Economic Impact of Nuclear Power Plant Shutdowns

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Fuel Prices (Won/ton, Won$/kℓ)

- Coal
- Oil
- LNG

Chart showing fuel prices from 2003 to 2014.
Nuclear Power Plant-Pressurized Water Reactor\(^1\)

\(^1\)http://www.thefullwiki.org/Power_Generation-nuclear_Power/Part2
The total electrical generation capacity of the nuclear power plants of South Korea is 20.5 GWe from 23 reactors. This is 22% of South Korea’s total electrical generation capacity, but 29% of total electrical consumption.

South Korea did have plans for continued expansion, to increase nuclear’s share of generation to 60% by 2035. Eleven more reactors were scheduled to come on stream in the period 2012 to 2021, adding 13.8 GWe in total.

South Korea has a relatively smaller number of generating stations, only four. Housing multiple units at each site allows more efficient maintenance and lower costs.
<table>
<thead>
<tr>
<th>Reactor</th>
<th>Type</th>
<th>Net capacity</th>
<th>Commercial operation</th>
<th>Planned close</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kori 1</td>
<td>PWR - Westinghouse</td>
<td>576 MWe</td>
<td>4/78</td>
<td>2017</td>
</tr>
<tr>
<td>Kori 2</td>
<td>PWR - Westinghouse</td>
<td>640 MWe</td>
<td>7/83</td>
<td>2023</td>
</tr>
<tr>
<td>Wolsong 1</td>
<td>PHWR - Candu 6</td>
<td>657 MWe</td>
<td>4/83</td>
<td>2022 or 2036</td>
</tr>
<tr>
<td>Kori 3</td>
<td>PWR - Westinghouse</td>
<td>1011 MWe</td>
<td>9/85</td>
<td>2025</td>
</tr>
<tr>
<td>Kori 4</td>
<td>PWR - Westinghouse</td>
<td>1010 MWe</td>
<td>4/86</td>
<td></td>
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<tr>
<td>Hanbit 1, Yonggwang</td>
<td>PWR - Westinghouse</td>
<td>961 MWe</td>
<td>8/86</td>
<td></td>
</tr>
<tr>
<td>Hanbit 2, Yonggwang</td>
<td>PWR - Westinghouse</td>
<td>977 MWe</td>
<td>6/87</td>
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</tr>
<tr>
<td>Hanul 1, Ulchin</td>
<td>PWR - Framatome</td>
<td>963 MWe</td>
<td>9/88</td>
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<tr>
<td>Hanul 2, Ulchin</td>
<td>PWR - Framatome</td>
<td>965 MWe</td>
<td>9/89</td>
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</tr>
<tr>
<td>Hanbit 3, Yonggwang</td>
<td>PWR (System 80)</td>
<td>1000 MWe</td>
<td>12/95</td>
<td></td>
</tr>
<tr>
<td>Hanbit 4, Yonggwang</td>
<td>PWR (System 80)</td>
<td>998 MWe</td>
<td>3/96</td>
<td></td>
</tr>
<tr>
<td>Wolsong 2</td>
<td>PHWR - Candu</td>
<td>650 MWe</td>
<td>7/97</td>
<td></td>
</tr>
<tr>
<td>Wolsong 3</td>
<td>PHWR - Candu</td>
<td>665 MWe</td>
<td>7/98</td>
<td></td>
</tr>
<tr>
<td>Wolsong 4</td>
<td>PHWR - Candu</td>
<td>669 MWe</td>
<td>10/99</td>
<td></td>
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<tr>
<td>Hanul 3, Ulchin</td>
<td>OPR-1000</td>
<td>997 MWe</td>
<td>8/98</td>
<td></td>
</tr>
<tr>
<td>Hanul 4, Ulchin</td>
<td>OPR-1000</td>
<td>999 MWe</td>
<td>12/99</td>
<td></td>
</tr>
<tr>
<td>Hanbit 5, Yonggwang</td>
<td>OPR-1000</td>
<td>994 MWe</td>
<td>5/02</td>
<td></td>
</tr>
<tr>
<td>Hanbit 6, Yonggwang</td>
<td>OPR-1000</td>
<td>993 MWe</td>
<td>12/02</td>
<td></td>
</tr>
<tr>
<td>Hanul 5, Ulchin</td>
<td>OPR-1000</td>
<td>998 MWe</td>
<td>7/04</td>
<td></td>
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<tr>
<td>Hanul 6, Ulchin</td>
<td>OPR-1000</td>
<td>997 MWe</td>
<td>4/05</td>
<td></td>
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<tr>
<td>Shin Kori 1</td>
<td>OPR-1000</td>
<td>999 MWe</td>
<td>2/11</td>
<td></td>
</tr>
<tr>
<td>Shin Kori 2</td>
<td>OPR-1000</td>
<td>1000 MWe</td>
<td>7/12</td>
<td></td>
</tr>
<tr>
<td>Shin Kori 3</td>
<td>APR1400</td>
<td>1340 MWe</td>
<td>(5/16)</td>
<td></td>
</tr>
<tr>
<td>Shin Wolsong 1</td>
<td>OPR-1000</td>
<td>998 MWe</td>
<td>7/12</td>
<td></td>
</tr>
<tr>
<td>Shin Wolsong 2</td>
<td>OPR-1000</td>
<td>10000 MWe</td>
<td>7/15</td>
<td></td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td><strong>25 23,017 MWe</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Shutdown of Nuclear Plants

- On 15th September in 2011 in Korea, total 4.0 million kW load was shed without pre-notification and about 7.5 million households were affected by the rolling blackout.
- Following several scandals related to falsification of safety documentation in 2013, the government submitted a reduced draft plan to parliament for nuclear output of up to 29% of generation capacity by 2035.
- The new plan still involves increasing 2035 nuclear capacity to 43 GWe.
Scenario Analysis

What if nuclear plant shutdown rate increases?

1. What happens to sectoral prices? System marginal prices?
2. Severity of market distortion (in terms of cross-subsidization)
3. Costs of operation and management? Cost of waste disposal?
4. What happens to sectoral consumer surplus?
Supply Side Equation

Supply side of the electricity price equation:

\[ p_{it} = \alpha_i + \gamma q_{it}^s + g_{it} + \varepsilon_{it}, \]

where

- \( p_{it} \): electricity price of the \( i \)th sector
- \( q_{it}^s \): electricity demand of the \( i \)th sector
- \( g_{it} \): price factor of the \( i \)th sector.

Here, \( i = 1, 2, 3 \) represent residential, commercial, and industrial sectors, respectively, and \( t \) is the monthly time index.

(* All values in rate of changes.*)
Demand Side Equation

Demand side of the equation:

$$q_{it}^d = \delta_i + \beta_i p_{it} + \theta_i' x_{it}^d + \xi_{it},$$

where

$q_{it}^d$: electricity demand of the $i$th sector

$x_{it}^d$: explanatory variables for the electricity demand such as

- heating degree days
- cooling degree days
- consumer price index
- consumer survey index
Equilibrium Price

When $q^s_t = q^d_t$,

$$p_{it} = \frac{\alpha_i + \gamma_i \delta_i}{1 - \beta_i \gamma_i} + \frac{1}{1 - \beta_i \gamma_i} g_{it} + \frac{\gamma_i \theta'_i}{1 - \beta_i \gamma_i} x_{it}^d + \frac{\varepsilon_{it} + \gamma_i \xi_{it}}{1 - \beta_i \gamma_i}$$

$$= a_i + \tilde{g}_{it} + d'_i x_{it}^d + e_{it}.$$ 

We require both $\tilde{g}_{it}$ and $x_{it}^d$ are exogenous to the error term $e_{it}$ to avoid endogeneity problems.
Price Factors

Price factors (unobserved factors):

\[ \tilde{g}_{it} = z_i w_{0t} + w_{it} \]

where

- \( w_{0t} \): common factor
- \( w_{it} \): idiosyncratic factor of the \( i \)th sector

Company-wise budget constraint:

\[ k_1 w_{1t} + k_2 w_{2t} + k_3 w_{3t} = 0 \]

where \( k_i \) is the \( i \)'th sectoral sales weight.
Price Factors

Price factor follows

\[ w_{it} = u_i + b_i w_{i,t-1} + c'_i x^s_{it} + v_{it} \]

where \( x^s_{it} \) are explanatory variables for the electricity supply such as

- coal price
- oil price
- LNG price
- industry production index
- producer price index
- \((\text{nuclear plant failure rate})/(\text{electricity power reserve rate})\)

* reserve rate = \((\text{capability} - \text{peak load})/(\text{peak load})\)
State Space Representation

Measurement equation:

\[ p_t = a + \begin{pmatrix} z_1 & 1 & 0 \\ z_2 & -k_1/k_3 & -k_2/k_3 \\ z_3 & 0 & 1 \end{pmatrix} w_t + Dx_t^d + e_t \]

Transition equation:

\[ w_t = u + Bw_{t-1} + Cx_t^s + v_t \]

where

\[ p_t = (p_{1t}, p_{2t}, p_{3t})' \]
\[ w_t = (w_{0t}, w_{1t}, w_{3t})' \]
\[ x_t^d = (x_{1t}^d, x_{2t}^d, x_{3t}^d)' \]
\[ x_t^s = (x_{0t}^s, x_{1t}^s, x_{3t}^s)' \]
Estimated Parameters

Common factor loadings

\[ z_1 = 0.31^*, \quad z_2 = 0.23^*, \quad z_3 = 0.25^* \]

Demand side explanatory variable coefficients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating degree days</td>
<td>0.013</td>
</tr>
<tr>
<td>Cooling degree days</td>
<td>0.008</td>
</tr>
<tr>
<td>Consumer price index</td>
<td>0.801</td>
</tr>
<tr>
<td>Consumer survey index</td>
<td>0.068</td>
</tr>
<tr>
<td>KOSPI stock index</td>
<td>-0.0063</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>-0.0059</td>
</tr>
</tbody>
</table>

(* Estimates with superscript * are statistically significant at the 10% level.)
Estimated Parameters

Supply side explanatory variable coefficients

Common factor

- coal price: 0.008 (one month ahead: 0.013)
- oil price: 0.041*
- LNG price: 0.01
- failure/reserve: 2.27*

Residential idiosyncratic factor

- industry production index: −0.136
- producer price index: 0.665*
- Won/Dollar exchange rate: −0.055

Industrial idiosyncratic factor

- industry production index: 0.009
- producer price index: −0.236*
- Won/Dollar exchange rate: 0.013
Price Distortion Due to Cross-Subsidization

Idiosyncratic Factor/Common Factor (in change rates)

- Residential
- Industrial
Scenario Analysis

What if nuclear power plants shutdown rate increases?

1. Sectoral electricity prices?
2. System marginal prices?
3. Size of cross-subsidization?
4. Residential consumer surplus?
5. Reactive waste disposal cost?
6. Saved operation and management cost?
7. Green house gas?