Experience of operating nuclear district heating in Switzerland

Technical & Economic Assessment of Non-Electric Applications Of Nuclear Power, 4 – 5 April 2013

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Axpo Group – 100% in Public Ownership

Axpo Holding Ltd.
- Roland Schmidiger, Axpo Power AG
  Head of Asset Management Nuclear Power Division,
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- MSc EE ETHZ / MBA (BWI) ETHZ
- married, 2 children
- Hobbies: family, skiing
Content

- NPP in Switzerland
- Suitability of NPPs as District Heating Suppliers
- Nuclear Safety in Heat Supply
- Economical Aspects
- NPP District Heating vs. CO₂ Emission Reduction Targets
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**NPPs in Switzerland**

**NPP Beznau**
- 2 x 365 MWe
- 1969 & 1971
- PWR
- Westinghouse “2-loop”

**NPP Gösgen**
- 970 MWe
- 1979
- PWR
- KWU „Vor-Konvoi“

**NPP Leibstadt**
- 1190 MWe
- 1984
- BWR
- GE BWR 6

**NPP Mühleberg**
- 373 MWe
- 1972
- BWR
- GE BWR 4
Background: Swiss Generation Portfolio

- Nuclear energy: 8539 (50%)
- Thermal/new renewable energy: 897 (5%)
- Hydro power plants: 4552 (26%)
- Pump storage power plants: 3230 (19%)

- Nuclear energy: 17799 (28%)
- Thermal/new renewable energy: 3287 (5%)
- Hydro power plants: 16123 (26%)
- Pump storage power plants: 26245 (41%)

Quelle: Axpo Analysis 2007/8, Schweizerische Elektrizitätsstatistik BfE
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Nuclear power plants are thermal power plants

- Nuclear power plants are – as all thermal power plants which are used to produce electricity – generally suitable for heat extraction.
- Positive effect: the utilization of the fuel is improved, which is more important for fossil-fueled thermal plants than for nuclear power plants.
- Necessary investments for a heat extraction in a nuclear power plant are low compared to the total investment (if built during construction of the NPP).
- Worldwide, NPPs are not often used as heat suppliers.
Nuclear power plants are thermal power plants

- Electricity
- Steam turbine
- Extraction of steam for district heating systems
- Condenser
- District heating
- Cooling water
- Feedwater

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### NPPs and district heating – Projects in Switzerland

<table>
<thead>
<tr>
<th>NPP</th>
<th>Project</th>
<th>Remark</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mühleberg</td>
<td>FEMBE</td>
<td></td>
<td>not realized</td>
</tr>
<tr>
<td></td>
<td>District heating system</td>
<td>comfort heat</td>
<td>realized</td>
</tr>
<tr>
<td>Beznau 1 + 2</td>
<td>Transwaal</td>
<td></td>
<td>not realized</td>
</tr>
<tr>
<td></td>
<td>Refuna</td>
<td>comfort heat</td>
<td>realized</td>
</tr>
<tr>
<td>Leibstadt</td>
<td>WARHENO</td>
<td></td>
<td>not realized</td>
</tr>
<tr>
<td></td>
<td>THERMOCULTA</td>
<td>residual heat</td>
<td>realized</td>
</tr>
<tr>
<td>Gösgen</td>
<td>FOLA</td>
<td></td>
<td>not realized</td>
</tr>
<tr>
<td></td>
<td>Aarepapier / Cartaseta</td>
<td>process steam</td>
<td>realized</td>
</tr>
<tr>
<td></td>
<td>Fernwärme Niederamt</td>
<td>comfort heat</td>
<td>realized</td>
</tr>
</tbody>
</table>
NPPs and district heating – Projects in Switzerland

**TRANSWAL**

- approx. 60 km of main lines
- Connected load 485 MW (up to 750 MW)
- Whereof 270 MW base load from Beznau NPP
- projected prices (1986) 6.5-8.4 Rp./kWh
- follow-up project WAL

Source: PSI presentation
NPPs and district heating – Projects in Switzerland

FOLA

- 20 km main lines
- Connected load 175 MW
- Whereof 150 MW base load from Gösgen NPP
- Projected prices (1986) 6.5-8.2 Rp./kWh

Source: PSI presentation
NPPs and district heating – Projects in Switzerland

WARHENO

not realized

- approx. 100 km main lines
- Connected load 792 MW
- Whereof 396 MW base load from Leibstadt NPP
- Projected prices (1986) 7.5-10.5 Rp./kWh

Source: PSI presentation
### REFUNA – District Heating System out of Beznau NPP

<table>
<thead>
<tr>
<th></th>
<th>2006/07</th>
<th>2005/06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent local networks</td>
<td>75'136</td>
<td>89'172</td>
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<tr>
<td>Customer distribution</td>
<td>33'578</td>
<td>37'634</td>
</tr>
<tr>
<td>Special contract customers</td>
<td>12'928</td>
<td>15'013</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>121'642</td>
<td>141'819</td>
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</tbody>
</table>

#### Customer

<table>
<thead>
<tr>
<th></th>
<th>2006/07</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home connections in operation</td>
<td>2'425</td>
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<tr>
<td>Industrial customers</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2'432</td>
</tr>
</tbody>
</table>
REFUNA district heating – facts and figures

- Heating without CO₂ emissions since 25 years.
- More than 2 million megawatt hours heat replaces approximately 200 million liter fuel oil. Nearly 8500 fuel trucks would have been necessary to transport these quantities, while producing 600‘000 tons of additional CO₂.
- 31 km backbone (high pressure system); 101 km distribution system.
- Connected load 76 MWₜₜ (max.).
- 142 GWh of heat sold per year -> avoids approx. 46‘000 t CO₂.
- Initial financial difficulties have been overcome by a recapitalization in 2001.
- Competitive compared to gas and oil, even without CO₂-taxes.
NPPs and district heating – Projects in Switzerland

Utilization of residual heat from Leibstadt NPP

Garden center Leuenberger’s THERMOCULTA using warm water from the cooling tower
Technical data

- Consumption 2008: 1,700 MWh<sub>th</sub>
- Temp. central heating: 125/65 °C
- Temp. district heating: 125/75 °C
- Flow rate: 4.4 l/s
- Length of the line: KKM → Steinriesel, 2 km

Description

- District heat extraction to heat KKM office building as well as BKW’s Steinriesel residential area
- Heat extraction takes place between the high and low pressure turbine
- In case of failure an auxiliary boiler is used to supply heat to the system
NPPs and district heating – Projects in Switzerland

Process heat from Gösgen NPP

**realized**

<table>
<thead>
<tr>
<th>Location</th>
<th>Heat (GWh&lt;sub&gt;th&lt;/sub&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aarepapier</td>
<td>190</td>
</tr>
<tr>
<td>Cartaseta</td>
<td>30</td>
</tr>
<tr>
<td>FW Niederamt</td>
<td>12</td>
</tr>
</tbody>
</table>

Process steam and district heating system Niederamt

→ Process steam system for Aarepapier / Cartaseta

→ District heating network Niederamt
## District and process steam from Gösgen NPP

<table>
<thead>
<tr>
<th>Process steam system</th>
<th>COD</th>
<th>technology</th>
<th>power</th>
<th>energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aarepapier</td>
<td>1979</td>
<td>12 bar</td>
<td>50 MW&lt;sub&gt;th&lt;/sub&gt;</td>
<td>190 GWh/a</td>
</tr>
<tr>
<td>Cartaseta</td>
<td>2009</td>
<td>15 bar</td>
<td>7 MW&lt;sub&gt;th&lt;/sub&gt;</td>
<td>30 GWh/a</td>
</tr>
<tr>
<td>Niederamt</td>
<td>1996</td>
<td>120/70°C</td>
<td>12 MW&lt;sub&gt;th&lt;/sub&gt;</td>
<td>12 GWh/a</td>
</tr>
</tbody>
</table>

**Quelle:** Alpiq
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Nuclear safety in heat supply

Example Beznau NPP

Primary system (in contact with nuclear fuel elements)

Secondary system (no contamination)

third circle (no contamination)
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Lost electricity due to heat extraction

Loss of electricity production due to heat/steam extraction depends on pressure and temperature.

Approaches to assess value of heat:

- Opportunity costs of power plant operators
- Opportunity costs of district heating network operators

<table>
<thead>
<tr>
<th>NPP Beznau</th>
<th>NPP Gösgen</th>
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</thead>
<tbody>
<tr>
<td>Heat production (kWhth)</td>
<td>8</td>
</tr>
<tr>
<td>Loss of power (kWhel)</td>
<td>1</td>
</tr>
<tr>
<td>Heat production (kWhth)</td>
<td>3</td>
</tr>
<tr>
<td>Loss of power (kWhel)</td>
<td>1</td>
</tr>
</tbody>
</table>
Lost electricity due to heat extraction

Illustrative example

Calculation from the perspective of the power plant operator:

Market price electricity 8 Rp./kWh_{el}

Lost electricity production 1 kWh_{el}/8 kWh_{th}
(corresponds to the situation of KKB)

Opportunity costs for heat 1 Rp./kWh_{th}
(without taking into account capital costs as well as operation and maintenance cost for the heat exchanger)
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Political claim: utilization of residual heat

Example: gas combined cycle power plant

- Gas turbine
- Steam turbine
- Condenser
- Cooling water
- Process steam for district heating
- Feed water
- Waste gas
- Steam/district heating
- Condenser
- Electricity
- Air
- Gas
- Steam
- District heating
Distinction between use of residual heat ...

Low temperature: warm water of 25-30 °C – potential customers:

- Greenhouses (required space approx. 1 ha; 2 MW\text{th})
- Production of exotic fruits (required space approx. 1 ha; 2 MW\text{th})
- Sport and leisure centers (for each facility 0.2 MW\text{th})
- Tropical greenhouses (for each facility 2.5 MW\text{th})
- Fish farms (for each facility of 400m\text{3} 0.2 MW\text{th})
- Drying of scrap wood (100'000 m\text{3} timber / year; approx. 10 MW\text{th})
... and decoupling of process steam

Decoupling of process steam for:
• District heating system
• Paper factories
• Food production
• Chemistry
Heat from NPPs – a contribution to the solution of the CO₂ problem?

Example REFUNA (70 MWₜ/140GWhₜ):
• 10 Mio. liter heating oil per year
• savings of more than 26‘500 t CO₂
• equivalent to the CO₂ emissions of about 12’000 cars every year
Thank you for your attention.