The OCTOPUS tool (REALISE project)

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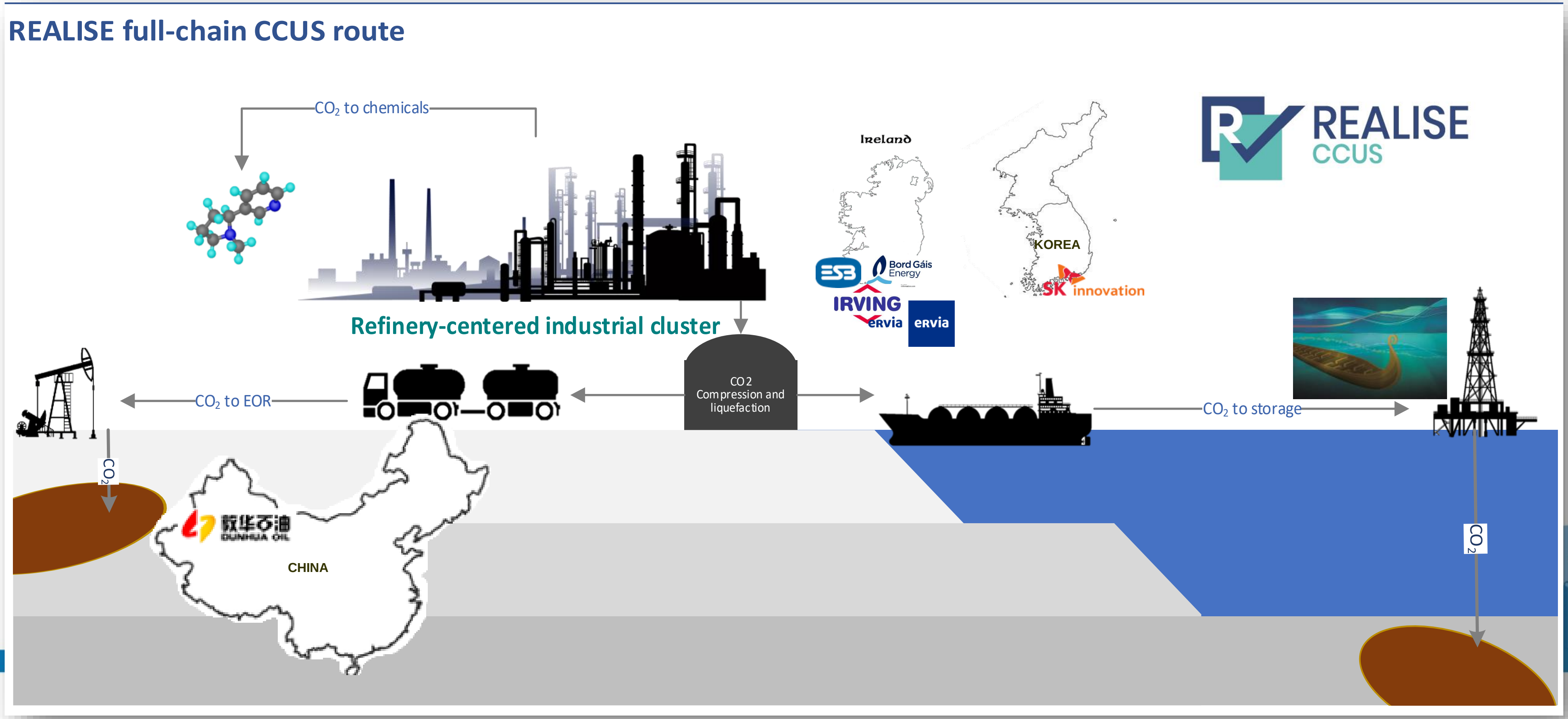
CATO Webinar **Online** **19-06-2024**

REALISE-CCUS project



Demonstration of a refinery-adapted cluster-integrated strategy to enable full-chain CCUS implementaion - REALISE

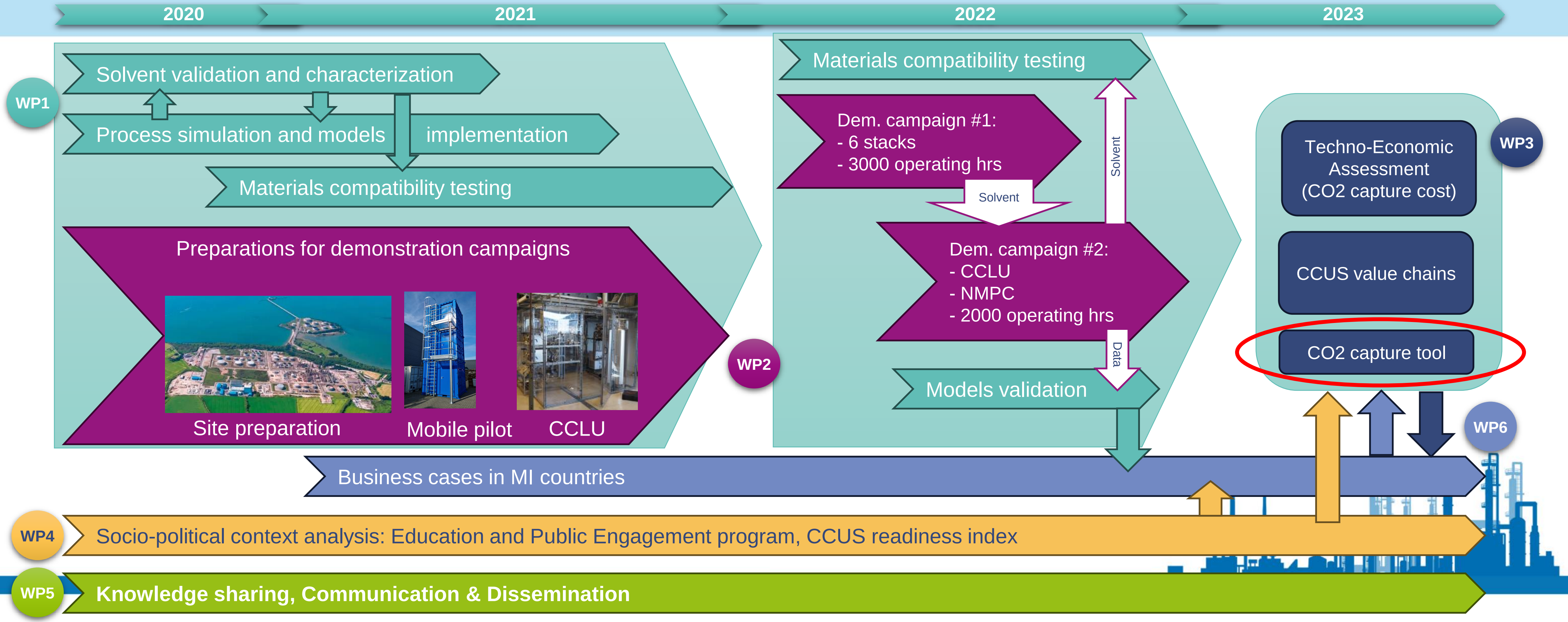
- ❑ ***Project period: 05.2020 - 10.2023***
- ❑ ***Project partners:***
  - *14 EU partners*
  - *2 partners in China*
  - *1 partner in S. Korea*
- ❑ ***Project budget: €7,131,752***

Funded by the European Unition's Horizon Europe Research and Innovation Program (Horizon Europe (europa.eu))

Partners

Advisory Board

The REALISE story



A highlight of the REALISE project

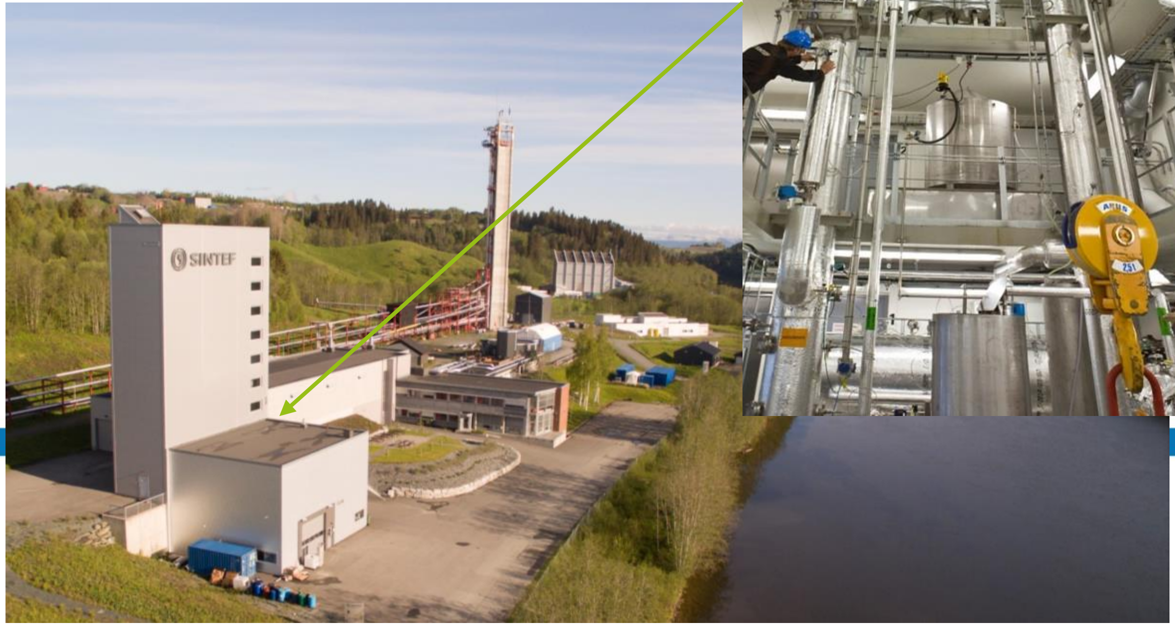
TNO mobile pilot → Irving Oil

- 32 weeks, 6 stacks
- Solvent management
- Emissions measurements

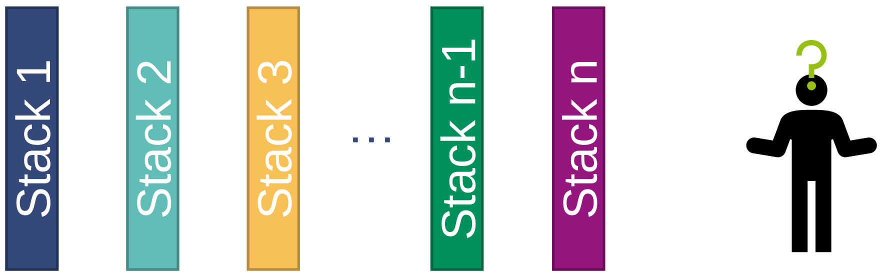
Image: https://www.cbc.ca/news/canada/new-brunswick/irving-oil-ireland-refinery-whitegate-1.3754690

Tiller CO_2 pilot → SINTEF

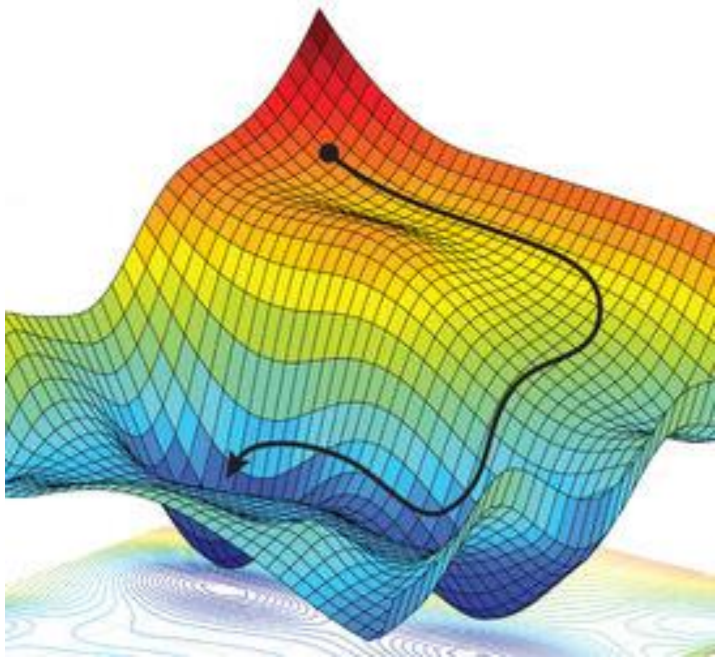
- 12 weeks
- CO_2 liquefaction prototype
- Energy and emissions measurements



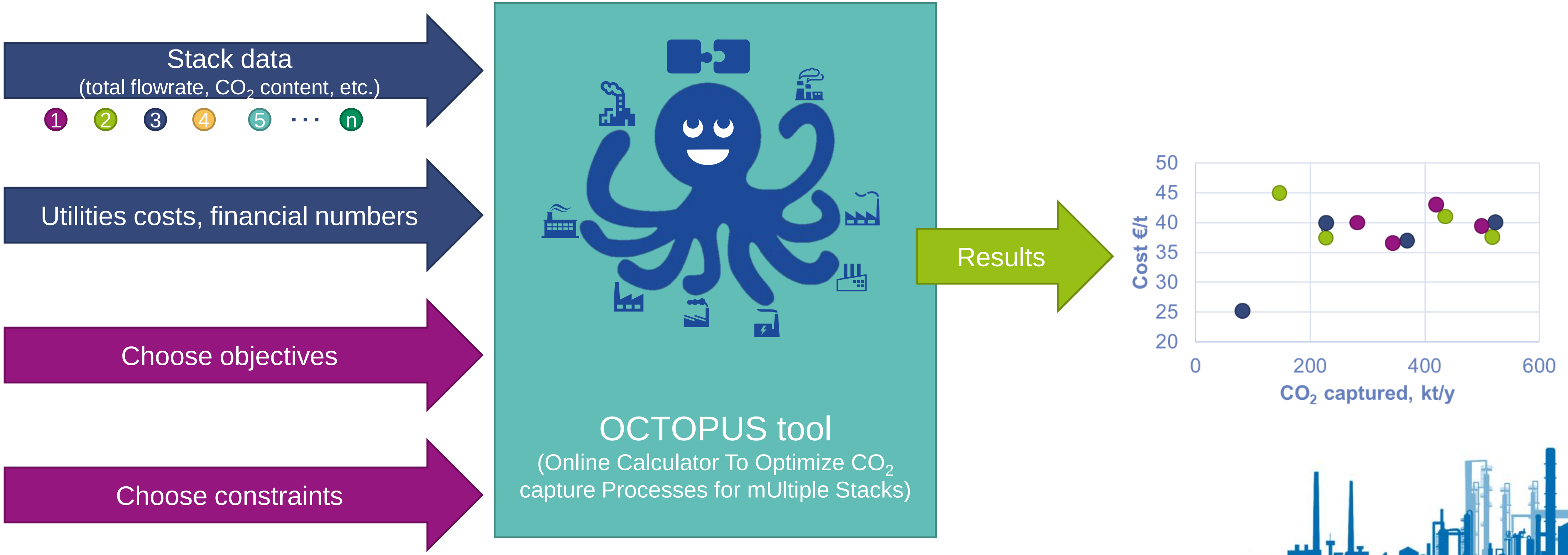
How to integrate and optimize carbon capture from multiple sources?



How to optimize?



The OCTOPUS tool



Structure of the OCTOPUS tool

User interface (web app)

User can supply general info, stack data, constraints and optimization objectives to tool

User receives main results from the engine regarding the solution for their query

Engine

Engine takes the data from the user interface, and matches this with the right data from the database

Engine performs calculations on all possible configurations, using given constraints and the optimization objective

Simulation database

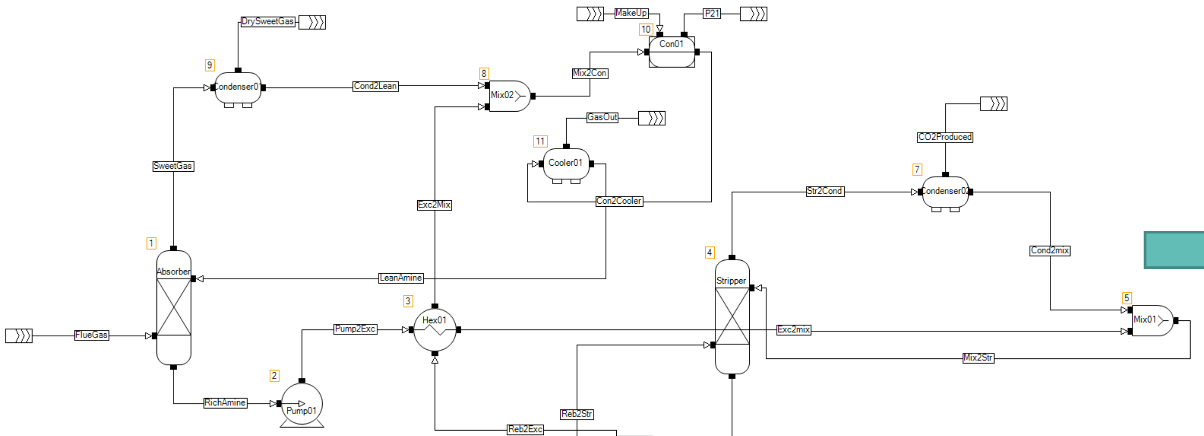
A CO_2 capture simulation database has been created using the CO2SIM software

In the CO2SIM program, many simulations are performed while varying: (1) Capture rate, (2) CO_2 concentration, (3) absorber packing height, (4) liquid flow rate

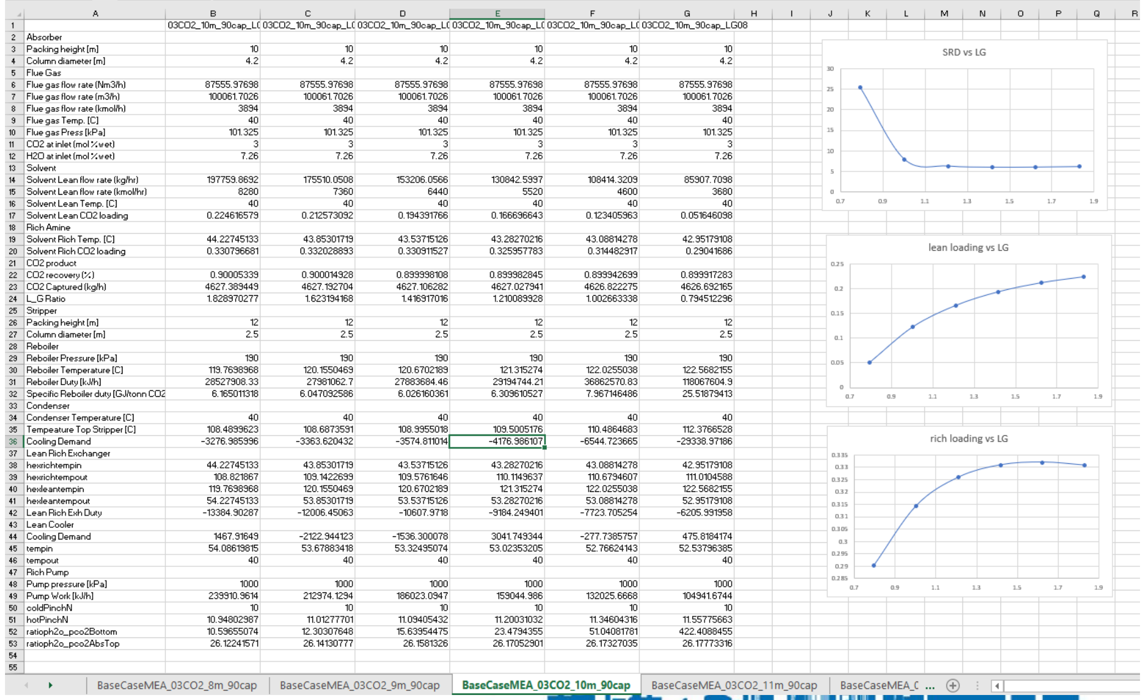
Note: By using this approach, results are generated instantaneous by the OCTOPUS tool

Creating simulation result database

The CO_2 capture flowsheet in CO2SIM



The database is created from simulation results



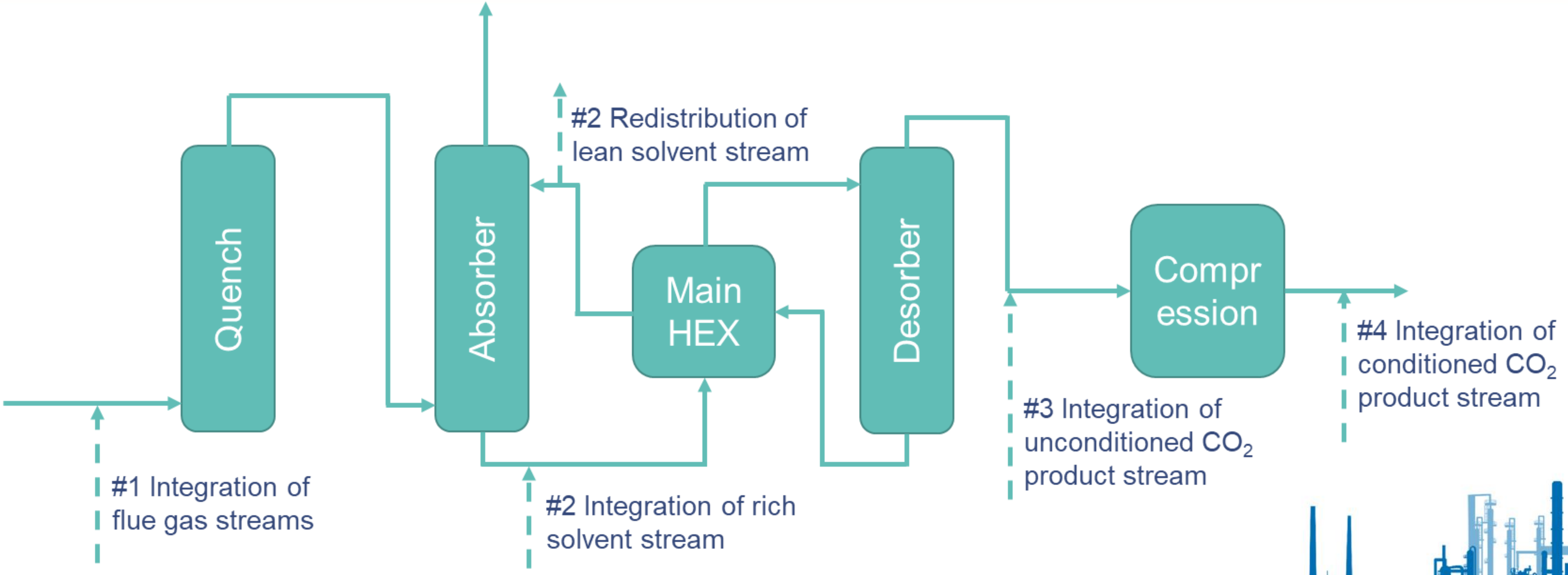
	A	B	C	D	E	F	G
1		03CO2_10m_90cap_L(	03CO2_10m_90cap_L(	03CO2_10m_90cap_L(	03CO2_10m_90cap_L(	03CO2_10m_90cap_L(	03CO2_10m_90cap_LG08
2	Absorber						
3	Packing height [m]	10	10	10	10	10	10
4	Column diameter [m]	4.2	4.2	4.2	4.2	4.2	4.2
5	Flue Gas						
6	Flue gas flow rate (Nm3/h)	87555.97698	87555.97698	87555.97698	87555.97698	87555.97698	87555.97698
7	Flue gas flow rate (m3/h)	100061.7026	100061.7026	100061.7026	100061.7026	100061.7026	100061.7026
8	Flue gas flow rate (kmol/h)	3894	3894	3894	3894	3894	3894
9	Flue gas Temp. [C]	40	40	40	40	40	40
10	Flue gas Press [kPa]	101.325	101.325	101.325	101.325	101.325	101.325
11	CO2 at inlet (mol %wet)	3	3	3	3	3	3
12	H2O at inlet (mol %wet)	7.26	7.26	7.26	7.26	7.26	7.26
13	Solvent						
14	Solvent Lean flow rate (kg/hr)	197759.8692	175510.0508	153206.0566	130842.5997	108414.3209	85907.7098
15	Solvent Lean flow rate (kmol/hr)	8280	7360	6440	5520	4600	3680
16	Solvent Lean Temp. [C]	40	40	40	40	40	40
17	Solvent Lean CO2 loading	0.224616579	0.212573092	0.194391766	0.166696643	0.123405963	0.051646098
18	Rich Amine						
19	Solvent Rich Temp. [C]	44.22745133	43.85301719	43.53715126	43.28270216	43.08814278	42.95179108
20	Solvent Rich CO2 loading	0.330796681	0.332028893	0.330911527	0.325957783	0.314482917	0.29041686
21	CO2 product						
22	CO2 recovery (%)	0.90005339	0.900014928	0.899998108	0.899982845	0.899942699	0.899917283
23	CO2 Captured (kg/h)	4627.389449	4627.192704	4627.106282	4627.027941	4626.822275	4626.692165
24	L_G Ratio	1.828970277	1.623194168	1.416917016	1.210089928	1.002663338	0.794512296
25	Stripper						
26	Packing height [m]	12	12	12	12	12	12
27	Column diameter [m]	2.5	2.5	2.5	2.5	2.5	2.5
28	Reboiler						
29	Reboiler Pressure [kPa]	190	190	190	190	190	190
30	Reboiler Temperature [C]	119.7698968	120.1550469	120.6702189	121.315274	122.0255038	122.5682155
31	Reboiler Duty [kJ/h]	28527908.33	27981062.7	27883684.46	29194744.21	36862570.83	118067604.9
32	Specific Reboiler duty [GJ/tonn CO2	6.165011318	6.047092586	6.026160361	6.309610527	7.967146486	25.51879413
33	Condenser						
34	Condenser Temperature [C]	40	40	40	40	40	40
35	Tempeature Top Stripper [C]	108.4899623	108.6873591	108.9955018	109.5005176	110.4864683	112.3766528
36	Cooling Demand	-3276.985996	-3363.620432	-3574.811014	-4176.986107	-6544.723665	-29338.97186
37	Lean Rich Exchanger						
38	hexrichtempin	44.22745133	43.85301719	43.53715126	43.28270216	43.08814278	42.95179108
39	hexrichtempout	108.821867	109.1422699	109.5761646	110.1149637	110.6794607	111.0104588
40	hexleantempin	119.7698968	120.1550469	120.6702189	121.315274	122.0255038	122.5682155
41	hexleantempout	54.22745133	53.85301719	53.53715126	53.28270216	53.08814278	52.95179108
42	Lean Rich Exh Duty	-13384.90287	-12006.45063	-10607.9718	-9184.249401	-7723.705254	-6205.991958
43	Lean Cooler						
44	Cooling Demand	1467.91649	-2122.944123	-1536.300078	3041.749344	-277.7385757	475.8184174
45	tempin	54.08619815	53.67883418	53.32495074	53.02353205	52.76624143	52.53796385
46	tempout	40	40	40	40	40	40
47	Rich Pump						
48	Pump pressure [kPa]	1000	1000	1000	1000	1000	1000
49	Pump Work [kJ/h]	239910.9614	212974.1294	186023.0947	159044.986	132025.6668	104941.6744
50	coldPinchN	10	10	10	10	10	10
51	hotPinchN	10.94802987	11.01277701	11.09405432	11.20031032	11.34604316	11.55775663
52	ratioph2o_pco2Bottom	10.59655074	12.30307648	15.63954475	23.4794355	51.04081781	422.4088455
53	ratioph2o_pco2AbsTop	26.12241571	26.14130777	26.1581326	26.17052901	26.17327035	26.17773316
54							
55							

Number of simulations for populating the database

Parameter	Range	Number of settings
Solvent type	MEA and HS3	2
CO_2 capture rate	90% and 95%	2
CO_2 concentration in flue gas	3 to 20%	18
Absorber packing height	7 to 30 meter	24
Liquid flow rates	Around optimal L/G	4 to 10

The total number of simulation results included in the tool is ~15000

Integration of capture processes in clusters



Demonstration of the tool – Stack selection

Single stack query

Stack 1

Flue gas flow rate (Nm³/hr)
100000

Temperature (°C)
100

Pressure (mbarg) (0 = atmospheric)
0

CO_2 concentration (vol% dry)
10

O_2 concentration (vol% dry)
8

H_2O concentration (vol%)
8

Multi stack query

	Stack 1	Stack 2	Stack 3	Stack 4	Stack 5
Flue gas flow rate (Nm³/hr)	100000	200000	300000	400000	500000
Temperature (°C)	100	100	100	100	100
Pressure (mbarg) (0 = at…	0	0	0	0	0
CO_2 concentration (vol% …	10	10	10	10	10
O_2 concentration (vol% dry)	8	8	8	8	8
H_2O concentration (vol%)	8	8	8	8	8

Demonstration of the tool – Integration option selection

+ Flue Gas Flow Integration

This component allows you to integrate Flue Gas Flows.

- [x] 1
- [x] 2
- [ ] 3
- [ ] 4
- [ ] 5

✓

ADD COMBINATION | REMOVE COMBINATION

+ Solvent Flow Integration

This component allows you to integrate Solvent Flows.

- [x] F12
- [x] F3
- [ ] F4
- [ ] F5

✓

ADD COMBINATION | REMOVE COMBINATION

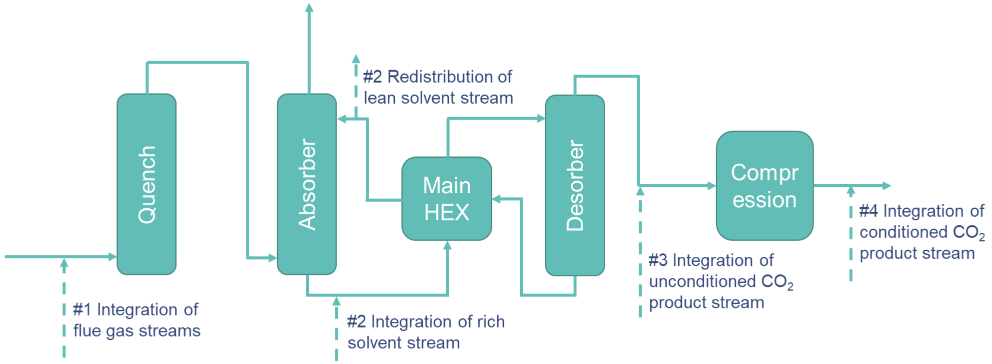
+ Unconditioned CO2 Flow Integration

This component allows you to integrate Unconditioned CO2 Flows.

- [x] SF12F3
- [x] SF4
- [ ] SF5

✓

ADD COMBINATION | REMOVE COMBINATION



Demonstration of the tool – Utilities, Financial parameters and Optimisation target

Utilities

Utility Prices

Steam price (€/GJ)
4

Electricity price (€/MWh)
50

Cooling water price (€/m³)
0.1

Financial Parameters

Financial parameters can be customised.

☑ Use default financial parameters

☐ Use default financial parameters

Plant lifetime (years)
20

Cost of capital (%)
8

Yearly maintenance costs (% of TPC) (TPC: Total Process Costs)
2.5

Yearly insurance costs (% of TPC)
1

Yearly overhead and administrative costs (% of TPC)
0.3

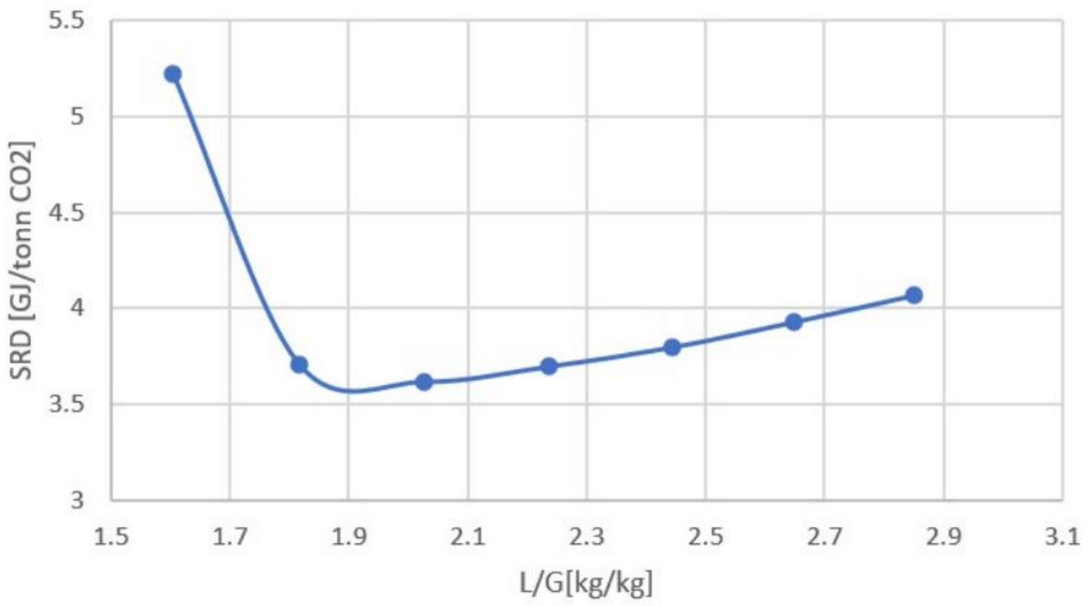
Optimisation Target

Optimisation target determines the parameter of focus, either energy (heat duty) or CAPEX.

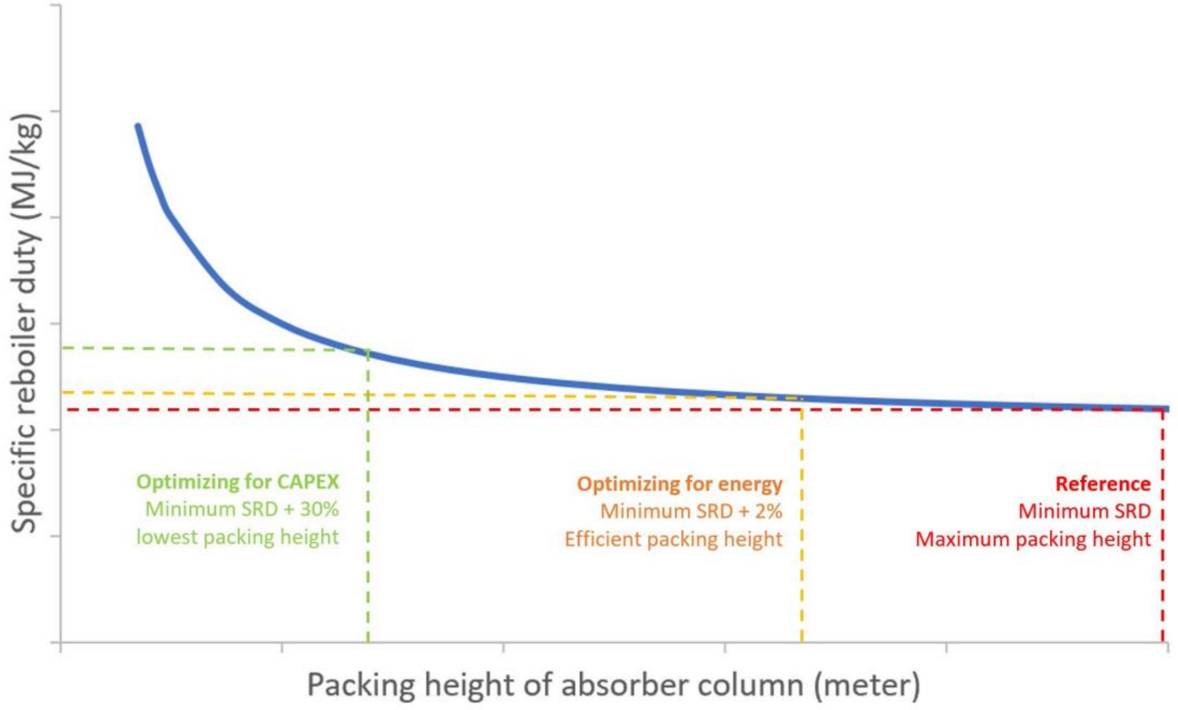
Optimisation target
Energy

Implementation of the optimisation target

Example of SRD curve for a certain packing height

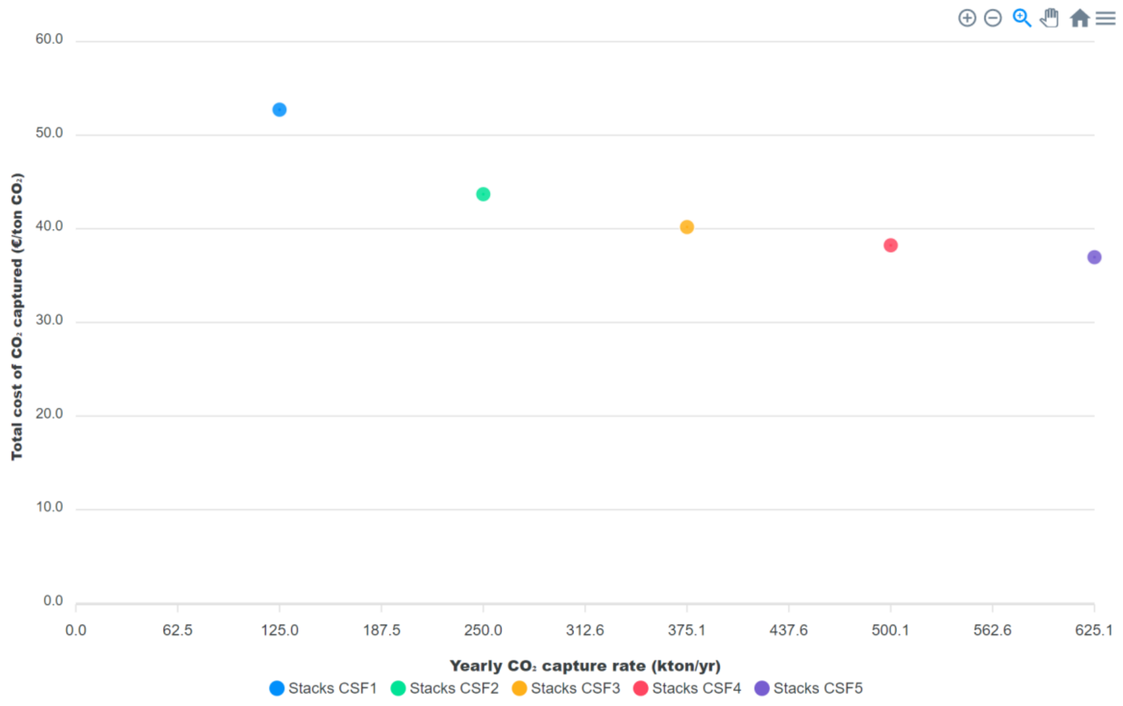


Optimisation routine used in the OCTOPUS tool

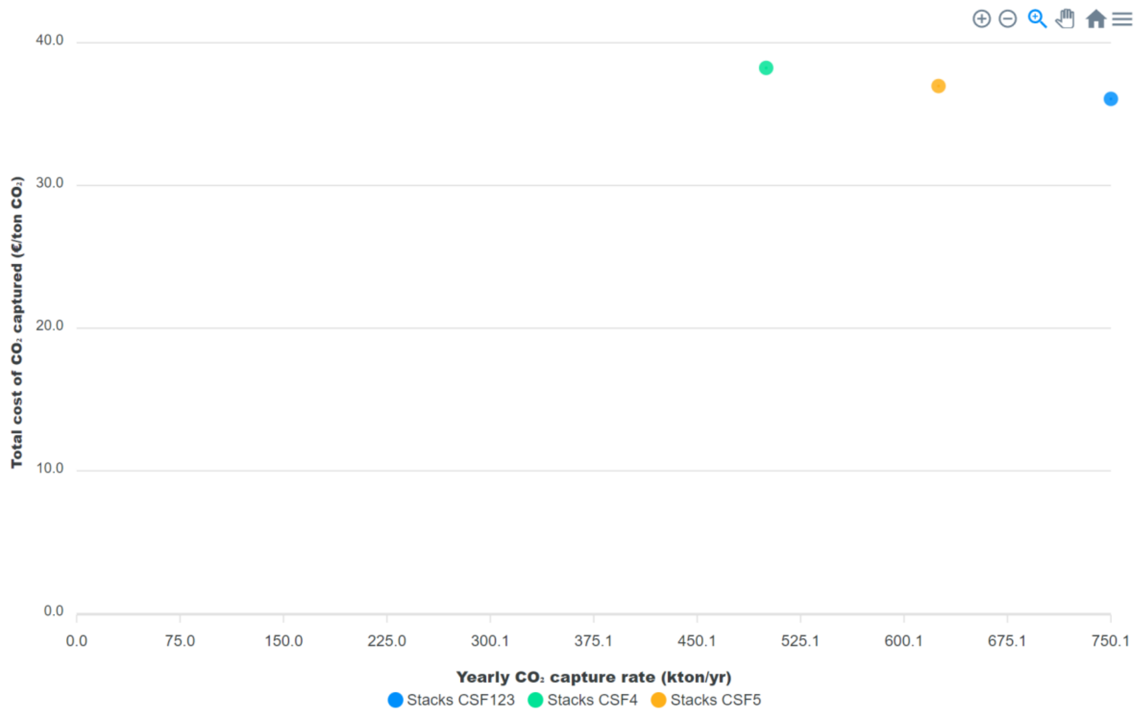


Demonstration of the tool – Results

5 stacks, non-integrated results



5 stacks, integrated results (stack 1+2+3)



Demonstration of the tool – results of the non-integrated case

Flue gas specific results

Flow ID	CO_2 capture rate (kg/h)	Absorber diameter (m)	Absorber packing height (m)	Absorber total height (m)	Absorber Packing Capex (MEUR)	Absorber Shell Capex (MEUR)
1	15857.92	4.49	17	33.76	2.51	3.36
2	31715.84	6.35	17	33.76	5.03	4.18
3	47573.77	7.77	17	33.76	7.54	4.76
4	63431.69	8.98	17	33.76	10.05	5.21
5	79289.61	10.04	17	33.76	12.57	5.6

Overall results

Flow ID	Total CO_2 captured (kton/yr)	Total CAPEX (M€)	Electricity demand (MW_e)	Total heat demand (MW_{th})	Cooling water demand (MW_{th})	Solvent costs (€/ton CO_2)	Specific CAPEX (€/ton CO_2)	Specific variable OPEX (€/ton CO_2)	Specific fixed OPEX (€/ton CO_2)	Total costs (€/ton CO_2)
CSF1	125.02	22.95	1.17	15.9	16.93	4.86	18.7	23.38	10.66	52.73
CSF2	250.05	33.05	2.34	31.79	33.87	4.86	13.46	23.37	6.86	43.7
CSF3	375.07	41.81	3.51	47.69	50.8	4.86	11.35	23.37	5.46	40.19
CSF4	500.1	49.88	4.68	63.58	67.73	4.86	10.16	23.37	4.71	38.24
CSF5	625.12	57.5	5.86	79.48	84.66	4.86	9.37	23.37	4.23	36.97

Information can be quickly gathered on:
- Amount of CO_2 captured
- Major equipment sizing and costing
- Total utility demand (heat, electricity, cooling)
- Total CAPEX and OPEX calculations

Practical information about the tool

The OCTOPUS tool is a free tool

An account can be requested by sending an email to me: jasper.ros@tno.nl

The tool can be accessed here: https://octopus.sensorlab.tno.nl/

An video introduction to the tool can be found here: https://www.youtube.com/watch?v=mG8e6nQWP_8

The tool contains an user manual to describe the structure of the tool and assumptions used for the calculations

The tool does not log any information that is entered by the user and the results are also not saved anywhere

Note: The OCTOPUS tool only generates results to assess initial high-level feasibility of carbon capture systems and should only be used as such. Detailed design studies are necessary to assess the actual feasibility specific to the considered process.

Future prospect of the tool

We are currently looking for opportunities to extend the tool, for example:

- Include other solvents (e.g. CESAR1)
- Include more detailed (cost) calculations on the integrated capture systems
- Include options for the user to constrain the tool (e.g. energy availability, plot space limitations)
- Include more capture rates (e.g. 99%)

Please contact us if you see possibilities to collaborate!

OCTOPUS Acknowledgements

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TNO innovation for life   NTNU   SINTEF

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Thank you for listening

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