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What it would take to order new nuclear plants — Japanese perspective

A. Omoto
The Tokyo Electric Power Company, Inc.,
Tokyo, Japan

Abstract. In most of the OECD countries, new nuclear capacity addition has been limited for the last one or two decades due mostly to the overcapacity or consideration of financial risk of capital-intensive nuclear investment. Japanese utilities have a dozen of new nuclear plants in a various stages of planning, licensing and construction. This is due to time-delayed demand and supply situation, a concerted effort to comply with the environmental agenda, and diversification incentives by regional Utilities and others. Beyond this stage, as Utility business deregulation progresses, new nuclear plant orders would depend on fundamental conditions such as the growth in electricity demand, competitiveness of nuclear power generating costs, and confidence in the Utility management of no stranded costs. Supporting institutional mechanisms such as environmental externality and the effort to cultivate confidence in the public for waste management and safety also help. This paper further discusses associated strategies to satisfy the fundamental conditions. This will range from strategies for replacement, technology development, and institutional arrangement to changes in Utility/Industry's structure & business practices.

1. INTRODUCTION

Deregulation of the electricity market has a fundamental potential to alter Utility corporate structure and business practices but it may also alter the power generating sources portfolio through competition in the electricity market. A capital-intensive nuclear power is prone to be considered as bearing such high financial risk that the investment may not be recovered from the competitive market. The conceived impediment to new nuclear plant installation stems not only from economics but political and regulatory instability and also public willingness. Against this background, concerted effort by IAEA membership countries for better use of nuclear power for the benefit and welfare of the public is deemed necessary.

2. NEW PLANT ORDERS IN THE WORLD AND JAPAN

2.1. The historical trend of the world's nuclear power plant orders

The historical trend of the world's nuclear power plant installation shows (Fig. 1):

a) The rapid growth and decline in the 70's and 80's among countries in Western Europe and North America;
b) Some delayed deployment in South and East Asian countries;
c) Active deployment in Japan after a decade of suspension.

The observed regional disparity in today's environment, dorman in Western Europe and North America and active in South and East Asian countries, is due to such factors as new plant deployment in general (fossil or nuclear or other) in regions where electricity demand growth is visible (Fig. 2) and may also correlate to the advent of Utility business deregulation in the specific region and the domestic energy supply portfolio.

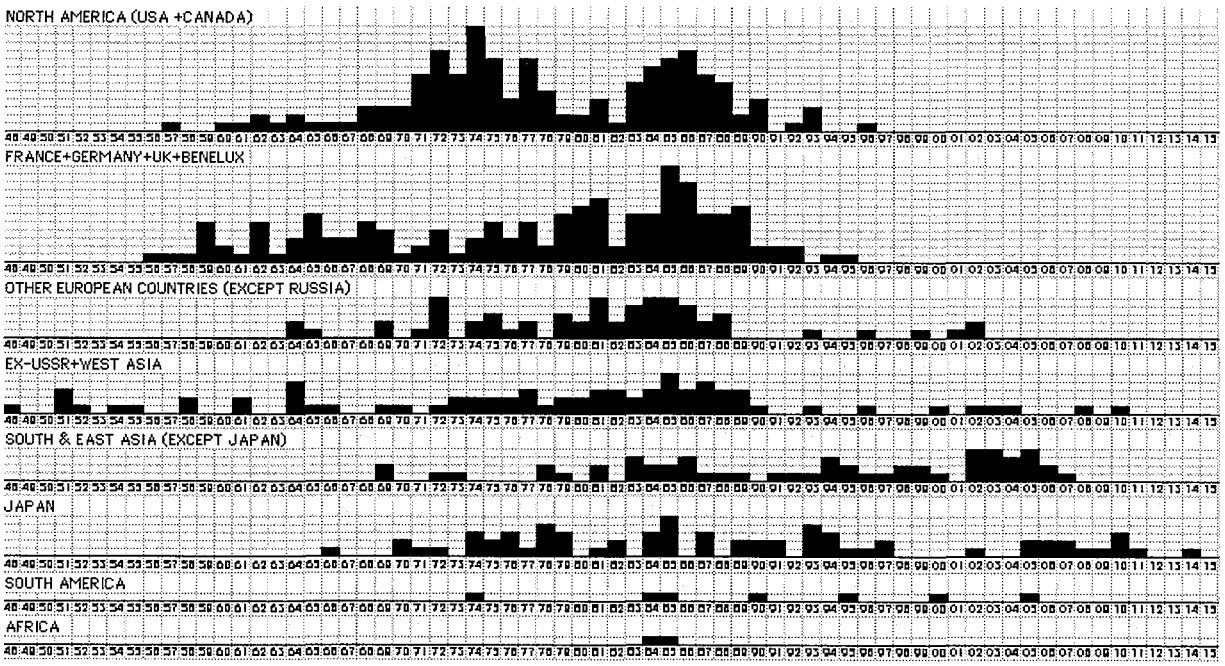


FIG. 1. The history of the world's nuclear power plant installation.

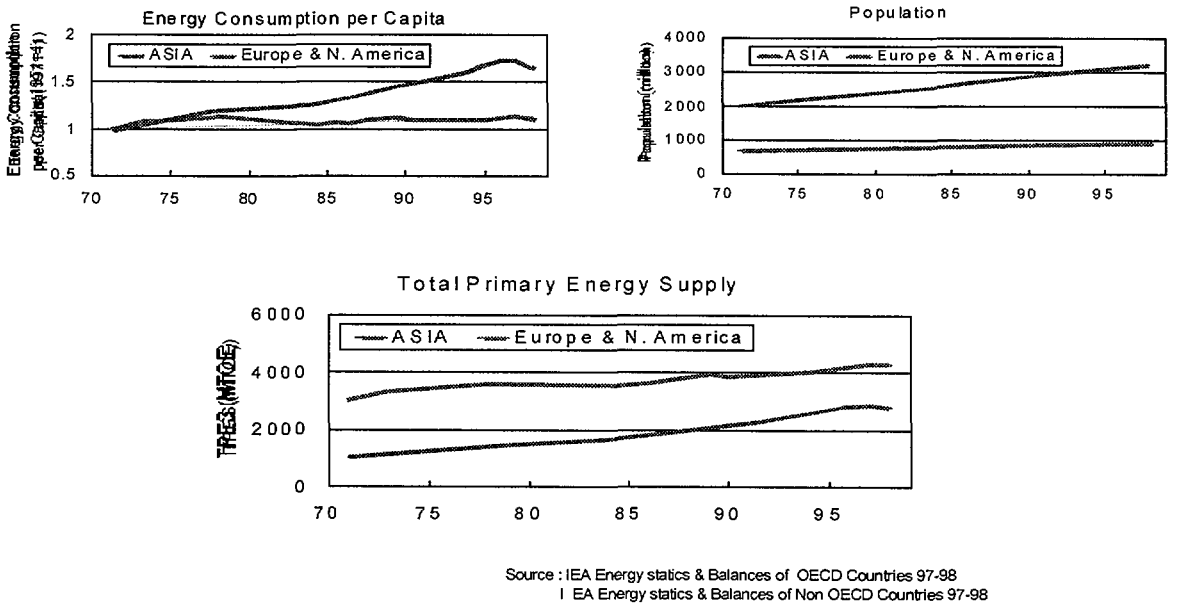


FIG. 2. Comparison of regional growth in the world [1] [2]

In general it is observed that those countries with abundant domestic energy resources such as gas or coal tend to be less aggressively promoting the use of nuclear power than those with a scarcity of domestic resources. Japan, France and Korea typically belong to the latter group and would regard nuclear power as quasi-domestic resources based on the use of technological resources.

2.2. Current nuclear power plant deployment in Japan

2.2.1. New nuclear plant projects

Currently more than a dozen new nuclear plants (10 ABWRs, two other types of BWR, three PWRs) are in various stages of development ranging from planning, environmental surveying, licensing or construction. Most of these will start commercial operation before 2010 (Fig. 3). Of these, construction plans were authorized by the government for at least 6 units, and in the history of Japan, all but one nuclear plants (out of 51 units) were completed once construction plans were authorized.

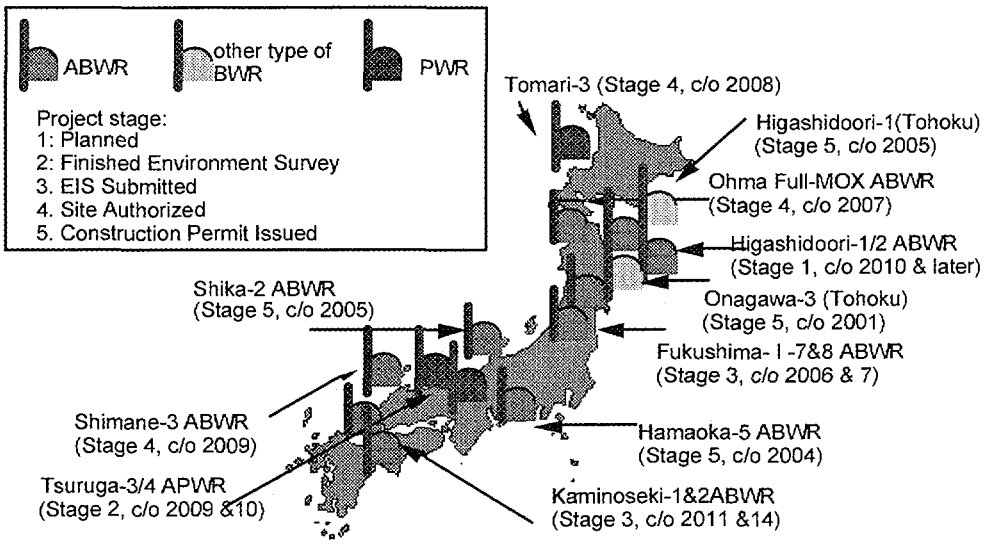


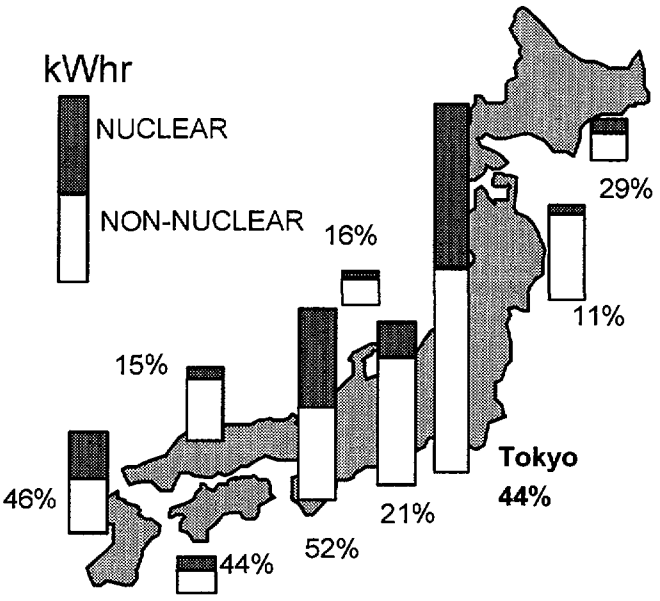
FIG. 3. New nuclear power plant projects.

2.2.2. Utilities incentives

The reasons for this active program in a country where electricity demand growth is relatively mild, especially in the wake of economic depression and Utility business deregulation can be explained as follows;

2.2.2.1. Diversification incentives by regional Utilities

Diversification of power generating sources has caused a strong drive for nuclear power among the Japanese Utilities which once depended on oil for around 80% of its electricity generation, and had experienced serious rate hikes in the wake of Arab Oil Embargo. Currently there is a observable disparity among the loosely-interconnected regional Utilities. Four regional Utilities (mostly large Utility) have a high percentage of electricity production from nuclear power (52%, 46%, 44%, 44%) and the remaining five have less than 30% (mostly 10-20%). It is not by coincidence that those Utilities with less nuclear electricity currently have active nuclear projects in advanced stages.



Kansai	52%
Kyusyu	46%
Tokyo	44%
Shikoku	44%
Hokkaido	29%
Chubu	21%
Hokuriku	16%
Chugoku	15%
Tohoku	11%

FIG. 4. Share of nuclear power of each regional Utility in Japan (FY 1999).

2.2.2.2. Economic perspective

The following estimation by the author for year 2020 is based upon respective Utility's publicly available financial reports that include FY1997-99 costs for power generations. The estimated relative economics of nuclear versus thermal power depends heavily on assumptions for fossil fuel price rise and nuclear fuel cycle cost. Waste disposal cost estimate is included for all types of waste. When asset depreciation progresses and fuel cycle and waste disposal costs are well controlled, nuclear electricity would remain competitive in year 2020 for those units already installed (The estimate included new units with ongoing stage or high probability of construction). This estimate (Fig. 5) is in line with the recent OECD report on nuclear power in deregulated environment [3] and is consistent with the information of current competitiveness of nuclear plants in the US. [4]

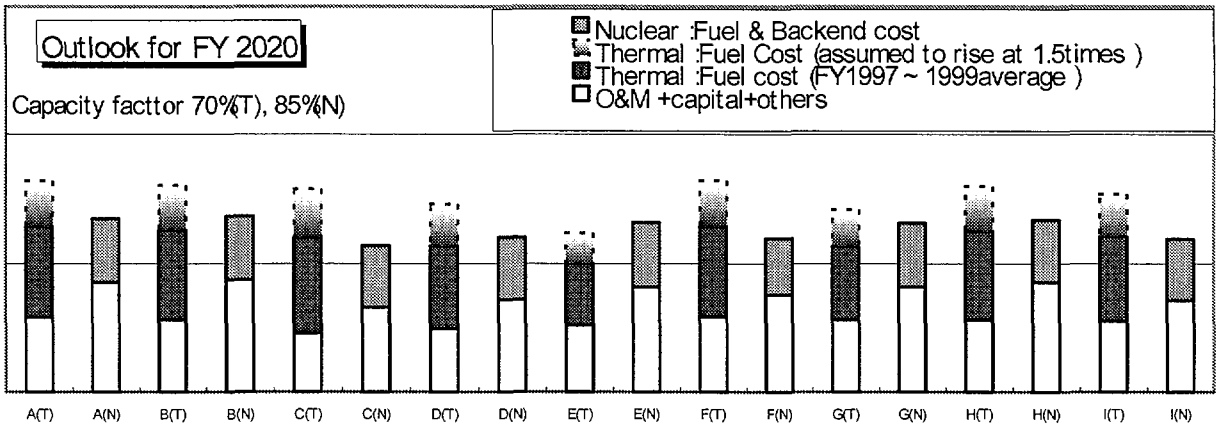


FIG. 5. Estimated economics of fossil/nuclear electricity in 2020.

2.2.2.3. Demand and supply situation

Some Japanese Utilities had seen a reduced reserved margin in the late 80's and the beginning half of 90's (Fig. 6), which motivated an active deployment program for all types of power generating sources. Nuclear power is not necessarily for peak load but its new deployment is affected by demand and supply situation.

New plant projects are now becoming a reality with a certain time delay ("latency effect" due to the long time required for consensus-building in the local community, environmental surveying and licensing.

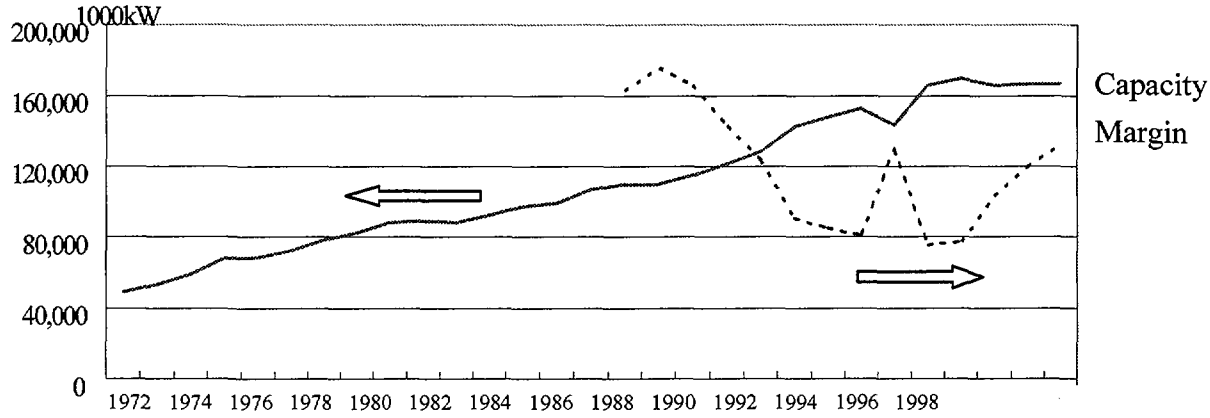


Fig. 6. Demand and supply situation and reserved margin (Japan).

However, a reserved margin is secured for most Utilities today, for instance, the addition of 7GWe to the grid over the last 4 years in a region where no kW increase is observed in the same period of time. Business deregulation starting in March 2000 has the potential to present a serious impediment for Utilities to invest in new capital-intensive nuclear projects in order to avoid financial risk.*

2.2.2.4. Environmental agenda

Utilities are expected to comply with the country-specific emission reduction targets set forth in COP3 (KYOTO, 1997), in which JAPAN promised to reduce global warming gas emission by 6% until year 2010 from 1990 level. [5]

The national plan to achieve this environmental agenda assumes the increased share of electricity from nuclear power by its capacity addition of 20GWe by 2010.

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* Utility business deregulation in Japan.
1st step: Amendment of Utility Business Law (Effective December 1, 1995)
Open the Wholesale Market to IPP & modify cost-plus rate making.
2nd step: Amendment of Utility Business Law (Effective March 1, 2000)
Open retail market to eligible customers (Contract w/ >20kV & >2000KW, 30% kWh)
Transmission lines remain as local monopoly. Access fee determined on the basis of forward-looking cost.
3rd step: Planned for three years later after review of status.

3. CONDITIONS FOR NEW NUCLEAR PLANT ORDERS

Conditions for new nuclear plant orders may vary depending on such factors as the type of ownership (privately owned or state owned) , the energy policy of the specific country of concern, and the level of Utility business deregulation.

However, they will generally rest on the following primary elements:

1) Demand growth and the reserved capacity in the network or connectable network;
2) Competitive power generating cost for new nuclear plants;
3) Supportive institutional mechanisms;
4) Public confidence in plant safety and waste management.

Although it is quite natural that new plant orders are a function of the prospect of electricity demand growth and the reserved capacity in the network or connectable networks, Utility management in deregulated countries tend to avoid investment until confidence is built that the subject investment is certain to be recovered and new plant construction is better than uprating of existing plants or purchase of operating plants from other utilities.

Since existing nuclear plants with asset depreciation well underway are competitive in the market, integrating nuclear power generating costs by using averaged generating costs over the generation of nuclear plants may help offset temporary stranded costs associated with the new nuclear plants.

Current market price of electricity does not account for costs that future generations will have to bear for environmental restorative actions or for incurred price hike due to energy supply security. Hence, it is expected that supporting institutional mechanisms are prepared in order for the decision-makers appropriately to take those factors into consideration when selecting from among alternative power generating sources.
Public confidence, especially nuclear plant safety and waste management, is a pre-requisite for the consensus building in the society. Credibility of people engaged in nuclear business would form the basis of this confidence.

4. ASSOCIATED STRATEGIES TO SATISFY THE CONDITIONS

This chapter raises some examples of strategies that may be considered by nuclear Utilities in order to bring the conceived plans for new nuclear plant to reality. These are relevant to the conditions for new orders discussed in the previous section.

4.1. Integrated nuclear power generating cost

Integrating nuclear power generating costs by using averaged power generating cost over all the generations of nuclear plants may help offset temporary stranded cost associated with new nuclear plants as shown on Fig. 7, because of the gain available through plant life extension*

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* Regulatory system for plant life extension and plant life management [6]
<Life @ start of operation> <institutional life extension mechanism>
Japan **Not specified** Operation of the next cycle after annual government inspection
+**PSR**(every 10 years) / **PLM** (every 10 years after age 25)
where, Japanese **PSR** (Periodic Safety Review) = (1) IPE (individual plant PSA) + (2) Review of operational Experiences + (3) Review against current licensing basis & new findings, and **PLM** = residual life assessment and planning for inspection/replacement for each plant w/age over 25.

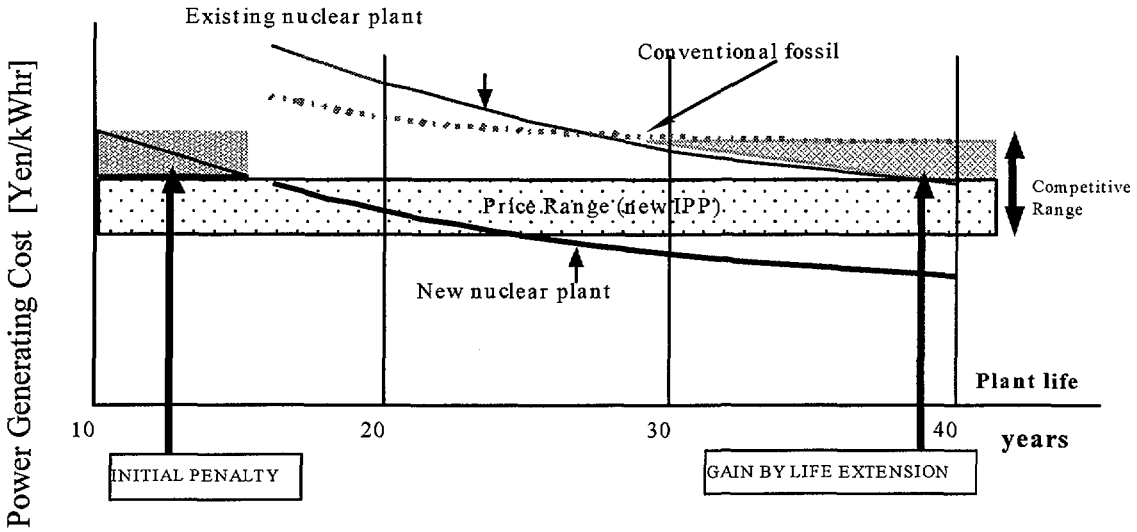

FIG. 7. Integrated nuclear power generating cost.

and power uprating experienced in various countries. Power uprating of existing nuclear power plants would be possible with small incremental cost as compared with the installation of new CCGT in terms of $/kW.

4.2. Levelized & controlled investment at the time of replacement

Japan, for instance, saw a sharp rise of investment in the 1970s. In case replacement of these units is to be planned on a simple programmatic basis that replace old units after pre-determined period expires, Utilities will face a sharp rise in investment. Consequently, we should levelize investment to avoid this situation and we will need a well defined program for replacement and new plant deployment that can be associated with technology development programs. (Fig. 8)

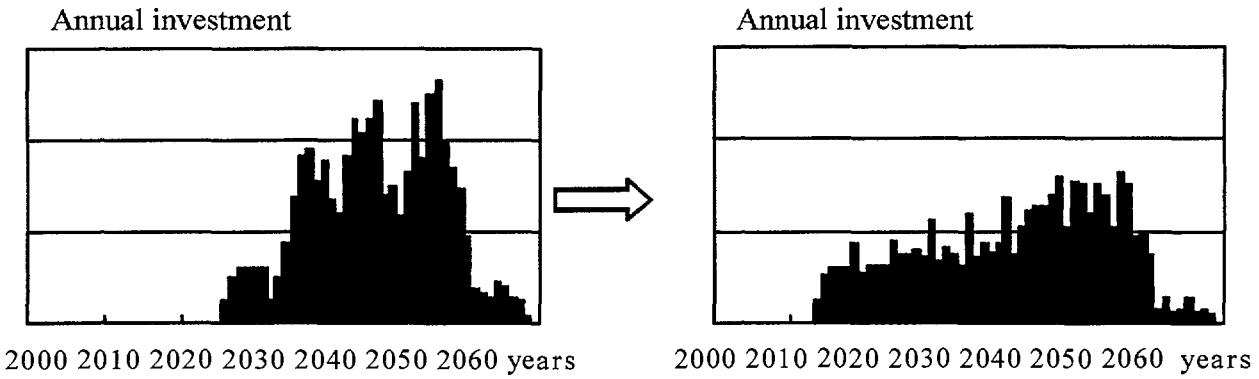

FIG. 8. Levelized investment.

For example, to control investment, a goal is set by TEPCO so that the total investment for new nuclear plant plus decommissioning costs for replaced units is less than the initial investment adjusted for escalation. This is made possible by fully utilizing existing infrastructure (land, harbor, transmission line etc) of existing plant sites and plant upscaling.

4.3. Incremental decrease in capital investment for new series

Standardization is a vitally important part of capital cost reduction. But it is often the case that the FOAK plant of new series is more expensive than the last unit of the previous series. This is relevant to the definition of the number of units for the recovery of T&D (Test &Development) and D&E (Design & Engineering) costs. The goal in TEPCO is that Δ1 is less than zero to smooth the transition and to control the T&D plus D&E costs in a reasonable range (Fig. 9). If the T&D plus D&E costs are to be recovered by the first four units of the series, it is shown that ABWR has achieved Δ 1 of almost zero as follows:

Δ 1 (ABWR(FOAK)-BWR5(Standardized))=-26$/kW
Δ 2 (ABWR(Standardized)-BWR5(Standardized))= -700$/kW due to standardization/scope split/others.
Naturally, TEPCO expects that Δ1 (ABWR-II(FOAK)-ABWR(Standardized)) would be less than zero, and
Δ 2 (ABWR-II(Standardized)-ABWR(Standardized)) would be minus 20-30% in terms of the magnitude of change.

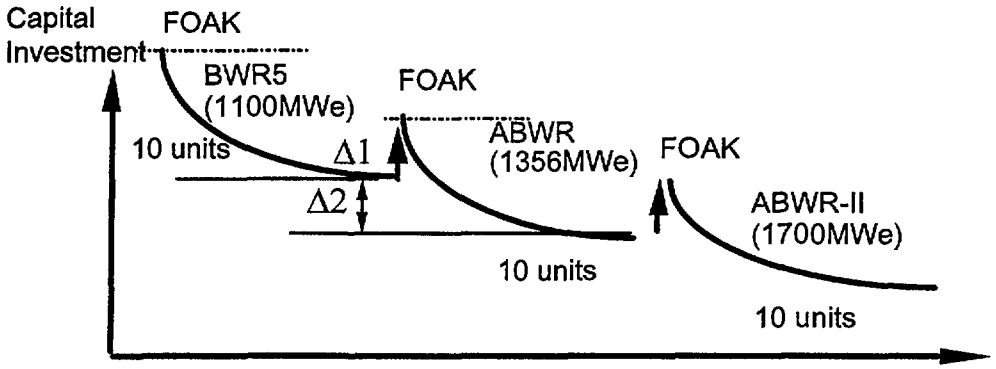

FIG. 9. Relative capital cost between series.

4.4. Control of Waste & Fuel (downstream) cost

As the investment level ($/kW) decreases by better technology and design and by high availability, waste & fuel (downstream) costs hold an increased share in nuclear power generating costs, especially in the case of countries with recycling policy. Without strict control of these costs, nuclear power will lose its competitive edge.

4.5. Change in Utility/Industry's structure & business practices

Re-organization of the nuclear industry including making alliances, M&A and expanding the business into international customer portfolios is visible in the shrinking nuclear market in OECD countries. On the part of Utilities, alliances for sharing resources among power stations or Utilities, M&A, purchase of operating units, and the transfer of good O&M practices to others are also prevailing. These changes in Utility and Industry's structure &

business practices would further enhance productivity of nuclear power and improve its competitiveness in the electricity market. Use of Information Technology to control the large volume of information for new plant design and construction will enable D&E cost reduction through concurrent engineering, will be beneficial in procurement in the e-market, and will help configuration management of plants after they start operation. In the case of TEPCO, some 200,000 design documents and 50m thick files of QA records are produced for each unit. The use of digital information control and project management tools such as ProjectNet is considered for pilot use for new nuclear facility in the next Fiscal Year in TEPCO. Also, a new form of collaboration by NSS vendors for T&D and D&E, "Virtual electronic consortium" is envisioned for the next generation BWR technology development.

4.6. Regulatory change

Modernization is expected, based on operational experiences and the advent of risk analysis methodology, for nuclear-related regulations in the area where the incremental cost increase associated with regulation does not positively correlate to the benefit of risk reduction. Utilities expect such regulatory changes as rated thermal power operation, extended operational cycle and use of risk information. It is estimated that the these, if permitted, would result in availability increase of more than 5%. Graded QA based on risk insight would enable equipment procurement from a large market and contribute to capital cost reduction.

4.7. Diversified options for future uncertainty

As Walt Patterson discusses in a book titled "Transforming Electricity" [7], two diverging paths into the future may exist for the future power generation. In fact, micro gas turbine and fuel cell technologies, although their share is limited, have a potential for energy supply that bypasses existing transportation/transmission networks. Decentralization would depend on technical achievement as well as economics that provide higher energy efficiency and versatility in the energy market.

4.8. Institutional scheme

As discussed previously (Chapter 3), the current market price of electricity do not account for the costs that future generations have to bear for environmental remedial actions or for incurred price hikes due to energy supply security.

This, combined with other factors, would raise a question on how to let both "energy policy agenda "and "market principle" stand. Consideration of such factors as environmental externalities will be necessary for decision-makers in selecting from among power generating sources. International organizations can help to establishing a defacto standard in external cost evaluation to be used in this process.

TABLE I. COMPARISON OF ENVIRONMENTAL EXTERNALITY [8]

		Coal & lignite	Oil	Gas	Nuclear	Biomass
Range (mECU/kWh)	Min	18	26	5	2.4	1
	Max	150	109	30	7.4	29

4.9. Public confidence in plant safety and waste management

Public perception of radiation and nuclear safety is a key in building a consensus for new plants. Of particular importance in today's environment are waste disposal (for which a significant progress is being made for HLW) and Spent Fuel Storage. Renewed public support for nuclear power is possible through providing the public with information to support their judgment, energy education in schools, accuracy in media reporting, and credibility of people engaged in the nuclear business.

Expected characteristics for the new nuclear plant design have been set as a candidate for replacement of existing nuclear plants. Neighbour friendly nature [Safety] as well as consumer friendliness [Economics] and user-friendliness constitute an essential part of the requirement for such designs. Neighbour friendliness requirement was defined in Japan for the design of next generation reactors in a way to comply with objectives of no evacuation and no land contamination. [9]

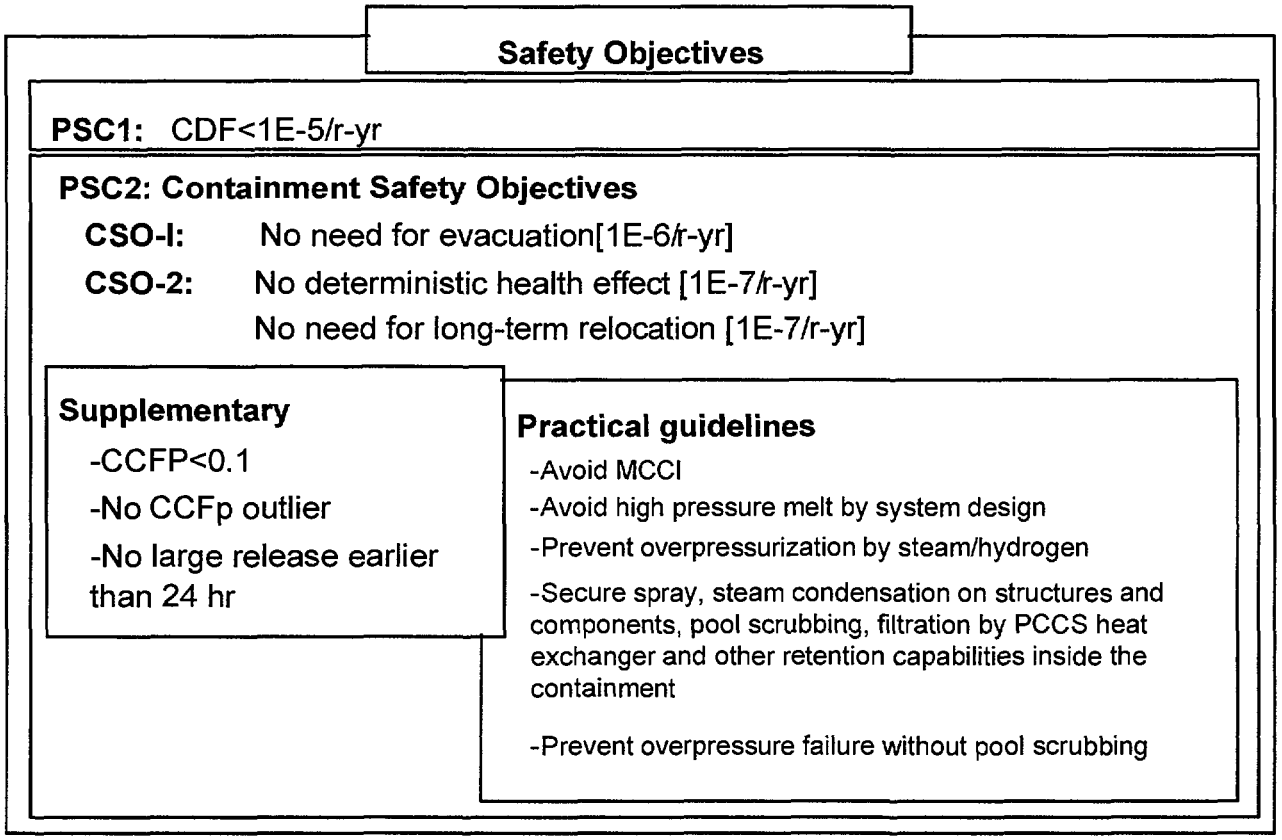

FIG. 10. Safety objectives for the next generation LWRs.

4.10. End-use approach

Deregulation of the Utility business provides Utilities with the opportunity to extend their services beyond just producing/transmitting/selling electricity. Looking at the advent of the technologies in the future, Utilities, as energy companies, can think about energy supply in the form of not only electricity and gas but also methanol or hydrogen. A simple calculation shows that if all the automobile is converted to EV and its electricity is supplied from nuclear

power (equivalent to 20 ABWRs), we can save greenhouse gas emission by 20%. Use of nuclear power to supply alternative form of energy (heat, hydrogen, methanol) supply also have a potential to expand the horizon.

4.11. Technology development

Technological advance is at the root of any successful business.
Advanced technology development is actively being pursued in areas such as passive safety system, condition monitoring & inspection using micro-technology, new materials (cathode protection by photo-catalyst workable in Cherenkov radiation environment, shape memory alloy, self-diagnosis capabilities), simulation, and new structure (steel-sided wall & floor, seismic isolation, magnetic dumper) and so on for application for new plants.

5. CONCLUSIONS

Ongoing nuclear projects Japan have their background in diversification incentives, power generating costs perspective, demand and supply situations, and environmental agenda shared by the public and private sectors.

Conditions for new nuclear plant orders will be summarized as, a) demand growth and the reserved capacity in the network or connectable networks, b) competitive power generating costs for new nuclear plants, c) supporting institutional mechanism, and d) public confidence in waste management and safety.

Associated strategies to satisfy the above conditions would range from an investment strategy at the time of replacement, cost control target to Institutional scheme. Concerted efforts by Utility, Industry and the Government will smooth the way for revitalization of nuclear power including new plant orders.

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