Economics of Nuclear Power: Case of Japan - update and back-end activities

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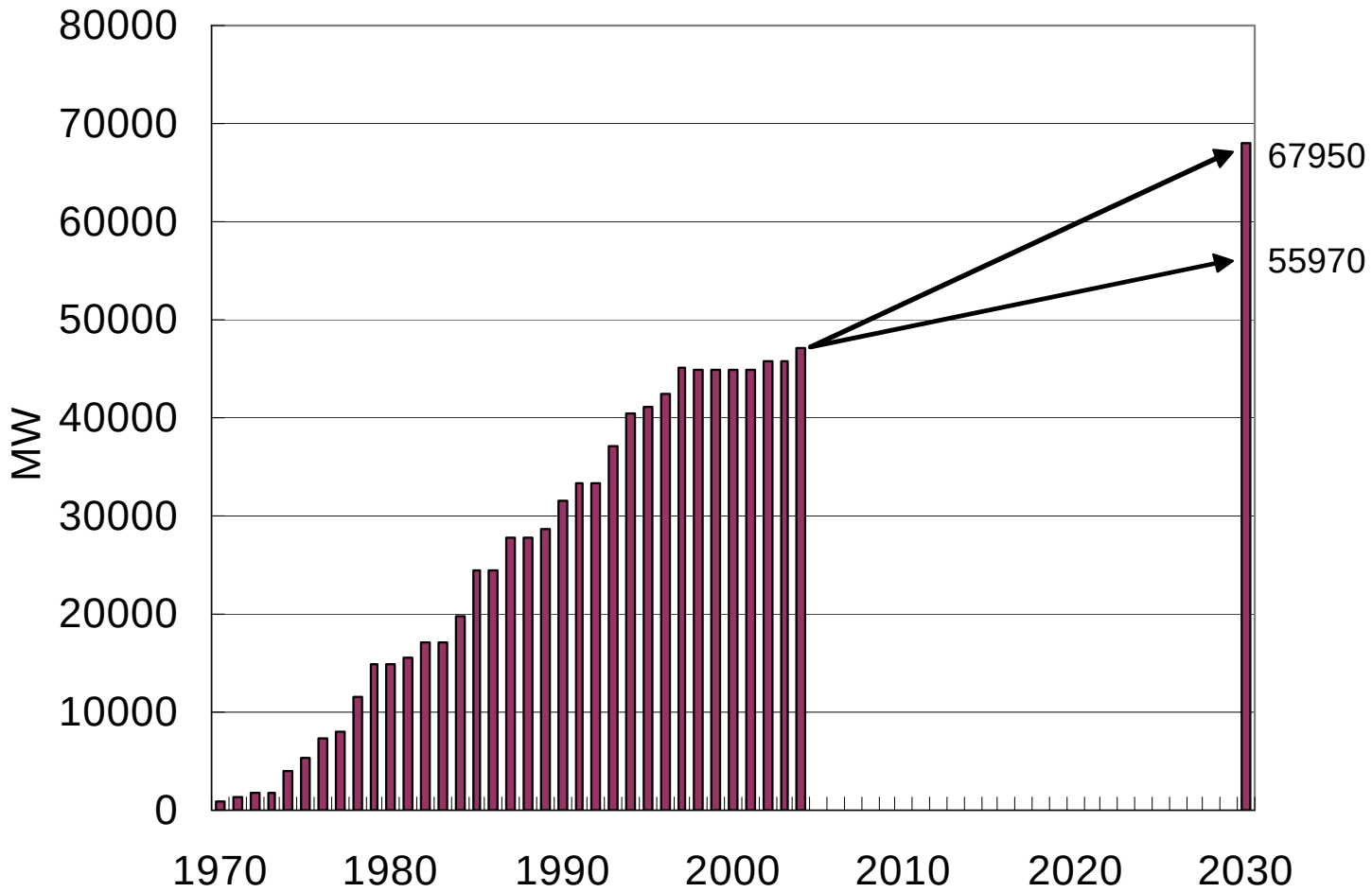
Outline

- Background
  - Development of nuclear power in Japan
  - Unit cost of generating electricity announced by the government
- Scope of my study: Is nuclear the cheapest?
  - Social cost
- Estimating cost of generating electricity
  - Unit cost borne by electric utilities
    - “Nuclear and pumping up hydro”
  - State aid by the government
- Economic Evaluation of reprocessing

Electricity in Japan (2006)

	Capacity MW	Generated electricity MWh	
Hydro	45,685	89,005	9.1%
Geothermal	497	2,878	0.3%
Thermal	138,903	577,570	59.4%
Nuclear	49,467	303,426	31.2%
Wind	4	5	0.0%
Solar	0	0	0.0%
Total	234,556	972,885	

Development of nuclear power in Japan



Nuclear Development Strategy

- "Framework for Nuclear Energy Policy"
  - Determined in October 2005
- "Nuclear Power Nation Plan"
  - Determined on 8 August 2006
- Under the current plans above, 30-40% of the electricity will be generated from nuclear power even after 2030.

Why nuclear power?

1. Energy security
   - Diversification of energy
   - “quasi” national energy
   - Nuclear fuel cycle depending on fuel reprocessing and fast breeders ?
2. GHG reduction
   - Only 7.5 % of primary energy in 2005
   - Japan’s 6% reduction target is based on the expansion of nuclear power. But, it is unrealistic because of difficulties of public acceptance. In addition, there occurred an big earthquake near the largest nuclear power plants, which are expected to be stopped at least for several years, in Japan: the Kashiwazaki Kariwa Nuclear Power Plants(8271MW)
3. Cost economy

   Is it true that nuclear power is the cheapest?

Question:
Is nuclear power the cheapest?

- Cost analysis by the Japanese Government, the Ministry of International Trade and Industry (from 2001, METI: the Ministry of Economy, Trade and Industry).
- According to the METI, nuclear is the rational source from the economic viewpoint.
- But, no detailed information publicized.

Cost per unit of electricity projected by the Japanese Government

	yen/kWh	Cent (Euro)/kWh	Cent ($)/kWh
Hydro	13.6	8.5	11.3
Oil	10.2	6.4	8.5
LNG	6.4	4.0	5.3
Coal	6.5	4.1	5.4
Nuclear	5.9	3.7	4.9

USD=120 yen

Euro =160 yen

Source: Advisory Committee for Energy (1999) (in Japanese)

Assumptions (1) (METI)

	Capacity	Years in operation	Capacity factor
Hydro	15 MW	40	45%
Oil	400MW	40	80%
LNG	1500MW	40	80%
Coal	900MW	40	80%
Nuclear	1300MW	40	80%

Assumptions (2) (METI)
Fuel price

- Fossil fuel: price will rise for 40 years at the following annual rate respectively.
  - Oil 3.36%, LNG 1.82%, Coal 0.88%
- Nuclear fuel: price will remain at the latest average price for 40 years.
  - Detailed data has not been disclosed.
  - But, why only the cost of nuclear fuel can be stable for 40 years??

Cost per unit of electricity projected by the Japanese Nuclear Industry

	yen/kWh	Cent (Euro)/kWh	Cent ($)/kWh
Hydro	11.9	7.4	9.9
Oil	10.7	6.7	8.9
LNG	6.2	3.9	5.2
Coal	5.7	3.6	4.8
Nuclear	5.3	3.3	4.4

USD=120 yen

Euro =160 yen

Source: Nihon Genshiryoku Sangyokaigi (2005), *Genshiryoku Poket book* (in Japanese)

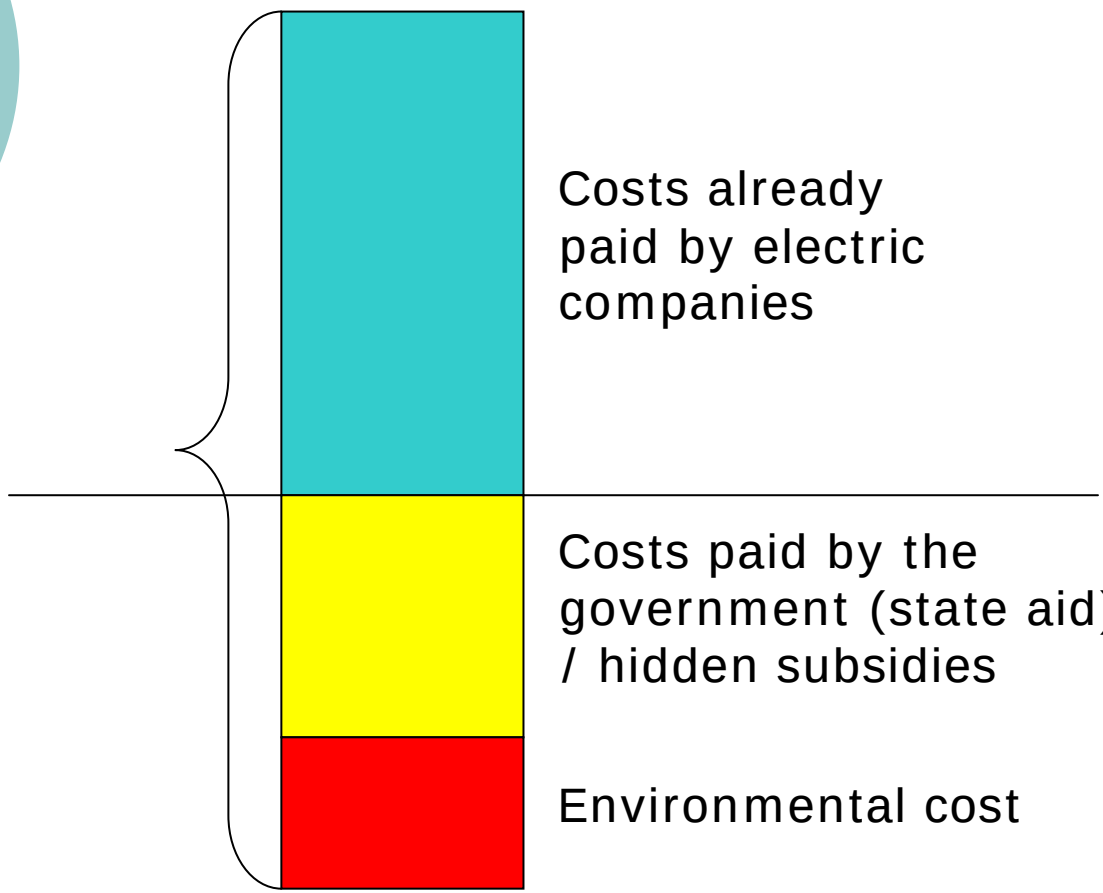
Cost per unit of electricity projected by the Japanese Nuclear Industry

	Capacity factor	Discount rate				
		0%	1%	2%	3%	4%
Hydro	45%	8.2	9.3	10.6	11.9	13.3
Oil fired	30%	14.4	15.0	15.7	16.5	17.3
	70%	10.4	10.6	10.9	11.2	11.6
	80%	10.0	10.2	10.5	10.7	11.0
LNG fired	60%	6.2	6.4	6.6	6.8	7.1
	70%	6.0	6.1	6.3	6.5	6.7
	80%	5.8	5.9	6.1	6.2	6.4
Coal fired	70%	5.3	5.6	5.9	6.2	6.5
	80%	5.0	5.2	5.4	5.7	6.0
Nuclear	70%	5.4	5.5	5.7	5.9	6.2
	80%	5.0	5.0	5.1	5.3	5.6
	85%	4.8	4.8	4.9	5.1	5.4

*Lifetime of all sources is 40years.

Source: Nihon Genshiryoku Sangyokaigi (2005), *Genshiryoku Poket book* (in Japanese)

What is the real cost of generating electricity?



Costs already paid by electric companies → Methodology (1)

Costs paid by the government (state aid) / hidden subsidies → Methodology (2)

Environmental cost → Not analyzed in this study

Methodology (1)

Unit cost of generating electricity

- Based on financial statements of nine electric utilities.
  - Published information
  - Real costs of generating electricity
- Using “the Rule of Cost Calculation of Power Supply for Electric Utilities” (METI) (in Japanese)
  - Published calculation method
- Calculate the real average cost from 1970, when commercial use of nuclear power started, to 2007 (UPDATE)

Calculation formula

$$P_h = \frac{B_h + (C_h + D_h + G_h) \times r}{A_h}$$

$$P_t = \frac{B_t + (C_t + D_t + F_t + G_t + H_t) \times r}{A_t}$$

$$P_n = \frac{B_n + (C_n + D_n + E_n + F_n + G_n) \times r}{A_n}$$

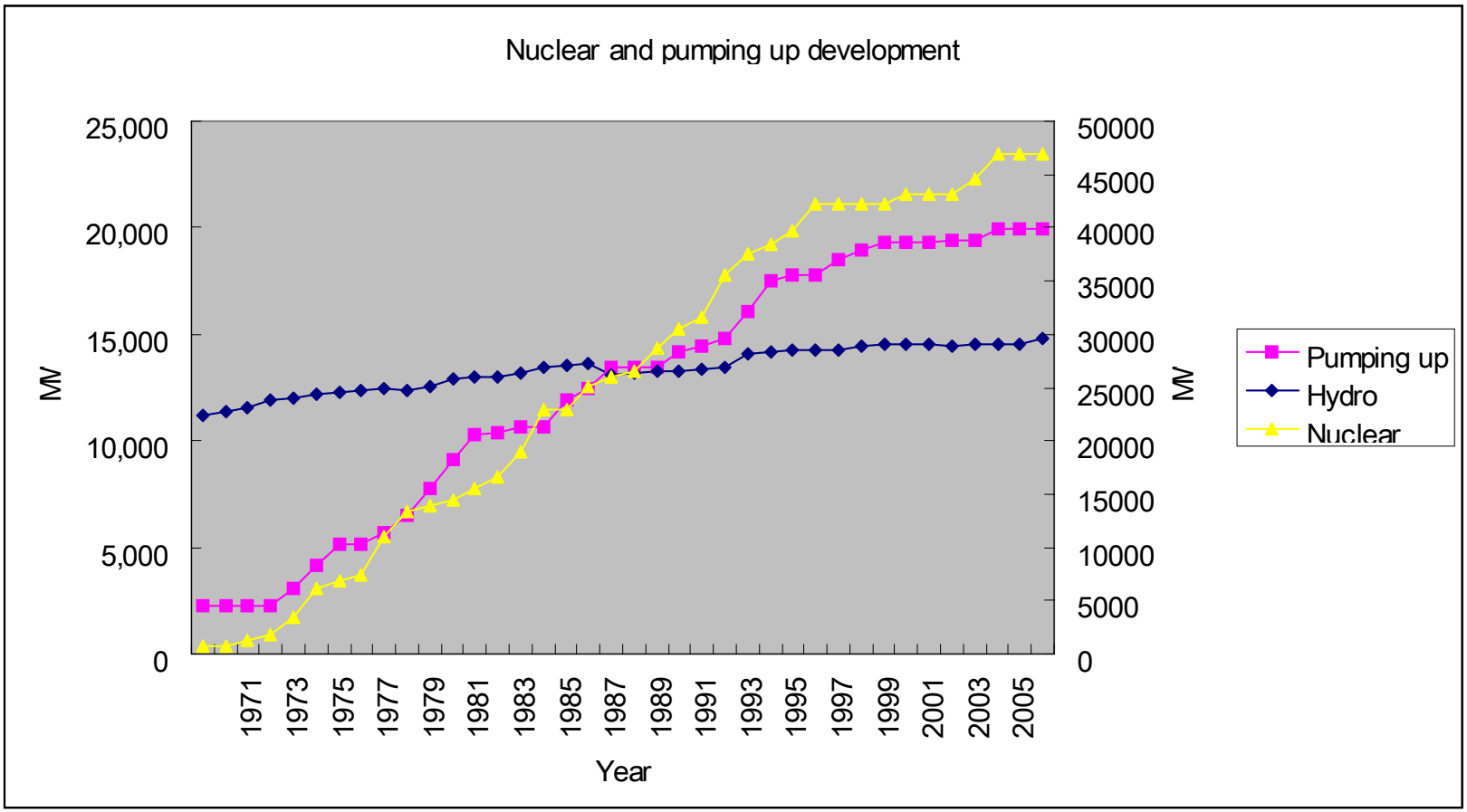
Source: Murota (1991) (in Japanese)

P: unit cost of generating electricity
A: total generated electricity
C: fixed assets
D: assets in construction process
E: nuclear fuel assets
F: specified investment
G: operating capital
r: rate of return
h: hydro
t: thermal
n: nuclear

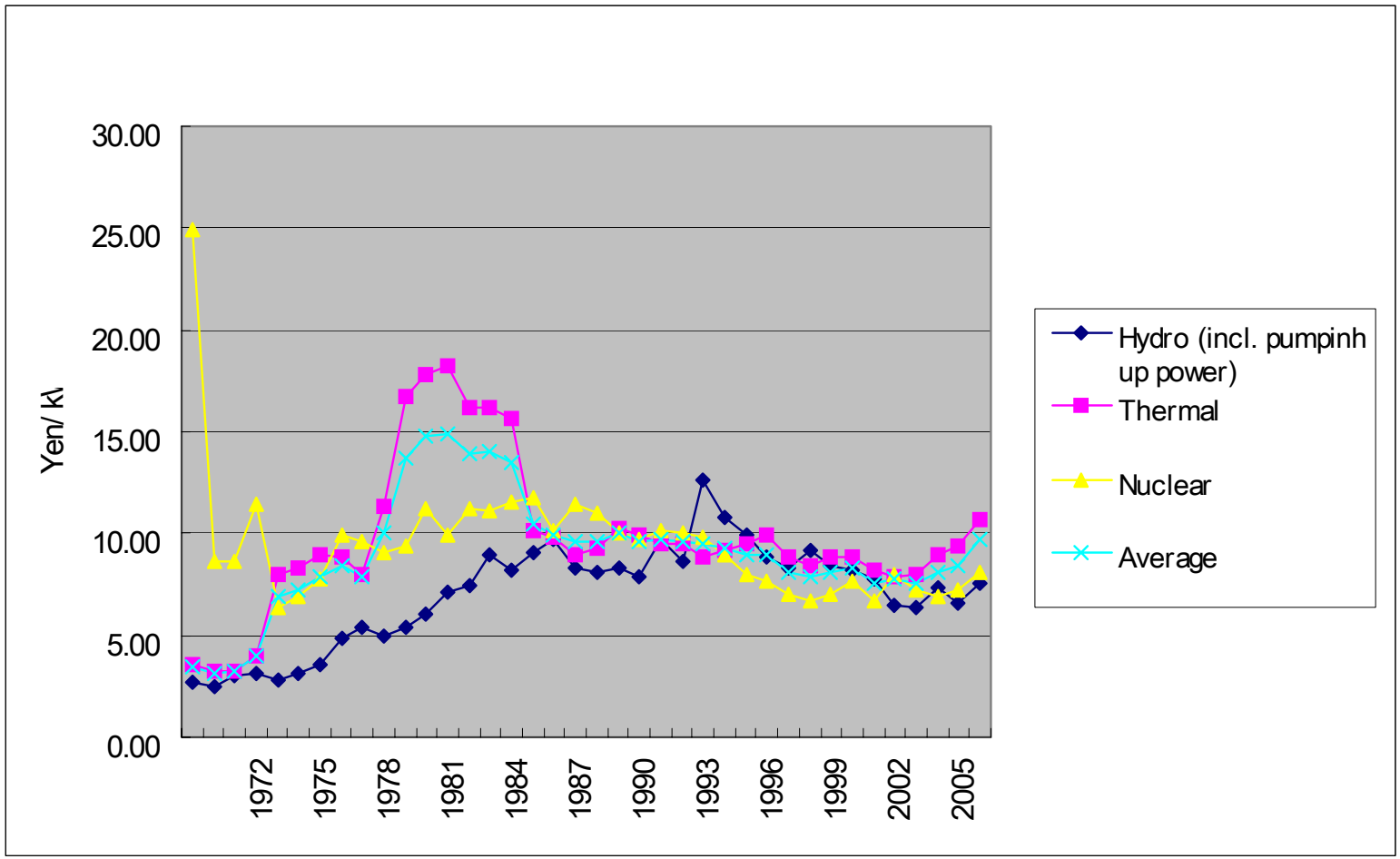
Methodology (1) - 2

- Separate “pumping up hydro” from “hydro” and define the cost of “nuclear and pumping up”. (NEW)
  - “Pumping up” hydro power stations have been developed together with nuclear power development like in a single body.

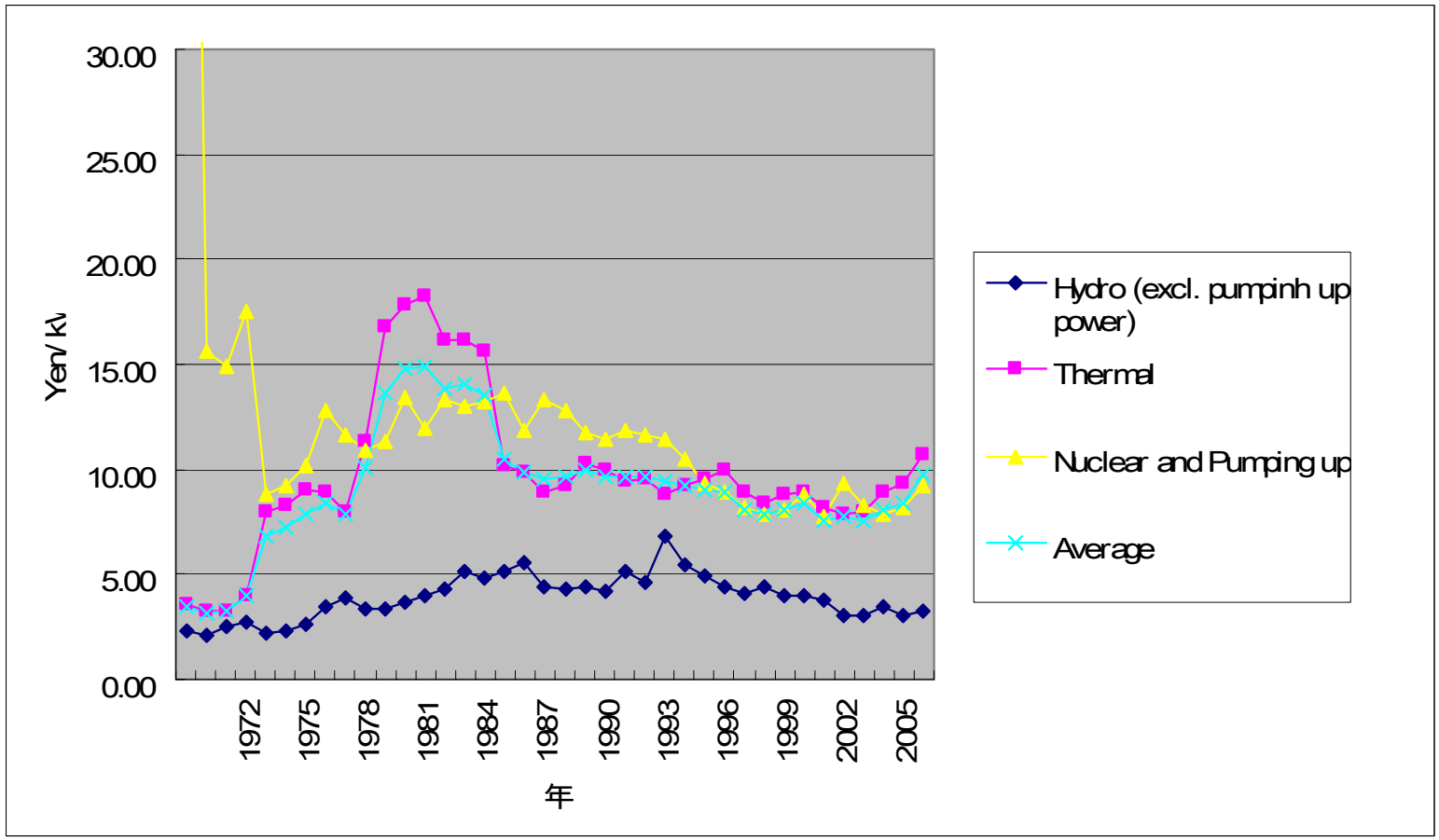
Nuclear and pumping up



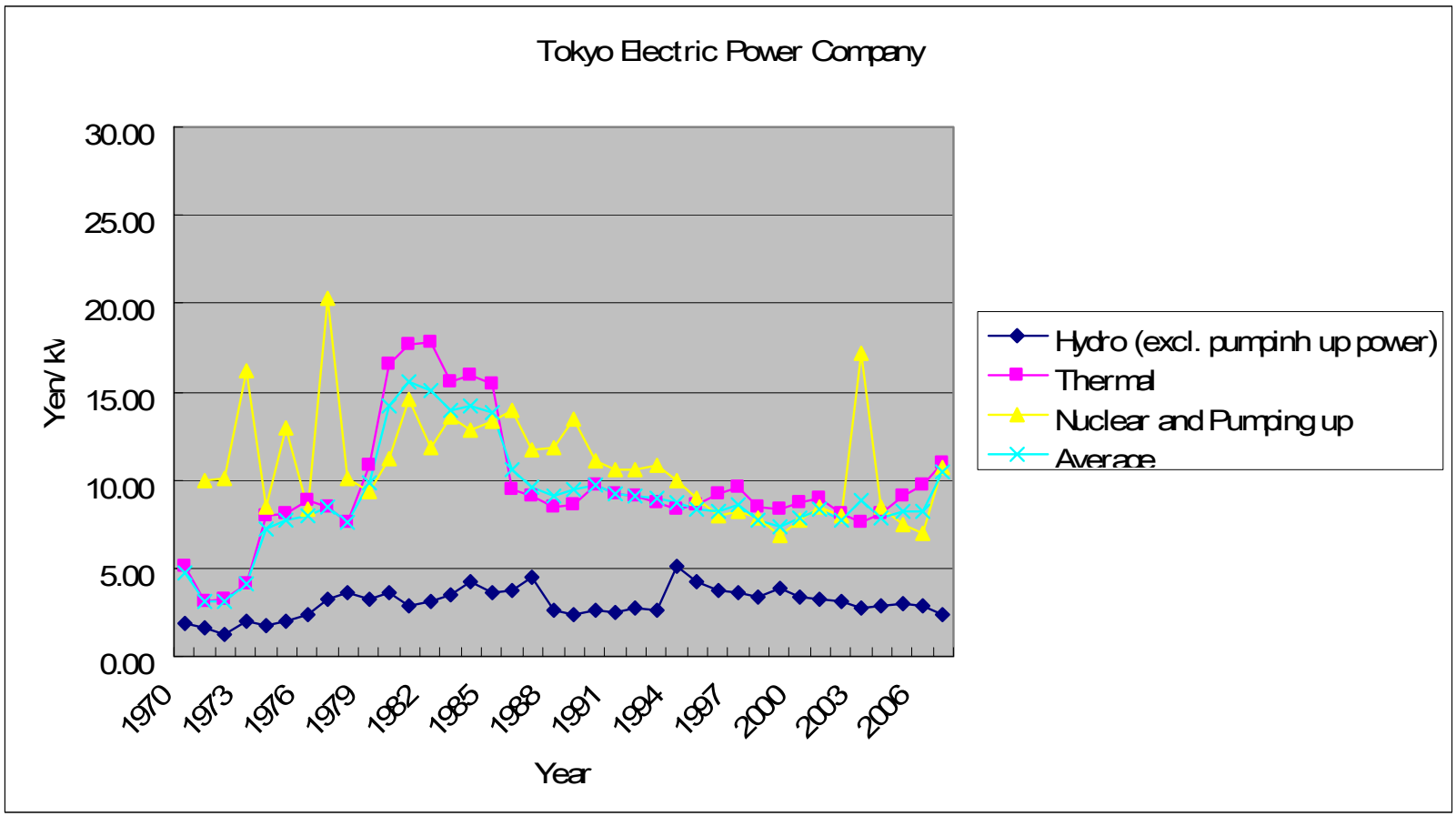
Unit costs of hydro, thermal and nuclear



Unit costs of hydro (excl. pumping up), thermal and “nuclear and pumping up”



Trend of unit costs (Tokyo Electric Power Company)



Result (1): average costs (1970-2007)

	Hydro incl. pumping up	Hydro excl. pumping up	Thermal	Nuclear	Nuclear and puming up
Yen/kWh	7.08	3.88	9.80	8.64	10.13
Cent(USD)/kWh	6.43	3.52	8.91	7.85	9.21
Cent(Euro)/kWh	4.72	2.58	6.53	5.76	6.75

1USD = 110 Yen

1Euro = 150 Yen

Costs of generating electricity

	1970s	1980s	1990s	2000-07
Hydro (incl. pumping up)	3.56	7.80	9.32	7.31
Hydro (excl. pumping up)	2.72	4.42	4.77	3.47
Pumping up	40.83	81.57	50.02	41.81
Thermal (Fossil Fuel)	7.11	13.67	9.39	8.90
Nuclear	8.85	10.98	8.61	7.29
Nuclear and pumping up	11.55	12.90	10.07	8.44

According to the calculated result (1),

- Nuclear is not the cheapest option for generating electricity;
- Hydro is the cheapest to generate electricity even if it includes pumping up.
- “Nuclear and pumping up” is the most expensive.

Methodology (2)

Calculate average state aid for each source of electricity on the National Budget

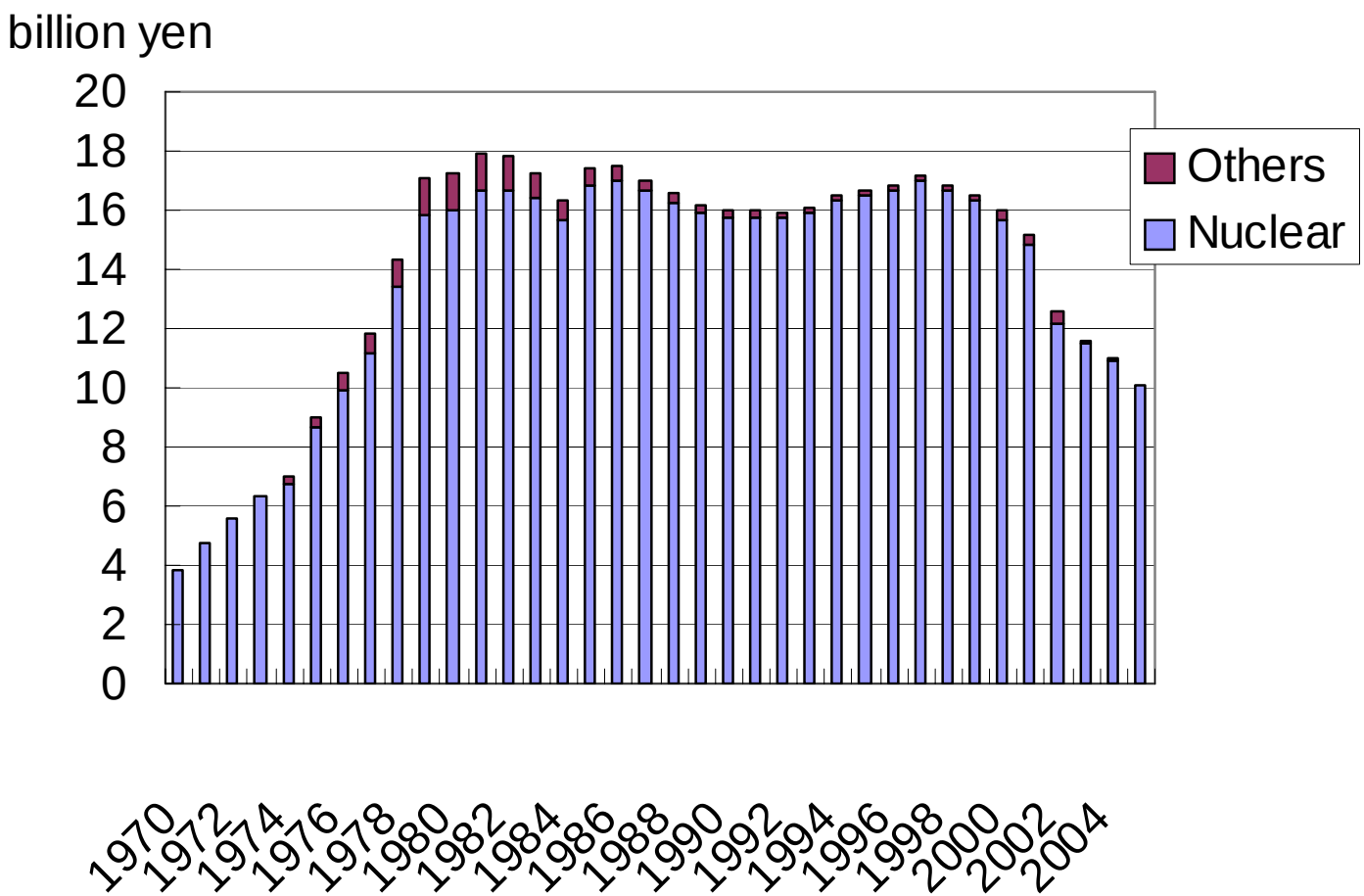
- Based on the national budget document
  - Published information
  - Real figure of state aid

1. Classify budget data into each source of electricity.
2. Accumulate the total amount of public expenditure for each source from 1970 to 2005.
3. Divide the total amount of public expenditure for each source by the total electricity of each source.

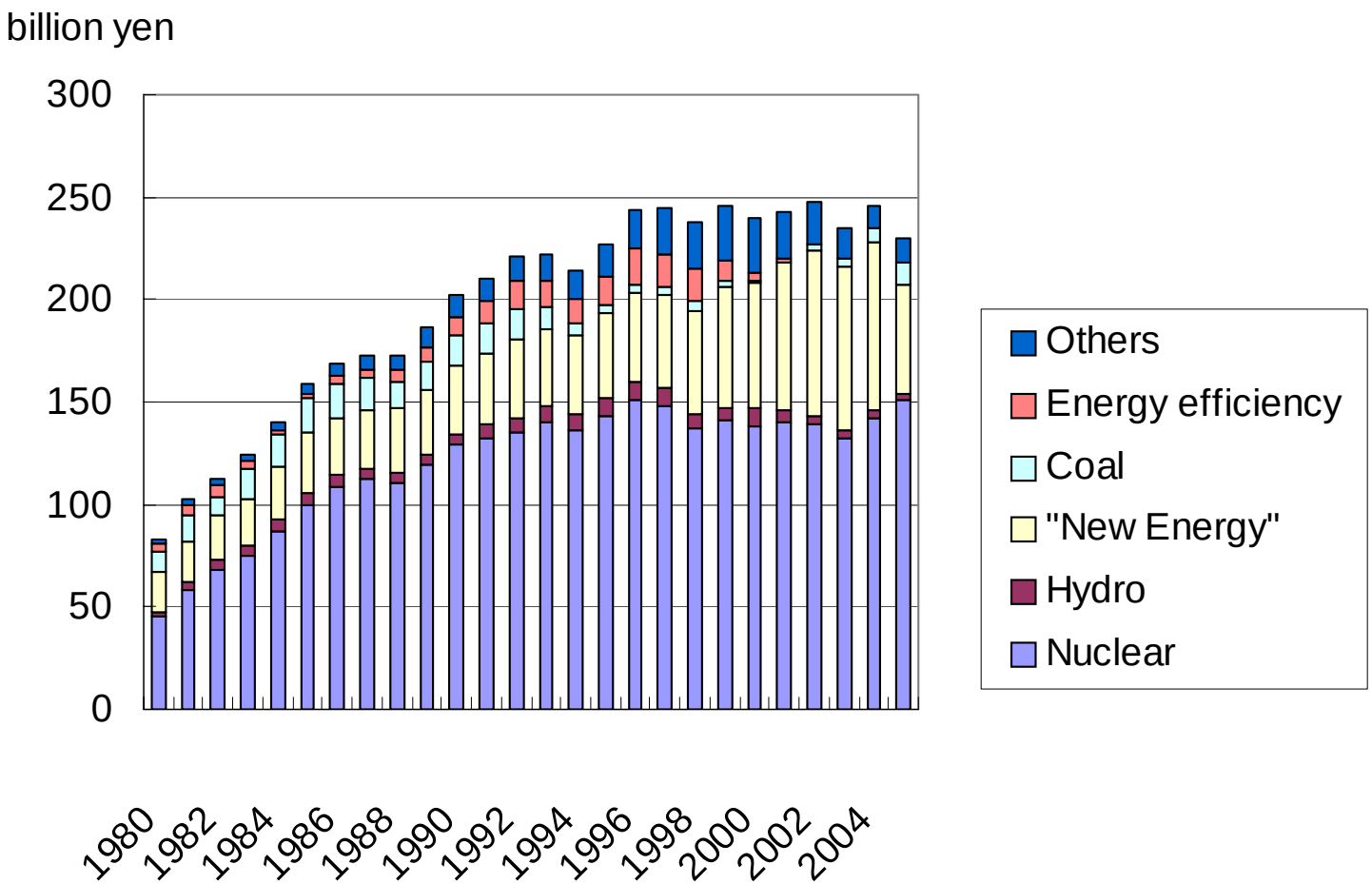
Japan's energy budget system

- Budget for energy in a general account
- Special accounts for energy
  - A special account for promotion of power resources development
  - A special account for upgrading the system of energy demand and supply

Budget for energy in a general account



Budget on an account for electricity use



Calculated result (2) : State aid for generating electricity (1970-2005)

	yen / kWh	cent (USD)/ kWh	cent (euro)/ kWh
Hydro (including pumped strage)	0.13	0.11	0.08
Thermal	0.02	0.02	0.01
Nuclear	1.56	1.30	0.98

USD=120 yen
Euro =160 yen

According to the calculated result (2),

- The Japanese government has paid huge amount of state aid for nuclear power development since 1970;
- Nuclear is the most expensive source of electricity for the Japanese government.

Result
(average 1970-2005)

	unit cost paid by	state aid (yen/kW	Total		
			yen/kWh	cent(US)/kWh	cent(euro)/kW
Hydro (including pumped strage)	7.22	0.13	7.35	6.13	4.59
Thermal	9.41	0.02	9.43	7.86	5.89
Nuclear	8.53	1.53	10.06	8.38	6.29

Conclusion

- As a whole, the cost of nuclear was the highest of conventional sources of electricity from 1970 to 2005 if state aid was considered.

Economics of back-end activities

- In addition to front-end costs, nuclear needs back-end costs.
- During 2002 – 2004, Japanese government held a special advisory committee on the total cost of back-end activities.
- According to the report published by the committee, the total cost of the whole back-end activities will be 18.8 trillion yen!

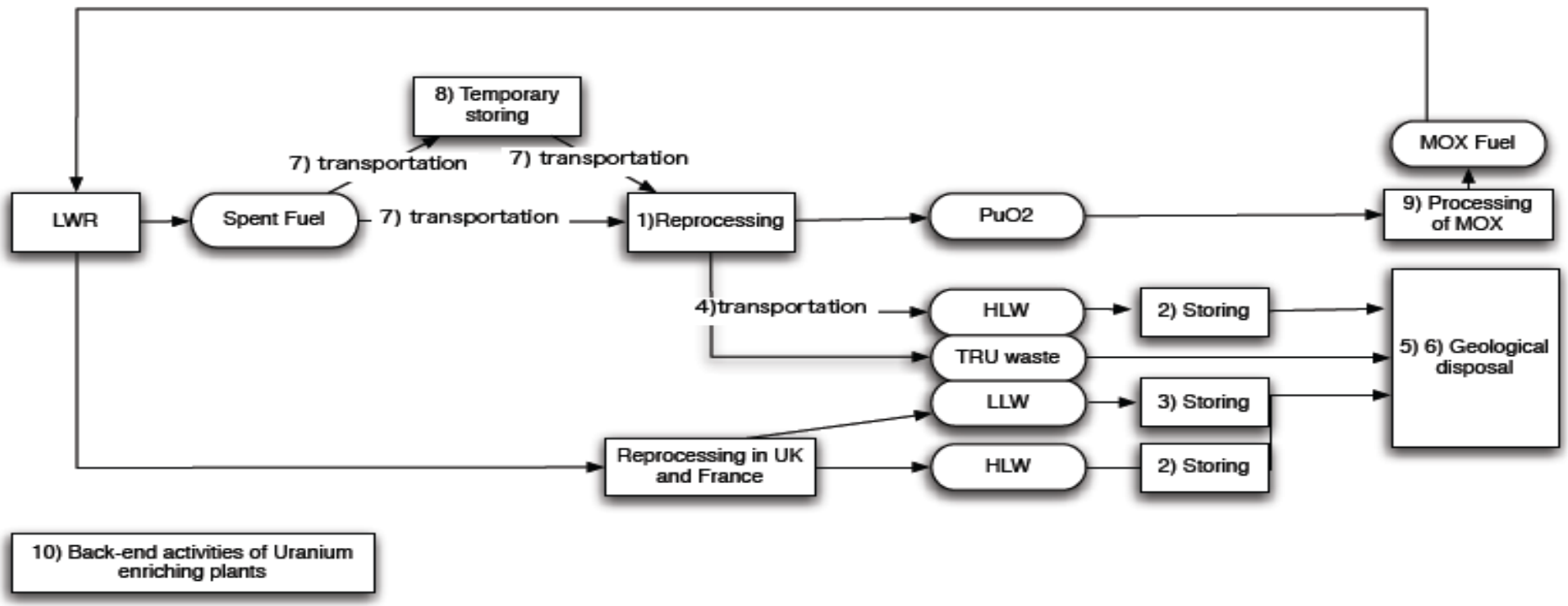
Back-end cost

	Yen	Euros
Reprocessing	11 trillion	73billion
Management of high level radioactive waste returned from foreign countries	300 billion	2 billion
Management of low level radioactive waste returned from foreign countries	570 billion	3.8billion
Transportation of high level radioactive wastes	190 billion	1.3 billion
Disposal of high level radioactive wastes	2.55 trillion	17 billion
Geological disposal of TRU waste	810 billion	5.4 billion
Transportation of spent fuel	920 billion	6.1 billion
Temporary storing of spent fuel	1.01 trillion	6.7 billion
MOX fuel processing	1.19 trillion	7.9 billion
Back-end activities of Uranium enriching plants	240 billion	1.6 billion
Total	**18.8 trillion**	**125.3 billion**

1 Euro = 150 Yen

Back-end activities calculated

Back end activities considered



Question & Methodology

- Is the back-end cost publicized by the government real?
  - Aren't there any other possible costs?
  - Are assumptions for the calculation adequate?
- Methodology
  - Read and analyze all background papers for the governmental calculation.

Findings 1/2

- The cost is not for the whole process of back-end activities.
  - The cost is just for half amount of the spent fuel and radioactive wastes until 2048.
  - Therefore, the cost will be doubled.
  - In addition, some activities are not included.
- Flawed assumption
  - 100% operating rate of a reprocessing plant
    - BNFL 4% (2007), AREVANC(COGEMA) 56% (2007)
    - Therefore, the cost will increase.

Findings 2/2

- The value of the MOX fuel (mixed oxide fuel) which will be produced by reprocessing is equivalent to just 0.9 trillion yen.
  - Remember that the cost of reprocessing is 11.8 trillion yen even with the 100% operation rate! The cost is 13 times more than the value.
  - The reprocessing is totally inefficient.

Concluding remarks on back-end costs

- Reprocessing is not efficient from the viewpoint of economics.
- The cost of back-end activities will rise dramatically in the future. (may be 30 trillion yen and more)
- Japan should abandon her reprocessing strategy immediately.

Thank you for your attention

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