Experience Feedback from Nuclear Cogeneration

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Context and Objectives

- Study conducted for the European NC2I-R project

Objectives:
- Collect feedback from experience and projects related to nuclear cogeneration
- Learn from past experience to reduce risk for future projects
- Identify Key Success Factors (KSFs)

Results published in:
Nuclear cogeneration consists in the **simultaneous generation of electricity and useful heat** by a nuclear power plant (NPP).
Various applications

- Town
- Power grid
- Nuclear heat source
- Steelmaking
- Hydrogen plant
- Seawater desalination
Industrial applications

- Several projects in Germany to power industrial sites (coal, chemicals, etc.) using an HTR
- Requirements
  - steam: < 600°C
  - capacity: around 100 MWth
- Projects supported by large industrial companies
- Did not lead to construction due to Chernobyl accident in 1986
- Large desalination installations in Japan
- Much technical information available in IAEA TECDOCS and OECD documents, but credible financial information is scarce
- Today: a number of countries and companies interested in the combination of nuclear electricity/heat for a range of applications
- **EU market potential approx. 87 GWth**
HT nuclear cogeneration

Higher temperature projects have not taken off yet

- natural gas too cheap
- economic/political pressure too low (e.g. CO$_2$ tax)
- political obstacles
- image of nuclear
- not right moment in end-user investment cycle
- high upfront investment required
- unrealistically high investor expectations
- innovation risk

We think that with the priorities of the European Energy Union this is likely to change:
- secure/diversify energy supply
- stop carbon leakage, re-industrialize
- reduce CO$_2$ emissions
Methodology

1. Identify prospects and contact by phone/e-mail
2. If interested send questionnaire
3. Prospects return questionnaire
4. Interview (WP2 + WP3) to address open questions
5. Analyze returned questionnaires
Methodology

Scope
all nuclear cogeneration, real installations, feasibility studies

Organization
• collection of returned questionnaires
• interviews for clarification

Structure of Interview
• 9 categories of questions
• open and semi-open
• qualitative and quantitative

Stakeholders interviewed
• NPP operators, end-users
• no complete vision (technical, financial, safety/licensing etc.)
• difficult to interview licensing authorities, politicians, investors etc. (retired, IP issues)
Methodology

9 Categories of questions for 38 projects:

- Motivation and initiative
- Role of key players
- Organizational structure
- Technical aspects
- Safety and licensing
- Financial aspects
- Timing
- Public relations
- Experience feedback

Total number of questions: 56
## Projects screened

<table>
<thead>
<tr>
<th>Received/Interviewed</th>
<th>Contacted but Abandoned</th>
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<tbody>
<tr>
<td>Hungary (Paks)</td>
<td>Kazakhstan (Aktau)</td>
</tr>
<tr>
<td>France (free response)</td>
<td>Canada (Bruce)</td>
</tr>
<tr>
<td>Czech Republic (Temelin)</td>
<td>UK</td>
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<tr>
<td>Slovakia (Bohunice)</td>
<td>Russia (Obninsk)</td>
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<tr>
<td>Sweden (Ågesta)</td>
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<td>Finland (Loviisa 3)</td>
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<tr>
<td>China (HTR-10)</td>
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<tr>
<td>Switzerland (Beznau &amp; Gösgen)</td>
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<tr>
<td>Germany (9 projects, but several incomplete)</td>
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<tr>
<td>Norway (Halden)</td>
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<td>Japan (several sites)</td>
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Projects screened
1. Motivation and initiative

Reasons that motivated the nuclear cogeneration projects:
- R&D on industrial nuclear cogeneration: 5%
- Security of supply: 5%
- Reduce carbon and other emissions: 16%
- Economic reasons: 58%

2. Role of key players

- Plant manufacturer
- Operator/Utility
- End-user (industry, municipality)
- Plant owner
- Political representatives at different levels
- International organisations (e.g. OECD in Halden project)
- Public:
  a) in past: through local government decision
  b) today: public inquiries
Key messages

3. Organizational structure

- Financially relatively small projects, could be handled within operational budget → **often no need to build a consortium**
  - cooperation between manufacturer and utility (Ågesta, S)
  - part of an international cooperation (OECD/NEA Halden, N)
  - financed and commissioned by Soviet Union (Paks in HU and Bohunice in SK).
  - in Temelin (CZ), 2 heat-supply companies were created (large public ownership fraction)
  - in Beznau (CH), the heat supply company is a 80-20 PPP
  - Germany/Finland: consortium with NPP manufacturer, utility, end user of the electricity/steam (industry or local municipality).
- **Insignificant interaction between similar projects** in the past with exception on safety and on technical information on district heating.
Most projects included cogeneration from the start, no upgrade/retrofit required.

Great majority did not encounter unexpected difficulties except Ågesta (S) (FOAK reactor) and Paks (HU) (coolant circulation system).

All cogeneration requires (fossil) back-up for O&M outages (planned in low duty periods).

IAEA has collected information and is preparing new TECDOCS on non-electric applications.
5. Safety and licensing

- Most used heat source is LWR
- Typically two barriers (HX) with isolation valves between primary circuit and end-user; single barrier would not be compatible with current EU safety standards
- Heat load is a relatively small fraction of reactor power → insignificant effect of heat load variations on reactor
- Generally, no specific safety cases were deemed necessary, except:
  - risk analysis for end-user contamination (e.g. by tritium)
  - cogen equipment failure (turbine de-blading, SG blasts)
  - end-user equipment failure (explosions, fire etc.)
Key messages

6. Financial aspects

- CAPEX depends on **type/size of reactor** (50–1000 M€); little usable feedback on OPEX
- But: CAPEX/OPEX of the cogeneration infrastructure negligible compared to
  - CAPEX/OPEX of the NPP
  - the dominant fuel costs of a fossil-fired cogeneration plant
  - Parameters: distance, customer density, geography, weather and climate, seasonal activities, evolution of demand
- Rough estimate for LCOE: generation cost of low temperature heat tapped from turbines is at least **3 times cheaper than the bus bar cost of sold electricity**.
- Beznau/Refuna, the price of the heat was **coupled to the price of fuel oil** and the delivered heat was not taxed
- An industrial customer needs **long-term price** certainty, which is favorable for NC
- Sale of heat is viable if electricity and, occasionally, also system services (grid stabilization, load following) are sold.
- Socio-economics: nuclear heat is often **most economic and beneficial** (air quality, security of supply, traffic reduction etc.).
Key messages

7. Timing

• Design – Licensing – Construction - Operational tests: 5-10 years
• Retrofitting: < 5 years
• Lifetime: 50 to 60 years
• Payback time: ≈ 20 years

⇒ **NC is an element of strategic long-term energy infrastructure development**

8. Public relations

• In the past, PR went via political representatives, no direct PR towards public
• Today: generalized communication paths

⇒ **Public involvement visibly enhances image of nuclear cogeneration**
9. Experience feedback

- Projects are **technically successful**
- 2/3 of the feedback was financially successful (several unsuccessful due to unexpected risk, changing boundary conditions, too little ambitious)

→ **Future projects should reduce risk and enlarge customer base** (heat, electricity, grid services)
Conclusion

- Nuclear cogeneration: in use for > 50 years
- Very high market potential, but mainly used for district heating, paper & pulp and desalination
- No major technical problems (most projects were technically successful)
- No safety/licensing issues
- Recognized environmental benefit
- Plans for extension of several installations
- Large variety of business models with usually strong public involvement
- Financial results mixed, little information accessible
- Local and political support is key