Heat powered Sorption Compressors for refrigeration and air-conditioning systems

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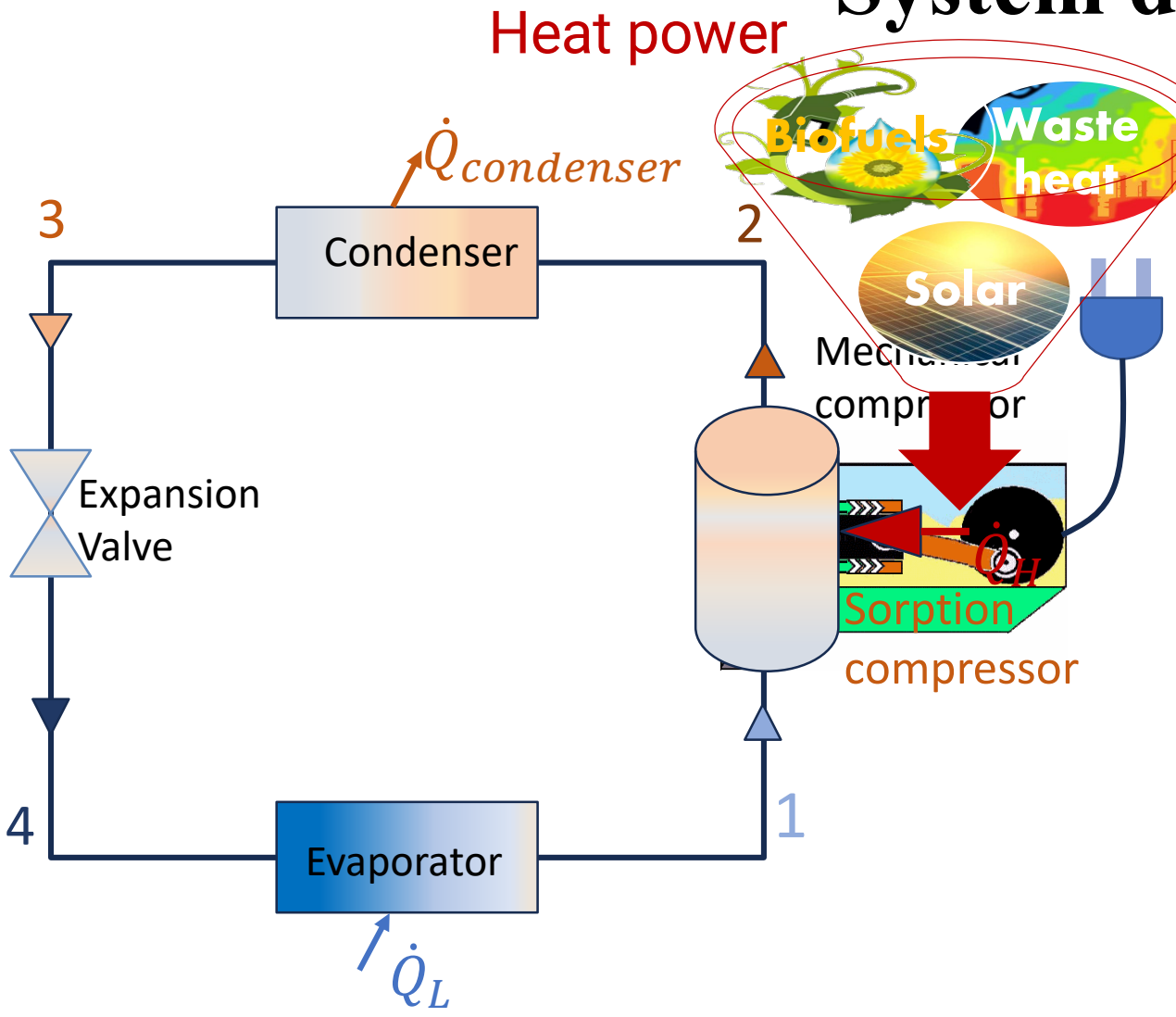
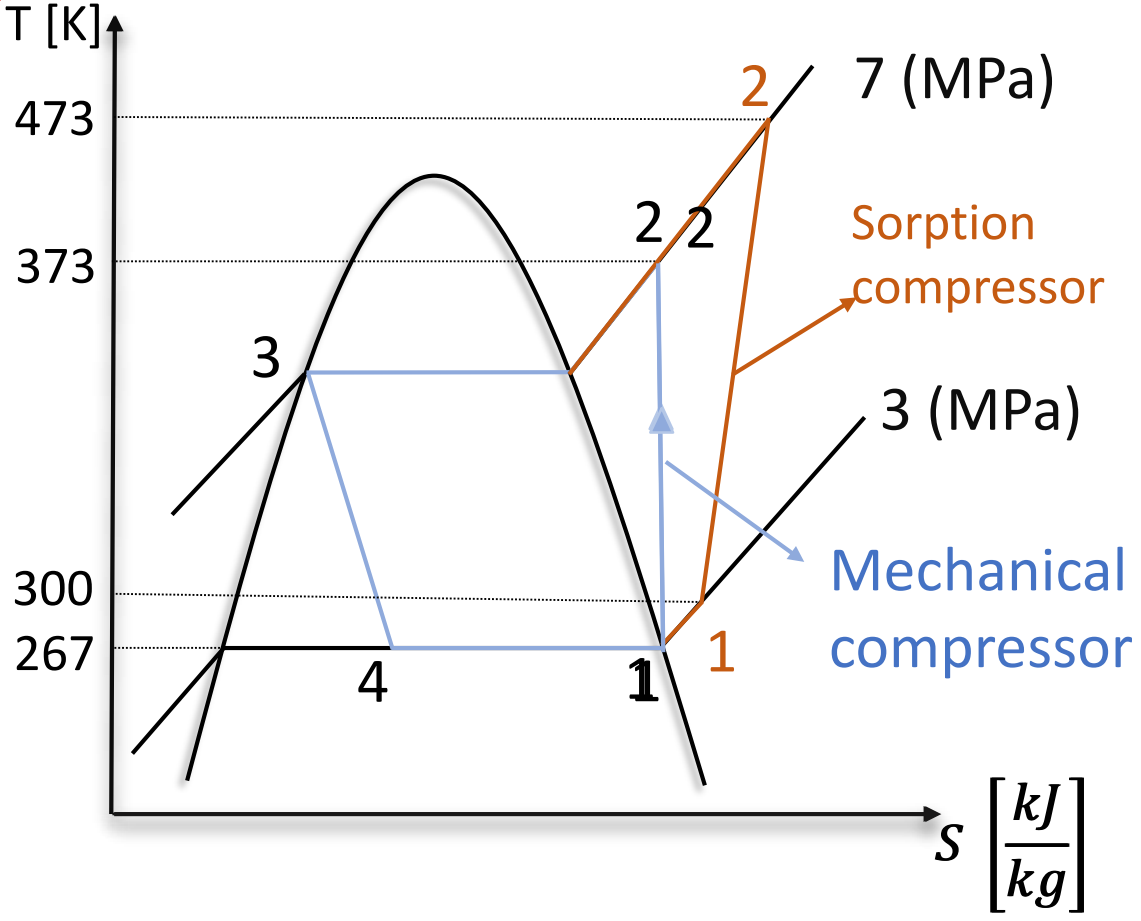
Motivation

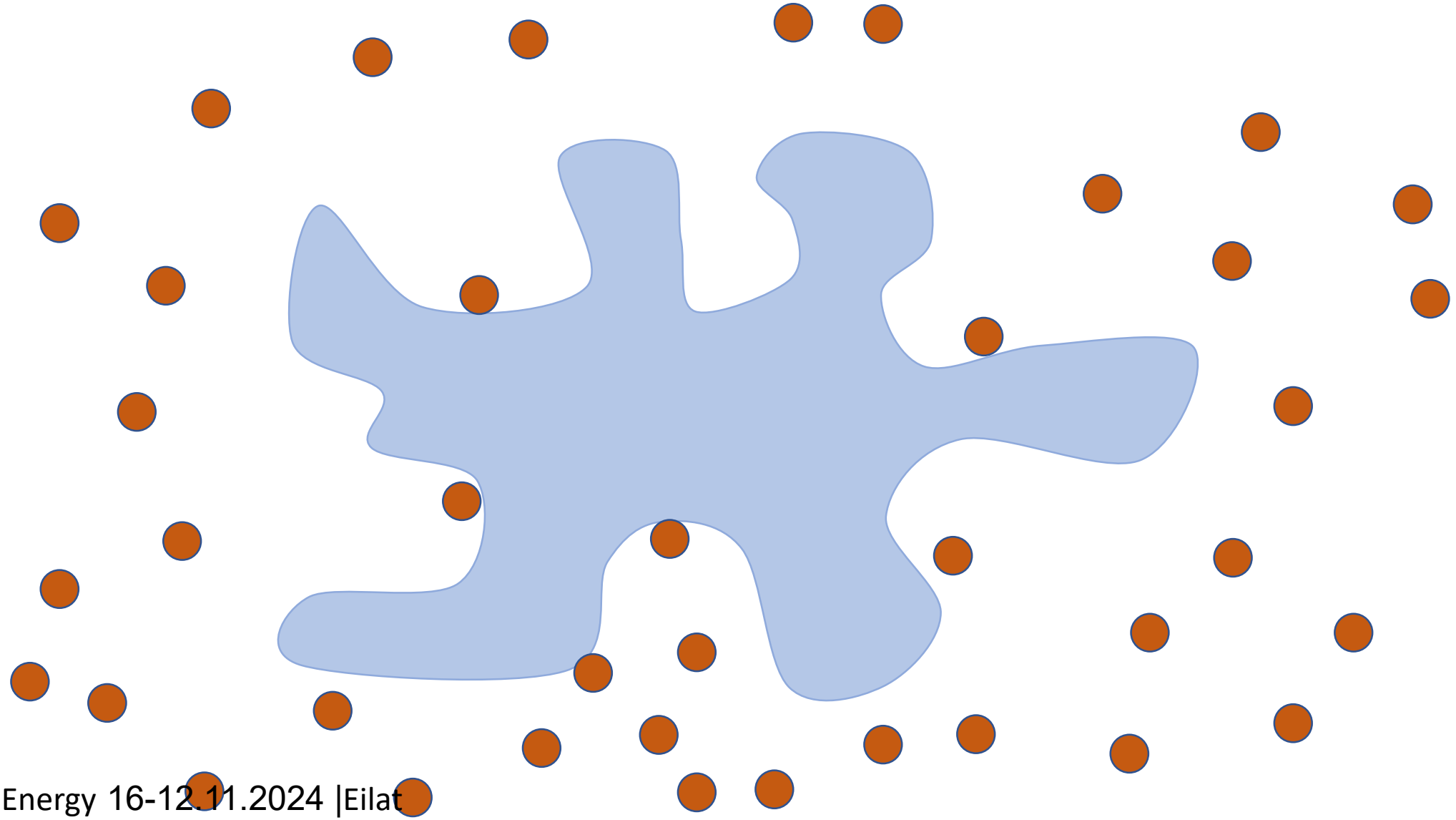
- Increase in electricity consumption
- Air conditioning and refrigeration systems consume a major part of the electrical energy.
- Replacing the energy source from electricity to thermal

System description

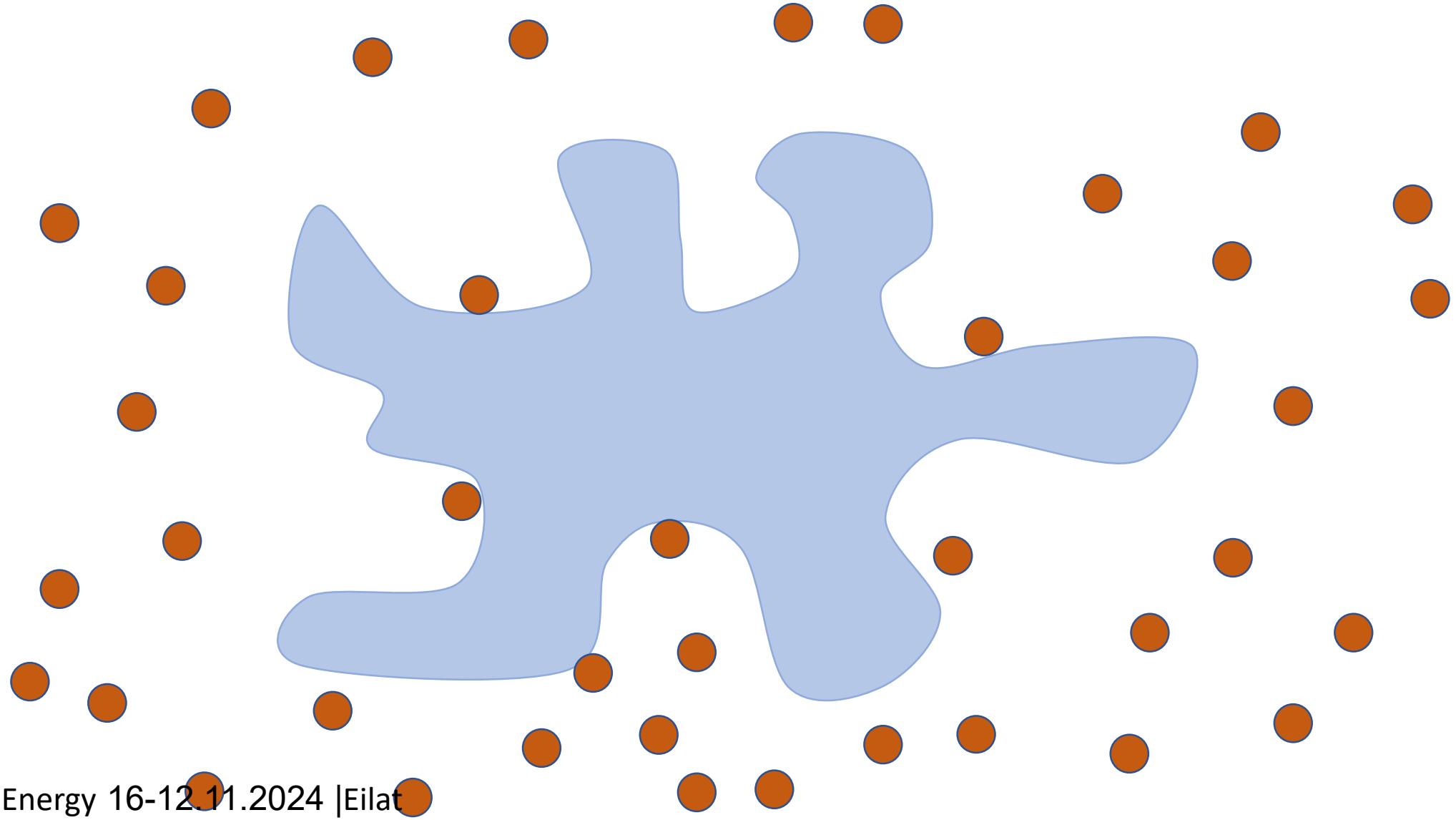




Sorption



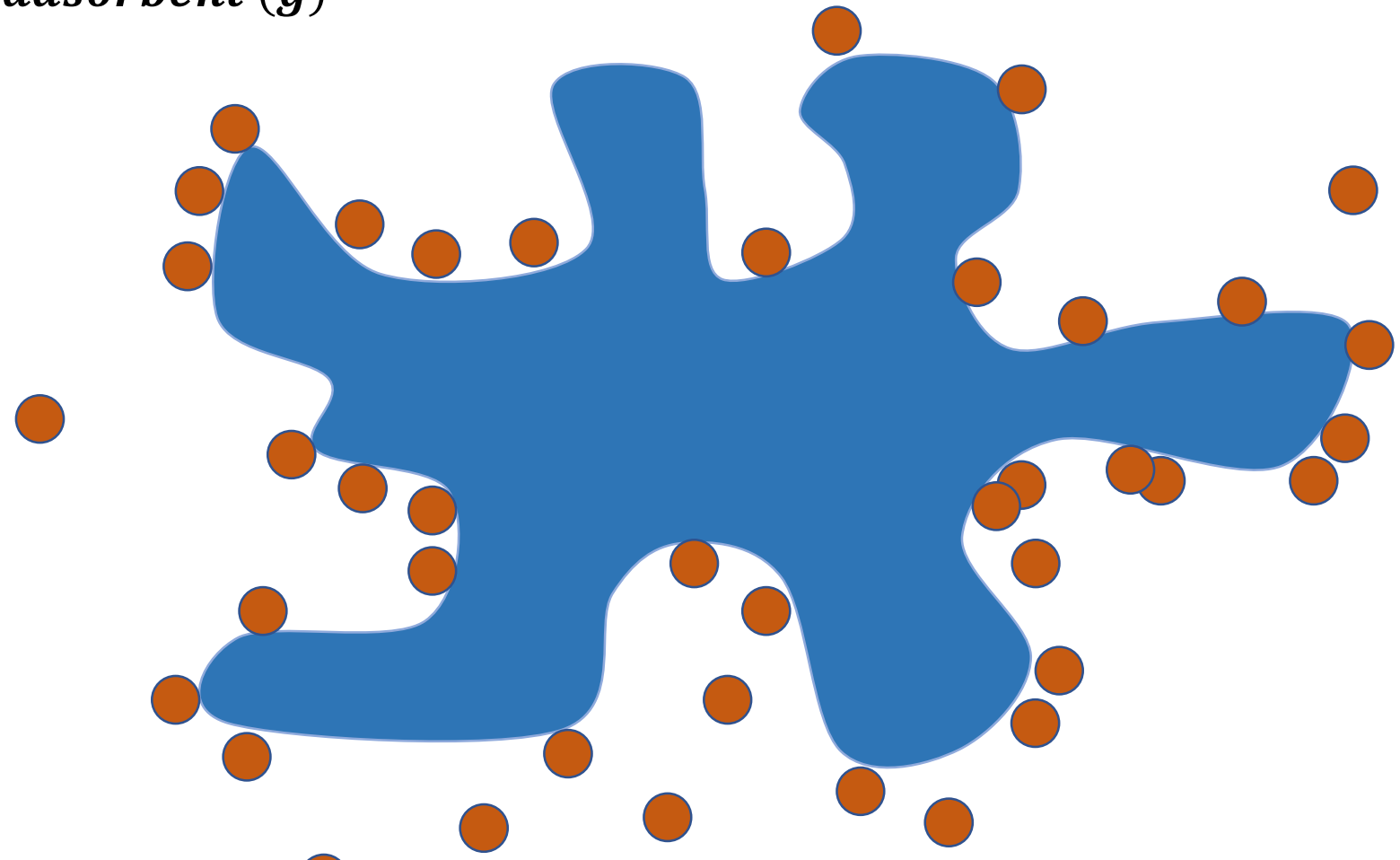
Sorption



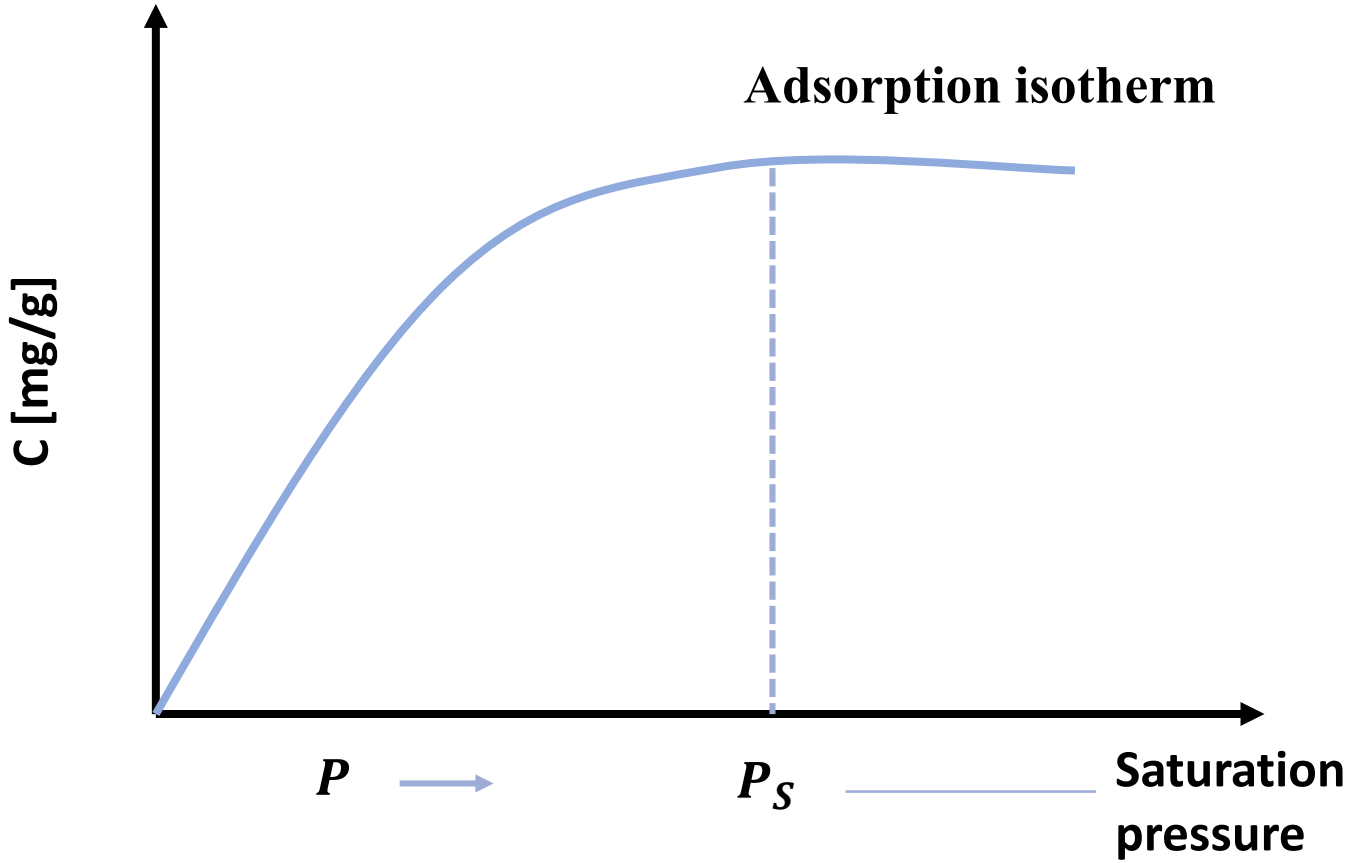
Sorption

Adsorption concentration

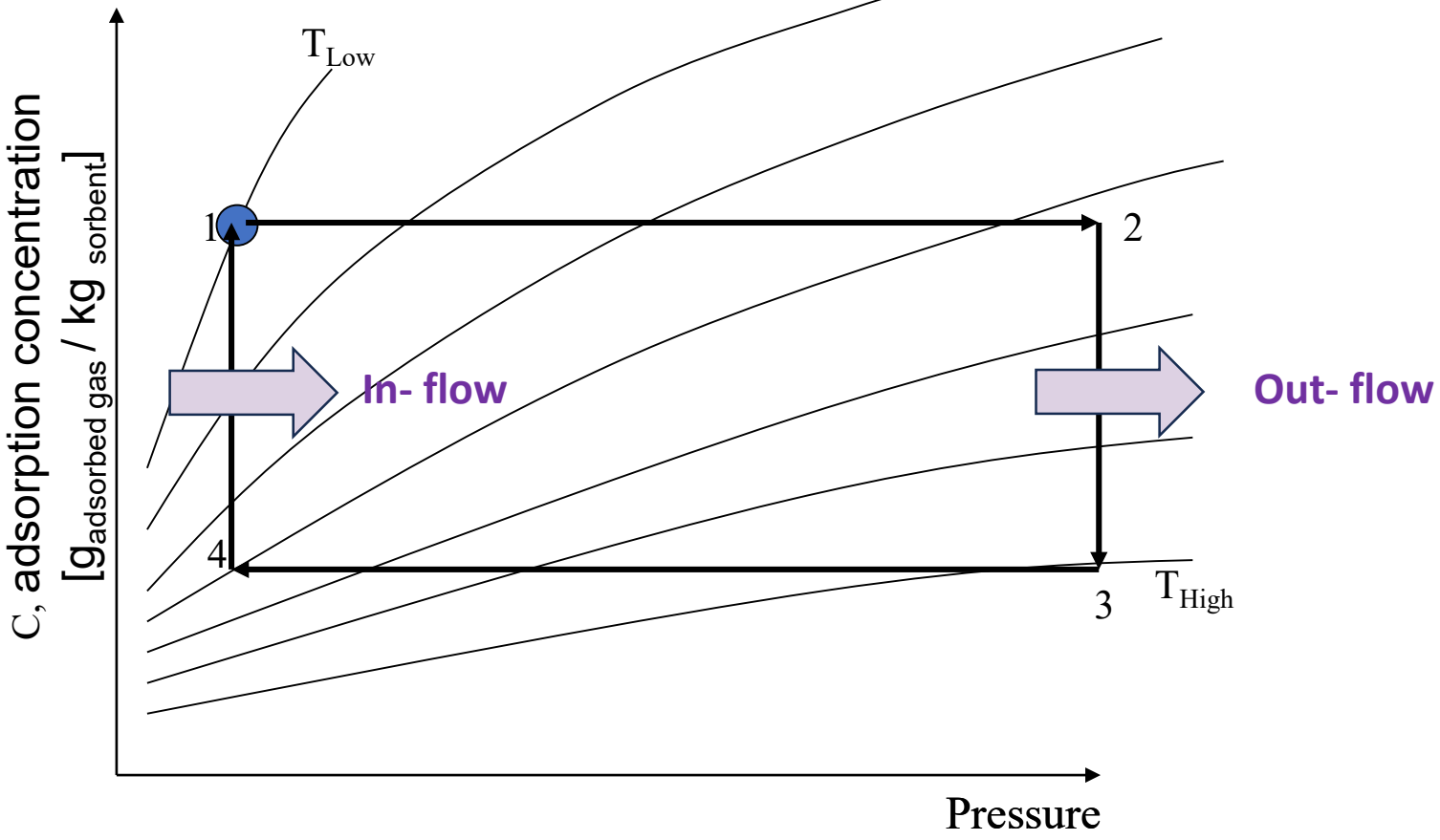
$$\mathbf{C} = \frac{\boldsymbol{mass\ of\ adsorbed\ gas\ (mg)}}{\boldsymbol{mass\ of\ adsorbent\ (g)}}$$

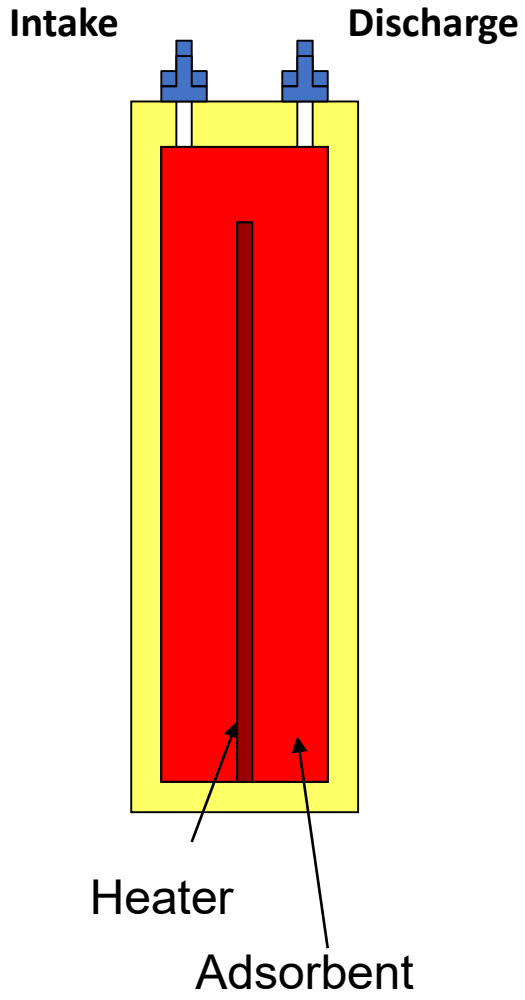


Sorption
Adsorption isotherm



Sorption compressors

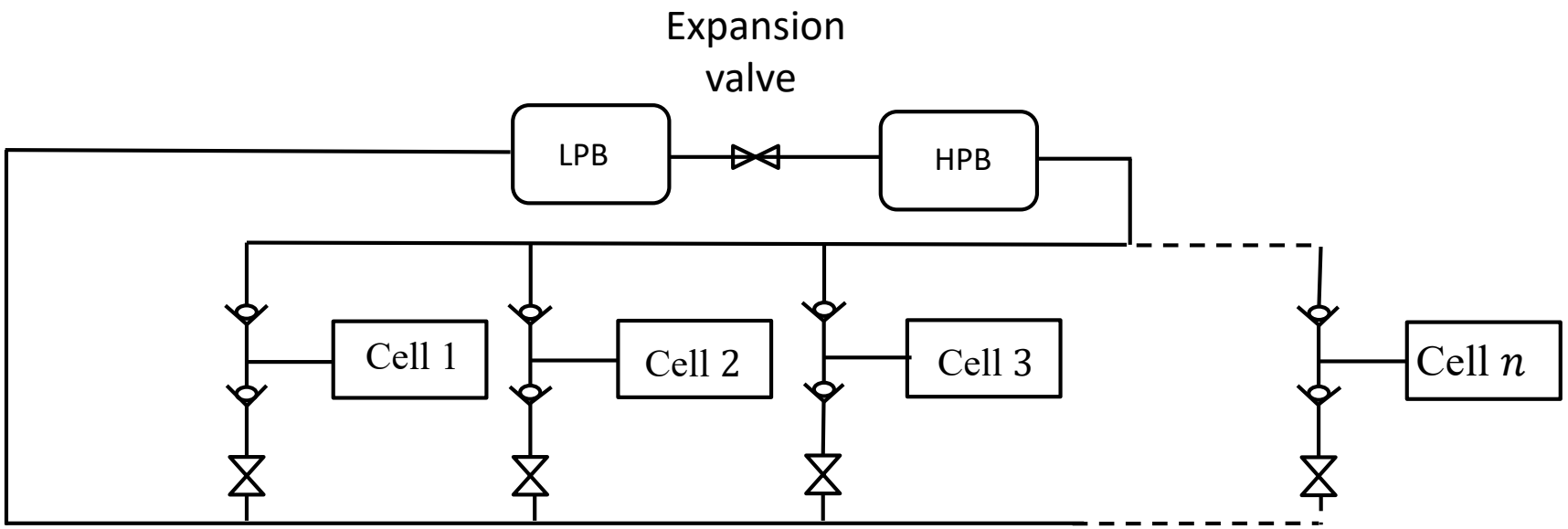




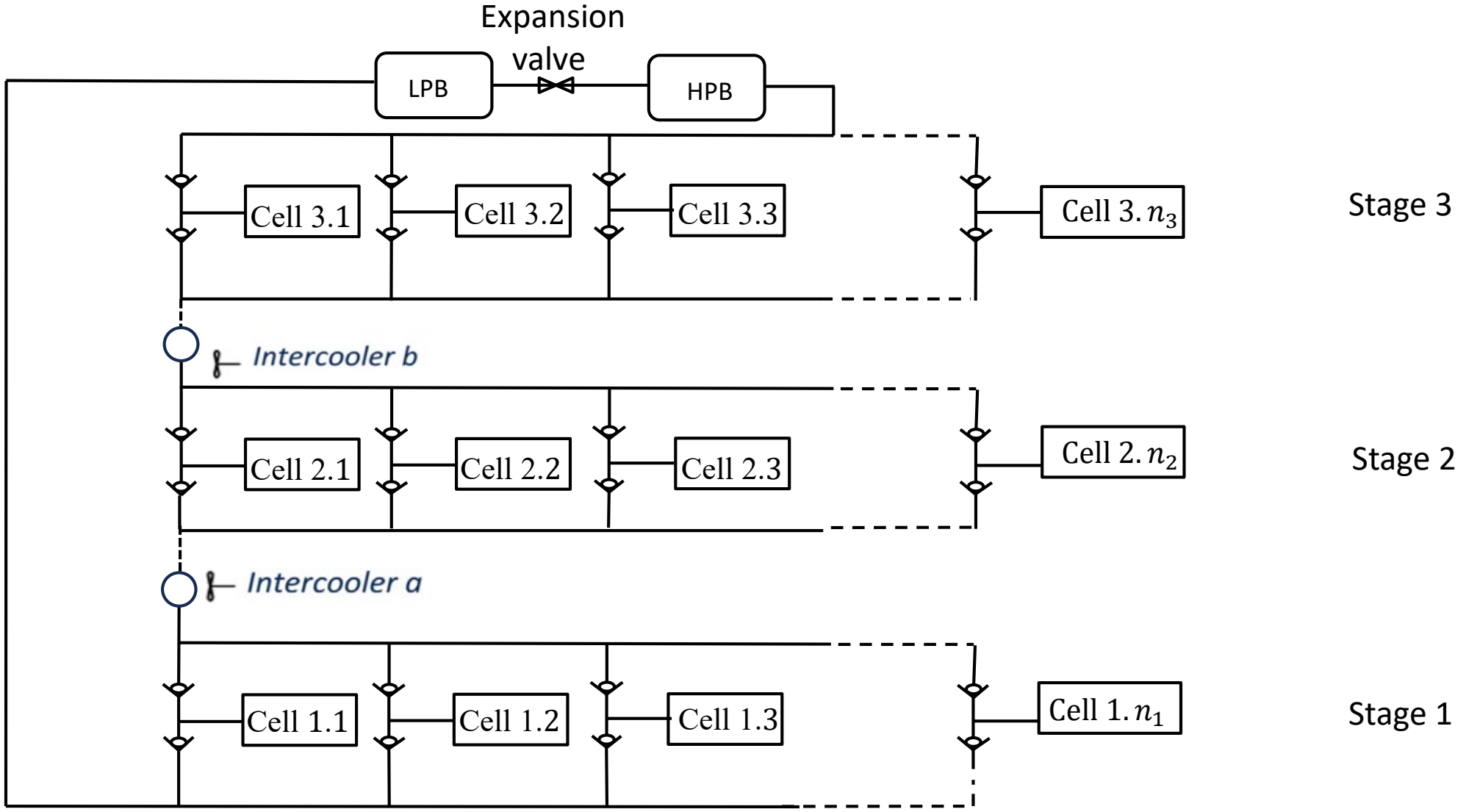
Sorption compressors

HPB = high pressure Buffer

LPB = low pressure Buffer

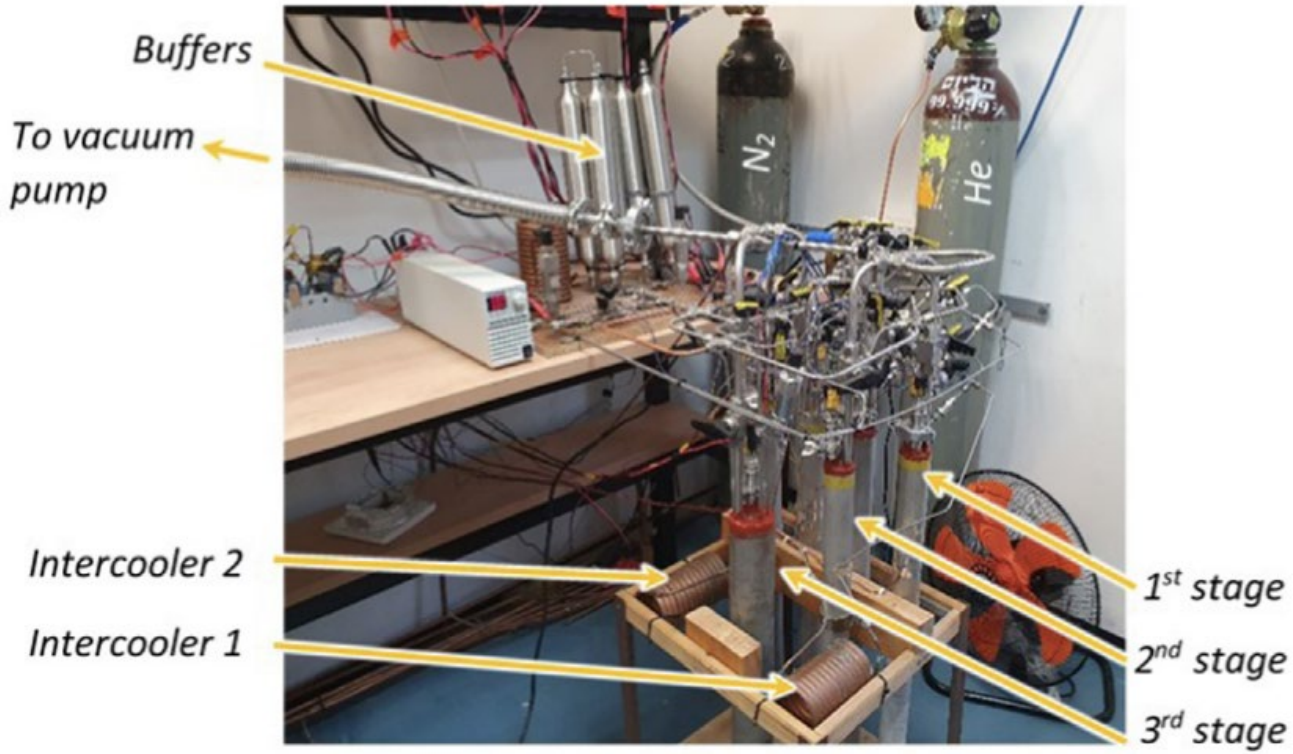


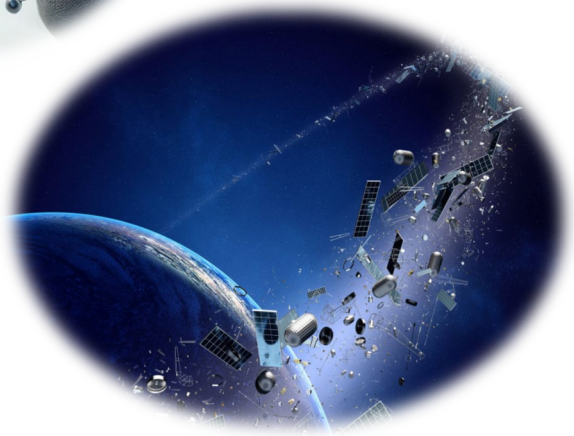
Sorption compressors



Sorption compressors

1st Compressor





N. Tzabar and A. Hamersztein, "Experimental study on activated carbon–nitrogen multi-stage thermal sorption compressors," *Renewable Energy*, vol. 181, pp. 666–674, Jan. 2022, doi: 10.1016/j.renene.2021.09.059.

Sorption compressors

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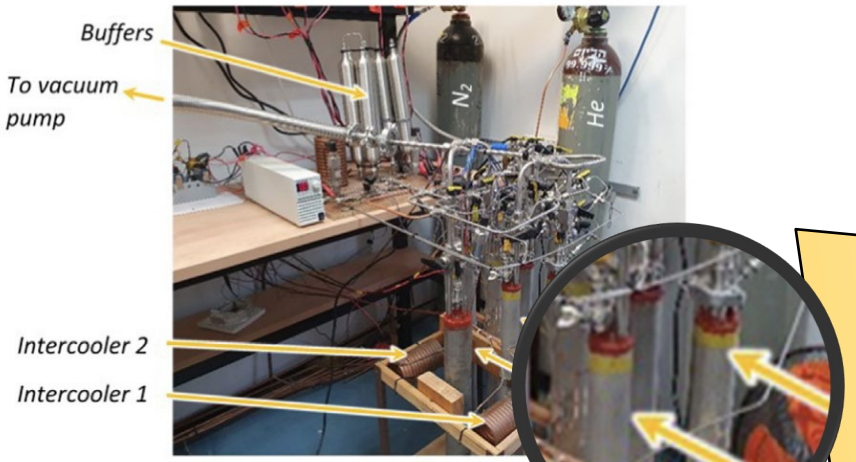

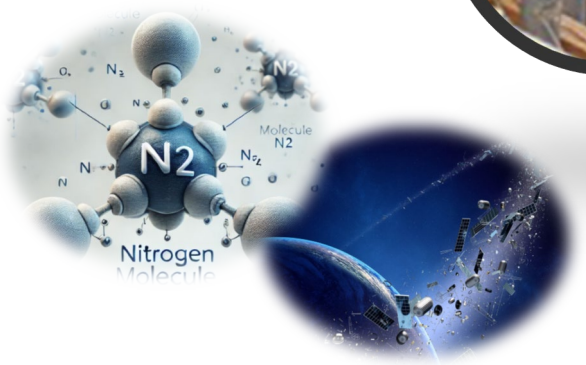

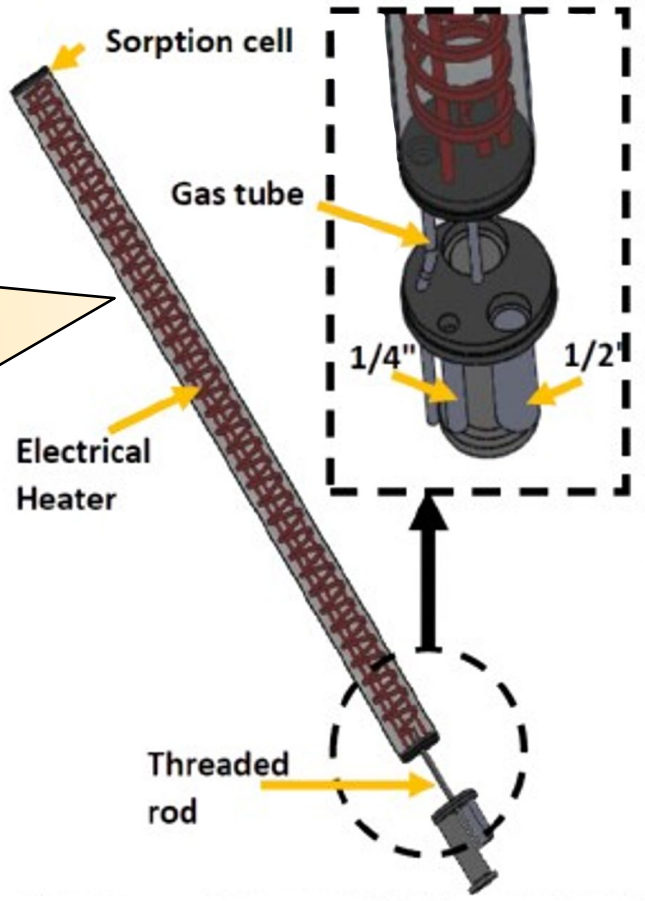

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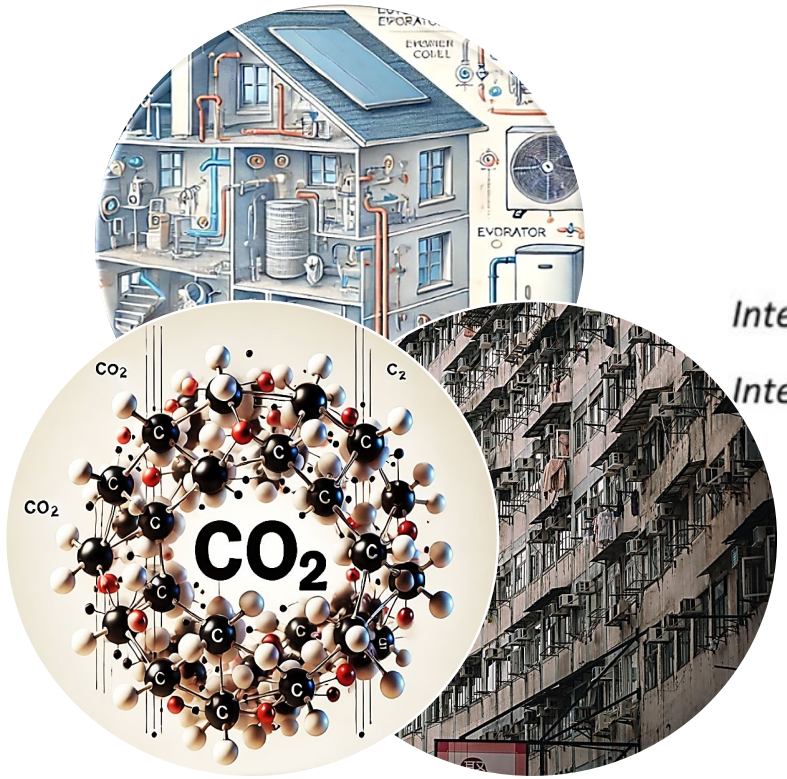
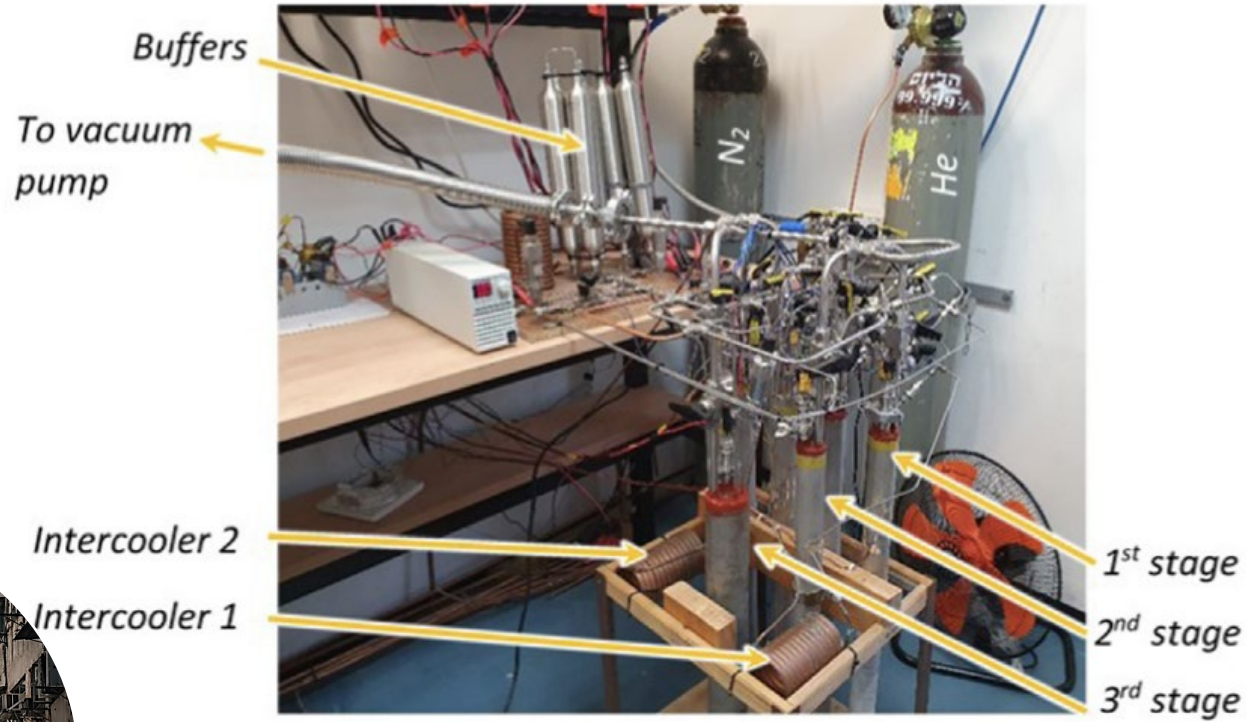
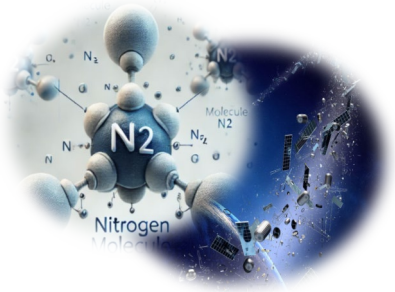


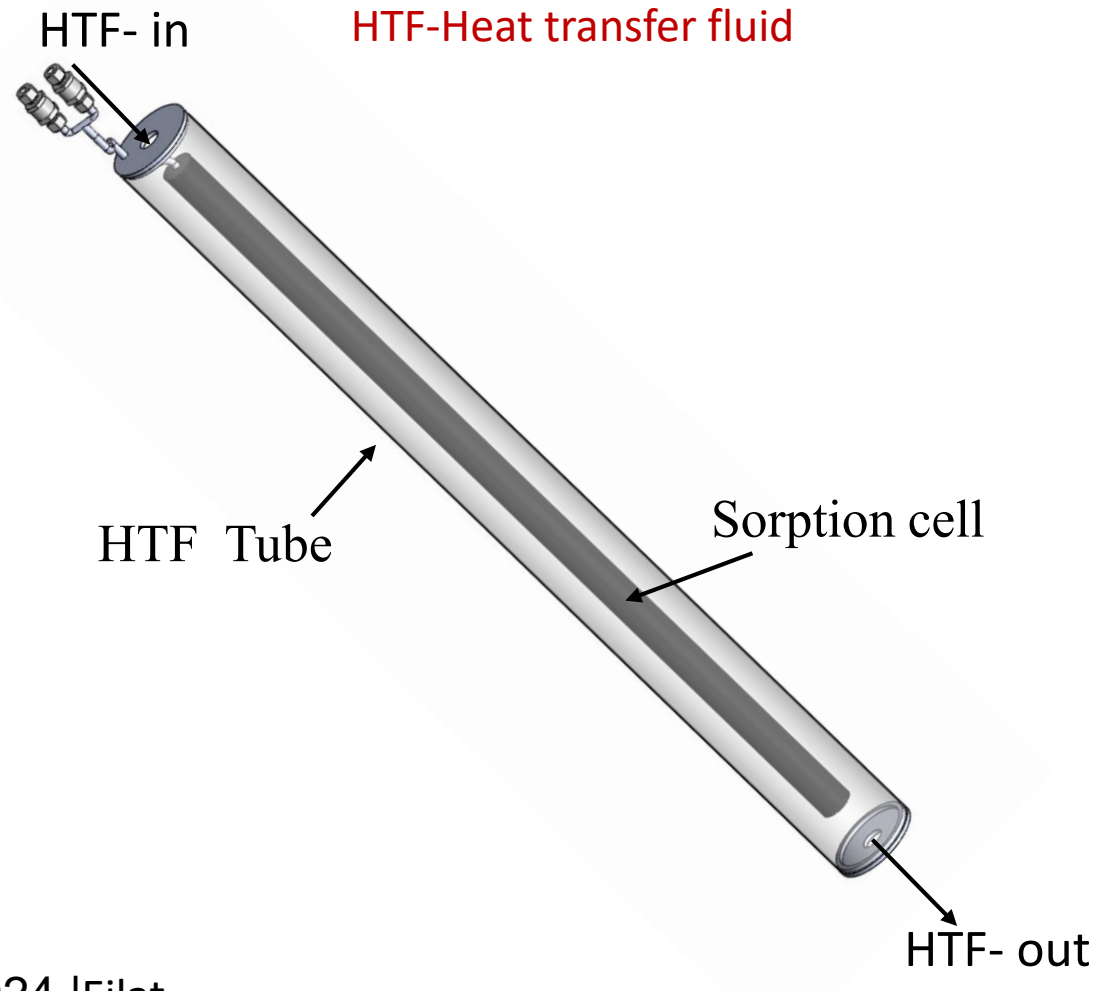




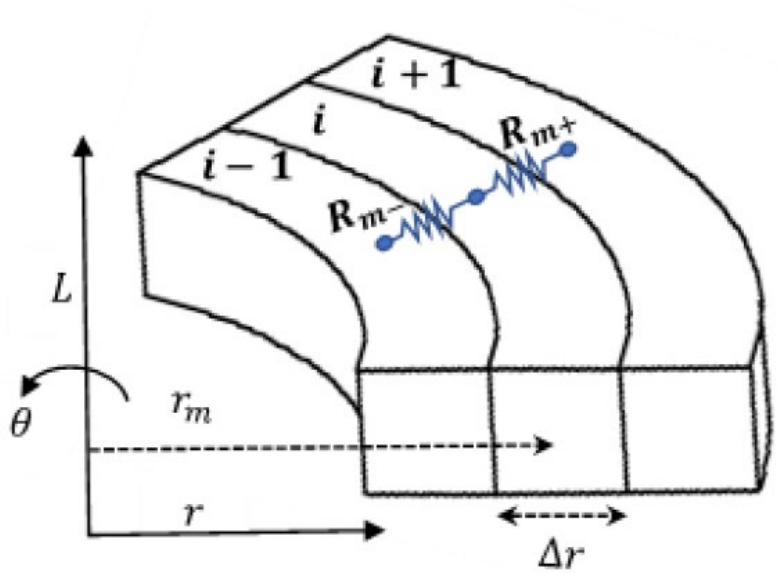
Sorption compressors

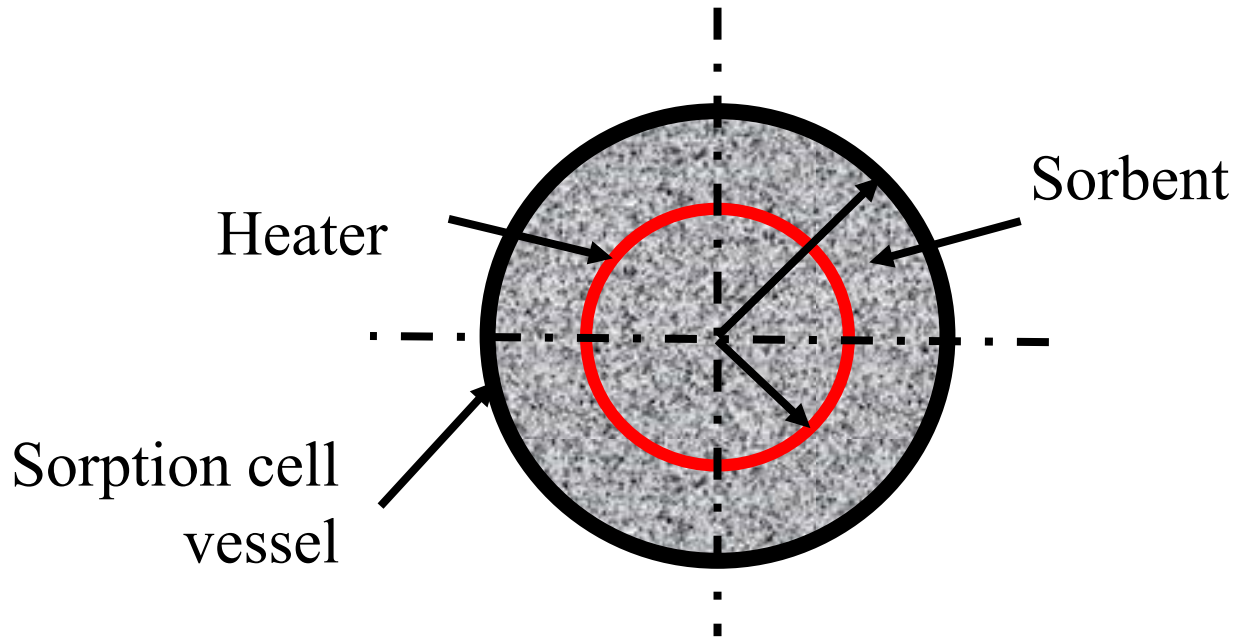
2nd Compressor

Sorption Cell Design



Numerical model





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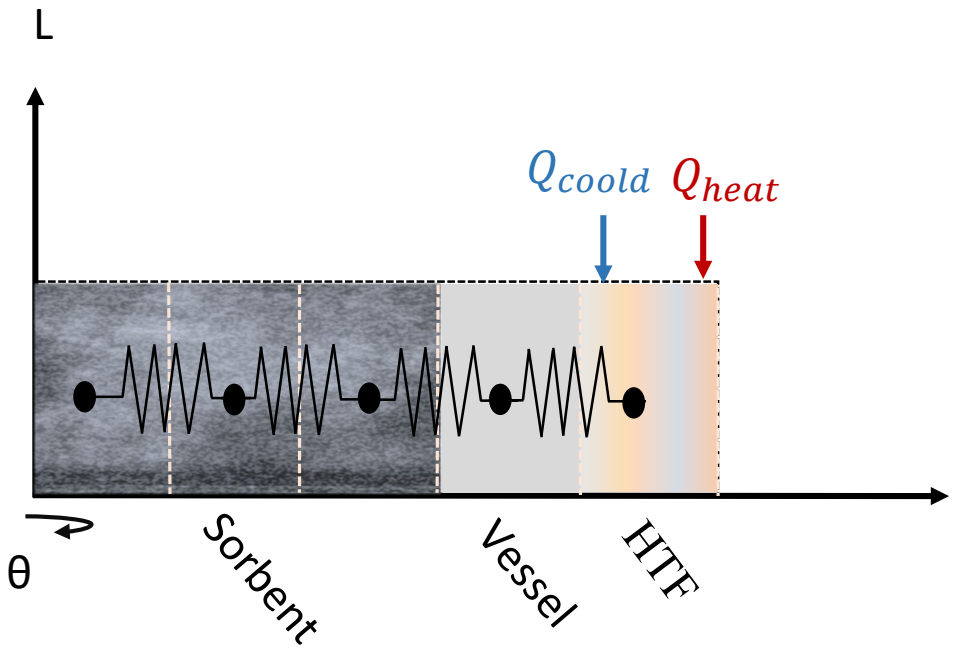
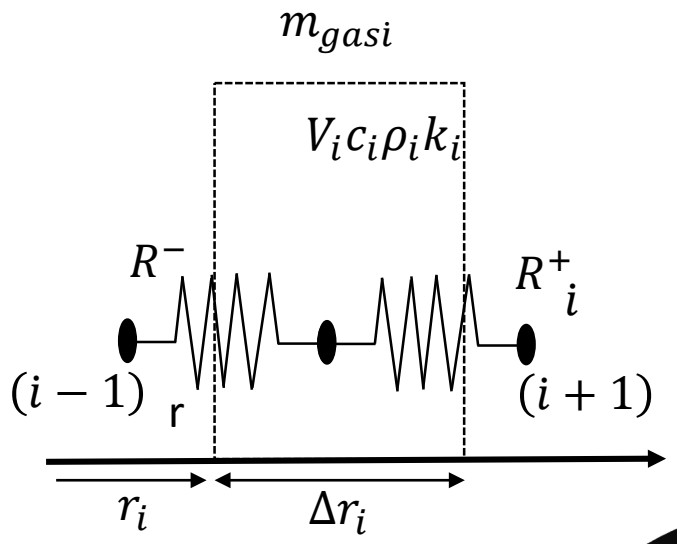
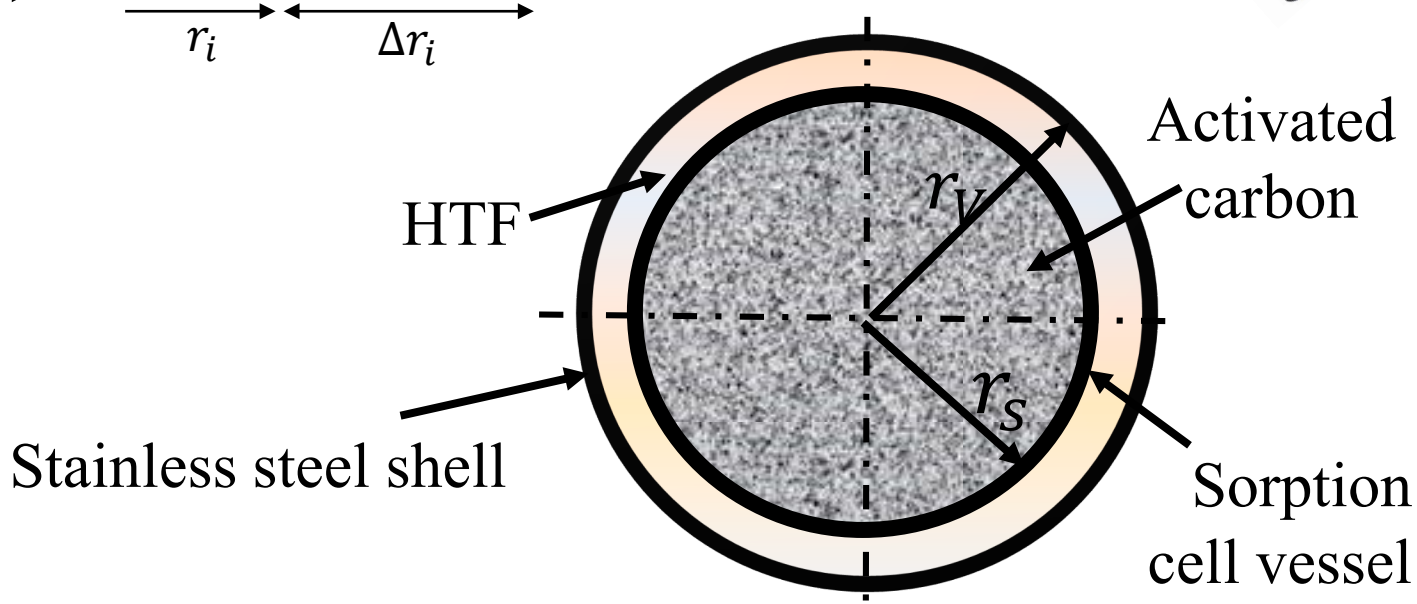






Numerical model

The energy equation:

$$\rho_i^n \cdot c_i^n \cdot V \frac{T_i^{n+1} - T_i^n}{\Delta t} = \left(\dot{q}_{gen(i)} \cdot V_i + \sum_j^m \frac{T_j - T_i}{R_{ij}} \right)_n$$

Mass balance:

Sips adsorption model:

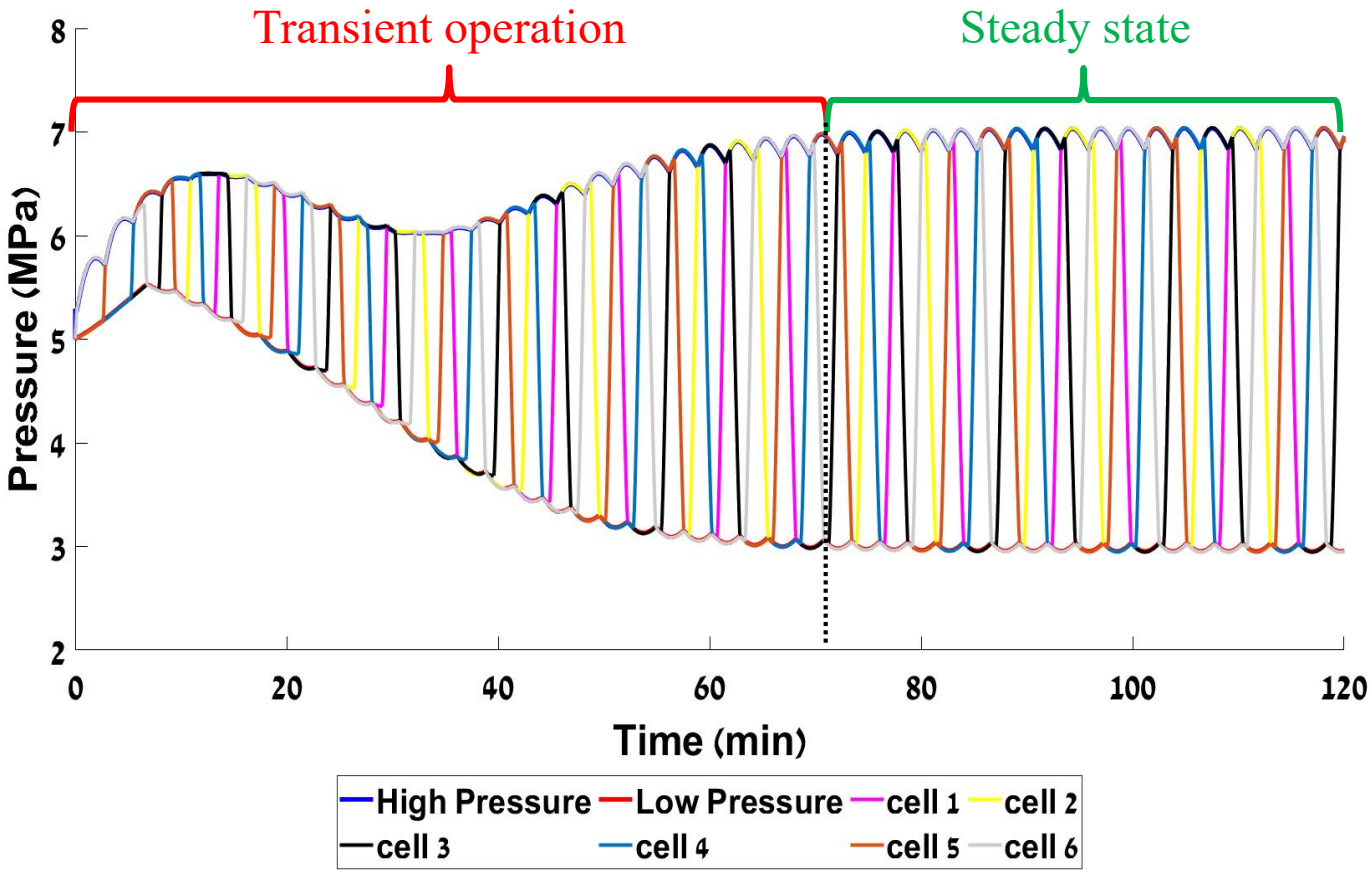
$$C = C_O \frac{(e_1 \cdot T^{e_2} \cdot p)^{\frac{1}{n}}}{1 + (e_1 \cdot T^{e_2} \cdot p)^{\frac{1}{n}}}$$

Peng–Robinson Equation of State :

$$p = \frac{RT}{\overline{V} - b} - \frac{a(T)}{\overline{V}\left(\overline{V} + b\right) + b(\overline{V} - b)}$$

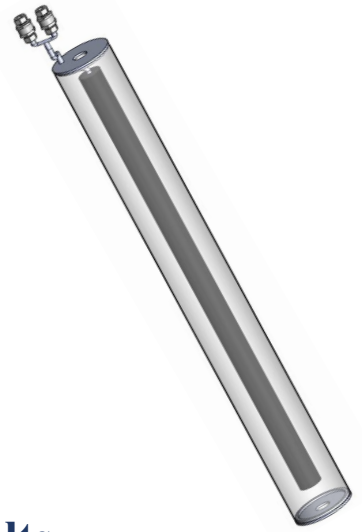
Results CO_2

Operation of a one-stage compressor (6 cells)



Operating Conditions

Cell diameter	1”
Gas flow	500 $\frac{mg}{s}$
HTF hot	453 K
HTF cold	298 K
$\dot{Q}_H$	6×145 W

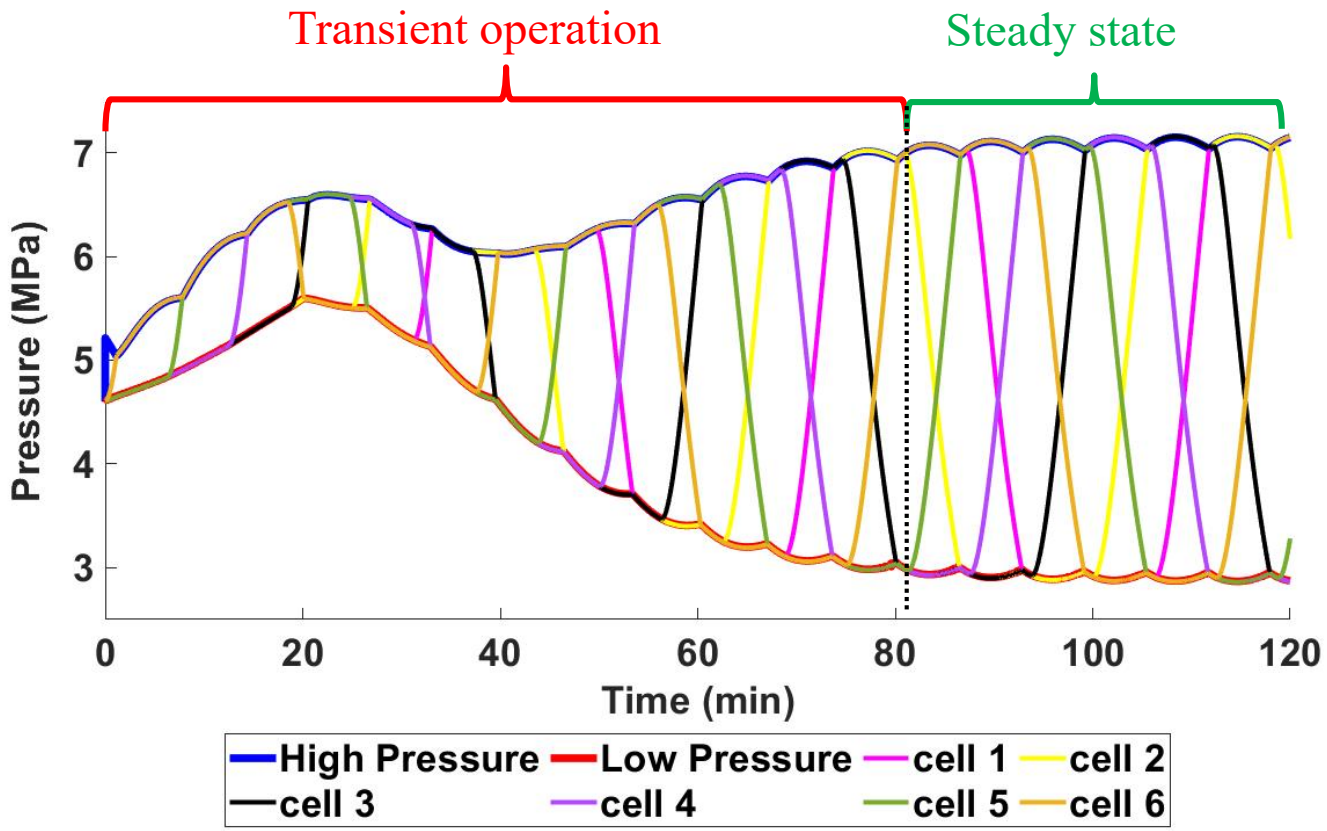


Results

High pressure	6.8- 7 MPa
Low pressure	2.9 - 3 MPa
High temperature in the cell’s centre	449K
Low temperature in the cell’s centre	300 K

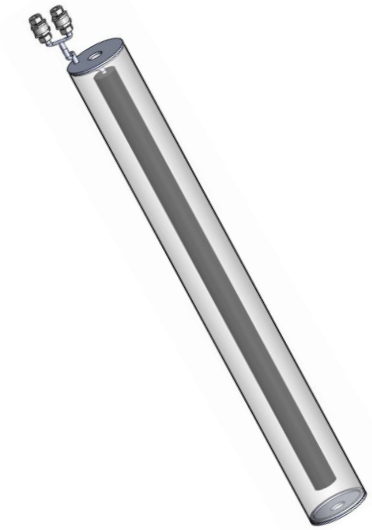
Results CO_2

Operation of a one-stage compressor (6 cells)



Operating Conditions

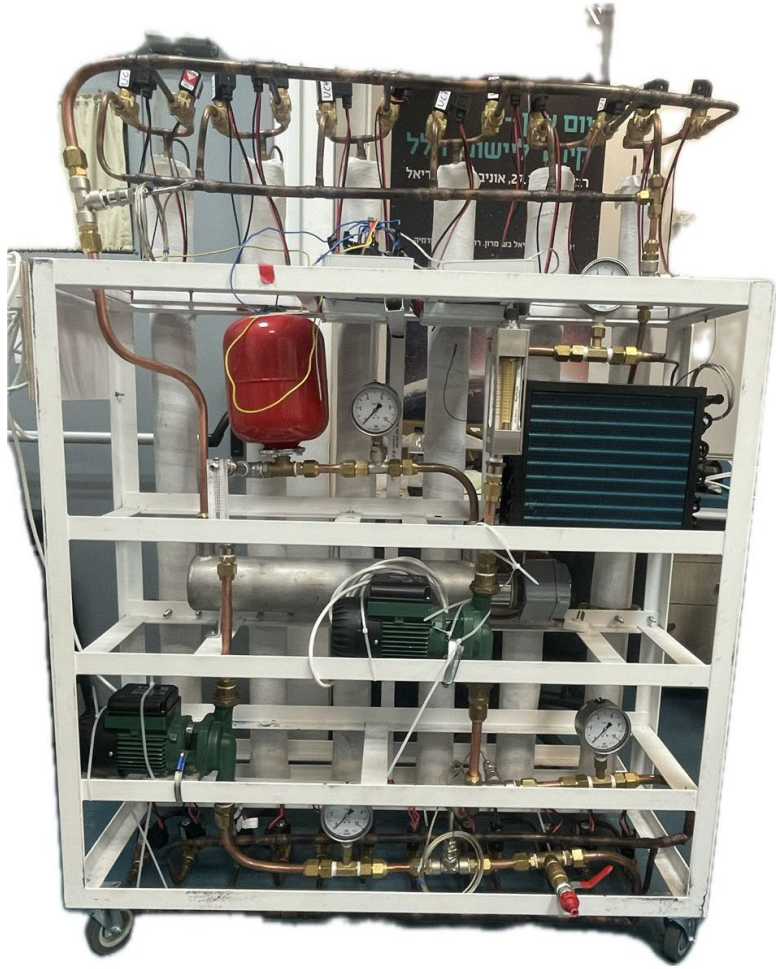
Cell diameter	2”
Gas flow	500 $\frac{mg}{s}$
HTF hot	423 K
HTF cold	298 K
$\dot{Q}_H$	6×190 W

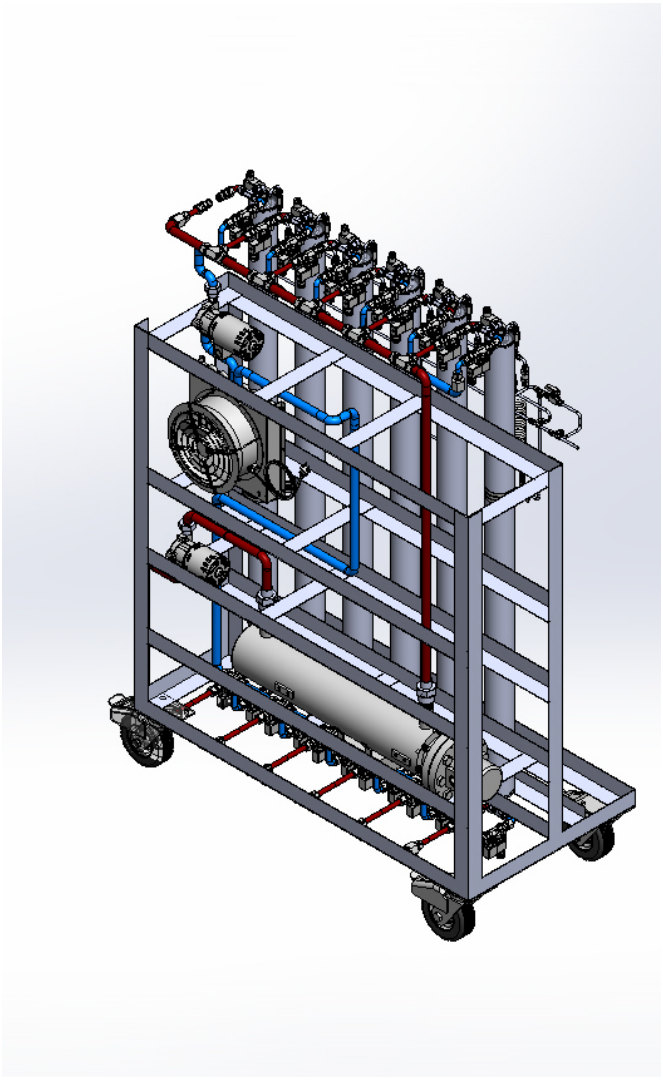


Results

High pressure	7- 7.05 MPa
Low pressure	2.9 - 3 MPa
High temperature in the cell’s centre	408K
Low temperature in the cell’s centre	310 K

Experimental demonstrator





Conclusions

- Sorption compressors are suitable for compressing any refrigerant, using the appropriate adsorbent, a suitable sorption cell design, and operating conditions.
- In the current research we focus on carbon dioxide as the refrigerant.
- Sorption compressors can replace existing mechanical compressors, while maintaining all other components in the refrigeration cycle as they are.
- The results of the numerical model confirm that the technology of thermally driven sorption compressors is suitable for refrigeration and air conditioning.
- Incorporating sorption compressors in refrigeration and air conditioning systems makes them thermally driven, instead of electrically driven. Consequently, we can significantly reduce the global electricity consumption.

Thank you for listening

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