# HTGR for heat market
# Plans in Poland

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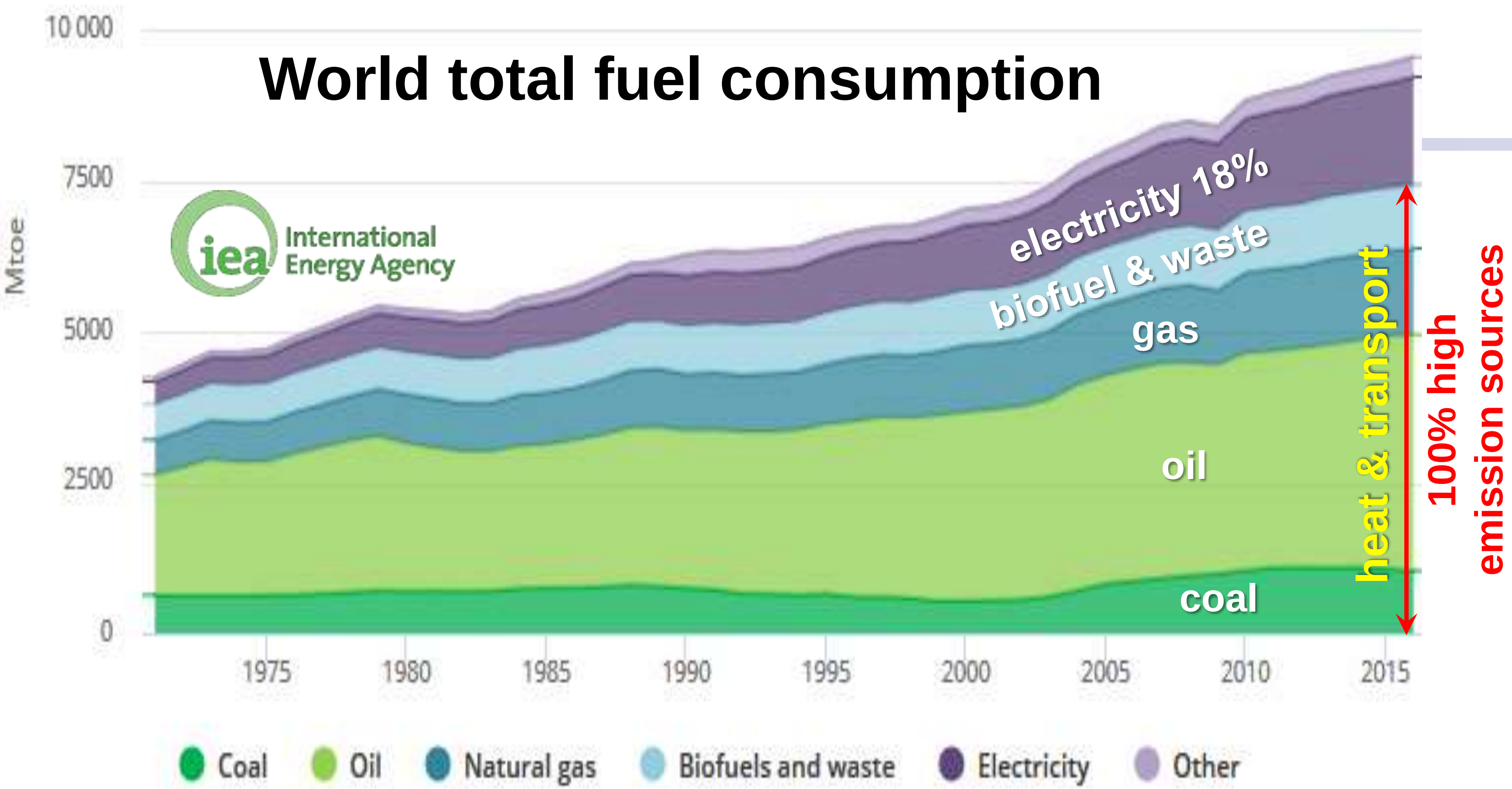
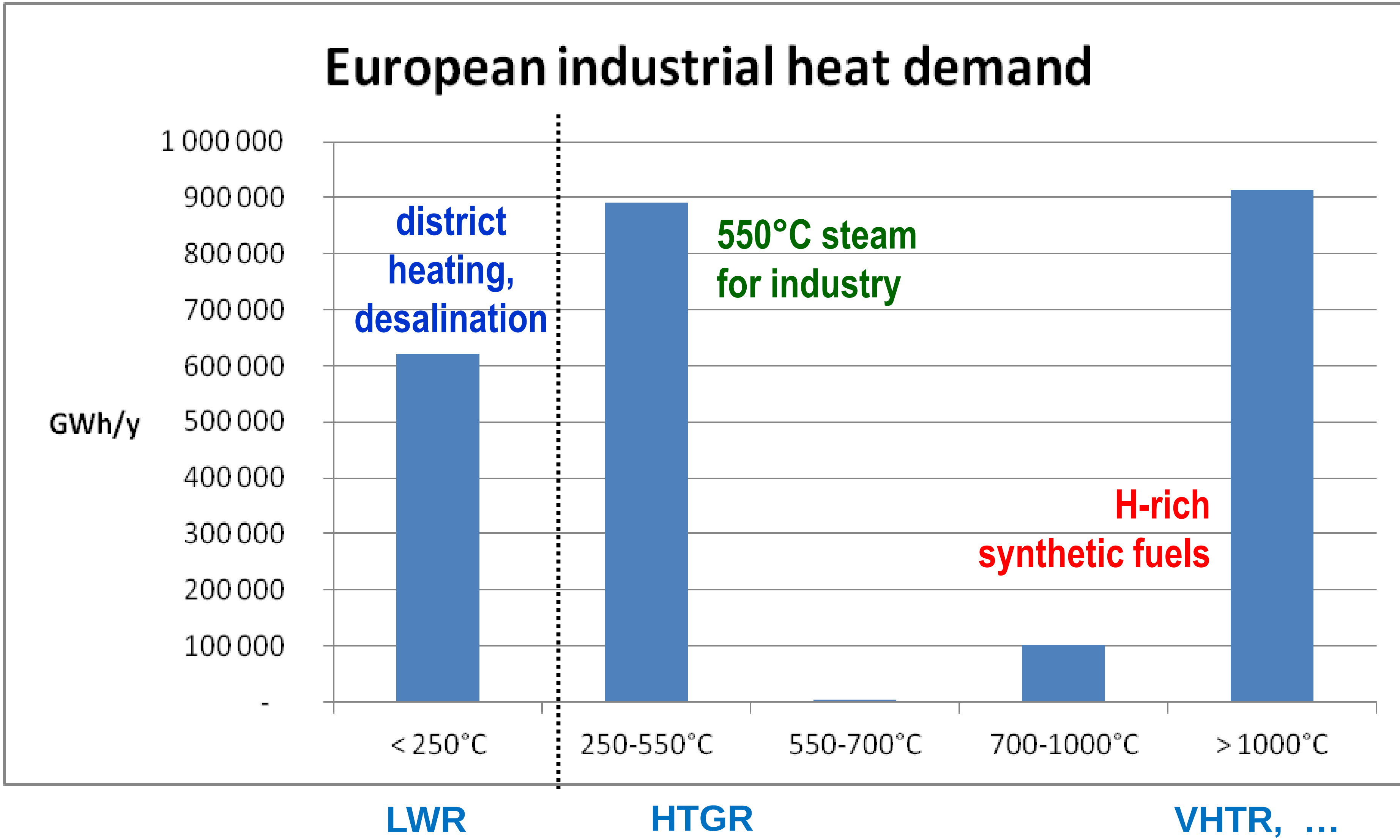
# World total fuel consumption




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

# Heat demand for different temperatures




*Source: EUROPAIRS study on the European industrial heat market*


# HTGR for Poland

| 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 Moscicach S.A. | 4 | 430 |
| MICHELIN POLSKA S.A. | 9 | 384 |
| PCC Rokita SA | 7 | 368 |
| MONDI ŚWIECIE S.A. | 3 | 313 |

- **13 largest chemical plants have installed today 6500MW of heat at T=400-550°C**
- **They use 200 TJ / year, equivalent to burning of >5 mln t of natural gas or oil**
- **165 $MW_{th}$ 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°C for $H_2$ production**

# HTGR deployment in Poland

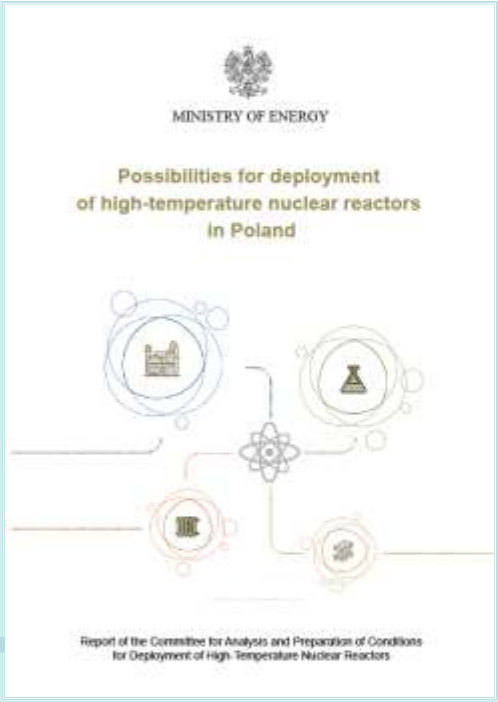
**Minister of Energy in July 2016 appointed**
**„Committee for deployment of high temperature reactors”.**

**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**

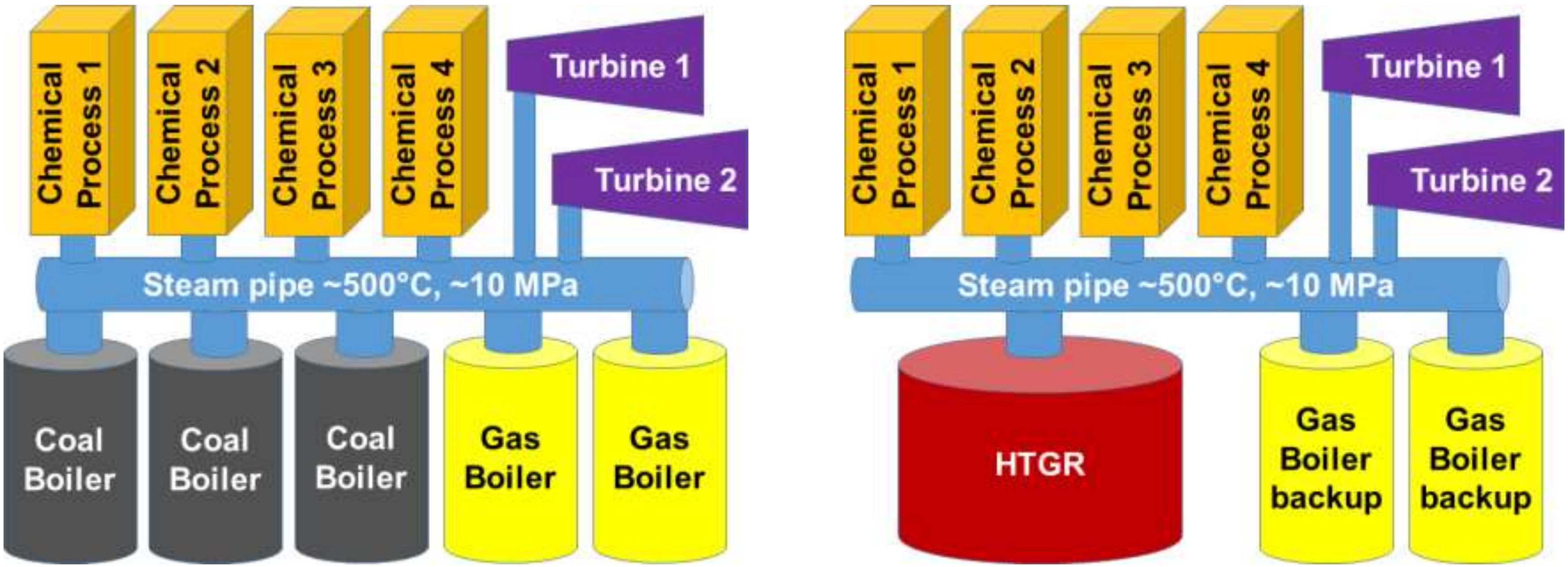
**Minister of Energy has given a green light to proceede with implementation of the conclusions.**

# 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 Enery 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**

# 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**

***) +10% for internal use**

# 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 | |
|---|---|---|---|---|---|---|---|---|
| Discount rate | 8% | | 4% | | 8% | 4% | 8% | 4% |
| $CO_2$ emission cost /t | 20€ | 50€ | 20€ | 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, $CO_2$ 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**

# *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 $CO_2$ 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 $CO_2$ 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

**Designing Experimental HTGR**
**150 M PLN**
50% from state?
~6 MPLN/year/partner

**Construction of Experimental HTGR**
**600 M PLN**
100% from EU?
(EU structural funds)

2018 — 2020 — 2023 — 2025 — 2031

**Designing Commercial HTGR**
**500 M PLN**
50% from state?
~12 M PLN/year/partner

OPEX (B+R)

**Construction of Commercial HTGR**
**2000 M PLN**
100% end-user
(UE/PL suport for long term loan)

CAPEX (investment)

Investment decisions

4 industrial partners assumed

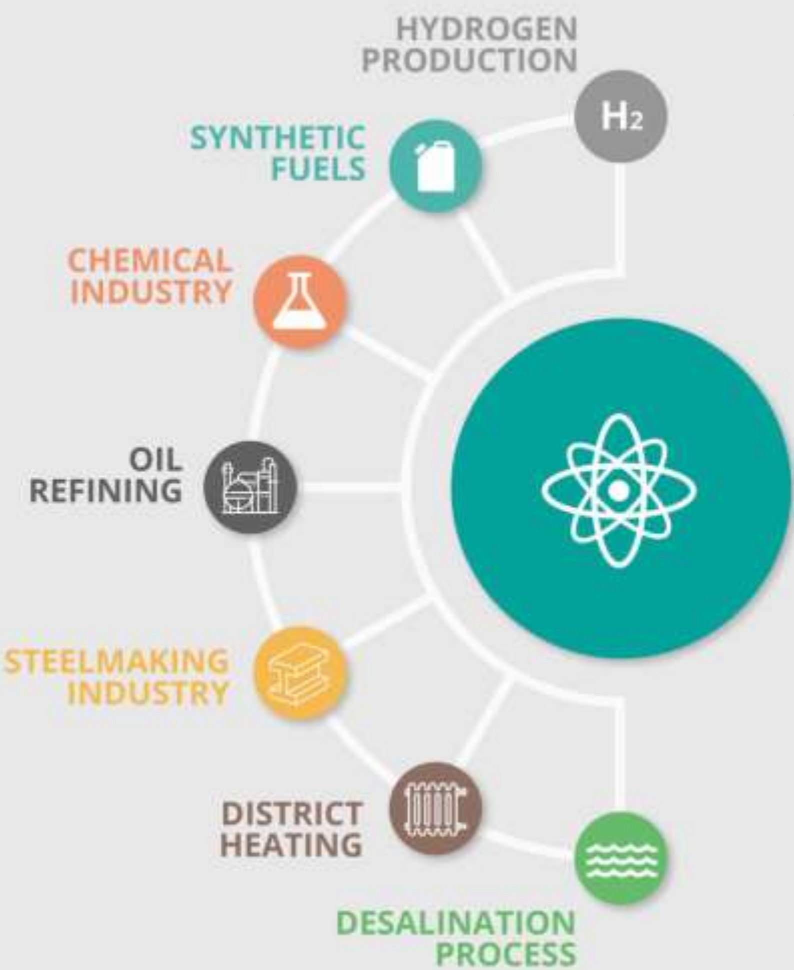
# Additional challenges

- **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 + disctrict 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 Sustainalbe Nuclear Energy Technology Platform




**www.nc2i.eu**

NC2I
Nuclear Cogeneration Industrial Initiative

*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

GEMINI+

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