

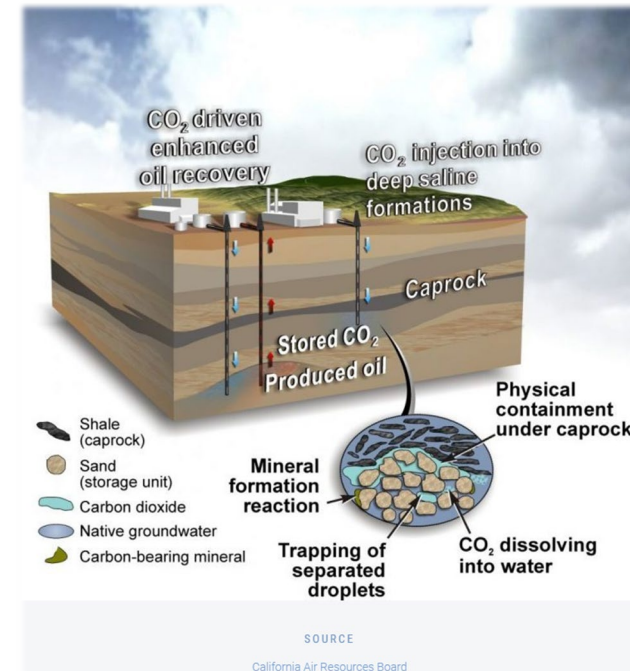
Carbon Capture using Amines

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Carbon Capture / Midstream / Refinery

Technical Marketing Manager

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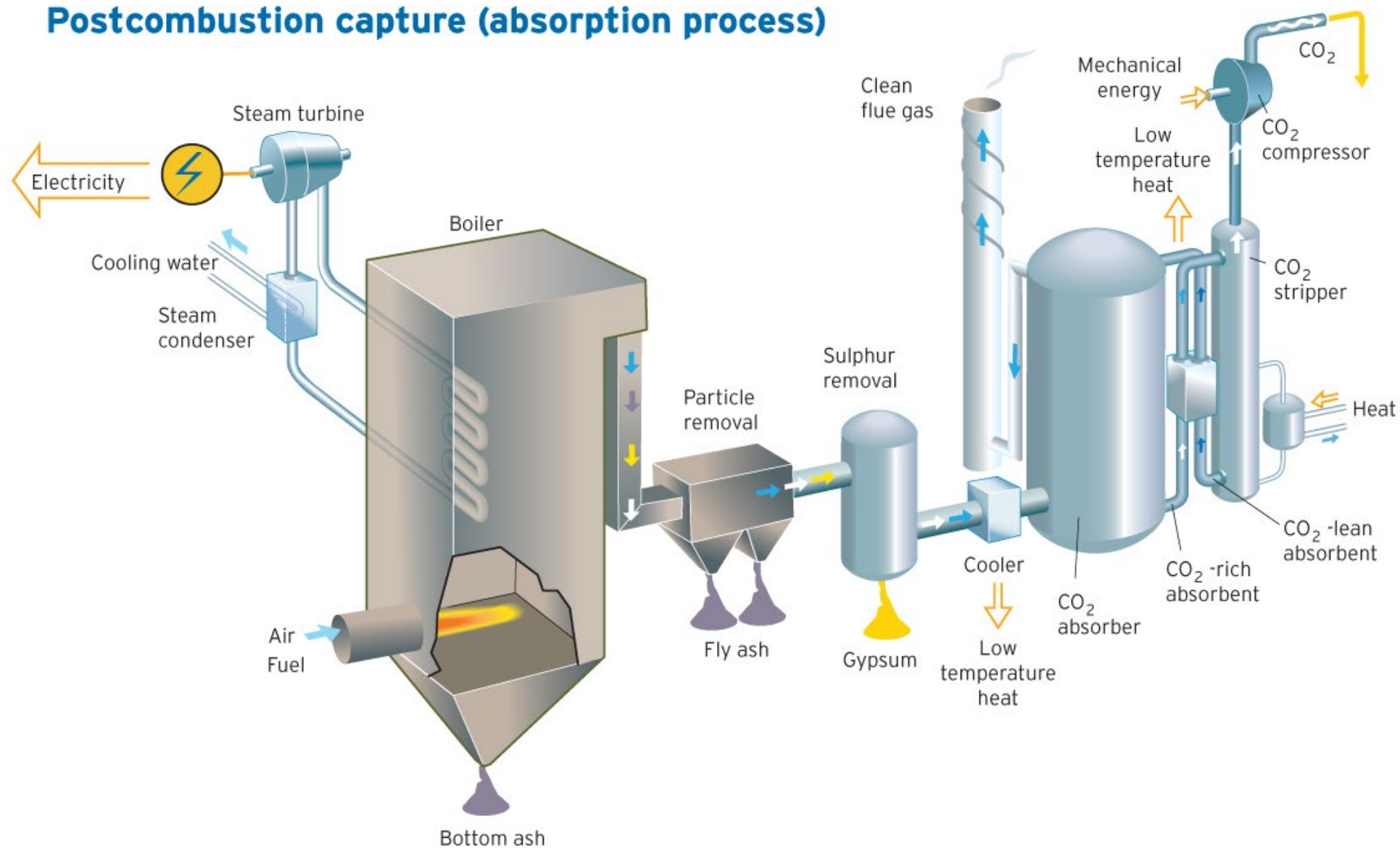


We create chemistry

Flue Gas CO₂ Capture

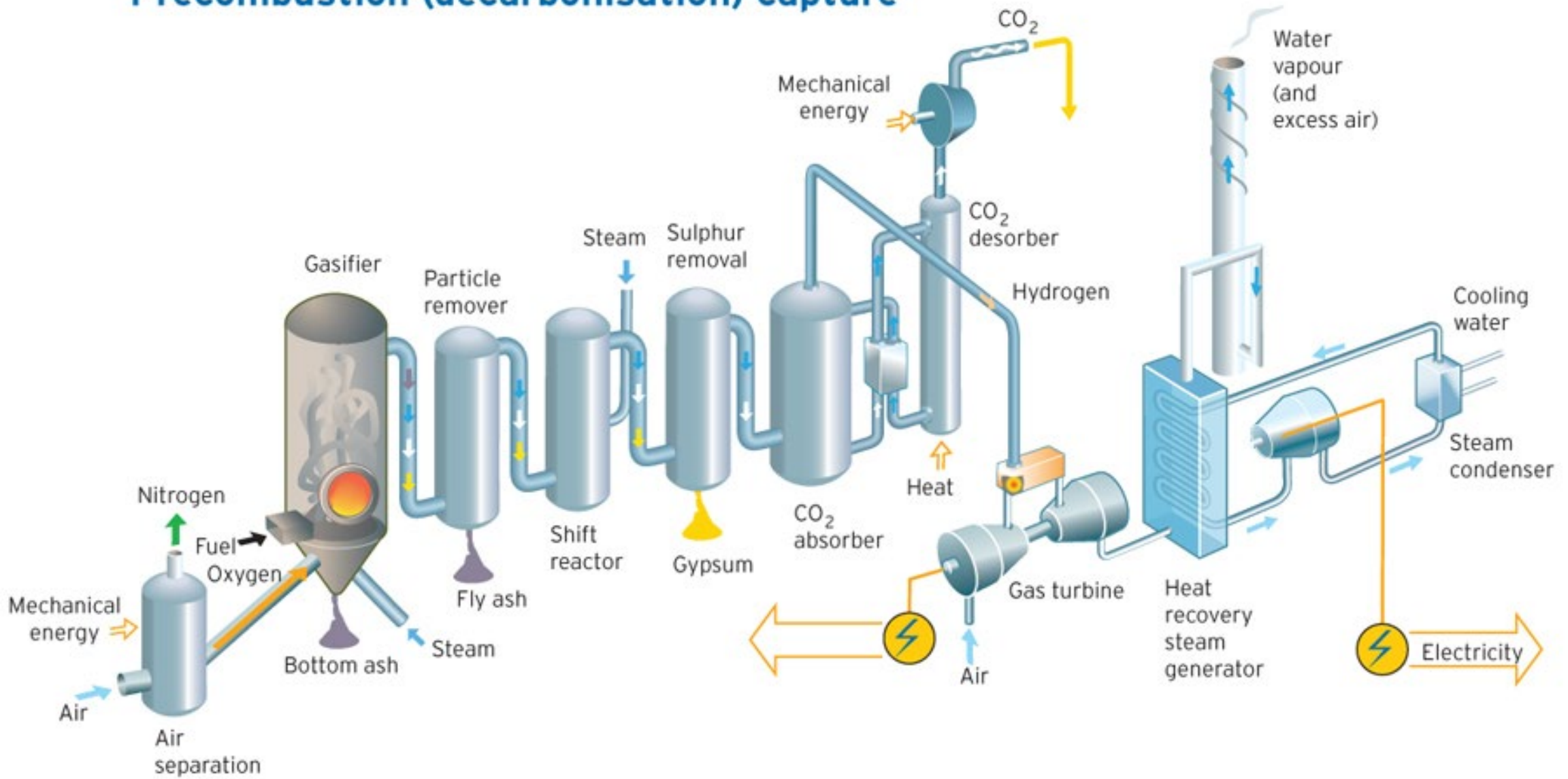
- **CCS and PCC Technology Overview**
 - **Power Plants**
- **Market Standings / Trends**
- **Technology Development**

Postcombustion capture (absorption process)



Source: Vattenfall

Precombustion (decarbonisation) capture

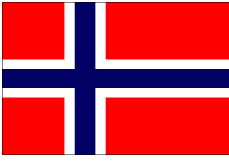


Source: Vattenfall

Flue Gas CO₂ Capture

- CCS and PCC Technology Overview
 - Power Plants
- Regulatory Environment
- Technology Development

2011 CO₂ Capture Regulatory Environment



- ❑ European key players driving PCC forward
- ❑ Up to eight 250 MW demo plants
- ❑ > € 5.5 Billion funding by EU (UK, NL, NO, DE)



- ❑ No legislation before 2011
- ❑ Regional initiatives: RGGI, WCI, Mid-west
- ❑ Strong funding by Dept of Energy
- ❑ Many activities, but industry still evaluating options



- ❑ In 2011, no legislation
- ❑ Canada-Alberta CCS Task Force relates to oil & gas legislation
- ❑ Target 2015: 14,000 t/d reduction of GHG emissions



- ❑ Start-up of a new coal-fired power plant once a week
=> biggest potential for CCS/PCC in the globe
- ❑ To develop own clean tech industry
- ❑ Likely to be largest PCC market after 2020



- ❑ Carbon Capture & Sequestration bill passed (AUS)
- ❑ Strong willingness to develop and export PCC technologies
- ❑ Research and technology standard

Flue Gas CO₂ Capture

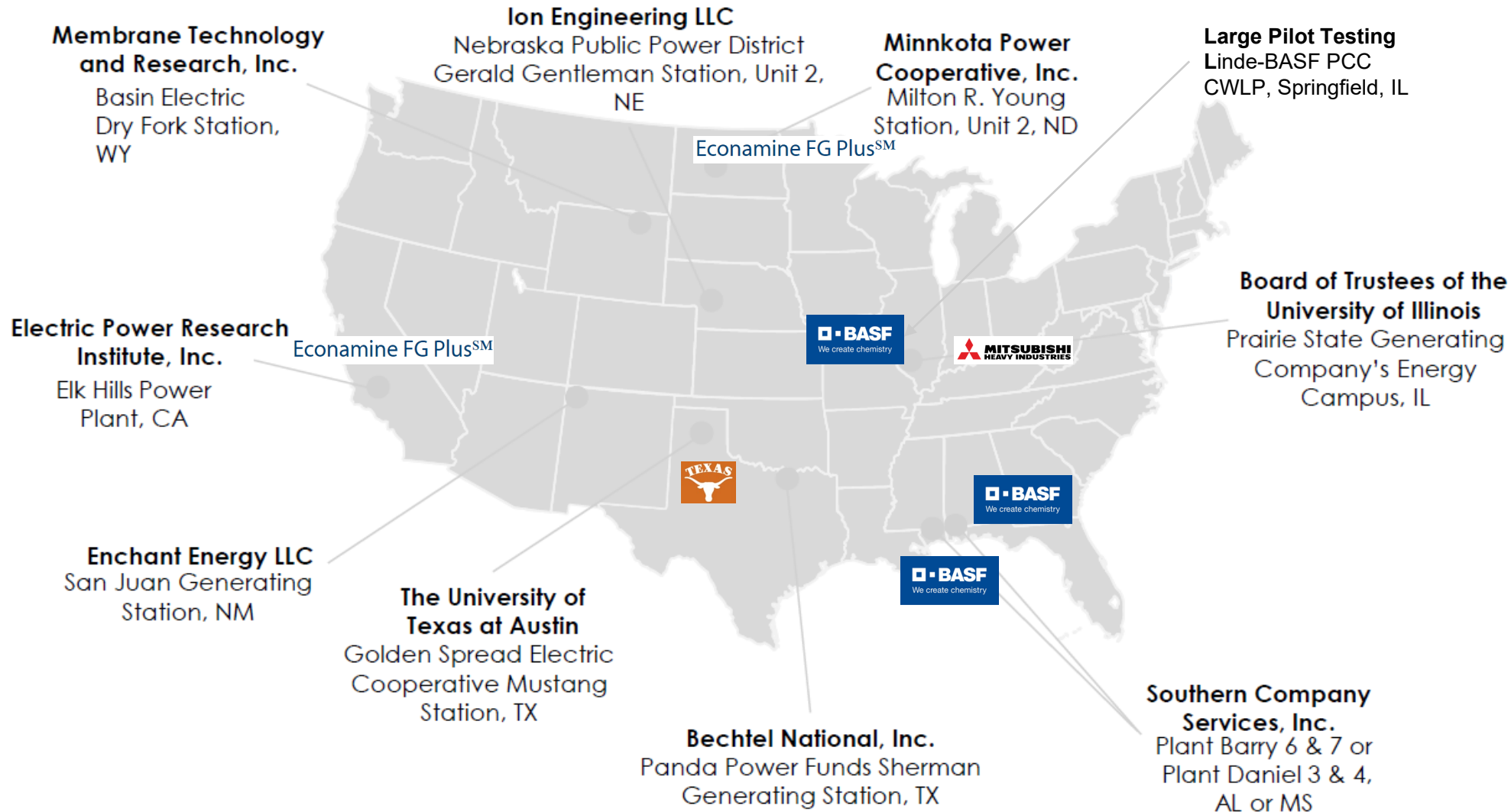
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Short List of CO₂ Capture Technologies

Licensing/Technology Company	Solvent	Reboiler duty [GJ/t CO ₂]
BASF	OASE Blue	2-3 - 2.8
Mitsubishi Heavy Industries	KS-1	2.7-2.9
Aker Clean Carbon	S21 / S26	2.8
Shell Global Solutions	CanSolv	3
Fluor	Econamine	2.8 - 3.5

Host Sites for 9 projects (~2019→current)

Fossil Energy & Carbon Mgmt (US Dept of Energy)



Attractive Techno-Economics for Linde / BASF Process

Baseline case: DOE-NETL supercritical PC power plants

Parameter	DOE-NETL Case B12A	DOE-NETL Case B12B	Linde-BASF LB1	Linde-BASF SIH	Linde-BASF WHR
Description	No CO ₂ capture	90% CO ₂ Capture w/ Cansolv PCC process	90% CO ₂ Capture w/ OASE® blue	90% CO ₂ Capture w/ OASE® blue and SIH	90% CO ₂ Capture w/ OASE® blue, SIH, and WHR
Net Power Output (MWe)	550	550	550	550	550
Gross Power Output (MWe)	580	642	630.4	629.3	626.3
Coal flow rate (tonne/hr)	179.2	224.8	221.9	218.5	210
Net HHV plant efficiency (%)	40.70%	32.50%	32.97.88%	33.40%	34.73%
Total Overnight Cost (\$2011) (\$/MM)	\$1,379	\$2,384	\$1,970	\$1,950	\$1,921
Cost of CO ₂ captured with T&S (\$/MT)*	N/A	\$68.00	\$53.58	\$52.71	\$51.31
Cost of CO ₂ captured without T&S (\$/MT)*	N/A	\$58.00	\$43.58	\$42.71	\$41.31
COE (\$/MWh) with T&S*	\$82.30	\$142.80	\$127.97	\$126.50	123.63
PCC specific reboiler duty (MJ/kg CO ₂)	N/A	2.48	2.6	2.3	1.5

* T&S: Transport and Storage

Possible Applications in Midstream Transportation and Processing

■ Energy Transfer LP

- ▶ Marcus Hook Liquids Terminal (PA)
 - Utilization vs venting (Does not require Fed Tax Credits)
- ▶ Texas Gas Processing Plants
 - Capture Equipment & Sequestration Wells (requires 45Q Tax Credits in JV)

■ Kinder Morgan Inc (Currently transports 1.2 BCFD of CO₂ to EOR)

- ▶ Use JV partners and alternative capital facilities to move from sequestration and transportation to upstream Carbon Capture (requires 45Q Tax Credits)

■ Enterprise Products Partners LP

- ▶ Evaluating Opportunities - CO₂ pipeline from Mt Belvieu to Permian ?

■ Cheniere Energy, Inc.

- ▶ 2022 – Committed engineering resources to evaluate CCS based on customer expectations for sustainable LNG.

■ Next Decade Corp.

- ▶ Proposed Rio Grande LNG export terminal to include CCS

Calpine, Chevron, Dow, ExxonMobil, INEOS, Linde, LyondellBasell, Marathon Petroleum, NRG Energy, Phillips 66, Valero, AirLiquide, BASF & Shell Oil.

(50 million metric tons of CO₂ per year by 2030)

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