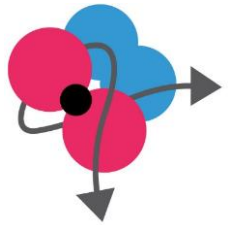
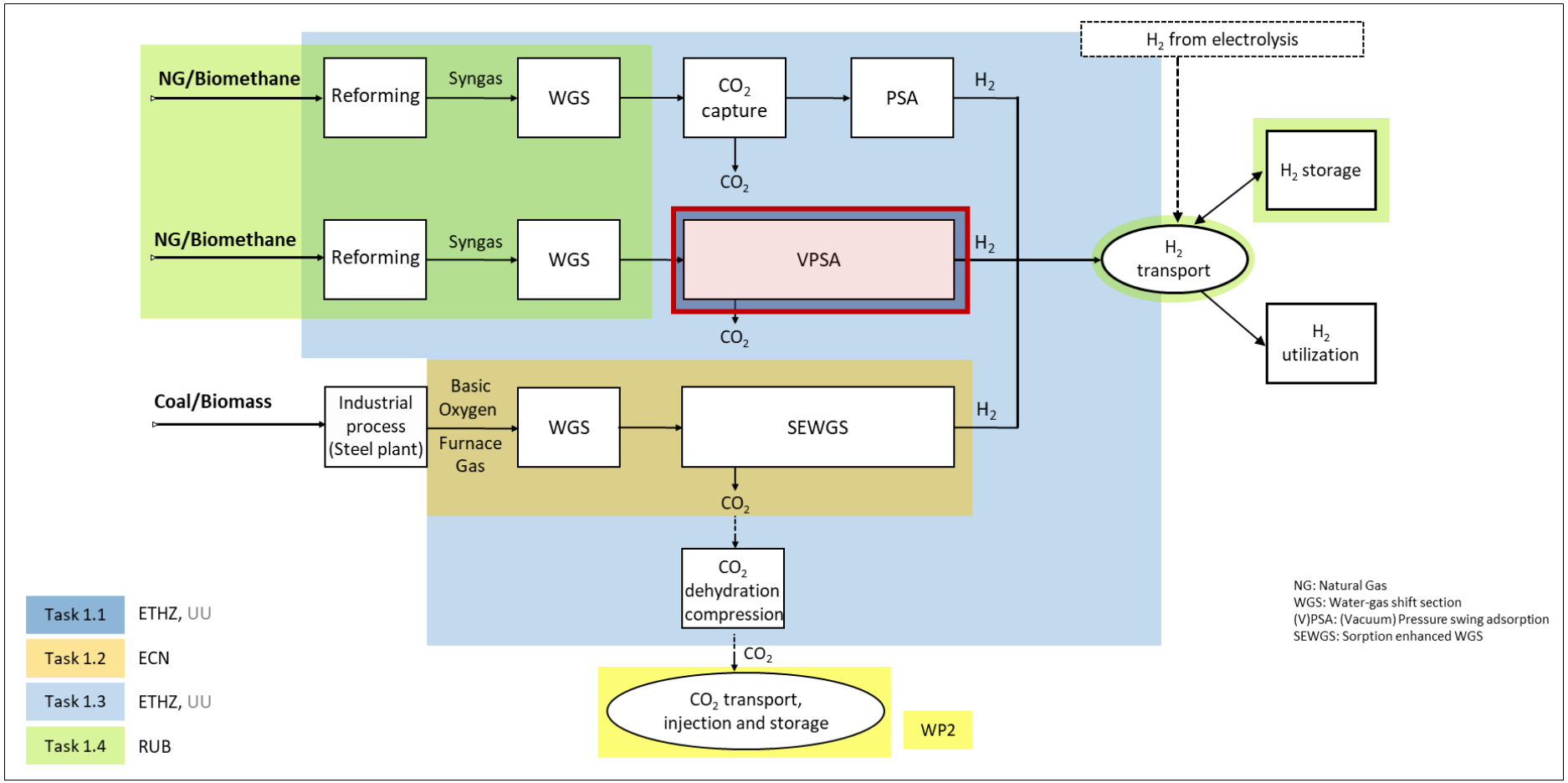


Demonstration of VPSA for CO_2-H_2 co-production

Anne Streb, Marco Mazzotti

2020-06-22

ELEGANCY – the potential of VPSA

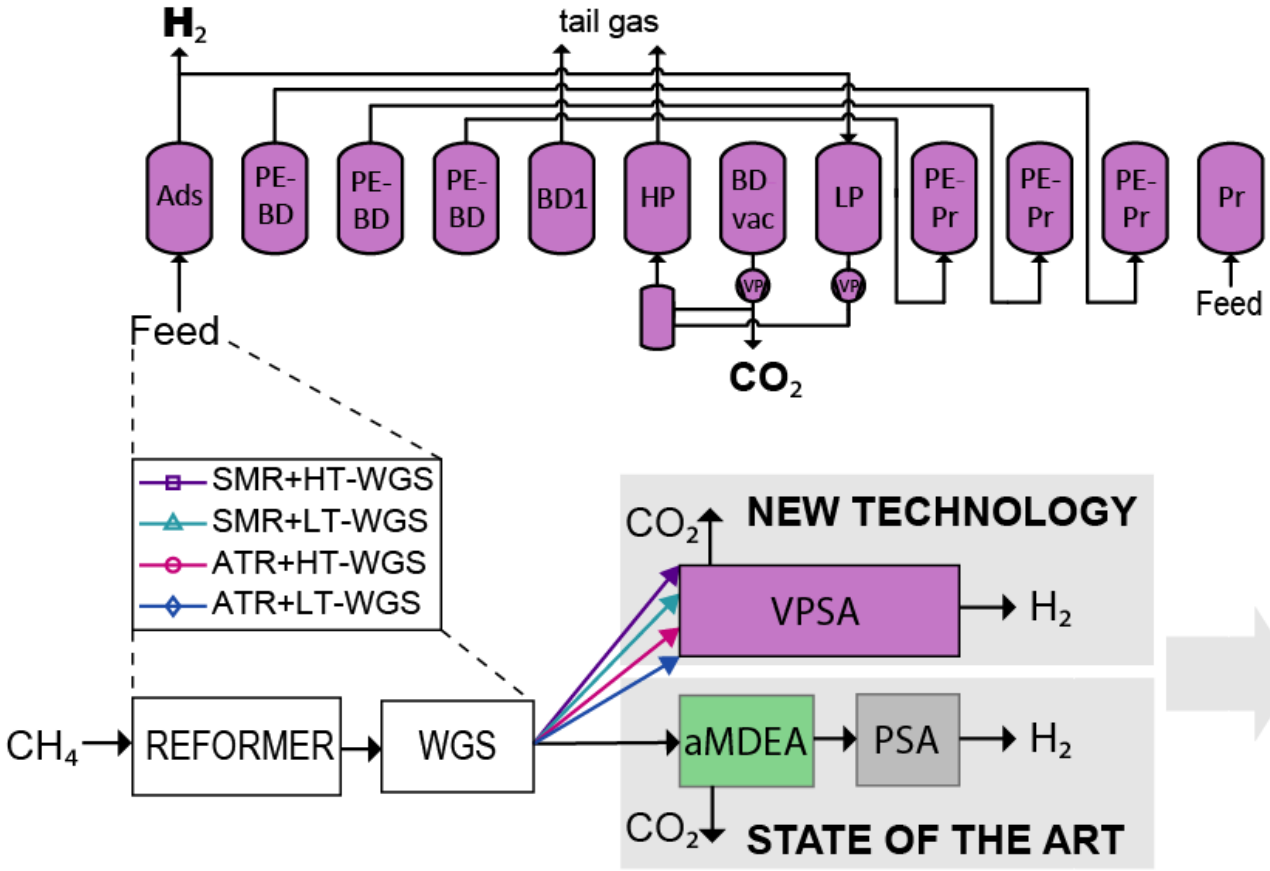


Goals:

1) Development
2) Modeling
3) Optimization
4) **Experimental Demonstration**

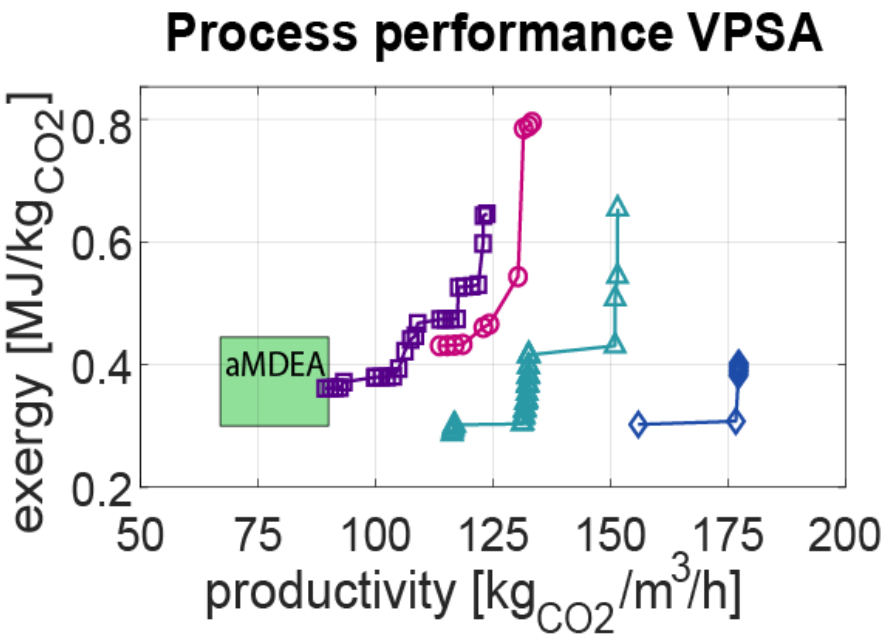
of novel Vacuum Pressure Swing Adsorption (**VPSA**) technology

1-3: development, modeling and optimization of VPSA cycles



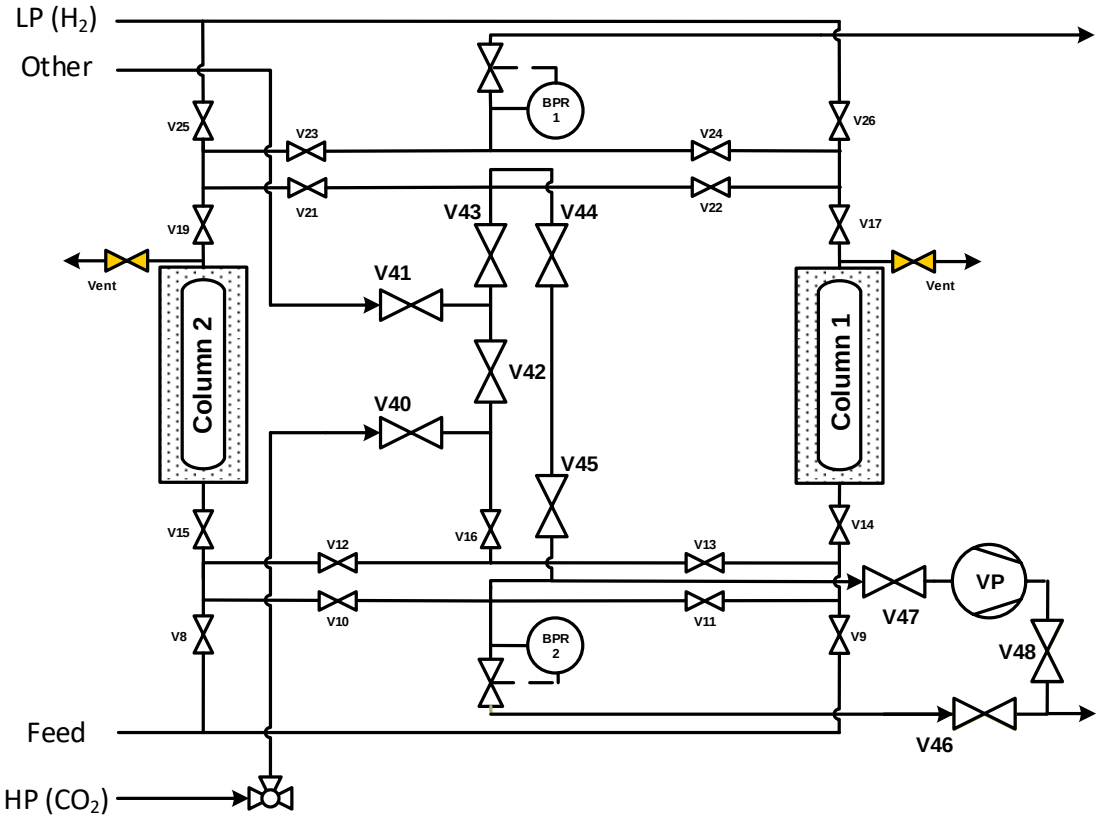
Streb, Hefti, Gazzani, Mazzotti; (2019); *Ind. Eng. Chem. Res*

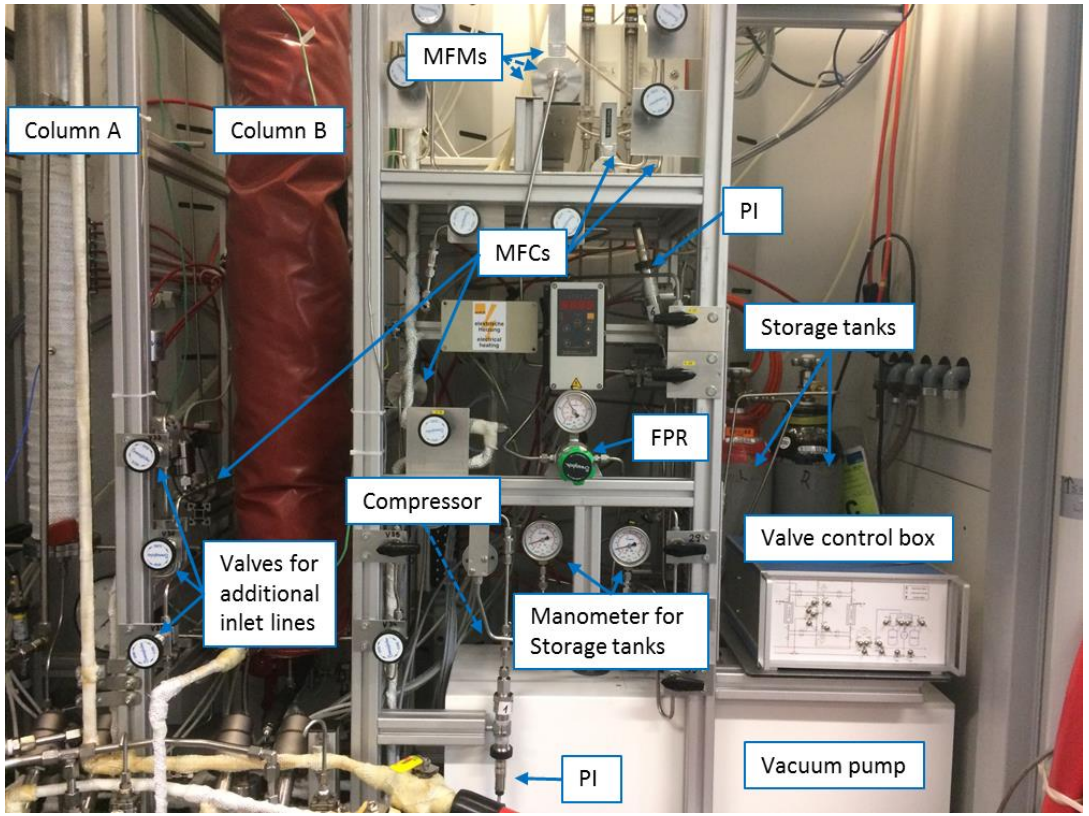
Streb, Mazzotti; (2020); *Ind. Eng. Chem. Res*



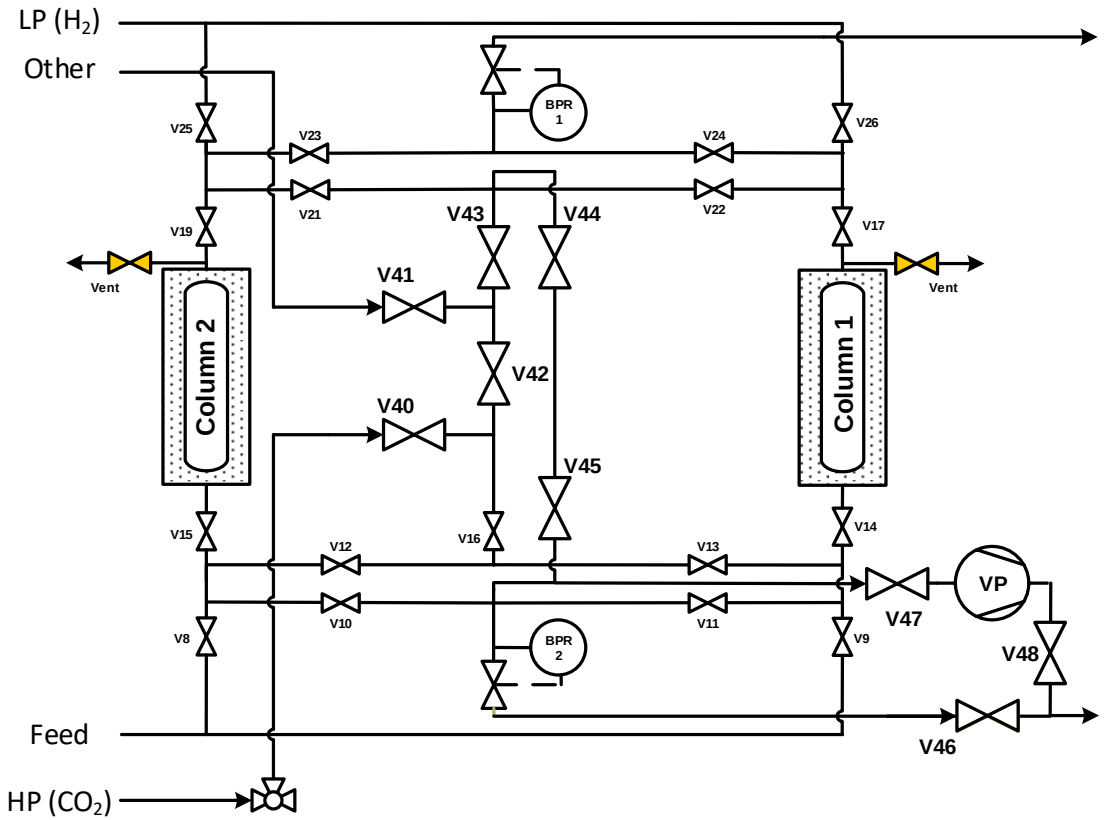
4: experimental demonstration – VPSA setup

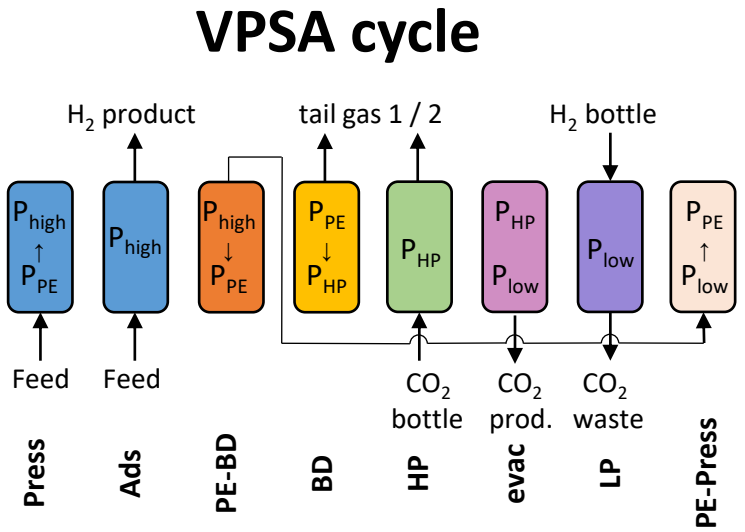
Design → Safety Analysis → Construction → Automation (LabVIEW)



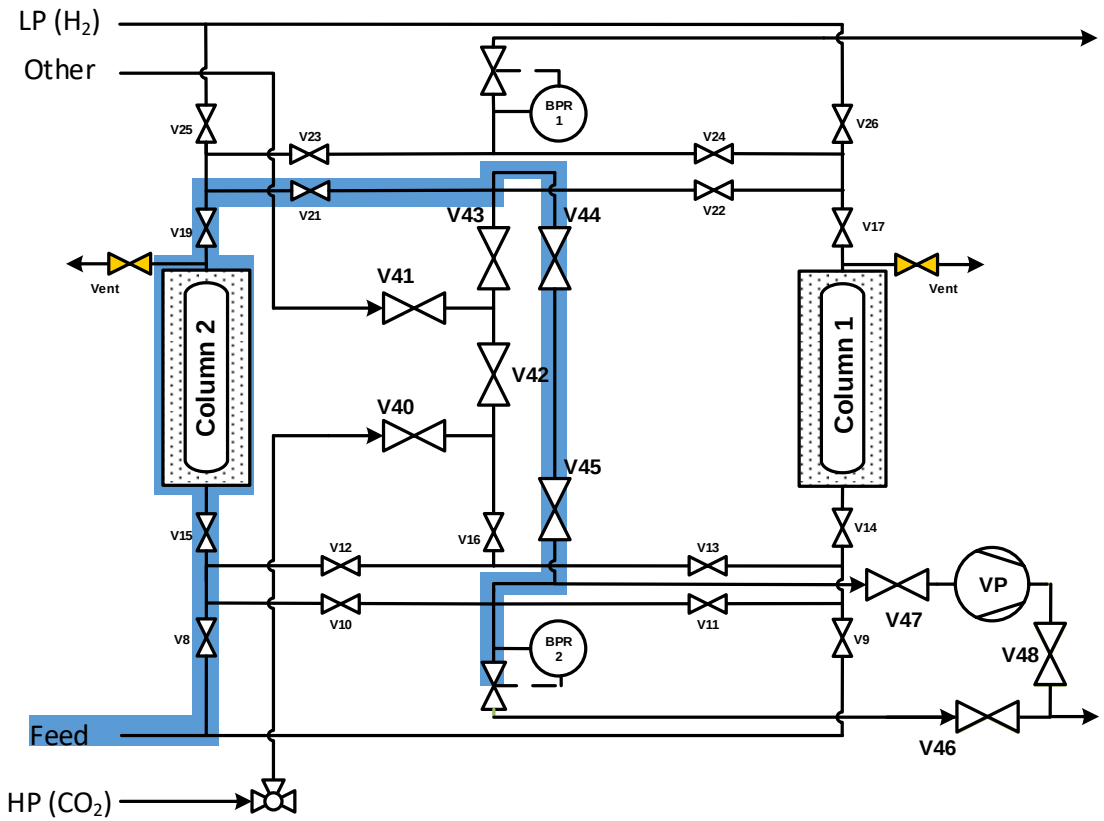


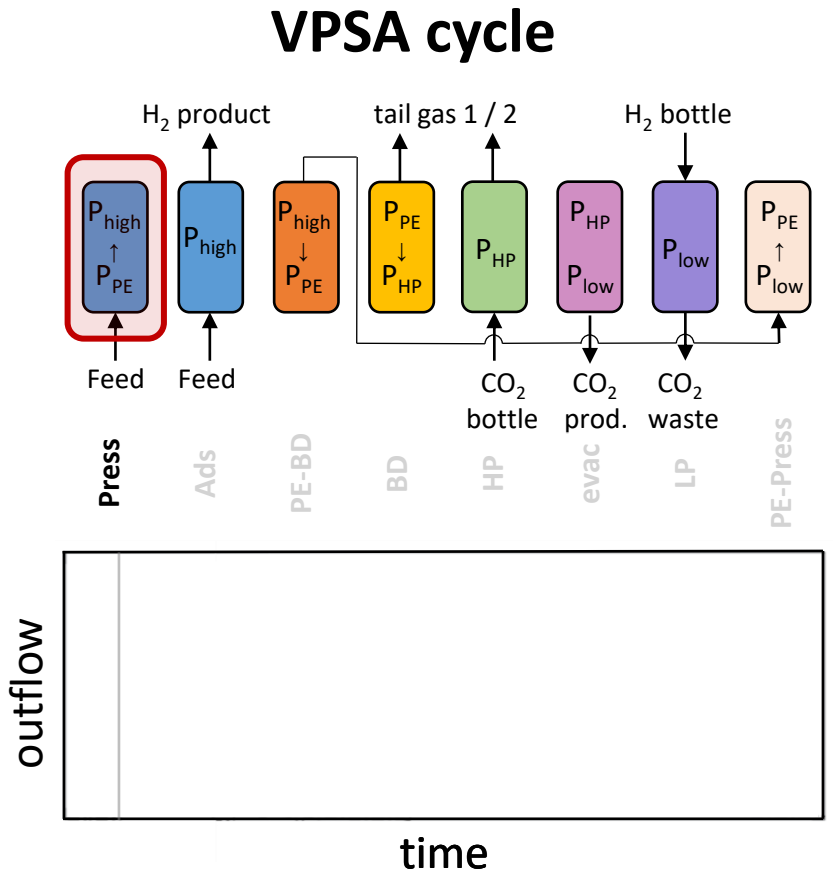
8 step VPSA cycle



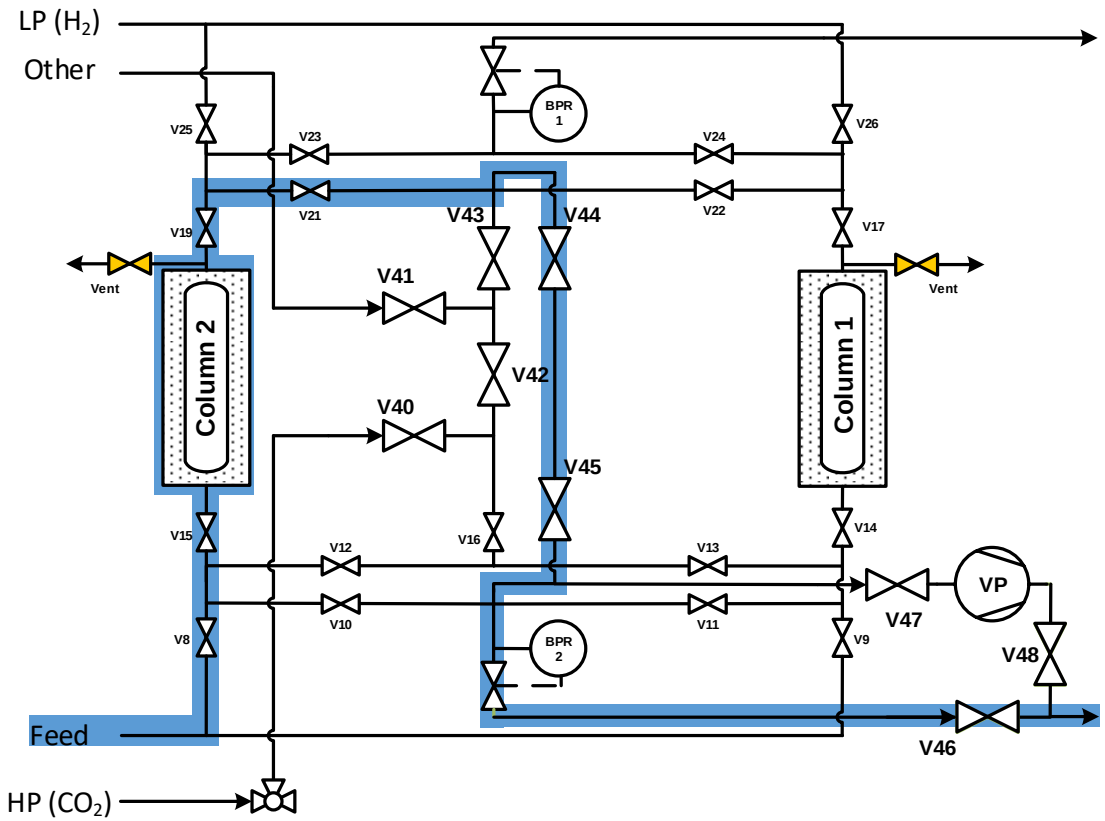


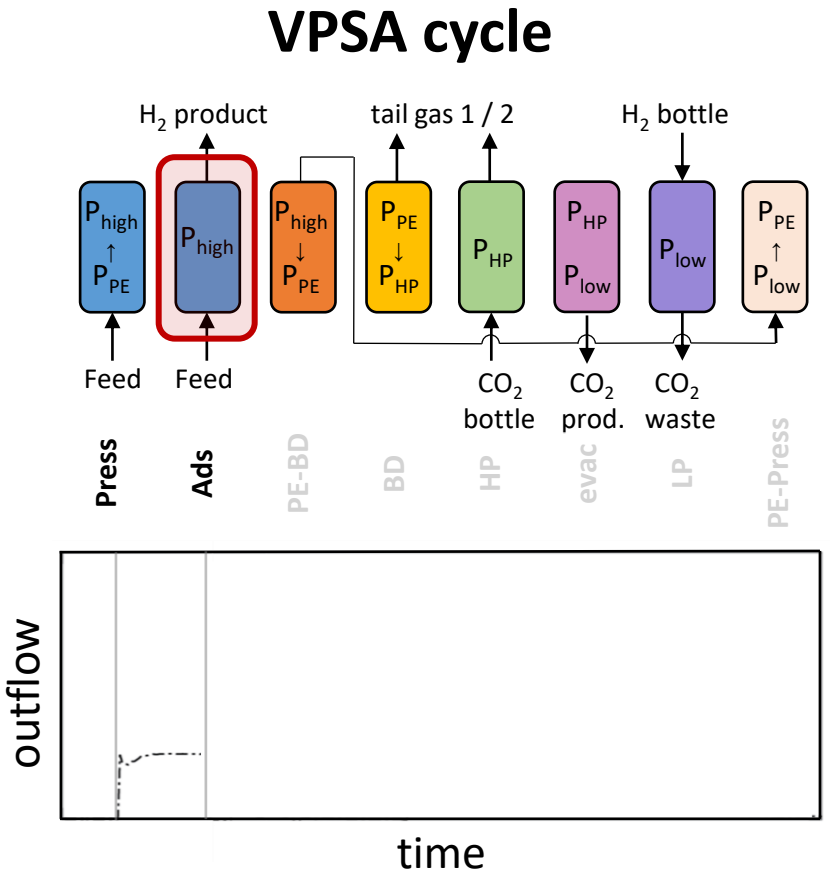
Cycle implementation



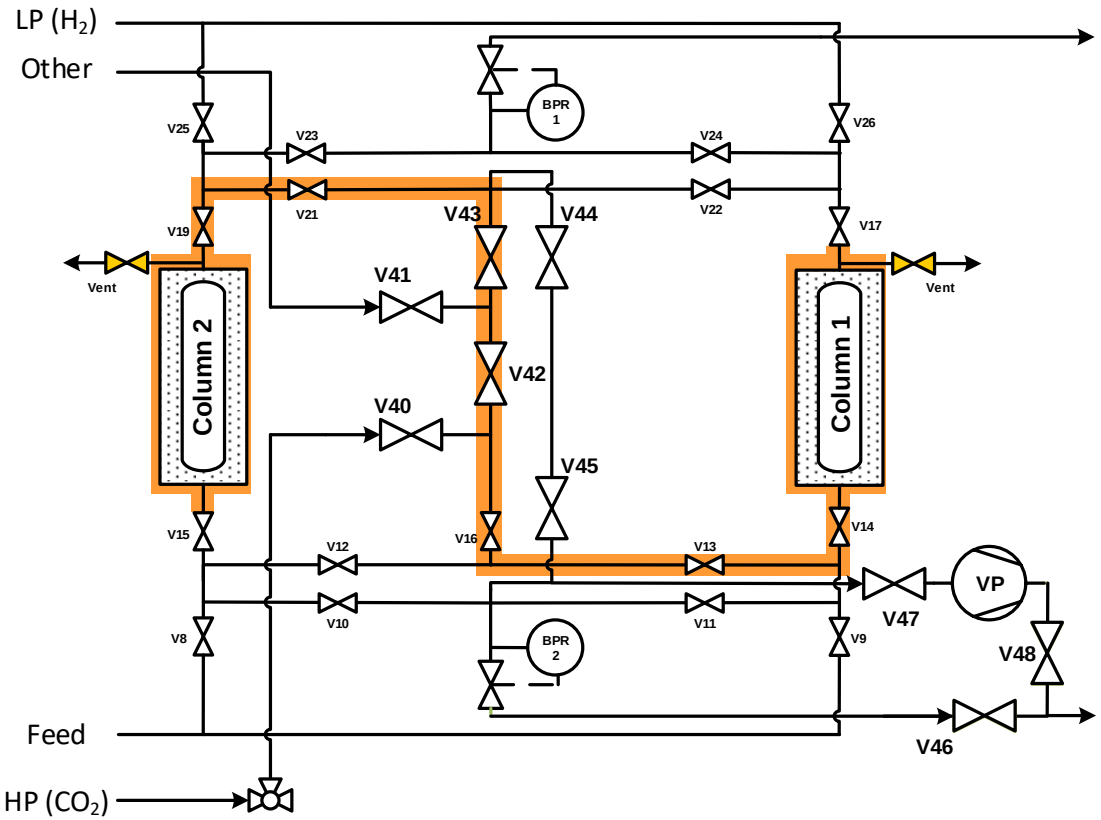


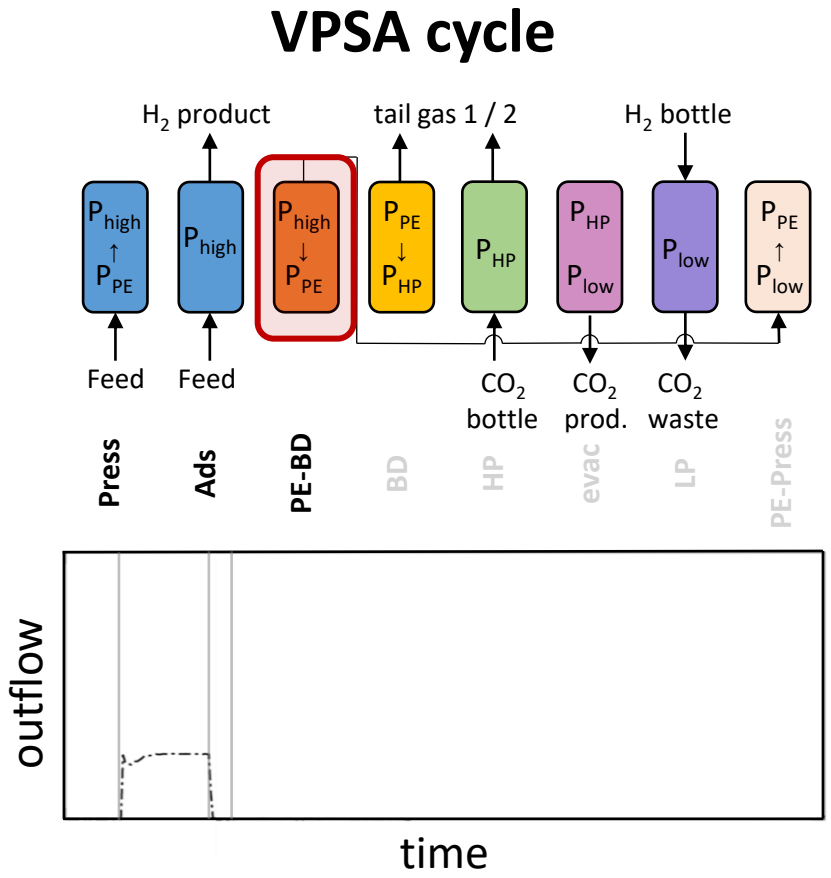
Cycle implementation



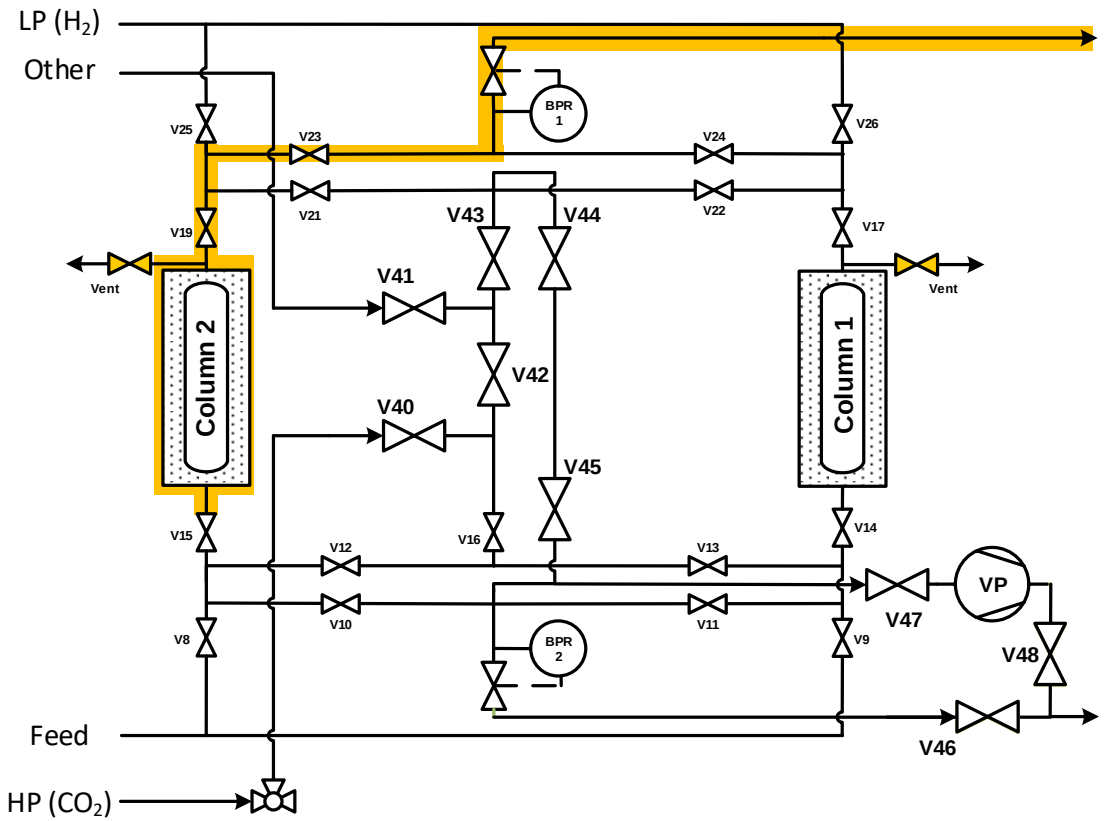


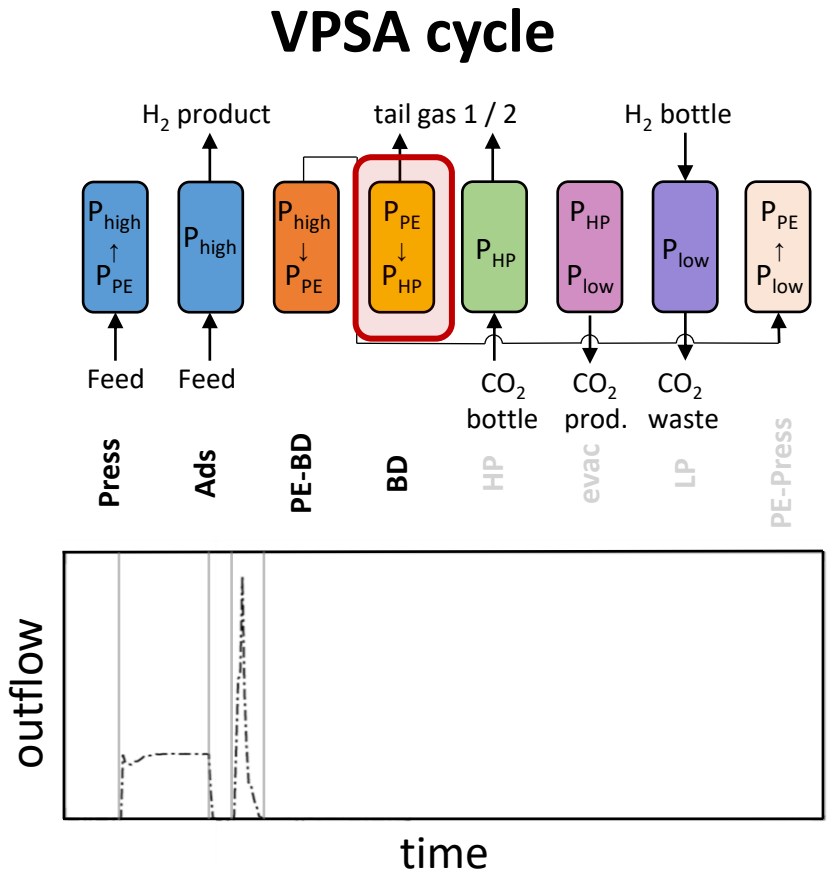
Cycle implementation



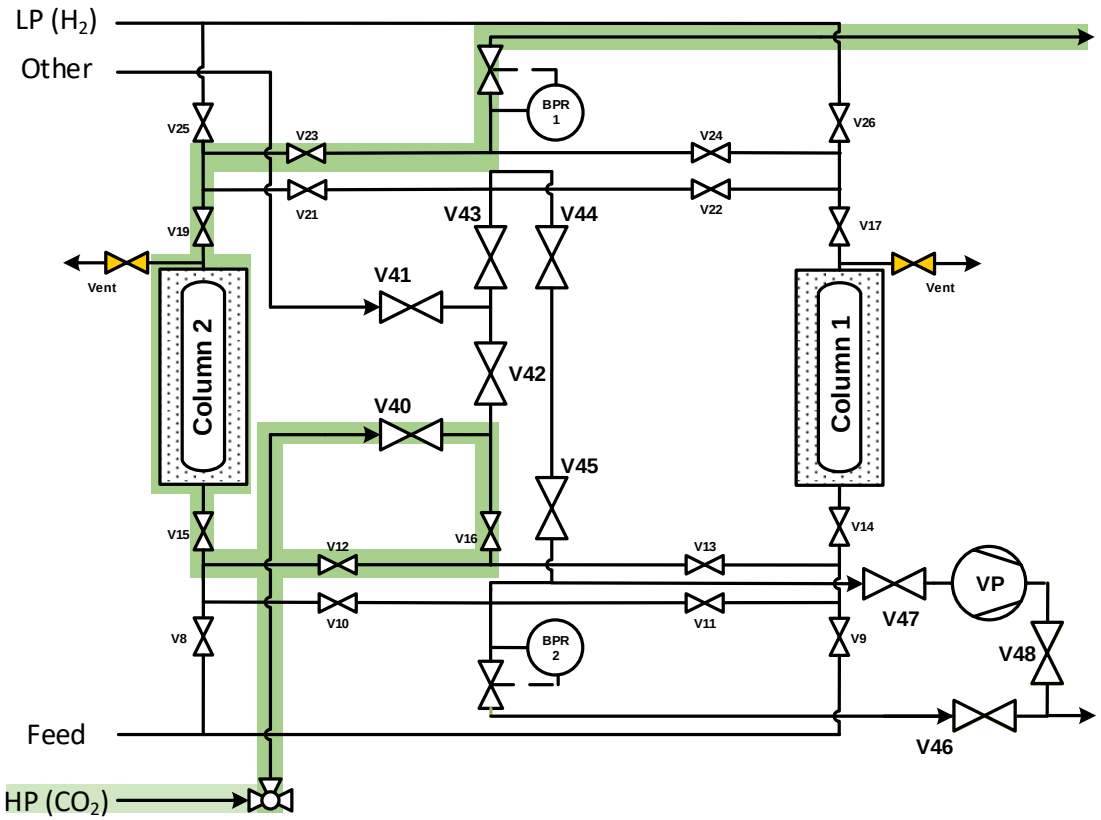


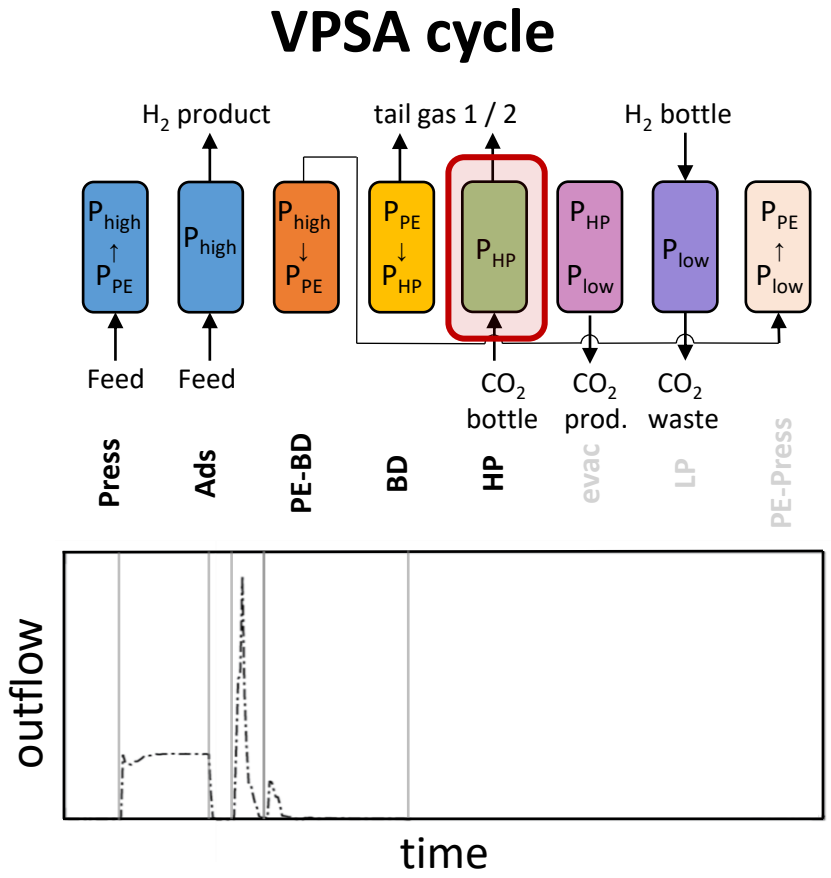
Cycle implementation



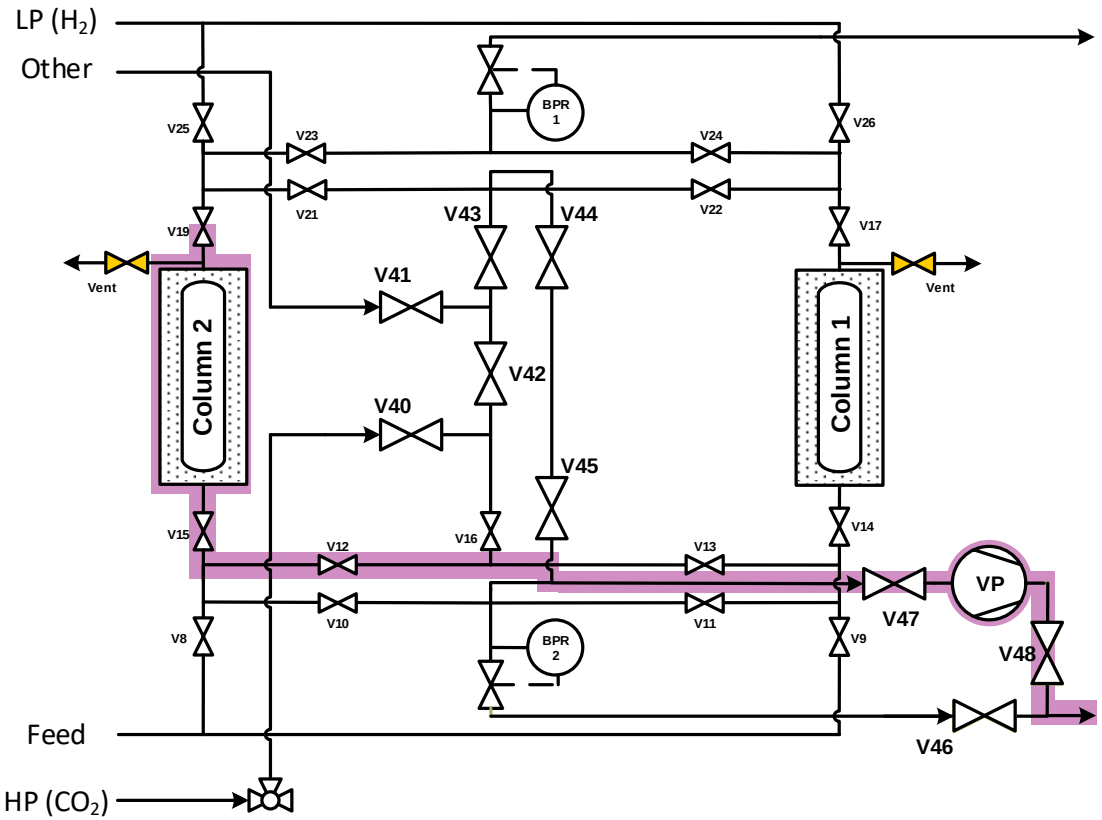


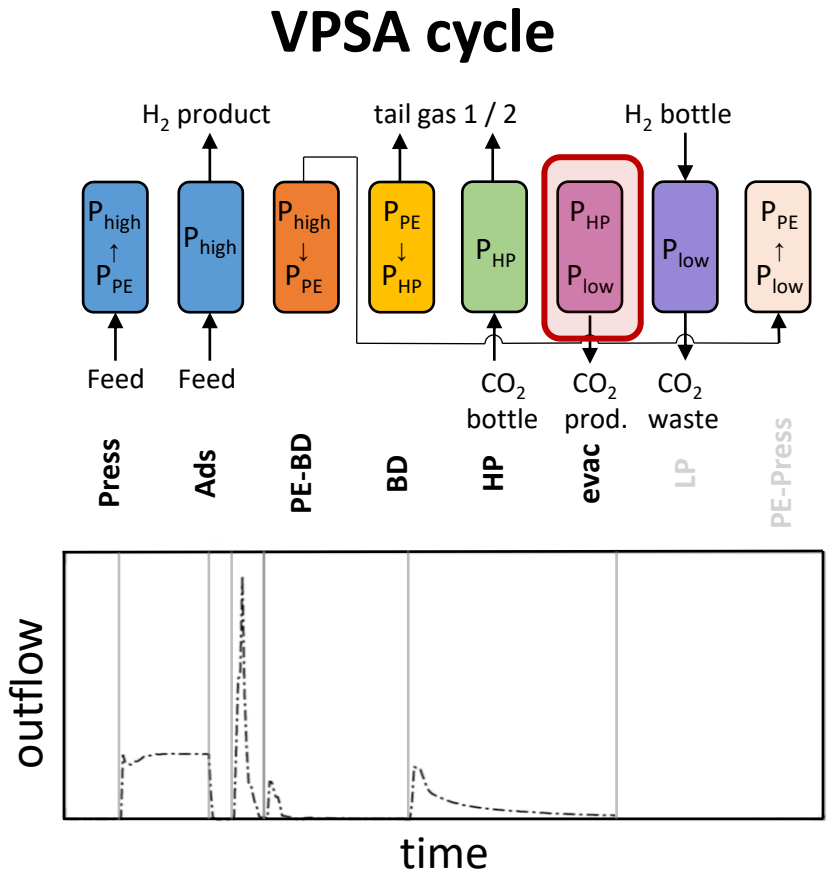
Cycle implementation



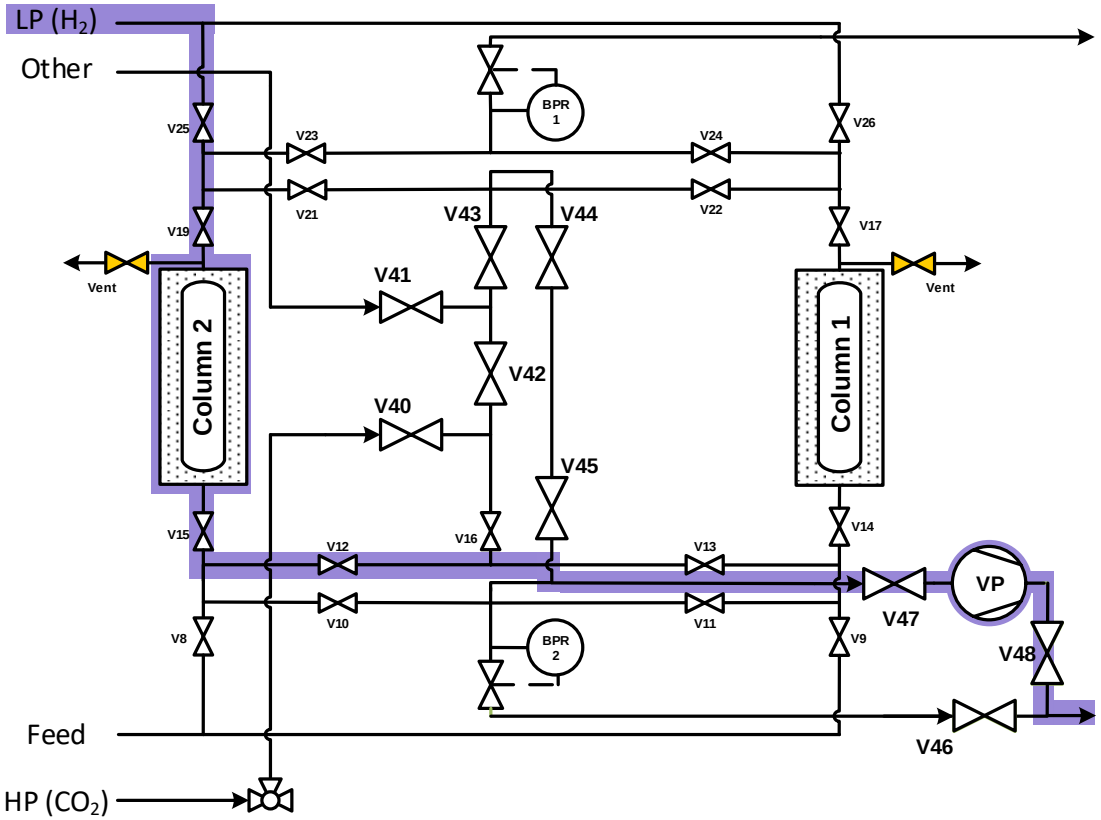


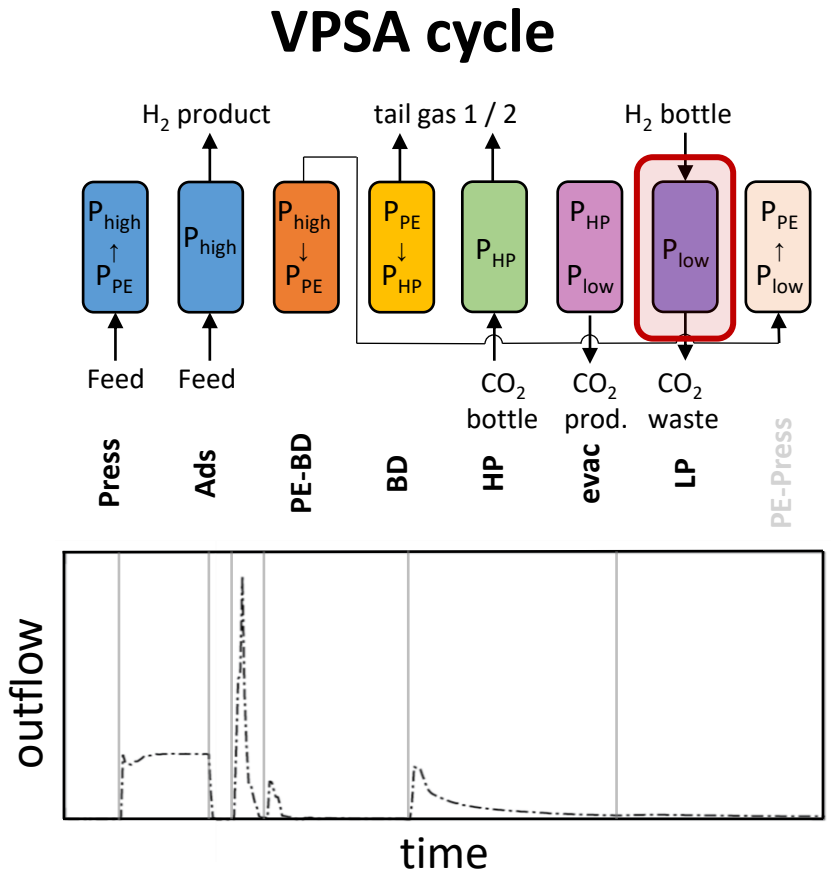
Cycle implementation



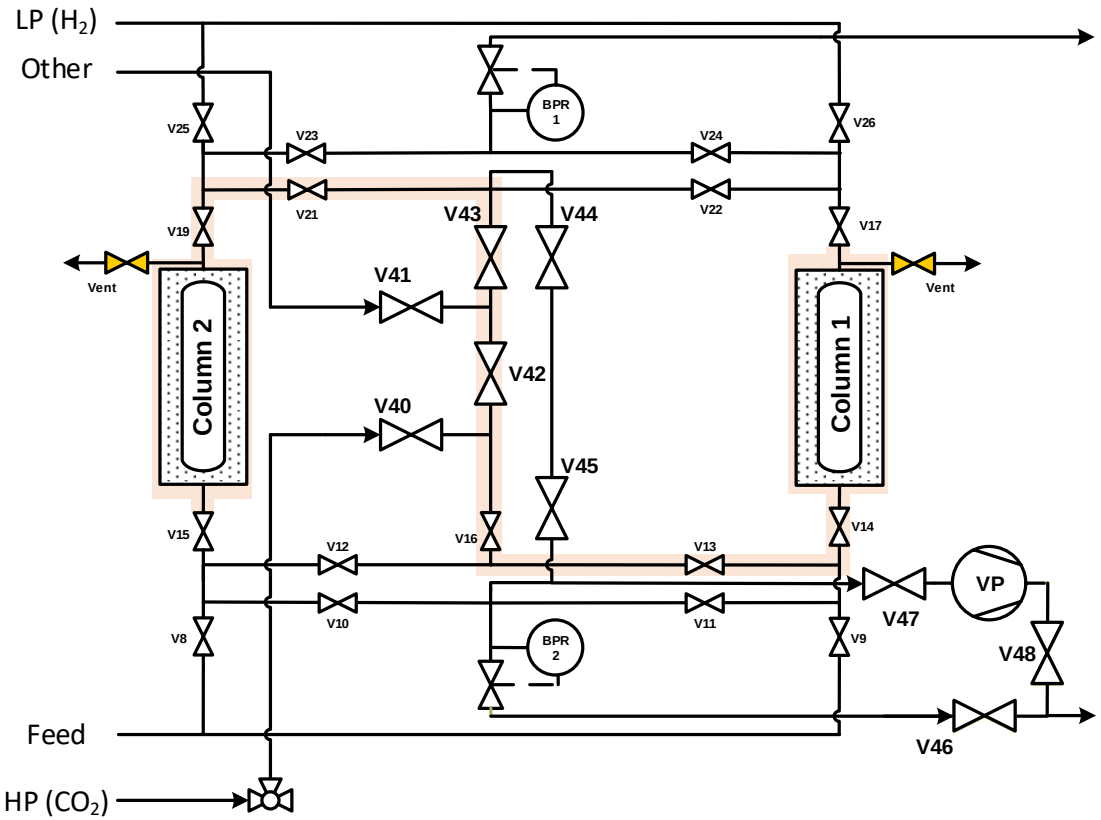


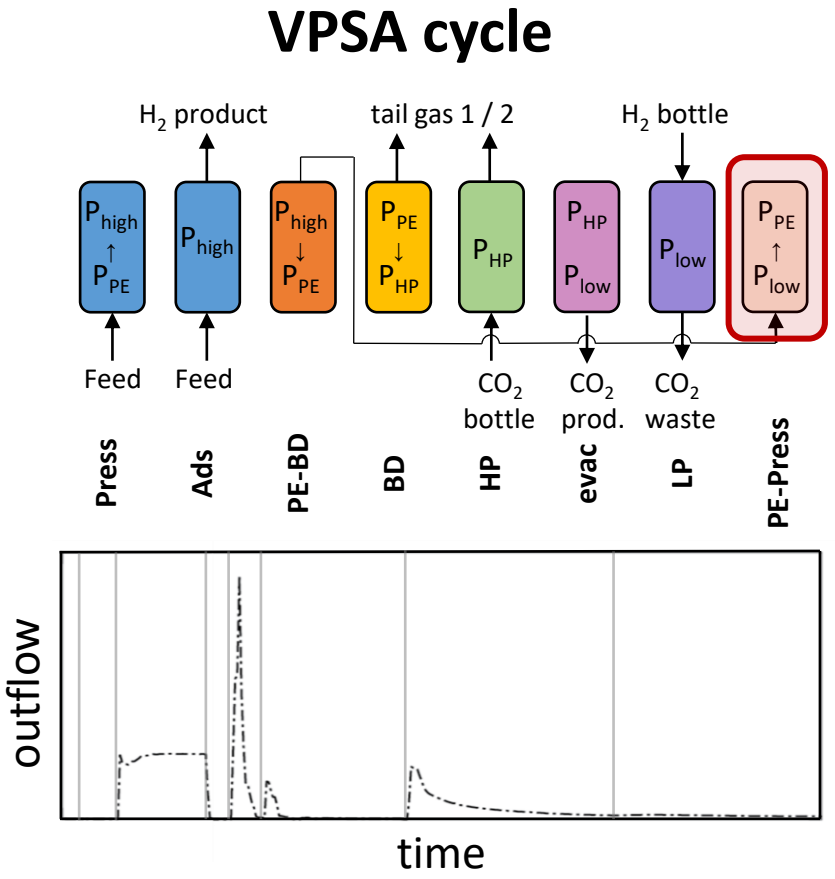
Cycle implementation



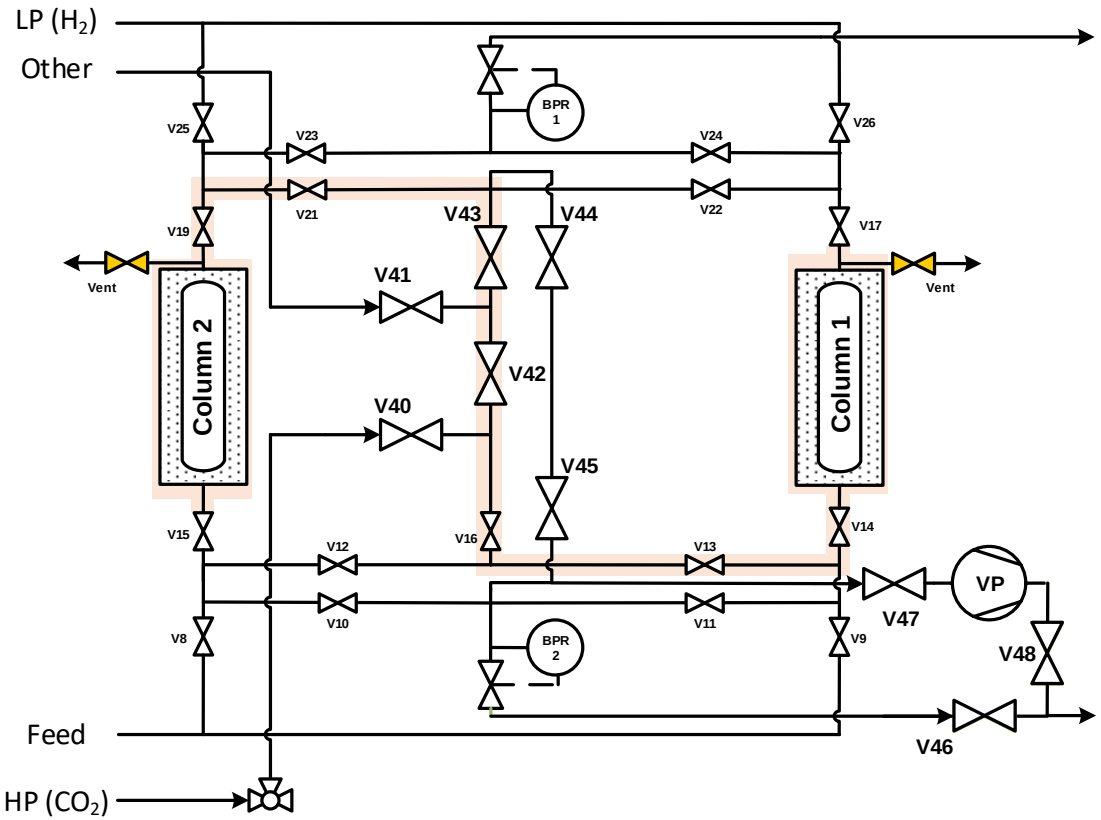


Cycle implementation

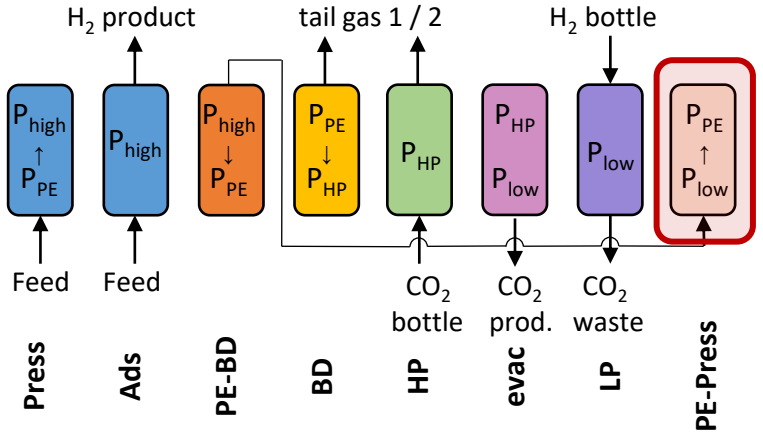




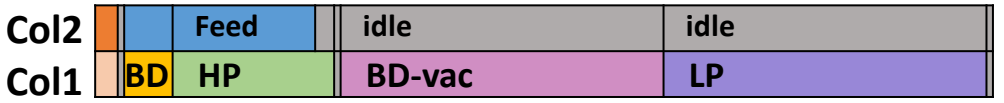
Scheduling



VPSA cycle

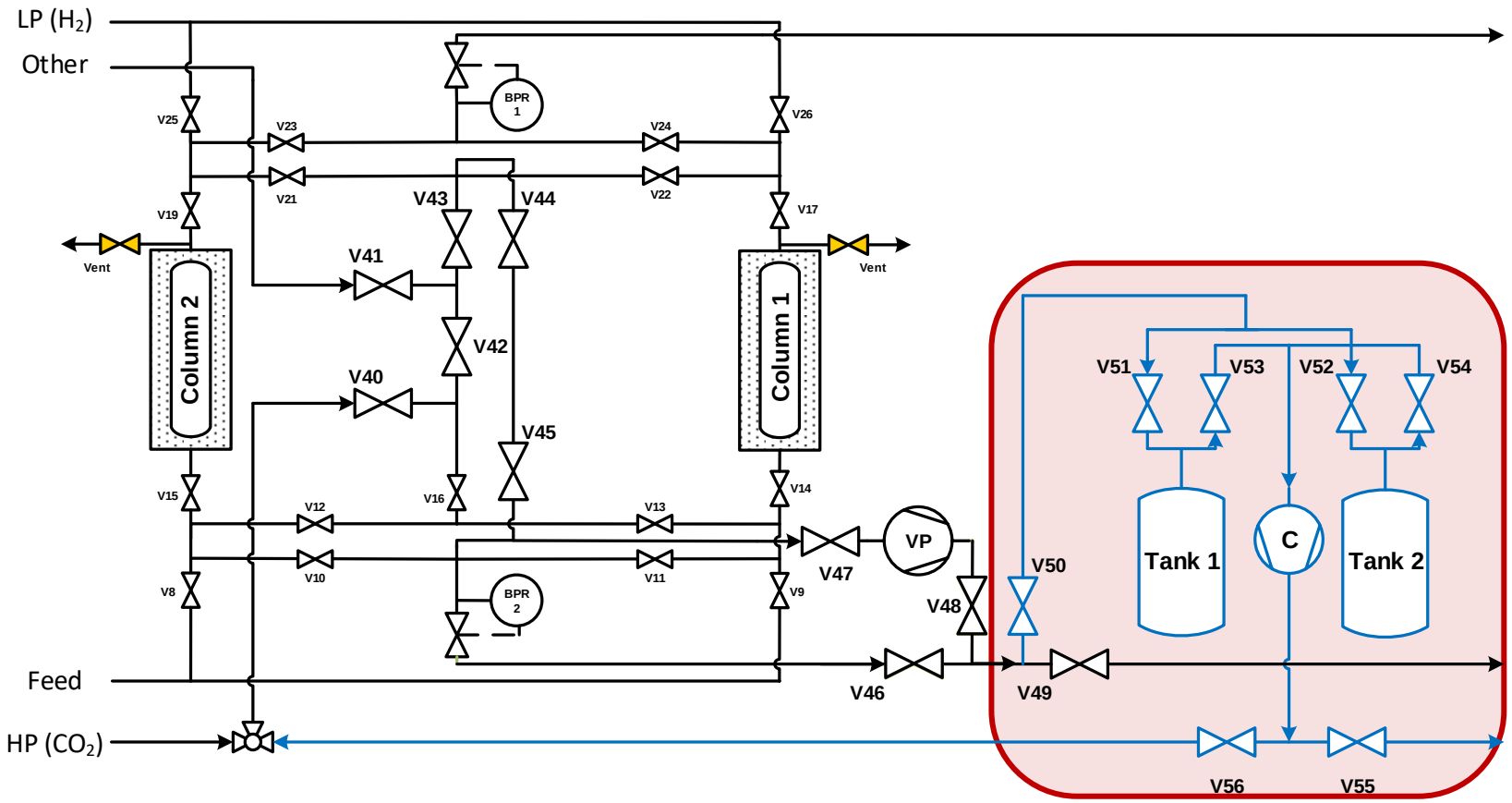


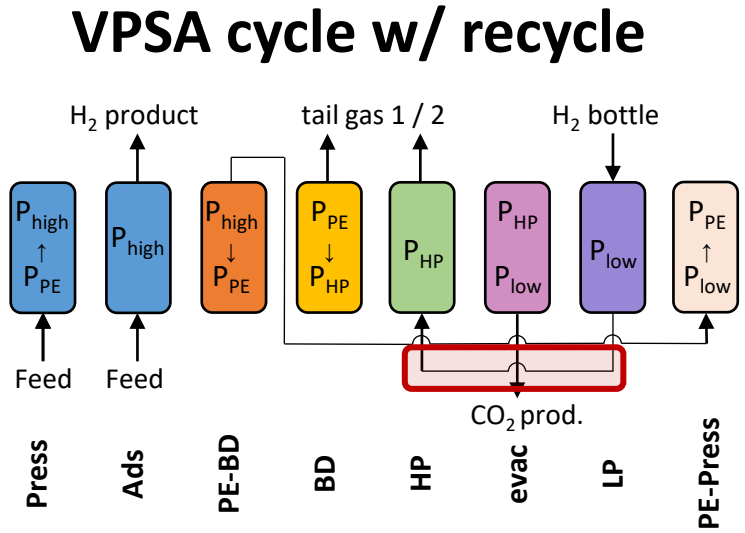
Schedule



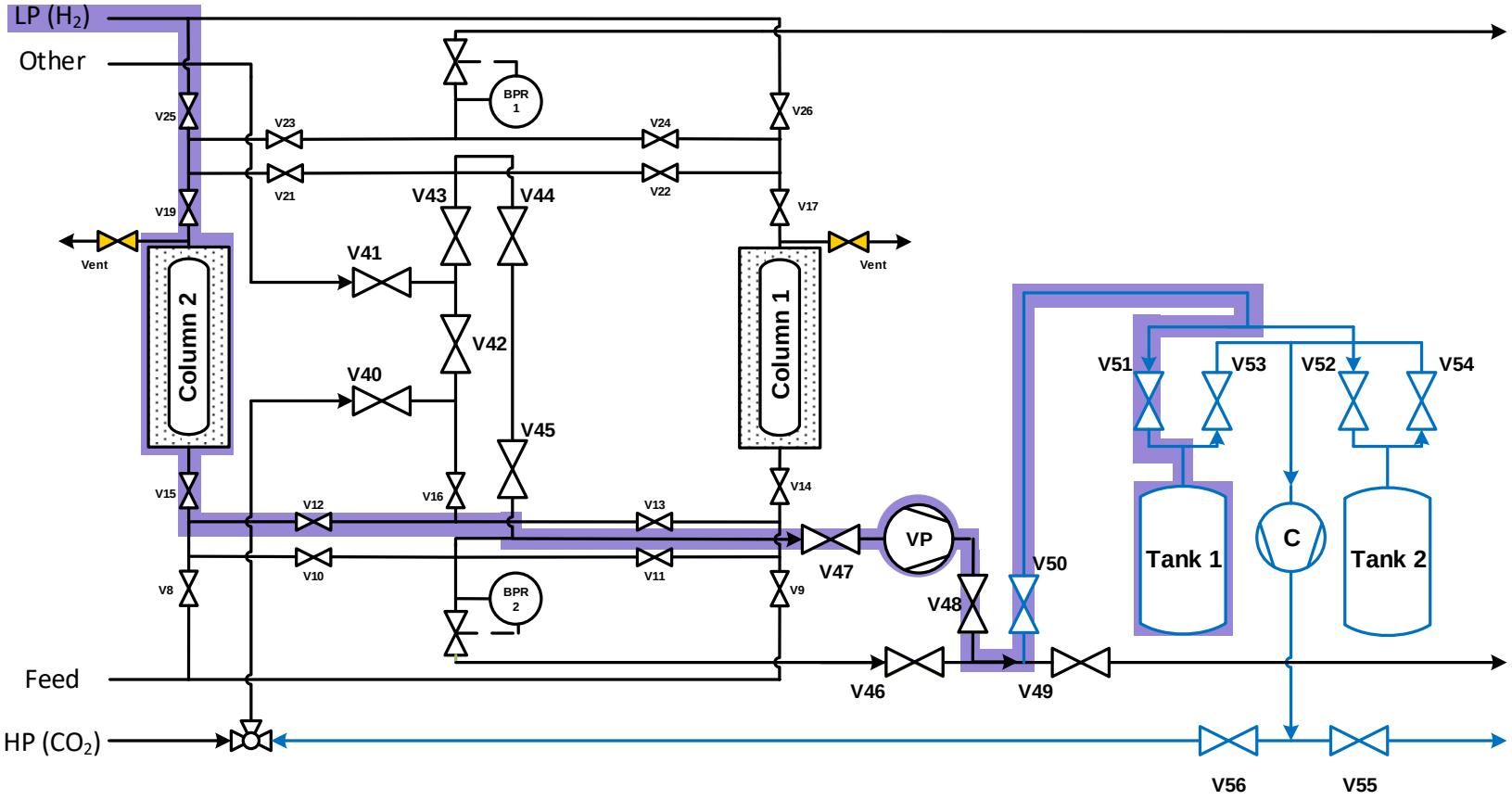
→ 2 column lab setup: long idle times necessary

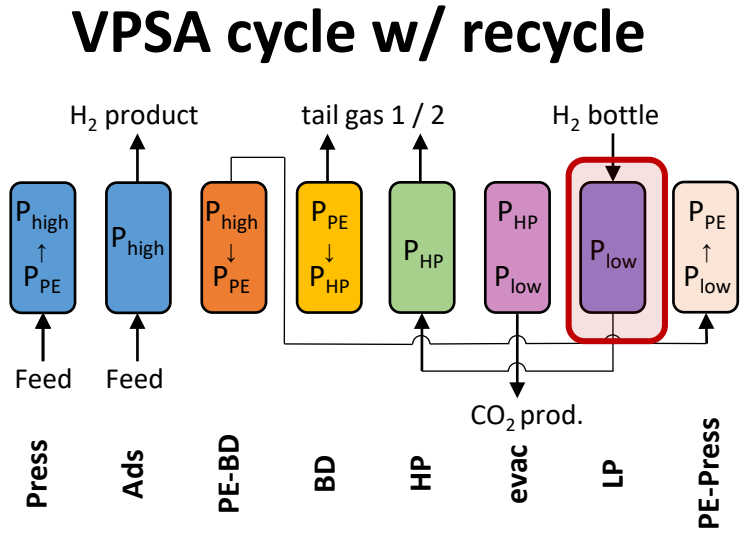
Recycle of HP: recycle section



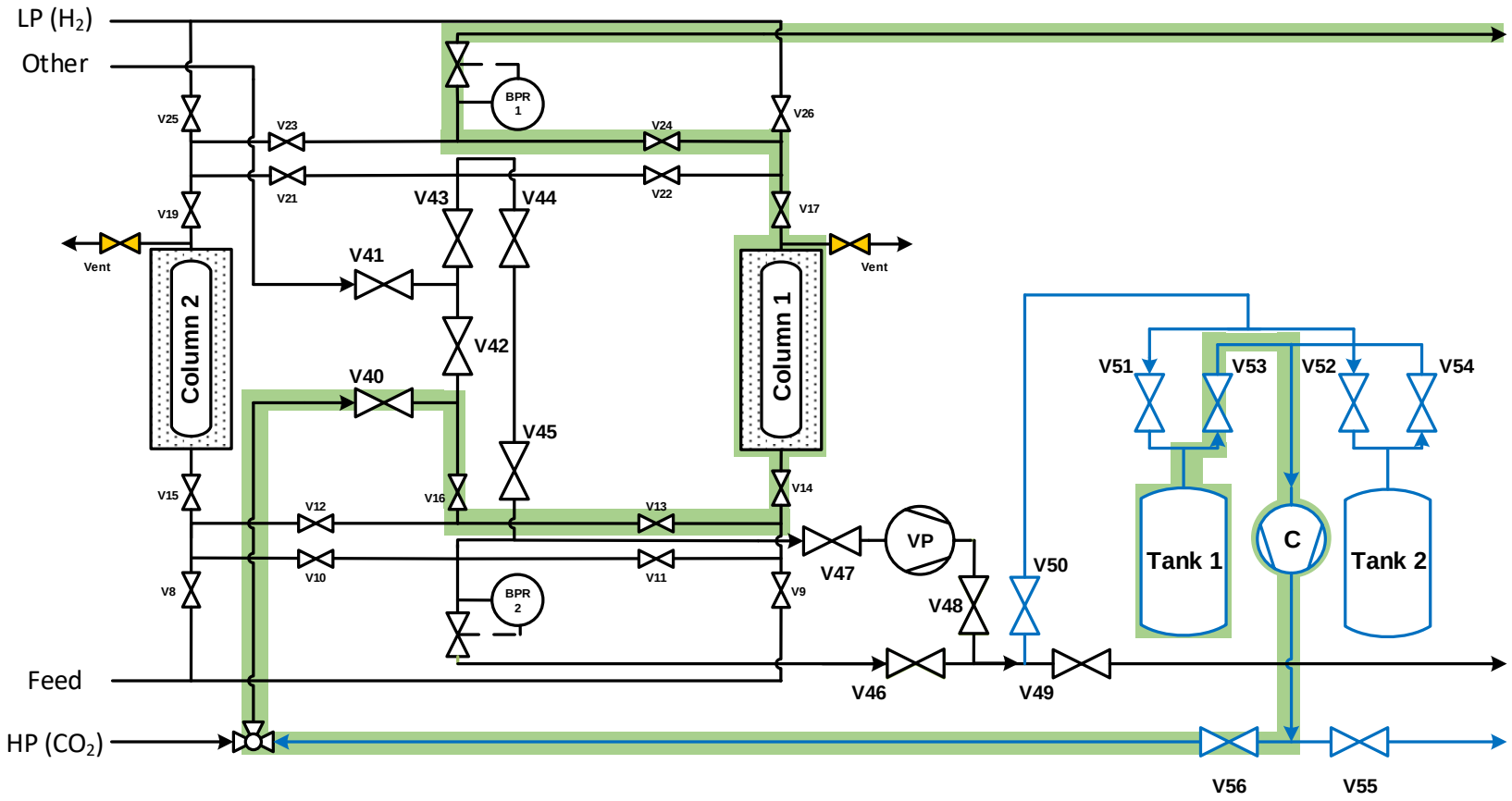


Recycle of HP: recycle section

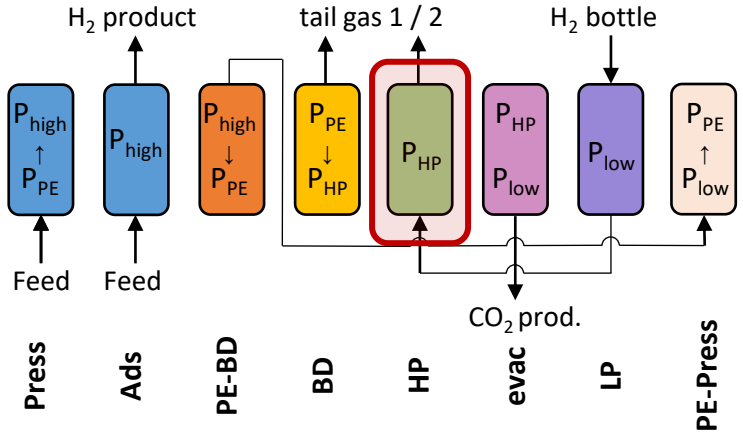




Recycle of HP: recycle section



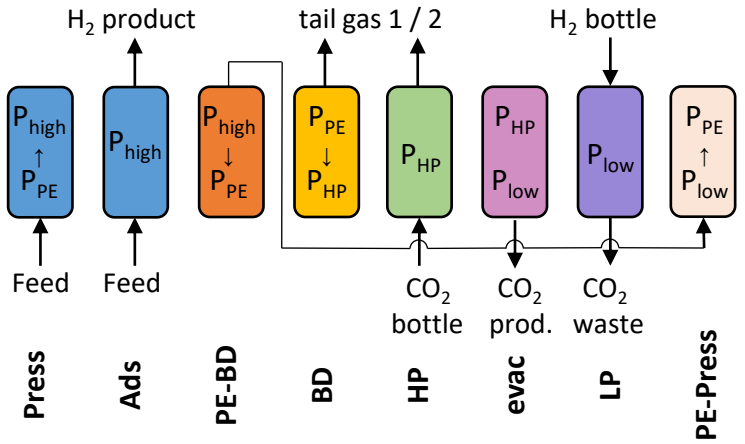
VPSA cycle w/ recycle



Experimental procedure

- The cycle sequence is repeated until a cyclic steady state **(CSS)** is reached (15-50 cycles)
- Outflow, composition, pressures and temperatures are monitored continuously

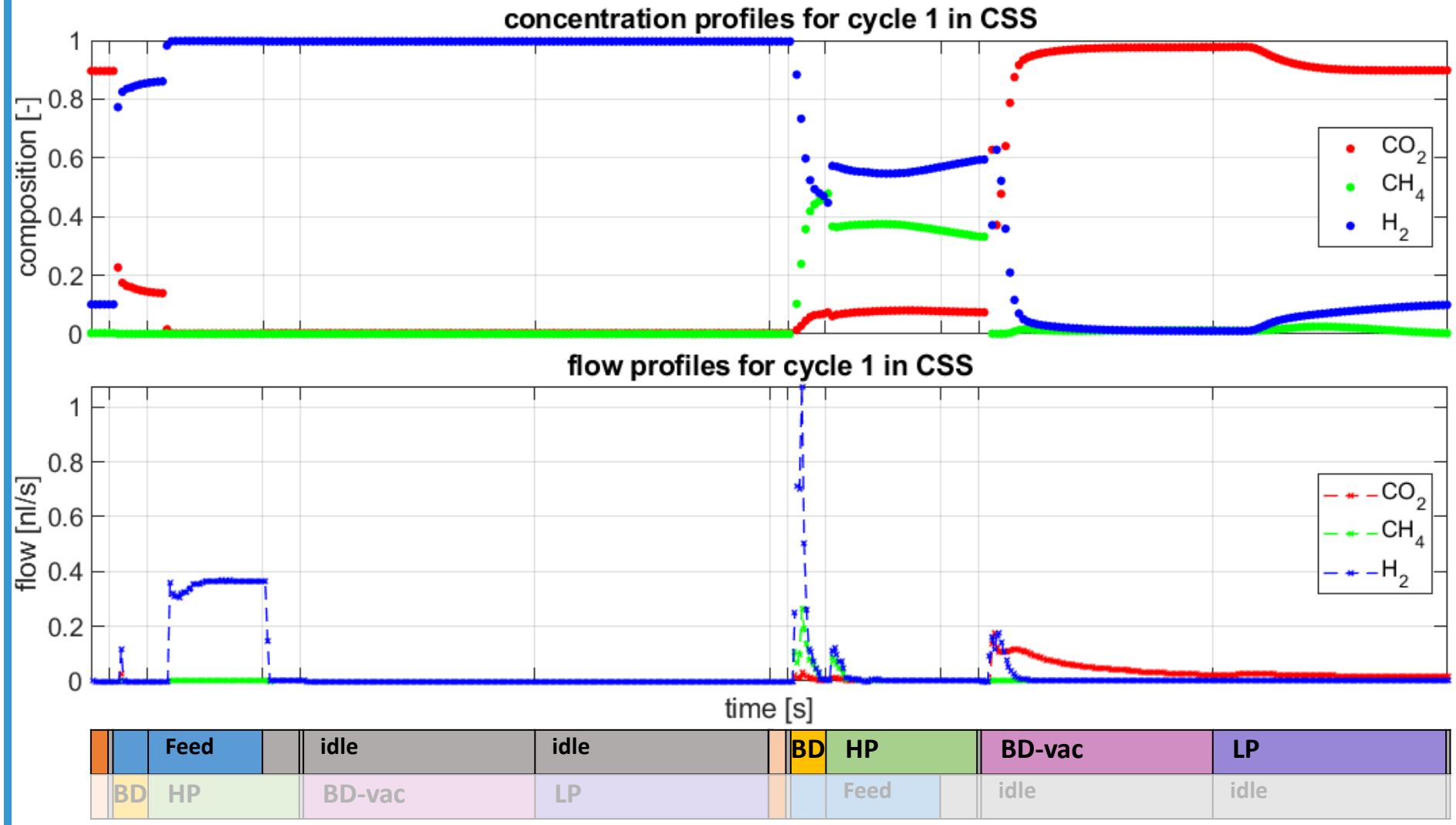
VPSA cycle

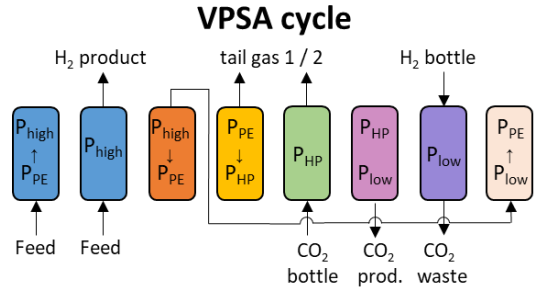


BASE CYCLE

	t_{PE}	t_{BD1}	t_{HP}	$t_{BD\text{-}vac}$	t_{LP}	t_{Feed}	$\dot{V}_{Feed}$	$\dot{V}_{LP}$	$\dot{V}_{HP}$	P_{vac}	P_{HP}	P_{Ads}	Feed	HP
Unit	s	s	s	s	s	s	10^{-5} m^3/s	10^{-5} m^3/s	10^{-5} m^3/s	bar	bar	bar	CH_4:CO_2:H_2	CH_4:CO_2:H_2
Exp 1: base case	7	15	65	100	100	65	2	2	4	0.15	1	25	5:20:75	0:100:0

Results: Concentration and flow profiles

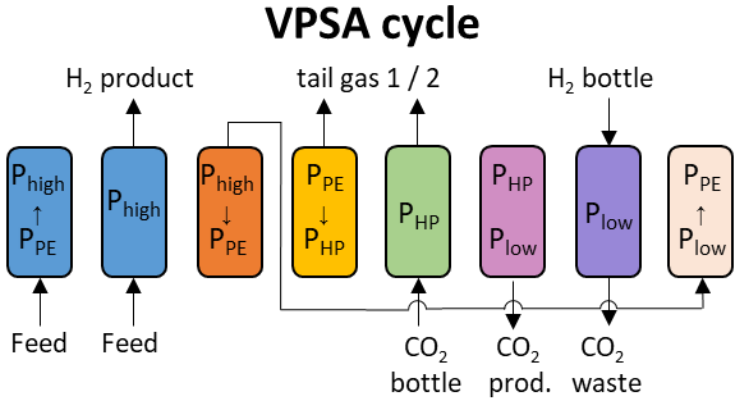


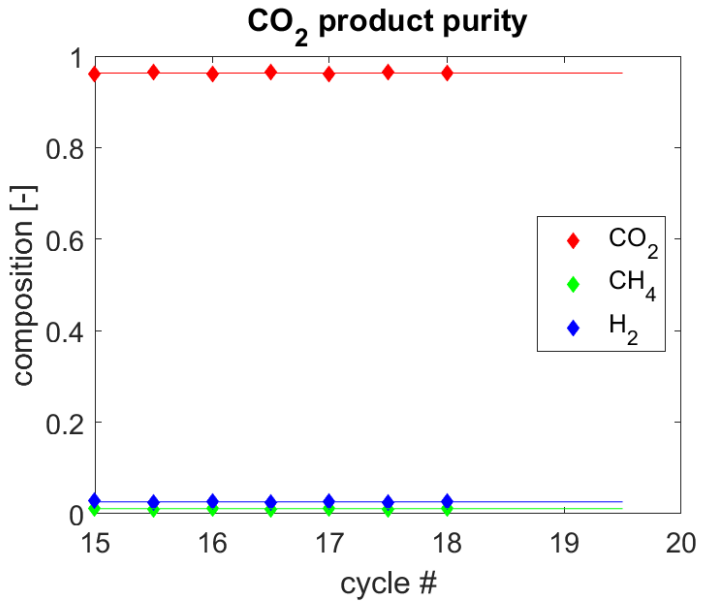


Results: Separation performance

	t_{HP}	t_{Feed}	$\dot{V}_{LP}$	$\dot{V}_{HP}$	P_{vac}	Feed	HP	purity		recovery	
	s	s	10^{-5} m^3/s	10^{-5} m^3/s	bar	CH_4:CO_2 :H_2	CH_4:CO_2 :H_2	H_2	CO_2	H_2	CO_2
1: base case	65	65	2	4	0.15	5:20:75	0:100:0	99.8	96.3	74	73

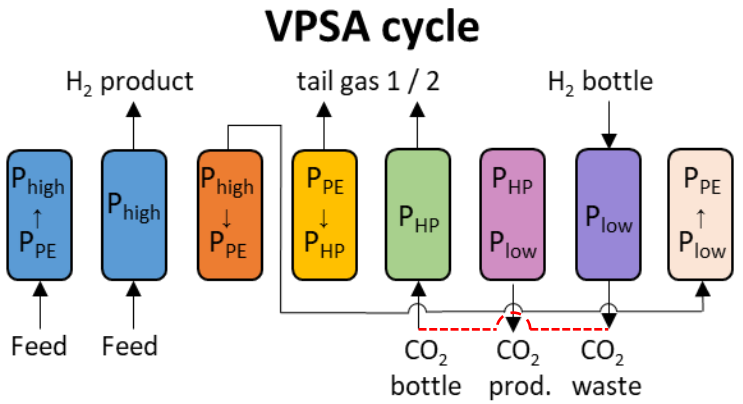
→ High purities for both products achieved





Results: Separation performance

	t_{HP}	t_{Feed}	$\dot{V}_{LP}$	$\dot{V}_{HP}$	P_{vac}	Feed	HP	purity		recovery	
	s	s	10^{-5} m^3/s	10^{-5} m^3/s	bar	$CH_4:CO_2:H_2$	$CH_4:CO_2:H_2$	H_2	CO_2	H_2	CO_2
1: base case	65	65	2	4	0.15	5:20:75	0:100:0	99.8	96.3	74	73
6: $\dot{V}_{LP}$ + 200 %	50	65	6	4	0.15	5:20:75	0:100:0	99.96	92.4	74	69
8: HP recycled	65	65	2	–	0.15	5:20:75	–	99.8	96.5	75	96



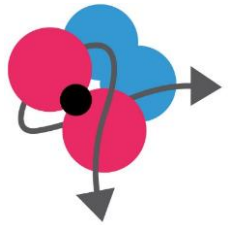
→ High purities for both products achieved

→ Very high H_2 purity possible when increasing the flowrate of the light purge (Exp.6)

→ High CO_2 recoveries are possible with recycle of CO_2 waste (Exp.8)

→ For an increase in H_2 recovery, more PE steps are required

Conclusions



ELEGANCY:

- New VPSA technology for H_2-CO_2 co-purification in the context of H_2 production with CCS was developed
- The technology was tested successfully and demonstrated at TRL 4
- Modelling and optimization shows the competitive performance (energy requirement, productivity) compared to state-of-the art

Possible next steps:

- Cost analysis (CapEx and OpEx) to quantify the advantage of the higher productivity reached by VPSA, and the reduced number of separation units
- Further development to higher TRL, best to be done in collaboration with a company

Acknowledgement

ACT ELEGANCY, Project No 271498, has received funding from DETEC (CH), BMWi (DE), RVO (NL), Gassnova (NO), BEIS (UK), Gassco, Equinor and Total, and is cofunded by the European Commission under the Horizon 2020 programme, ACT Grant Agreement No 691712. This project is supported by the pilot and demonstration programme of the Swiss Federal Office of Energy (SFOE).