INPRO Dialogue Forum on

Opportunities and Issues in Non-Electric Applications of Nuclear Energy,

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Perspectives on Non-Electric Use of Nuclear Energy

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Contents

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,
- H_2 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

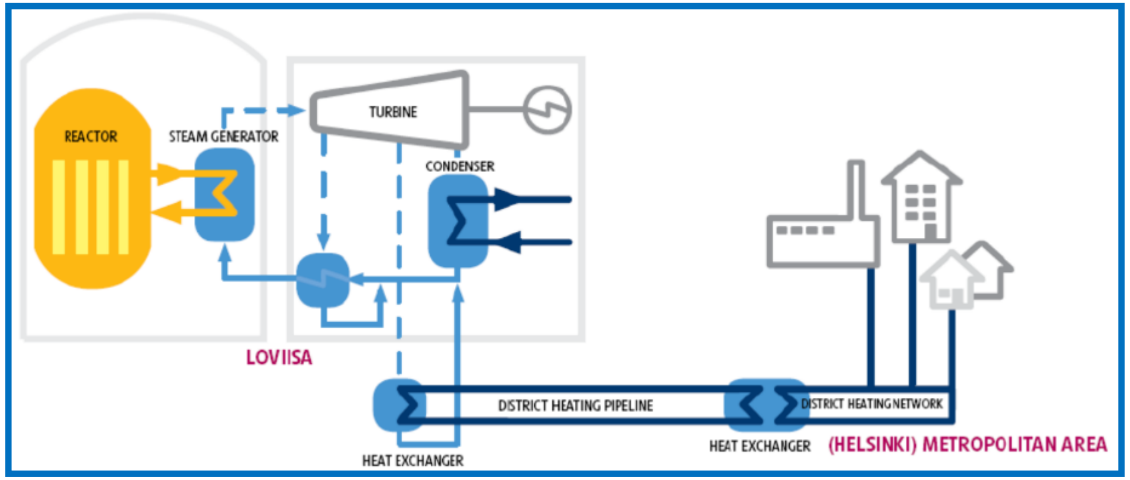
- Finland (Loviisa → Helsinki), distance ~80 km,
- Sweden (Forsmark → Stockholm), distance ~130 km,
- France (Nogent → Paris), distance ~100 km.

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}

PWR Connection:



Planned transport pipeline about 80 km:

Heat transport in tunnel:

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Nuclear Heating Reactor (NHR) Technologies

Concepts in Past:

SECURE Technology by Asea-Atom

- heating reactors with output at temperature 100°C (-L) and 150°C (-H),
- 200 and 400 MW_{th}

KWU Simple and Safe NHR

- 200 MW_{th} concept, can be adapted in range of 100...500 MW_{th}

NHR-200: Chinese 200 MW_{th}

- application studies also for desalination purposes

AST-500, Russia

- Delivered but not commissioned

SLOWPOKE-3 (2...10 MW_{th}), Canada

Swiss 10 MW_{th} BWR type NHR

New concepts:

Yanlong reactor (DHR-400)

- swimming pool type low-temperature reactor
- feasibility demonstrated 2017 with a research reactor
- design completed 2018 by CNNC

NHR200-II by CGN

- based on NHR-5 reactor and concept NHR-200 at INET (Tsinghua Univ)

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**

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Nuclear desalination

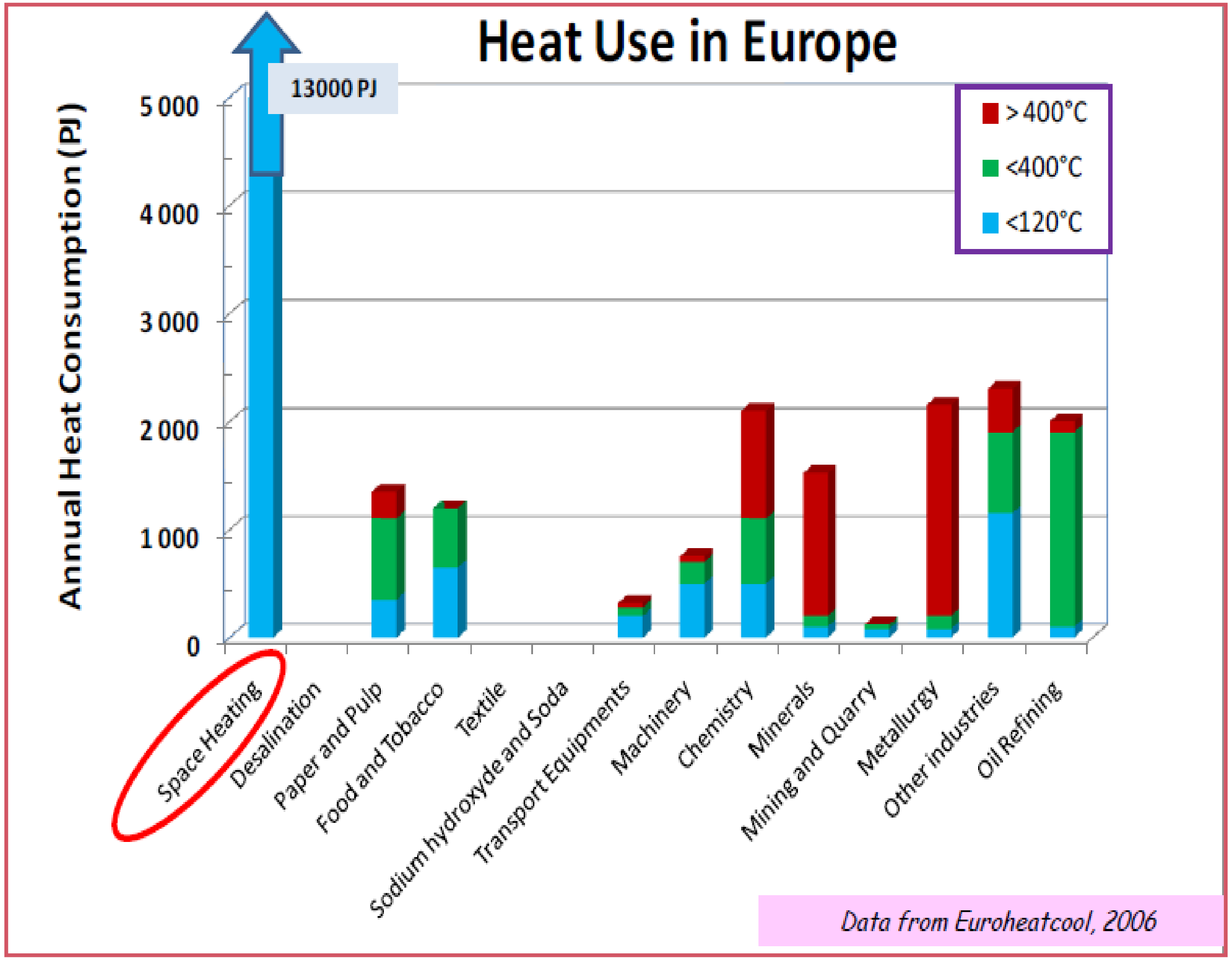
Desalination

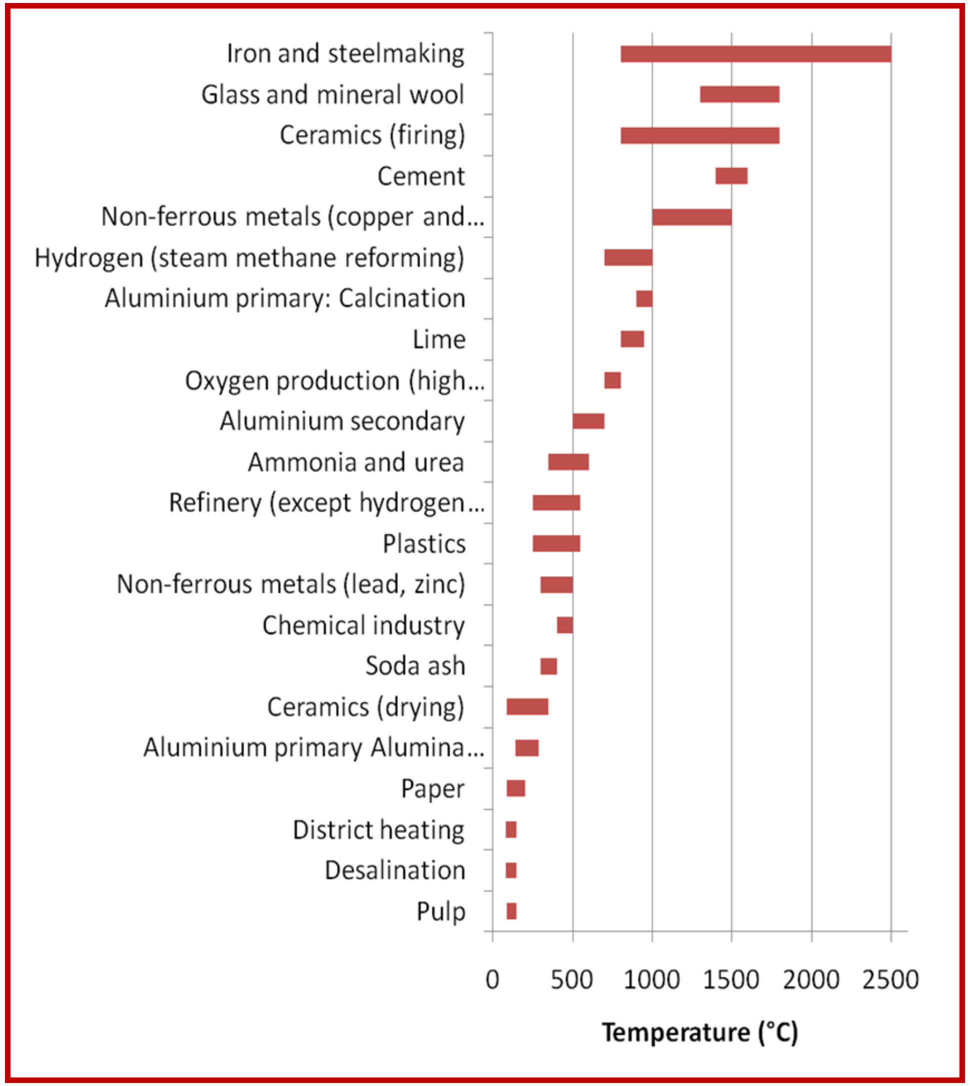
- Worldwide almost 100 million m^3/d desalinated water produced in 19 000 plants
- Main technologies: reversed osmosis (65%), thermal methods (multi-stage flash, multi-effect distillation etc) and thermal-membrane hybrids
- Energy needs:
  - reversed osmosis: 3-6 kW_eh/m^3 for sea water
  - thermal methods: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

Nuclear applications

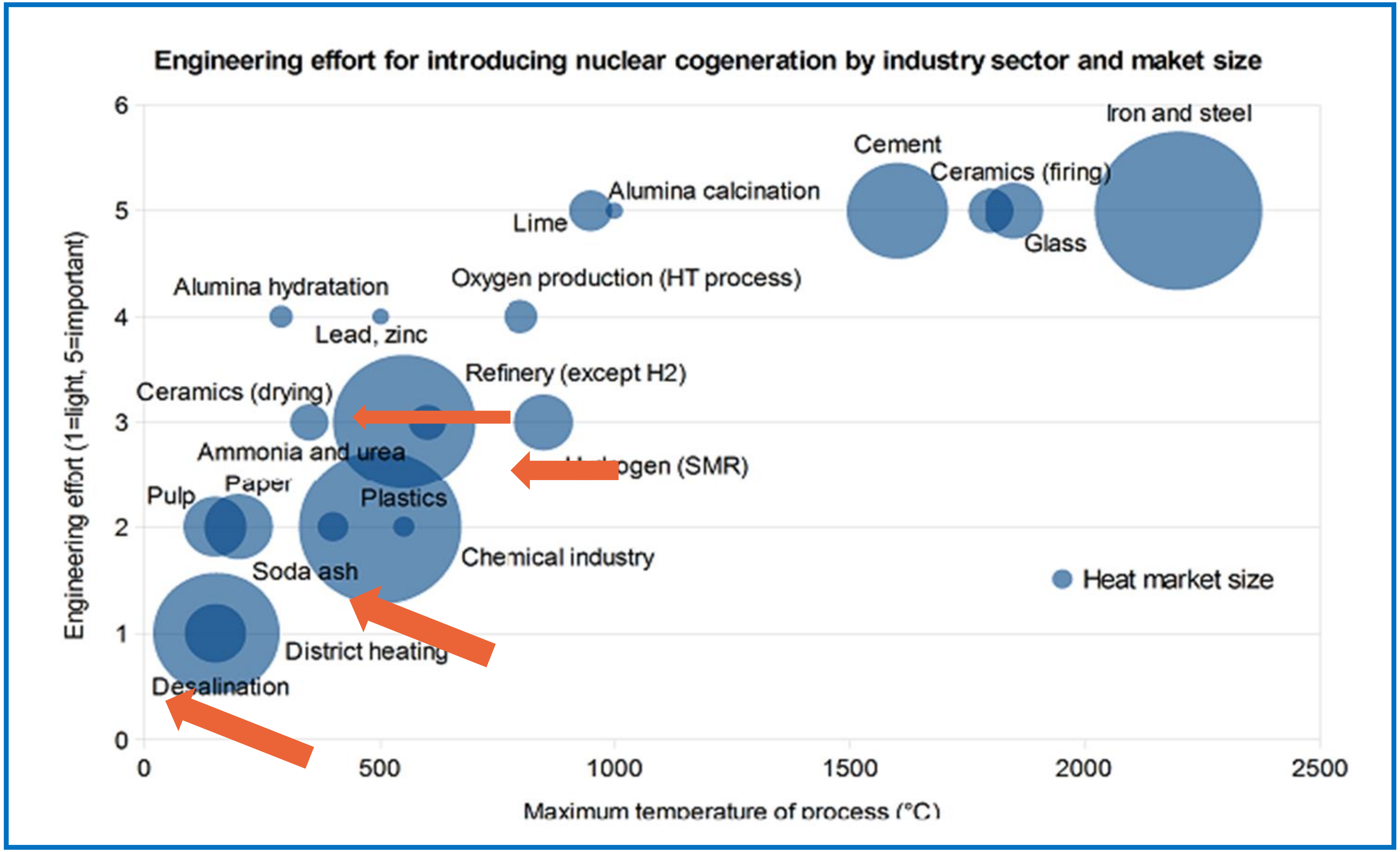
- Aktau BN-350: producing 80 thousand m^3/d potable water until 1999
- Desalination in range of thousands of m^3/d deployed in existing NPPs: Japan, India, Russia, Pakistan
- Studies and considerations of using nuclear energy to large-scale desalination:
  - Large LWRs
  - SMRs: SMART (Korea), CAREM (Argentina), NHR-200 (China), floating KLT-40S and others (Russia), NuScale (USA)

Need for district and process heat and temperature range





Readiness and capacities



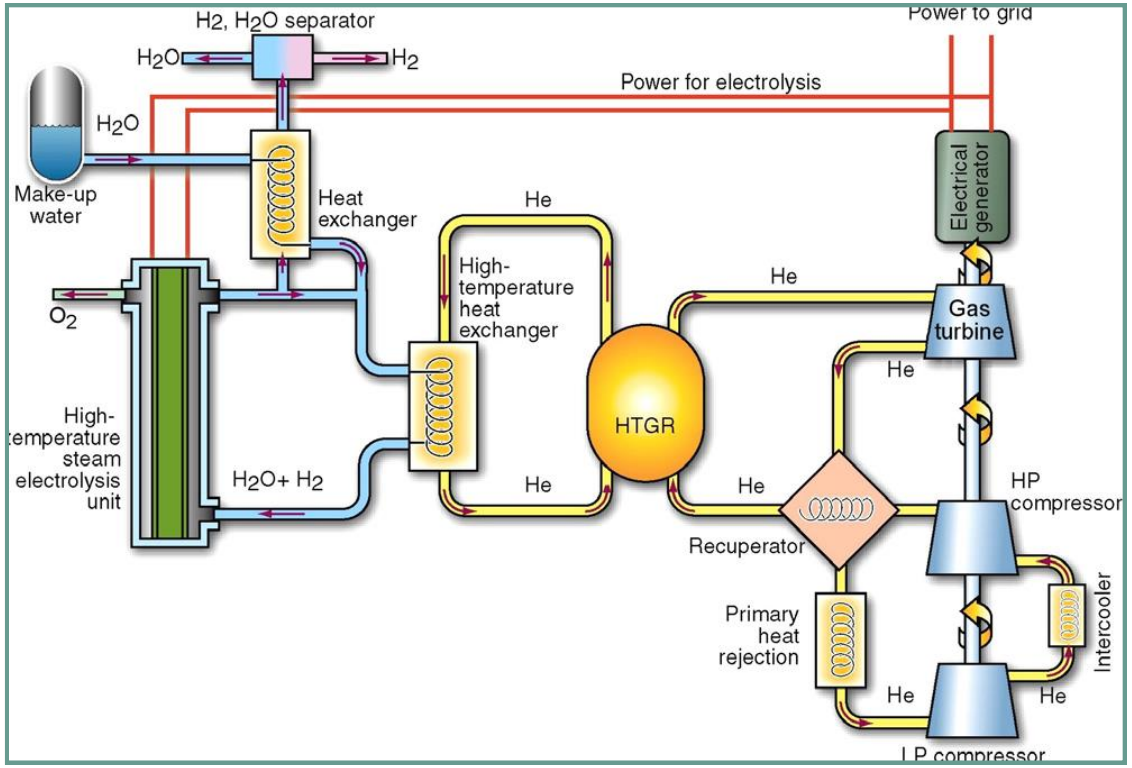
Hydrogen Production

H_2 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
  http://juser.fz-juelich.de/record/58871/files/Energietechnik_58.pdf
- IAEA, NP-T-4.2 (2013)
  ”Hydrogen Production Using Nuclear Energy” 379 p
  https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1577_web.pdf
- IAEA-TECDOC-1085 (1999)
  “Hydrogen as an Energy Carrier and Its Production by Nuclear Power” 345 p
  https://www-pub.iaea.org/MTCD/Publications/PDF/te_1085_prn.pdf



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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

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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.
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GEMINI+

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