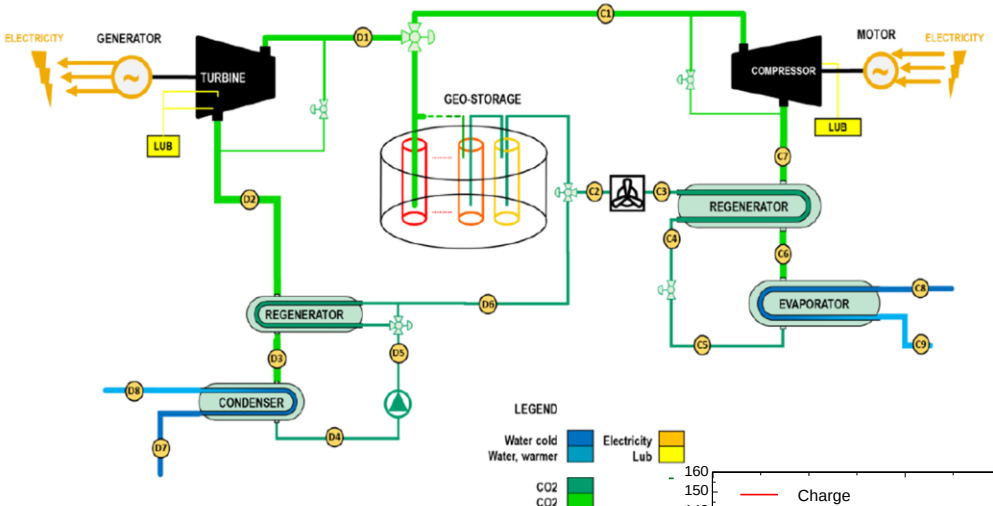
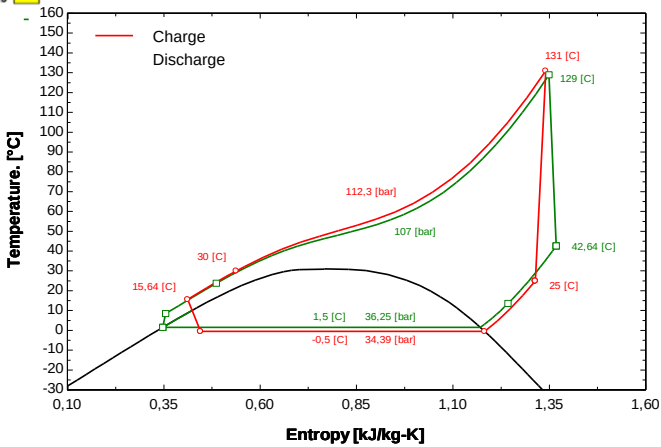




EXPERIMENTAL STUDY OF SUPERCRITICAL CO2 HEAT TRANSFER IN A THERMO-ELECTRIC ENERGY STORAGE BASED ON RANKINE AND HEAT-PUMP CYCLES

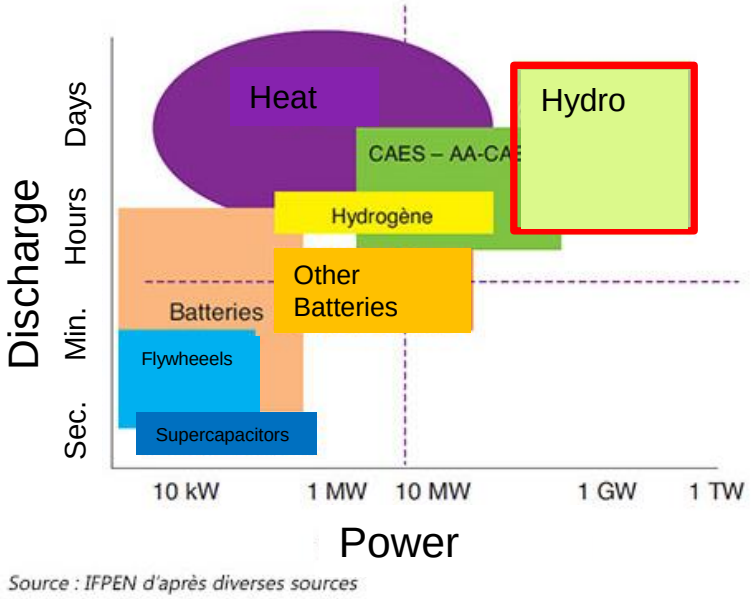
IV International Seminar on ORC Power Systems, ORC2017| **N. Tauveron**[a], E. Macchi[b], D. Nguyen[c], T. Tartière[d]

a :CEA, LITEN – DTBH/SBRT/LS2T, 17 rue des Martyrs Grenoble, 38054, France.
b :IMFT, Université de Toulouse, 2 Allée du Professeur Camille Soula, 31400 Toulouse, France .
c :BRGM Languedoc-Roussillon, 1039 rue de Pinville, 34000 Montpellier, France
d :Enertime, 1 rue du Moulin des Bruyères Courbevoie, 92400, France.

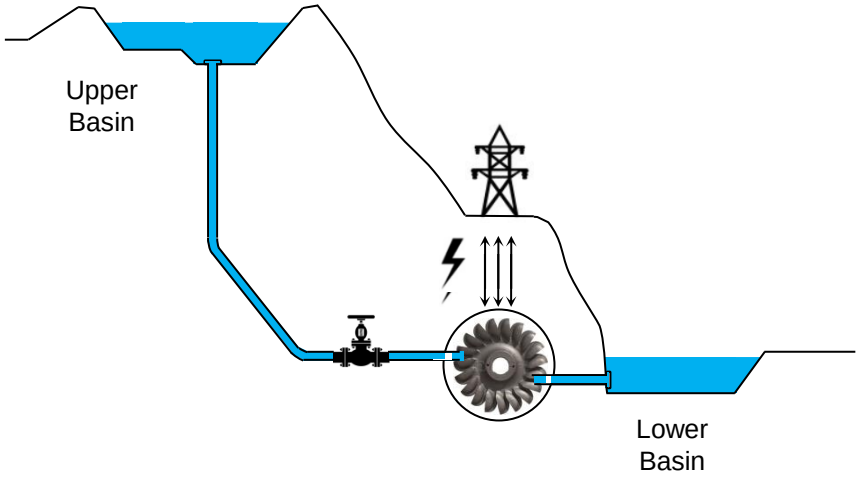
SCOPE OF THE PRESENTATION

- State of the art
- ANR-SELECO2 Concept & Parametric Thermodynamic Simulations
- Experimental set-up of hot storage underground heat exchangers
- Results
- Conclusion

Electricity storage: State of the art (1)

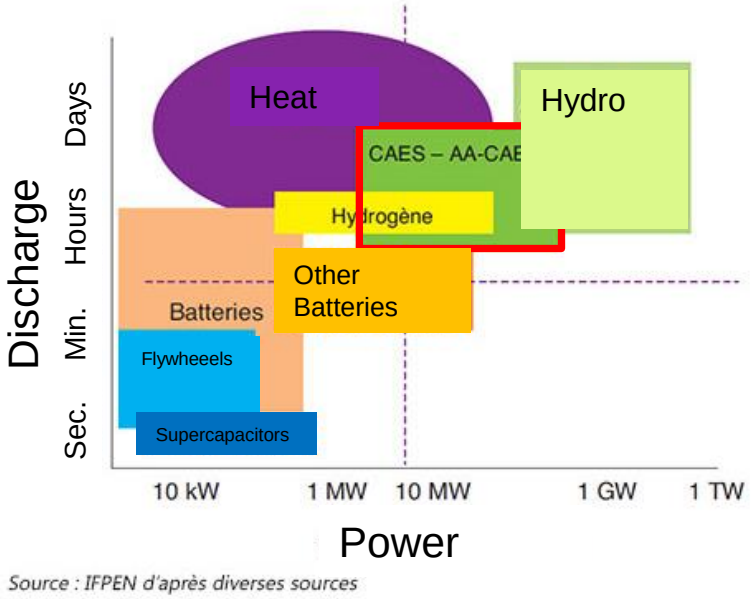


Source : IFPEN d'après diverses sources



Maturity	**Mature (< 1890's)**
Deploiement	200 sites (140 GW)
Efficiency	> 80%
Scale	500 MW – 3 GW // 1 – 100 GWh
Discharge	Few hours – Few days
Expected Life	40 ans

Electricity storage: State of the art (2)



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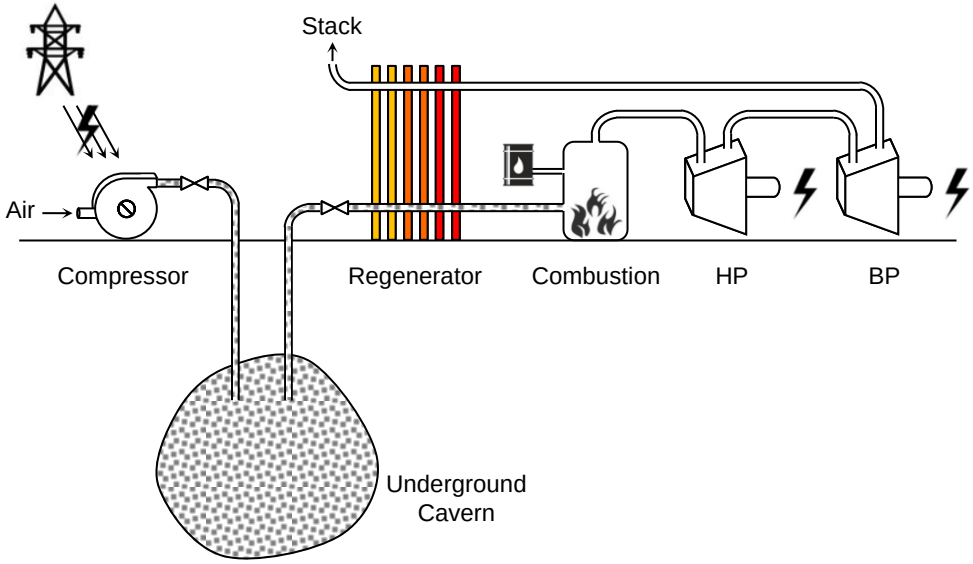
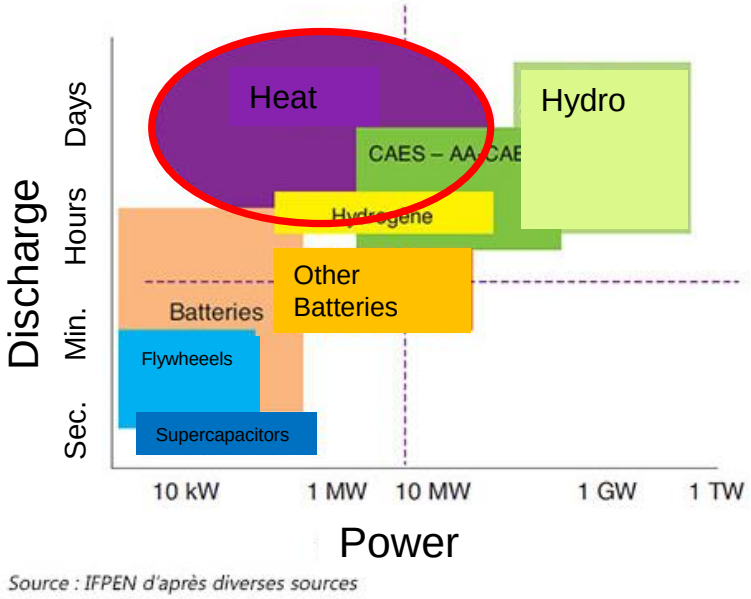


Maturity	**Commercialised**
Deploiement	2 sites (USA) { 290 MW – 2h / 110 MW – 26h > 12 projects
Efficiency	~ 55%
Scale	10 – 400 MW // 0,5 – 20 GWh
Discharge	1 – 26 hours
Expected Life	30 ans

Electricity storage: State of the art (3)



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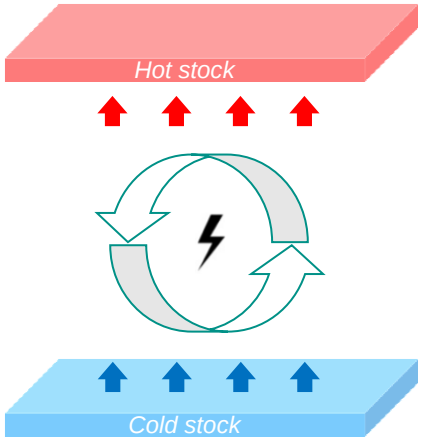

Maturity	**Several R&D projects** Various fluids and cycles (Ar, CO_2, …)
Deploiement	No installed capacity
Efficiency	> 40%
Scale	< 100 MW
Discharge	Few hours – Few days
Expected Life	25 ans

SCOPE OF THE PRESENTATION

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ANR Project – SELECO$_2$

SeleCO2 project

seleco2.free.fr

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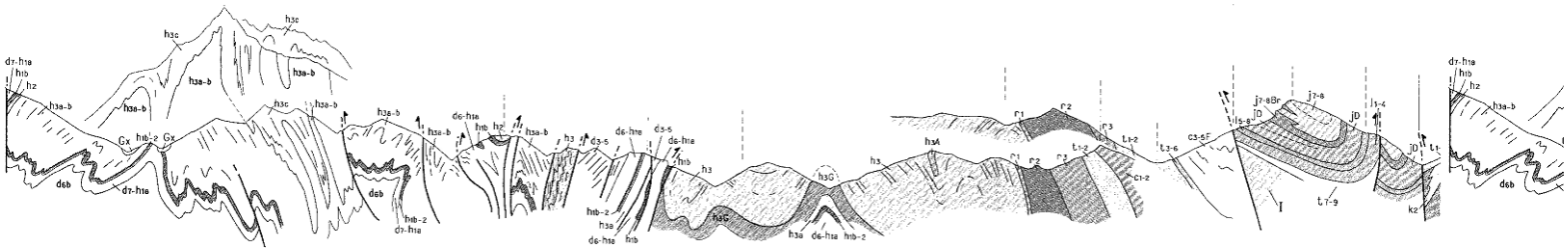
(Updated July 2017)

SeleCO2 research project

Large-scale electricity storage by "Ground storage + Ice storage" thermal doublet & CO2 as working fluid



Summary of SeleCO2 project

Context of the project

Scientific objectives and technological challenges

Concept history background

Project main events

Publications & patents

Contacts for the project

CFD modeling of the geothermal exchanger

Thermodynamic modeling of SeleCO2 process

Thermal modeling of the ground storage

Ice storage modeling

Modeling thermodynamic machines

Geomechanical modeling of the ground storage

Experimental project bench

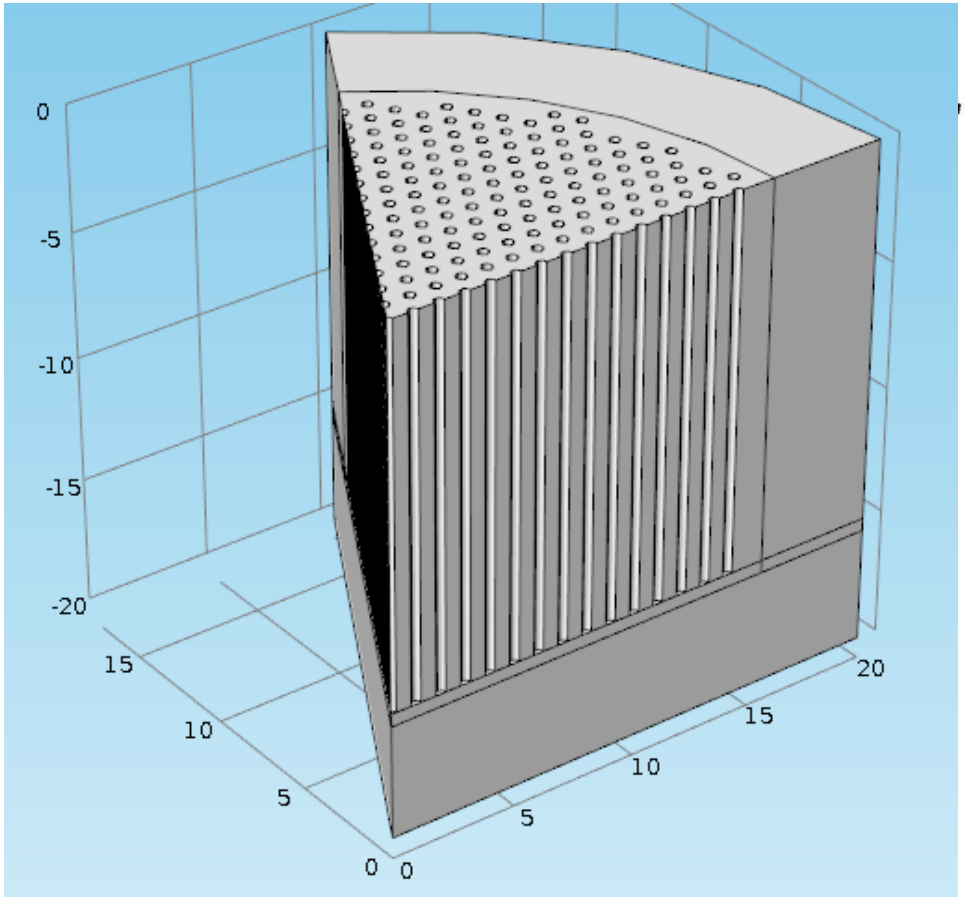
Other experimental acquisitions

-

Electricity market analysis

Project website: http://seleco2.free.fr/

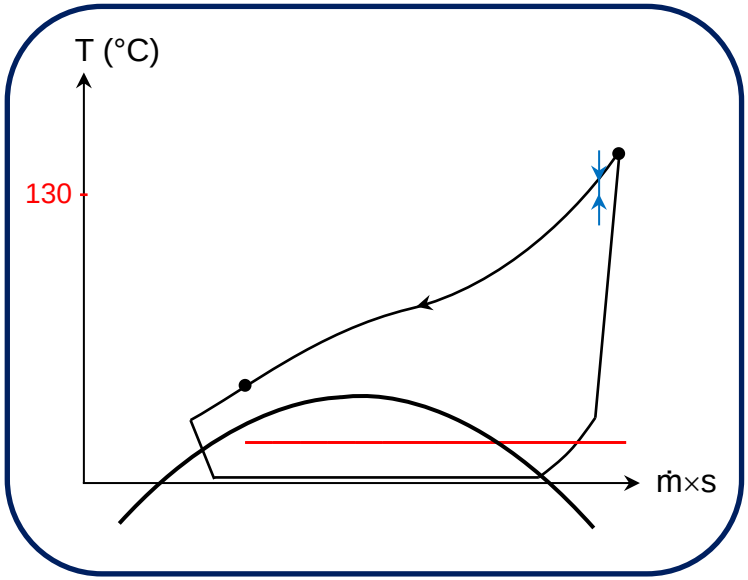
SELECO$_2$ Concept (1)



$\varnothing_{column}$ ~ 1 m / column , T_{max} ~130°C

Rock conductivity =3,4 W/m.K

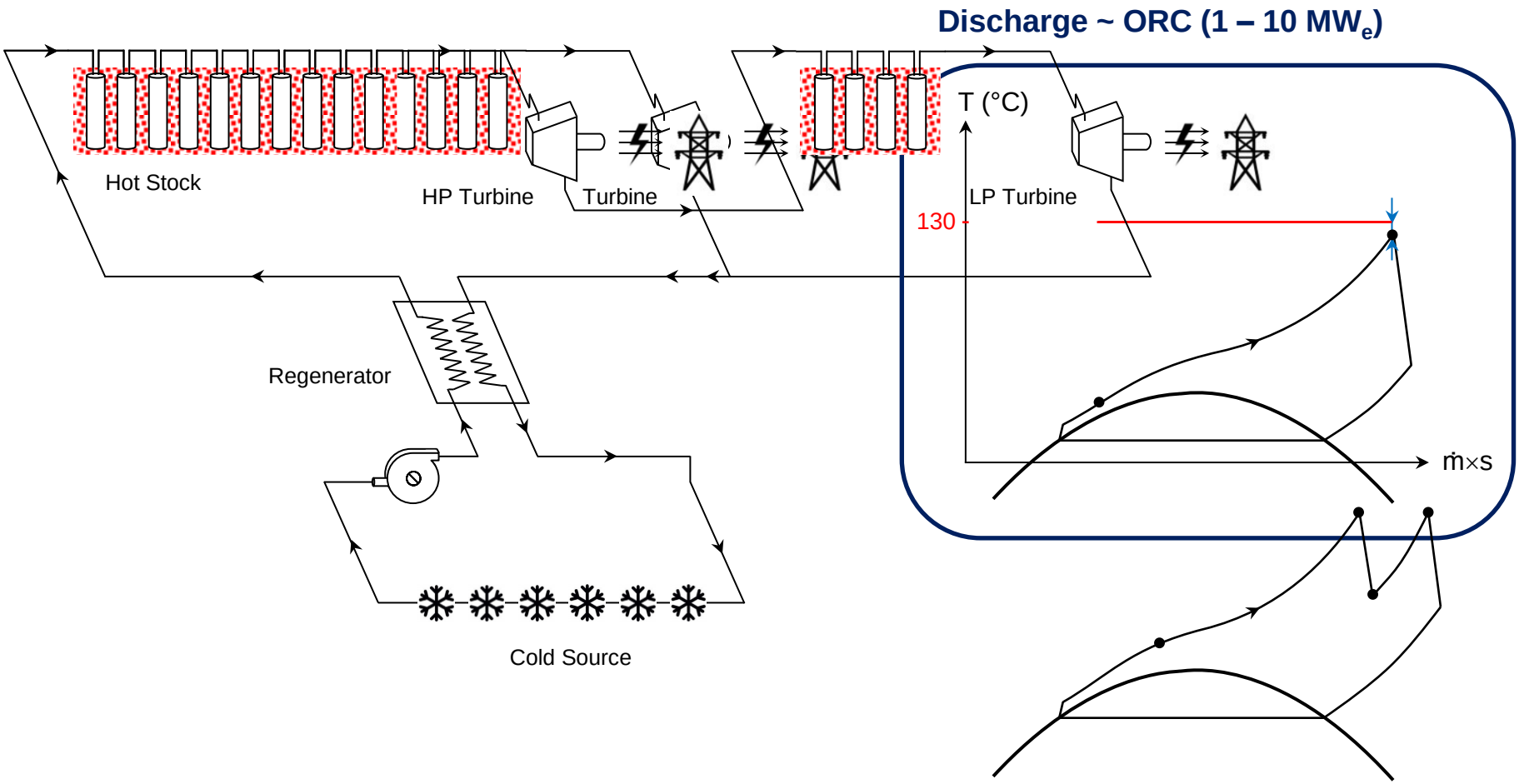
Charge : Heat-Pump cycle (≥ 8 hours)



1st characteristics : Hot storage medium: in situ rock (granite)

2nd characteristics : CO_2 supercritical

SELECO$_2$ Concept (2)



Parametric studies & static results

$$\eta_{sys} = \frac{\dot{W}_{el}'}{\dot{W}_{el} + \dot{W}_{el}''}$$

Code : EES

Architecture : single stage

Net Power: 1 MW_e

Rock Temp : $T_{rock\_max} = 130\,°C$

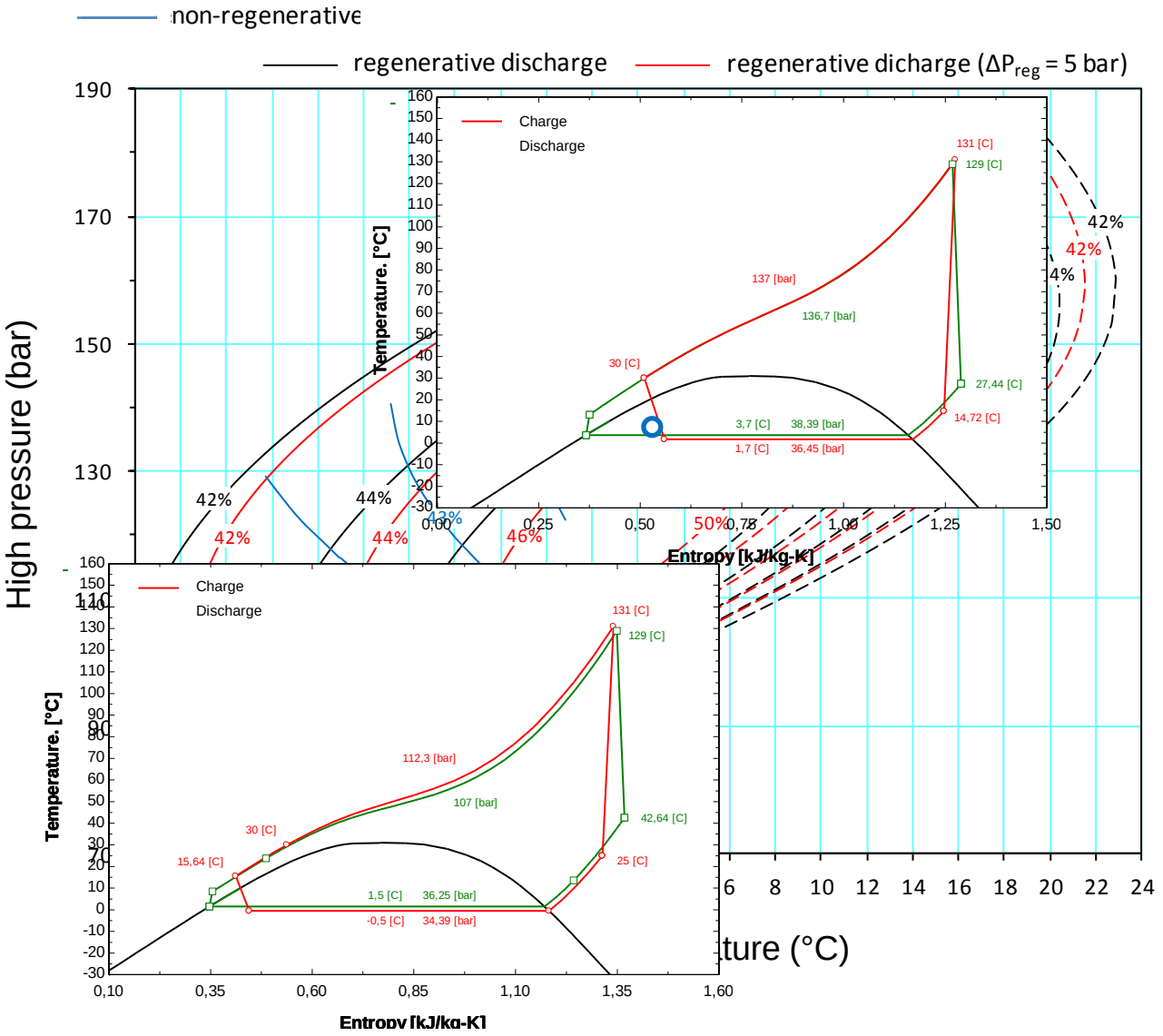
« Pinch » : upper limit

$$\Delta T_{min} = \left| T_{CO_2} - T_{rock} \right|_{min} = 1K$$

Double regenerated

1- Global efficiency ↗
2- High pressure ↘
3- Pressure ratio ↘
4- Hot stock power ↘
5- Chiller contribution ↘

⇒ Cost ↘



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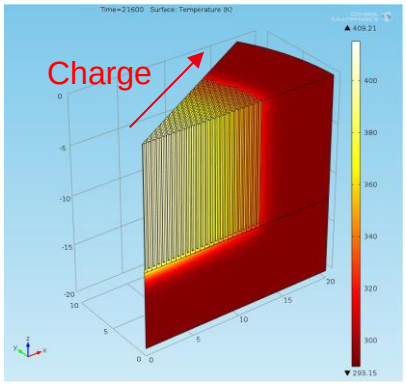
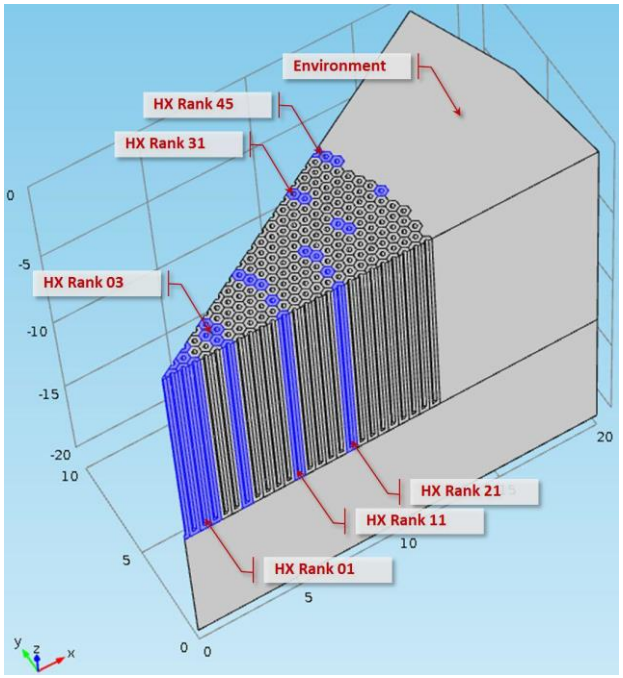
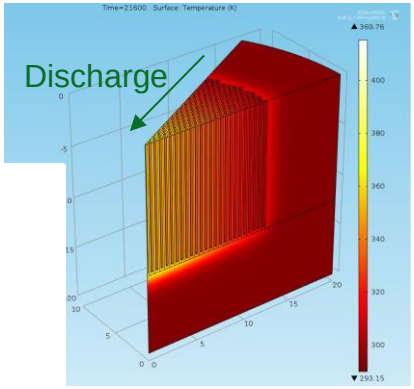
Hot storage underground heat exchangers

Several hundred of geothermal heat-exchangers (HX), typically: 2160 HX, 12m long, 200mm diameter and 50cm apart on hexagonal lay-out.

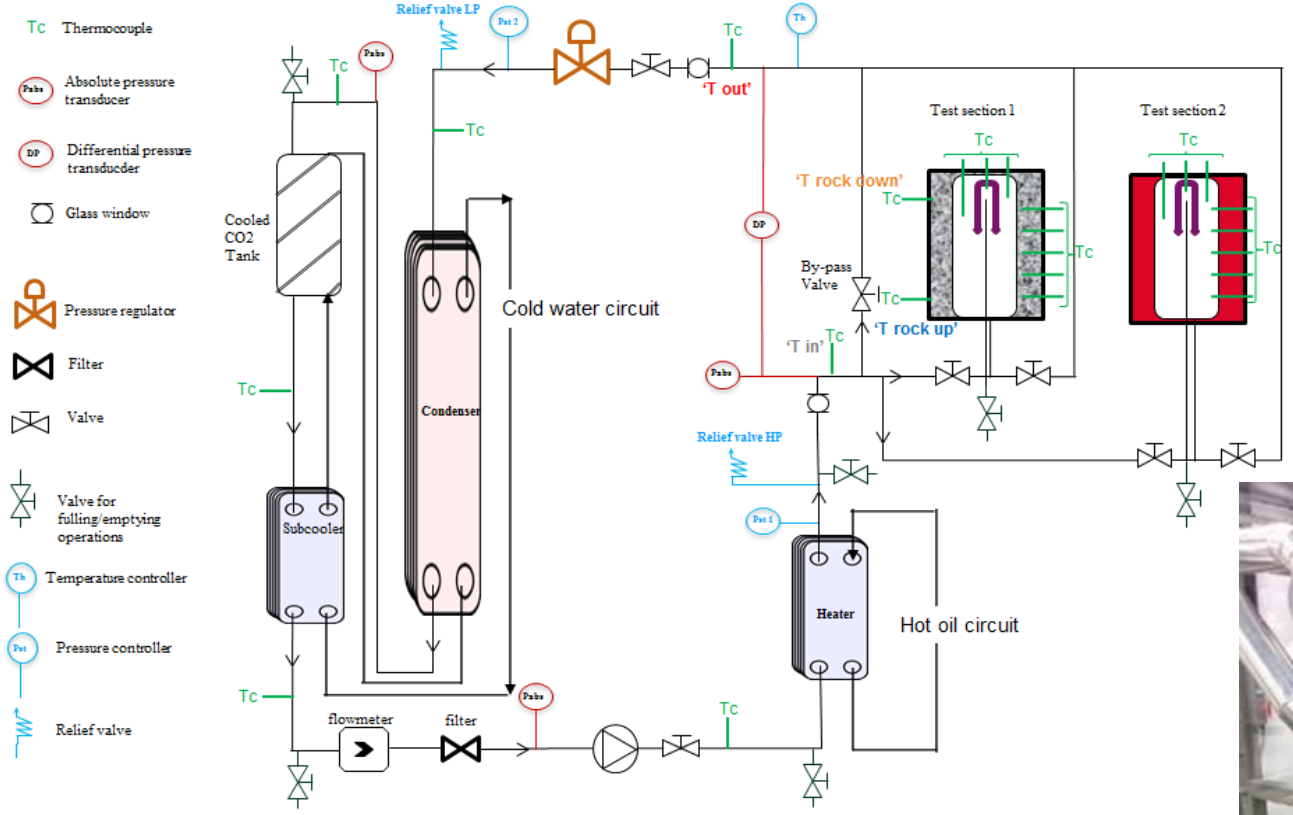
HX set up on serial/parallel configuration into unfractured dry crystalline bedrock : 48 lines of 45 HX in series.



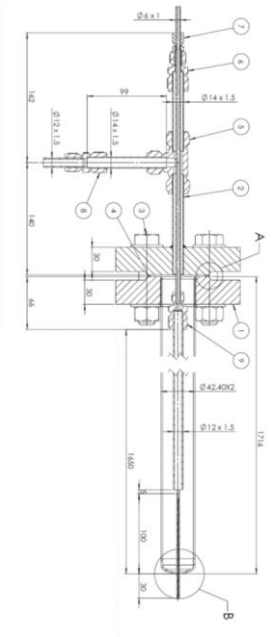




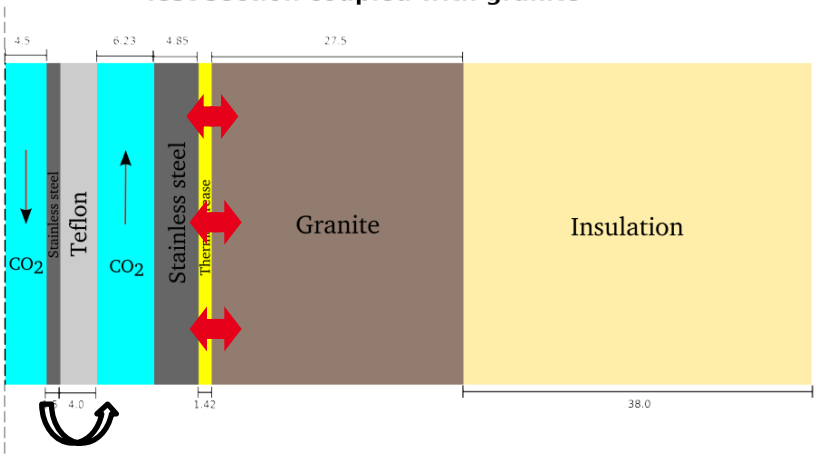
Experimental device to study hot storage underground heat exchanger



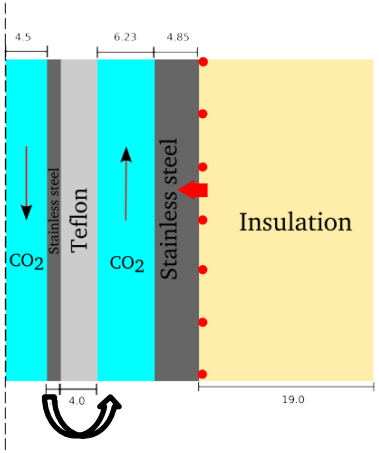
Two test sections: Test section coupled with granite & Imposed heat flux test section



Test section coupled with granite



Imposed heat flux test section



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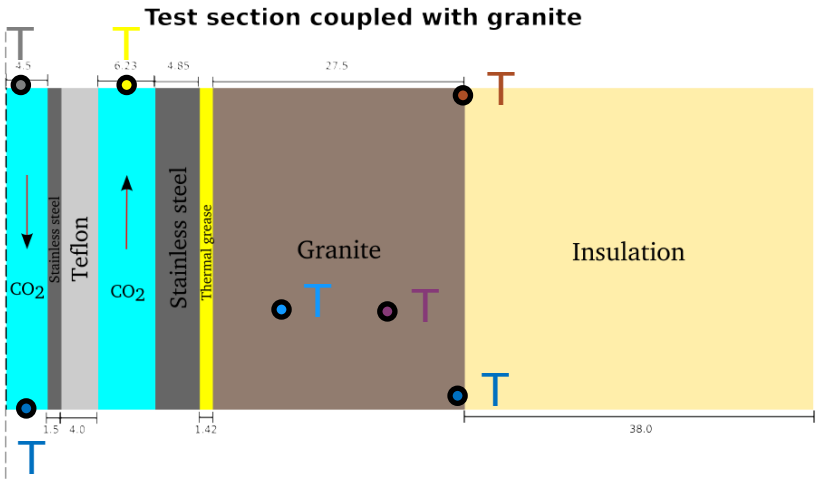
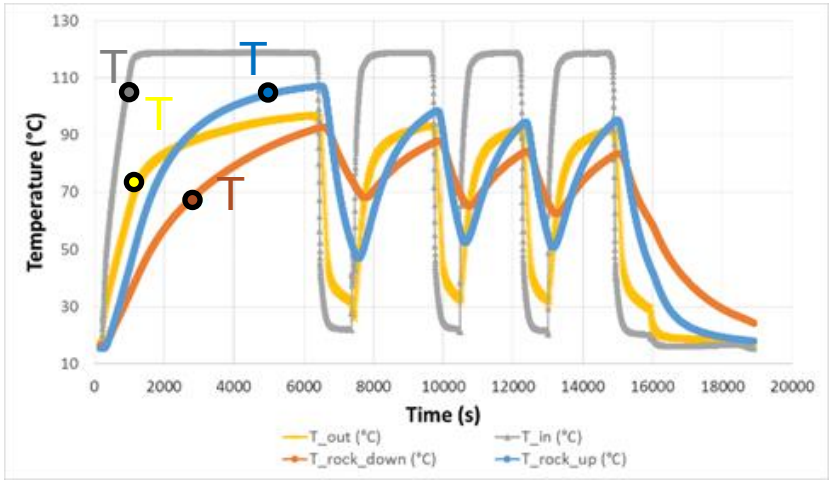
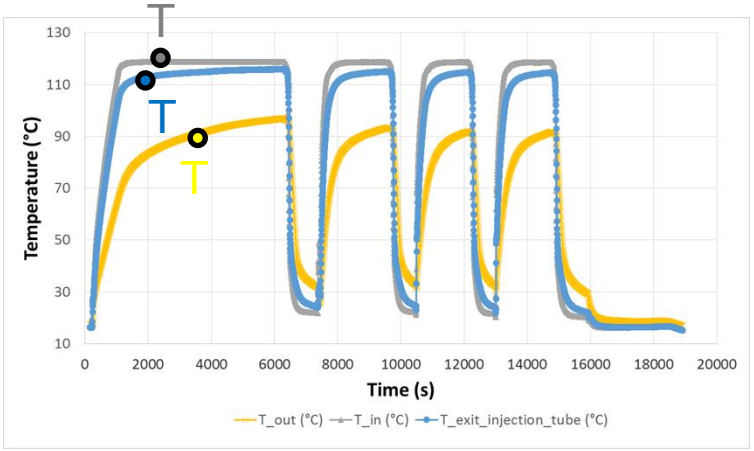
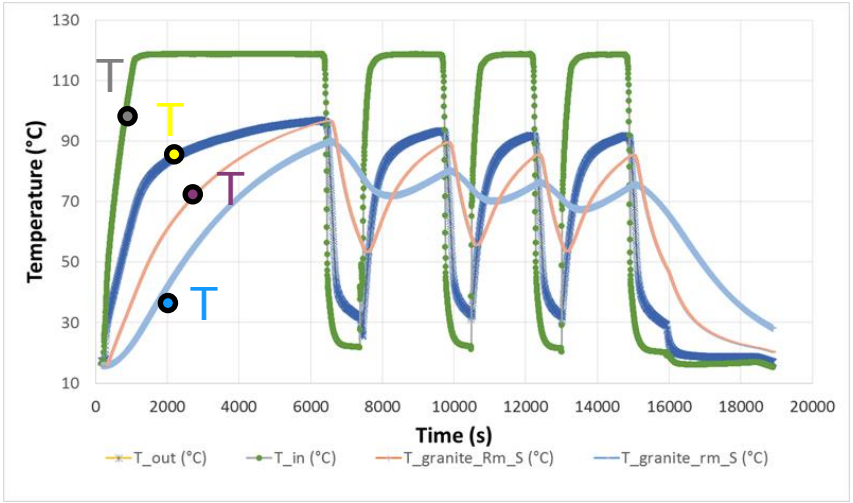
Test section coupled with granite





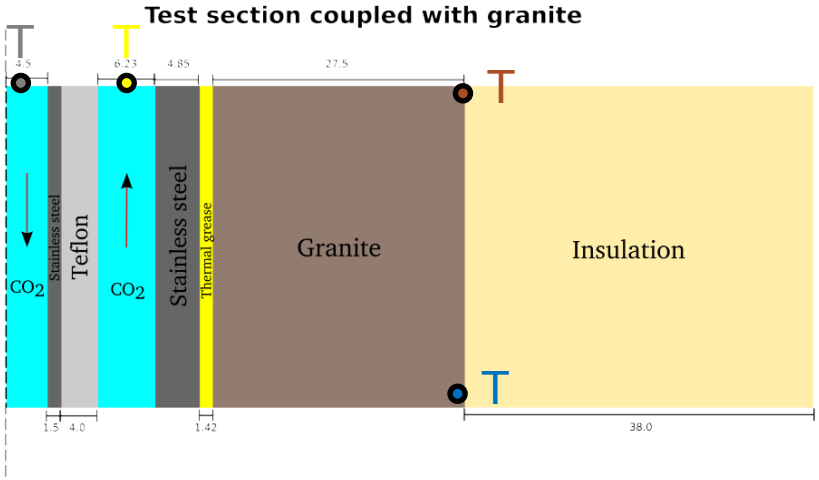


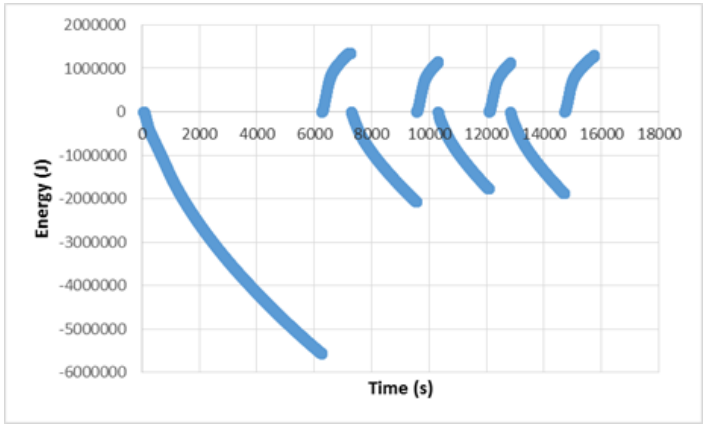
±1,5 or 2 °C



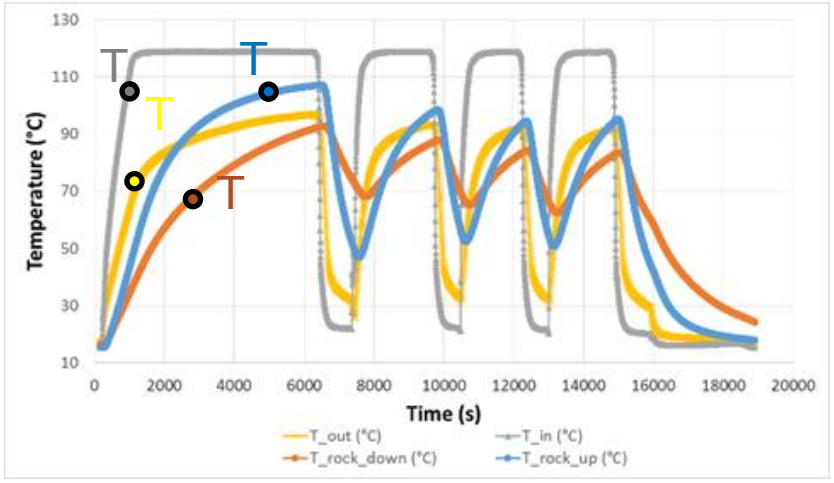
Test section coupled with granite

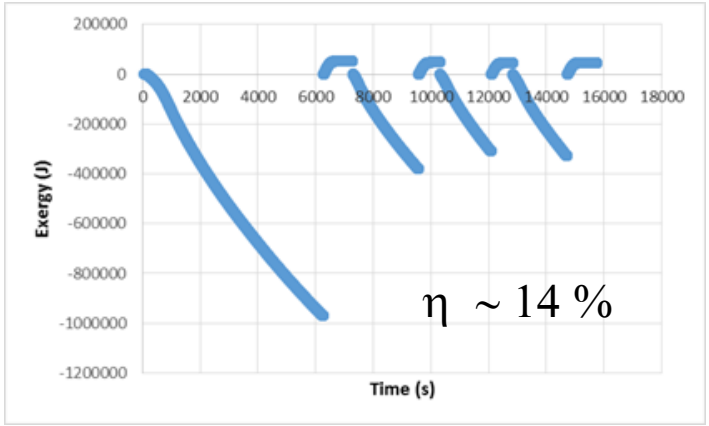
Energetic & exergetic view





$\eta \sim 68\ \%$



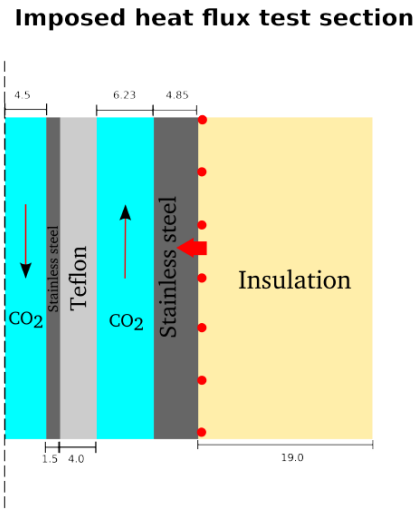


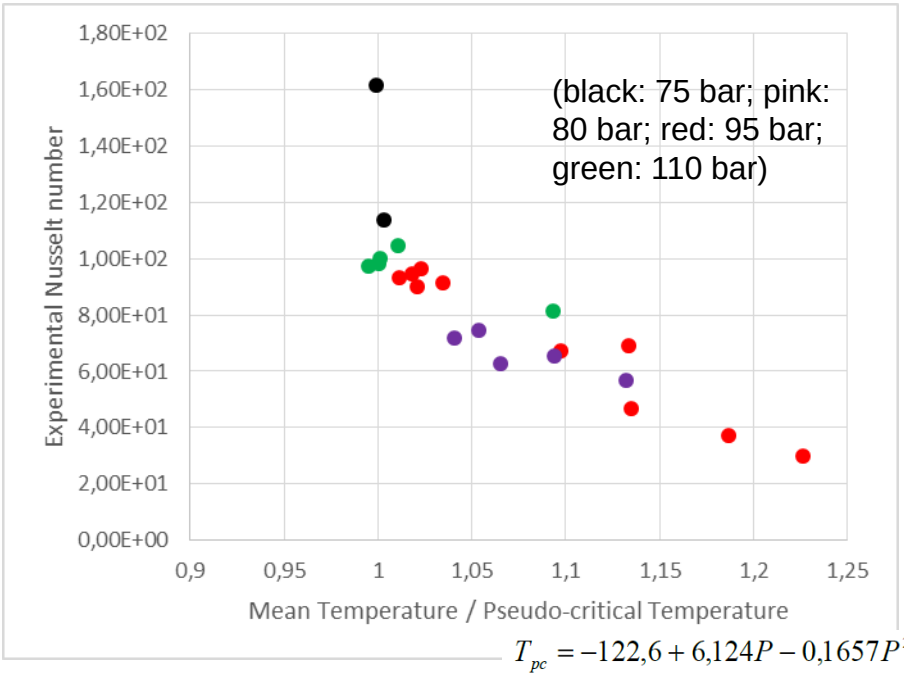
$\eta \sim 14\ \%$

±1,5 or 2 °C

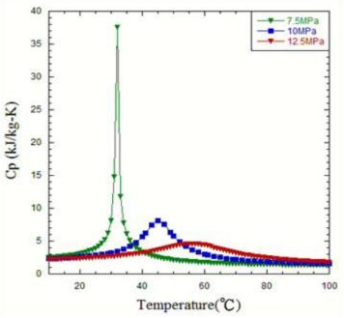
$$\eta_{ex} = \left(Ex_{out} - Ex_{in}\right)_{discharge} / \left(Ex_{in} - Ex_{out}\right)_{charge}$$

Imposed heat flux test section

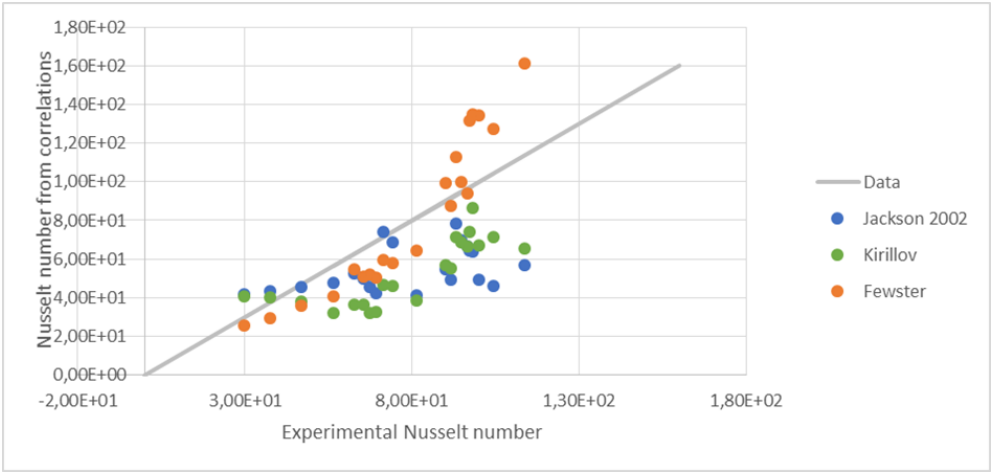




$$T_{pc} = -122{,}6 + 6{,}124P - 0{,}1657P^2 + 0{,}01773P^{2.5} - 0{,}0005608P^3$$



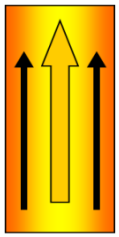
Hsieh et al., 2015

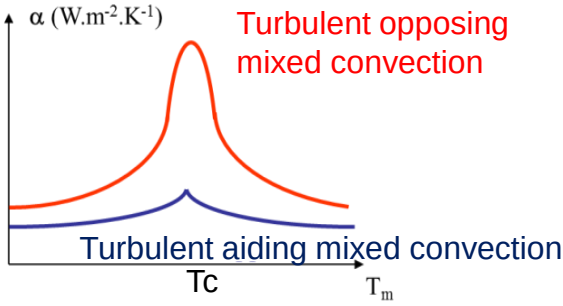


Imposed heat flux test section

Heating mode (Hot storage → Discharge Cycle)

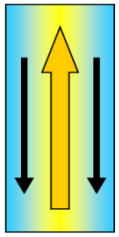
- **For Upward Flow → Turbulent aiding mixed convection**



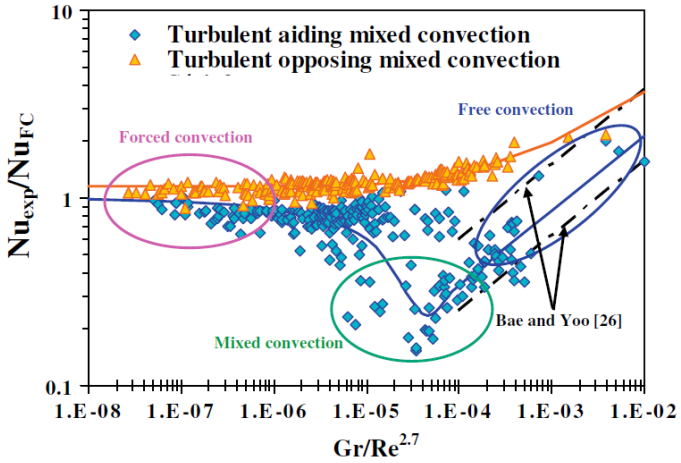


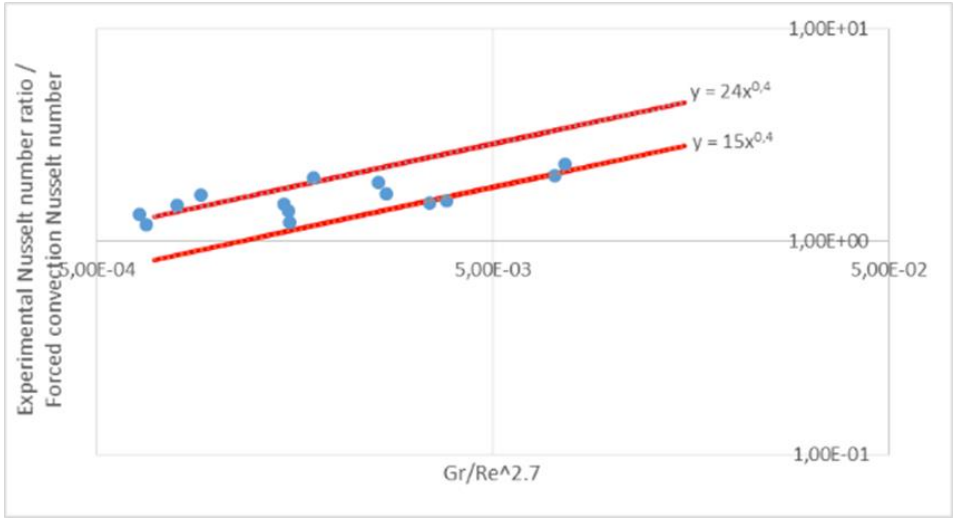
Information: Cooling mode (Charge Cycle → Hot storage)

- **For Upward Flow → Turbulent opposing mixed convection**



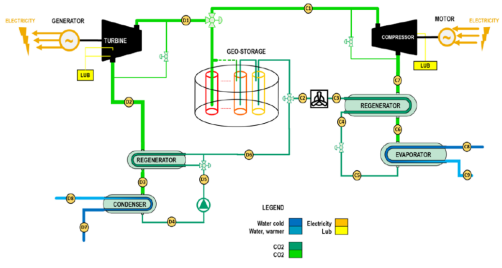
Literature data on small diameter cylinder



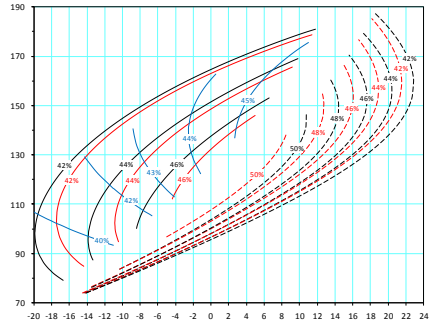


Bruch et al., 2009 International Journal of Heat and Mass Transfer 52 (2009) 2589–2598

CONCLUSION

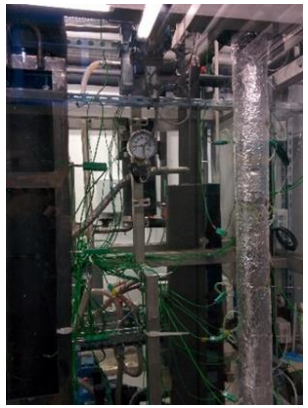


- **Concept of massive electricity storage based on 2 sCO2 cycles and underground thermal storage (sensible heat)**



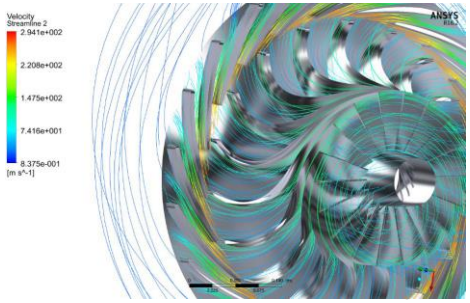
- **Parametric studies at steady-state → potential interest**

- **1/10^{e} experimental device for geothermal HX study**



- **Imposed heat flux test section and test section coupled with granite**
  - Investigation of transient behaviour
  - Validation of unsteady simulations of HX and granite

- **Other important tasks in the project**
  - Turbomachinery design
  - Off-design simulations & Transient multi-D coupling
  - Economy
  - Environmental impact



Acknowledgments

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Commissariat à l'énergie atomique et aux énergies alternatives
17 rue des Martyrs | 38054 Grenoble Cedex
www-liten.cea.fr

Établissement public à caractère industriel et commercial | RCS Paris B 775 685 019

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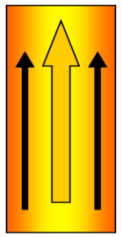

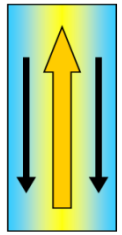

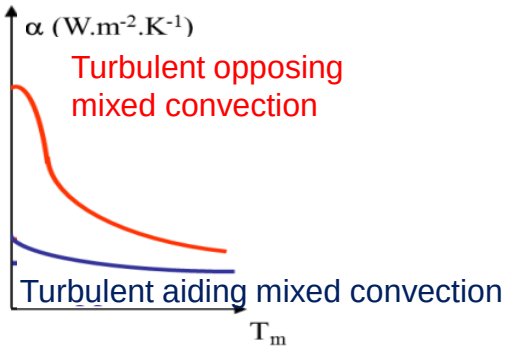

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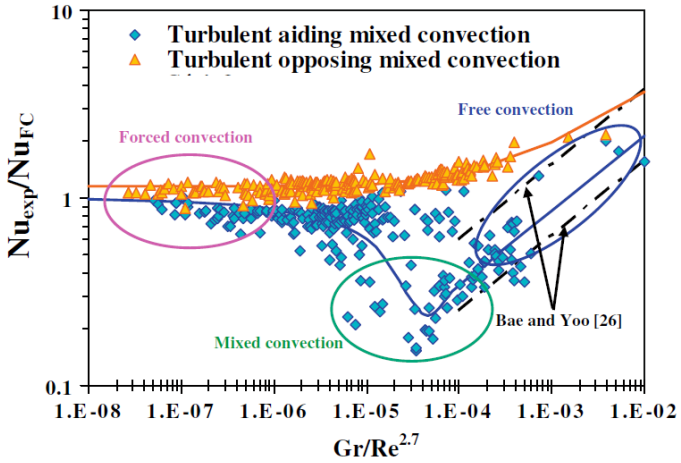

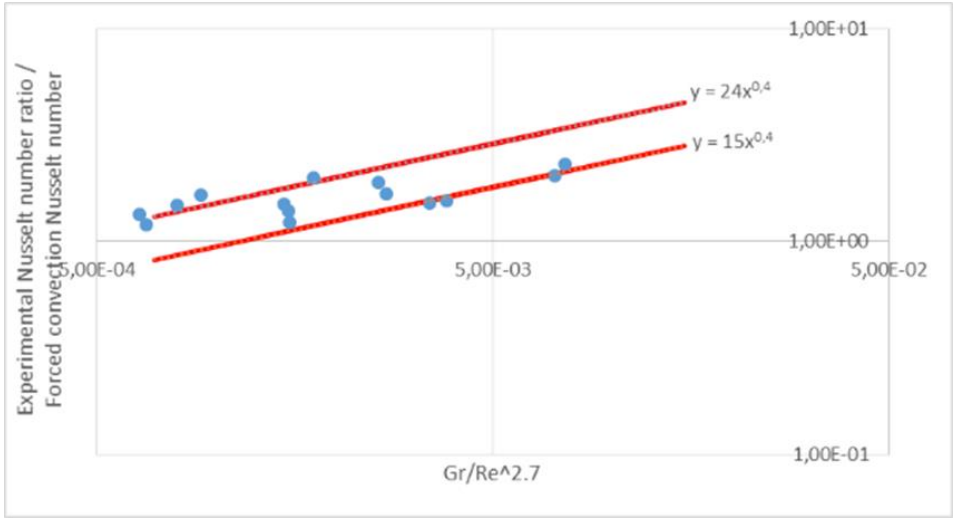

Bruch et al., 2009 International Journal of Heat and Mass Transfer 52 (2009) 2589–2598