Developing Oxy-combustion for Retrofitting Coal-fired Boilers

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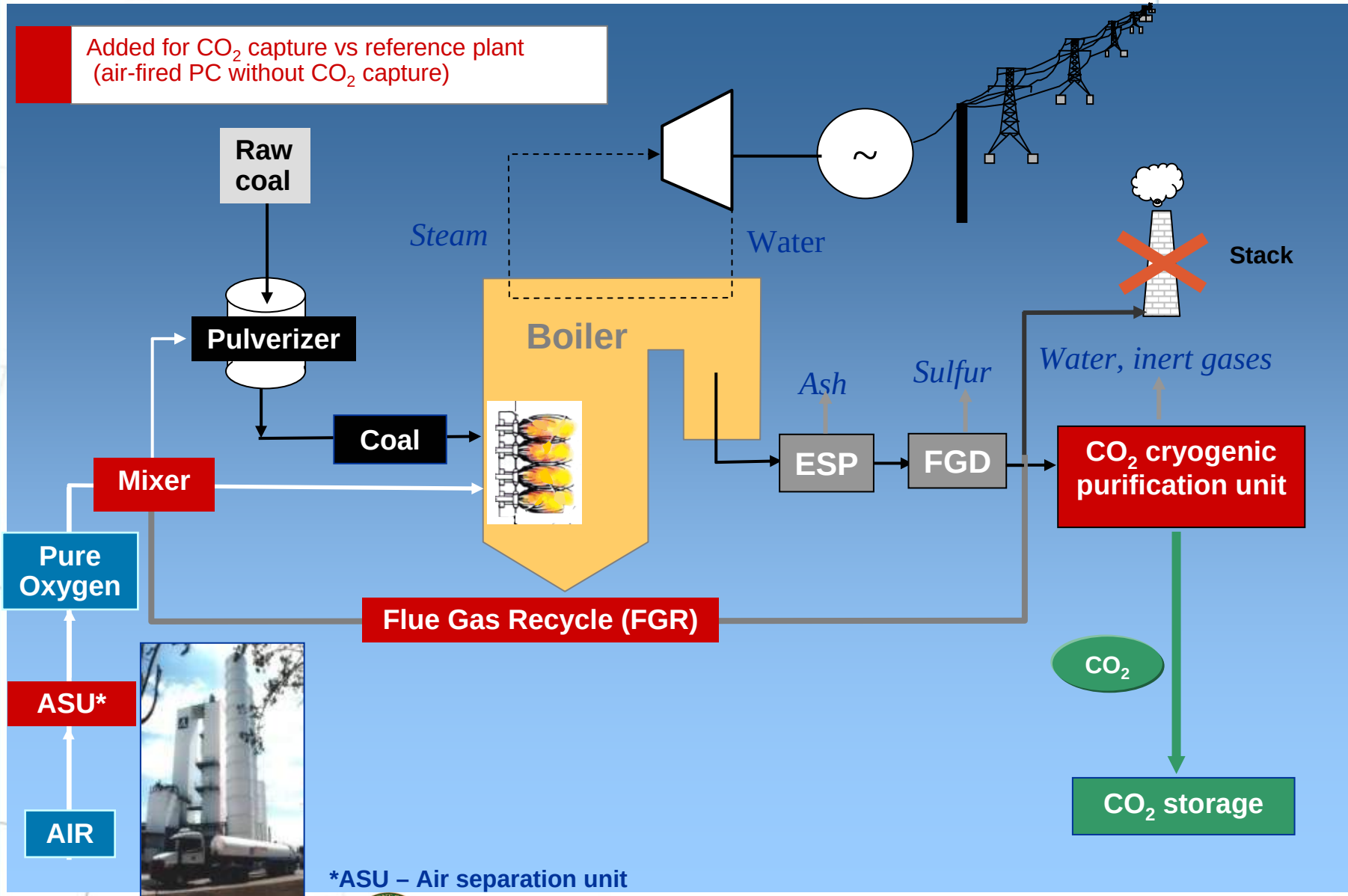
Project Objectives

- **Develop oxy-combustion as a *clean coal* technology for retrofitting coal-fired boilers**
  - Cyclone boilers
  - Wall-fired boilers

- **Two phase project**
  - **I : Pilot scale evaluation**
    - Process modeling of boiler, CO_2 capture and CO_2 sequestration
    - Pilot test of coal oxy-combustion in cyclone & wall-fired boilers
  - **II : Engineering & Economic Analysis**
    - Selection of two 500 MW plants (1 cyclone, 1 wall-fired)
    - Full-scale engineering & economic study to retrofit these plants with oxy-combustion and CO_2 capture for sequestration

Oxy-Combustion



Phase I Activities

Task 1: Process modeling

- Boiler island: modeling to predict flue gas compositions
- Sequestration: simulations to determine “sequestration-ready” gas specifications
- CO_2 CPU: process design to capture CO_2 from flue gas for sequestration purposes
- 3 coals considered
  - North Dakota Lignite
  - Decker coal (sub-bituminous)
  - Illinois #6 coal (bituminous)

Flue Gas Compositions

- **Flue gas compositions predicted assuming high air infiltration rate**

	ND Lignite		Decker		Illinois # 6	
	Wet	Dry	Wet	Dry	Wet	Dry
Item	mol%	mol%	mol%	mol%	mol%	mol%
H2O	17.41	0.00	17.42	0.00	17.43	0.00
CO_2	**59.63**	**72.20**	**59.57**	**72.14**	**58.18**	**70.46**
N_2	16.01	**19.38**	16.32	**19.76**	17.63	**21.35**
O_2	4.10	4.96	4.00	4.85	4.11	4.97
SO_2	0.3797	0.46	0.1350	0.16	0.1004	0.12
Ar	2.40	2.90	2.50	3.03	2.50	3.03
NO_2	0.0619	0.075	0.0248	0.030	0.0380	0.046
CO	0.0165	0.020	0.0165	0.020	0.0165	0.020

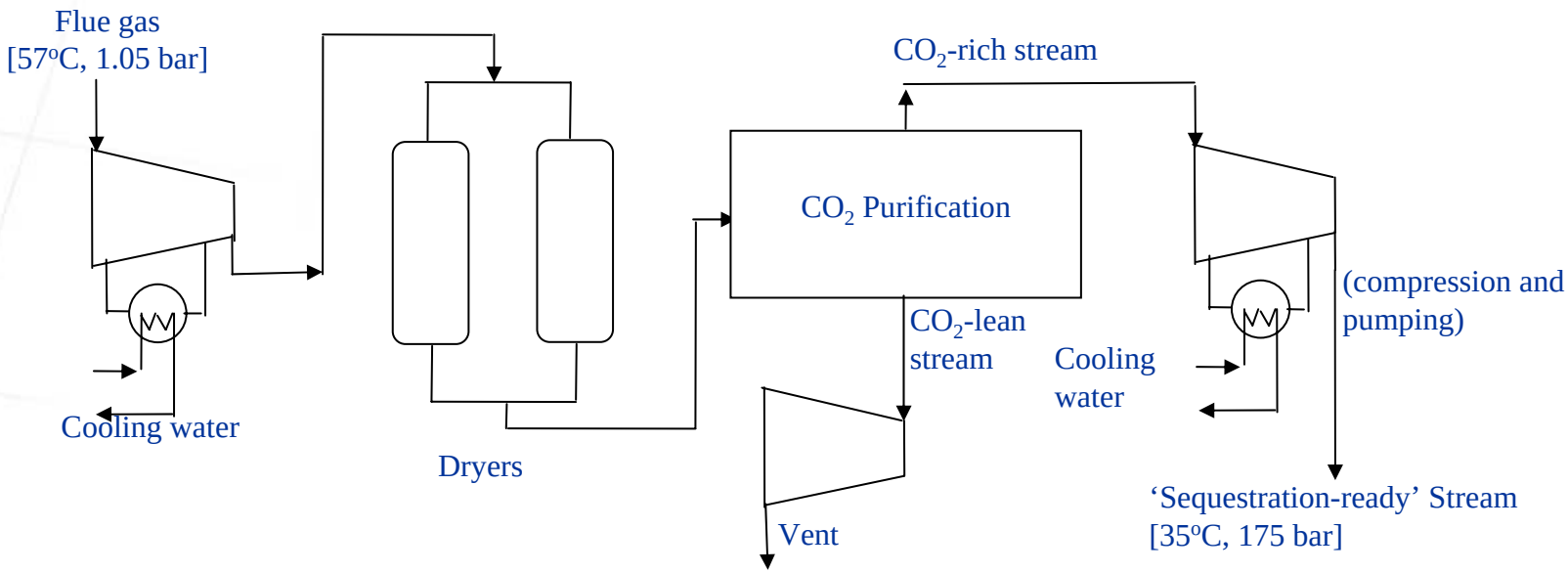
- **Low air infiltration case also considered**
  - N_2 reduced to 10%

Product Gas Specifications

- **Existing CO_2 pipeline specifications are mainly for gasification units**
  - No NO_x guidelines
  - Limited SO_x guidelines
  - Significant variation in other specifications
    - H_2O: -5°C to -40°C dew point
    - O_2: 10 to 100 ppmv

- **Specifications assumed for this study:**
  - 175 bara
  - 90% CO_2 capture (DOE target)
  - H_2O reduced to 30lb/MMSCF (~600ppmv)
    - existing Kinder Morgan specification
  - No restriction on other gas components
    - Possibility of co-sequestration
    - Chance to assess tradeoff between purification cost and sequestration cost

Basic CO_2 CPU Process



3 processes

- No purification
- Partial condensation at cryogenic conditions (cold box)
- Cold box, including distillation to achieve 1ppm O_2

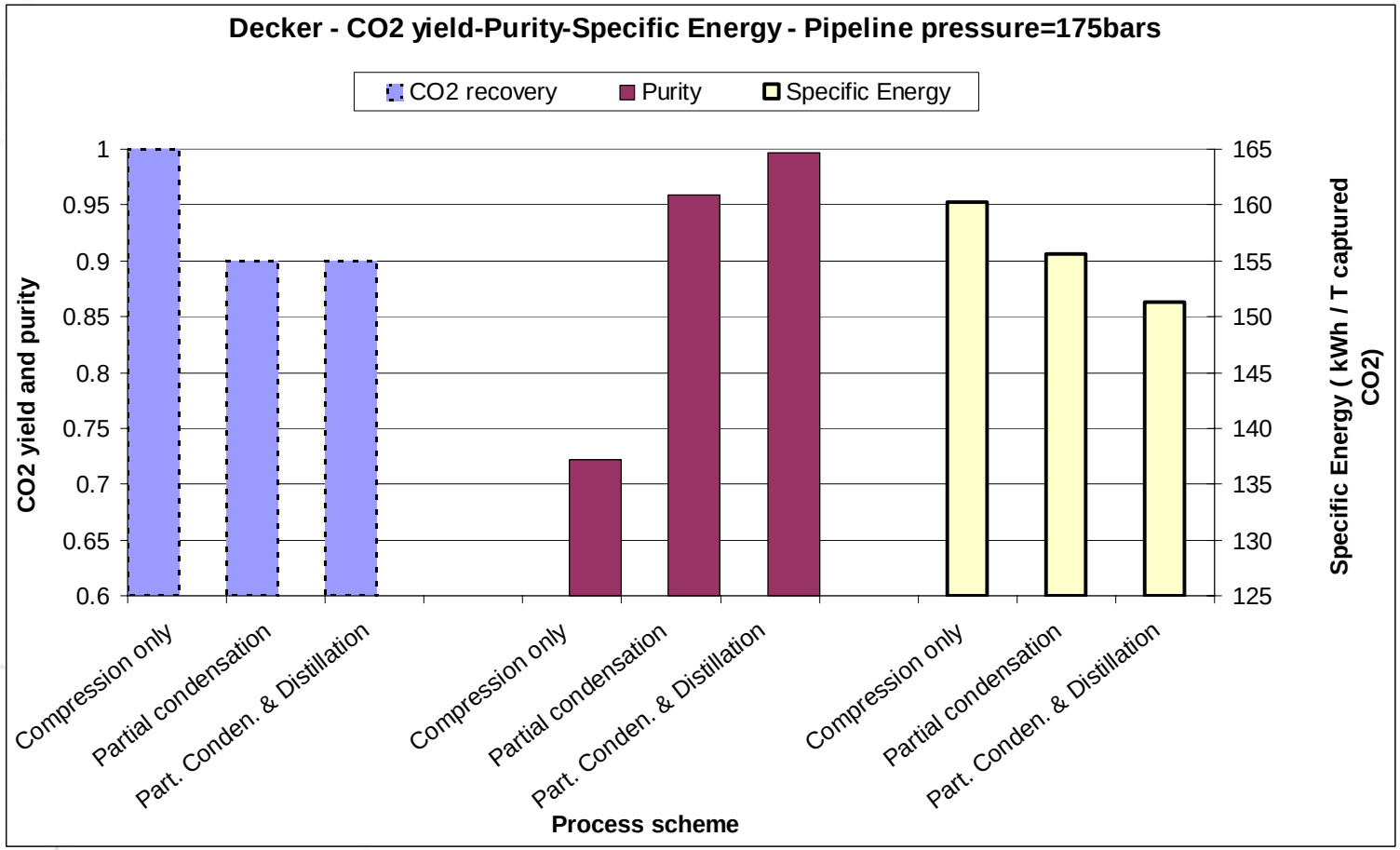
NOTE:

- All simulations done for dry flue gas

- 3 coals considered but only Decker coal results shown on subsequent slides

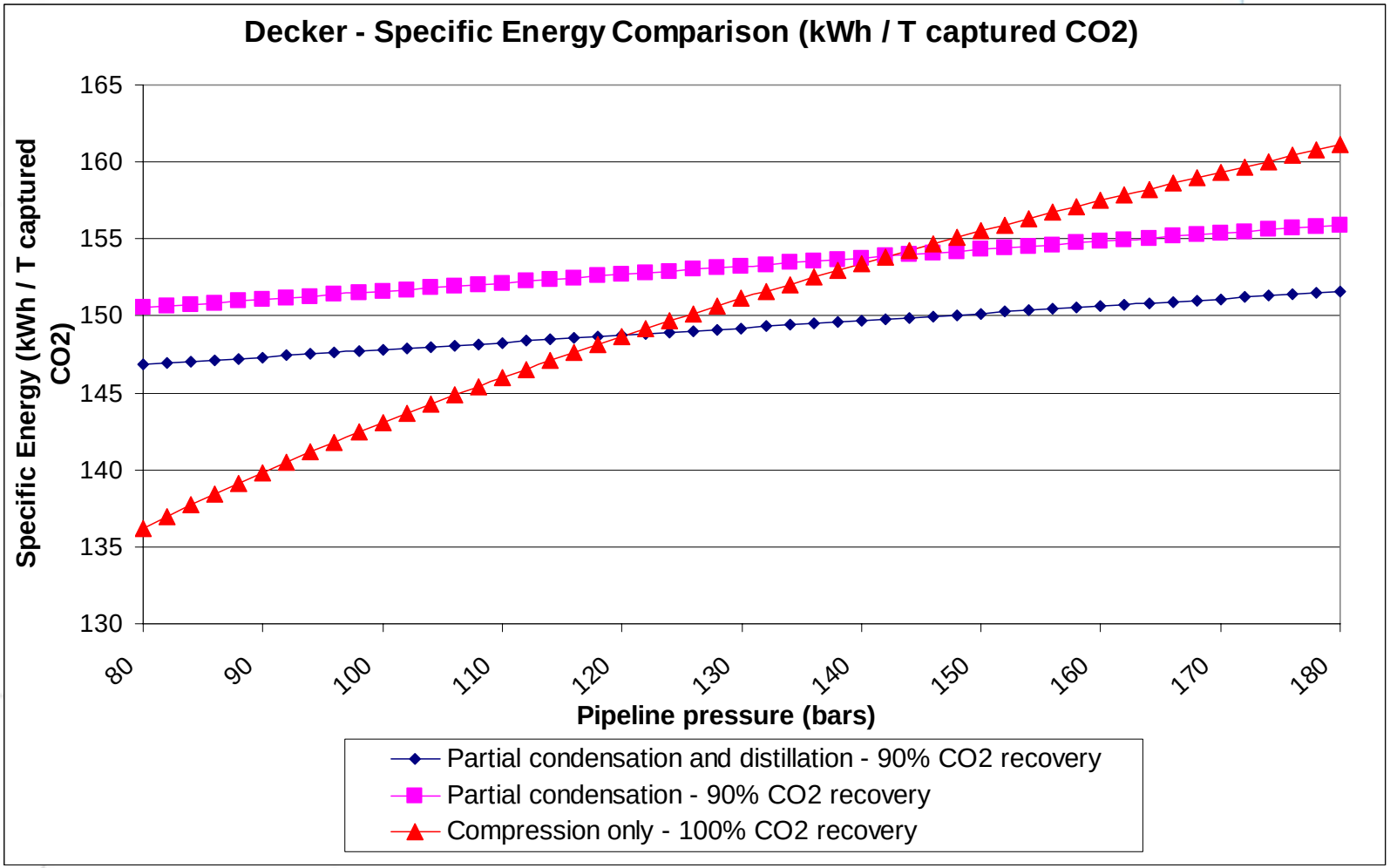
Effect of Gas Purification on Operating Cost

- **Compression power was the only operating cost considered**



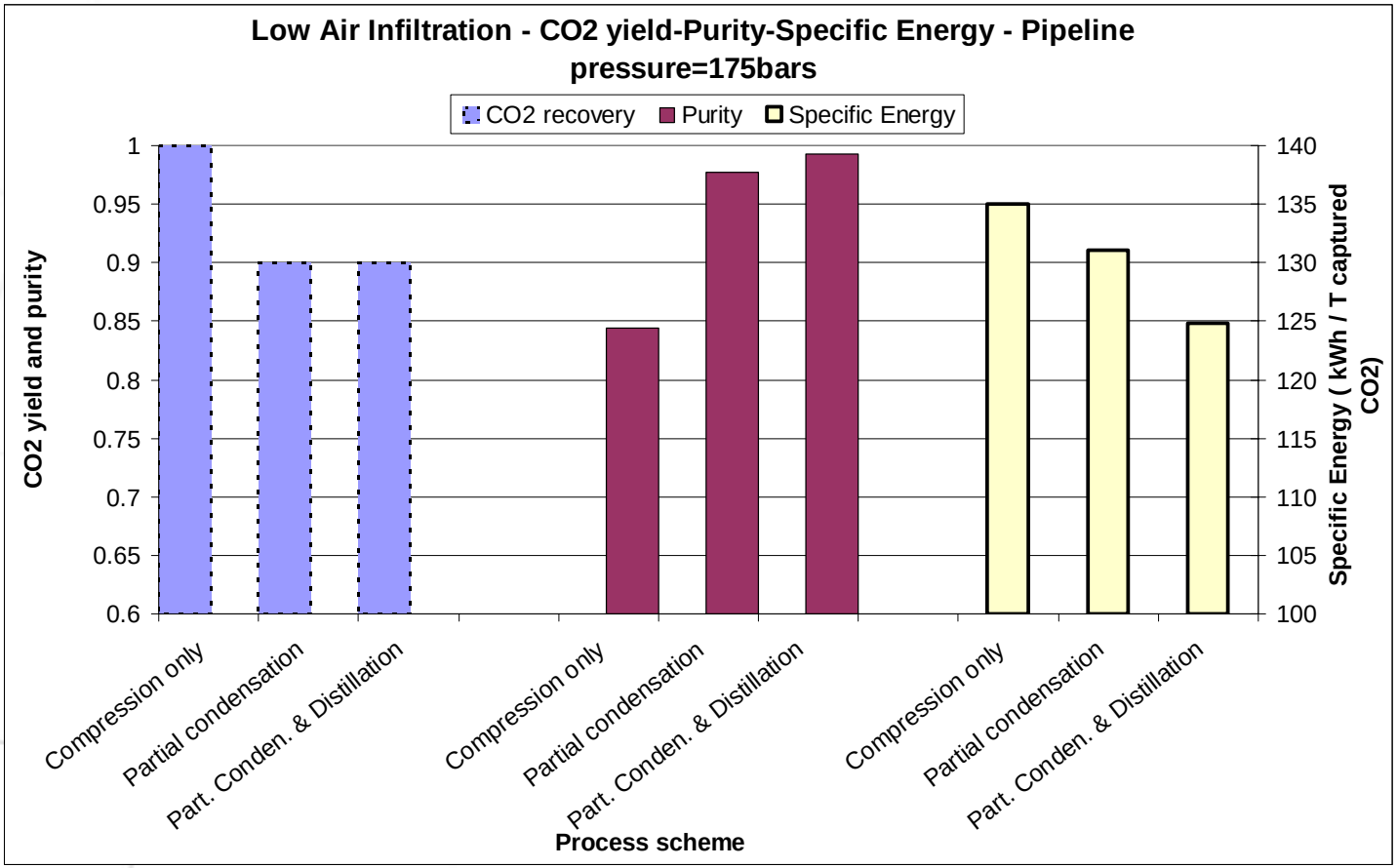
- **Addition of a cold box REDUCES specific energy requirement!**
  - Will a different pipeline pressure requirement give different results?

Effect of Product Pressure on Energy Need



- **Above 125 bar (1815 psi) pipeline pressure, cold box + distillation has lowest specific energy requirement**

Effect of Air Infiltration



Compare with 150-160 kWh/ton

- **Low air infiltration reduces power need by 15-18%**

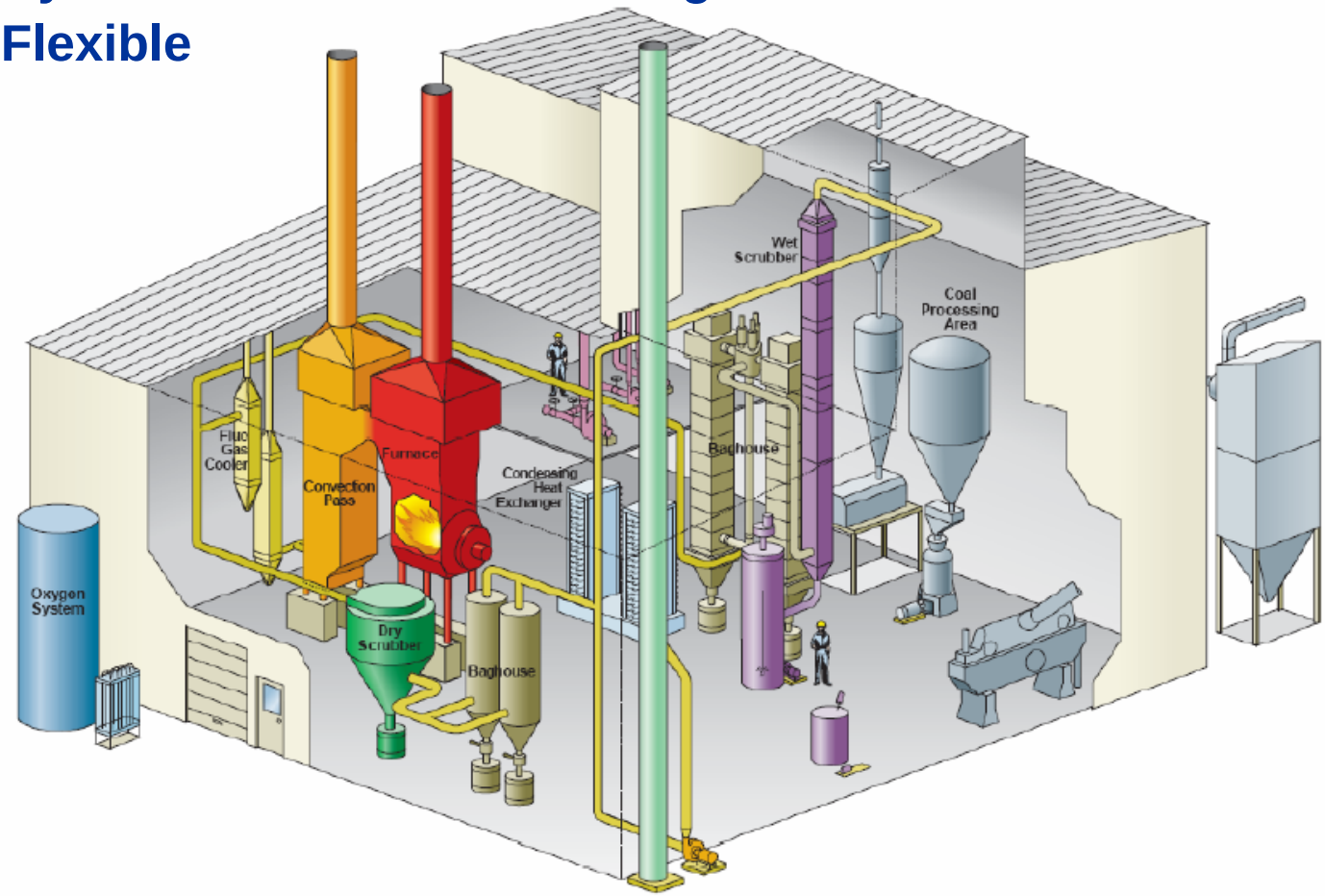
Effect of Distillation Column

Item	Decker		
	No purification	Cold box	Cold box + distillation
	mol%	mol%	mol%
CO_2	72.15	94.47	99.71
N_2	19.76	3.28	0.00
O_2	4.85	1.08	0.00
SO_2	0.16	0.23	0.25
Ar	3.03	0.90	0.00
NO_2	0.03	0.04	0.05
CO	0.02	0.00	0.00

Distillation column does not remove SO_x and NO_x appreciably
- These components can be removed, if desired.

Phase I Activities continued …

- **Task II: Pilot-test evaluation**
  - **1.8 MW_t facility constructed**
  - **Cyclone and wall-fired configurations**
  - **Flexible**



  - **Testing starts August 1, 2008**

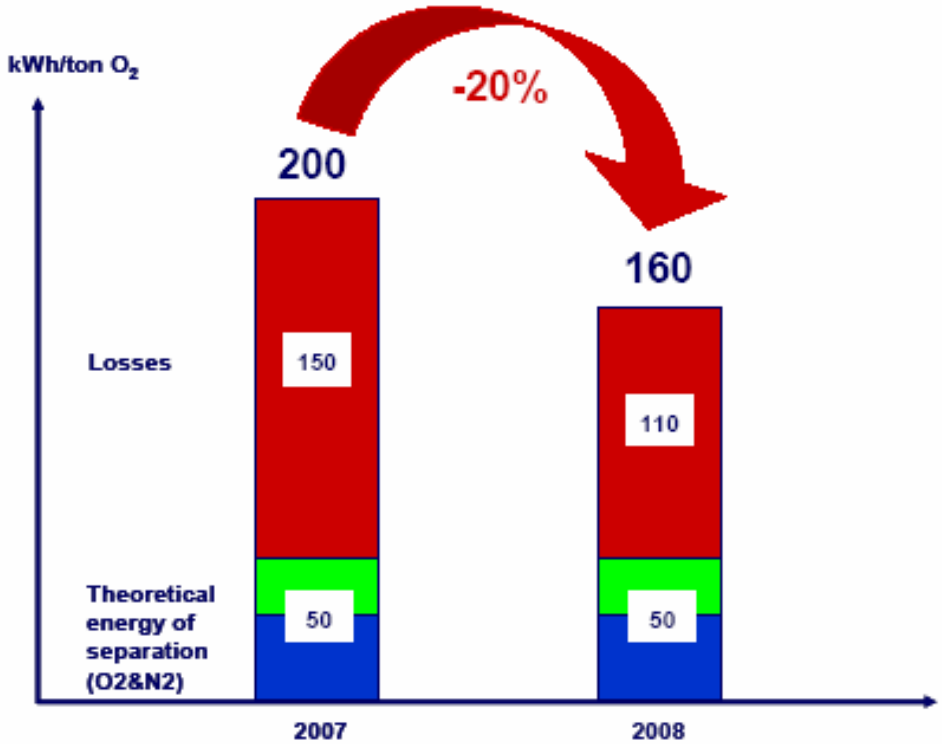
Phase II Activities

- **Task 3: Boiler selection & data gathering**
  - **28 cyclone boilers were identified as potential candidates**
  - **Short-listed 7 units**
    - Located in Mid-west and Western US

Plant Designation	Electric Generation (MW_e)	Vintage (Year Built)
A	660 × 2	1967; 1968
B	521	1974
C	600 × 2	1972; 1977
D	605 × 2	1971; 1973
E	617	1972
F	440	1977
G	650 × 2	1963

Phase II Activities continued …

- **Tasks 4 & 5: Engineering design & Economic analysis**
  - **ASU is a major cost of the overall process**
    - ~50% of parasitic power
    - Improvements in ASU efficiency can lower parasitic power requirement significantly
  - **Air Liquide continues to improve the ASU process**



Acknowledgement

US Dept. of Energy

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CO2 Pipeline Specifications

AIR LIQUIDE

	Dixon Consulting EOR, Aug 2001	Kinder Morgan EOR, 2003	Industry Working Group Prelim Spec 2005	Dakota Gasification Aug 2005	Canyon Reef EOR, Dec 05	Strawman Composite
CO_2		95% min	95% min	96.80%	95% min	97% min
CH_4	<1.0%			0.30%		<1.0%
C_2H_6	<1.0%			1.0%		<1.0%
C_3+	<1.0%					<1.0%
Total HC's		5% max	5% max		5% max	<3.0%
H_2	<1.0%					<1.0%
CO			0.1% max			0.5% max
N_2	<2.0 N_2 & H_2	4% max	4% max		4% max	1-3% max TBD
Other Inerts						
Total Inerts						<3%
O2	<2.0 ppmw	10ppm	100 ppmv max		10 ppmv max	2 ppmv
H_2S	<100 ppmw	10-200 ppm	10-200 ppmv max	1.10%	1,500 ppmv max	10-200 ppmv TBD
SO_2	<5.0 ppmw					5 ppmv
Total Sulfur	<300 ppw				1,450 ppmv max	10-200 ppmv
H_2O	<-5C DP @ 300 psia	30 lbs/MMCF max	<-40C DP	Bone dry	28 lbs/MMCF max	<1 ppv
Hg			Controlled			TBD
Other				0.90%		TBD
Glycol		0.3 gal/MMCF max	0.174 m3/MMm3		0.3 gal/MMCF max	TBD
Methanol						TBD
Selexol						TBD
Amine						TBD
Delivery Pressure			2,000 psia	2,190 psia		2,200 psig
Temperature		120F max	120F max	(2,700 psig @ source)	120F max	120F max

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