
Progress of Analytical Studies in JAERI

ETSAP Semi-Annual Workshop
IIASA-Laxenburg, Austria
23-27 June 2003

Osamu Sato
Research Group for Energy System Assessment
Japan Atomic Energy Research Institute

1

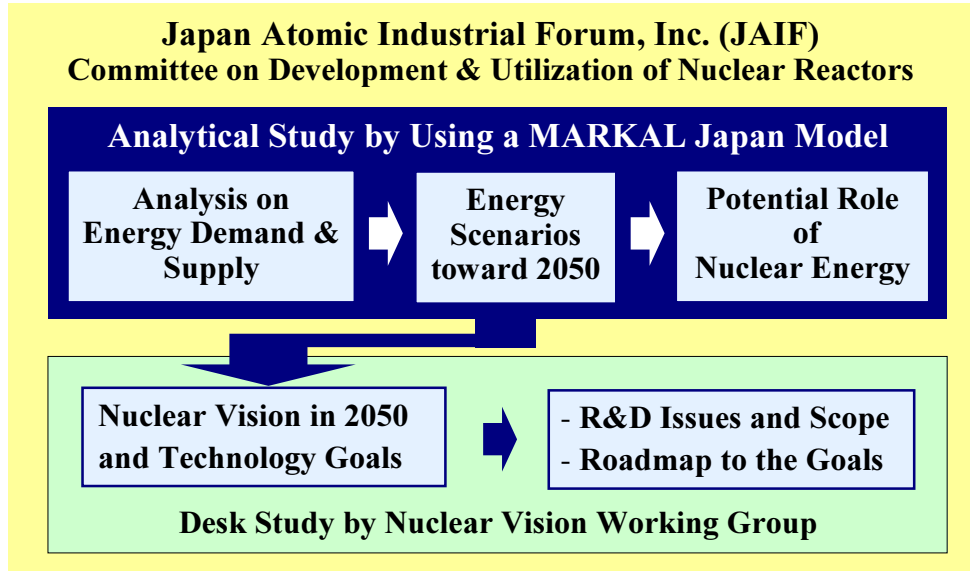
Status of On-Going Work

- **Study on Innovative Nuclear Reactors and Effective Utilization of Plutonium**
 - Comparative Cost Assessment of Fuel Cycle Systems
- **Analysis on Macro-Economic Impacts by Nuclear Phase-out**
 - Interrupted
- **Development of Long-Term Energy Scenarios for 2050 Nuclear Vision of JAIF**
 - A Set of Scenarios Developed by MARKAL

 *To be Presented Below*

Development of Long-Term Energy Scenarios for 2050 Nuclear Vision of JAIF 2

1. Background



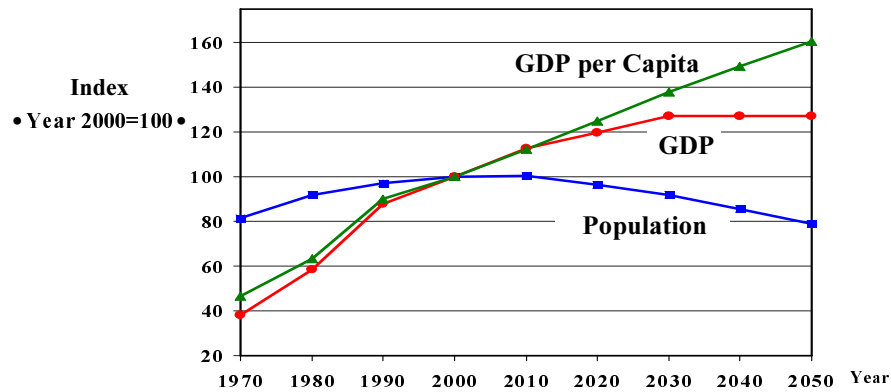
2. Assumptions and Definitions 3

(1) Basic Assumptions

-
- **GDP Growth Rates (Annual Average):**
1.2% in 2000-2010, 0.6% in 2010-2030, 0% in 2030-2050
(0.5% over the Period 2000-2050)
 - **Energy Intensity (Final Energy per GDP):**
Improved at Annual Rate 0.8% over the Period 2000 - 2050
 - **Imported Fossil Fuel Prices (page 5):**
 - Oil Price Doubling during 2000 - 2050
 - LNG Price 1.5 Times Increase during 2000 - 2050
 - **CO₂ Emissions: 2050 Emissions Limited at 60% of 2010 Levels (page 6)**
 - **Nuclear Energy: Reference / Phase-out / Expansion (page 8)**
-

(2) Socio-Economic Assumptions

	1970	1980	1990	2000	2010	2020	2030	2040	2050
Population (Million)	103.7	117.1	123.6	127.1	127.6	124.1	117.1	109.0	100.5
GDP (Trillion Yen)	204.1	312.7	469.8	535.7	603.6	642.0	680.3	680.3	680.3
GDP Growth Rate (%)		4.36	4.15	1.32	1.2	0.6		0	
GDP per Capita (Million Yen)	1.97	2.67	3.80	4.21	4.73	5.17	5.81	6.24	6.77
Household (Million)	30.3	35.8	40.7	46.7	49.1	48.7	46.9	44.5	41.9
Persons per Household	3.42	3.27	3.04	2.72	2.60	2.55	2.50	2.45	2.40



(3) Assumptions on Energy Imports

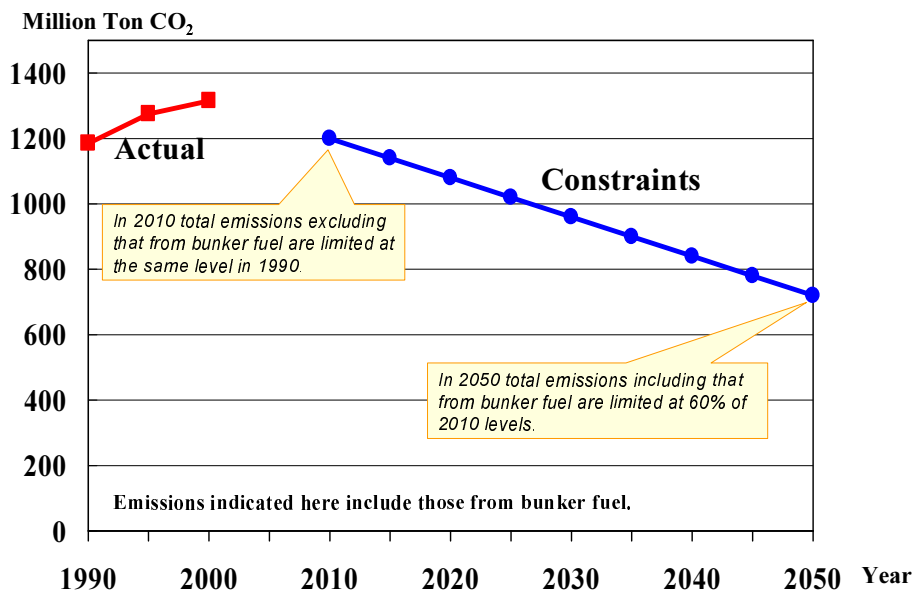
Prices

		2000	2010	2020	2030	2050
Crude Oil	(\$/bbl)	20	26	30	34	40
Crude Oil	(\$/GJ)	3.54	4.59	5.30	6.00	7.06
Natural Gas	(\$/GJ)	4.01	4.61	5.01	5.41	6.02
Coal	(\$/GJ)	2.00	2.15	2.25	2.35	2.50
Nat. Uranium	(\$/lbU ₃ O ₈)	19.0	21.9	23.8	25.7	28.5

Limits to Imports

		2000	2010	2020	2030	2050
Oil	Billion Liter	304	290	255	218	190
Natural Gas	Million Ton	53	65	110	160	-
Coal	Million Ton	137	202		-	

(4) Constraints on CO₂ Emissions



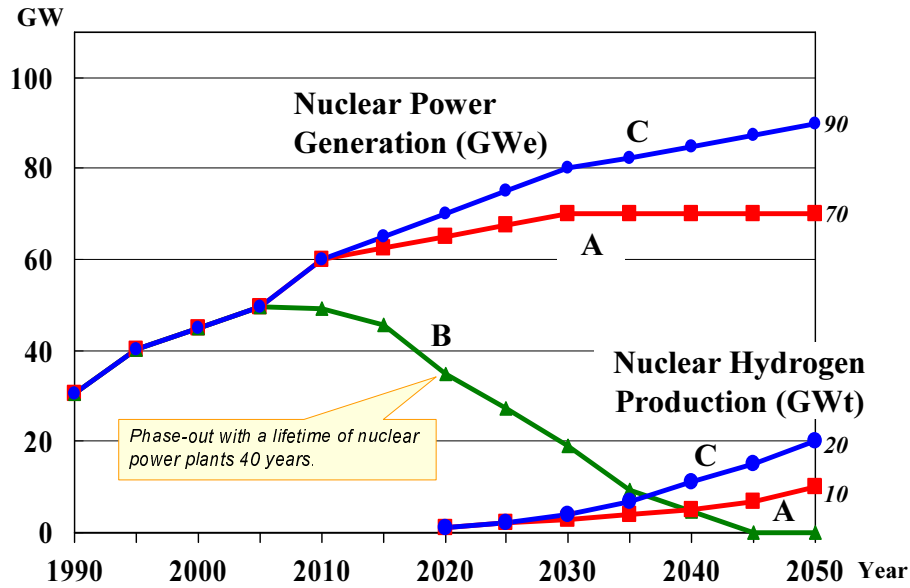
(5) Definition of Energy Scenarios

Scenario	Nuclear Power Generation	Nuclear Hydrogen Production *1
A (Reference)	70 GWe in 2030 and thereafter	10 GWt in 2050
B *2 (Phase-out)	No Investment after 2010	None
C (Expansion)	90 GWe in 2050	20 GWt in 2050

*1 • Nuclear hydrogen production is assumed to start at 2020.

*2 Utilization of renewable energy is expanded (page 9), and CO₂ sequestration is used (page 22) in order to meet emission targets.

(6) Installed Capacity of Nuclear Technologies



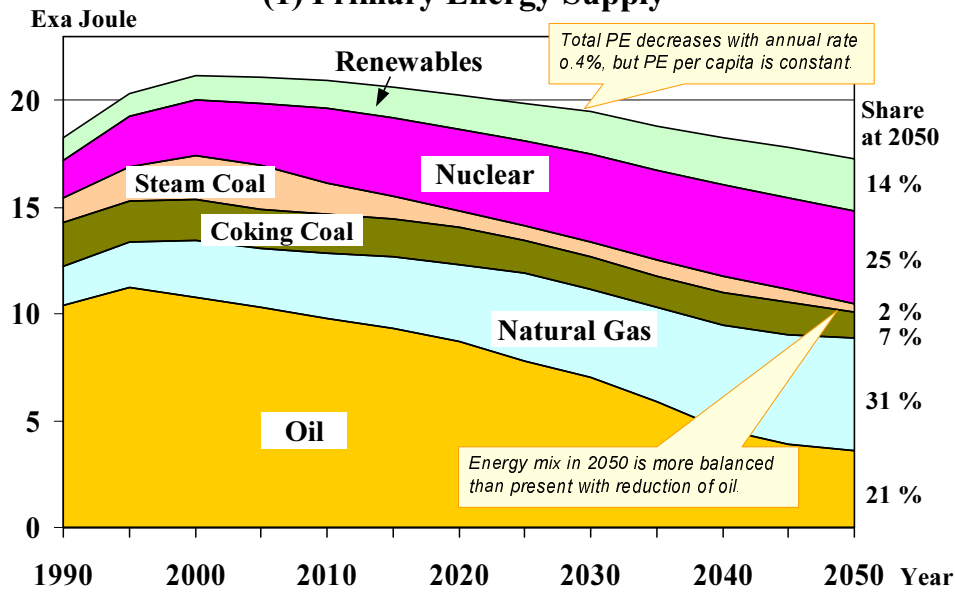
(7) Upper Limit to Installed Capacity (Renewables and CHP Technologies)

Technologies		2000	2010	2020	2030	2050	
Renewables	Scenario A and C	Hydroelectric	22.2	24	26	26	26
		Geothermal	0.53	0.7	1.3	2	2
		Solar PV	0.28	4.6	20	40	70
		Wind Power	0	1	6	10	10
	Scenario B (Phase-out)	Hydroelectric	22.2	26.5	28	28	28
		Geothermal	0.53	1	2	3	4
		Solar PV	0.28	4.6	25	50	100
		Wind Power	0	1	7	12	12
Coupled Heat & Power	Conventional	5.4	10	10	10	10	
	PAFC		0.2	5	10	15	
	MCFC		0.1	2	8	25	
	PEFC (Town Gas)		0.1	2	8	25	
	PEFC (Hydrogen)			.5	3	20	

3. Outline of Reference Scenario

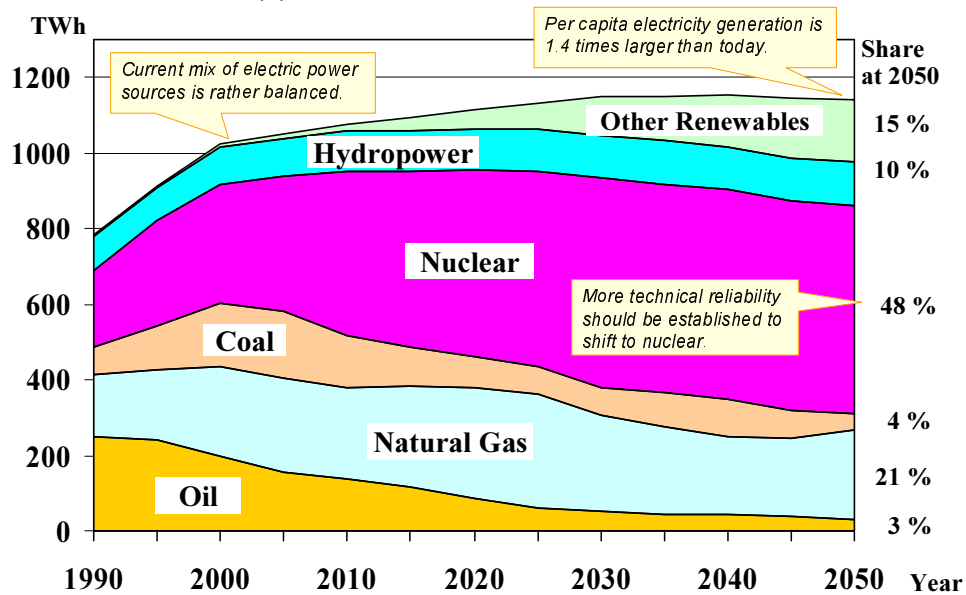
10

(1) Primary Energy Supply

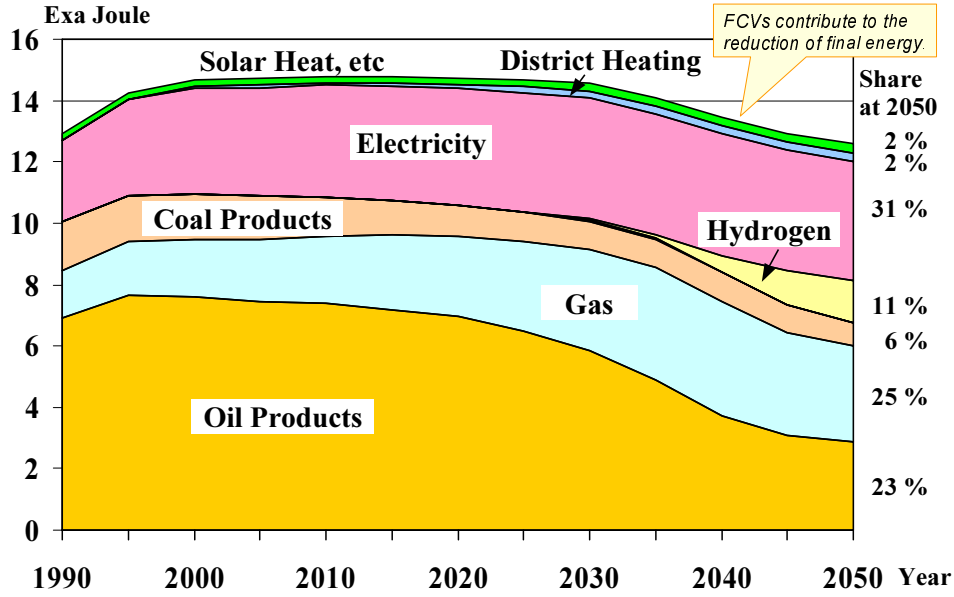


11

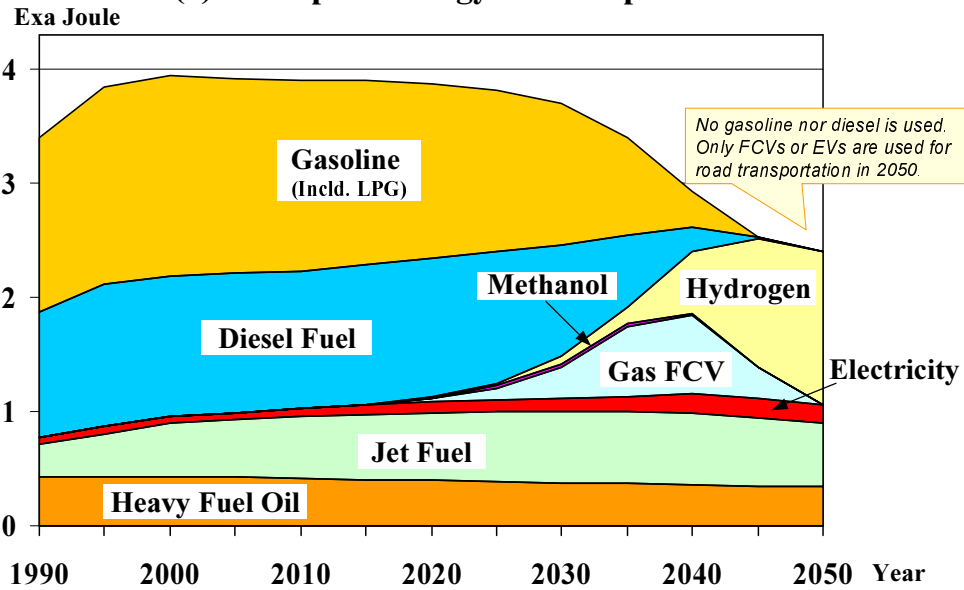
(2) Electric Power Generation



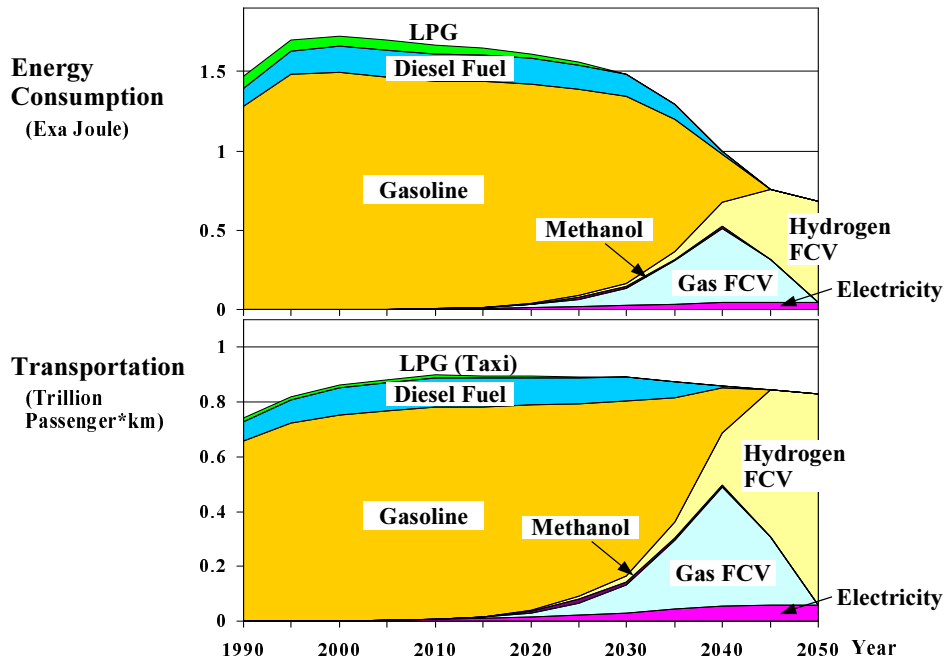
(3) Final Energy Consumption



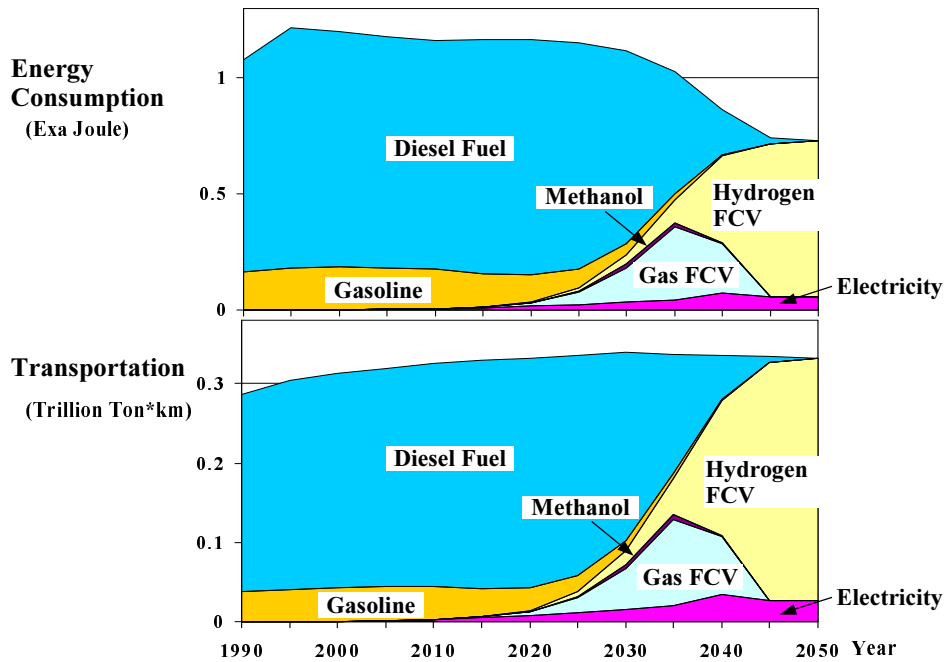
(4) Transport Energy Consumption



(5) Energy Consumption & Transportation by Passenger Car 14



(6) Energy Consumption & Transportation by Truck 15



4. Comparison of Scenarios

16

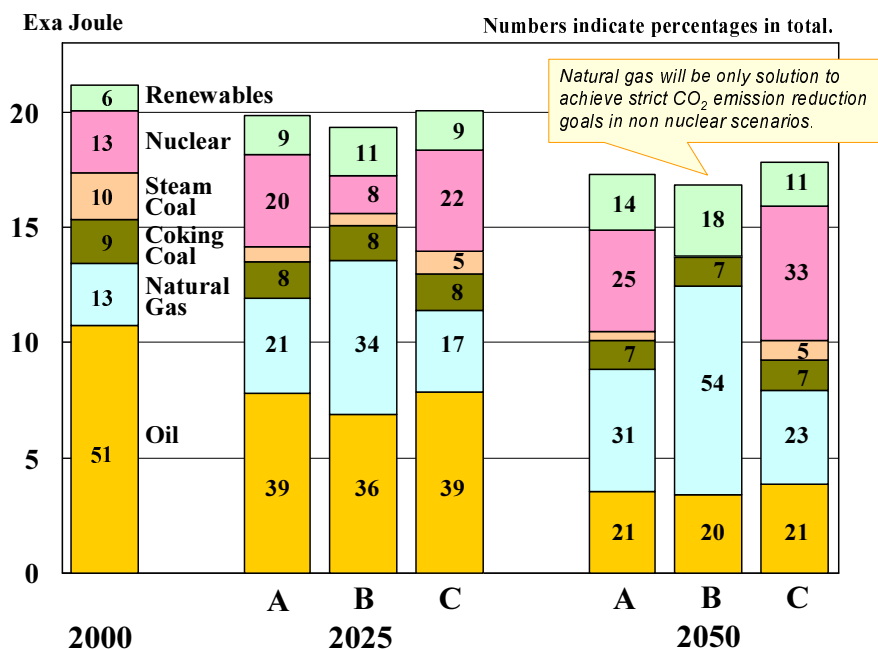
(1) Summary Table of Energy Scenarios

		2000	2050					
			A	Index	B	Index	C	Index
GDP	Trillion Yen	536	680	127	680	127	680	127
(Per Capita)	Million Yen	4.21	6.77	161	6.77	161	6.77	161
Primary Energy	EJ	21.2	17.3	82	16.8	79	17.8	84
(Per Capita)	GJ	167	172	103	167	100	178	107
Oil Imports	Billion Liter	301	100	33	96	32	108	36
Natural Gas Imports	Million Ton	53	109	204	185	347	84	157
Share of Fossil Energy	%	82.0	60.8		81.8		56.5	
Share of Nuclear	%	12.5	25.3		0.0		32.7	
Electric Power Generation	TWh	1025	1142	111	114	111	1177	115
(Per Capita)	MWh	8.1	11.4	140	11.4	140	11.7	145
Share of Fossil-Fired	%	58.8	26.9		66.3		21.5	
Share of Nuclear	%	30.7	48.4		0.0		60.3	
Final Energy	EJ	14.7	12.6	86	12.6	86	12.6	86
(Per Capita)	GJ	115	125	109	125	109	125	109
Share of Electricity	□	23.7	31.1		30.6		31.0	
CO2 Emissions	Million Ton	1300	719	55	719	55	719	55
(Per Capita)	Ton	10.3	7.2	69	7.2	69	7.2	69
Energy Supply Cost	Trillion Yen	20.2	19.0	94	23.2	115	18.9	94
Ratio of GDP	%	3.8	2.8		3.4		2.8	
Fuel Import Cost	Trillion Yen	6.3	6.9	110	9.2	146	6.5	102

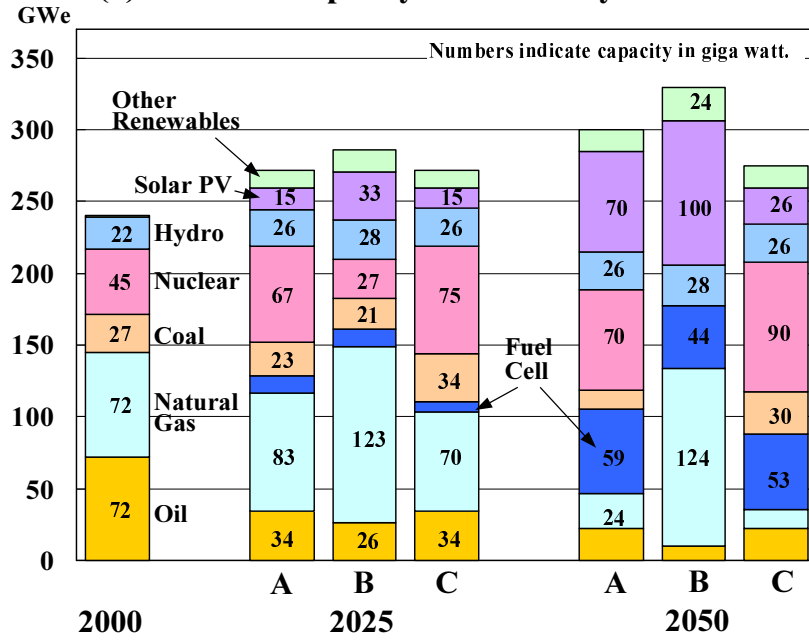
Note: *Index* indicates relative values to the year 2000 (year 2000 = 100)

(2) Primary Energy Supply

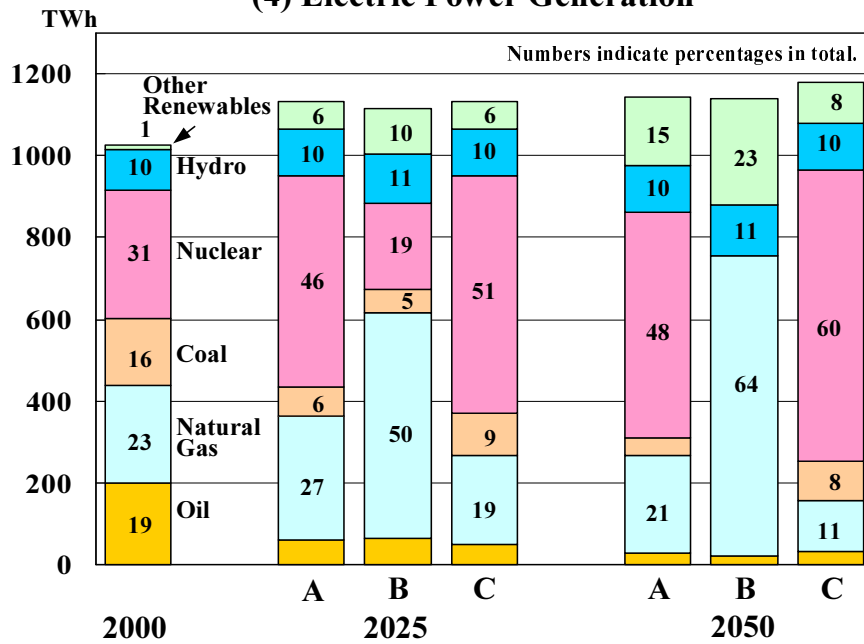
17



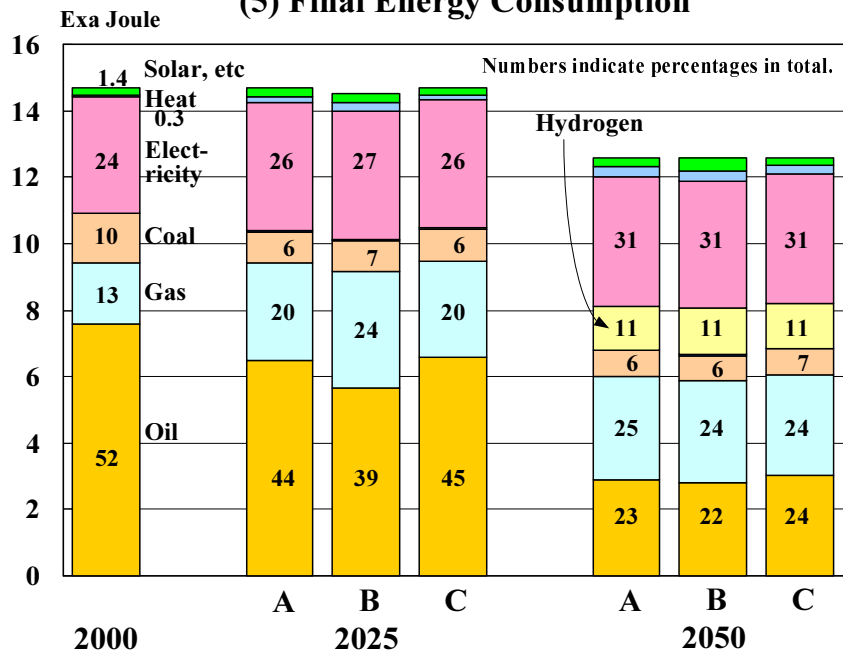
(3) Installed Capacity of Electricity Generation



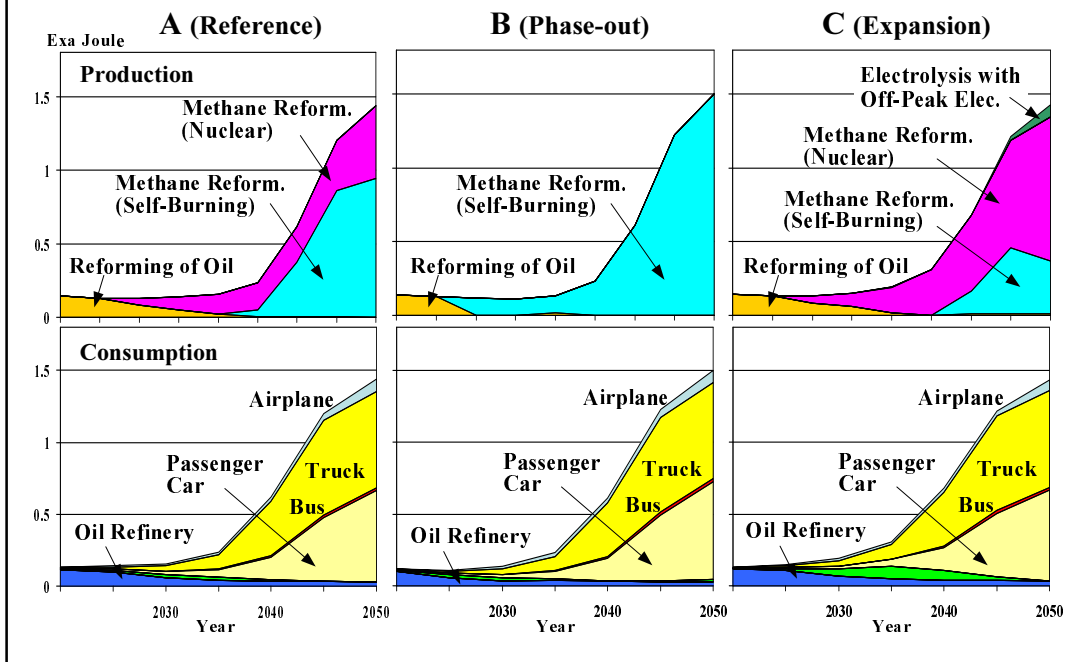
(4) Electric Power Generation



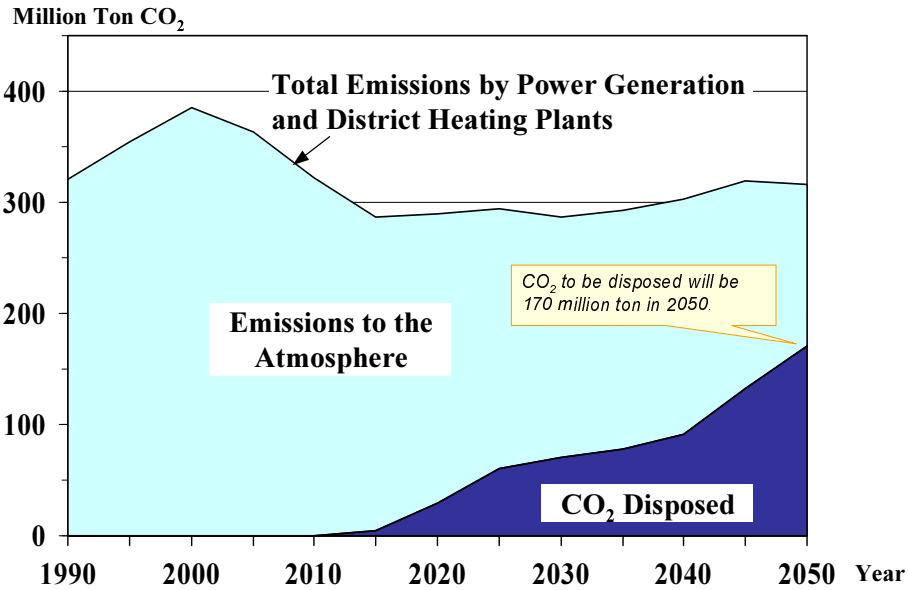
(5) Final Energy Consumption



(6) Hydrogen Production and Consumption



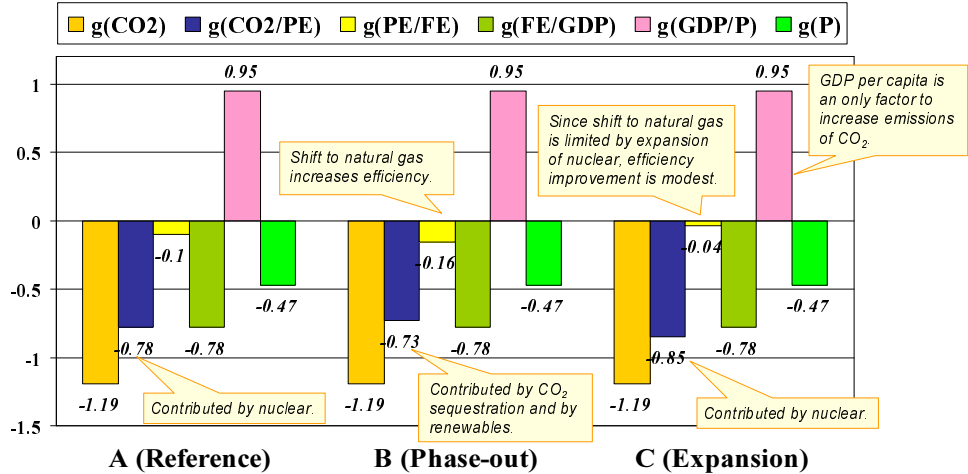
(7) CO₂ Sequestration in Scenario B (Phase-out)



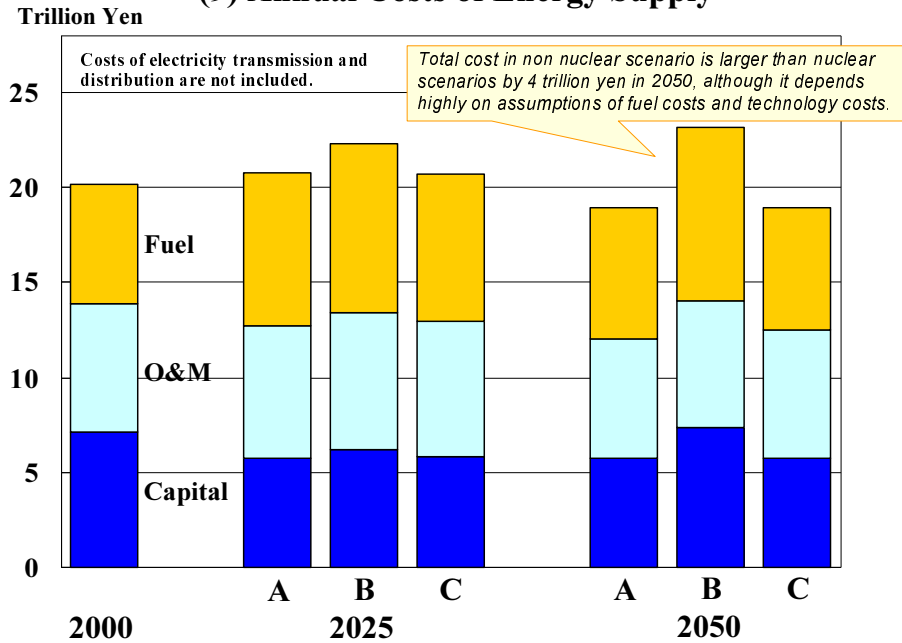
(8) Factor Disaggregation of CO₂ Emission Reduction

- g(CO₂) Growth Rate of CO₂ Emissions
- = g(CO₂/PE) Growth Rate of Average Emission Factor (CO₂ Emissions per Primary Energy)
- + g(PE/FE) Growth Rate of Energy Conversion Efficiency (Primary Energy per Final Energy)
- + g(FE/GDP) Growth Rate of Energy Efficiency (Final Energy per GDP)
- + g(GDP/P) Growth Rate of GDP Per Capita
- + g(P) Growth Rate of Population

Annual Average Growth Rates over 2000 - 2050



(9) Annual Costs of Energy Supply



5. Concluding Remarks

- **Future Energy Demand**
 - Modest Growth with Decreasing Population & Low GDP Growth
 - Shift to Clean and Convenient Electricity and Hydrogen
- **Important Energy Options**
 - Natural Gas: for Electricity, for Hydrogen, and as Fuel to Substitute Petroleum Products in Industry and Transportation
 - Renewables: for Electricity
 - Nuclear: for Electricity and for Process Heat to Produce Hydrogen
- **Key Issues**
 - Natural Gas: Development of Resources in Central and East Asia
Development of International & Domestic Main Pipelines
 - Renewables: Continuing Subsidies on High Cost Options such as PV
 - Nuclear: Restructuring of Regime for Development and Utilization
More Reliability to Take Larger Part in Power Generation
Develop. of Fuel Cycle & Hydrogen Production Technologies