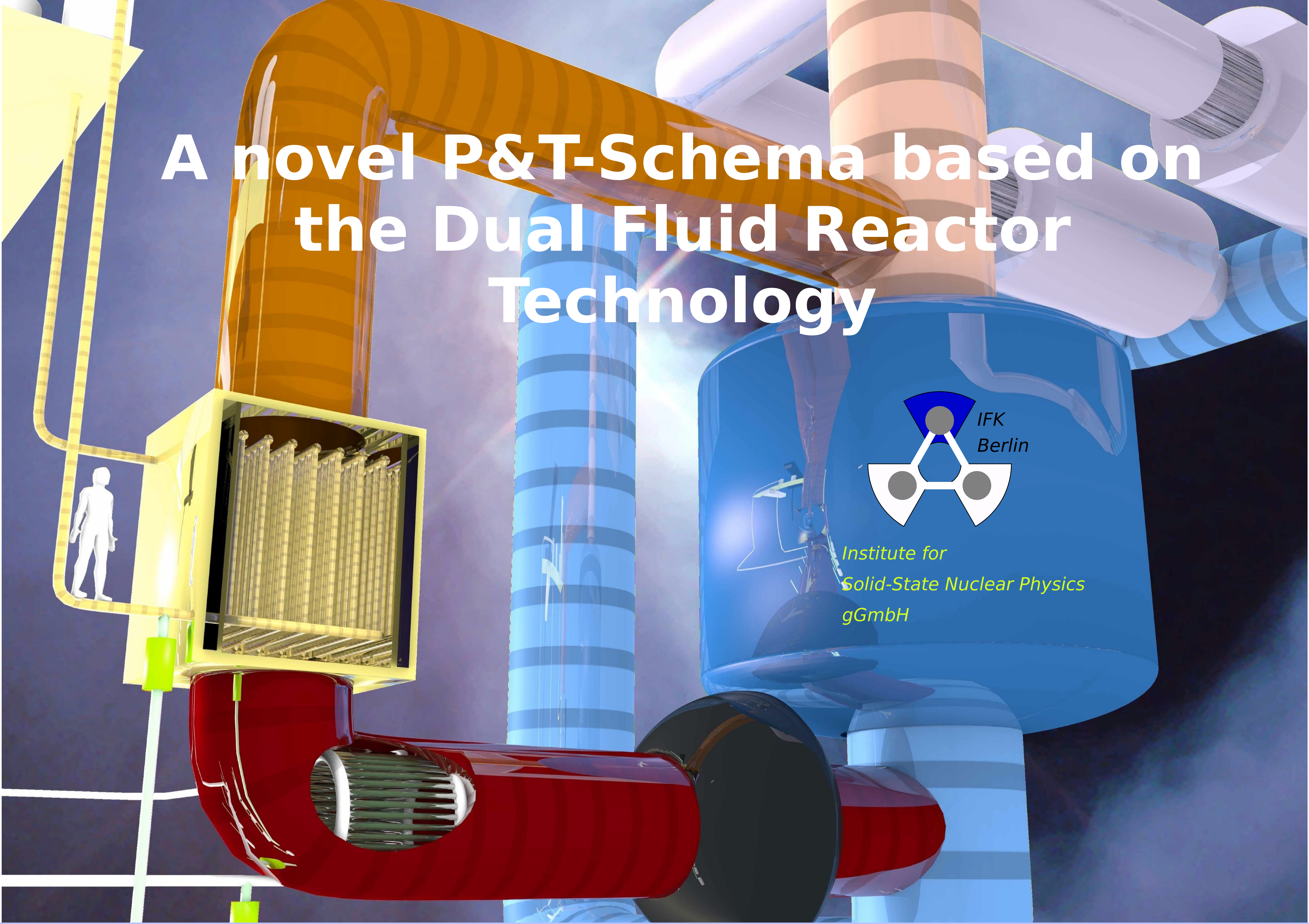
# A novel P&T-Schema based on the Dual Fluid Reactor Technology



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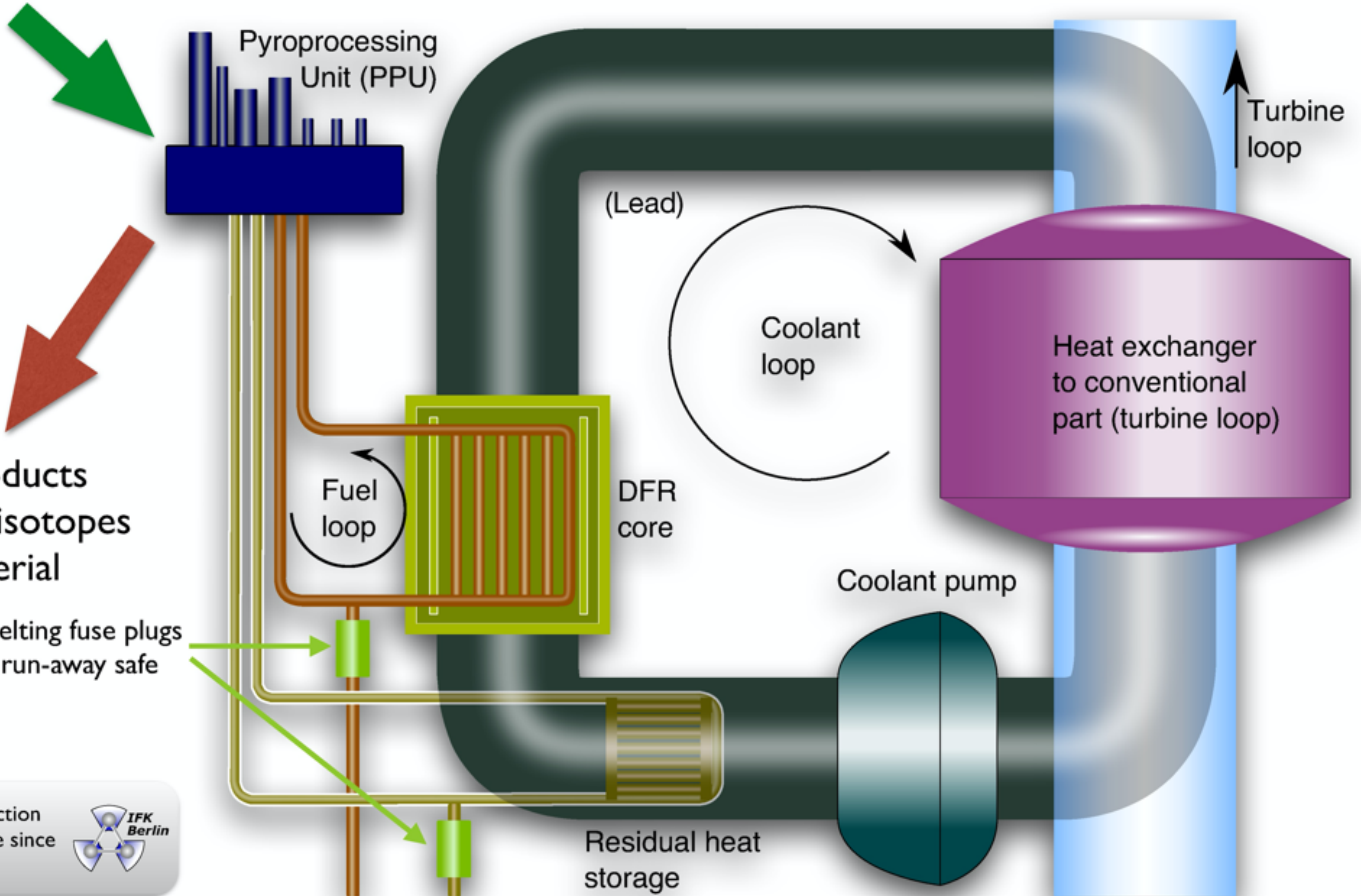
*gGmbH*

# The Dual Fluid Reactor
## A concept beyond Generation IV

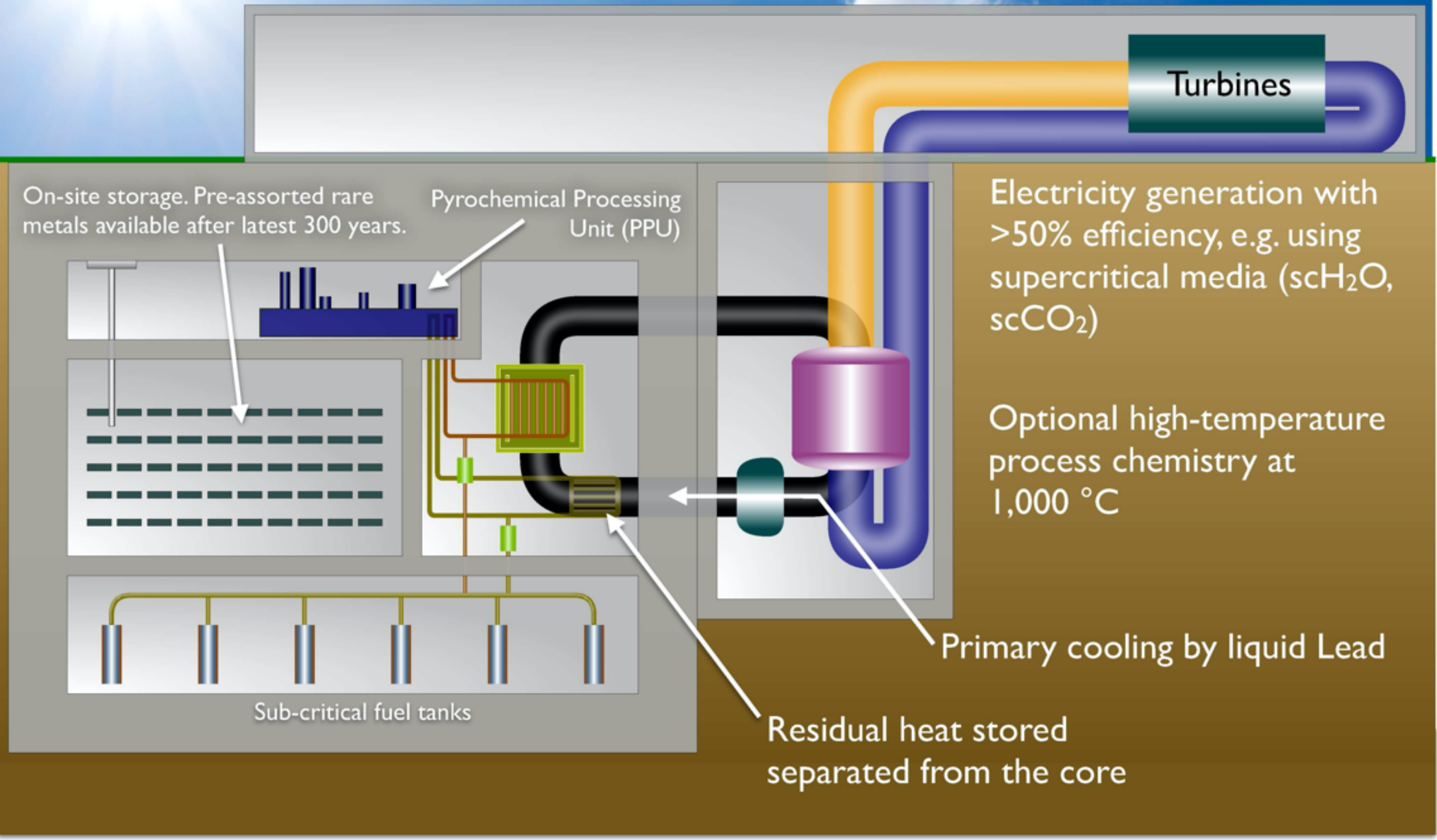
- Natural Uranium
- Depleted Uranium
- Thorium
- Used fuel elements




- Fission products
- Med. radioisotopes
- Fissile material

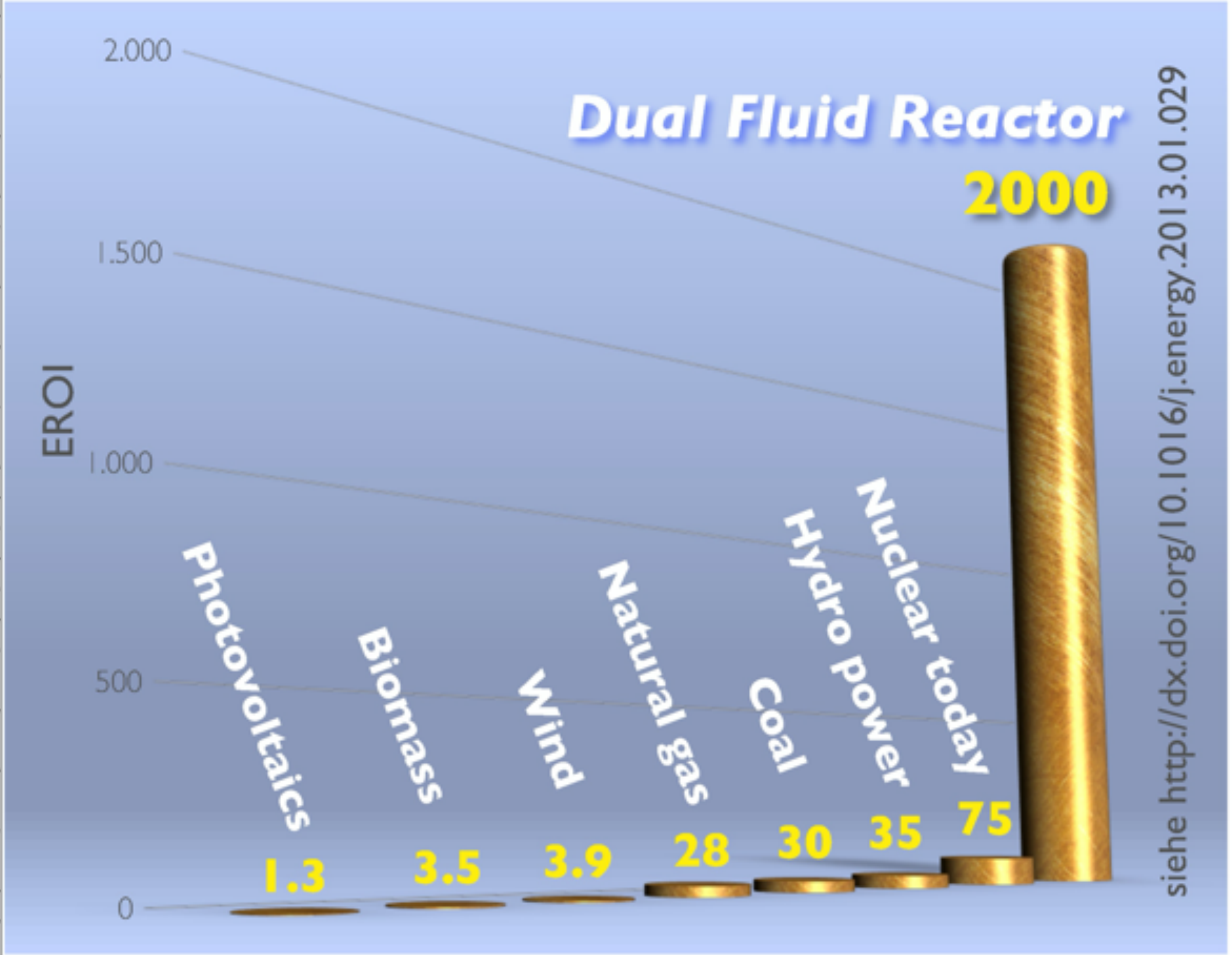
International patent protection for the Dual Fluid principle since Sep. 2011

# DFR power plant



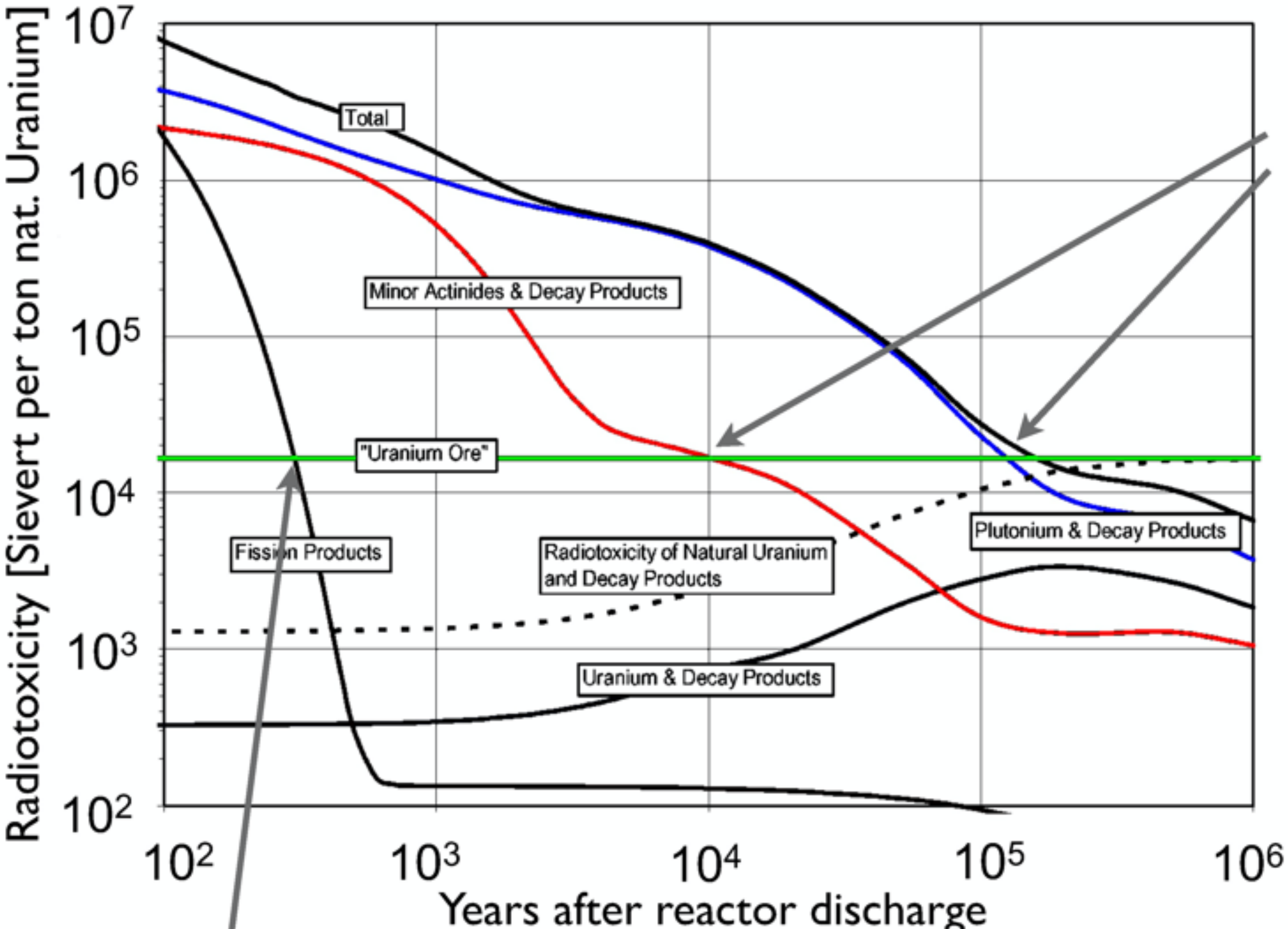
# EROI of the DFR

| **Item** | **Units (or total amount in 1000 kg)** | **Energy inventory in TJ/(1000 kg)** | **Total inventory in TJ** |
|---|---|---|---|
| Concrete containment for reactor, fission products and turbine building | 21000 | 0.0014 | 30 |
| High performace refractory metals and ceramics (PPU and core) | 60 | 0.5 | 30 |
| High temperature isolation material for PPU and core | 100 | 0.1 | 10 |
| Initial load, isotopically purified $^{37}$Cl + fuel | 25+60 | 2.5 / 0.4 | 50+25 |
| Refractory metals and ceramics for the heat exchanger | 180 | 0.5 | 90 |
| Isolation and structural materials, heat exchanger | 300 | 0.1 | 30 |
| Unfabricated, low-alloyed metal for fission product encapsulation | 3000 | 0.033 | 100 |
| Structural materials (steel) for non-nuclear part | 1000 | 0.02 | 20 |
| Lead coolant | 1200 | 0.036 | 45 |
| Turbines with generators | 3 | 40 | 120 |
| Mechanical engineering parts | | | 150 |
| Cooling tower (special concrete) | 20000 | 0.003 | 60 |
| Refueling, 1200 kg/a actinides over 50 years | ~60 | 0.4 | ~25 |
| $^{37}$Cl loss compensation | 2 | 2.5 | 5 |
| Maintenance, high-performance refractories + isolation for 1 new core | 30+50 | 0.5 / 0.1 | 20 |
| Maintenance, 50% of other reactor parts, refractories + isolation | 90+175 | 0.5 / 0.1 | 62.5 |
| Maintenance, 50% of mechanical engineering and turbines | | | 135 |
| Maintenance electricity, 2 MW over 20 days/a and heating, 50∗0.2 TJ | | | 182.5 |
| **Sum** | | | **1190** |
| **Output over 50 years lifetime, ~1500 MW net, ~8300 full-load hours** | | | **2,250,000** |



# Nuclear waste

## The most exaggerated problem in history




Long-lived (100,000 years) radiotoxicity dominated by transuraniums (plutonium and minor actinides)

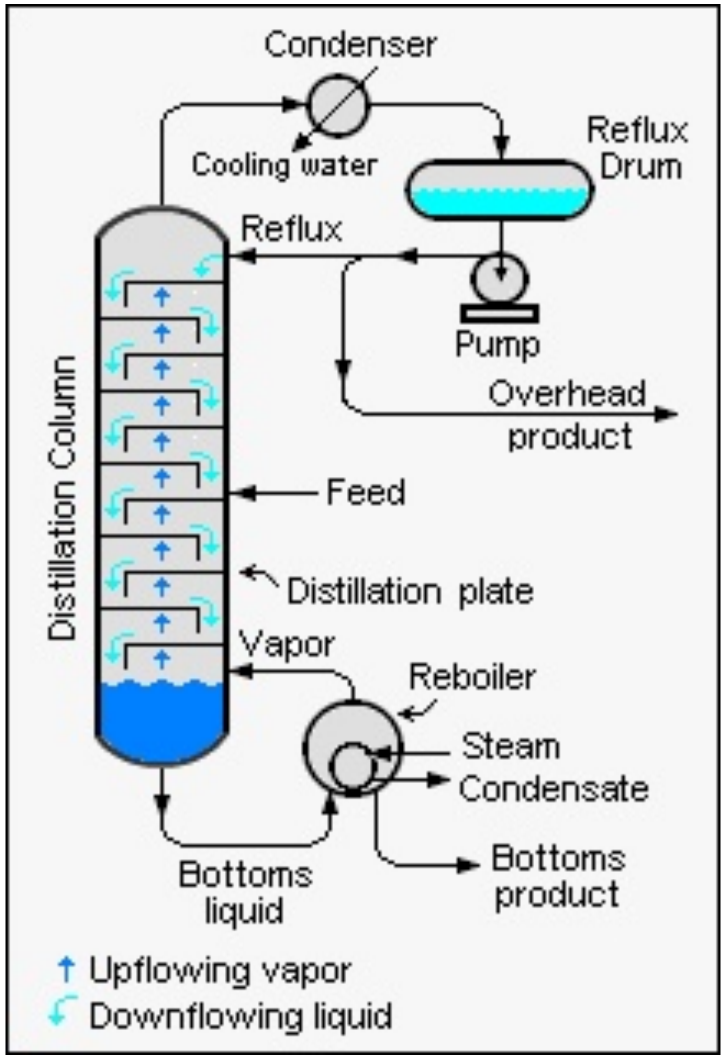
Only produced in thermal reactors

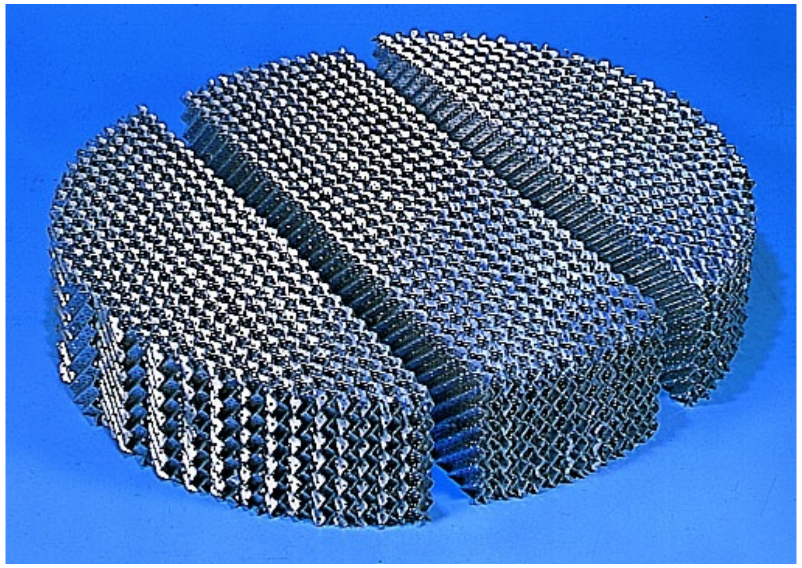
Fast fission as opposed to thermal reactors do not leave long-lived "waste". They can also transmute fission products.

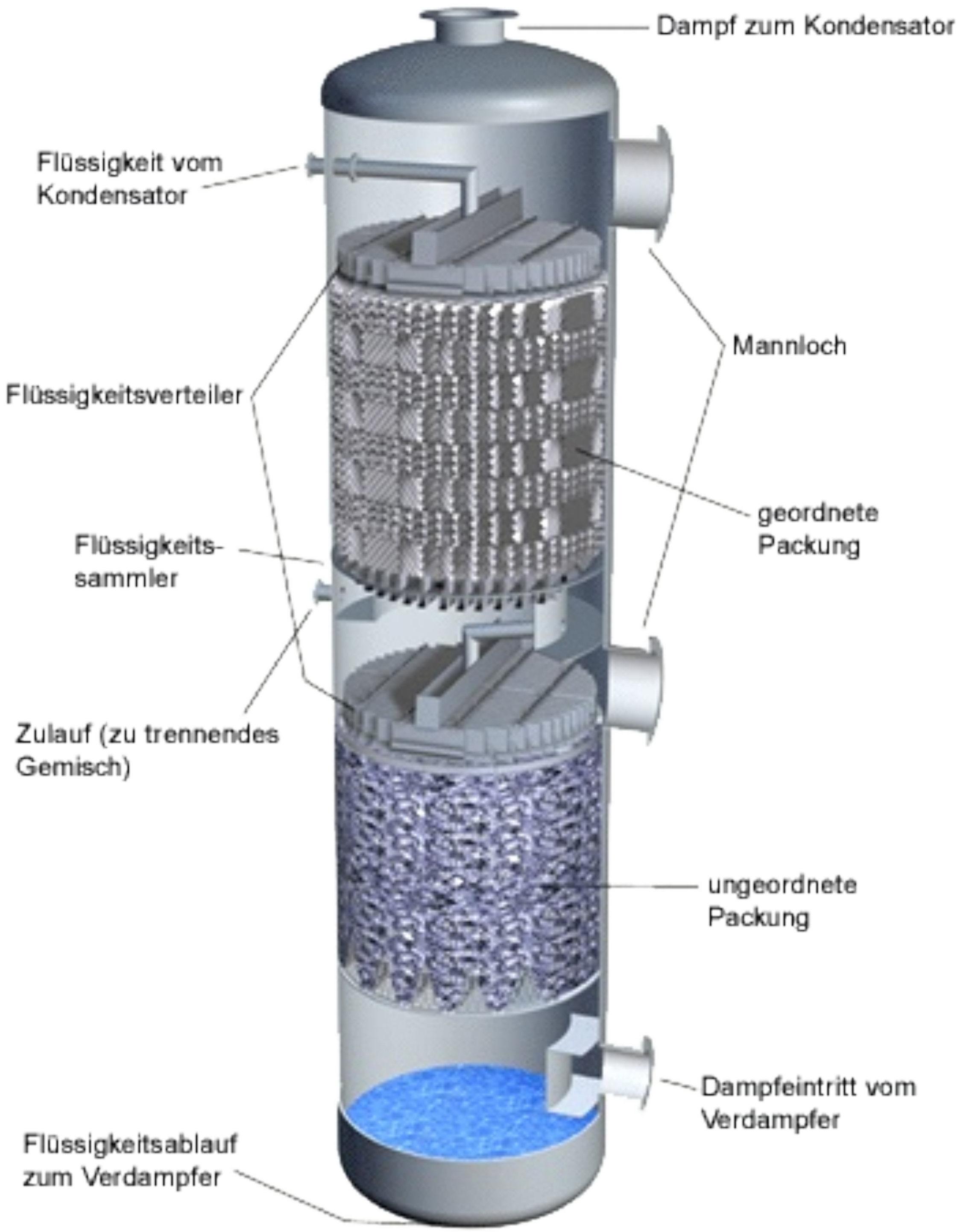
Short-lived (300 years) radiotoxicity dominated by fission products

Can by transmuted

# Fractionated Distillation

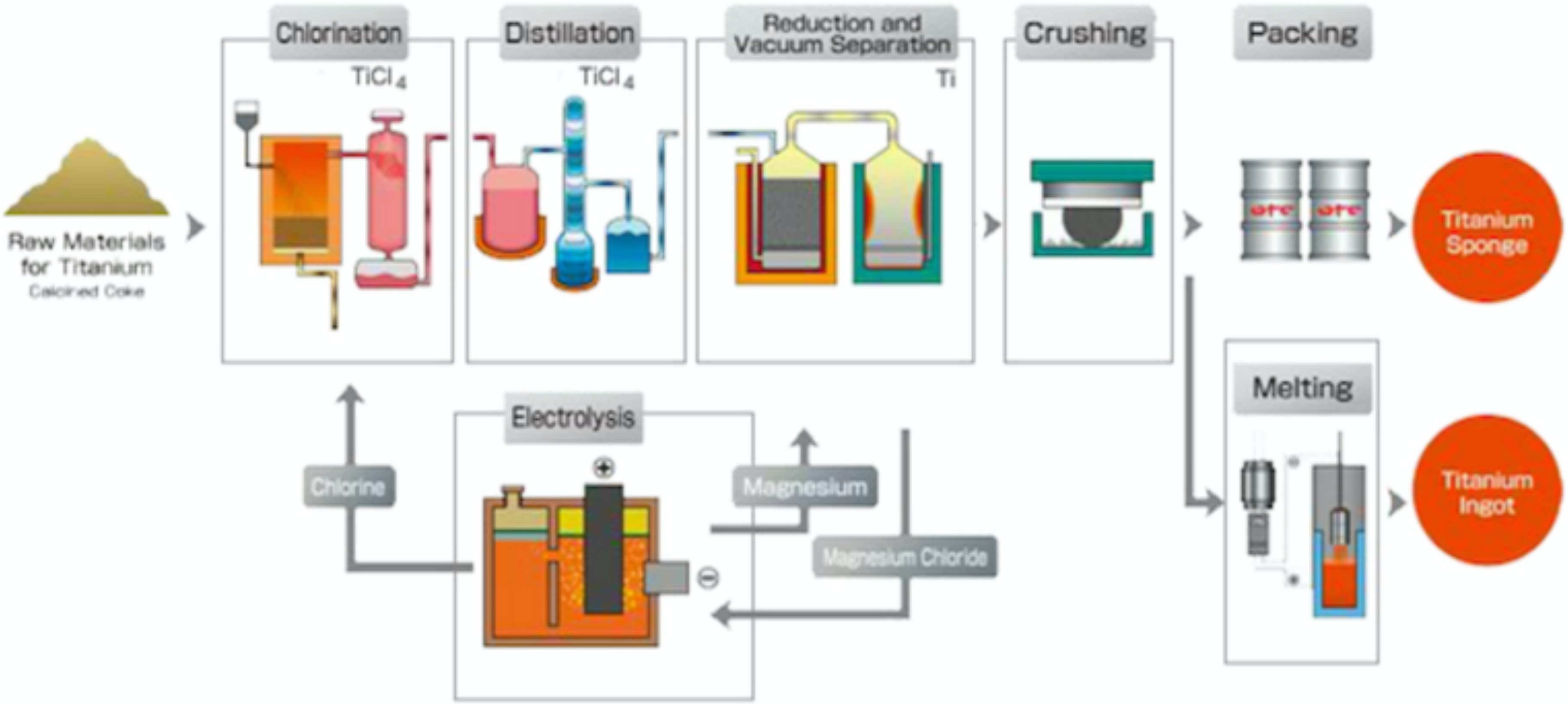




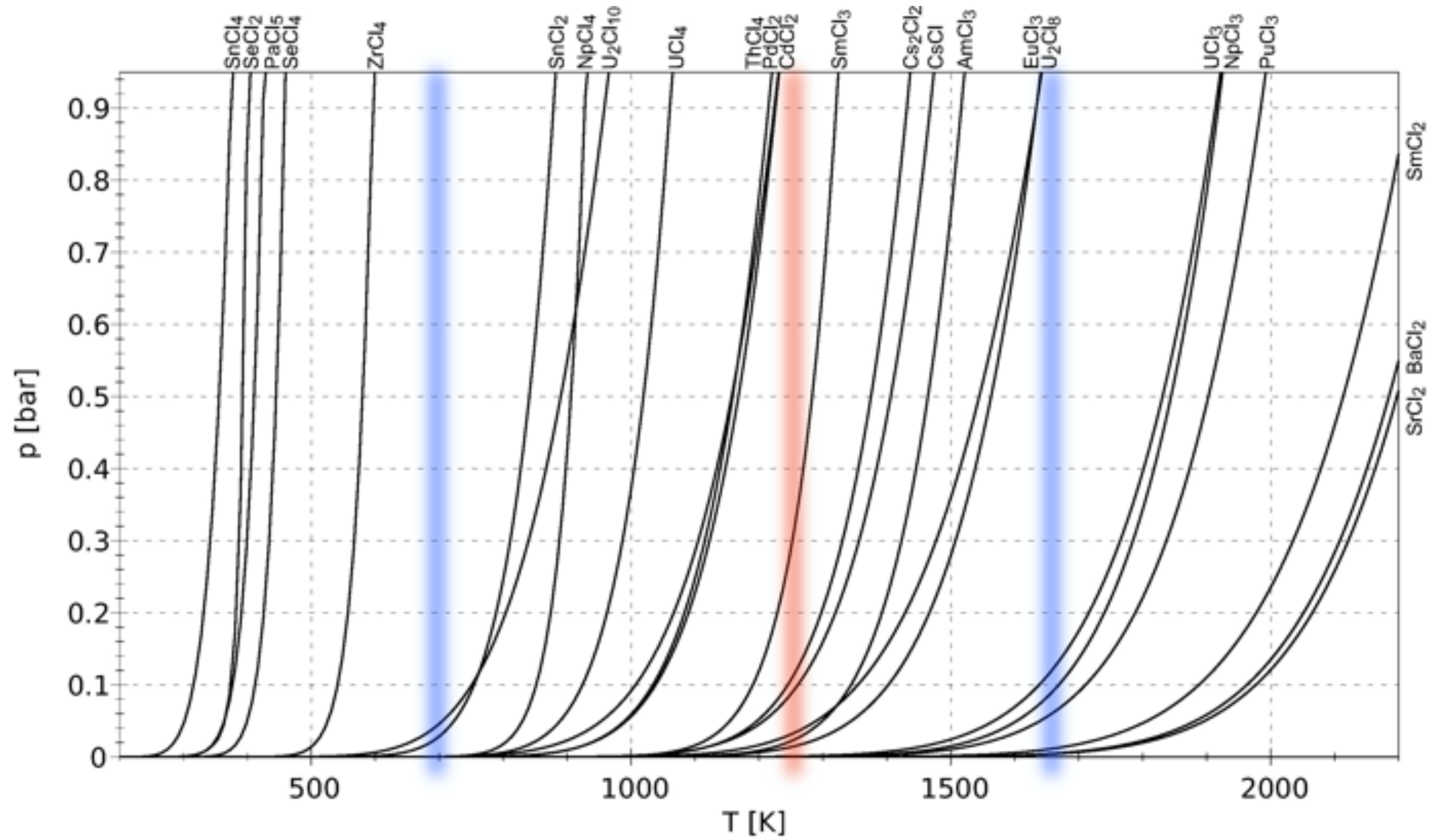
# The Kroll Process

- State-of-art since a long time
- Used for all metals of the Ti group (e.g. Zr, Hf)
- Developed in the 1930ies
- Titanium ore is reduced and chloridized
- Distillation to the single chlorides at clearly above 1000 °C to 1400 °C
- Then reduction of $TiCl_4$ with alkaline metals
- High purity Titanium is sold for 10 $/kg



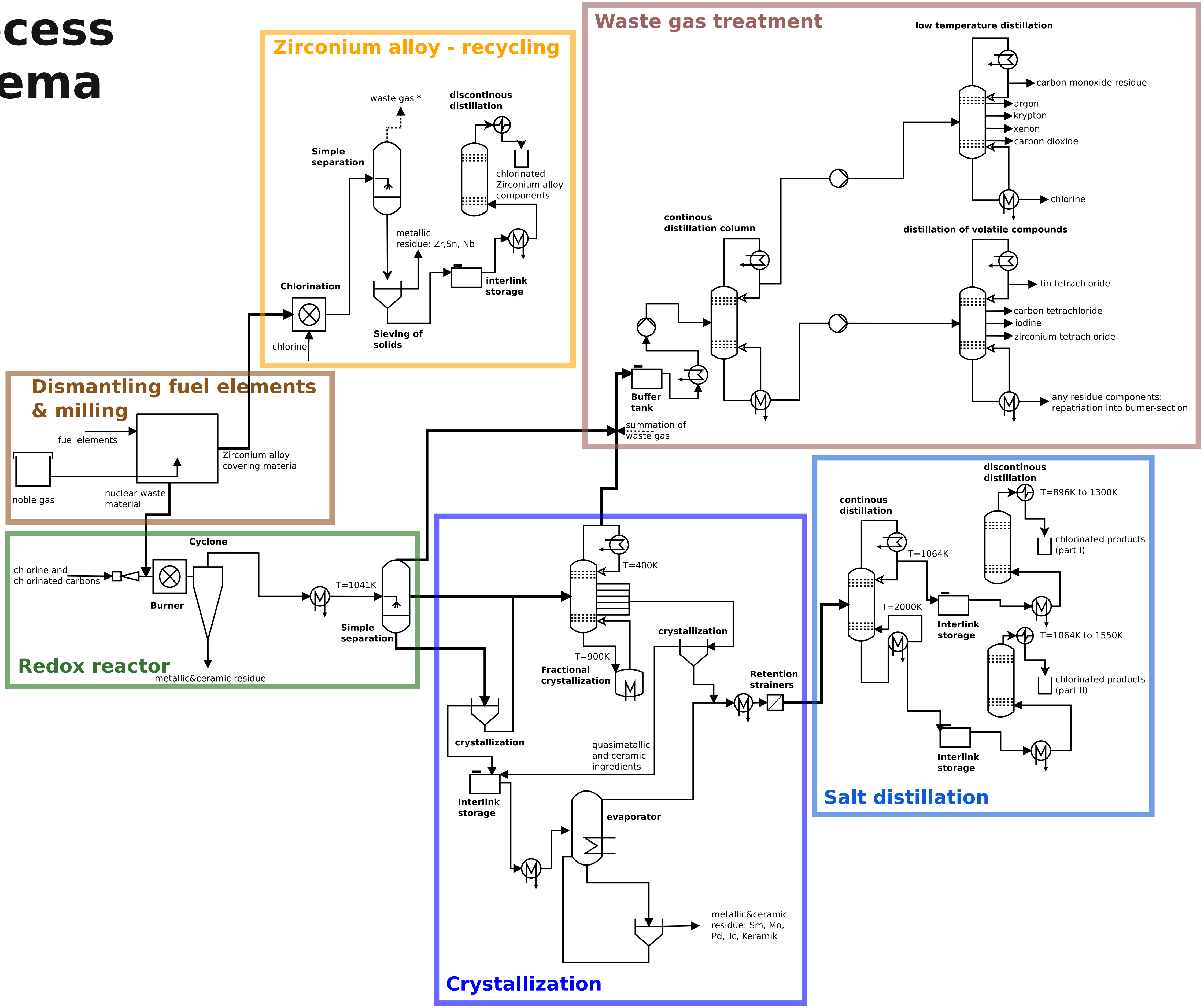

Ti-Produktion at Osaka Titanium Technologies
http://www.osaka-ti.co.jp/e/

# Vapour pressure curves of HM chlorine compounds

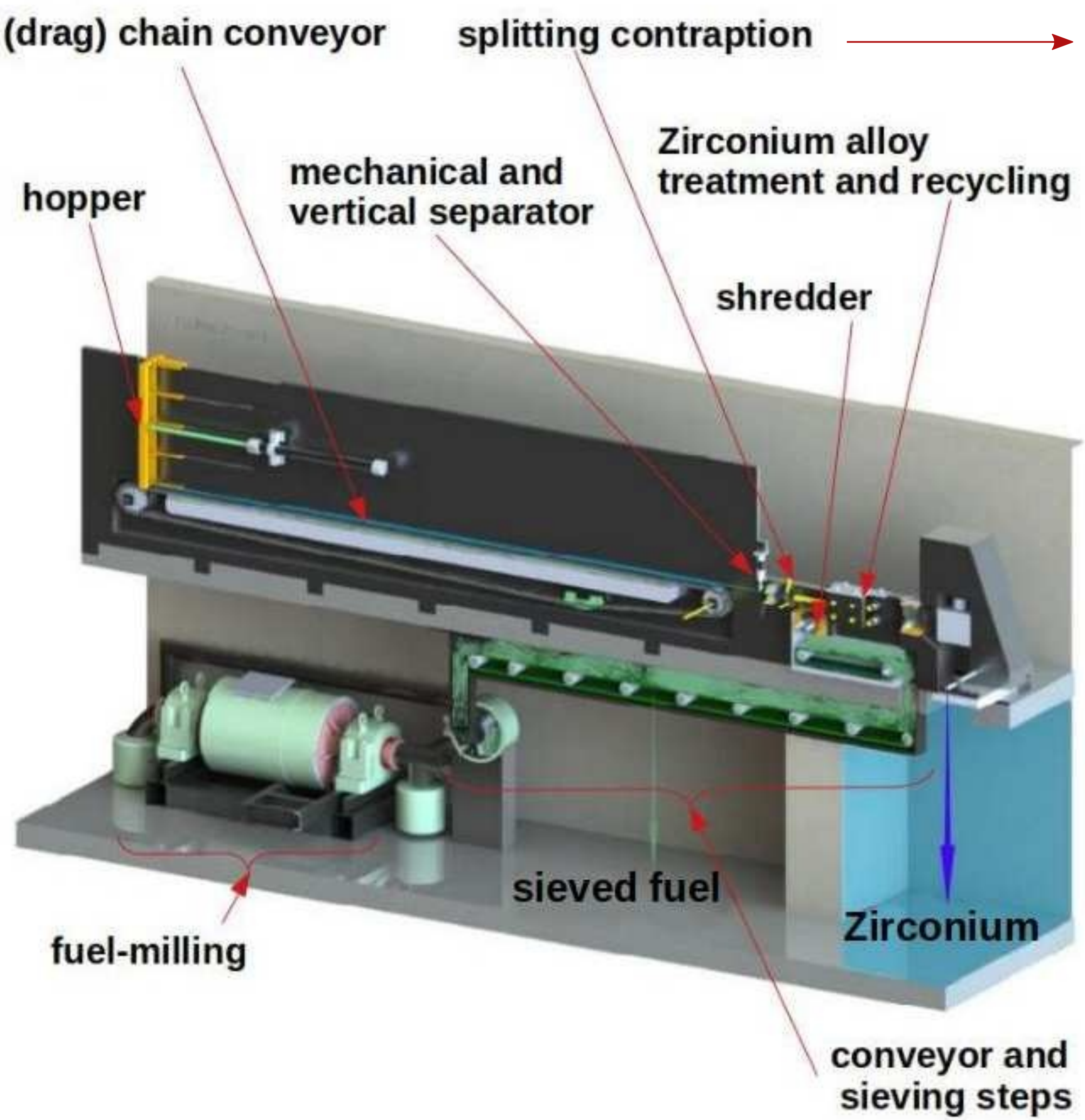


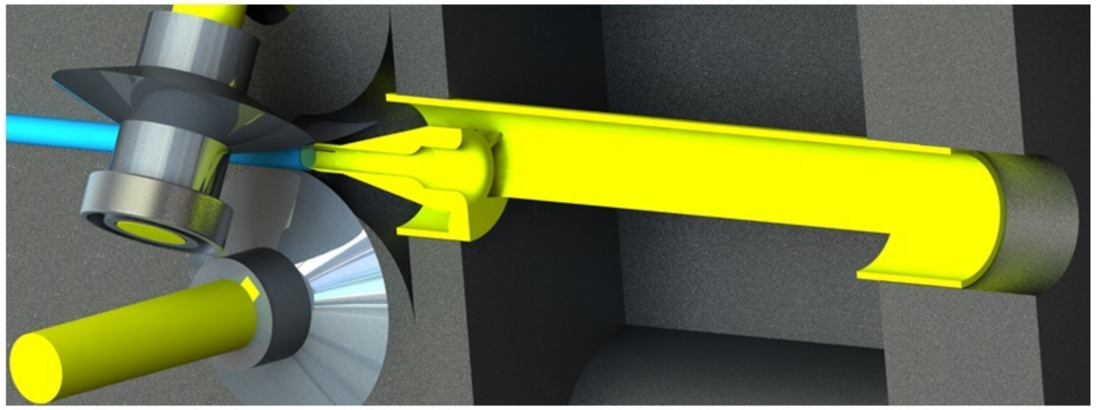

- Fractionation of compounds along their vapour pressure curves.
- Modularization of the distillation unit according to the 4 fractions.
- Preseperation in continious operating column.
- High purity seperation in subsequent batch operating columns.
- Volatile compounds seperated in gas distillation unit.

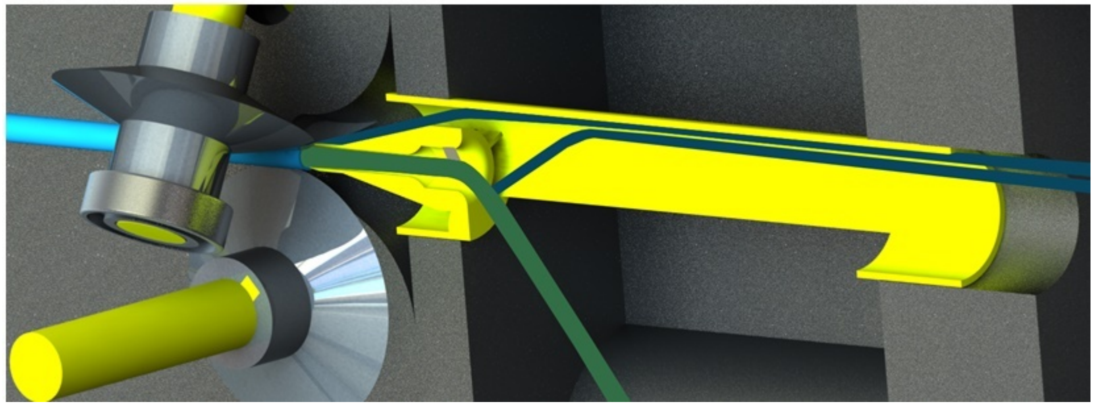
# Pyro Process P&T Schema

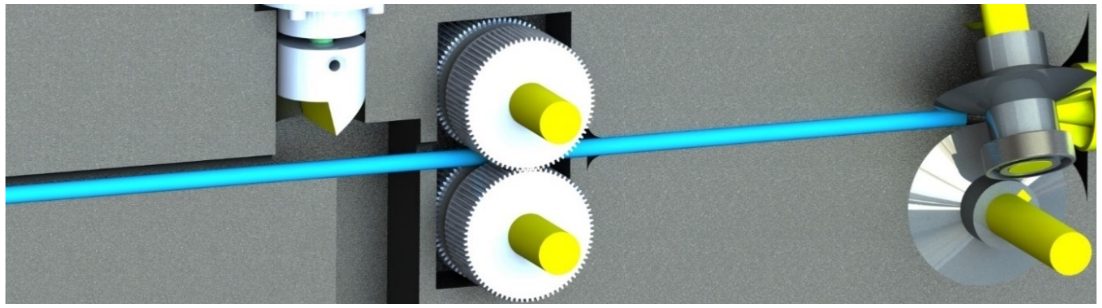


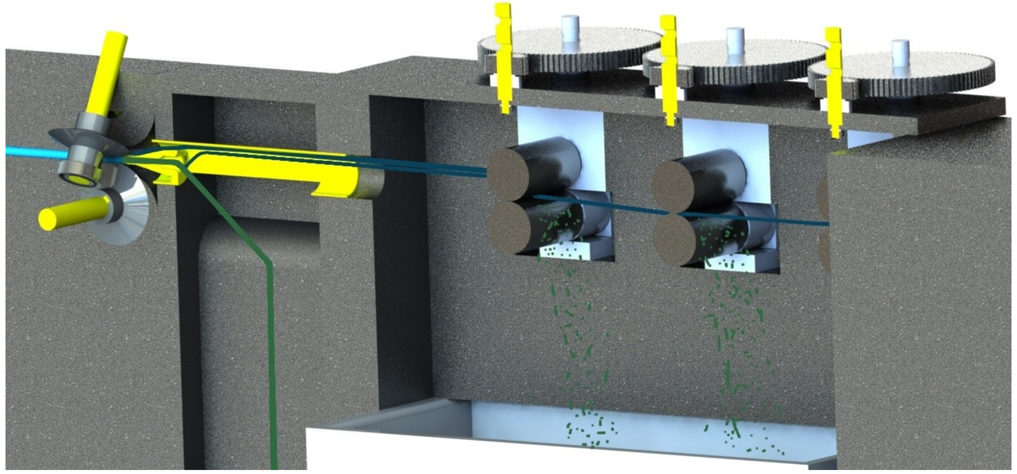
# Fuel element decomposition apparatus



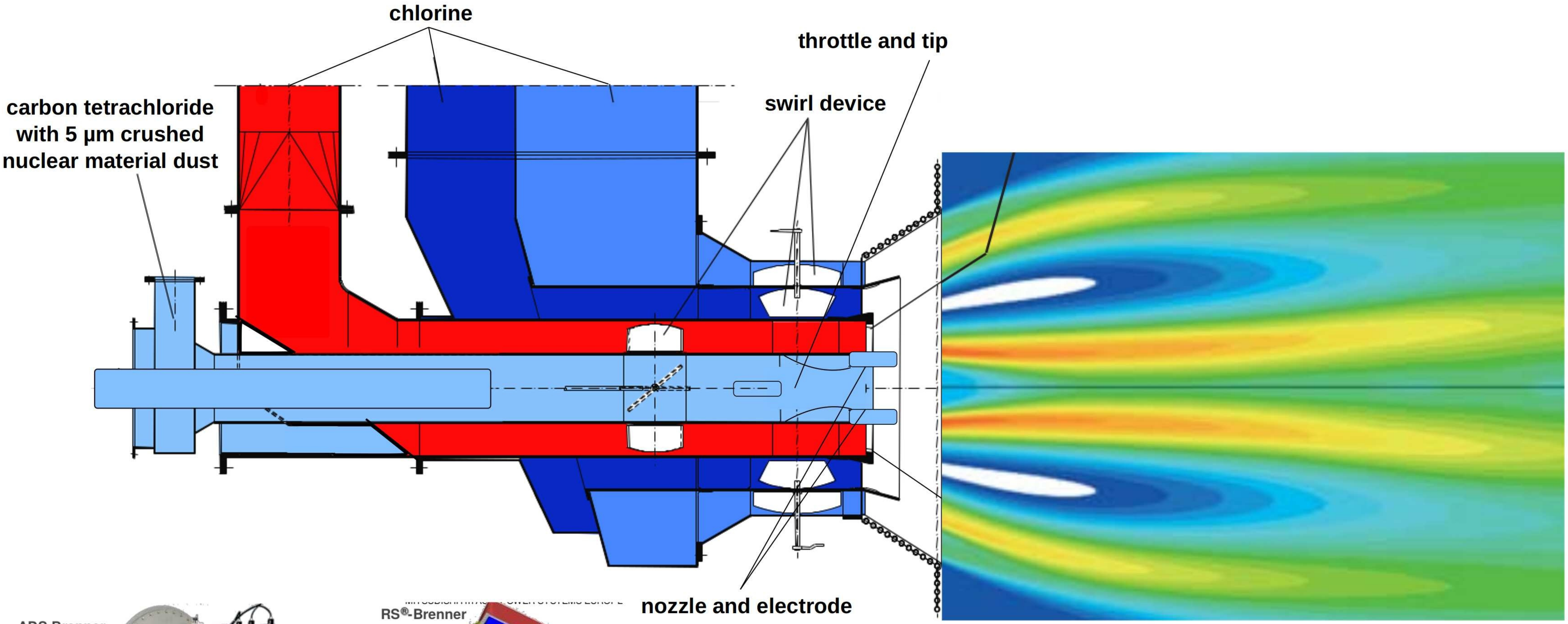



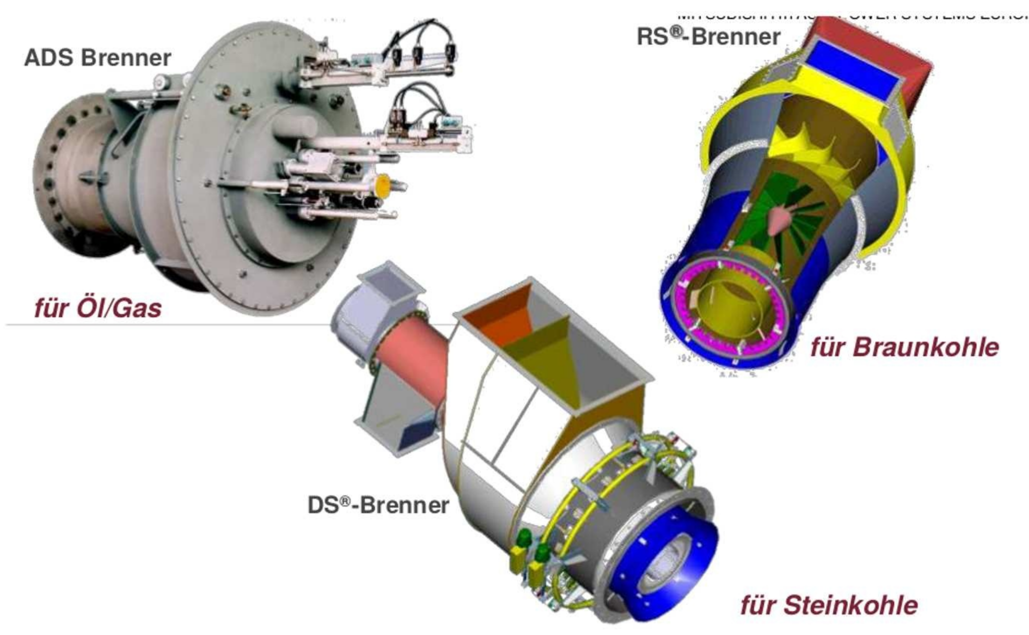






# Redox Reactor



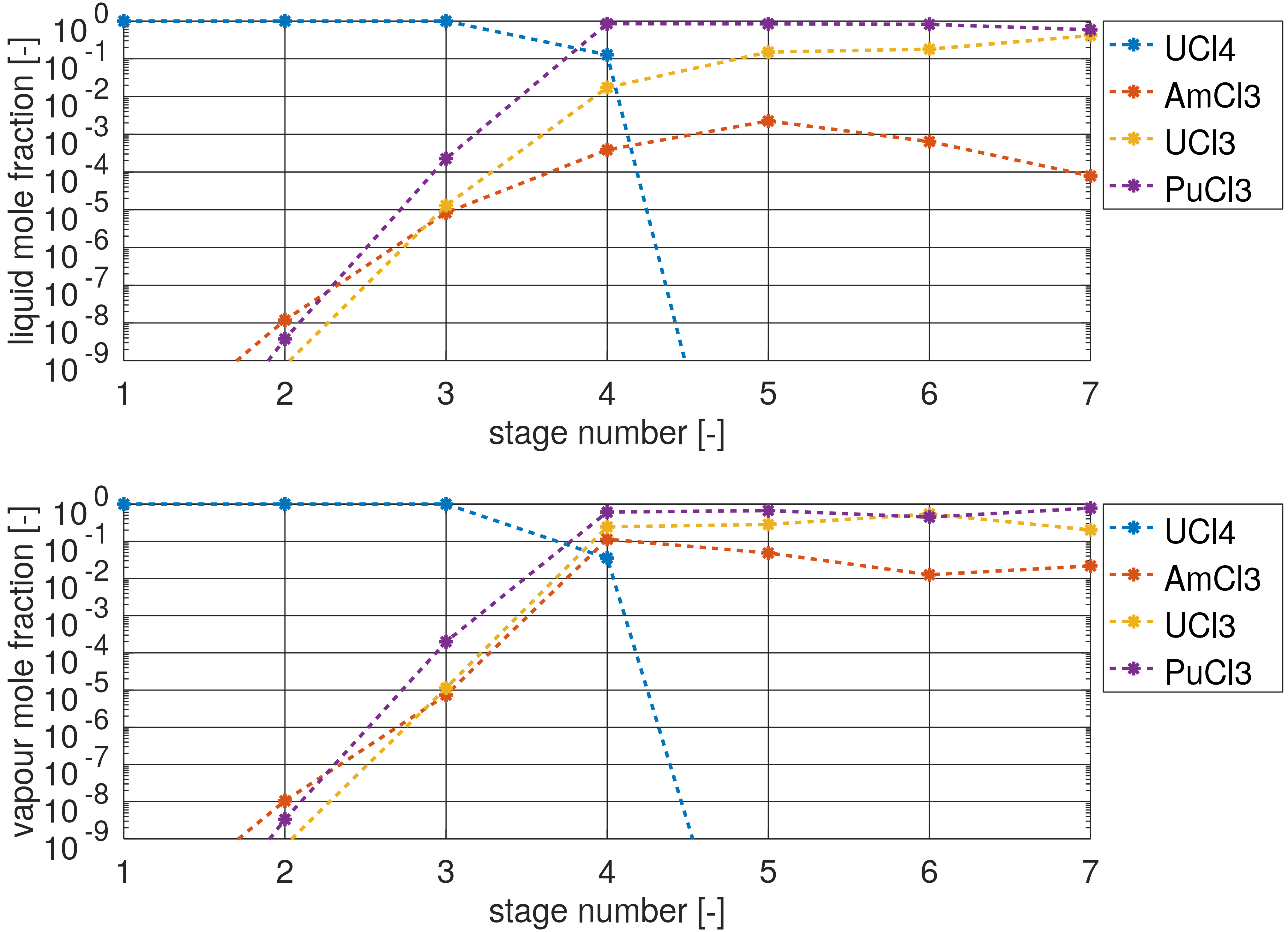




- Industrial burner for chemical reactions.
- Electric arc discharge plasma flame.
- Redox agent chlorocarbons (i.e. tetrachlormethane) and chlorine gas.
- Capable to reduce oxides with high binding energies including borosilicate glass of the moulds from the PUREX plants.

# Distillation Column Simulation

- Accumulation of a concise substance database for the metal chloride compounds by sifting thousands of literature sources.
- Classification and evaluation of data kategories for increased depths of simulation.
- Identification of data inaccuracies and gaps.
- Simulation of simple columns without insets in continous operation mode. Products are withdrawn at top and bottom.
- Physical problem: turbulent flow of unmixable liquid and vapour streams
- Mathematical problem: non-linear partial differential equations which behave chaotically.
- No meaningful solution by CFD possible.
- Approach: Linear discretization of the column by decomposition into staged simple distillation units.
- Coupled ordinary differential equations solved in equilibrium state. Implemented with the numerical analysis package OCTAVE.

# Distillation Column Simulation Results - exemplary



# Summary

- In accordance with the experience in the chemical and metallurgy industry fractionated distillation is principally capable to seperate the HM-mix of nuclear fuel with high precission.
- The simulation of simple columns shows that already <10 stages are sufficient to seperate Uranium from TRU with high precission, effectively decontaminating it.
- This performance can readily be increased by insets and combination with the much more precise batch distillation as outlined in the P&T schema.
- Design estimation for a column with a throughput of 1000 t/a is a diameter of ~5 dm and a height of 1-4 m.
- Due to the chaotic nature of the physical problem a design by computer simulation alone is not possible if specific operation parameters are required. A laboratory scale facility is mandatory which is also used to measure missing substance data.
- The DFR technology allows for a highly efficient P&T schema which can consume all actiniods for cheap energy production (electric, chemical) rendering a geological deposit obsolete.
- Can be swiftly implemented because designed with respect to contemporary industrial manufacturing proficiencies.
- Due to its high efficiency it can outperform other waste treatment options economically, especially a geological waste disposal site.

# P&T strategy with the DFR