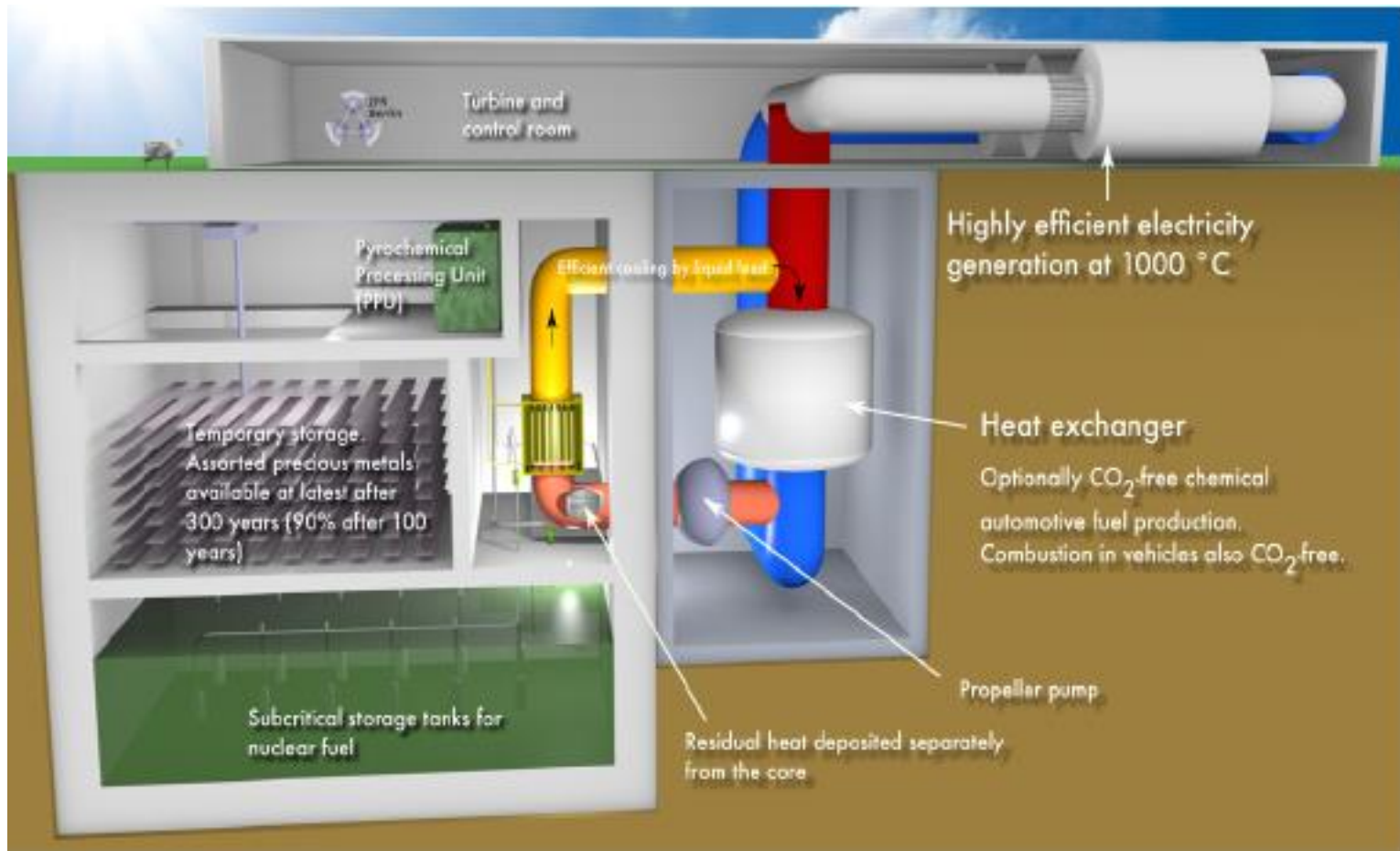
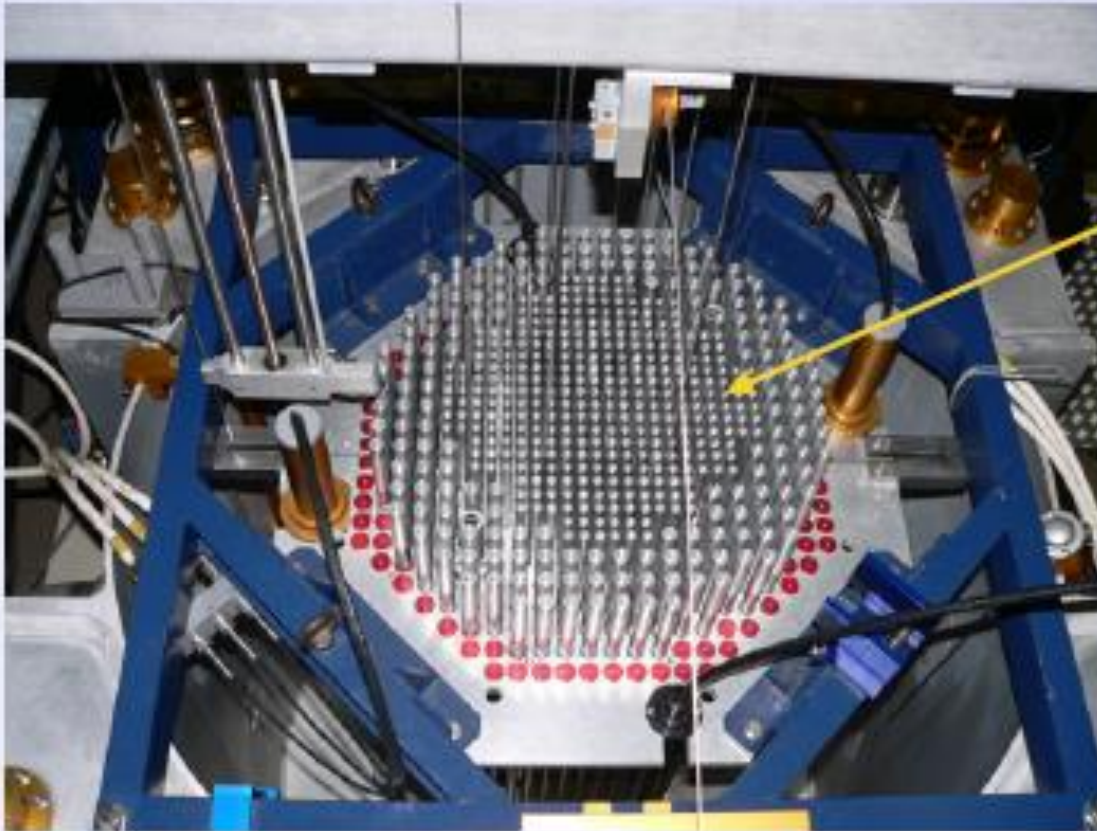


New Concept for Nuclear Power Plants: Dual Fluid Reactor



Today's reactor designs



Almost all are water-moderated and based on solid fuel rods:

- Expensive external fuel cycle
- Using only 1% of the mined Uranium
- 99% waste that needs geological storage
- Low power density

Today's nuclear reactors are more effective than other power generating systems, but **nuclear power can do much better!**

Energy Return on Invested - EROI

The EROI describes the efficiency of a power plant by comparing the electricity **output** with all the expended exergy **input**.

$$\text{EROI} = \frac{\text{Total energy output}}{\text{Total energy input}}$$

All „produced“ energy during lifetime of a power plant

All expended energy to construct and operate the plant, including indirect processes like mining and fuel provisioning („from the cradle to the grave“)

Better efficiency means

- Smaller impact/footprint on nature
- Lower costs

Energy Efficiency of Power Plants

Efficiency by **EROI** (Energy Return on Energy Invested)

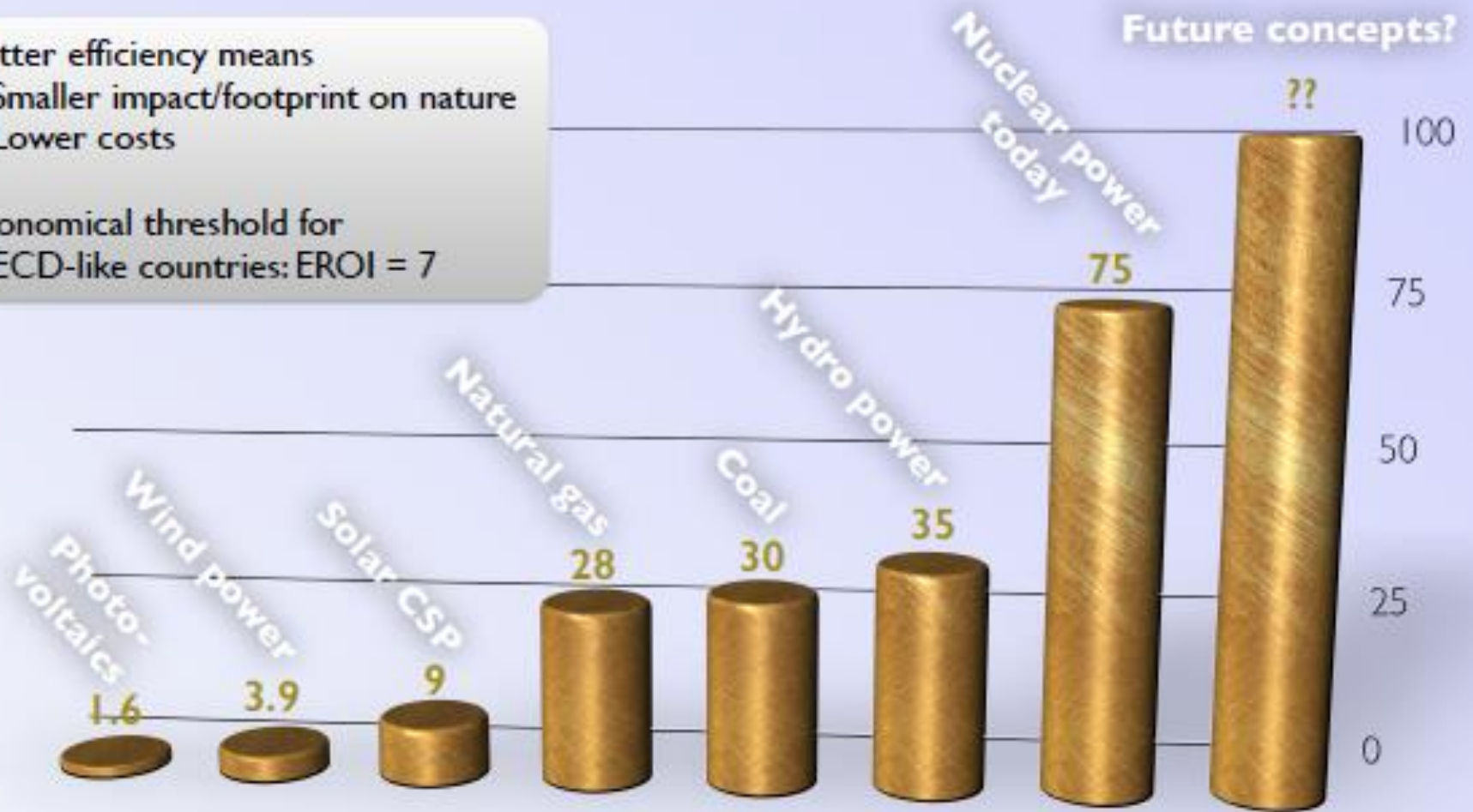
see Weißbach et al., *Energy*, vol. 52 (2013), pp. 210–221

Better efficiency means

- Smaller impact/footprint on nature
- Lower costs

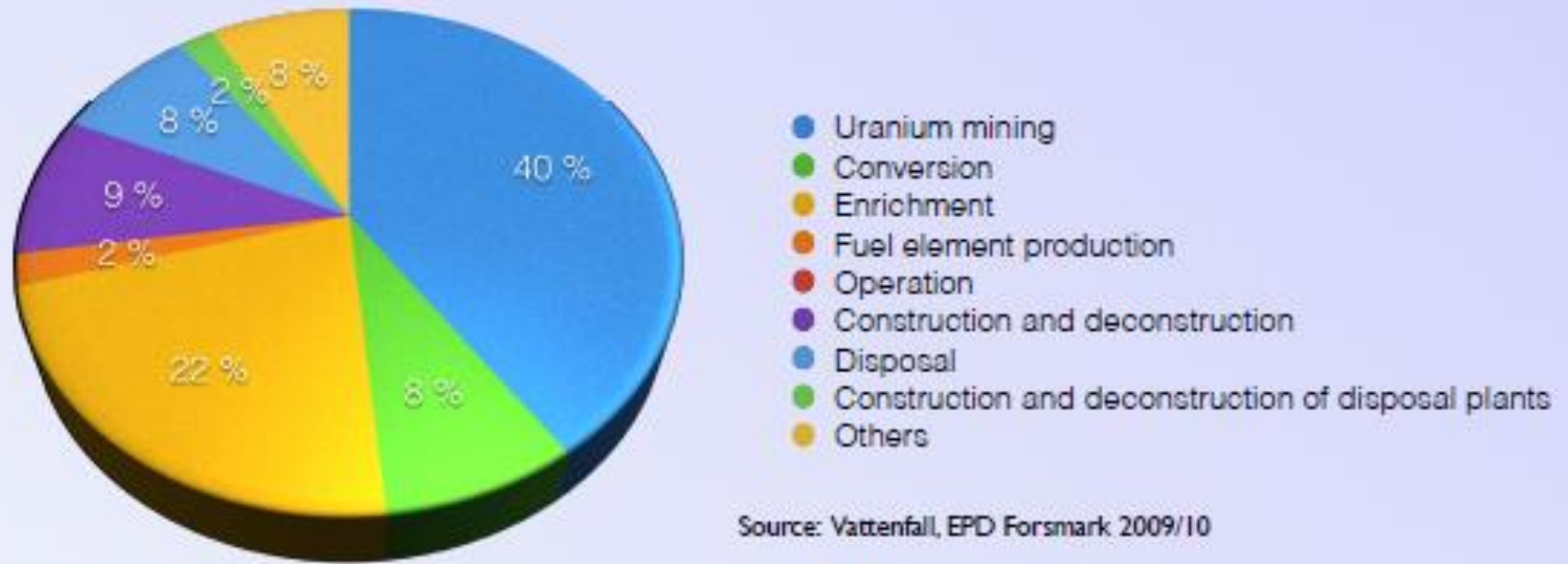
Economical threshold for
OECD-like countries: EROI = 7

Future concepts?
??



The expensive nuclear fuel cycle

Contributions to the energy demand in the nuclear power production



EROI: 29 → 75 → 105 → 115

100% Diffusion → 17% Diffusion + Centrifuge (today) → 100% Centrifuge → 100% LASER

How efficient is the DFR

If these expenses are reduced to DFR level, EROI and costs change to...

	Enrichment		Construction and Operation		Uranium Supply		Fuel Cycle		Deconstruction		DFR/s	DFR/m
EROI:	75	→	115	→	120	→	390	→	1000	→	2000	5000
Costs: <small>cent/kWh overnight</small>	2.7	→	2.3	→	1.5	→	1.1	→	0.8	→	0.65	?

From LWR to DFR.

Many steps are repealed or reduced, increasing the EROI and decreasing the costs.

DFR/m comes close to the theoretical limit of nuclear energy, dominated by the Uranium mining expense.

For comparison:

Wind and PV: 1-4

Fossil fuels: 30

Hydro: 35

Nuclear:

Today's LWRs: 75

Theoretical limit: 10,000

Energy Efficiency of Power Plants

Efficiency by **EROI** (Energy Return on Energy Invested)

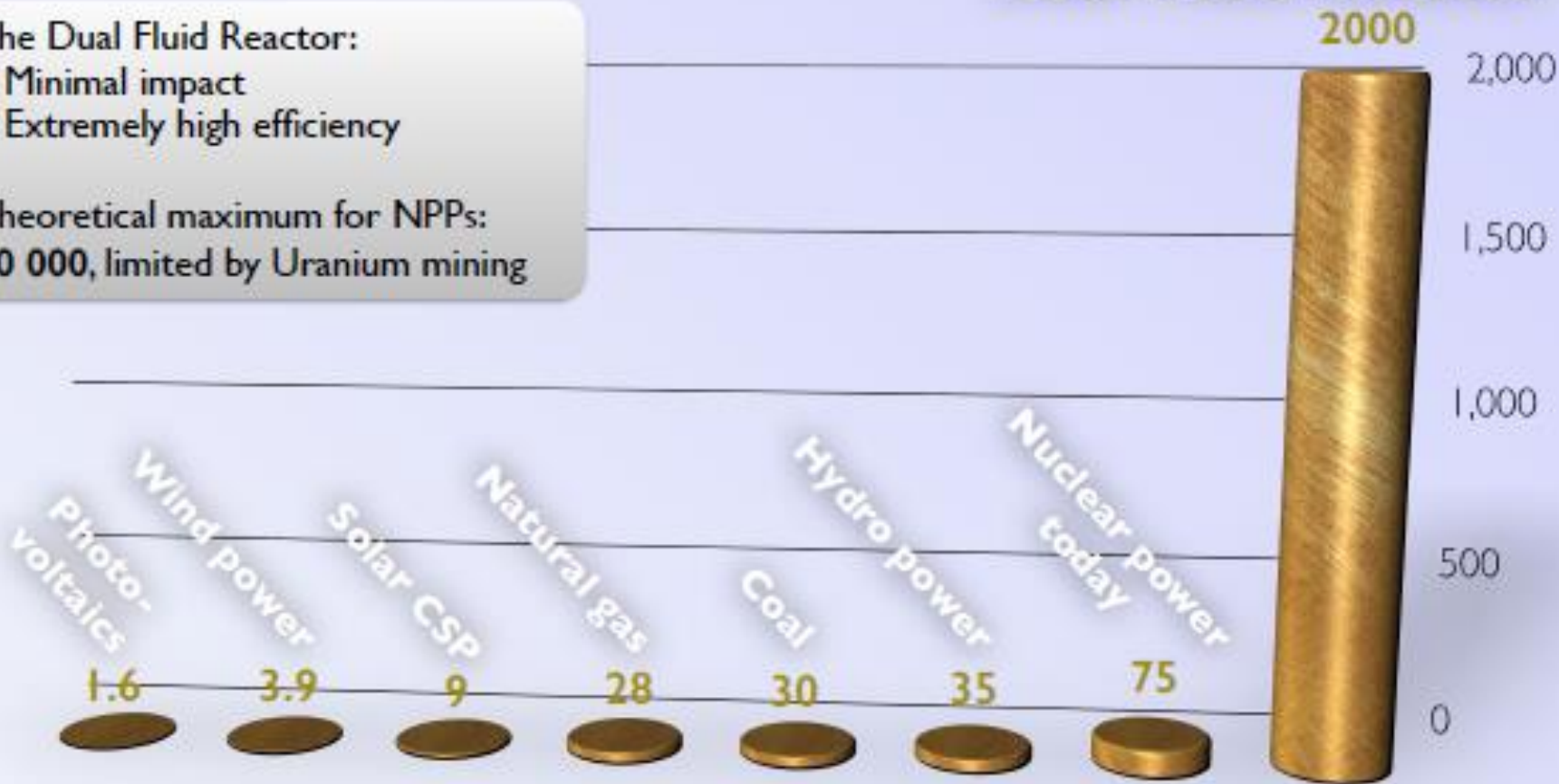
see Weißbach et al., *Energy*, vol. 52 (2013), pp. 210–221

Dual Fluid Reactor

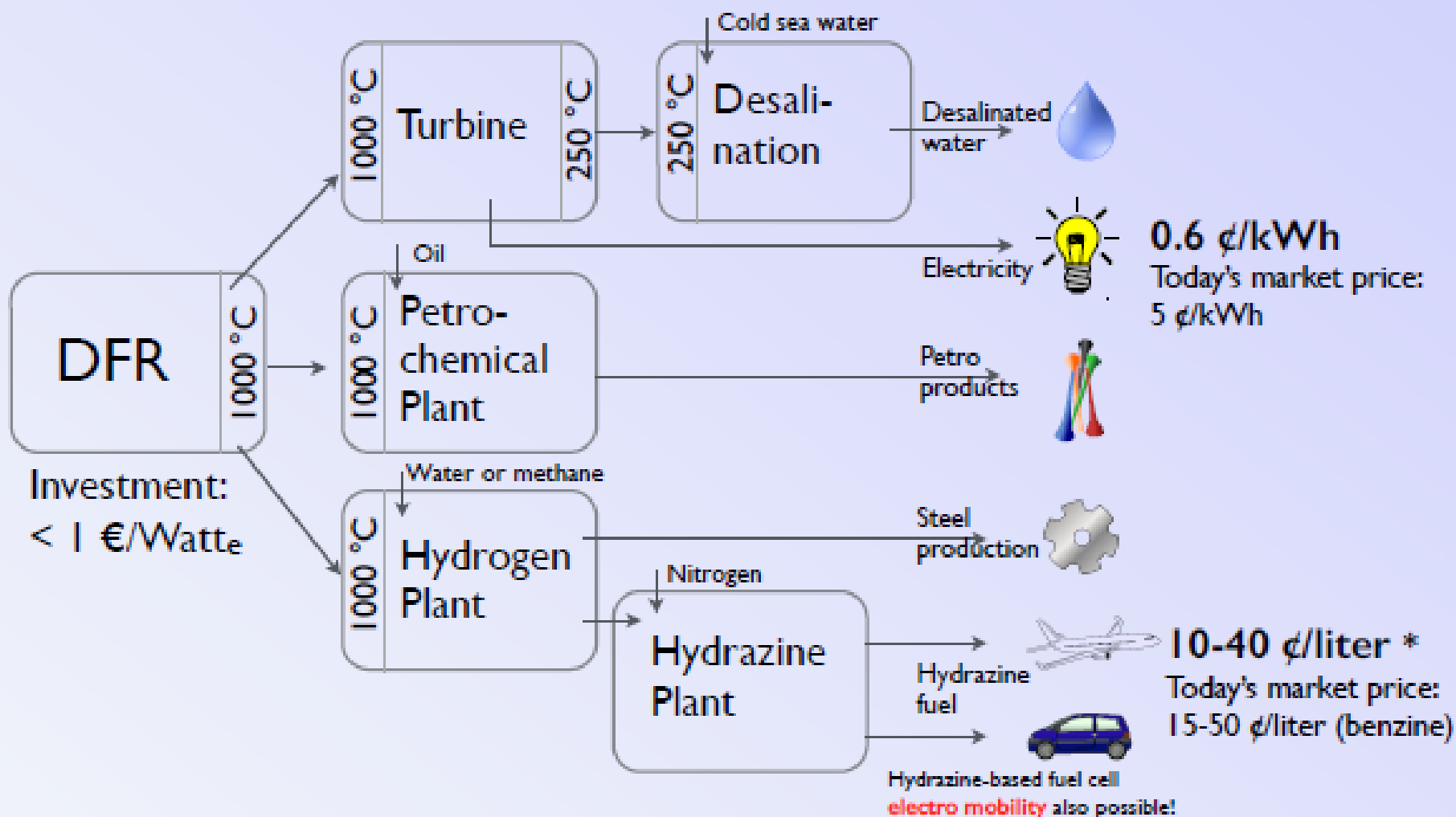
The Dual Fluid Reactor:

- Minimal impact
- Extremely high efficiency

Theoretical maximum for NPPs:
10 000, limited by Uranium mining



DFR applications



* Gasoline equivalent

Hydrogen production

- Water dissociation by high temperature
- Hot-ELLY KfA Jülich for THTR
- Sulfur Iod process for VHTR (GenIV)

- Gasoline synthesis by coal hydration similar to crude oil reforming

- Lignite transport by ship to the NPP where they are anyway for cooling.
- Process heat by DFR from nuclear waste

- Alternatively CO₂ usage from power plant exhaust



Key properties of the DFR

- Adiabatic power plant: No external fuel cycle needed
- Investment costs: 1 €/Watt^a → Comparable with coal power plants
- Energy efficiency (EROI) 20 times as high as for pressurized water reactors
- Electricity production costs: 0.6 ¢/kWh^a. Per serial DFR annual profit of 300 mio. € possible
- Oil-equivalent fuels can be produced for 50 US\$/barrel^{a,b} (0.3 €/liter^b)
- Electromobility based on hydrazine fuel cells possible with 1.5 ¢/km^a and ranges of more than 1,000 km

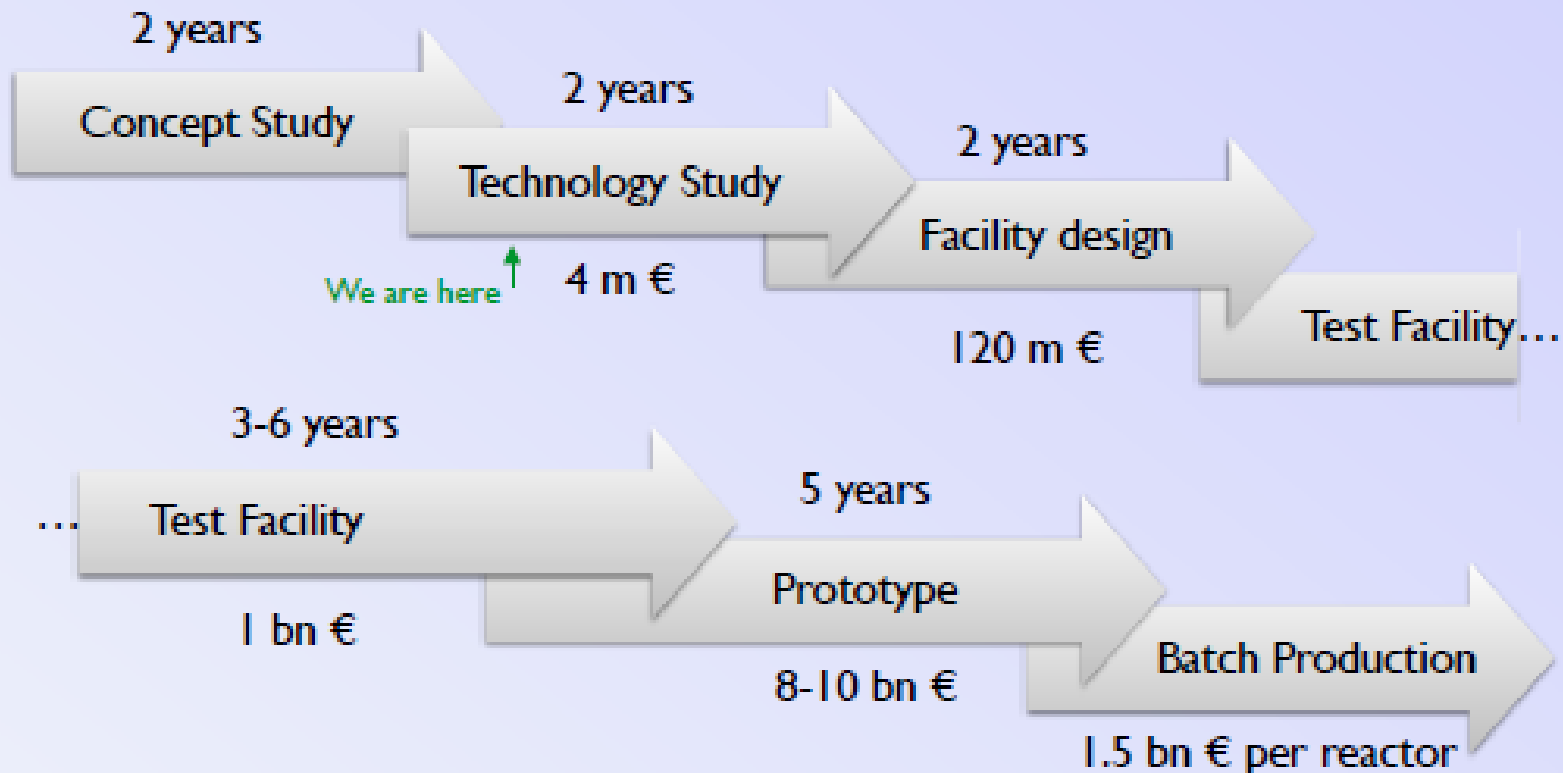
Alle costs are based on today's energy mix.

When the entire economy changes to DFR technology the costs further drop to the ratio of the EROIs.

a) Overnight costs

b) Energy equivalent

DFR development: Schedule and costs



Development of the DFR prototype: 10 years, 10 bn €
Serial type: 1.5 bn €

For comparison: Germany's Renewable Energy Law (EEG): 25 bn € per year

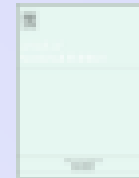


ELSEVIER

Contents lists available at ScienceDirect

Annals of Nuclear Energy

journal homepage: www.elsevier.com/locate/annuclene



The Dual Fluid Reactor – A novel concept for a fast nuclear reactor of high efficiency



Armin Huke^{a,*}, Götz Ruprecht^a, Daniel Weißbach^{a,b}, Stephan Gottlieb^a, Ahmed Hussein^{a,c}, Konrad Czarski^{a,b}

^a Institut für Probierverfahrenstechnik (IPVT), Leibnizstraße 2, 34090 Kassel, Germany

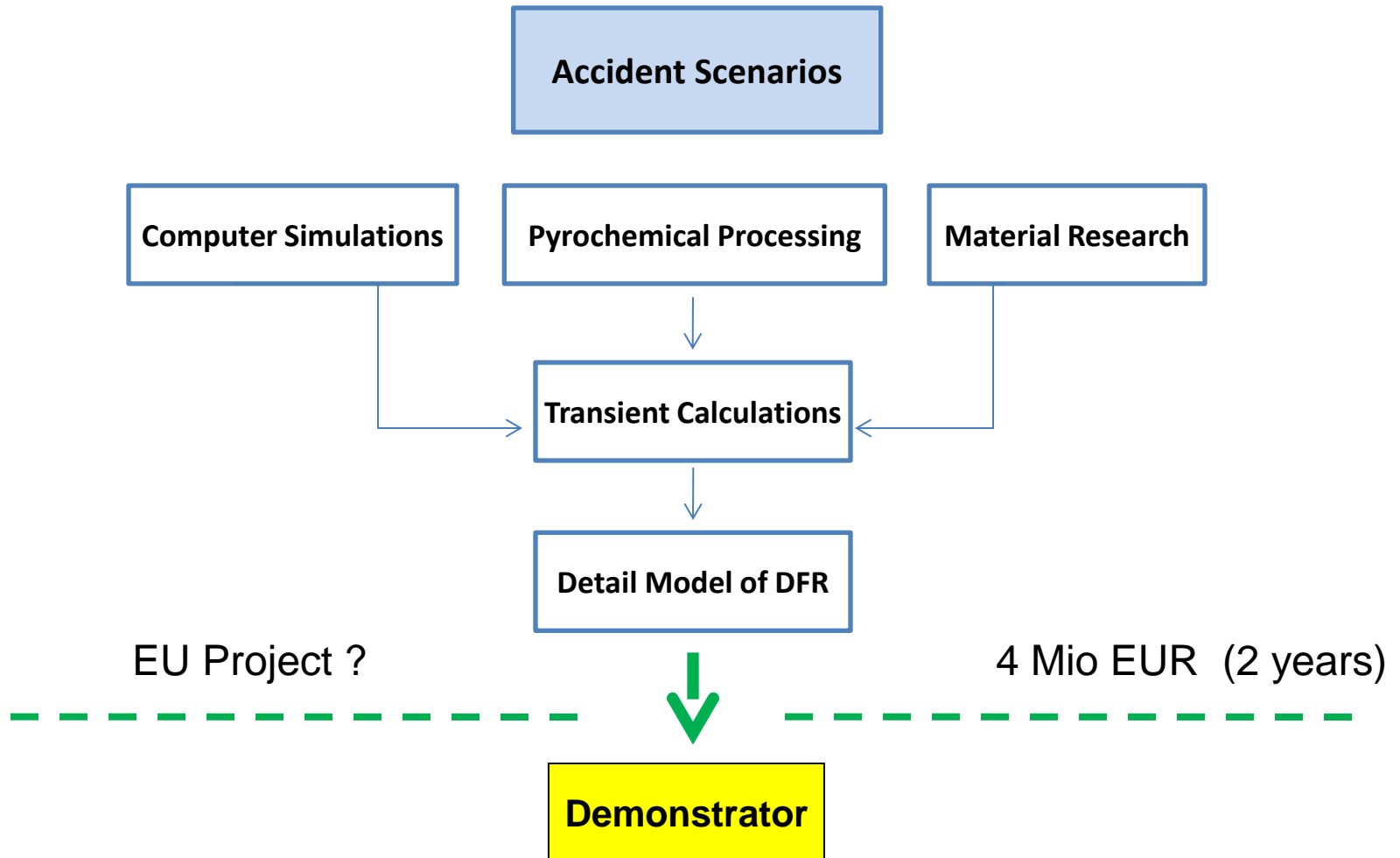
^b Institute of Physics, Jagiellońska Street 10, 31-033 Kraków, Poland

^c Department of Physics, University of Northern British Columbia, 3333 University Way, Prince George, BC V2P 3S6, Canada

Annals of Nuclear Energy 80 (2015) 225–235

Patent pending in 8 countries

Computer Model of DFR Transient Calculations



Participants

Participant No *	Participant organisation name	Country
1 (Coordinator)	University of Szczecin	Poland
2	Institute for Solid-State Nuclear Physics	Germany
3	Technical University of Dresden	Germany
4	Technical University of Munich	Germany
5	National Center for Nuclear Research	Poland
6	Universitat Politècnica de València	Spain
7	ConAT	Germany
8	Grupa Azoty Police	Poland
9	NUKEM	Germany

New Partners: Chalmers University, Sweden
PSI, Switzerland

EON, Germany
PGE, Poland

New Call

CALL: EURATOM FISSION 2016-2017

Call identifier: NFRP-2016-2017

Publication date: 14 October 2015

Topic: [NFRP-2:Research on safety of fast neutron Generation-IV reactors](#)

Publication date: 14 October 2015

Types of action: RIA Research and Innovation action **DeadlineModel:**

Opening date: single-stage 11 May 2016

Deadline: 05 October 2016 17:00:00

Topic: [NFRP-3:Investigating the safety of closed nuclear fuel cycle options and fuel developments](#)

Publication date: 14 October 2015

Types of action: RIA Research and Innovation action **DeadlineModel:**

Opening date: single-stage 11 May 2016

Deadline: 05 October 2016 17:00:00

Topic: [NFRP-5:Materials research for Generation-IV reactors](#)

Publication date: 14 October 2015

Types of action: RIA Research and Innovation action **DeadlineModel:**

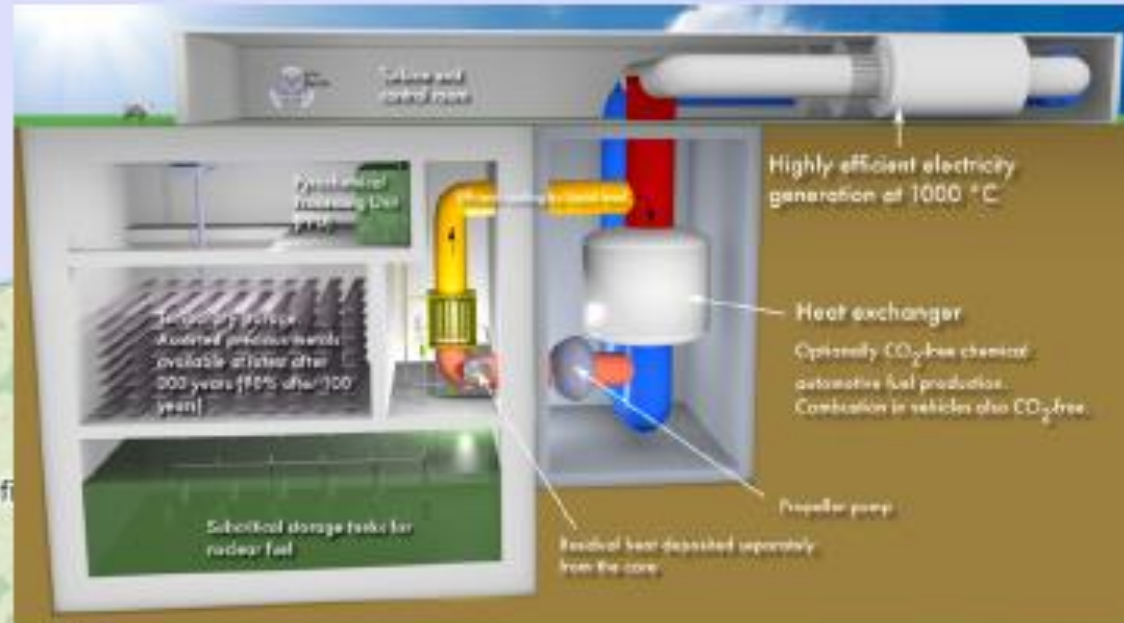
Opening date: single-stage 11 May 2016

Deadline: 05 October 2016 17:00:00

University of Berlin and of Szczecin



Test Facility



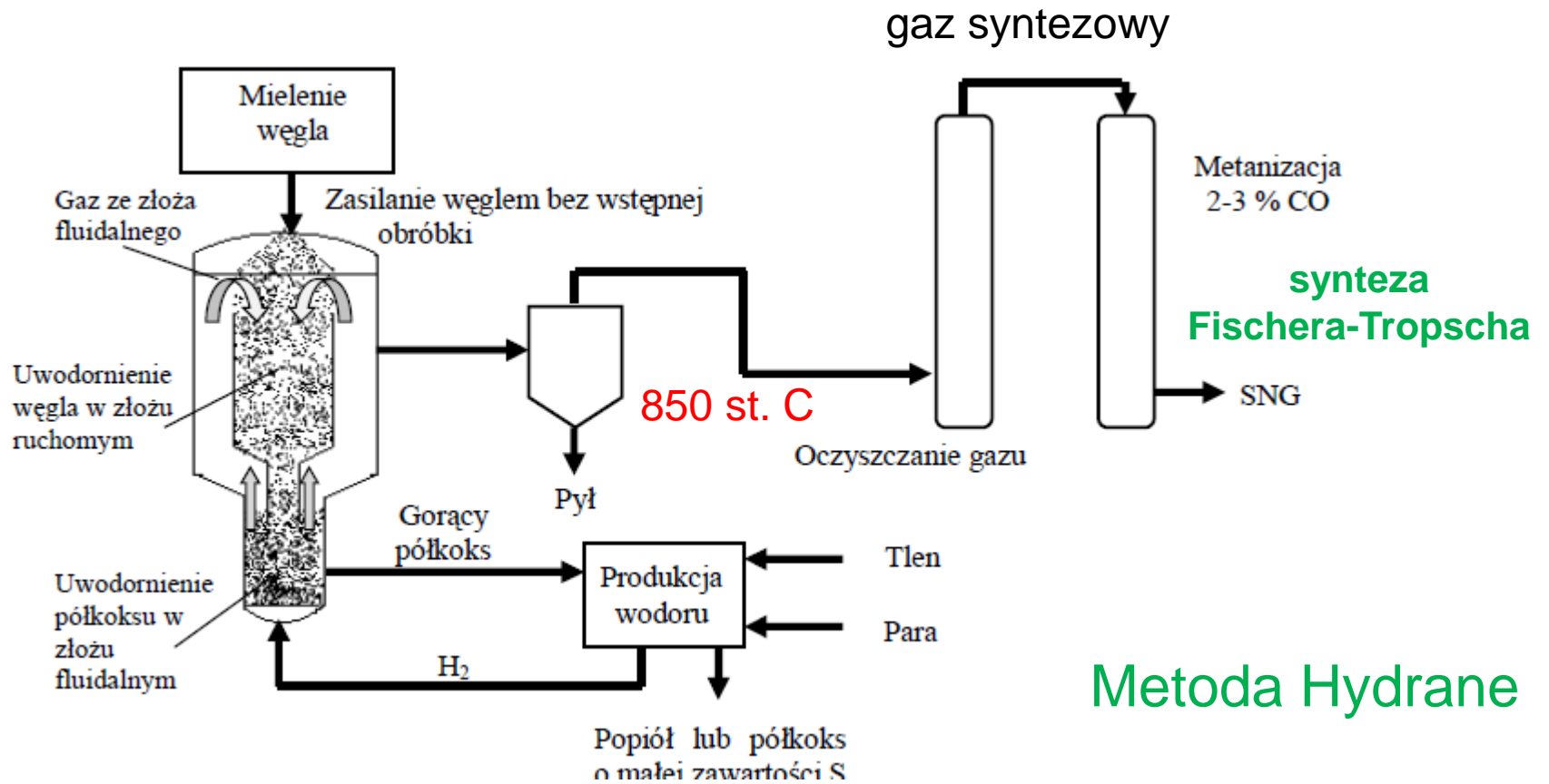
100 MWth, 5-6 years, 150-200 Mio EUR

Hydrogen Production

Grupa Azoty Police (GAP) Chemical Group Police



Gazyfikacja węgla



Department for Nuclear and Medical Physics

accelerator
with high vacuum



accelerator
with **ultra**
high vacuum

