Study on Competitive Exporting Price-forecast of the SMART in the U.S.

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BACKGROUND

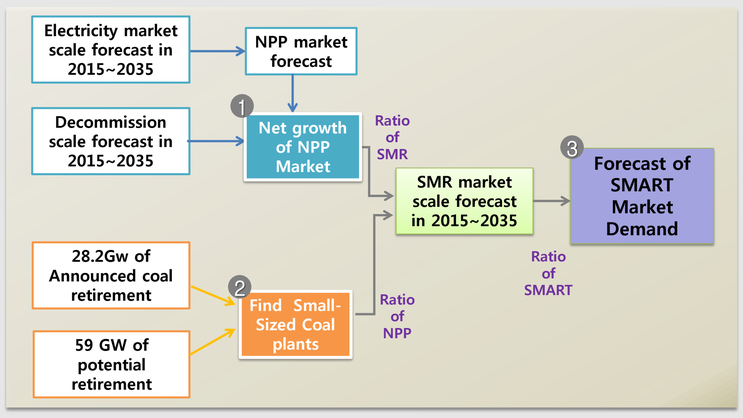
- **Nuclear energy is a indispensable option** for many countries as **a sustainable energy source** for energy security and climate change mitigation.
- **Large reactors have some controversy** to expand due to their safety issues and high capital cost.
- In a **future energy mix**, where a small grid capacity and intermittent production from Renewable Energy Systems will become more common, **SMRs** (Small Modular Reactor) could **play an important role** in supporting reliable electricity market.
- **The U.S.**, where has a small grid capacity, low population density, and decentralization power system, **has a renewed interest in SMRs** rather than large reactors.
- **The Korean SMART has been developed and licensed** for standard design, and has a good chance for export in the near future.
- CCGT (Combined Cycle Gas Turbine) is currently a very attractive option for generating due to the shale innovation, but emits air pollutant.
- **Target Price can be derived** based on generally determining market price, "sell your stuffs at cheaper price than alternatives when you advance to the market at first."

OBJECTIVES

- To **Suggest a target price** of the SMART exported to the U.S.
- To **Conduct economic evaluation** of the SMART considering Carbon Tax
- To **Conduct a potential market survey** on the SMART in the U.S.
- To **Demonstrate the excellence** of the SMART comparing to alternative

METHODOLOGY & RESULT

1. Potential Market Demand for the SMART



Results

1

Source	NPP Capacity 2015 (a)	NPP Capacity 2035 (b)	NPP* Decomm. (c)	NPP Net Growth (b-a+c)	SMR Market Scale
WEO 2012 (new)	**108**	**119**	**65**	**76**	**2.3GW**
WEO 2012 (450)	108	140	65	97	2.9
WEO 2011 (New)	112	124	65	77	2.3
WEO 2011 (450)	112	156	65	109	3.3
IEO 2013	104	109	65	70	2.1
IEO 2011	106	111	65	70	2.1

* NPP whose license will expire from 2015 to 2035 are considered potential Decomm. plants

2

Coal Retirement	Small-sized Coal Retirement* Announced	Potential	Sum	SMR Market Scale
87GW	8.3GW (64 units)	11.1GW (96 units)	19.4GW (160 units)	**1.75GW**

* assumes that 30MW ≦ Small-Sized coal retirement ≦ 300MW

3

SMR Market Scale			SMART Market Demand			
From 1	From 2	Total	Market * Share	Market Scale	Unit / Capacity	Unit
2.3GW	1.75GW	4GW	10%	400MW	100MW	4ea

* was predicted on the anticipated ratio of market share in the U.S. because Korea is considered one of the leading countries and 12 current leading SMR designs exist.

2. Economic Analysis for alternatives

LCOE can be simplified below:

$$\text{LCOE}\left(\frac{\$}{\text{MWh}}\right) = \frac{\text{I(FCR)+O\&M+}Fuel}{\text{Capacity}*\text{C.F}*8760} + \text{Carbon Tax}$$

Here:
I = overnight cost + IDC, FCR = Levelized Fixed Charged Rate in year
O&M = Levelized Operating Expense in year, C.F = Capacity Factor

Economy of Scale (scaling law)

$$\text{Cost P}_1 = CostP_0\left(\frac{P_1}{P_o}\right)^n$$

Here: P_0, P_1 = Power Plant
n = scaling law parameter

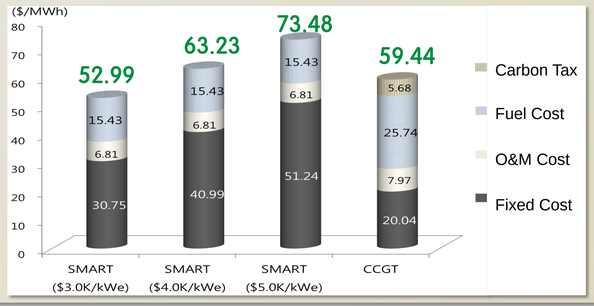
Results

❖ **Major Input Data ($ in 2005)**

Components	SMART	CCGT
Capacity(MWe)	100	100
Overnight Cost($/kWe)	3,000 ~ 5,000*	2,294**
O&M Cost($/MWh)	6.81*	7.97**
Fuel Cost	15.43($/MWh)*	7.544($/Mbtu)
Economic Plant Life(year)	60	30
Capacity Factor (%)	90	85
Discount Rate (%)	8	5
Scaling Factor	0.5	0.5
Carbon Tax ($/t-$CO_2$)	-	16.24

☞ SMART cost from OPR 1000 or APR 1400 wasn't suitable for this study, so it referred to data developed by KEPCO Research Institute, while CCGT uses scaling law in overnight cost and O&M, while, and fuel cost was projected by this study itself.

❖ **The LOCE for alternatives**



3. Estimated a Target Price

This study assumed that **$LCOE_{SMART}$ should be lower than the sum of $LCOE_{CCGT}$ and Carbon Tax** so that the SMART could have an opportunity to build in the U.S.

$$\text{LCOE}_{\text{smart}} = \frac{I_{smart} \times FCR(r,n) + \text{O\&M}_{\text{smart}} + \text{Fuel}_{\text{smart}}}{\text{P.G.}} \leq \text{LCOE}_{\text{CCGT}} + \text{Carbon}_{\text{tax}}$$

Here, I_{smart} is overnight cost, $Fuel_{smart}$ is the fuel cost, $O\&M_{smart}$ is operating expense, FCR is Fixed Charged Rate with discount rate (r) and life time of plant (n), $Carbon_{tax}$ is CO_2 cost ($/MWh), and P.G is annual power generation. Equation (1) can be rearranged to equation (2), and all cost factors in equation (2) are Levelized values

$$\mathbf{I_{smart}} \leq \frac{(\text{LCOE}_{\text{CCGT}} + \text{Carbon}_{\text{tax}} - \text{O\&M}_{\text{smart}} - \text{Fuel}_{\text{smart}}) \times \text{P.G}}{FCR(r,n)}$$

I_{smart} is a target price of the SMART, which could be interpreted as the construction cost for the SMART as well.

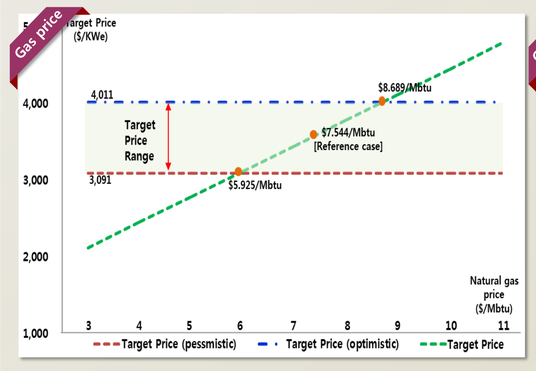
Results

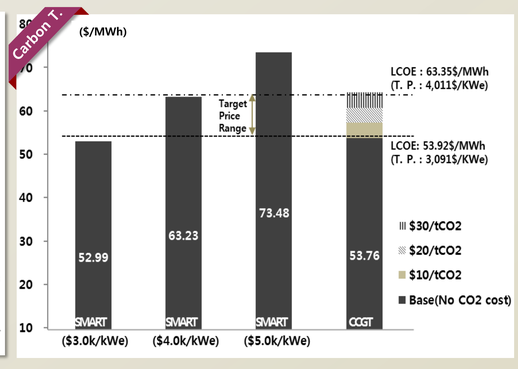
❖ **Input and Output ($ in 2005)**

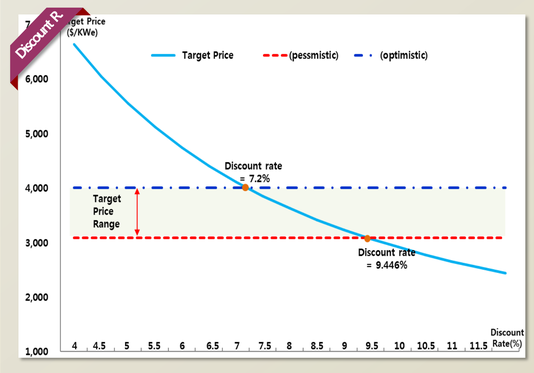
Components	Unit	Min	Reference	Max
LCOE (CCGT)*	$/MWh	50.13	53.76	55.77
Carbon Tax	$/MWh	3.79	5.68	7.58
O&M (Smart)	$/MWh	6.81	6.81	6.81
Fuel (Smart)	$/MWh	15.43	15.43	15.43
P.G. (Smart)	GWh	788.4	788.4	788.4
FCR(r, n)	%	8.0798	8.0798	8.0798
Target Price(I_{smart})	$/KWe	3,091	**3,630**	4,011

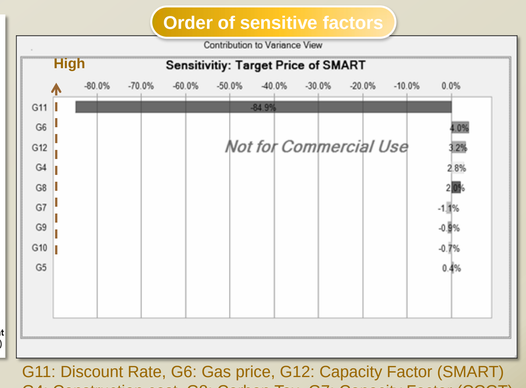
- The range of scaling factors: 0.45(max) ~ 0.6(min)
- Other data which is not shown above follows the data described in Economic Analysis's table

4. Sensitivity Analysis









G11: Discount Rate, G6: Gas price, G12: Capacity Factor (SMART)
G4: Construction cost, G8: Carbon Tax, G7: Capacity Factor (CCGT)

CONCLUSIONS

- This paper demonstrates the **target exporting price of the SMART in the U.S**. ranging from **3,091~ 4,011$/kWe** depending on the **scaling factor and carbon tax**, assuming that discount rates are fixed. This value could be a target cost of construction, developing the **U.S market** whose demand of the SMART is potentially **4 units 2015~2035**.
- Sensitivity analysis shows that the **price goes up in proportion to the gas price, the capacity factor of the SMART, the overnight cost of CCGT**, etc. On the other hand, the price **goes up in inverse proportion to the interest of the SMART, the capacity factor of CCGT, O&M costs of the SMART**, and so on.
- **For the price competitiveness**, **construction cost should first be reduced** because construction cost is the largest component of LCOE as well as the effect of interest rate is the most sensitive for target price. Therefore, design simplification, shorter construction period, serial production and factory fabrication will be necessary.
- If the SMART are successfully exported to the U.S. where most technologies and regulations of nuclear energy are being made, it may lead to new nuclear renaissance in Korea as well as to prove the excellence of the SMART, along with a lot of intangible effects.

LIMITATIONS

This paper was not able to estimate the economics of the SMART with real data and restricted the capacity of CCGT in 100MWe. Accordingly, it is necessary to consider 200MWe and 300MWe of capacity in order to conform to market demand forecast. In addition, a review on co-generation of the SMART remains for a further study.