Introducing COMPASsCO2: Shaping the Future of Sustainable Energy

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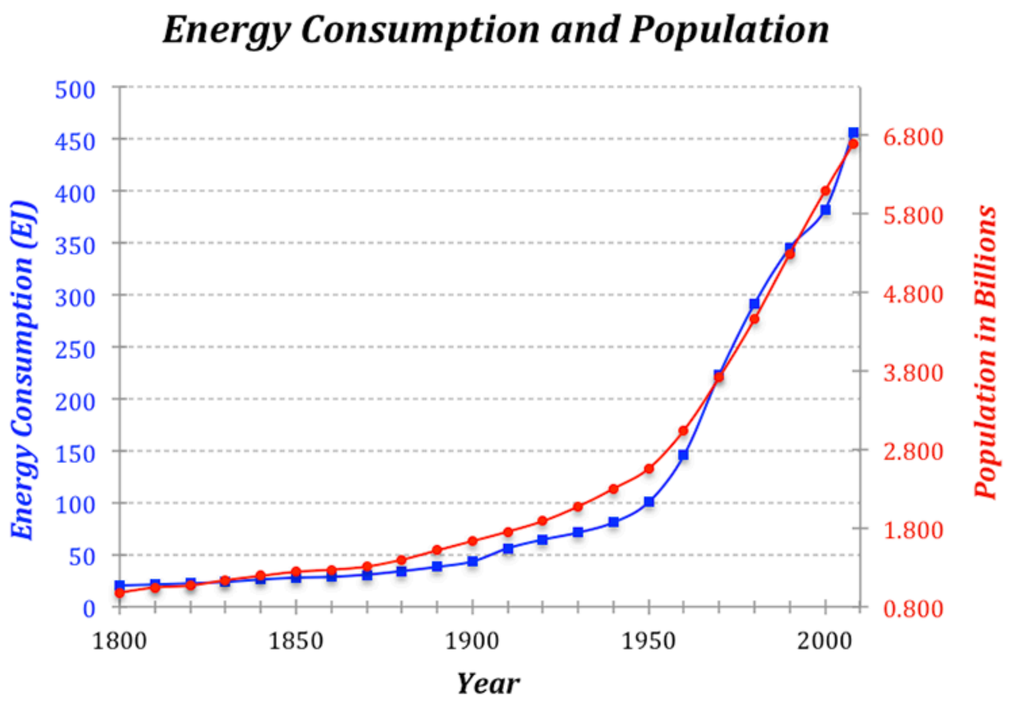
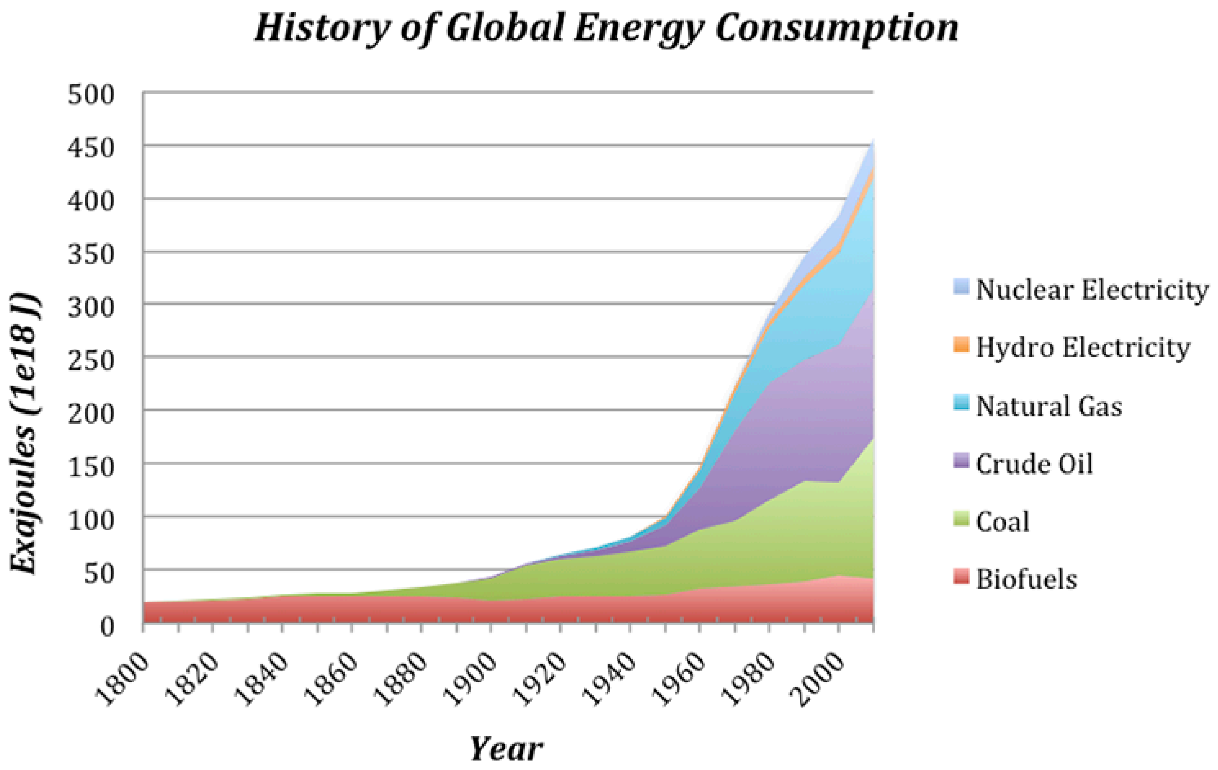
Agenda

- Introduction into Energetics
- Identifying the Problem and Potential solutions in Energetics
- TES (Thermal energy storage)
- COMPASsCO2 Project
- Wrap up
- Q&A

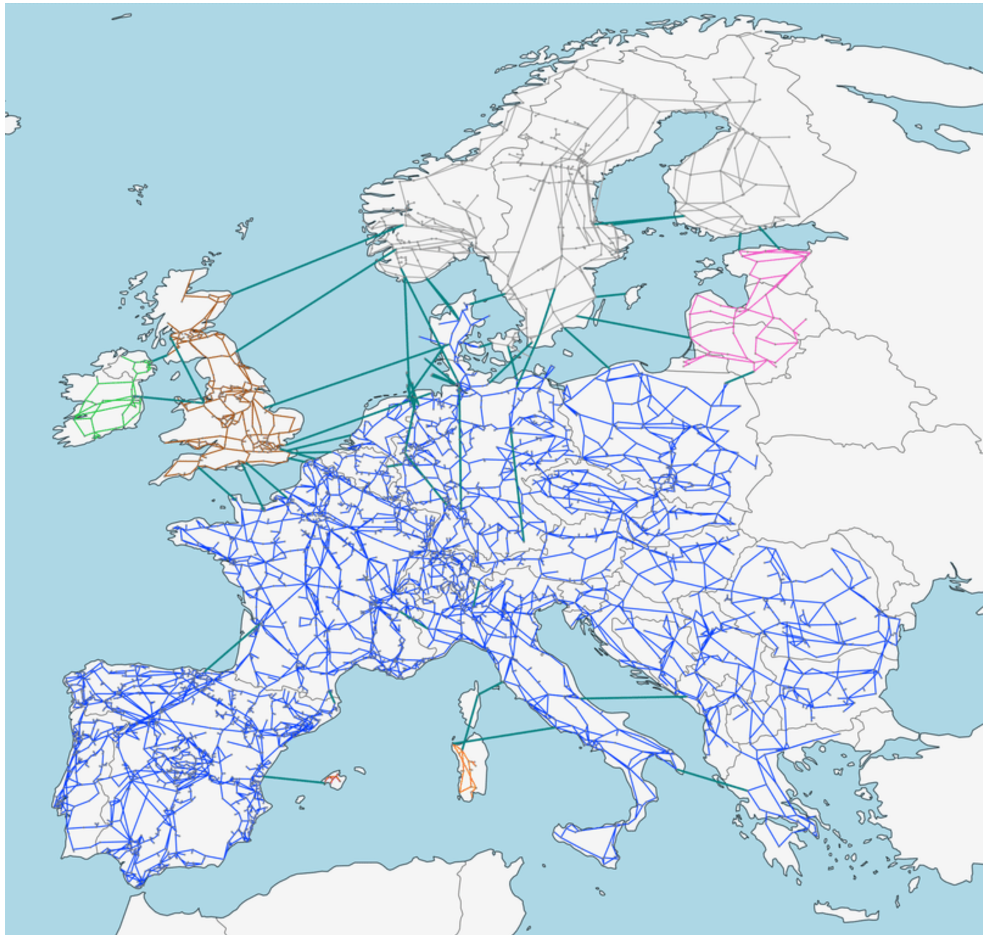
Energy demand and production. Past&Future?





Smil, Vaclav. (2010). Energy Transitions: History, Requirements, Prospects. 10.5040/9798400646133.

The grid that connect us



- Synchronous network
- 220-500kV 50 Hz
- Power in = Power out

Challenges:

- Grid stability
- Regulation

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Hofmann, Fabian & Schlott, Markus & Kies, Alexander & Stöcker, Horst. (2020). Flow Allocation in Meshed AC-DC Electricity Grids. 10.20944/preprints202001.0352.v1.

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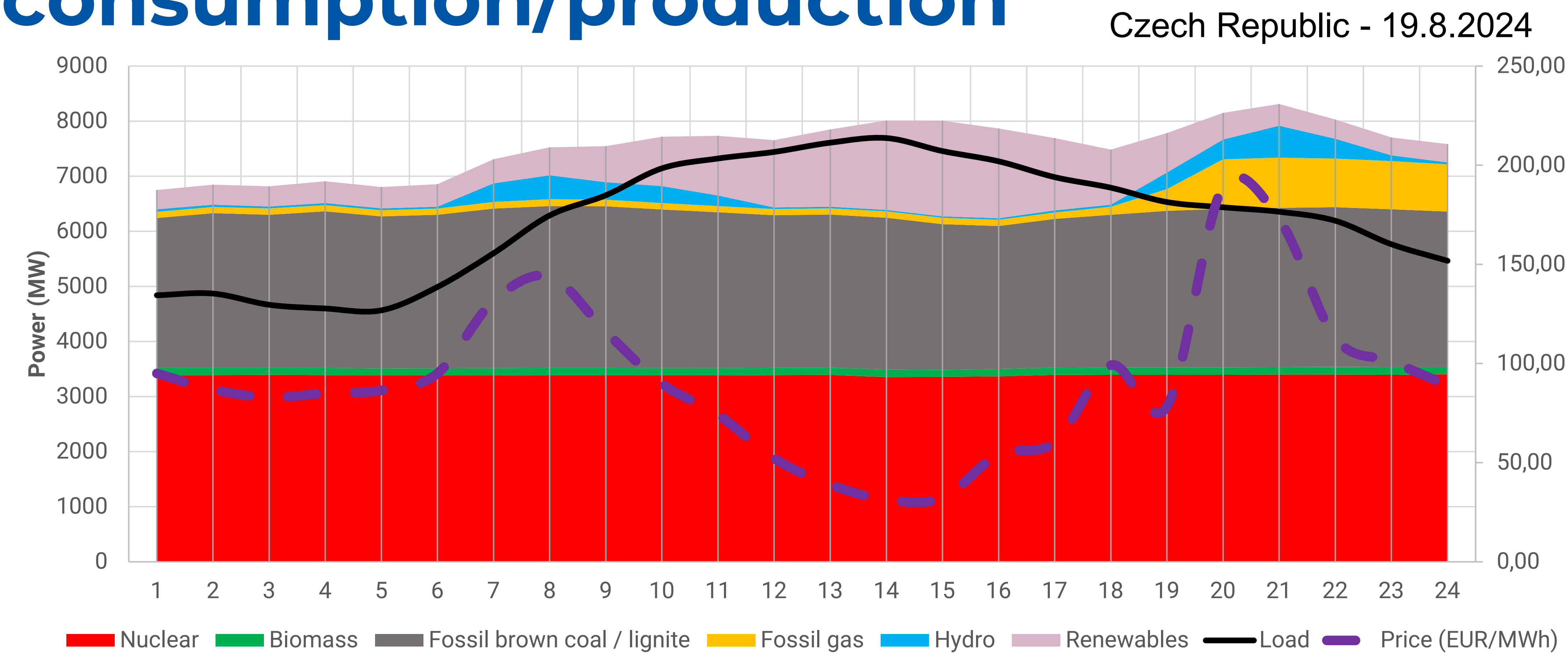
Example - power consumption/production



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https://www.energy-charts.info/

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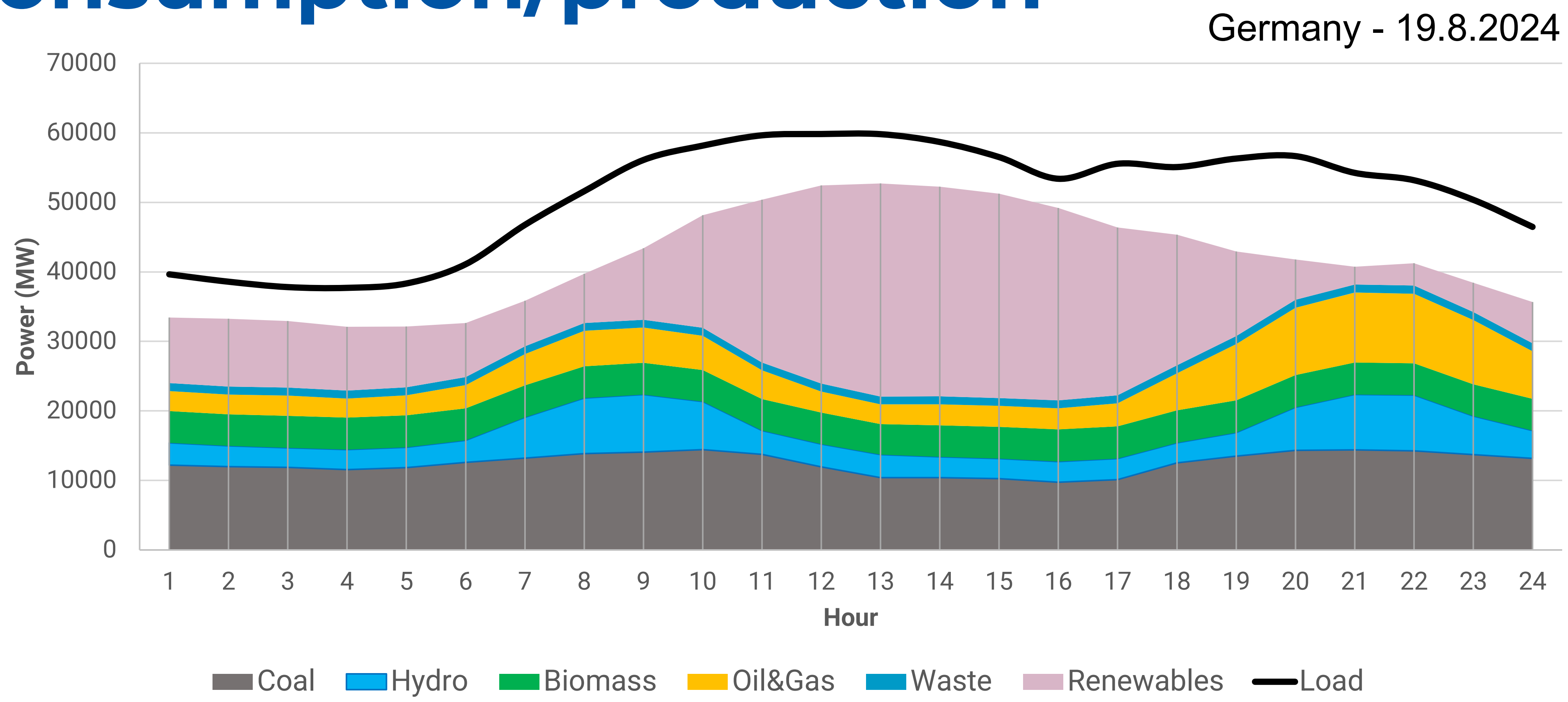
Example - power consumption/production



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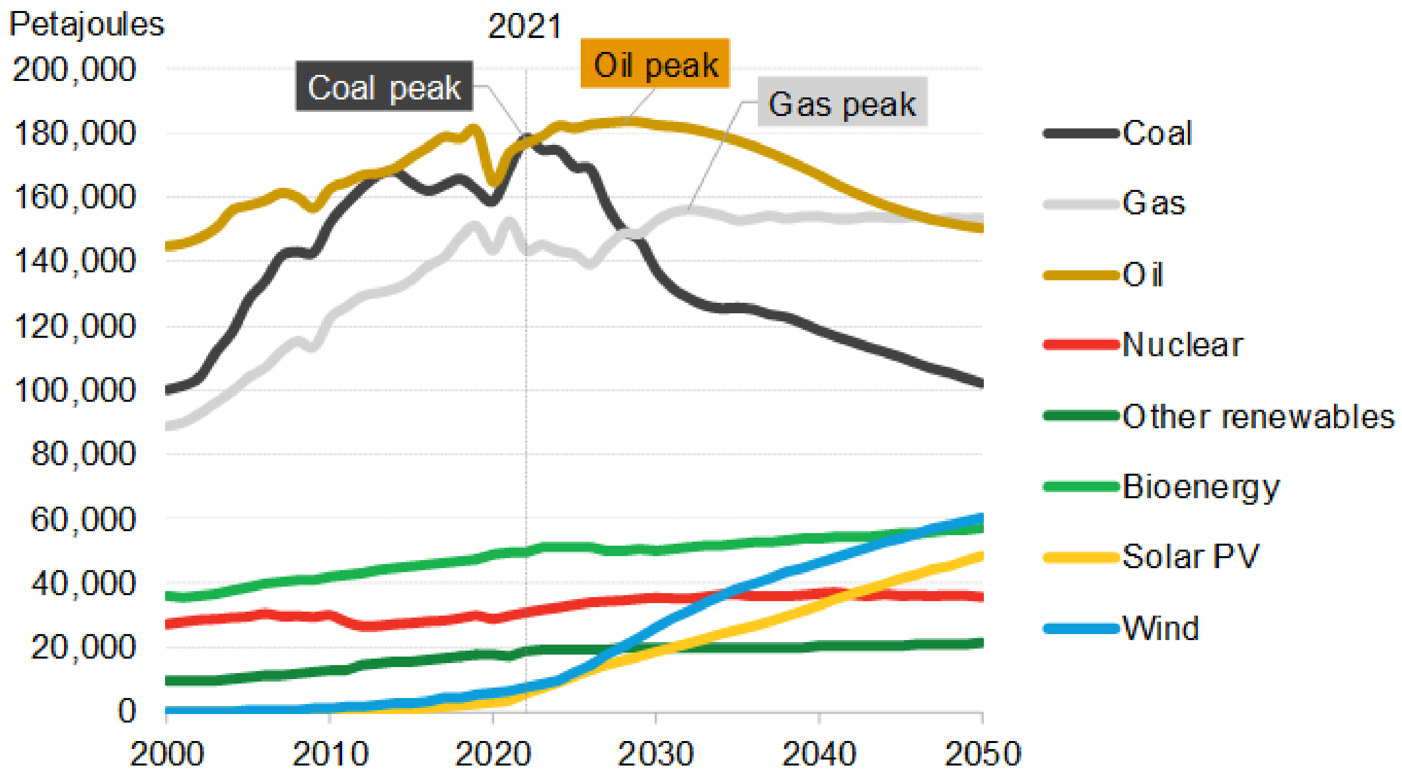
Electricity maps

https://app.electricitymaps.com/map

Identifying the Problem in Energetics

Figure 1: Primary energy consumption by fuel, Economic Transition Scenario



Source: BloombergNEF. Note: 'Other renewables' includes all other non-combustible renewable energy in electricity generation, including hydro, geothermal and solar thermal.

2032 - end of coal in EU

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https://about.bnef.com/blog/new-energy-and-climate-scenario-shows-a-path-to-stay-on-track-for-paris-agreement-goals/ (2022)

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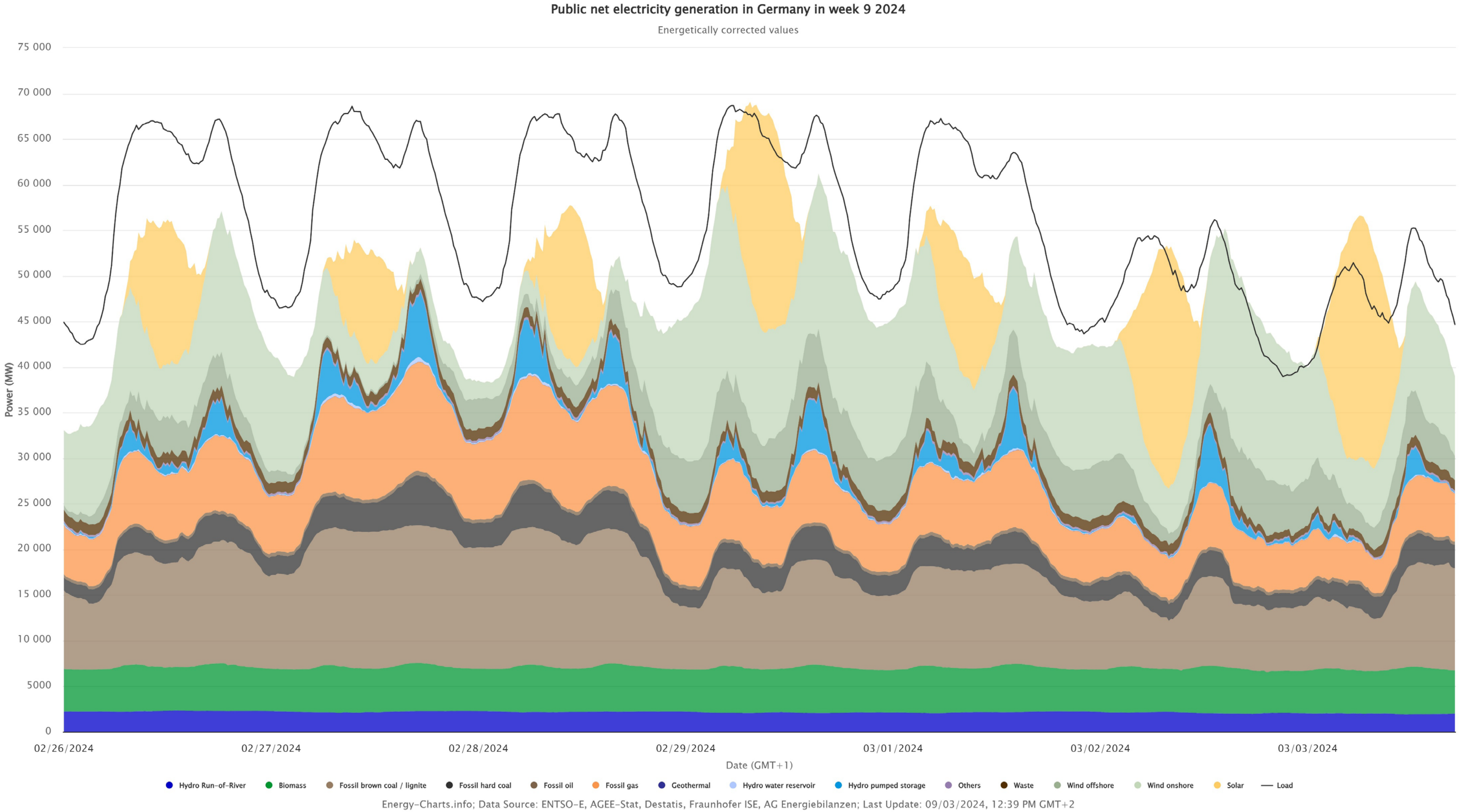
Renewables as primary source - example



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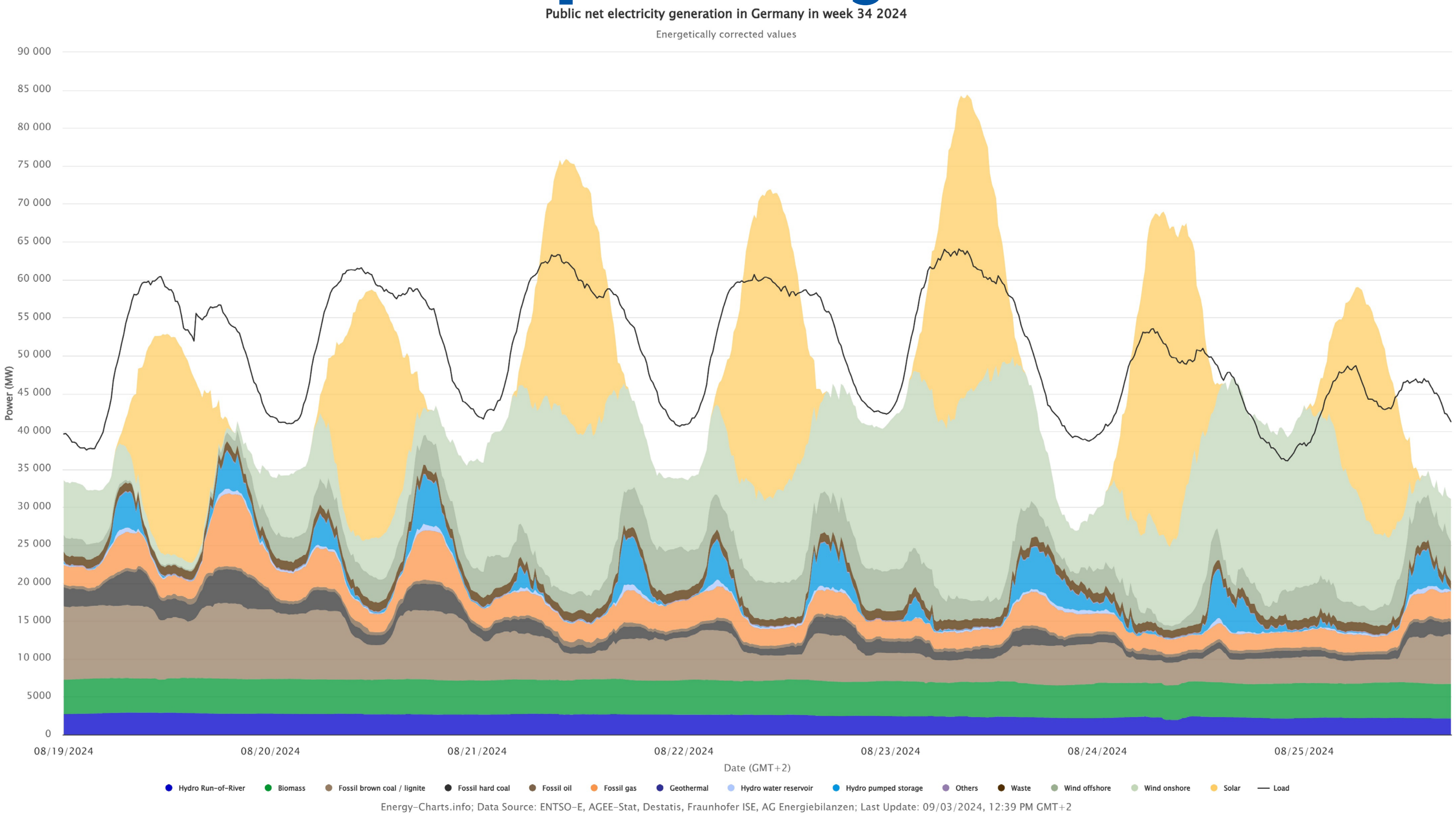
Renewables as primary source - example



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https://www.energy-charts.info/

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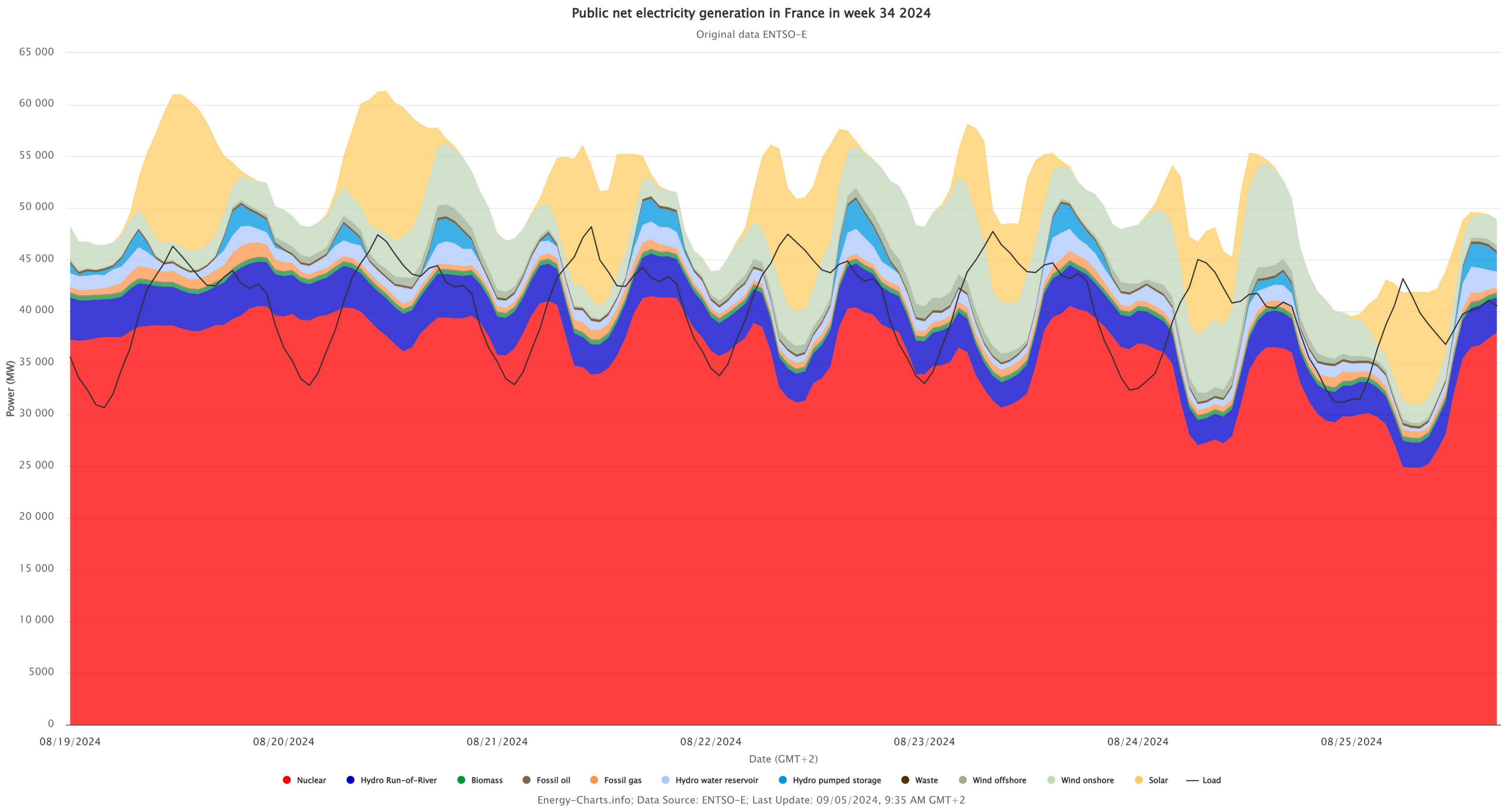
Nuclear as primary source - example



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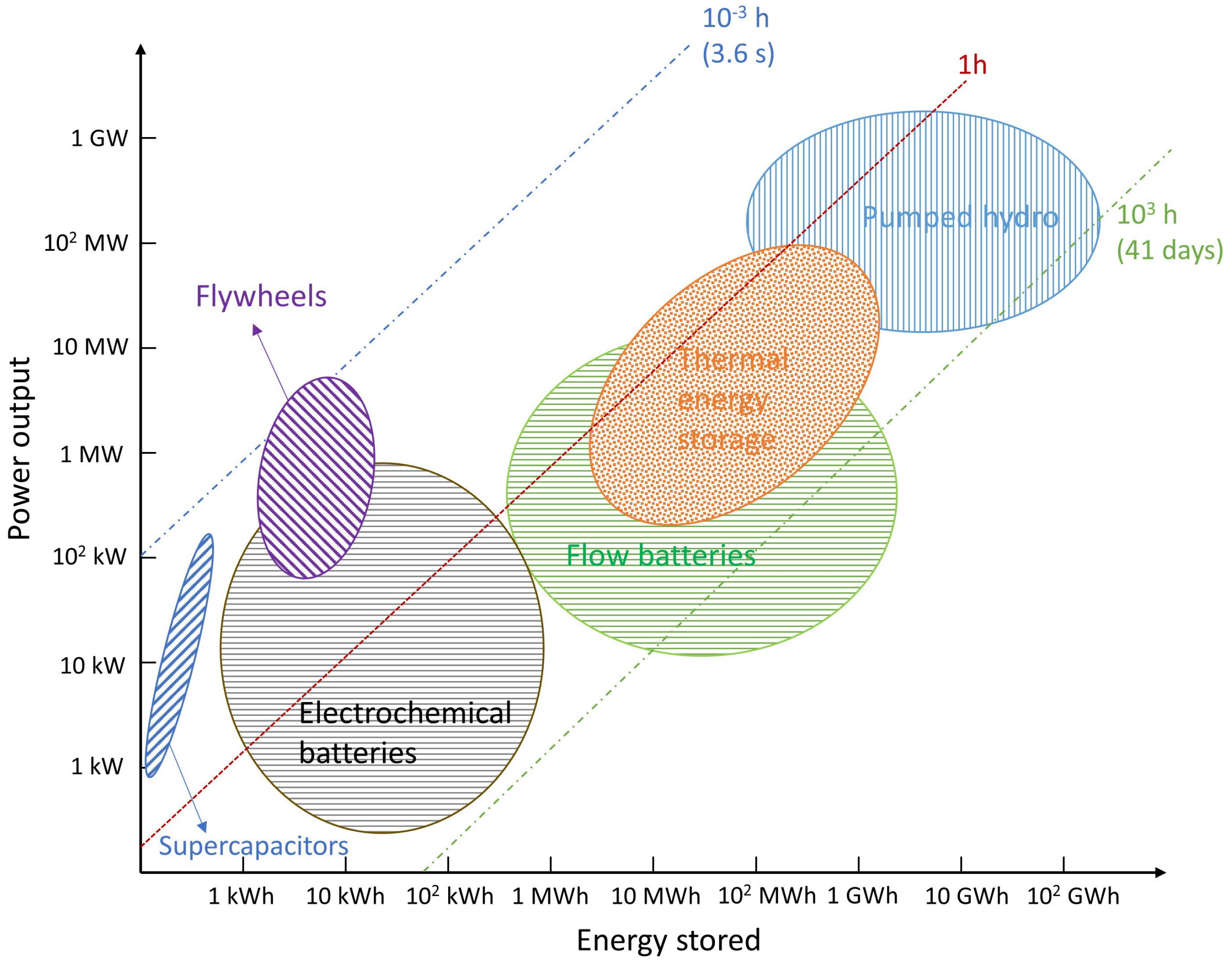
Challenges & Opportunities

- Market for grid stabilization services
- Power production/consumption regulation
- Investment in new infrastructures
- Negative energy prices

Meanwhile in France

Potential solutions>> Energy storage



Based on: Emerging Energy Storage Technologies in Europe. Rapport Frost & Sullivan; 2003

Dlouhé stráně (CZECH R.)

650 MW / 3700 MWh

Andasol TES (Spain)

150MWe / 1125 MWhe

FPL Manatee Energy Storage Center (USA)

409 MW / 900 MWh

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Why TES?

Energy source:

- Electric energy
- CSP
- Industrial waste heat

Heat →

Conversion efficiency (>90%)

Storage:

- Solids
- Liquids
- PCMs

Heat →

Conversion efficiency:

- Electricity (≈40%)
- Heat (>90%)

Discharge:

- Heat to electricity
- Heat to heat

- Realatively cheap storage material and easily scalable
- Not depended on geographical location
- Ideal for day to day accumulation cycles
- Applicable for heat/electricity cogeneragion
- Wide range of applicability (Renewables, fossil, nuclear)

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CSP - concentrated solar power

PCM - Phase change materials

TES - Thermal energy storage

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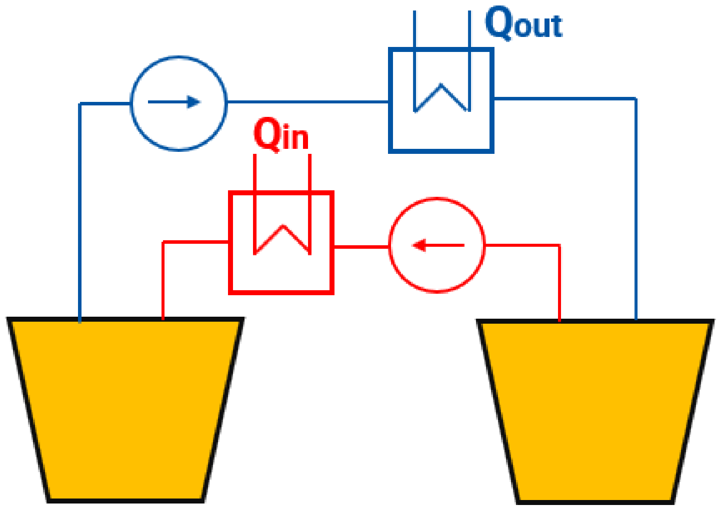
TES - Liquids

- Water, Thermal oils, Molten salts
- **PROS**
  - readily available
  - High TRL level
  - WORKS!
- **CONS**
  - Solidification (270°C*)
  - Thermally stable > 600°C*



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*Solar salt - mixture 60% $NaNO_3$ 40% KNO_3

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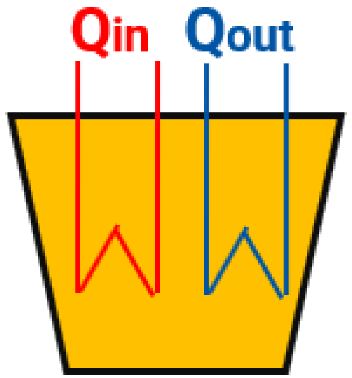
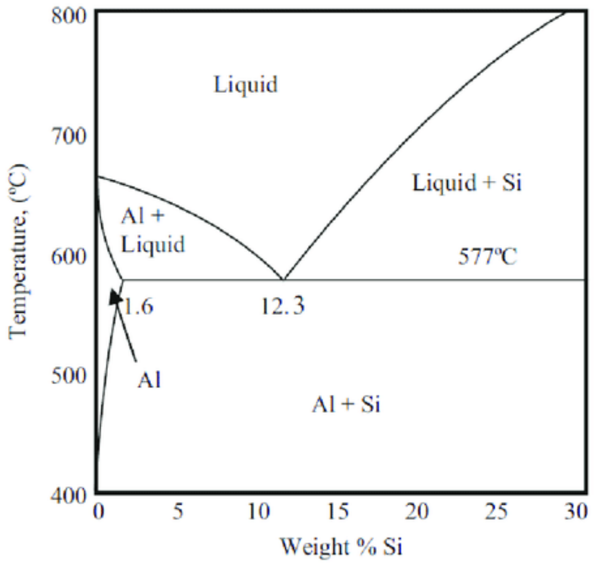
TES - PCM



- Utilizing the latent heat >> constant Temperature
- Metals (AlSi12)

AlSi12 phase diagram



PROS

- Very compact
- Great heat transfer
- Stable output

CONS

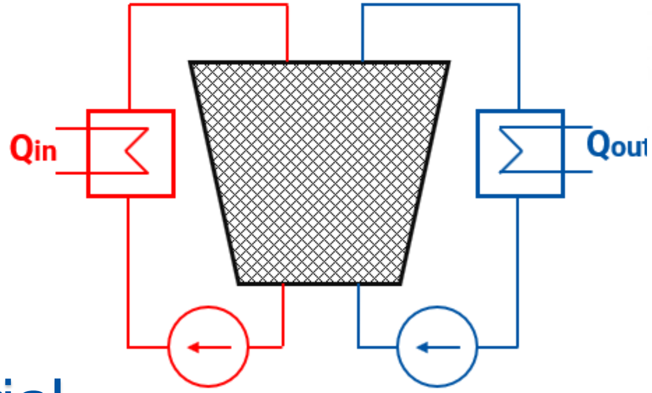
- Problems with corrosion
- Small lifetime

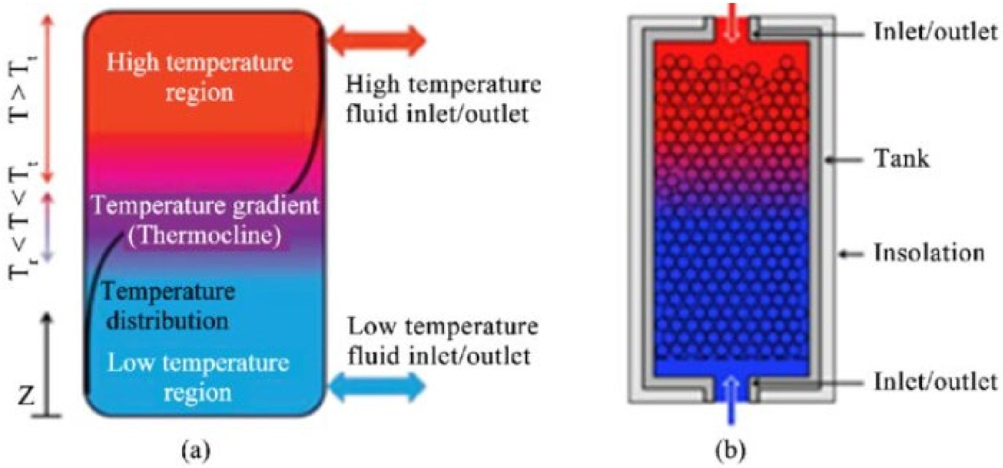
https://www.rechargenews.com/transition/novel-long-duration-energy-storage-system-installed-at-worlds-largest-csp-plant/2-1-768980

PCM - Phase change materials

TES - Solid materials - packed bed, Thermocline

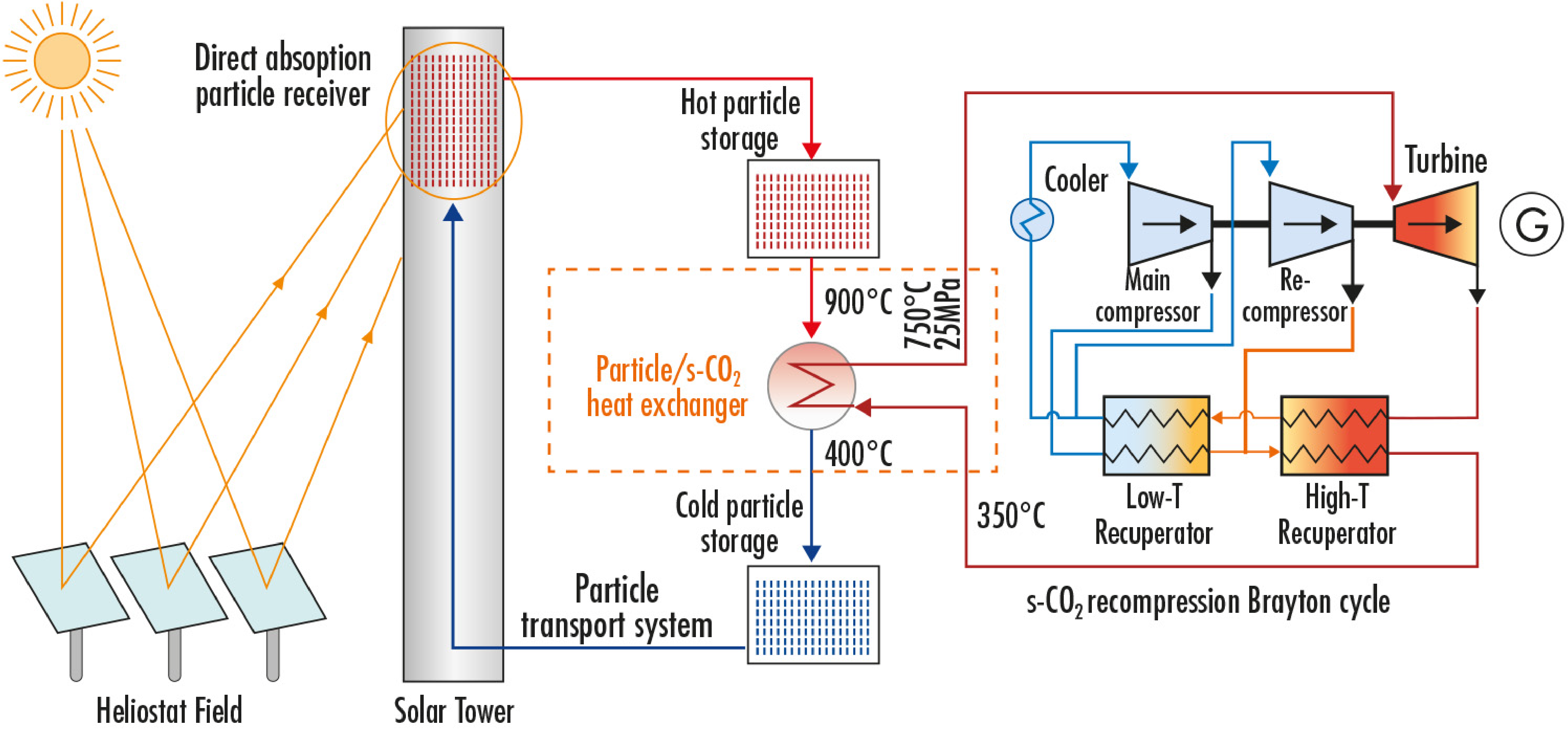
- Stone, sand, blocks
- **PROS**
  - Cheap storage material
- **CONS**
  - Unstable power output
  - Secondary medium to carry the heat





G. Zangahen, A. Pedretti, S.A. Zavattoni, M.C. Barbato, A. Haselbacher A. Steinfeld: Design of a 100 MWhth packed-bed thermal energy storage, Energy Procedia 49 (2014) 1071-1077

Components' and Materials' Performance for Advanced Solar Supercritical CO_2 Powerplants (COMPASsCO2)



This project has received funding from the European Union's Horizon 2020 Research and Innovation Action (RIA) under grant agreement No. **958418.**

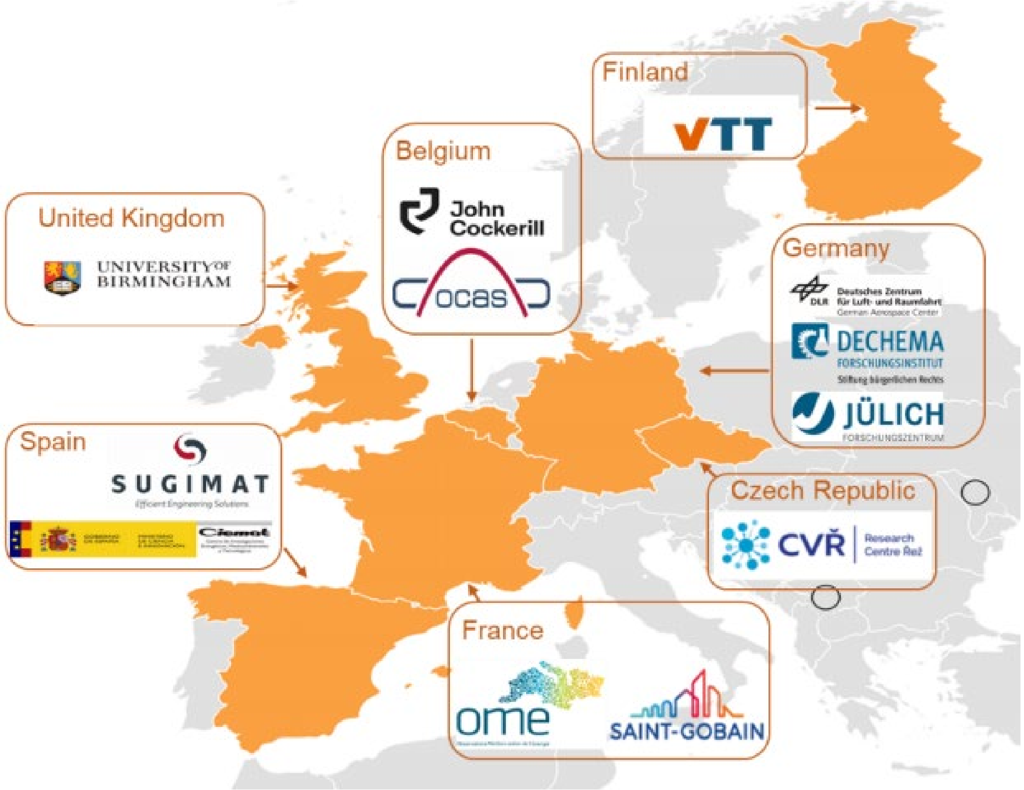
About COMPASsCO2

Funding source	Horizon2020 Topic: Novel high performance materials and components (RIA)
Budget	Approx. 6 Mio. EUR
Duration	52 months (November 2020 – April 2025)
Start TRL	2
End TRL	5

The project focus is to develop new materials for extreme conditions in order to integrate two innovative systems:

CSP plants with particles and sCO2 Brayton power cycles

12 partners from 7 countries



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CSP: concentrated solar power, sCO2: supercritical carbon dioxide

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Project Objectives / Expected Outputs

- Develop highly durable and efficient particles for CSP plants
- Develop optimized structural materials for heat exchanger tubes in contact with particles and sCO2
- Demonstrate material lifetime by measuring and modeling the degradation of the materials
- Design, construct and operate a particle/sCO2 heat exchanger section in order to validate the degradation and heat transfer models
- Evaluate the economic benefits of a CSP-sCO2 plant using the materials and components developed in COMPASsCO2 and compare it with state-of-the-art CSP plants

CVR contribution

WP4 - Evaluation and modelling of metal/medium interaction

- Testing of material degradation in sCO_2 atmosphere
  (P = 25 MPa, T < 550-700°C>)

WP5 - Technology validation

- Design manufacture and test hot particle loop
- Integrate hot particle loop with heat exchanger and sCO2 loop, evaluate performance, corrosion and wear of the components to reach TRL5.

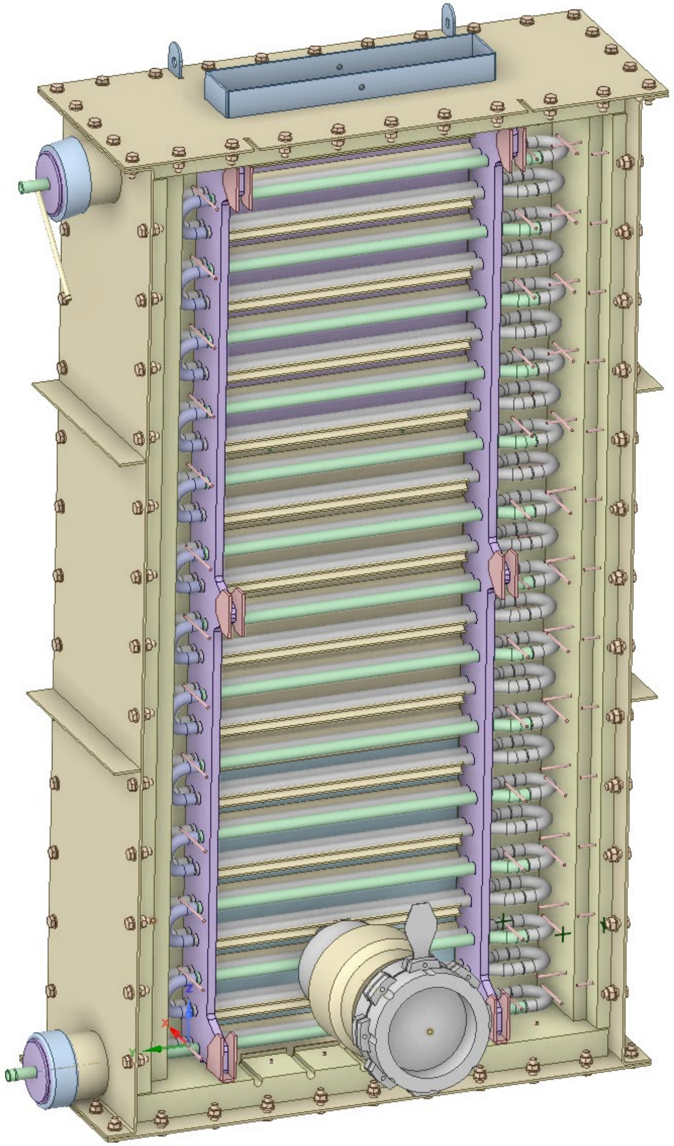
WP5 - Technology validation - HX

Particle/sCO2 heat exchanger

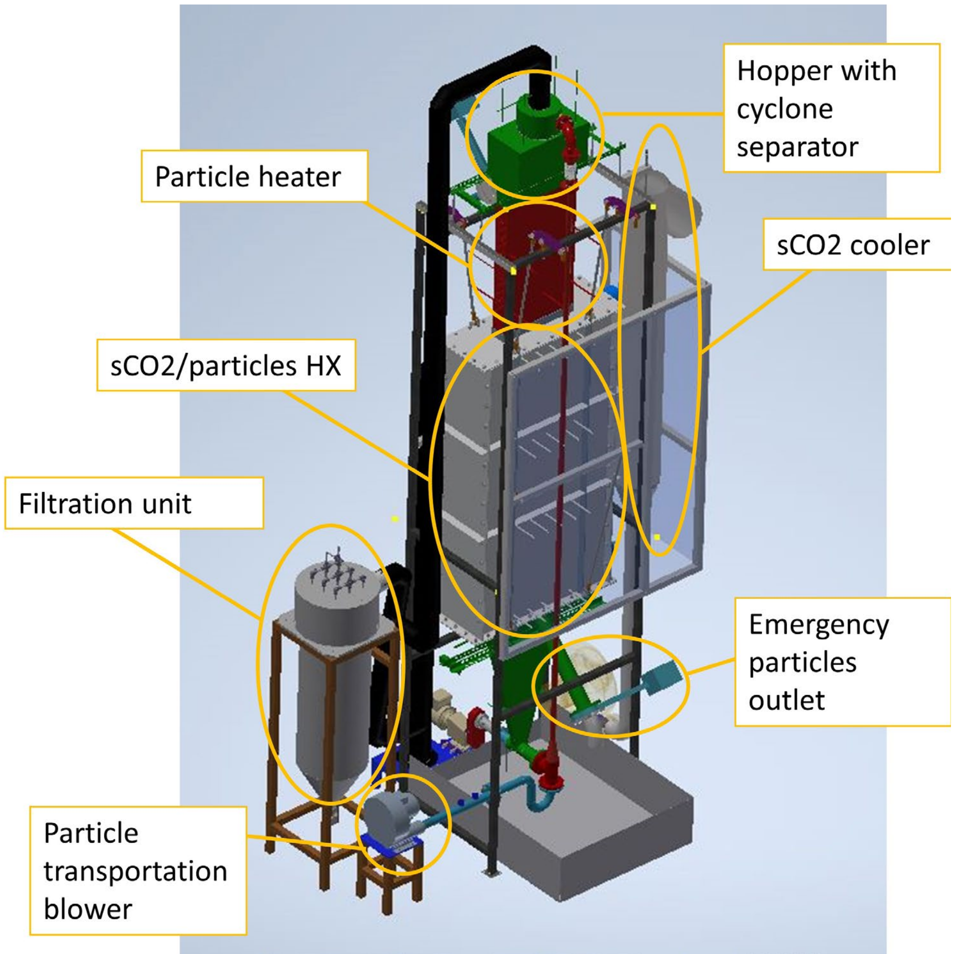
Designed by **JohnCockerill** (Belgium)
Manufactured by **CVR** (CZ)

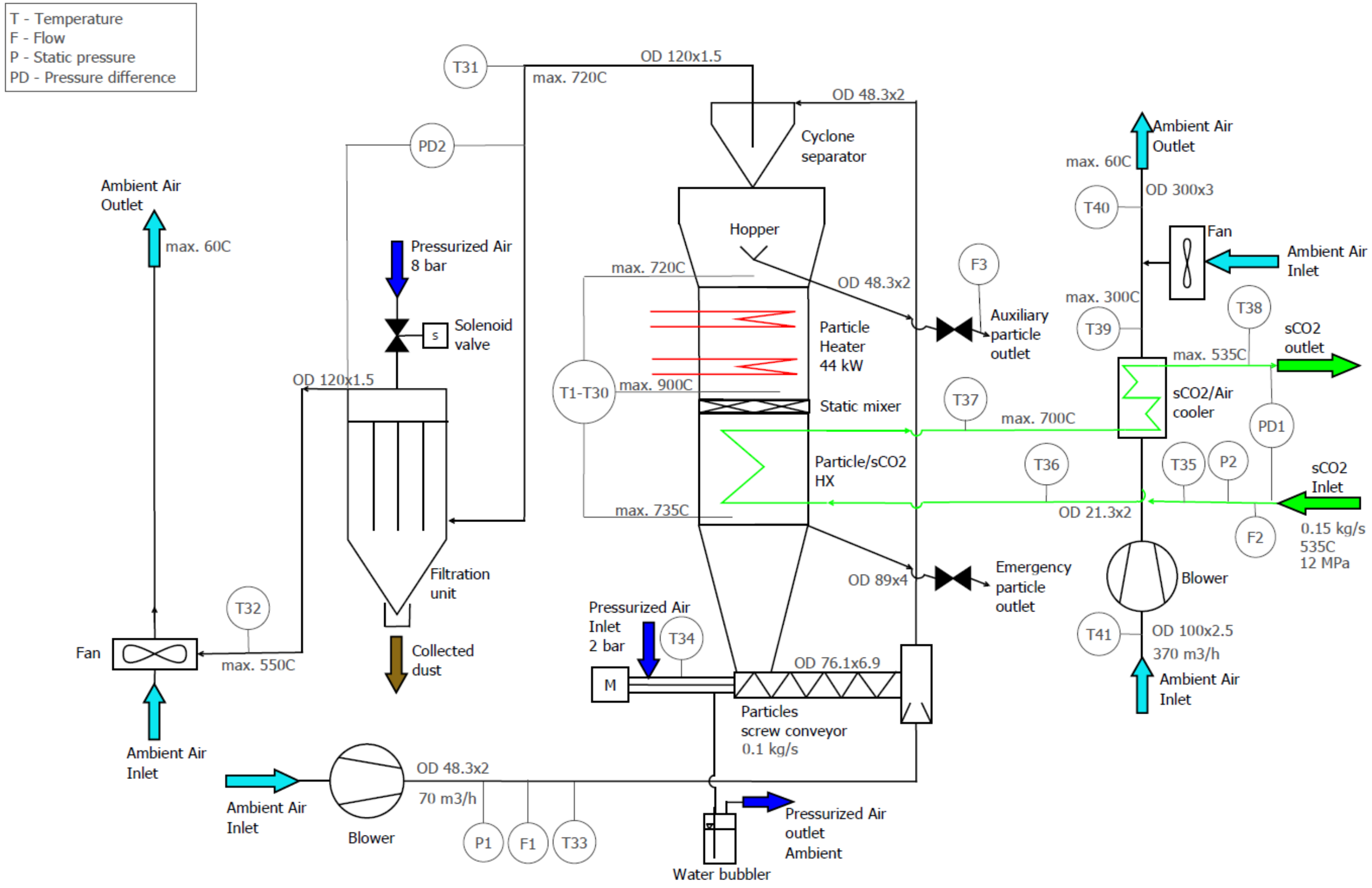
Material: **Inconel625**

Operation pressure:	12MPa
sCO2 inlet temperature:	535°C
sCO2 outlet temperature:	700°C
Particles Inlet temperature:	900 °C
Max. wall temperature:	745°C
Transferred heat:	30kW



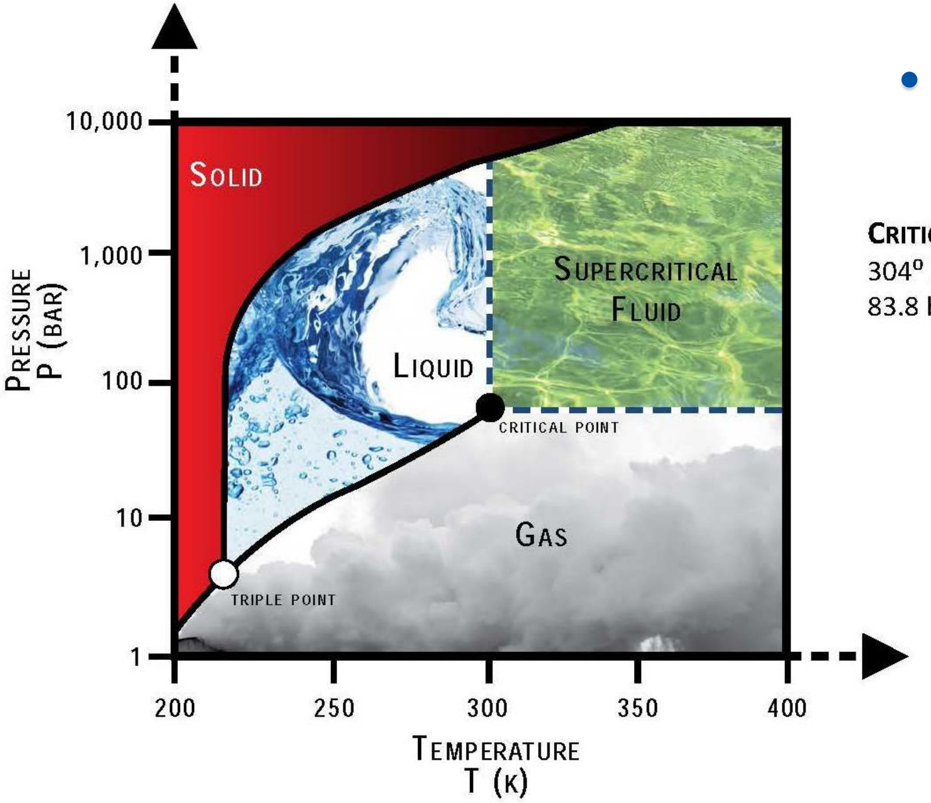
WP5 - Technology validation - HX



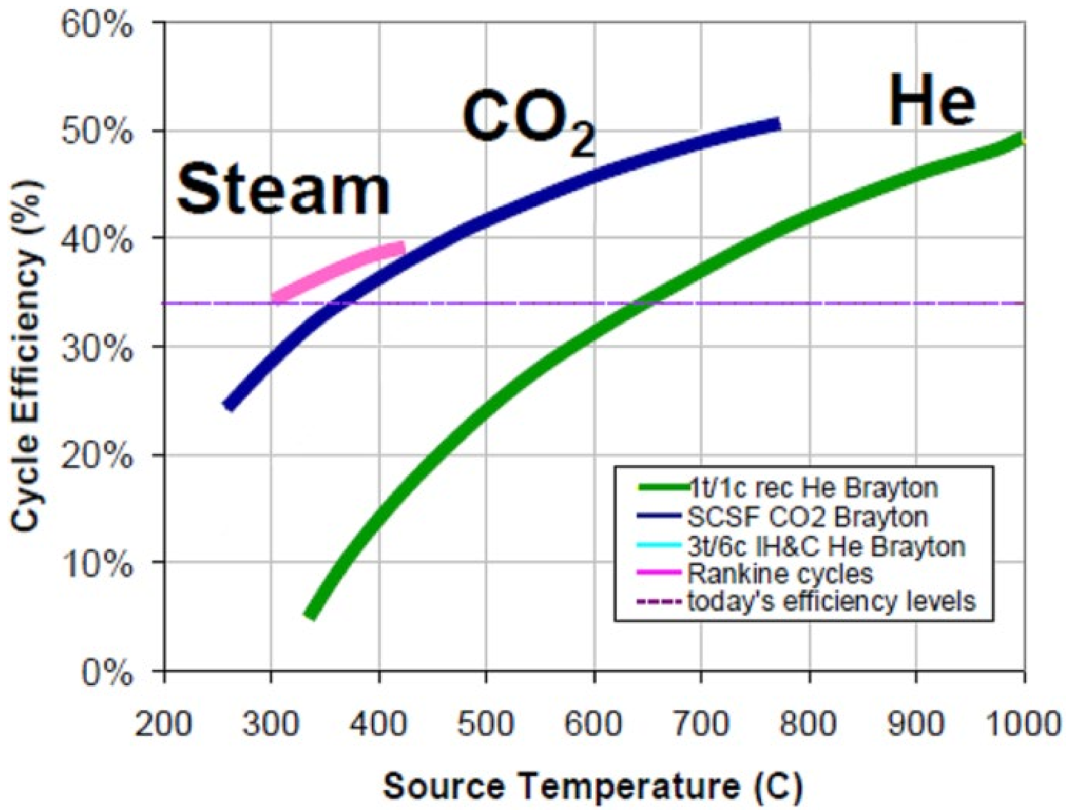


Why sCO2?

- Utilizing closed loop Bryton cycle
- High thermal mass
- No phase change
- Higher cycle efficiency



Critical Point
304° K = 31° C = 88° F
83.8 bar = 8.38 Mpa
= 1,070 psi



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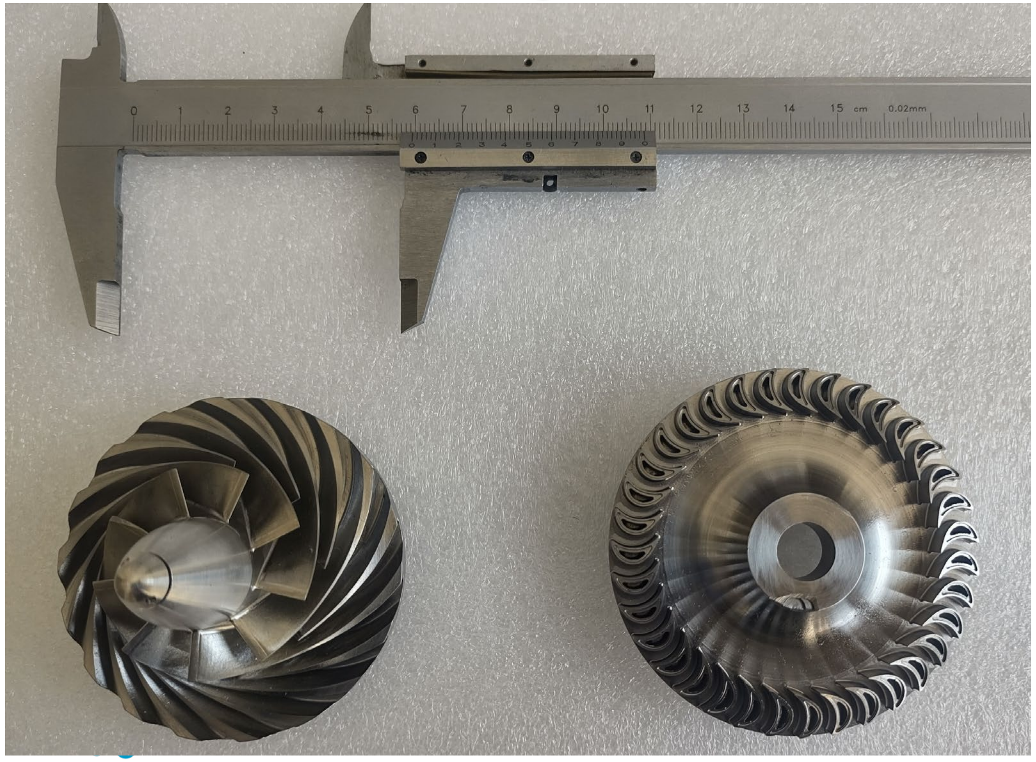
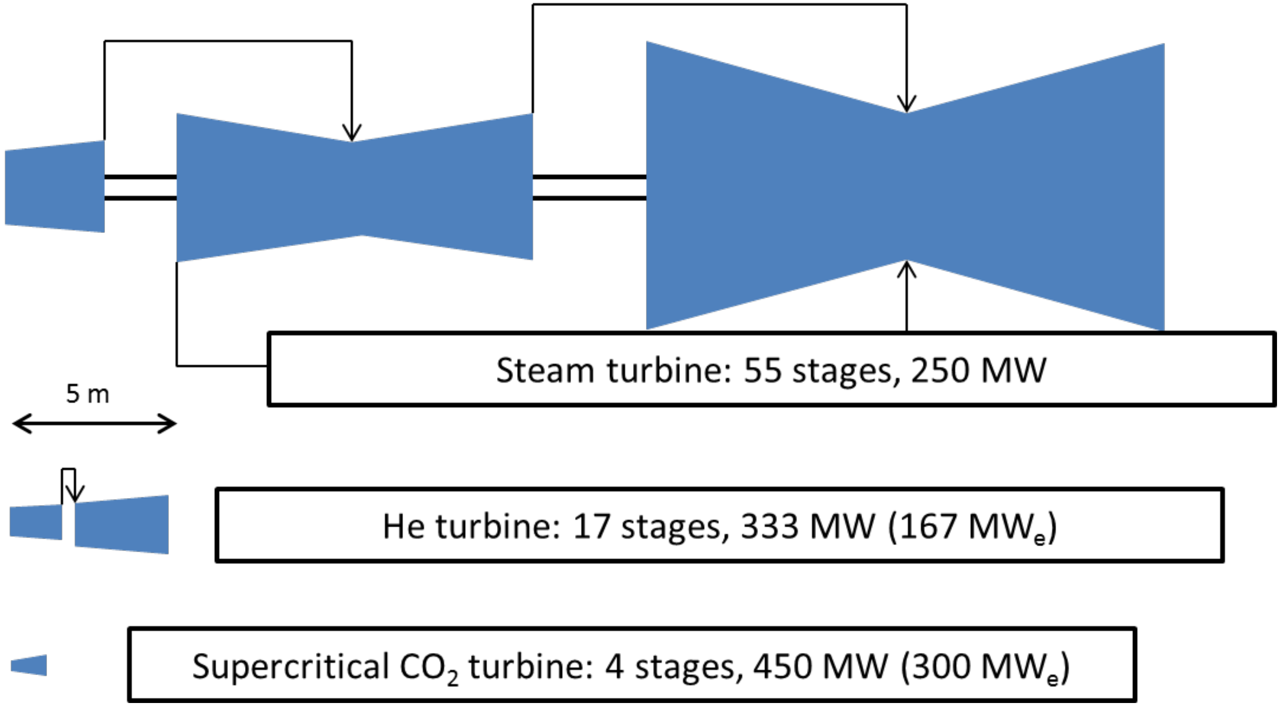
Why sCO2?

- Compact components
  - Turbomachinery
  - Heat exchangers



Compressor + Turbine wheels. Rated power 800kW



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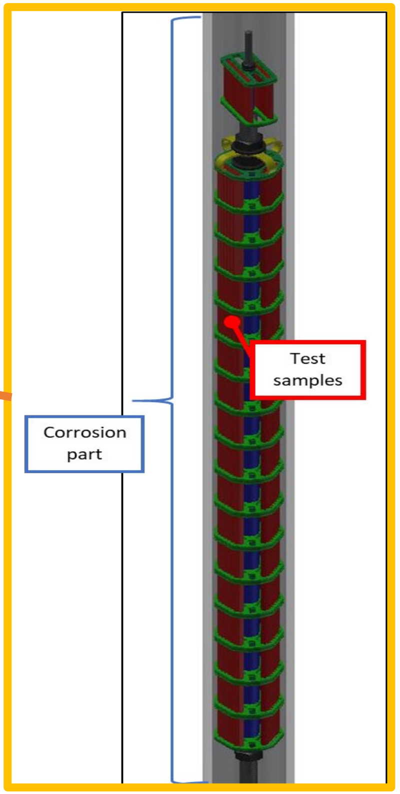
WP4 - Evaluation and modelling of metal/medium interaction

sCO_2 autoclave

P = 25 Mpa

T < 550-700°C>



List of tested materials
Inconel 625
Inconel 740
Haynes 282
Inconel 617
Sanicro25
P92
Sanicro25 with coating- DECHEMA
IN617b with coating - DECHEMA
New materials UoB Cr-based superalloys

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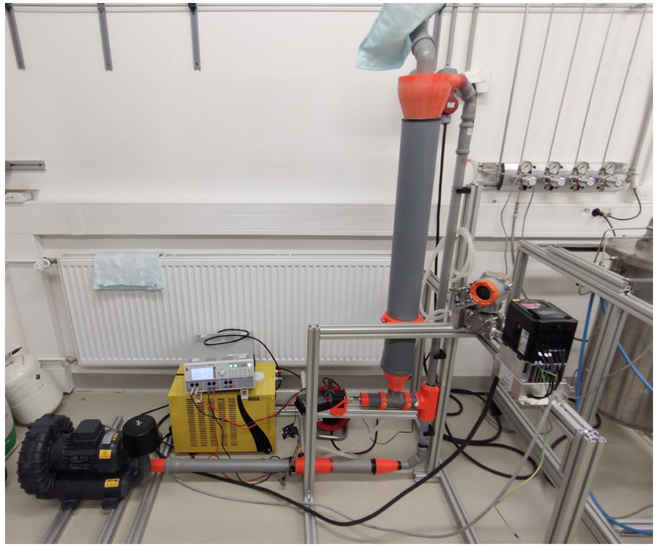
WP5 - Technology validation

Particle Cold flow pretest

Particle Air transportation system 1.st iteration



Particle Air transportation system 2.nd iteration

Particle Cold-flow

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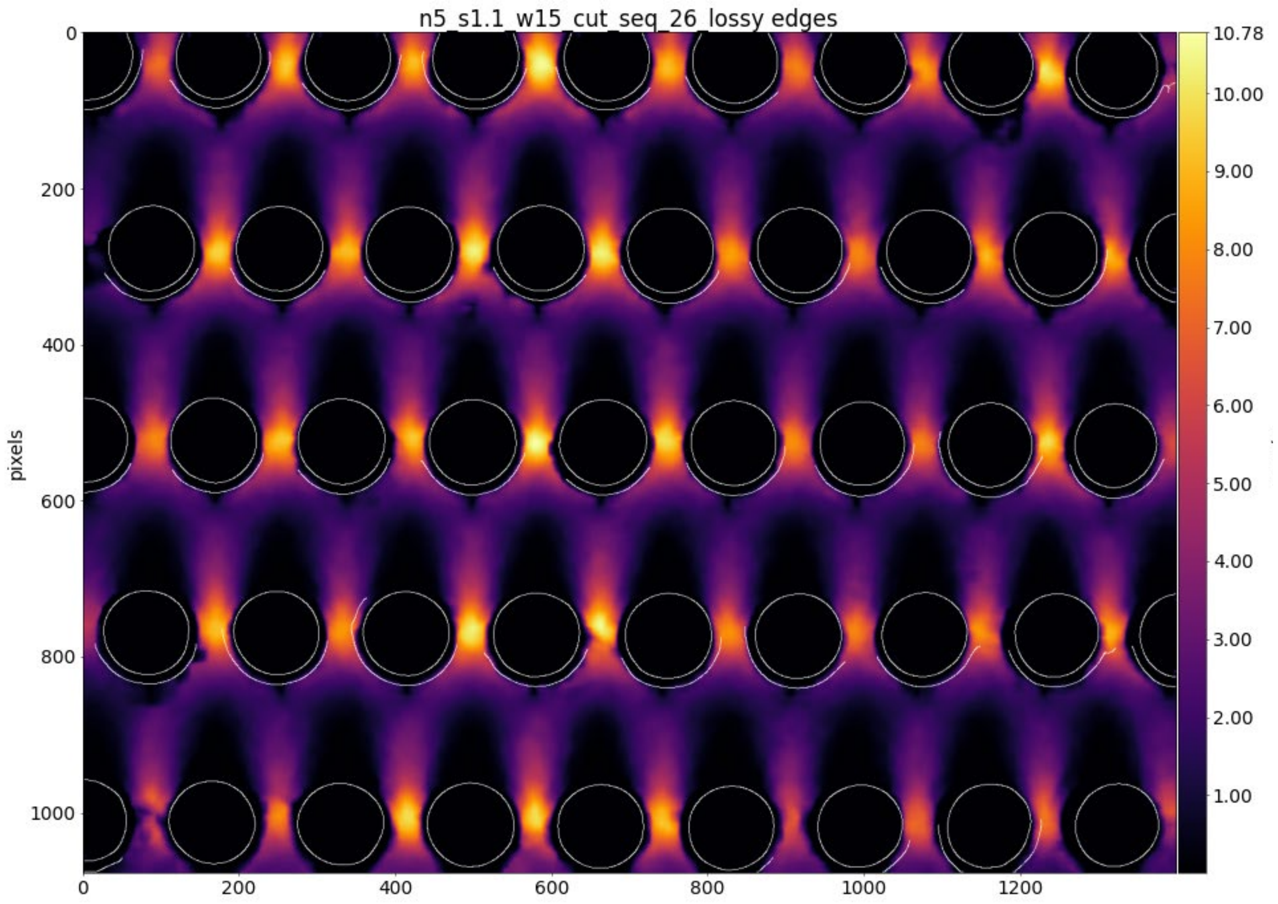
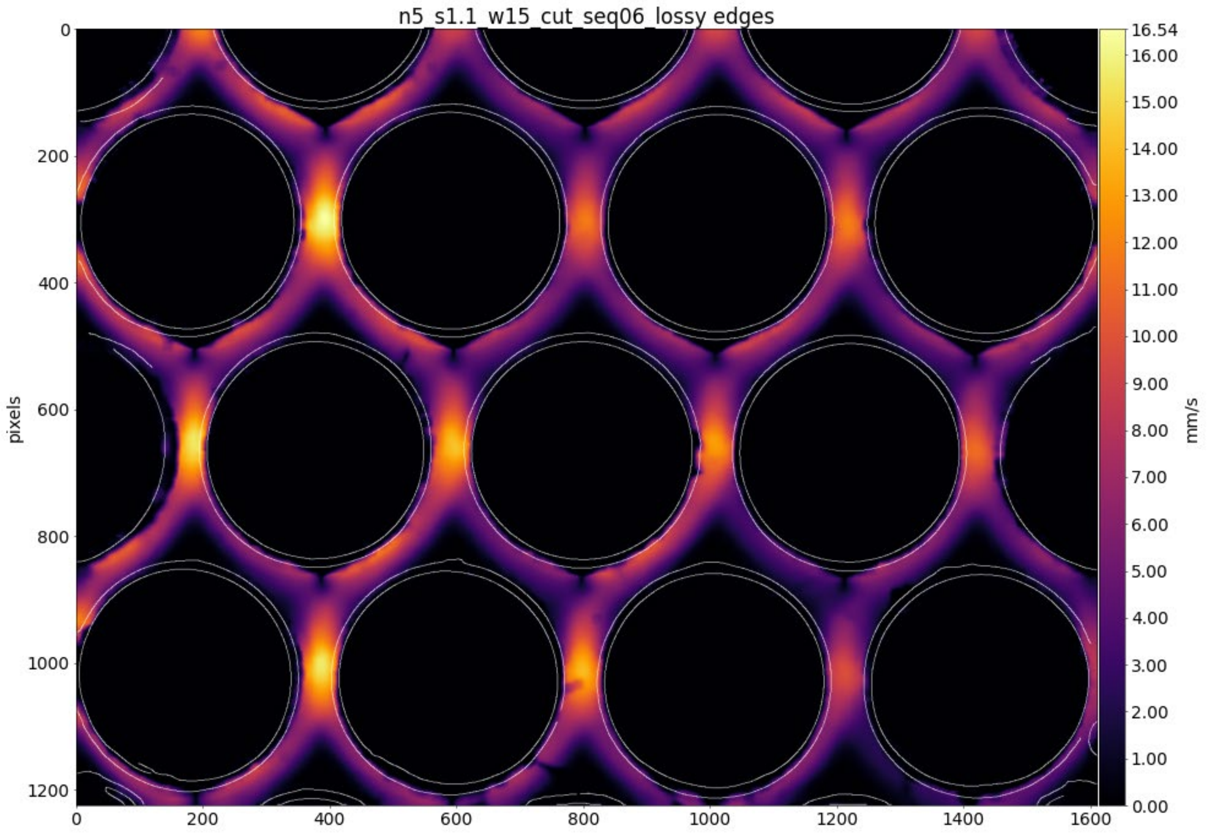
WP5 Results - cold flow PIV





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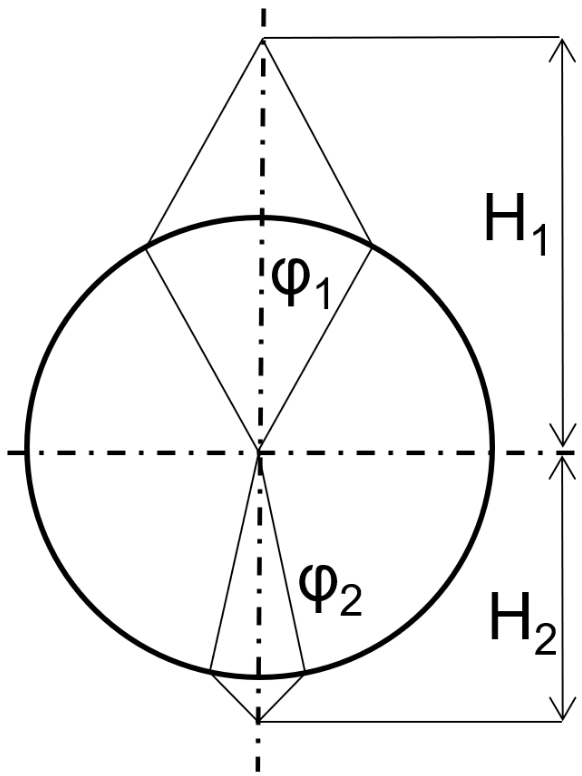
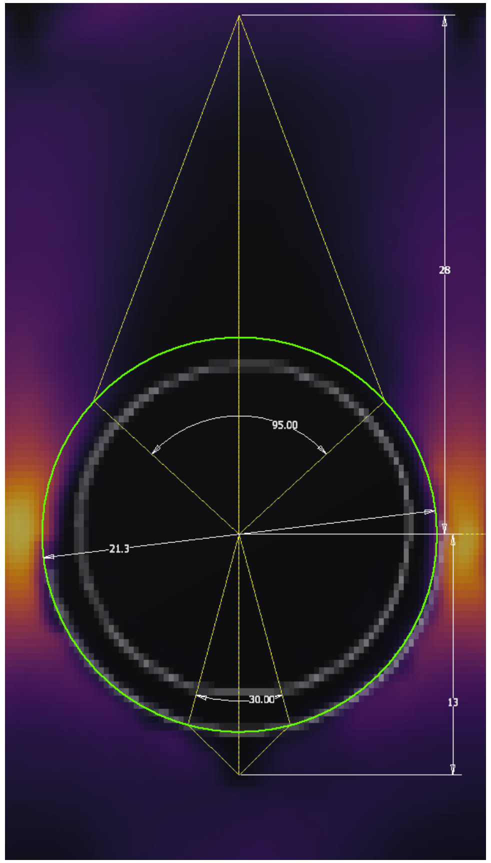
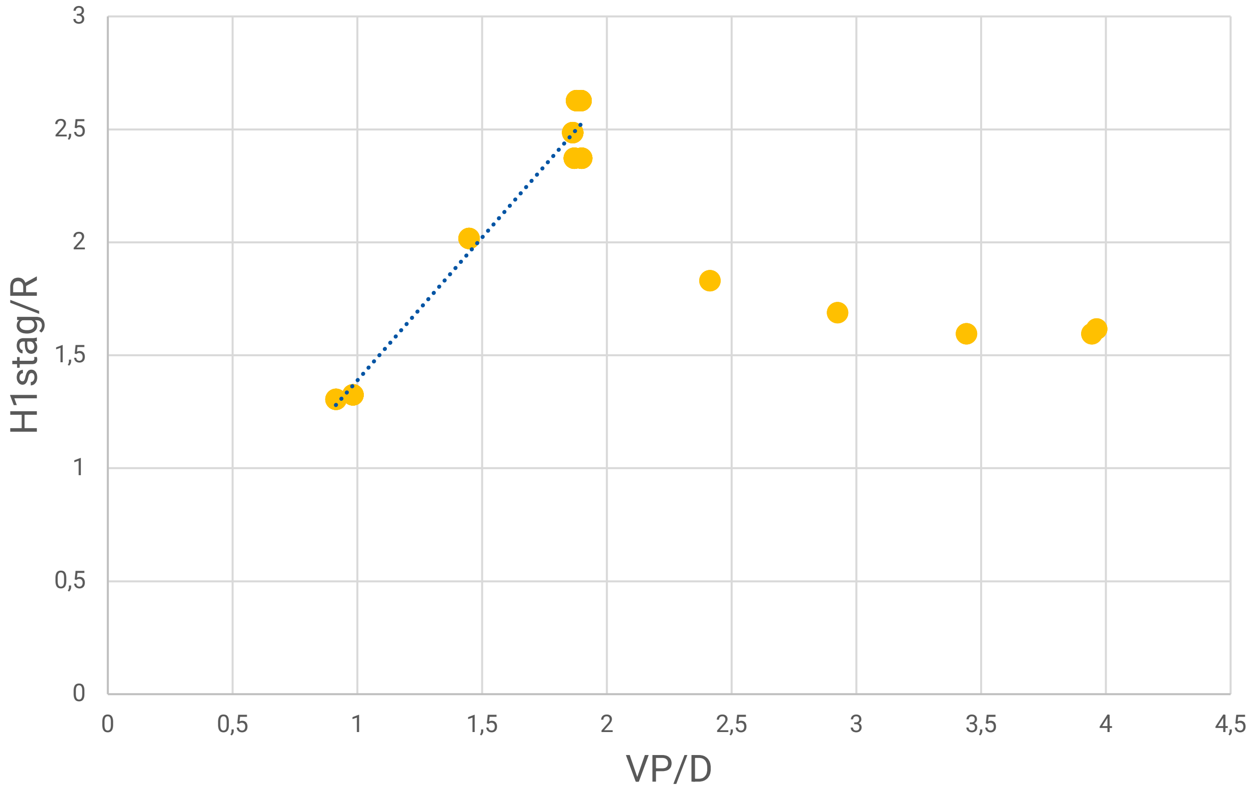
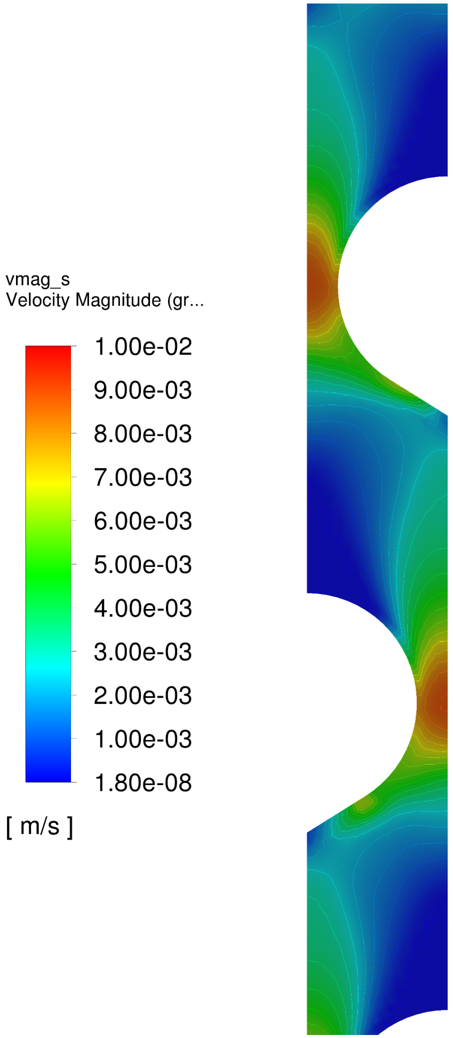
WP5 Results - cold flow

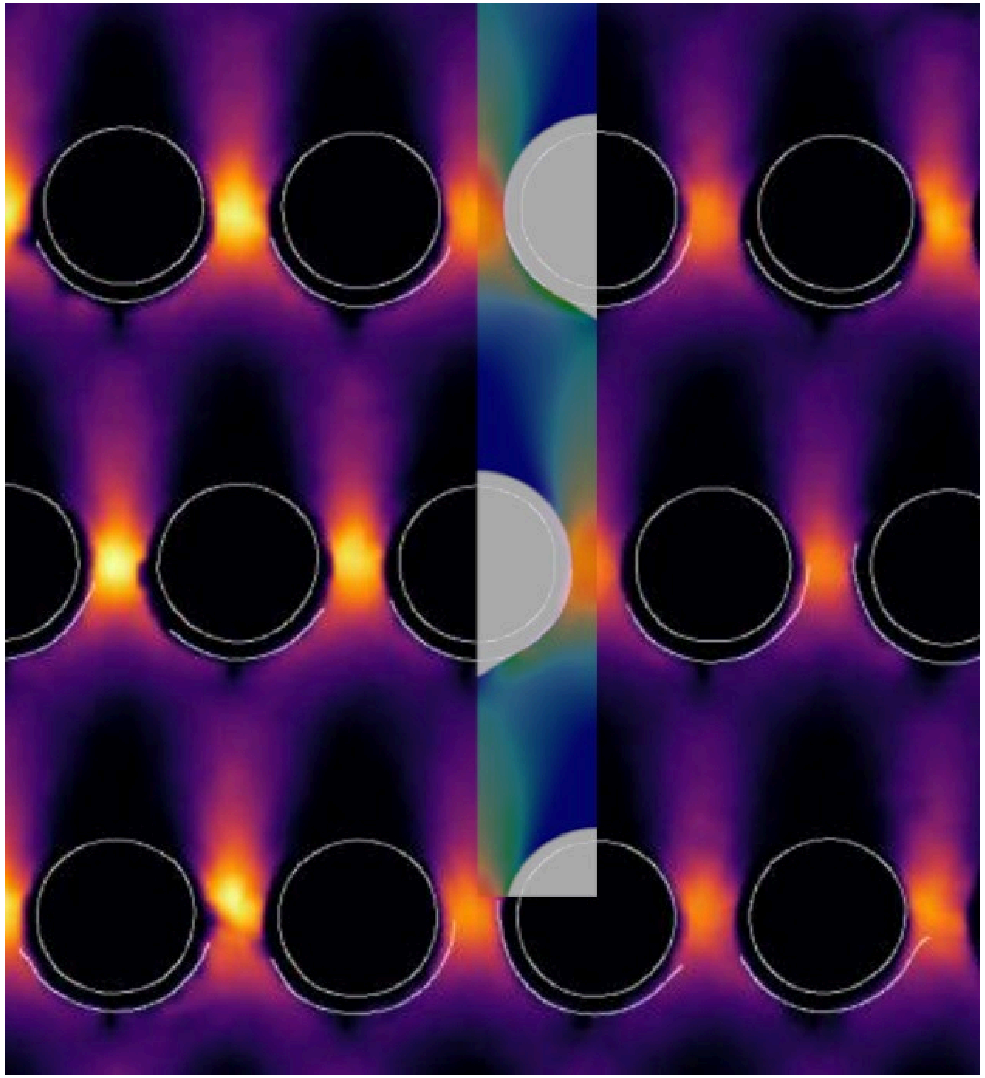






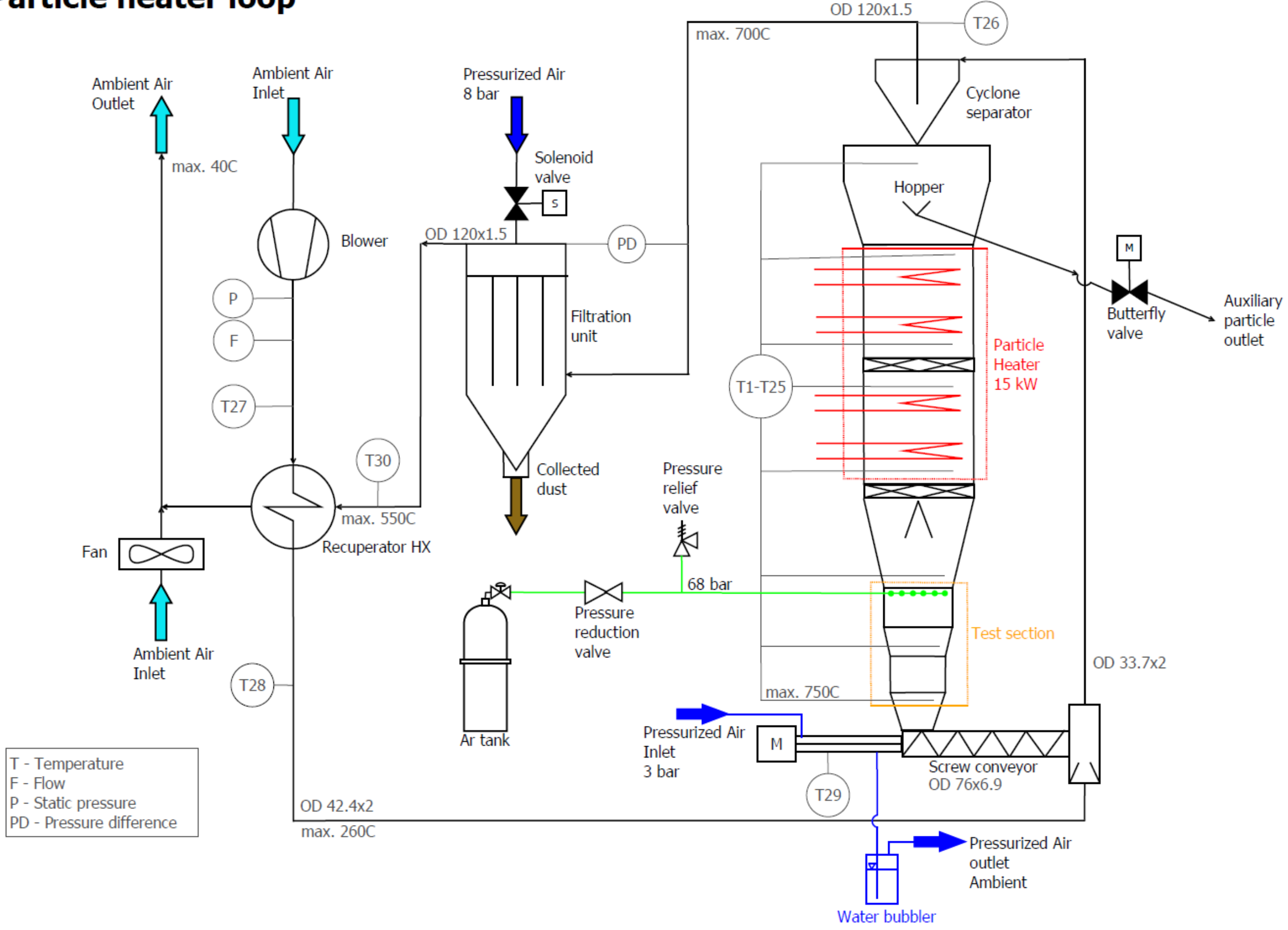
WP5 Results - CFD validation



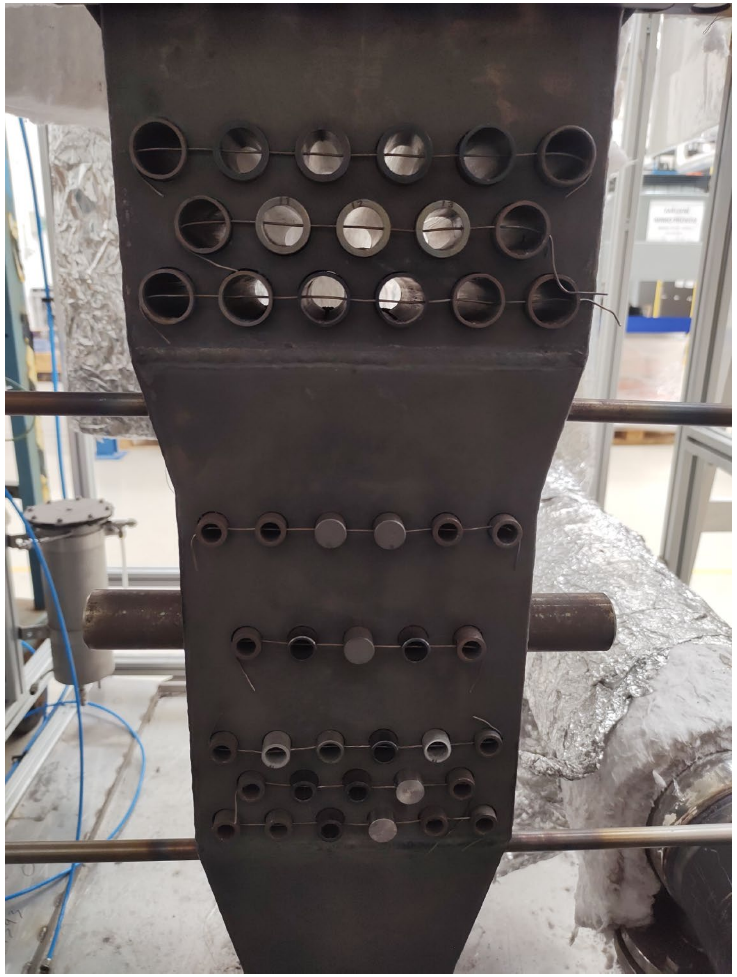


WP5 - Technology validation

Particle heater loop



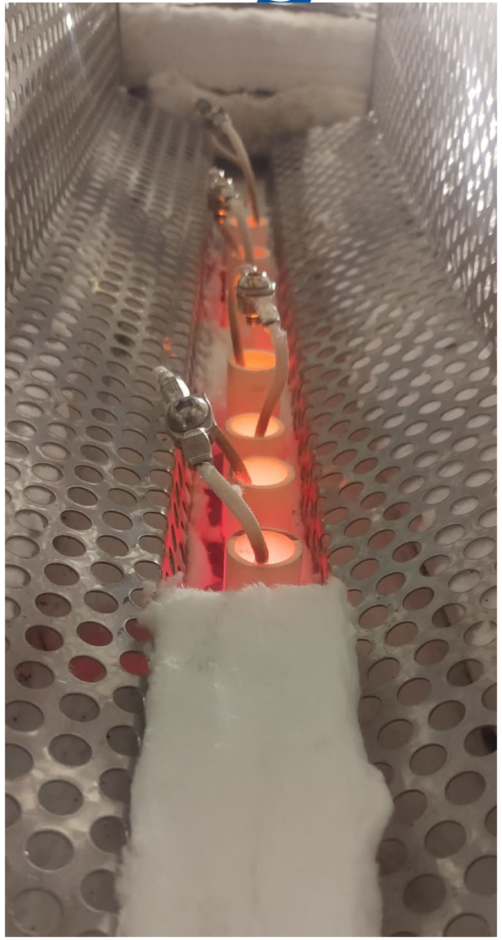
WP5 - Technology validation



Particle heater loop - Test section

- 28 slots - ø13.7
- 22+6 slots - ø21.3
- Particle temperature 750°C
- Particles velocity up to v_0=5mm/s

Challanges



Particle heater

Knee bend - abrasion

Wrap up

- Principles in energetics
  - production/consumption, problems
- Thermal energy storage
  - basic concepts, pros/cons
- COMPASsCO2
  - Project, Introduction, activities, challenges

Q&A