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CO_2 ADSORPTION CAPACITY OF ZEOLITES SYNTHESIZED FROM COAL FLY ASH

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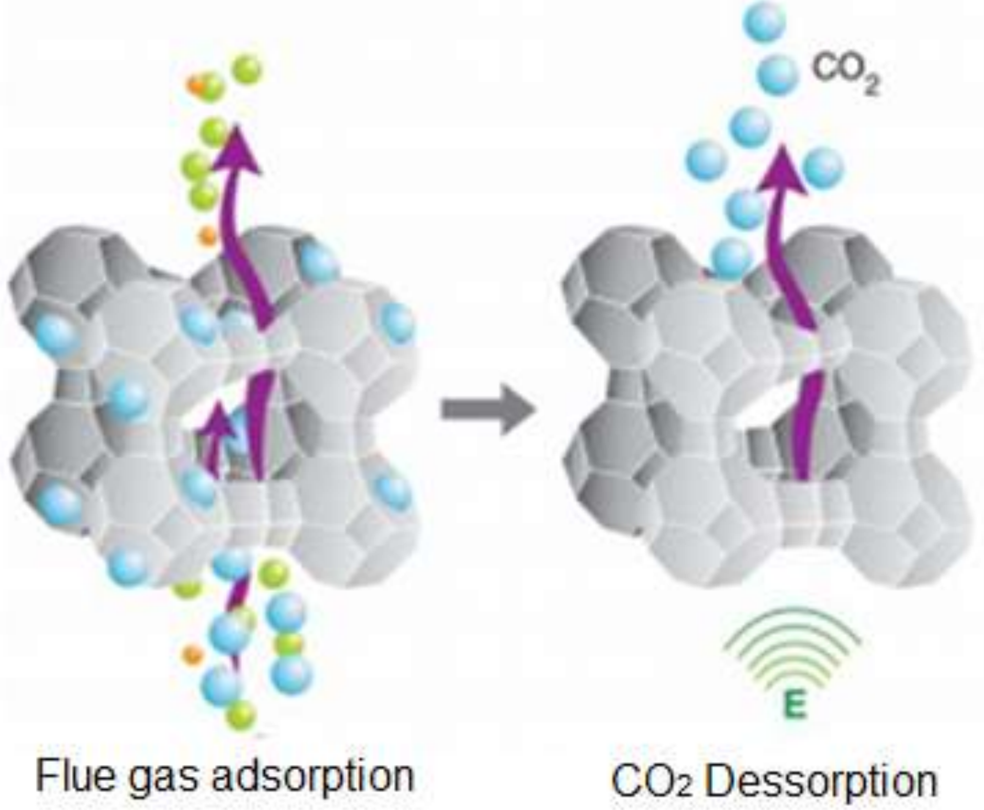
OUTLINES

- INTRODUCTION
- MATERIALS AND METHODS
- RESULTS AND DISCUSSIONS
- CONCLUSIONS
- SATC CO_2 CAPTURE PROGRAM

INTRODUCTION

Fig. 1. Conventional post-combustion CO_2 capture using absorption process.

Fig. 2. Adsorption and desorption in zeolites type X



INTRODUCTION

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Table 1: CO_2 capture capacities of commercial zeolites.

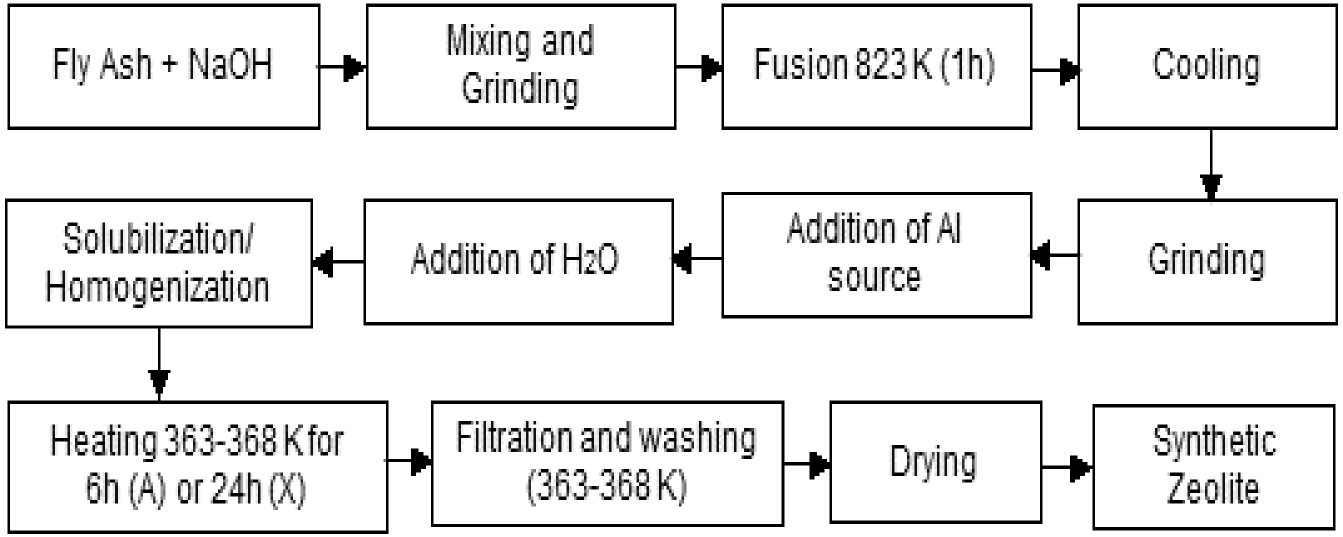
Type of zeolite	Temperature (°C)	$Pressure_{max}$ (bar)	Adsorption capacity using pure CO_2 (mmol/g)	References
NaX (Aldrich)	0-60	1.20	4.1	Hefti et al. (2015, p.421)
NaX	22	1.01	4.61	Lima (2012, p.41)
NaX	25	1.01	4.21	Hauchhum e Mahanta (2014, p.352)
NaA	25	1.01	3.26	Hauchhum e Mahanta (2014, p.352)
NaA	25	1.01	3.07	Dantas (2009, p.83)
NaA	25	-	3.10	Hedin et al. (2013, p.216)
NaX	28, 50, 100 e 150	1.01	3.59; 3.07; 1.79 e 0.93	Dantas (2009, p.83)
*NaX	28, 50, 100 e 150	1.01	2.49; 1.97; 0.98 e 0.40	Dantas (2009, p.105)

*Values obtained using a mixture of 20% CO_2 and 80% N_2.

MATERIALS AND METHODS

Zeolite synthesis from coal fly ash

Fig. 3. Basic zeolite synthesis procedure.



Characterization of the ash and zeolites

- ✓ Chemical, mineralogical and morphological analysis.
- ✓ Textural properties and thermogravimetric analysis.

TGA Analysis Procedure

a) Pretreatment at 723 K for 30 min and a flow rate of 100 mL/min of N_2 for sample activation;
b) Gas exchange of N_2 for a 14% CO_2/N_2 mixture at 100 mL/min, producing a 7 % CO_2 chain, for 20 min at 303 K for the adsorption stage;
c) Further exchange to a N_2 atmosphere at 100 mL/min for 10 min and heating up to 573 K with a 30 min plateau for CO_2 desorption;
d) Repetition of steps b and c four more times.

RESULTS AND DISCUSSIONS

Chemical and mineralogical characterization of ash

Table 2. Chemical composition of the major elements in the ash used for synthesis on a per mass basis and in the form of oxides.

Composition (wt %)	SiO_2	Al_2O_3	Na_2O	Fe_2O_3	MgO	CaO	TiO_2	K_2O	SO_3	P_2O_5	LOI
Jorge Lacerda Ash	60.76	25.48	0.56	5.00	0.79	1.54	1.11	2.91	0.47	0.07	1.33
Pecém Ash	49.96	21.14	1.85	8.66	3.33	6.73	0.86	1.80	1.61	0.14	3.95

* LOI – Loss on ignition

Fig. 4. Diffractogram of the (a) Jorge Lacerda and (b) Pecém fly ash samples.

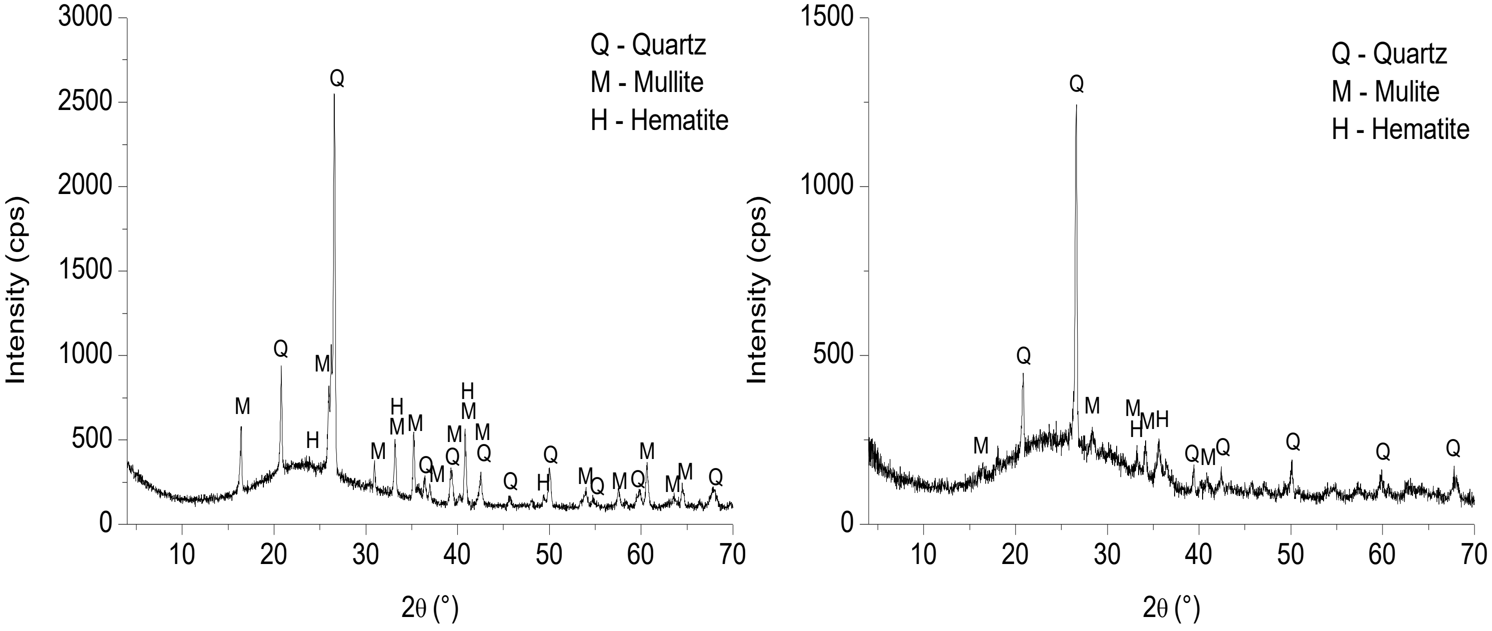


Table 3. Quantification of the phases present in the Jorge Lacerda and Pecém fly ash with lime.

State	Phases	%wt, Jorge Lacerda ash	%wt, Pecém ash
Amorphous	-	74	85
Crystalline	Quartz	9	8
	Mullite	16	4
	Hematite	1	3

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RESULTS AND DISCUSSIONS

Chemical composition of the zeolites

Table 4. Chemical composition of the major elements in the commercial and synthetic zeolites.

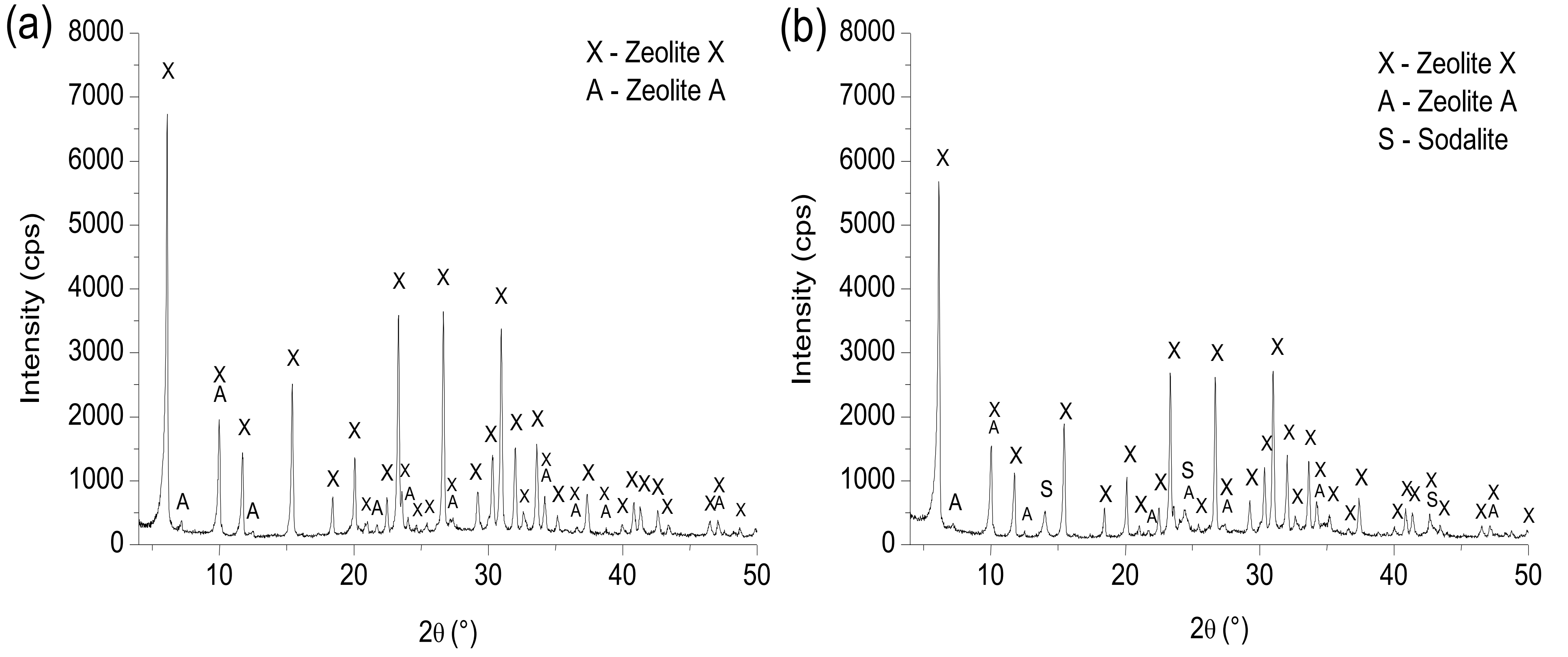
Composition (wt%)	CZX	SZX	CZA	SZA
SiO_2	43.35	39.90	48.95	37.79
Al_2O_3	21.45	22.57	27.39	23.60
Na_2O	7.39	11.29	9.19	6.83
Fe_2O_3	1.71	6.68	1.67	9.05
MgO	1.16	<0.01	1.91	0.75
CaO	0.70	2.14	2.26	5.59
TiO_2	0.23	1.52	0.20	1.04
K_2O	0.81	1.44	1.04	0.69
SO_3	0.21	0.15	0.14	0.38
Minor elements	0.05	0.21	0.04	0.17
LOI	22.94	14.10	7.20	14.10
SiO_2/Al_2O_3 (molar)	3.44	3.01	3.04	2.72

* LOI – Loss on ignition

RESULTS AND DISCUSSIONS

Mineralogical composition of the zeolites

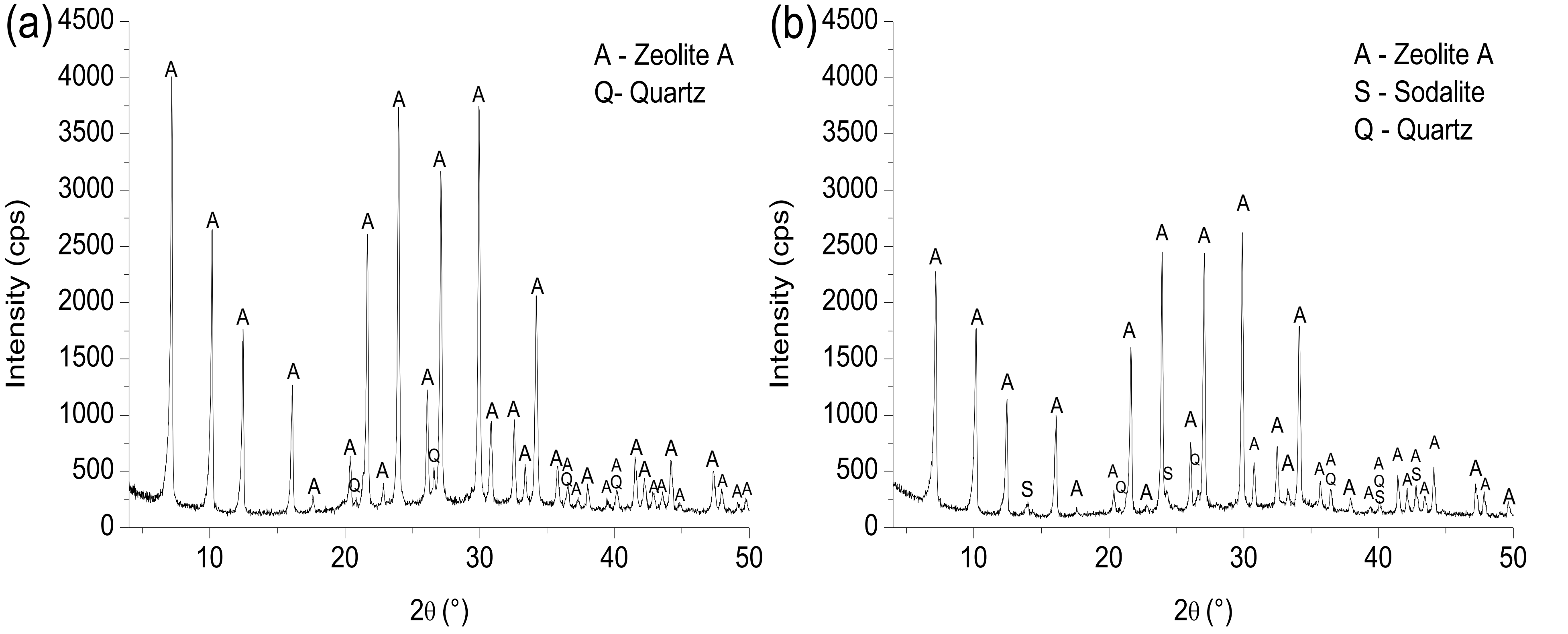
Fig. 5. X-ray diffractograms of the 13 X (a) CZX and (b) SZX zeolites.



RESULTS AND DISCUSSIONS

Mineralogical composition of the zeolites

Fig. 6. X-ray diffractograms of the 4A (a) CZA and (b) SZA zeolites.



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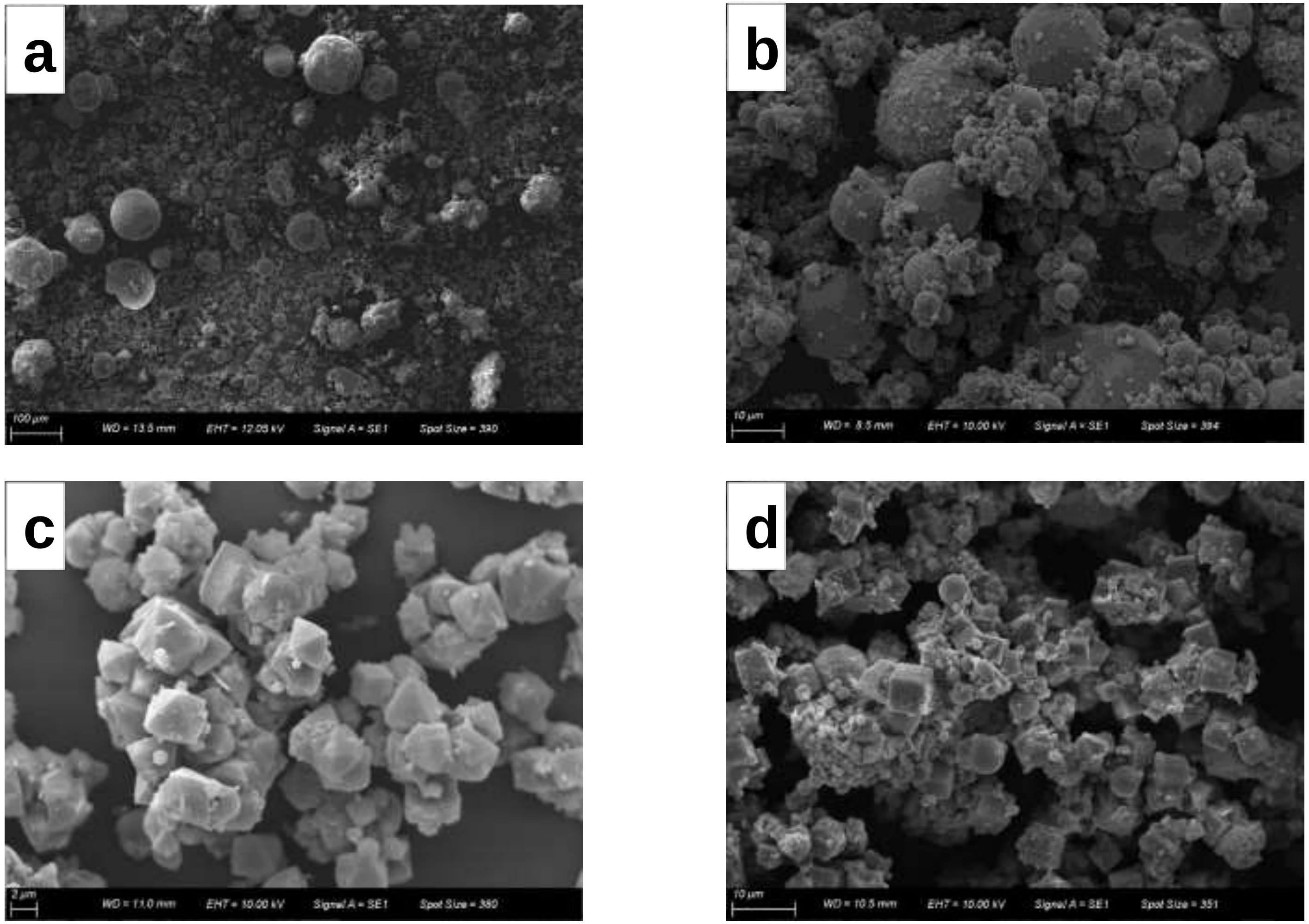
RESULTS AND DISCUSSIONS

Morphological analysis of the ash and synthesized zeolites

Fig. 7. Micrographes (SEM): Fly ashes Jorge Lacerda (a) and Pecém (b); Synthetic zeolites SZX (c) and synthetic SZA (d).



RESULTS AND DISCUSSIONS

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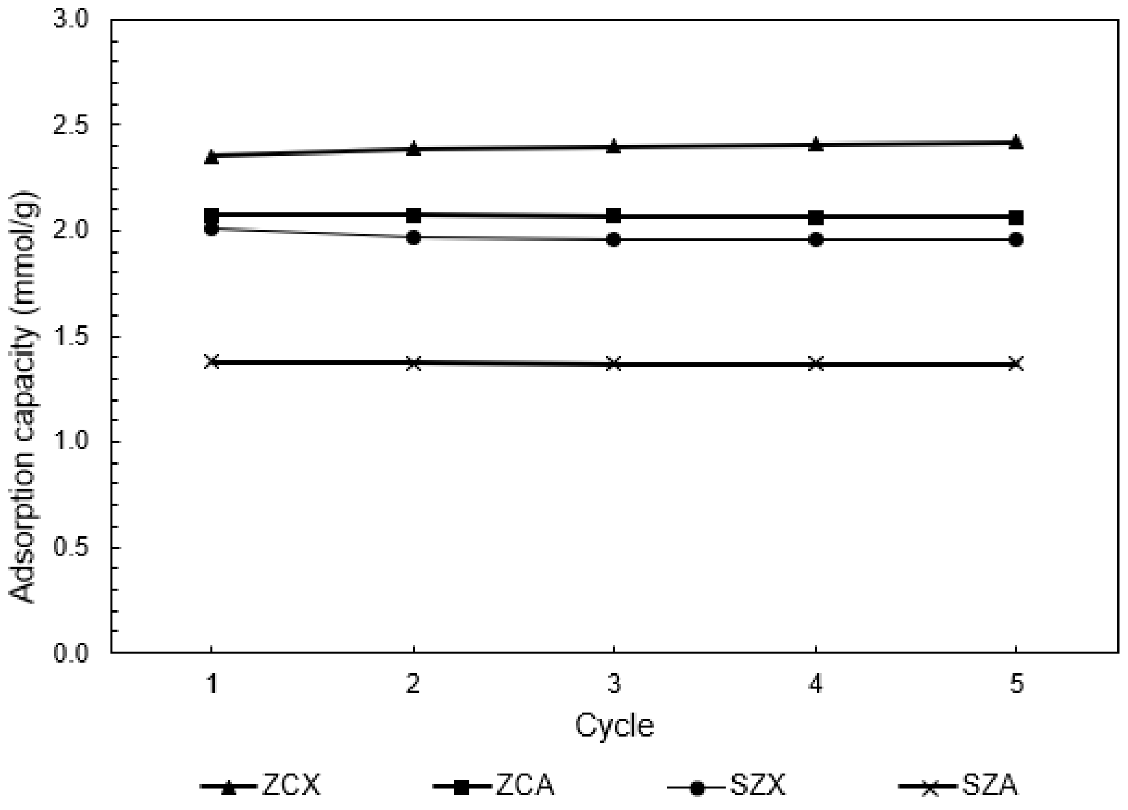
Textural properties

Table 5: Textural property results.

Zeolite	Surface Area (m²/g)	Pore Volume (cc/g)	Average Pore Diameter (Å)
CZX	497.80	0.349	28.060
SZX	247.23	0.205	16.596
CZA	27.56	0.138	100.498
SZA	39.40	0.099	50.463

CO_2 adsorption

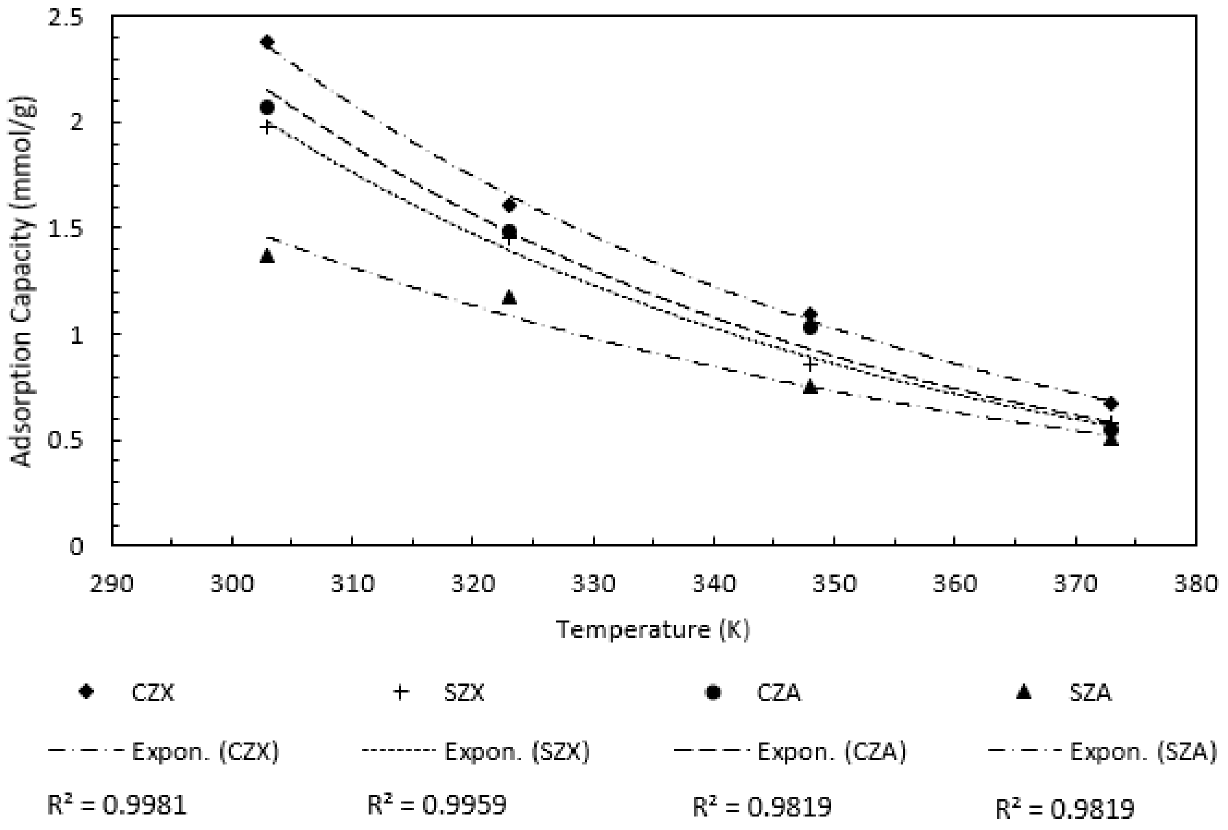
Fig. 8. Adsorption capacity of the commercial and synthetic zeolites in five adsorption/desorption cycles.



RESULTS AND DISCUSSIONS

CO_2 adsorption

Fig. 9. Adsorption capacity of the commercial and synthetic zeolites at different adsorption temperatures.



CONCLUSIONS

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- ✓ Good quality NaX and NaA zeolites were obtained from both coal fly ash samples used, exhibiting similar properties to the commercial zeolites, even the ash submitted to flue-gas desulfurization (Pecém).
- ✓ The zeolites synthesized from coal fly ash displayed high CO_2 adsorption capacities (1.97 mmol/g for SZX and 1.37 mmol/g for SZA), with synthetic zeolite X exhibiting an adsorption capacity similar to that of the commercial zeolites (2.39 CZX and 2.07 mmol/g CZA).
- ✓ All the samples studied showed a high regeneration capacity after thermal activation, with their CO_2 capture capacity remaining almost unchanged after five adsorption/desorption cycles (loss <3 % for all samples), confirming their potential for application in cyclic processes.
- ✓ As observed in previous studies, adsorption analyses at different temperatures confirmed that CO_2 adsorption capacity is strongly influenced by and inversely proportional to temperature, justified by the exothermal nature of the process.

ACKNOWLEDGEMENTS

This work was developed within the scope of the Program of Research and Technological Development of Electric Energy regulated by ANEEL, with the support of Eneva S.A. The work also received financial support from FAPESC (Research Support Foundation of Santa Catarina State).

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SATC CO_2 CAPTURE PROGRAM

TECHNOLOGICAL CENTER SATC

International Partners

NATIONAL ENERGY TECHNOLOGY LABORATORY

carbon sequestration leadership forum

ARI

West Virginia University

b-tu
Brandenburg
University of Technology
Cottbus - Senftenberg

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2019

APR , 2008
Short Course
in Brazil
Gas Cleaning

JUN, 2009 Program Planning at NETL

SEPT, 2009 – Short Course in Brazil Gasification

APR, 2010 Short Course in Brazil Gasification Modeling

JUN-AUG, 2010 Internship at NETL

FEB, 2011 Short Course in Brazil Gasification

MAR-MAY, 2011 Internship at NETL

MAR, 2012
Short Course in Brazil
Gasification

APR-JUL, 2012
Internship at NETL

OCT-DEC, 2012
Internship at NETL

DEC, 2012
Short Course in Brazil
Overview about CO2 Capture

AUG, 2013
Short Couse in Brazil
Gasification

SEPT, 2013
Short Course in Brazil
Process Simulation
CO2 Capture

FEB-MAY, 2014
Internship at NETL
Carbon Capture

Current activities:
*R&D Project between SATC/NETL: "**CO2 Capture from Coal Combustion - Laboratorial Infrastructure, Synthesis and Tests of New Sorbents**" (2014-2017). CRADA AGMT-0456
Future activities:
*CSLF Capacity building for CO2 capture: short practical trainings at NETL.
*New proposals for R&D projects involving CCS, gasification and combustion.

Publications:
* 11 publications including 5 joint publications with NETL.

SATC CARBON CAPTURE PROGRAM

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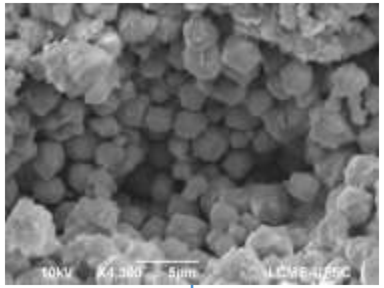
THE UNIVERSITY of EDINBURGH

2010
Visit at Edinburgh

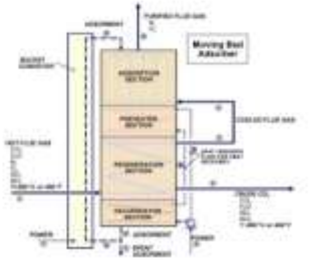
2014
Start of activities regarding synthesis of sorbents for CO_2 capture: zeolites and solid amine

2016
Sorbents tests in lab scale



2017
- **CO_2 Capture Lab ready;**
- **Scaling of sorbents synthesis.**

2019
CO_2 capture pilot plant using TSA process (ARI)



2021
Results from pilot tests for a demo scale

2030
Commercial scale

CO_2 CAPTURE PILOT PLANT USING SORBENTS: PROJECT AND ASSEMBLING

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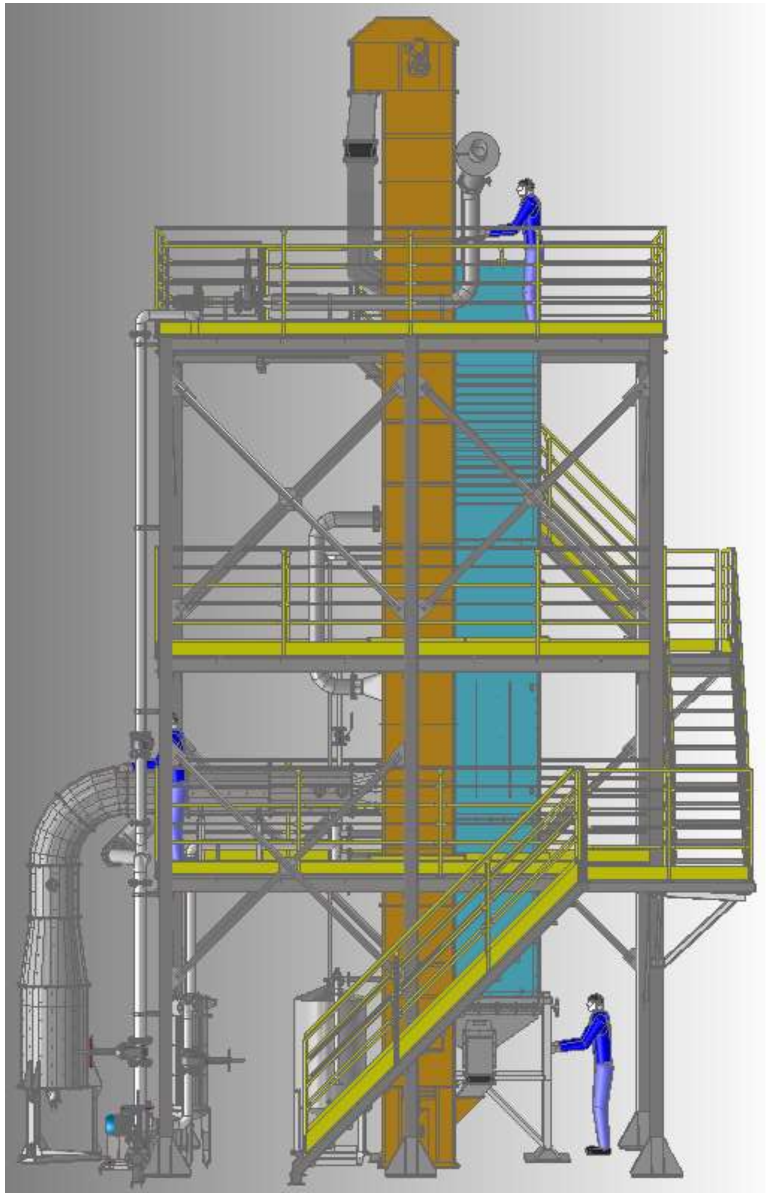
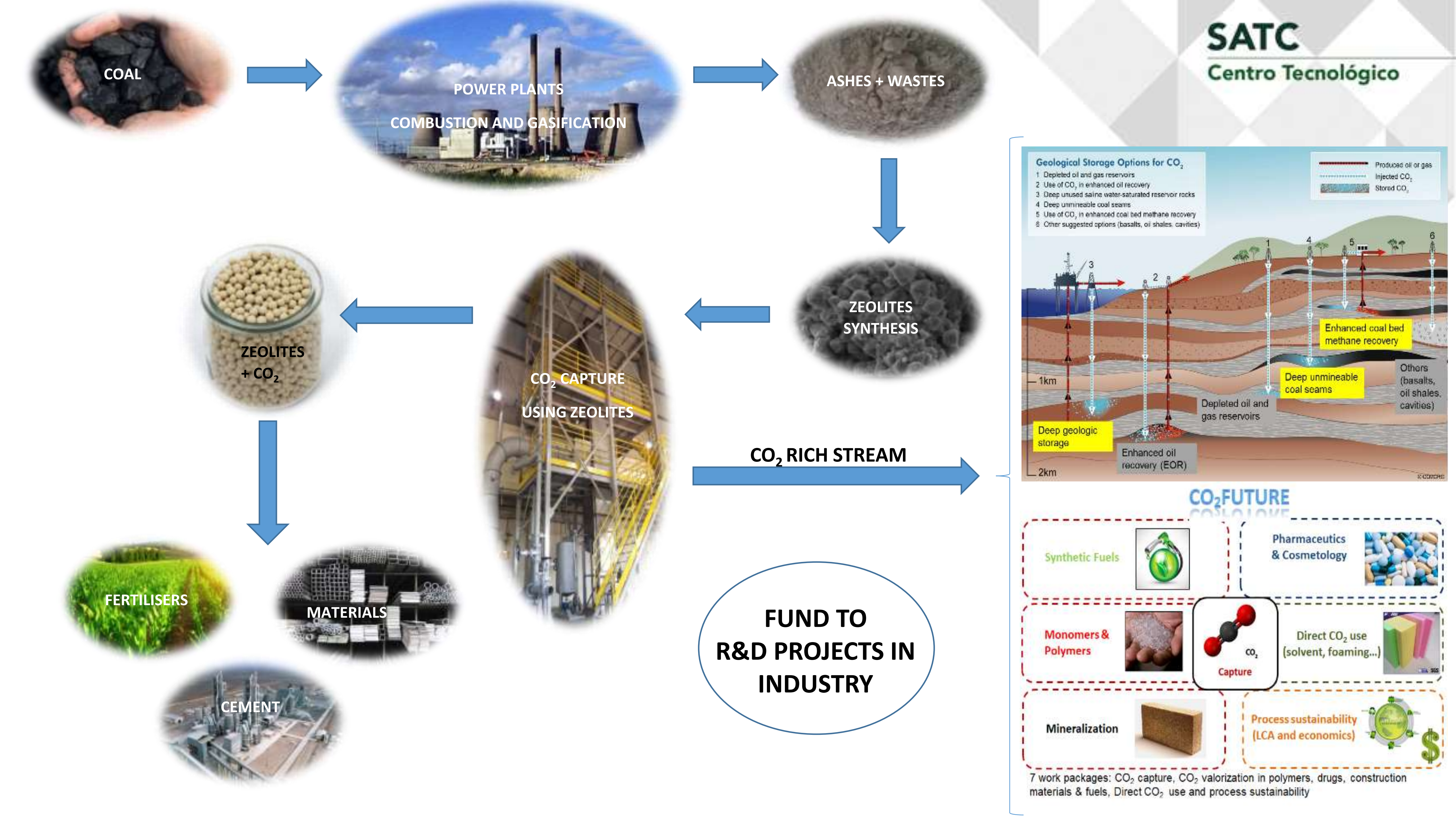


eneva



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COAL
POWER PLANTS
COMBUSTION AND GASIFICATION
ASHES + WASTES
ZEOLITES SYNTHESIS
CO$_2$ CAPTURE
USING ZEOLITES
ZEOLITES + CO$_2$
FERTILISERS
MATERIALS
CEMENT
CO$_2$ RICH STREAM
FUND TO R&D PROJECTS IN INDUSTRY
Geological Storage Options for CO$_2$
1 Depleted oil and gas reservoirs
2 Use of CO$_2$ in enhanced oil recovery
3 Deep unused saline water-saturated reservoir rocks
4 Deep unmineable coal seams
5 Use of CO$_2$ in enhanced coal bed methane recovery
6 Other suggested options (basalts, oil shales, cavities)
Produced oil or gas
Injected CO$_2$
Stored CO$_2$
Enhanced coal bed methane recovery
Deep unmineable coal seams
Others (basalts, oil shales, cavities)
Depleted oil and gas reservoirs
Deep geologic storage
Enhanced oil recovery (EOR)
1km
2km
CO$_2$FUTURE
Synthetic Fuels
Pharmaceutics & Cosmetology
Monomers & Polymers
CO$_2$
Capture
Direct CO$_2$ use (solvent, foaming...)
Mineralization
Process sustainability (LCA and economics)
7 work packages: CO$_2$ capture, CO$_2$ valorization in polymers, drugs, construction materials & fuels, Direct CO$_2$ use and process sustainability

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