HTGR, a promising technology to contribute to Green Deal objectives

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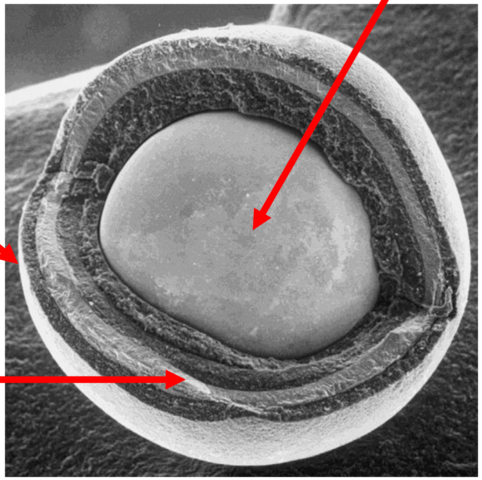
Main features of modular HTGR

- HTGR = High Temperature Helium-cooled Reactor

	LWR	HTGR
Coolant	Water	Helium
Moderator		Graphite
Operating temperature	300˚C	750˚C*

** With qualified existing industrial materials; with advanced materials, in the longer-term, 900-1000˚C*

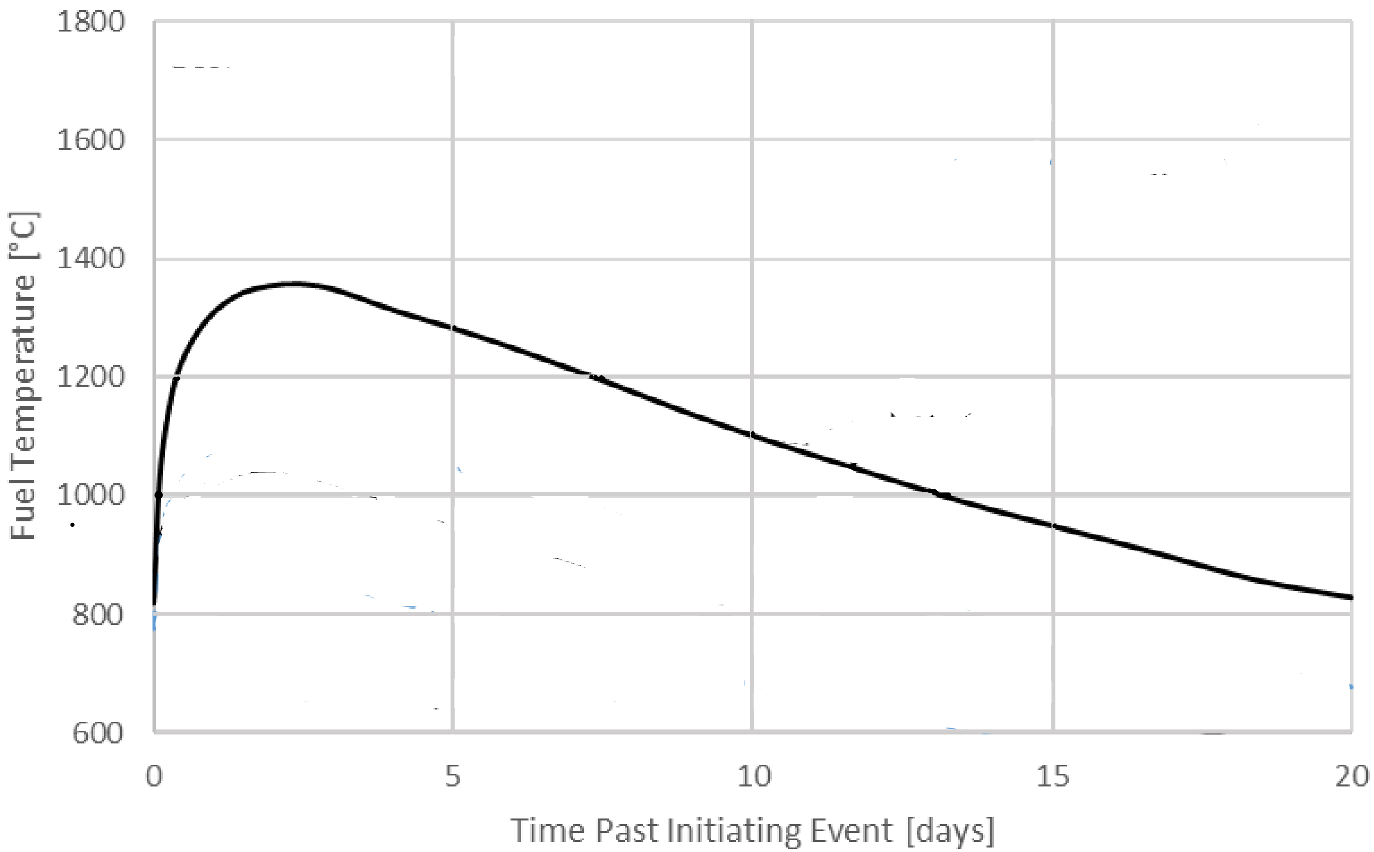
- Power limited to a few hundred megawatts
- Fuel based on TRISO particles dispersed in a graphite matrix



Outstanding safety of modular HTGR

- Very favourable safety features: huge inertia, refractory materials, leak tight fuel up to very high temperature
- If power not exceeding a few hundred megawatts
  - ✓ Safety based on inherent physical properties of the reactor and purely passive behaviour (no need of action from personnel or from any powered automatic device).
  - ✓ Temperature of the fuel kept without any action need below limits that would threaten its integrity
    ⇒ No physical possibility of core melting and of significant radioactive release

Outstanding safety of modular HTGR



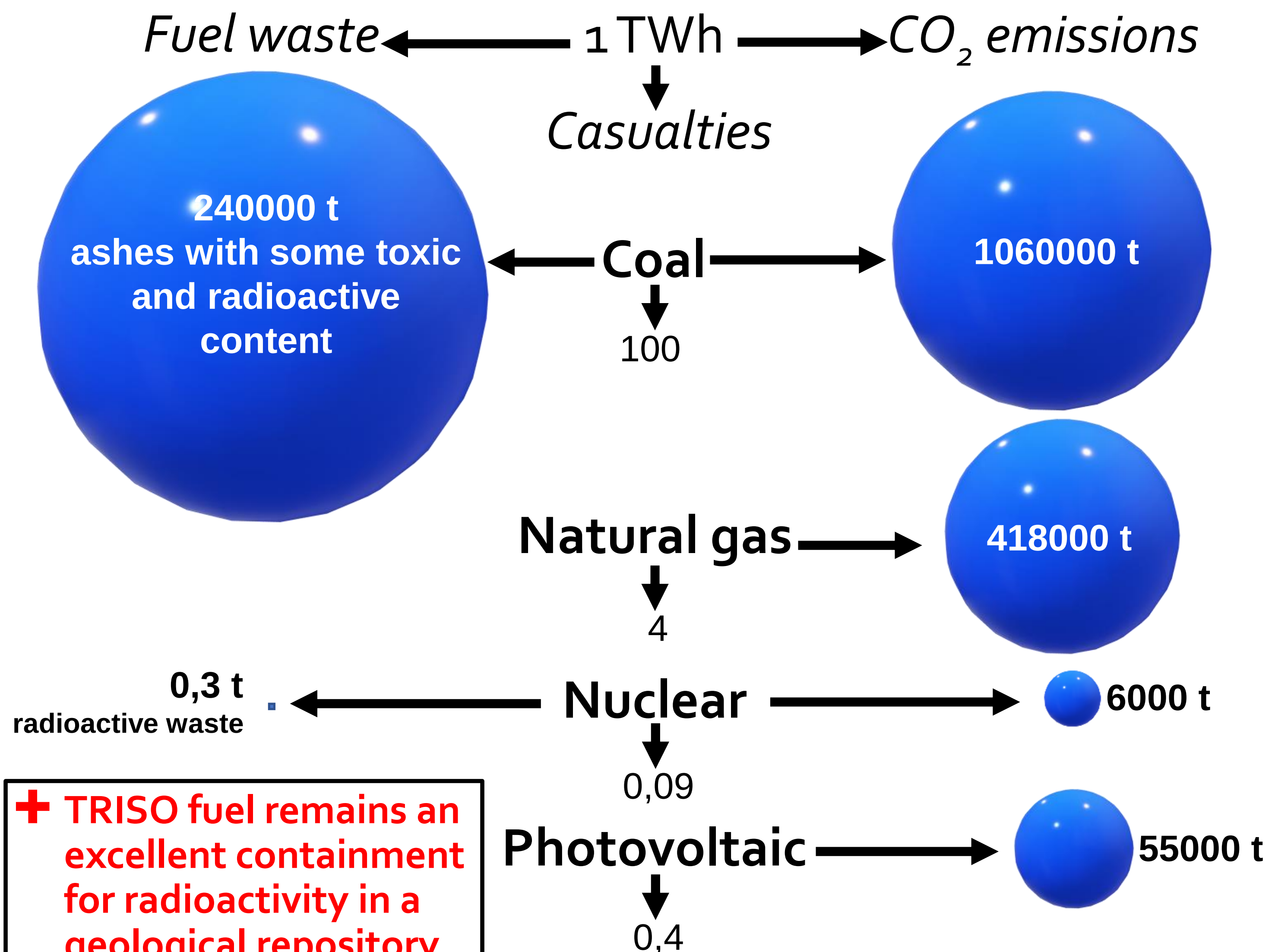
Maximum fuel temperature after a depressurisation accident

Outstanding safety of modular HTGR

⇒No exclusion zone around the nuclear plant: possibility to locate the nuclear plant close to the industrial site to which it supplies heat and electricity

⇒Suppression of many redundant active safety systems existing in present reactors: an asset for competitiveness

Environmental and health impact



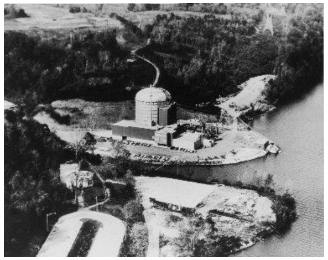
+ TRISO fuel remains an excellent containment for radioactivity in a geological repository

GEMINI+

HTGR technology is mature and available for early implementation

- Several test reactors and industrial prototypes
- In the last 2 decades
  - ✓ Several design projects
  - ✓ Large progress in the technology
    - National R&D programmes
    - Euratom funded projects (17 projects)
    - International cooperation (Generation IV International Forum)
- An industrial prototype, HTR-PM, on the verge of starting operation in China

DRAGON, U.K. 20 MW, 1963-76



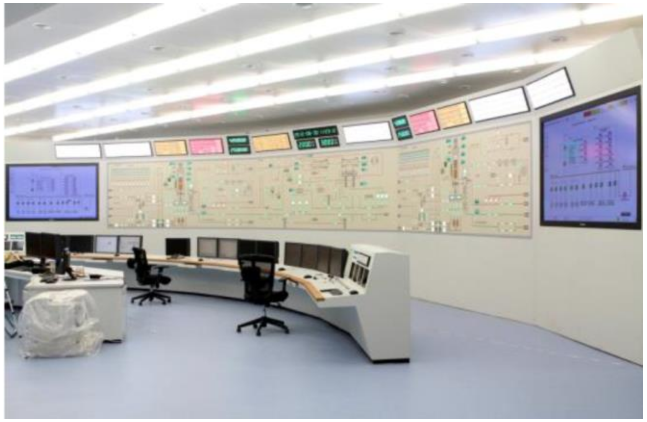
Peach Bottom, US 200 MWth, 1967-74

AVR, Germany 15 MWe, 1967-88

Fort Saint-Vrain, US 300 MWe, 1976-89

THTR, Germany 300 MWe,1986-89

HTR-10, China 10 MWth, since 2000



HTR-PM control room

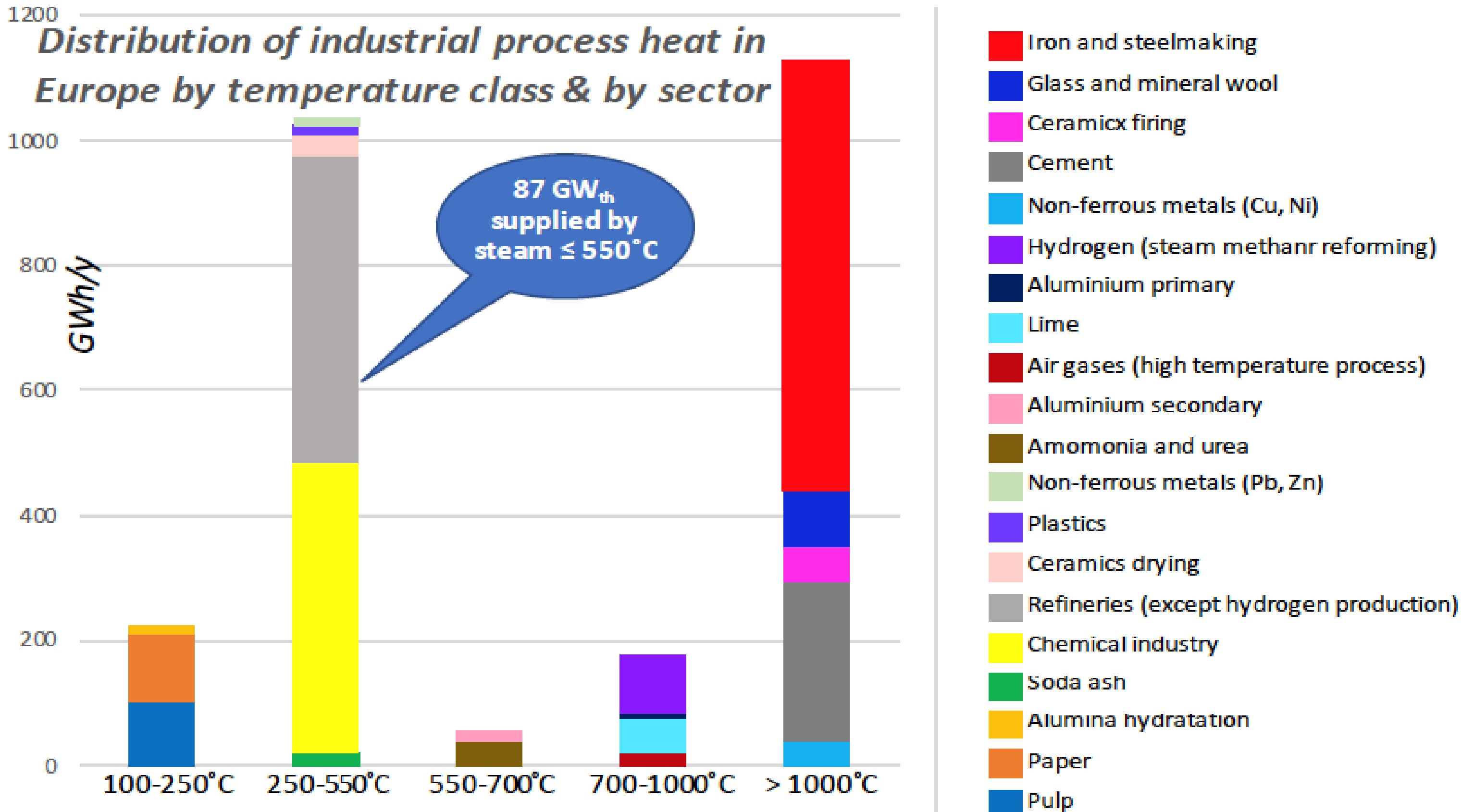
HTTR, Japan, 30 MWth, since 1998

The market

- Electricity : Particularly suitable for
  - ✓ Small electric networks
  - ✓ Arid zones (less water requirement)
- Electricity + district heating
  - ✓ Can provide cogeneration with very limited degradation of the electric output
- **Industrial process heat** (+ electricity)

GEMINI+

The market of industrial process heat

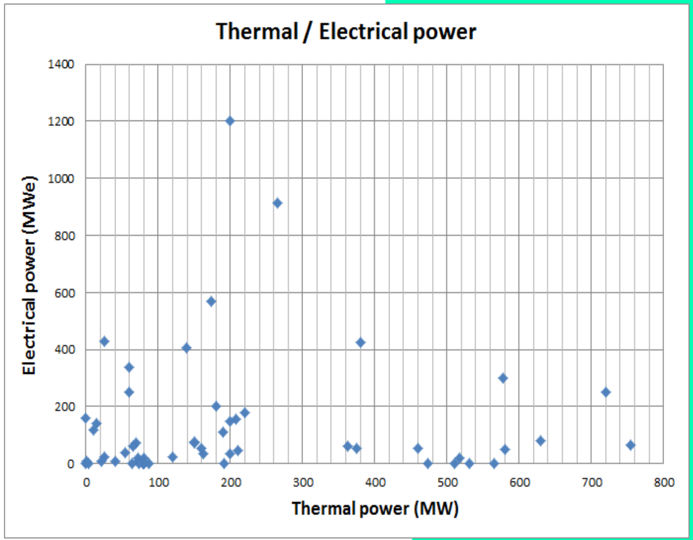


From "Market study on energy usage in European heat intensive industries" EUROPAIRS Euratom project FP7

⇒ **First target: chemical and petrochemical sites with steam networks already in place**

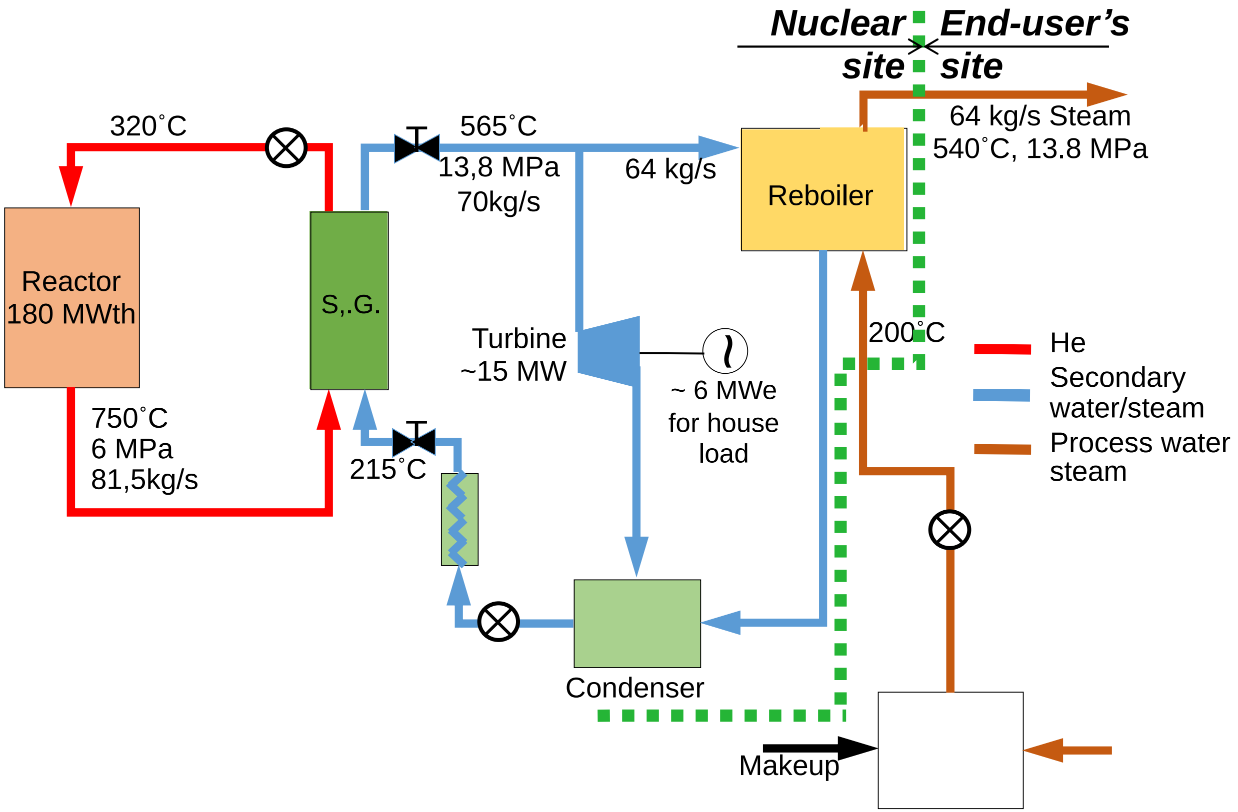
The challenges for a nuclear plant to supply energy to industrial sites

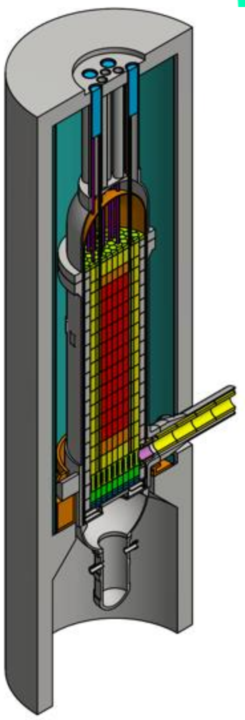
- To reconcile flexibility and economic competitiveness, both expected by customers:
  - ✓ Contrary to power plants delivering a single product, electricity, distributed by a grid on a large area, a system supplying energy only locally to an industrial site has to face versatile needs
    - Variable power
    - Variable sharing between heat and electricity
    - Variable load transient capability
  - ✓ For being economically viable, nuclear plants must be as much as possible standardised
- To exclude any risk of accident impact
  - ✓ From the nuclear plant to the industrial site: radio-contamination
  - ✓ From the industrial site to the nuclear plant: blast, toxic gas, etc.



From NC2I-R Euratom FP7 project, survey of European industrial sites

The design basis of the H2020 project GEMINI+, a proposed solution





The design basis of the H2020 project GEMINI+, a proposed solution

- Small power, 165 MW_{th}:
  - ✓ To adapt to the needs of multiple sites
  - ✓ To be able to systematically use modular manufacturing and construction techniques ⇒ cost reduction
- Steam is the sole product supplied by the nuclear plant, delivered to the steam distribution network of the industrial site
- The electricity required by the site is produced in the steam network by a standard non-nuclear turbo-generator (much cheaper than nuclear)
- A steam heat production cost in the range 8-9 €/GJ appears achievable.

Next step

- The nearly exclusive application of civil nuclear power has been until now electricity generation
- No application of HTGR to high temperature industrial process heat supply

⇒Even if the technology is mature, demonstration of coupling a HTGR with industrial processes is necessary:

  - ✓ To verify that this type of reactor can work reliably in an industrial environment, and satisfy industrial requirements
  - ✓ To show that the licensing of a modular HTGR coupled to industrial process heat applications is feasible
  - ✓ To show that economic viability can be achieved
  - ✓ To initiate a reliable European supply chain that can then face the needs of a rapid commercial deployment

- **Poland opens today the most promising opportunity to have an early demonstration in Europe**

Conclusion: prospects for Europe

- With HTGR, there is an available technical solution for nuclear energy to provide the CO_2 free energy (heat and electricity) that European industry needs
- This technology
  - ✓ can reach economic competitiveness
  - ✓ Offers an outstanding safety level that allows locating energy production close to human activities
- HTGR cogeneration of heat and electricity opens also the door to CO_2 free hydrogen production
- A short term demonstration in Poland followed by a steady, but realistic commercial deployment can allow **a significant contribution to the Green Deal objective of carbon neutrality in 2050** (NC2I roadmap, https://snetp.eu/wp-content/uploads/2020/10/NC2I-roadmap-October.pdf)