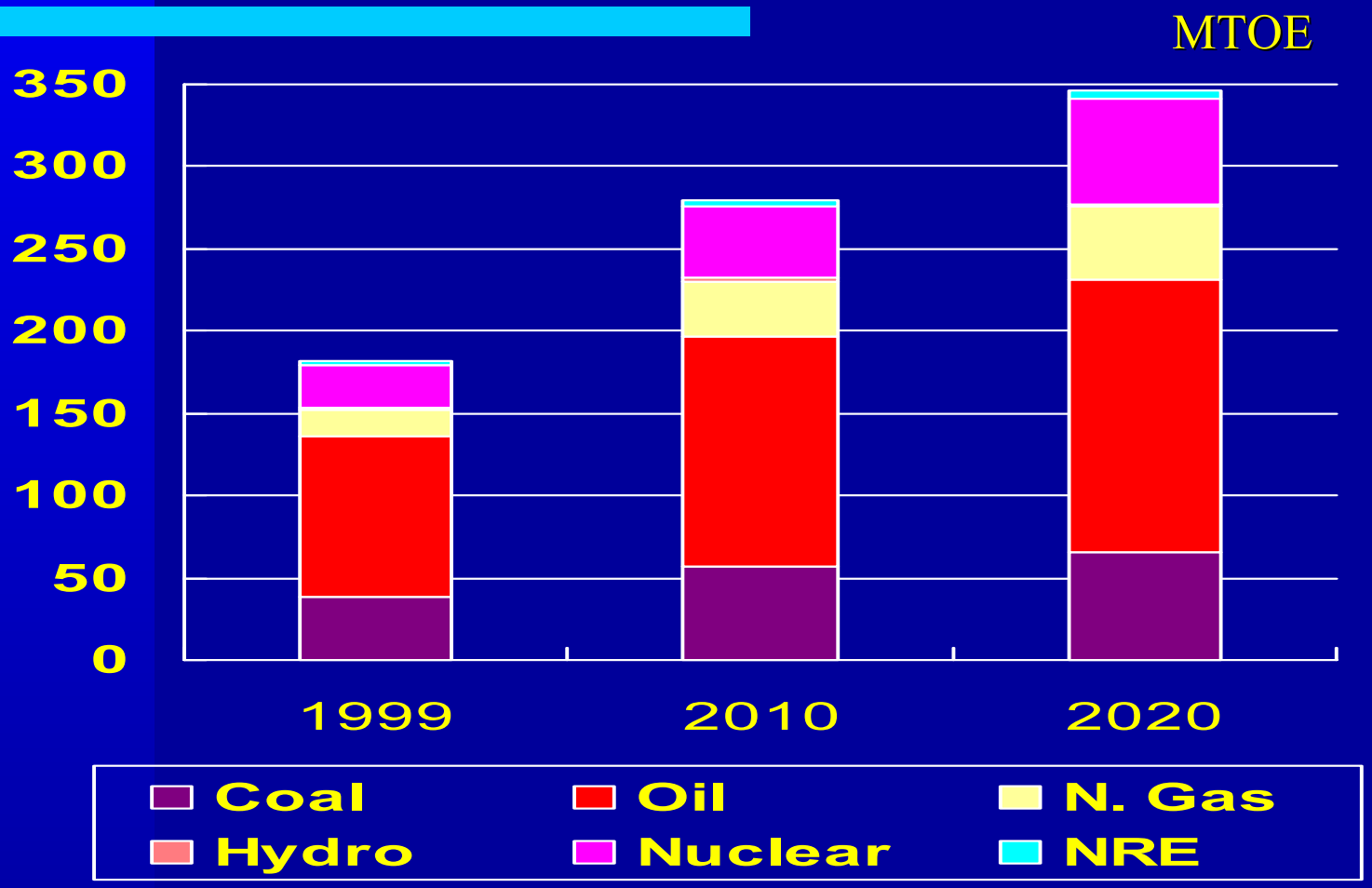
	1999	2005	2010	2015	2020
Coal	17.8	20.1	21.2	21.8	22.1
Petroleum	47.5	53.3	58.2	61.9	64.9
naphatha	*27.8*	*31.0*	*32.4*	*32.5*	*31.8*
City gas	2.5	4.8	6.2	7.6	9.1
Electricity	10.4	14.5	17.4	20.1	23.0
Others	1.6	2.5	2.8	3.4	4.0
Total	79.9	95.3	105.7	114.9	123.1

Primary Energy Demand

MTOE

	1999	2000	2005	2010	2015	2020
Coal	21.0%	21.0%	20.6%	20.4%	19.8%	19.6%
Oil	53.6%	53.9%	51.5%	50.0%	48.1%	46.8%
Non-energy	*16.8%*	*16.2%*	*14.6%*	*13.3%*	*12.2%*	*11.3%*
LNG	9.3%	9.7%	11.6%	12.4%	14.1%	14.9%
Hydro	0.8%	0.6%	0.5%	0.4%	0.4%	0.4%
Nuclear	14.2%	13.9%	14.6%	15.6%	16.4%	16.9%
NRE	1.0%	1.0%	1.2%	1.2%	1.2%	1.4%
Total	181.4	195.1	235.8	275.1	307.1	334.2

Energy Outlook



Energy and GHG Indicators

	Unit	1999	2005	2010	2015	2020
Primary Energy	MTOE	181.4	235.8	275.1	307.1	334.2
Per capita Ener.	TOE	3.87	4.80	5.43	5.92	6.38
Energy/GDP	TOE/won	0.42	0.38	0.35	0.31	0.28
CO2 Emission	MTC	111.3	146.4	170.6	188.8	205.3
Per capita CO2	TC	2.38	2.98	3.37	3.64	3.92
CO2/GDP	TC/won	0.25	0.24	0.21	0.19	0.17
CO2/Energy	TC/TOE	0.61	0.62	0.62	0.62	0.61

Energy Related Issues

- Energy demand grows steadily, but at slower pace
  - Moderate economic growth
  - Industrial structural change
  - Energy demand saturation in some sectors
- Electricity and Gas Demand
  - Grows faster than expected
  - New additional capacity necessary
  - Additional import of gas to be considered

Modeling Issues & Future Development

- Trade-off between Disaggregation Level & Data Availability
  - Special survey data ?
- Effect of policies and measures
  - How to incorporate in the model
  - Way to analyze price effect