# Nuclear Cogeneration

International Workshop on Acceleration and Applications of Heavy Ions
27 February - 12 March
Heavy Ion Laboratory University of Warsaw

Ludwik Pieńkowski
*Heavy Ion Laboratory University of Warsaw*

# Why the need to keep and to expand nuclear energy?

- **Nuclear energy** plays an important role today in the world energy production
  - There are more than 400 commercial nuclear power reactors
  - with ≈ 370 GWe of total power and
  - they **provide about 15% of the world's electricity**
- Nuclear power is
  - cost competitive with other forms of electricity generation
  - $CO_2$ emission free technology
- It would be very costly to replace nuclear power by other technologies in a near future
  - The expansion of nuclear power is necessary in order to keep alive the nuclear energy market

# The key challenges of nuclear energy

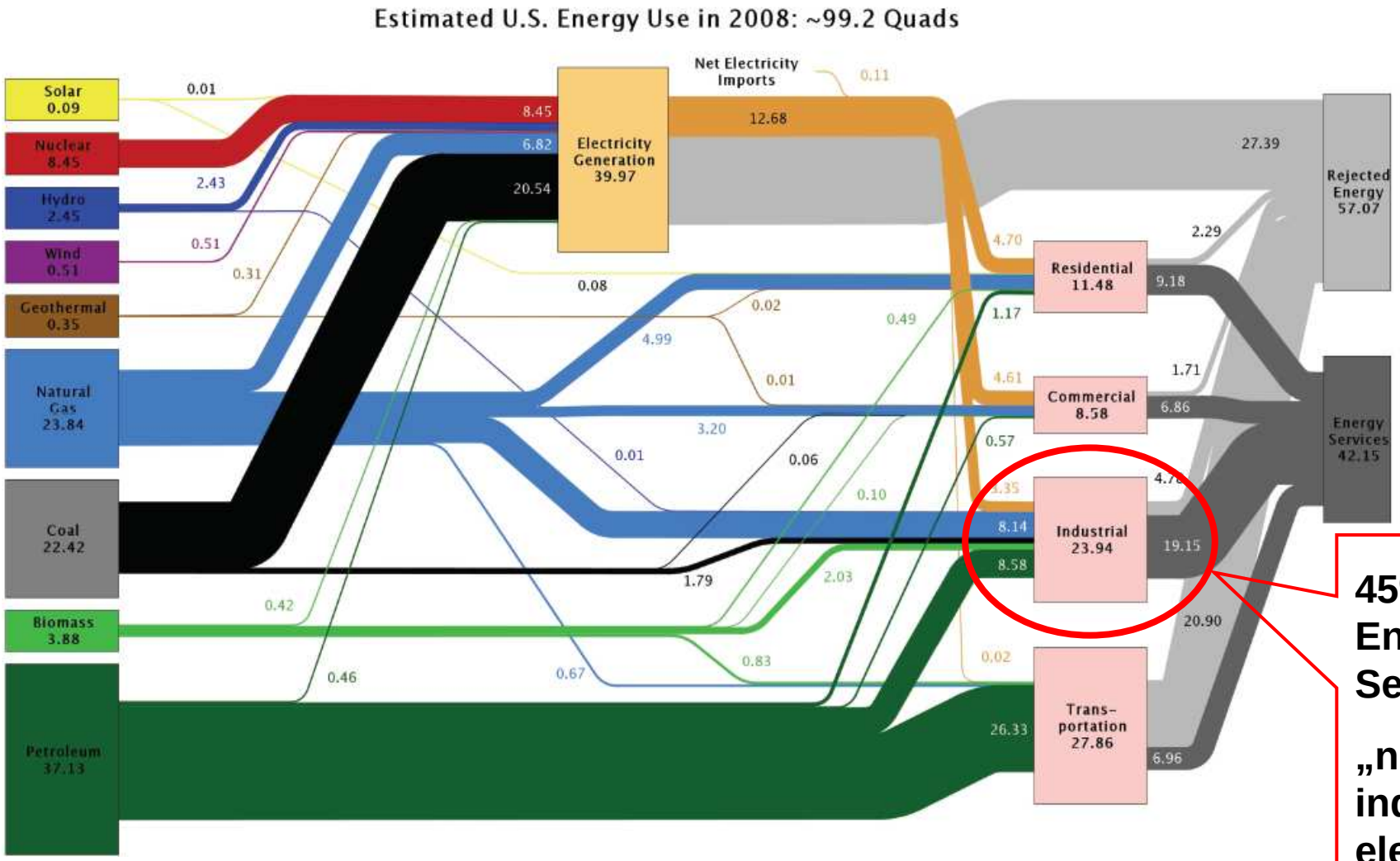
- **High capital costs for building the new plants**
  - Currently only large reactors are available
- Spent fuel, high-level nuclear waste
  - There are currently no permanent solutions
  - The main subject of public debate
- Limited resources of uranium
  - Challenge, but not for current fleet
- Nuclear safety
  - Absolute priority
- Risk of nuclear proliferation
  - Nuclear energy expansion will raise concerns

primary barriers to growth

# Actions to keep and expand nuclear energy

- Extend the useful life of existing nuclear power plants
- Public support for new nuclear power plant construction
- R&D, new technologies
  - There are no simple solutions
    - *Two times smaller plant is not two times less expensive*
    - *Revolutionary technologies, like nuclear fusion, are long-term visions*
  - **Small and medium size reactors (SMR)**
    - *capital cost reduction*
    - *at least partial response in other challenging fields*
  - Fast reactors
    - *To Close nuclear fuel cycle*
    - *Overcome limiting uranium resources and nuclear spent fuel problem*
  - Fuel cycle technologies including spent fuel managing
- R&D, new market
  - **Nuclear cogeneration**
    - *Useful thermal energy and electrical energy simultaneous production*
    - ***Nuclear process heat for industry***

# Energy market overview
# US case

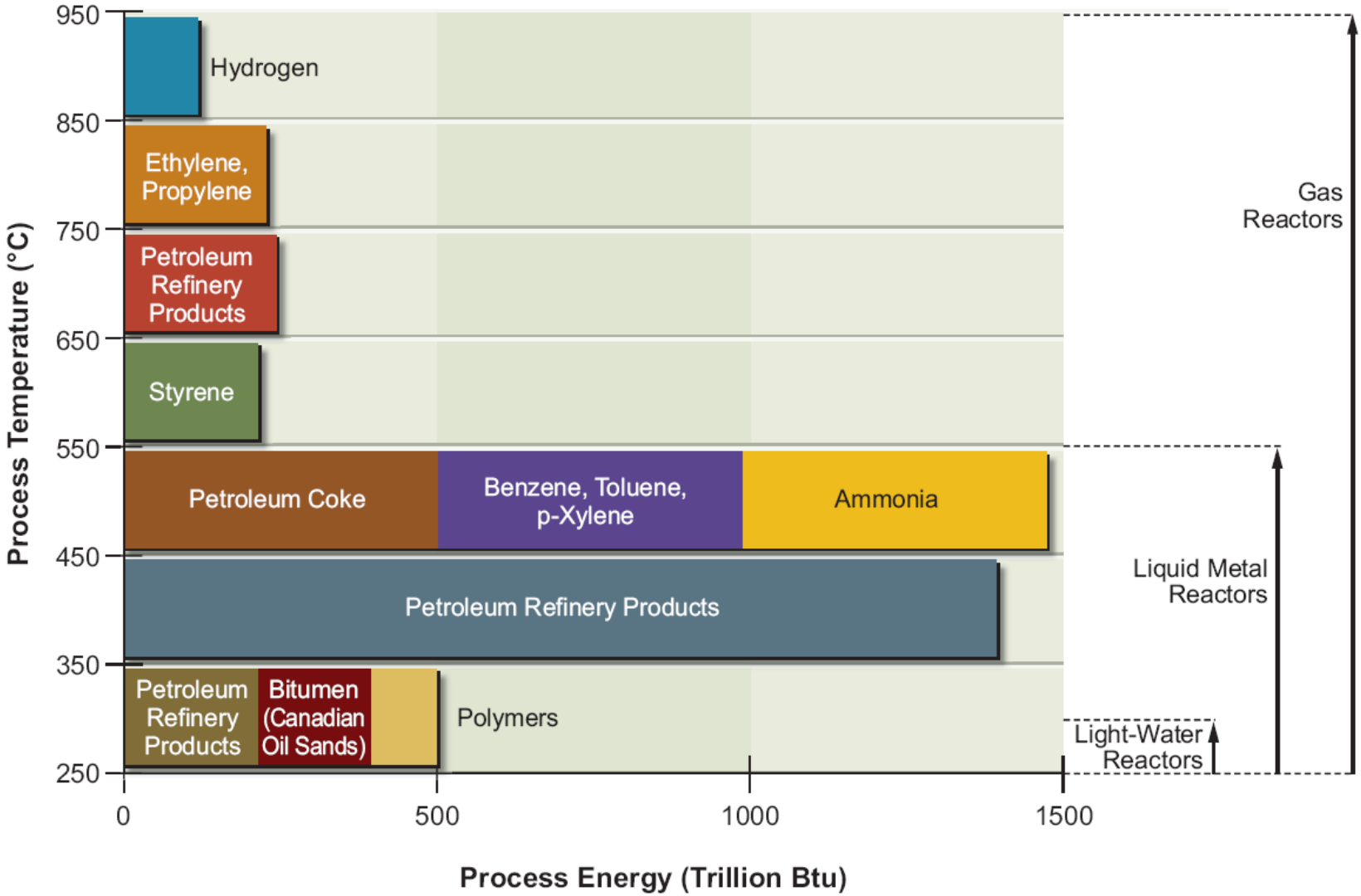



**45% of all Energy Services**

**„nuclear" only indirectly, electricity**

http://nuclear.gov/pdfFiles/NuclearEnergy_Roadmap_Final.pdf

# Process heat for industry today, space for nuclear cogeneration US case

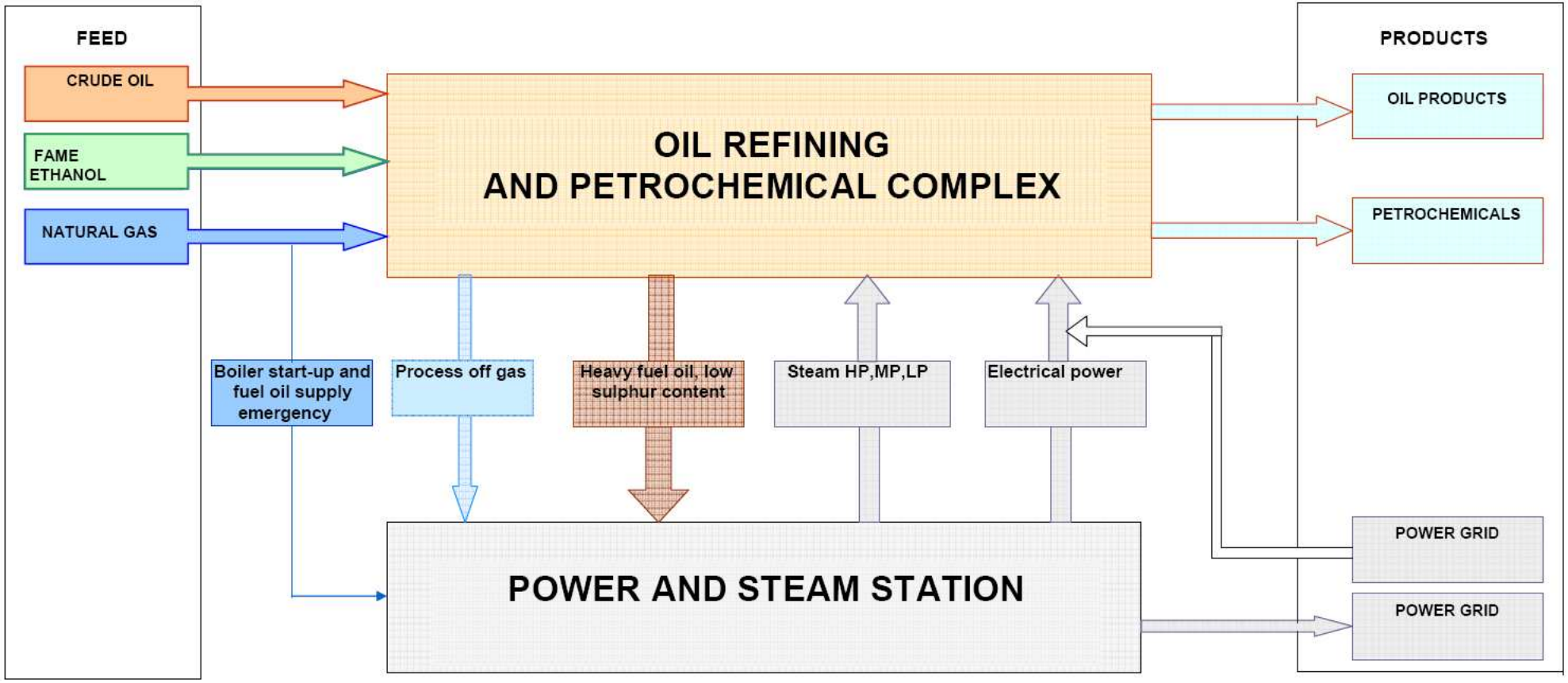



America's Energy Future: Technology and Transformation (2009)
http://www.nap.edu/catalog/12091.html

**1000 Trilion Btu ≈ 24 mln tons of oil**

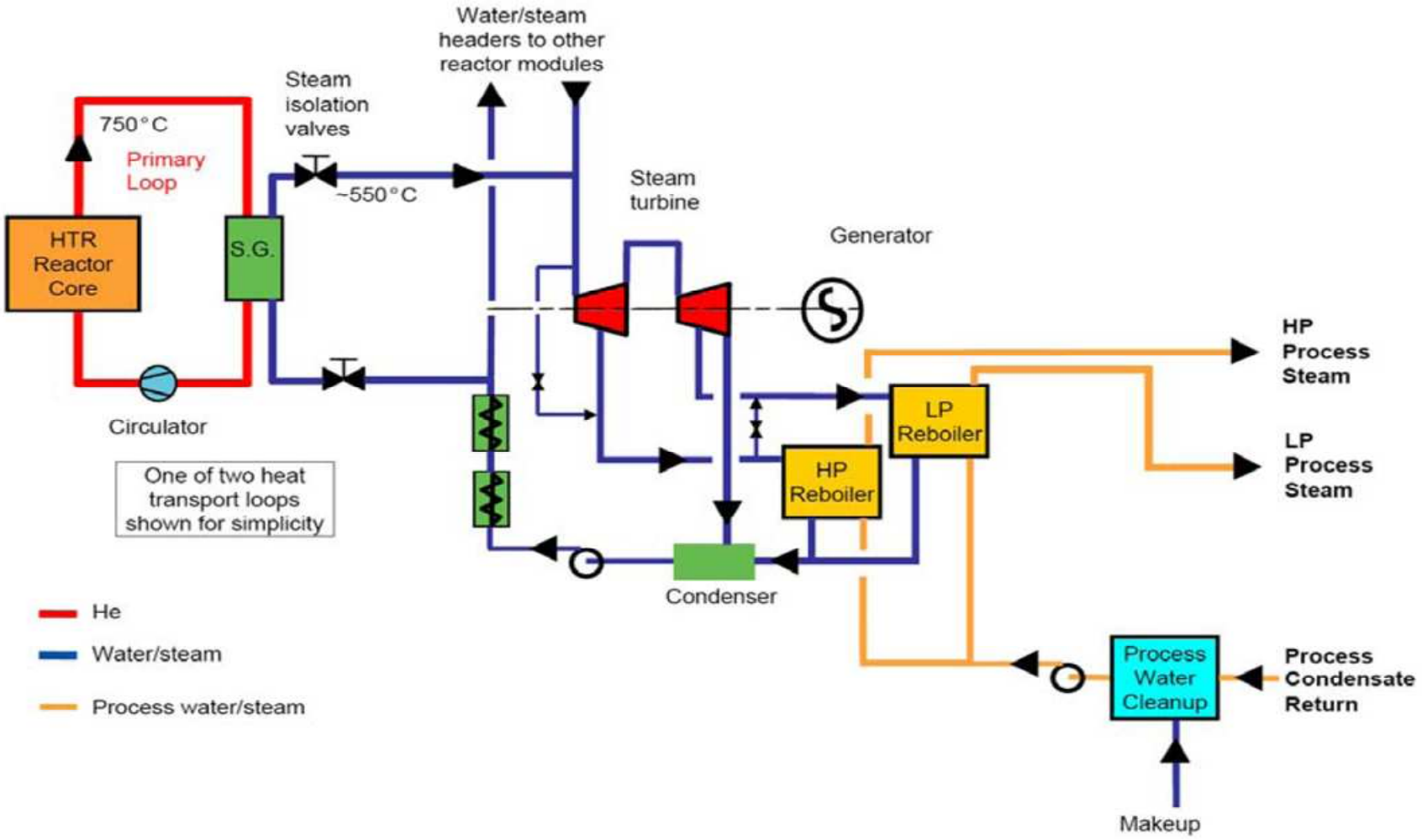
# Petrochemical industry

## → feed, cogeneration (electricity and steam), products



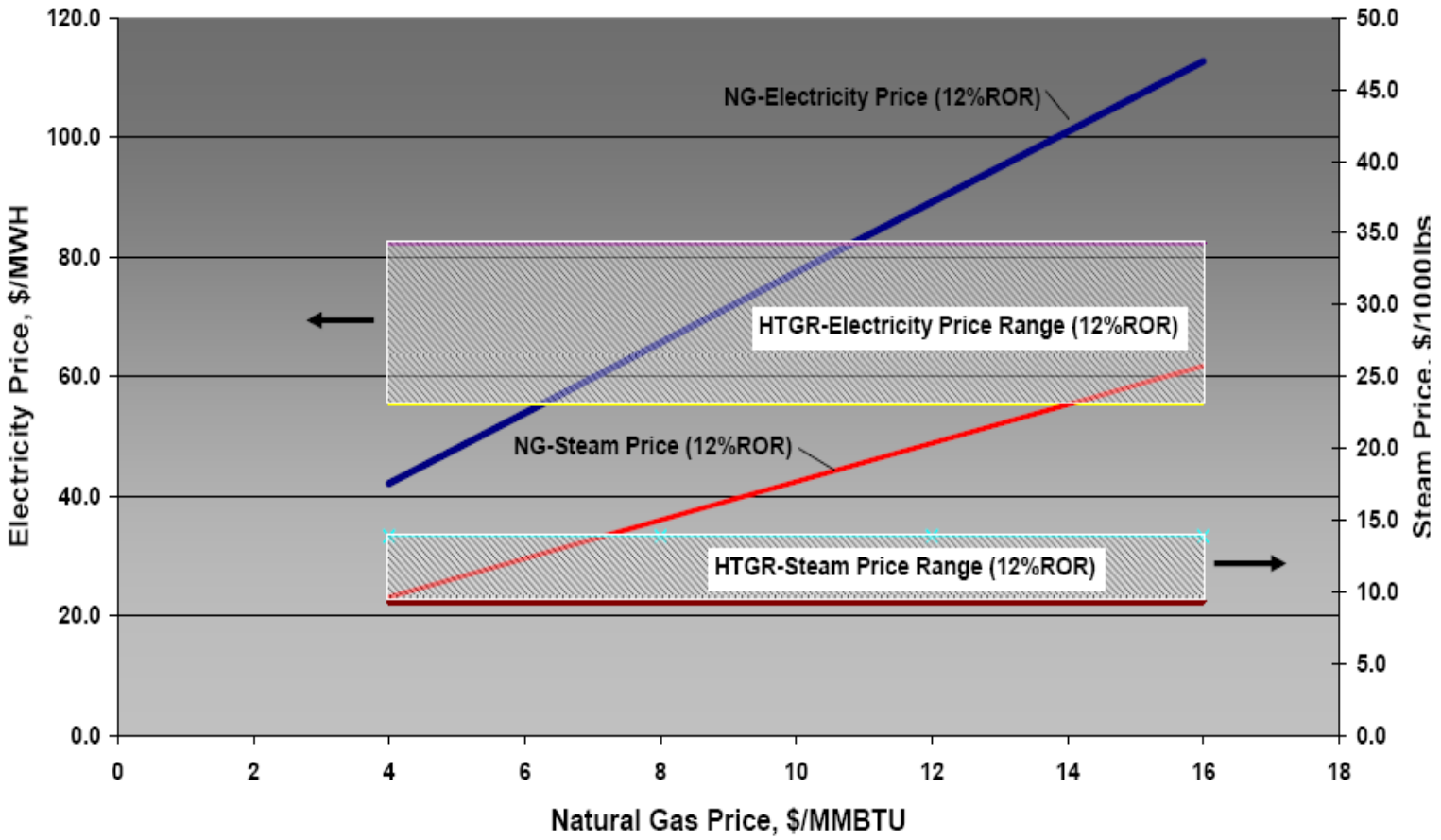

- electricity and steam production consume ~10% of oil
- HTR and nuclear cogeneration to improve productivity

# Nuclear cogeneration; reference plant design




**NGNP Project Technology Development Roadmaps:Technical Path Forward for 750–800℃ Reactor Outlet Temper ature**
**INL/EXT-09-16598, August 2009, http://nextgenerationnuclearplant.com/**

# Co-Generation Pricing Comparison



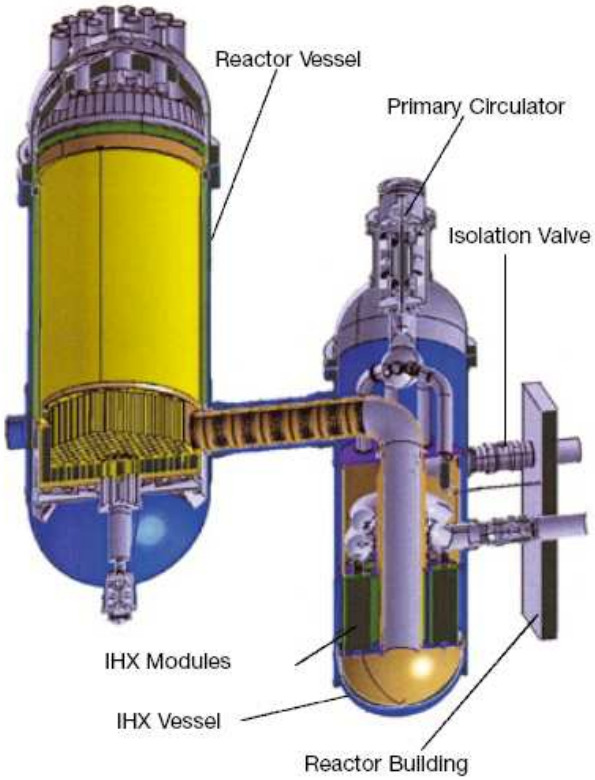

**MEX Natural Gas Prices 5 Years**


**1 MMBtu ≈ 28 $m^3$**

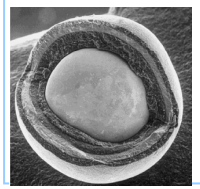
http://www.ne.doe.gov/newsroom/2008PRs/ProcessHeatApplication_100308/OwnersOperators_DanKeuter.pdf

# High Temperature Reactor (HTR)

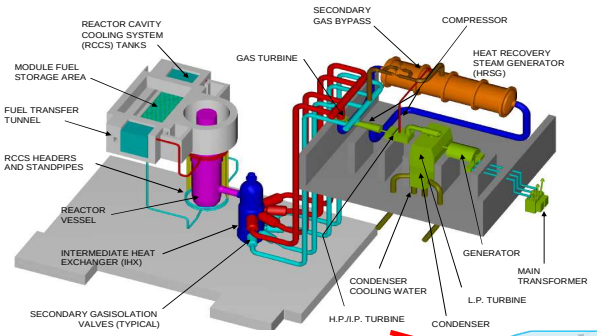
## ANTARES
AREVA design




- **High temperature**
  - HTR are the only reactors that can produce **in the short term** high temperature heat (750°C) required by industrial processes
- **Flexibility**
  - Cogeneration of electricity and process heat
  - Modular concept
- **Sustainability**
  - Opportunity for burning uranium, plutonium, thorium and minor actinides
    - *Huge resources, limited waste*
- **Passive safety concept**
  - Natural phenomena keep the reactor in safe conditions including in emergency situations
  - Fully ceramic core
    - *No physical possibility to melt the core*



# Status of HTR development in the world




**France: ANTARES programme for a CHP system, 600 MWth**

## R&D
## Very High Temperature Reactor


**~2015**

**China: HTR-PM, industrial prototype, 2x250 MWth, commissioning 2013**

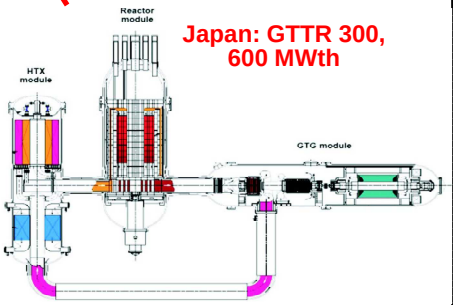
**China: HTR-10, test reactor, 10MWth, in operation since 2000**

**Russia: GT-MHR project**

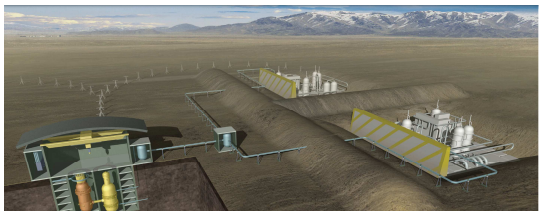



**Korea: NHDD project**

**Japan: HTTR test reactor, 30MWth, in operation since 1998**

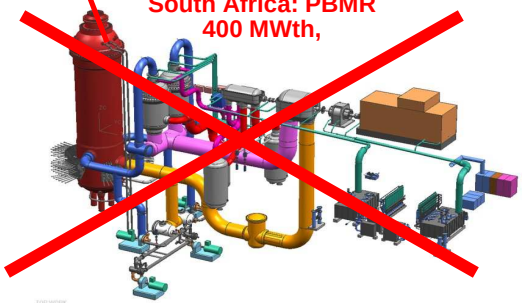



**Japan: GTTR 300, 600 MWth**



**USA: NGNP, industrial prototype for CHP and hydrogen production**

**~2021**



**South Africa: PBMR 400 MWth,**

# HTR programme in US
## Next Generation Nuclear Plant



**Goal: commissioning ~ 2020**
**Budget (DOE):**

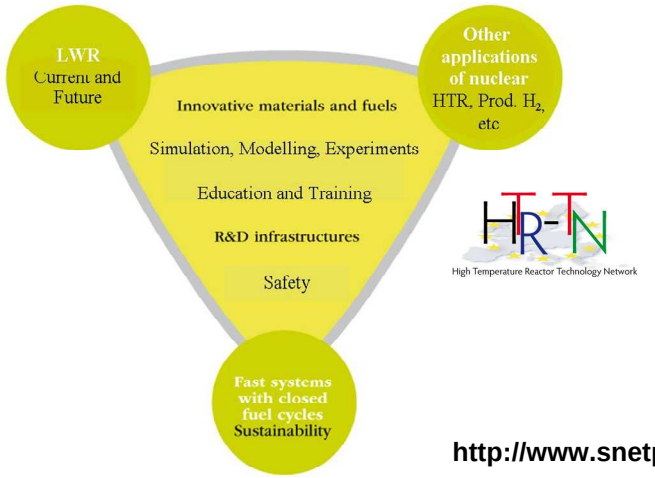
- **2007: 30 M$**
- **2008: 118 M$**
- **2009: 169 M$**
- **2010: 169 M$ + 40 M$ + ~30M$**

http://www.nextgenerationnuclearplant.com/

# Present European strategy for nuclear development

- **Light Water Reactors (LWR)**
  - Currently available technology for industrial applications
  - LWR providers and users identify the main development streams
- **Fast systems with closed fuel cycles**
  - Long term development to give the response on limited uranium resources and spent fuel reprocessing demand
  - European project led by France. The prototype – Sodium-cooled Fast Reactor (SFR) – is expected around 2020
- **High Temperature Reactors (HTR) for process heat, electricity and hydrogen production**

- Strategic Energy Technology Plan (SET-Plan), issued by the European Commission in 2007:
  - ***Europe needs to act now, together, to deliver sustainable, secure and competitive energy***
- European Sustainable Nuclear Energy Technology Platform (SNE-TP) recognized HTR as one of the major R&D pillars




**http://www.snetp.eu**

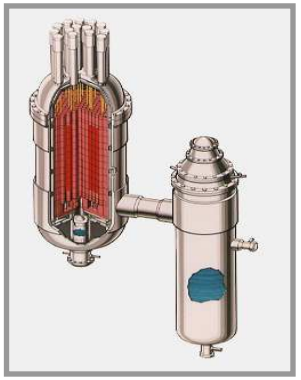
# European experience in HTR technology

- Europe built HTR up to the industrial prototype scale

DRAGON (U.K.)
1963 - 76

AVR (FRG)
1967 - 1988

THTR (FRG)
1986 - 1989



**EXPERIMENTAL REACTORS** → **DEMONSTRATION OF BASIC HTR TECHNOLOGY** → **MODULAR CONCEPT**

- Europe developed the technology of components for industrial process heat applications

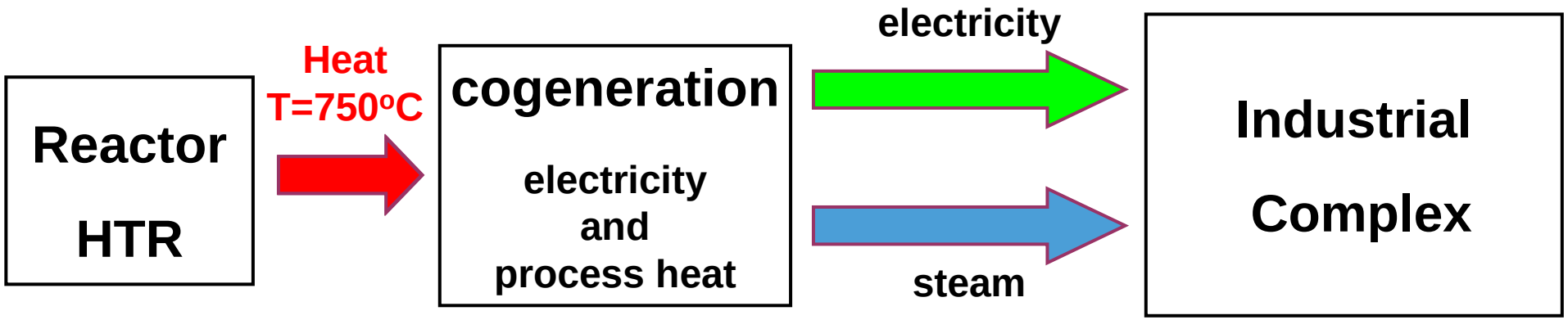
*10 MW mock-up of a He-He heat exchanger*


*10 MW steam $CH_4$ reformer mock-up for nuclear application*

# EUROPAIRS

End-User Requirements fOr industrial Process heat Applications with Innovative nuclear Reactors for Sustainable energy supply

European programme launched in September 2009




Main task:

- EUROPAIRS should aim at initiating an international consensus on the conditions for **industrial emergence of nuclear cogeneration**

Heat
T ≥ 750°C

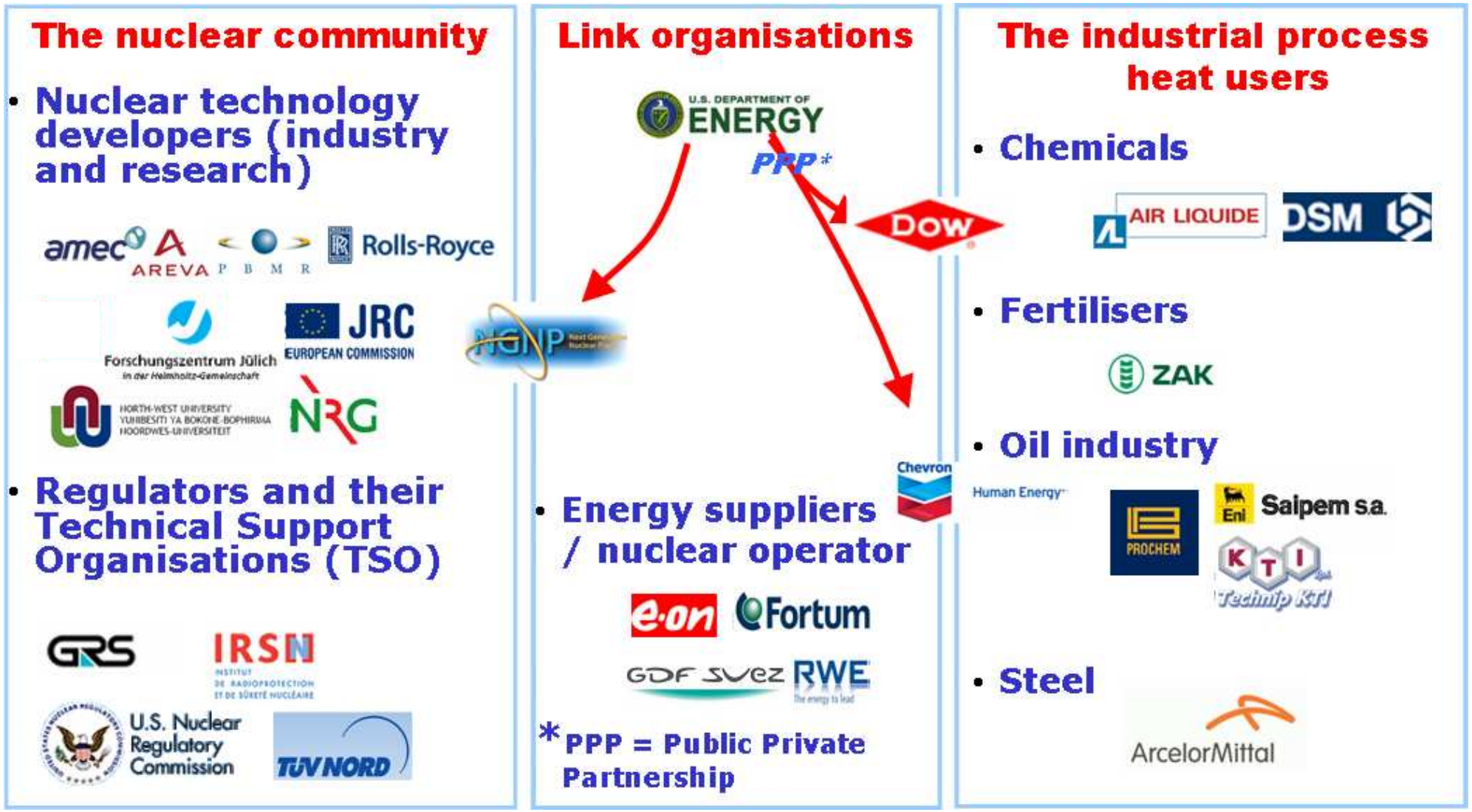
**R&D**
**hydrogen production, new technologies**

Additional task:

- R&D strategy

http://europairs.eu

# EUROPAIRS partnership
## including observers



High Temperature Reactor Technology Network

SNETP
Sustainable Nuclear Energy Technology Platform

# Deployment Strategy

May 2010

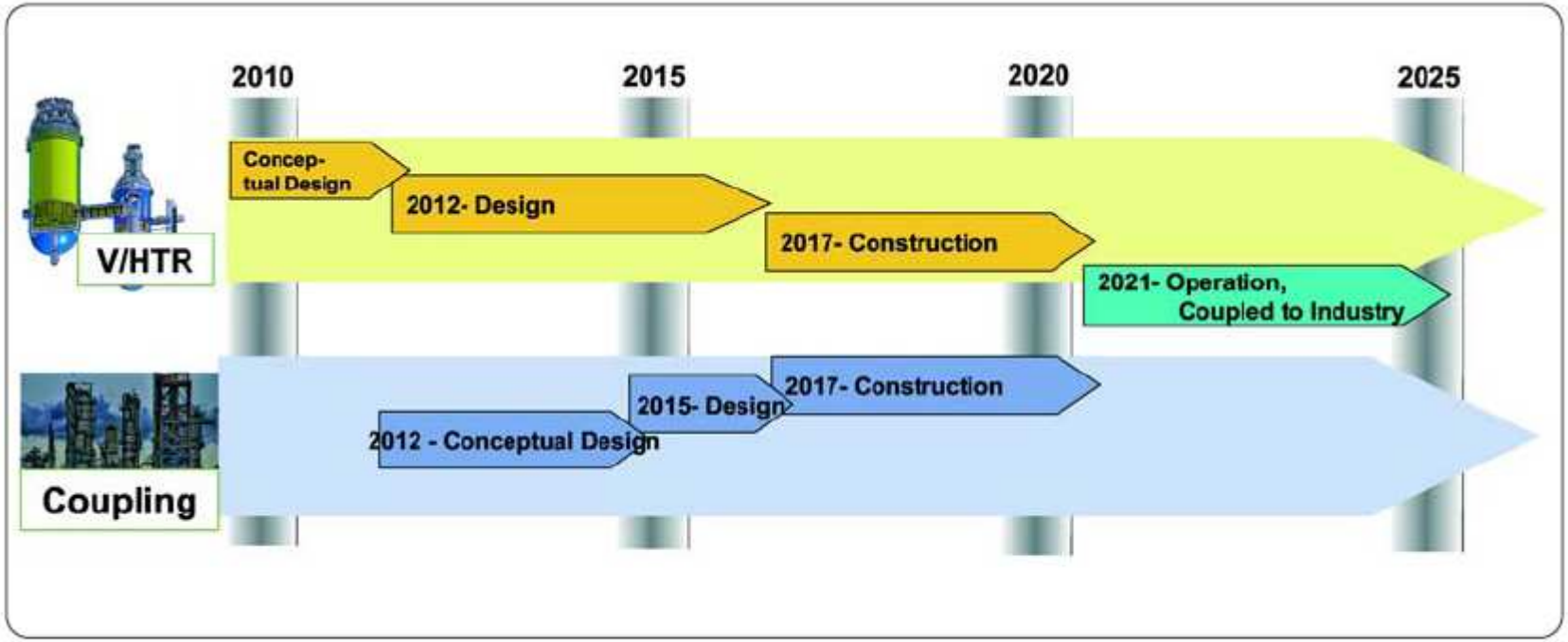



Fig. 13. Preliminary roadmap for cogeneration (Courtesy by HTR-TN)

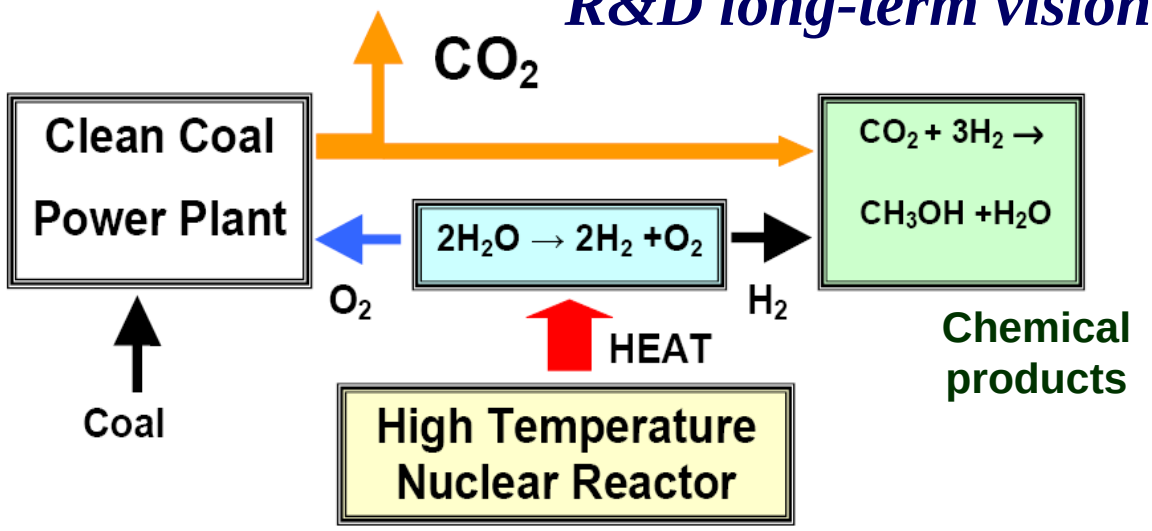
http://www.snetp.eu/

# Vision of the nuclear – coal synergy programme in Poland

High Temperature Reactor Technology Network

- **Programme constrains:**
  - Support to nuclear energy project in Poland
  - First European HTR industrial scale demonstration available around 2020 - 2025
- **The basis of the programme**
  - European experience in HTR technology
  - Coal resources and chemical industry needs in Poland and in Europe

***R&D long-term vision***




What is important to start HTR European demonstration project in Poland?

- Intentions at the national level
  - ☞ ***Energy Policy of Poland until 2030***
- Preparatory programme
- Decision to host the programme

# Conference HTR2010

## http://www.htr2010.eu/

# Summary

- A breakthrough of HTR in the energy market requires a large scale demonstration of the industrial feasibility of the coupling of such a nuclear reactor with process heat applications.
  - This is possible in a period of time of 10 - 15 years
  - Europe has the technological potential to do it
  - European industry needs $CO_2$ free and competitive process heat that HTR can provide
    - *Poland would benefit from this technology for coal processing.*
- The first installation requires large R&D and combined licensing for a nuclear reactor and an industrial plant
- In order to minimize development risks, large international coope-ration with other HTR projects in the world should be looked for.