Perspectives on Non-Electric Use of Nuclear Energy

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Contents

• Non-electric nuclear energy applications
  – Existing and Planned District Heating Applications
  – Long-distance Heat Transport
  – Nuclear Heating Reactor (NHR) Technologies
  – Nuclear desalination
  – Hydrogen production
• NC2I
• Gemini+
• RTD needs
• Summary
Non-electric nuclear energy applications

Low Temperature Heat
(<250°C)

Applications
- District Heating
- Desalination

Heat sources
- Gen II&III LWRs, HWRs
- Nuclear Heating Reactors (for urban siting)

High Temperature Process Heat
(>250°C: 550-900+°C)

Applications
- Chemical industry,
- H₂ production,
- Refineries and Petrochemical industry,
- Shale Oil/Gas production,
- Steel production etc.

Heat sources
- HTGR/VHTR for Cogeneration

Other applications
- Nuclear Propulsion, Other Transport Applications etc.
Existing and Planned District Heating Applications

The following countries have utilized nuclear district heat at least to some extent:

• Bulgaria, Canada, China, the Czech Republic, Germany, Hungary, India, Japan, Kazakhstan, Russia, Slovakia, Sweden, Switzerland, and Ukraine,

• In Russia nuclear heat has been extracted from various NPPs

• In Slovakia, town Trnava is heated by nuclear from the Bohunice VVER-440 power plant

• In Switzerland nearby villages extract heat from the Beznau NPP

The range of used heating power ranges from the few MW$_{th}$ level to few hundreds of MW$_{th}$

Studies exist for thousand MW$_{th}$ range heat supply

• Finland (Loviisa → Helsinki), distance ~80 km,
• Sweden (Forsmark → Stockholm), distance ~130 km,
• France (Nogent → Paris), distance ~100 km.
Long-distance Heat Transport

Case:
CHP option planned for Loviisa Unit 3 in Finland

• Study performed in 2008-2010
• Capacity in range of 1000 MW_th

Planned transport pipeline about 80 km:

Heat transport in tunnel:
Nuclear Heating Reactor (NHR) Technologies

Concepts in Past:

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<tr>
<th>Technology</th>
<th>Details</th>
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<tr>
<td><strong>SECURE Technology</strong> by Asea-Atom</td>
<td>• heating reactors with output at temperature 100°C (-L) and 150°C (-H),</td>
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<tr>
<td></td>
<td>• 200 and 400 MW&lt;sub&gt;th&lt;/sub&gt;</td>
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<tr>
<td><strong>KWU Simple and Safe NHR</strong></td>
<td>• 200 MW&lt;sub&gt;th&lt;/sub&gt; concept, can be adapted in range of 100...500 MW&lt;sub&gt;th&lt;/sub&gt;</td>
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<tr>
<td><strong>NHR-200</strong></td>
<td>• Chinese 200 MW&lt;sub&gt;th&lt;/sub&gt;</td>
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<tr>
<td></td>
<td>• application studies also for desalination purposes</td>
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<tr>
<td><strong>AST-500</strong>, Russia</td>
<td>• Delivered but not commissioned</td>
</tr>
<tr>
<td><strong>SLOWPOKE-3</strong> (2...10 MW&lt;sub&gt;th&lt;/sub&gt;)</td>
<td>• Canada</td>
</tr>
<tr>
<td>Swiss 10 MW&lt;sub&gt;th&lt;/sub&gt; BWR type NHR</td>
<td>• 10 MW&lt;sub&gt;th&lt;/sub&gt; BWR type NHR</td>
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New concepts:

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<th>Technology</th>
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<td>Yanlong reactor (DHR-400)</td>
<td>• swimming pool type low-temperature reactor</td>
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<td>• feasibility demonstrated 2017 with a research reactor</td>
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<td></td>
<td>• design completed 2018 by CNNC</td>
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<tr>
<td>NHR200-II by CGN</td>
<td>• based on NHR-5 reactor and concept NHR-200 at INET (Tsinghua Univ)</td>
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Common NHR design features:

- Low design pressure
- Low power-to-volume ratios
- Extensive use of passive systems
- Deployment of natural circulation for reactor cooling
- Integrated structure with heat exchangers inside the reactor vessel
- Long fuel management cycles
- Utilization of underground structures
- Planned for urban siting
Nuclear desalination

Desalination

- Worldwide almost 100 million m³/d desalinated water produced in 19 000 plants
- Main technologies: reversed osmosis (65%), thermal methods (multi-stage flash, multi-effect distillation etc) and thermal-membrane hybrids
- Energy needs:
  - reversed osmosis: 3-6 kWₑ h/m³ for sea water
  - thermal methods: few tens of kWₜₕ h/m³ + few kWₑ h/m³

Nuclear applications

- Aktau BN-350: producing 80 thousand m³/d potable water until 1999
- Desalination in range of thousands of m³/d deployed in existing NPPs: Japan, India, Russia, Pakistan
- Studies and considerations of using nuclear energy to large-scale desalination:
  - Large LWRs
  - SMRs: SMART (Korea), CAREM (Argentina), NHR-200 (China), floating KLT-40S and others (Russia), NuScale (USA)
Need for district and process heat and temperature range

Heat Use in Europe

- Space Heating
- Desalination
- Paper and Pulp
- Food and Tobacco
- Textile
- Sodium hydroxide and Soda
- Transport Equipments
- Machinery
- Chemistry
- Minerals
- Mining and Quarry
- Metallurgy
- Other industries
- Oil Refining

Data From Euroheatcool, 2006

Temperature (°C)

- Iron and steelmaking
- Glass and mineral wool
- Ceramics (firing)
- Cement
- Non-ferrous metals (copper and...)
- Hydrogen (steam methane reforming)
- Aluminium primary: Calcination
- Lime
- Oxygen production (high...)
- Aluminium secondary
- Ammonia and urea
- Refinery (except hydrogen...)
- Plastics
- Non-ferrous metals (lead, zinc)
- Chemical industry
- Soda ash
- Ceramics (drying)
- Aluminium primary Alumina...
Readiness and capacities
Hydrogen Production

H₂ in the refining of petroleum products
The available crude stocks become heavier. These and the “dirty fuels” (heavy oils, oil shale, tar sands) require larger amounts of both process heat and hydrogen to produce cleaner burning end-point fuels with a higher hydrogen-to-carbon ratio.

Reports on Nuclear H₂ Production:

• 5FWP Project MICANET - Final report 2005 (publ. 2007) "Nuclear Energy for Hydrogen Production” 184 p

• IAEA, NP-T-4.2 (2013) "Hydrogen Production Using Nuclear Energy” 379 p

  https://www-pub.iaea.org/MTCD/Publications/PDF/te_1085_pm.pdf
NC2I Nuclear Cogeneration Industrial Initiative

**Purpose:** to drive the development and deployment of high temperature nuclear cogeneration for industrial use

- NC2I was set up in 2011 as Europe’s initiative for nuclear cogeneration – under the Sustainable Nuclear Energy Technology Platform (SNETP)
- HTGR was selected as the reference technology in order to reach higher temperatures for industrial applications
- NC2I builds on French & German legacy + 15 years of EU R&D programmes + Polish programme
- The task force gathers the nuclear developers, and the business group will allow a structured dialogue with end-users and investors to drive the demonstration programme
GEMINI+

Horizon 2020 project

• Works towards the demonstration of high temperature nuclear cogeneration with HTGR
• Provides
  • a conceptual design of a high temperature nuclear cogeneration system that supplies process steam to industry,
  • a licensing framework for this system, and
  • a business plan for a full-scale demonstration.
• Launched in September 2017 for 36 months (Coordinator: G. Wrochna, NCBJ, Poland)
• Builds on earlier RTD projects: ARCHER, EUROPAIRS, NC2I-R
• 26 partners from Europe, USA, Korea and Japan

This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement n°755478. The content of this presentation reflects only the author’s view. The European Commission is not responsible for any use that may be made of the information it contains.
Development needs

District heating
• Transport of heat on long distances
• Coupling to existing district heat networks
• Socioeconomics for decision making

Process heat applications
• Coupling between the reactor and the user process (including Business Models)
• Flexibility in use
• HTGRs exist (several plants operated: HTTR, HTR-10 and HTR-PM), but there are major development needs such as
  – **Demonstrator** for the coupling
  – Qualification of materials and components for high temperature applications
Summary

• There is a huge potential for non-electric applications of nuclear energy in low and high temperature heat supplies, desalination, hydrogen production and in transportation

• Development efforts are needed particularly for
  – Socioeconomics of district heating applications
  – Establishing the coupling between the reactor and user processes
  – Materials for high-T process heat applications

• For high-temperature applications the necessary first step is to build a coupling demonstrator based on existing HTGR technologies