

HTGR for heat market Plans in Poland

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Coordinator of EURATOM project



GEMINI+

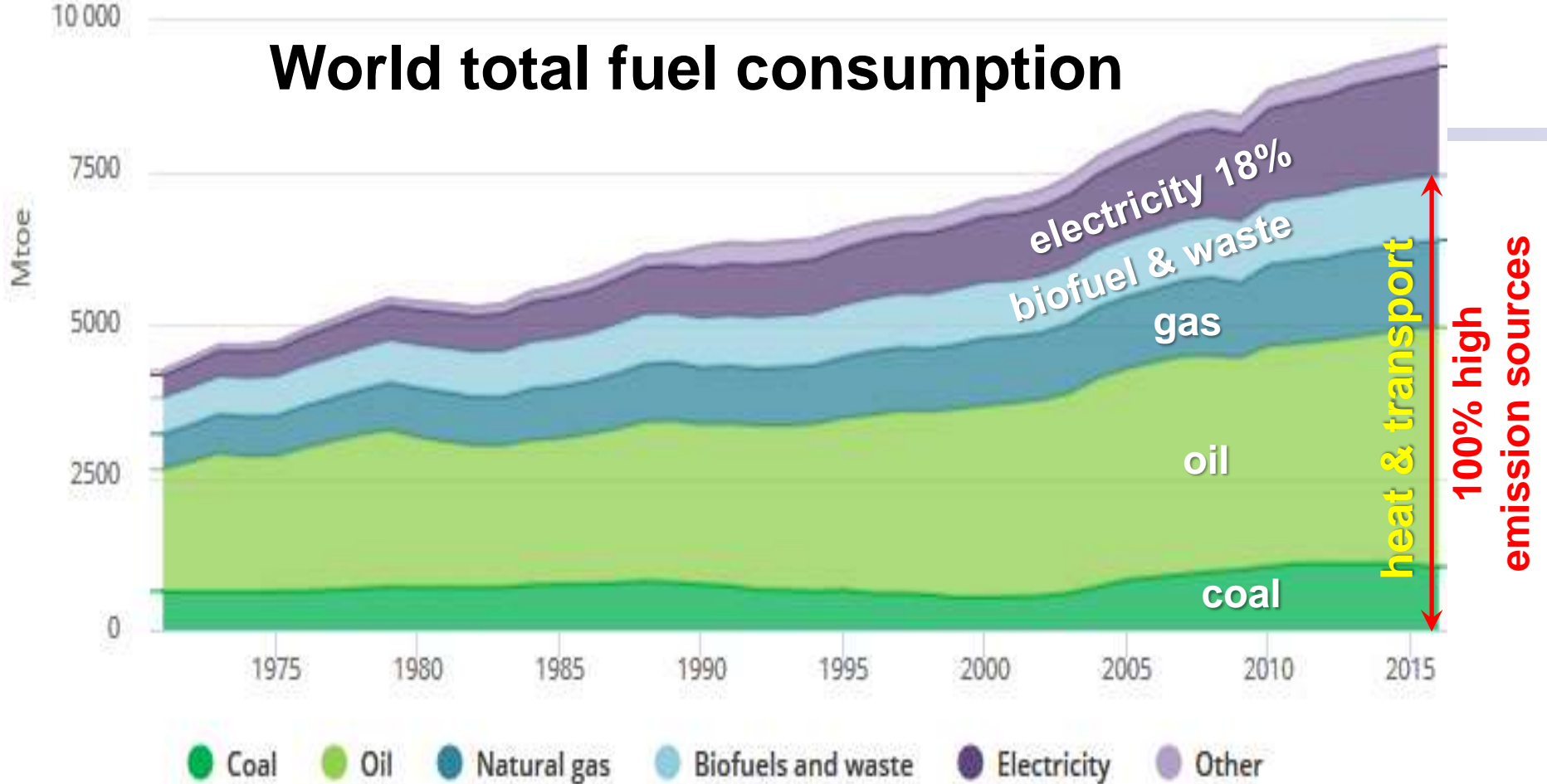
Chairman of European consortium



NC2I

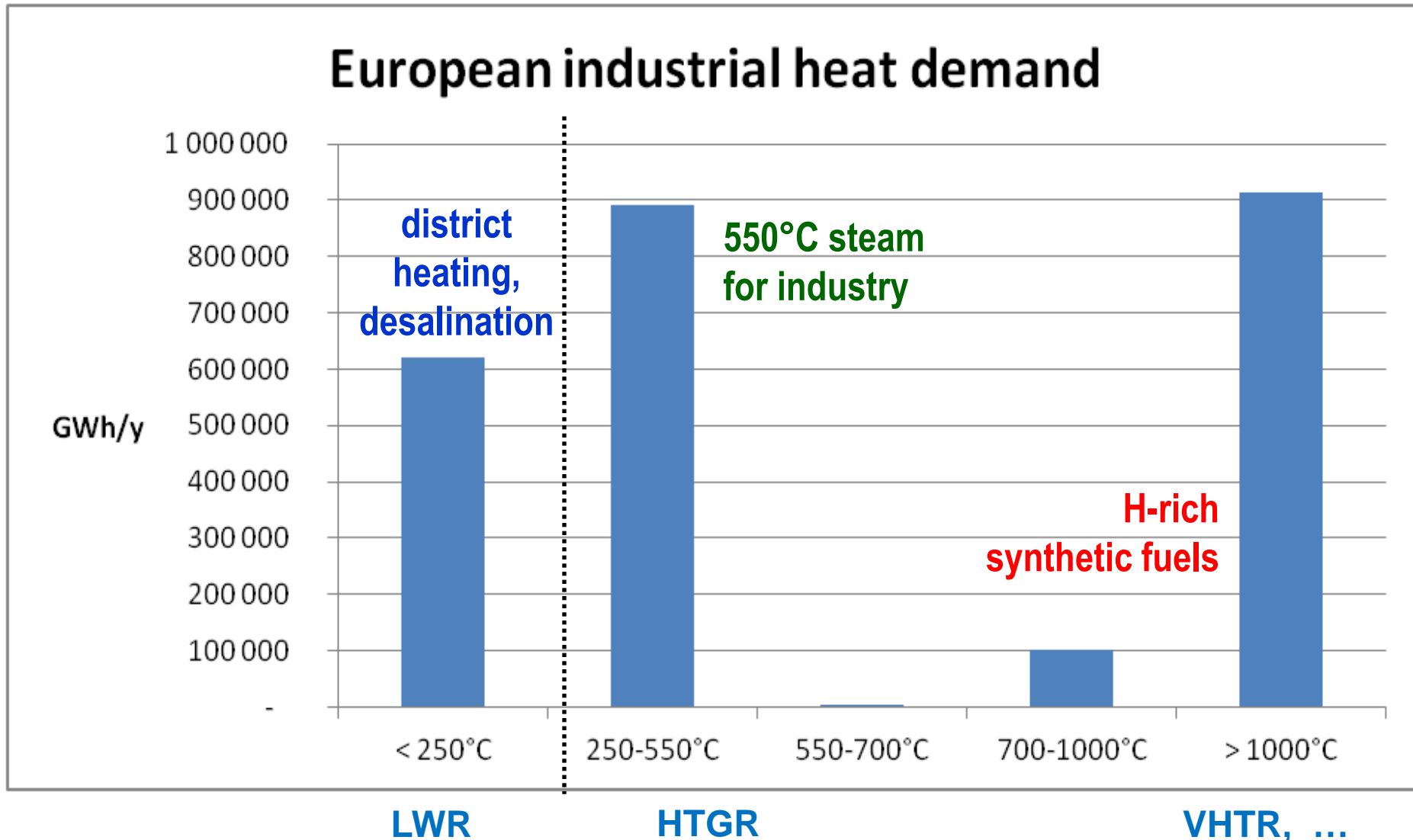
Nuclear Cogeneration Industrial Initiative

World total fuel consumption



- Reducing to zero emission from electricity production would solve only 1/6 of the problem
- Industry needs high temperature heat ($>500^{\circ}\text{C}$)
- Synthetic H-rich fuels for electric cars with fuel cells is the future of transport ($>700^{\circ}\text{C}$ heat needed to produce them)

Heat demand for different temperatures



Source: EUROPAIRS study on the European industrial heat market

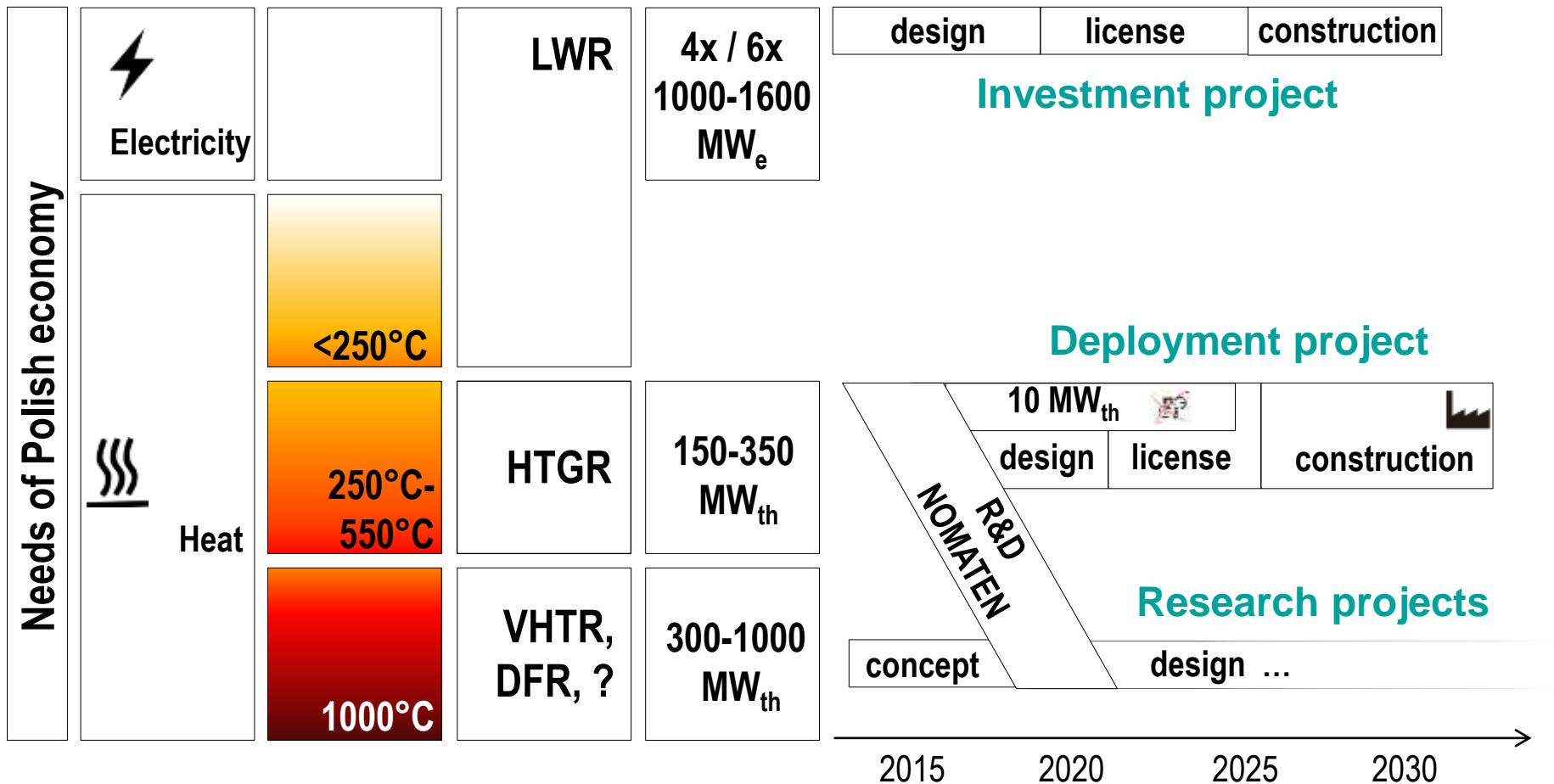
HTGR for Poland



- **13 largest chemical plants have installed today 6500MW 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**
- **$165 \text{ MW}_{\text{th}}$ reactor size fits all the needs**
- **Estimated market by 2050
PL: 10-20, EU:100-200,
world:1000-2000**
- **Possible replacement of 200 MW_e cogeneration units in future**
- **Increasing interest in $T=500-1000^{\circ}\text{C}$ for H_2 production**

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	313

Nuclear Roadmap of Poland



HTGR's are not to replace LWR's! They address different market niche.

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.



HTGR deployment in Poland

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

Chairman: G.Wrochna

Members from:

- Nuclear R&D: NCBJ
- Engineering: Energoprojekt, Prochem
- End-users: Azoty, Orlen, Enea, Tauron, KGHM

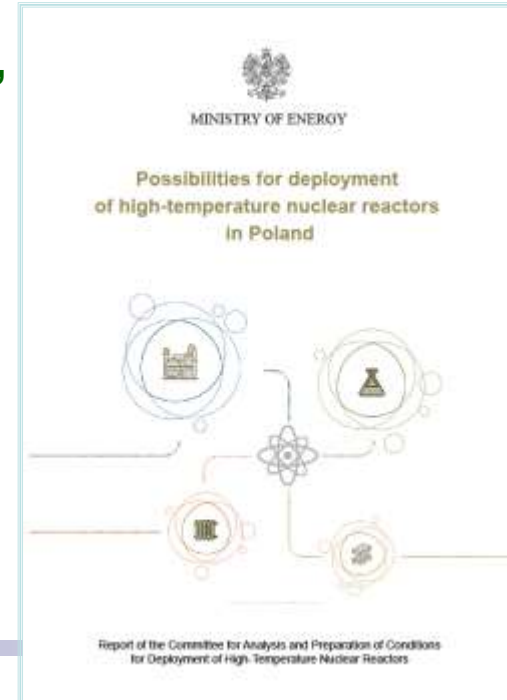
Associates: PAA (regulator), NCBR (R&D funding agency), PKO BP (bank)



Report published January 2018:

tiny.cc/htr-pl

Minister of Energy has given a green light to proceed with implementation of the conclusions.



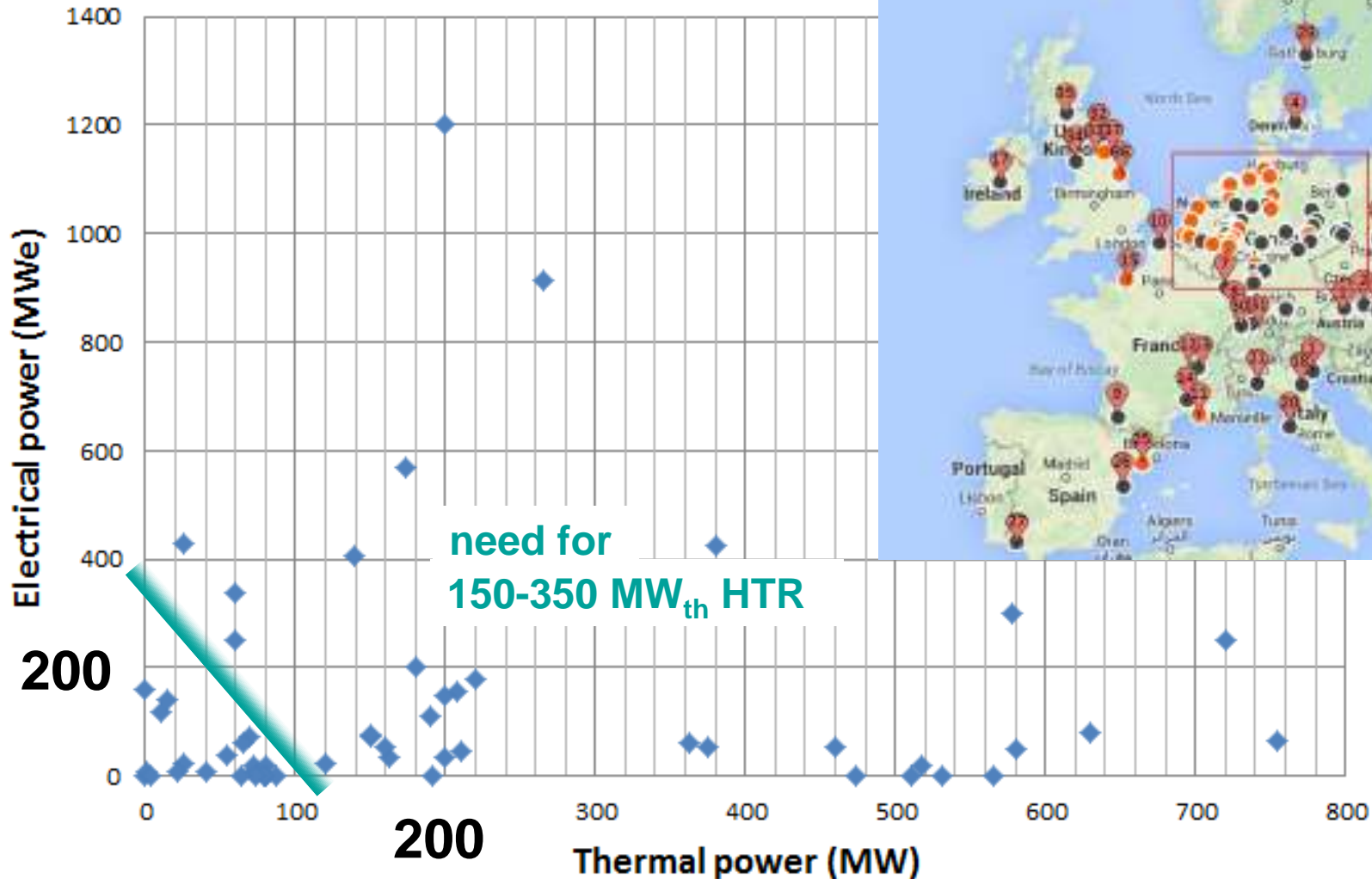
Conclusions of the HTR Committee

In agreement with other international studies:

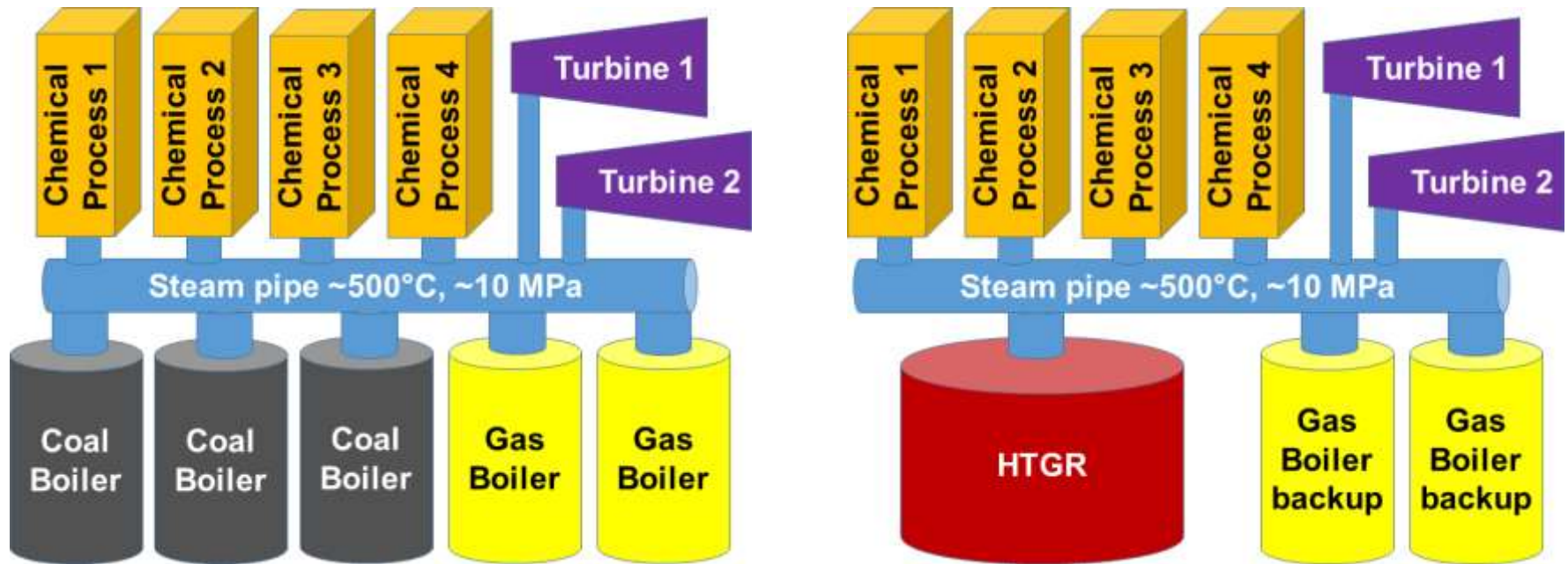
- **SNETP - Sustainable Nuclear Energy Technology Platform** „Deployment Strategy”, 2015, www.snetp.eu/publications
- **OECD Nuclear Energy Agency** „Nuclear Innovations 2050”, www.oecd-nea.org/ndd/ni2050
- **IAEA - International Atomic Energy Agency** “Industrial Applications of Nuclear Energy”, IAEA Nuclear Energy Series No. NP-T-4.3, 2017.
- **UK gov. (BEIS):** “Small Modular Reactors: Techno-Economic Assessment”, 2017
www.gov.uk/government/publications/small-modular-reactors-techno-economic-assessment

End-user needs

- Sample of >130 sites in Europe
- Mostly chemical industries



Feedback from industry



- Several sites use $\sim 500^{\circ}\text{C}$ steam networks
- Need to exchange old boilers with HTGR
- Electric island already there
- HTGR parameters matching standard boilers:
 540°C , 13.4 MPa , $165\text{ MW}_{\text{th}}^*$, 230 t/h

*) +10% for internal use

Cost estimate

1\$ ≈ 3.5 PLN

1€ ≈ 4.2 PLN

- The cost of design and general license: ~ 500 million PLN
 - It virtually does not depend on the reactor power
- The construction cost was calculated by scaling the costs of larger models down to 165 MW_{th}:

Oryginal power [MW _{th}]	600	2×250	350	165
Type	prismatic block			pebbles
Cost 165 MW _{th} [M PLN]	2566	1995	1519	1358

- The cost of HTGR of a block type should be 5-10% lower than the HTGR of a pebbled type
- Reducing the power may enable breaking technological barriers and result in lower cost,
 - e.g. a tank made entirely in a steel mill by rolling
- A middle option, close to PLN 2000 million, was adopted for economic analyzes
 - The dispersion of PLN 600 million is a measure of the uncertainty of estimation
- The construction cost includes 10% of the design cost

Coal, gas & HTGR economy

Coal & gas boilers compared to HTGR 165 MW_{th},
230 t/h of steam 540°C, 13.8 MPa.

Current fuel prices. 30/60 years boiler/HTGR lifetime.

For HTGR: 15 idle days/year, 80% of power used.

Design cost covered by the first 10 HTGR's.

1\$ ≈ 3.7 PLN

1€ ≈ 4.2 PLN

F-NPV: financial

E-NPV: economic

	Steam cost LCOE M PLN /GJ				F-NPV M PLN		E-NPV M PLN	
	8%	4%	8%	4%	8%	4%		
Discount rate	8%	4%	8%	4%	8%	4%	8%	4%
CO ₂ emission cost /t	20€	50€	20€	50€	50€	50€	50€	50€
Coal boiler OP-230	27	37	25	35	158	619	-91	-119
Gas boiler OG-230	37	43	36	42	20	144	4	98
HTGR 165 MW	55	55	36	36	-268	538	-268	538

Cost of steam from HTGR could be comparable to that from coal/gas

Largest uncertainties:

discount rate, CO₂ emission cost, coal & gas price & availability.

Why HTGR not used widely?

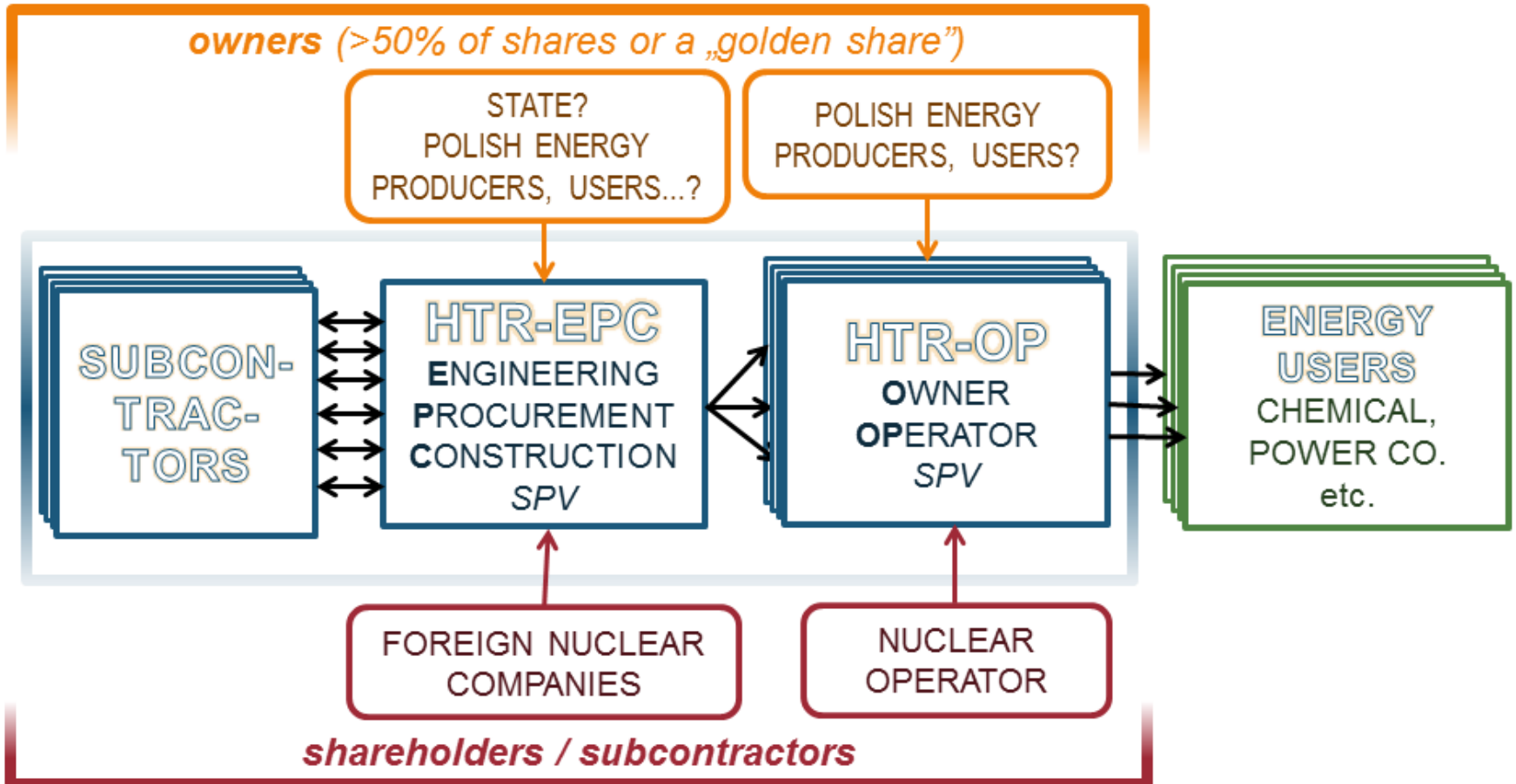
- **Traditional business model:**
 - Big contract between big Vendor and big Utility
 - Vendor could be sure to find a buyer sooner or later
 - Utility was not afraid to order a reactor similar to others already in use
- **Such approach for HTGR created „chicken and egg” dead loop**
 - No vendor can afford detailed design before having an order
 - No user (e.g. chemical company) will order a reactor not even designed
 - **Too high level of risk on both sides (vendor and user) is the barrier**
- **Solution: let's users become the vendor**
 - reactor designed by SPV own by users

HTR business model

Large nuclear vendors not interested to take lead in HTR project

A new company should be established in Poland

Foreign expertise should be involved by hiring, contracts and shares



A user point of view

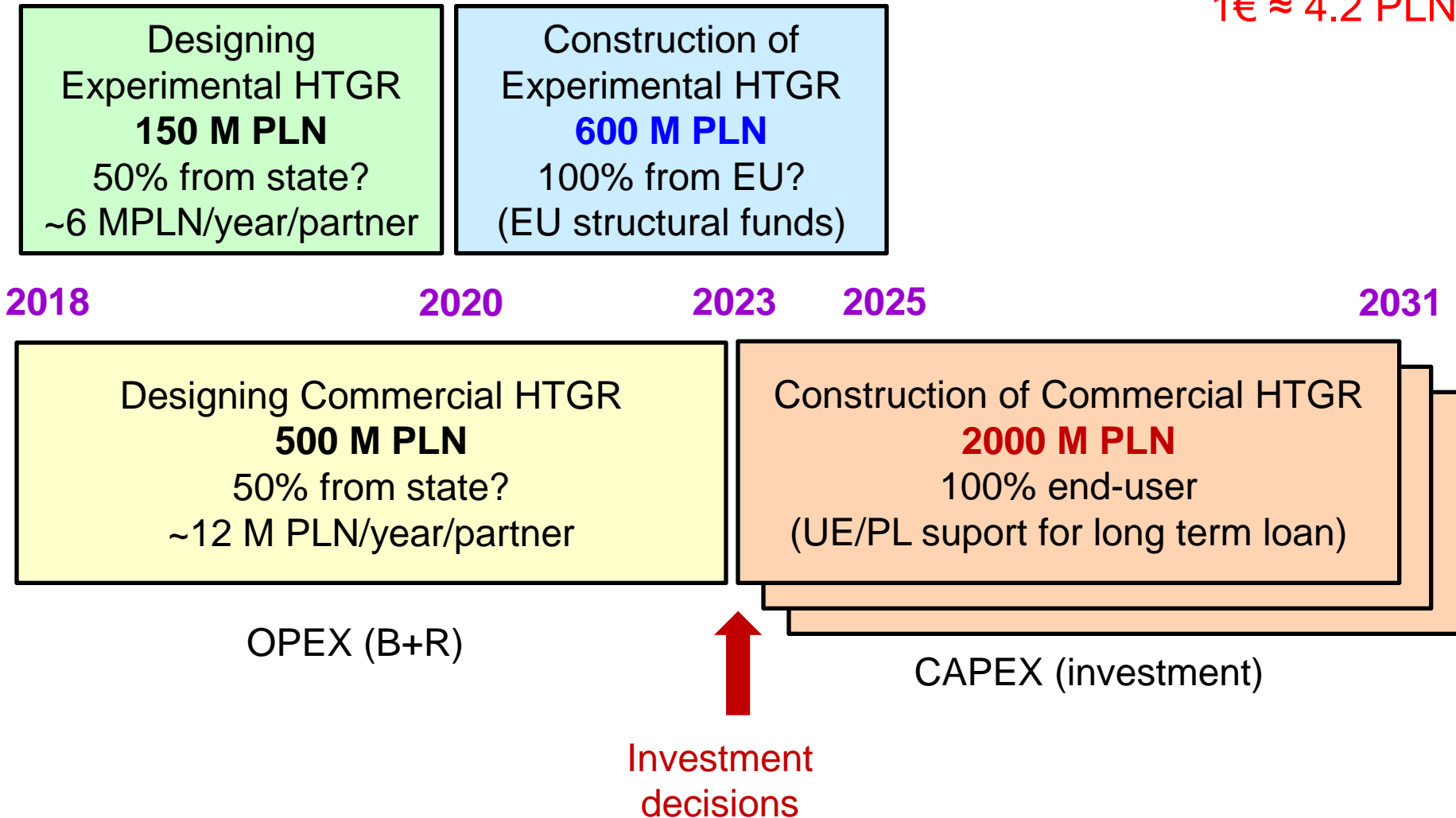
- Power and chemical companies use today coal- and gas-fires boilers to produce heat
 - In 2030-2050 most of them will need to be replaced
- Replaced with what? What will be less expensive and less risky?
 - Coal and gas
 - Large uncertainty on fuel price and cost of CO₂ emission (20-75€/t)
 - Risk of finishing domestic coal resources
 - Risk of gas supply from a single source
 - Nuclear HTGR
 - Technological risk – no design ready to buy
 - Uncertainty of „overnight” reactor cost (2,0±0,6 MPLN / 165 MW_{th})
 - Strong dependence of profitability on cost of money (discount rate)

Changing the user's point of view

- **Division of the project into 2 phases (design + construction) delays the investment decision by 5 years**
 - **Uncertainty on fuel prices and CO₂ cost largely reduced**
 - **Design is known and construction cost much better predicted**
- **Designing controlled by the users ensures:**
 - **fulfilling the user requirements**
 - **trust of the users in the design**
- **Cofinancing by several users ensures:**
 - **cost sharing and possibility of using R&D funds**
- **Cofinancing by public money ensures:**
 - **reduction of the users expenses**
 - **decisive security for managers**

HTGR programme

1\$ ≈ 3.7 PLN
1€ ≈ 4.2 PLN



4 industrial partners assumed

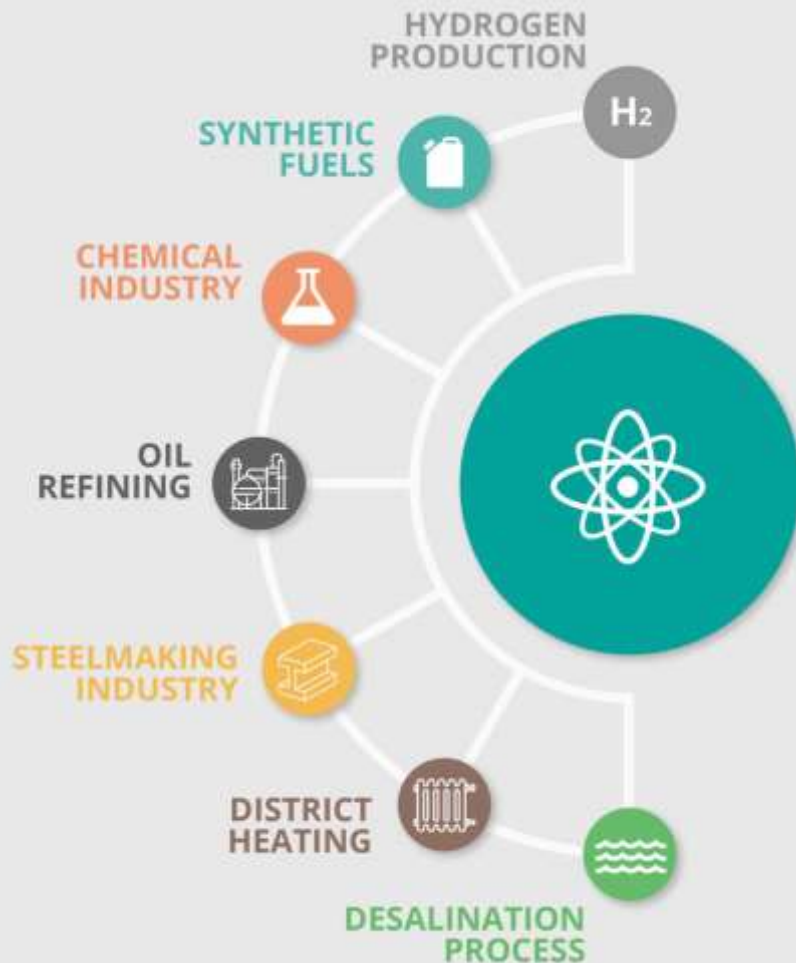
Additional challenges

- **Breaking economy of the scale**
 - **cogeneration** (~100% use of energy)
 - **large market** (PL: 10-20, EU: 100-200, world >1000)
 - **SMR: factory fabrication** (not construction at a site)
- **Universality**
 - **Same design for different applications**
 - steam for chemical factory
 - cogeneration: turbines + district heating
 - ???
 - **Separation from the user installations**
 - no influence of user installations on the reactor

These challenges are addressed by the Gemini+ project

Nuclear Cogeneration Industrial Initiative

- Part of Sustainable Nuclear Energy Technology Platform



www.nc2i.eu



Mission:

Contribute to clean & competitive energy beyond electricity by facilitating deployment of nuclear cogeneration plants

GEMINI - partnership of EU NC2I with US NGNP Industrial Alliance



Euratom project: 4 M€/3y
Winner of Euratom SMR competition
26 partners from EU, Japan, Korea & US