Nuclear Economics in Finland

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Agenda

1. Schedule of nuclear projects in Finland
2. Nuclear in Nordic electricity markets
3. Nuclear economics in Finland
4. Nuclear financing
5. Nuclear cogeneration
6. Nuclear in solar economy

INPRO User Requirements for SA of NES - Economics

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<th>Economic basic principle BP</th>
<th>Energy and related products and services from nuclear energy systems shall be affordable and available.</th>
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<td>UR1 (Cost of energy)</td>
<td>The cost of energy supplied by nuclear energy systems, taking all relevant costs and credits into account, CN, should be competitive with that of alternative energy sources, CA, that are available for a given application in the same time frame and geographic region/jurisdiction.</td>
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<td>UR2 (Ability to finance)</td>
<td>The total investment required to design, construct, and commission nuclear energy systems, including interest during construction, should be such that the necessary investment funds can be raised.</td>
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<td>UR3 (Investment risk)</td>
<td>The risk of investment in nuclear energy systems should be acceptable to investors.</td>
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<td>UR4 (Flexibility)</td>
<td>Innovative nuclear energy systems should be compatible with meeting the requirements of different markets.</td>
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Two new nuclear projects are at sight in Finland depending on the economics.

Olkiluoto 4 and Fennovoima’s Hankikivi 1 are expected to apply for their construction permits in the coming years.

- **OL3 Olkiluoto 3**: Construction, OLA, test runs, operation
- **OL4 Olkiluoto 4**: Preparations, construction permit, construction
- **FH1 Fennovoima Hanhikivi 1**: Construction permit, construction, commissioning, OLA, operation

Timeline:
- 2012: Final deposit
- 2013: OL3 Construction permit
- 2014: OL4 Construction, OLA, test runs, operation
- 2015: FH1 Construction permit
- 2016: OL3 OLA operating licence application
- 2017: OL4 Construction, commissioning, OLA
- 2018: FH1 Operation
With low variable costs nuclear has a favourable position in the Nordic market’s merit order

**Economic basic principle BP:** *Energy and related products and services from nuclear energy systems shall be affordable and available.*

*) Normal annual Nordic hydro generation 200 TWh, variation +-40 TWh.
Current forward prices for electricity in the Nordic markets are not encouraging to any invests in energy generation

User requirement UR1 (Cost of energy): The cost of energy supplied by nuclear energy systems, taking all relevant costs and credits into account, CN, should be competitive with that of alternative energy sources, CA, that are available for a given application in the same time frame and geographic region/jurisdiction.

Source for LUEC: Lappeenranta University of Technology: Comparison of electricity generation costs, 2012
Latest nuclear financing models have been based on so-called Mankala principle in Finland

**User requirement UR2:** The total investment required to design, construct and commission nuclear energy systems, including interest during construction, should be such that the necessary investment funds can be raised.

- Mankala is a business model used in the Finnish electricity sector
  - Mankala company is a limited liability company making zero-profits for the benefit of its shareholders
- Each of the shareholders holds an imaginary “slice” of the Mankala company, corresponding to its shareholding
- The Mankala model is established on a case-by-case basis through Articles of Association and Shareholders’ Agreement
  - Shareholders are responsible for the fixed costs of the power company, including servicing of debt
  - Shareholders have the right to purchase the electricity produced, at cost, in accordance with their respective share in the company

**Finnish Mankala business model**

- **Shareholder-buyers**
- **Mankala company**
- **Lenders**
- **Electricity (and heat), Volume and price risk**
- **Operating costs and debt service**
- **Debt service**
- **Debt**
Small modular reactors (SMR) could improve nuclear project flexibility and accelerate revenue flows

UR3 (Investment risk): The risk of investment in nuclear energy systems should be acceptable to investors.

- SMRs vs. large scale NPP
  - higher economies of scale
  - advantages in unit timing and build schedule
  - simplified plant design
  - mass production efficiencies, and
  - multiple-unit siting
- SMRs overnight cost can be competitive with larger reactors
Nuclear cogeneration could provide stable priced and competitive heat and steam to district heating and industrial processes

**UR4 (Flexibility):** *Innovative nuclear energy systems should be compatible with meeting the requirements of different markets.*

- **Nuclear Cogeneration:**
  - $= Electricity + Process Heat from nuclear energy$
  - enhances efficiency, saves prime fossil fuel, cuts emissions, if (waste) heat is used
  - unlocks a huge new market and GHG reduction opportunity

- Several current end user energy usages can be met with modest gas temperature conditions ($750^\circ\text{C}–800^\circ\text{C}$) particularly in supply of steam and heat

- Moderate size nuclear reactors connected to heat processes can replace fossil fuel based cogeneration supply

  $\rightarrow$ Mature technology, but demonstration is required
In Finland the soundest solution would be to utilise extracted heat from a NPP in district heating

Cogeneration impacts

- District heating could cover 62% of the heat demand in the metropolitan area
- Combined production of DH would increase the efficiency of a NPP plant up to 55-65%
- Connection would be made so that no leakage towards DH system will happen from the secondary/primary cycle
  - Plant types (PWR and BWR) encompass two physical barriers
  - Pressure differences will be designed so that the possible leakage is always towards the turbine plant processes
- Positive impact to environment and economics
  - NPV could improve up to €3 billion compared to traditional NPP solution
  - CO₂ emissions in the metropolitan area would reduce over 50 percent

General implementation of district heat generation in a PWR plant
Transition towards Solar Economy

Solar Economy

Solar based production with high overall system efficiency

Finite fuel resources     Large CO2 emissions
Infinite fuel resources   Emissions free production

Geothermal
Hydro
Ocean
Wind
Sun
Geo
Bio

Traditional energy production
Exhaustible fuels that burden the environment

Advanced energy production
Energy efficient and/or low-emission production

Oil
Coal
Gas

CHP
CCS
Nuclear today
Nuclear tomorrow
Thank you!