Nuclear Cogeneration Industrial Initiative

www.nc2i.eu

European Projects

Dominique Hittner

NC2I is one of SNETP's strategic technological pillars, mandated to coordinate the demonstration of high temperature nuclear cogeneration.

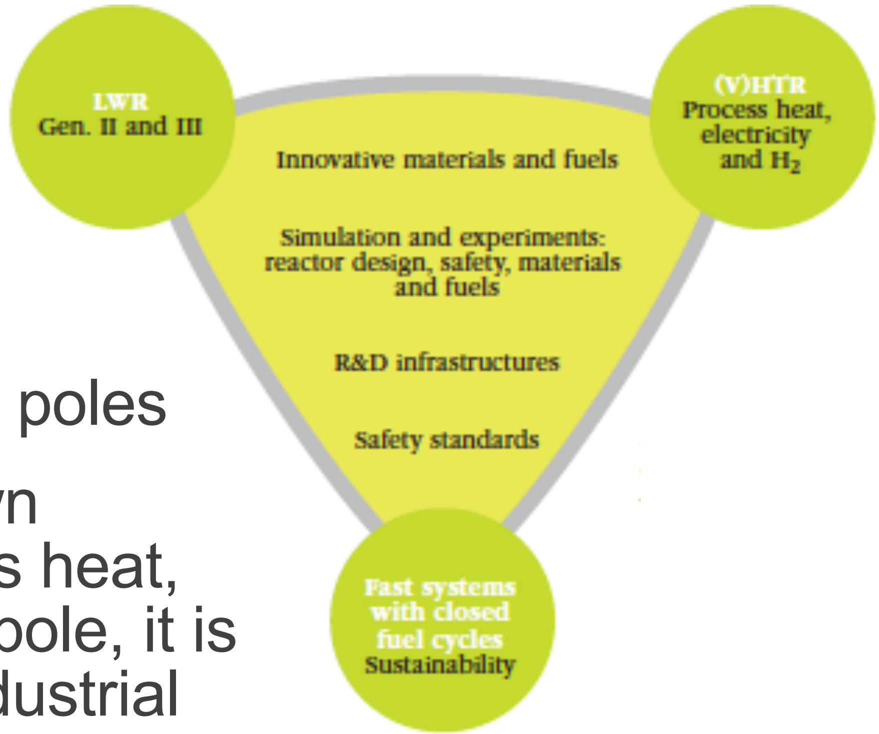
Sustainable Nuclear Energy Technology Platform
www.snetp.eu

The European framework

- The European Commission is widely funding R&D in Europe, with part of it for nuclear R&D (Euratom funding):
  - Fusion
  - Waste management
  - Safety of fission
- The EC works by defining Work Programmes and organising competitive calls in the frame of these programmes
- The Work Programmes are organised under Framework programmes (FP) lasting ~ 5 years

The European framework

- To advise them on strategic orientations to their programmes, the EC encouraged the creation of “Technology Platforms” grouping stakeholders of industry and research in each field of European economic activity.
- In the field of nuclear fission, the stakeholders are grouped in the “Sustainable Nuclear Energy Technology Platform (SNETP)” > 100 members
- SNETP is organised around 3 poles
- Each of the 3 poles has its own organisation. For the ”process heat, electricity and H_2 production” pole, it is the “Nuclear Cogeneration Industrial Initiative (NC2I)”.



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Objective and roles of NC2I

NC2I
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- Objective:
  - To promote the development of industrial nuclear cogeneration in Europe
  - To focus on early industrial deployment
    - ⇒ *The HTGR technology identified as the most mature for deployment*
- How?
  - To develop the technology through Euratom funded projects
    - *Define NC2I strategy*
    - *Advise the European Commission on the orientations of its programmes*
    - *Get organised to respond to calls*
    - *Define the strategic content of the proposals submitted by NC2I partners*
    - *Survey the implementation of projects*
  - To interact with decision making organisations and persons
  - To support initiatives in favour of the development of industrial nuclear cogeneration

History of activities

- The European HTGR programme started late 1990s' on the basis of the German HTGR programme legacy.
- Right from early 2000's, European activities for nuclear cogeneration have been coordinated (HTR-TN).
- Early in 2010s', Ruropean activities became focused on industrial nuclear cogeneration (HTR-TN → NC2I-R).
- 3 phases
  - 1998-2014: Recovery of the results of past developments (mainly from German programme) and new technology developments
  - 2009-2015: Study of application to heat/steam supply to industry, interactions with end-user industries
  - After 2015: Design and licensing of an industrial cogeneration plant

First phase of the European HTGR programme

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- Several projects funded by Euratom:
  - INNOHTR (FP4)
  - HTR-N, HTR-F, HTR-M. HTR-E, HTR-L (FP-5)
  - RAPHAEL, PUMA (FP6)
  - CARBOWASTE, ARCHER (FP7)
- Focused on the recovery of the technology developed in Germany and on new technology developments
  - Improvement in the reactor physics modelling
  - Irradiations of graphite and fuel
  - Study of components (e.g. testing of heat exchanger in He loop)
  - Assessment of the capacity of HTGR to burn Pu
  - HTGR waste behaviour and management
  - ….
- Linked with existing design projects (ANTARES in AREVA, and participation of partners in international projects (PBMR, NGNP…))

Second phase of the European HTGR programme

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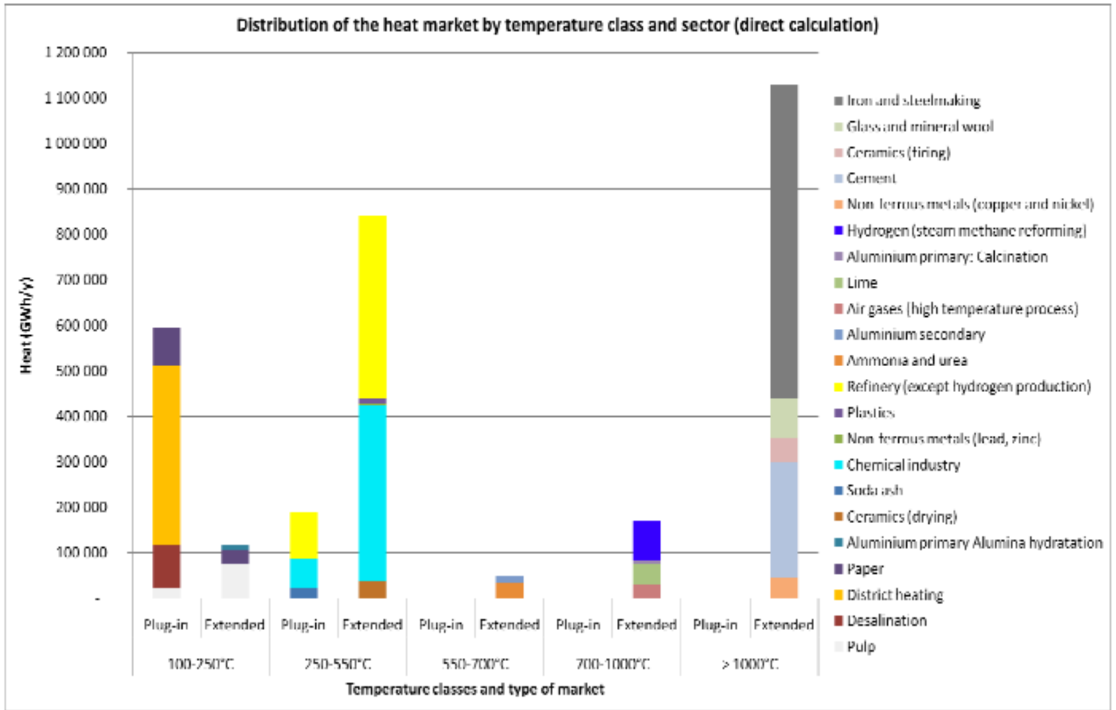
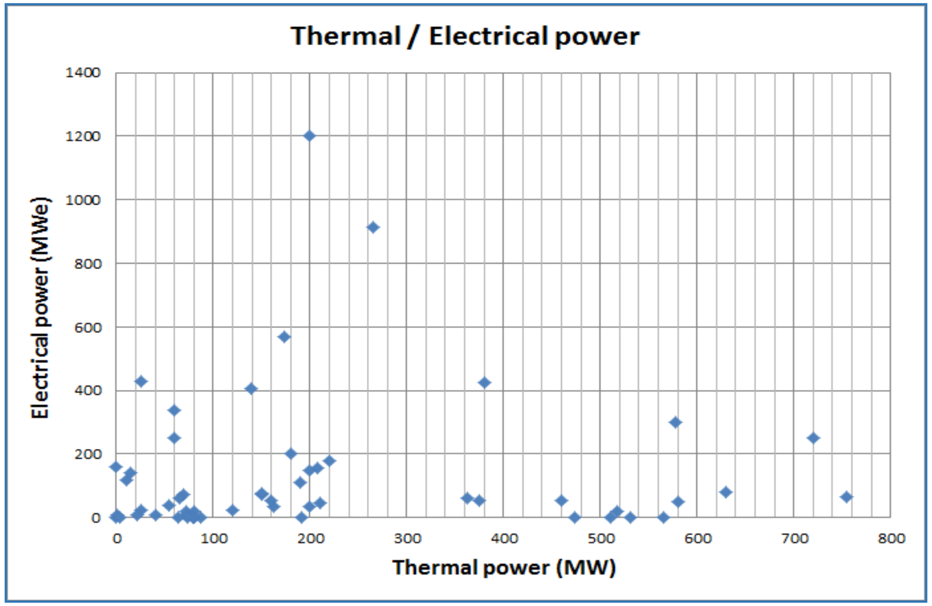
- 2 projects
  - EUROPAIRS (FP6)
  - NC2I-R (FP7)
- Better understanding of the market, of its needs and expectations





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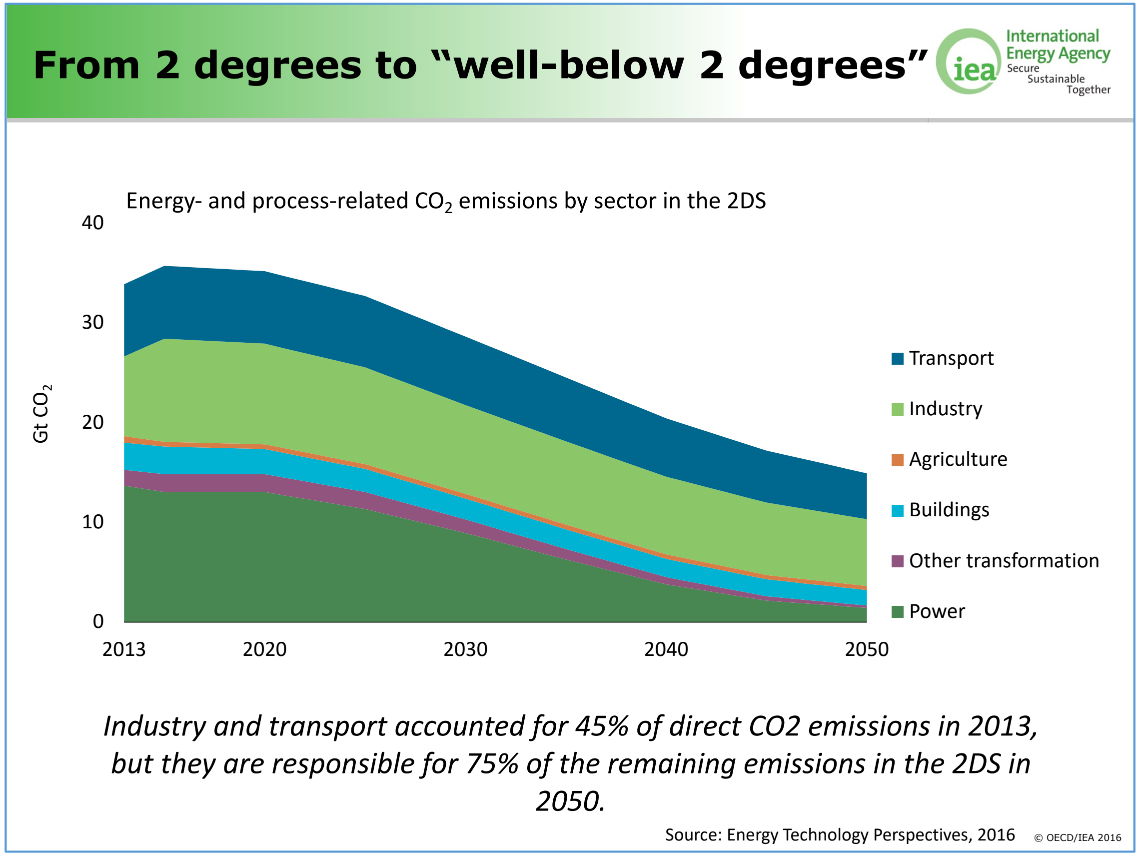
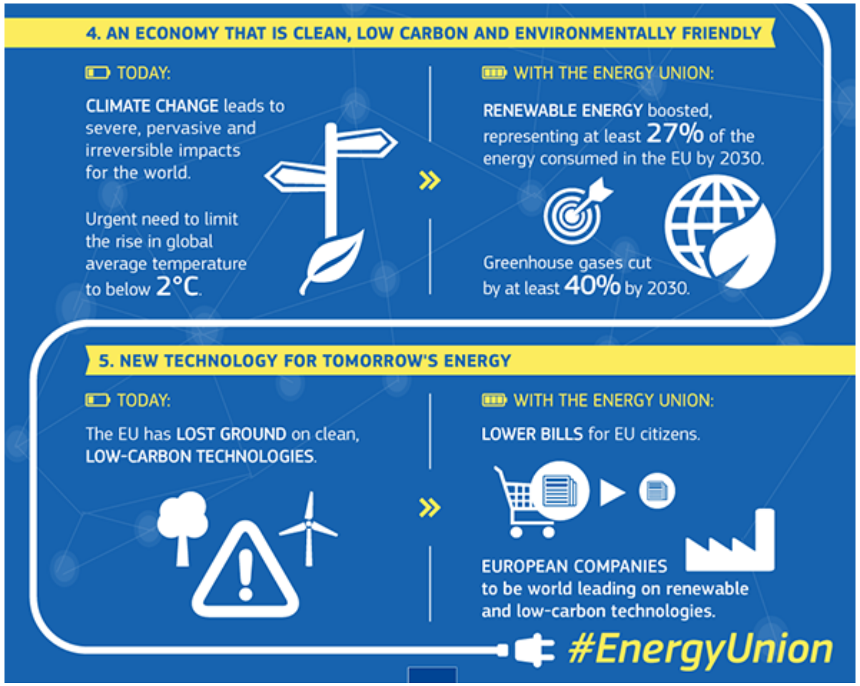
International & European context

- COP 21:
  2˚C "commitment"



- European "Commitments"
  - "Energy Union"
  - SET-Plan:
    - *To develop decarbonized technology for European economy*
- The UK and Polish context



UK AMR programme (1)

Department for Business, Energy & Industrial Strategy

- 2015-2016 SMR competition
  => Conclusion:
  - LWR SMR technology is mature and it is the responsibility of vendors to bring them to the market
  - Government support to be granted only to advanced non water-cooled reactors

⇒AMR competition 2017-2018
  - ~ 20 vendors proposed projects
  - 8 winners for a first phase of 8 months for presenting
    - ✓ *A concept and business case for the UK market*
    - ✓ *A licensing feasibility study for UK*
    - ✓ *A development programme for a 2nd phase*
  - Phase 2 was supposed to be launched mid 2019 for a selection of systems within the 8 ones presented in phase 1

+ National research programme (in particular on TRISO fuel fabrication)

UK AMR programme (2)

- Phase 1 winning projects
  - Moltex: UK Stable Salt Reactor Feasibility
  - Tokamak Energy: Advanced Modular Fusion - The Spherical Tokamak
  - Westinghouse: An Innovative Nuclear Solution based on Lead Fast Reactor Technology
  - LeadCold: Small, Economic and Agile Lead-cooled Reactors for the UK
  - U-Battery Developments: U-Battery
  - Advanced Reactor Concepts: ARC-100: Sodium Cooled Fast Reactor Employing Metallic Fuel
  - DBD: AMR Feasibility and Development Project - High Temperature Gas Cooled Reactors
  - USNC: MMR, a novel nuclear cogeneration system for multipurpose applications

Poland (1)

- Interest of Poland, where electricity is ~ 80% from coal, for nuclear energy in the last 10 years
  - Buying a large nuclear plant for electricity generation
  - Creating a Polish based HTGR technology for industrial energy needs


MINISTERSTWO ROZWOJU

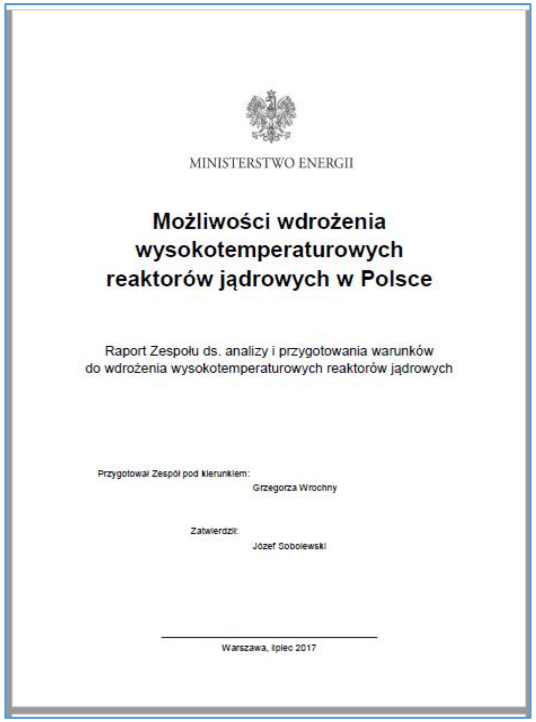
STRATEGIA
NA RZECZ
ODPOWIEDZIALNEGO
ROZWOJU *projekt do konsultacji społecznych*

WARSZAWA 2016

- 2016: The government
  - Published its “strategy for responsible development”, which included the development of HTGR for industrial cogeneration
  - Appointed a “Committee for deployment of high temperature reactors”, with participation of industry (heat users, engineering companies), R&D, the regulator and a bank

Poland (2)

- 2017: The HTR Committee produced its report
  - Business case
  - Development strategy
  - End-users needs → the HTGR plant should deliver 165 MWth of steam
- 2018-2019:
  - The report of the HTR Committee has been endorsed by the Ministry of Energy http://www.tiny.cc/htr-pl
  - The project is entering into a phase of organisation
    - *Creating an entity that will implement the project*
    - *Defining the funding mechanism*
    - *Changing the atomic energy law*


MINISTERSTWO ENERGII

Możliwości wdrożenia wysokotemperaturowych reaktorów jądrowych w Polsce

Raport Zespołu ds. analizy i przygotowania warunków do wdrożenia wysokotemperaturowych reaktorów jądrowych

Przygotował Zespół pod kierunkiem:
Grzegorza Wrochny

Zatwierdził:
Józef Sobolewski

Warszawa, lipiec 2017

Third phase of the European HTGR programme

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- In the frame of the present FP: H2020
- Objectives of the project:
  - To start designing a HTGR for process heat supply to industry for deployment ASAP in support of Polish plan
  - To develop a licensing framework for the nuclear plant and for its coupling with industrial processes
- GEMINI+ project (2017-2020)
  - Focus on steam supply to steam networks existing on industrial sites
- New proposal, HYDRO-GEN IV
  - Can we produce hydrogen with the GEMINI+ reactor?
  - Additional topics:
    - *Residual safety issues*
    - *Non-proliferation, sustainability*

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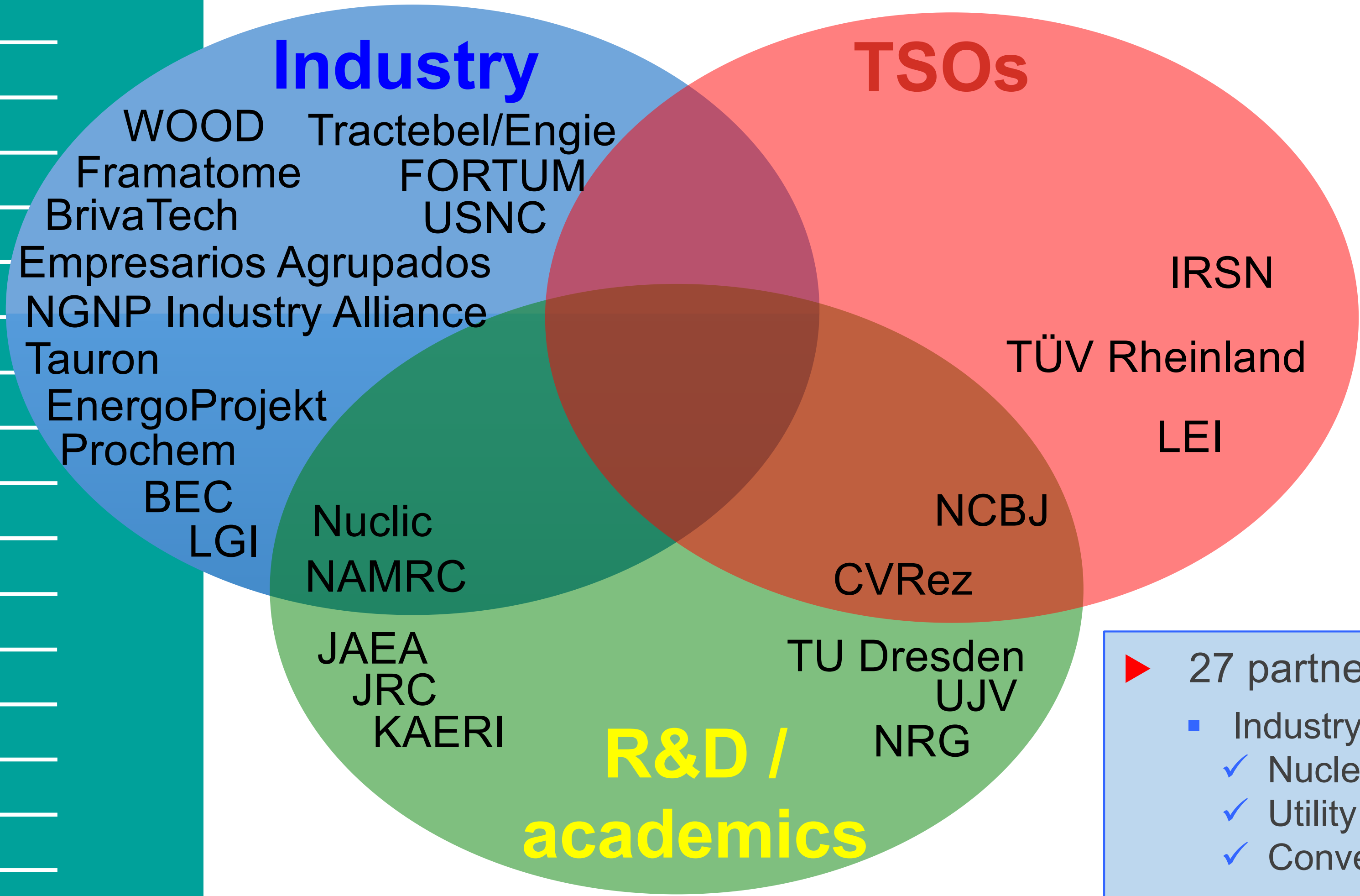
GEMINI+ partnership



- 27 partners
  - Industry
    - ✓ Nuclear
    - ✓ Utility
    - ✓ Conventional industries
  - R&D + academics
  - TSOs
- 12 countries (9 European + USA, JP, KR) + JRC:
  PL: 4, DE: 4, FR: 3, etc.

GEMINI+ scope

- Design requirements
- Selection of main design options
- Safety approach and basis of a licensing framework for
  - The reactor
  - Its coupling with industrial processes
- Plan for demonstration
  - Appropriateness of some Polish sites
  - Supply chain
  - Technology gaps
  - Business plan
- Can we introduce innovative features, though endeavouring to focus on mature technologies for a deployment ASAP?

GEMINI+ design requirements (1)

- To be able to get a nuclear offer to provide industrial process heat as soon as possible
  - ⟹To use as much as possible mature technologies
- Safety
  - No impact of possible accidents on the industrial site on the nuclear plant
    - ⟹ *Distance and obstacles between the nuclear reactor and the applications*
      - ⟹ *Need to transport heat*
        - ⟹ Use of steam distribution networks (existing)
  - No radio-contamination of the non-nuclear industrial facilities from the nuclear plant
    - ⟹ *Need of an intermediate circuit between the reactor and the industrial steam network*
- Flexibility in spite of standardisation
  - To adapt to various shares between electricity and process heat from 100% elec. to 100% heat
  - To adapt to load variability

GEMINI+ design requirements (2)

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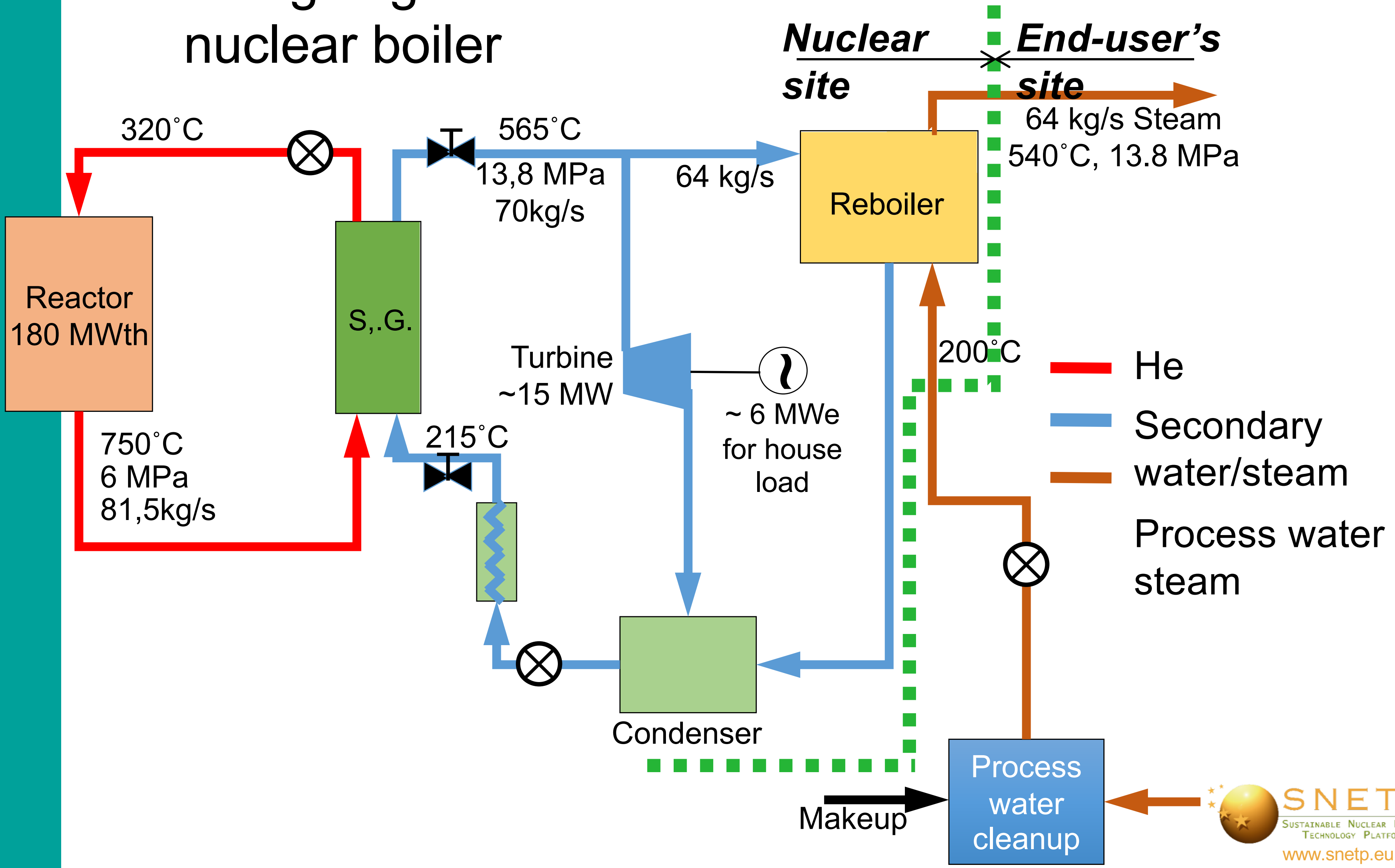
- To provide a product (steam) and a service corresponding to industry needs
  - For Poland:
    - *64 kg/s steam 540˚C, 540˚C, 13,8 MPa, water return 200˚C*
    - *Only steam, no electricity from the nuclear plant*
  - Availability > 90%
    - *But no possibility to reach ~ 100% availability expected by industry*

    ⟹*Need of a back-up (site dependent: can provided by multiple nuclear reactors, conventional fossil fuel-fired boilers or heat storage depending on the required availability)*
- Competitiveness
  - To minimise the investment cost: tracks followed
    - *Standardisation*
    - *Use of modular manufacturing and construction techniques*
      - ⟹ Transportability of components and systems
    - *Benefit of large series expected*
    - *Design simplifications*
      - ☞ In particular minimisation of the number of safety classified components
  - *To minimise other life cycle costs (operation, waste management)*

General configuration of GEMINI+ system (1)

- Designing a 165 MWth nuclear boiler



General configuration of GEMINI+ system (2)

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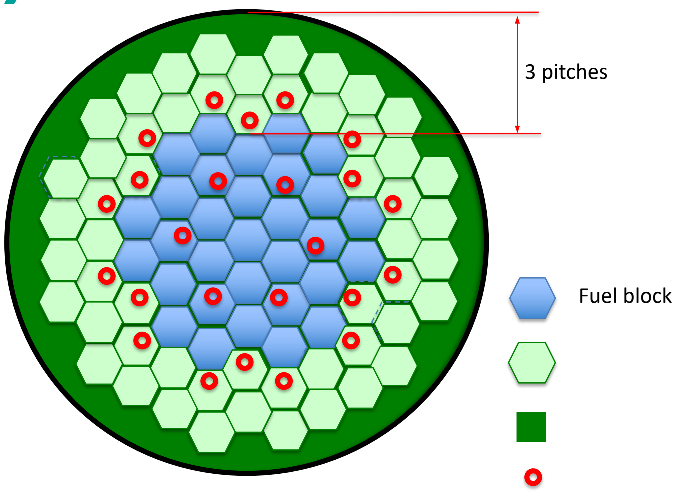
- The nuclear system is plugged into an existing steam distribution network in substitution to a conventional boiler, without any change in the steam network and the non-nuclear industrial site.
- The nuclear reactor is separated from the industrial site (steam network) by a secondary system
  - 3 functions:
    - *Transport of heat from the reactor to the industrial site*
    - *Generation of house load and accommodation of higher loads in some transient situations*
    - *Prevent radio-contamination of the industrial site*
- Flexibility
  - The design of the nuclear plant is independent of the use of the steam (electricity, process steam or both)
  - Operational flexibility
    - *Load following possible*
    - *Possibility to restart at anytime after full loss of load on the industrial site*

General configuration of GEMINI+ system (3)

- Compact design
  - A block type core provides a higher power density (~ 6 MW/m^3)
  - Cylindrical and not annular
  - Enriched UO_2 fuel, ~ 90 GWd/tU. with a potential for higher burnup with UO_2 or even higher using UCO (validated in the US AGR programme up to ~ 140 GWd/tU)

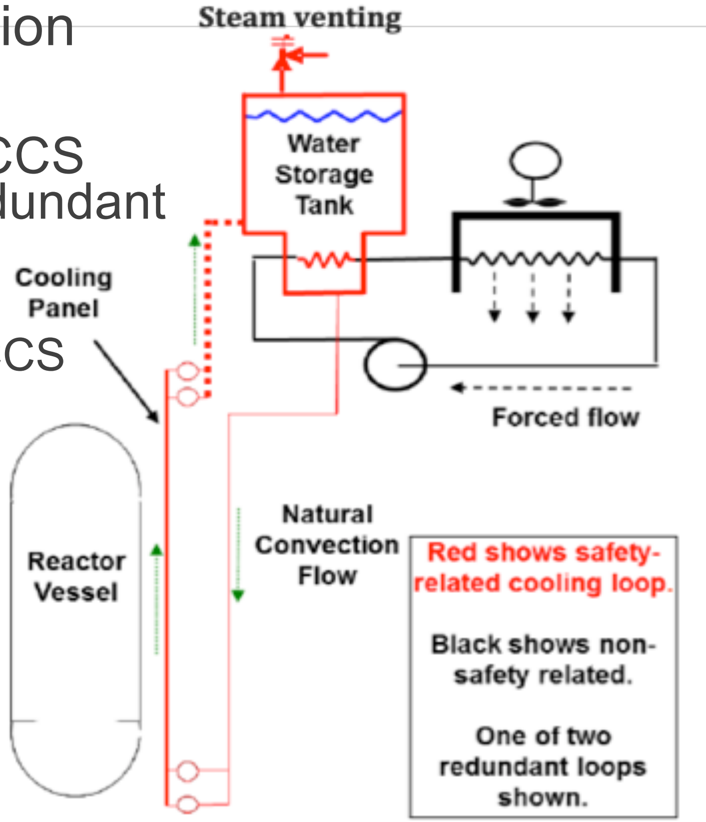
⟹ Road transportable (ø vessel ~ 4,5 m)



GEMINI+ safety design basis

Full use of the modular HTGR intrinsic and passive safety approach and an appropriate design

- Intrinsic: the release of decay heat from the core to the RCCS takes only into account thermal conduction and radiative heat transfer
- Fully passive: release of decay heat by a RCCS based on natural circulation of water in a redundant circuit operated permanently in normal and accident conditions
  - In normal operation, active cooling of the RCCS
  - If active cooling fails, 3 to 7 days of full autonomy by boiling off of the water storage tank
- Appropriate design:
  - Low power, widely in the range allowed for fully passive and intrinsic safety
  - The structural materials and the fuel selected allow maintaining the geometrical integrity of the reactor in accident conditions



Conclusion

- The European programme will not replace national and industrial engagement for a real industrial project
- But it prepares the ground for such a project
  - It keeps and develops the technologies
  - It keeps competences
  - It gathers a large engineering and R&D partnership, including partnership with key international actors
  - It initiates the basis of the future design