NUCLEAR NEW BUILD: INSIGHTS INTO FINANCING AND PROJECT MANAGEMENT

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Context

Results are based on study of the OECD Nuclear Energy Agency (NEA) *Nuclear New Build: Insights into Financing and Project Management* (August 2015) written by Jan Horst Keppler and Marco Cometto, both NEA NDD.

Since 2000, the construction of 77 new reactors was started and 47 new reactors were connected to the grid. Vastly different forms of project management and financing in different contexts have generated ample experience.

Based on modelling, conceptual analysis, expert opinion and 7 case studies, study identifies perspectives for commercially and economically sustainable new build in two areas:

I. Managing long-term electricity price risk and allocating financial risk among stakeholders,

II. Project and supply chain management.
Context: Challenges for Nuclear New Build

- Massive and discontinuous technological change as Generation II nuclear power plants are substituted by larger, more expensive and often more complex Generation III+ plants (FOAK risks as well as licensing and regulatory change);
- Loss of expertise and human capital as projects are, with the exception of China and Russia, few and far between;
- A particularly complex supply chain with quality control issues at different levels of externalisation;
- Very long time frames at all levels of the value chain. From design and licensing to construction, operations and decommissioning, changes in nuclear new build can take a decade or more until all contributing factors have adjusted and they have found their economically optimal equilibrium level;
- Shifts in political and social support after Fukushima. While only a small number of countries have actually decided to phase out nuclear, their decisions have created uncertainties beyond their national boundaries.
### Reactors Currently under Construction or Planned

<table>
<thead>
<tr>
<th>Region</th>
<th>Under Construction</th>
<th>Planned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>Russia and FSU</td>
<td>11</td>
<td>30</td>
</tr>
<tr>
<td>China</td>
<td>27</td>
<td>56</td>
</tr>
<tr>
<td>Rest of East Asia</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>West Asia</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>South Asia</td>
<td>7</td>
<td>24</td>
</tr>
<tr>
<td>South East Asia</td>
<td>--</td>
<td>4</td>
</tr>
<tr>
<td>Africa</td>
<td>--</td>
<td>1</td>
</tr>
<tr>
<td>North America</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>South America</td>
<td>2</td>
<td>--</td>
</tr>
<tr>
<td><strong>SUM</strong></td>
<td><strong>68</strong></td>
<td><strong>227</strong></td>
</tr>
</tbody>
</table>

*Source: WNA*
Construction Times of New Reactors

Source: IAEA PRIS and press reports.
Outline of Presentation

1. Value of Price Stability for Nuclear Energy
   a) Long-term electricity price stability and the competitiveness of new nuclear projects
   b) The value of long-term pricing arrangements for risk-averse investors
   c) The impact of different market designs on the technology choices of private investors

2. Risk Exposure of Different Investor Groups
   a) Present value of new nuclear projects taking into account taxation and different debt-equity splits
   b) Relative risk exposure of debt and equity holders in the case of a sub-par evolution of nuclear projects

3. Case Studies on Akkuyu, Barakah and Vogtle

4. Remarks on Project Management

5. Conclusions
1. The value of price stability for different power generation technologies

2. The impact of different financing structures on investor risk
Methodology

1. NPV calculations following methodology in *Carbon Pricing and the Competitiveness of Nuclear Energy* (NEA, 2011);

2. Cost data from *Projected Costs of Generating Electricity* (IEA/NEA, 2010); no externalities, public goods or system costs (NEA, 2011, 2012).

3. Logic of real-valued option following Dixit and Pindyck (1994) as the value of flexibility ("value of waiting") in the face of unanticipated uncertainty, which is possessed by technologies with low fixed costs (FC);
   a) Share of FC in LCOE nuclear up to 73% or 85% at 5% or 10% interest rate;
   b) Share of FC in LCOE gas (CCGT) 8% to 13% at 5% or 10% interest rate;

4. Risk aversion modelled as constant relative risk aversion (CRRA) that takes into account wealth effects;

5. Further research on more realistic representation of private investor choices through inclusion of tax effects and debt-equity splits.
The NPV of Nuclear in Function of Different Price Risks

The NPV of a Nuclear Power Plant in Function of a Fall in Electricity Prices and the Onset of the Price Fall Years after Commissioning (r = 5%)
The NPV of a Gas-Fired Power Plant in Function of a Fall in Electricity Prices and the Onset of the Price Fall Years after Commissioning (r = 5%)

NPV under certainty
The Value of Price Stability
(Strike price corresponds to average of past prices)
The Value of a Contract-for-Difference at Different Price Levels

The Value of a CFD and the NPV of a Nuclear Plant at Different Strike Prices

NPV w/ CFD (Market price 2005-10)
NPV w/ CFD (110 €/MWh)
Value of CFD (Market price 2005-10)
Value of CFD (110 €/MWh)
Institutional Choices are Technology Choices

Levelised Costs of Electricity (LCOE) under Different Financing and Regulatory Arrangements
(USD/MWh, Commissioning 2018)

Source: California Energy Commission (2010), Comparative Costs of California Central Station Electricity Generation
• Long-term electricity price volatility is a major source for risk and uncertainty facing investors in nuclear new build and needs to be appropriately managed.

• Technologies with high fixed to variable cost ratios are particularly vulnerable even at similar LCOEs (fixed price by definition).

• Technologies with low fixed costs, however, are almost by definition carbon-intensive fossil fuel technologies.

• **Institutional choices (regulated vs. deregulated markets) are neither technology-neutral nor environmentally neutral and need to be discussed in broader fashion.**

• Independent of the cost and competitiveness of different technologies current electricity market prices would currently not allow *any* new dispatchable capacity to be built in most OECD countries.
2. The impact of different financing structures on investor risk
Modelling Investor Risk with Price and Cost Volatility

Modelling choices of a private investor, taking into account the effect of taxes, depreciation and the capital structure of the project

- **Construction risk**
  - Uncertainty regarding overnight costs
  - Uncertainty on length on construction period (IDC)
  - Correlation of construction delays and overnight cost

- **Electricity market risk**
  - Uncertainty on load factor: triangular distribution between 75% and 95%
  - Short-term variability of prices
    - First-order auto regressive model: $P_{t+1} = P_t + \alpha (\mu - P_t) + \varepsilon_t$ (random component)
    - Possibility to suspend production when electricity prices are below variable costs
  - Constant long-term average price at € 80/MWh but
    - Parametric study (-50% → +50%, i.e. ±40 €/MWh)
    - Creation of 3 scenarios of electricity price variations (low to high price risk)
Statistical distribution of future cash flows once the plant has been build

CfD or long term contract reduce significantly the variability of future cash flows

Construction cost risk is of a similar magnitude of electricity market risk in the high electricity price risk scenario.
Metric for risk: total value of the debt losses as percentage of total financial investment.

- No losses for bond-holders in a wide range of scenarios even at 30% to 50% price falls.
- At low debt ratios risk for bond-holders is limited even for large electricity price falls.
- At 70% DR and above, electricity market risk for bondholders starts to be important.
# 3. Real-life Nuclear Projects
## Pay Attention to Long-Term Finance

- **Akkuyu**
  - Long-term power purchasing agreement (PPA) between the project company and the Turkish government:

  **Table 1: Present value of the power purchase agreement at different discount rates (USD/MWh)**

<table>
<thead>
<tr>
<th>Discount Rate (%)</th>
<th>2.0%</th>
<th>2.5%</th>
<th>3.0%</th>
<th>3.5%</th>
<th>4.0%</th>
<th>4.5%</th>
<th>5.0%</th>
<th>5.5%</th>
<th>6.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant price trajectory</strong></td>
<td>92.10</td>
<td>85.76</td>
<td>79.92</td>
<td>74.53</td>
<td>69.56</td>
<td>64.98</td>
<td>60.73</td>
<td>56.81</td>
<td>53.18</td>
</tr>
<tr>
<td><strong>Maximal value</strong></td>
<td>93.74</td>
<td>87.66</td>
<td>82.04</td>
<td>76.83</td>
<td>72.00</td>
<td>67.53</td>
<td>63.37</td>
<td>59.52</td>
<td>55.93</td>
</tr>
</tbody>
</table>

- **Barakah**
  - Costs and risks are shared by the government of Abu Dhabi (30%), Export Import Bank of Korea (50%), US Export Import Bank (10%) and commercial banks (10%). Level of electricity tariffs not yet decided.

- **Vogtle**
  - Three shareholders of the projected all work in regulated environments with stable revenue stream
    - Georgia Power, rate-regulated by supportive Georgia Public Service Commission (CWIP)
    - Oglethorpe Power, long-term PPAs with Electric Membership Corporations (EMCs), part-owners
    - MEAG Power, owned by municipalities who are also sole customers.
  - Production tax credit and loan guarantees.
4. Remarks on Project Management
Nuclear new build characterised by large scales, long time frames, complexity and externalities ("an accident anywhere is an accident everywhere").

Three basic models of project management prevail in nuclear:
1. Turnkey project provided by integrated reactor vendor
2. Operator-assembler works with small number of key sub-contractors
3. EPC contractor manages project with competitive procurement

The theory of transaction costs (Coase, Williamson) holds that vertical integration should substitute for contractual relationships if the following prevail:
   a) High frequency of transactions (not necessarily the case in nuclear industry),
   b) Industrial assets are "specific", i.e. not commoditised (very much the case), and
   c) Opportunities for contractual "hold-up" due to asymmetries of information and incomplete contracts (somewhat the case).

Model 1 and 2 can reduce uncertainties and provide clear interlocutor for customers and governments. Model 3 may have advantages in reducing costs.

Increasing the scope for more competitive procurement and externalities call for international standard-setting through regulation or auto-regulation.
### Which form of cooperation in different aspects of nuclear power plant construction following the structure provided by Williamson?

<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>ASSET SPECIFICITY</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Spot market provision (Building services)</td>
<td>LT Outsourcing/Tender (Construction of headquarters)</td>
<td>Joint venture (Building of power plant in specific country)</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Spot market provision (Standard IT Supplies)</td>
<td>LT Outsourcing/Tender (NPP Maintenance)</td>
<td>LT Outsourcing/Tender (Provision of specialised valves and pumps)</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>LT Outsourcing/Tender (Payroll management)</td>
<td>Vertical Integration (Human resource management)</td>
<td>Vertical Integration (Fabrication of reactor vessel, I&amp;C)</td>
<td></td>
</tr>
</tbody>
</table>
Is De-verticalisation Driving Costs?

Factors for Increases in Overnight Capital Costs
(USD per kW)

USD

Supplier Agreements & Risk Management, USD 1,360
Owners' Cost, USD 350
Commodity Prices, USD 500
Recurring themes
- No single model of project management, different customers want different things;
- Transfer of lessons learned and change management (including the adoption of new technologies such as automatic welding) need to be organised;
- Plan for long-lead time between authorisation to proceed (ATP) and first concrete; completion of design, early contract involvement (EWI) and early work agreements (EWA) must precede final contract;
- Stability and transparency of governance; recurring theme of soft issues: “trust”, “mutual understanding” (including with regulators), “team spirit”, “shared vision”, “common goals”, “leadership”.

Modularisation, standardisation, benchmarking
- Nuclear is still “special” with respect to aerospace or oil and gas industry but becoming more normal, like other complex infrastructure projects.
- Modularisation promising but no panacea, requires up-front investment and scale
- Benchmarking of best practice as in oil and gas might be logical next step.
- Cost now key driver for technological and logistical change
- Global harmonisation of design and quality codes (RCC-M, ASME, NSQ-100) step towards competitive supply chain better integrated across companies.
4. Lessons Learnt and Conclusions

ON FINANCING

1. Electricity market design, technology choices and carbon emissions are intrinsically linked.
2. The greater long-term electricity price risk, the greater the bias against high capital cost technologies such as nuclear.
3. The more stable electricity prices, the more stable NPVs, the lower are interest rates and the more competitive is nuclear.
4. Risks for bondholders and share holders are not symmetrical; even with high leverage nuclear projects pose limited risks to bondholders.

ON PROJECT MANAGEMENT

1. Different models of project management offer different trade-offs between internal and external transaction costs.
2. Less vertically integrated projects (EPC contractor-model) offer efficiency gains through competitive pressures but may add financial costs by “layering” of responsibilities without a dedicated entity to assume residual project risk.