

Optimization of a hybrid CO₂ capture process combining a vacuum pressure swing adsorption and a carbon purification unit

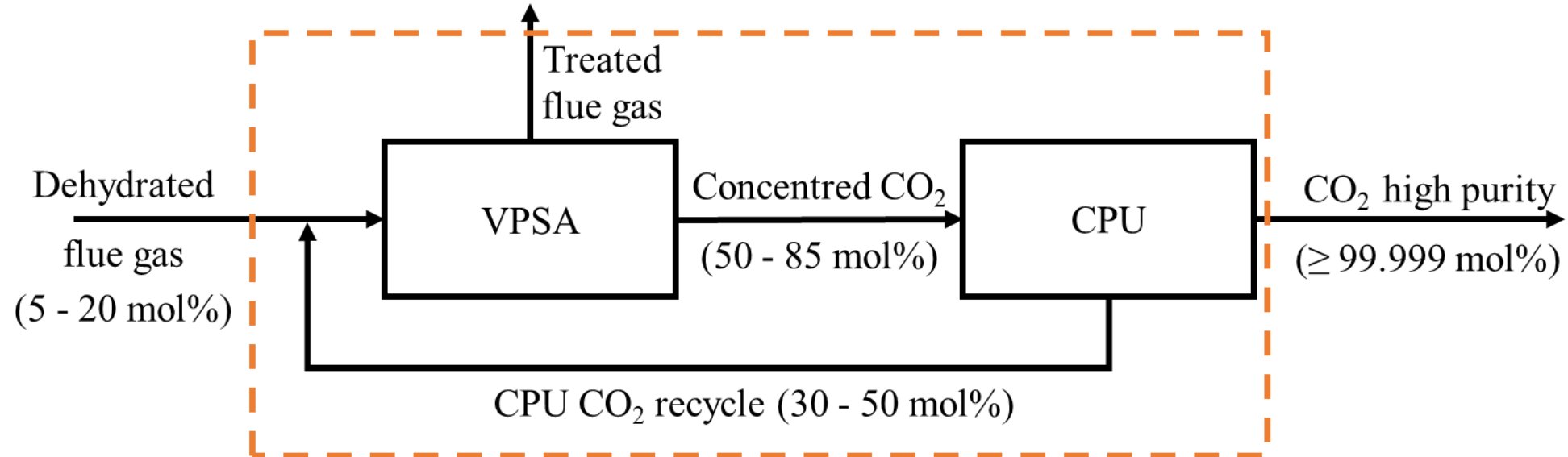
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VPSA + CPU objectives

- Linking VPSA and CPU

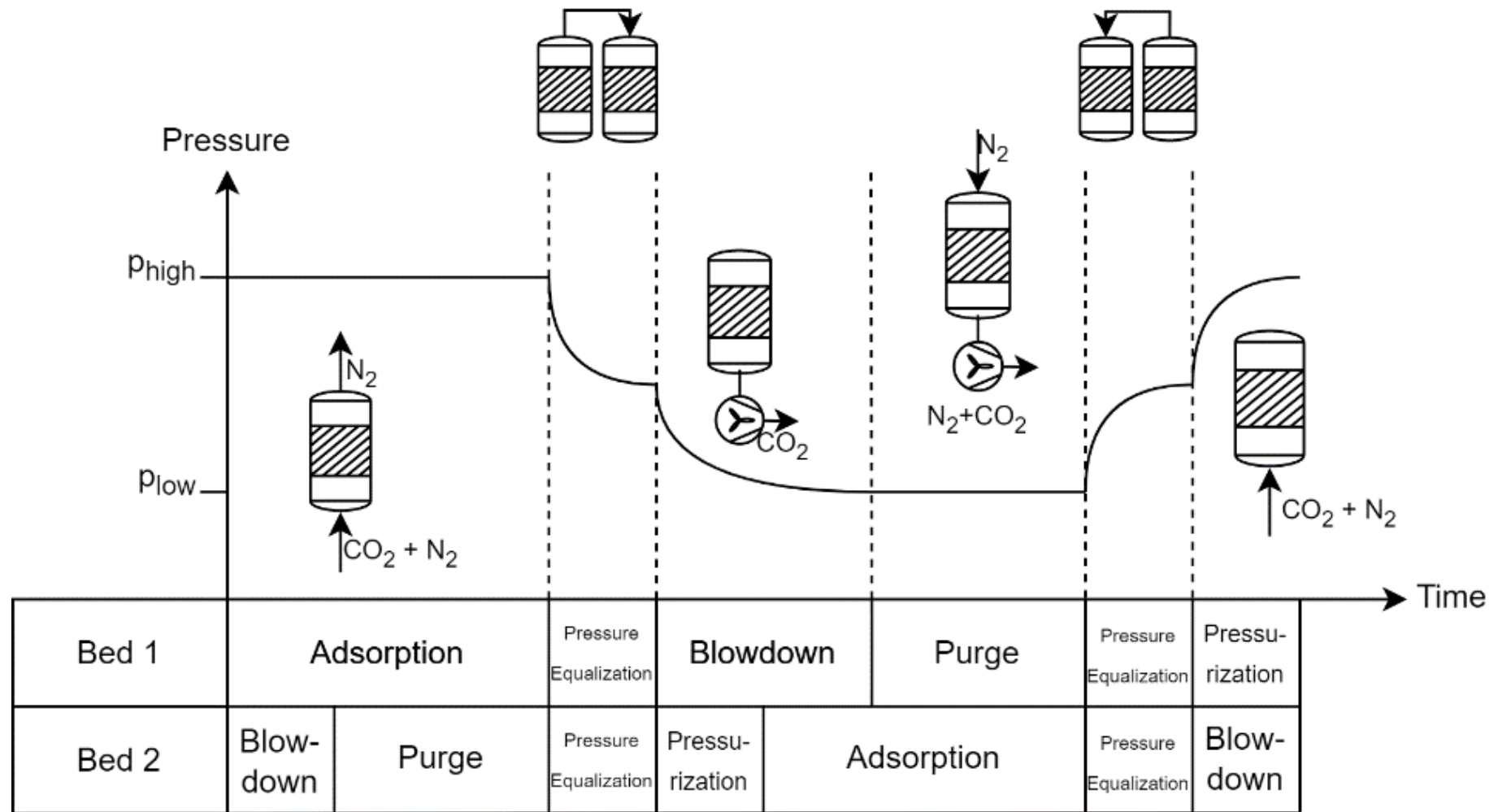


VP SA schematization

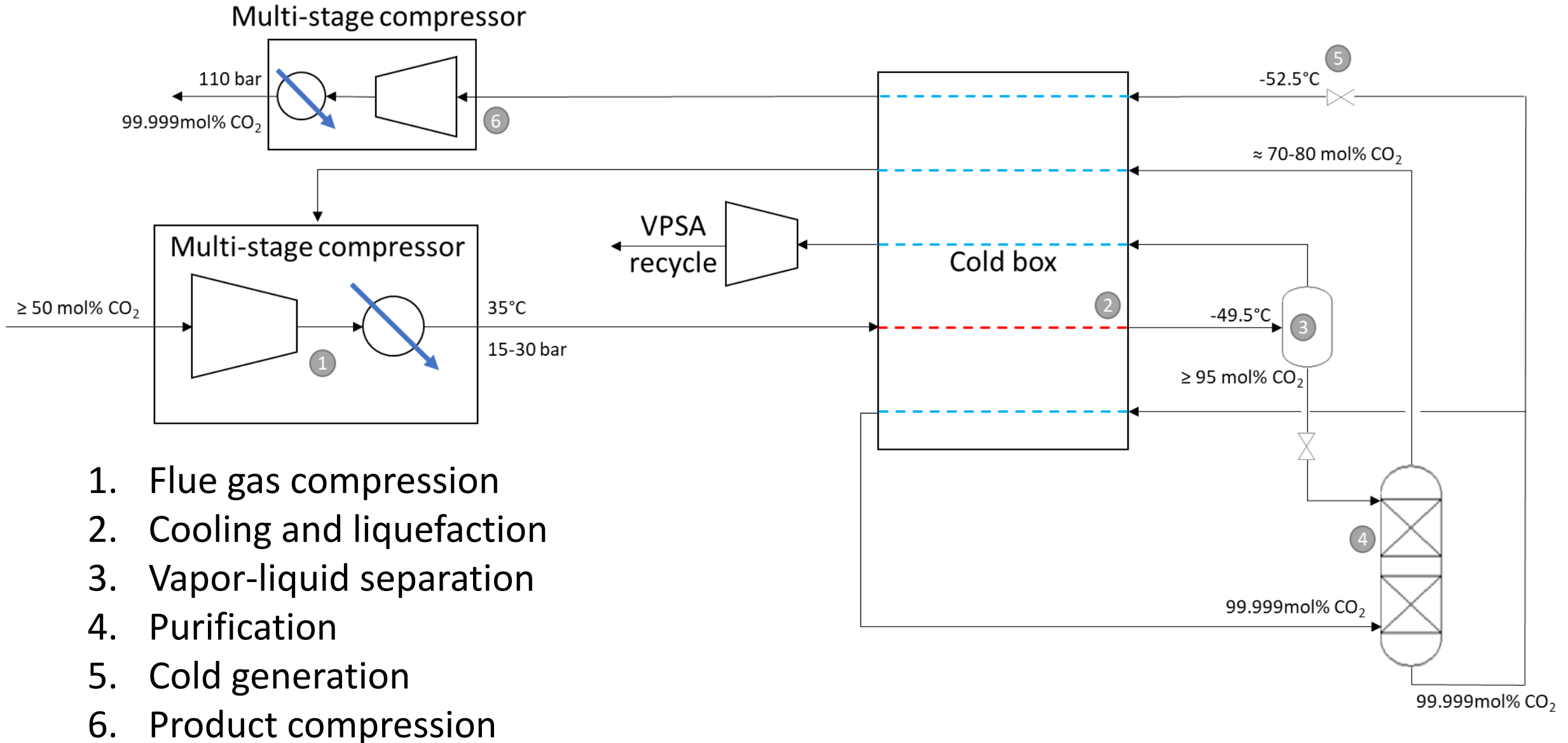
Work of A. Henrotin

VP SA configuration
2 bed – 6 step

Adsorbant
Zeolite 13X

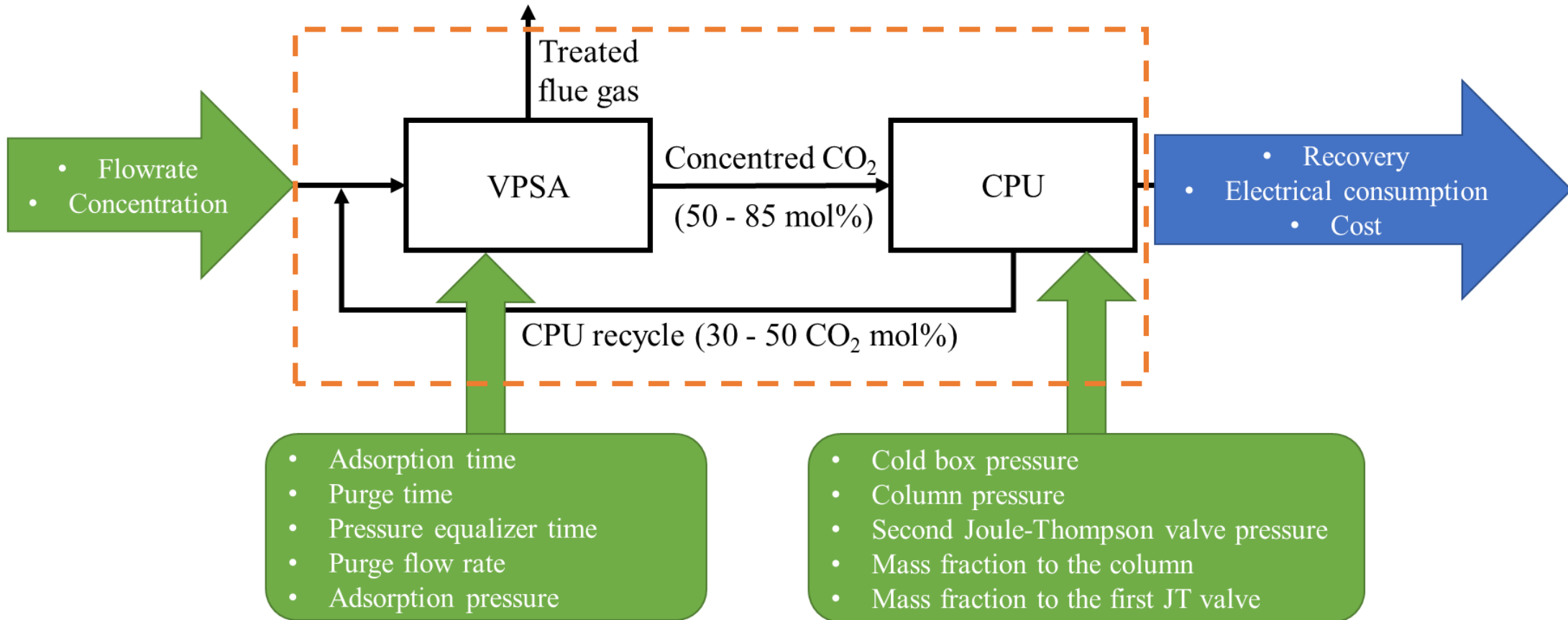


CPU schematization



1. Flue gas compression
2. Cooling and liquefaction
3. Vapor-liquid separation
4. Purification
5. Cold generation
6. Product compression

VPSA + CPU input & output

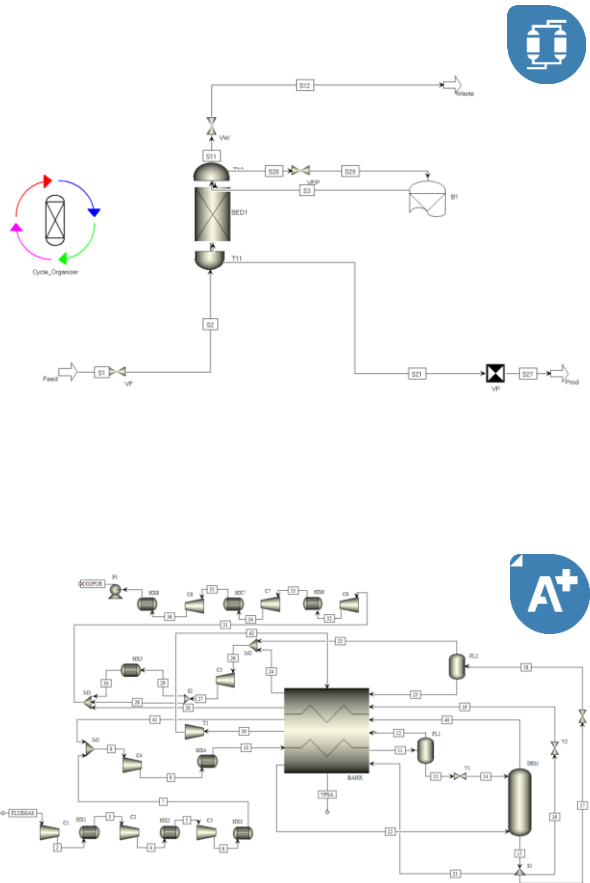


Definitions	Units	Lower bounds	Upper bounds
Inlet CO ₂ concentration from flue gas	mol%	5	27
Inlet flue gas flowrate of VPSA	Nm ³ /h	14,000	25,000
Adsorption time	s	60	1500
Purge time	s	10	1490
Pressure equalizer time	s	10	50
Purge flowrate	Nm ³ /h	100	20,000
Adsorption pressure	bar	1.01325	3

Definitions	Units	Lower bounds	Upper bounds
Inlet CO ₂ concentration from VPSA	mol%	50	85
Inlet pre-concentrated flowrate of CPU	Nm ³ /h	1000	40,000
Cold box pressure	bar	15	30
Desorption column pressure	bar	9	17
Second Joule-Thompson valve pressure	bar	7	14
Mass fraction towards desorption column	-	0.05	0.20
Mass fraction towards first JT valve	-	0.05	0.75

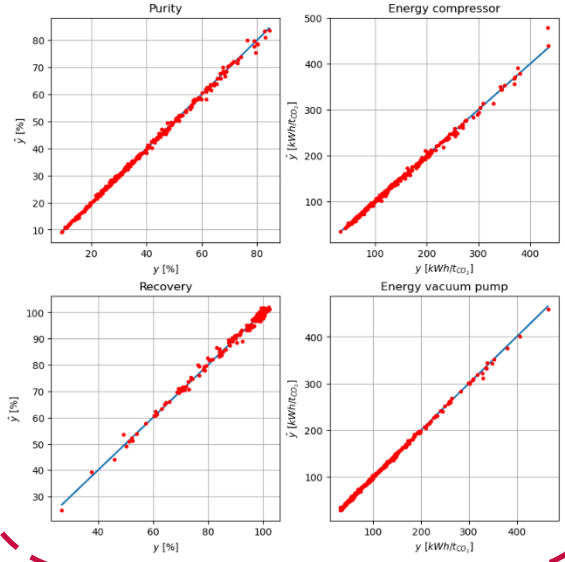
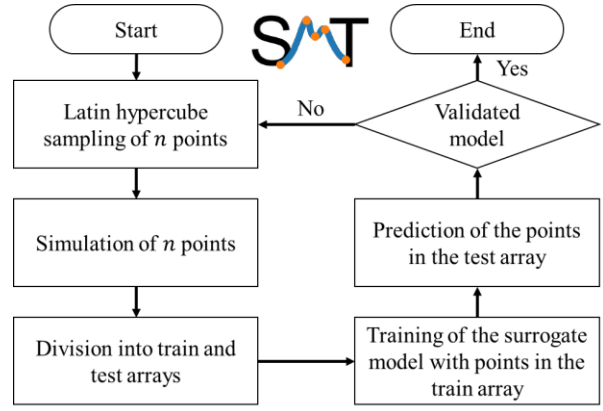
VPSA + CPU proceeding

Aspen modeling



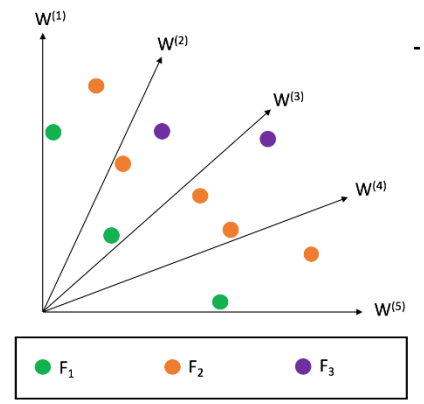
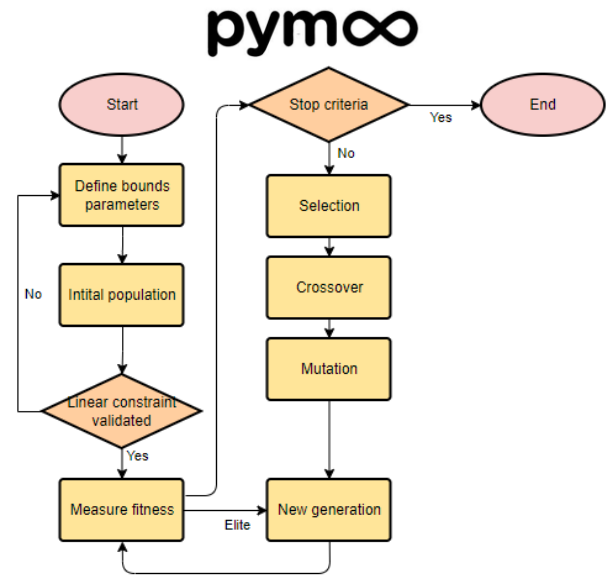
Data treatment

Surrogate building

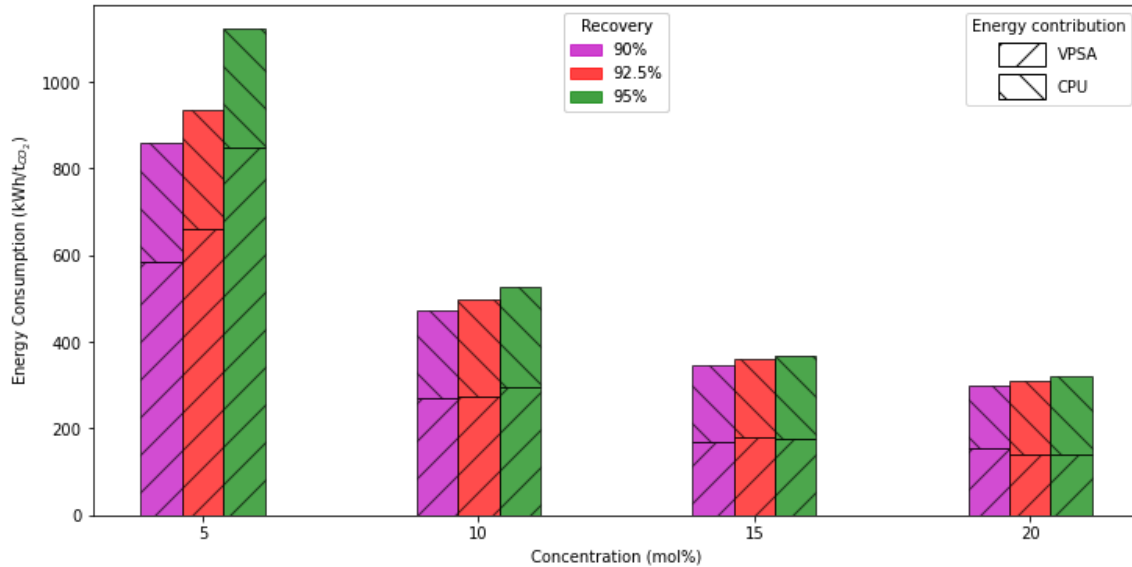


VPSA + CPU coupling

Optimization



Energy and cost results



Cost has similar trend as energy

➤ More than 90% of the cost from electricity

5 and 10% are very expensive

15 and 20% can be interesting

➤ Strong dependance on

- carbon tax
- electricity price

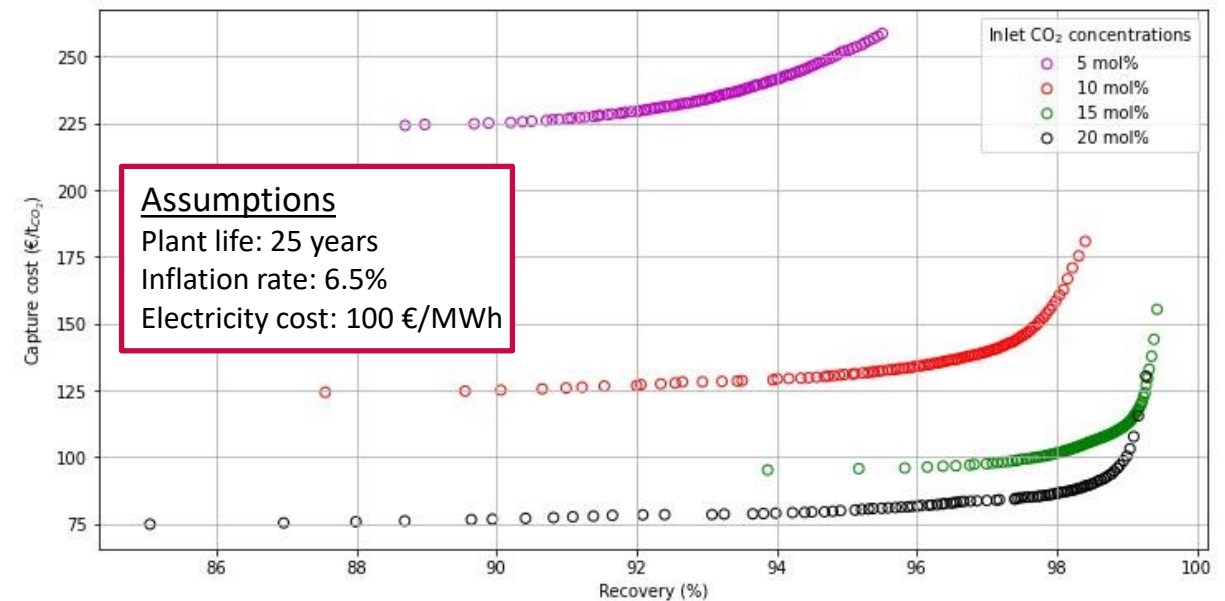
Gap between 5% and others is more important

- Higher VPSA consumption
- CO₂ purity limit reached for the CPU inlet (50%)

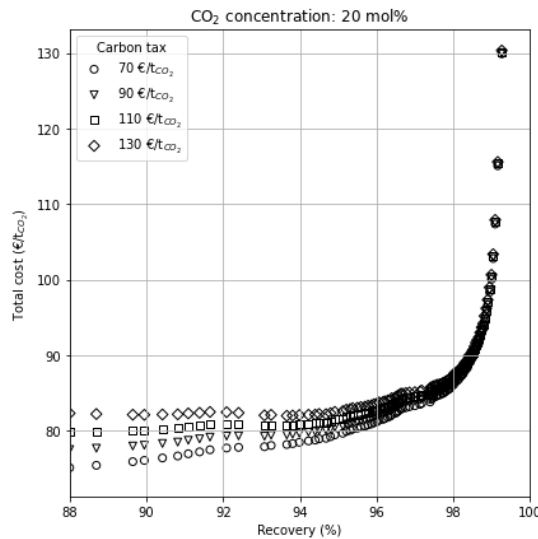
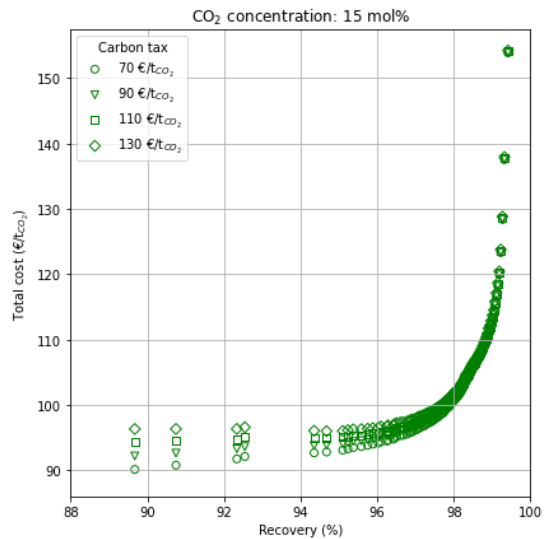
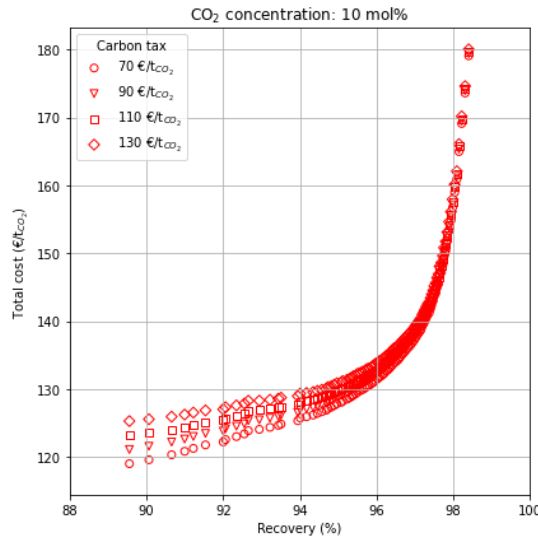
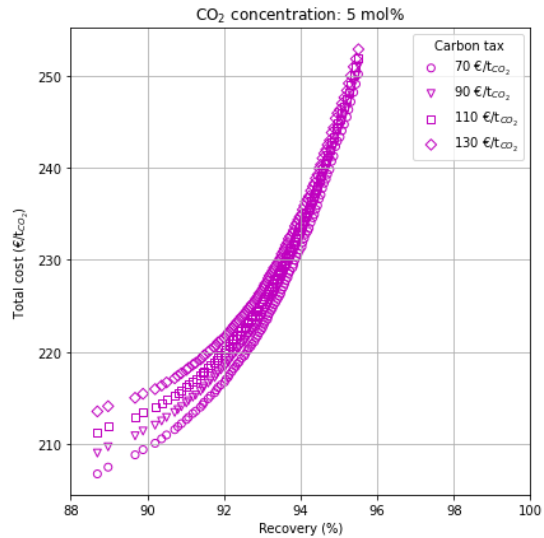
VPSA energy consumption > CPU energy consumption for 5 to 15 %

Increase recovery by 2.5%

- Increase electrical consumption by a 3-5%



Total cost with carbon tax



$$Total\ cost = \frac{CO_2\ recovery}{100} * CO_2\ capture\ cost + \frac{(100 - CO_2\ recovery)}{100} * carbon\ tax$$

In 2023: EU-ETS varying between 77.39 and 100.34 €/t_{CO2}

Optimum for several cases study

- Recovery more than 90% can be interesting for 15 and 20%

Optimum evolves to higher recovery when carbon tax increases

Considering only carbon capture cost

- 5 and 10% not interesting
- 15 and 20% more or less close to the carbon tax

Electricity price impact

The price of electricity will determine the choice of technology

A decrease of the electricity price

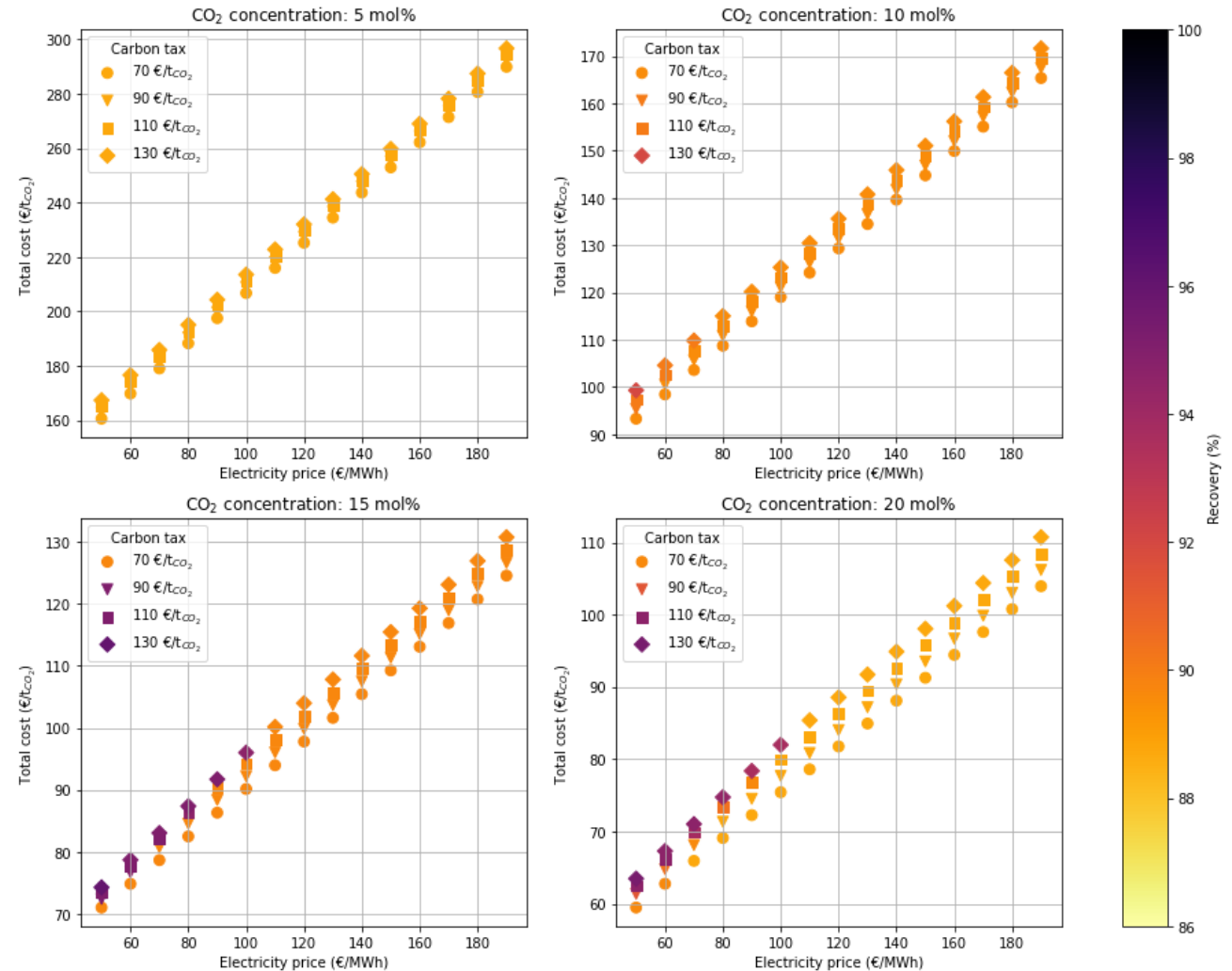
- Recovery optimum increase
- Total cost decrease

Considering only carbon capture cost

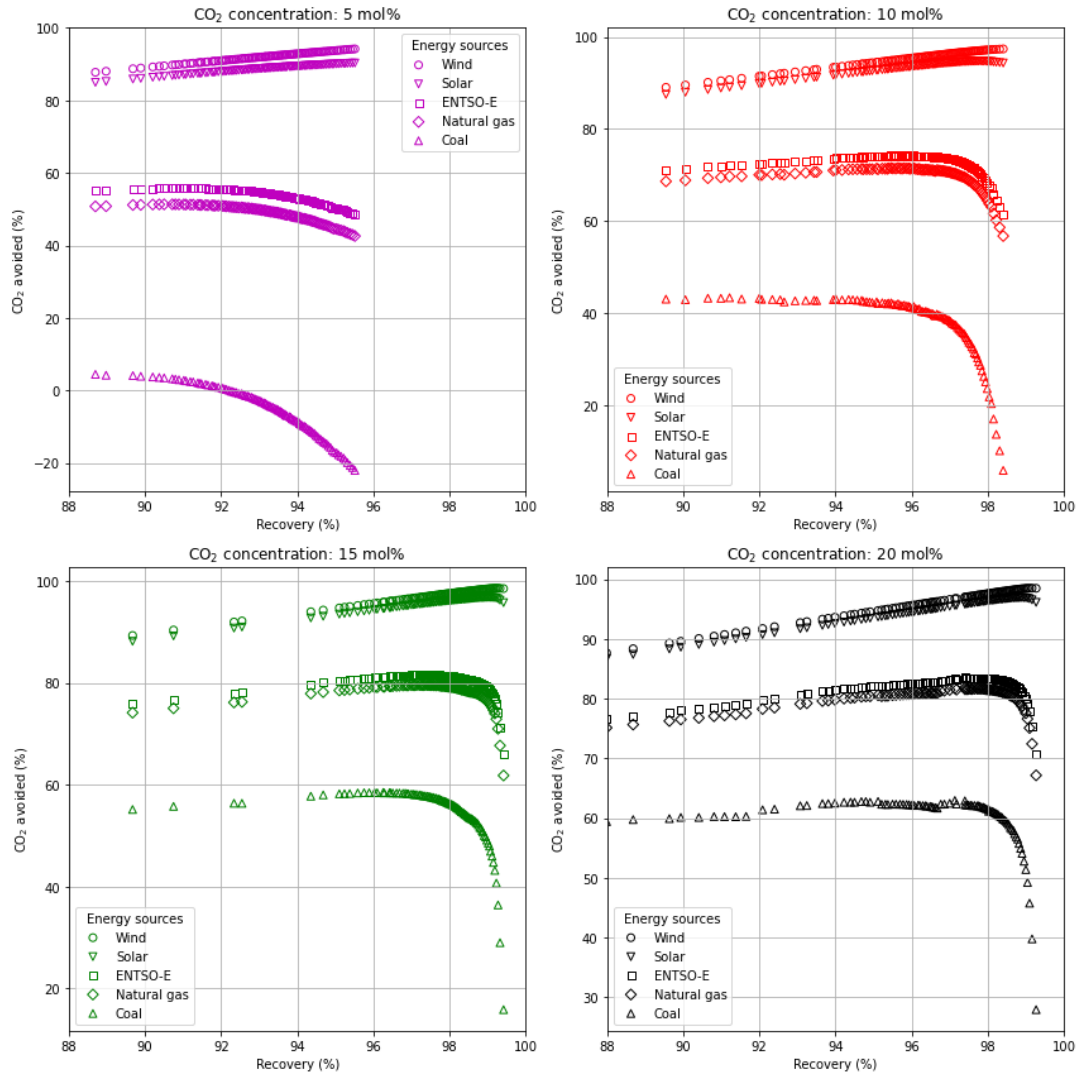
- 5% not interesting
- 10% more or less close to the carbon tax
- 15 and 20% can be interesting

Optimal windows

- Carbon tax higher than 100 €/t_{CO2}
- Electricity price lower than 100 €/MWh



Emission from electricity source



Electricity production has impact on total CO₂ avoided

$$CO_2 \text{ avoided} = \frac{CO_2 \text{ captured} - CO_2 \text{ emitted by power production}}{CO_2 \text{ flue gas}}$$

Emissions factor of electricity (kg_{CO₂e}/kWh):

- Wind = 0.011;
- European Network of Transmission System Operators (ENTSO-E) = 0.399;
- Natural gas = 0.450;
- Coal = 1.000

European mix reduce recovery at 90% of 5% to 20% by:

- 32%, 20%, 15% and 13%
- Non-neglectable impact of the electricity source

Optimum for coal

- As effective in capturing + while consuming + as in capturing - while consuming -

THANKS VERY MUCH FOR YOUR ATTENTION

ANY QUESTIONS?

CPU Aspen Plus results

Process constraint  Limit between the variables

