

REINHOLD ENVIRONMENTAL Ltd.



2011 NO_x-Combustion Round Table & Expo Presentation

February 7-8, 2011, in Birmingham, AL / Hosted by Southern Company

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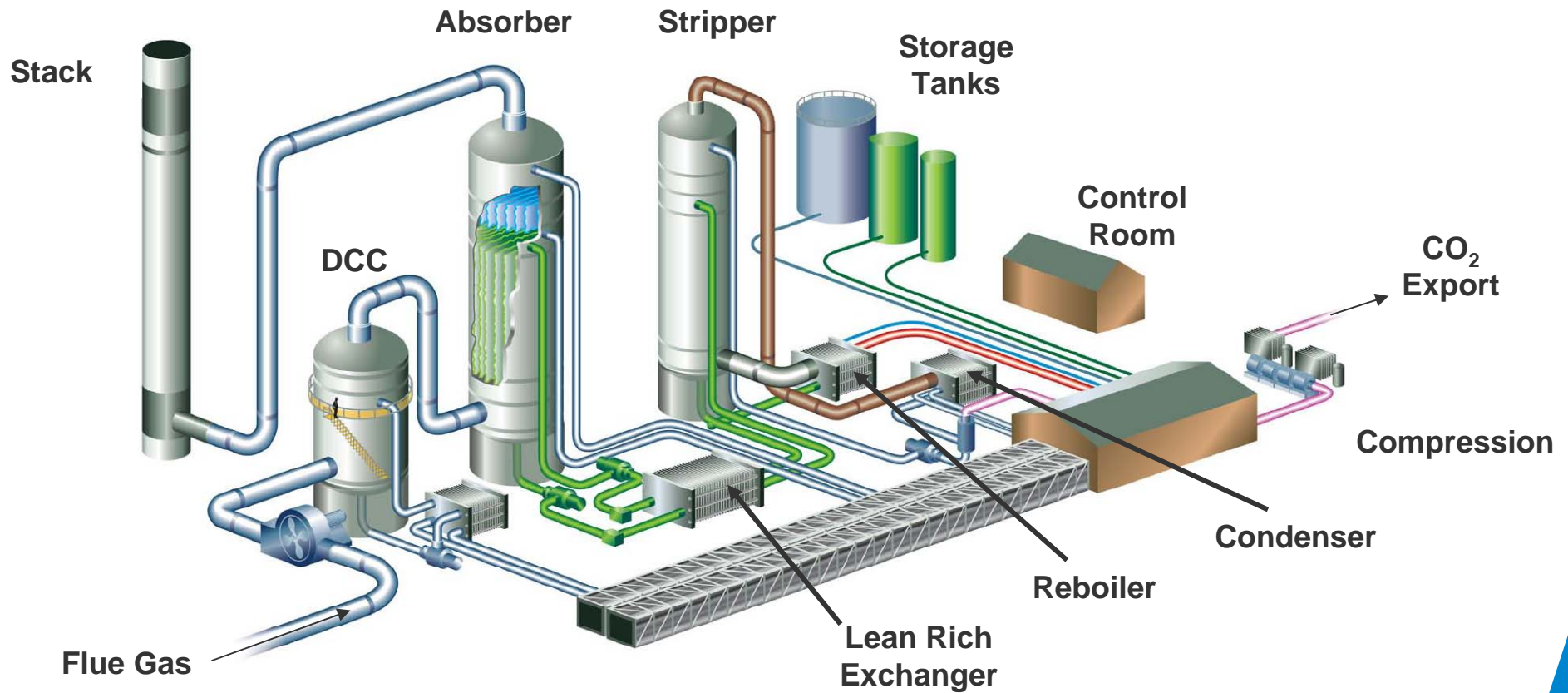


Post Combustion Capture



Doosan Power Systems

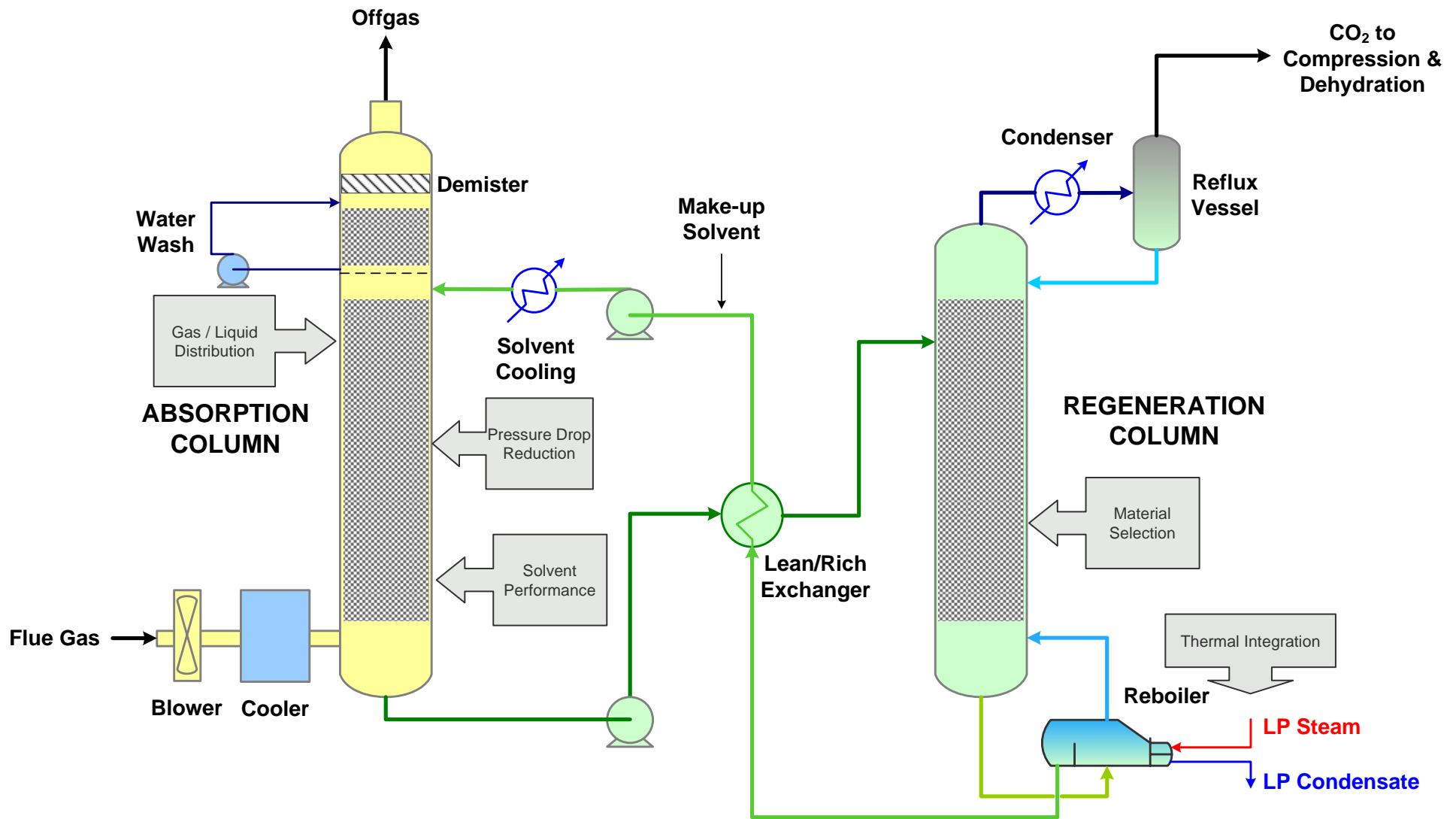
Post Combustion Capture – Typical Process Layout



Largest Commercial CO₂ Recovery Plants

Operator	Location	Capacity (MT/day CO ₂)	Fuel Source	CO ₂ Use	Status
Carbon Dioxide Technology	Lubbock, TX	1200	Gas Boiler	EOR	Shut
Searles Valley	Trona, CA	800	Coal Boiler	Carbonation of Brine (soda ash)	Operational since 1978
Mitchell Energy	Bridgeport, TX	493	Gas Heaters, Engines, Turbine	EOR	Shut
Indian Farmers Fertiliser Co-Op, Ltd.	Aonla, India	450	Natural gas fired steam reformer	Urea	Start-up Dec 2006
Indian Farmers Fertiliser Co-Op, Ltd.	Phulpur, India	450	Natural gas fired steam reformer	Urea	Start-up Dec 2006
Japan Chemical Company	Fukuoka, Japan	330	Natural gas and heavy oil boiler flue gas	General Use (dry ice, beverages, welding)	Start-Up Oct 2005
Northeast Energy Associates	Bellingham, MA	320	Gas Turbines	PURPA (food-grade)	Operated from 1991 – 2005
Soda Ash Botswana	Sua Pan, Botswana	300	Coal Boiler	Carbonation of Brine (soda ash)	Operational since 1991
Peronas Fertilizer	Kedah, Malaysia	200	Natural gas fired steam reformer	Urea	Start-Up Oct 1999
Applied Energy Systems	Poteau, OK	200	Coil Boiler (Fluidized Bed)	PURPA (food-grade)	Operational since 1991
Sumitomo Chemicals	Chiba, Japan	165	Gas Boilers plus Oil/Coal Boiler	Food-grade	Operational since 1994

Development Opportunities



Development of CCS Technology for Power Generation
Reinhold Conference 2011

University of Regina / HTC Pureenergy

- University of Regina (UoR) has specialized in Carbon Capture since 1987 – Initially driven by Enhanced Oil Recovery in the Province.
- HTC's Technology Centre is commercially aligned with Doosan, University of Regina's International Test Centre (ITC) for CO₂ Capture, and International Risk Assessment Centre.
- CO₂ Enhanced Oil Recovery technical expertise and close proximity to the Weyburn EOR field.
- Laboratories for Solvent development, material and process
- Doosan, HTC and the UoR has a long term technology investment programme in place. Funded by the partners and Canadian Government.

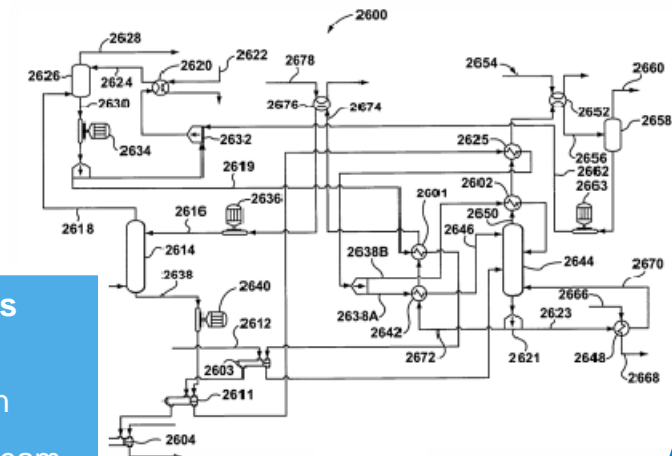
HTC Engineering Center located at the University of Regina in Regina, Saskatchewan, Canada



One stop for solvent development, process enhancement and plant integration

Technology Leaders

- Advanced Solvent designer (RS family) solvent providing:
 - Low cost commercially available ingredients
 - High efficiency system
 - Low degradation rates
 - Tailored to meet operating and flue gas conditions
- Scale-up validated against actual operating data from several plants as large as 800 TPD (with +/- 3% accuracy)
- Most importantly, scale-up is only achievable through a complete and thorough understanding of:
 - All physical and chemical properties (kinetics, diffusivity, etc.)
 - Operating conditions
 - Proper application of numeric modeling tools
- Patents in place for high efficiency configured to advanced solvent
- Patents in place for steam side plant integration



Optimised Process Design (TKO™)

- Heat Integration
- Reduction in Steam

Advanced solvent, advanced process and optimised integration provide maximum customer value

Facilities and Projects

Facilities & Technology create winning edge

20+ Years of Demo

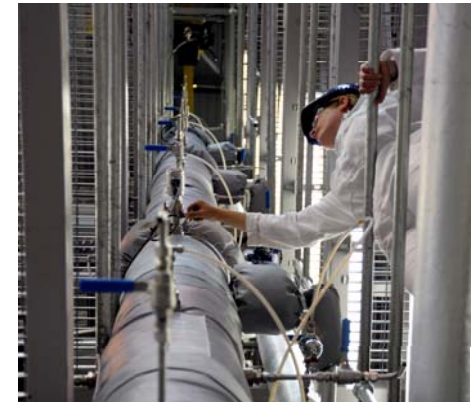
ITC 1t/day & Boundary Dam, 4t/day

- University of Regina have been developing Carbon Capture technology for over 20 years / Boundary Dam in Operation since 2000 / ITC opened in 2003



ERTF, 1t/day

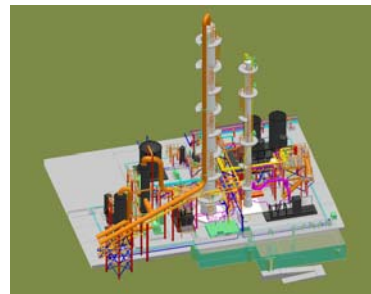
- Doosan PCC Solvent Scrubbing pilot facility currently in initial testing
- High degree of flexibility and accuracy to test wide range of Solvents & Coals



Industry Leading Scale

Ferrybridge, 110t/day

- Largest PCC demonstration plant in the UK
- Operational within 12 months
- Access to test any solvent



Basin Electric, 3,000 t/day

- Project selected for US DOE CCPI III funding
- CO₂ from the adjacent Dakota Gasification Company (~3.0 MTPY) is sold for Enhanced Oil Recovery
- FEED completed Nov 2010



Performance demonstrated on wide range of fuels and different plant configurations

Boundary Dam Demonstration Plant

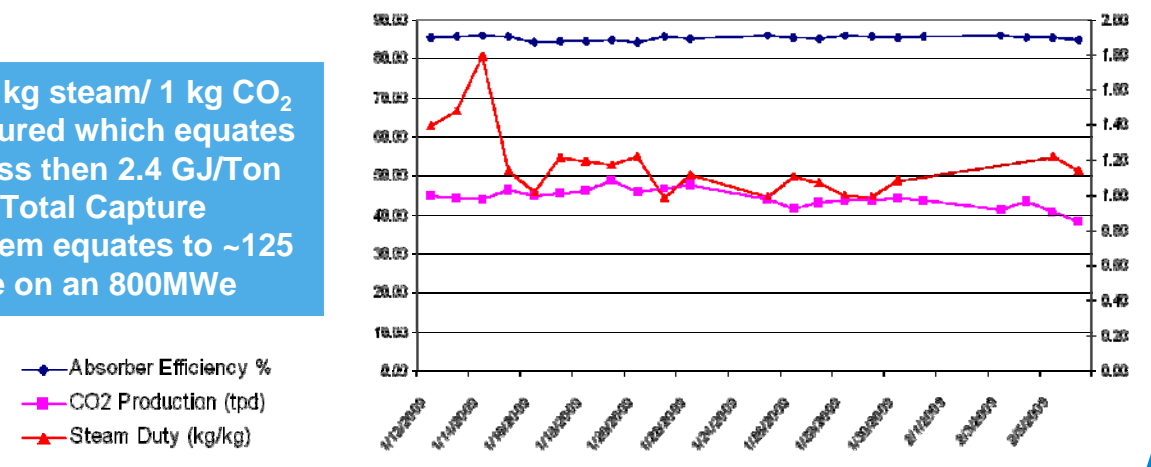
Technology Demonstration Plant

- Operating since 1987
- Donated to UoR in 2000
- Upgraded 2008 (for TKO)
- Capture capabilities are 4 TPD
- Operating on lignite fuel
- Technology demonstration facility for client-specific parameters



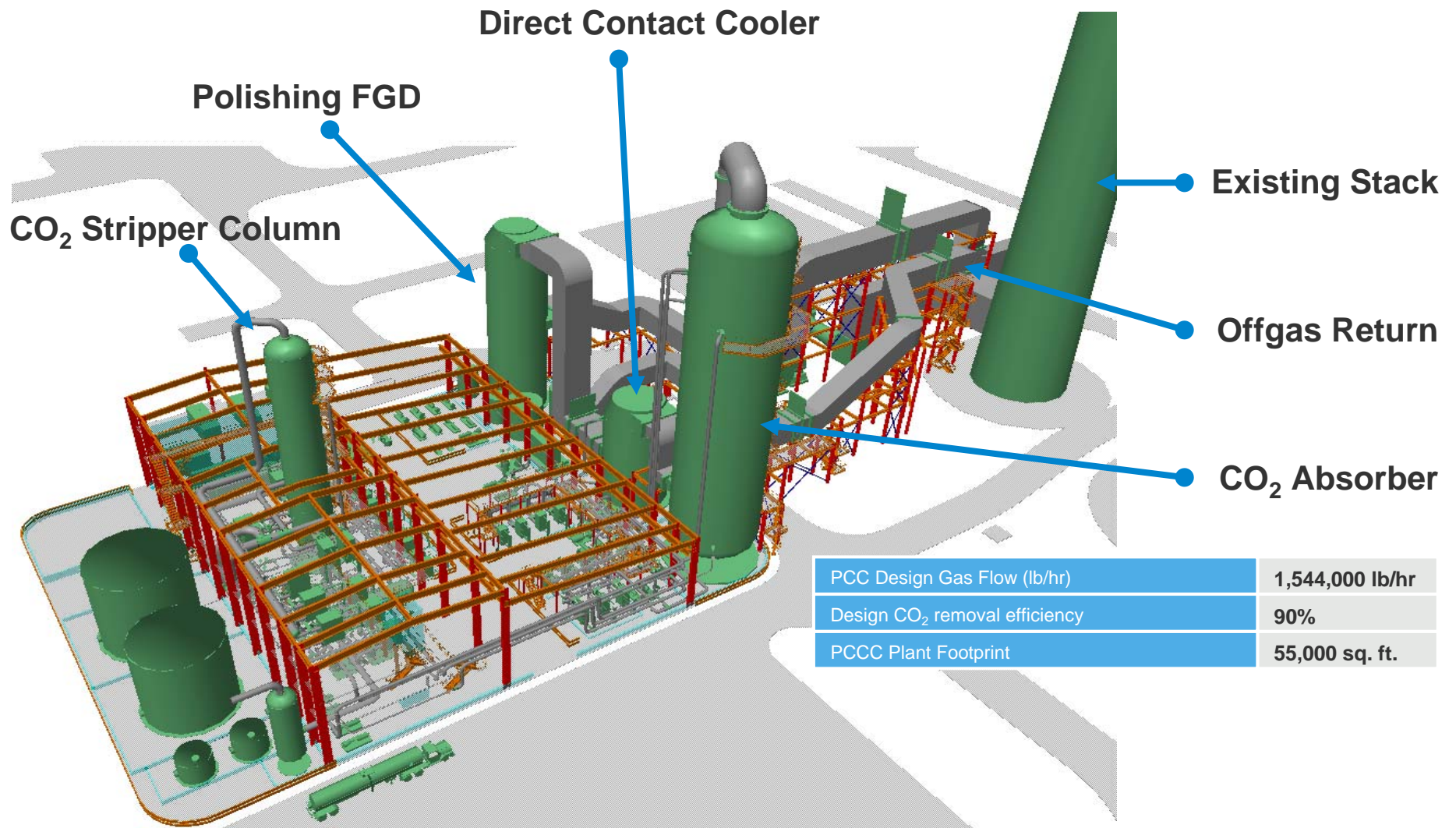
< 1.1kg steam/ 1 kg CO₂ captured which equates to less than 2.4 GJ/Ton CO₂ Total Capture System equates to ~125 MWe on an 800MWe

BDPS CO₂ Capture Plant Performance

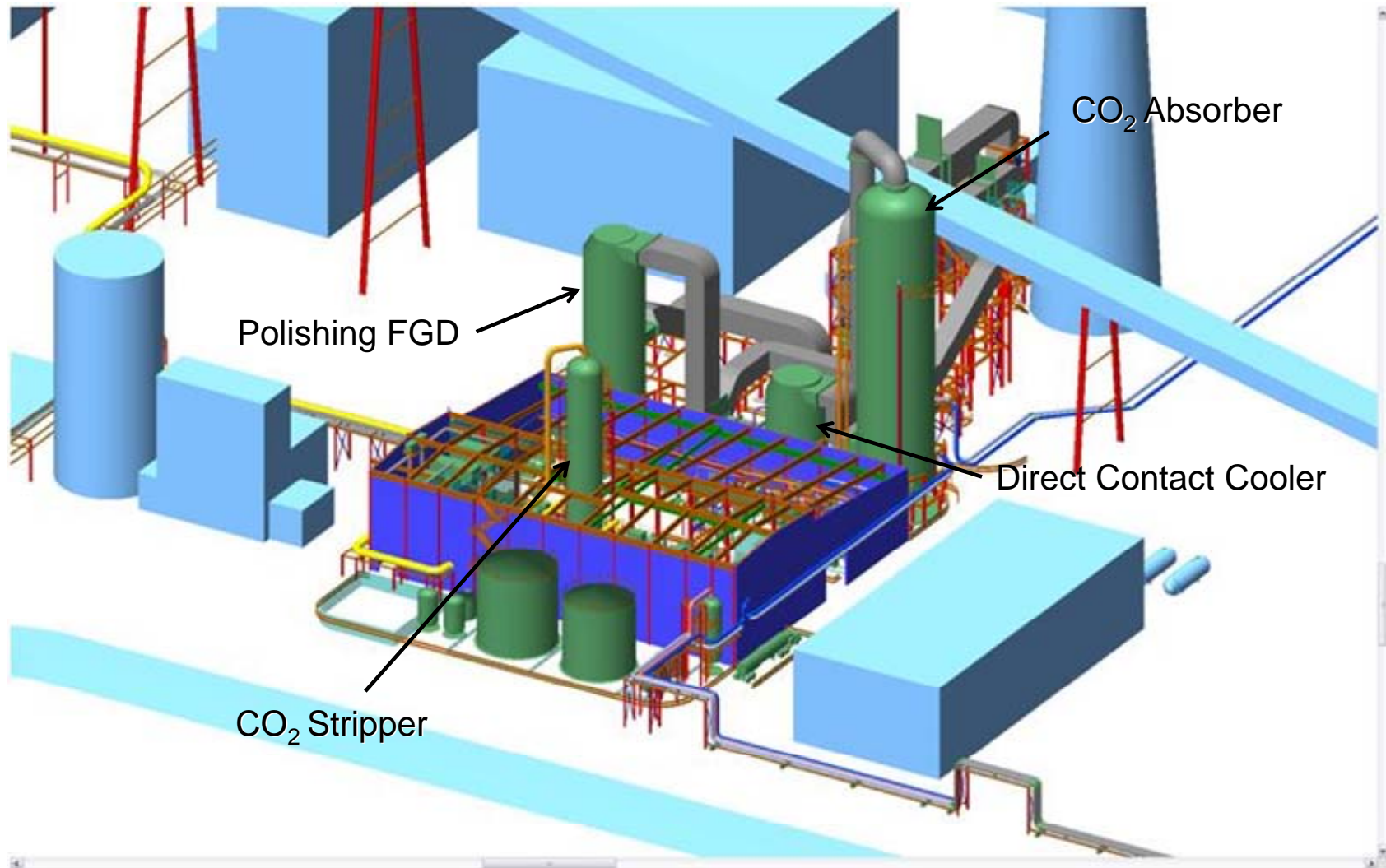


Minimised impact to existing plant performance – Industry leading plant efficiency

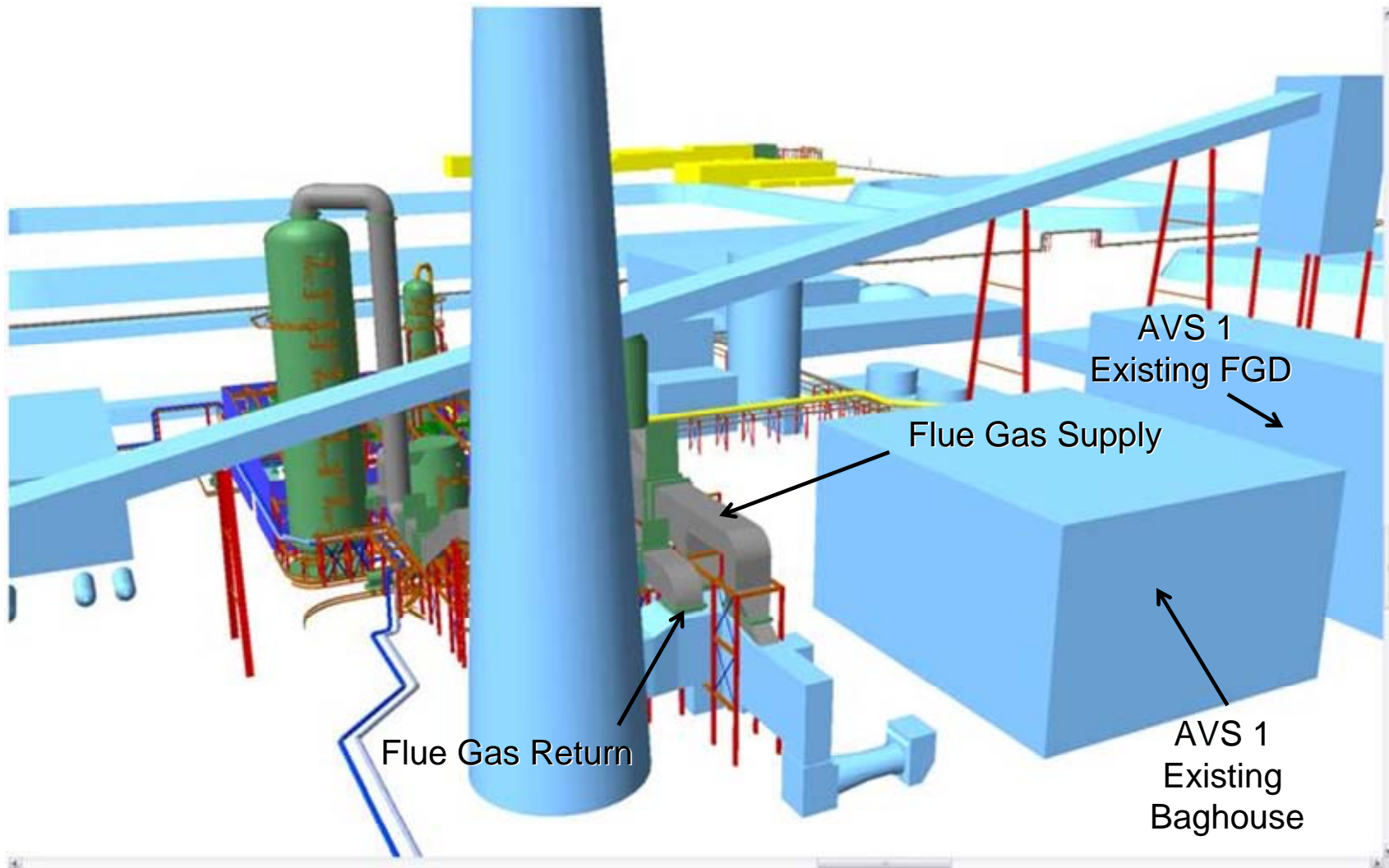
Basin Electric – Process Layout and Key Parameters



Basin Electric – PCC Plant Layout within AVS Plant (1/2)



Basin Electric – PCC Plant Layout within AVS Plant (2/2)



Key Costs

■ CAPEX

- PCCC Plant
- Compression and Dehydration
- Plant Integration
 - » Polishing FGD, Steam Supply, Cooling, Auxiliary Load

■ OPEX

- Parasitic Load
 - » Steam Regeneration Energy
 - » Auxiliary Load (CO₂ Compression & Dehydration, Pressure Drop, Pumping/Cooling)
- Solvent Replacement (Degradation)
- Maintenance Costs (Parts and Labor)

Agenda

- Introduction to Doosan Power Systems
- Carbon Capture Technologies in Development
 - Pre-Combustion Capture
 - Oxy-Combustion Capture
 - Post-Combustion Capture
- Utilization/Storage of CO₂
- Key Challenges Associated with Development and Commercialization
- Conclusions

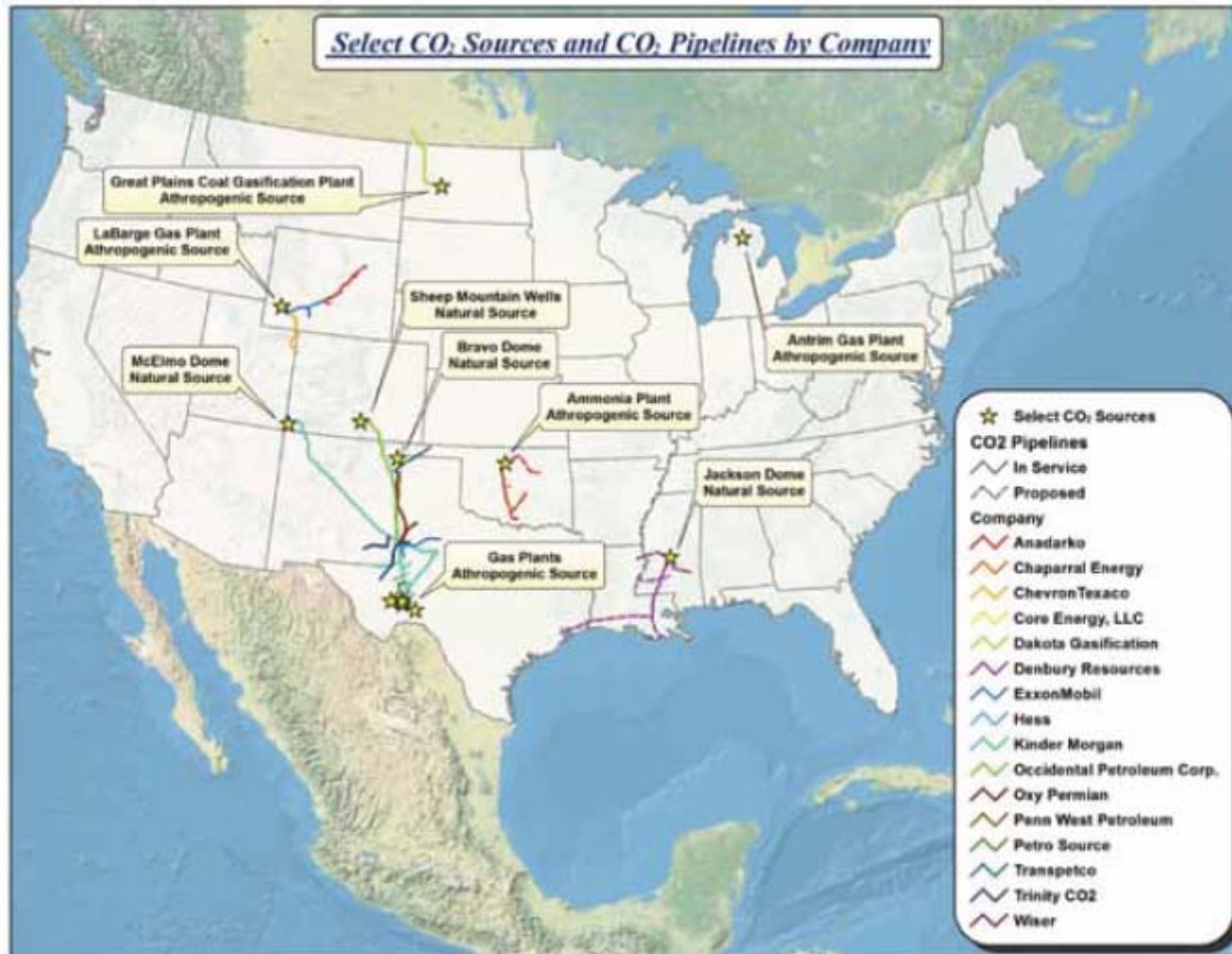
Established

- Enhanced Oil Recovery (EOR)
- Storage
 - Depleted Oil and Gas Wells
 - Saline Aquifers

Developing

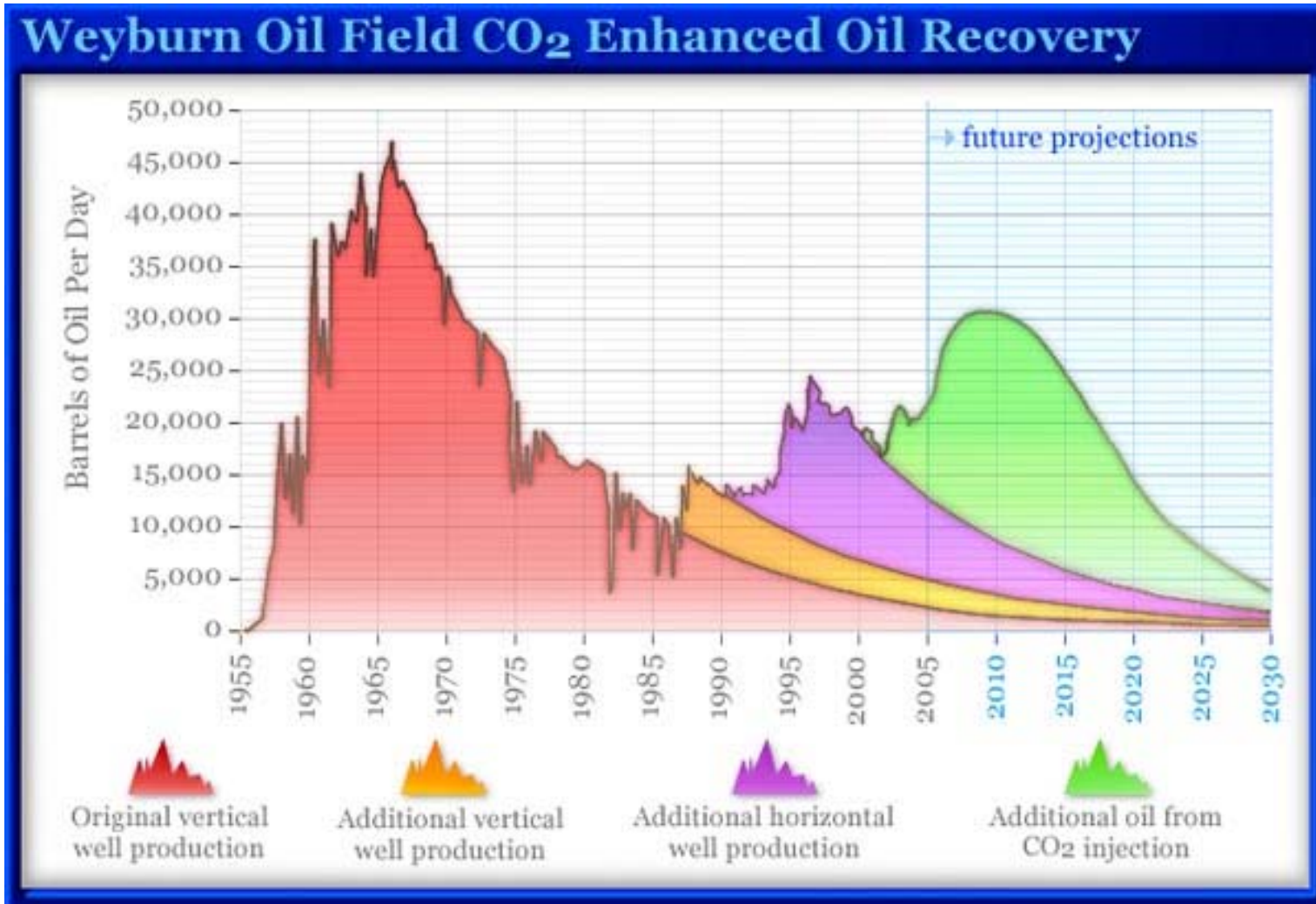
- Grow Algae
- Conversion to Aggregates/Cement
- Others?

Existing CO₂ Infrastructure in North America



Source: US DOE NETL CCS Roadmap

EOR in the Weyburn Oil Field



Source: EnCana

CO₂ Quality Specifications for EOR

Component	Corrosion Issues	HSE issues	Possible EOR Case Specification	Possible Severe Limit Case Specification
CO ₂	C	NC	≥ 95 mol %	≥ 95 mol %
H ₂ O	C	NC	< 6 ppmv	< 1 ppmv
H ₂ S	C	C	< 3.3 ppmv	< 3.3 ppmv
CO	C	C	< 4 mol % *	< 30 ppmv
Ar	NC	NC	< 4 mol % *	< 4 mol % *
O ₂	C	NC	< 10 ppmv	< 10 ppmv
N ₂	NC	NC	< 4 mol% *	< 4 mol % *
H ₂	NC	NC	< 4 mol % *	< 4 mol % *
NH ₃	NC	C	From MB	< 25 ppmv
Hg	C (if aluminium equipment is used)	C	From MB	< 1 ppmv

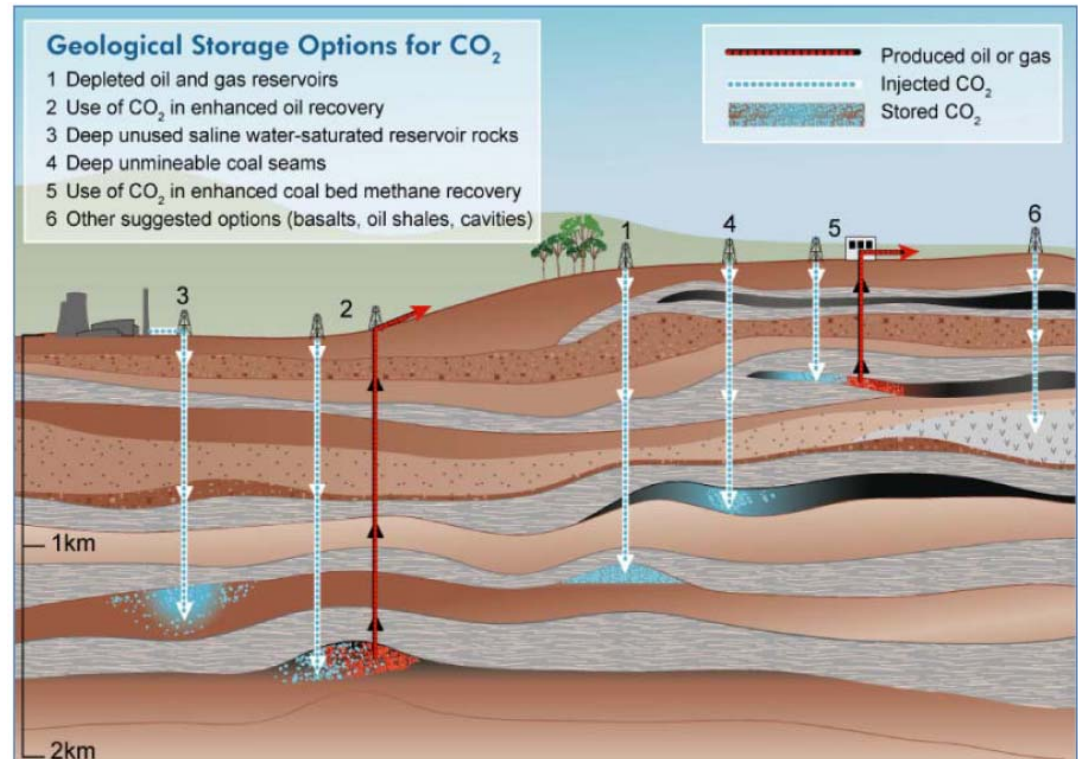
MB – Mass Balance, C – Critical, NC – Not critical.

* Total inerts and H₂/CO < 4 mol%.

Source: IEA Report 7565; *Processes for the removal of impurities from captured CO₂ streams*; March, 2008; p.8.

Challenges with CO₂ Storage

- Public Acceptance
- Long-term Liabilities
 - Concerns about of leakage and/or groundwater contamination
- Monitoring and Verification
- Legal challenges
 - Impact on Mineral Rights (who owns the porespace)?
- Transportation of CO₂
 - Same rights as Natural Gas?
- Cost
 - No utilization benefit

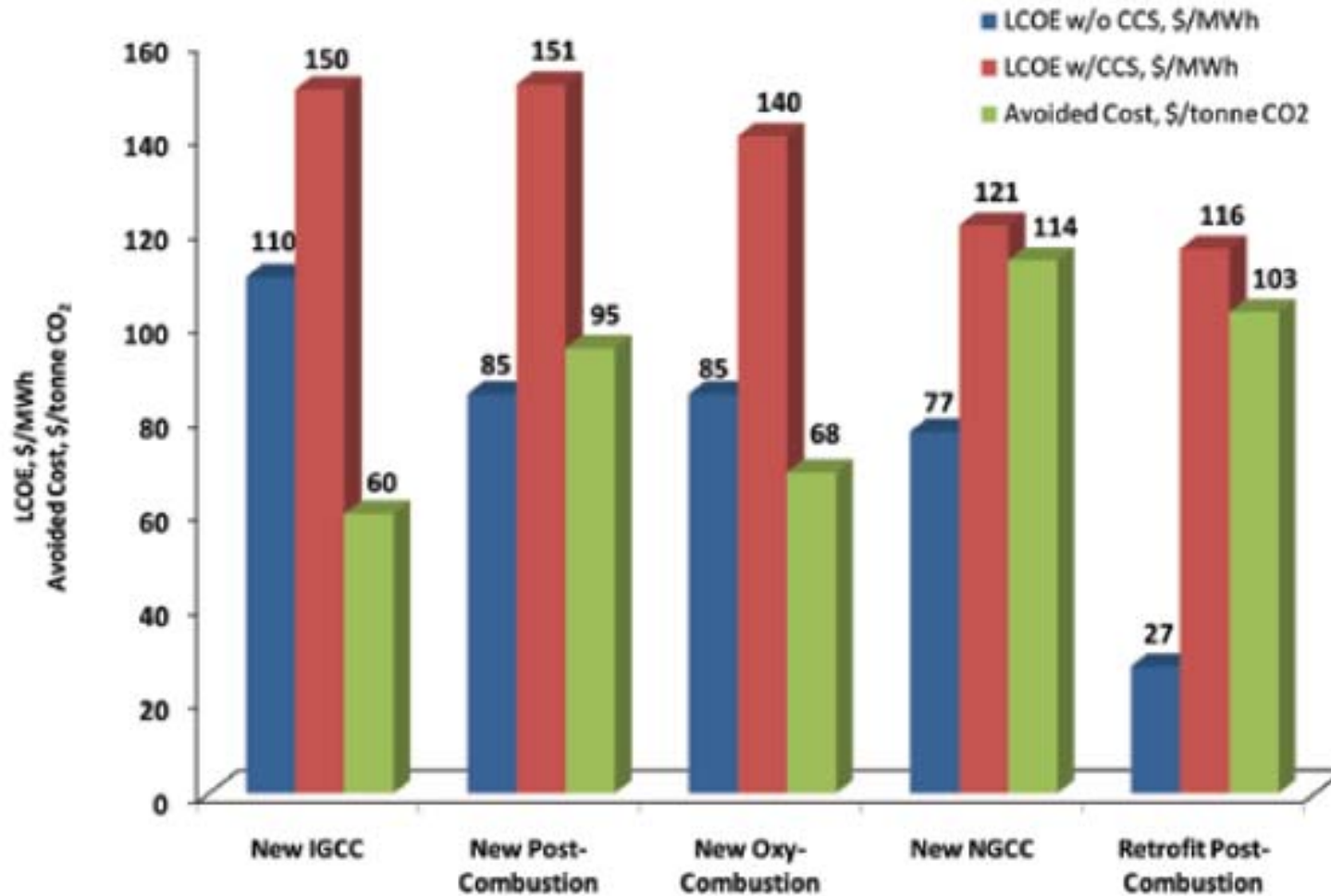


Source: Cooperative Research Center for GHG Technologies

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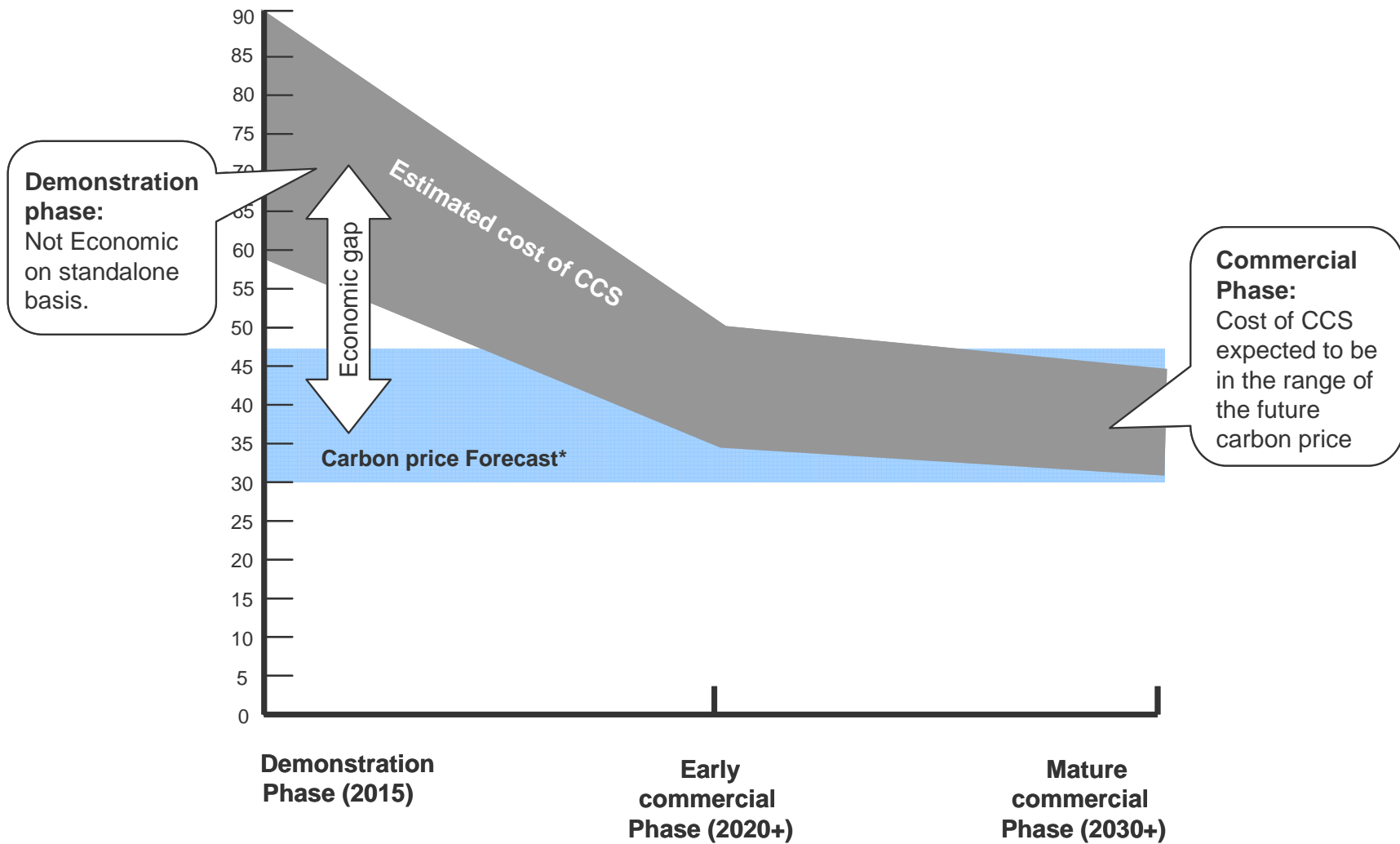
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Current Cost Estimates for CCS



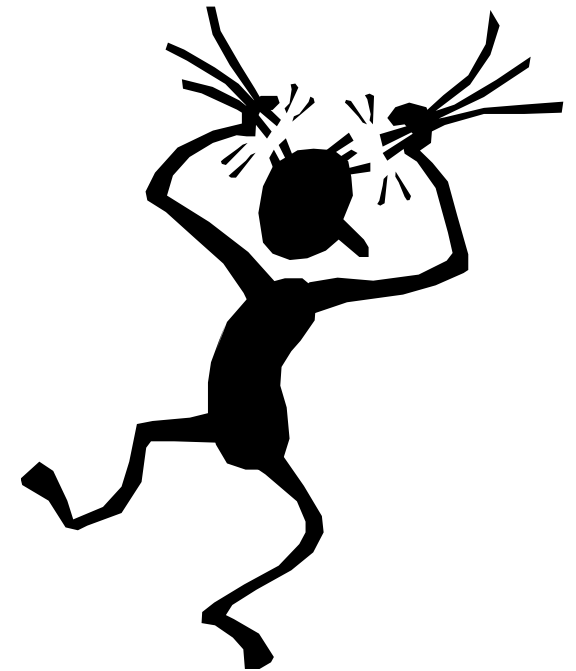
Source: US DOE NETL CCS Roadmap

Forecast of development of CCS costs and carbon price



Challenges in Developing Large-Scale CCS Demonstration Projects

- Significant capital investment to erect, commission and operate a large-scale CCS demonstration project:
 - Public investment often limited to 50% of the total investment cost
 - Who can or should fund the balance of the investment?
 - Uncertainty over development of GHG regulations infers a significant risk on any private investment
- Might offset investment by selling the CO₂ (e.g., EOR), but:
 - How much EOR is really available?
 - Exposes the owner to commercial risk because the off-taker makes a significant capital investment to accept the CO₂
- Concerns regarding transportation and storage of CO₂
- In contrast to post-combustion capture, there is increased complexity/cost with Oxyfuel demonstrations:
 - Can do partial capture; can't do partial combustion
 - Difficult/costly to permit and finance a new coal-fired power plant
 - Retrofit may require significant downtime and lost generation



Managing the Risk

Engineering				Procurement and Construction Management
Process Technology	Process Design	Equipment Design		
Key Issues	<ul style="list-style-type: none"> ■ Process Performance ■ Process Reliability 	<ul style="list-style-type: none"> ■ Safety ■ Process Performance ■ Process Reliability 	<ul style="list-style-type: none"> ■ Safety/Quality ■ Design Integrity ■ Quantities/weights ■ Constructability ■ Maintainability 	<ul style="list-style-type: none"> ■ Safety ■ Quality ■ Cost ■ Schedule
Risk Mitigation	<ul style="list-style-type: none"> ■ Successful pilot plant operation at ITC and BD ■ Validated simulation models against large scale commercial plants ■ Testing performed at: the ERTF and Ferrybridge demonstration project 	<ul style="list-style-type: none"> ■ Experience at commercial scale ■ Experience of key suppliers/partners at commercial scale ■ RAM Studies ■ HAZIDs/HAZOPs ■ CFD Modeling ■ Proper design margins 	<ul style="list-style-type: none"> ■ Experience at commercial scale ■ Application of safety factors and/or design margins ■ Proven engineering processes ■ Proven QA/QC processes 	<ul style="list-style-type: none"> ■ Doosan Experience at commercial scale ■ Proven processes and controls for project execution, procurement and construction management ■ Modularization ■ Safety procedures for site erection ■ In house Construction

Mitigate risk to our Clients through proven experience and performance guarantees

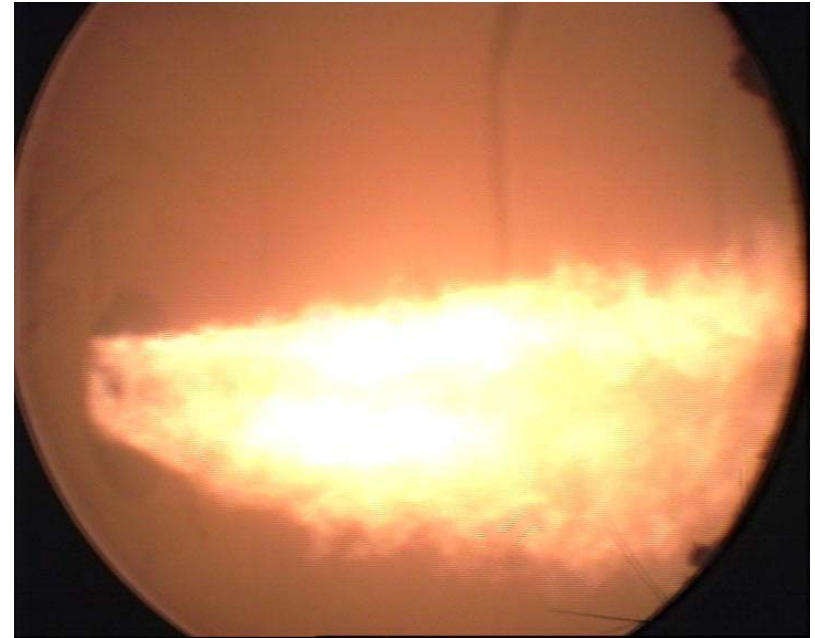
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Conclusions

CCS Solutions are developing for Power Generation, but:

- Expensive to implement
 - Significant CAPEX and OPEX costs
 - Challenging to retrofit to existing plants
- Lack of regulatory clarity for CCS
- Must address challenges with long-term CO₂ storage
- Difficult to mitigate the risk for large-scale demonstrations
 - EOR can present a revenue stream for demonstration projects, but adds commercial risk
- Additional R&D work underway to bring down the cost of Carbon Capture



40 MWth OxyCoal™ burner operation firing coal and using recycled flue gas

Address key challenges to support commercial-scale demonstration projects

Contact Details

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