Potential for Nuclear Process Heat Application

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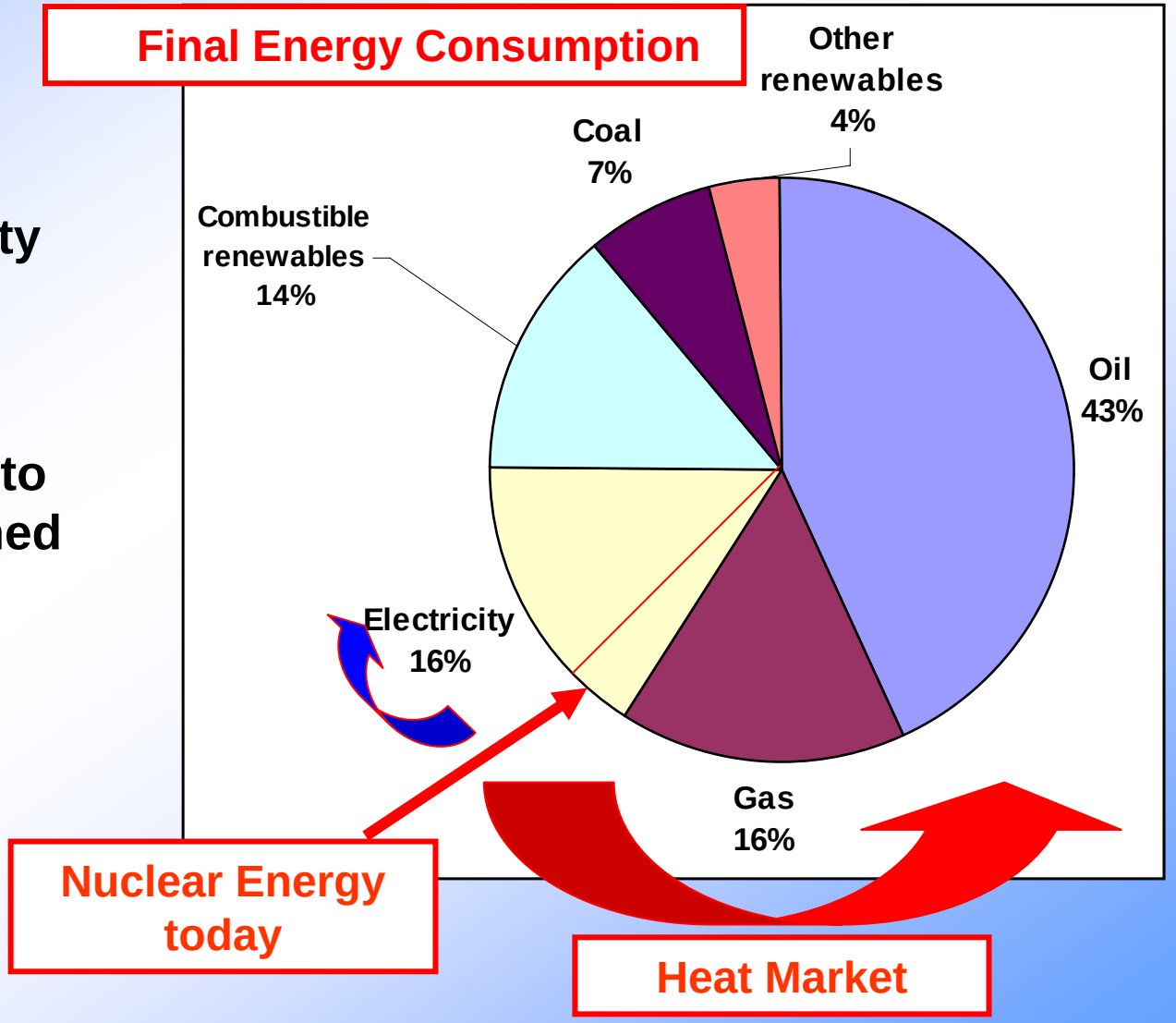
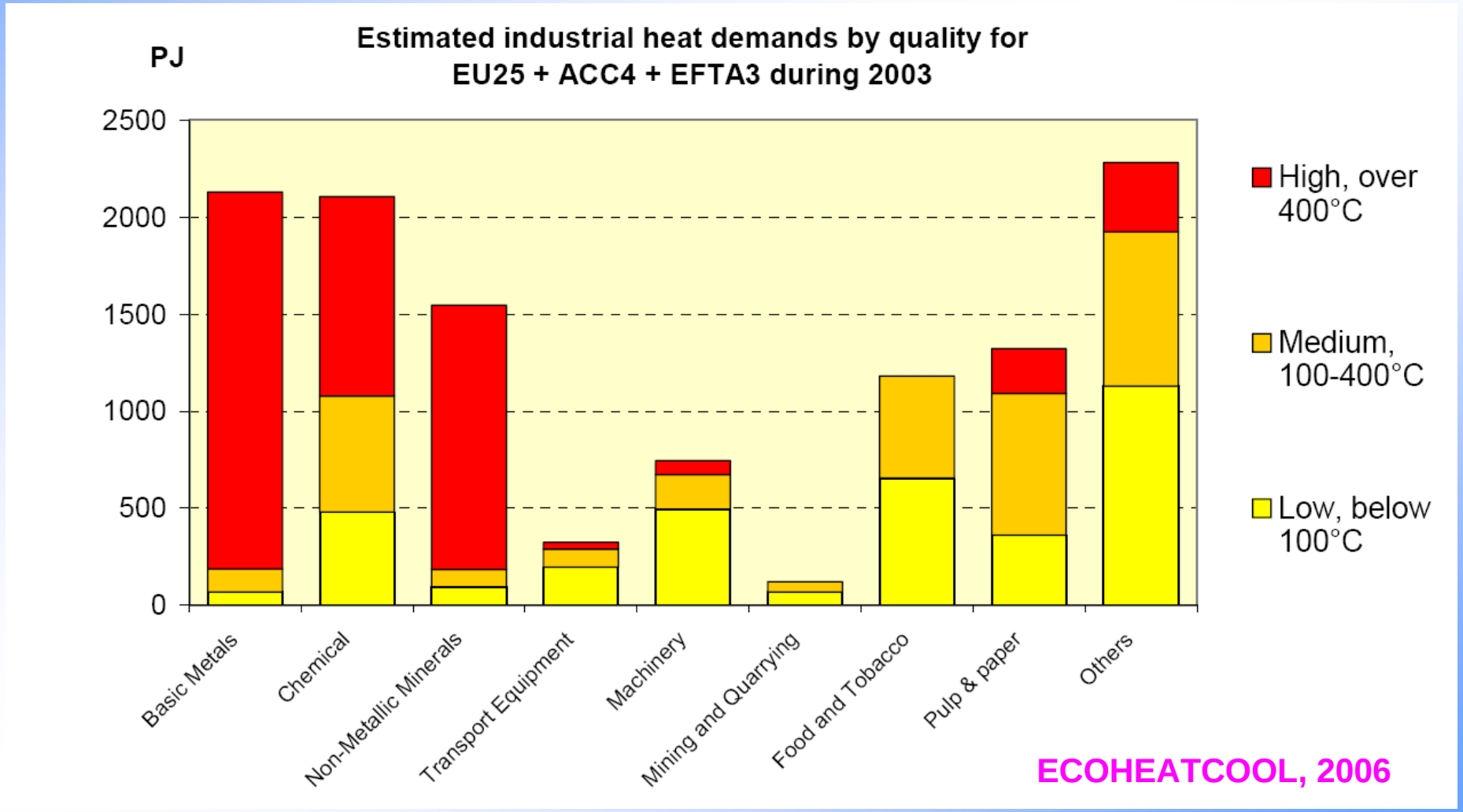
Forms of Energy Utilization

- **Electricity only 16 % (25 % for OECD)**
- **Nuclear only for electricity**
- **Heat Market & Transport dominating**
- **Penetration of nuclear into two directions or combined**
- **Combined Heat & Power saves resources & CO_2 emissions**
- **NPH a real innovation in the energy sector !!!**



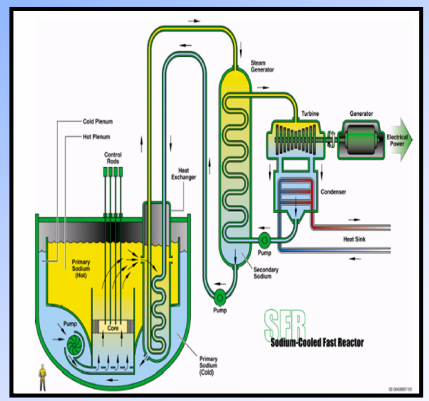
Industrial Heat Demand (Ex.: Europe)



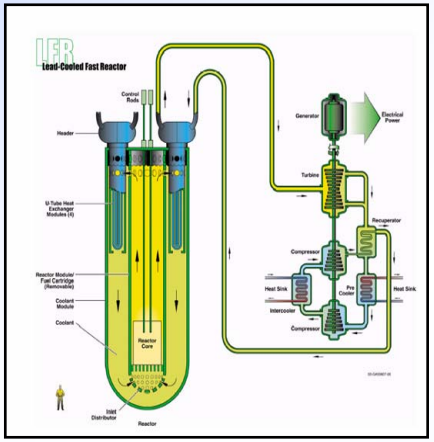
The Strong Points of Nuclear Combined Heat and Power

- More independence of energy imports
- Increase in efficiency by ~ 15 % → competitive
- Reduced heat waste and CO_2 emissions
- Adaped to industrial needs (modular size)
- Good social acceptance

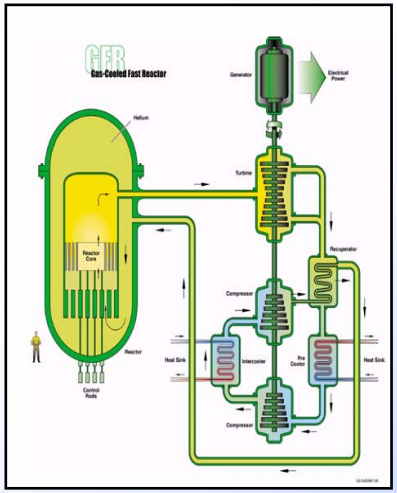
Gen-IV Nuclear Reactor Systems



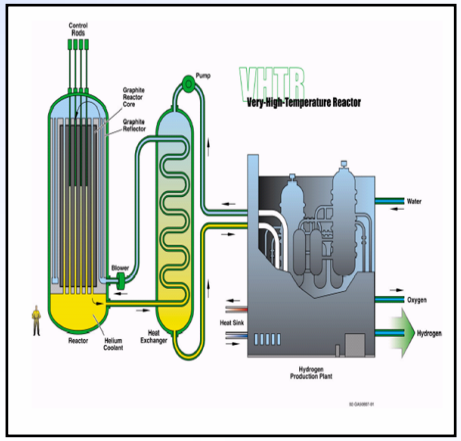
Sodium Fast Reactor



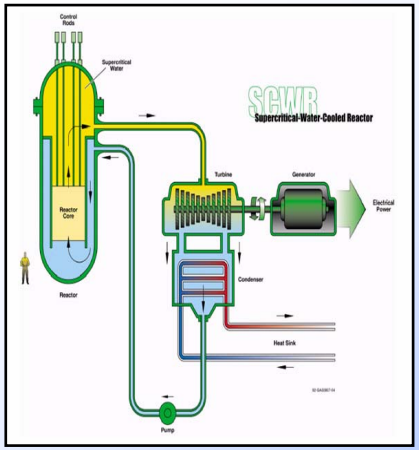
Lead Fast Reactor



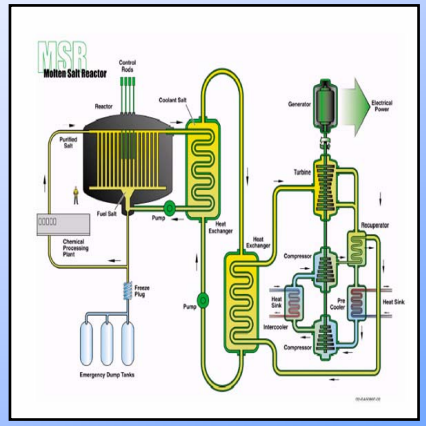
Gas Fast Reactor



Very High Temperature Reactor

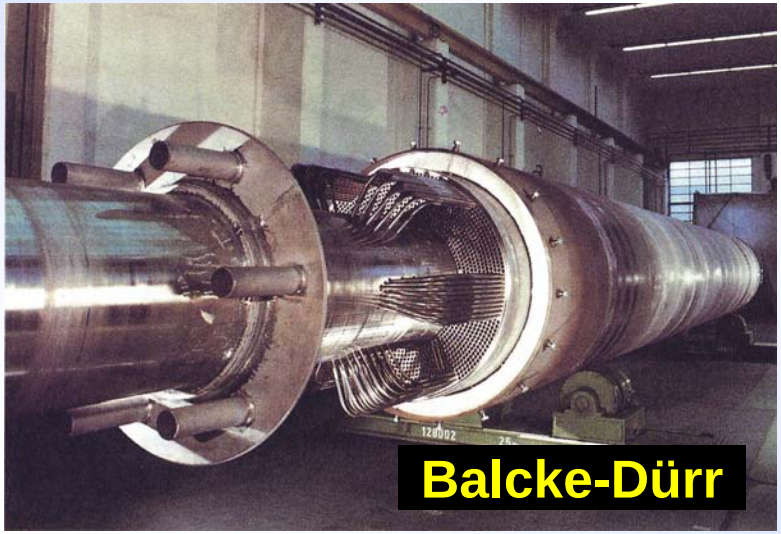


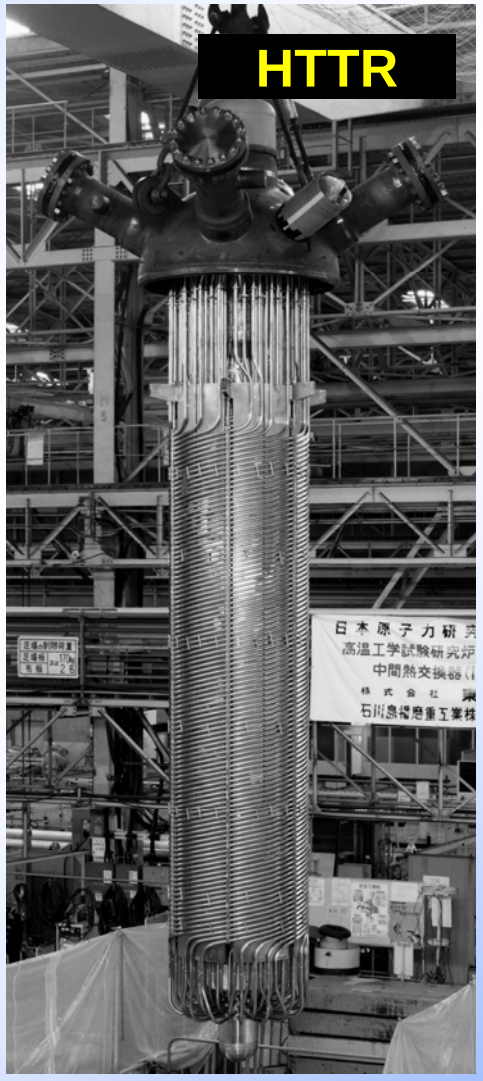
Supercritical Water Reactor



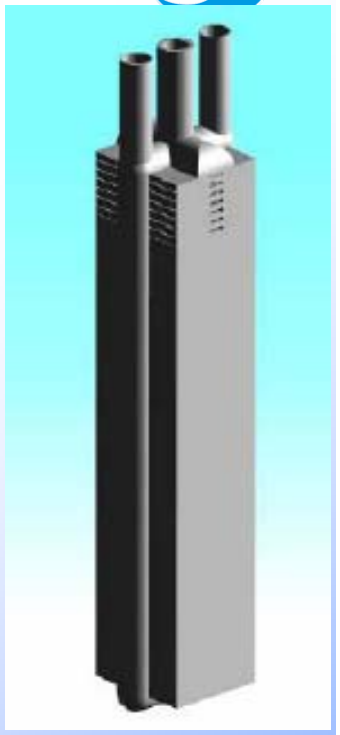
Molten Salt Reactor

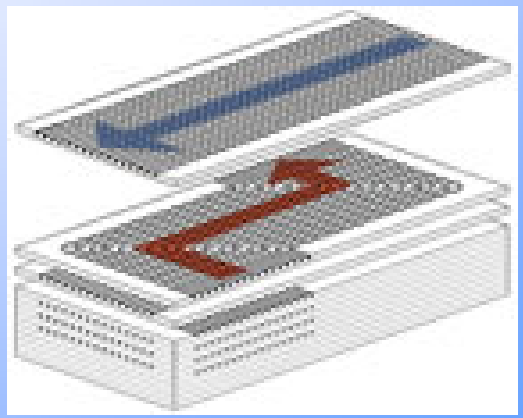
Intermediate Heat Exchanger





Heatrix





Examples of Commercial Use of Nuclear Process Heat

- Canada, Bruce NPP with 5350 MW to D_2O production plant and other industries
- Germany, Stade NPP with 30 MW to salt refinery
- Switzerland, Goesgen NPP with 25 MW to cardboard factory

D_2O production, Bruce

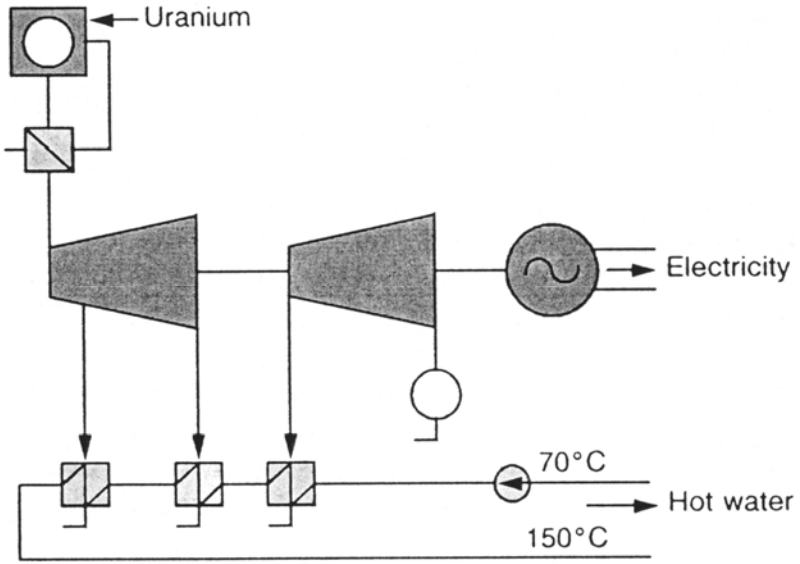
District Heating

- Hot water or steam supply decentralized at 80 – 150°C temperature and at low pressures
- Developed networks in many countries with sizes of 600-1200 MW(th) for large cities and 10-50 MW(th) for smaller communities (total: ~50,000)
- Hot water systems wide spread in Germany, steam systems in the USA
- Insufficient economy for nuclear systems

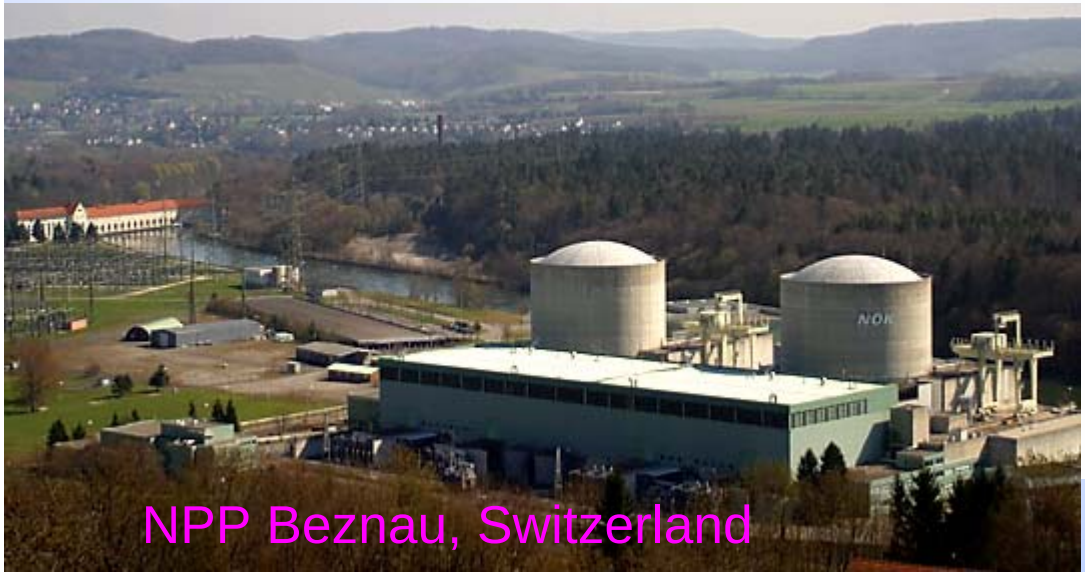
Nuclear District Heating

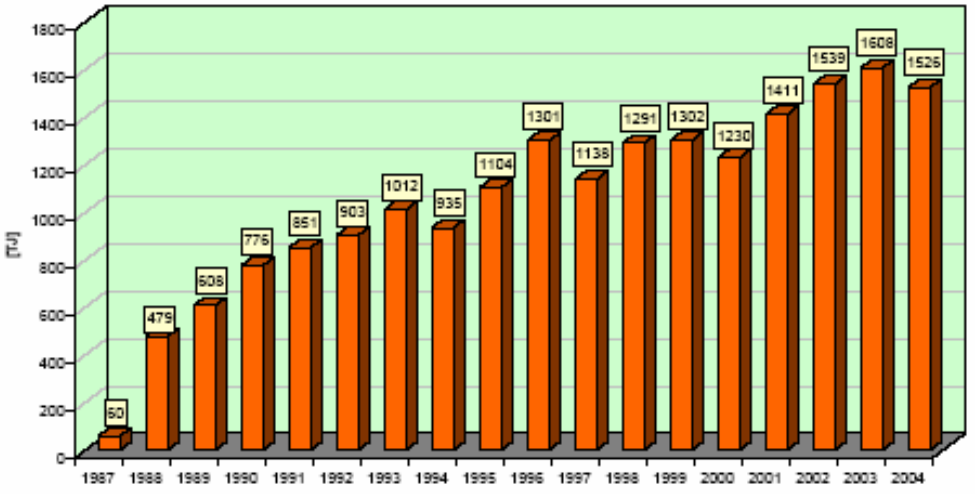
Technical feasibility demonstrated

Experience from 46 reactors in 12 countries with two dedicated plants in Russia (Obninsk) and China (NHR-5) **(IAEA 1998)**



NPP Bohunice, Czech Rep., with a 40 km grid to provide hot water at 300 kg/s at 150°C


NPP Beznau, Switzerland



Nuclear District Heating at the Tsinghua University in Beijing

NHR-5 (since 1989)

Primary:

186 / 146°C @ 1.5 MPa

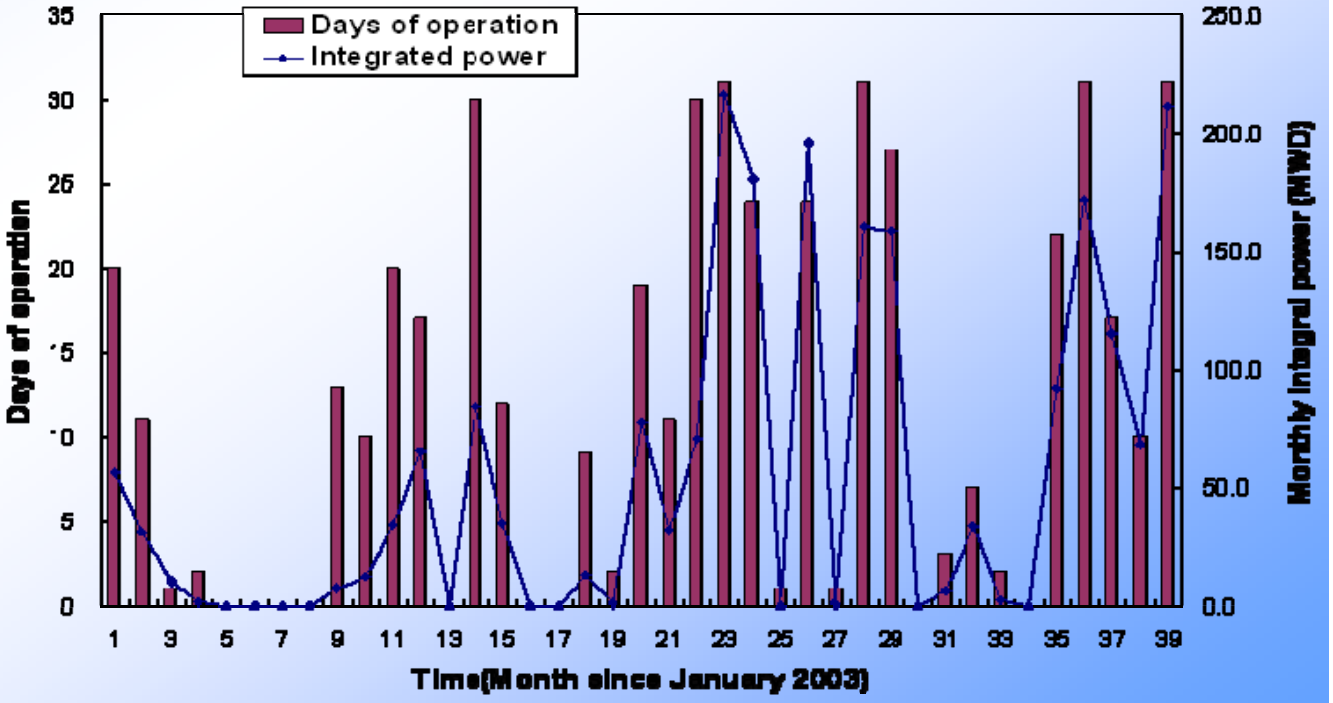
Secondary:

186 / 146°C @ 1.7 MPa

Heat grid:

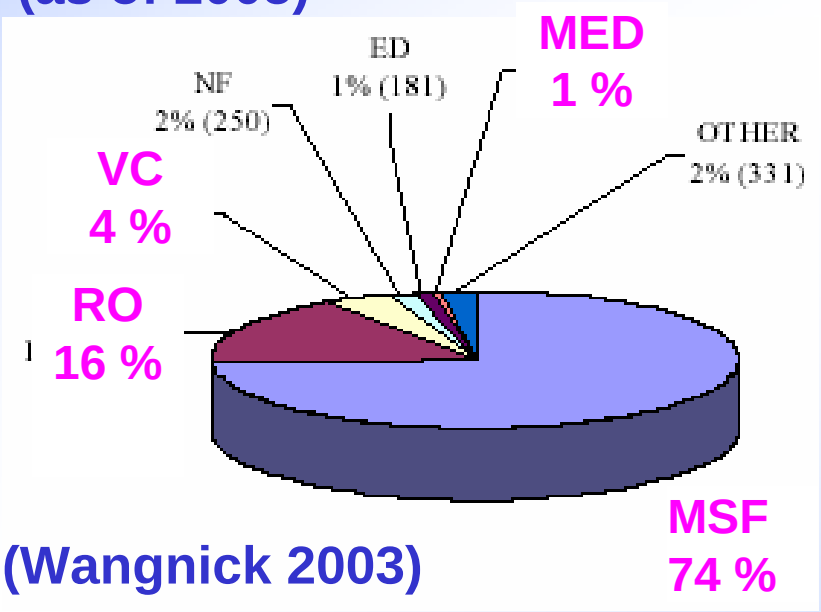
90 / 60°C

HTR-10 (since 2003)

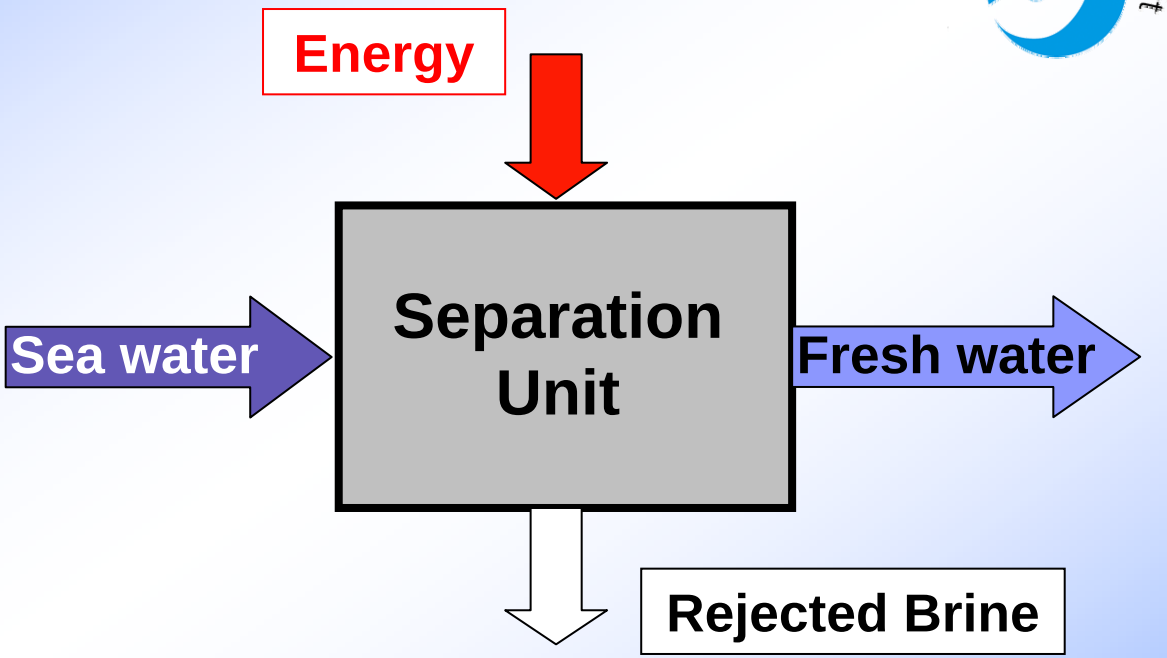


Desalination

Fully developed to a large-scale commercial process providing 36 Million m^3/d of fresh water in 120 countries **(as of 2005)**



(Wangnick 2003)



Distillation
Multi-stage flash (MSF)
Multi effect (MED)
Vapor compression (TVC)

Membrane separation
Reverse osmosis (RO)

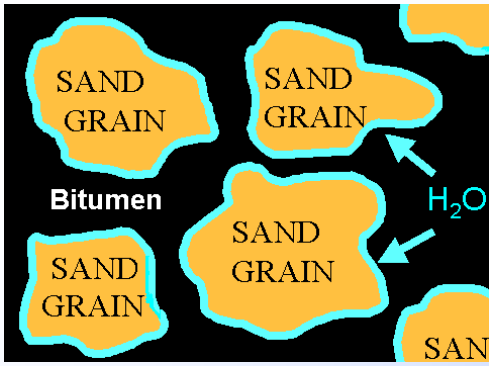
Energy Demand in Distillation Processes

	MSF	
Global capacity	10	Mm^3/d
Single plant size	45,000	m^3/d
Steam temperature	100-130	°C
Steam pressure	0.1-0.15	MPa
Steam flow rate	100-150	t/h
Electricity	5.5	kWh/m^3
Heat	53.8	kWh/m^3
Conversion	10-25	%

Nuclear Desalination

- Experience with nuclear desalination since 1960s,
  1 plant in Kazakhstan, FBR, 80,000 m^3/d water by MED
  9 plants in Japan, 1000-3000 m^3/d for on-site supply with a total of ~150 accumulated operation years **(IAEA 2002)**
- Still needs to be demonstrated on large scale
- Project studies on-going in several countries,
  European project EURODESAL to prove competitiveness of nuclear desalination

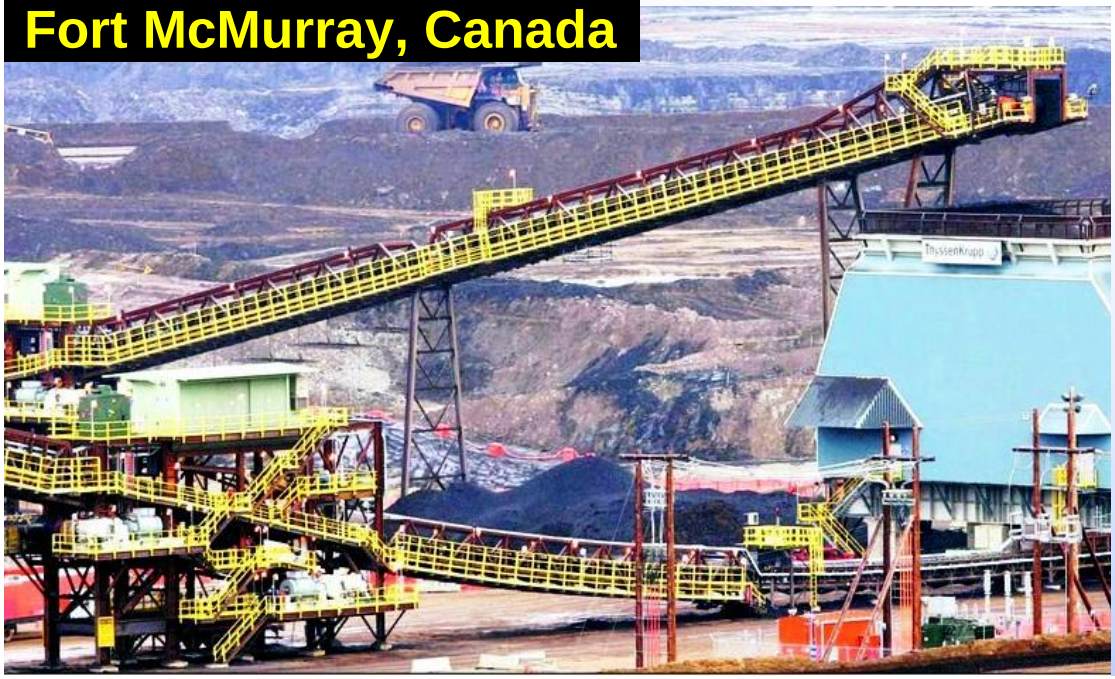
Tertiary Oil Recovery



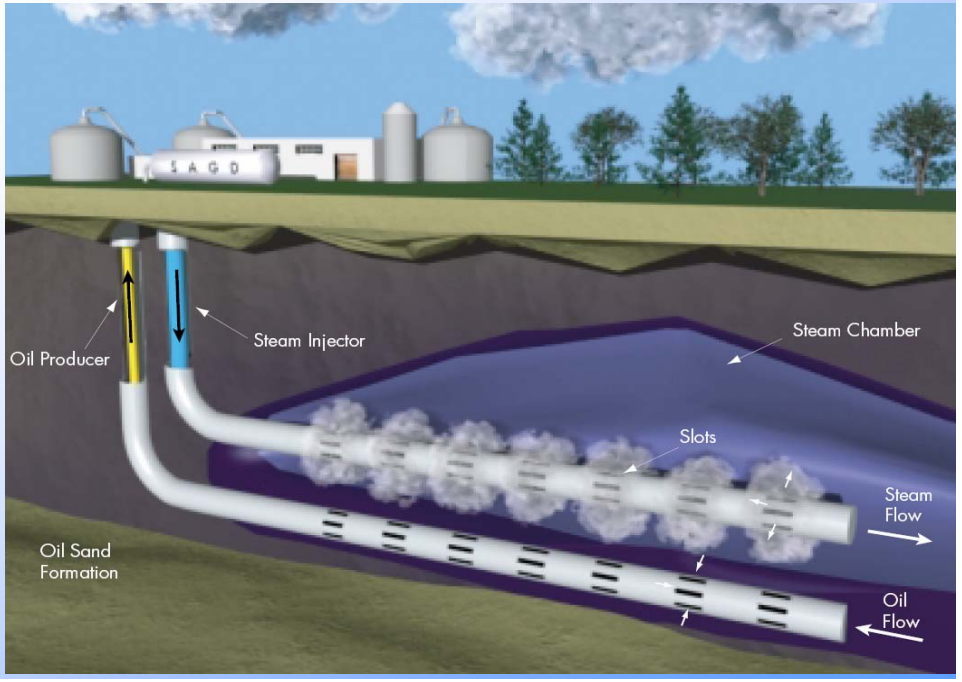
Flooding with steam

@ 200-340°C, 10-15 MPa

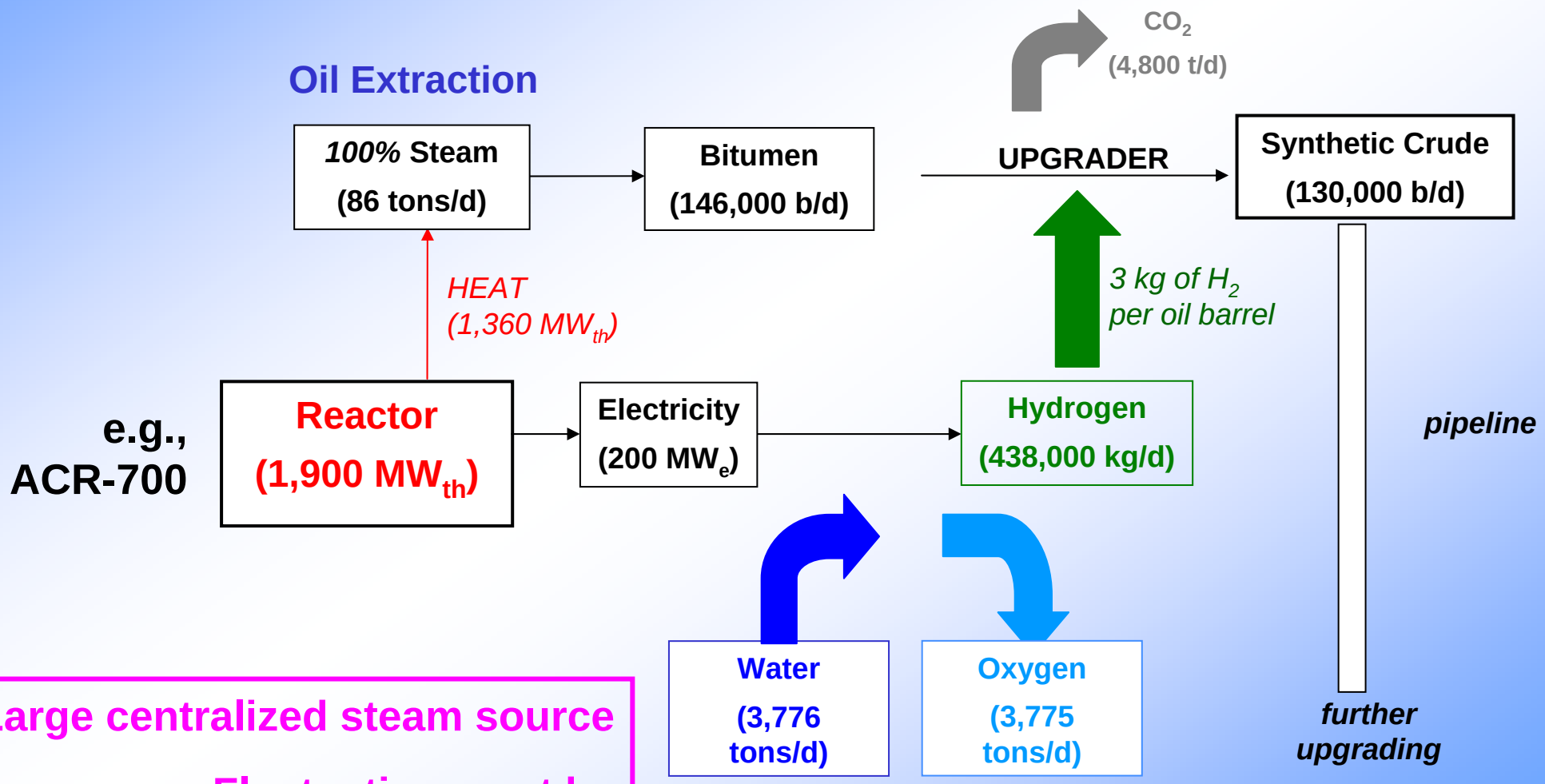
Fort McMurray, Canada



Steam-Assisted Gravity Drainage



Nuclear Production of Synthetic Crude Oil

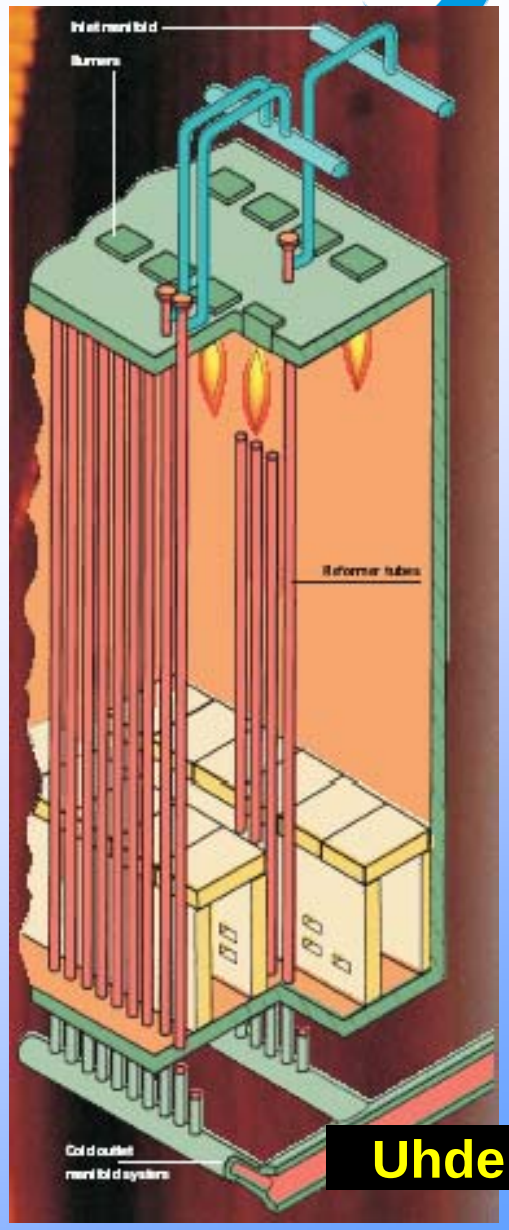


Large centralized steam source

Fluctuations met by cogeneration of electricity

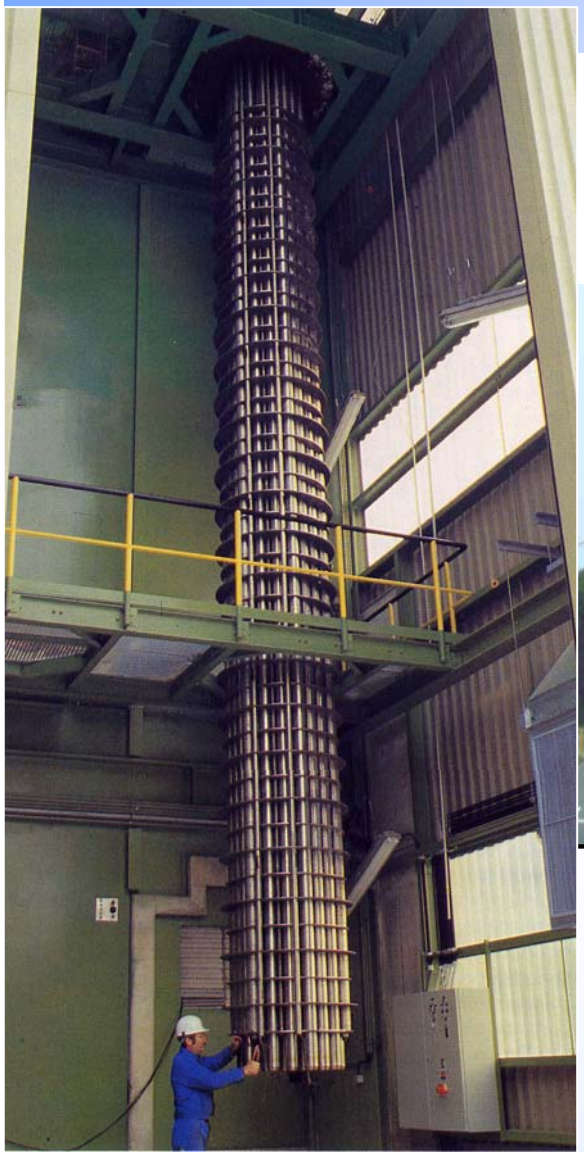
Refinery

- Worldwide throughput of crude oil $3*10^9$ t/yr requiring ~ 200 GW(th) or 8% of energy contents
- Total system has large number of individual units
- Refinery with annual throughput of 6-7 Mt typically needs 400 MW(th)

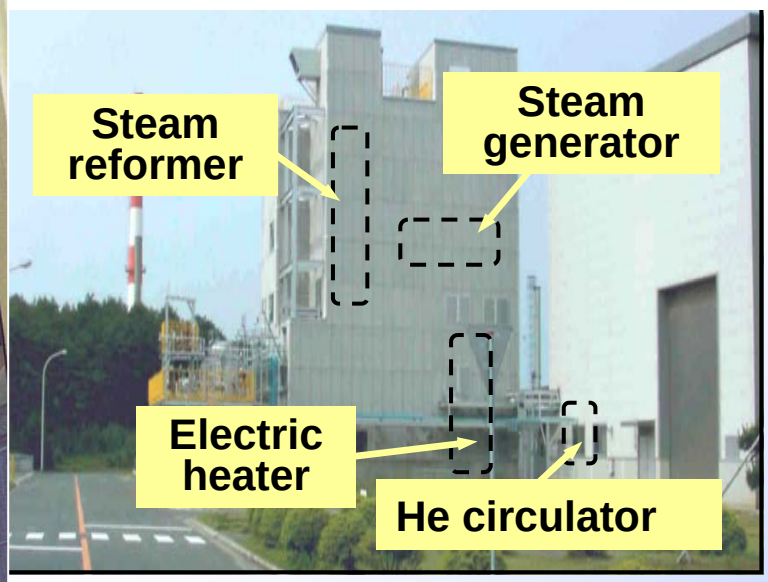


Capacity: 13.8 t/h or 153,000 Nm^3/h corresponding to 550 – 630 MW (HHV)

Steam Methane Reforming



Most widely applied conventional hydrogen production method



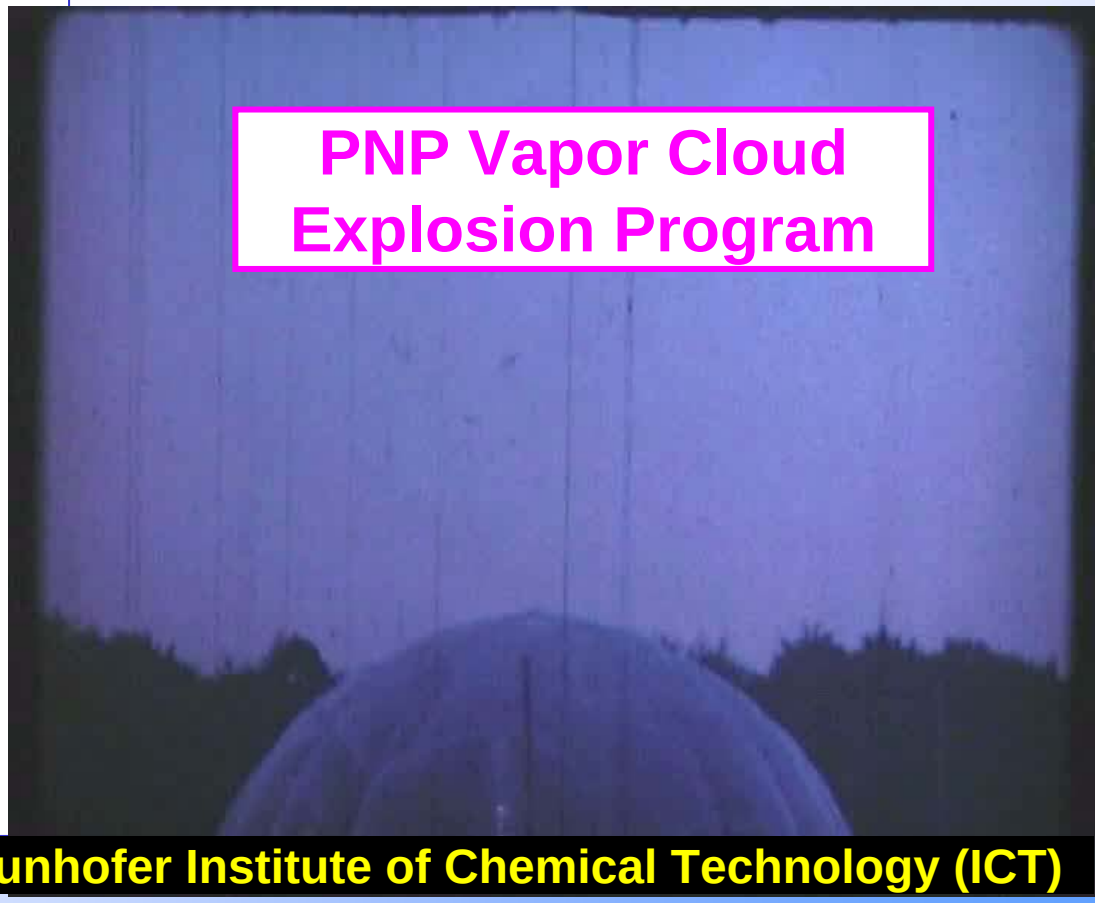
Oarai, Japan

Jülich, Germany

- Savings of ~ 35%, if process heat is from nuclear
- Tested under nuclear conditions in pilot plants in Germany and Japan

Requirements to Nuclear Refinery System

- Flexible in operating conditions, i.e., easily adjustable to customer‘s requirements
- Guaranteed reliable supply of process heat
- Small-size (modular-type) reactor (170 – 250 MW_{th})
- Safety concept
  - Thermodynamic interaction
  - Explosion hazards
  - Licensing and emergency plans.



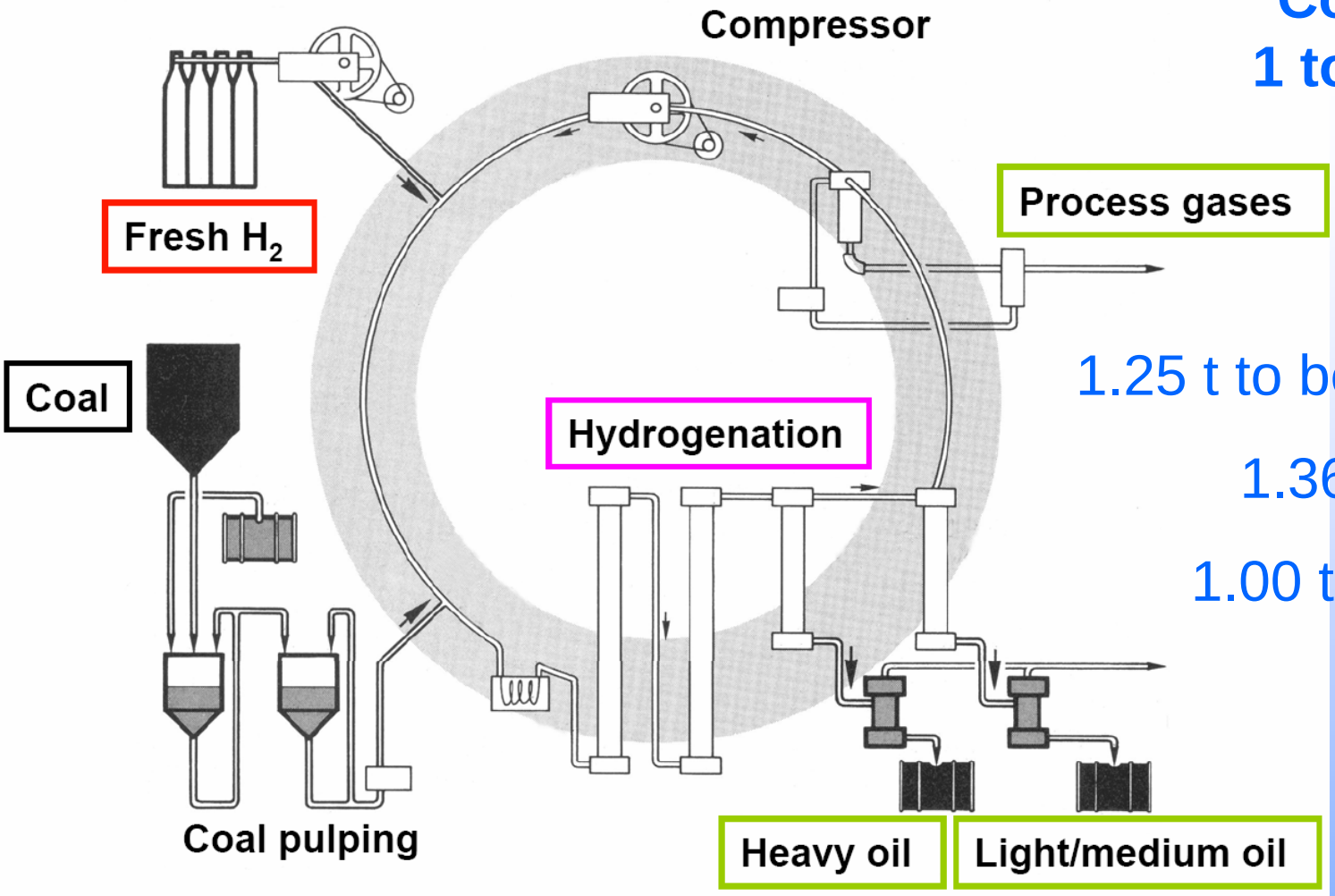
Fraunhofer Institute of Chemical Technology (ICT)

Upgrading of Coal

Conversion of 1000 kg of German Lignite

- **790 kWh of electricity**
- **360 kg of coal dust**
- **250 kg of coke**
- **280 l of methanol**
- **160 kWh of gasoline**
- **550 m^3 of synthesis gas**
- **150 m^3 of SNG**

From Coal to Oil



Coal demand for 1 ton of „coal oil“

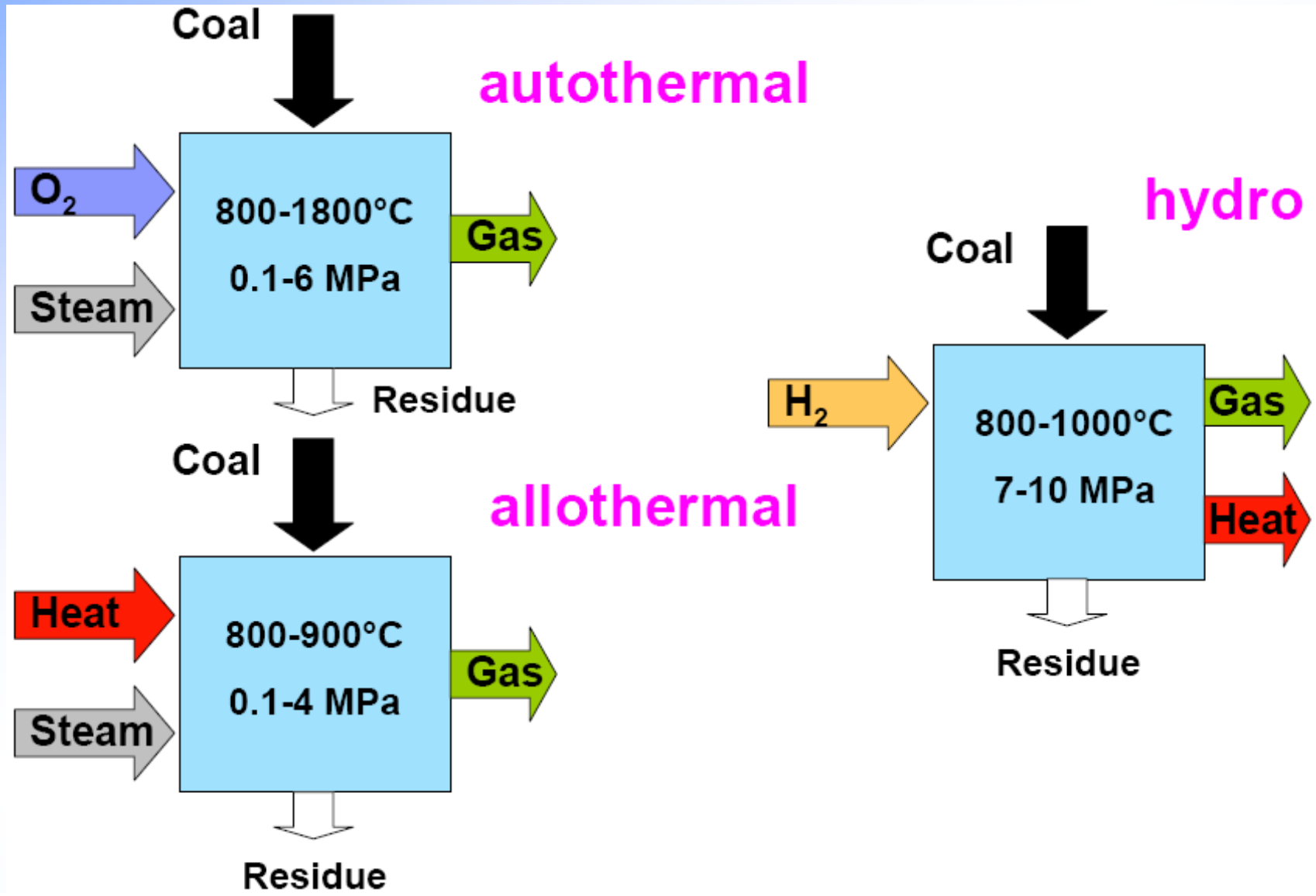
1.25 t to be hydrogenated

1.36 t of coal for H_2

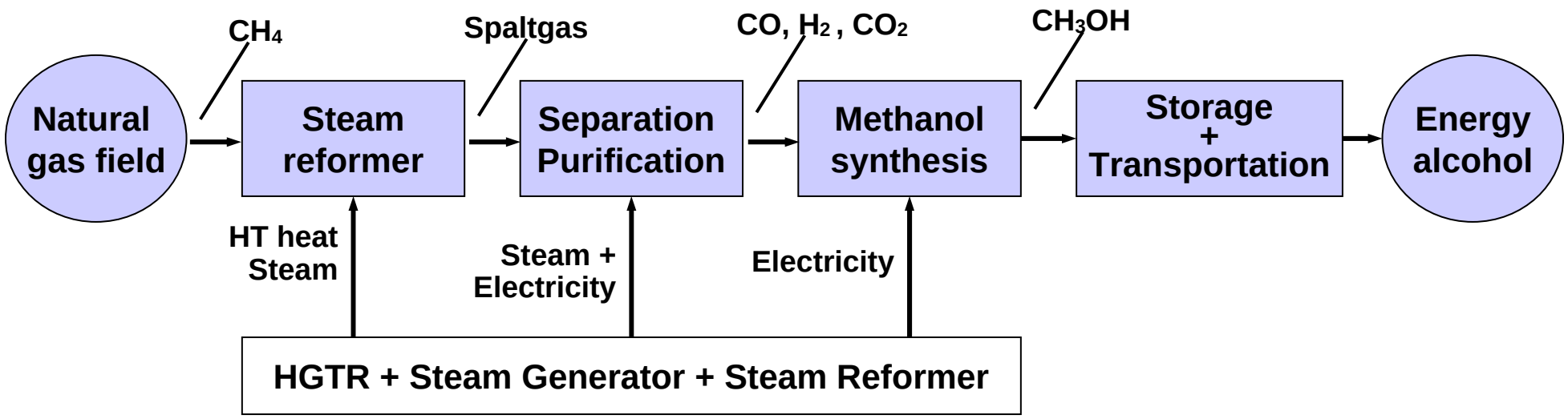
1.00 t of coal for heat

Adding hydrogen will change the products towards lighter (gaseous) products

Types of Coal Gasification

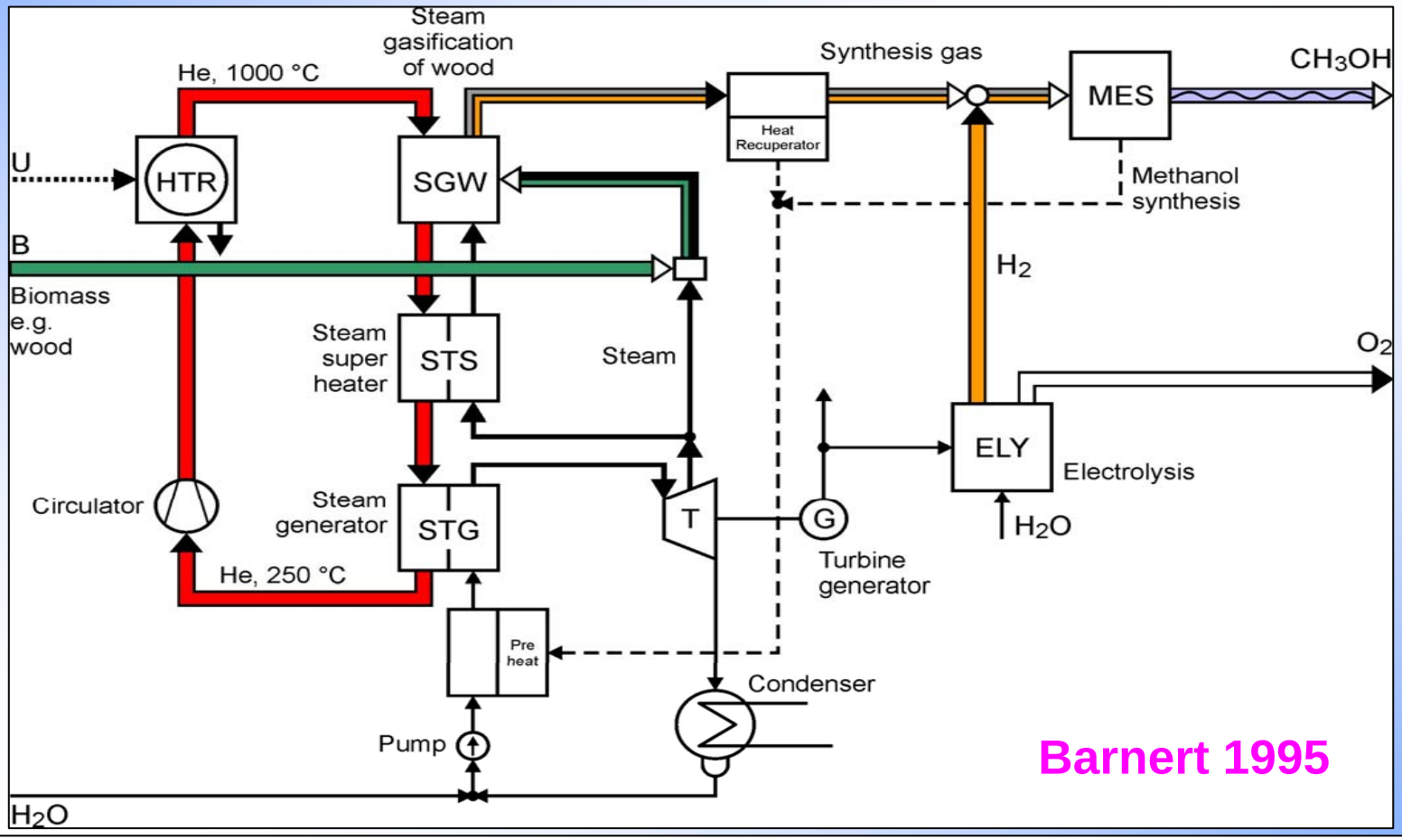


Methanol from Natural Gas



- Conv.: 1000 m³ Erdgas ⇒ 1 t Methanol + 1.5 t CO_2
- Nuclear: 1000 m³ Erdgas + 10 MWh_{th} ⇒ 2 t Methanol

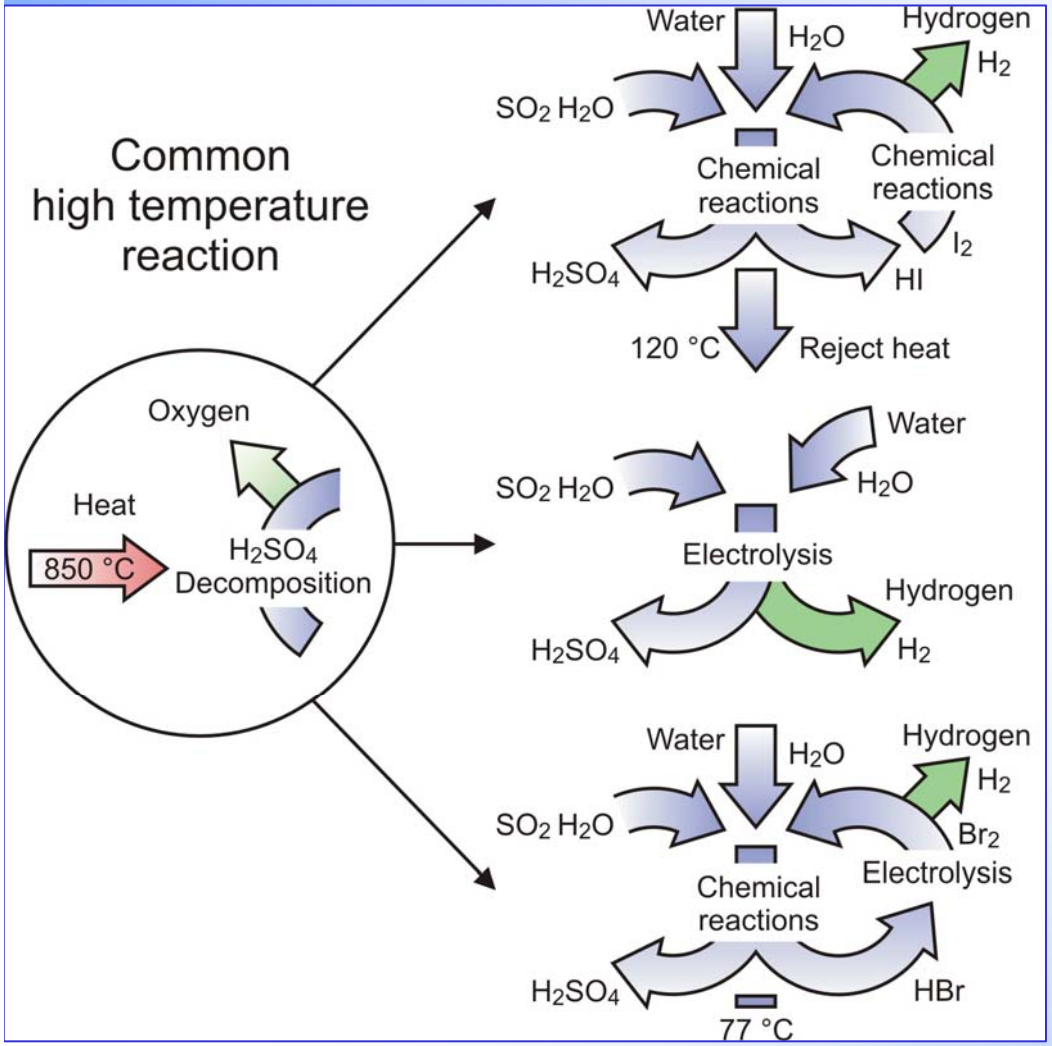
Liquid Fuels from Biomass and Nuclear



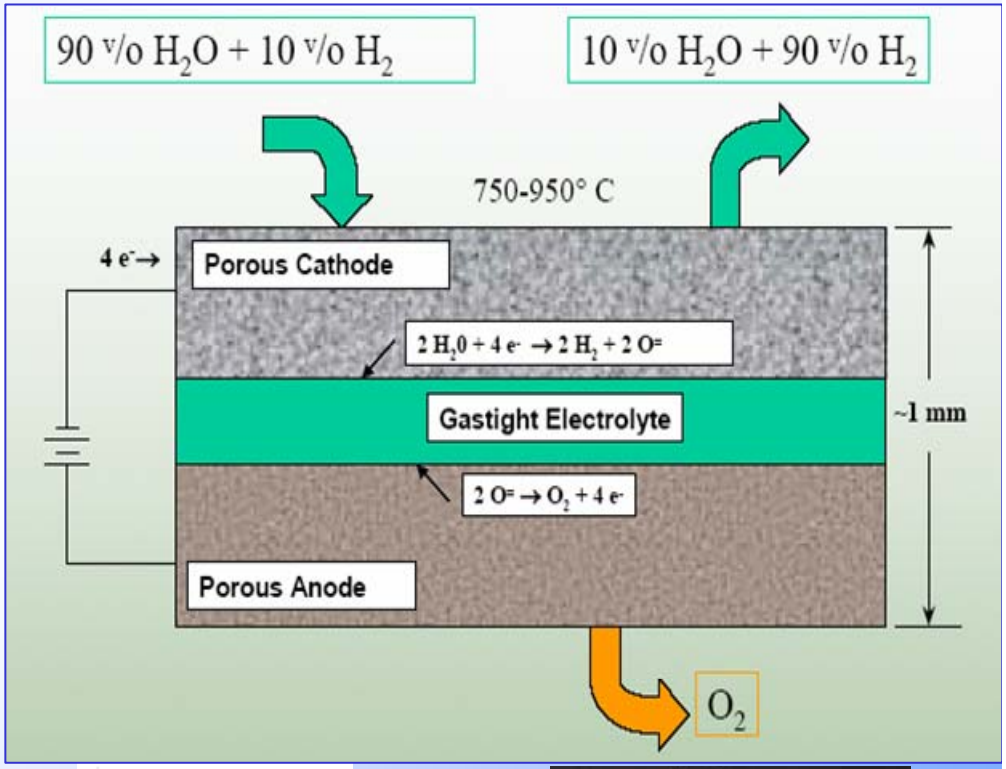
- Conv.: 12 t Biomasse $\Rightarrow$ 1 t liquid HC (e.g., CH_3OH)
- Nuclear: 12 t Biomasse + 10 MWh_{th} $\Rightarrow$ 2 t liquid HC (e.g., CH_3OH)

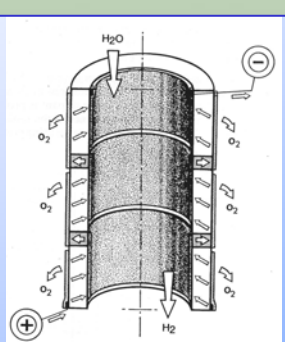
Nuclear Hydrogen from Water

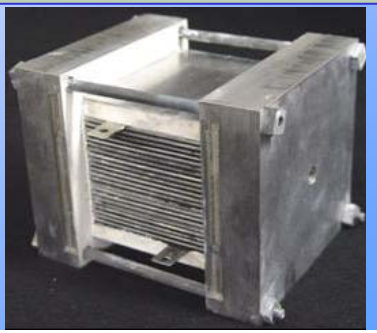
S-based Thermochemical Cycles



High-Temperature Electrolysis

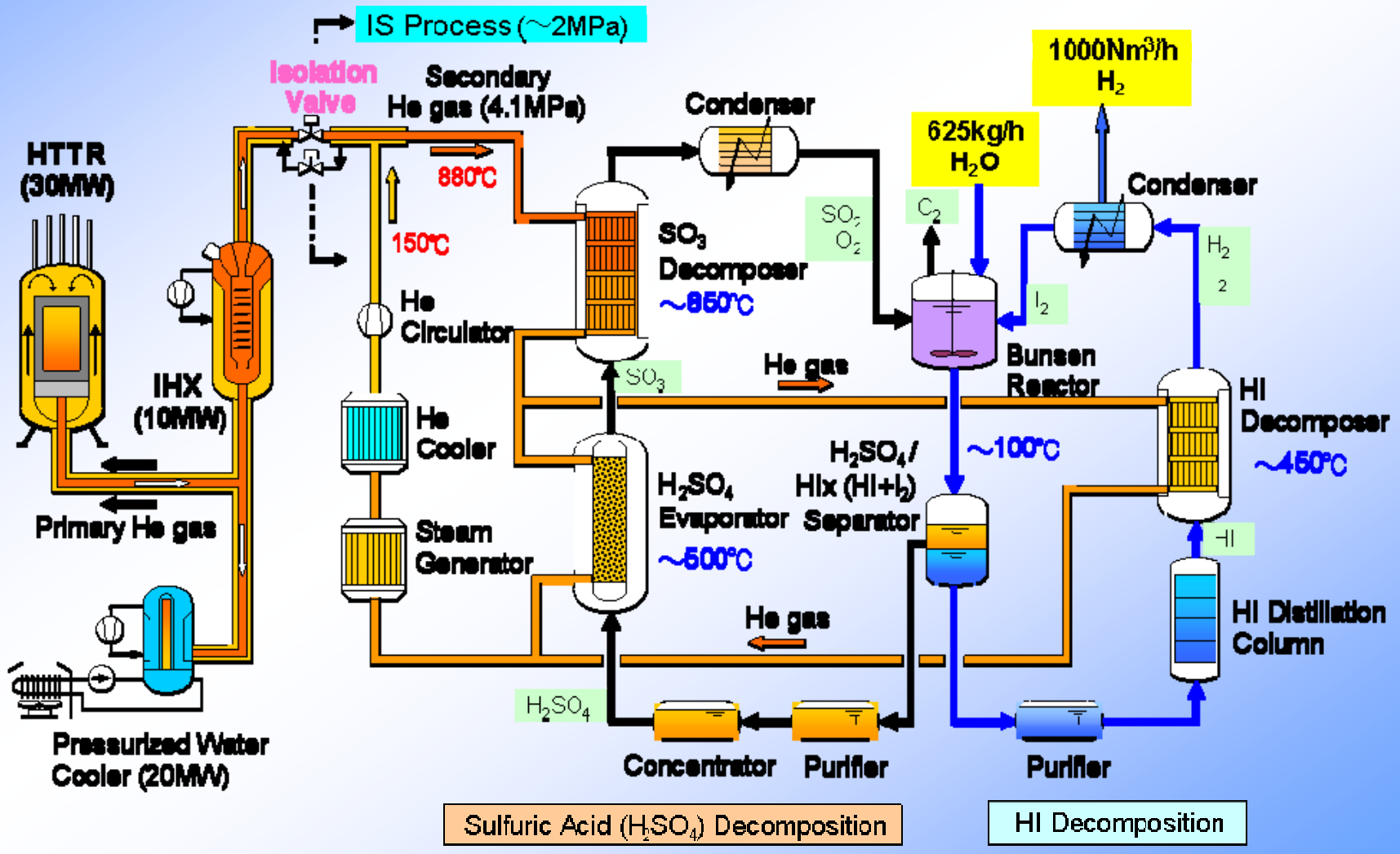






Nuclear H_2 R&D Project in Japan

HTTR + S-I to become the world's first nuclear H_2 production plant



Conclusions (1/4)

Nuclear energy is a clean, safe, and powerful greenhouse gas emission-free option to help meet the world‘s demand for energy.

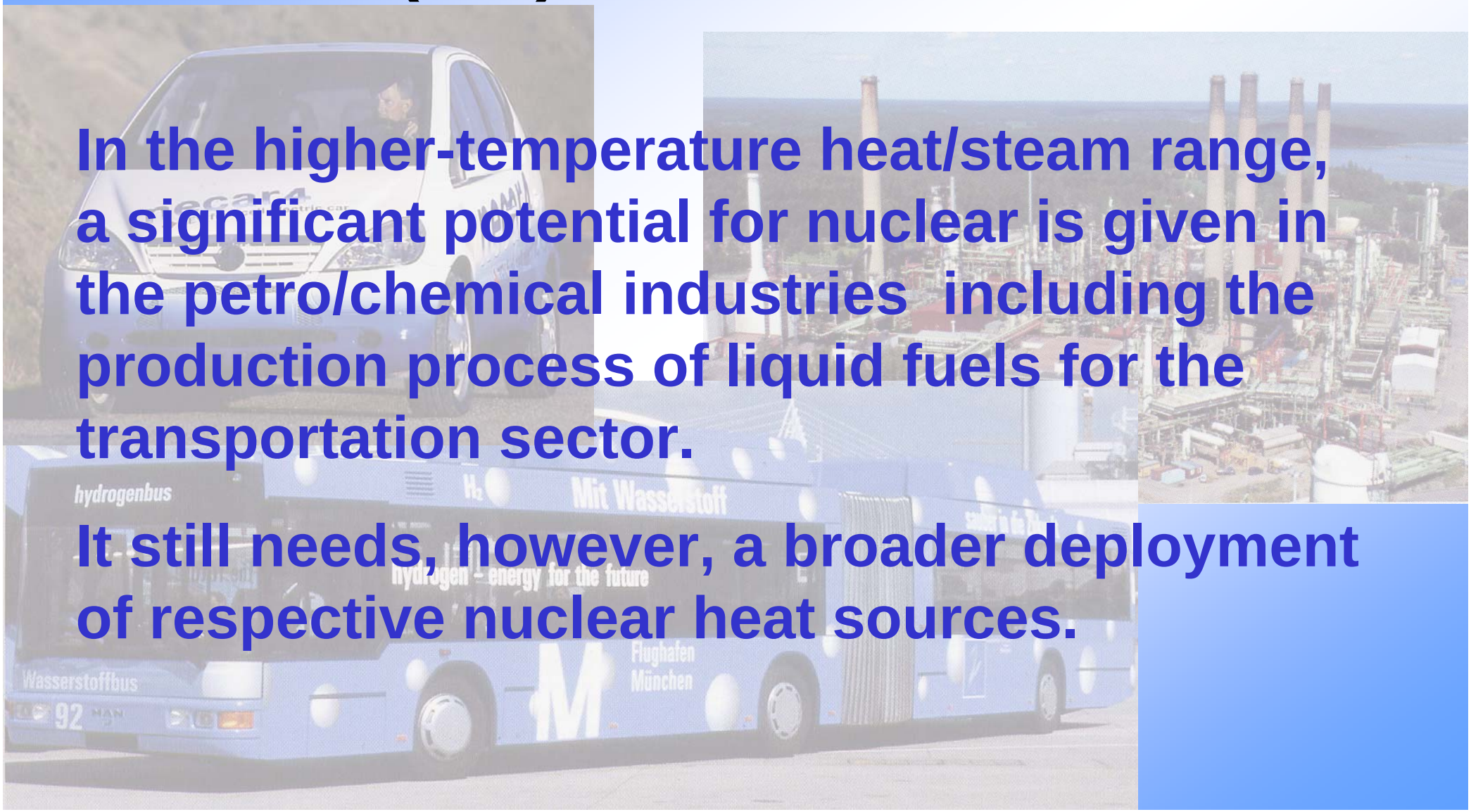
It has a still unexploited potential of producing, in the CHP mode, process heat and steam in a broad temperature range.

Conclusions (2 / 4)

There is experience with nuclear in the heat and steam market in the low temperature range.

An extension appears possible on a short term in the areas of desalination, district heating, and tertiary oil recovery.

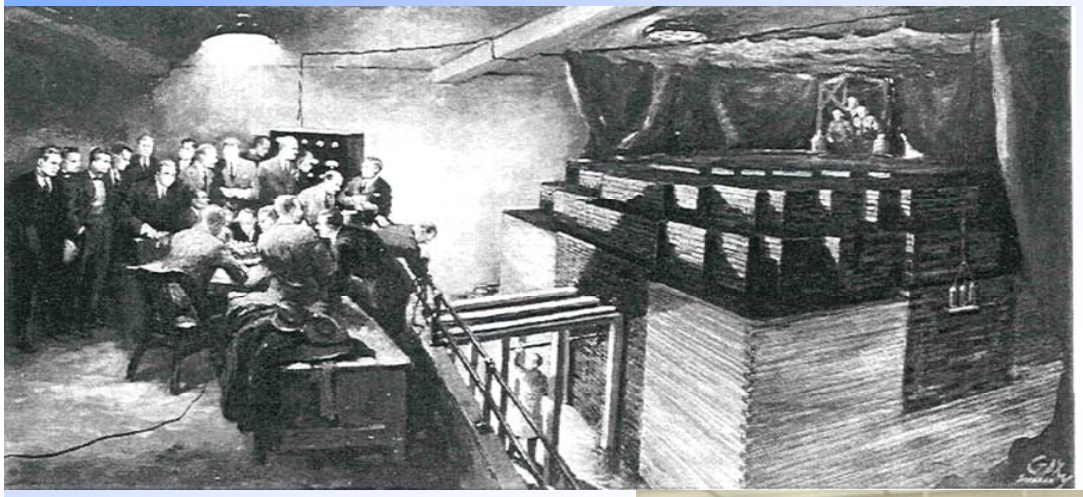
Conclusions (3 / 4)



In the higher-temperature heat/steam range, a significant potential for nuclear is given in the petro/chemical industries including the production process of liquid fuels for the transportation sector.

It still needs, however, a broader deployment of respective nuclear heat sources.

Conclusions (4/4)



The VHTR represents a highly promising, near-term option of a GenIV type nuclear reactor of the future.

Chicago
1942

Oarai
1999

Thank you
for your kind attention !

私の話を聞いていただいて
ありがとうございました。

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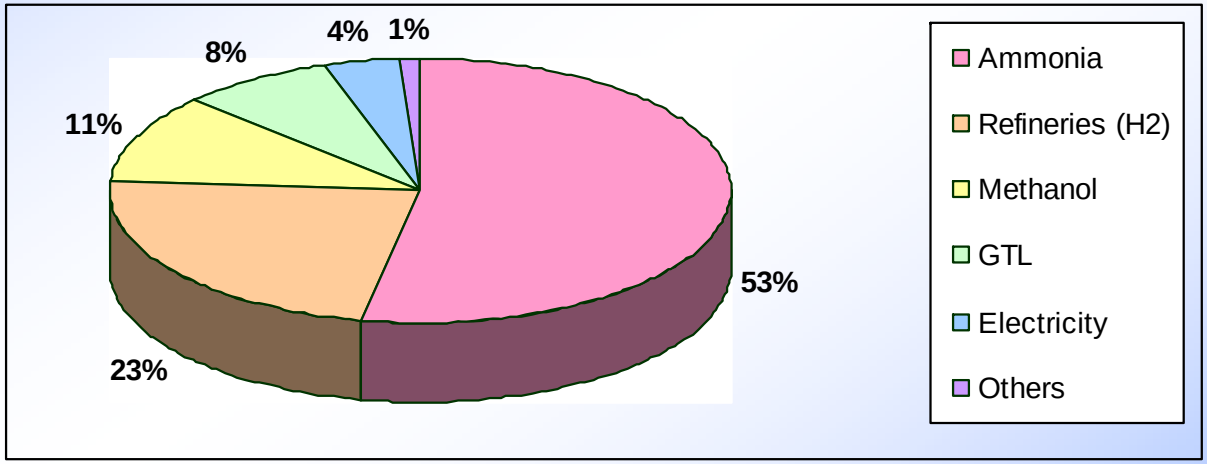
World Syngas Market



European Commission 2006

Steam Demand for Typical Refinery
(7 – 8 million t/yr of crude oil at 8000 h/yr)

	Steam Demand [t/h]		
	High press.	**Medium press.**	**Low pressure**
	4-4.5 MPa, 400°C	1.5-2 MPa, 220°C	0.4-0.6 MPa, 150°C
Fuel production	80-90	120-140	140-160
Utilities	50-80	15-25	40-50
Miscellaneous	–	< 10	10-40
Total	**130-170**	**135-175**	**180-230**