Economic Evaluation of Long-term Operation of NPPs in Korea

Kihyun Lee, Taeryong Kim, Cheolwook Jeong

KEPCO International Nuclear Graduate School, 658-91 Heamaji-ro, Seoseong-myeon, Ulju-gun, Ulsan 689-882 Republic of Korea

1. Introduction

It is inevitable for Korean government to establish the energy policy which can support the energy security and independence since Korea depends on approximately 97% of energy resources from abroad. Nuclear power generation has been played a big role in providing about 30% of total electricity supply in Korea. This paper will deal with the economic benefits for the contribution of nuclear power generation especially long-term operation(LTO) of NPPs to Korea.

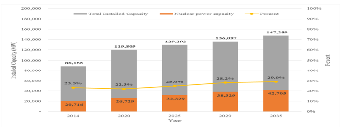
2. Nuclear Power Prospect

According to the second energy basic plan, Korean government plans to secure the nuclear power capacity up to 29% of total amount by 2035. Approximately 43GW of nuclear power plant should be equipped by 2035 based on the plan as shown in Table I and Fig.1. [1][2]

Table I: Nuclear power capacity

Year	Nuclear power capacity(MW)	Total installed capacity(MW)	Percent	Operating NPPs (EA)
2014	20,716	88,155	23.5%	23
2020	26,729	119,809	22.3%	27
2025	32,329	129,292	25.0%	31
2029	38,329	136,097	28.2%	35
2035	42,705	147,259	29.0%	39

Fig.1. Nuclear power capacity



The aggregate will be thirty six NPPs by adding twelve NPPs more by 2029. The emerging issue is LTO problem that we should consider the existing plant to be shut down as an alternative way to increase the capacity. The target NPPs for LTO to be considered by 2028 are ten except for Kori unit 1 to be shut down and Wolsong unit 1 to be operated by 2022. [1][2]

3. Methods

The economics of long-term operation for existing nuclear power plants that we are considering to decommission on their design life was analyzed by comparing the results obtained from the following equations.

Four indicators selected are saved capacity, electricity sales, equivalent NPPs, and cost savings. Basically we assumed 10years, 20years, and 30years for life extension periods; 3%, 6%, and 10% for discount rate; 60%, 70%, 80%, and 90% for capacity factors.

First, we figured out the saved capacity by calculating the accumulated capacity acquired from LTOs. And we projected capacity factor and compared the NPVs(Net Present Value) by applying discount rate.

- $\text{Saved capacity(MW)} = \left(\sum_{t=1}^{t^{EO}} \frac{Capacity_t^{EO}}{(1+r)^t}\right) \times \text{Capacity factor}$

The subscript "t" denotes the year in which the electricity production takes place or the expenses are made:
t^{EO} : Duration of extended operation
r : discount rate, constant (3%, 6%, and 10%)
$Capacity_t^{EO}$: The amount of capacity in year "t", after extended operation
Capacity factor: 60%, 70%, 80%, and 90%

Second, electricity sales can be obtained from the saved capacity multiplied by electricity sales price as of 2014. We can estimate and compare the amounts of economic effect among the other industries.

- $\text{Electricity sales} = \text{Saved capacity(MW)} \times 24(hours) \times 365(days) \times Electricity\ price\ (Won/kWh)$

Where,
Electricity price: 54.70 Won/kWh. [5][6]

Third, from the equivalent NPPs, we can estimate how many NPPs we can save thanks to long-term operation contrary to the observance of original life time. We considered APR1400 as an equivalent NPP.

- $\text{Equivalent NPPs} = \frac{Saved\ capacity\ of\ individual\ NPPs\ (MW) \times Extended\ lifetime}{Unit\ capacity\ of\ APR1400\ model\ NPP\ (MW) \times (Design\ life + Extended\ lifetime)}$

Where,
Saved capacity: Total sum of saved capacity for all existing NPPs
Unit capacity: Unit capacity of NPP to be compared (APR1400, 1400MW)
Extended life time: 10years, 20years, and 30years

At last, cost savings shows how much we can save the cost by applying the levelised cost of electricity, when we extend the life time of existing NPPs.

- $\text{Cost savings} = (LCOE - LCOE_{EO}) \times Saved\ capacity_o\ (MW)$

Where,
LCOE: Levelized cost of electricity reflected by construction cost for new APR1400 NPP
$LCOE^{EO}$: Levelized cost of electricity reflected by refurbishment cost for LTO of NPP
Saved $capacity_o$: Total sum of saved capacity of all existing NPPs without applying discount rate and capacity factor.

The LCOE is used to compare the economics of different generation type.[3] The estimated LCOE and $LCOE_{EO}$ values were referred from Reference [4].

4. Results

The results obtained from the equations specified in methods section are showed in tables and graphs below. We analyzed economic benefits by comparing given indicators between new construction of APR1400 and existing NPPs for several cases of Long-term Operation.

Table II: Saved capacity and Electricity sales

Discount rate	Capacity factor	Saved Capacity (MW)			Electricity Sales (Million USD)		
		for 10 years	for 20 years	for 30 years	for 10 years	for 20 years	for 30 years
3%	60%	59,735	104,798	138,329	24,890	43,666	57,638
3%	70%	69,690	122,264	161,384	29,038	50,944	67,244
3%	80%	79,646	139,731	184,439	33,186	58,222	76,851
3%	90%	89,602	157,197	207,494	37,334	65,499	86,457
6%	60%	31,686	49,848	59,989	13,203	20,770	24,996
6%	70%	36,967	58,156	69,987	15,403	24,232	29,162
6%	80%	42,248	66,463	79,985	17,603	27,693	33,328
6%	90%	47,529	74,771	89,984	19,804	31,155	37,494
10%	60%	15,655	22,020	24,475	6,523	9,175	10,198
10%	70%	18,264	25,691	28,554	7,610	10,705	11,898
10%	80%	20,873	29,361	32,633	8,697	12,234	13,597
10%	90%	23,482	33,031	36,712	9,784	13,763	15,297

Fig.2. Accumulated capacity savings

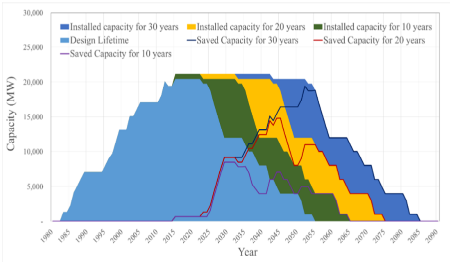


Fig.4. Electricity sales

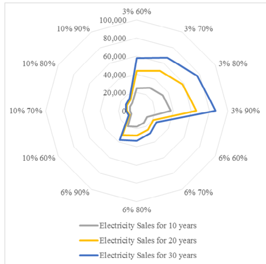


Fig.3. Equivalent NPPs of APR1400

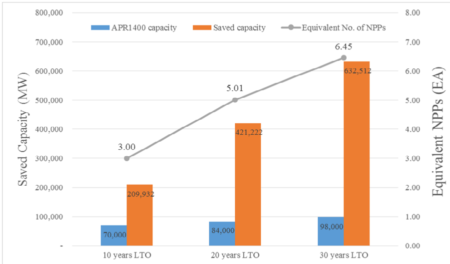


Fig.5. Cost savings

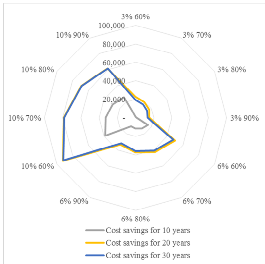


Table III: Cost savings compared to APR1400 NPP

Discount rate	Capacity factor	Generation costs for extended operation (ⓐ)			Generation costs for New APR 1400 (ⓑ)			Cost savings (ⓐ-ⓑ)		
		10 years	20 years	30 years	10 years	20 years	30 years	10 years	20 years	30 years
3%	60%	83,333	146,070	233,821	84,401	168,802	253,203	1,068	22,732	19,382
3%	70%	72,258	126,845	202,886	73,199	146,398	219,597	941	19,553	16,711
3%	80%	63,935	112,417	179,674	64,782	129,563	194,345	846	17,146	14,671
3%	90%	57,473	101,206	161,618	58,247	116,494	174,741	774	15,288	13,123
6%	60%	86,287	153,909	258,027	101,928	203,857	305,785	15,642	49,948	47,757
6%	70%	74,778	133,562	223,620	88,216	176,431	264,647	13,438	42,869	41,027
6%	80%	66,158	118,301	197,812	77,915	155,830	233,745	11,757	37,529	35,932
6%	90%	59,442	106,442	177,758	69,916	139,832	209,747	10,474	33,389	31,990
10%	60%	90,540	165,789	295,398	128,951	257,903	386,854	38,411	92,114	91,457
10%	70%	78,427	143,746	255,658	111,376	222,752	334,128	32,949	79,006	78,470
10%	80%	69,351	127,220	225,841	98,194	196,389	294,583	28,844	69,169	68,742
10%	90%	62,274	114,354	202,655	87,942	175,884	263,826	25,668	61,530	61,171

Unit: Million USD; Exchange rate: 1,150 KRW/USD (As of July 2015)

5. Conclusion

The economic analysis of the LTO for the existing power plant (≤ 1,000MW) compared to "No extension" was investigated. The selected durations of LTO are 10 years, 20 years, and 30 years beyond design life. The result from the analysis is that LTO of NPPs is more beneficial than observance of its design life. In the aspects of utility's electricity sales increase and reducing the new construction of APR1400 NPPs with cost savings, LTO is one of the best options in order to provide electric energy with Korean society.

References

[1] MOTIE, The 7th Basic Plan for Long-term Electricity Supply and Demand, 2015
[2] MOTIE, The 2nd Energy Basic Plan, 2014
[3] NEA/OECD, The Economics of Long-term Operation of Nuclear Power Plants, 2010
[4] Yoon Kyoung Kim and Sung Jin cho, Generation Cost Estimation of Nuclear Power Plants Life Extension in Korea, KEBA, 2014
[5] KEPCO, The power statistics, 2014
[6] KPX, The statistics of electric power market, 2014