

Innovative nuclear reactors for Polish economy

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Nuclear Cogeneration Industrial Initiative
Sustainable Nuclear Energy Technology Platform

Polish Nuclear Roadmap

Polish Nuclear Power Programme provides an opportunity for the development of new technologies, through associated research and development projects.

Two major goals of the projects:

- Addressing predicted needs of the economy
 - (eg. high temperature heat for industry).
- Development of competences, technologies and products
 - (eg. components and new types of reactors).

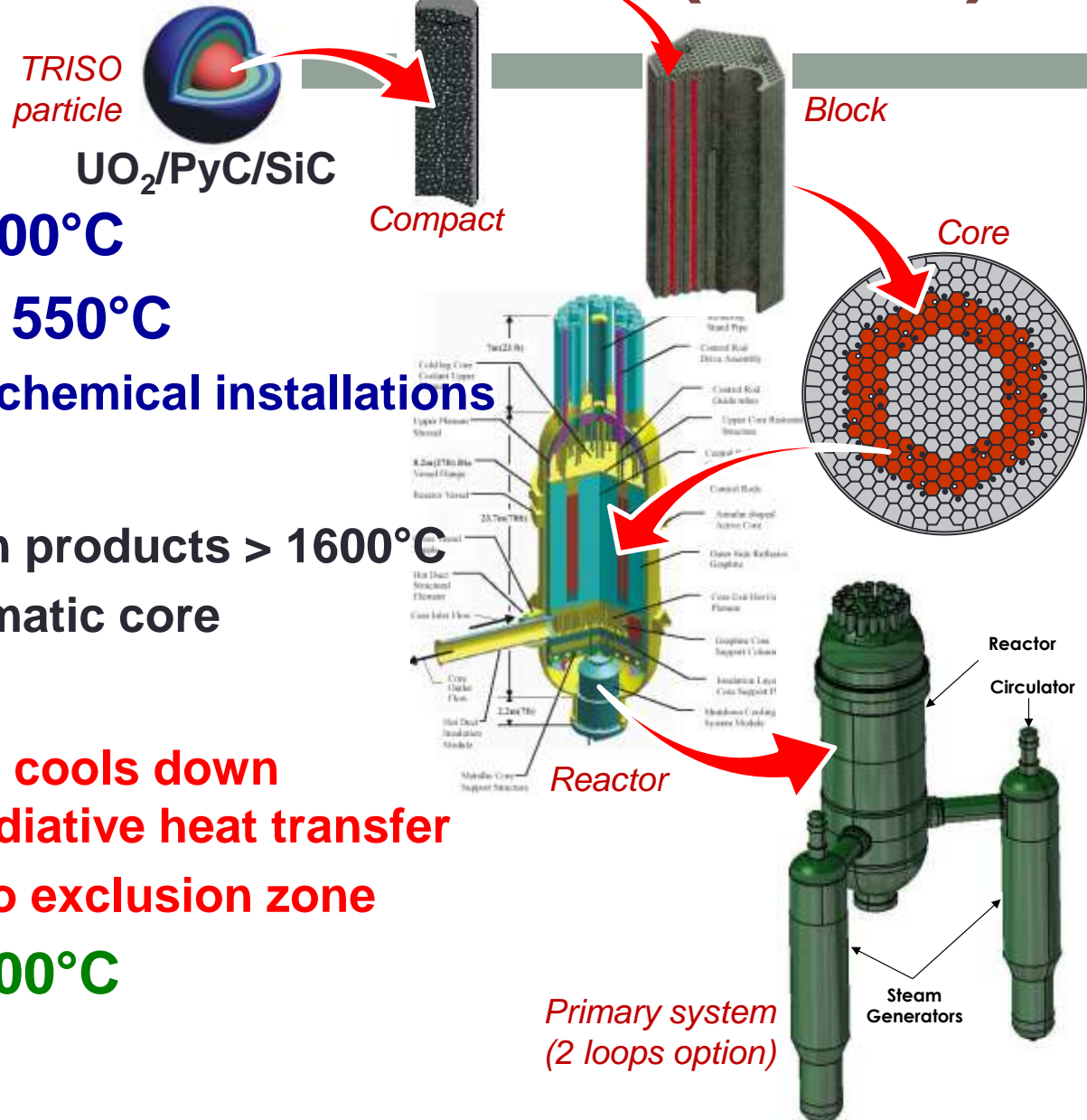
The more added value (intellectual property) generated by projects, the stronger boost for economy.

- Therefore, one needs to look for new technologies and new application areas.

Polish Nuclear Roadmap

- Electric power market dominated by large (~ 1000 MWe) light water reactors (LWR).
 - Intense competition in the market
 - 5 suppliers declared their participation in the Polish tender
 - China and Russia are active on other markets
- Heat market today 100% dominated by fossil fuels.
 - Huge potential for nuclear reactors
 - Currently addressed only in terms of LWR, i.e. $T < 250^{\circ}\text{C}$.
 - District heating, desalination, ...
- Need for new technologies
 - HTGR (High Temperature Gas Reactor) $\sim 600^{\circ}\text{C}$
 - VHTR (Very HTR), DFR (Dual Fluid Reactor) $\sim 1000^{\circ}\text{C}$

High T Gas-cooled Reactor (HTGR)



- **Coolant: Helium 700°C**
- **2nd circuit: steam 550°C**
 - typical for existing chemical installations
- **TRISO fuel**
 - Leak tight to fission products > 1600°C
 - Pebble-bed or prismatic core
- **Intrinsic safety**
 - In case of accident, cools down by conduction & radiative heat transfer
 - No core damage, no exclusion zone
- **Future: VHTR >1000°C**

The Dual Fluid Reactor

A concept beyond Generation IV

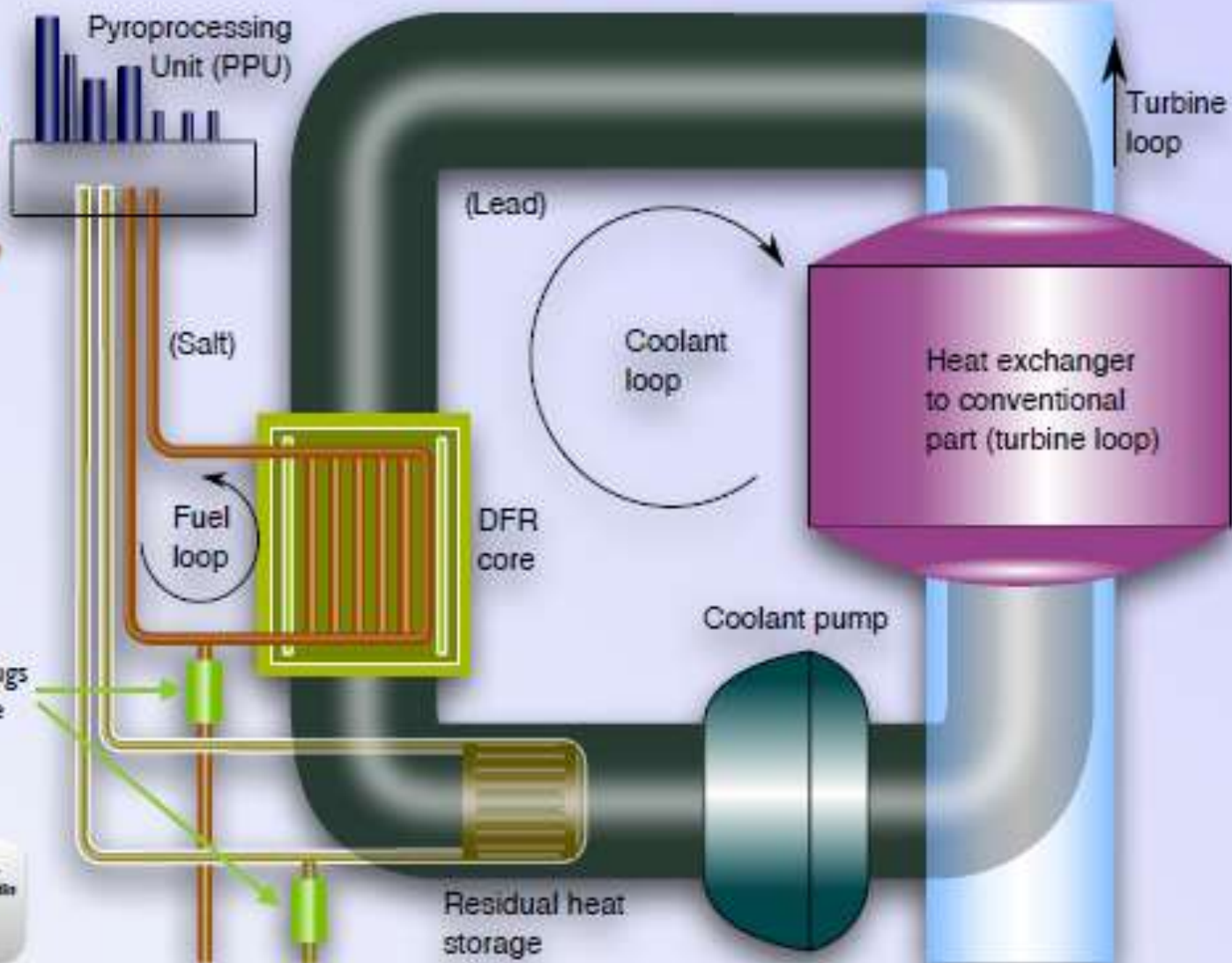
- Natural Uranium
- Depleted Uranium
- Thorium
- Used fuel elements



- Fission products
- Med. radioisotopes
- Fissile material

Melting fuse plugs = run-away safe

International patent protection for the Dual Fluid principle since Sep. 2011



HTGR deployment in Poland

Government on 14 February 2017 published „Strategy for responsible development”.
- the governmental plan for Polish economy grow

List of energy actions contains:

Preparation of HTR deployment for industrial heat production in cogeneration, using industrial & scientific potential of Poland. Support for Polish R&D on materials for gen.IV reactors.

Vice-ministers meetings:

- 5.2016 with Euratom-fission & NC2I
- 2016 with CEA (*Frank Carré nominated HTR liaison by CEA*)
- 3x2016, 5.2017 with UK DECC/BEIS
- 3.2016, 2.2017 with US DoE, NGNP IA, X-energy



HTGR deployment in Poland

Minister of Energy on 13 July 2016 appointed „Committee for deployment of high temperature reactors”.

Chairman: G.Wrochna



Terms of reference:

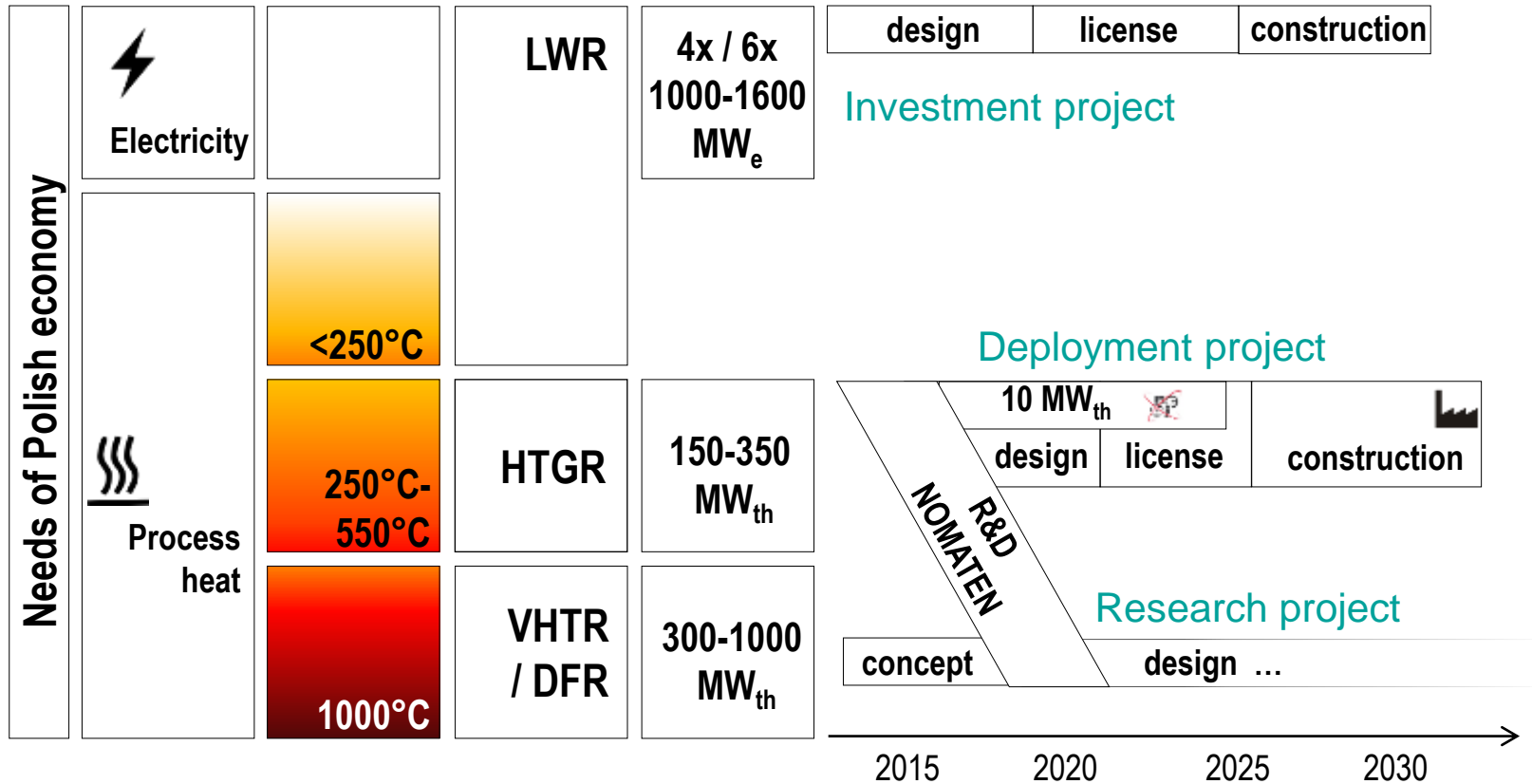
- Analysis of Polish economy needs & export potential
- Inventory of relevant design & manufacturing capabilities of Polish science & industry
- Cost estimate, business model, funding possibilities
- Analysis of legal framework
- Establishing international cooperation

Members from:

- Nuclear R&D: National Centre for Nuclear Research (NCBJ)
- Engineering: Energoprojekt, Prochem
- End-users: Azoty, Orlen, Enea, Tauron, KGHM

Associates: PAA (regulator), NCBR (R&D funding agency), PKO BP (bank)

Nuclear Roadmap of Poland



U-Battery for Poland



U-Battery is 10 MW_{th} / 4 MW_e HTGR.

Construction at National Centre for Nuclear Research (NCBJ) is intended to speed up capacity building, develop skills and facilitate licensing of large HTGR

Letter of Intent signed by Urenco & NCBJ May 2016 during visit of Polish viceministers of energy in UK



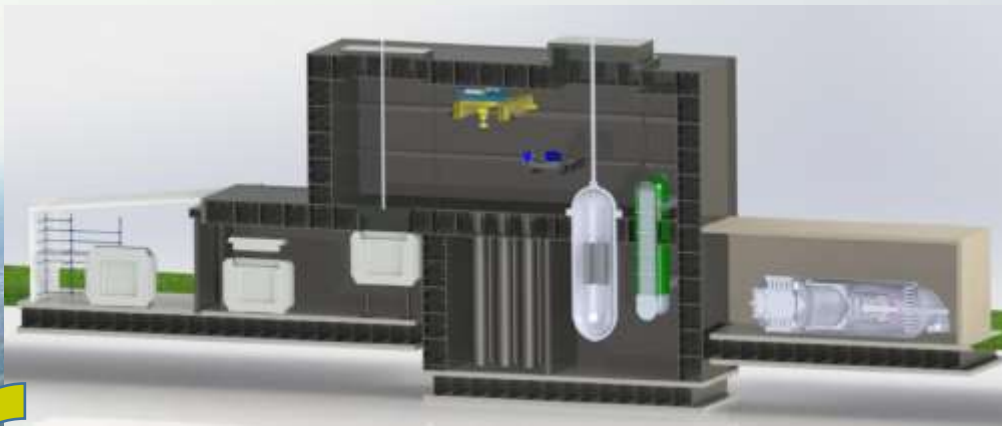
www.nc2i.eu

Other vendors are also being considered

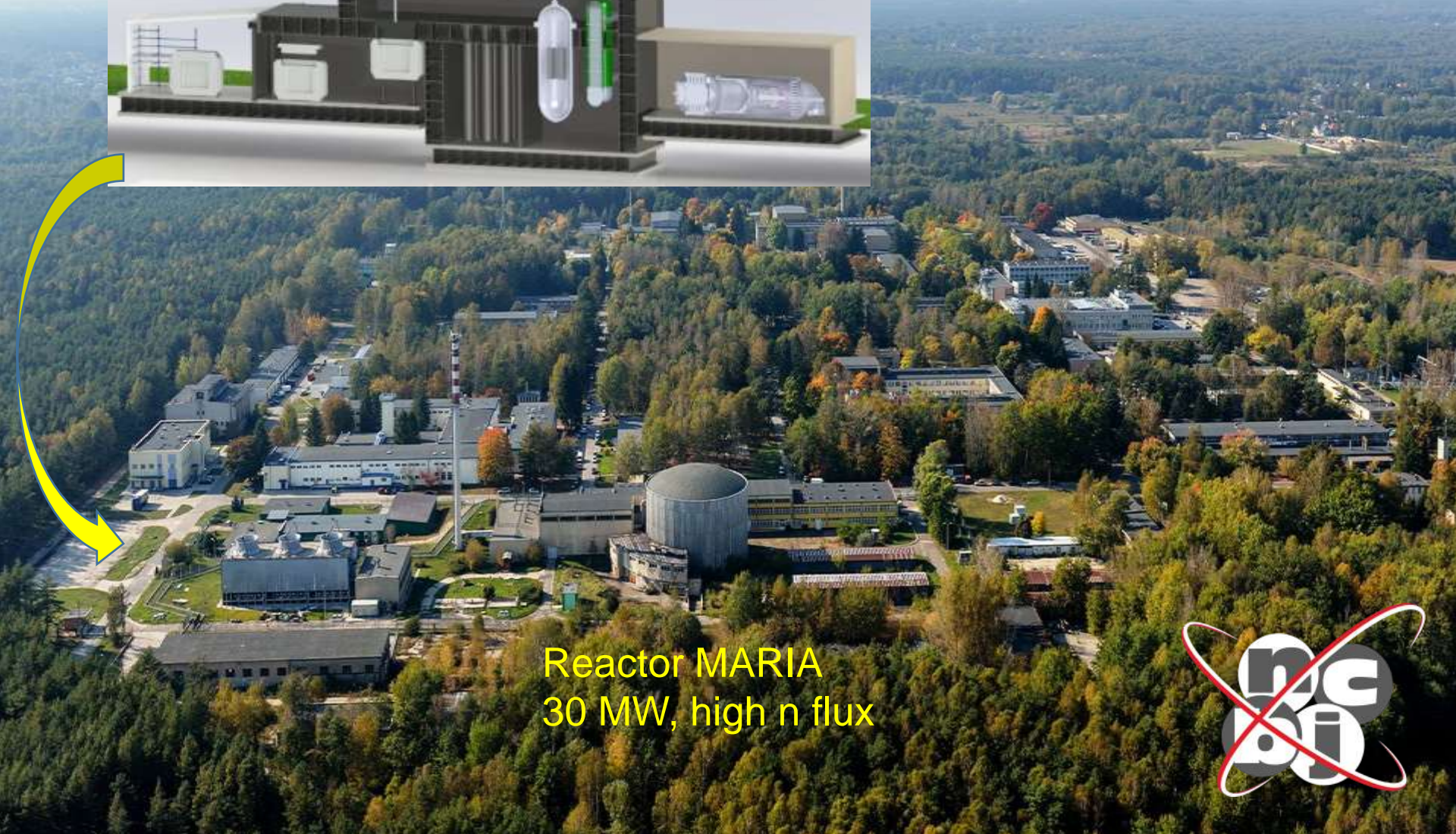
NC2I is one of SNETP's strategic technological pillars, mandated to coordinate the demonstration of high temperature nuclear cogeneration.



www.snetp.eu



U BATTERY
Local Modular Energy



Reactor MARIA
30 MW, high n flux



National Centre for Nuclear Research, Poland

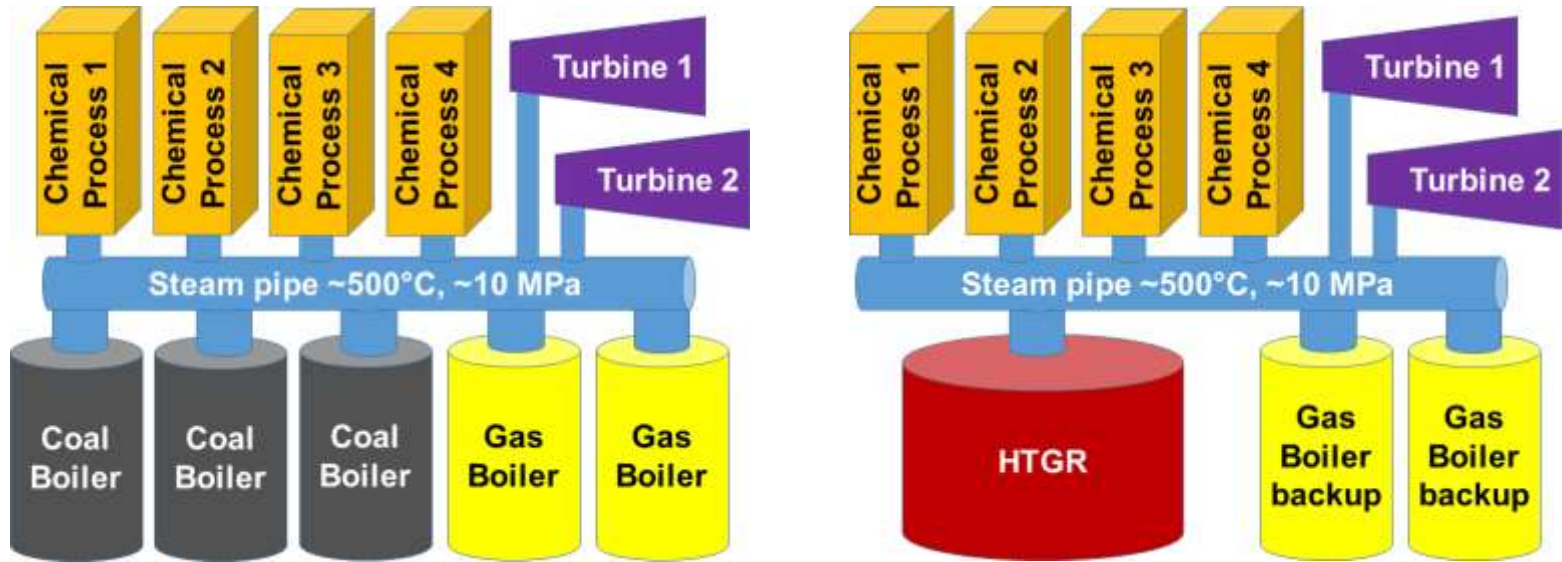
HTGR for Poland



- 13 largest chemical plants need 6500 MW of heat at $T=400-550^{\circ}\text{C}$
- They use 200 TJ / year, equivalent to burning of >5 mln t of natural gas or oil
- Replacing by HTGR would reduce CO_2 emission by 14-17 mln t / year
- 165 MW_{th} reactor size fits all the needs

Plant	boilers	MW
ZE PKN Orlen S.A. Płock	8	2140
Arcelor Mittal Poland S.A.	8	1273
Zakłady Azotowe "Puławy" S.A.	5	850
Zakłady Azotowe ANWIL SA	3	580
Zakłady Chemiczne "Police" S.A.	8	566
Energetyka Dwory	5	538
International Paper - Kwidzyn	5	538
Grupa LOTOS S.A. Gdańsk	4	518
ZAK S.A. Kędzierzyn	6	474
Zakl. Azotowe w Tarnowie Moszczicach S.A.	4	430
MICHELIN POLSKA S.A.	9	384
PCC Rokita SA	7	368
MONDI ŚWIECIE S.A.	3	11313

Feedback from industry



- Several sites use ~500°C steam networks
- Need to exchange old boilers with HTGR
- Electric island already there
- HTGR parameters matching standard boilers:
540°C, 13.4 MPa, 165 MW_{th}, 230 t/h

Optimum HTGR size

- HTGR economy vs market size trade-off
 - Industry don't want to exchange all boilers at once
 - $>200 \text{ MW}_{\text{th}}$ fits to only a few of sites in PL
 - **Small size fits all !**
- $165 \text{ MW}_{\text{th}}$ poses economy challenge
 - $165 \text{ MW}_{\text{th}}$ cost $\sim 50\%$ of $650 \text{ MW}_{\text{th}}$ cost
- Need to optimise $165 \text{ MW}_{\text{th}}$ design
 - Vessel rolled in one piece & road transportable
 - Preassembly in factory, ...
 - 165 MW or 2×83 or 3×55 ? ...

Boiler made by RAFAKO.com.pl



HTR business model

owners (>50% of shares or a „golden share“)

STATE?
CHEMICAL/ENERGY
COMPANIES?

CHEMICAL/ENERGY
COMPANIES?

HTR-EP
ENGINEERING
PROCUREMENT
SPV

HTR-C
CONSTRUCTION
*companies
from the market*

HTR-OP
OWNER
OPERATOR
SPV's

END-USERS
CHEMICAL
COMPANIES,
etc

NUCLEAR
COMPANIES

NUCLEAR
OPERATOR(S)

shareholders / subcontractors

Towards 1st HTGR in Poland

June:

- Report of HTR Committee

July:

- Minister's decision to proceed
- Start negotiations with partners

October:

- Signing agreements
- Start of HTGR design