

Subcommittee on Nuclear Power and Nuclear Fuel Cycle Technologies

Estimation of Accident Risk Cost of Nuclear Power Plants

May 28, 2013

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Reference: “Estimation of Accident Risk Cost in Nuclear Power Plants”(November 10, 2011)
http://www.aec.go.jp/jicst/NC/tyoki/tyoki_hatsukaku.htm

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Request to Estimate Accident Risk Cost from the Cost Review Committee※

The cost of nuclear power generation should include accident risk cost, i.e. expected cost associated with damage compensation, decontamination of contaminated areas and decommissioning of damaged plant that should be charged to the operator of the plant as in the case of accident at the Fukushima Dai-ichi NPS of TEPCO.

Evaluation of Accident Risk Cost as the Expected Accident Cost

- The expected accident cost for model plant is calculated using the following equation;

$$CAR = \frac{\text{Total damage(yen)} \times \text{Accident frequency (per reactor year)}}{\text{Gross Annual output (kWh)}}$$

- Model plant is 1GWe NPP located in Japan. Three cases of Gross annual output are considered based on the availability factor: 60%, 70%, 80%
- The total damage is the sum of expenses for decontamination cost, additional decommissioning cost and damage compensation associated with a severe accident at model plant.
- The expense for damage compensation is obtained by adjusting that of Fukushima considering the difference in economic activities represented by GDP/person, income/person employed, commodity price and population in area within 30 km from the plant between Fukushima and national average site where a model plant is located.

Expense for Damage Compensation

- The following damages should be expected to occur when severe accident occur at NPP:
 - Physical damage such as loss of assets, contamination of property and land for which decontamination is done to restore their economic values or protect environment etc.)
 - Human damage (death, injuries, evacuation, emigration, etc.)
 - Economic and social losses (production loss, damage due to joblessness, damage to sales due to rumors, etc.)
- The figures publicly announced in the case of Fukushima can be used for estimating these damages.

Estimation of Total Damage Cost (1)

Report by the TEPCO Management and Finance Investigation Committee

- TEPCO Management and Finance Investigation Committee Report
(Published on October 3, 2011)

- Additional expenses necessary for decommissioning the reactors at the Fukushima Dai-ichi NPS
 - Units 1 to 4 964.3 billion yen

- Damage compensation
 - One-time compensation 2,618.4 billion yen
 - Yearly compensation
 - 1st year 1,024.6 billion yen
 - Second year (and thereafter) 897.2 billion yen

Total: 5,504.5 billion yen

Additional Decommissioning Cost

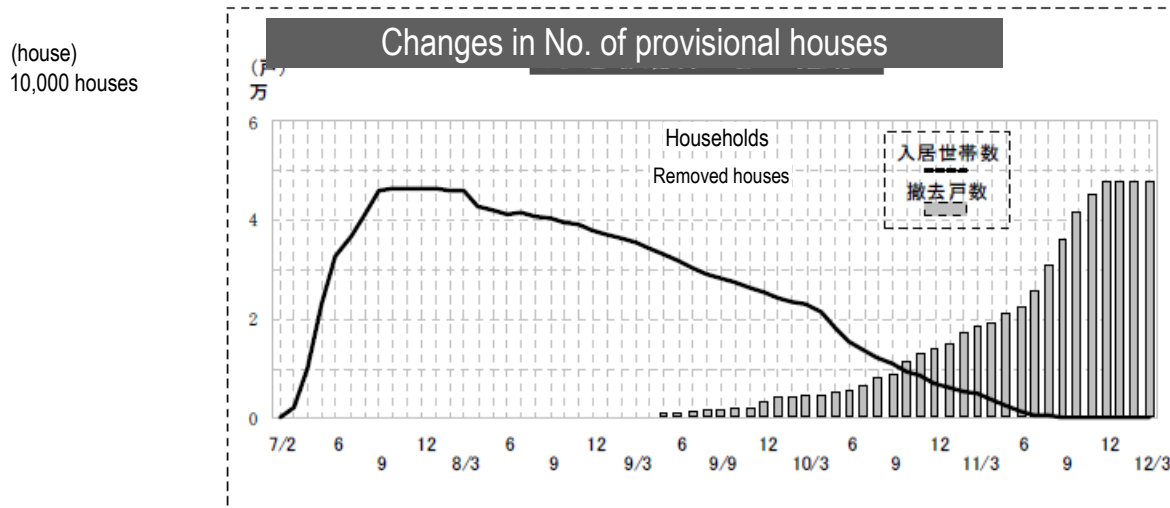
- Additional cost for decommissioning Units 1 to 4 of the Fukushima Dai-ichi NPS depicted in the TEPCO Management and Finance Investigation Committee Report is 964.3 billion yen
- It is assumed that decommissioning costs of unit 1, 2 and 3 are not so different from each other.
- Considering a lower level of contamination at Unit 4 compared with Units 1 to 3, it can be assumed that no significant additional cost will be required for Unit 4.
- A conservative estimation of additional decommissioning cost will be obtained if this cost is cost for three units.
- Assuming that the cost is independent of output power in the range of operating units, additional decommissioning costs for the model plant is estimated to be one-third of the said cost or **321.4 billion yen.**

Estimation of Total Damage Cost (3)

Damage Compensation after 2nd Year

- It is assumed that annual expense for damage compensation will continue to be paid up to fifth year, decreasing its amount linearly based on the past experience and the fact that currently five year decontamination plan is under discussion. Then the sum of expenses for 2nd, 3rd, 4th and 5th year damage compensation can be estimated as **2,242.8 billion yen.**

Reference data: Changes in number of people who lived in provisional housing in the Great Hanshin-Awaji Earthquake.



Source) "Recovery and Reconstruction Following the Great Hanshin-Awaji Earthquake" Hyogo pref., December 2010

Estimation of Total Damage Cost (4)

Note: Decontamination Cost in Damage Cost

- TEPCO Management and Finance Investigation Committee Report said that;
 - While restoration using a lower-cost decontamination method is possible, it might be required to promote decontamination even if its costs exceed the value of the property. Therefore it will take some time to make a realistic estimation.
- Interim guidelines to determine the scope of nuclear damages caused by the accident at the Fukushima Dai-ichi and Dai-ni NPSs of TEPCO (August 5, 2011) specifies that except for particular cultural assets, the costs exceeding the value of relevant properties are excluded from the scope of compensation for damage in principle.

Therefore it was assumed in this estimation that the cost of decontamination works should be within the value of property. However, the expenses for decontamination of forest, which will probably cost more than its monetary value, and the construction and operation of interim storage facilities for waste from decontamination activities and so on should be added to the cost when **the Government decide to promote such activities.**

Adjustment of the Regional Difference (1)

- The damage compensation cost of a model plant should be evaluated by adjusting the damage compensation for the Fukushima Dai-ichi NPS taking into consideration of difference in economic activity level between Fukushima area and model plant area:
 - Annual compensation cost should be adjusted by considering the ratio of GDP, income and consumer price of Fukushima Prefecture ("Fukushima") to the mean of other prefectures where nuclear power plants are located ("Mean").
 - **GDP/person (Mean /Fukushima): 0.97** is used for adjusting Business loss and Indirect damage resulting from business loss
 - **Income/person (Mean /Fukushima): 1.03** is used for adjusting Damage due to joblessness
 - **Consumer price regional difference (National /Tohoku area): 1.02** is used for adjusting Temporary entry cost and Homecoming cost

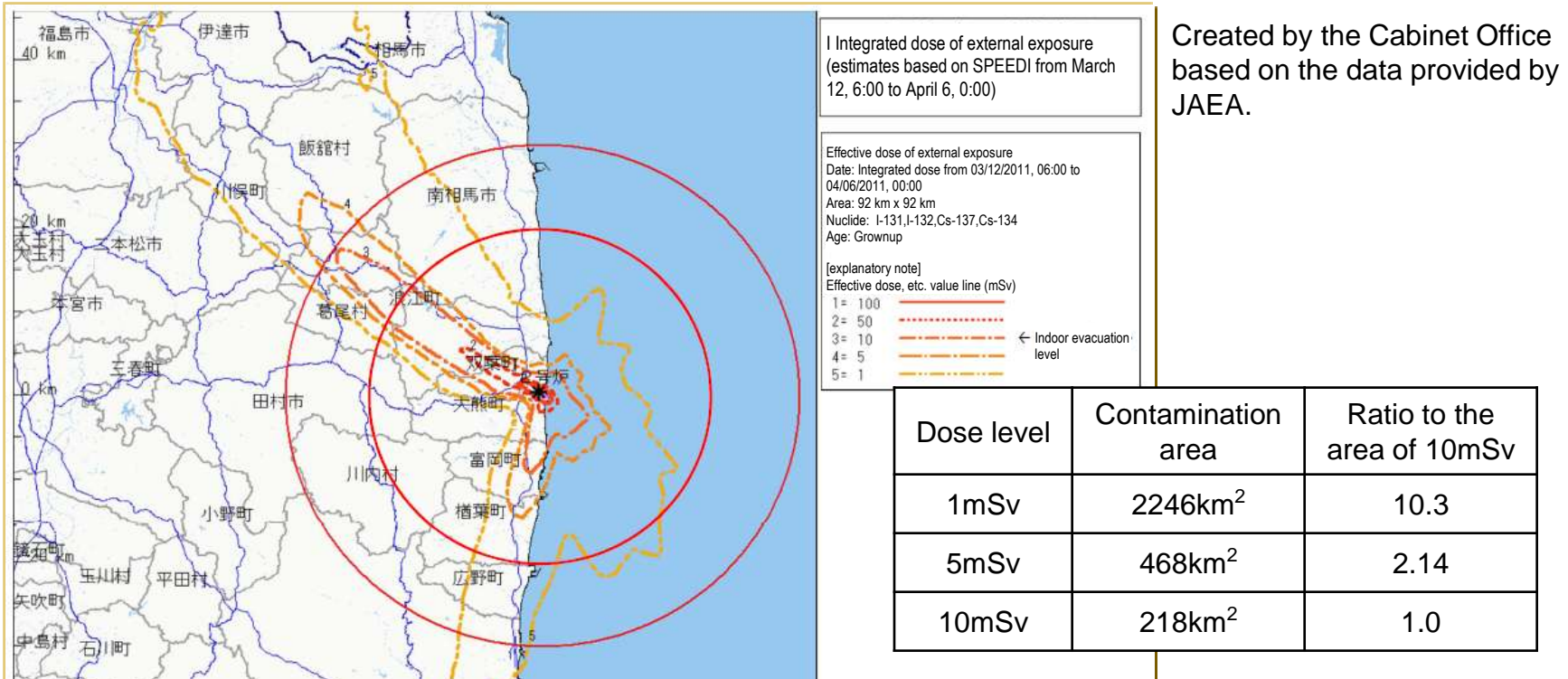
Adjustment for the Contamination (1)

- Amount of radioactive materials released
 - For simplistic use of data of Fukushima, it is assumed that the total amount of radioactive materials released is proportional to the reactor output.(similar accident at similar burn-up).
 - ✓ 1.2 GW (Model Plant) / 2.028 GW(Fukushima Unit 1-4) = 0.59

- Economic Damage
 - At the beginning of the accident, the government determined the evacuation areas that defined from the physical distance from the Fukushima NPS, regardless of the amount of radiation released. After that, the evacuation areas were determined according to the distribution of contamination. Considering current situation it is proper to assume that
 - ✓ **One-time damage** (damage to sales due to rumor, inspection cost, etc.) **is NOT proportional** to the area of contamination.
 - ✓ **Annual damage (the 1st, 2nd and subsequent years)** **is proportional** to the area of contamination.

Estimation of Total Damage Cost (8)

Adjustment for the Contamination (2)



In the accident at the Fukushima plant, a constant relation is also true between the released amount of radiation (proportional to the effective dose) and the area of diffusion of radiation.

Example: If the amount of released radiation is decoupled, the effective dose is also decoupled, namely, the area of dose level 1mSv becomes 10mSv area. In this regard, the contamination area is 10.3 times as large as the previous 10mSv area.

Total Damage Cost

Additional decommissioning cost

321.4 billion yen

+

Damage Compensation cost

4,672.1 billion yen

One-time cost

2,697.0 billion yen^{*1}

Sum of annual cost

1,975.1 billion yen^{*2}

^{*1} corrected with regional characteristics and population in evacuation area

^{*2} corrected with regional characteristics, population in evacuation area and reactor capacity

Total Damage Cost = 4,993.6 billion yen

Concepts of Accident Frequency

Accident Frequency of Model Plant

Several values of the frequency of accident at the model plant were estimated based on the latest knowledge and alternative assumptions.

Frequency	Description
1.0×10^{-5} / reactor year	Frequency is early large release frequency of existing reactors depicted in the IAEA safety standard. This is based on the assumption that taking in account the lessons learned from the accident at the Fukushima plant, the frequency of severe accident in the future should meet at least the IAEA safety standard.
2.1×10^{-4} / reactor year	Frequency is calculated based on the operation years of commercial reactors in the world and three accidents at TMI-2, Chernobyl-4 and Fukushima Dai-ichi NPS by regarding the incidents in units 1 to 3 as a single event because damage to all three units was caused by the great tsunami following the Great East Japan Earthquake. It is synonymous with a continuous use of old type reactors as those at the Fukushima plant without any safety measures in reference to the Fukushima accident.
3.5×10^{-4} / reactor year	Frequency is calculated based on the operation years of commercial reactors in the world and five accidents at TMI-2, Chernobyl-4 and Fukushima Dai-ichi NPS by regarding the incidents in units 1 to 3 as three separate events. It is synonymous with a continuous use of old type reactors as those at the Fukushima plant without any safety measures in reference to the Fukushima accident.
6.7×10^{-4} / reactor year	Frequency is calculated based on the operation years of commercial reactors in Japan and one event by regarding the incidents in units 1 to 3 at the Fukushima Dai-ichi NPS as one event because damage to all three units was caused by the great tsunami following the Great East Japan Earthquake. It is synonymous with a continuous use of old type reactors as those at the Fukushima plant without any safety measures in reference to the Fukushima accident.
2.0×10^{-3} / reactor year	Frequency is calculated based on the operation years of commercial reactors in Japan and by regarding the incidents in units 1 to 3 at the Fukushima Dai-ichi NPS as three separate events. It is synonymous with a continuous use of old type reactors as those at the Fukushima plant without any safety measures in reference to the Fukushima accident.

Estimation of Accident Risk Cost of NPP based on Accident Frequency (1)

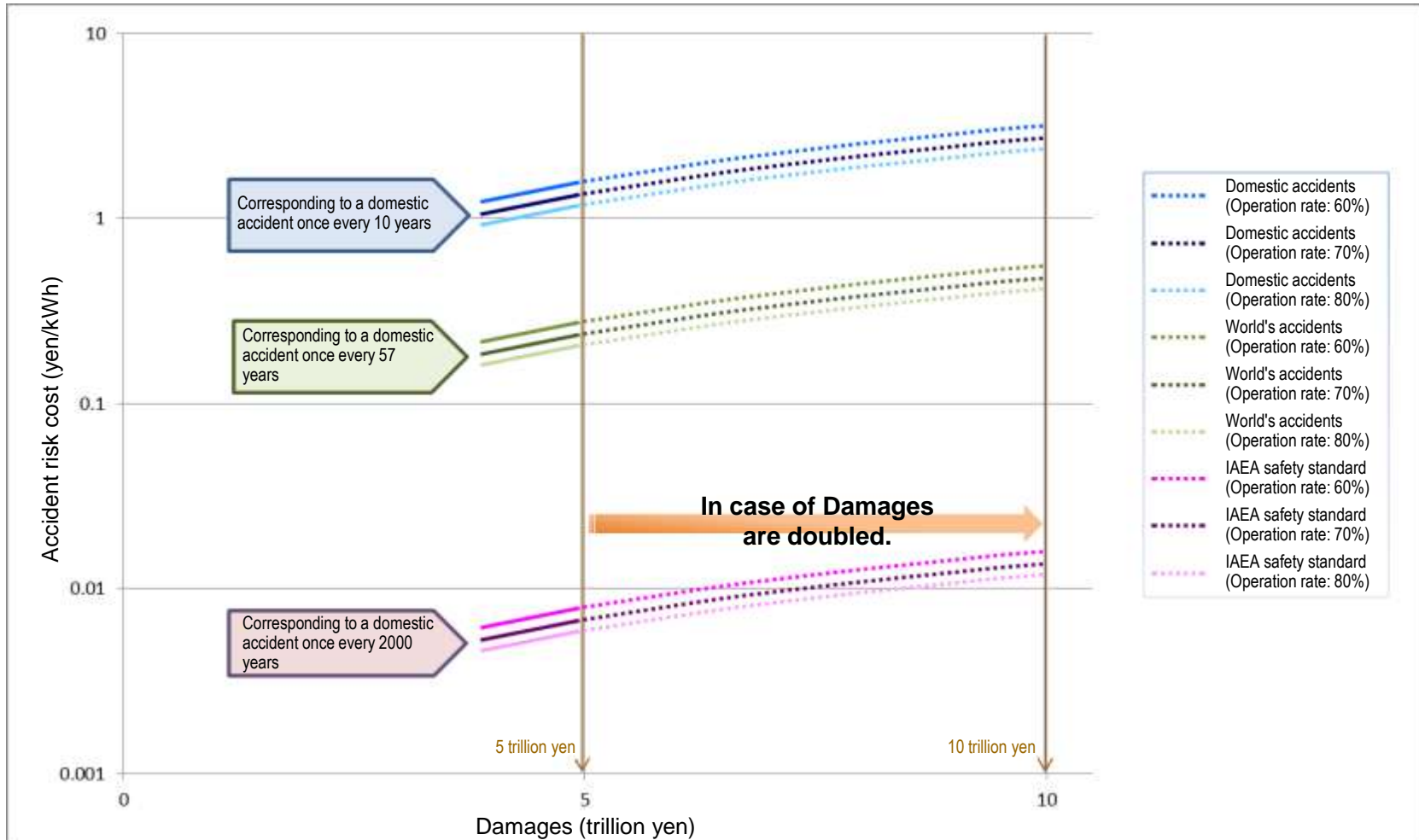
Accident Risk Cost based on Accident Frequency and Its Sensitivity

Frequency (/reactor year) Availability factor	Accident risk cost of model plant (yen/kWh)			Increase in the accident risk cost due to 1 trillion yen increase in the total dame cost (yen/kWh)		
	60%	70%	80%	60%	70%	80%
1.0×10^{-5} (IAEA safety standard for early large release from existing reactor)	0.008	0.007	0.006	0.002	0.001	0.001
3.5×10^{-4} (Severe accident frequency of world's commercial reactors, equivalent to once every 57 years ^[1])	0.28	0.24	0.21	0.06	0.05	0.04
2.0×10^{-3} (Severe accident frequency of domestic commercial reactors, equivalent to once every 10 years ^[1])	1.6	1.4	1.2	0.32	0.27	0.24

[1] Accident frequency for 50 reactors in operation

Sensitivity Analysis of Accident Risk Cost

- Changes in accident risk cost when damages costs are doubled



Estimation of Accident Risk Cost in the Case of a Mutual Aid (Insurance) System

- In order to prepare for monetary claims due to nuclear accidents, the nuclear reactor operators jointly establish a mutual aid fund as an insurance for the payment in such case caused by any member.
- The fund is paid by each operator based on their amount of nuclear electricity production in order to be able pay the estimated accident damage cost of 5 trillion yen (4, 993.6 billion yen) in 40 years.
- As a sensitivity study, the amount of the fund is doubled: it is equivalent to the case that the payment time is halved to 20 years.

Fund	Payment term	Total nuclear generation ^[1]	Accident risk cost
5 trillion yen	40 years	280 billion kWh	0.45 yen/kWh
10 trillion yen			(0.89 yen/kWh)

[1] Data of the Results and Energy Environment Committee, 2010

- If the nuclear operators in the world share the payment, the damages will be further decreased.

Conclusion

- The accident damage cost of a model plant was estimated as about five trillion yen, using the verifiable data, and referring to the report at October 2011.
- The accident risk cost as an expected damage cost based on accident frequency was less than 0.01 yen/kWh if the frequency is once in 100 thousand years or equivalent to the large release frequency mentioned in the IAEA's standard. If the frequency estimated, limiting the data base to Japanese experiences, it is 1.2 -1.6 yen/kWh.
- If the all Japanese nuclear operators establish a mutual aid (insurance) fund for preparing to pay total damage cost of 5 trillion yen in forty years, the accident risk cost was estimated to be 0.5yen/kWh.
- The guideline of damage compensation was updated three times after this estimation, and another updating is under consideration at present. It should be expected that the total damage cost will be increased from 5 trillion yen in near future.