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Original Article

Innovative Nuclear Power Plant Building Arrangement in Consideration of Decommissioning

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ABSTRACT

A new concept termed the Innovative Nuclear Power Plant Building Arrangement (INBA) strategy is a new nuclear power plant building arrangement method which encompasses upfront consideration of more efficient decommissioning. Although existing decommissioning strategies such as immediate dismantling and differed dismantling has the advantage of either early site restoration or radioactive decommissioning waste reduction, the INBA strategy has the advantages of both strategies. In this research paper, the concept and the implementation method of the INBA strategy will be described. Two primary benefits will be further described: (1) early site restoration; and (2) radioactive waste reduction. Several other potential benefits will also be identified. For the estimation of economic benefit, the INBA strategy, with two primary benefits, will be compared with the immediate dismantling strategy. The effect of a short life cycle nuclear power plant in combination with the INBA strategy will be reviewed. Finally, some of the major impediments to the realization of this strategy will be discussed.

1. Introduction

A nuclear power plant has to be decommissioned at the end of its designed lifetime. However, unlike other power plants, it requires a unique decommissioning process which involves radiation protection, decontamination, spent fuel treatment, and radioactive waste disposal due to potential radioactive contamination.

There are two primary decommissioning strategies for a nuclear power plant: immediate dismantling and deferred dismantling. In the immediate dismantling strategy, decommissioning is started immediately after the permanent shutdown of a nuclear power plant, giving a benefit of recovery and being able to reuse the decommissioned site quickly. The deferred dismantling strategy incorporates a 40–60 years safe storage period after permanent shutdown. It reduces radiation exposure and the radioactive waste generated by decommissioning.

A utility company planning to decommission a nuclear power plant currently chooses either the immediate

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dismantling strategy for early utilization of the site or the deferred dismantling for lower radiation exposure and reduced radioactive waste generation.

The Innovative Nuclear Power Plant Building Arrangement (INBA) strategy combines the advantages of both the immediate dismantling and the deferred dismantling strategy with solving the dilemma of a utility company in choosing a decommissioning strategy.

2. Concept and operation

2.1. *Concept of the INBA strategy*

The key idea of the INBA strategy is the circulative utilization of the nuclear power plant site. The INBA strategy, as shown in Fig. 1, allocates an additional space for future construction of containment (CONT) buildings, auxiliary (AUX) buildings, and a compound building. This allows for the rapid construction of new nuclear power plants on the site while providing for safe storage of the old nuclear power plants at the same time.

2.2. *Operating method of the INBA strategy*

The INBA strategy is implemented as follows.

In Phase 1, two units of a nuclear power plant are constructed with a space set aside for future construction as shown in Fig. 1. The plants are then operated for their designed lifetime.

In Phase 2, the nuclear power plants which have reached the end of their designed lifetime are decommissioned immediately. However, by contrast to conventional decommissioning strategy, only the Turbine-Generator (T/G) buildings are dismantled, and the CONT buildings, the AUX buildings, and the compound building are not dismantled (Fig. 2).

In Phase 3, new nuclear power plants are constructed on the site of the dismantled T/G buildings and the previously allocated empty space. The new plants are then operated until the end of their designed lifetime (Fig. 3). During the construction and operation of the new nuclear power plants, the CONT buildings, the AUX buildings, and the compound building from the nuclear power plants are maintained in a safe storage condition.

In Phase 4, when the designed lifetime of the new nuclear power plants is over, their T/G buildings are dismantled immediately except for the CONT buildings, the AUX buildings, and the compound building. However, in this phase, the CONT buildings, the AUX buildings, and the compound building of the old nuclear power plants, which have been under safe storage condition, are dismantled at the same time (Fig. 4). After decommissioning is completed, new nuclear power plants are constructed on the decommissioned site and operated (Fig. 5).

3. Benefits of the INBA strategy

The primary advantage of the INBA strategy is that early site restoration, the advantage of immediate dismantling strategy and radioactive waste reduction, and the advantage of deferred dismantling strategy can be accomplished concurrently. There are also some additionally expected benefits of the INBA strategy which are not guaranteed but highly probable such as maintenance cost reduction for CONT and AUX buildings during their safe storage period, and the reuse of some structures of retired nuclear power plants.

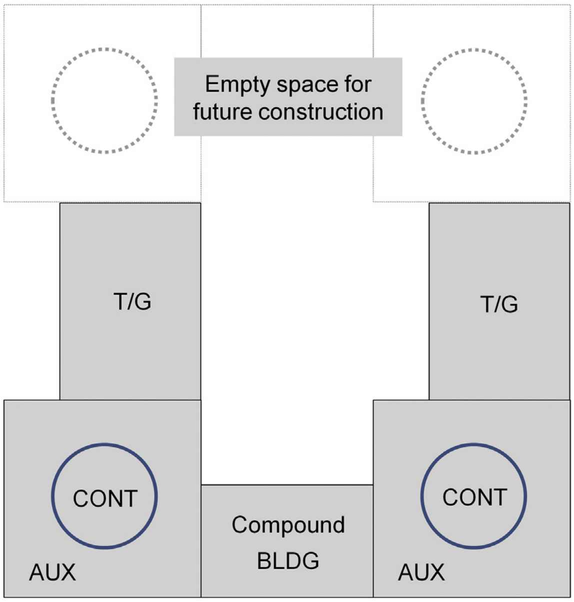

Fig. 1 – Site arrangement for the INBA strategy. AUX, auxiliary; BLDG, building; CONT, containment; INBA, innovative nuclear power plant building arrangement; T/G, turbine-generator.

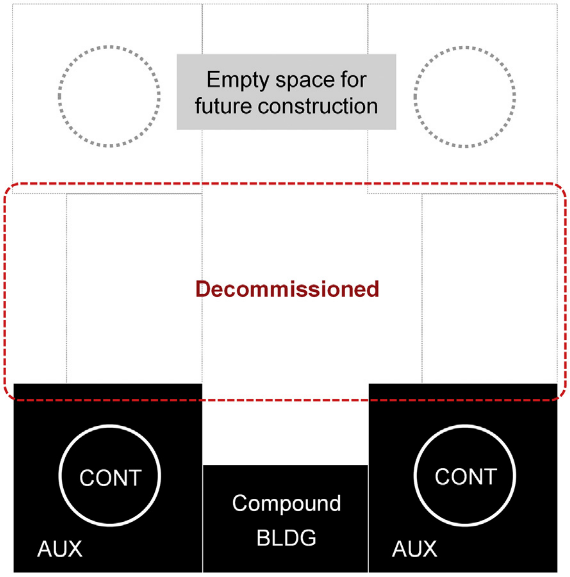

Fig. 2 – Retired (1st) nuclear power plants' T/G buildings dismantling. AUX, auxiliary; BLDG, building; CONT, containment; T/G, turbine-generator.

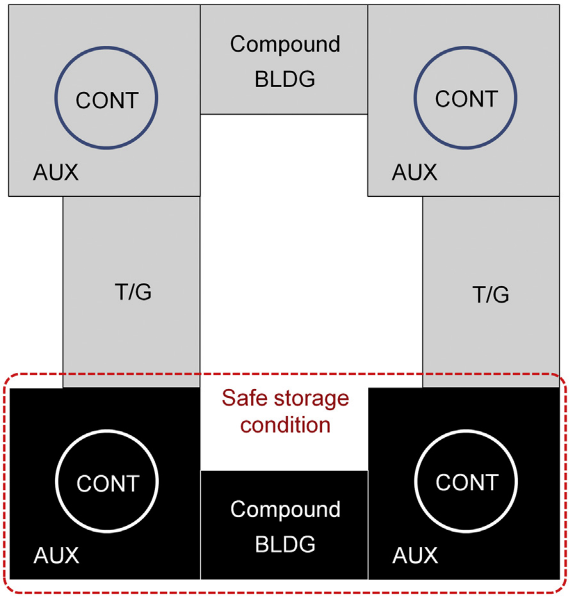

Fig. 3 – Construction and operation of new (2nd) nuclear power plants. AUX, auxiliary; BLDG, building; CONT, containment; T/G, turbine-generator.

3.1. *Early site recovery*

The first main advantage of the INBA strategy is that the site can be restored earlier than other decommissioning strategies. If three strategies are applied to APR1400 nuclear power plants with a standard life cycle composed of 5 years construction, 60 years operation, 5 years spent fuel residual heat removal period, and 7 years decommissioning respectively, one cycle of a nuclear power plant takes only 72 years in the INBA strategy whereas it takes 77 years in the immediate dismantling strategy and 127 years in the deferred dismantling strategy with 50 years safe storage period (Table 1).

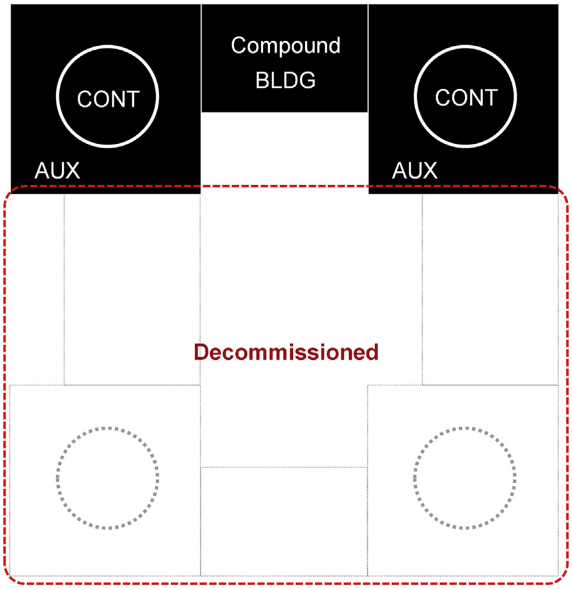

Fig. 4 – Dismantling T/G buildings of new (2nd) nuclear power plants and CONT buildings, AUX buildings, and a compound building of (1st) retired nuclear power plants. AUX, auxiliary; BLDG, building; CONT, containment, T/G, turbine-generator.

In this research paper, it is assumed that the 7 years decommissioning process can be separated into two parts: uncontaminated area (T/G building) dismantling within 2 years and contaminated area (CONT, AUX, compound building) dismantling within 5 years. In the INBA strategy, only the uncontaminated area is immediately dismantled, and a new nuclear power plant is constructed on the site of the decommissioned T/G buildings and the additional empty space, whereas the contaminated area dismantling is delayed until the second nuclear power plant's uncontaminated area is dismantled. The use of this strategy, the required time for decommissioning can be shortened from 7 years to 2 years, and this enables site restoration and new nuclear power plant construction to begin 5 years earlier than the time required for the immediate dismantling strategy.

3.2. *Radioactive decommissioning waste reduction*

The second main advantage of the INBA strategy is the reduction in radioactive waste generated from decommissioning. According to the Nuclear Regulatory Commission (NRC) NUREG/CR-0130, ~90% of radioactive waste volume is reduced after 50 years of safe storage (Table 2) [1]. Radioactive waste reduction for an additional 50 years of safe storage is not significant because Class A radioactive waste which has a short half-life is substantially reduced by the end of the first 50 years of safe storage and radioactive waste above Class A has a much longer half-life and is not reduced to a significant extent by an additional 50 years of safe storage.

In the application of the INBA strategy to the APR1400 with a standard life cycle, 74 years of safe storage is allowed for the CONT and AUX buildings. A reduction of 90% is expected for radioactive waste for this scenario.

This significant reduction in radioactive waste volume is a great benefit for countries such as South Korea where the cost of radioactive waste disposal is high (Table 3) [2].

3.3. *Additional benefits*

There are several tertiary benefits to the INBA strategy also:(1) maintenance cost for safe storage of the CONT buildings, the AUX buildings, and the compound building is reduced by sharing resources for safe storage with the new nuclear power plants that are operating adjacent to those buildings; (2) some structures of the retired nuclear power plants such as the T/G building foundation and sea water inlet/outlet structure can be reused. If feasible, reusing of these structures will save both construction time and cost for new nuclear power plants and dismantling time and cost for retired nuclear power plants as well as reducing the quantity of decommissioning waste; and. (3) spent fuel from the retired nuclear power plants can be stored in the AUX buildings during the safe storage period without the construction and operation of an interim spent fuel storage facility. Many decommissioning projects in the United States have chosen the construction of an interim storage facility instead of renovating the spent fuel pools in AUX buildings to an isolated spent fuel pool island based on an

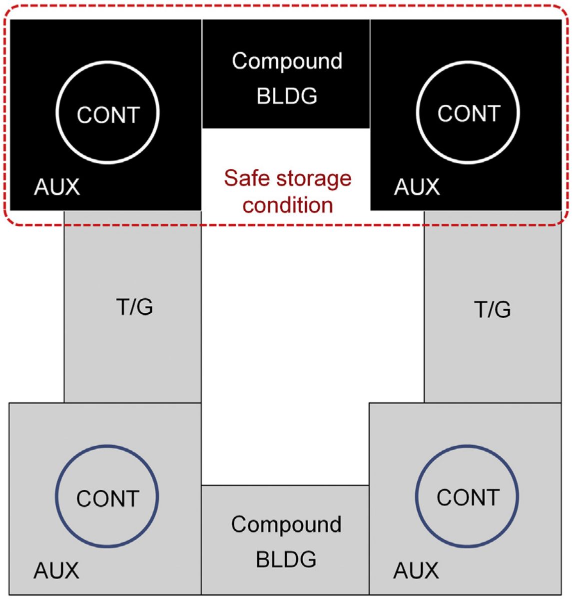

Fig. 5 – Construction and operation of new (3rd) nuclear power plants. AUX, auxiliary; BLDG, building; CONT, containment; T/G, turbine-generator.

economic comparison of those two options. However, storing spent fuel in an isolated spent fuel pool island might be more economical if there was an operating nuclear power plant adjacent to the AUX buildings that supplied the resources to maintain it with marginal cost (e.g., Dresden Unit 1 in USA, adjacent to operating Units 2 and 3). Those potential benefits require additional investigation and evaluation to prove their practicality, but if they are realized, it will improve the economics of the INBA strategy significantly.

4. Economic impact of the INBA strategy

4.1. *Methodology*

Two scenarios have been selected for a comparison in order to estimate the economic impact of the two primary advantages of the INBA strategy. Scenario 1 is based on a current nuclear power building arrangement that implements an immediate dismantling strategy, and Scenario 2 is based on a nuclear power plant that selected a building arrangement following the INBA strategy.

As part of the comparison, the 5 years difference in life cycle between Scenarios 1 and 2 needs to be accounted for. The best way to compare two scenarios which have a different life cycle is to perform estimates during the least common multiple period. Instead, in this paper, another Scenario 2 is projected to the extra 5years in Scenario 2. As a result, the modified Scenario 2 has 77 years life cycle which is the same duration as for Scenario 1, and an additional 4.17 years operation period (Fig. 6).

In the economic comparison, the total cost, revenue, profit, and power generation of the two scenarios are estimated and compared.

4.2. *Cost*

There are several recent studies which address the cost of nuclear power plants in Korea. As shown in Table 4, results from three recent studies are similar if the effect of the different capacity factors applied to each study is excluded [3]. In this research paper, the cost data of the latest study by the Korea Environment Institute, Sejong, Korea is applied with the exception of the construction cost.

Construction cost is determined by the average construction cost of two recently built APR 1400 nuclear power plants (Table 5) [4] in place of the 22.6 KRW/kWh in Table 4.

The construction cost of Scenario 2 is higher than Scenario 1. Scenario 2 requires an additional space to implement the INBA strategy. This increases the land cost of Scenario 2. Table 6 lists the land space occupied by each building in two units of APR1400. The additional space required for Scenario 2 is consistent with the land size for two CONT buildings, AUX buildings, and a compound building which is 237,988 ft^2. It is 63% larger than the land size of Scenario 1 and increases the land cost from 17 billion Korean Won (KRW) (see Table 5) to 27 billion KRW. Due to the increased land cost, the total construction cost of Scenario 2 is increased to 6,441 billion KRW which equates to 2,300,539 KRW/kW.

In order to convert the construction cost to levelized construction cost, the following equation and parameters are applied.

$$\text{Levelized construction cost} = \frac{Construction\ cost\ per\ kW \times Fixed\ charged\ rate}{365 \times 24 \times cf \times (1 - ipc)} \tag{1}$$

where fixed charged cost = 0.006462, *cf* (capacity factor) = 80%, *ipc* (internal power consumption) = 4%

The fixed charged cost is calculated from the following equation and parameters.

$$\text{Fixed charged rate} = \frac{i \times (1+i)^n}{(1+i)^n - 1} \tag{2}$$

where *i* (discount rate) = 6%, *n* (life cycle of a power plant) = 40 years.

With this formula, the levelized construction cost is calculated as 22.7 KRW/kWh for Scenario 1 and 22.7 KRW/kWh for modified Scenario 2.

The decommissioning cost for Scenario 2 also needs to be adjusted for the radioactive waste disposal cost reduction due to safe storage for CONT and AUX buildings. This research paper assumes that 40% of the decommissioning cost is for radioactive waste disposal, and conservatively, 60% of it is reduced by 74 years of safe storage. By this accounting, the

Table 1 – Life cycle comparison in various strategies.

Activity	Duration (yr)	Activity	Duration (yr)	Activity	Duration (yr)
Construction	5	Construction	5	Construction	5
Operation	60	Operation	60	Operation	60
SF residual heat removal	5	SF residual heat removal	5	SF residual heat removal	50
Safe storage	50	Decommissioning	7	Decommissioning (T/G buildings)	2
Decommissioning	7	–	–	Decommissioning (Other buildings)	0
Total	127	Total	77	Total	72
(Conventional design & deferred dismantling)		(Conventional design & immediate dismantling)		(INBA)	

INBA, innovative nuclear power plant building arrangement; SF, spent fuel.

Table 2 – Radioactive waste reduction for varying safe storage periods.

Strategy		Class A volume	Class B volume	Class C volume	Exceeds Class C volume	Total volume
Immediate dismantling (m^3)		17,521	214	17	133	17,885
Deferred dismantling (m^3)	30-yr	17,615	123	17	133	17,888
	50-yr	1,565	115	17	133	1,830
	100-yr	1,530	100	17	133	1,780

levelized decommissioning cost for modified Scenario 2 is 3.61 KRW/kWh.

From the above calculations, the total power generation cost is 49 KRW/kWh for Scenario 1 and 48.3 KRW/kWh for Scenario 2 (Table 7) [5].

4.3. *Revenue*

The revenue of a nuclear power plant is derived from the sale of electric power. In this research paper, the revenues of Scenarios 1 and 2 are calculated based on the average electric power market price between Korean Hydro and Nuclear Power (KHNP) and Korean Power Exchange (KPX) in 2014 (Table 8). An 80% capacity factor and 4% internal power consumption are assumed. The total revenue of modified Scenario 2 is higher than Scenario 1 due to an additional 4.17 years of power generation.

4.4. *Economic estimation result*

Generally, in an economic estimation, all values are converted to net present values (NPV). The additional power generation period in modified Scenario 2 is one of the main advantages of the INBA strategy. However, this period is positioned at the end of the life cycle and it is underestimated when converted to NPV with the application of 6% discount rate and 0% inflation rate. Therefore, in this research paper, two scenarios are estimated and compared with low inflation (6% discount rate and 0% inflation rate) and high inflation (6% discount rate and 6% inflation rate). In case of the estimation with high inflation, the discount rate is assumed to be cancelled out by the inflation rate.

Table 3 – Radioactive waste disposal cost in various countries.

Country	Waste type	Disposal cost (million KRW/m^3)
South Korea	MLW/LLW	66.5
United States	LLW	24.5
United Kingdom	MLW	16.4
	LLW	1.6
France	MLW/LLW (short term)	4.6
	LLW (long term)	6.5
	Under LLW	0.69

LLW, Low-level waste; MLW, Medium-level waste.

4.5. *Economic estimation with low inflation*

In order to convert values to NPV, the following equation and parameters are applied.

$$Present\ value = \sum_{t=1}^{n} \frac{Cash\ Flow_t}{(1+i)^t} \quad (3)$$

where n (life cycle) = 77 years, i (discount rate) = 6%.

$$Cash\,flow_t = Revenue_t - Cost_t \quad (4)$$

The economic estimation results of Scenarios 1 and 2 with low inflation are summarized in Table 9.

Compared with Scenario 1, the total cost of modified Scenario 2 is decreased by ~1%. This is primarily associated with the savings due to reduced radioactive waste disposal cost with 74 years safe storage for the CONT and AUX buildings being slightly higher than that of the land cost increase for the additional space required in Scenario 2. The total revenue of Scenario 2 is increased by ~0.5% as a result of the additional 4.17 years of increased power generation due to early site restoration in the INBA strategy. The total profit is increased by ~12% in Scenario 2 in which 11.4% is contributed by radioactive waste disposal cost reduction, and ~0.5% is associated with the additional 4.17 years of power generation. The contribution of the additional power generation period to the increase of total profit is much smaller than the ~7% of increased power generation due to the application of low inflation.

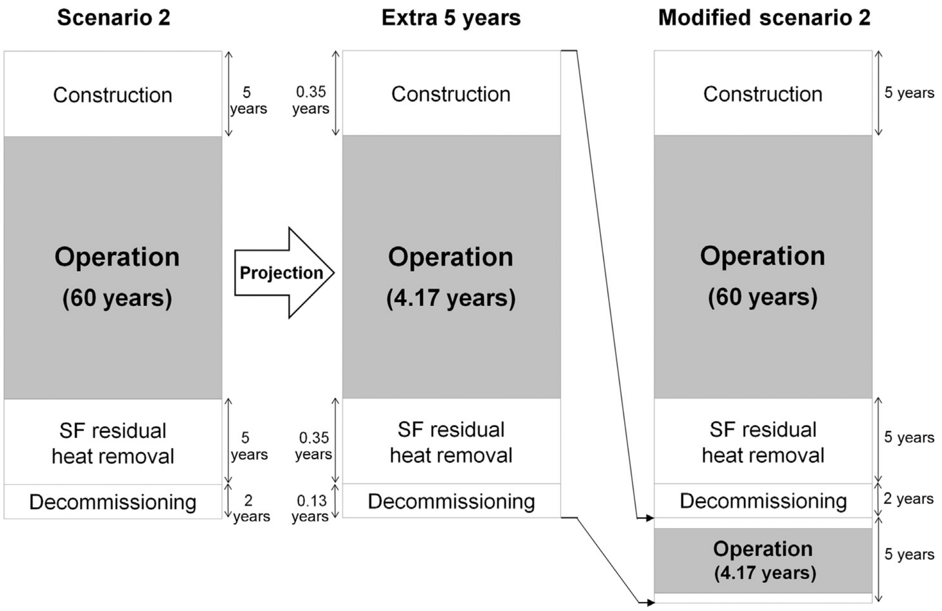

Fig. 6 – Modified Scenario 2 by projection. SF, spent fuel.

4.6. *Economic estimation with high inflation*

The economic estimation results of Scenarios 1 and 2 with high inflation are shown in Table 10. Compared with Scenario 1, the total cost of Scenario 2 is increased by ~5.5%. This is because the impact of the cost increase during the 4.17 years of additional power generation is not reduced in the high inflation case and overcomes the impact of radioactive waste disposal cost reduction. The total revenue for Scenario 2 is increased by ~7% which is same amount of the total power generation increase. The total profit is increased by ~19% in Scenario 2 in which 11.4% is contributed by radioactive waste disposal cost reduction, and ~8% is associated with 4.17 years of additional power generation. As shown, the impact of the total power generation increase in Scenario 2 is significantly increased when evaluated with high inflation.

Table 4 – Nuclear power generation cost analysis in recent studies.

Item	6th Power supply plan (Feb 2013)	2nd Energy basic plan working group (Nov 2013)	Korea Environment Institute (Dec 2013)
Construction cost (KRW/kWh)	22.1	22.1	22.6
O&M cost (KRW/kWh)	16.1	16.1	19.7
Fuel cost (KRW/kWh)	3.7	3.7	6.6
Levelized power generation cost (KRW/kWh)	41.9	43.02–47.93	48.8
Capacity factor (%)	90	80–90	80

5. INBA strategy with a short life cycle nuclear power plant

The economic impact of the INBA strategy is significantly increased with a short life cycle nuclear power plant. It is assumed that the INBA strategy can be applied to two different types of nuclear power plants: Type A with a 40-year operational period and Type B with a 60-year operational period. When the INBA strategy is applied, the decommissioning period for both types is reduced from 7 years to 2 years. As shown in Table 11, the increase of the operation period shared in the life cycle in Type A is higher than for Type B.

A nuclear power plant with a short life cycle increases the impact of the INBA strategy but also involves additional costs. The profit increase or decrease factors are discussed in following sections.

5.1. *Profit-increase factors*

(1) A short life cycle nuclear power plant reduces costs by replacing long lifetime facilities and equipment with short lifetime thus driving cost down, e.g., the price of cables with a 40 year lifetime is significantly less than cables with a 60 year lifetime; (2) a short life cycle nuclear power plant can reduce maintenance costs. Various facilities and equipment in a nuclear power plant need to be repaired and replaced before the end of its designed lifetime. If the life cycle of a nuclear power plant is reduced, the maintenance requirements and costs are also reduced. For example, a generator needs to be rewound after 30–40 years. The cost for generator rewinding would not be applicable to a nuclear power plant with a short life cycle; and (3) as indicated, a nuclear power plant with a short life cycle combined with the INBA strategy can increase the power generation period further than a nuclear power plant with a long life cycle.

Table 5 – Construction cost of APR1400.

Item				Shin Kori Unit 3,4	Shin Hanul Unit 1,2	Average construction cost (2 units)
Pure construction cost (billion KRW)	Direct cost	Equipment cost	NSSS	1,649.7	1,435.7	1,542.7
			T/G	360.8	369.8	365.3
			BOP	1,292.8	1,354.4	1,323.6
		Construction cost		1,402.5	1,215.9	1,309.2
		Subtotal		4,705.9	4,375.7	4,540.8
	Indirect cost	A/E cost		426.2	525.3	475.75
		Administrative expense		212.0	197.3	204.65
		Foreign capital management cost		14.3	25.9	20.1
		Land cost		23.9	9.7	16.8
		Contingency		252.0	210.7	231.35
		Subtotal		928.4	968.9	948.65
	Subtotal			5,634.2	5,344.6	5,489.4
Interest during construction (billion KRW)				1,012.2	870.8	941.5
Total construction cost (billion KRW)				6,646.4	6,215.5	6,430.95
Total construction cost per kW (thousand KRW)				2,373.7	2,219.8	2,296.77

T/G, turbine-generator.

Table 6 – Land size for buildings in APR1400 design (2 units).

Item	Land size (ft^2)
Containment building	37,254
AUX building	162,286
T/G building	140,280
Compound building	38,448
Total	378,268

AUX, auxiliary, T/G, turbine-generator.

5.2. *Profit-decrease factors*

In a short life cycle nuclear power plant, the fixed costs are higher than for a long life cycle plant. Although variable costs, such as Operation and Maintenance (O&M) cost, fuel cost, and spent fuel management cost are proportional to the operation period, the fixed costs such as construction cost and decommissioning cost are independent from the operation period. When the operation period is shortened, the total power generation in the life cycle is reduced thus increasing the fixed cost per kWh of the nuclear power plant.

The combination of a nuclear power plant with a short life cycle and the INBA strategy has numerous pros and cons, and it is unclear whether the impact of INBA strategy is economically positive or negative. A more through estimation is required to draw conclusions.

Table 7 – Power generation cost of Scenarios 1 and 2.

Item	Levelized cost (KRW/kWh)	
	Scenario 1	Scenario 2
Construction cost	22.69	22.74
Fuel cost	6.6	
Spent fuel management cost	1.8	
Pure O&M cost	13.6	
Decommissioning cost	4.3	3.61
Total	48.99	48.34

Table 8 – Average electric power market price between KHNP and KPX in 2014 (KPX website).

Month	Price (KRW/kWh)
Jan	58.89
Feb	57.62
Mar	61.37
Apr	57.49
May	55.35
Jun	52.87
Jul	58.95
Aug	54.57
Sep	49.92
Oct	52.17
Nov	52.86
Dec	44.35
Average	54.70

KHNP, Korean Hydro and Nuclear Power; KPX, Korean Power Exchange.

6. Limitations

The implementation of the INBA strategy poses many detailed challenges before it can be realized: (1) the existing APR1400 design must be redesigned or modified for application of the

Table 9 – Economic comparison of Scenarios 1 and 2 with low inflation.

Item	Scenario 1	Scenario 2	Variation	Variation (%)
Total cost (million KRW)	11,813,574	11,707,854	−105,720	−0.89
Total revenue (million KRW)	13,190,672	13,248,624	57,951	0.44
Total profit (million KRW)	1,377,097	1,540,769	163,671	11.89
Total power generation (million kWh)	565,125	604,401	39,276	6.95

Table 10 – Economic comparison of Scenarios 1 and 2 with high inflation.

Item	Scenario 1	Scenario 2	Variation	Variation (%)
Total cost (million KRW)	55,370,230	58,429,067	3,058,837	5.52
Total revenue (million KRW)	61,824,688	66,118,412	4,293,724	6.95
Total profit (million KRW)	6,454,457	7,689,345	1,234,887	19.13
Total power generation (million kWh)	565,125	604,401	39,276	6.95

Table 11 – Impact of the INBA strategy for different life cycles.

Item	Conventional strategy		INBA strategy	
	Type A	Type B	Type A	Type B
Life cycle (yr)	57	77	52	72
Operational period (yr)	40	60	40	60
Operational period % (variation from conventional strategy)	70.2	77.9	76.9 (+6.9)	83.3 (+5.4)

INBA, innovative nuclear power plant building arrangement.

INBA strategy. If significant design changes are required, this may eliminate the economic advantages of the INBA strategy, e.g., steam lines connecting the steam generator and the turbine pass through the underground between an AUX and a T/G building in the current APR1400 design. To reuse the foundation of the T/G building, the path of the steam lines would have to be redesigned. Also, the CONT buildings, the AUX buildings, and the compound building are relocated in every phase of the INBA strategy. To adapt it, the switchyard located on the upper side of the AUX building in the current design would also need to be relocated; (2) limitations and/or restrictions on construction activities have to be taken into consideration. In the INBA strategy, the dismantling of the retired nuclear power plants and the construction of the new nuclear power plants will be conducted immediately adjacent to the CONT and the AUX buildings that have to be maintained under safe storage conditions. In order to protect the safe storage buildings, the dismantling and the construction activities will need to be carefully coordinated. This could impact the schedule and the cost of the dismantling and the construction; and (3) the INBA strategy may require additional safety evaluations and studies to support a license application to carry out several different licensed activities concurrently on the same site.

7. Conclusion

The INBA strategy is a new nuclear power plant building arrangement method which takes efficient decommissioning into consideration when designing the building arrangements and determining land usage for the site. The application of the INBA strategy reduces the decommissioning time by 5 years, allows for early restoration of the site for construction of a new nuclear power plant, reduces radioactive decommissioning waste, and reduces the maintenance costs for the safe storage period. The INBA strategy is able to achieve the benefits by allocating an empty space for future use on the upper side during the building arrangement layout. This available space makes it possible to construct new nuclear power plants immediately after dismantling only the T/G buildings of the retired nuclear power plants. Essentially, the new nuclear power plants are constructed and operated whereas the CONT buildings, the AUX buildings, and the compound building of the retired nuclear power plants are maintained in a safe storage condition achieving the benefits of both immediate dismantlement and deferred dismantlement.

In the economic estimation with low inflation, the INBA strategy shows ~12% profit increase and an additional 7% of power generation compared with the current nuclear power design and decommissioning strategy. The ~12% profit increase is comprised of ~11.4% due to radioactive waste disposal cost reduction and ~0.5% due to an additional 4.17 years of operation.

In the economic estimation with high inflation, the total profit is increased by ~19% (Scenario 2) comprised of ~11.4% due to radioactive waste disposal cost reduction and ~8% due to an additional 4.17 years of operation.

The INBA strategy is a concept being presented for additional evaluation and assessment. There are many challenges for this concept. However, if practicable, it will make a significant contribution to improving the economy of nuclear power. In particular, it is absolutely necessary to reuse the decommissioned site of an old nuclear power plant for the construction of a new nuclear power plant where there are limited sites for the construction of nuclear power plants but high energy consumption. Given these conditions, it would be dominant factors to shorten the decommissioning period and to reuse the decommissioned site for a new nuclear power plant. Then the effectiveness of INBA strategy can be significant.

In conclusion, the INBA strategy is a sound concept with great potential. This research paper is expected to trigger follow-up studies and discussions regarding the concept of the INBA strategy. There is every possibility that the INBA strategy may play a significant role in improving the economics of nuclear power.

Conflicts of interest

The authors have no conflicts of interest to declare.

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