Reinhold Environmental Ltd.

2007 NOx Round Table & Expo Presentation

February 5-6, 2007 in Cincinnati, OH

Clean Coal Combustion
Presentation to Reinhold Conference

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CO_2 Mitigation Options for Coal Based Power

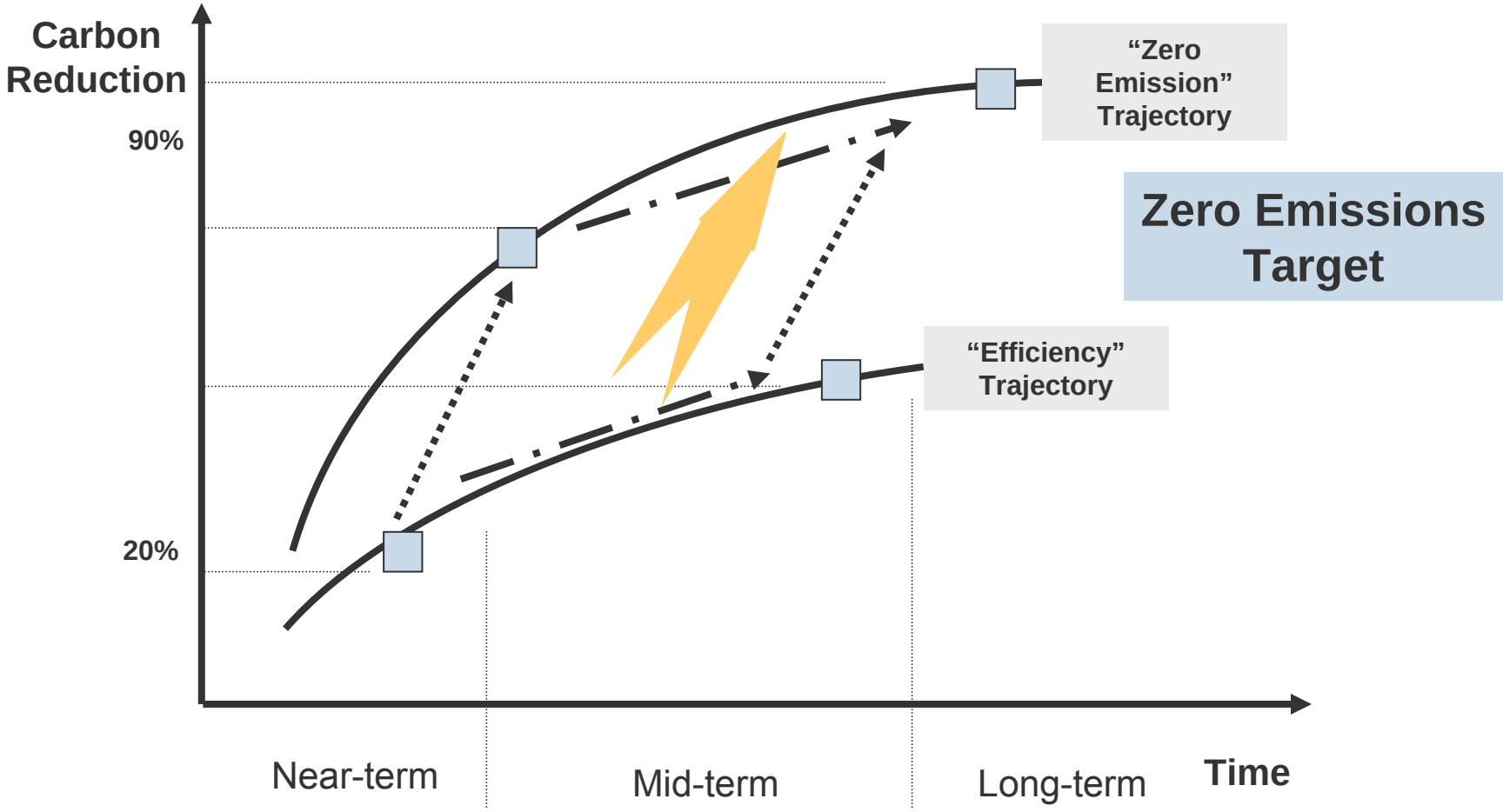
- Increase **efficiency**
  - Maximize MWs per lb of carbon processed
- Fuel switch with **biomass**
  - Partial replacement of fossil fuels = proportional reduction in CO_2
- Then, and only then ….**Capture** remaining CO_2 for EOR/Sequestration
- **Logical path to lowest cost of carbon reduction**

CO_2 Capture Approaches

- Post Capture
  - Adsorption
  - Absorption
  - Hydrate based
  - Cryogenics / Refrigeration based
- Oxy-fuel Firing
  - External oxygen supply
  - Integrated membrane-based
  - Oxygen carriers (chemical looping)
- Decarbonization
  - Reforming (fuel decarbonization)
  - Carbonate reactions (combustion decarbonization)

Innovative options continue to emerge and develop

Pathway to zero emission power for fossil fuels



Integrated strategy for `zero emission`

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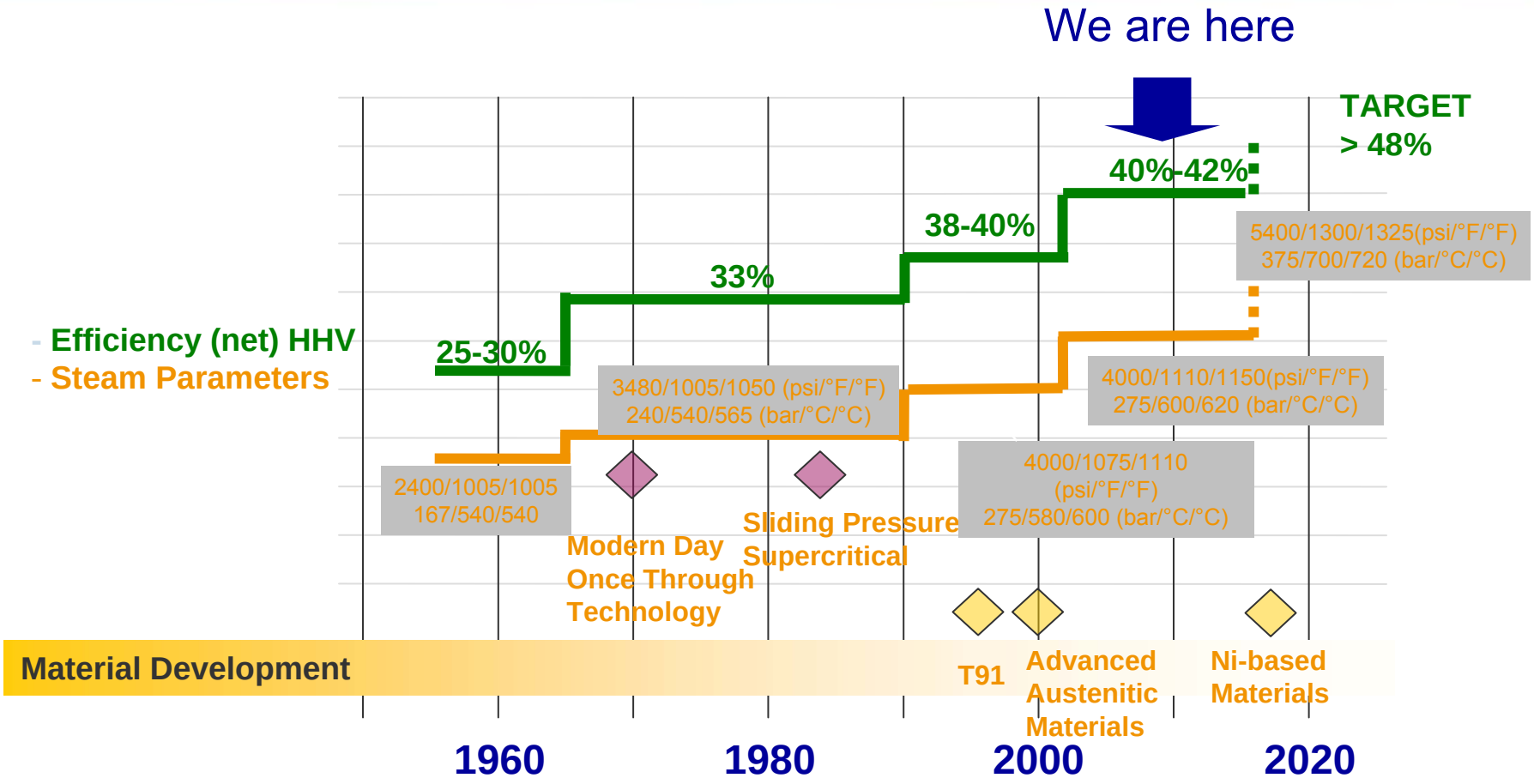
Progression of Plant Efficiency via Advanced Steam Conditions and Plant Designs



Continuing Advancements = lower fuels costs and emissions

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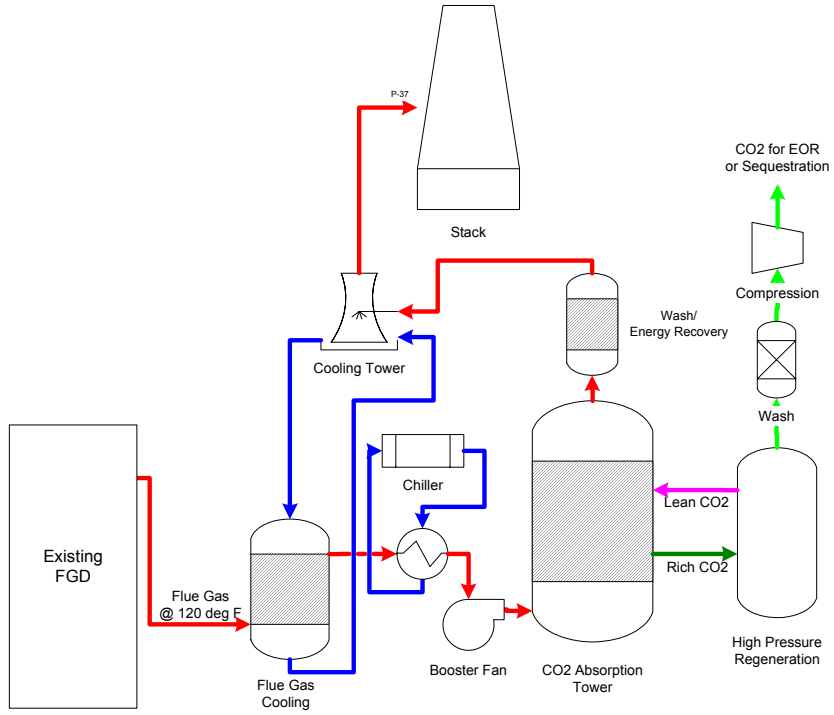
Low Carbon Combustion
Alternate Paths to CO_2 Capture

Technology	Status
CO_2 Scrubbing options – ammonia based	**Demonstration in 2006. Advantage of lower costs than Amines.** **Applicable for retrofit & new applications**
Advanced Amine Scrubbing	Further Improvements in Solvents, Thermal Integration, and Application of Membranes Technologies Focused on Reducing Cost and Power Usage – Multiple suppliers driving innovations
CO_2 Frosting	Uses Refrigeration Principle to Capture CO_2 from Flue Gas. Process Being Developed by Ecole de Mines de Paris, France, with ALSTOM Support
CO_2 Wheel	Use Regenerative Air-Heater-Like Device with Solid Absorbent Material to Capture ~ 60% CO_2 from Flue Gas. Being Developed by Toshiba, with Support from ALSTOM
CO_2 Adsorption with Solids	Being Developed by the University of Oslo & SINTEF Materials & Chemistry (Oslo, Norway), in Cooperation with ALSTOM

Chilled Ammonia Process

- High efficiency capture of CO_2
- Low heat of reaction
- High capacity for CO_2 per unit of solution
- Easy and low temperature regeneration
- Low cost reagent
- No degradation during absorption-regeneration
- Tolerance to oxygen and contaminations in gas



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Basic Comparison with MEA

	Supercritical PC Without CO_2 Removal	SCPC With MEA CO_2 Removal Parsons Study	SCPC With NH_3 CO_2 Removal Current Study
Coal Feed rate, lb/hr	333,542	333,542	333,542
Coal heating value, Btu/lb (HHV)	11,666	11,666	11,666
Boiler heat input, MMBtu	3,891	3,891	3,891
LP Steam extraction, lb/hr for reboiler	0	1,215,641	179,500
Steam Turbine Power, kWe	498,319	408,089	484,995
Generator loss, kWe	(7,211)	(5,835)	(7,018)
Gross plant, kWe	491,108	402,254	471,301
Plant Auxiliary Load (IDF, FGD, BFW pumps, Water pumps, Cooling Towers, CO2 unit, Chillers, CO2 compressor, BOP), kWe	(29,050)	(72,730)	(53,950)
Net Power Output	462,058	329,524	421,717
Net efficiency, % HHV	40.5	28.9	37.0
Avoided Cost, $/ton CO2	Base	51.1	19.7

We Energies Pleasant Prairie
Host Site Location for 5MW Pilot

we energies

EPRI ELECTRIC POWER RESEARCH INSTITUTE

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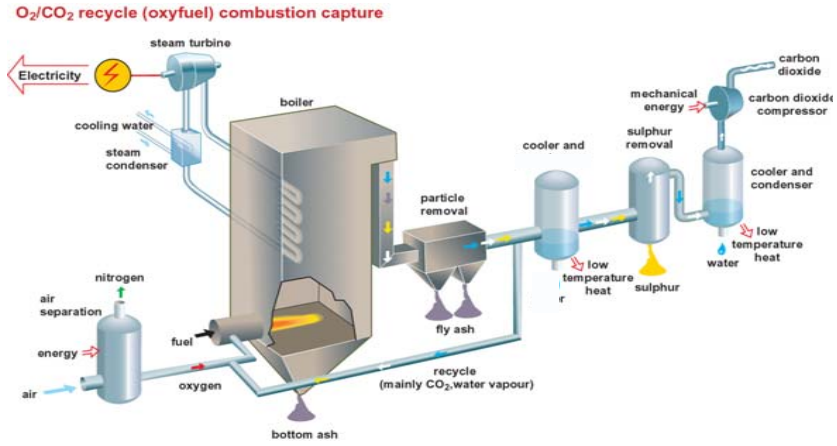
Oxygen-Fired Combustion

30 MWth Schwarze Pumpe Vattenfall

- Near-term solution for CO_2 capture
  - Uses commercially available air fired PC technology
  - O_2 production by commercial cryogenic air separation
  - CO_2 cleanup, compression, and liquefaction
  - Intermediate step leading to advanced processes



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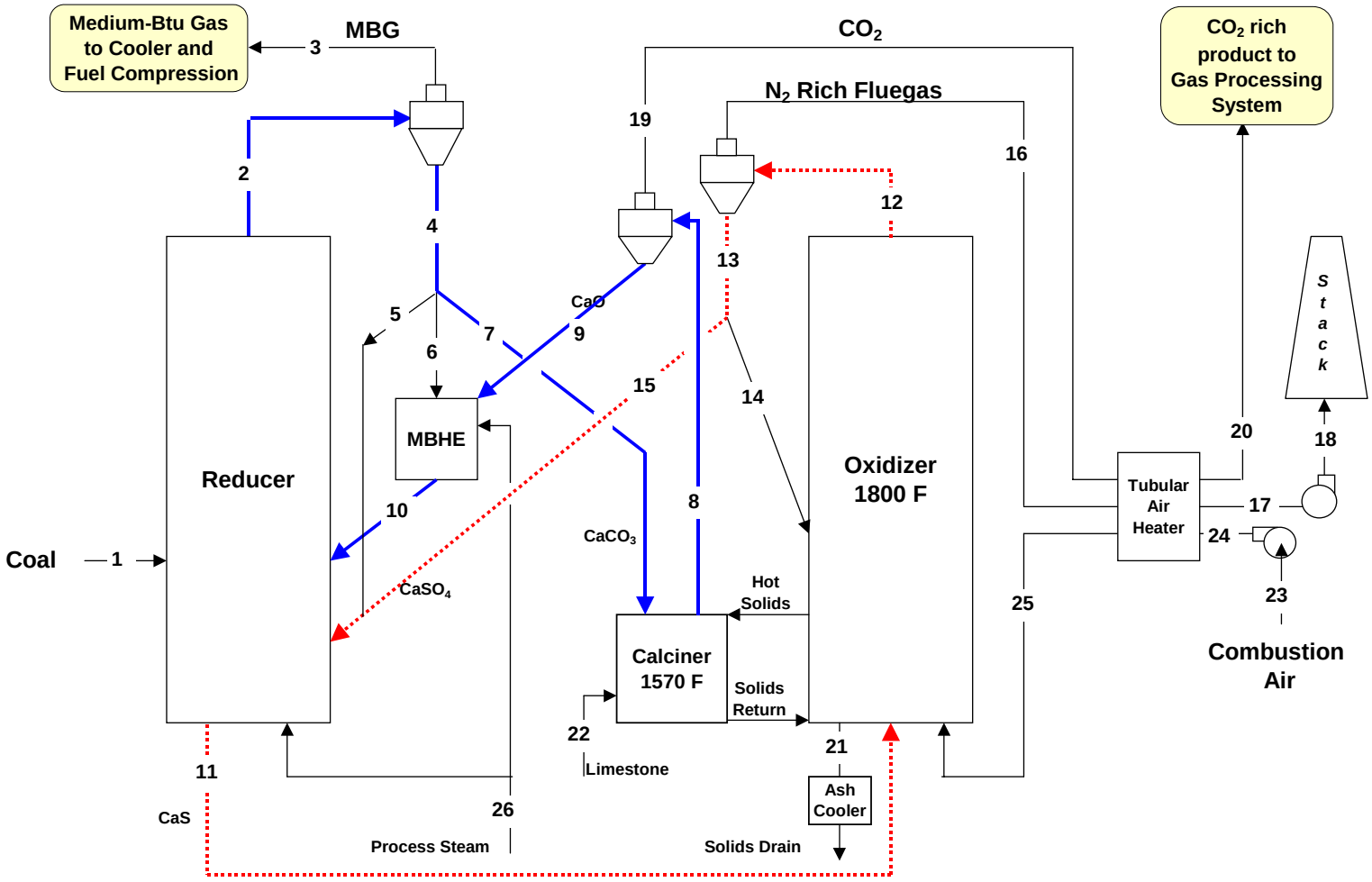
Chemical Looping



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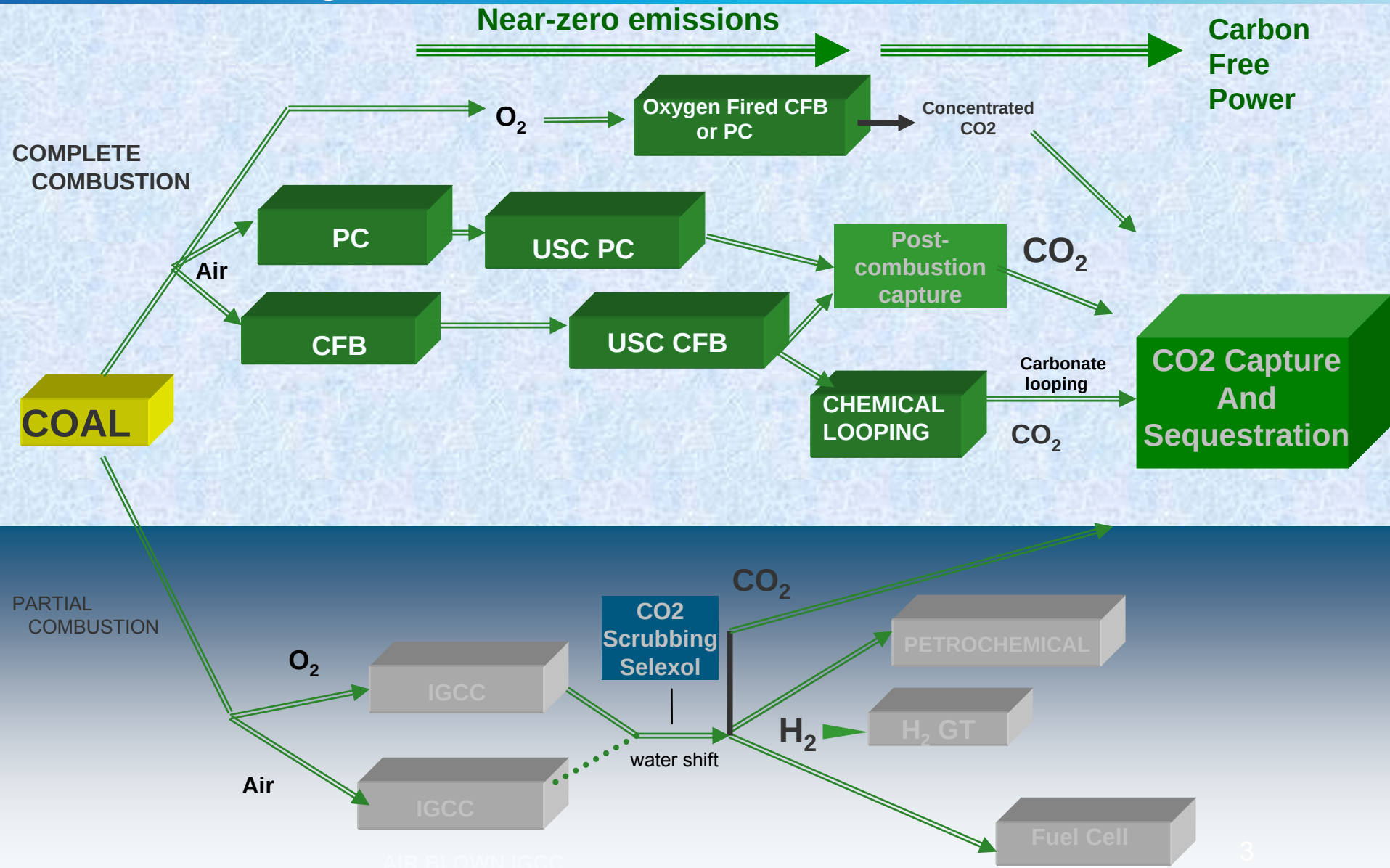
Our Vision for New Coal Power Portfolio of Clean Technologies



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