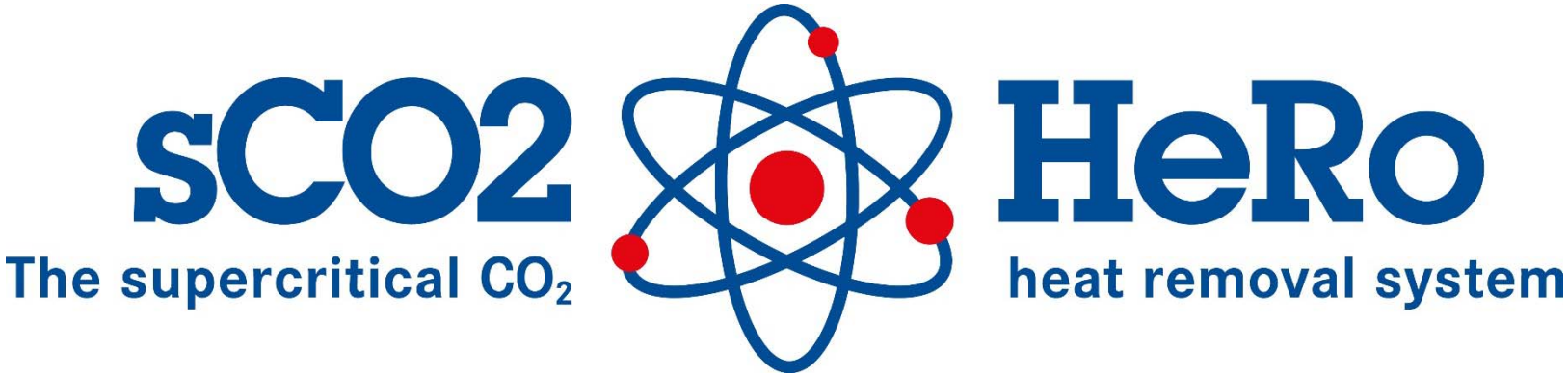
UNIVERSITÄT DUISBURG ESSEN

Open-Minded

This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 662116.



A supercritical CO_2 low temperature Brayton-cycle for residual heat removal

F.-K. Benra, D. Brillert, O. Frybort, P. Hajek, M. Rohde, S. Schuster, M. Seewald, J. Starflinger

Presenter: A. Hacks

The idea …

http://www.spreadnews.de/wp-content/uploads/2013/11/artikelbild-offizielles-foto-kkw-akw-fukushima-daiichi-tepco.jpg

The accident at Fukushima

Earthquake destroys offsite power supply.

- Emergency power supply with diesel generators

Tsunami destroys the water intake structures and floods the emergency generators.

- Station blackout
- Loss of ultimate heat sink

Steam-driven Reactor Core Isolation Cooling (RCIC) takes over

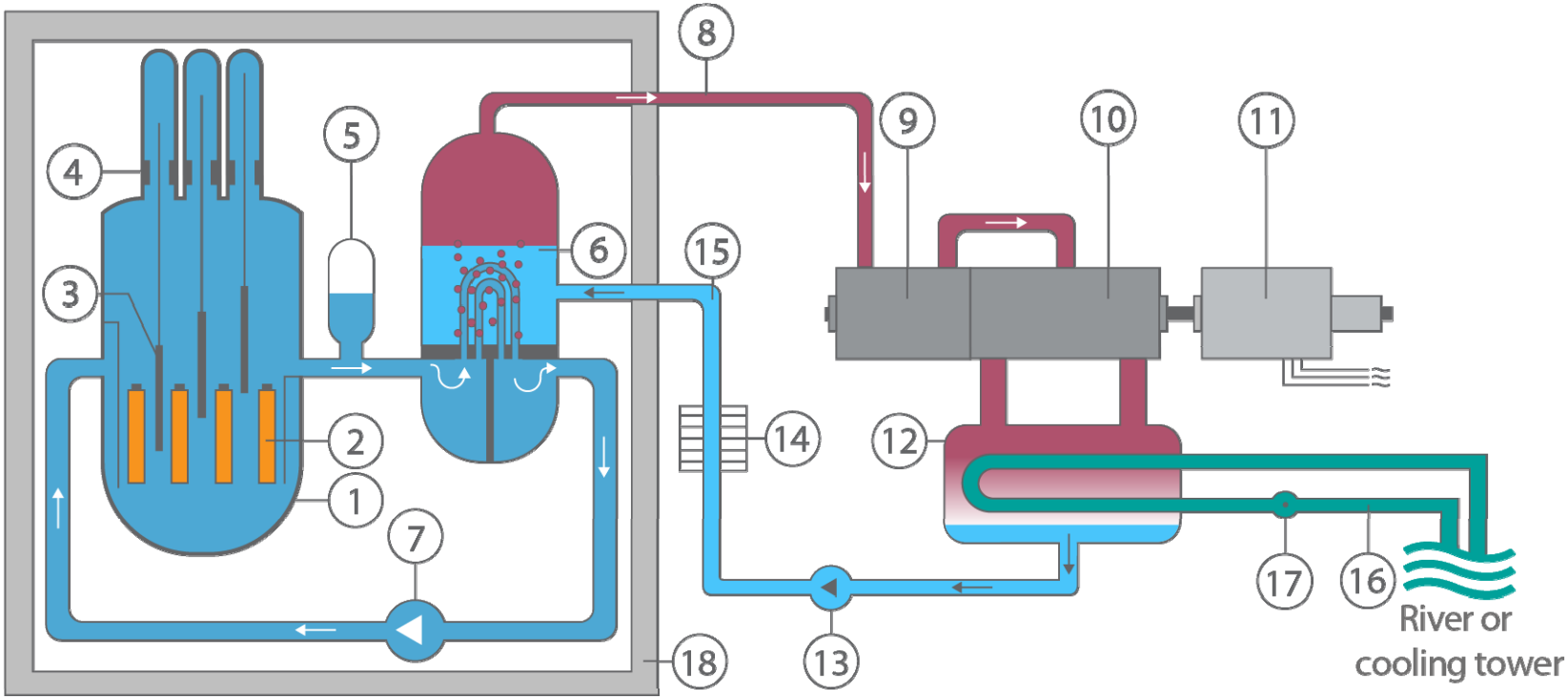
- Injection of water to provide core cooling for a certain time
- Fails when batteries for the control system are empty

Damaged infrastructure delays external measures

Evaporation of water and damaged fuel claddings lead to production of hydrogen

- Explosion
- Radioactive material is set free

Pressurized water reactor (PWR)



1. Reactor pressure vessel
2. Fuel element
3. Control rods
4. Control rod drive
5. Pressuriser
6. Steam generator
7. Coolant pump
8. Live steam
9. High pressure turbine
10. Low pressure turbine
11. Generator
12. Condenser
13. Feed water pump
14. Preheater
15. Feed water
16. Coolant
17. Coolant pump
18. Concrete shielding

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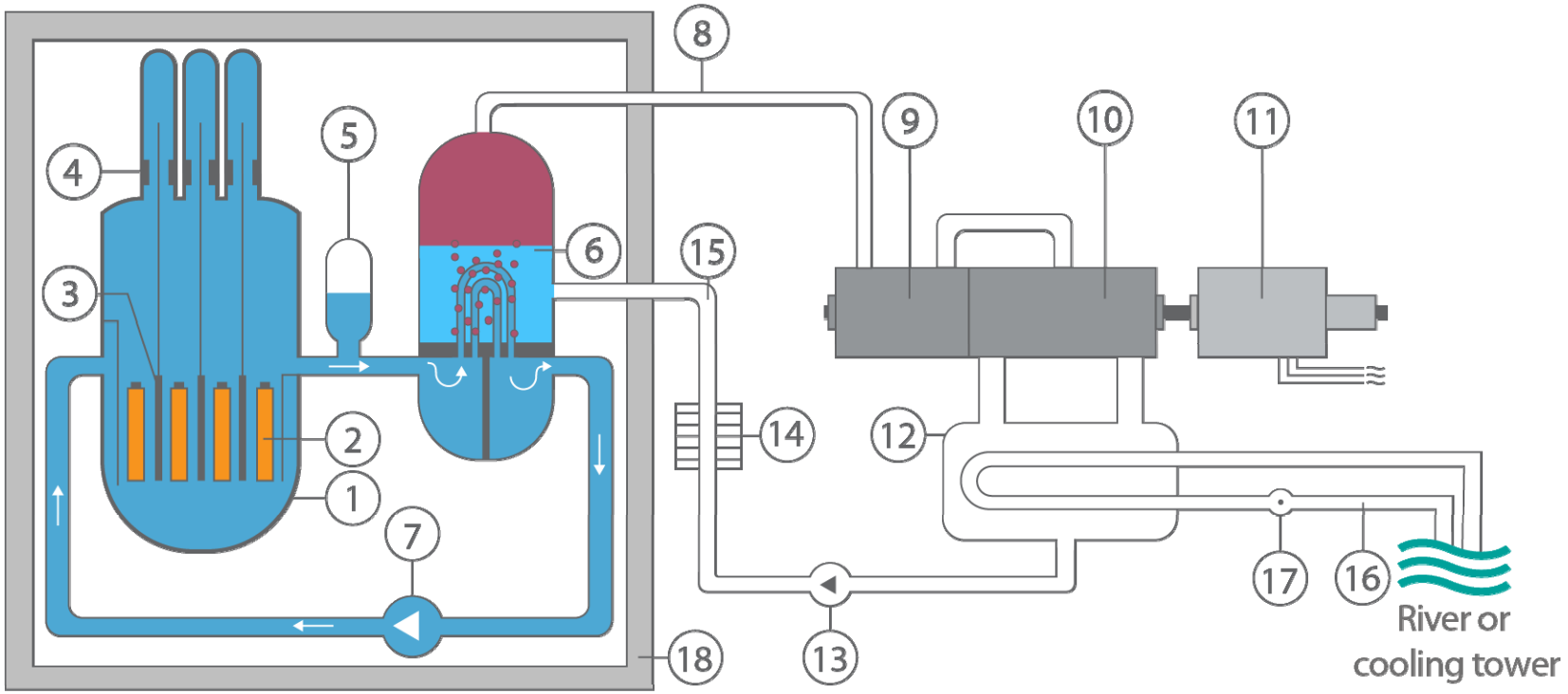
Station Black Out



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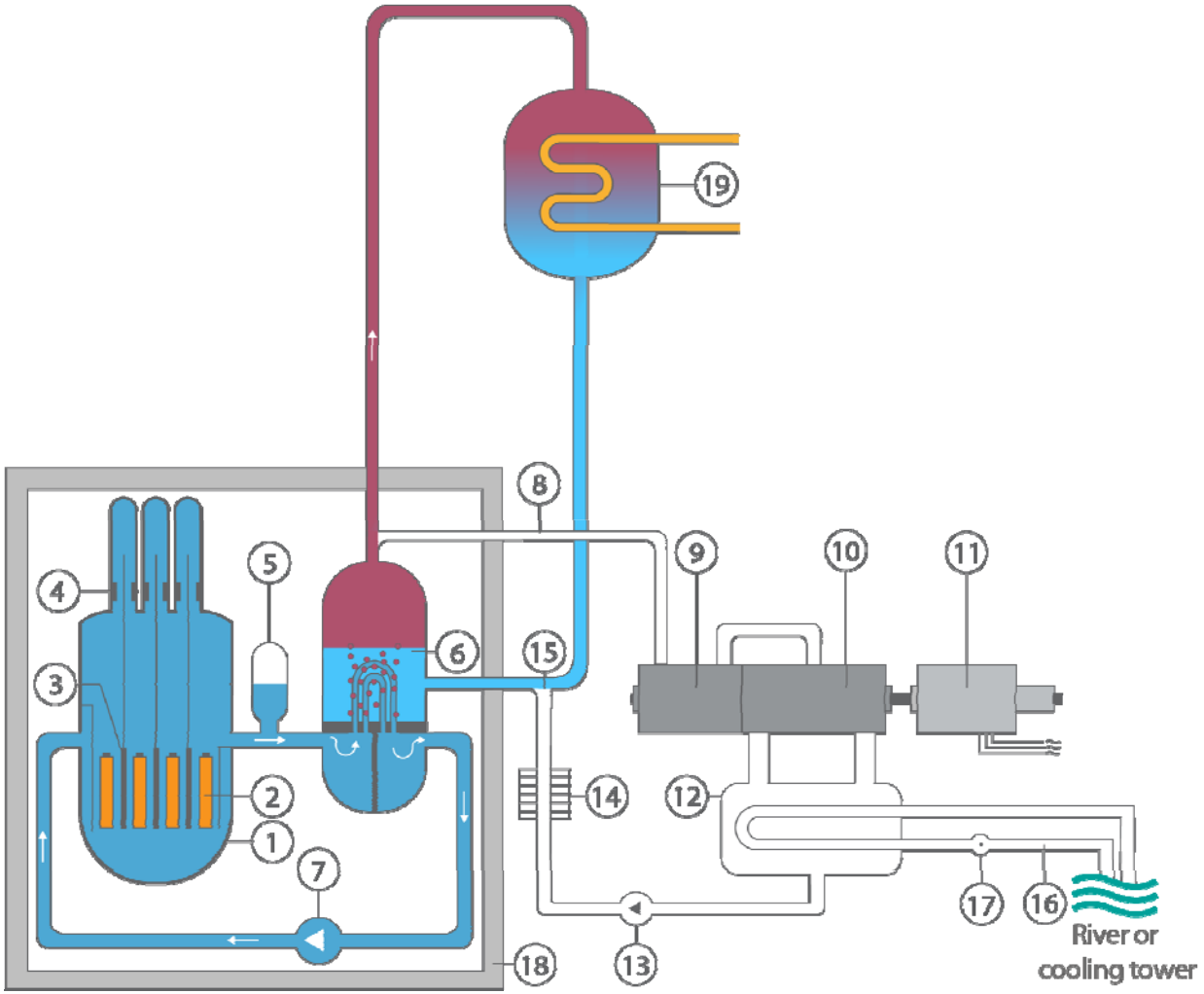
Station Black Out – Transport of decay heat



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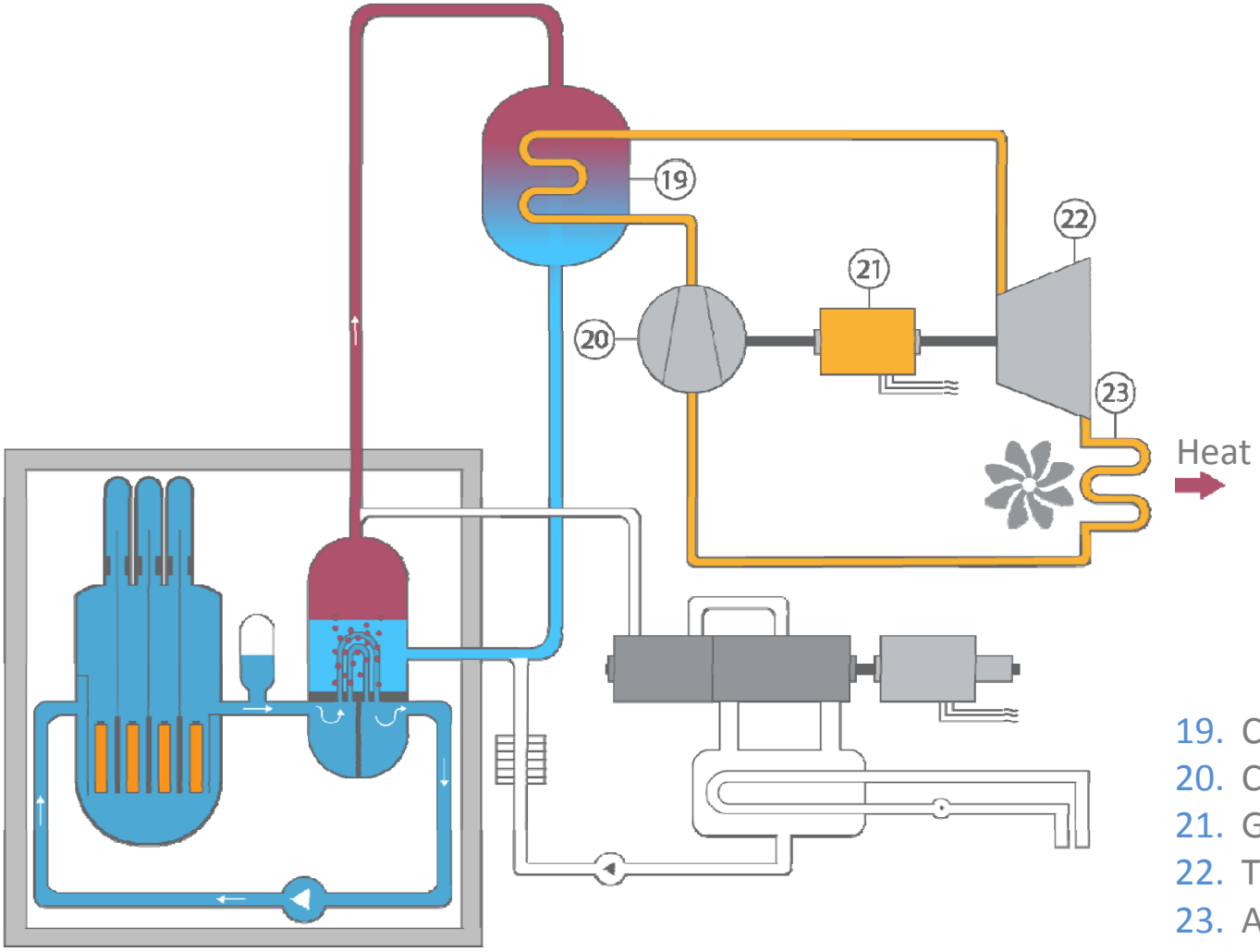
17. Coolant pump
18. Concrete shielding
19. Compact heat exchanger

PWR sketch based on Martin Volkmer DAtF Deutsches Atomforum e.V. Kernenergie Basiswissen page 50

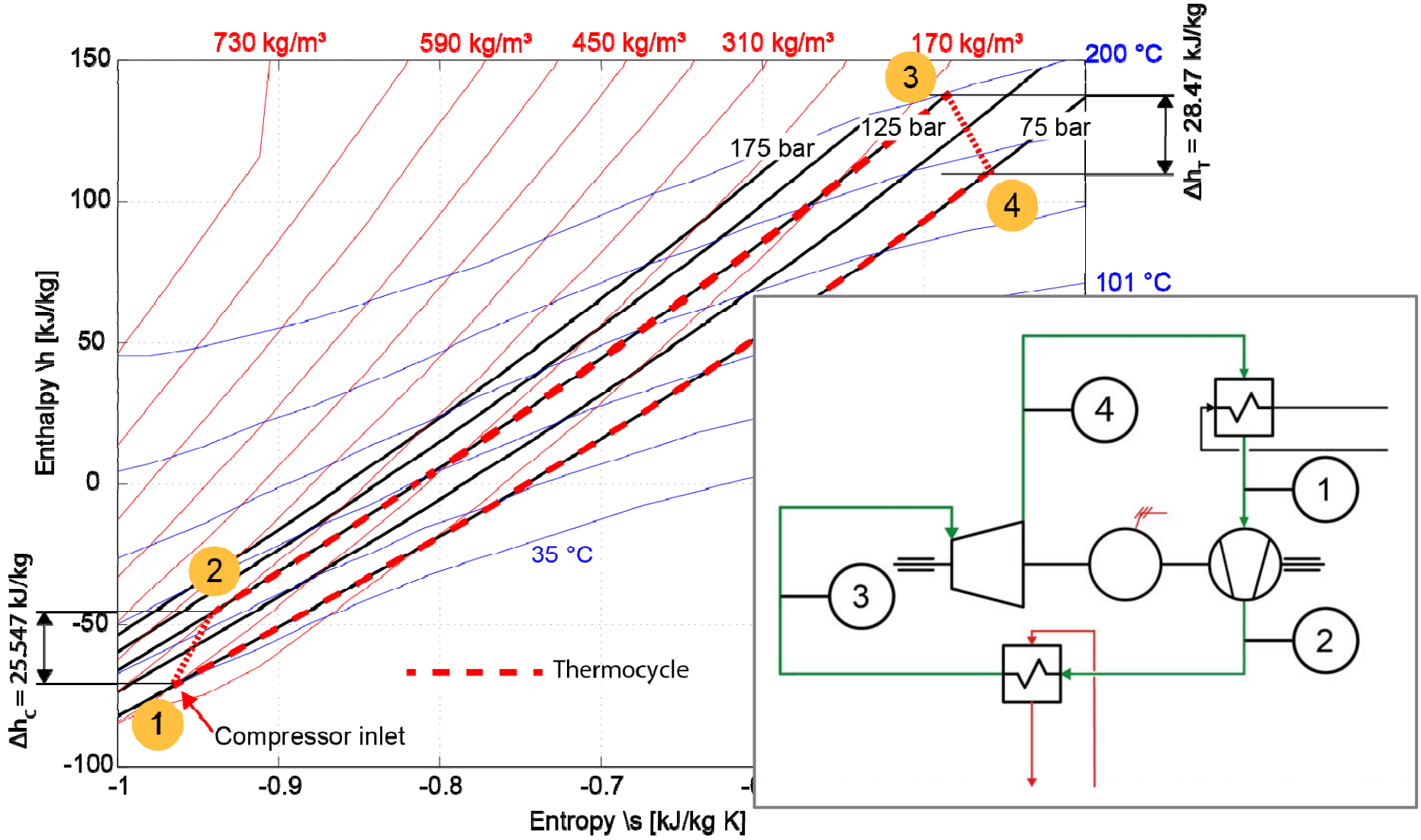
Remove the decay heat with the sCO2-HeRo



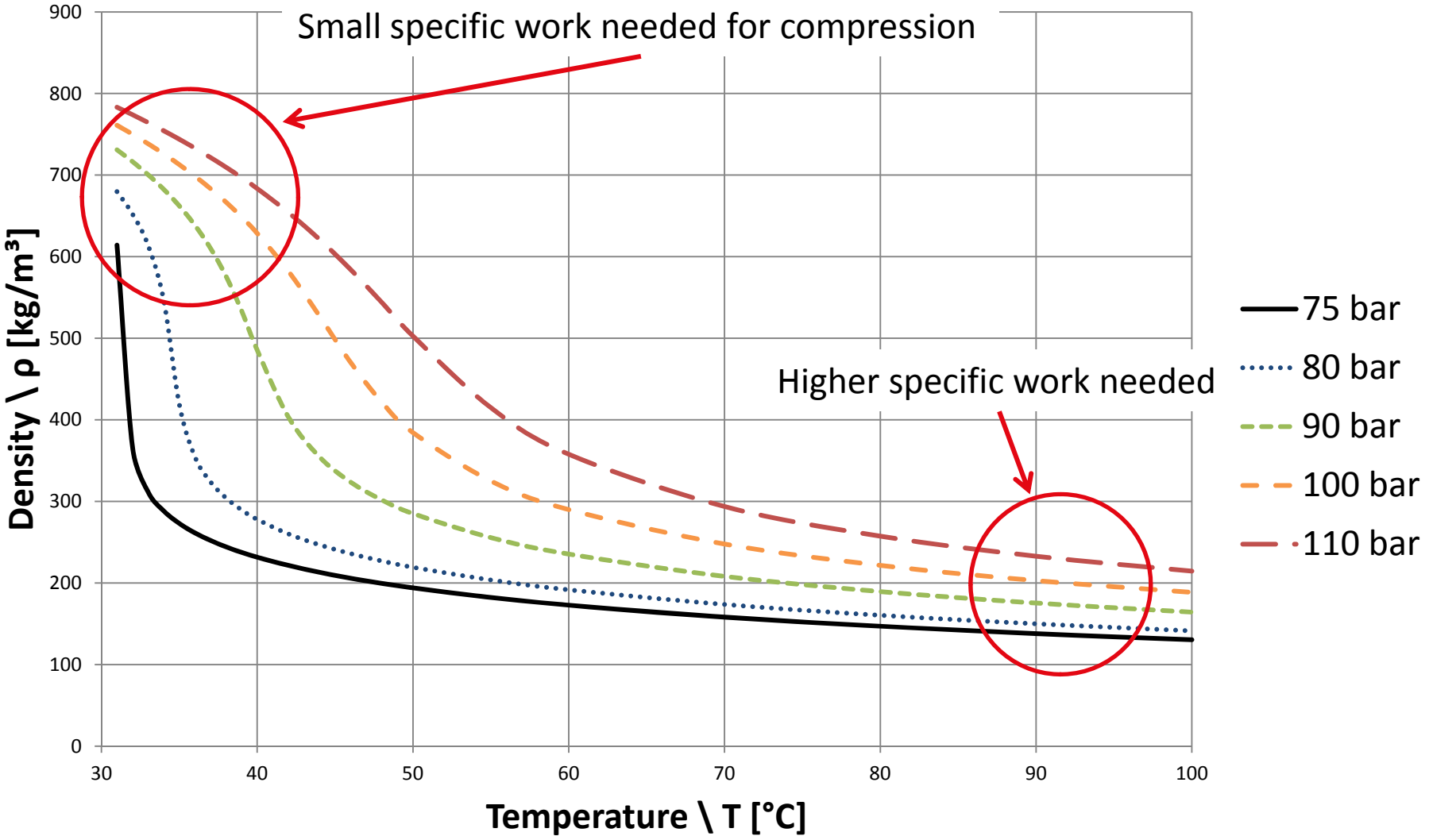
19. Compact heat exchanger
20. Compressor
21. Generator
22. Turbine
23. Air heat sink

PWR sketch based on Martin Volkmer DAtF Deutsches Atomforum e.V. Kernenergie Basiswissen page 50

The thermodynamics behind …

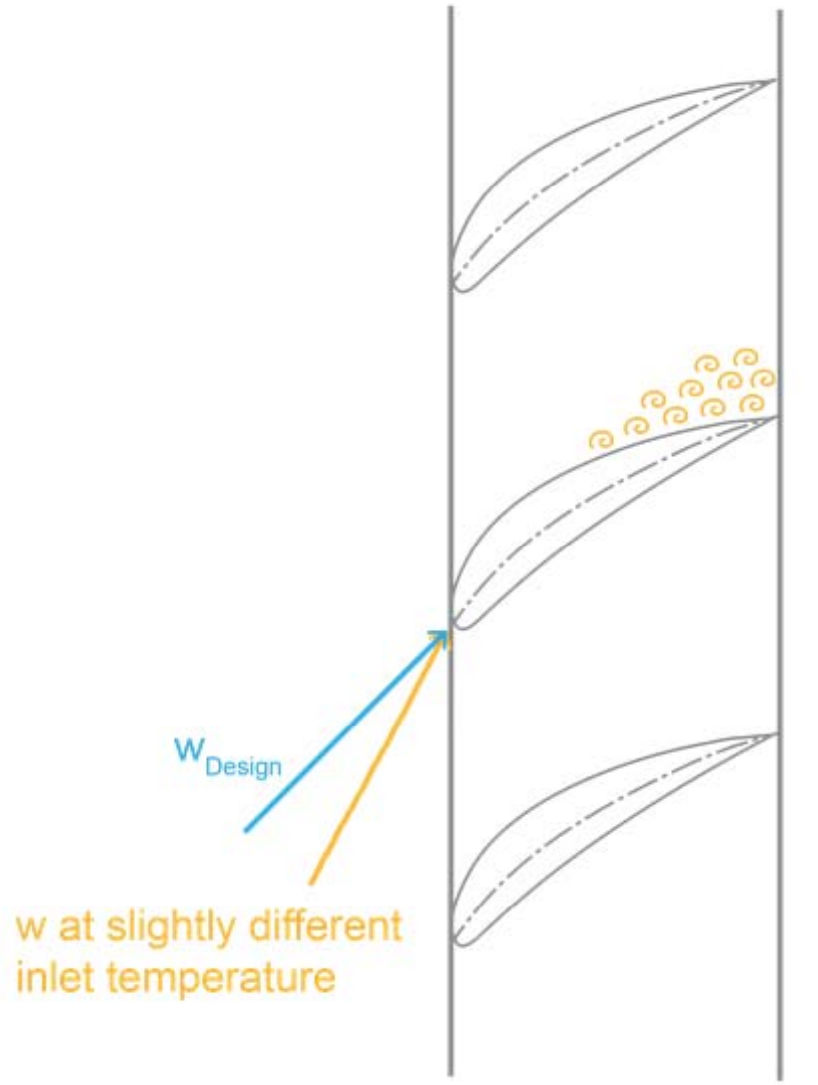


Density …

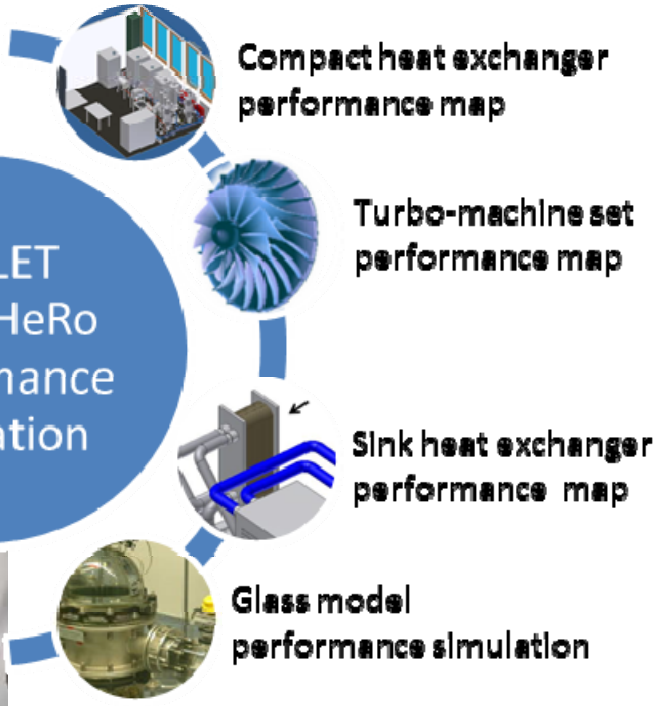

Small specific work needed for compression
Higher specific work needed
Density \ ρ [kg/m³]
Temperature \ T [°C]
900
800
700
600
500
400
300
200
100
0
30
40
50
60
70
80
90
100
75 bar
80 bar
90 bar
100 bar
110 bar

Incidence caused by density variation

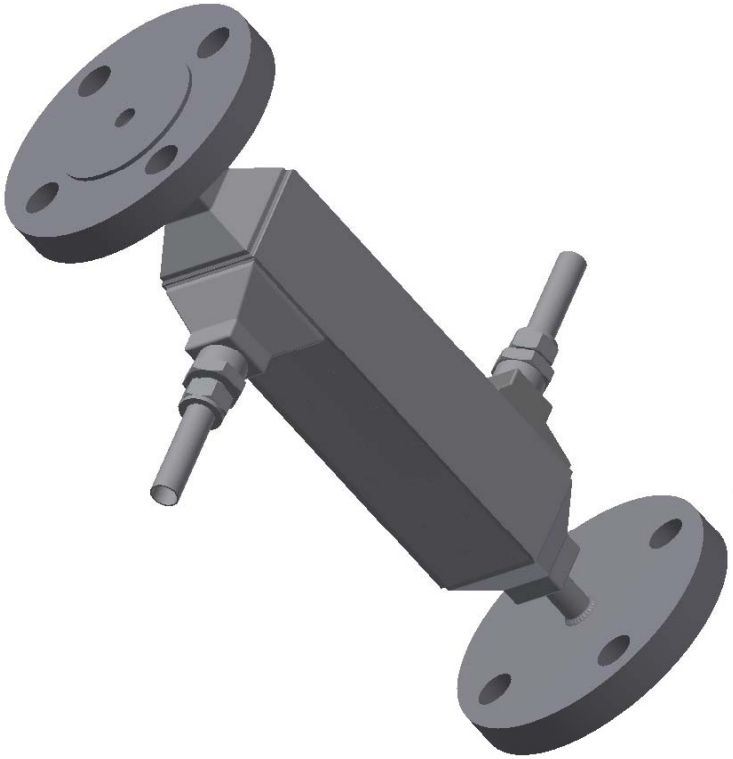
- **Inlet close above the critical point**
- **Changes of the inlet temperature will have a strong impact on the density**
- **Induced variation of inlet conditions requires a special blade shape design**
- **To preserve a wide range of operation and to sustain the efficiency on a high level**



Properly implement the action…



Consequences for heat transfer



Compact HX

Design based on preliminary calculations with ATHLET

↓

Experiments → (validation data) → **CFD**

↓ ↓

Performance maps for design and off-design conditions

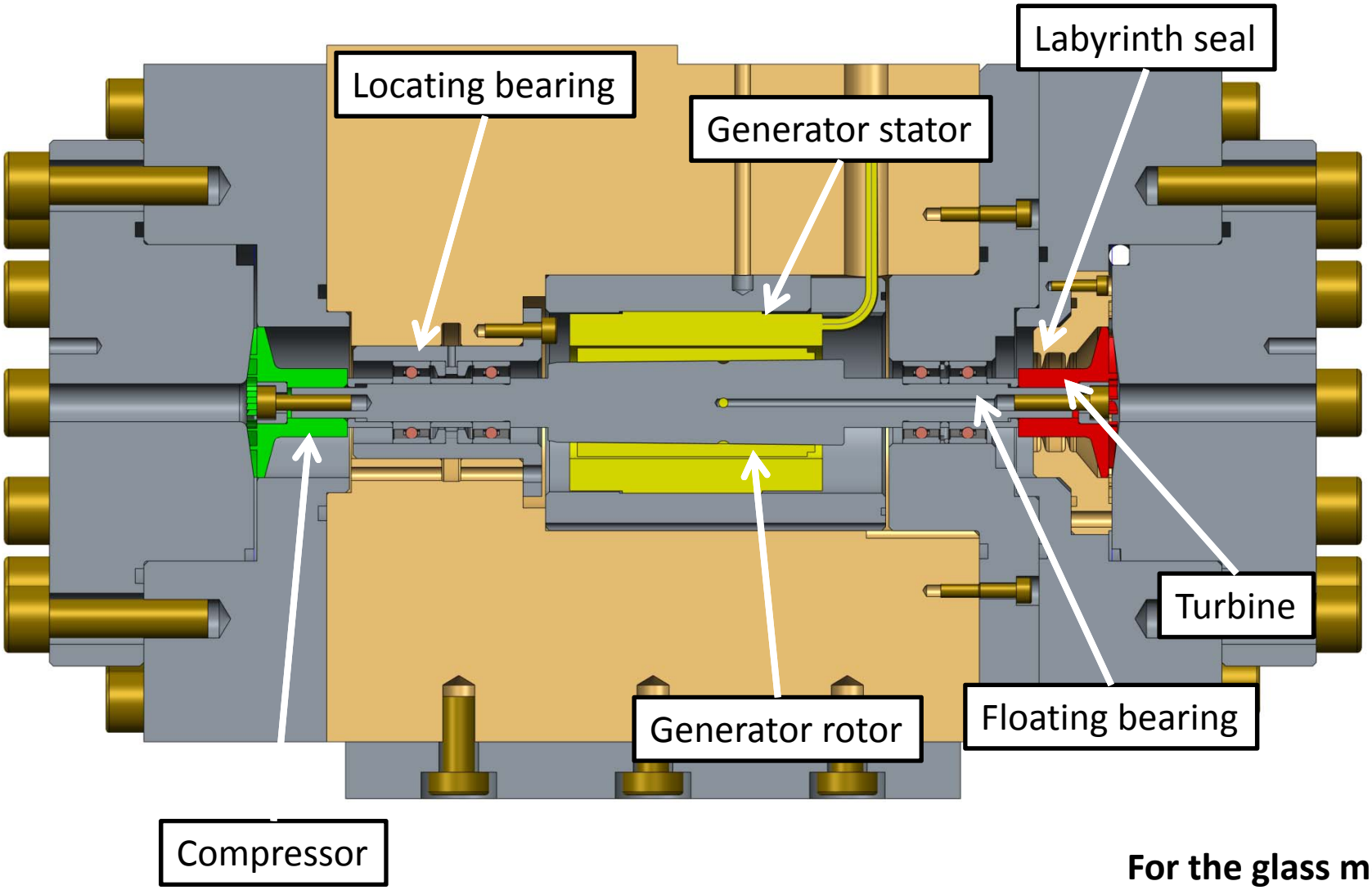
Correlations for heat transfer (CO2 side)

↓ ↓

Compact HX

Modifications ATHLET

The driving unit …



For the glass model

Ground breaking aspects…

- **Development of a self-propellant safety system for heat removal in nuclear power plants**
- **Fundamental knowledge about heat transfer in turbulent, supercritical flows, and its translation to practical heat transfer correlations**
- **The application of diffusion welded compact heat exchanger to nuclear reactors**
- **Design criteria for the turbomachines working in the supercritical regime close to the critical point**
- **Advanced blade contouring for operation in the supercritical regime close to the critical point**
- **Autarkic start-up system (self-launching)**

Impact…

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- ✓ System provides more time for additional severe accident scenarios
- ✓ Increases acceptance of Nuclear power plants within population
- ✓ Reduces CO2 emissions
- ✓ Increase competiveness of industry

- ➢ Further develop sCO2-HeRo from Technology Readiness level 2 (TRL2 - technology concept formulated) to TRL3 (experimental proof of concept)

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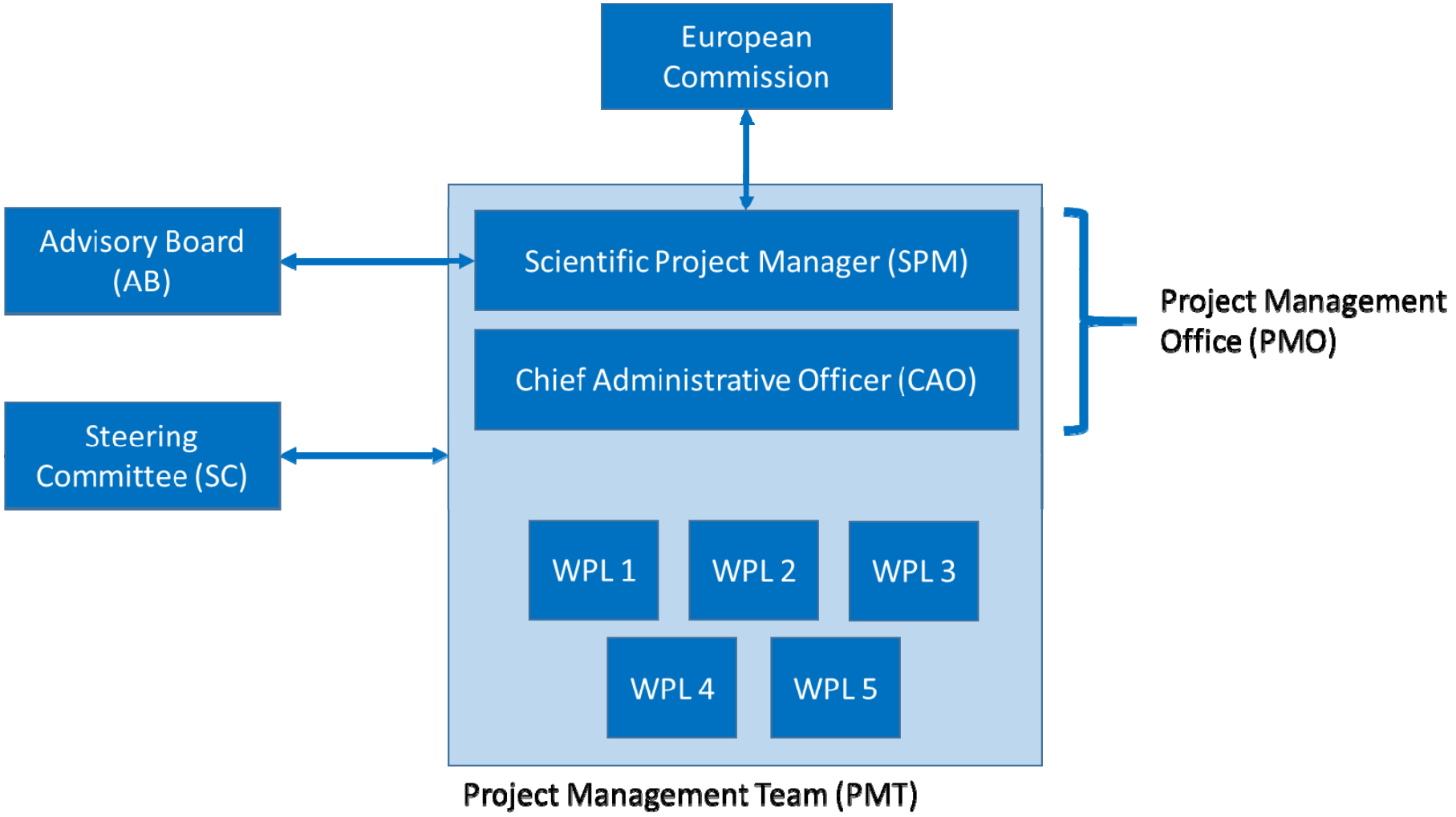
sCO2 HeRo

The supercritical CO_2 heat removal system

Thank you for your attention!

The team…


European Commission
Advisory Board (AB)
Scientific Project Manager (SPM)
Chief Administrative Officer (CAO)
Steering Committee (SC)
WPL 1
WPL 2
WPL 3
WPL 4
WPL 5
Project Management Office (PMO)
Project Management Team (PMT)

Properly implement the action …

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- **Further develop sCO2-HeRo from TRL2 to TRL3**

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment
- TRL 6 – technology demonstrated in relevant environment
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)