Sustainable PUR material and products

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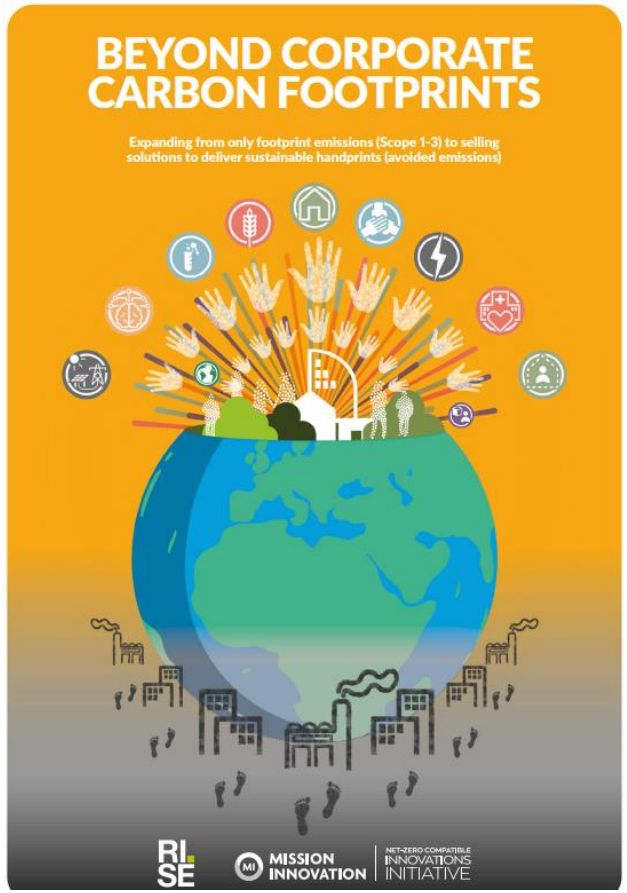
Sustainable PUR material and products



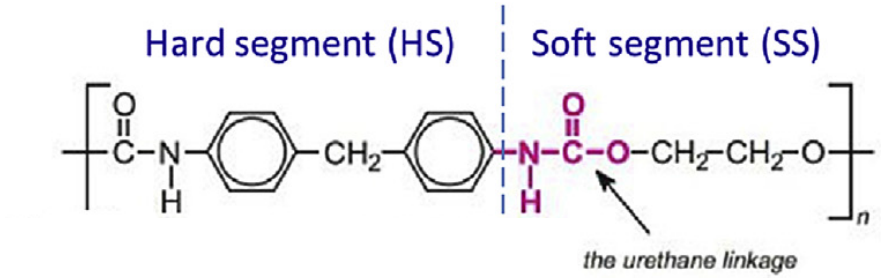
Focus has been on reduction of emissions from companies and their value chains. Most tools and initiatives have therefore focused on measuring and reporting emissions from value chain emissions.

Incentive structures have been developed based on the assumption that the best a company can do is reduce emissions and reach “Net-Zero”.

The common denominator is that all of the above is based on a **”static reduction approach”,** an approach where the large companies, the infrastructure and consumption patterns, are assumed as static and where improvements in existing systems is the focus.

Instead of the reduction of emissions from existing companies and structures that are inherently unsustainable, the main challenge from a long-term perspective is to avoid emissions and deliver on human needs with the help of innovative companies that can deliver what is needed in a sustainable way.

Sustainable PUR



Material: Biobased

Service life: Durable

End of life or circularity: Recycling by mechanical, chemical and biological recycling or reuse (such as adsorbent)

Biobased material

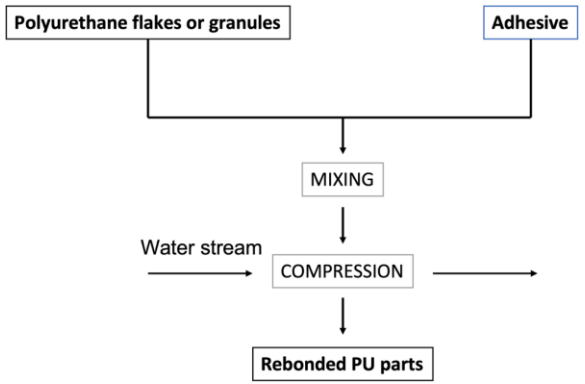
“Starting materials, processes and characteristics of bio-based foams: A review”- Journal of Bioresources and bioproducts- Volume 9, Issue 2, may 2024

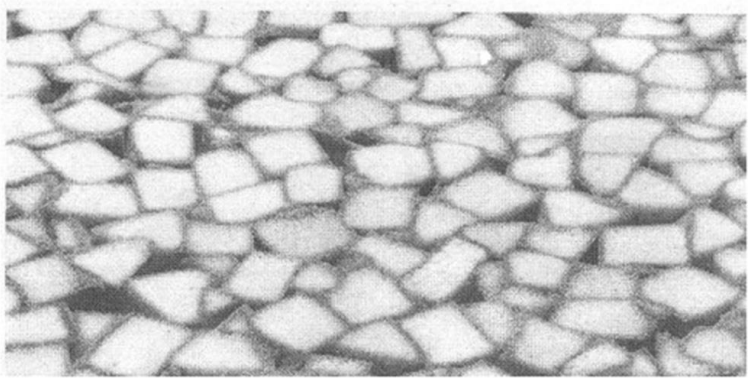
- Bio Polyol (vegetable oil, palm oil, soyabean oil, casteroil, etc. or waste from lignin from paper industry), lower reactivity compared with petroleum-based phenols.
- Bio Isocyanate (synthesize linear saturated terminal diisocyanate from oleic acid or vanilic acid derivate hydroxymethylfural (HMF) for reactive isocyanate monomer)

End of life or circularity:
Recycling by mechanical, chemical and biological recycling or reuse (such as adsorbent)

“Recycling of polyurethanes: where we are and where we are going”-Royal Society of Chemistry- Green Chem. 2024, v. 26 p.1132

- PU recycling *via* Mechanical recycling- represents the easiest and most basic strategy **for thermoplastic PUR** men problem of mechanical recycling is related to the degradation of the polymer properties after each recycling cycle, because of the degradation caused by reprocessing (thermo-mechanical degradation) that sums to the degradation during lifetime (thermo-oxidative one).



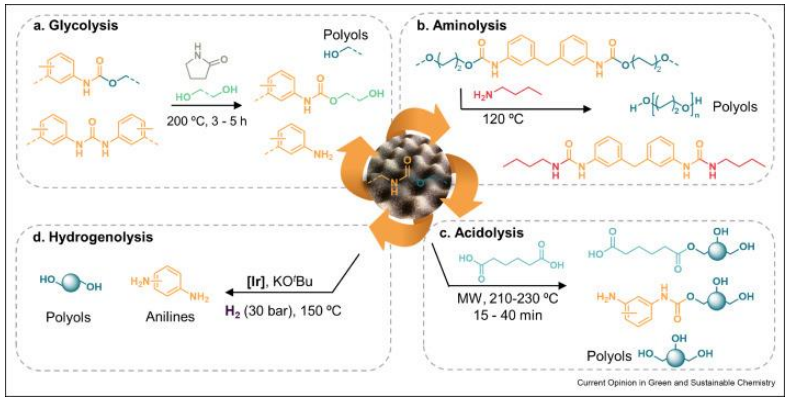


Rebonded foam: homogeneous distribution of the flake-binder mixture

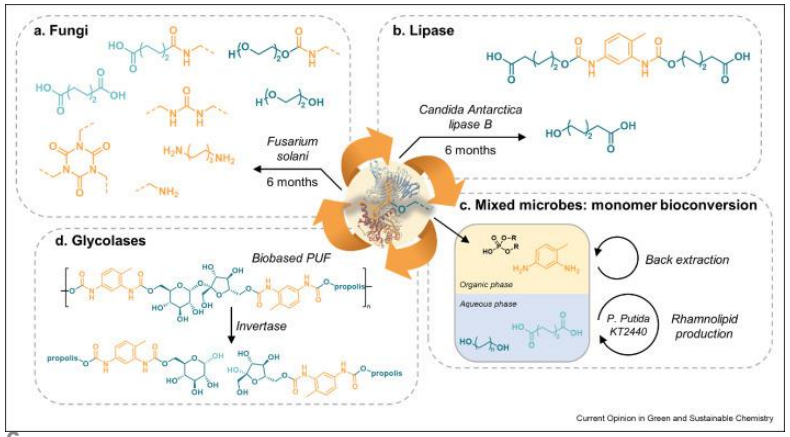
Sustainable PUs and reducing our reliance on fossil resources

“Reducing the carbon footprint of polyurethanes by chemical and biological depolymerization: Fact or fiction?” Current Opinion in Green and Sustainable Chemistry, Volume 41, June 2023, 100802

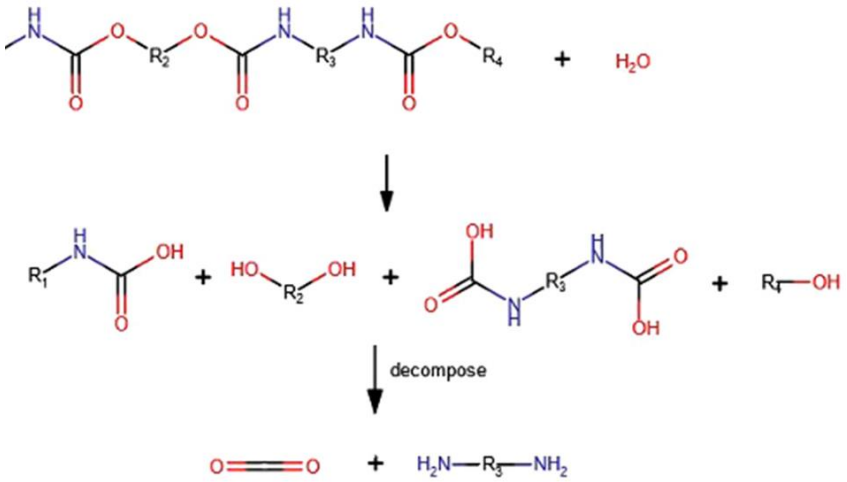
- PU depolymerization *via* chemical catalysis



- Depolymerization of PUs via biological catalysis



- Depolymerisation via biological catalysis or enzymatic degradation of PUs remains mainly limited to polyester-PUs.
- Chemical depolymerization:
- the recovery of polyols (reused in a closed-loop recycling approach), low molar mass diols [e.g., ethylene glycol (EG), 1,4-butanediol (BDO)], diacids [e.g., succinic acid, adipic acid (AA)] or ω-hydroxy acids [e.g., 6-hydroxycaproic acid (6-HCA)], depending on the nature of the polyester polyol used.



Conclusion for recycling

Green Chem., 2024, 26,1132,

the recycling strategies that have been designed and exploited so far, or are being developed for polyurethane waste streams,

- it is not possible to identify an ideal, unique, feasible, reliable, and even scalable recycling technology that should be suitable for all polyurethanes, but it is necessary to develop specific recycling approaches that maximize the yields, purity, and exploitability of the resulting recycled products, trying, at the same time, to minimize the environmental impact and the overall energy consumption

Reuse (such as adsorbent)

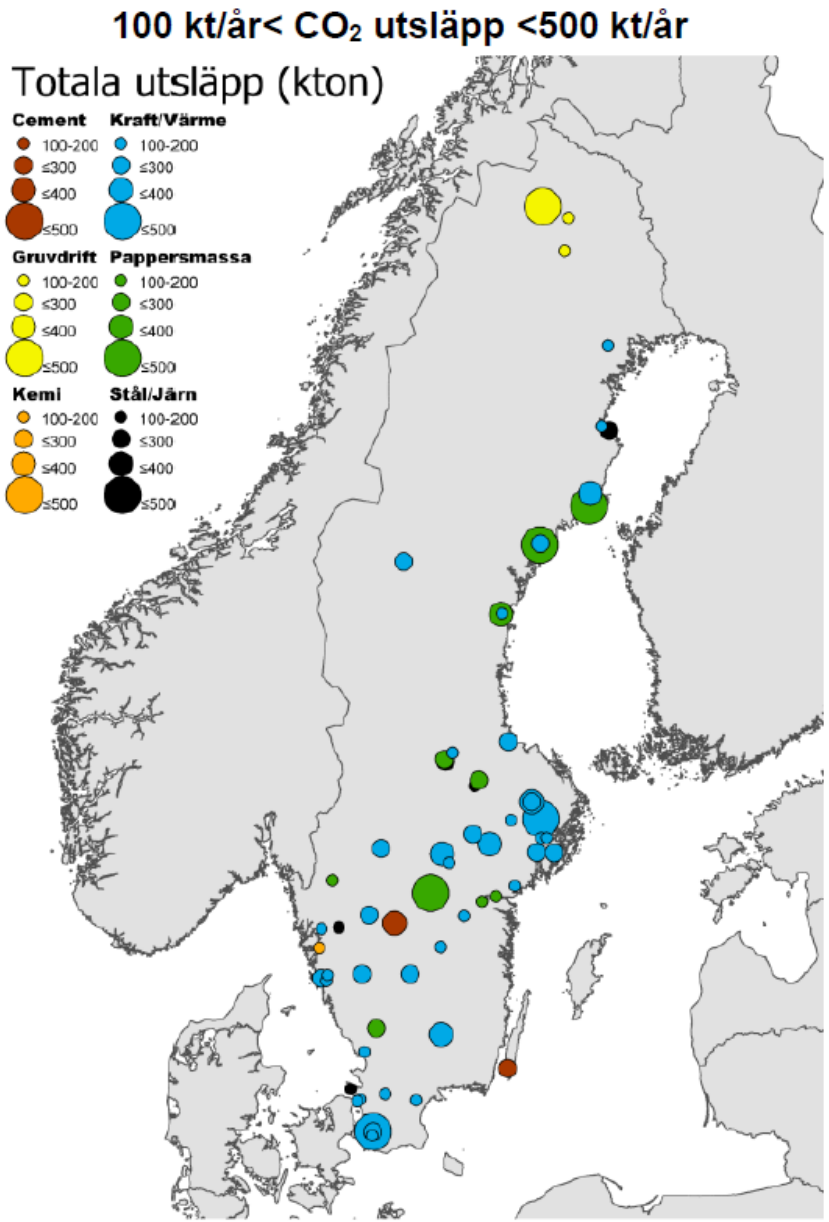
RISE earlier project- Development of Cost-Efficient CO_2 Adsorbents from Low-value Polymers

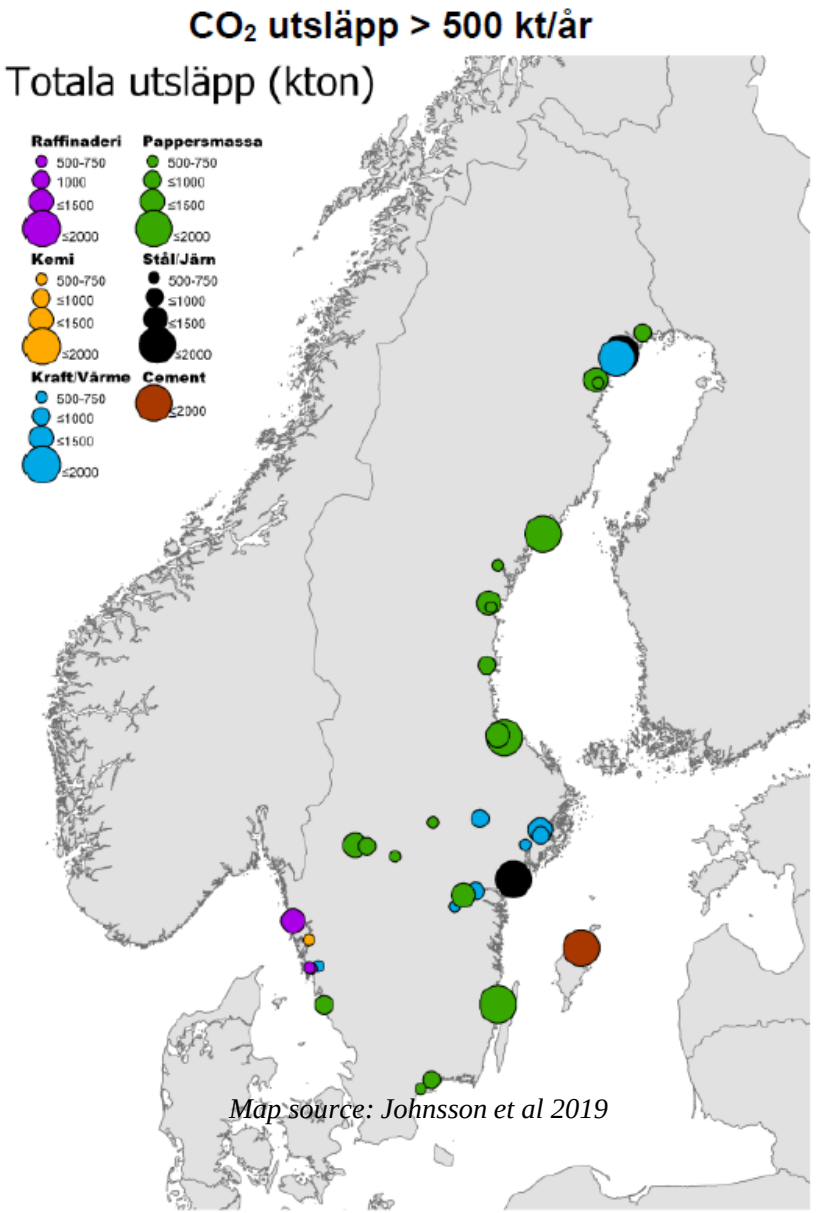
1. Background
2. Step 1 project–Proof of concept
3. Step 2 project (application)–Design and optimization

- Reach zero-net emission of greenhouse gases by 2045, and thereafter achieve net negative emissions.
- CO_2 emissions should reduce by 85 % compared to the level in 1991 (71 Mt CO_2eqv)
- CDR* measures should be applied to achieve negative emissions amounting to at least 10.7 Mt CO_2 per year by 2045.

*__Carbon dioxide removal__ (__CDR__), also known as __negative CO_2 emissions__, is a process in which carbon dioxide gas (CO_2) is removed from the atmosphere and sequestered for long periods of time

Sweden's climate goals





Map source: Johnsson et al 2019

Utsläpp straffavgift år 2021= 1200kr / ton

Utsläppen 2023 från anläggningarna (ej flyg) inom utsläppshandeln i Sverige var drygt 17,2 miljoner ton koldioxidekvivalenter, vilket innebär att utsläppen minskat med 2,4 procent från föregående år.

Major point source emitters of CO_2 in Sweden

CO_2 separation → CO_2 Transportation → CO_2 Storage

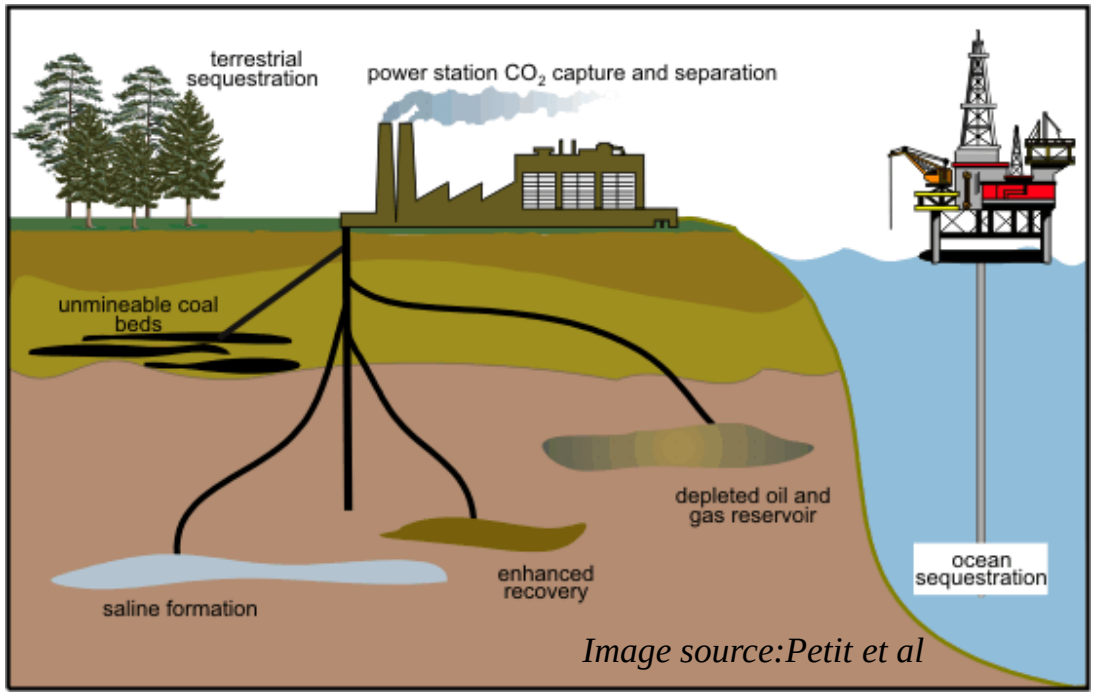
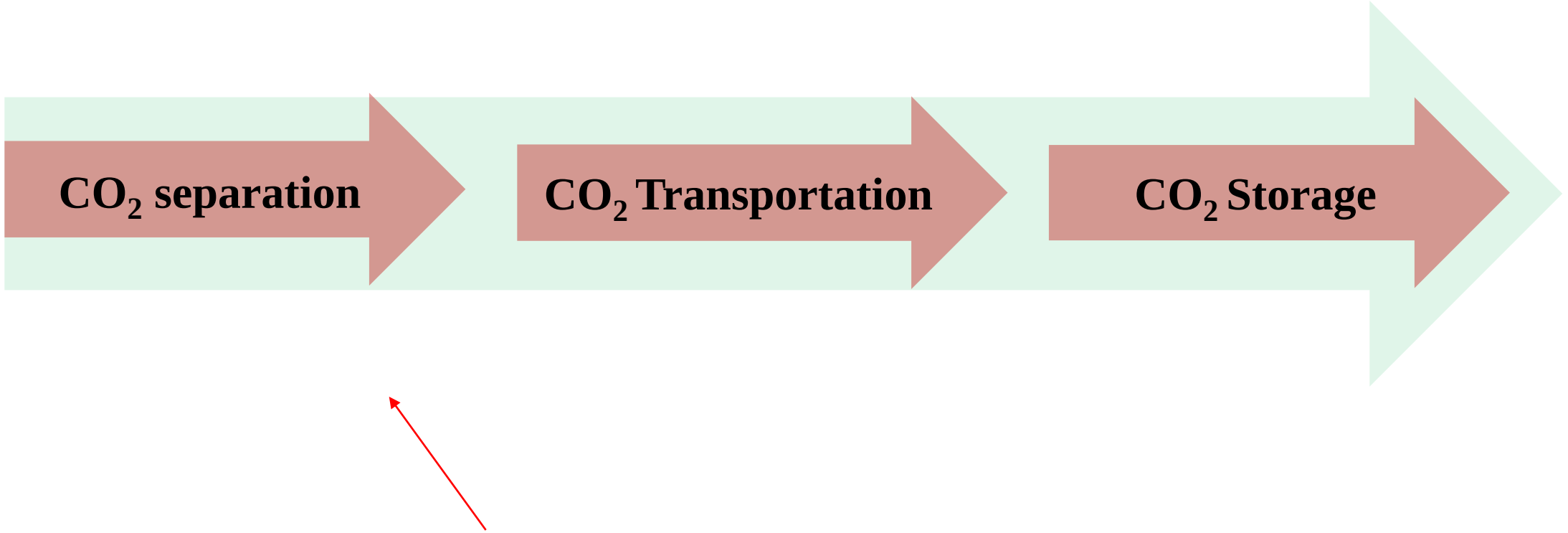
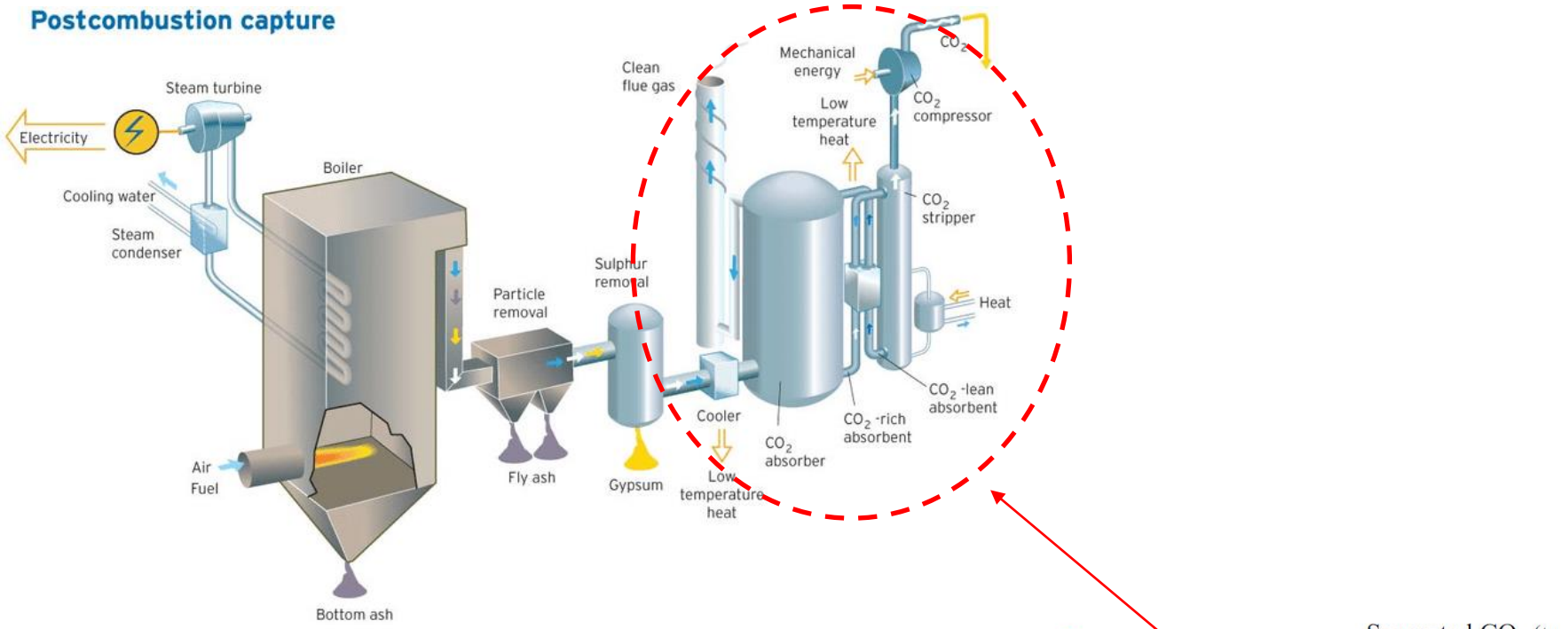


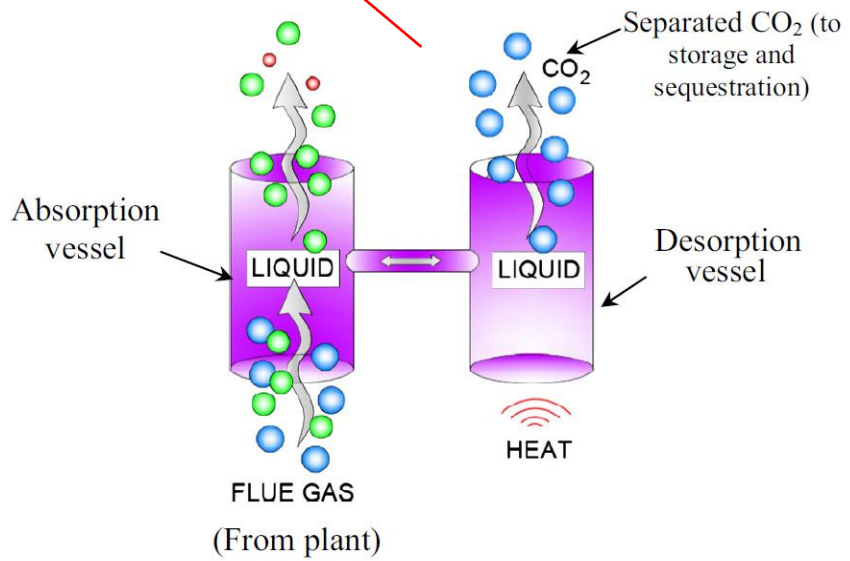
Image source:Petit et al

Geological CO_2 storage

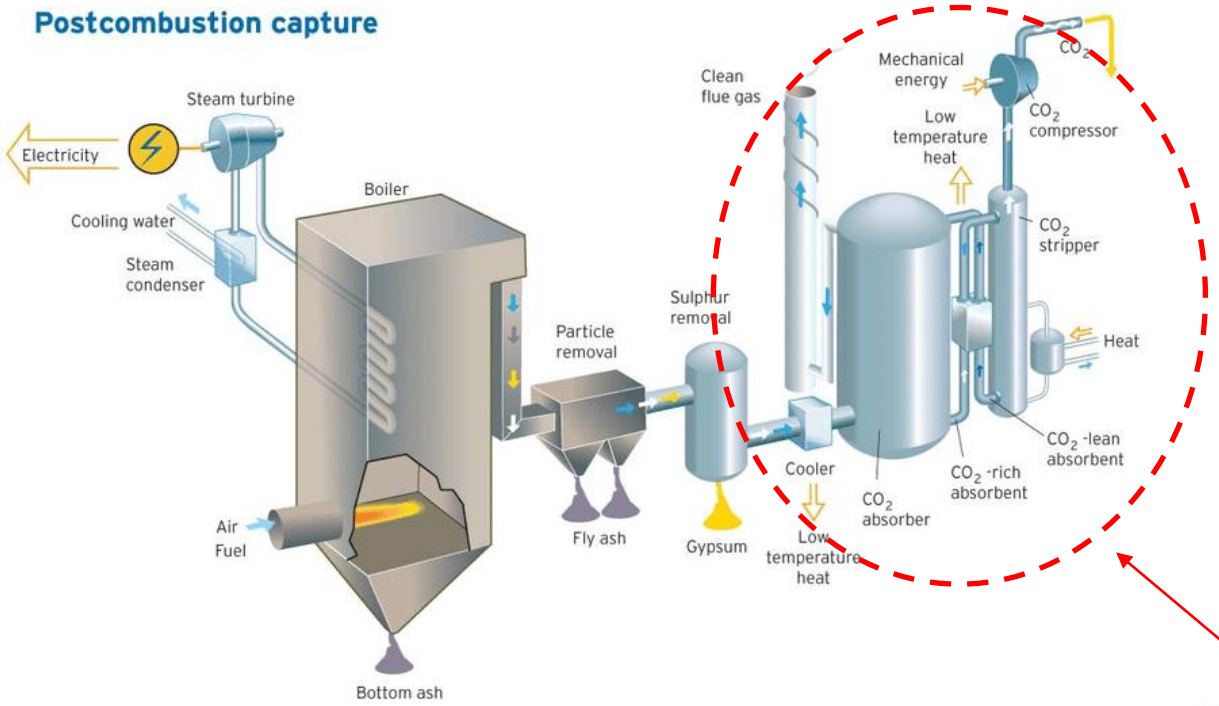


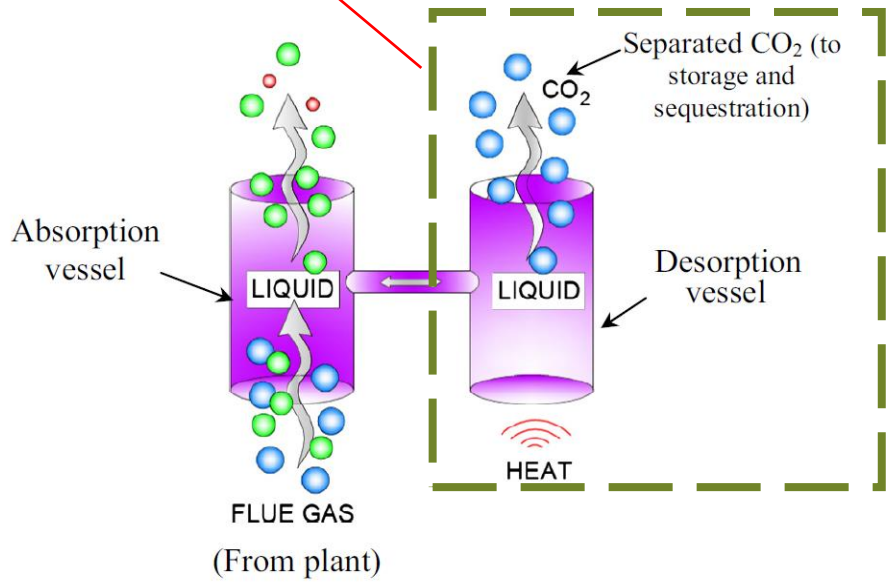
- *Accounts for 70 %–80 % of the overall bio-CCS (CCS) cost*
- *Thus, the development of a cost-efficient CO_2 separation process and material are crucial for the economic viability of bio-ccs*





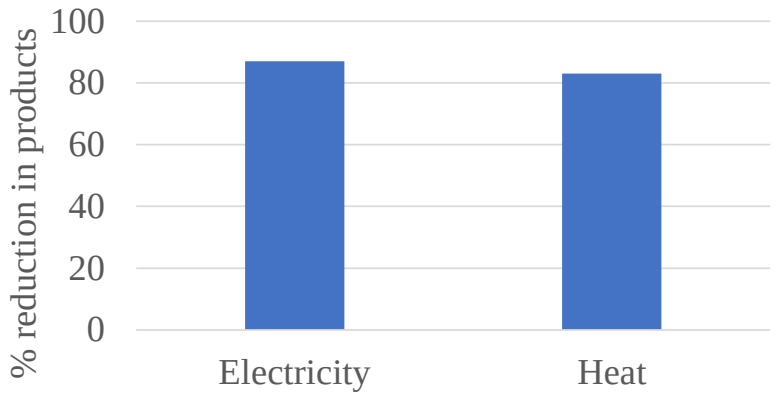
CO_2 separation benchmark: Chemical absorption with monoethanolamine (MEA)



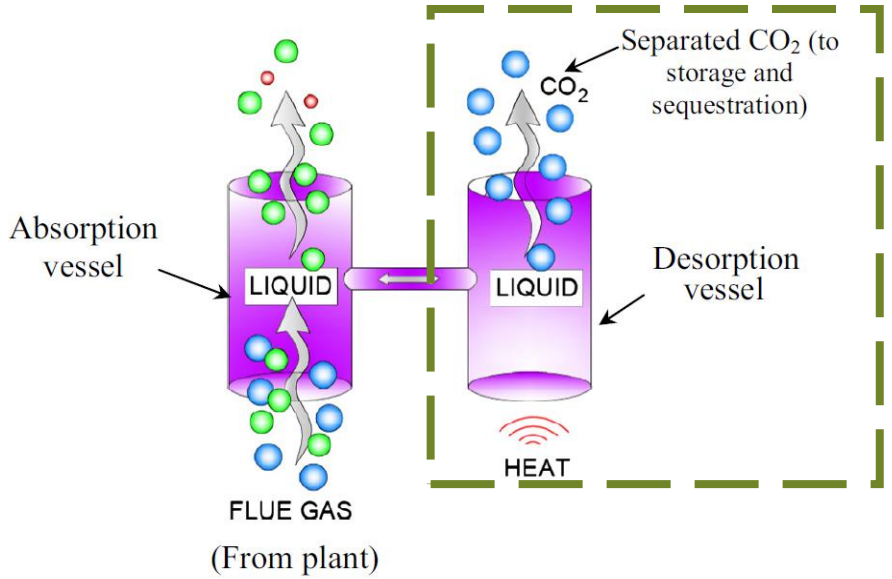


Key problem:
Energy intensive regeneration:
3–6 GJ/tonne of CO_2

CO_2 separation benchmark: Chemical absorption with monoethanolamine (MEA)



Percent reduction in the sale of electricity and heat when MEA is applied for CO_2 separation



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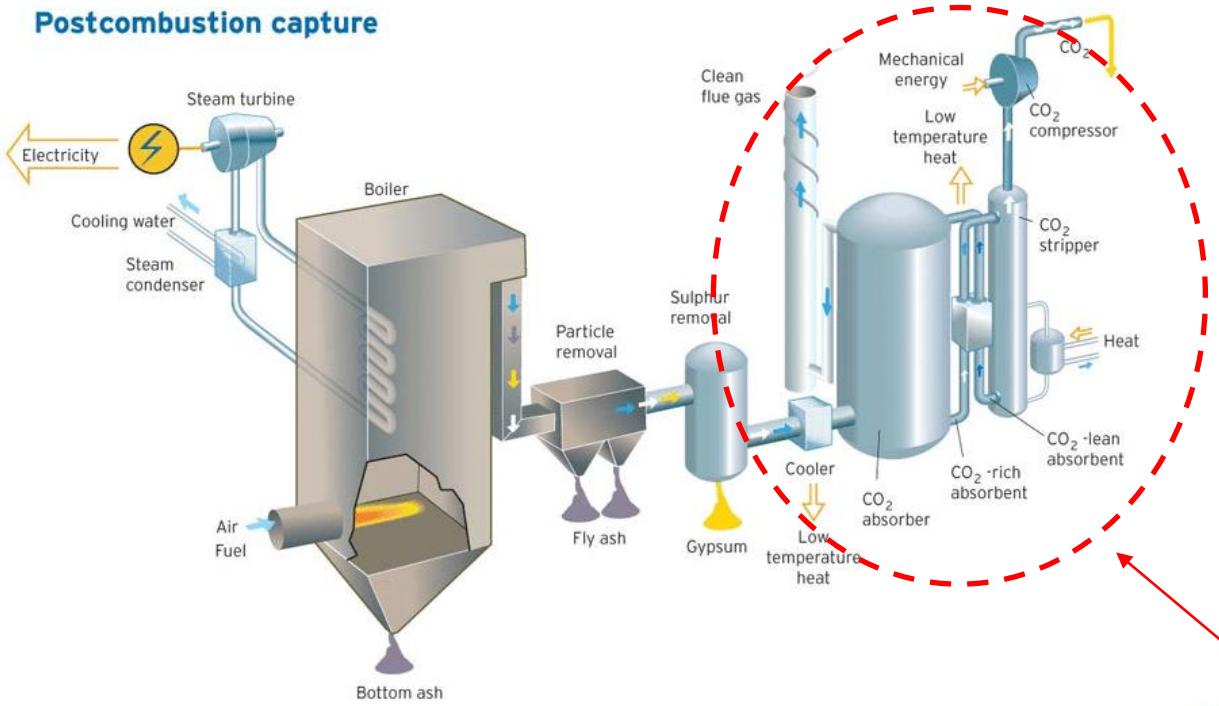
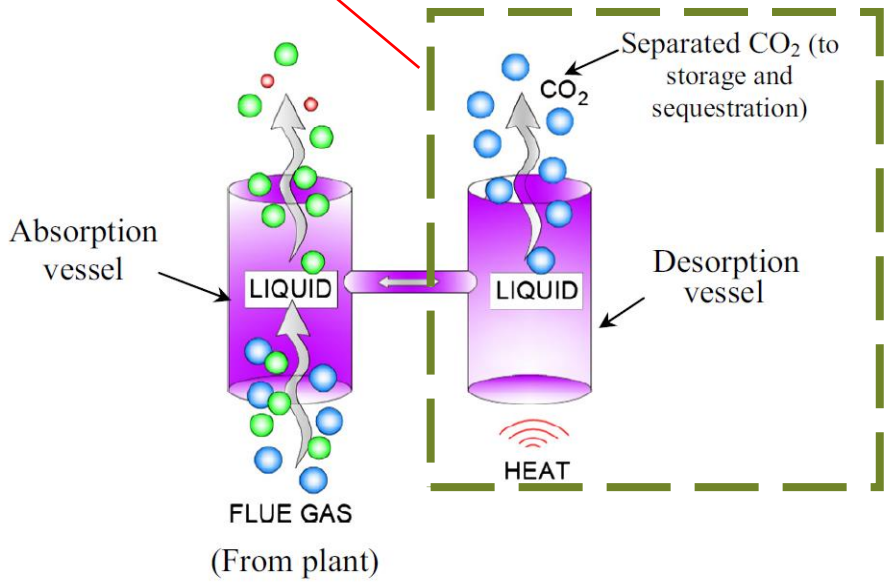
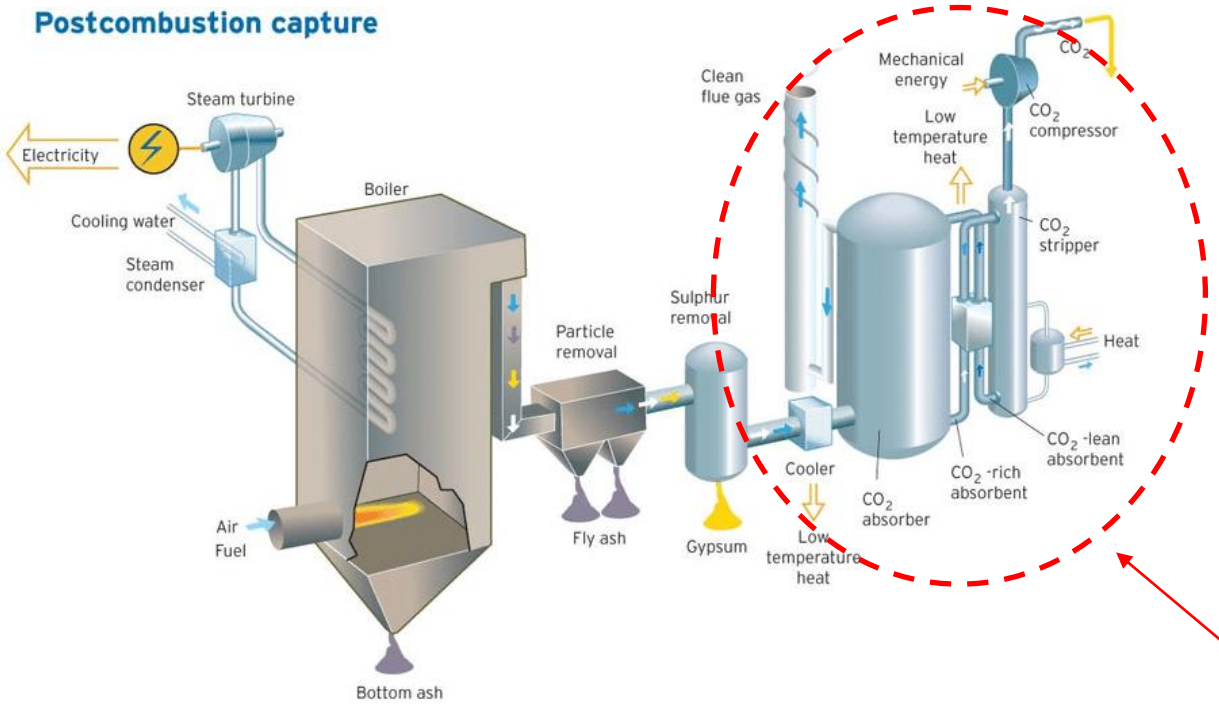


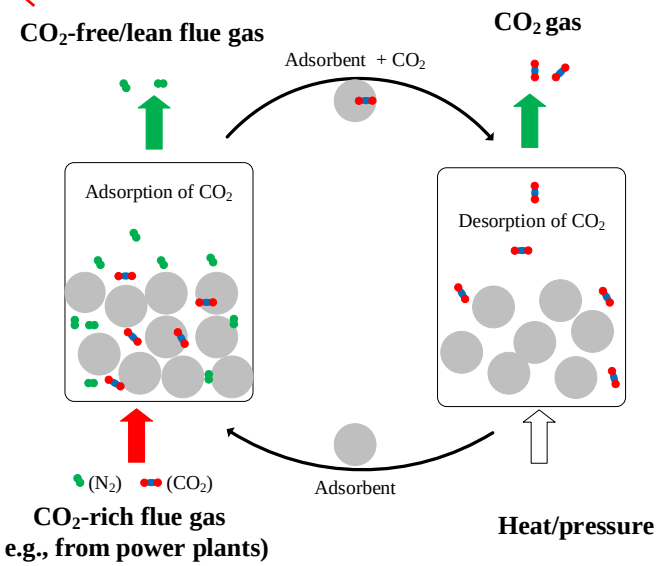


Key problem:
Energy intensive regeneration: 3–6 GJ/tonne of CO_2

Solution:
Energy demand for the regeneration step should < 2 GJ/tonne of CO_2 to enable theCO_2 separation process to be economically viable .

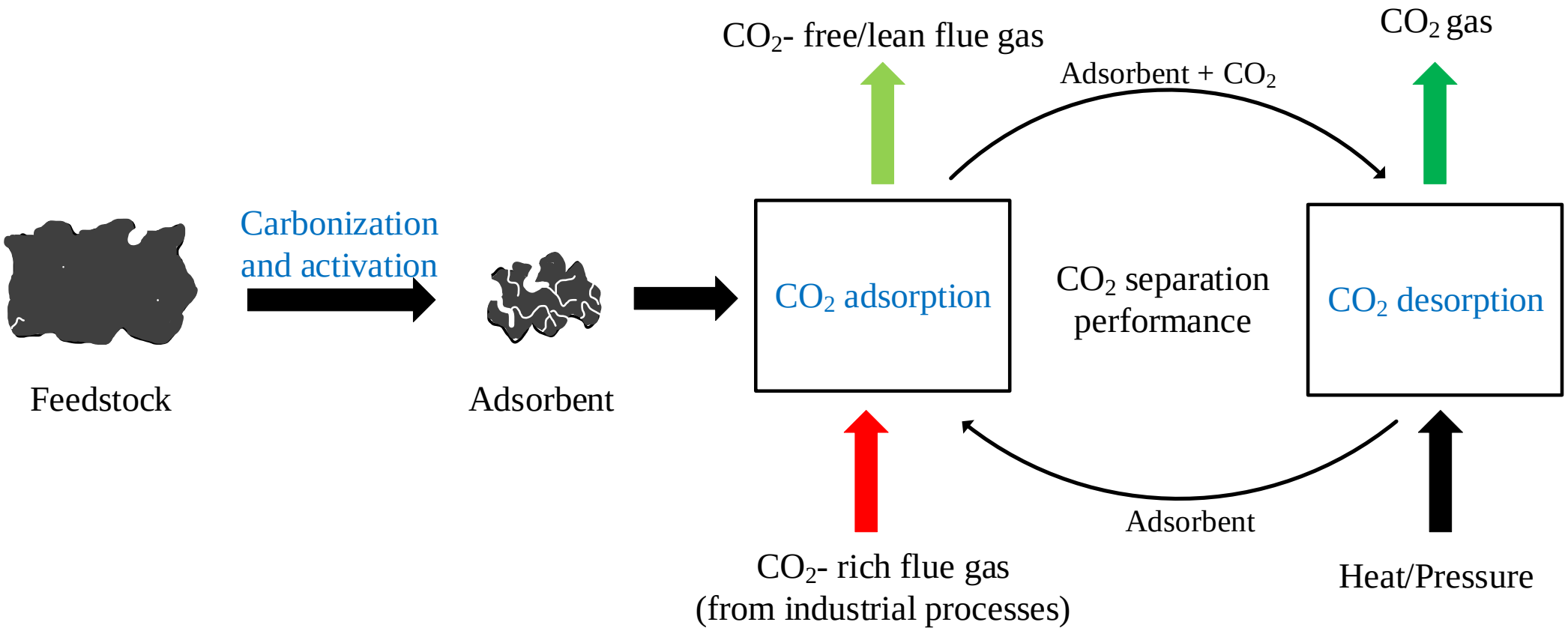
CO_2 separation benchmark: Chemical absorption with monoethanolamine (MEA)



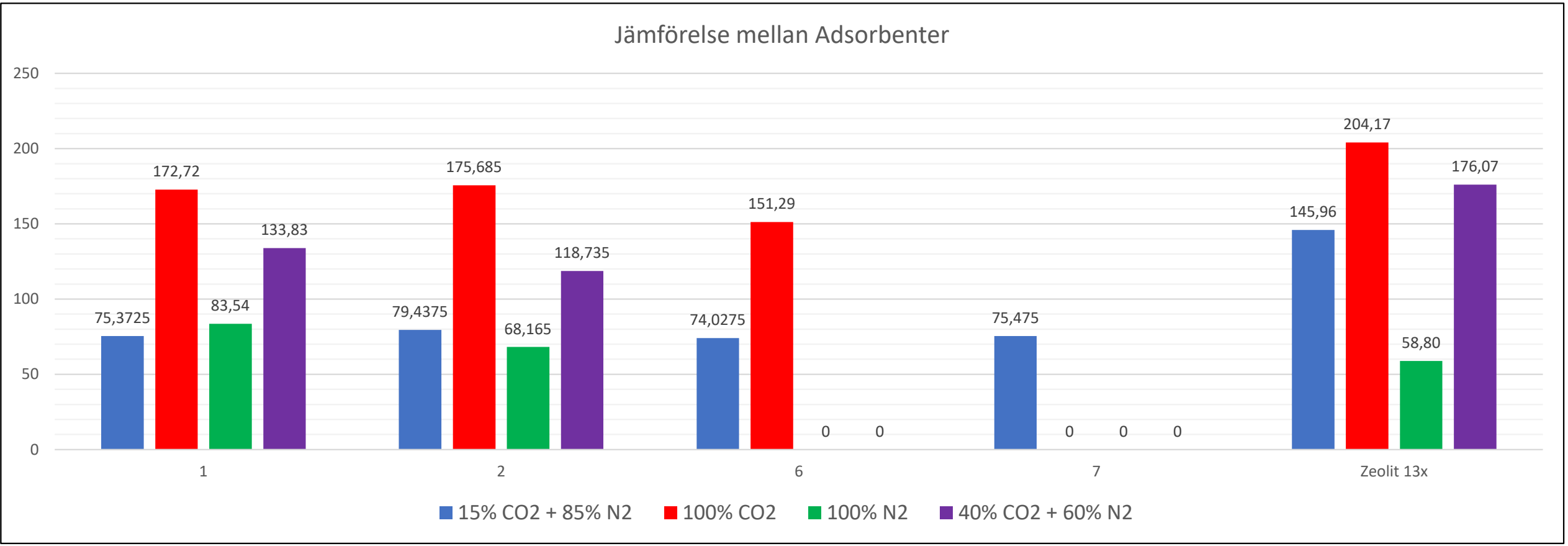


Generally less energy intensive than MEA.

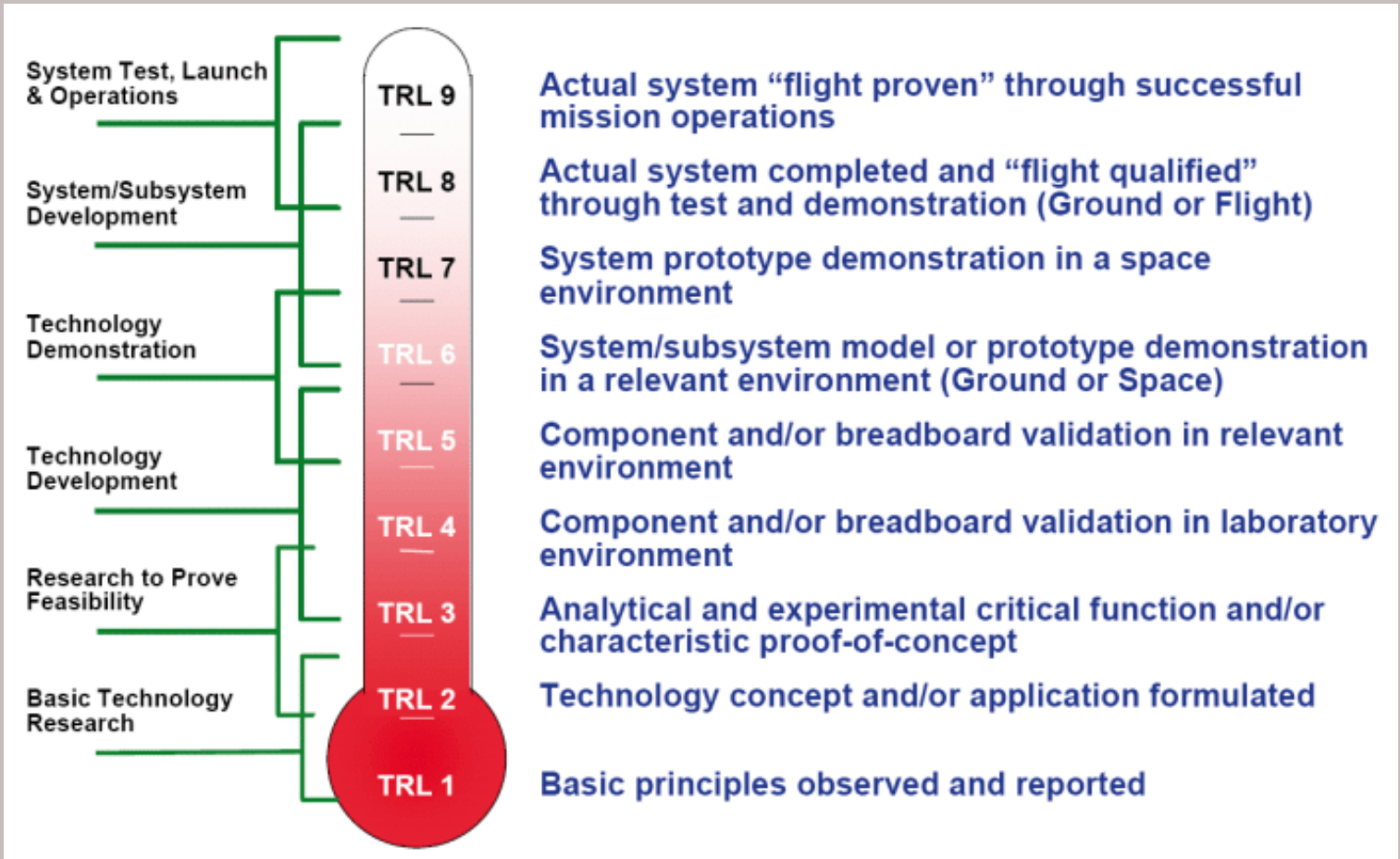
CO_2 separation by physical adsorption



Proof of concept: *Can a CO_2 adsorbent be produced from polymer residues with a similar performance as commercial zeolites?*


Jämförelse mellan Adsorbenter
250
200
150
100
50
0
75,3725
172,72
83,54
133,83
79,4375
175,685
68,165
118,735
74,0275
151,29
0
0
75,475
0
0
0
145,96
204,17
58,80
176,07
1
2
6
7
Zeolit 13x
15% CO2 + 85% N2
100% CO2
100% N2
40% CO2 + 60% N2

Titel förslag till projektet: Process optimisation of CO2 separation for polymer based adsorbent-TRL3 to TRL4



Development of Cost-Efficient CO_2 Adsorbents from Low-value Polymers

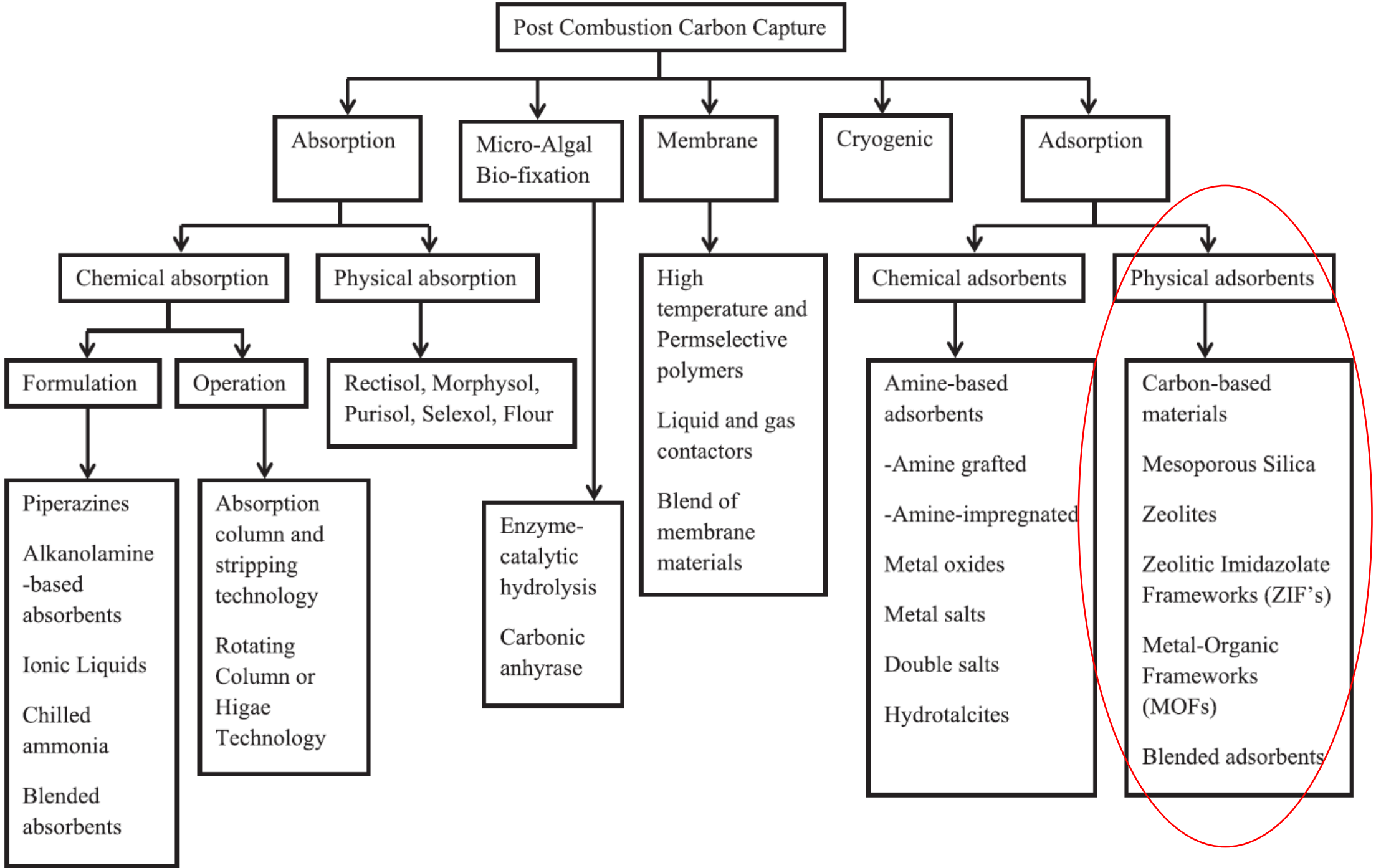
- Project partners:
  - Powerpipe systems AB (Jan Frick)
  - PUR Gruppen: Prio Plastic AB (Dragan Vasic)
  - Plixxent (Håkan Bengtsson)
  - Nässjö affärsverk AB (Andreas Lindahl)
  - RISE (Placid Atongka Tchoffor, Nazdaneh Yarahmadi, Anders Höije)

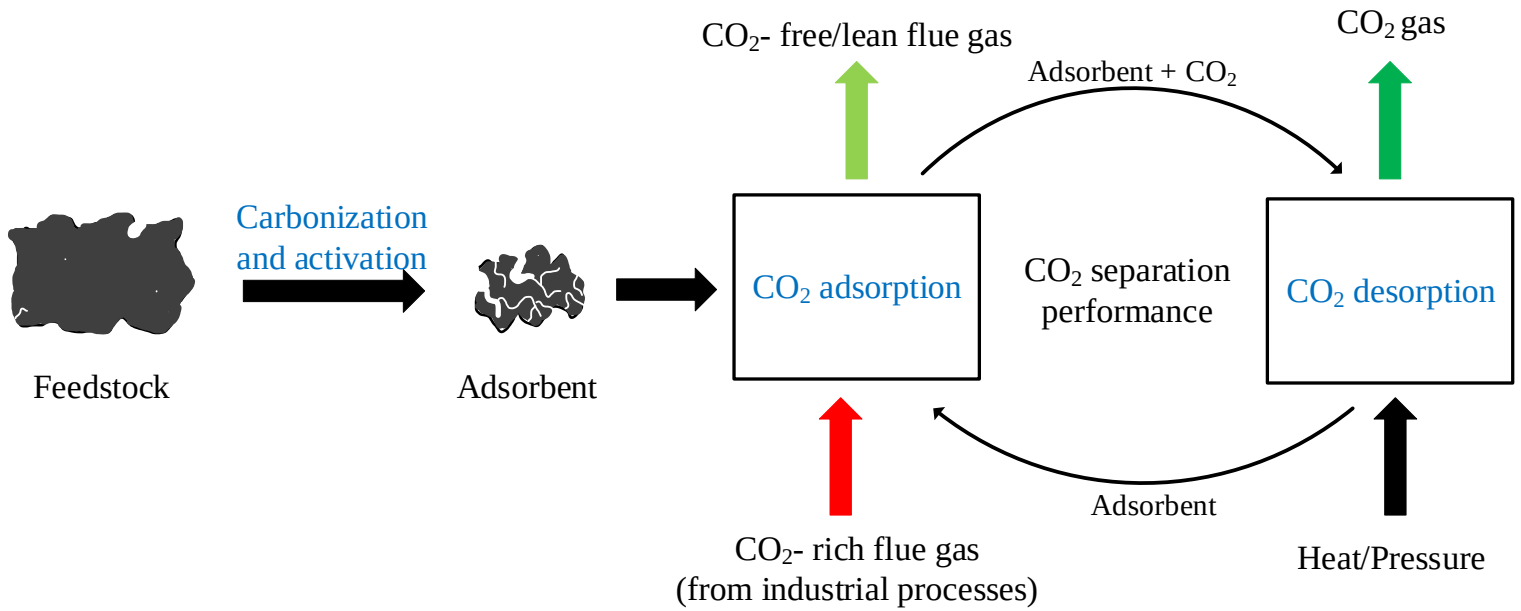
LoxiTec AB

Financed by: Energimyndigheten – PUR gruppen, Powerpipe Systems AB, Nässjö Affärsverk AB
Project time: 2021-01-15 to ~~2022-02-30~~ 2022-12-31

What will we do?

- Collaborate with PUR- gruppen
- Define optimum experimental conditions to produce CO_2 adsorbents from PUR and PIR waste from various products
- Evaluate the CO_2 separation performance of the produced CO_2 adsorbents
- Preliminary estimation of the cost to produce CO_2 adsorbents from PUR/PIR


Post Combustion Carbon Capture
Absorption
Micro-Algal Bio-fixation
Membrane
Cryogenic
Adsorption
Chemical absorption
Physical absorption
Formulation
Operation
Rectisol, Morphysol, Purisol, Selexol, Flour
Piperazines
Alkanolamine -based absorbents
Ionic Liquids
Chilled ammonia
Blended absorbents
Absorption column and stripping technology
Rotating Column or Higae Technology
Enzyme-catalytic hydrolysis
Carbonic anhyrase
High temperature and Permselective polymers
Liquid and gas contactors
Blend of membrane materials
Chemical adsorbents
Physical adsorbents
Amine-based adsorbents
-Amine grafted
-Amine-impregnated
Metal oxides
Metal salts
Double salts
Hydrotalcites
Carbon-based materials
Mesoporous Silica
Zeolites
Zeolitic Imidazolate Frameworks (ZIF's)
Metal-Organic Frameworks (MOFs)
Blended adsorbents



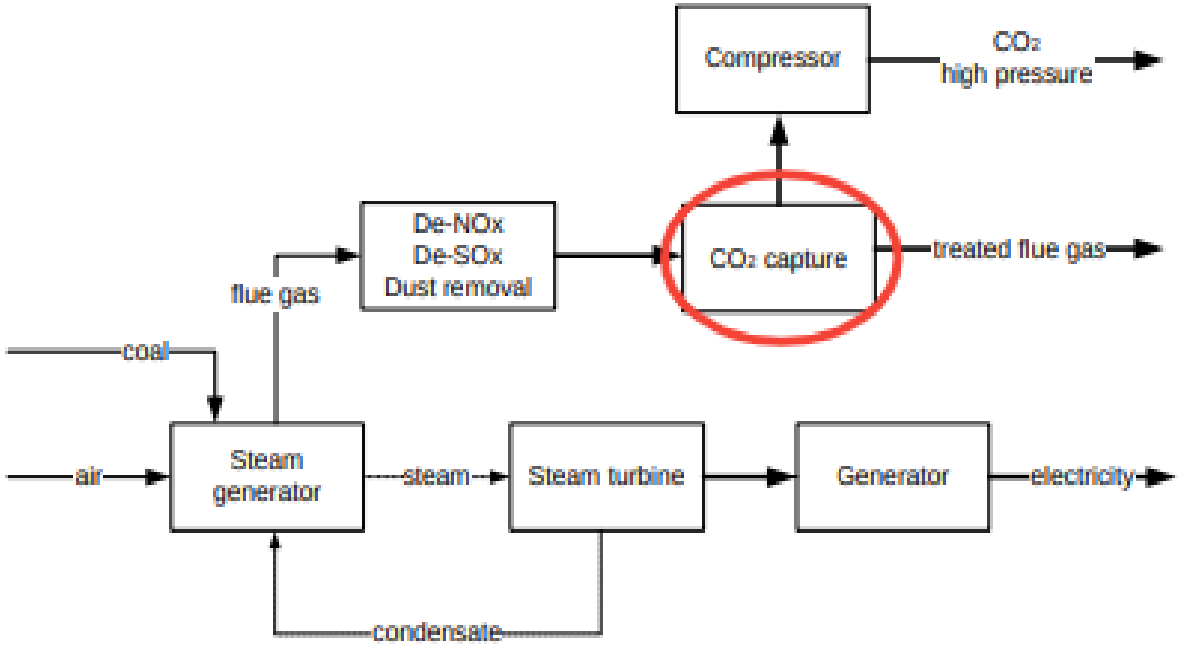


Fig. 1. Schematic diagram of a power plant with post-combustion CO_2 capture [6]

Characterization and material selection

- PIR and PUR has been investigated with TGA to
  - Determine the amount of organic and inorganic parts
  - Determine thermal stability of the material

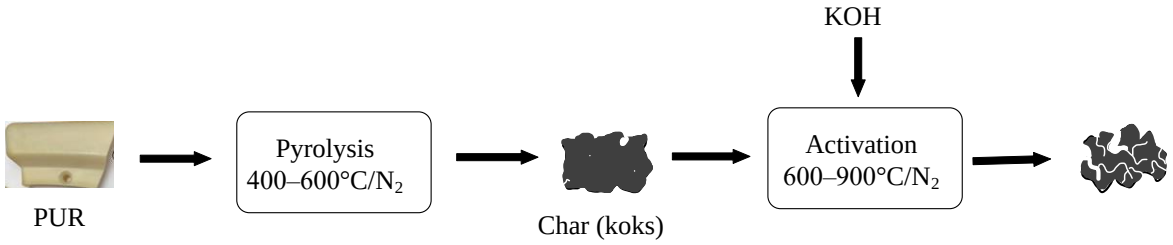
LX2, LX4, **PIR** and **Power Pipe** as well as zeolit for the reference material

- Production of adsorbent
- Measuring the porosity

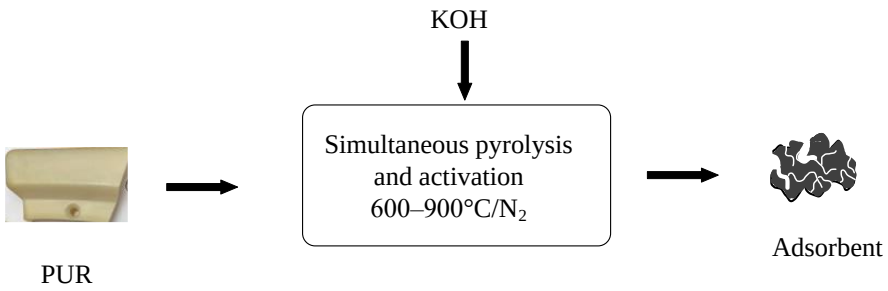
Find the correct paramters and production method for the adsorbent

Adsorbent production (modification of the capacity of CO_2 by impregnation using K)

chemical production

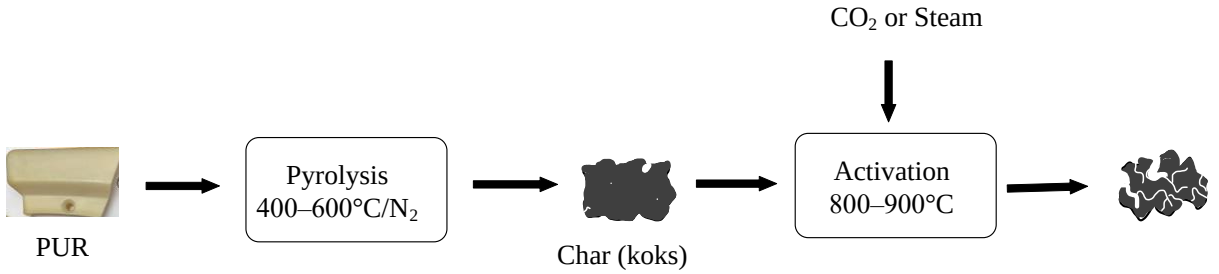


Indirect production of adsorbents by chemical activation

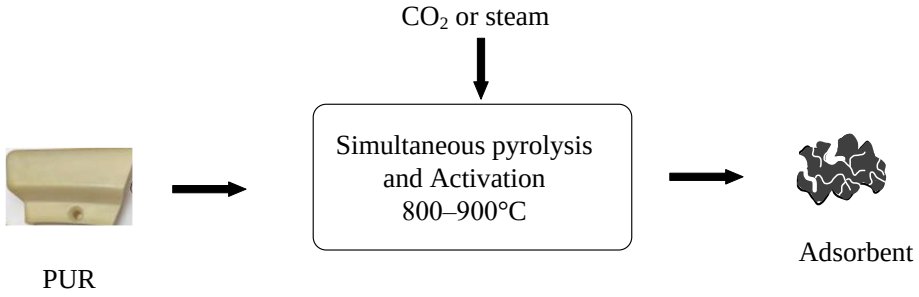


Direct production of adsorbents by chemical activation

physical production



Indirect production of adsorbents by physical activation

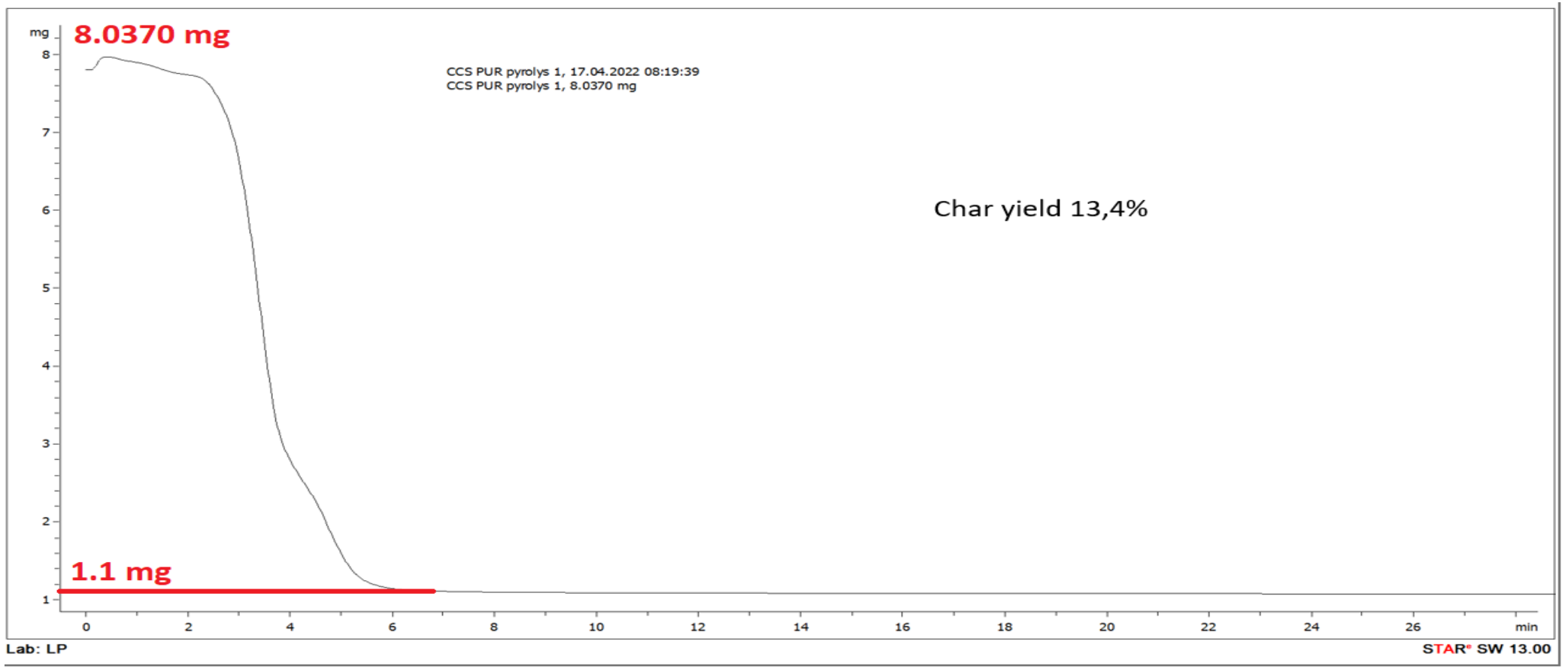


Direct production of adsorbents by physical activation

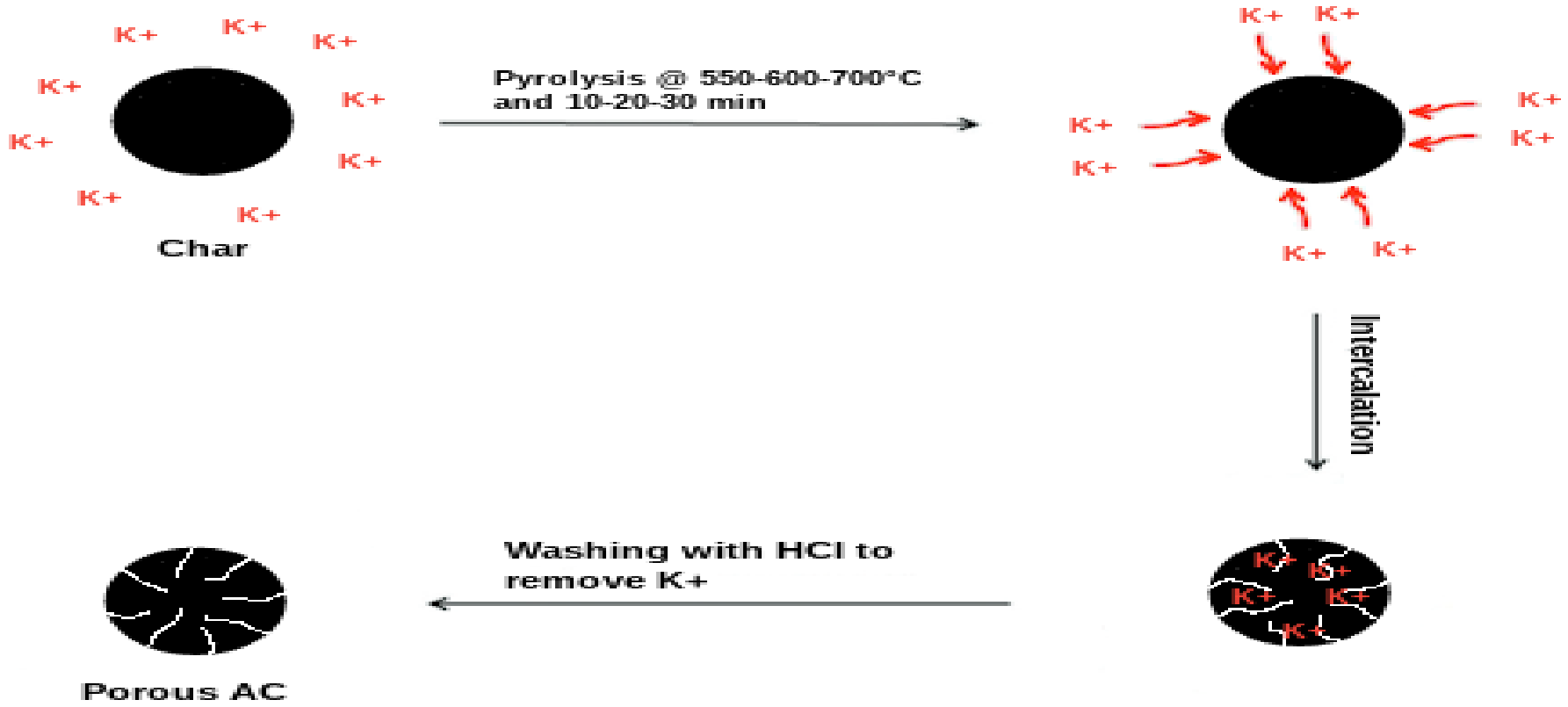
By altering time, temperature and KOH concentration

Run #	Sample	Activation method	K (m) ÷ Sample m)	Temperature, °C	time, min	N2 flow, ml/min	CO2 adsoption temp. °C
1	PUR	Indirect	0	650	20	200	25
2	PUR	Indirect	0,5	650	10	200	25
3	PUR	Indirect	0,5	650	20	200	25
4	PUR	Indirect	0,5	650	30	200	25
5	PUR	Indirect	0,5	550	Best time	200	25
6	PUR	Indirect	0,5	600	Best time	200	25
7	PUR	Indirect	0,5	700	Best time	200	25
8	PUR	Indirect	1	Best temp	Best time	200	25
9	PUR	Indirect	1,5	Best temp	Best time	200	25
10			Best C		Best time	200	25
11			1,5	650	Best time	200	25
12			1,5	700	Best time	200	25

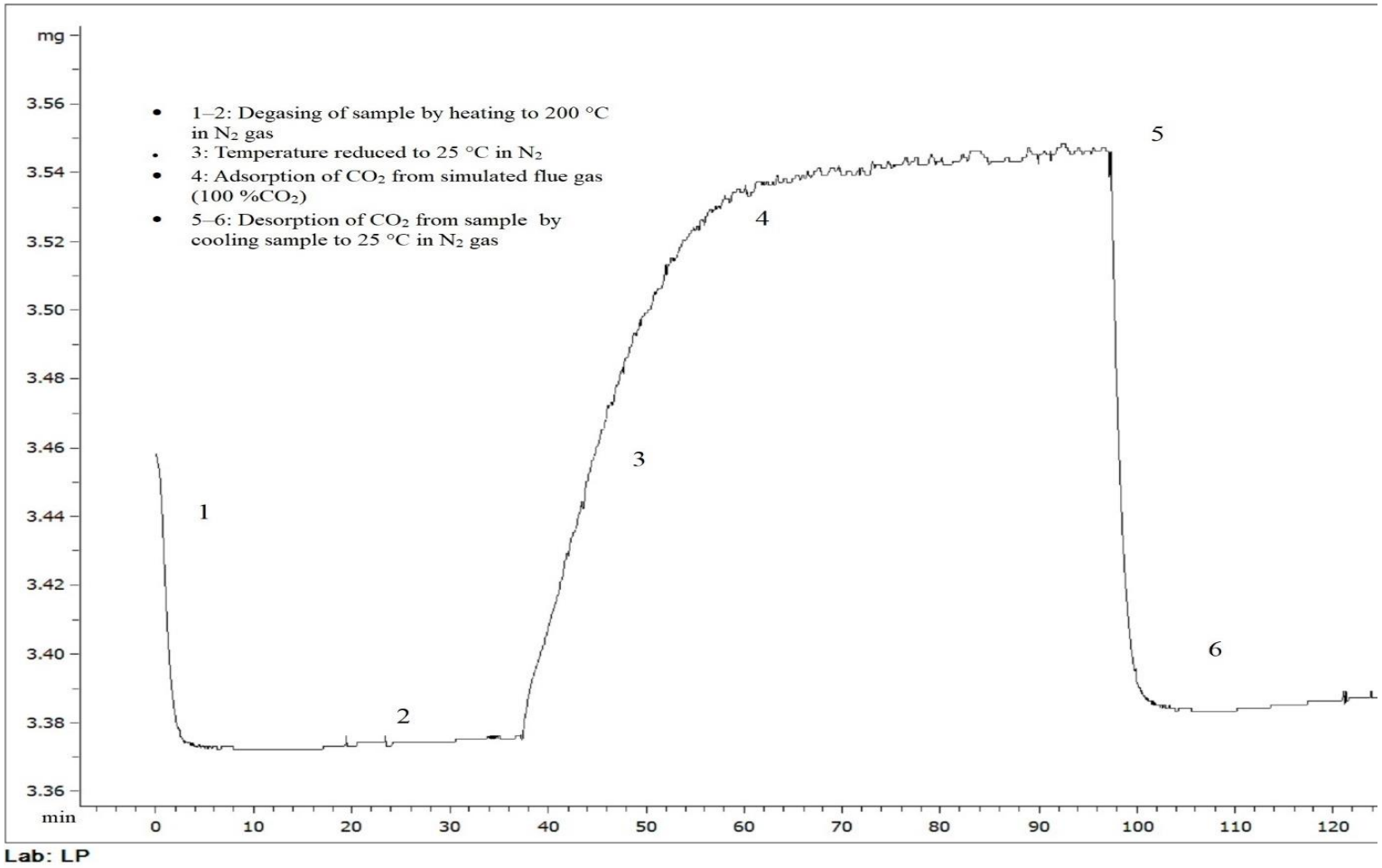
Char yield calculation by using TGA



KOH impact on char



Evalulation of adsorption and desorption by TGA



CO_2 adsorption evaluated by TGA
PUR, Indirect chemical activation

Run #	Sample	Activation method	K (m)÷ Sample m)	Temperature, °C	time, min	N2 flow, ml/min	CO2 adsoption temp. °C	Sample 1 (mg/g)	Sample 2 (mg/g)	Average
0	PUR	Indirect	0	650	20	200	25	51,17	51,24	51,2
1	PUR	Indirect	0,5	650	10	200	25	81,44	68,33	74,89
2	PUR	Indirect	0,5	650	20	200	25	66,55	77,46	72,01
3	PUR	Indirect	0,5	650	30	200	25	112,83	107,54	110,19
4	PUR	Indirect	0,5	650	40	200	25	49,42	68,2	58,81
5	PUR	Indirect	0,5	650	60	200	25	44,64	86,31	65,48
6	PUR	Indirect	0,5	550	30	200	25	38,09	31,55	34,82
7	PUR	Indirect	0,5	600	30	200	25	20,69		
8	PUR	Indirect	0,5	700	30	200	25	71,23	50,62	60,93
9	PUR	Indirect	1	650	30	200	25	73,02	95,52	84,27
10	PUR	Indirect	1,5	650	30	200	25	152,10	131,42	141,76

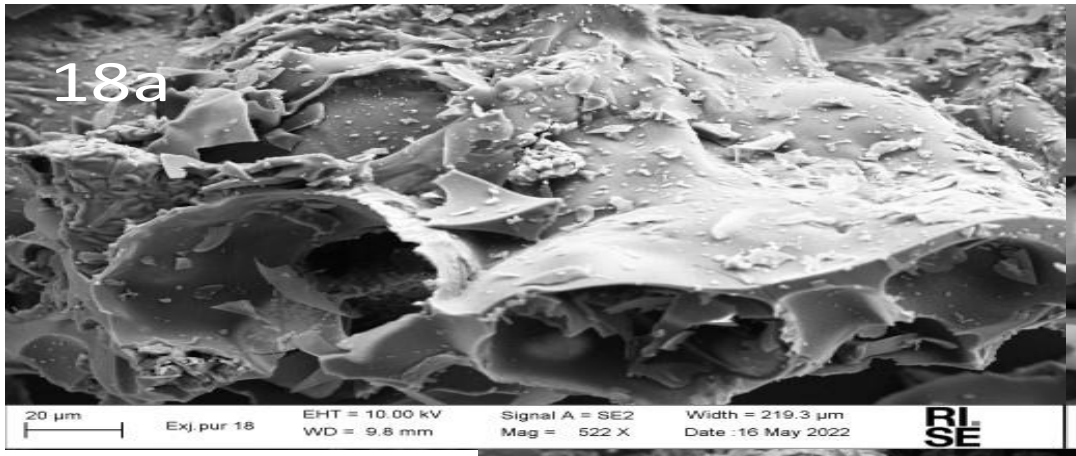
CO_2 adsorption evaluated by TGA
PUR, Direct Chemical activation

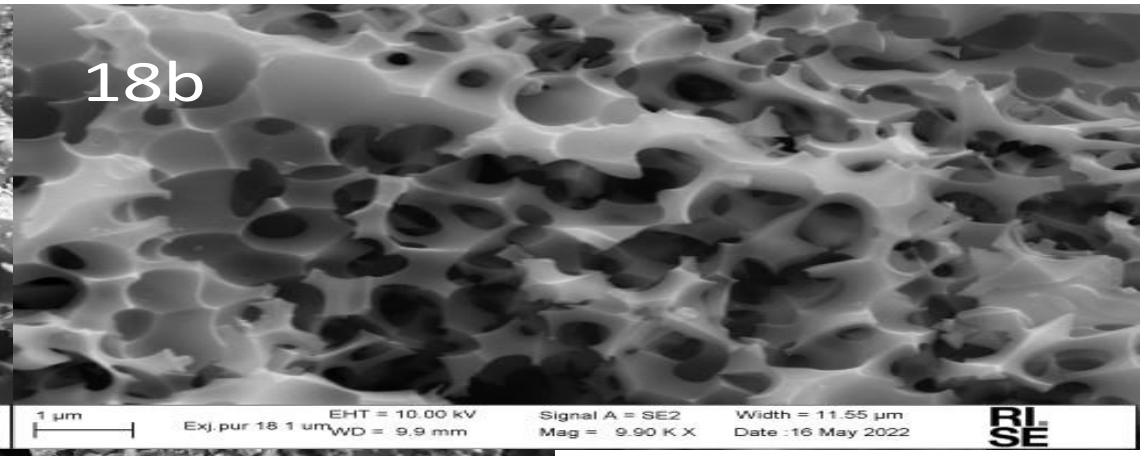
Run #	Sample	Activation method	K (m)÷ Sample m)	Temperature, °C	time, min	N2 flow, ml/min	CO2 adsoption temp. °C	Sample 1 (mg/g)	Sample 2 (mg/g	Average
15	PUR	Direct	0,5	650	10	200	25			
16	PUR	Direct	0,5	650	20	200	25	93,86	92,42	93,14
17	PUR	Direct	0,5	650	30	200	25	95,06	100,36	97,71
18	PUR	Direct	0,5	650	40	200	25	115,48		115,48
19	PUR	Direct	0,5	650	50	200	25	53,32		53,32
20	PUR	Direct	0,5	650	60	200	25	90.36		
21	PUR	Direct	0,5	650	90	200	25	90,49		90,49
22	PUR	Direct	0,5	550	40	200	25	22,17		22,17
23	PUR	Direct	0,5	600	40	200	25	53,59		53,59
24	PUR	Direct	0,5	700	40	200	25	116,35		116,35
25	PUR	Direct	1	650	40	200	25	124,28		124,28
26	PUR	Direct	1,5	650	40	200	25	145,48		145,48
27	PUR	Direct	1,5	650	40	200	25	151,29		151,29

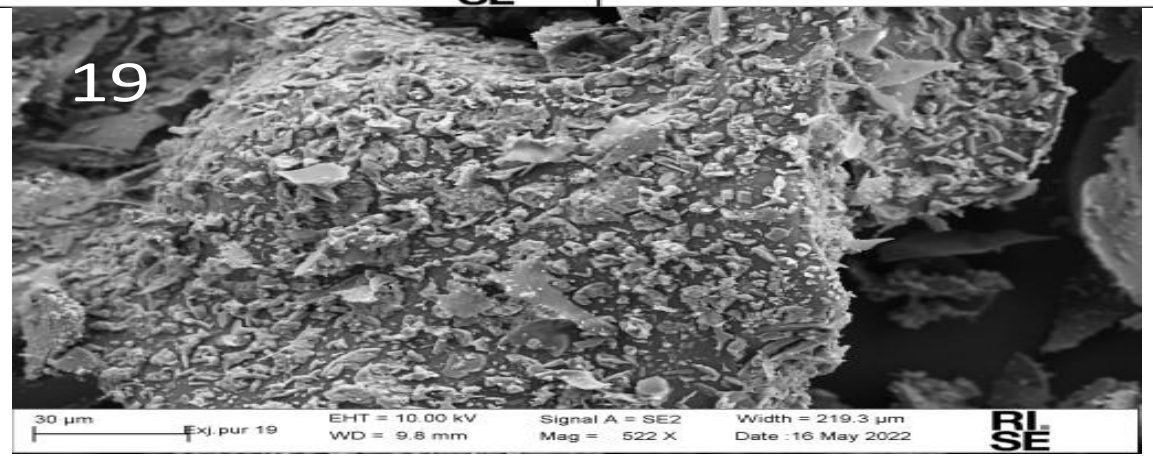
CO_2 adsorption evaluated by TGA
PIR, Direct Chemical activation

					15% CO2 + 85% N2			100% N2			40% CO2 + 60% N2			100% CO2		
Run #	Sample	K(m)÷Char(m)	Temp, °C	Time, min	Sample 1	Sample 2	**Average**	Sample 1	Sample 2	**Average**	Sample 1	Sample 2	**Average**	Sample 1	Sample 2	**Average**
14	PIR	0	650	45	26,86	26,48	**26,67**	8,45	8,72	**8,59**	36,42	40,71	**38,57**	44,57	62,84	**53,71**
15	PIR	0,5	650	45	65,02	64,87	**64,95**	24,66	24,04	**24,35**	91,94	94,87	**93,41**	118,18	133,82	**126,00**
16	PIR	0,5	650	90	55,92	58,19	**57,06**	21,75	22,93	**22,34**	83,00	85,29	**84,15**	103,88	126,13	**115,01**
17	PIR	0,5	650	20	71,26	72,18	**71,72**	26,72	26,99	**26,86**	106,62	110,94	**108,78**	137,73	157,41	**147,57**
21	PIR	0,5	700	45	100,94	98,55	**99,75**	65,24	59,66	**62,45**	88,22	92,28	**90,25**	122,08	153,88	**137,98**
22	PIR	1,5	600	45	116,33	104,51	**110,42**	70,19	65,90	**68,05**	104,66	112,55	**108,61**	142,32	161,93	**152,13**
23	PIR	1,5	650	45	110,11	111,13	**110,62**	65,79	70,54	**68,17**	116,07	121,40	**118,74**	170,73	180,64	**175,69**
24	PIR	1,5	700	45	99,76	96,47	**98,12**	63,34	64,73	**64,04**	98,12	105,47	**101,80**	161,97	185,84	**173,91**
25	PIR	1	600	45	119,29	129,42	**124,36**	70,45	71,87	**71,16**	117,36	129,64	**123,50**	155,27	174,96	**165,12**
26	Zeolite 13X				146,78	145,14	**145,96**	51,23	66,37	**58,80**	180,40	171,73	**176,07**	205,13	203,21	**204,17**
27	PIR	1,5	600	20				37,96	35,28	**36,62**	104,40	114,25	**109,33**	156,43	156,27	**156,35**
28	PIR	1,5	650	20				80,79	86,29	**83,54**	119,88	147,78	**133,83**	170,77	174,67	**172,72**
29	PIR	1,5	700	20				77,64		**77,64**	116,12	158,82	**137,47**	166,22	165,21	**165,72**
30	PIR	0,5	600	45				34,8	34,34	**34,57**	80,94	91,98	**86,46**	112,94	112,08	**112,51**
31	PIR	0,5	600	90				36,5	36,37	**36,44**	94,82	90,63	**92,73**	130,82	128,97	**129,90**
32	PIR	0,5	600	20				32,59	31,4	**32,00**	82,15	76,82	**79,49**	112,69	113,98	**113,34**
33	PIR	0,5	600	180				38,84	38,56	**38,70**				133,87	133,25	**133,56**
34	PIR	1	600	180				45,39	46,72	**46,06**				155,66	154,68	**155,17**
35	PIR	1	600	90				51,46	52,35	**51,91**				168,97	168,62	**168,80**
36	PIR	1	650	20				43,63	44,87	**44,25**				147,16	148,05	**147,61**

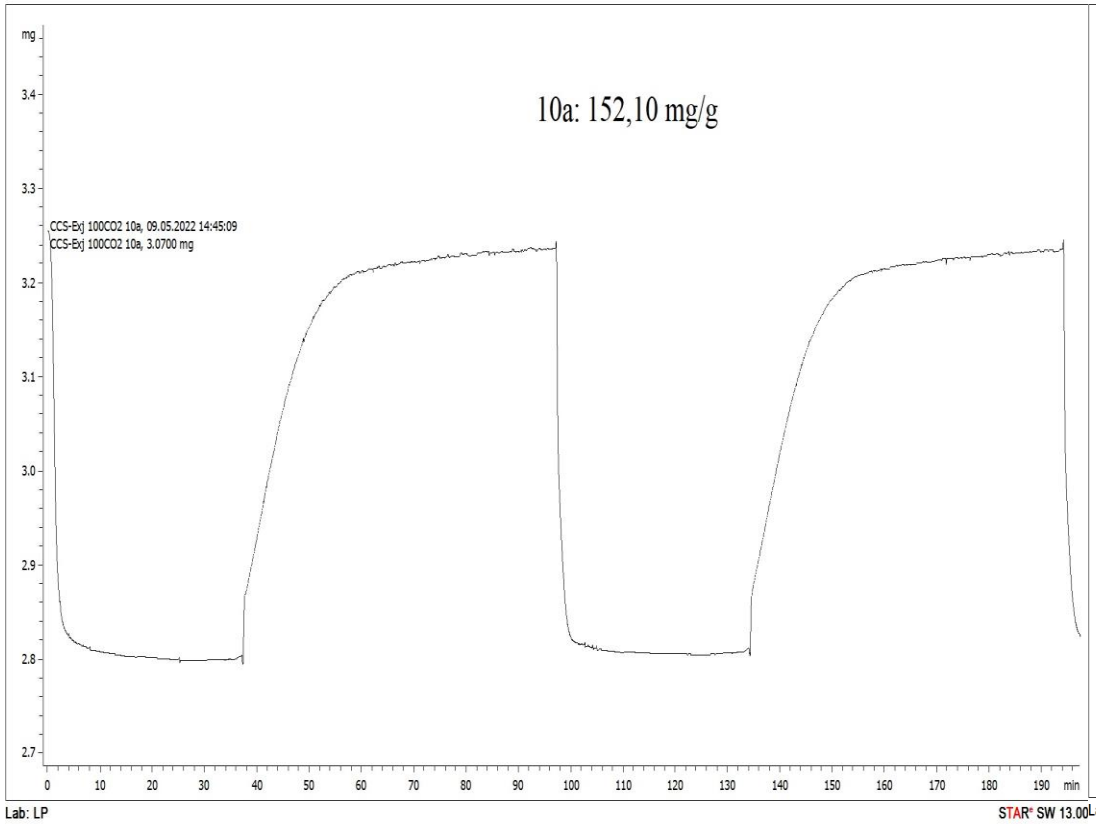
Comparison of surface between sample 18 and 19 using SEM

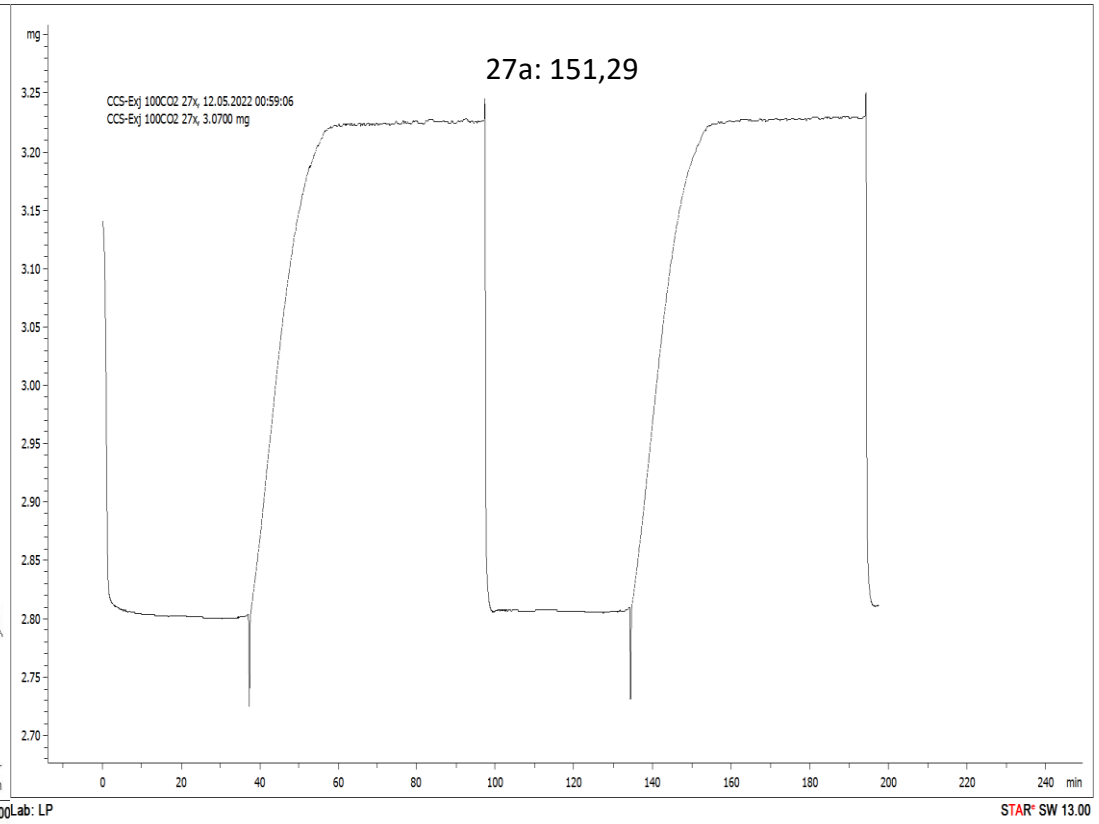




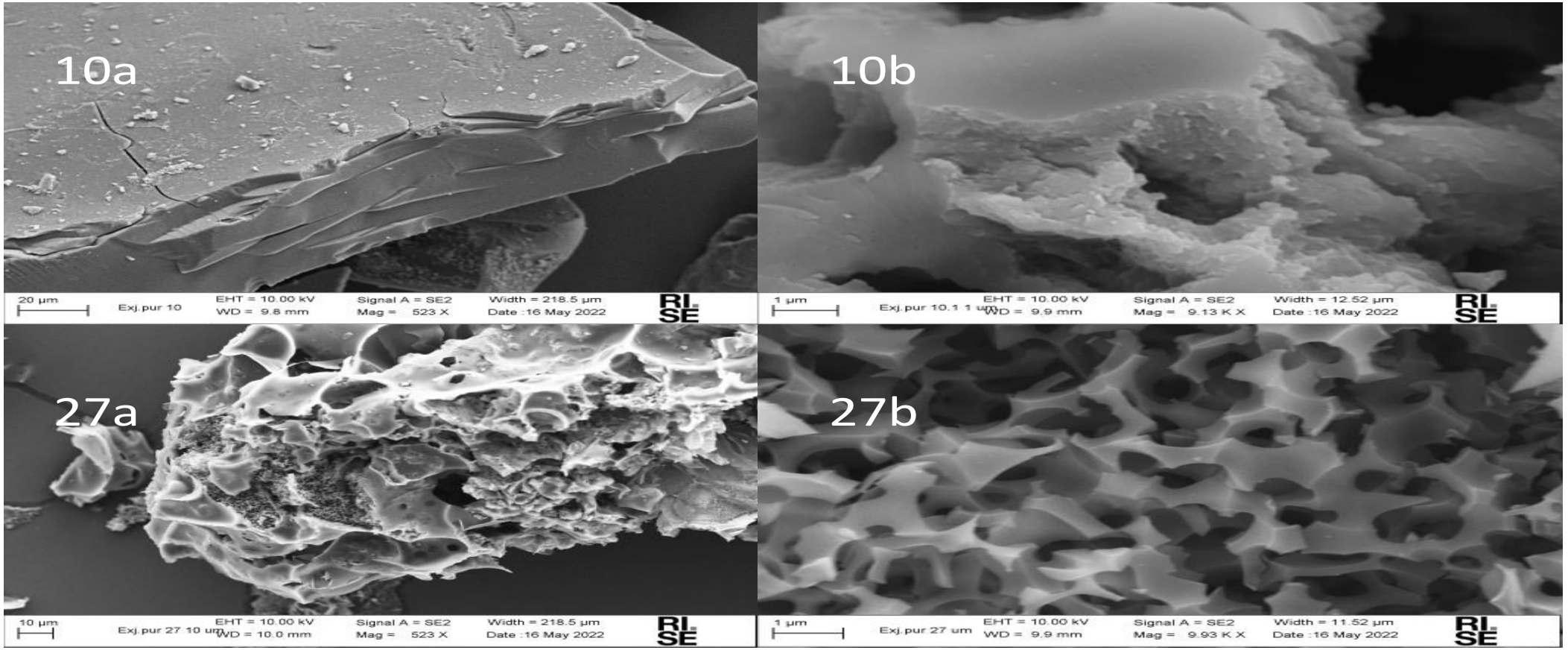


Comparison between the best samples with the optimum parameters using TGA from indirect and direct activation methods





Comparison of surface between sample from indirect and direct activation using SEM



Summary

- Results show diffrence in surface structure between indirect and direct activation
- Similar CO_2 adsoption capacity between indirect and direct activation
- The PIR material adsorbent produced by 1,5 K/char ratio at 650 C during 45 minutes has shown best CO2 capture capacity corresponding 175,7mg/g compare to Zeolit 13X for 204mg/g