Status of CO_2 Capture Technology for Existing Coal-Fired Generation

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McIlvaine Hot Topic Hour

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  - Focused on Air Pollution Control/Monitoring
- Software and licensed reports

Clients

- Government
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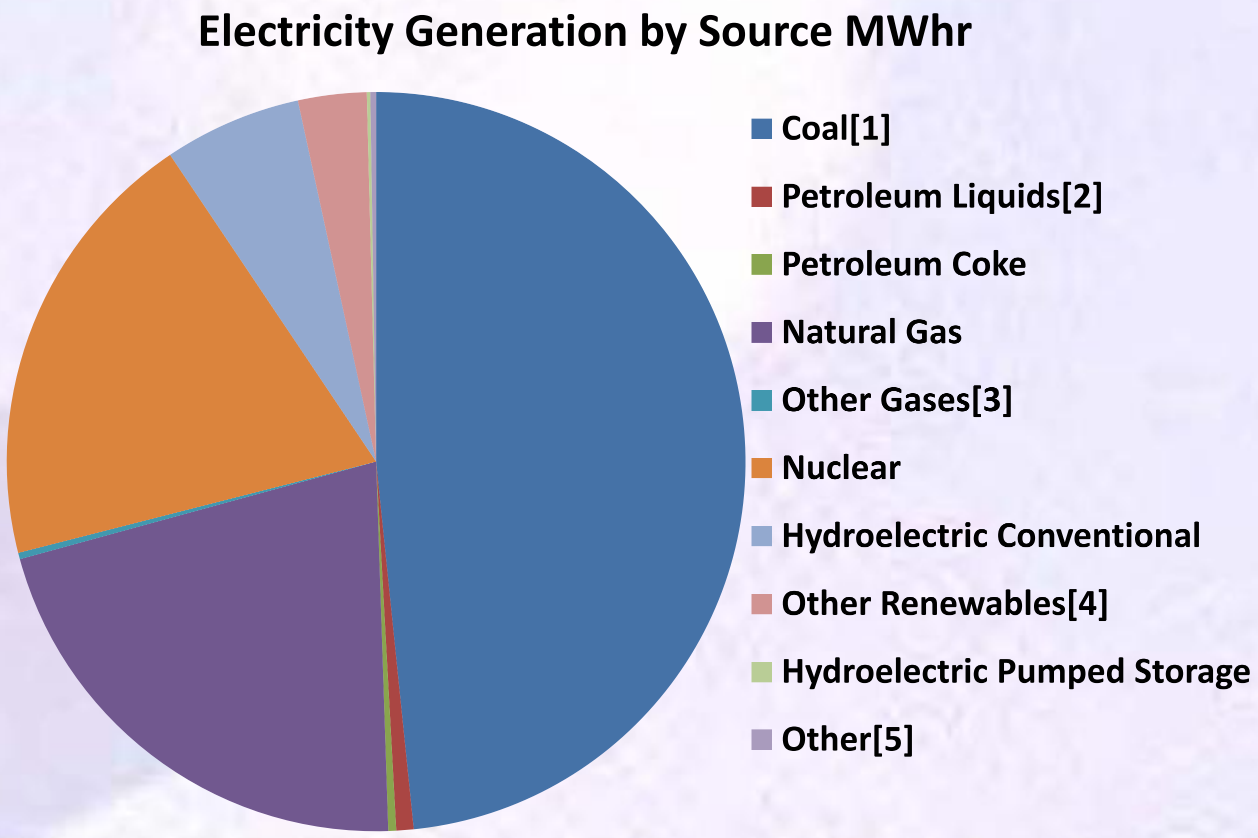
Current GHG Activities/Analysis

- Private Sector – independent analysis/benchmarking of carbon capture technologies, other GHG mitigation strategies, and associated companies
- US EPA's GHG technology database
  - Not to be confused with the GHG Inventory!
- US EPA's Industrial Sector model
  - GHG mitigation measures as well as criteria pollutant

“Ballpark” CO_2 Emissions by Source Type

Technology	CO_2, tons/MWhr
Coal (Subcritical)	~1 .0
Coal (Supercritical)	~0.89
Coal (UltraSupercritical)	~0.78
NGCC	~0.40-0.50

2008 US Electricity Generation



Coal's Future

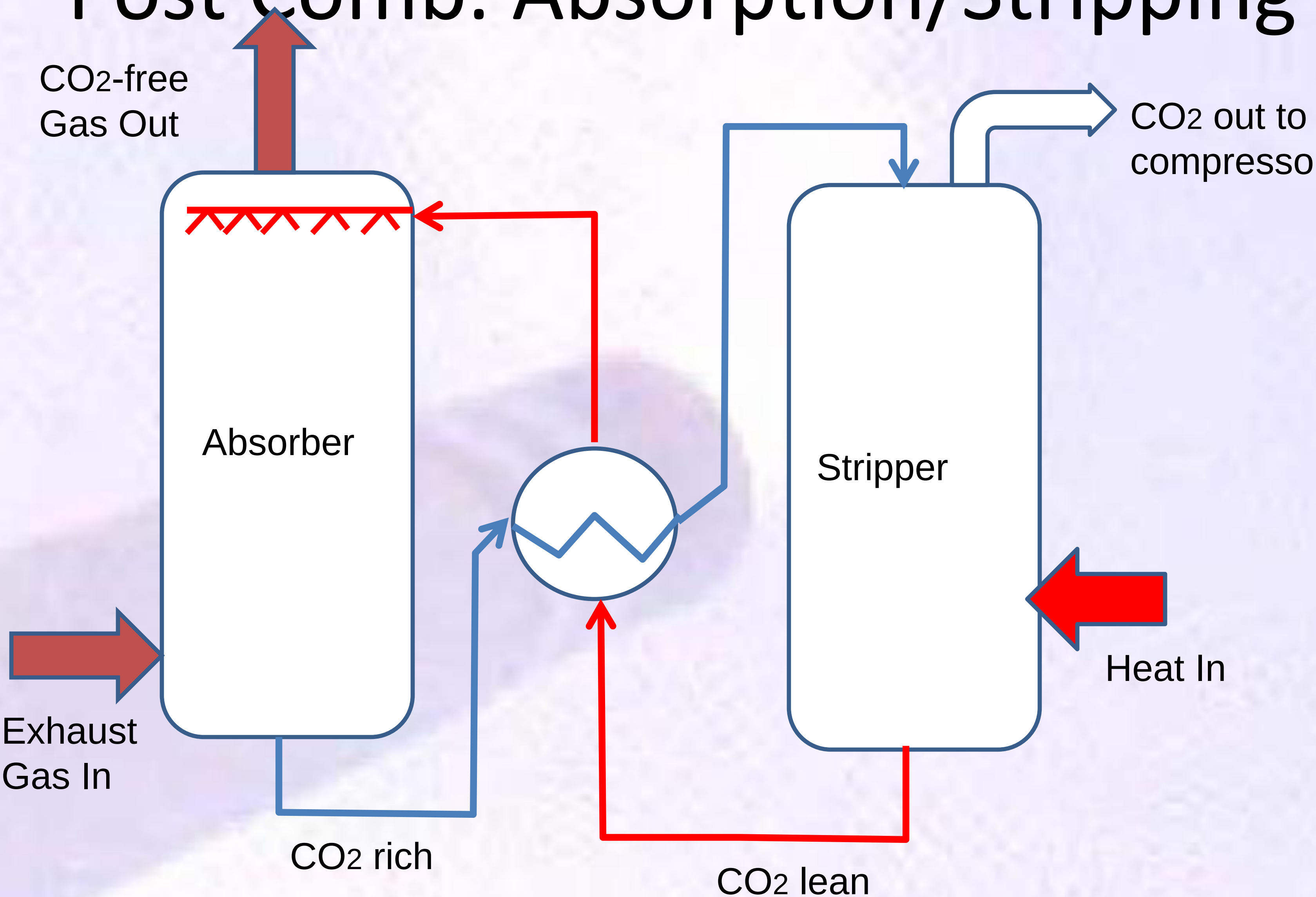
- Too much of the "pie" to be quickly or easily replaced as a source of power generation
- To reduce CO_2 emissions significantly in next few decades, measures are necessary for existing units
  - Carbon Capture technologies are needed
- President Obama establishes Interagency Task Force on Carbon Capture and Storage

Technologies for CO_2 Capture

		5-10 yrs "Near" term	10-15 years "Medium" term	15+ years "Long" term
Existing Facilities	Post Combustion	Amine Scrubbing Ammonia Scrubbing	Advanced or Second Generation Amine or NH_3, Antisublimation	membranes, solid sorbents, metal-organic frameworks, algae
	Oxy-Firing	Oxyfiring with cryogenic ASU	Advanced Separation, Chem Looping, CAR	
New Facilities	Pre Combustion	IGCC/Selex		

Post combustion and Oxyfiring are the possible approaches for existing facilities

Post Comb. Absorption/Stripping



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History of Amines

- Has been used for many decades for gas cleaning
- First use on combustion gases by Dow during energy crisis of 70's/80's for EOR, technology later sold to Fluor and named Econamine FG
- MHI, with Kansai Electric, develops KS-1 in 1990's
- Both technologies in commercial use
  - But on smaller scale than envisioned for CCS
- Extensive R&D on improved amines and amine processes by numerous organizations

Amines Versus Ammonia

Amines

- Absorption/stripping
- More experience
- Special reagents
- Corrosiveness of MEA
- Sensitive to O_2, SO_2 and NO_2
- 25-30% output impact
  - likely to improve
- Several suppliers

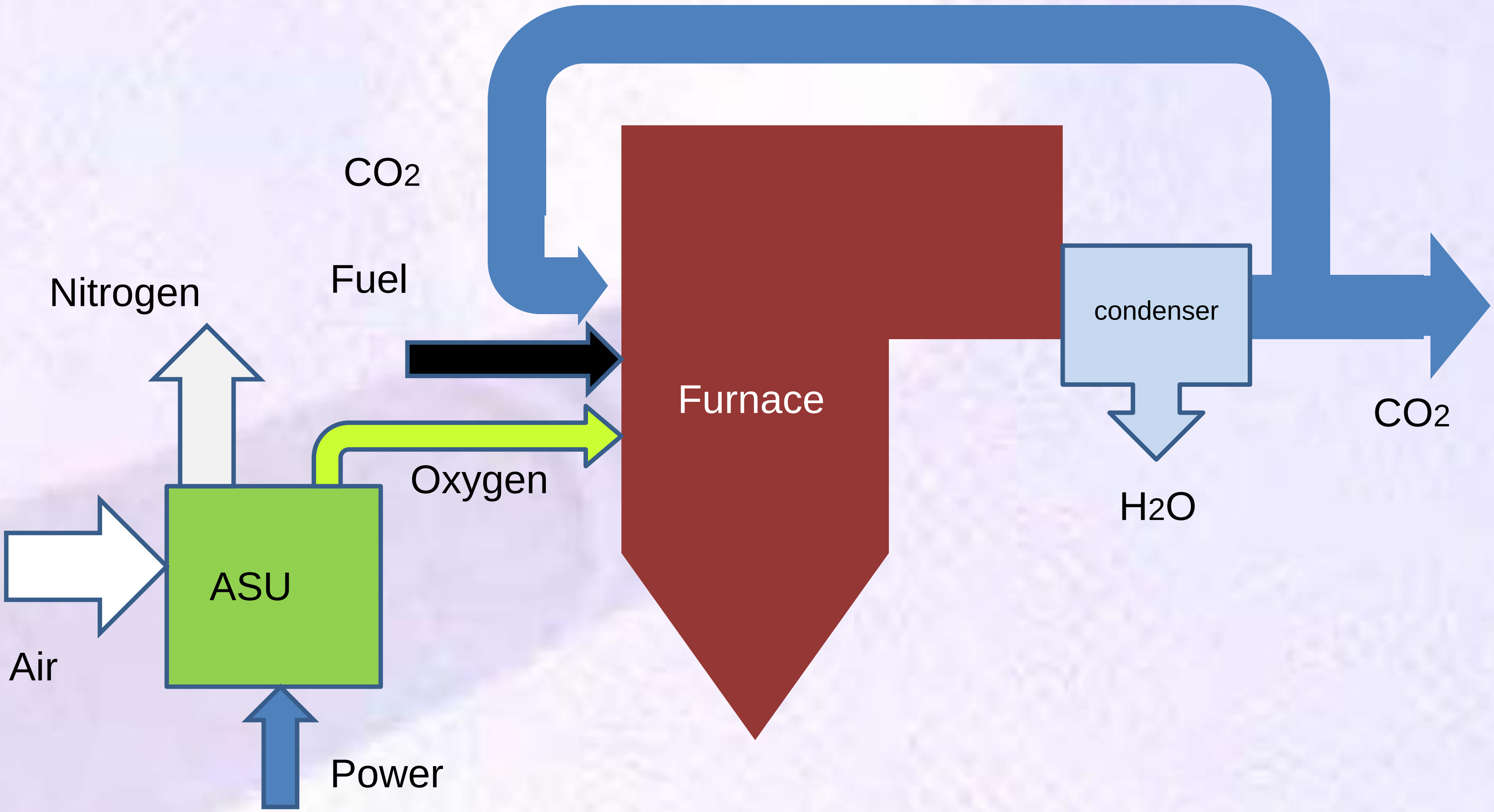
Ammonia

- Absorption/stripping
- Limited experience
- Widely avail reagent
- Non corrosive aq. ammonia
- No impact of O_2, SO_2 and NO_2
- 15%-22% output impact target
  - Higher pressure output
- Two suppliers

Retrofit Issues for Current Amine/NH_3 Designs

- Proximity to CO_2 pipeline or injection well
- Space – more space than LSFO is needed
- Significant loss of generation capacity and impact to steam system
  - High steam requirements
  - Parasitic electric load
- Quality of flue gas
  - Impact of SO_2 and NO_2 on Amines
  - May need polishing scrubber and NOx control

Oxyfiring



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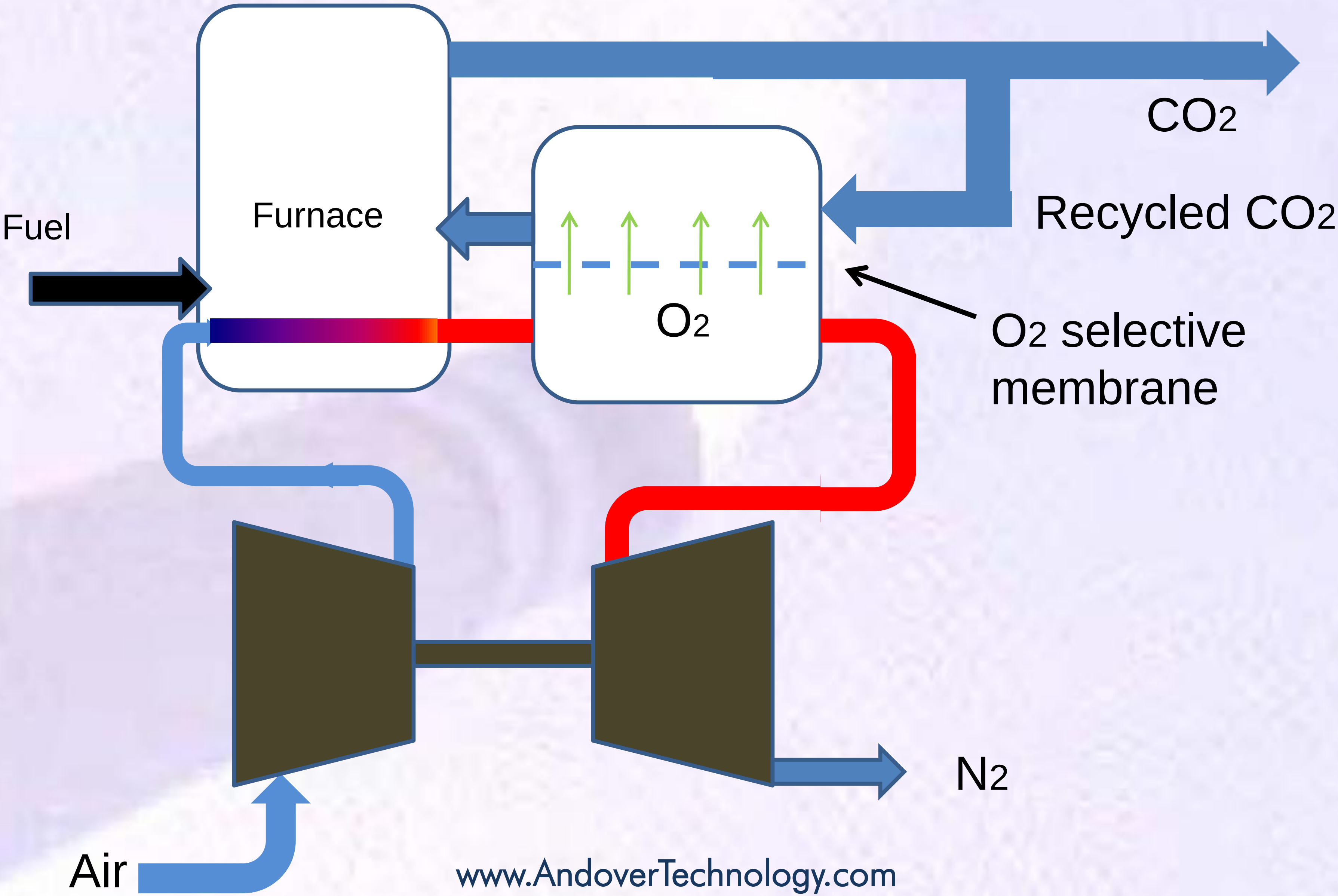
Issues for Oxy Combustion

- High power demand of Air Separation Unit
  - Cryo ASU has parasitic power of 36% versus about 8% for normal EGU
  - Methods underway for reducing
- Purification of flue gas
  - Inerts and moisture
  - SOx, NOx, O2 removal
- Proximity to CO_2 pipeline or injection well

Advanced Separation Unit with Oxy Firing



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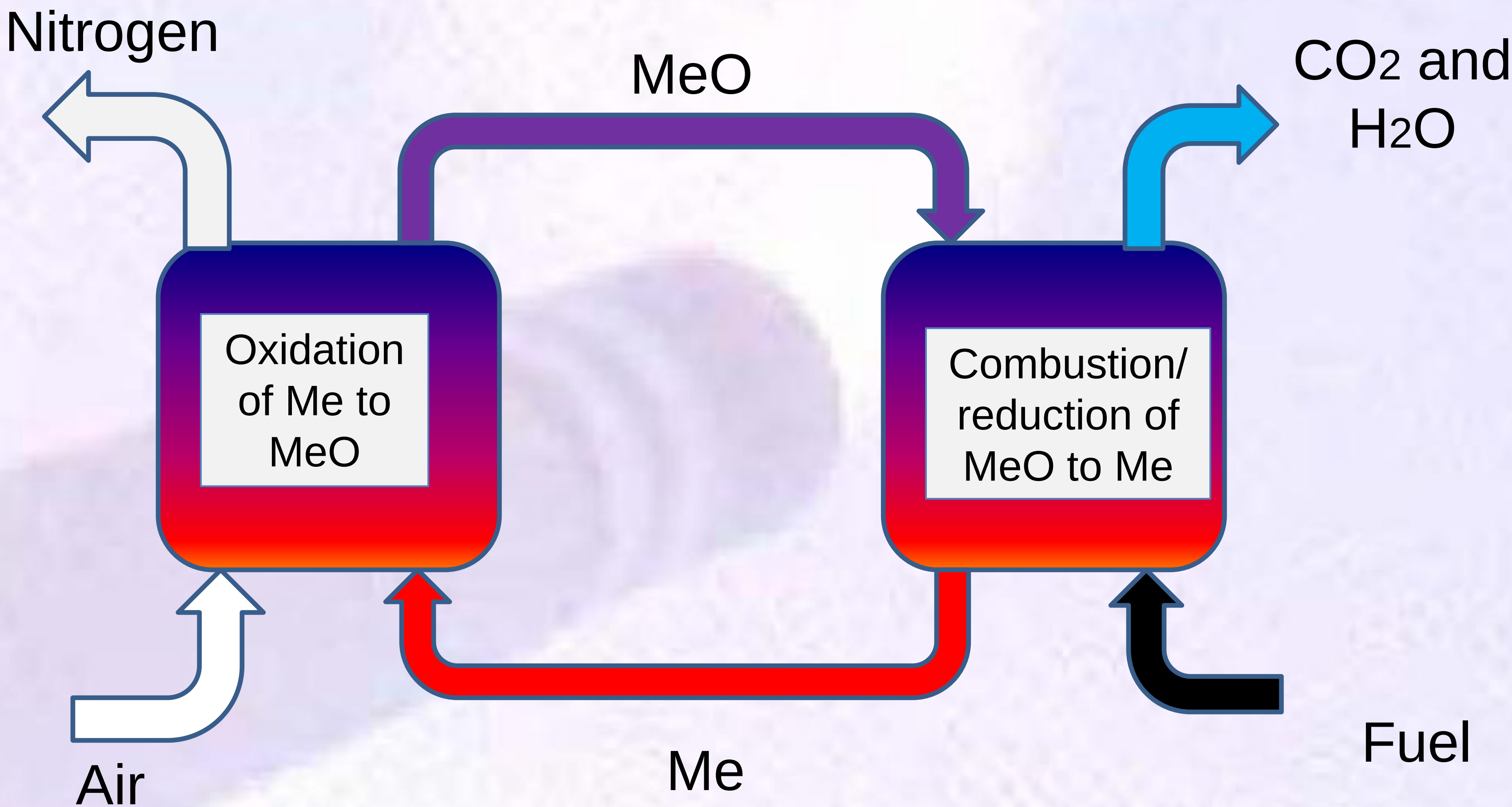
Chemical Looping Combustion



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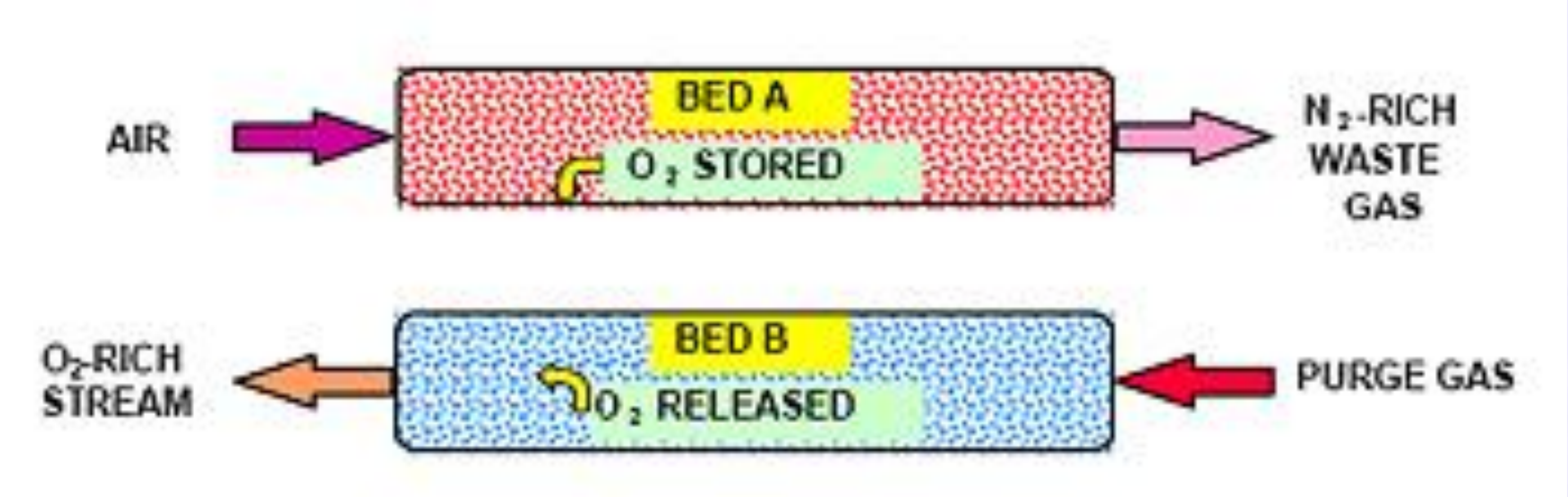
Ceramic Autothermal Recovery



Source: NETL

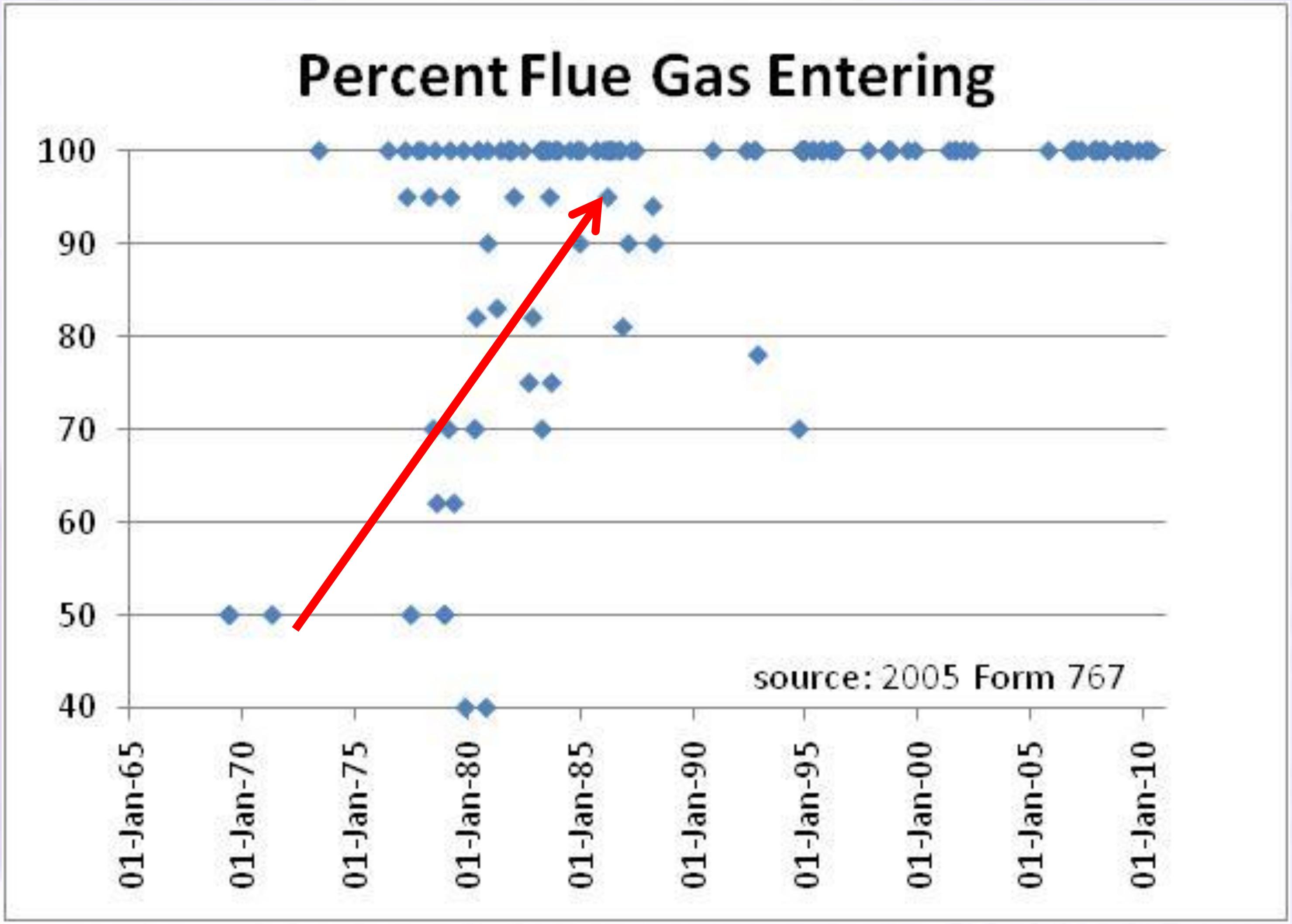
Reducing Compression Cost

- Higher pressure evolution of CO_2
  - Ammonia or Advanced Amines
- Ramgen Supersonic Shock-Wave Compressor
  - $1/10^{th}$ the size of conventional compressor
  - Lower capital cost
  - 2-stage compressor
  - More sensible heat to recover

Lessons from SO_2 Scrubber Evolution

- Reliability Evolution
  - Improved materials, better chemistry control
  - Far more reliable - less need for redundancy or for bypass
- Performance Evolution
  - Much higher removal efficiencies and lower parasitic loads due to technology improvements
- Cost Evolution
  - Larger scale and less redundancy, reducing capital costs
  - Ongoing costs lowered
    - Less waste – high quality dewatered gypsum product
    - Lower energy consumption

Evolution of Use of Bypass



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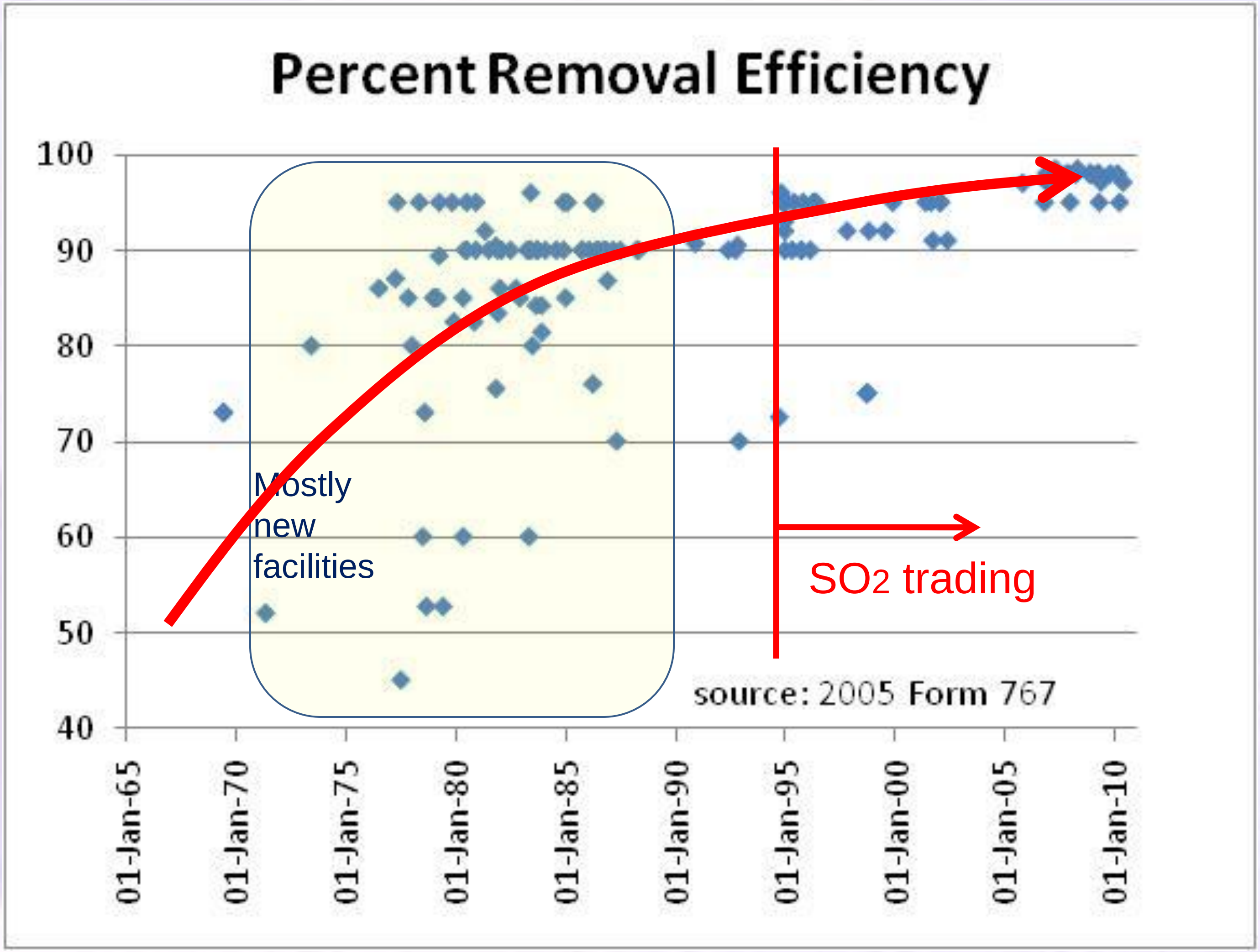
Evolution of Scrubber Efficiency



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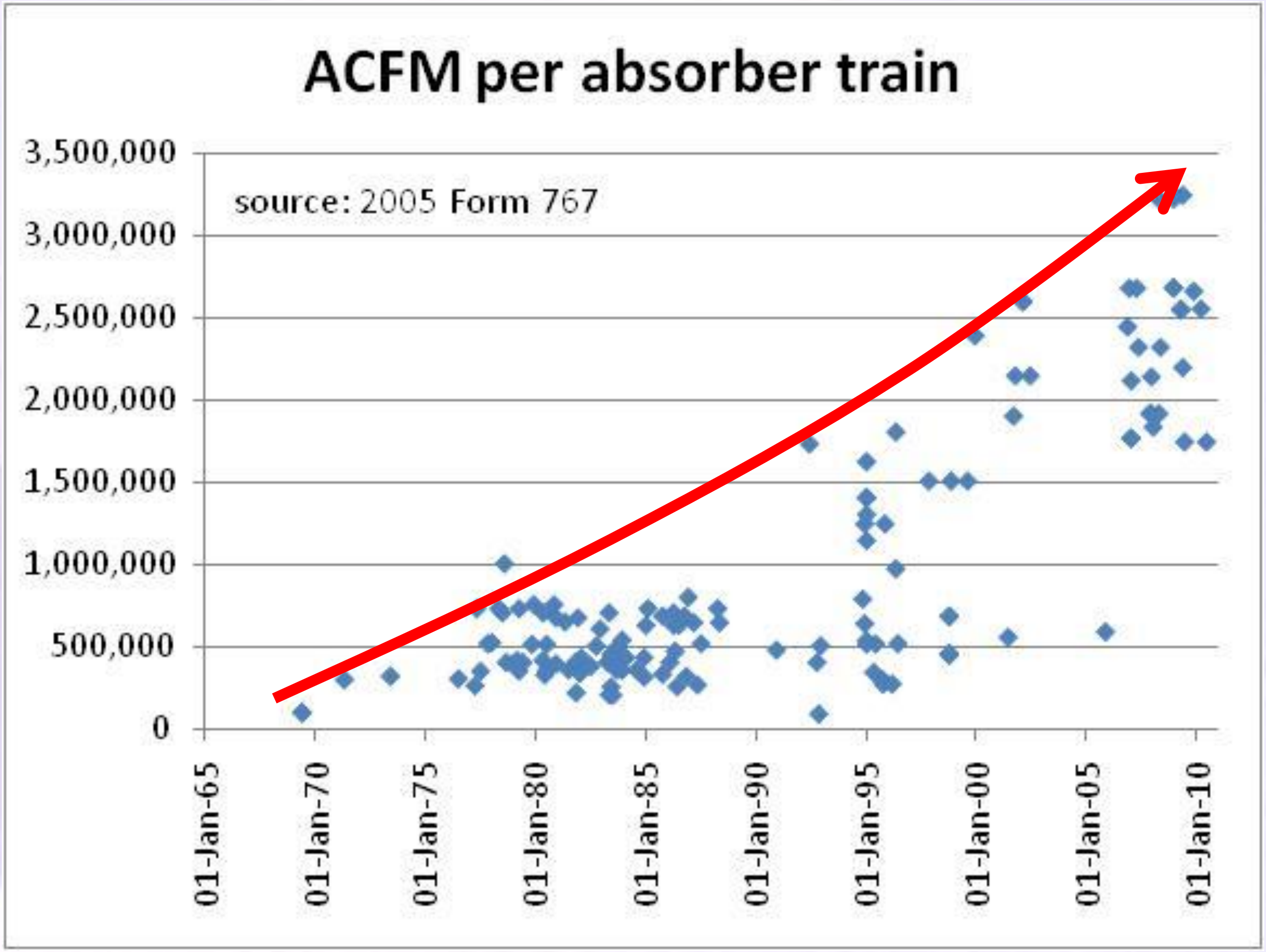
Evolution of Scrubber Size



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Scrubber technology evolution

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Key Takeaways

- For existing units technologies will be available for CO_2 capture
- Application will likely be more limited by sequestration than carbon capture
- Early deployments of technology will incorporate risk mitigation measures
- Early deployments of technology will not achieve the full performance potential of the technology
- Long-term, scale and technology improvements will be used to drive down cost and increase performance
- Trading programs mitigate risk and incentivize efforts to maximize performance and use of economic scale.
- Sometimes a much cheaper option comes along that is “good enough” for the moment