Retrofit Potential for Indiana Coal-Fired Power Plants, Including Oxy-fuel

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Organization

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- Clean Coal Options
- Oxy-fuel basics
- Economics of clean coal options
- Cite evaluation of potential retrofits
- Current funded work through CCTR
- Comments on current clean coal legislation

Clean Coal Options

- **Oxygen combustion (Oxy-fuel)**
  - Concentrated CO_2 in products
  - Spend energy on generating oxygen to use instead of air leads to very little NO_x is produced and combustion products can be sequestered with water condenser and SO_2 removal
- **Amine (or others) scrubbing**
  - Extracts the CO_2 from the flue gas using a regenerable sorbent-catalyst such as momoethanolamine (or MEA)
  - Spend energy on separating NO_x and CO_2 after burning fuel
- **Integrated Gasification Combined Cycle (IGCC)**
  - Also concentrates CO_2
  - Attractive approach, but challenges include complexity of operation

Why use Oxy-Fuel?

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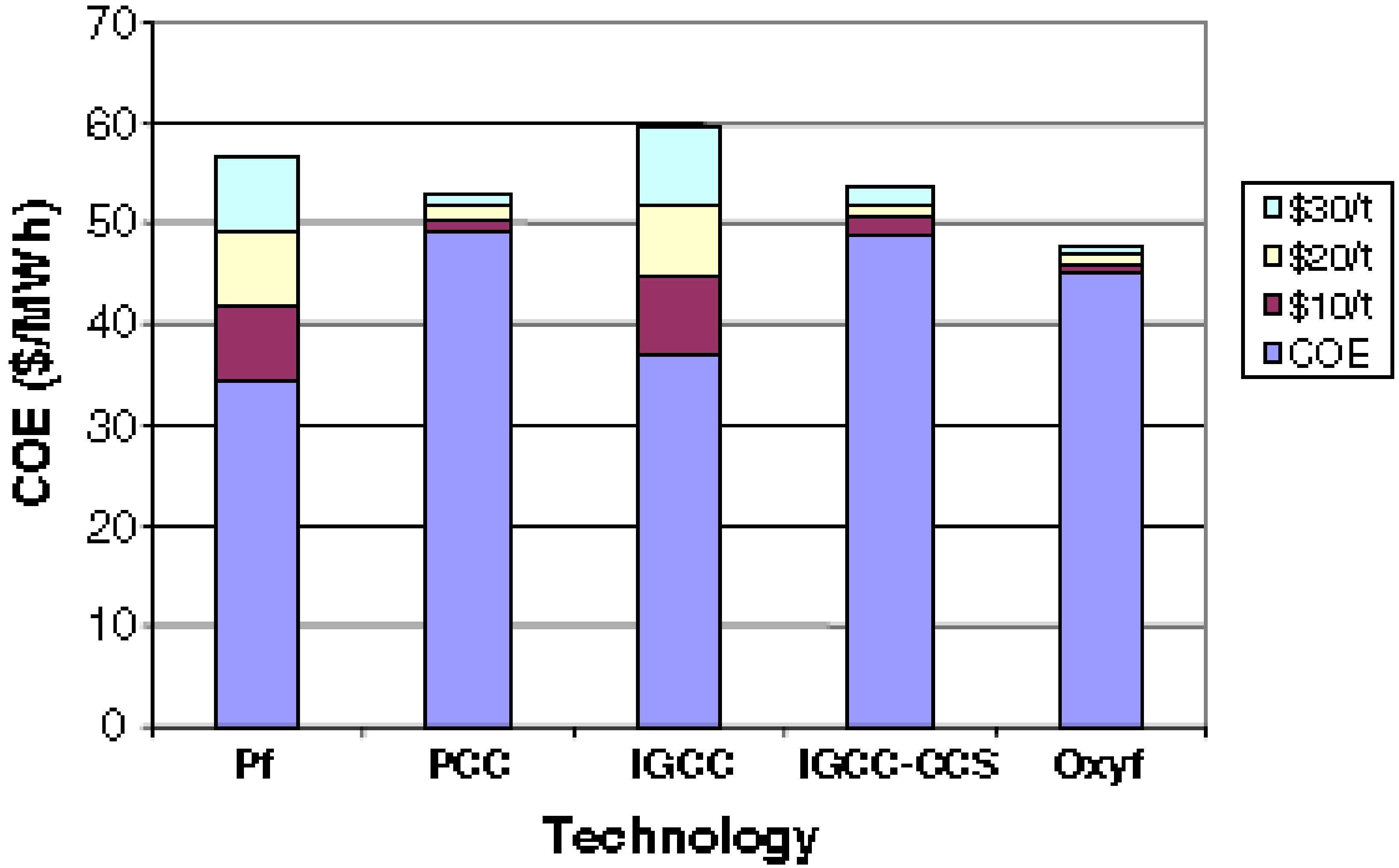
Oxy-fuel is inherently designed for CCS and would not generally be used if sequestration is not required because of the added cost.

However, as carbon taxes rise, oxy-fuel quickly becomes an economically viable option.



Source: (9)

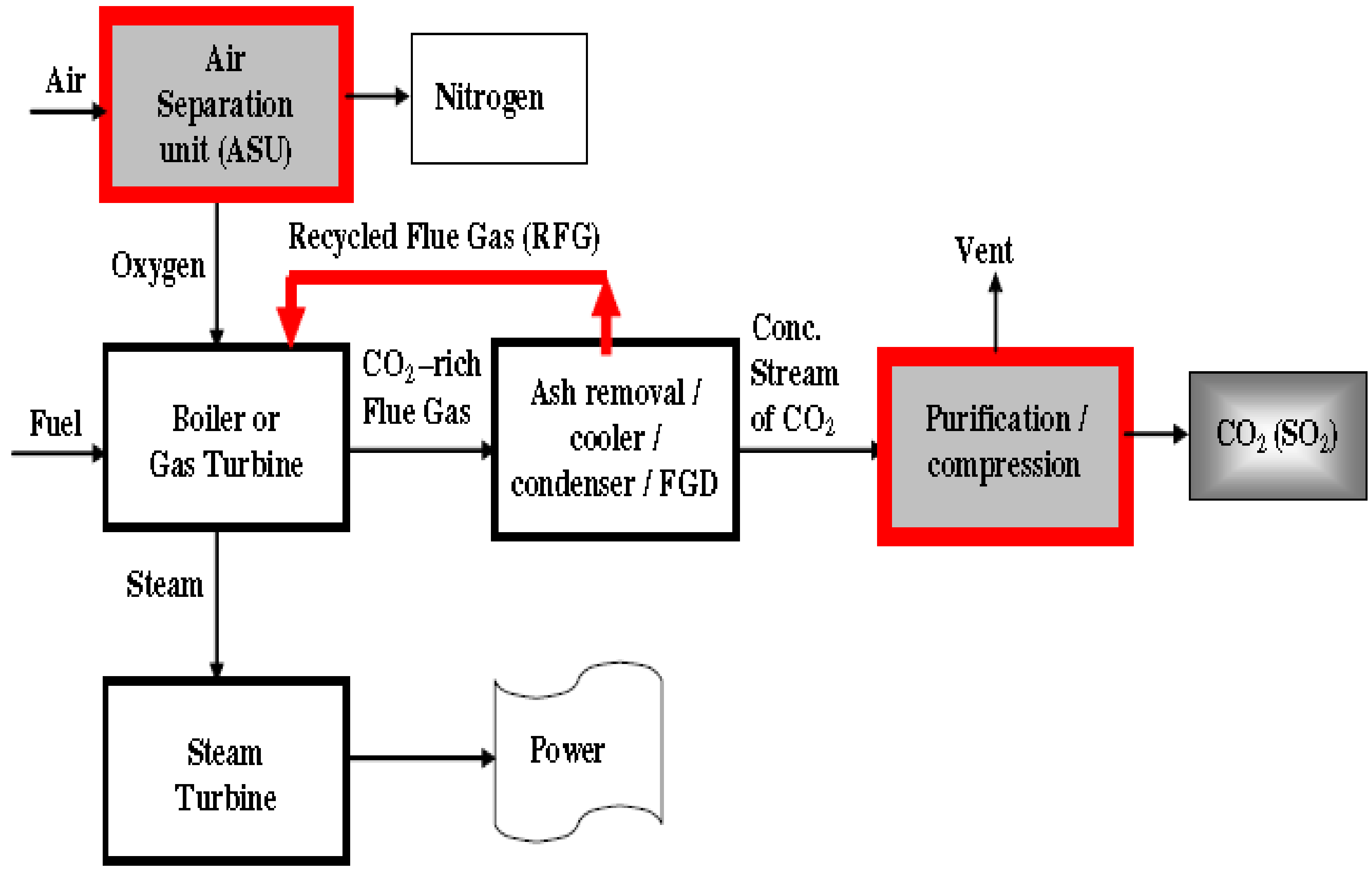
What Does Oxy-Fuel Look Like?

The simplest oxy-fuel retrofit for a existing coal power plant is shown here.

Major components needed for an oxy-fuel retrofit are highlighted in red. These include:

- Air Separation Unit (ASU)
- Flue Gas Recirculation
- CO_2 Purification and Compression

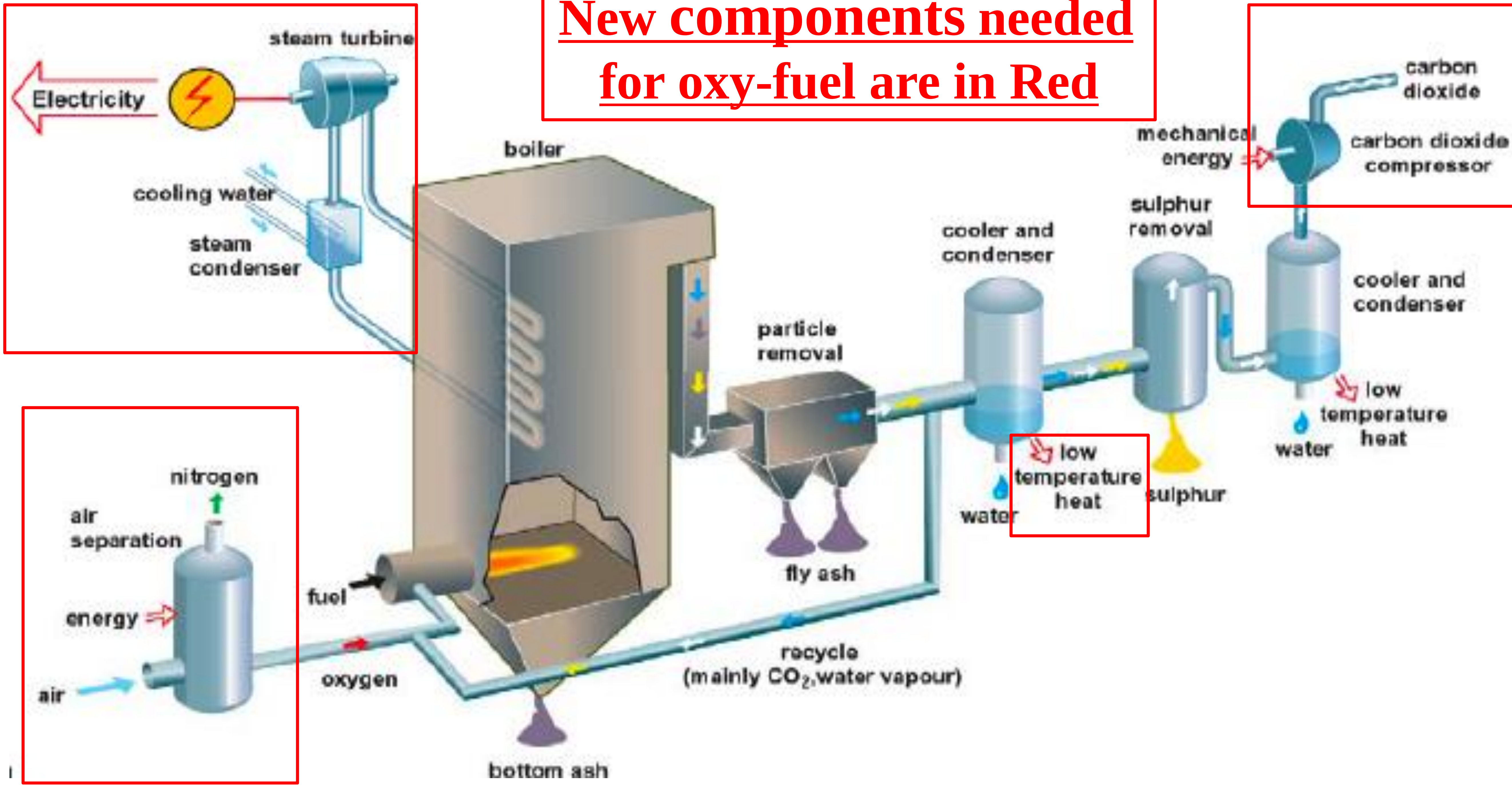
However, one of the biggest problems with justifying an oxy-fuel retrofit is the overall loss in plant efficiency due to additional energy requirements.



Source: (9)

What Changes Does an Oxy-Fuel Retrofit Require?

New components needed for oxy-fuel are in Red



Source: (2)

Air Separation

<u>Oxy-fuel's biggest problem is inefficient ASU!</u>

- In some plants, in order to continuously run an oxy-fuel scenario, as much as 7400 tons/day of oxygen would be needed
- The largest single ASU can produce roughly 3500 tons/day of O_2
  - This can support a plant that produces approximately 200 MWe
- There are several commercial methods for large-scale oxygen production (both ~<u>200kWh/ton of O_2</u>)
  - Vacuum Swing Absorption (VSA) ~ 90-94% O_2
  - Cryogenic separation ~ 99% O_2

Source: (6),(11)

Air Separation Comments

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Air Separation is by far the largest consumer of energy in oxy-fuel operations. This leads to lower overall plant efficiency and makes oxy-fuel less attractive economically.

According to an engineering analysis of the basic functions of an ASU, current ASUs use 6x more energy than they need to!

An ASU capable of 300 tones of O_2 /day

Source: (6),(9)

Modifications to Energy Recovery Systems

Many demonstration scale oxy-fuel projects have used various improved heat recovery systems in an attempt to offset the decrease in plant efficiency.

- Many facilities capture additional rejected heat from the condensers to supplement power to the steam turbine
- Some facilities integrate the ASU, steam turbine and CO_2 compression systems which has been proven to lessen the overall power consumption

Source: (2),(11),(12)

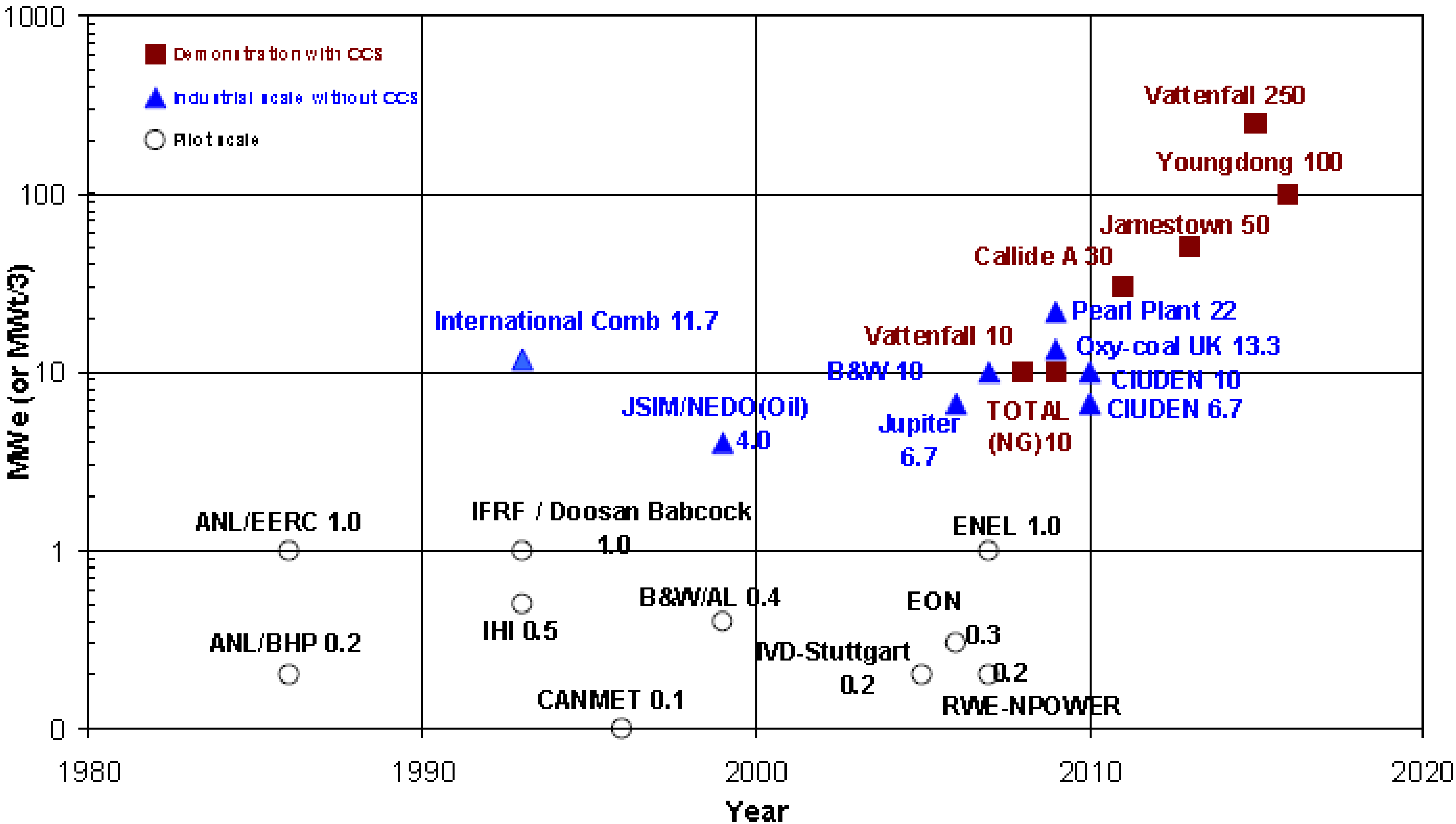
CO_2 Compression and Storage

- Oxy-fuel produces 80-95% CO_2 prior to capture
  - ~3% N_2 from air leakage
  - Ar from the ASU, O_2 from oxygen rich burning
- Compression of flue gas is a relatively low energy requirement and optimization depends on the composition of the flue gas
- Sequestration options depend on location and may require further purification of flue gases
  - Enhanced Oil Recovery (EOR) requires CO_2 concentration >95% and O_2 <10ppm

Source: (9),(11)

Historical Progress of Oxy-fuel

Oxy-fuel Projects are growing Quickly!



Source: (8)

Economic Case Study for Oxy-Fuel Retrofit from a Coal-Powered Power Plant

Source: (5)

Capital Cost Estimates of Oxy-Fuel

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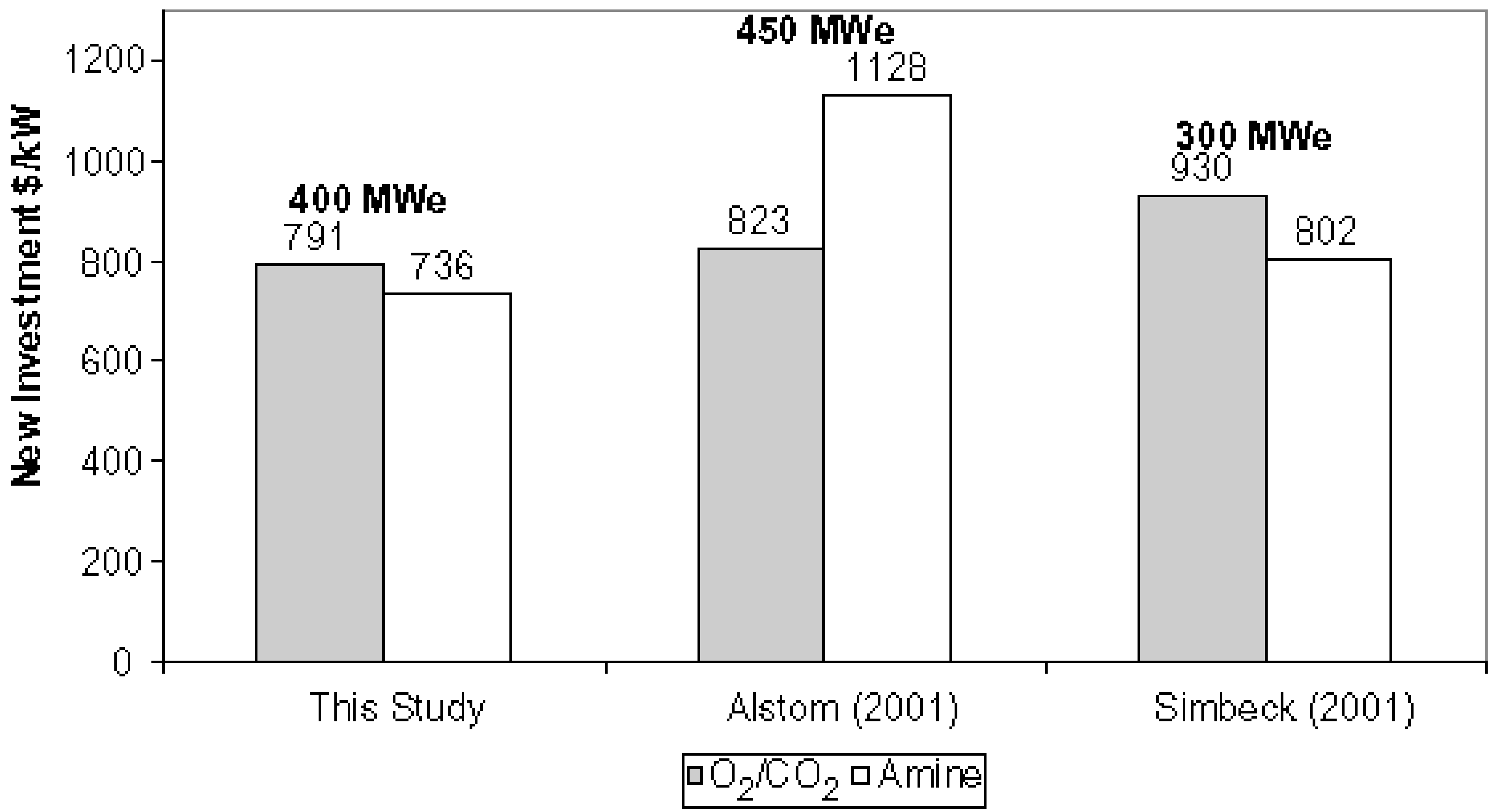
Oxy-fuel has lower capital costs when capturing large amounts of CO_2

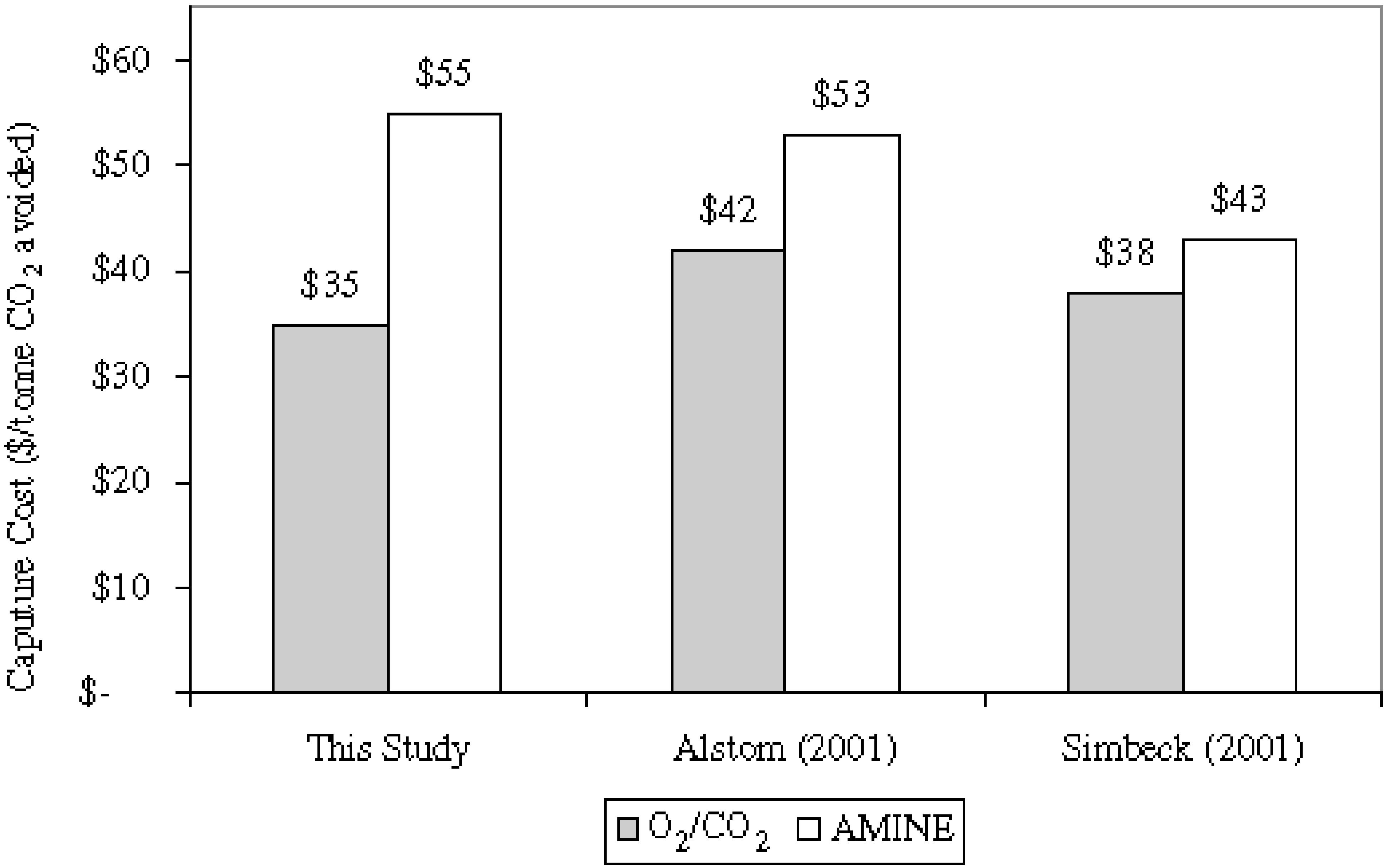


- Three economic studies of capital costs of Amine Scrubbing Retrofit vs. O_2/CO_2 Retrofit of 300MWe, 400MWe and 450MWe facilities
- Amine scrubbing with 65% CO_2 removal vs. oxy-fuel with 74% CO_2 removal

Source: (5)

CO_2 Capture Costs of Oxy-Fuel

Oxy-fuel is cheaper per ton of CO_2 avoided



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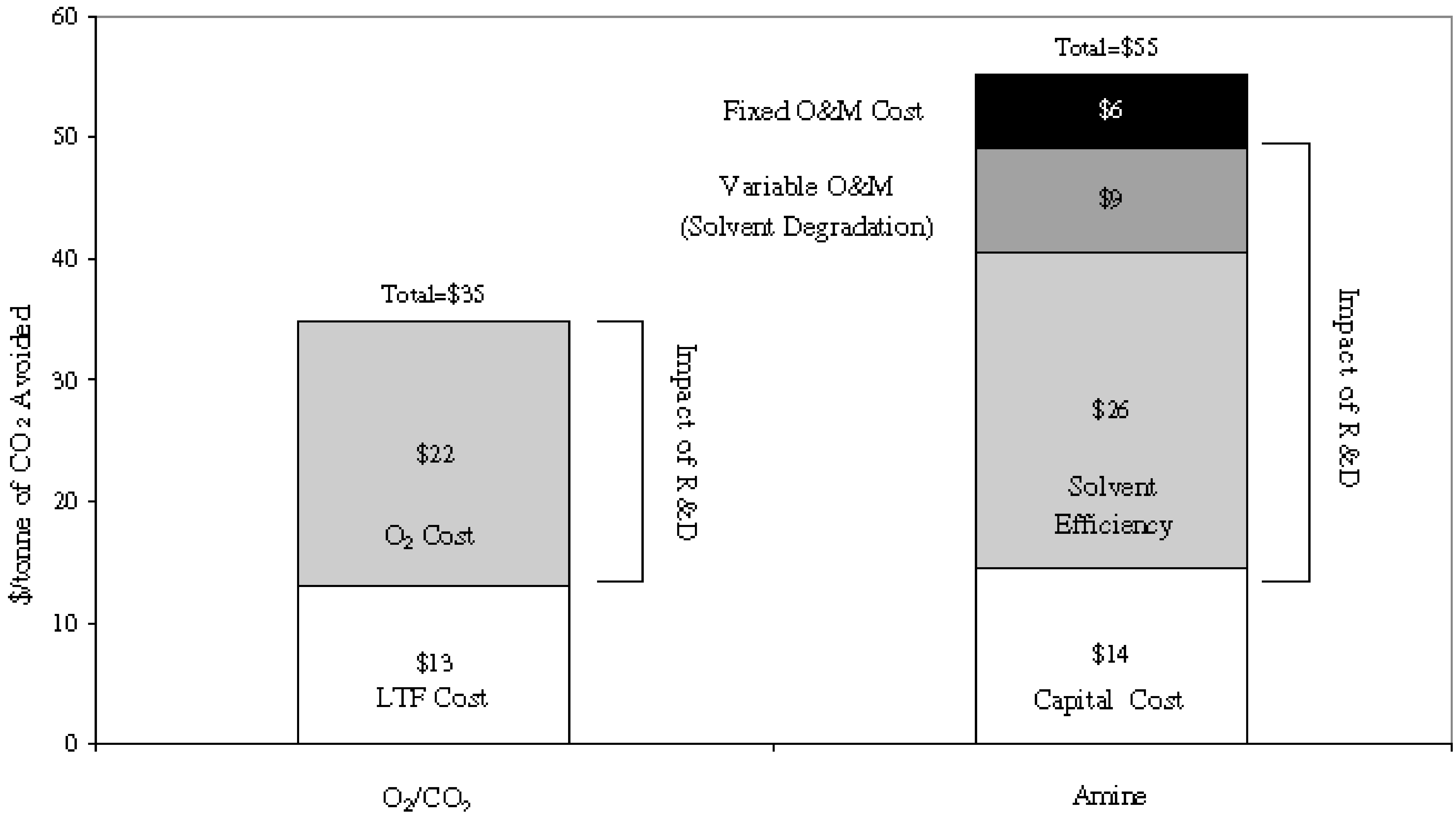
Room for Improvement?



Source: (5)

Summary of Other Economic Studies on Oxy-fuel Retrofit

- Oxy-fuel retrofits for pulverized coal power plants are technically and economically feasible
  - Large Capital Investment
- Oxy-fuel is competitive for CO_2 sequestration when a substantial percent of CO_2 will be sequestered
- Retrofitted oxy-fuel power plants are more economical at smaller sizes (<200MWe)
  - At plant sizes larger than 200MWe, multiple ASUs may be required which will significantly increase the capital cost of the oxy-fuel retrofit
- Sensitivity analysis indicates that improvements in the ASU technology will have a significant impact on the overall cost of annual oxy-fuel costs

Source: (1),(6)

Cite evaluation for Oxy-fuel retrofit

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"Engineering feasibility and economics of CO_2 capture on an existing coal-fired power plant"

Evaluate the Conesville Power Plant (Ohio)

Is a great example of a study of appropriate depth to properly evaluate if a cite is feasible for a an oxy-fuel retrofit and how much it may cost.

Approach

Evaluate 3 concepts:

1. Concept A: Coal combustion in air, followed by CO_2 separation with specific commercial MEA-based absorption/stripping process
2. Concept B: Coal combustion with O_2 firing and flue gas recycle (oxy-fuel firing)
3. Concept C: Coal Combustion in and CO_2 separation by a mixture of primary and tertiary amines

Each of these technologies was evaluated against the existing design without CO_2 capture, from the standpoints of:

- Power generation efficiency
- Impacts on power generation cost (with and without supplemental plant)
- Impacts on CO_2 emissions

450 MW Conesville Unit No. 5, located in Conesville, Ohio, was used for the power plant case study.

Approach – Space Evaluation

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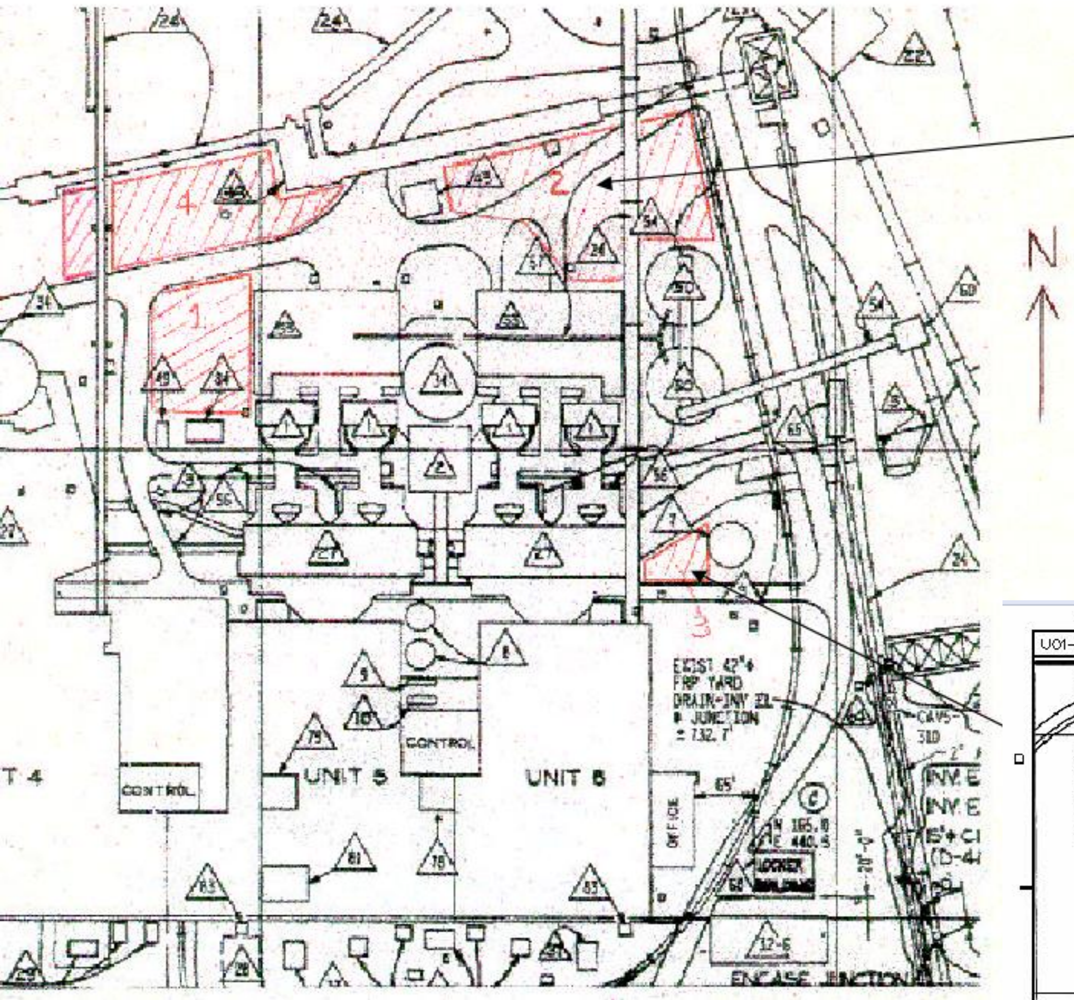
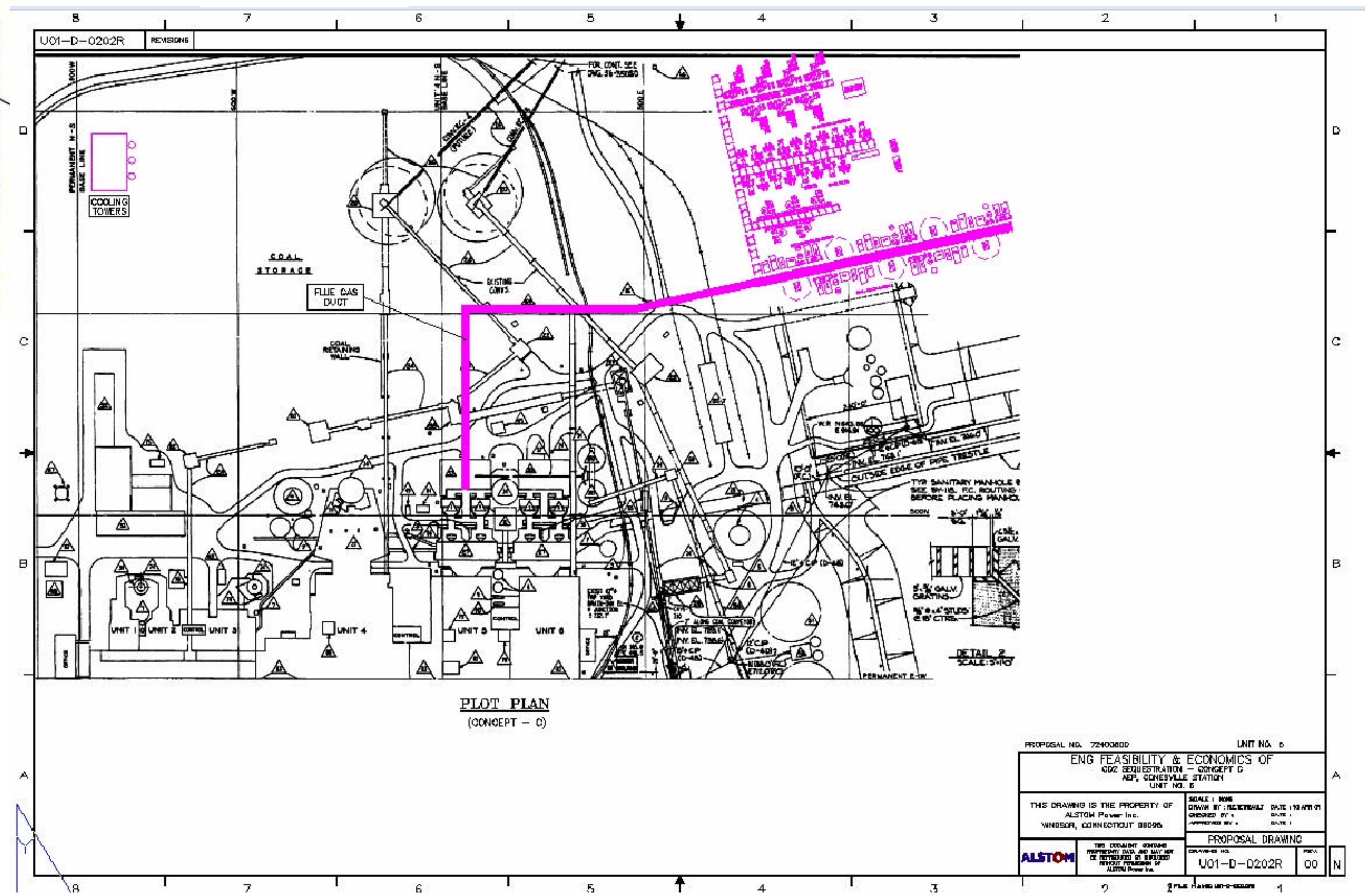


Partially not available

5-8 acres of new equipment space is needed for Unit #5 alone on the existing 200-acre power plant site



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Major Conclusions:

- No major technical barriers exist for retrofitting AEP's Conesville Unit #5 to capture CO_2 for any of the three concepts considered under this study.

- Concept B (**oxy-fuel) appears clearly to be the best alternative** of the three concepts… for systems designed for **very high CO_2 capture** (i.e. > 90%)!!!

- If lower CO_2 capture fractions are considered, it appears that Concept A would likely be the best alternative for capture fractions below some as yet undetermined value. Concept C would also improve considerably with lower capture fractions.

Ongoing Project through CCTR

Characterize statewide coal power plant retrofit potential (simplified Conesville study)

Benefits:

- A single database that can help make decisions where a retrofit could have the most impact on emissions
- Quantify financial benefit of making one plant do a massive CO_2 sequestration project instead of a lot of smaller ones across the state

Obstacles:

- Evaluating available space from Google map images
- Finding details about different furnaces

Source: (1),(6)

Comments on current clean coal legislation

- If CO_2 is calculated on a state wide basis then a big plant retrofit would allow for smaller plants to continue operating (favors one big oxy-fuel retrofit). If it is counted on a plant by plant basis then you would not be able to use one big site as an offset for other sites (favors chemical scrubbing).
- Efficiency requires modifications of the plant, any modification that would require substantial work requires that the entire plant be brought up to Best Available Technology standards.
- Current EPA rules say propose that there be no new rules for 3 years. That means that if you start building now you won't know for 3 years if you got it right, and then the EPA can order you to start over.

Source: (1),(6)

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Questions?

Source: (1),(6)

Appendix A: Breakdown of Oxy-Fuel Costs

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Comparison of annual costs for O_2/CO_2 and amine scrubbing

	Amine	O_2/CO_2
Capital cost	$294,249,975	$316,292,097
Amortised capital cost ($/year)	$27,775,116	$29,855,736
O&M (4% of capital cost)	$11,769,999	$12,651,684
Cooling water ($0.01/m^3)	$2,869,812	$947,641
Scrubber chemicals (from Fluor study)	$7,000,000	–
MEA make-up ($1.55/ton CO_2 produced)	$6,606,720	–
Operating subtotal ($/year)	$28,246,531	$13,599,325
GT fuel (MMBtu/year)	2,821,824	8,193,997
NB boiler fuel (85% efficiency) (MMBtu/year)	9,742,923	–
ASU NG (MMBtu/year)	–	50,541
Total NG (MMBtu/year)	12,564,747	8,244,538
Annual NG cost ($4.00/MMBtu)	$50,258,989	$32,978,153
Total annual cost	$106,280,636	$76,433,214
Original CO_2 emissions (ton/year)	2,960,000	2,960,000
CO_2 avoided from coal plant (ton/year)	2,664,000	2,664,000
CO_2 emissions from natural gas (ton/year)	740,315	466,701
NET CO_2 avoided (ton/year)	1,923,685	2,197,299
% CO_2 avoided	65%	74%
Capture cost ($/ton CO_2)	$55	$34
Capture cost (¢/kWh)	¢3.3	¢2.4

Source: (5)