Unity Power Alliance

One Goal – Zero Emissions

Pressurized Oxy-Combustion

An Advancement in in Thermal and Operating Efficiency for Clean Coal Power Plants

Jan, 2013

Advantages of Pressurized Oxy-Combusition

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- POXC™ can be retrofitted into existing plants utilizing existing infrastructure of steam cycle, coal handling and transmission lines.
- POXC™ plants can achieve net efficiency's >35%
- LCOE < 1.3X vs conventional PC
- Proven ability to utilize low rank coals
- Virtually no emissions; Fly Ash eliminated and vitrified slag classified as inert in the EU
- Dramatically improved water profile
- Captures CO2 at pressure requiring minimal CPU treatment

POXC™: Regarded as the most efficient and cost effective carbon capture combustion technology for coal, natural gas and biogas

[1]*Study by Canadian government (CANMET)*

Technology Status of Pressurized Oxy-Combustion

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1. Proven Technology: 8+ Years of results at 5 and 15MWth
2. Outstanding environmental results: CO2 ready for CCUS with minimal CPU treatment
3. Engineering sufficiently advanced to complete 50MWth Pilot and 320MWe Demonstration
4. DOE award to study optimized pressure

Plant 15 MWth - Jurong, Singapore

Technology, Performance, and Benefits

POXC™– Poised for Success

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- Clean Power: 5MWth Pilot in Italy– *in operation since 2004*
  - Pressurized oxy-fuel combustion of coal has been proven to be economic and environmentally sound.
  - All emissions are virtually eliminated
  - Modular Units applicable for brownfield and greenfield sites
  - Flexible boiler allows integration into grids with increasingly variable demand patterns
  - Ability to utilize low rank coals

Cost Effective & Grid Compatible

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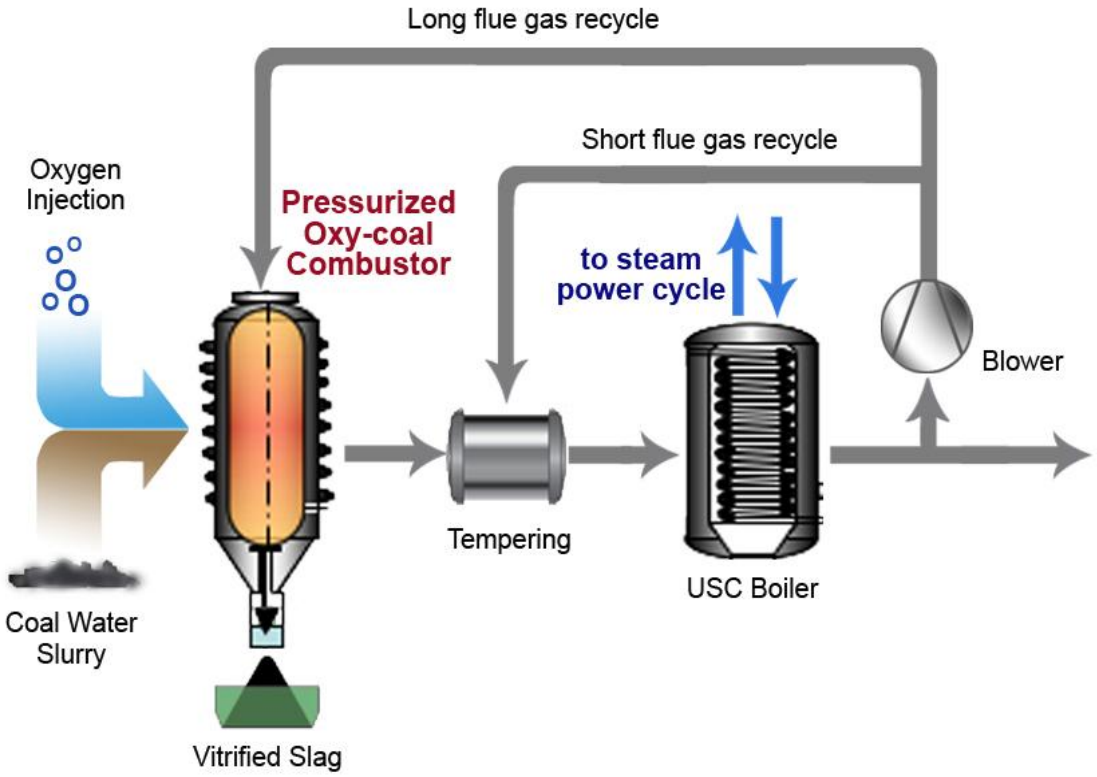

- New POXC™ Process can replace existing Boiler
- Brownfield application can utilize existing turbines
- Size POXC™ for power plant output steam requirements
- Tremendous Energy cycle flexibility: 10-100% in 30 min.
- Much smaller footprint, capable of retrofit into existing facilities
- Captures all emissions (*e.g.*, CO_2, S, Hg, etc.) for sale or sequestration
- Plant will reduce water consumption by 50-60%: large environmental benefit.

Key feature with new boiler design is ability to vary production rates quickly, allowing flexibility to utilize low-cost coals while accommodating Electric Grid load variances due to solar and wind inputs

320 MWe CCUS Power Plant

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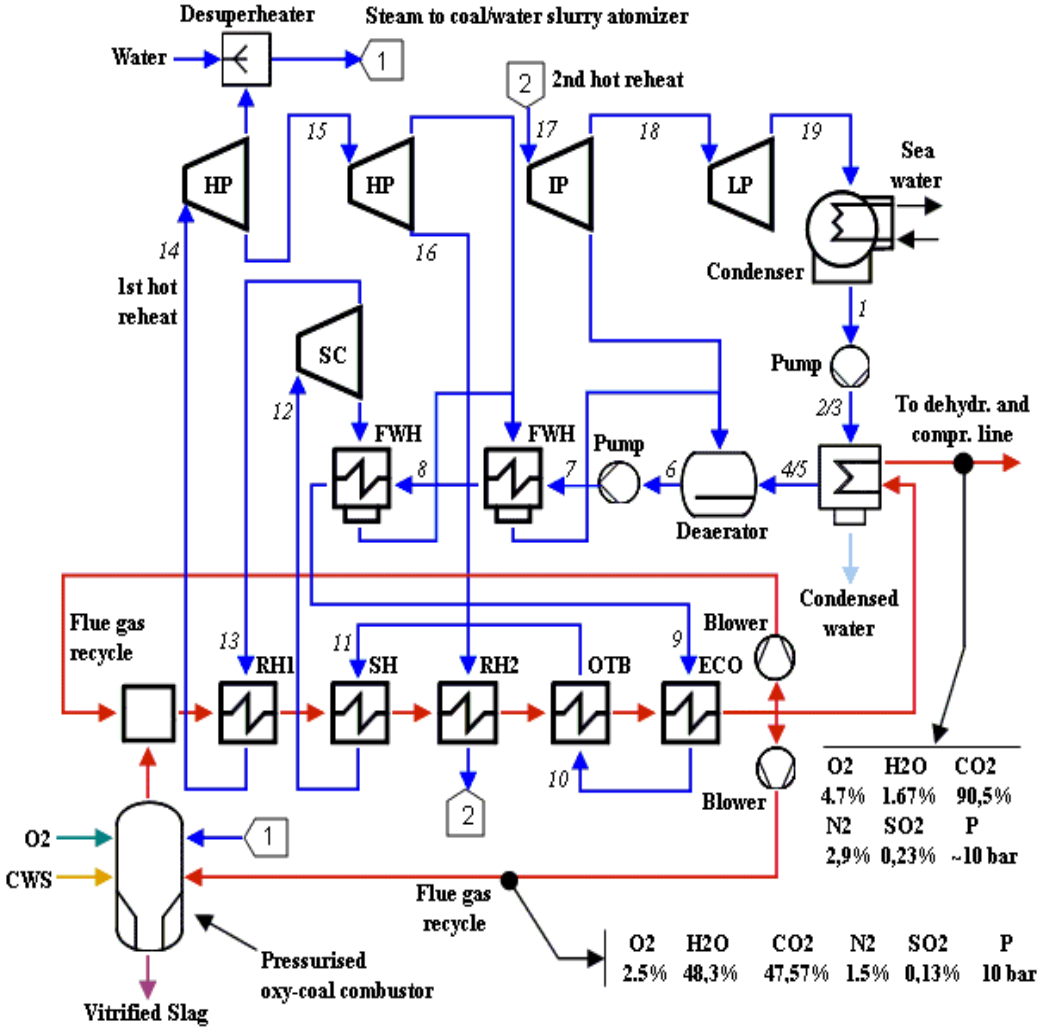
Target:

- Power:
  > 320 MWe
- FEED:
  Low rank coals
- Net efficiency:
  > 35 %
- Capex:
  < 1900 €/kW



Energy from Coal

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NO FLUE GAS !!!
NO STACK !!!

EFFLUENTS ARE READY FOR EOR or CCUS

Chemical analysis of the effluents	Isotherm PWR®
CO	< 1 mg/m^3
NOx	< 100 mg/m^3
SOx	< 30 mg/m^3
TOC	<0.05 mg/m^3
HCl	< 0.1 mg/m^3
PAH	<0,0001mg/m^3
Dust (total)	< 1 mg/m^3
PM 2.5	<10 µg/m^3
Dioxin, Furans	<0,0001 ng/m^3
Heavy metals	< 0,1 mg/m^3
SOOT	Zero
CO2 v (in flue gas)	>93 %

Normalized LCOE

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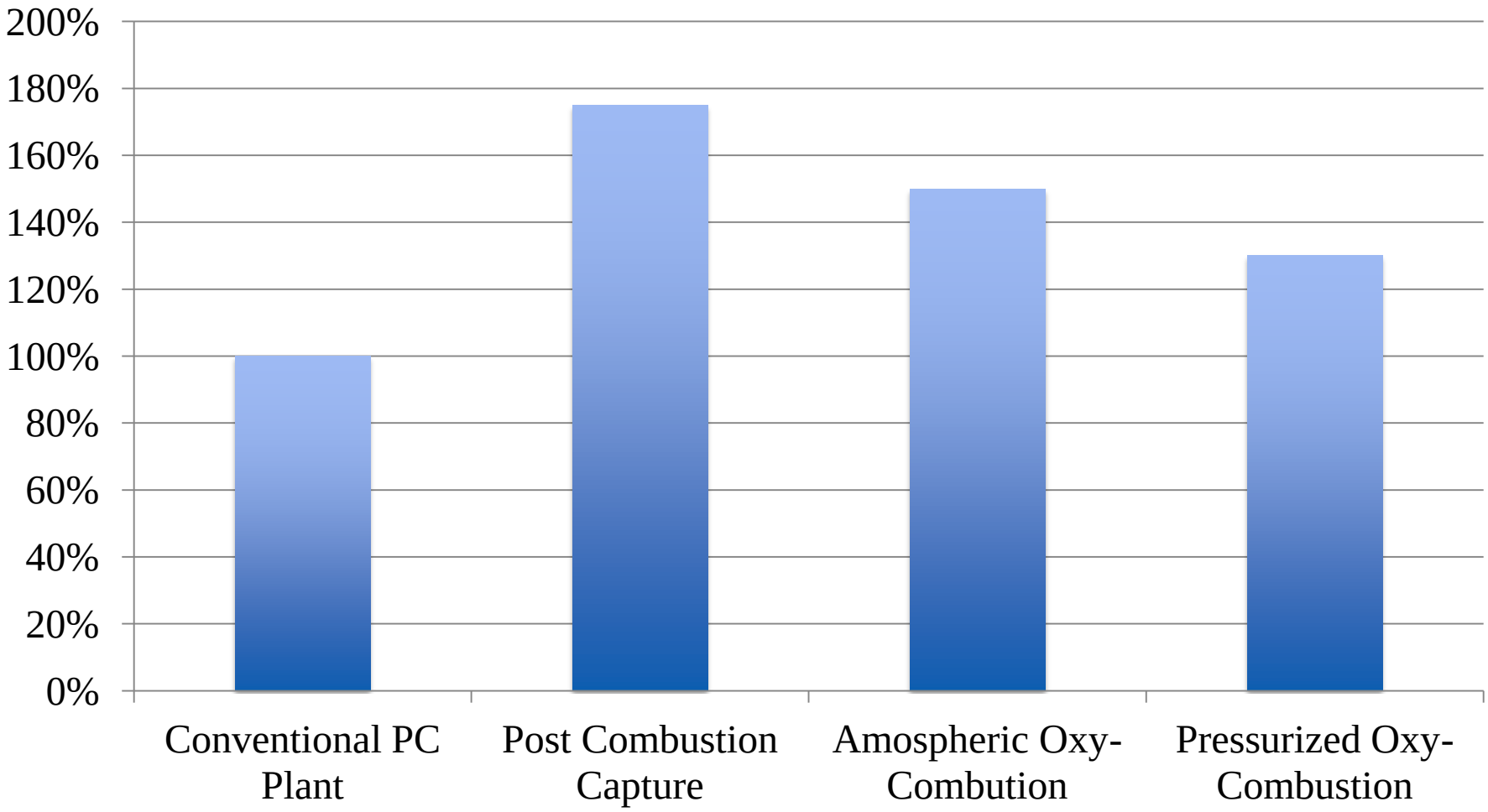

Cycle performance

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Assumptions

- O2 Production cost: 0.275 kWh/kg
- O2 mole fraction @ outlet: 2.5%
- O2 Purity: 98%
- Convective Boiler Inlet T: 820°C
- Combustor ΔP/P: 1%
- Combustor Heat Loss: 2%

Cycle Performance Summary

	CO_2 Capture Case
Gross Performance	
Net Fuel Input	903 MW
Gross Power	430 MW
Gross Efficiency	47.6%
Plant Auxiliaries	
ASU	75 MW
CPU	17 MW
Other Plant Auxiliaries	18 MW
Total Auxiliaries	110 MW
Net Performance	
Net Power	320 MW
Net Heat Rate	10158 kJ/kWh
Net Efficiency	**35.44%**

Why are pressurized conditions related to high efficiency?

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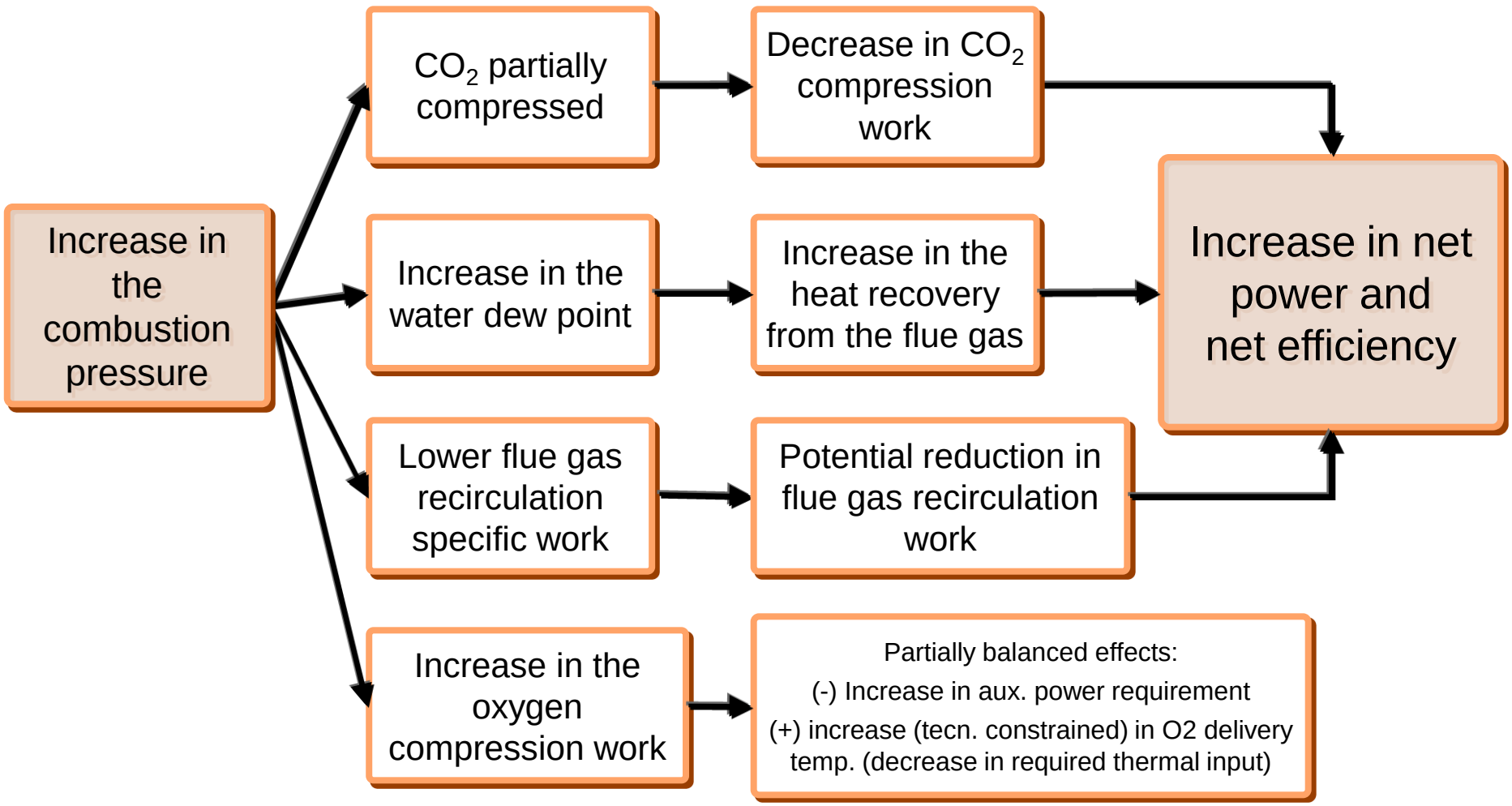

Pressurized OxyCombustion:
Latent Heat of Water is Available at Useful Temperature;
CO_2 Condenses to Liquid at Ambient Heat Sink Temp.

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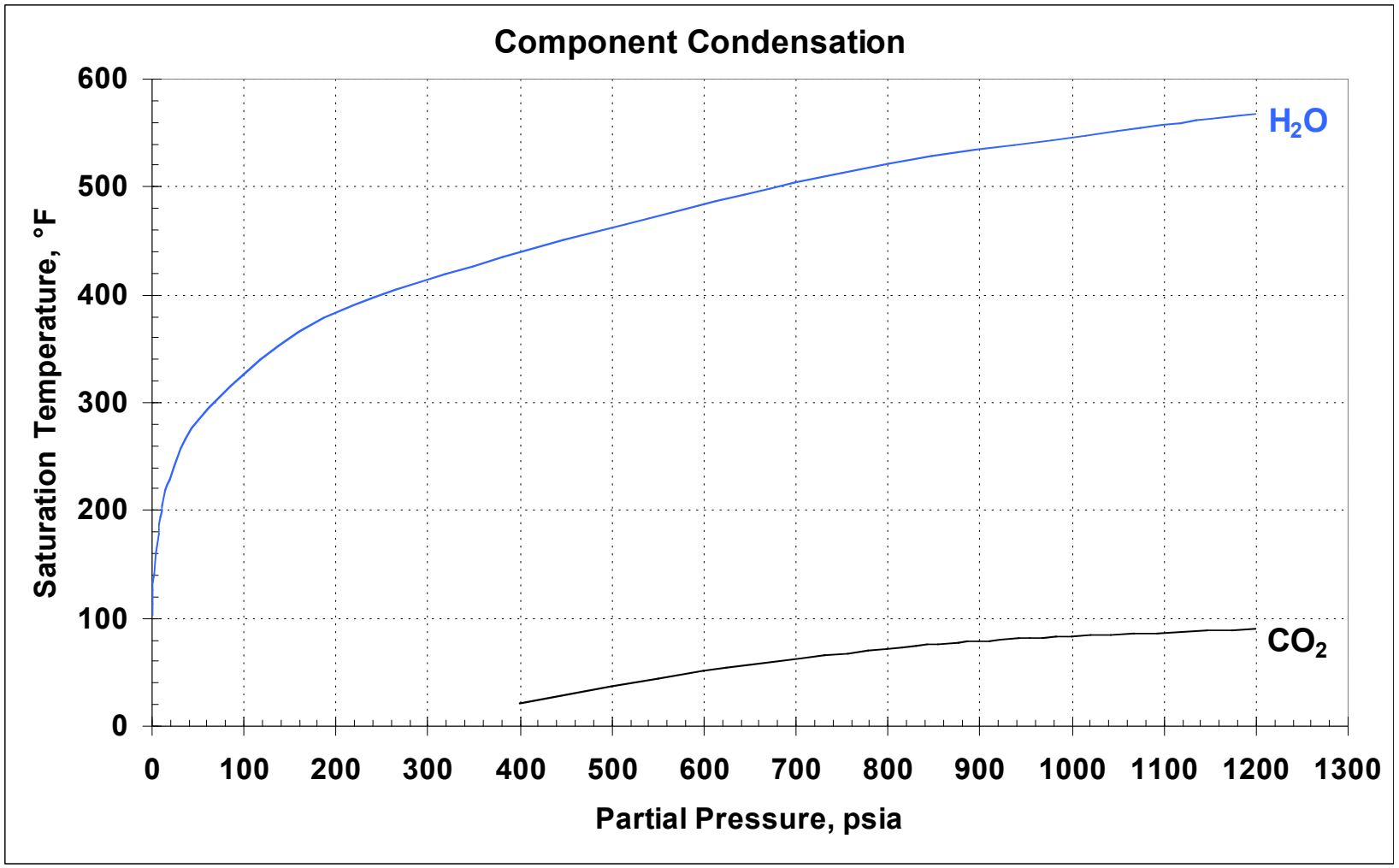

POXC® Efficiency vs. Pressure: Improvement over Ambient Oxy-combustion

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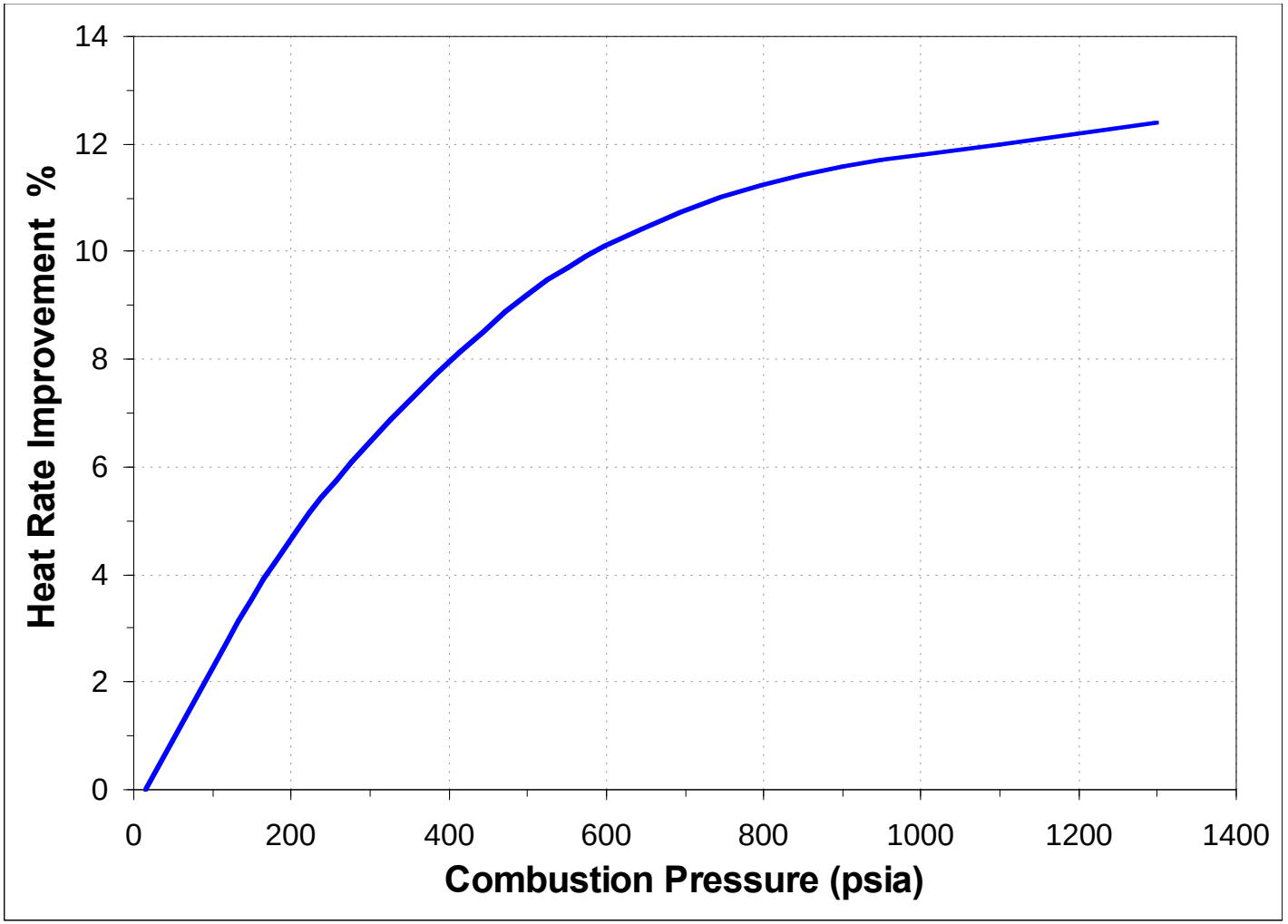

Why are COE and CAPEX reduced ?

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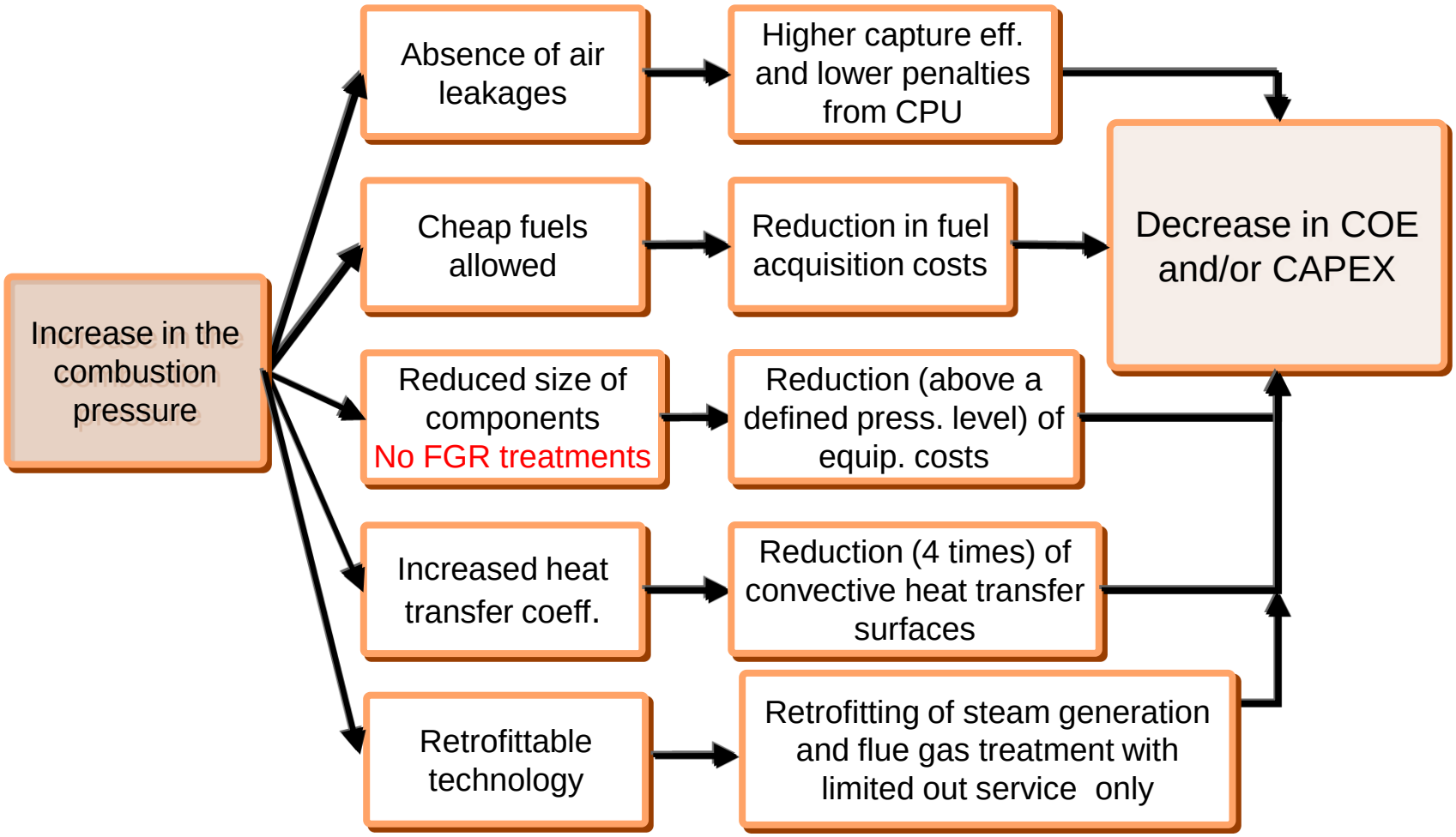

The Market and Beneficiaries

Repowering Applications

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- Potential market 50-100 GW.
- POXC® replaces steam generator; two options:
  - Complete replacement of existing steam generator.
  - Operate in parallel with existing steam generator.
- Older steam generator could remain as backup.
- Existing BOP and steam turbine utilized.
- Potential for turbine steam path upgrade.
- POXC® steam generator will match any turbine / BOP requirement.

New Plant Applications:
POXC can be Designed for Any New Plant

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- POXC® can be designed for any steam cycle:
  - Subcritical, supercritical, UltraSuperCritical (USC).
  - Modular design accommodates double reheat, with low pressure drops and enhanced efficiency.
  - Feedwater heating cycle integration in plant design will optimize plant efficiency.
  - Subsystem heat recovery / integration less than for ambient-pressure oxy-combustion.
- Fuel-flexible: Wide range of coals, pet coke, some biomass. Very little efficiency penalty for high-moisture fuels.
- Partial oxidation / gasification is an option provided in patents.
- Compact footprint, modular vessel designs.
- Up to ~320 MWe per train. Multiple trains for larger plants.

Repowering Existing Units: Emissions Regulations: Retrofit, Repower, or Retire?

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MACT emissions regulations: SOx, NOx, Hg, PM

- Plants currently without SCR or FGD would require investment, ~$30/MWhr.
- Plants currently with some emissions controls may require ~$6/MWhr.
- If CO_2 is also regulated,
  - One option is to retrofit with both MACT controls and post-combustion CO_2 capture system (PCC).
  - Alternative is to repower (replace boiler system) with POXC integrated, multi-pollutant capture system.
  - Cost of CO_2 avoided can be thought of as the 'break-even' valuation of CO_2 that would result in the non-capture base plant having the same LCOE (or dispatch cost) as that from the capture case. (In other words, it is the CO_2 'tax' that would justify installing the retrofit or repowering equipment.)

Emissions control cost range representative of 90% of the total capacity requiring some additional controls.
Sources include HIS CERA and Ventyx.
$6/MWhr ~ $460/kW; $30/MWhr ~ $2300/kW; based on 25 yrs, 8.47%, 85% capacity factor.

Repowering Existing Units
Benefits

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Re-Powering America's coal-fired power plants with POXC® means that:

- In addition to capturing CO_2 in a supercritical state, SO_x, NO_x, chlorides, mercury, and particulate emissions are eliminated, meeting EPA air regulations.
- Much of the existing power generation and transmission infrastructure can be utilized, minimizing new investment.
- Converted plants may utilize complete range of coal types, pet coke, or biomass.
- Jobs will be kept and created instead of lost.
- State and local government will maintain tax bases.
- Higher electricity prices that would have resulted from expensive plant replacements will not harm industry and consumers.
- POXC® would make a significant contribution towards addressing CO_2 emissions or providing the options for future implementation.

Coal Market Evaluation:
200 GW CCS Market Represents $17-24B Annually in Coal Revenue

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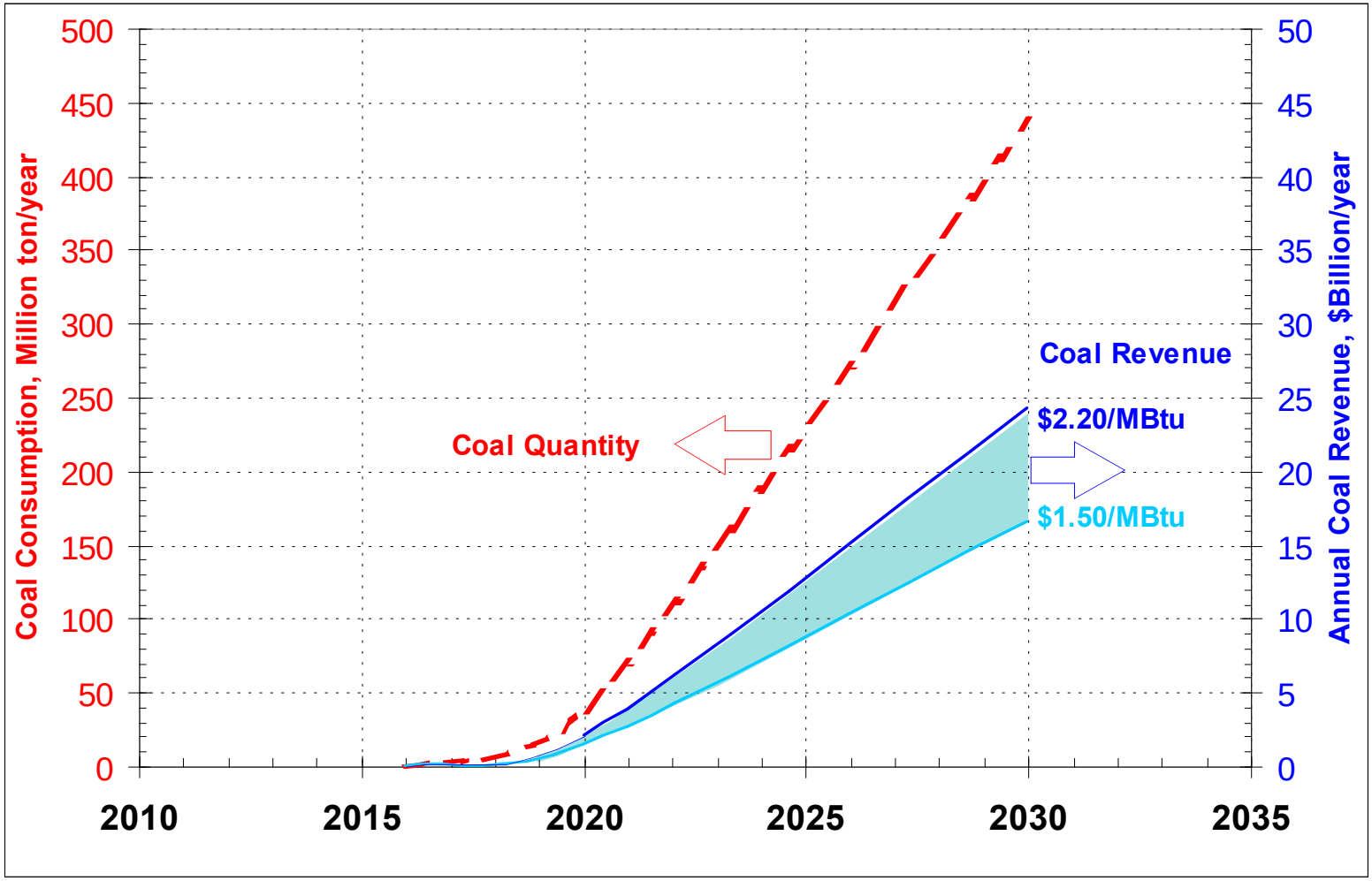

ASU Oxygen Requirement

Each 600MWe plant represents > $100MM/yr Oxygen contract

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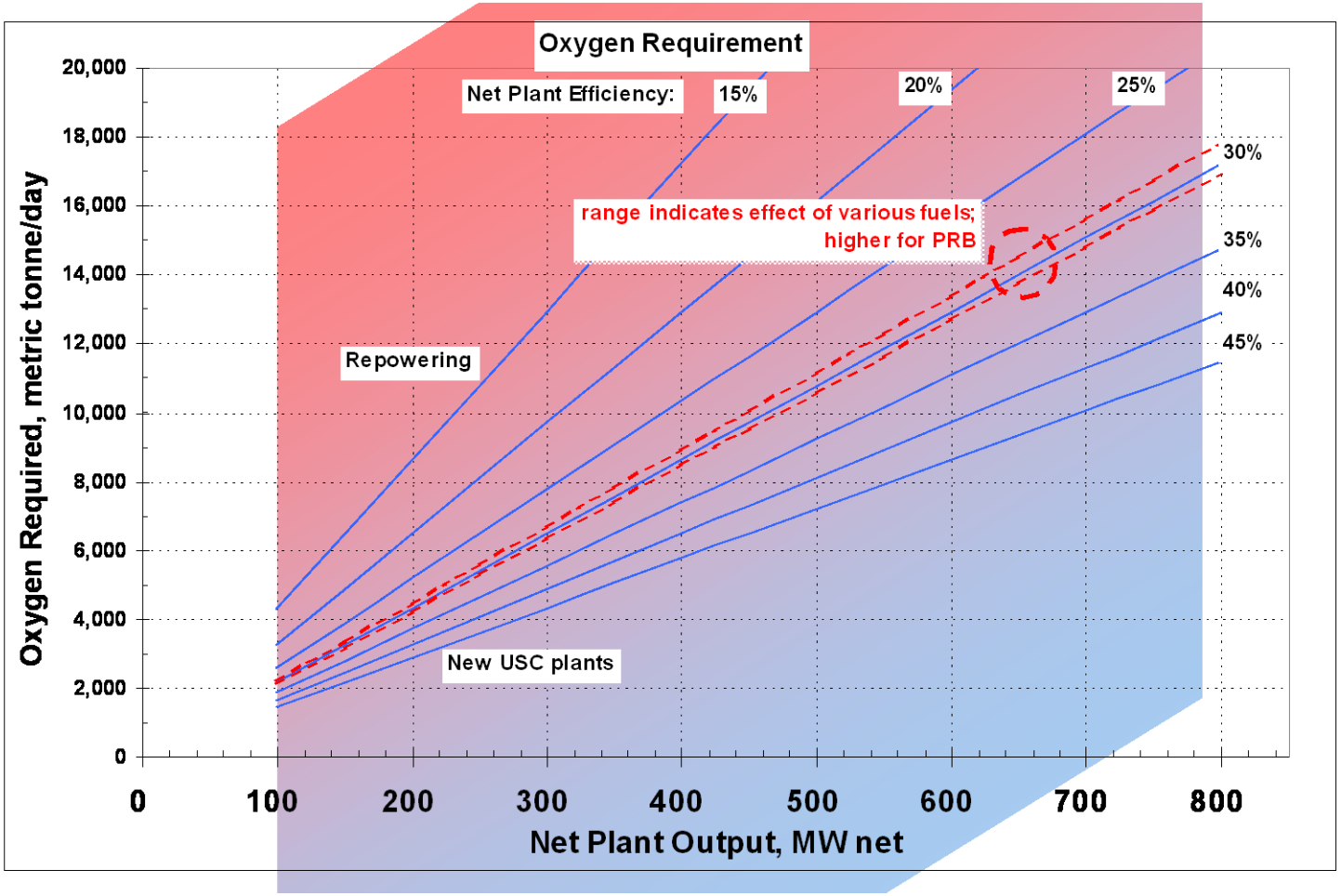

POXC® Advantage
Summary

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- Proven carbon capture technology at 5 and 15 MW.
- Highest plant efficiency and lowest cost among CCS options.
- Suitable for repowering existing plants and for optimized new plants.
- Scale is compatible with EOR needs.
- Multi-pollutant capture system exceeds all pending emissions regulations.
- Technology that has global potential.

Ready for Deployment

50 MWth Pilot Plant

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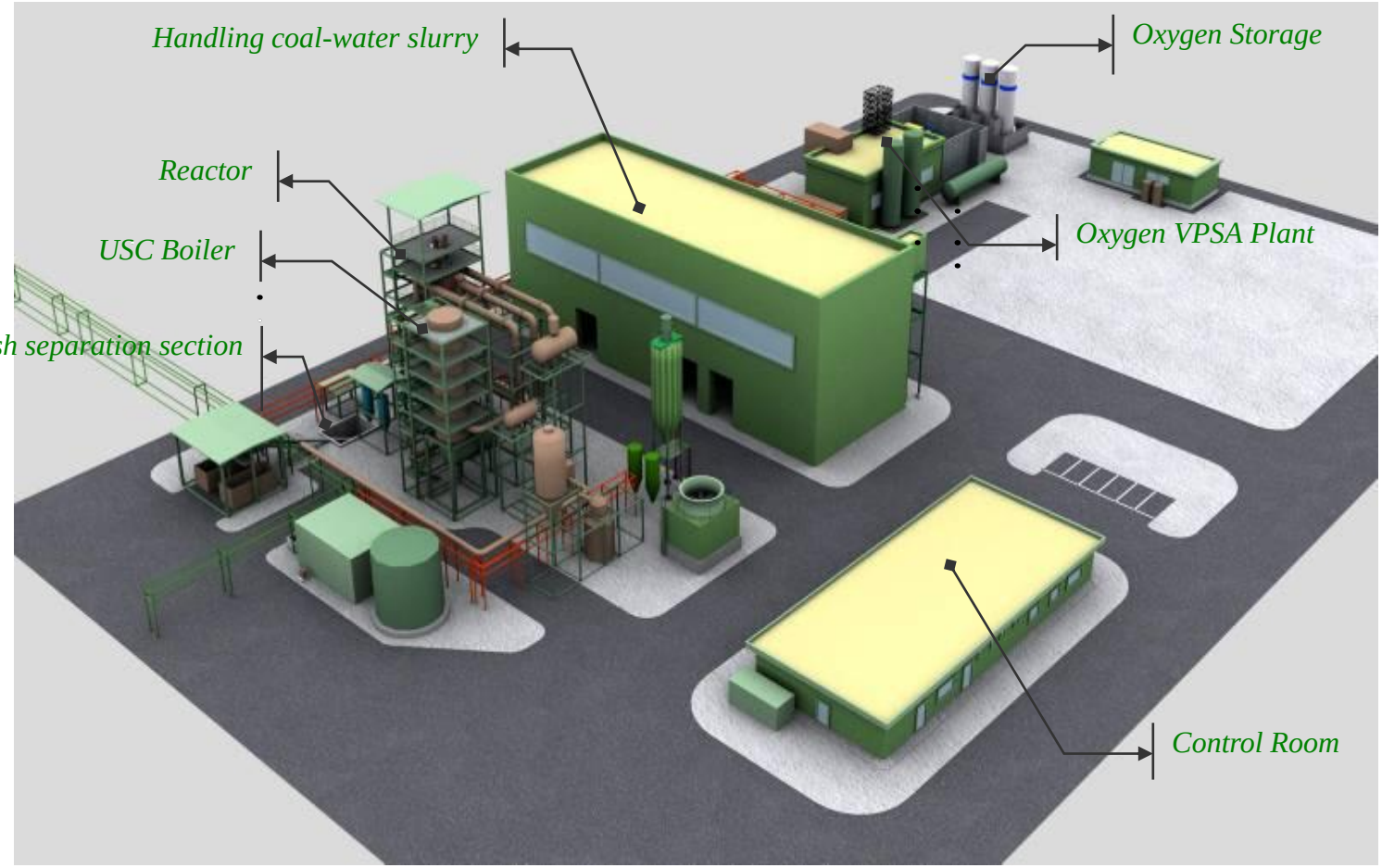

Thank-you!

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ENEL –MIT cost assessment

Thermodynamic Cycle and data costs assessment

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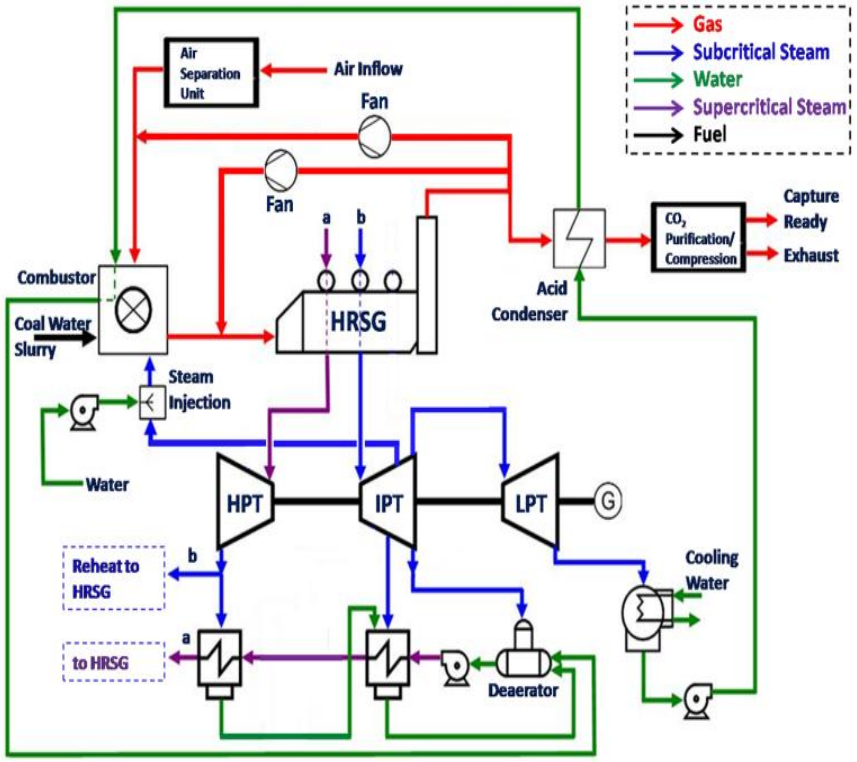

Parameters	Values
Plant Life (years)	25
Plant Capacity (%)	85
Contingency (% of capital costs)	15
Discount Rate (%)	10
Interest Rate (%)	10
Inflation Rate (%)	4
Overall Tax Rate (%)	38
Debt Term (years)	15
Depreciation Life (years)	25
Debt vs. Equity (%)	70/30
Fixed O&M Cost (% of capital costs)	4
Variable O&M Cost ($/kWh)	0.002
Coal Price ($/GJ-LHV)	2
Water Price ($/$m^3$)	0.28