Atmospheric Carbon Dioxide Capture Technology

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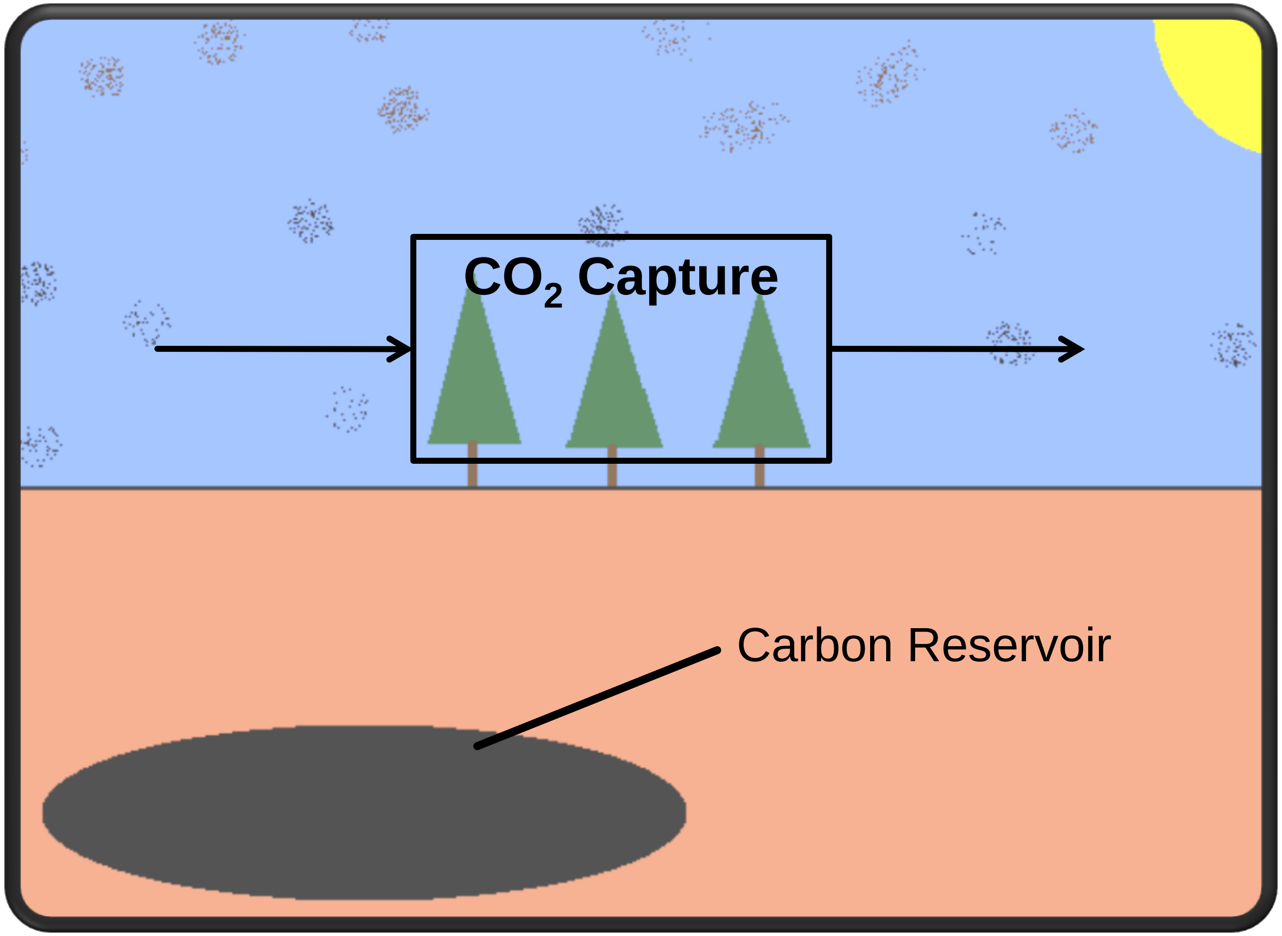
The Agenda

- The Twofold Situation
- Overview of Atmospheric CO_2 Capture Technology
- What to do with all the CO_2?
- Final Comments and Conclusions

The Situation

Fixed Amount of Carbon in Process

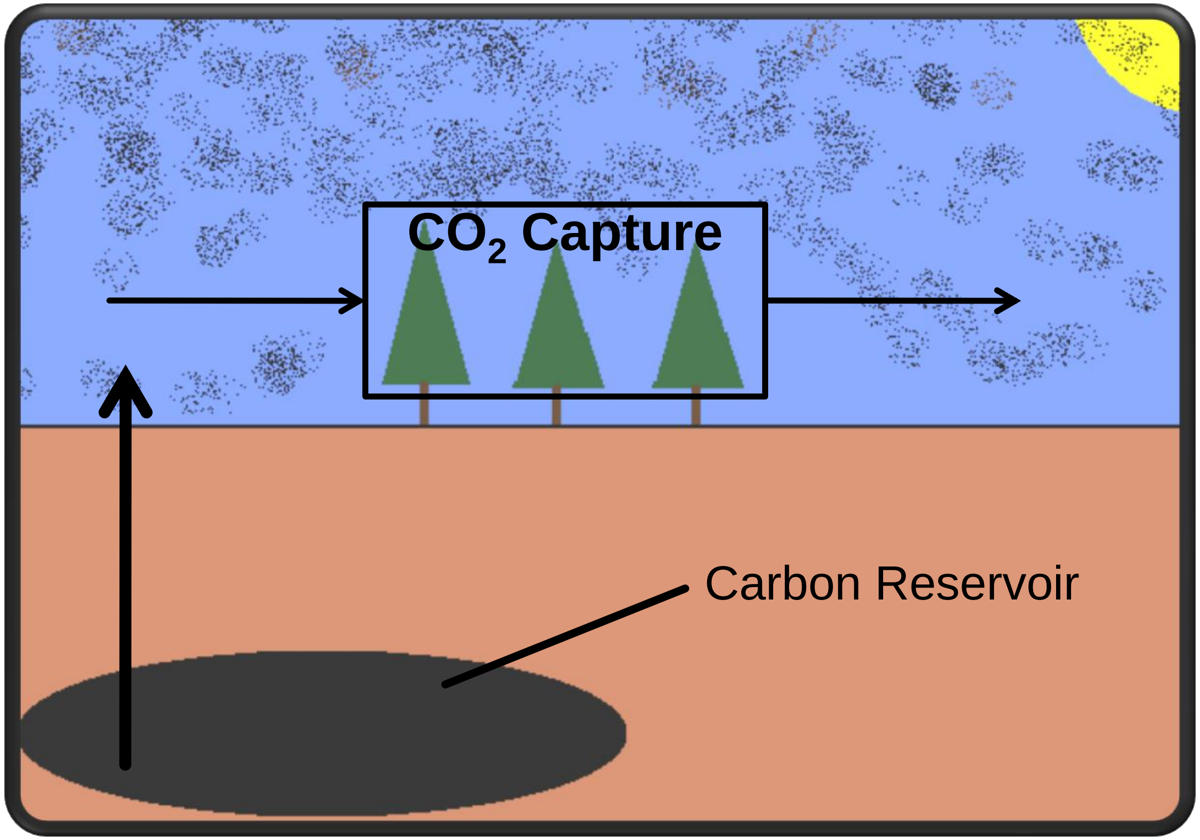


•Constant levels of CO_2 in atmosphere

•Maintains Temperature

The Situation

Mass Balance Problem!



System can't handle the extra load; thus, Global Warming becomes an issue!

The Situation

- Problem is two-fold:
  - Must solve CO_2 emissions problem
  - Must find viable future energy source

- Challenges to Reducing CO_2 emissions:
  - Non CO_2 sources are unlikely to displace fossil fuels at substantial levels
  - Coal and other fossil fuels will remain as major sources of energy regardless of the price issues
  - Coal is abundant

What if there was a system that solved <u>ALL</u> of these problems simultaneously?

The Technology

Dilute state (CO_2 at 360 ppm) ➡ Concentrated state (CO_2 at > 90%)

$P_0 = 3.6 \times 10^{-4}$ atm ➡ $P = 1$ atm

<u>Lower limit</u> necessary to separate CO_2 from air given by energy needed to overcome free energy of mixing:

$$\Delta G = RT \ln\left[\frac{P}{P_0}\right]$$

$$\Delta G = 20\,{}^{kJ}\!/_{mol} = 1.7\,{}^{GJ}\!/_{tC}$$

The Technology

- What is <u>Atmospheric</u> Carbon Dioxide Capture?
  - The process of separating CO_2 from air at atmospheric conditions and delivering a pure stream of CO_2.

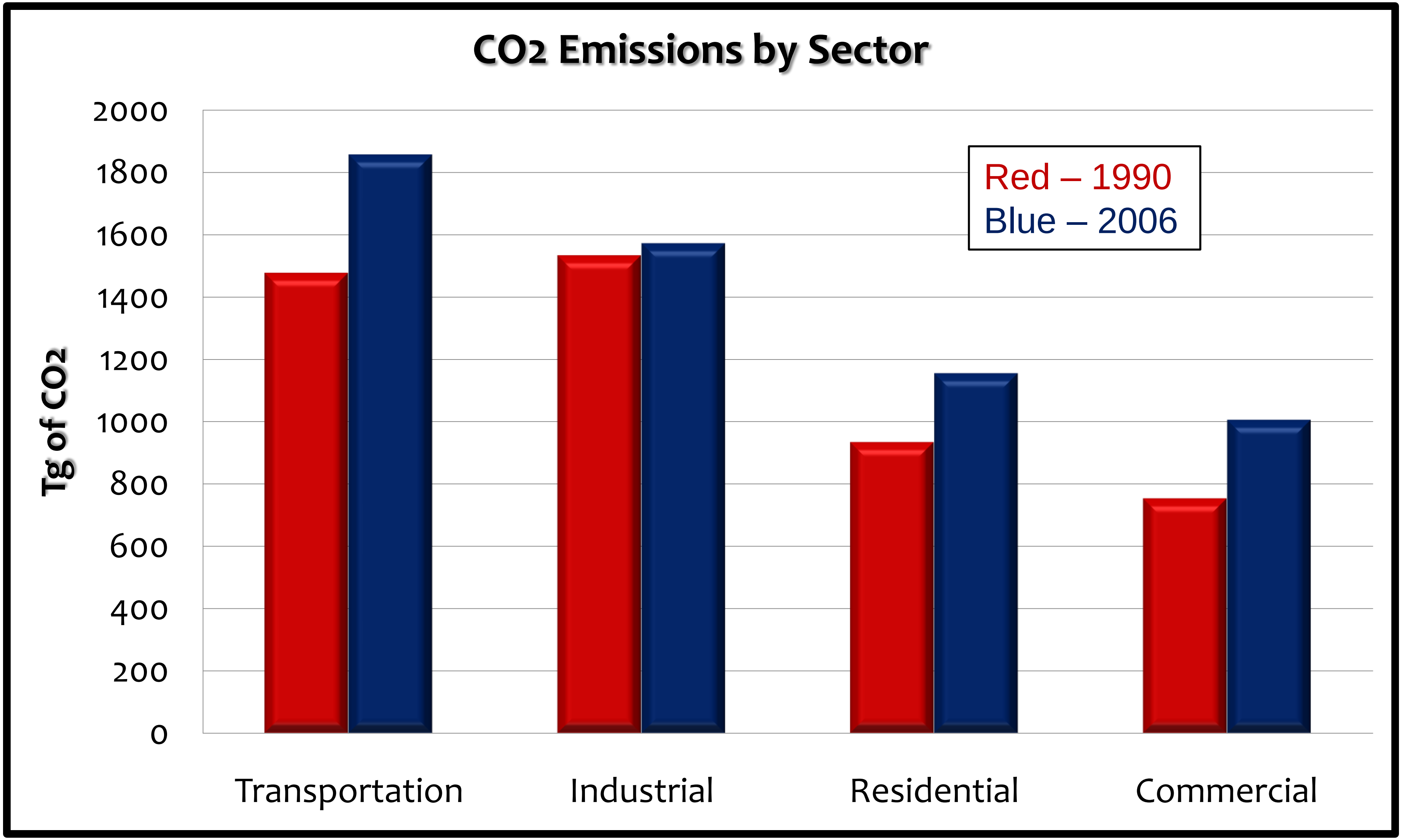
- Atmospheric Carbon Capture Methods
  - Sorbant Separation Methods
    - Na/Ca Capture - proven technology on small scale
    - GRT has Proprietary Sorbant
    - $Ca(OH)_2$
  - Electrochemical Separation - research in progress
  - Biomass
  - Metal-carbonate production

The Technology

Advantages

- Can not only provide “zero emissions energy” but also begin to remove the current buildup of CO_2
- Does not immediately make existing energy and transportation infrastructure obsolete
- No need for pipeline ~ atmosphere can serve as temporary storage and transport system
- Collects CO_2 after the fact from <u>ANY SOURCE</u>

The Situation



Data: US Environmental Protection Agency – Feb. 2008

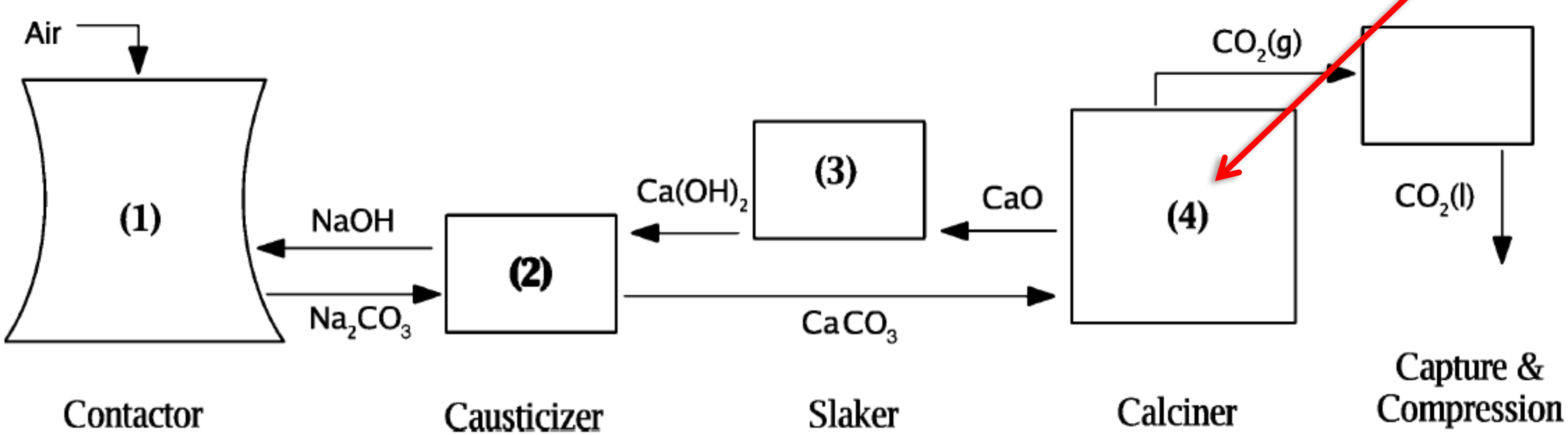
The Technology

Chemistry of Na/Ca capture system

	Reaction	Enthalpy of reaction[a], ΔH°	
		kJ/mol-C	GJ/tC
(1)	$CO_2(g) + 2Na^+ + 2OH^- \rightarrow CO_3^{2-} + Na^+ + H_2O$	−110	−9
(2)	$CO_3^{2-} + Ca^{2+} \rightarrow CaCO_3(s)$	12	1
(3)	$CaO(s) + H_2O(l) \rightarrow Ca^{2+} + 2\,OH^-$	−82	−7
(4)	$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$	179	15

[a]Derived from Weast (2003).

Lower Bound



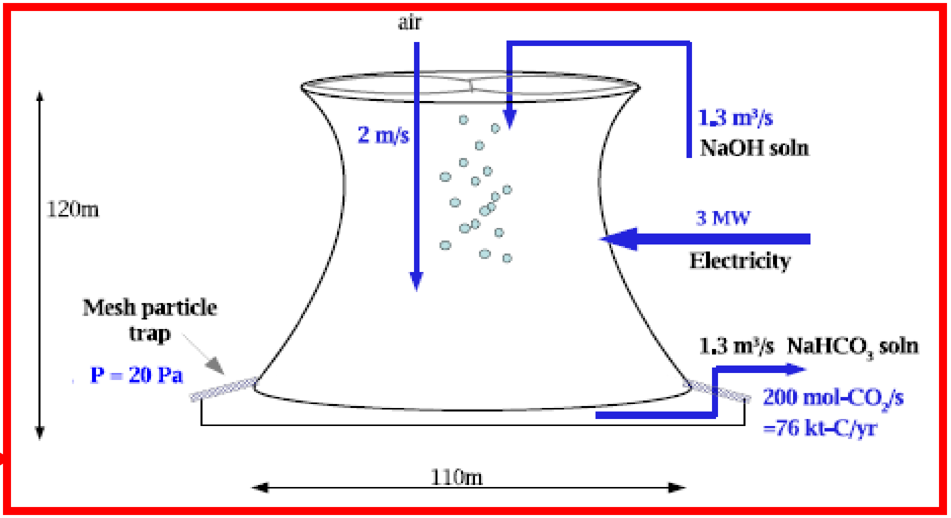
The Technology

Na/Ca Capture

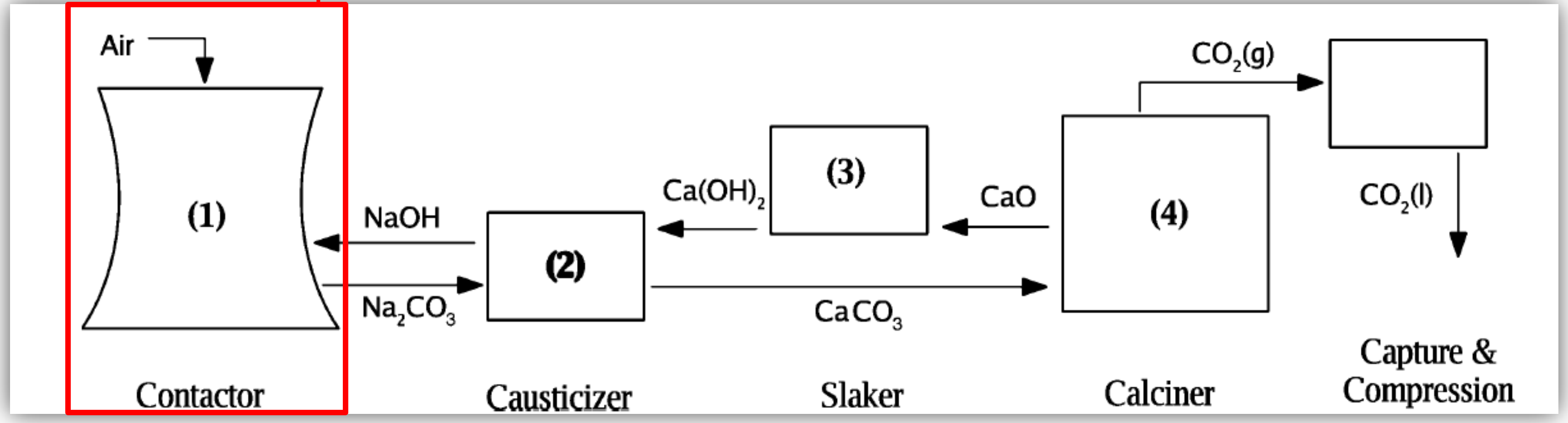
Contactor

$$(1) \qquad CO_2(g) + 2Na^+ + 2OH^- \rightarrow CO_3^{2-} + Na^+ + H_2O$$

- Captures CO_2 from Air
- Modeled as modified cooling tower
- Large capital cost



Stolaroff, Lowry, and Keith; CO2 Capture from Air; March 2005



The Technology

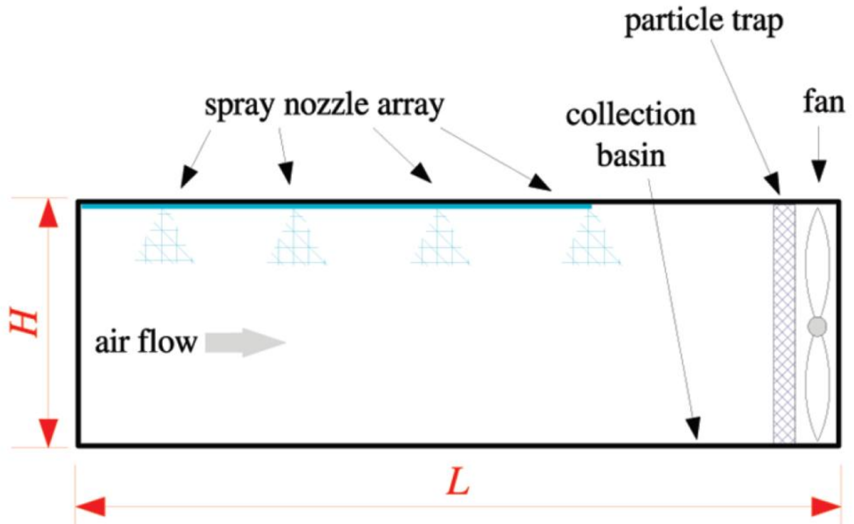
NaOH spray tower air capture unit: key parameters

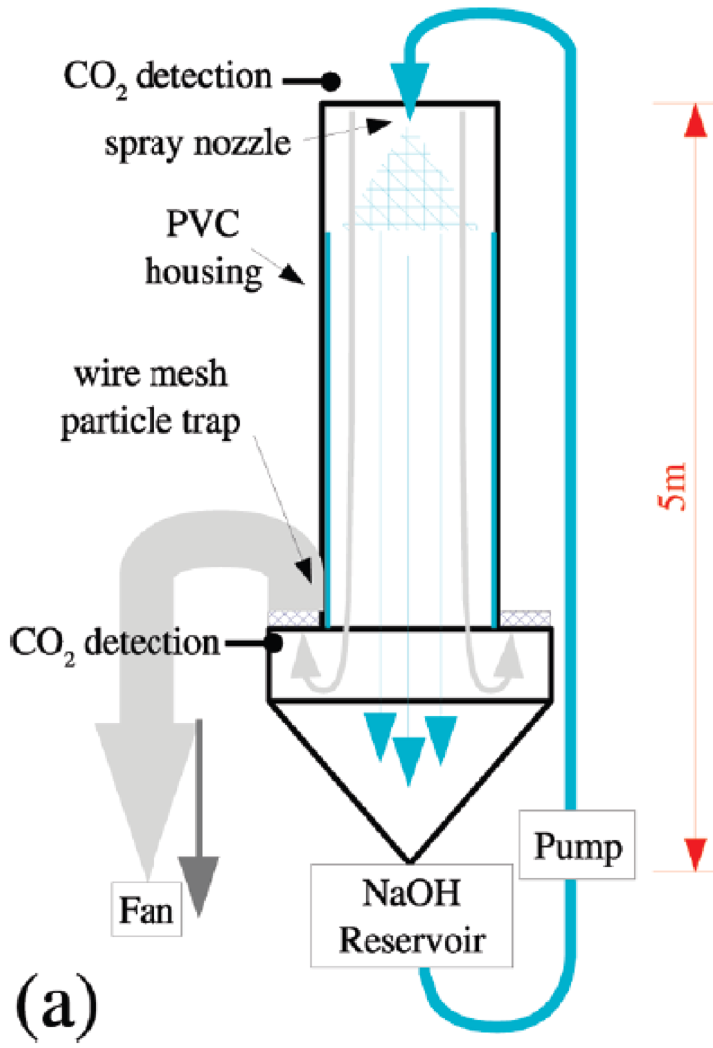
Parameter	Value	Motivation
Tower diameter	110 m	Equal to cooling tower
Tower height	120 m	Equal to cooling tower
Air velocity	2 m/s	Reasonable value[a]
CO_2 capture efficiency from air	50%	Reasonable value[b]
Mean drop diameter	0.7 mm	Spray distribution from a hollow-cone spray nozzle
NaOH concentration in solution	3–6 mol/l	Adjusted to minimize evaporative loss based on local climate.
Carbonate captured per pass[b]	0.2 mol/l	Based on numerical model of falling drops
Solution flow rate	1 m^3/s	Fixed by above parameters
Pressure drop accross tower[b]	22 Pa	Based on numerical model of falling drops; excludes wall friction.
Electricity use	1.4 MW	Based on 75% fan and 85% pump efficiency
Carbon capture rate	76000 tC/yr	Fixed by above parameters
Capital cost[c]	$12 million	(Cooling tower cost)×1.5[c]
Operation and maintenence cost	400,000 $/yr	Conservative guess

The Technology

Alternative Suggested Contactor

- Many of these housed in larger unit





The Technology

Causticizer and Slaker

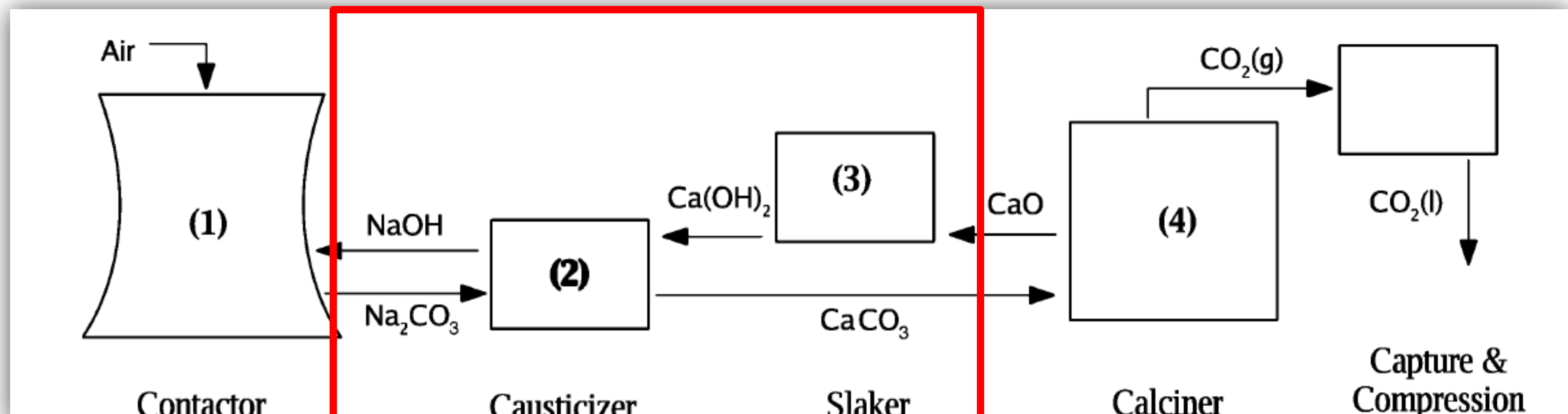
$$(2) \quad CO_3^{2-} + Ca^{2+} \rightarrow CaCO_3(s)$$

$$(3) \quad CaO(s) + H_2O(l) \rightarrow Ca^{2+} + 2\,OH^-$$

- Modeled as one unit: similar to Kraft Process

- Part of Na/Ca chemical loop

- Causticizer
    - swaps Na with Ca on “bottom pass”
    - Swaps Ca with Na on “top pass”



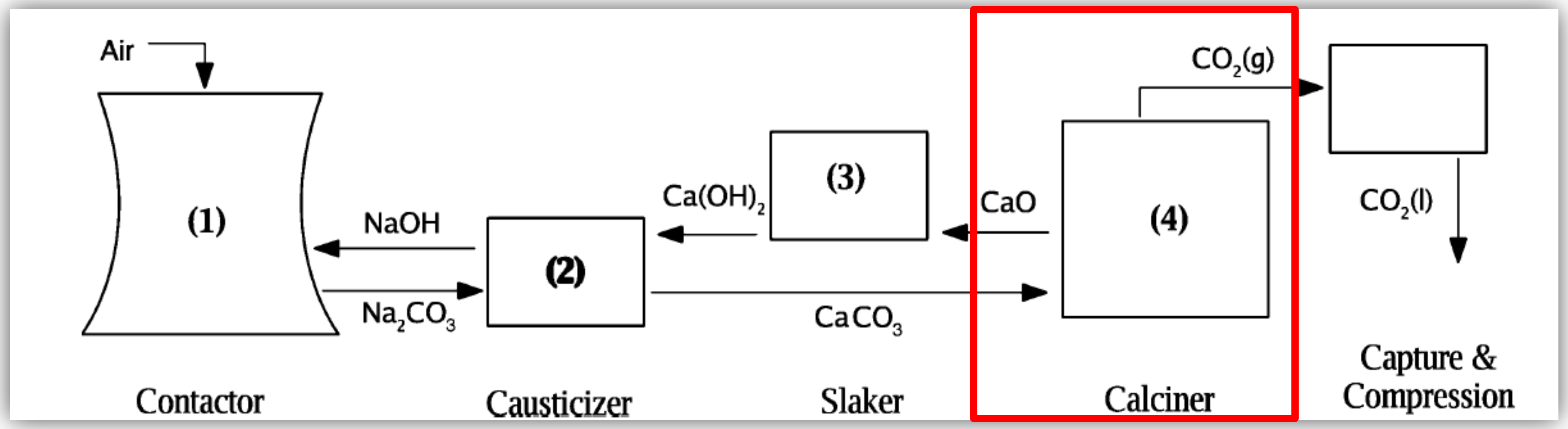
The Technology

Na/Ca Capture

Calciner

(4) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

- Drives CO_2 out of mud
- Produces lime to return to chemical loop
- Requires a great deal of energy



The Technology

Example air capture system: estimated and analogous costs and energy requirements

System	Mechanical energy (GJ/tC)	Thermal energy (GJ/tC)	Cost [$/tC][a]
Calcination			
Calcination in lime production	0.3	17	230[b]
Calcination in Kraft process	(small)	32	?
Calcination + caustization in Kraft Process	(small)	40	373[c]
CO_2 capture and compression			
Amine capture	0.4[d]	14[d,e]	49[d,f]
CO_2 compression	1.6[d]	0	43[d]
Contacting			
Spray tower	1.0	0	41[f]
Packed tower	1.2[g]	0	?

The Technology

BIOMASS CAPTURE	BIOMASS DRIVEN CAPTURE	METAL CARBONATE CAPTURE	INDUSTRIAL CAPTURE	PROPOSED CARBON TAX	Na/Ca SORBANT CAPTURE
0.1 - 28	160	30 - 32	160 - 260	26 - 58	240 - 550
Limited by space	One time capture only Impacts on agriculture	Can only capture < 1% of US emissions	Point Source Capture	Kyoto Protocol McCain-Liberman NCEP	Potential to capture 76kT/yr/unit

UNITS: $ / tonne of Carbon

What to do with CO_2?

- Sequestration – not proven
- Oilfield stimulation – current use, but small
- Use as Feedstock for Methanol Production $CO_2 + 2\ H2O \rightarrow CH_3OH + 3/2\ O_2$

		YEAR (Hydrogen Storage R&D Targets)			
Storage Parameter	**Units**	**2007**	**2010**	**2015**	**Methanol**
Gravimetric Capacity	kWh/kg	1.5	2.0	3.0	6.3
	kg H_2/kg	4.5%	6.0%	9.0%	12.5%
Volumetric Capacity	kWh/L	1.2	1.5	2.7	4.98
	g H_2/L	36	45	81	98.9

Personal Communication with Dr. Scovazzo

Conclusions*

- Using existing technologies, atmospheric CO_2 removal is feasible, but often not feasible economically

- When targeting the transportation sector, atmospheric CO_2 removal is cheapest of proposed methods

- Atmospheric CO_2 removal is not economically feasible as a replacement for point source recovery

- The research of this technology is worthwhile!

? GRT ?

* If GRT has really done what they say, the conclusions could change

Comments

- Atmospheric extraction is only one solution to the problem
- The Global Warming industry is profitable for private environmental remediation organizations
- Population must be educated
- Conservation must be instilled into upcoming generations
- Will require global effort

References

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- Olah, Goeppert, and Prakash; Beyond Oil and Gas: The Methanol Economy; Feb. 2006

- www.grestech.com: Global Research Technologies website and press releases

- Personal communication with Dr. Paul Scovazzo

Questions?