Provisional Translation

Technical Subcommittee on Nuclear Power, Nuclear Fuel Cycle, etc. Data Sheet 1

Estimation of Nuclear Fuel Cycle Cost

November 10, 2011

Edited by Atomic Energy Commission Bureau

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Requests from the Cost Review Committee※

- Nuclear fuel cycling costs in nuclear power generation
  - A variety of methods are available for processing spent fuel by nuclear power generation. The costs of these methods need to be estimated according to the latest knowledge and circumstances.
- Main specifications of 2010 model plant and estimation conditions

Plant capacity	1.2 million kW
Specification base	Plant data for the latest 7 years
Capacity factor	80%, 70%, 60%
Durability	40 yr, 30 yr, 16 yr (legal useful life)
Exchange rate	85.74 yen/dollar
Discount rate	0%, 1%, 3%, 5%

※ the Energy and Environment Council's Cost Review Committee, http://www.npu.go.jp/

Estimation Models (1)

- This estimation will be used for comparisons with generation costs by electric systems, the fuel cost in nuclear power generation cost are estimated using the "model plant system."
- Two models are used for estimation:
  - With nuclear fuel cycle → Reprocessing model
  - Without nuclear fuel cycle → Direct disposal model
- Additionally, the present status of energy supply in Japan is still unfolding; estimations are being used → Latest model

Estimation Models (2)

- The future costs derived from fuel acquisition and loading into reactors and generated energy are converted to the present values for finding the levelized cost of generation (yen/kWh).

Techniques Used by the Cost Subcommittee[1] is used.

- Present nuclear fuel cycle costs are estimated in accordance with situational changes from 2004 to the present
  - Steep rise of uranium resources price
  - Strong yen
  - Enforcement of the Spent Nuclear Fuel Reprocessing Fund Act , etc.

[1] Subcommittee to Study Costs and Other Issues, Electricity Industry Committee, Advisory Committee on Energy and Natural Resources (2004)
http://www.meti.go.jp/policy/electricpower_partialliberalization/contentscost.html

Estimation Models (3)

- Methodology of the Cost Subcommittee
  - A nuclear fuel cycle of “reprocessing at Rokkasho + subsequent reprocessing” was assumed, because the Rokkasho Reprocessing Plant has caused in test operations.
  - Assuming the NPP capacity and processing capacity of the reprocessing plant, 64% of the generated spent fuel is predicted for the reprocessing, and the remaining 36% is assumed to be stored in the interim storage facilities.
- The costs were estimated using reprocessing or direct disposal models.
- The estimation using the latest model is presented for reference.

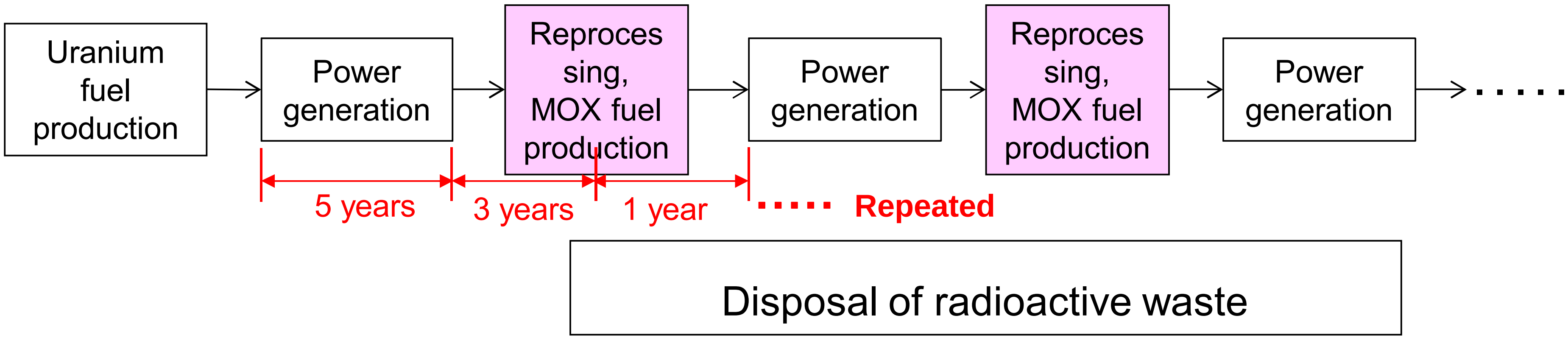
Cycle Cost Estimation Conditions (Common to All Models)

Item		Cost Subcom. (2004)	This time	
Uranium fuel enrichment		BWR 3.8% PWR 4.1%	RP model Latest model	BWR 3.7% PWR 4.6%
			DD model	PWR 4.5%
Average burnup at discharged		UO_2 fuel: 45,000 MWd/t MOX fuel: 40,000 MWd/t	←	
Incore fuel dwelling time		5 years	←	
Heat efficiency		34.5%	←	
Exchange rate		121.98 yen/dollar	85.74 yen/dollar	
Discount rate		0, 1, 2, 3, 4 %	0, 1, 3, 5 %	
RP model, latest model	Reprocessing and interim storage ratio	64 : 36	50 : 50	
	Next generation production ratio	15%	←	

RP: Reprocessing Plant, DD: Direct Disposal Site

Reprocessing Model

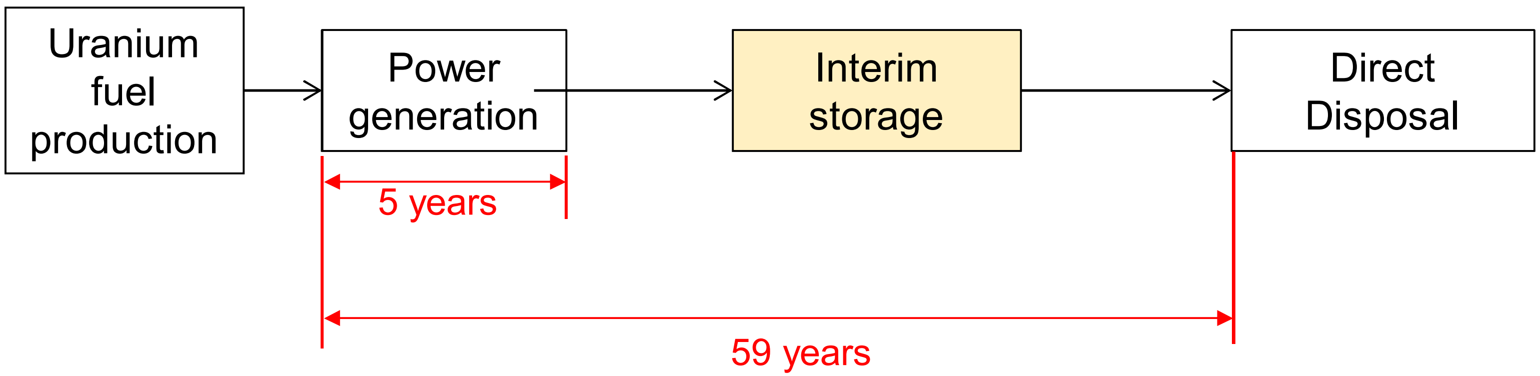
- Spent fuel is reprocessed and recycled.



- All spent fuel is reprocessed.
- Recovered Plutonium is recycled as MOX fuel.

Direct Disposal Model

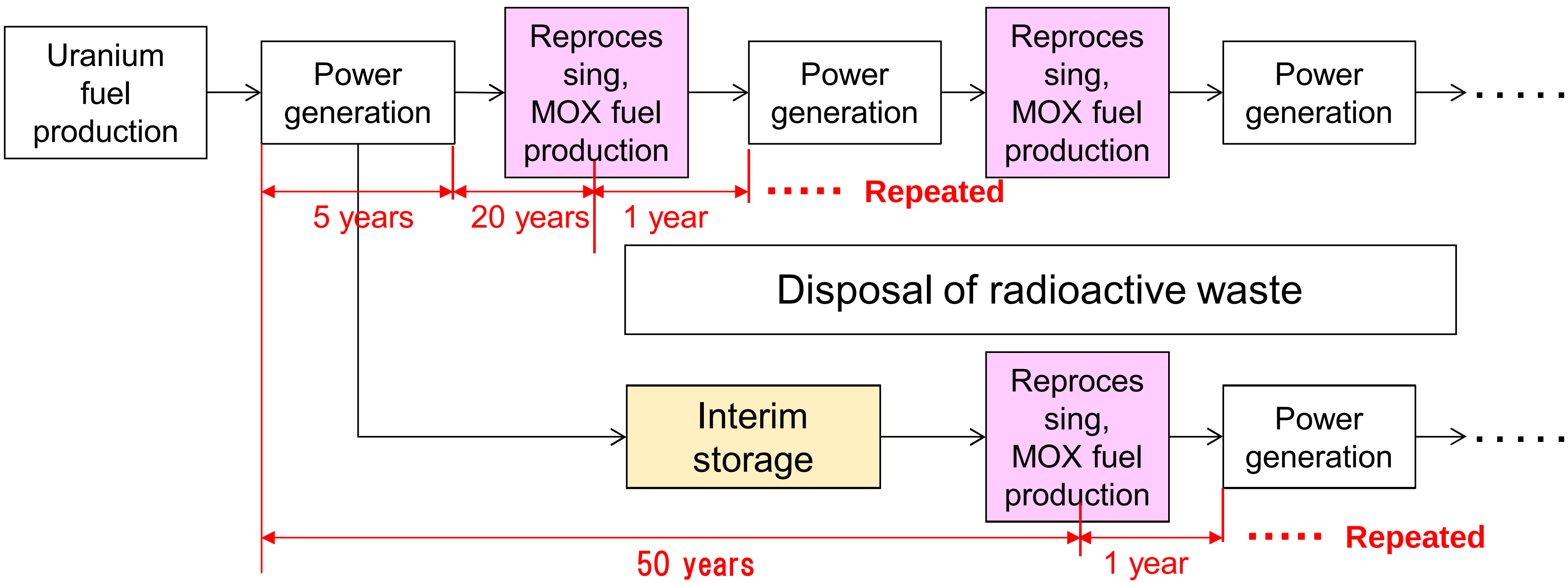
- All spent fuel is directly disposed after interim storage.



Estimation Model (reference)

Latest Model

- Part of spent fuel is reprocessed and recycled, and the remaining fuel is reprocessed after interim storage.



Front-end

- Recent spot prices of uranium concentrate (yellow cake: U_3O_8) have fluctuated significantly. Although the past market price were stable around $10/lb., recent price has increased to as high as $130 temporarily and it is fluctuating between $40 and $60/lb$U_3O_8$ during 2008 to 2010.
- As for exchange rates, the yen has strengthened significantly: although the rate in August 2004 was around 110 yen/dollar, an average rate is around 86 yen/dollar in 2010.

Back-end

- A fund system for reprocessing, etc. was established. (refer to p.12)
  - The costs concerning reprocessing, including decommissioning costs and TRU waste disposal costs, have been reserved from 2005. The fund is collected from electricity charges.
- Test operation using spent fuel (active tests) started at the Rokkasho Reprocessing Plant in March 2006.
  - The tests became stagnant in the vitrification process of high level radioactive waste, and the completion was postponed to October 2012.
- Four NPP started to use MOX fuel.
- Construction of the Rokkasho MOX Fuel Fabrication Plant started in October 2010.
  - The construction is expected to be completed in March 2016.
- Construction of the first spent fuel interim storage facilities in Japan started at Mutsu City of Aomori Prefecture in August 2010.
  - The construction is expected to be completed in July 2012.

Development of System and Provision for Spent Fuel Reprocessing Fund

- The Spent Nuclear Fuel Reprocessing Fund Act was enforced in 2005 (for the Rokkasho Reprocessing Plant)
  - Costs of reprocessing at the Rokkasho Reprocessing Plant are reserved for future use.
  - The yearly assignments of reprocessing costs and relevant spent fuel generated are simultaneously converted when the spent fuel is generated, using the discount rate to find the levelized cost for unit weight.
- The report of the Investment Environment Improvement Subcommittee (2007) of the Electricity Industry Committee indicated a decision to include the costs of reprocessing the spent fuel other than that reprocessed at the Rokkasho Reprocessing Plant in the reserve.

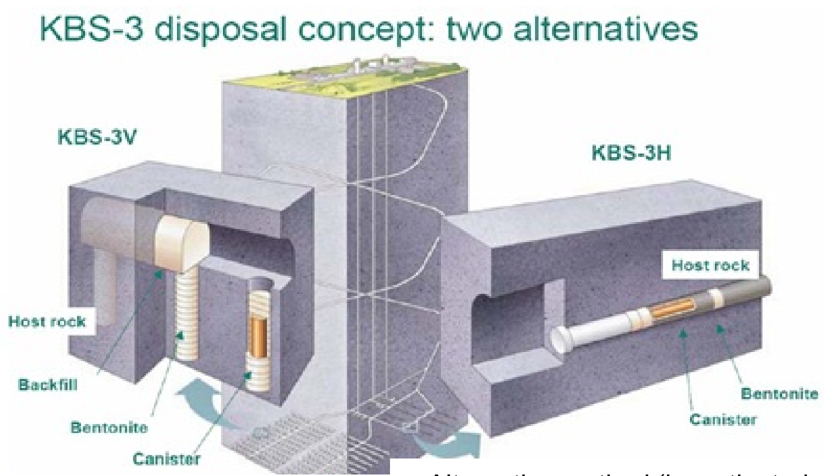
Direct Disposal

[Basic concept]

- Basic Technologies for the geologic disposal of vitrified radwastes can be used as the direct disposal.
- Existing data and precedent technological developments in overseas operations (in Sweden, Finland, and elsewhere) are investigated.

[Issues potentially containing uncertainty of feasibilities and costs]

1. Behavior and effects of radiaolysis and development of redox front
   ⇒Effects are not significant when processing environment and the existence of canisters (iron) are taken into account.
2. Evaluation of effects of waste heat on processing system design
   ⇒There is not a significant difference in the areas of disposal system (m2/tU) discussed in the Technology Subcommittee at the previous meeting for determining the framework, and those in Sweden and Finland.
3. Waste emplacement method and geological repository design technique
   ⇒**While there is potentially a large reduction in the cross section area of tunnels**, it is almost within the reference width for horizontal positioning discussed in the Technical Subcommittee at the previous New Nuclear Policy-Planning Council.
4. Prevention and evaluation of criticality
   ⇒The consideration of burnup credit and FP concentration are important.
5. Evaluation and setting of heat ing and nuclide concentration of fuel assembly
   ⇒LWR and LWR-MOX analysis instances were examined.



Basic method (under demonstration)

Alternative method (investigated as an option to reduce the amount of drilling)

Data used the 4th New Nuclear Policy-Planning Council

About Costs of Individual Operations by Processes

- Evaluating the costs of individual operations (the cost per ton of uranium fuel) is required for estimating the future costs in front-end and back-end.

Front-end	Uranium fuel	Latest procurement by utilities
	MOX fuel	The latest moves of construction costs are considered for the estimate used at the Cost Subcommittee 2004.
Back-end	Reprocessing	Estimated based on the reprocessing costs estimated by the Government (METI) according to the law and the latest notices from utilities and Japan Nuclear Fuel Ltd.
	Disposal of high-level radioactive waste	Estimated based on the latest disposal costs estimated by the Government (METI) according to the law.
	Interim storage	The latest construction costs of the estimates used at the Cost Subcommittee 2004 are considered.
	Direct disposal	The latest technological insights are considered , based on the estimates at the previous Technology Subcommittee.

Costs of Individual Operations by Processes

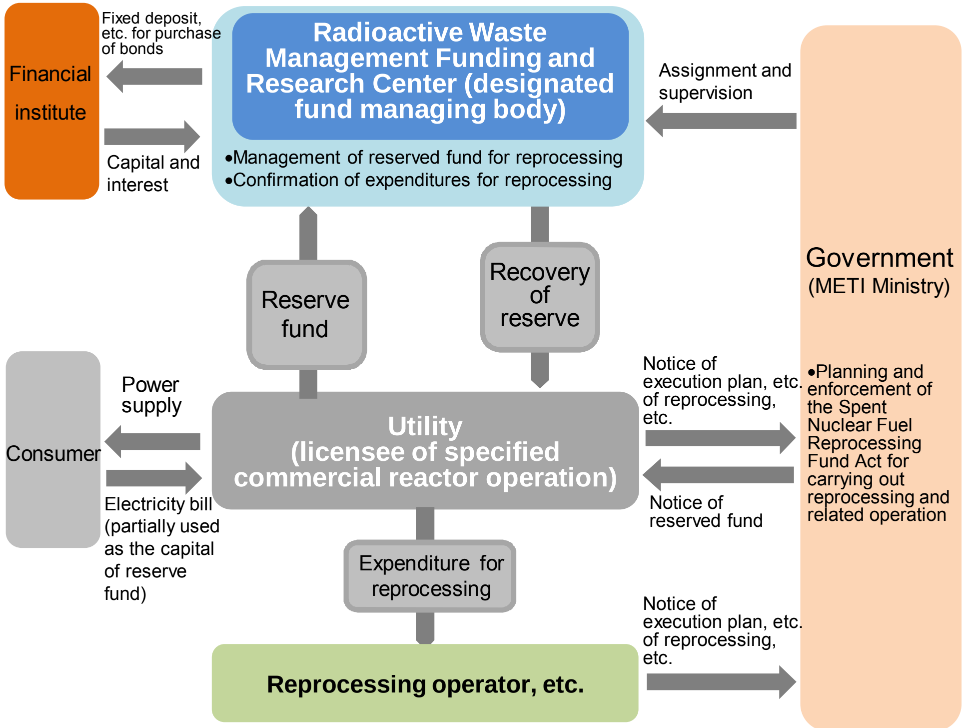
- The estimated total cost of reprocessing is around 12.6 trillion yen at the Cost Subcommittee 2004 based on the reasonable estimates of the operation and maintenance of the Rokkasho Reprocessing Plant.
- After that, the reprocessing fund system (p.16) was started. The total operation cost is estimated every fiscal year by the Government (METI) according to the law and based on the notices from utilities and Japan Nuclear Fuel Ltd. The effects of postponed completion of construction of the Rokkasho Reprocessing Plant, etc. are considered.
- The reprocessing costs used for the current estimation are, therefore, estimated based on the total operation costs (p.17) estimated based on the latest notices from utilities.
  - Sensitivity analysis will be conducted as needed in case of difficulties in rational estimation.

Costs of individual operations by processes (reprocessing)

Reprocessing Fund Scheme

- The reprocessing of nuclear fuel, which forms the basis of nuclear fuel cycle, requires a significantly long period and massive amounts of money, and ensuring the safety and transparency is essential for securing the necessary funds. For this reason, utilities deposit the money required for reprocessing according to the law*.
- The amount of reserved funds is estimated by the government, based on the notifications submitted from the utilities.

* Law: Act concerning Funding and Management of Reserve Fund for Reprocessing of Spent Fuel in Nuclear Generation (2005 law No. 48)



Basic scheme of reserve fun for reprocessing

Reservation of fund for reprocessing, etc.

(unit: 100 millionyen)

	2005	2006	2007	2008	2009	2010
Estimated sum	126,850	126,873	127,038	118,958	121,308	122,516
Balance	10,384	12,479	15,682	18,389	21,443	24,416

* Estimated sum in 2011: 12,223,700 million yen (Estimated based on notices from utilities in March 2011)
* The estimated sum is calculated according to the law.

- **The estimated sum is the costs for reprocessing of spent fuel (32,000 tU) at the Rokkasho Reprocessing Plant.**

Source: Data created by the Cabinet Office from data presented by the Natural Resources and Energy Agency

Costs of Individual Operations by Processes (reprocessing)

Total Cost of Reprocessing, etc. (1)

		Latest notice	Cost Subcom.
Reprocessing project	Period	2005 to 2052	2005 to 2046
	Total amount	Approx. 32kt	Approx. 32kt

- Reprocessing costs are calculated by selecting the relevant figures from this table.

Unit: 10 billion yen		Latest notice	Cost Subcom.	Difference	Basic calculation process	Major changes presented by Cost, etc. Subcom.
Rokkasho Reprocessing Plant	Operation	927	905	22	Investments (e.g. construction), operation and maintenance costs, and other expenditures based on latest business plan of Japan Nuclear Fuel Ltd.	• Increase in cost due to prolonged period of reprocessing by 6 years • Decrease in paid interest due to capital increase • Decrease in paid interest due to tax revision (front-load depreciation)
	Disposal	154	155	▲1	Changes (e.g. price fluctuation) based on unit costs and quantities at Cost Subcom.	• Decline of resource related indexes
Returned high-level radioactive waste management	Storage	29	27	2	Investments (e.g. construction), operation and maintenance costs, and other expenditures based on latest business plan of Japan Nuclear Fuel Ltd.	• Increase in cost due to prolonged storage period by 2 years
	Disposal	1	1	0	Changes (e.g. price fluctuation) based on unit costs and quantities at Cost Subcom.	• Decline of resource related indexes
Returned low-level radioactive waste management	Storage	18	35	▲16	Investments (e.g. construction), operation and maintenance costs, and other expenditures at Cost Subcom	• Decrease in low-level waste with acceptance of alternative
	Disposal	1	4	▲3	Changes (e.g. price fluctuation) based on unit costs and quantities at Cost Subcom.	• Decline of resource related indexes • Decrease in stored waste with acceptance of alternative
Transport of waste to disposal site	High-level	10	9	1	-ditto-	• Increase in high-level waste with acceptance of alternative • Increase in transport related indexes
	Low-level	21	22	▲1	-ditto-	• Increase in low-level waste with acceptance of alternative • Increase in transport related indexes
Disposal of waste	High-level	0.3	———	0.3	Contributed unit cost based on Final Disposal Act x Q'ty of alternative high-level waste	• Addition of items with acceptance of alternative
	Low-level [geological Disposal]	37	78	▲41	Unit price of contribution based on the Final Disposal Act x Q'ty of waste for geological disposal based on Final Disposal Act	• Decrease in quantity due to revised Final Disposal Act and application of unit price to contribution in accordance with this act
	Low-level	23	23	0	Changes (e.g. price fluctuation) based on unit costs and quantities at Cost Subcom.	• Increase in quantity due to revised Final Disposal Act • Decrease in low-level waste with acceptance of alternative
Total		1,222	1,259	▲37		

Source: Data created by the Cabinet Office from data presented by the Natural Resources and Energy Agency

Total Cost of Reprocessing, etc. (2)

Of the latest reported amount of 12.22 trillion yen, 11.68 trillion yen is used as the cost for domestic reprocessing.

Excerpt from data at the 1st Technical Subcommittee on Nuclear Power, Nuclear Fuel Cycle, etc.

Unit: 10 billion yen		Latest notice		Cost of domestic reprocessing	Other (Returned waste costs)	Remark
Rokkasho Reprocessing Plant	Operation	927	Investments (e.g. construction), operation and maintenance costs, and other expenditures based on latest business plan of Japan Nuclear Fuel Ltd.	**927**	―――	Costs at Rokkasho Reprocessing Plant **⇒All costs for domestic reprocessing**
	Decommissioning	154	Changes (e.g. price fluctuation) based on unit costs and quantities at Cost Subcom.	**154**	―――	
Returned high-level radioactive waste management	Storage	29	Investments (e.g. construction), operation and maintenance costs, and other expenditures based on latest business plan of Japan Nuclear Fuel Ltd.	―――	29	Costs for domestic management of waste returned from overseas reprocessing contractors **⇒All returned waste related costs**
	Decommissioning	1	Changes (e.g. price fluctuation) based on unit costs and quantities at Cost Subcom.	―――	1	
Returned low-level radioactive waste management	Storage	18	Changes (e.g. price fluctuation) based on unit costs and quantities at Cost Subcom.	―――	18	
	Decommissioning	1	Changes (e.g. price fluctuation) based on unit costs and quantities at Cost Subcom.	―――	1	
Transport of waste to disposal site	High-level waste	10	-ditto-	**9.7**	0.6	Sum of transport costs for waste resulting from reprocessing at the Rokkasho plant and that for waste returned from oversea reprocessing contractors **⇒"Unit cost x Quantity of waste from domestic reprocessing" is the domestic reprocessing related costs.**
	Low-level waste	21	-ditto	**20.0**	0.5	
Disposal of waste	High-level waste	0.3	Unit price of contribution based on Final Disposal Act x Q'ty of alternative high-level waste	―――	0.3	Costs for domestic disposal of alternative waste returned from overseas reprocessing contractors **⇒All returned waste related costs**
	Low-level waste [classified to Geological disposal]	37	Unit price of contribution based on Final Disposal Act x Q'ty of waste for geological disposal based on Final Disposal Act	**34**	2	Sum of transport cost for waste resulting from reprocessing at Rokkasho plant and that for waste returned from oversea reprocessing contractors **⇒"Unit cost x Quantity of waste from domestic reprocessing" is the domestic reprocessing related costs.**
	Low-level waste [Other]	23	Changes (e.g. price fluctuation) based on unit costs and quantities at Cost Subcom.	**23**	―――	All costs for disposal of waste resulting from Reprocessing at the Rokkasho plant. **⇒"Unit cost x Quantity of waste from domestic reprocessing" is the domestic reprocessing related costs.**
Total		1,222		**1,168**	54	

Source: Data created by the Cabinet Office from data presented by the Natural Resources and Energy Agency

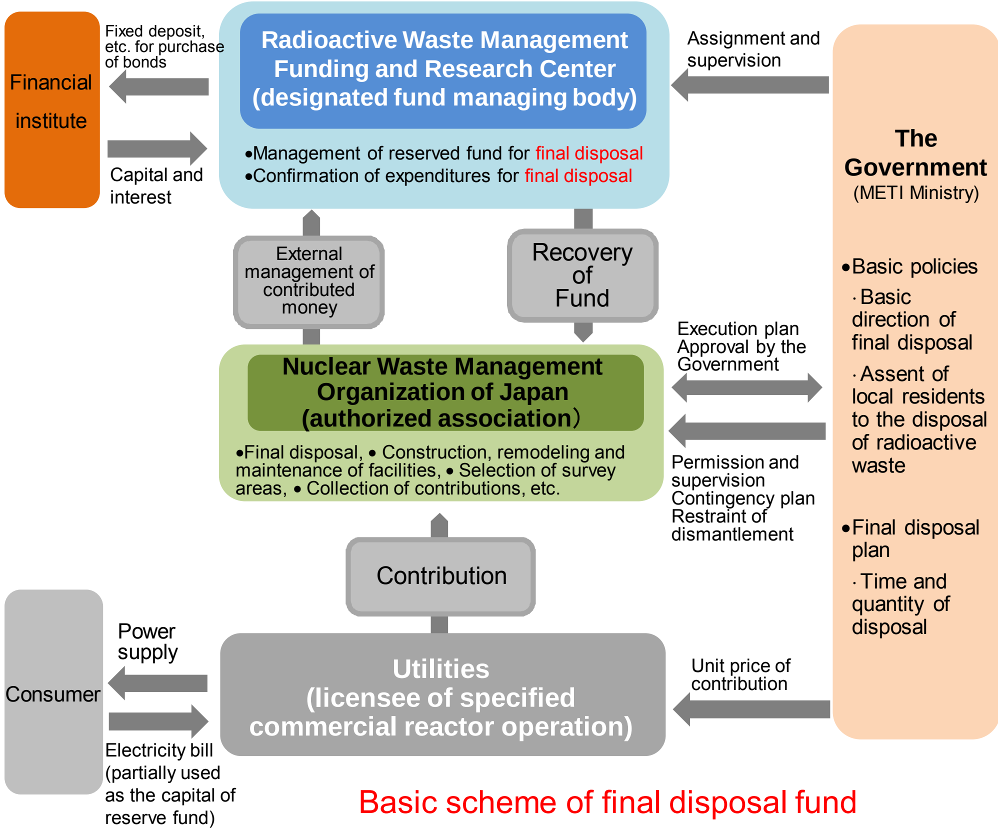
Costs of Individual Operations by Processes

- In the waste disposal operation (vitrification of waste), the costs for geological disposal of 40,000 bodies of vitrified radwaste were confirmed to be around 2.9 trillion yen at the Nuclear Energy Group of the Advisory Committee on Energy and Natural Resources in September 2000, based on the standard processes and technical conditions clarified by the R&D results of the Japan Atomic Energy Agency (former Japan Nuclear Cycle Development Institute) and the investigation of operational concepts by the Atomic Energy Commission.
- After that, the Contribution Scheme for Final Disposal Fund (P.20) was started, and the government (METI) estimates the total operation costs based on the latest standard of personnel expenditure, etc. every year according to the law.
- For this reason, the calculation of the waste disposal costs, used for the present estimation, should be based on the most recent total operation costs (p.21).
  - Sensitivity analysis will be conducted as needed in case of difficulties in rational estimation.

Contribution Scheme for Final Disposal Fund

- Considering the importance of a systematic accumulation of funds for the final disposal of vitrified radwastes, the Radioactive Waste Management Funding and Research Center was designated as the fund managing body in 2000 according to the related law, and manages a fund with contributions from the Nuclear Waste Management Organization of Japan (NUMO).
- The government reviews the unit price of contribution required for the reserve every year.

  * Law: Designated Radioactive Waste *Final Disposal Act*, Act No. 117 of 2000



Basic scheme of final disposal fund

Reservation of final disposal fund

(Unit: 100 million yen)

	2000	2001	2002	2003	2004	2005
Estimated sum	29,305	28,911	28,819	28,297	27,843	27,652
Balance	0	1,020	1,705	2,372	2,940	3,566

(Unit: 100 million yen)

	2006	2007	2008	2009	2010
Estimated sum	27,728	27,879	27,582	27,922	27,769
Balance	4,241	4,999	5,763	6,498	7,394

* Estimated sum in 2011: 2,718,300 million yen

* The estimated sum is calculated according to the accumulation method ensured at the Nuclear Energy Group of the Advisory Committee for Energy.

- The estimated sum is the costs required for the geological disposal of 40,000 bodies of vitrified radwaste by NUMO.

Source: Data created by the Cabinet Office from data presented by the Natural Resources and Energy Agency

Costs of Individual Operations by Processes (disposal of high-level radioactive waste)

Waste Disposal Costs (Vitrification)

Unit: 100 million yen

Cost	2011			2000			Mean diffe'ce	Major change from 2000	Principle of estimation
	Soft rock	Hard rock	Mean	Soft rock	Hard rock	Mean			
Technology R&D	1,031	1,031	1,031	1,118	1,118	1,118	▲ 87	Decrease in unit personnel costs	<Accumulation method> • Accumulation of direct costs of personnel, materials, machinery, etc. and indirect costs of on-site management and general management, etc. • Costs and methods used for general civil work, geological survey and general public work are used for the accumulation method, and the estimation of personnel and material costs. <Estimation case setting> • Because of the dependency of final disposal costs on the rock types and depth settings, a case of 500m for soft rock system, and a case of 1,000m for hard rock system (crystalline rock) are estimated and their average is used. <Scale of facilities> • Facilities that can accommodate 40,000 bodies of vitrified radwaste. <No. of sites in cost estimation stages > • Together with TRU waste, costs are estimated given 10 areas for literature search, 5 areas for general survey, 2 areas for detailed survey and 2 areas as the site of final disposal facilities. <Disposal schedule> • 2000 The executing body was selected. • 2036 Operation is commenced. • 2086 Teardown and closure of the facilities begin. • 2096 The disposal tunnels are closed. • Afterwards, the site will be monitored for 300 years.
Survey and land Purchase	1,591	1,782	1,687	2,252	2,501	2,376	▲ 689	Decrease in unit personnel costs; decrease due to proportional changes with introduction of TRU; decrease in land price	
Design and construction	9,750	8,110	8,930	10,476	8,725	9,600	▲ 670	Decrease in personnel costs; fall of installation related indexes	
Operation	7,041	7,674	7,358	6,805	7,736	7,271	87	Increase in material related indexes	
Teardown and closure	861	909	885	801	884	842	43	Increase in material related indexes	
Monitoring	1,187	1,187	1,187	1,236	1,236	1,236	▲ 49	Fall of installation related indexes	
Project management	5,407	4,722	5,065	6,132	5,396	5,764	▲ 699	Decrease in unit personnel costs; decrease due to proportional changes with introduction of TRU; decrease in property tax	
Consumption tax	1,055	1,020	1,037	1,107	1,087	1,097	▲ 60		
Total	27,927	26,438	27,183	29,927	28,683	29,305	▲ 2,122		

Source: Data created by the Cabinet Office from data presented by the Natural Resources and Energy Agency

Cost Estimation Case

- The model plant used in this estimation is a case of constructing a repository site with the emplacement in vertical position, which is a prevailing method of overseas final disposal operations.

Rock type	Estimation case in 2004 [1]	Emplacement method	No. of stored bodies	No. of sites	Total cost in previous estimation (trillion yen)	Current estimation
Soft rock	1	Vertical	2	1	7.80	○
	2		4	1	6.03	○
	3		2	2	9.46	
	Additional review 1	Horizontal	2	1	4.09	
	Additional review 2		4	1	3.84	
Hard rock	1	Vertical	2	1	5.33	○
	2		2	2	7.34	
	Additional review 2	Horizontal	2	1	4.54	

* The emplacement four-piece canisters in vertical position in the hard rock geology is excluded from the review because it does not meet the heat limit.

[1] AEC Technical Subcommittee of the New Nuclear Policy-Planning Council (2004)
http://www.aec.go.jp/jicst/NC/tyoki/tyoki_gijyutu.htm

Cost Review Points

- Costs are directly reviewed by applying the latest insight to the following points based on the investigation at the Technical Subcommittee [1] in 2004.

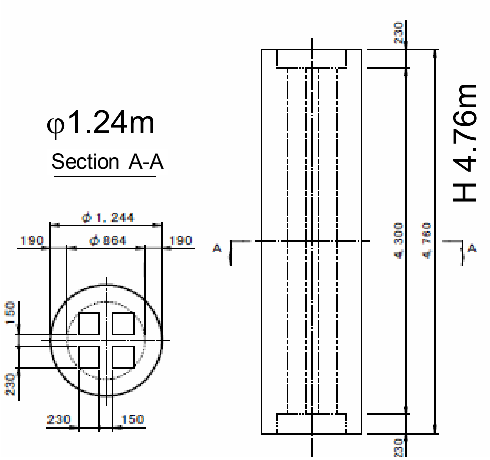
1. Review of disposal tunnel specification
   The disposal tunnel specification is reviewed based on the latest investigation of the spent fuel emplacement method (spent fuel is conveyed in horizontal position) in Finland and Sweden, the countries which have a lead in the direct disposal [vertical arrangement only, and no change in horizontal arrangement] (a reduction in the sectional area of disposal tunnels with the reduction in diameters, etc.).
2. The settings in the above 2004 report are used for cost estimation except the use of the latest open construction costs.
3. No change is made for other preconditions set in 2004.

[1] AEC Technical Subcommittee of the New Nuclear Policy-Planning Council (2004)
http://www.aec.go.jp/jicst/NC/tyoki/tyoki_gijyutu.htm

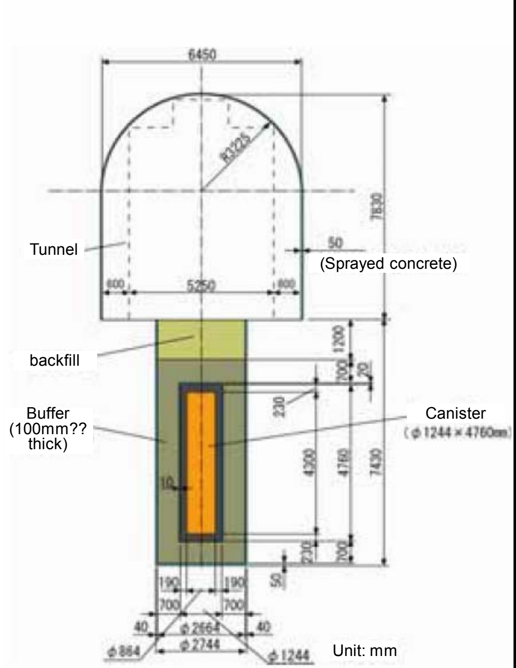
Review of Disposal Tunnel Specification (1)

- Examined instance of direct disposal in Japan (hard rock)

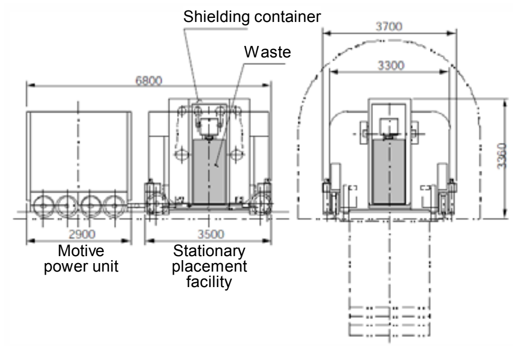
Canister (for 4 bodies)	Tunnel/hole specification	Emplacement method
Thickness: 190 mm (Lid: 230 mm) Material: Carbon steel	Tunnel: 7.8mH, 6.5mW Hole: 2.70m dia, 7.40mH	Conveyance and emplacement in vertical position (same as the vitrified bodies)



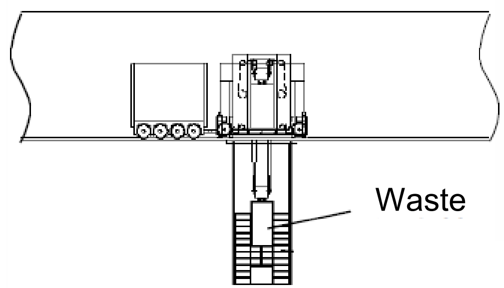
(Atomic Energy Commission, 2004)



(Atomic Energy Commission, 2004)



(Japan Nuclear Cycle Development Institute, 1999)

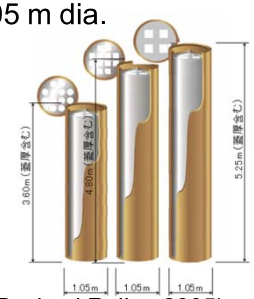
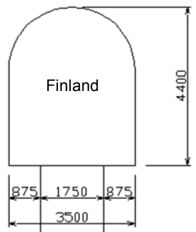
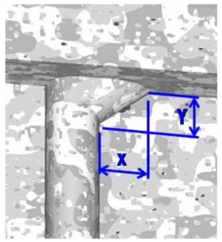
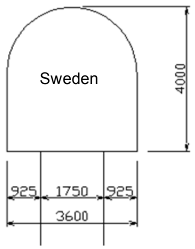
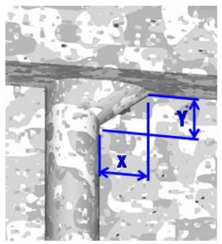
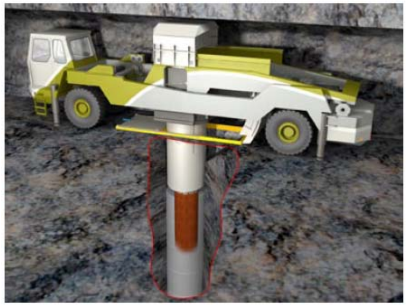


(Japan Nuclear Cycle Development Institute, 1999)

Costs of Individual Operations by Processes (direct disposal)

Review of Disposal Tunnel Specification (2) Overseas Instances

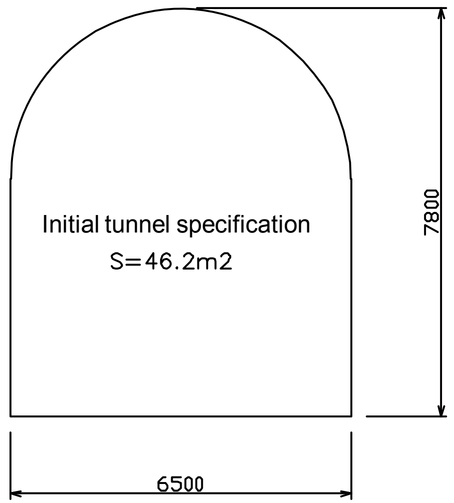
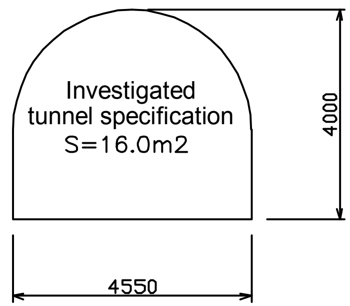
【November 2008 Atomic Energy Commission, Policy Evaluation Group】

Type	Canister	Tunnel/hole specification	Conveyance/emplacement method
Finland (hard rock)	50 mm Thick (Side: 48 mm). Outer: Copper, Inner: Cast iron 1.05 m dia.  5.25 mH (Revised Raiko, 2005)	Tunnel: 4.4 mH, 3.5 mW Hole: 1.75 m dia., 8.25 mH Slope: X1.0 m, Y1.0 m   	Conveyance in horizontal position and emplacement in vertical position  (Saanio et. al., 2007)
Sweden (hard rock)	 50 mm thick Outer: Copper Inner: Cast iron (Andersson , 2002)	Tunnel: 4.0 mH, 3.6 mW Hole: 1.75 m dia., 7.83 mH Slope: X1.6 m, Y1.2 m   	Conveyance in horizontal position and emplacement in vertical position  (SKB, 2007)

Review of Disposal Tunnel Specification (3)

【AEC Policy Evaluation Group, November 2008 】

- After investigating emplacement methods (spend fuel is conveyed in horizontal position) used in Finland (POSIVA) and Sweden (SKB), the specification with a reduced section area of tunnels in hard lock systems by about 65% of the previous estimation was employed.

Specification by Atomic Energy Commission (2004)	Present specification
H=7.8m, W=6.5m, S=46.2m^2 	H=4.0m, W=4.6m, S=16.0m^2 ⇒ Approx. 65% reduction in cross section of tunnel  (The width was reduced according to Sweden spec. for improving workability.)

Presumed Schedule of Operation

- Same as the previous Technology Subcommittee is assumed.

Period	Schedule
First year	Selection of the executing body
- 9th year (10 years)	Selection of potential sites
10th - 24th year (15 years)	Survey of potential sites and demonstration of disposal technologies
25th - 84th year (60 years)	Construction and Operation - Start of construction: 25th year - Start of operation: 35th year (spent fuel acceptance period: 40 years) - End of operation: 84th year
85th - 94th year (10 years)	Dismantling of facilities and closure of site
95th - 394th year (300 years)	Post-closure site management

Costs of Individual Operations by Processes

Unit Cost of Individual Operations

Discount rate		0%	1%	3%	5%
Uranium fuel	(10,000 yen/tU)	25,900	26,200	27,100	28,200
MOX fuel	(10,000 yen/tHM)	40,600	40,700	41,500	42,700
Reprocessing, etc.	(10,000 yen/tU)	37,200	37,800	41,100	46,400
Spent fuel transportation (NPP→ Reprocessing)	(10,000 yen/tU)	1,700	1,700	1,700	1,700
Spent fuel transportation （NPP → Interim storage)	(10,000 yen/tU)	1,600	1,600	1,600	1,600
Interim storage	(10,000 yen/tU)	3,600	4,000	5,200	6,900
Disposal of high-level radioactive waste	(10,000 yen/tU)	8,500	8,700	11,000	15,700
Spent fuel transportation (Interim storage → Direct disposal site)	(10,000 yen/tU)	1,600	1,600	1,600	1,600
Direct disposal (min value)	(10,000 yen/tU)	13,200	13,700	17,400	24,900
Direct disposal (max value)	(10,000 yen/tU)	15,700	16,300	20,100	27,600

Source: Data created by the Cabinet Office from data presented by utilities, Japan Atomic Energy Agency and Natural Resources and Energy Agency

Costs of Individual Operations by Processes

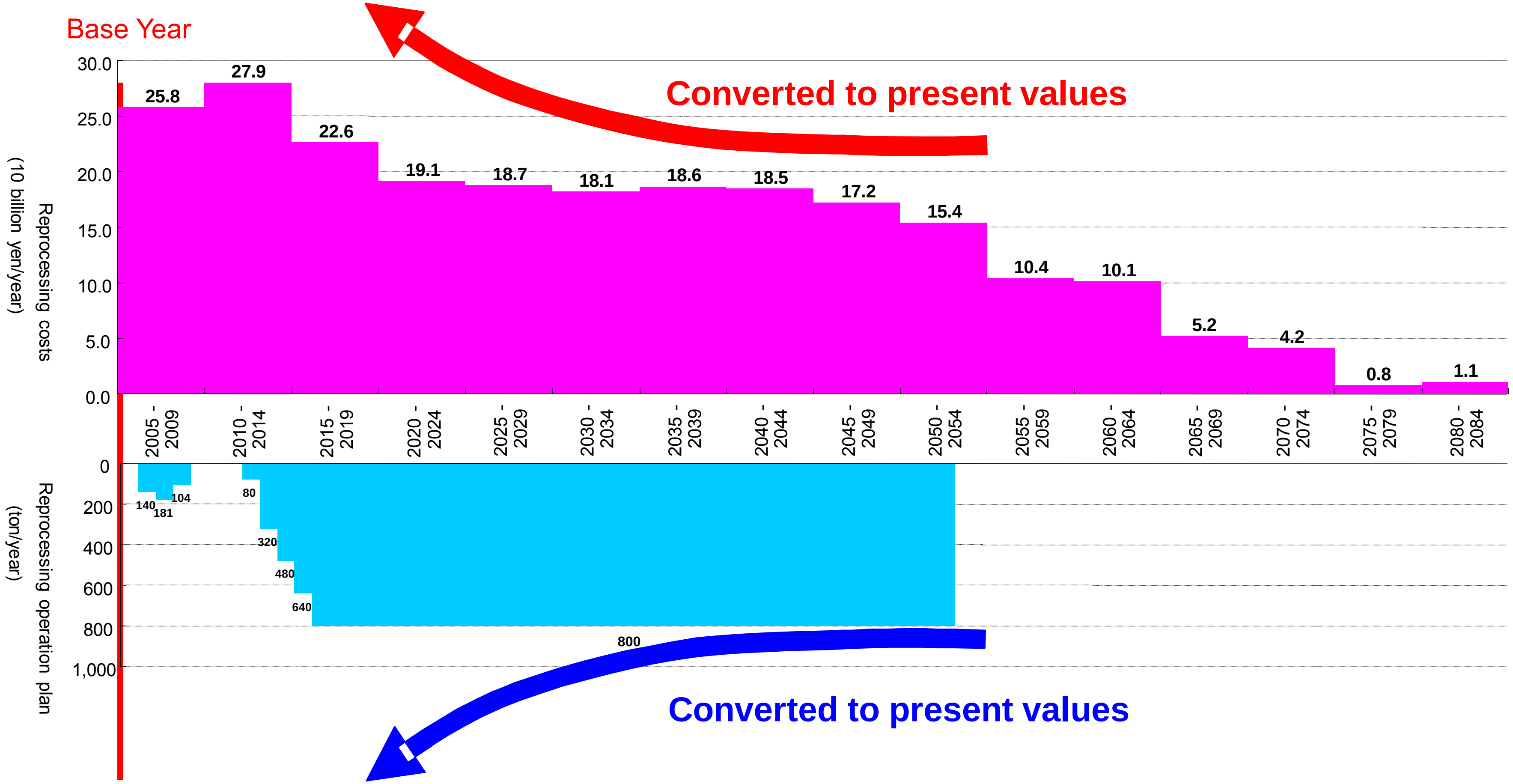
Comparison of Previous and Present Cost Sorting

Category of cost in the present estimation	Category of cost in the previous estimation	Reference data in the present estimation
Uranium fuel	-	Latest procurement results of utilities (2008 to 2010)
MOX fuel	MOX fuel fabrication	Increase in the total operation costs from the estimation used at Cost Subcommittee in 2004 (increase from 120 billion to 190 billion yen) in line with the latest trends of construction costs.
Reprocessing, etc.	Reprocessing HLW storage HLW transportation TRU waste disposal / storage TRU disposal Reprocessing plant decommissioning measures	Estimated was based on the costs of reprocessing, etc. estimated by the Government (METI) according to the law and in line with the latest notices from utilities and Japan Nuclear Fuel Ltd. The costs of emergency safety measures reported by Japan Nuclear Fuel Ltd. were also included. Compared with assumptions by the Cost Subcommittee, cost sorting presented by utilities and Japan Nuclear Fuel Ltd. differs from the previous one due to difference in the classification of actual facilities, and to the emphasis of Japan Nuclear Fuel Ltd. on the total cost management in order to promote efficiency, dissolve accumulated losses, and gain profits as a private company.
Spent fuel transportation (NPP→ Reprocessing)	SF transportation to reprocessing plant	The latest quantity of transportation and contract rates was reflected on the estimation used at the Cost Subcommittee in 2004.
Spent fuel transportation (NPP→ Interim storage)	SF transportation to int. storage site	The latest quantity of transportation and contract rates were reflected on the estimation used at the Cost Subcommittee in 2004.
Interim storage	Interim storage	The latest trends of construction costs (Mutsu, decrease from 130 billion to 100 billion yen) was reflected on the estimation used at the Cost Subcommittee in 2004.
Disposal of HL radwaste	HLW disposal	Estimation was made in line with the latest disposal costs estimated by the government (METI) according to the law.
Spent fuel transportation (Interim storage → Direct disposal site)	-	Transportation costs to the interim storage site were applied.
Direct disposal	-	The latest perspectives and integrated value were reflected on the estimation in the Technical Subcommittee[1] in 2004.

[1] AEC Technical Subcommittee of the New Nuclear Policy-Planning Council (2004)
http://www.aec.go.jp/jicst/NC/tyoki/tyoki_gijyutu.htm

Costs of Individual Operations by Processes

Cost Estimates (Reprocessing, etc.)



Cost per ton = Reprocessing cost [converted to base year's value] / Reprocessing Amount [converted to base year's value]

Nuclear Fuel Cycle Cost

Costs for Various Models (1) - Discount rate: 0% and 1% -

(yen/kWh)

Item	Discount rate: 0%			Discount rate: 1%		
	Reprocessing model	Direct disposal model	Latest model	Reprocessing model	Direct disposal model	Latest model
Uranium fuel	0.62	0.72	0.62	0.65	0.75	0.68
MOX fuel	0.17	-	0.17	0.16	-	0.12
(Front-end total)	0.79	0.72	0.79	0.82	0.75	0.80
Reprocessing, etc.	1.10	-	1.10	1.06	-	0.79
Interim storage	-	0.14	0.07	-	0.12	0.06
HLW disposal	0.24	-	0.24	0.16	-	0.12
Direct disposal	-	0.41 - 0.48	-	-	0.24 -0.28	-
(Back-end total)	1.34	0.56 -0.63	1.41	1.21	0.37 - 0.41	0.98
Total	2.14	1.28 - 1.35	2.21	2.03	1.11 - 1.15	1.78

Note) The total may not correspond to the sum of all the items due to rounding. (Electricity generation at sending end)

Costs for Various Models (2) - Discount rate: 3% and 5% -

(yen/kWh)

Item	Discount rate: 3%			Discount rate: 5%		
	Reprocessing model	Direct disposal model	Latest model	Reprocessing model	Direct disposal model	Latest model
Uranium fuel	0.73	0.81	0.77	0.81	0.88	0.86
MOX fuel	0.15	-	0.07	0.14	-	0.04
(Front-end total)	0.88	0.81	0.84	0.94	0.88	0.90
Reprocessing, etc.	1.03	-	0.46	1.04	-	0.30
Interim storage	-	0.09	0.05	-	0.07	0.04
HLW disposal	0.08	-	0.04	0.05	-	0.01
Direct disposal	-	0.10 - 0.11	-	-	0.05 - 0.05	-
(Back-end total)	1.11	0.19 - 0.21	0.55	1.08	0.12 - 0.12	0.36
Total	1.98	1.00 - 1.02	1.39	2.03	1.00 - 1.01	1.26

Note) The total may not correspond to the sum of all the items due to rounding. (Electricity generation at sending end)

Comparison with Previous Estimation (1)

- Discount rate: 3% -

Discount rate: 3% (yen/kWh)

Item	Reprocessing model	Latest model		Direct disposal model	
		Present	Cost Subcom. in 2004	Present	Tech, Subcom. in 2004
Uranium fuel	0.73	0.77	0.59	0.81	0.64
MOX fuel	0.15	0.07	0.07	-	-
(Front-end total)	0.88	0.84	0.66	0.81	0.64
Reprocessing, etc.	1.03	0.46	0.65	-	-
Interim storage	-	0.05	0.04	0.09	0.12
HLW disposal	0.08	0.04	0.12	-	-
Direct disposal	-	-	-	0.10 - 0.11	0.12 - 0.21
(Back-end total)	1.11	0.55	0.81	0.19 - 0.21	0.24 - 0.33
Total	1.98	1.39	1.47	1.00 - 1.02	0.9 - 1.0

Note 1) The total may not correspond to the sum of all the items due to rounding.
Note 2) The unit of contribution (2% discount rate) was uniformly applied to the HLW disposal in the estimation in 2004, while costs were estimated at different discount rates in this estimation.

Comparison with Previous Estimation (2)

- Discount rate: 0% -

Discount rate: 3%

(yen/kWh)

Item	Reprocessing model	Latest model		Direct disposal model	
		Present	Cost Subcom. in 2004	Present	Tech, Subcom. in 2004
Uranium fuel	0.62	0.62	0.49	0.72	0.57
MOX fuel	0.17	0.17	0.11	-	-
(Front-end total)	0.79	0.79	0.60	0.72	0.57
Reprocessing, etc.	1.10	1.10	1.05	-	-
Interim storage	-	0.07	0.06	0.14	0.18
HLW disposal	0.24	0.24	0.12	-	-
Direct disposal	-	-	-	0.41 - 0.48	0.51 - 0.87
(Back-end total)	1.34	1.41	1.23	0.56 - 0.63	0.69 - 1.05
Total	2.14	2.21	1.83	1.28 - 1.35	1.26 - 1.62

Note 1) The total may be inconsistent owing to round-off of individual values.
Note 2) The unit of contribution (2% discount rate) was uniformly applied to the HLW disposal in the estimation in 2004, but costs were estimated at different discount rates in this estimation.
Note 3) The direct model at 0% discount rate was omitted from estimation in 2004, but estimated this time for comparison using the method used in 2004.

Results of Estimation

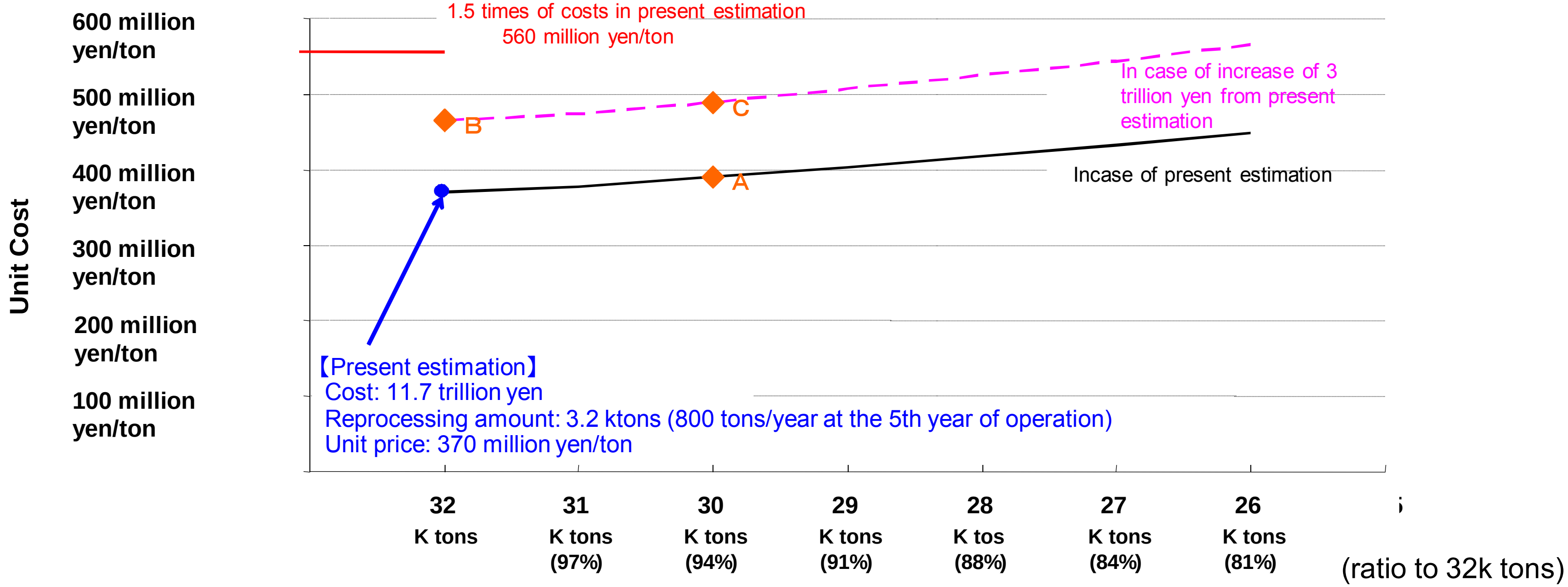
- Front-end
  - In addition to yen appreciation in the exchange rate, substantial increases in the uranium concentrate price affect the costs of the direct disposal model.
  - The proportion of MOX fuel loaded in reactors is small and the effects of MOX fuel cost in the front-end costs are insignificant.
- Reprocessing, etc.
  - The difference between the costs of the reprocessing and direct disposal models is about 1 yen/kWh (at 3% discount rate), and this is caused by the presence of reprocessing etc.
  - When the nuclear fuel recycle is included, the difference between the costs of the reprocessing and latest models is about 0.6 yen/kWh (at 3% discount rate), and this is caused by the length of storage period.

A comprehensive evaluation of various nuclear fuel recycle options will be continued, including the perspectives other than economical efficiency.

Sensitivity Analysis (1) Reprocessing & MOX Cost

- The reprocessing, etc. and MOX fuel cost are subject to sensitivity analysis using a sensitivity of 1.5 times of unit cost (sensitivity analysis case) for the latest model (basic case).
- 【Reprocessing, etc.】
  - Complete denial is hard for a potential decrease in the reprocessing amount (reduced operating rate) due to the delayed achievement of the rated reprocessing quantity (800tU/year), and a potential increase in the cost of construction for the planned expansion of facilities in the future, and a possibility of additional investments for maintaining the operating rate.
- 【MOX fuel】
  - Construction cost have increased from 120 billion to 190 billion yen owing mainly to 1) increases in the price of construction materials and 2) requirement of antiseismic installation. Complete denial is hard for a potential increase in the construction cost due to the same reasons until the time the construction is completed in March 2016.

Reasons of Setting 1.5 times in Sensitivity Analysis



		Present	A	B	C
Total Cost		11.7 trillion yen	Same as present	Present estimate + 3 trillion yen	Present estimate + 3 trillion yen
Reprocessing plan	800 tons/yr	5th yr of operation	10th yr (5 yr delay)	5th yr (same as present)	10th yr (5 yr delay)
	Reprocessing q'ty	32k tons	30k tons	32k tons	30k tons
Unit Cost		370 million yen/ton	390 million yen/ton (5% increase)	460 million yen/ton (25% increase)	490 million yen/ton (30% increase)

3 trillion yen increase: Corresponds to cost increase equal to the construction cost of 3.3 trillion yen including the future investment amount.

- Analysis includes the excess of case C in the range of a sensitivity of 1.5 times.

Results of Sensitivity Analysis (1) Reprocessing and MOX costs

(Discount rate: 3%)

(yen/kWh)

Item	Latest model		
	Basic case	Sensitivity analysis case	Cost ratio
Uranium fuel	0.77	←	---
MOX fuel	0.07	0.10	1.5
Reprocessing, etc.	0.46	0.68	1.5
Interim storage	0.05	←	---
HLW disposal	0.04	←	---
Total	1.39	1.64	1.2

Sensitivity Analysis (2) Front-end Costs

- The element of uranium concentrate in the uranium fuel price is subject to sensitivity analysis using a sensitivity of 2.0 times (sensitivity analysis case) for the reprocessing, direct disposal and latest models (basic cases).
  - The present spot uranium price is approx. $140/kgU, but the fluctuation in the latest three years ranged $100 to $180/kgU.
  - There is no publication for future price estimates by public organizations, but the report by OECD/NEA and IAEA is attached for reference.
    - "Uranium 2009" (July 2010) published by OECD/NEA and IAEA analyzed the amount of resources based on the new product costs up to $260/kgU (formerly up to $130/kgU) which reflect the rising uranium production costs and the basic moves of the uranium markets.
  - Considering the sharply rising spot uranium, which once exceeded $260/kgU, the future hike of the uranium price around twice the present level is taken into account.

Future Prospects of Uranium Demand (1)

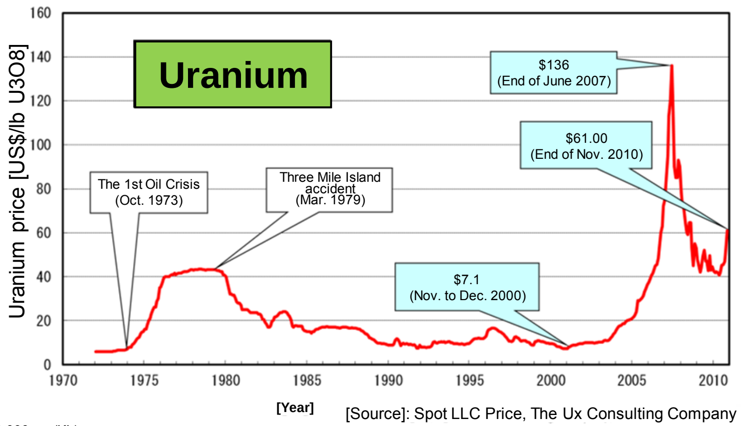
- Uranium demand in 2030 will be about twice the present level.

Evaluation body	Evaluation case	Demand in 2008 (tU)	Demand in 2015 (tU)	Demand in 2020 (tU)	Demand in 2025 (tU)	Demand in 2030 (tU)	Demand in 2035 (tU)
Uranium 2009	Low case	59,065	71,965	76,920	86,325	87,790	87,370
	High case		79,650	91,445	107,480	126,665	138,165
WNA	Low case	64,464	64,739	64,735	54,642	41,708	—
	Reference case		76,937	91,637	101,993	106,128	—
	High case		84,841	106,591	127,152	140,052	—

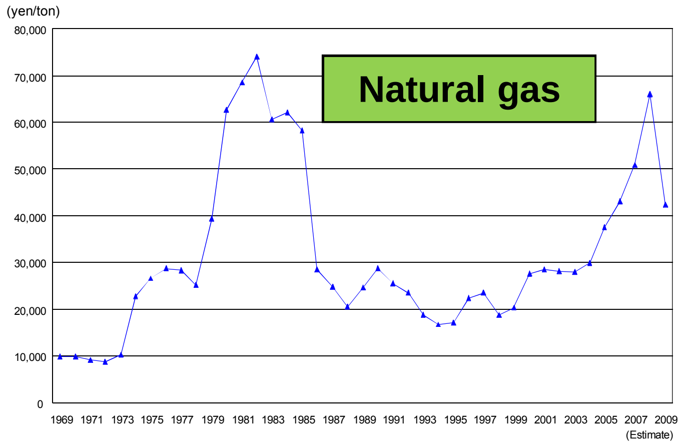
"Recent Trends of Uranium Resources" (Nov.2010), Sudo, JAEA

Future Prospects of Uranium Demand (2)

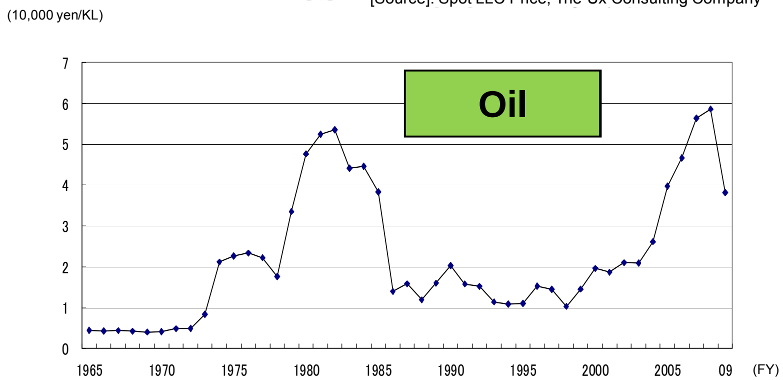
- The uranium price changes in conjunction with the fossil fuel price.
- The WEO predicts a hike of oil price in 2030 to 2.25 times the present price.



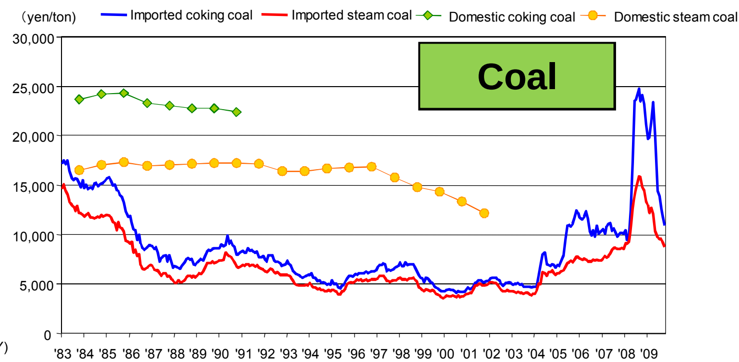
[Source]: Spot LLC Price, The Ux Consulting Company



Source: Trade Statistics of Japan, Ministry of Finance



(Source) Created based on "Trade Statistics" of the MOF and "Domestic and Overseas Data" of the Petroleum Association of Japan. Note that the figure in FY2009 is the mean value of April to November 2008.



(Source) "Japan Trade Statistics," "Call Note 2003"

Source: Data at the New Nuclear Policy-Planning Council (4th)

Results of Sensitivity Analysis (2) Front-end Costs

(yen/kWh)

Item	Reprocessing model			Direct disposal model			Latest model		
	Basic case	Sensitivity analysis case	Cost ratio	Basic case	Sensitivity analysis case	Cost ratio	Basic case	Sensitivity analysis case	Cost ratio
Uranium fuel	0.73	1.04	1.4	0.81	1.16	1.4	0.77	1.10	1.4
MOX fuel	0.15	←	---	---	---	---	0.07	←	---
Reprocessing, etc.	1.03	←	---	---	---	---	0.46	←	---
Interim storage	---	---	---	0.09	←	---	0.05	←	---
HLW disposal	0.08	←	—	---	---	---	0.04	←	---
Direct disposal	---	---	---	0.10 - 0.11	←	---	---	---	---
Total	1.98	2.29	1.2	1.00 - 1.02	1.35 - 1.36	1.3 - 1.4	1.39	1.72	1.2

Results of Sensitivity Analysis (3) Burial Disposal Costs

- The HLW disposal and direct disposal are subject to sensitivity analysis with 1.5 tirnes costs.

Discount rate: 3% (yen/kWh)

Item	Direct disposal model			Latest model		
	Basic case	Sensitivity analysis case	Cost ratio	Basic case	Sensitivity analysis case	Cost ratio
U fuel	0.81	←	-	0.77	←	-
MOX fuel	-	-	-	0.07	←	-
Reprocessing, etc.	-	-	-	0.46	←	-
Interim storage	0.09	←	-	0.05	←	-
HLW disposal	-	-	-	0.04	0.05	-
Direct disposal	0.10 - 0.11	0.15 - 0.17	-	-	-	-
Total	1.00 - 1.02	1.05 - 1.07	1.05 - 1.05	1.39	1.41	1.01

- The impact on the whole cycle is on order of 1% in the latest model which contains HLW disposal, or 5% in the direct disposal model though the latter depends on the disposal method.

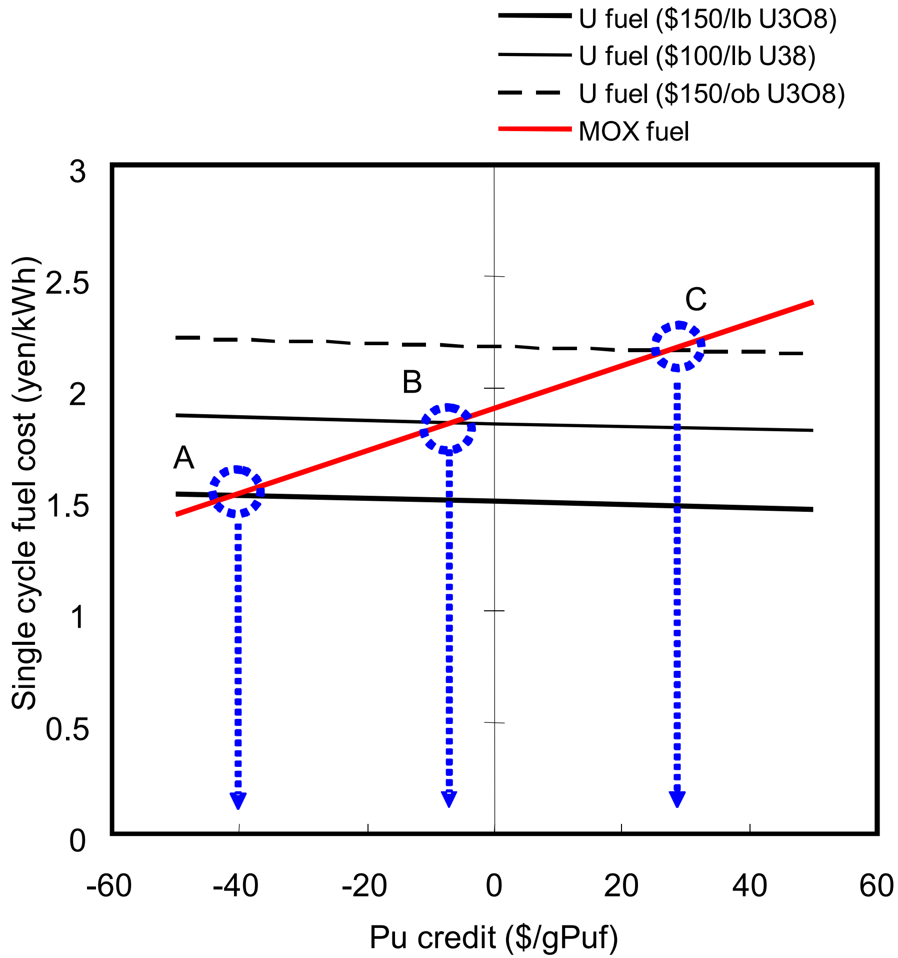
Handling of the Pu Credit

- If the Pu credit is decided, the uranium fuel cycle cost is given by subtracting the Pu credit from the sum of the front-end costs (uranium refining, conversion, enrichment and fabrication) and back-end costs (reprocessing, waste disposal) in one cycle from the initial loading of uranium fuel on the reactor to the discharge of it from the reactor, and then dividing it with the amount of generation.
- The MOX fuel cycle cost is given by adding the Pu credit as expenses for purchasing plutonium to the MOX fuel fabrication costs.
- However, there is no plutonium market in the world, and in Japan, the utilities are supposed to sustain the peaceful use of plutonium, recovered from the reprocessing of spent fuel, in their reactors in principle (each utility should make its plutonium utilization plan public).
- As the uranium price significantly varies, and the instability of MOX fuel fabrication costs is undeniable, the Pu credit is difficult to decide, and **depending on the assumption, it can be either negative or positive.**
- Hence, a technique to repeat the cycle of utilizing plutonium produced in nuclear power generation in an infinite period of time is used in the conventional calculation of fuel cycle cost to avoid the need to handle the Pu credit explicitly.
- Although the recycle is infinite, the infinite series in the integration of the cost and generated energy will, with certainly, converge because 1) the delay of time results in a discount, and 2) the proportion of reproducing MOX fuel from the reprocessing of LWR spent fuel is smaller than 1.

Source: Japan Nuclear Fuel Ltd（The 4th Data, No. 2)

Calculation of the Pu Credit

- The figure shows an example of calculating the Pu credit that makes the fuel cycle costs of uranium fuel and MOX fuel equal (indifference value).
- The Pu credit is negative at the uranium price of $50/lb U_3O_8 and the present MOX fuel fabrication cost, but turns to positive if the uranium price, having the records in the past, rises sharply.
- Changes in the conditions, such as increase in the uranium or MOX fuel reprocessing costs, can make the Pu credit either positive or negative.
- $160/kgU (equivalent to $24/gPuf) in the report of the Boston Consulting Group (BCG), and - $15,743/kgPu (equivalent to -$24/gPuf) in the report of Massachusetts Institute of Technology (MIT) are within the results of this calculation.



Source: Japan Nuclear Fuel Ltd. (Data No. 2 at the 4th meeting)

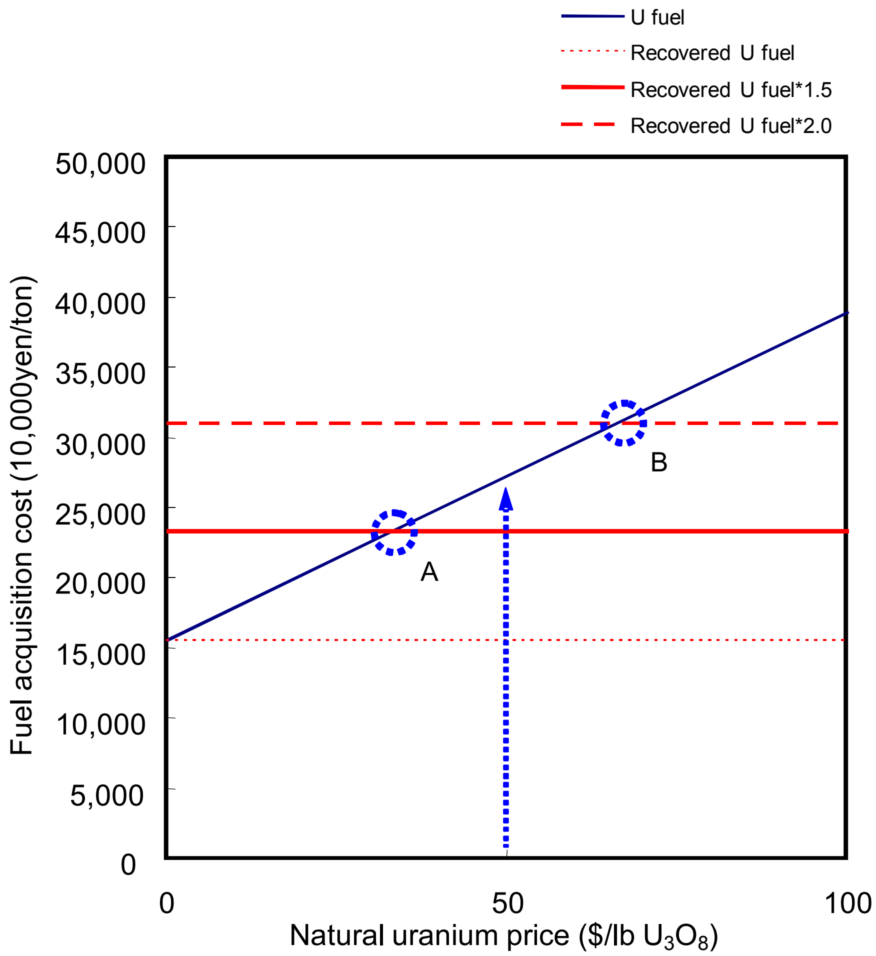
Handling of the Recovered Uranium Credit

- The conversion, re-enrichment and fabrication of recovered uranium may save expenses for purchasing uranium concentrate (recovered uranium price).
- The recent improvements in burnup has contributed to reducing the residual concentration of recovered uranium, and soon it cannot be said "significantly expensive" in comparison with natural uranium.
- There is a tendency to increase the separative work unit (SWU) for ^{236}U produced by uranium burnup and causing burnup reactivity losses due to neutron absorption.
- The daughter nuclides of ^{232}U and ^{234}U contained in the spent fuel also emit strong gamma rays, and shielding is necessary in the conversion, enrichment and fabrication processes, which increases the processing costs.
- Meanwhile, no design is made for the recovered uranium utilization process, a post-process at the Rokkasho Reprocessing Plant, and cost estimation is not available.
- **If increase in the uranium concentrate price makes the use of recovered uranium beneficial**, and recovered uranium is significantly accumulated in the operation at the reprocessing plant for re-enrichment and utilization, the fuel cycle costs will definitely decrease.
- Only the increase in the cost required for storing recovered uranium is included in the present fuel cycle cost estimation, and the reduction in the recovered uranium credit is not taken into account.

Source: Japan Nuclear Fuel Ltd. (Data No. 2 at the 4th meeting)

Costs of Fuel Acquired from Re-enrichment of Recovered Uranium

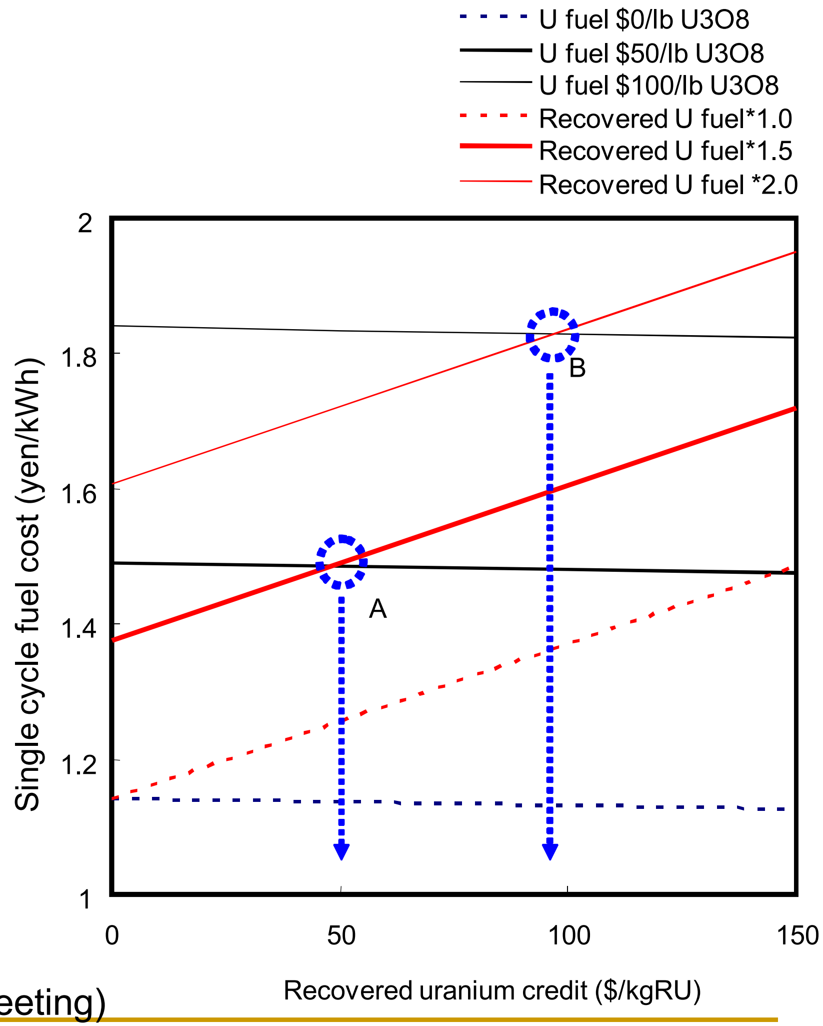
- The figure shows a comparison of the costs of fuel acquired from the enrichment of natural uranium and the re-enrichment of recovered uranium (converted to the initial loading values).
- Even if the costs of the conversion, enrichment, and fabrication of recovered uranium is 1.5 times those of the natural uranium, the benefit is already obvious with the current uranium price of $ 50/lb U_3O_8.
- Even if the front-end cost of the recovered uranium are twice that of the natural uranium, the refining cost of $70/lb U_3O_8 makes the both equal.
- In short, benefits of the re-enrichment of recovered uranium are likely to be realized.



Source: Japan Nuclear Fuel Ltd. (Data No. 2 at the 4th meeting)

Calculation of Recovered Uranium Credit

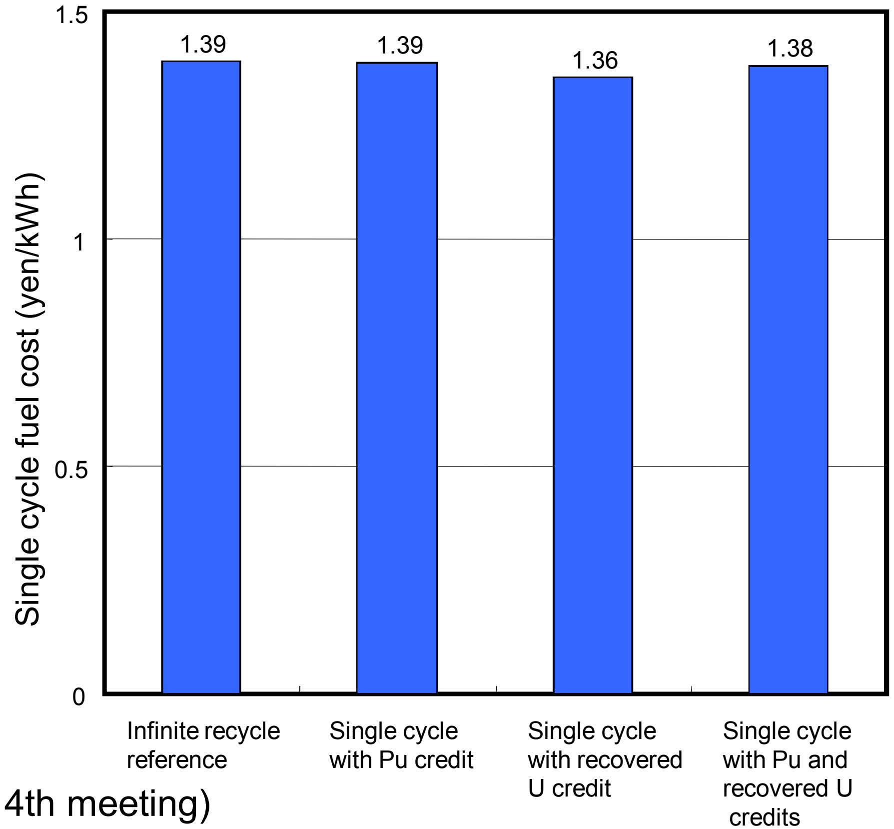
- The figure shows an example of calculating the recovered uranium credit that makes the fuel cycle costs of enriched natural uranium fuel and re-enriched recovered uranium fuel equal (indifference value).
- Assuming the conversion, enrichment and fabrication costs of recovered uranium are 1.5 times those of natural uranium, the recovered uranium credit which is equal to the natural uranium price of \$50/lb U_3O_8 is \$50/kg RU.
- If the natural uranium price is \$100/lb U_3O_8, the recovered uranium credit can be slightly less than \$100/kg RU even though the front-end cost of recovered uranium fuel are double.
- \$30/kg SF (equivalent to \$32/kg RU) in the BCG report, and \$108.3/kg RU in the MIT report fall into this calculation.



Source: Japan Nuclear Fuel Ltd. (Data No. 2 at the 4th meeting)

Consideration with Pu and Recovered U Credits

- The fuel cycle cost was estimated for a single cycle with the Pu credit (-$40/g Puf) and recovered U credit ($50/kg RU) taken into account for evaluating the effects of these credits.
  - In the infinite cycle calculation, the Pu credit is offset, while the processing costs for MOX fuel are explicitly taken into account. This makes the calculation results using these credits almost equal.
  - Hence, the LWR fuel cost may be estimated using a simplified calculation with the Pu credit and without MOX fuel (=0), and the difference from the result of a full calculation is not significant.
  - The difference caused by the presence or absence of the recovered uranium credit is significant because the use of recovered uranium is not considered in the calculation of the present fuel cycle cost (infinite recycle).
  - The calculation is made according to the fact that the half of spent fuel is sent to the interim storage facilities.



Source: Japan Nuclear Fuel Ltd. (Data No. 2 at the 4th meeting)

Reference

Calculation of Nuclear Fuel Cycle Costs

[Uranium fuel]

Converted to the initial loading value

[Other process cost]

$$F_a = F_{a0} \times \sum_{k=1}^{\infty} \frac{r^{k-1}}{(1+q)^{y+m(k-1)}}$$

[Generated energy]

$$P = H \times 24 \times \eta \times (1-L) \times 1000 \times \frac{1}{T} \int_0^T \left(\frac{1}{1+q} \right)^x dx \times \sum_{k=1}^{\infty} \frac{r^{k-1}}{(1+q)^{m(k-1)}}$$

[Nuclear fuel cycle cost]

$$C = \frac{F_a + F_b + \cdots\cdot}{P}$$

F_a: Cost at initial loading in process a

F_{a0} : Cost at the beginning of process a

q: Discount rate

r: Next generation production ratio of next generation fuel in the reprocessing of spent fuel

m: 9 for reprocessing, 51 for interim storage

η: Heat efficiency (0.345)

y: Lag time at each process

P: Generated energy (converted to the initial loading value: kWh)

H: Average discharge burnup (MWd/t)

L: Auxiliary power ratio (0.035)

T: Incore fuel dwelling time (5 years)

C: Nuclear fuel cycle cost

Nuclear Fuel Cycle Cost Calculation Sheet (Reprocessing Model) -Example-

Cost		0%	1%	3%	5%
U fuel	(10,000 yen/tU)	25,900	26,200	27,100	28,200
MOX fuel	(10,000 yen/tHM)	40,600	40,700	41,500	42,700
Reprocessing, etc.	(10,000 yen/tU)	37,000	37,600	40,800	46,200
Transport to reprocessing	(10,000 yen/tU)	1,700	1,700	1,700	1,700
HLW disposal	(10,000 yen/tU)	8,500	8,700	11,000	15,700

Discount rate	**3%**
Generated energy (kWh/t)	**3.9E+08**

	Lag time	Cost (yen/kWh)
U fuel		7.3E-01
MOX fuel	8	1.5E-01
Reprocessing, etc.	8	9.8E-01
Transport to reprocessing	6	4.3E-02
HLW disposal	48	8.1E-02
	Total	**1.98**

Time Axis of Scenario

(year)

Process	Reprocessing model	Direct disposal model	Latest model	
			Reprocessing	Interim storage
MOX fuel	8 [*1]	—	25 [*2]	50 [*1]
Reprocessing, etc.	8 [*1]	—	25 [*2]	50 [*1]
SF transport (PP→RP)	6 [*1]	—	6 [*1]	50 [*1]
SF transport (PP→IS)	—	10 [*1]	—	10 [*1]
SF transport (IS→DD)	—	58 [*1]	—	—
Interim storage	—	34 [*1,3]	—	30 [*1]
HLW disposal	48 [*1]	—	65 [*1,4]	90 [*1,4]
Direct disposal	—	59 [*1]	—	—

*1 According to the previous technical subcommittee.
*2 The actual current domestic cycle is reflected.
*3 An intermediate phase between the 10th year when transporting to the interim storage facility starts and the 58th year when transport to the disposal site starts.
*4 The 40th year from reprocessing.

PP: Power Plant, RP: Reprocessing Plant, IS: Interim Storage Facility, DD: Direct Disposal Site

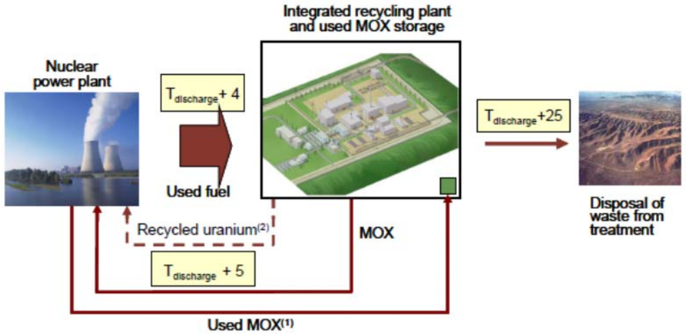
Total Operation Cost for Direct Disposal Model

Rock type	Estimation case	Emplacement method	No. of Stored bodies	No. of sites	Previous total cost (trillion yen)	Current total cost (100 million yen)			
						0%	1%	3%	5%
Soft rock	1	Vertical	2	1	7.80	**50,114**	**43,139**	**38,258**	**39,789**
	2		4	1	6.03	**42,222**	**36,355**	**33,191**	**35,847**
Hard rock	1	Vertical	2	1	5.33	**46,518**	**40,021**	**35,755**	**37,877**

(Note) The year to start operation (the 35th year) is set as the base year.

Overseas Cycle Cost Estimates (1)

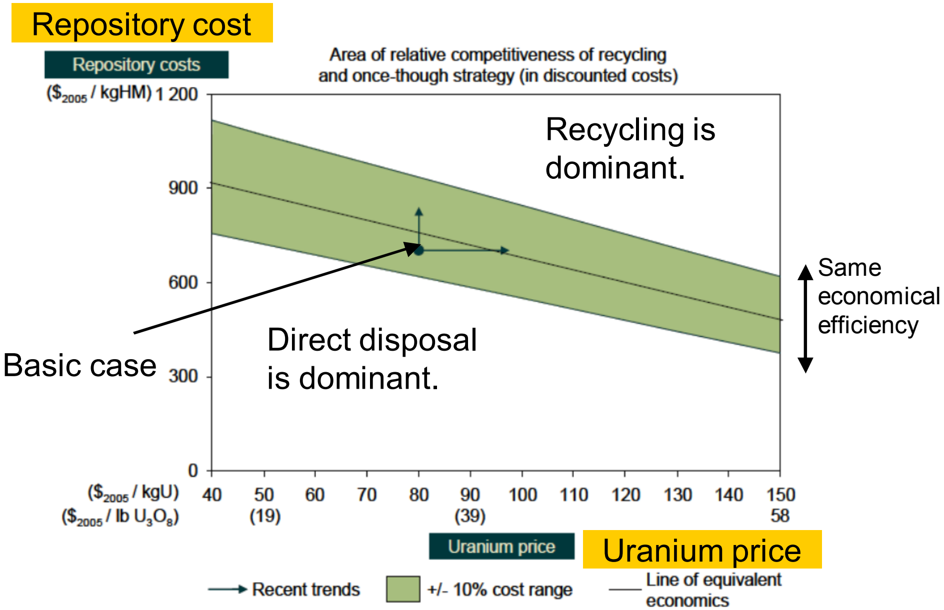
BCG Report (2006)



Reprocessing with the integrated recycling facilities
(reprocessing & MOX fabrication facilities)

Direct disposal			Reprocessing		
Item	Before discount	After discount	Item	Before discount	After discount
Interim storage	150	125	Integrated recycling facilities	630	525
Final disposal	700	320	Final disposal	175	80
Transport (SF)	70	55	Transport (SF, HLW)	95	75
			Pu/U credit	-190	-160
Total	920	500		710	520

($/kg, discount rate: 3%)



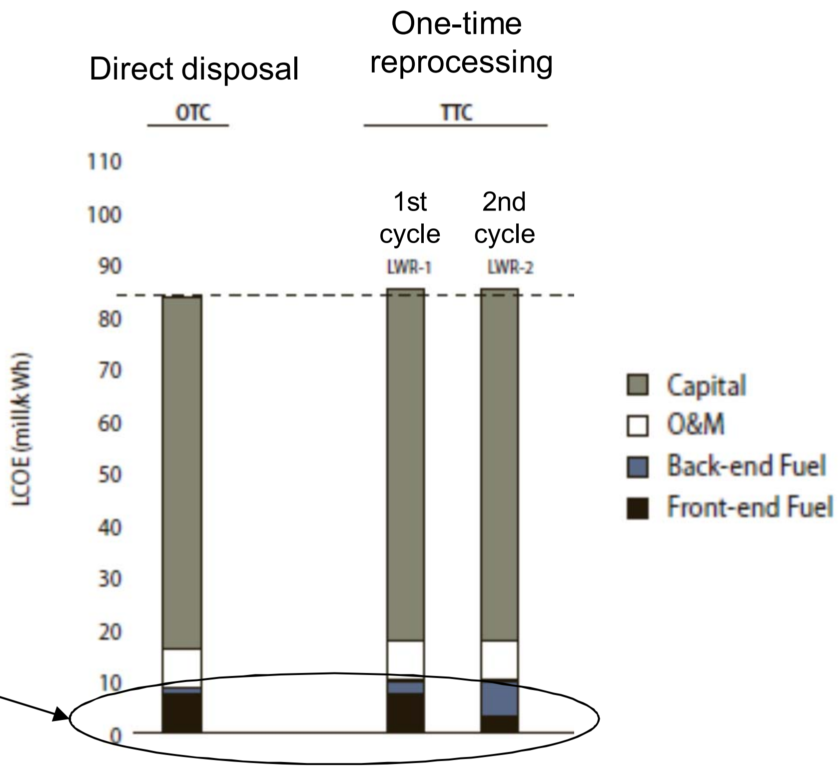
Source: “Economic Assessment of Used Nuclear Fuel Management in the United States” 2006, Boston Consulting Group (BCG)

Overseas Cycle Cost Estimates (2)

MIT Report (2011)

Direct disposal		Reprocessing 1st cycle: U fuel		Reprocessing 2nd cycle: MOX fuel	
U	2.76	U	2.76	DU	0.03
				Pu	-4.39
Fuel production	4.35	Fuel production	4.35	Fuel production	7.38
Back-end	1.30	Reprocessing	2.36	Back-end	6.96
		HLW disposal	0.4		
		Recovered U price	-0.14		
		Recovered Pu price	0.25		
Total fuel cost	8.41	Total fuel cost	9.98	Total fuel cost	9.98

(mill/kWh)



* In this reprocessing scenario, uranium fuel is loaded in the 1st cycle, and the MOX fuel is loaded in the 2nd cycle.

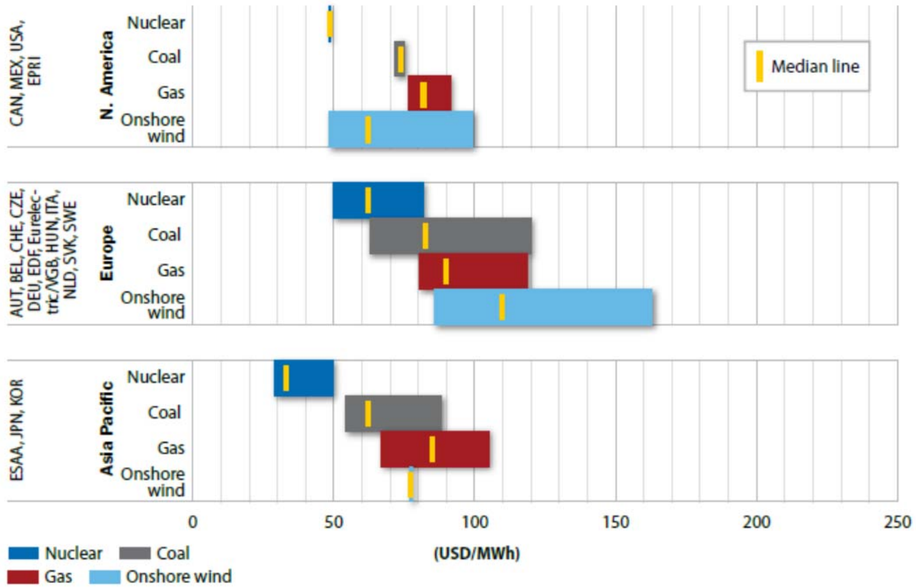
Source: “The Future of Nuclear Fuel Cycle” 2010, Massachusetts Institute of Technology (MIT)

Overseas Cycle Cost Estimates (3)

OECD/NEA Report (2010)

There is no detailed analysis on the nuclear fuel cycle, and the following assumption is used for all estimates:

Front-end: $7/MWh
Back-end: $2.33/MWh



Costs of nuclear, coal, gas and wind generation
(Discount rate: 5%)

Source: “Projected Costs of Generating Electricity” 2010 edition, **OECD/NEA**