Outline of DNE21+ Model
-Electricity Generation Sector-

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1. Introduction

- ○ For the power supply to compensate load fluctuations, electricity demand is modeled to be balanced between demand and supply by setting four time periods with respect to the degree of power load based on an annual load duration curve.
- ○ Coal (low, medium, high efficiency), oil (low, medium, high efficiency, CHP), natural gas (low, medium, high efficiency, CHP), nuclear (conventional, advanced), hydro power and geothermal, wind power, photovoltaics, biomass (low or high efficiency), IGCC/IGFC with CO_2 capture (note: IGCC/IGFC which does not consider CO_2 capture is modeled as high efficiency in the classification of "Coal". IGCC: Integrated Gasification Combined Cycle Power Generation, IGFC: Integrated Coal Gasification Fuel Cell Power Generation), oxy-fuel combustion power generation using natural gas are considered. However capital costs for hydro power and geothermal, wind power and photovoltaics have not been explicitly estimated and rather the cost per power generation amount has been estimated.

2. Modeling of Electricity Generation Sector

- ○ Electricity demand is modeled so that demand and supply are in balance by setting four time periods (1) instantaneous peak, (2) peak, (3) medium (4) off peak with respect to the level of power load based on an annual load duration curve.
- ○ Since the peak of wind power generation does not always correspond to the instantaneous peak for power demand, output of wind power generation at instantaneous peaks is assumed to be 30% of the maximum capacity of wind power generation.
- ○ Since the power generation time period of photovoltaics is limited, power supply is assumed to be possible only during instantaneous peaks and peaks.

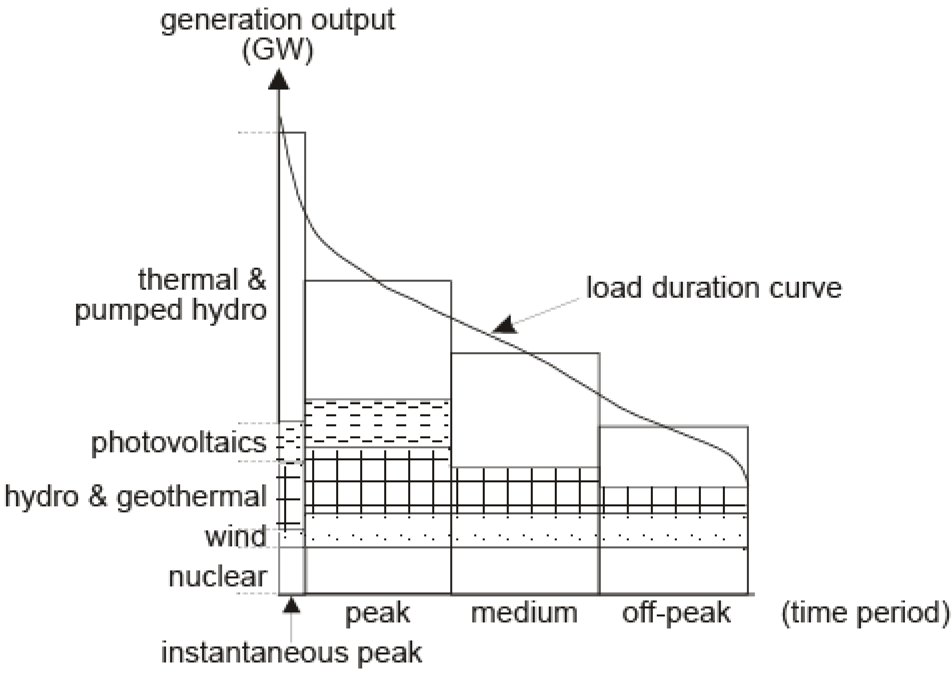

Fig.1 Generation modeling along the annual load duration curve.

3. Fossil Fuel, Nuclear and Biomass Power Generation

- ○ Capital costs are estimated as shown in Table 1 based on the NEA/IEA Report. However location factors are used in order to consider regional capital cost differences.
- ○ The durable lifespan of facilities is assumed to be 30 years with the exception of nuclear which is 40 years.
- ○ OECD countries are assumed not to exceed the current total power generation facility capacity for oil (low, medium and high efficiency).
- ○ The facility utilization rate apart from nuclear is assumed to be 90%.
- ○ The facility utilization rate for nuclear is assumed to be 85%. The power generation amount for nuclear is capped at 50% of the total power generation amount for a given region (regions currently exceeding this figure are not included).
- ○ Conventional nuclear power generation is assumed to have an annual 0.33% expansion potential with respect to overall power demand in a given region (approximately 10% expansion potential in overall power demand during 30 years). In contrast, advanced nuclear power generation is assumed to have high social acceptance due to higher safety than conventional generation and therefore

is assumed to have an annual expansion potential of 1.0 % with respect to total power generation in a given region.

○ The capacity of fossil fuel power generation plants by fuel type is estimated for OECD countries using "Electrical Information" from the OECD/IEA and for non OECD countries using power generation facility capacity data from DOE/EIA and power generation data by fuel type from OECD/IEA.

Table 1 Assumed capital costs, power generation efficiency for various power generation plants

		Capital Costs [US$/kW]	Power Generation Efficiency [LHV %]
Coal Power Generation	Low efficiency(conventional (subcritical) currently used in developing countries)	700	22.0–27.0
	Medium efficiency (mainly currently used in developed countries (supercritical) including future use of combined power generation)	900	36.0–43.5
	High efficiency (currently used in developed countries, future use of combined power generation (IGCC, IGFC))	1,050	42.0–55.0
Oil Power Generation	Low efficiency (e.g. diesel power generation)	200	20.0–25.0
	Medium efficiency (subcritical)	300	37.0–47.0
	High efficiency (supercritical)	450	50.0–60.0
	CHP	350	37.0–47.0*
Natural Gas Power Generation	Low efficiency (steam turbine)	200	24.0–29.0
	Medium efficiency (combined power generation)	300	38.0–48.0
	High efficiency (high-temperature combined power generation)	450	52.0–62.0
	CHP	350	38.0–48.0*
Biomass Power Generation	Low efficiency (steam turbine)	1,300–700	18.0–28.0
	High efficiency (combined power generation)	1,800–1,200	36.0–46.0
Nuclear Power Generation	conventional	1,900	
	advanced	1,200	
IGCC/IGFC with CO_2 Capture		1,700–1,325	34.0–51.0
Natural Gas Oxy-fuel Combustion Power Generation		1,495–1,245	40.7–50.7
Hydrogen Power Generation(FC/GT)		450	52.0–64.5
Power Storage (pumped storage power etc.)		1,000	

Notes) It is assumed that the power generation efficiency will be improved over time within the range shown in the table. Annual expense rate is assumed to be in the range 17% to 19% by facility and region.
*Heat recovery efficiency is assumed with balance on energy supply & demand and is assumed to be in the range of 5 to 20% by region.

4. CO_2 Capture & Storage

○ CO_2 and capture in the power generation sector is assumed on the basis of (1) post-combustion capture (chemical adsorption method etc.). (2) pre-combustion capture (physical adsorption methods in the contact of IGCC/IGFC) and (3) oxy-fuel combustion power generation. The capital costs and power generation efficiency of (2) and (3) are listed in the previous section and assumptions regarding (1) are listed in this section.

Table 2 Assumed Capital Costs and Required Power of Various CO_2 Capture Plants

	Capital Costs (US$/(tC/day))	Required Power (MWh/tC)
Post-combustion CO_2 capture from coal power generation	59,100–52,000	0.792–0.350
Post-combustion CO_2 capture from natural gas power generation	112,500–100,000	0.927–0.719
CO_2 capture from biomass power generation	112,500–100,000	2.588–1.144

Note) Within the range shown in the table, 1) capital costs are assumed to decrease over time, 2) required power is assumed to improve over time.

5. Hydro Power & Geo Thermal, Wind Power and Photovoltaics

○ The potentials for hydro power and geothermal power, wind power and photovoltaics are listed in the file on primary energy production.

○ A power generation unit cost for power generation of hydro power and geothermal power, wind power and photovoltaics is assumed in the model rather than explicitly treating capital costs. Although capital costs can be calculated by assuming respective usage rates, there is no impact on the calculations in the model. The calculations of the model for power generation by hydro power and geothermal power, wind power and photovoltaics are only performed with respect to power generation amount and not with respect to the facility capacity. In the same manner, if usage rates are assumed, it is possible to calculate facility capacity after performing the model calculations.

- The unit cost of hydro power is assumed to be 30 - 180$/MWh. Future cost reduction is not assumed.
- Wind power and photovoltaics are assumed to have an annual cost decrease rate of 1.0% and 3.4%. In 2000, the unit cost of wind power is 56 - 118$/MWh and photovoltaics 209 - 720$/MWh. In 2050, the power generation unit cost is assumed to respectively become 34 - 71$/MWh and 37 - 128$/MWh (Figure 2, Figure 3).
- Since the peak of wind power generation does not always correspond to the instantaneous peak for power demand, output of wind power generation at instantaneous peaks is assumed to be 30% of the maximum capacity of wind power generation. Since the power generation time period of photovoltaics is limited, power supply is assumed to be possible only during instantaneous peaks and peaks.
- In view of stability of the power system, the maximum useable amount of power generation by wind power and photovoltaics is respectively assumed to account for 15% of total power generation. However it is assumed that use of storage batteries may expand the upper supply limit by 15% (total 30%). Wind power with storage batteries is assumed to account for up to 60% of maximum output during instantaneous peaks. When storage batteries are used in association with photovoltaics, power supply is possible during medium demand periods in addition to instantaneous peaks and peaks. The water electrolysis for hydrogen production by photovoltaics has no upper limit (naturally restrictions on supply of natural resources are treated separately).
- Battery costs when used in conjunction with expanding wind power or photovoltaics is assumed to be 375$/MWh in 2000. In 2050, this is assumed to fall to 7.6$/MWh as a result of cost decreases (up to 2030, the annual decrease rate is 5% and thereafter is 7.5%).

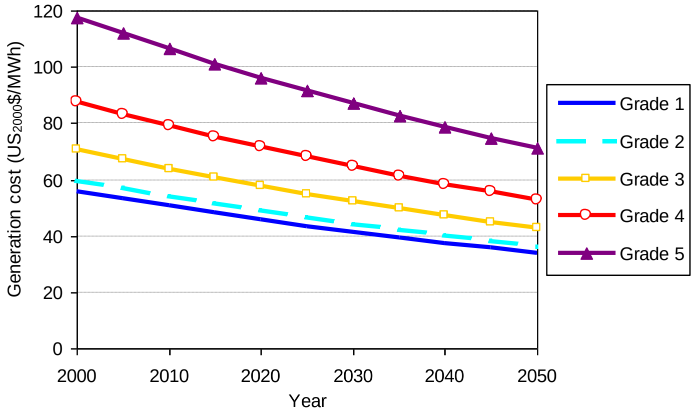

Fig.2 Estimated cost of wind power

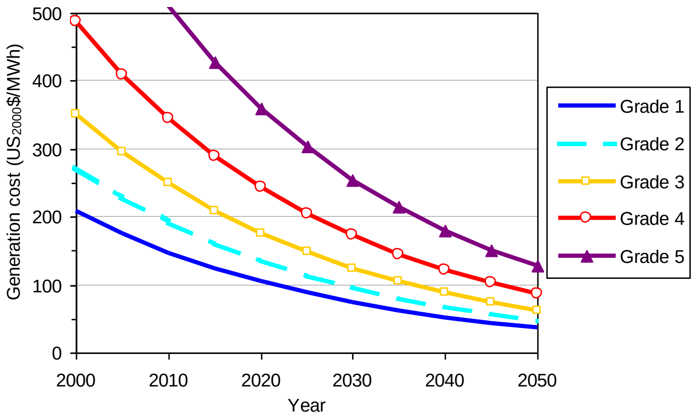

Fig.3 Estimated cost of photovoltaics