

Japan's cost verification of electricity generated by nuclear power plants: achievements and challenges

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Abstract: This article illustrates the cost verification works of nuclear power generation plants conducted by the Japanese government in 2011 and 2015 and shows the achievements and challenges of cost simulation in terms of inclusion of social costs. In response to the Fukushima nuclear power accident, the government stepped into simulation of cost of nuclear power accidents and other costs in relation to nuclear power development including such costs as R&D and site selection. Since the impact of the nuclear power accident is severe and expected to last long period of time, essential issues raised have to be studied further and incessant fine-tuning of cost simulation methods is necessary in the future. Since the similar efforts have started overseas, more active discussions have to be reactivated. Having been still experiencing the Fukushima catastrophe, Japan should continue to play the central roles in analyzing the social costs of nuclear power plants.

Keyword: electricity generation costs; social costs; Fukushima nuclear power plant accident

1 Introduction

The Japanese Basic Act on Energy Policy (Act No. 71 of June 14, 2002) stipulates that the government shall formulate a basic plan on energy supply and demand (the "Basic Energy Plan") and review it at least once every three years in order to promote measures on energy supply and demand on a long-term, comprehensive and systematic basis. In response to this requirement, the government is expected to decide the "Long-term energy supply and demand outlook" (the "Energy Mix") and to verify the simulated costs of electricity generation. Most recently, the Ministry of Economy, Trade and Industry decided the Energy Mix for 2030 in July 2015 based on the forth "Basic Energy Plan" approved by the Cabinet in April 2014. To support the Ministry's process to decide the Energy Mix, a Sub-Committee was formulated, and a working group (WG) was also composed to verify the costs of electricity generation ("Cost Verification 2015"⁽¹⁾) as the "referential information" for the Sub-Committee's discussions on the Energy Mix. Needless to say, in order to formulate the energy supply and demand structure in the future, cost is one of the various factors that have to be taken into account. However, in the face of the Fukushima nuclear power accident and the development of power liberalization, the

power generation cost is the important information for the Japanese people to understand Japan's future picture of energy and to decide which electricity to choose.

In reality, the discussions at the WG tended to be made on the assumptions that existing nuclear power plants will be recommissioned and safety enhancement is achieved by the introduction of the new regulatory standards of July 2013. In response to this, the discussions at the WG were not necessarily sufficient. However, as is stipulated in the Basic Act on Energy Policy, the Basic Energy Plan has to be periodically reviewed, which means that there will be another cost verification of the electricity generation. Therefore, there is a need to continuously examine and upgrade the methodology to verify the electricity generation cost.

Based on this understanding, the purpose of this article is to analyze to what extent the discussions of Cost Verification 2015 at the WG was made and what issues are left open as the future challenges. The Chapter 2 illustrates the contents of the recent 2 cost verification works by the government and the Chapter 3 discusses on the achievements and challenges. The Chapter 4 is the conclusion.

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2 Recent cost verification: comparison of works in 2011 and 2015

2.1 Cost verification in 2011

The cost verification in 2011 introduced a new methodology which is the development from the one conventionally used in the past, in the sense that it tried to include the costs borne not only by the power generating entities but also the public, *i.e.* the social costs. Here, the social costs are defined as the environmental costs (CO₂ costs), the costs coping with future accident risks, and the expenses required for power generation including those related to policy measures funded mainly by the government (research and development costs and grants for plant siting municipalities). By doing this, the cost verification in 2011 tried to calculate the power generation costs for the people, not for the electricity generating entities. In order to more accurately calculate the costs, various types of essential issues were raised and discussed actively including those related to the fundamental analysis basis and approaches to those subjects that were not discussed in-depth in the past verification. For example, the appropriate discount rate and inter-generational equity issue were vigorously studied taking account of the long-term nature of nuclear power accident costs. The possible frequency assumptions of nuclear power plant accidents, the nature of grants for nuclear power plant siting municipalities, and assumptions of plant lifetime and capacity factors were also thoroughly discussed. As for the nuclear power plants, as a "thorough verification", the study of costs coping with future accident risks spread wide and tried to include the actually accrued and estimated costs of the Fukushima nuclear power plant accident including the government spending by that time. Estimations were also attempted based on contemplation on costs of nuclear fuel reprocessing, nuclear fuel cycle and decommissioning of the accident-experienced plants.

These calculation methods of Japan's 2011 cost verification are quite different from those adopted by OECD / IEA / NEA cost projections for more than 30 years (OECD/NEA/IEA ^[2] ^[3]), which focus on costs that directly accrue to the power generating entities in

the phases of construction, operation and decommissioning of plants ("plant level costs" (OECD/NEA/IEA)), and do not cover the costs of accidents or other expenses borne by the government (from the 2010 edition, OECD/NEA/IEA's cost study started counting CO₂ costs (OECD/NEA/IEA^[4])). Taking advantage of the 2011 cost verification, a lot of studies have been made in Japan to be the basis of economic and pecuniary evaluation of the impacts of nuclear power plant accidents.

Table 1 Issues in cost verification 2011

	Description
Essential issues	Appropriate discount rate to be applied
	Inter-generational equity
	Frequency of nuclear power plant accidents and its reflection to costs
	Nature of site grants
	Life time and capacity factor of nuclear power plants
	Treatment of internal rate of returns
	Definition of costs (whose costs to calculate)
Individual issues	Elaboration on costs of nuclear power accidents and its accuracy
	Coverage of R&D and assumptions of total volume of power generation per year
	Capturing expenses related to policy measures by the government and donations spent by the power generating entities for site communities
	Evaluation of nuclear fuel reprocessing costs and identifying the calculation formula
	Costs of nuclear fuel reprocessing facilities accidents
	Uncertainty of nuclear power decommissioning costs and those of accident-experienced plants
	Costs of construction lead time
	Costs of power transmission system stabilization measures and connecting power lines

(Source) created by the author based on the records of proceedings.

Table 1 illustrates the issues actively discussed in relation to nuclear power based on the records of proceedings of the 2011 cost verification. The newly introduced cost counting principles which include such government supports as grants for the plant siting regions or subsidies for future power generation technology development contributed to the nuclear power generation costs as much as ¥1.1/kWh (¢ 1.1/kWh assuming the exchange rate at 1U.S. \$ =

¥100.00) and became one of the reasons for the nuclear power generation costs to increase compared to those in the past verification.

2.2 Costs specified as non-inclusion in the 2011 cost verification

Although cost calculation methods introduced in the 2011 cost verification were the attempts to go beyond the international cost verification standards, there of course still remained issues that cannot be easily resolved. The report issued after 2011 cost verification (Cost verification committee^[5]) clearly states the followings as the costs that are not included: (1) the cost of the period between planning until actual construction (so-called the cost of "construction lead time"), (2) (apportionment of) the costs of the power transmission system stabilization measures, (3) (apportionment of) the advertising expenses and donations, (4) costs of connecting power lines (primarily for renewable power plants), and (5) damages caused by nuclear power accidents but not included as costs (descriptions in parentheses added by author). As for the effects not included or not evaluated are (6) effects of additional safety measures and expenses due to the enhancement of safety regulations, (7) evaluations of impacts on energy security, and (8) macro-economic effects. In this way, the cost verification of 2011 showed the achievements and challenges of cost verification, and revealing them itself seemed meaningful when cost verification comes to focus not only on the conventional plant level costs but also on the social costs.

However, some of the open issues were needed to be studied further: For example, even though the costs of "construction lead time" were evaluated as "difficult to quantify" (cost verification committee^[5]), other governmental agencies (USDOE EPA^[6]) tries to estimate them. Also, in addition to these specified items, there were cost categories which are related to nuclear power accidents and need careful examination due to the possibilities of non-inclusion or underestimation. Those include the decommissioning and dismantling costs of plants after accidents, insufficient compensation of contaminated real estates, costs of accidents during reprocessing of fuel and depositing of high level radioactive wastes. Further, the expenses to cope with Fukushima nuclear accident

by the public sector (municipal governments, related agencies and institutions and central government) and not counted are expected to be tremendous. Thus, there are many issues which need to be continuously studied to more precisely count the costs, especially in the area of costs of nuclear power plant accidents.

2.3 Cost verification in 2015

2.3.1 Distinctive features of the cost verification 2015

Following cost verification in 2011, another cost verification was attempted in 2015 and it introduced 2 new methods to estimate the costs of electricity generation: one is to calculate the cost of feed in tariff (FIT) by adding the internal rate of return which constitutes a part of the tariff of each category of renewable energy, and another is to evaluate the effects of the new regulatory standards for nuclear power plants by estimating accident frequency taking advantage of the probabilistic risk assessment (PRA). Issues including others discussed in relation to nuclear power in the cost verification in 2015 are listed in Table 2.

2.3.2 Issues discussed in the cost verification 2015

The cost verification in 2015 can be evaluated in terms of the coverage and depth of discussions, making the issues and the depth of discussions in the cost verification in 2011 as the basic reference of analysis.

Comparison of issues listed in Table 1 and Table 2 shows, first, that discussions on the most of the essential points were avoided in 2015 cost verification. For example, whose costs were on the table to calculate should still be the fundamental point for discussions in the verification process (which is the question of discount rate selection: the private discount rate or the social discount rate), and the inter-generational equity had to be another essential issue following the contemplation in 2011. As for individual issues, the elaboration on the cost estimation of the Fukushima nuclear power plant accident, and trial to accurately estimate the nuclear fuel reprocessing costs were not analyzed, and the decommissioning and dismantling costs were not be the focus which will inevitably become the main costs in the future stage of the Fukushima restoration. Thus, the discussions did not try to cover the issues

that had been left open in 2011 except for the effects of additional safety measures and the costs spent for the safety regulations and the overall costs of the transmission system stabilization measures.

Table 2 Table 2 Discussions of WG 2015

Issues expected for discussions	Discussions of WG 2015
(i)Elaboration on costs of nuclear power accidents and its accuracy	<ul style="list-style-type: none"> • Not included in the list of discussion points prepared by the secretariat
(ii)Evaluation of nuclear fuel reprocessing costs	<ul style="list-style-type: none"> • Not included in the list of discussion points prepared by the secretariat • Estimation made following existing methods
(iii)Decommissioning costs of accident-experienced plants	<ul style="list-style-type: none"> • Not included in the list of discussion points prepared by the secretariat
(iv)Evaluation of the nature of site grants	<ul style="list-style-type: none"> • Opinion raised to recognize them as zero costs on the whole Japanese society
(v)Evaluation of additional safety measures expenses	<ul style="list-style-type: none"> • The efforts should be recognized (Chairman's summary) • The accident frequency is expected to be reduced (Chairman's summary) • PRA number of core damage reduced by 1/2.4 on average in response to the new regulatory standards(prepared by the secretariat) • Reduction of frequency of accidents by 1/2 proposed by the secretariat • PRA progress should be considered (Chairman's summary)
(vi)Evaluation of the new regulatory standards (*)	
(vii)Coverage of R&D and assumptions of total volume of power generation per year	<ul style="list-style-type: none"> • Methods of 2011 should be the basis (Chairman's summary)
(viii)Evaluation of construction costs	<ul style="list-style-type: none"> • Not included in the list of discussion points prepared by the secretariat • Inflation rate is added

(Source) created by the author based on the records of proceedings.

Note: (*) shows the issue not raised in 2011 cost verification.

In terms of development of discussions from 2011, there was no sufficient analysis on the nature of location grants and it was rather discussed as the equivalence to the cost of FIT for renewable energy. An opinion was raised which claimed that the internal rate of return in FIT constitutes costs for power consumers but at the same time the profits for power producers and that thus the costs for Japan on the whole would be zero. Based on this opinion, claims were made that the internal rate of return and

the location grants are examples of transfer payment and if the location grants are to be calculated for nuclear power, the internal rate of return should also be added to the cost of renewable energy. Some opinions opposing the claims stressed that the cost verification of power generation plants and macroeconomic effects should be treated differently. Others pointed out that the internal rate of return for those electricity generated by plants other than renewable energy would be higher and the costs should be added to keep comparability. However, no following discussions were made and the both location grants and internal rate of return for renewable were recognized as costs in 2015 cost verification.

As for introduction of PRA based severe accident costs calculation, following discussions took place. First, the cost verification in 2011 assumed that funds needed to compensate the costs coping with future accident risks would be deposited over 40 years. The cost verification in 2015 translates this method as assuming one severe accident in 40 years with 50 nuclear plants operating and this means one severe accident per 2000 reactor years (40 years x 50 reactors). Second, based on this understanding, most of the members at the WG agreed that the accident frequency is expected to be reduced under the new regulation standards. Third, since the PRA number of core damage for those nuclear power plants under the Nuclear Regulation Committee's examination showed its reduction by 1/2.4 on average in response to the new regulatory standards, reduction of frequency of accidents by 1/2 was proposed. As a result of these discussions, introduction of the new evaluation method to utilize PRA was agreed but during the discussions there were no contemplation on the presupposed use of the PRA theory itself, the uncertainty involved in the methodology nor the adequacy to utilize PRA figures for the accident frequency not for a part of but for the overall of a plant.

In addition, no in-depth discussions on capacity factors were made for (a) a nuclear power plant in response to the new regulatory standards nor (b) conventional power plants using fossil fuel.

3 Discussion

As described above, the cost verification in 2015 can be said to have concentrated on technical calculation aspects. This left the problems that the development on the essential issues raised in cost verification in 2011 was not fully attained, and some of the contents can be explained as follows. First, the definition of cost remained still vague, *i.e.* whose cost it is estimating. Second, it did not pursue improvement of methodology to calculate future costs, *i.e.* cost verification can be regarded as an attempt to accumulate normative approaches including how to cope with equity issues between present and future generations.

With regard to the new initiative to utilize the PRA theory, as Leveque^[7] states PRA is "not directly linked to the risk assessment of the whole plant" and Lee McCormick^[8] indicates it's suitable for "the purpose to clarify the weaknesses or vulnerability of systems" and Sato^[9] suggests PRA as "a tool of regulatory improvement purposes." Therefore, if we follow the opinions of experts shown above, we can at least point out that we should confirm carefully its theoretical basis in incorporating PRA to the cost verifying methodology.

As for the individual issues, the actual difficult situations for recommissioning of nuclear power plants due to so-called the "back-fit" had to inevitably result in smaller number of plants in operation in the future, which will lead to reduction of total volume of power generated per year. In addition, as studies point out (Harris, *et al.*^[10]: US DOE EIA^[6]), there is a sharp increase of construction costs of nuclear power plants in overseas, which indicates the need to scrutiny the Japanese market as well.

4 Conclusion

The methodology which steps into calculation of social costs has been maintained in cost verification process of Japanese government. This verification is quite unique compared to those cost estimations of other international institutions, and it is informative when you need to estimate the costs of electricity generation to the public. Since the possibilities of nuclear power accidents are concerns of many people

not only in Japan but also in other countries, this trial should be pursued further. On one hand, a new method such as utilizing the PRA for nuclear power plant accidents was tried out. On the other hand, deepening of essential issues which has to be the basis of calculation of social costs has been interrupted. Since the similar efforts have started overseas (Court de Comptes^[11], IRENA^[12]), more active discussions have to be reactivated and exchange of views are expected.

As for the new method initiating the PRA for nuclear power plants, sophistication of the method including appropriate application following the theory precisely may be needed for further contemplation. Having been still experiencing the Fukushima catastrophe, Japan should continue to play the central roles in analyzing the social costs of nuclear power plants.

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