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Overview of DEARS

RITE Global Energy-Economic Model

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Economic analysis frames of options for energy and environment

Major input

- Power supply configuration (energy mix options)
- Unit construction costs of each power supply (source: Committee of Cost Verification)
- Future prospects for fuel costs of each power supply (source: Committee for Cost Verification)
- CO2 emissions from each option (source: the document 4 of the 18th Fundamental Issues Subcommittee, the Advisory Committee for Natural Resources and Energy
- Population and the number of households (referred to a medium variant case of National Institute of Population and Social Security Research), etc.

Economic model (DEARS)

Estimates by the combination of equation

Major output

- Electricity price (nominal value)
- Energy bill (nominal value)
- Household consumption expenditure (real value)
- Private capital investment (real value)
- Crude production (all industries)
- Crude production (energy-intensive industries)
- Amount of power generated
- Final energy consumption (real value)
- Residential energy consumption (real value)
- Export (real value)
- Import (real value)
- GDP (real value)
- Marginal abatement cost (real value)

Though cost-effective measures are usually solved, including the power supply configuration under the CO2 reduction target (only nuclear power is usually given exogenously), analyses in this paper include all the scenarios. DEARS model, as described later, bottom-up modeling for technologies in energy supply, can perfectly manage such analyses.

Model calculation method

- **[Reference case] In "reference case (BAU)", by adjusting the parameters of the model (such as the growth rate of improvement in total factor productivity), the model is able to reproduce the exogenous Government Secretariat's assumptions (uniform values to facilitate comparisons among models) to be consistent with endogenous GDP, household consumption expenditure, electricity generation, CO2 emissions, etc. We used generation costs by source and the future perspective of fuel costs by source that were directed from the Secretariat (estimates provided by the Committee of Cost Verification Committee) .**

- **[Options without CO2 constraints] Based on the reference case, power supply configuration is calculated to be consistent with each option without the constraint of CO2 emissions considered. (Other items remains in the reference case.) calculate the case, without considering, was allowed to meet only the power supply configuration to each choice**

- **[Options with CO2 constraints] Based on the options without CO2 constraints, CO2 emissions estimated in each option are added to the model as constraints**

Features of DEARS

- **Since the information on energy supply and the power generation sector is not enough in the input-output table, we conduct bottom-up modeling by technology, as well as adjust to have consistence with IEA statistics, which makes consistent analyses and assessments of energy and economy possible. It also enables economic analyses which generation costs provided by Committee of Cost Verification and configuration of power generation by option are prerequisites for.**
- **Dynamic optimization is conducted up to the middle of the 21st century, 2047. （Forward-looking model） For example, on considering the support for around 2030, the optimal measures in 2020 are derived.**
- **Since the input-output table is based on GTAP which is commonly used for international CGE model analysis, the international transfer of industry (leakage of industry) can be analyzed. (GTAP is a static model, while DEARS is a dynamic model.)**

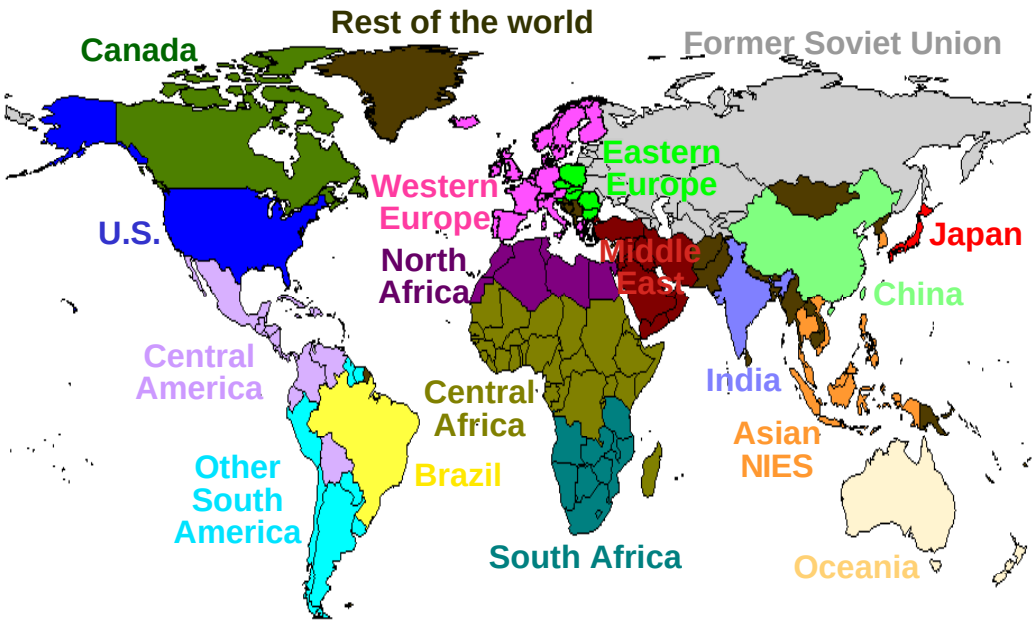
Global Energy-Economic Model: DEARS

(Dynamic Energy-economic Analysis model with multi-Regions and multi-Sectors)

- Integration model of top-down-typed economic module and bottom-up-typed energy systems module
- Dynamic non-linear optimization model (Maximization of global consumption utility)
- Evaluation time period: up to middle of this century (10 years steps)
- World divided into 18 regions
- Non-energy sectors: 18 sectors
- Energy: 8 types of primary energy and 4 types of secondary energy
- Economic module that represents international economic structures based on input-output tables of GTAP (Global Trade Analysis Project) database.
- Simplified energy systems module
  - ✓ Bottom-up modeling for technologies in energy supply (e.g. , power generation) and CCS (carbon capture and storage)
  - ✓ Primary energy (8 types): coal, crude oil, natural gas, hydro & geothermal, wind, photovoltaics, biomass and nuclear
  - ✓ Top-down modeling for energy demand (residential sector: price and income elasticities of demand for energy and income, industrial and transport sectors: price elasticity, linked to economic module)
  - ✓ Final energy (4 types): solid, liquid and gaseous fuels and electricity

Regions and Industries in DEARS

- **18 regions and 18 non-energy industries**



18 industries in DEARS	Major division
Agriculture	Agriculture, forestry and fishery industry
Iron and steel	Material industry
Chemical	
Non-iron	
Nonmetal	
Paper and pulp	
Lumber	
Car	Automotive and machinery industry
Machinery	
Other manufacturing	
Mining	
Food	Light industry
Textile	
Construction	Construction industry
Business service	Service industry
Social service	
Land and shipping transportation	Transportation industry
Aviation	

DEARS Model Details

♦ Objective function（Utility maximization consumption）

$$\sum_t \sum_r d_t \cdot L_r \cdot \sum_i \theta_{i,r,t} \cdot \log \frac{C_{i,r,t}}{L_{r,t}} \rightarrow \max .$$

$C_{i,r,t}$: consumption amount in period t, region r, sector i (endogenous)

$L_{r,t}$: population in period t, region r (exogenous)

d_t : discount factor in period t (exogenous) (discount rate=5%/yr)

$\theta_{i,r,t}$: consumption-utility weights in period t region r and sector i (exogenous)

♦ Capital accumulation function

$$K_{r,t} = (1 - dep_{r,t}) K_{r,t-1} + \sum_i I_{r,i,t}$$

$I_{r,i,t}$: investment amount in period t, region r, sector i (endogenous)

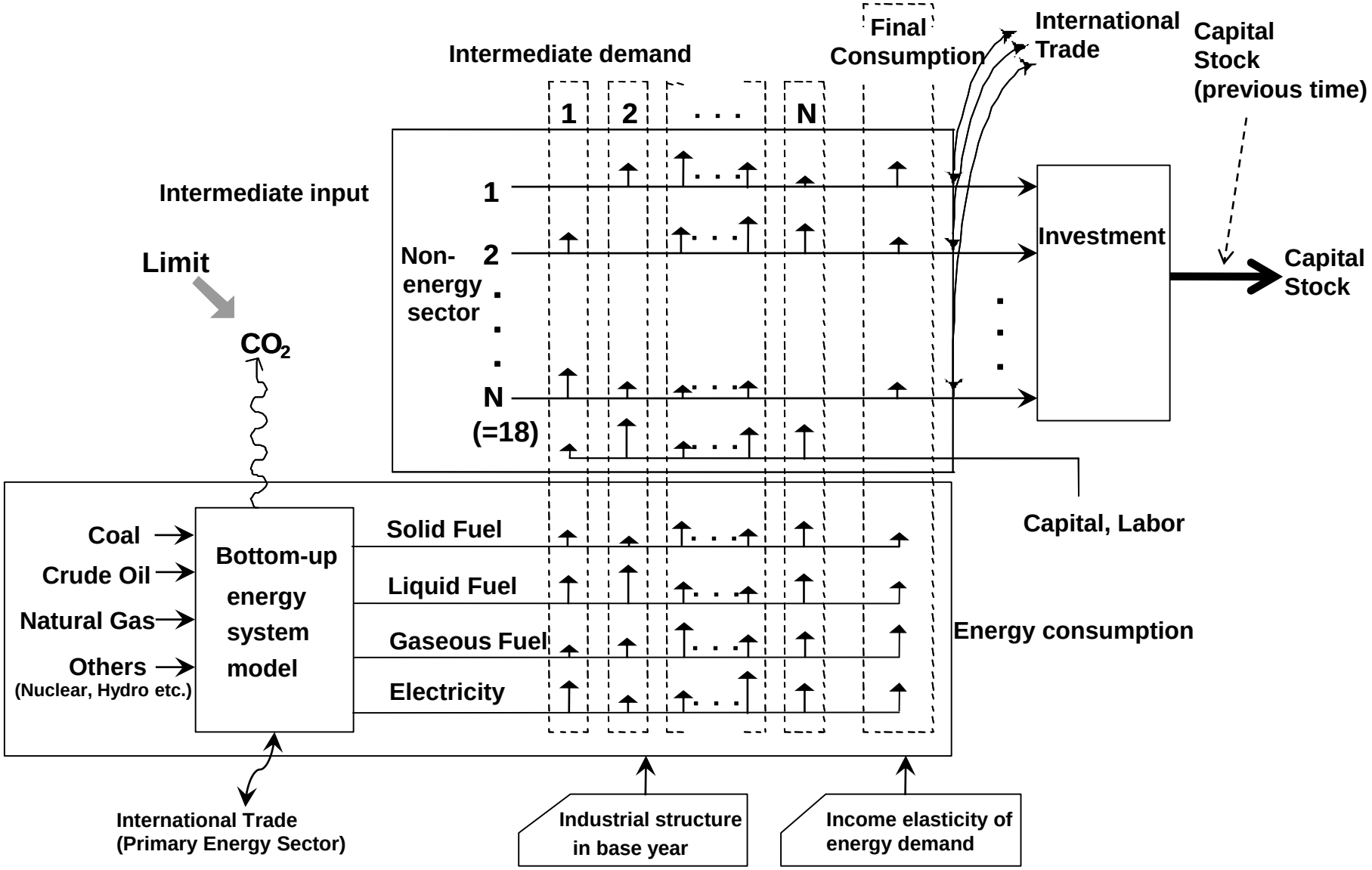
$K_{r,t}$: capital stock in period t, region r (endogenous)=

$dep_{r,t}$: Depreciation rate of capital in period t, region r (exogenous)=5%/yr

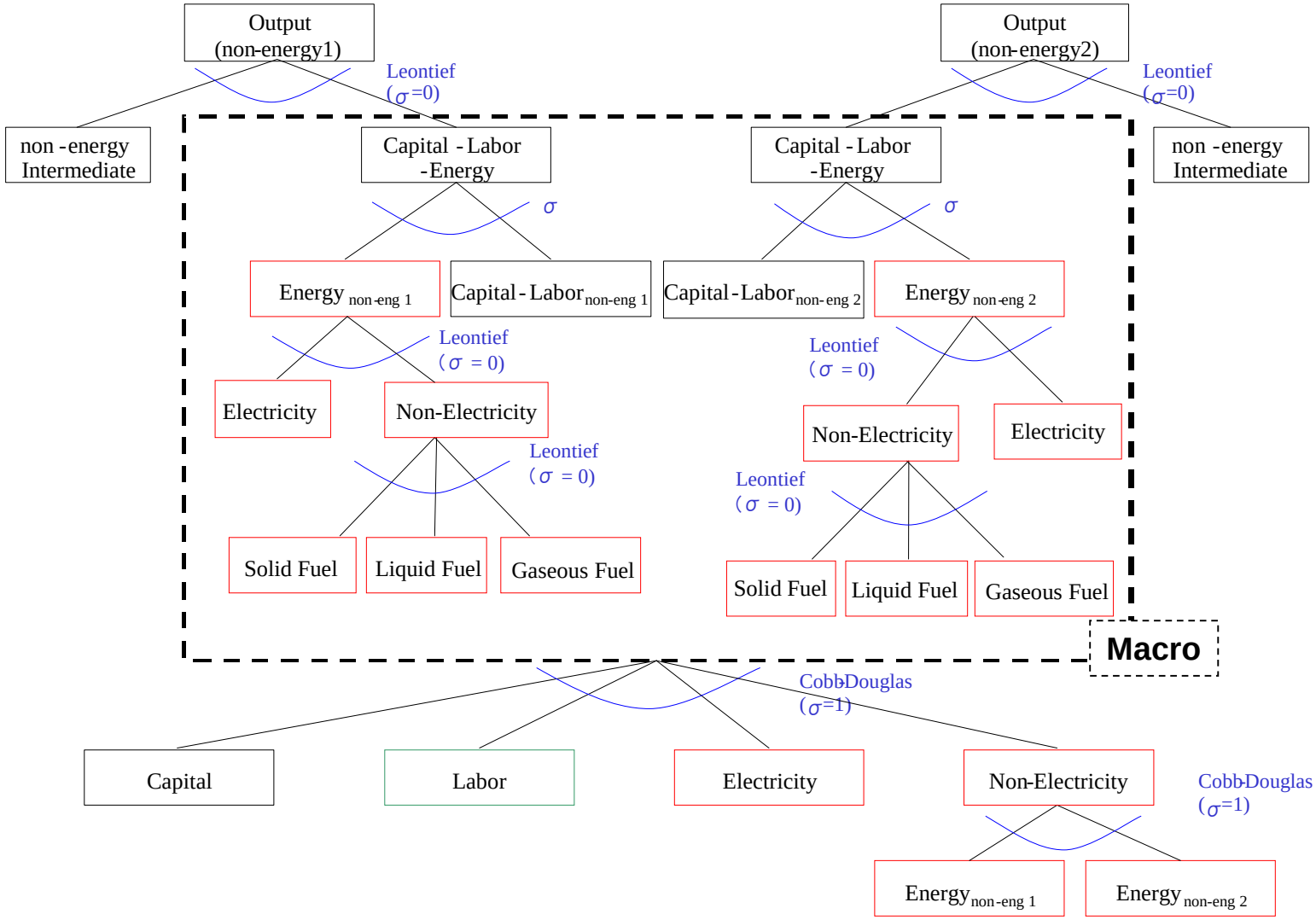
♦ Modeling the production in non-energy sector

The model has a structure that goods are produced and exported only in the regions where production of goods is efficient, assuming the production function in the inter-industry structure under the consumption utility maximization. However, taking into account that products and consumption of agriculture and food are different in nature from those of industry and services, products and consumption of agriculture and food are modeled, using the food production and demand scenario as a constraint so that the variation would be reduced.

DEARS Model: Inter-industry
-Integration of energy and non-energy sectors-

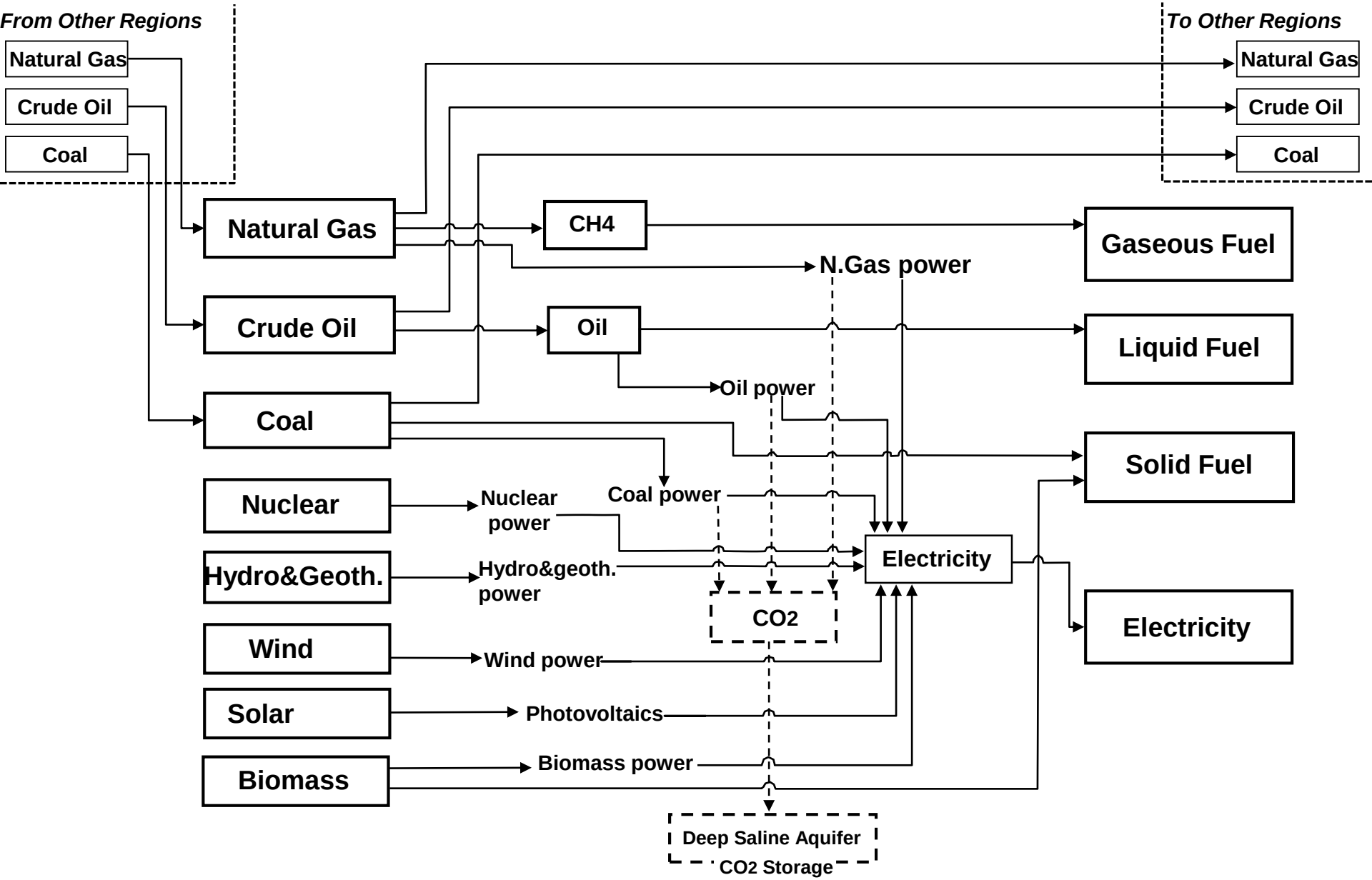


Structure of DEARS Economic Modules



*** Only 2 industrial sectors are in the figure.（18 industrial sectors are practically modeled)**

Assumptions of Energy Conversion Processing in DEARS



Trade Constraints in DEARS

♦ Trading

For trading (export and import), the model has a structure that goods are produced and exported only in the regions where production of goods is efficient under the consumption utility maximization

- **In order to avoid unrealistic solution with the respect to the balance of trade at the macro level by country , such as continuously accumulated debt of a particular region, the regional net exports within the range of GDP ratio are exogenously given as scenarios of trade balance by region of 18, based on Crowther's international balance of payments development stage theory[2].**

year	US	Canada	Central America	Brazil	South America	Western Europe	Eastern Europe	Former Soviet Union	North Africa	Central Africa	South Africa	Japan	China	India	Asian NIES	Middle East	Oceania	Others
1997	Ⅵ	Ⅲ	Ⅲ	Ⅰ	Ⅰ	Ⅴ	Ⅰ	Ⅲ	Ⅰ	Ⅰ	Ⅲ	Ⅳ	Ⅲ	Ⅱ	Ⅱ	Ⅱ	Ⅱ	Ⅰ
2007	–	Ⅲ	Ⅲ	Ⅰ	Ⅰ	–	Ⅰ	Ⅲ	Ⅰ	Ⅰ	Ⅲ	–	Ⅲ	Ⅱ	Ⅱ	Ⅱ	Ⅱ	Ⅰ
2017	–	Ⅳ	Ⅳ	Ⅱ	Ⅱ	–	Ⅱ	Ⅳ	Ⅱ	Ⅱ	Ⅳ	–	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅱ
2027	–	Ⅳ	Ⅳ	Ⅱ	Ⅱ	–	Ⅱ	Ⅳ	Ⅱ	Ⅱ	Ⅳ	–	Ⅳ	Ⅲ	Ⅲ	Ⅲ	Ⅲ	Ⅱ
2037	–	Ⅴ	Ⅴ	Ⅲ	Ⅲ	–	Ⅲ	Ⅴ	Ⅲ	Ⅲ	Ⅴ	–	Ⅴ	Ⅳ	Ⅳ	Ⅳ	Ⅳ	Ⅲ
2047	–	Ⅴ	Ⅴ	Ⅲ	Ⅲ	–	Ⅲ	Ⅴ	Ⅲ	Ⅲ	Ⅴ	^–	Ⅴ	Ⅳ	Ⅳ	Ⅳ	Ⅳ	Ⅲ

Note: Ⅰ: current account balance to GDP ratio -8.2~-1.9%, Ⅱ: current account balance to GDP ratio -1.9~0%,
Ⅲ: current account balance to GDP ratio 0~+1.8%, Ⅳ: current account balance to GDP ratio +1.9~+8.2%
Ⅴ: current account balance to GDP ratio 0~+1.9%, Ⅴ: current account balance to GDP ratio -1.9~0%,

- **With respect to balance of trade of goods level, the constraints of growth and self-sufficiency rate are given to each goods in order to avoid unrealistic bias to a particular region.**

Source: [2]White Papers on International Economy and Trade 2002/METI

Policy-making Using the Economic Model

- Models can be a powerful tool to support policy-making.
- However, the models are not necessarily to predict future simply. In addition, the models are not able to represent all the real society.
- However, good models enable consistent assessments in the simplified form without loosing the essence of real-world movements.
- On the other hand, bad models collapse logically and consistently.
- Attention should be paid to the clarity of logic and the probability of the premised data.
- It is improper both to deny all the results of the model and to accept the results blindly. It is important to utilize models properly as means to support policy-making, understanding the model features, uncertainty and manners.