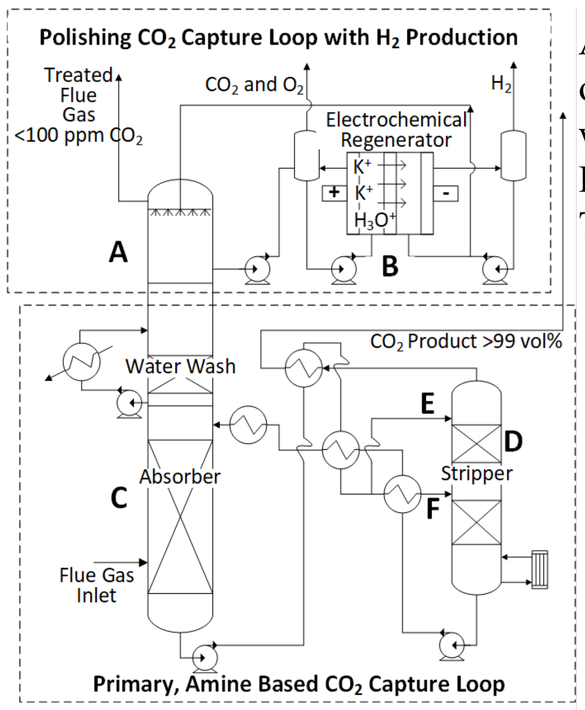
Pigman College of Engineering, University of Kentucky

Institute for Decarbonization and Energy Advancement at PPL R&D Center

DE-FE0032134, Dual-loop Solvent-based CCS for Negative CO_2 Emissions with Lower Cost

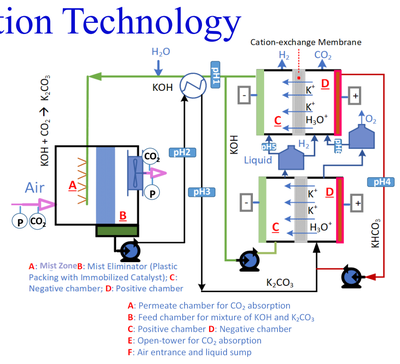
UK Dual Loop Approach for Point Source Treated Flue Gas with <100 ppm CO_2

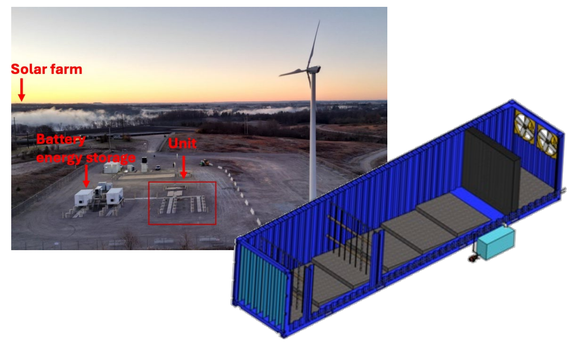


Adaptation of UK DAC with H_2 Production Technology

Building on DAC with H_2 Production Technology

- Inorganic, solvent-based
- Electrochemical regeneration with H_2 and O_2 production
- 7,700 kg CO_2/year Demo at EW Brown Generating Station, a PPL Corporation Facility, 350 kg H_2/year, 470 W Regenerator, 2025-2026
- DAC Hub Feasibility Study, ≥3,500 tonne CO_2/year per capture location with 160 tonne H_2/year and 1040 kW regenerator

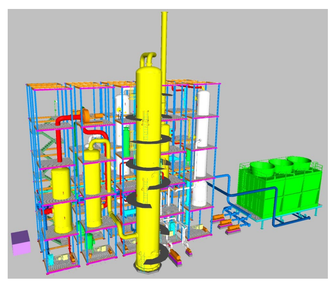


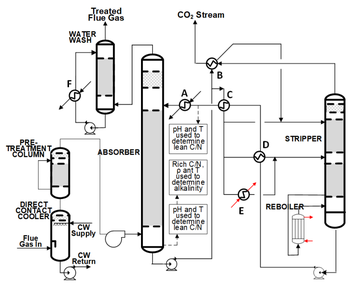


UK Point Source CO_2 Capture Technology, such as for NGCC

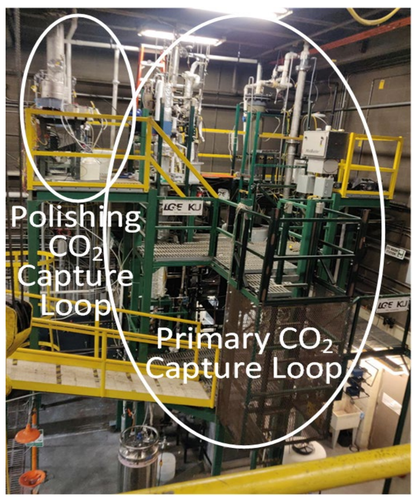
Building on Point Source Technology

- Solvent-independent process
- Engineering Scale, 15 TPD, Since 2015 at EW Brown Generating Station, a PPL Corporation Facility
- 3 TPD, Nucor Steel Gallatin, 2025
- 9.3 TPD, Vitro Architectural Glass,
- 215 TPD, Cane Run Generating Station (CRGS), a PPL Corporation Facility, 20230
- 1.7M TPY, CRGS, FEED complete 8/2025



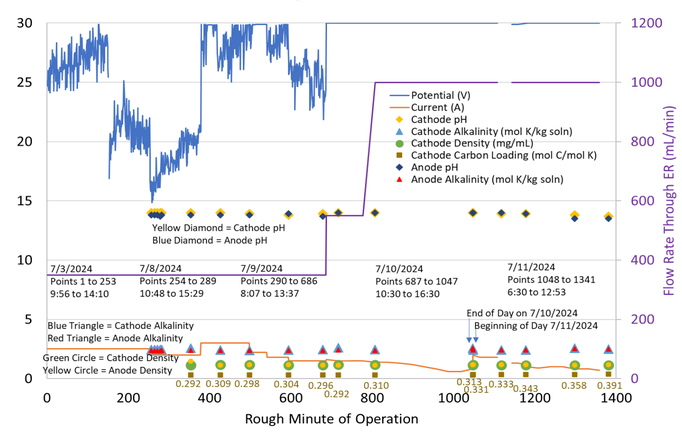


Bench Demonstration at 0.1 MWth Unit

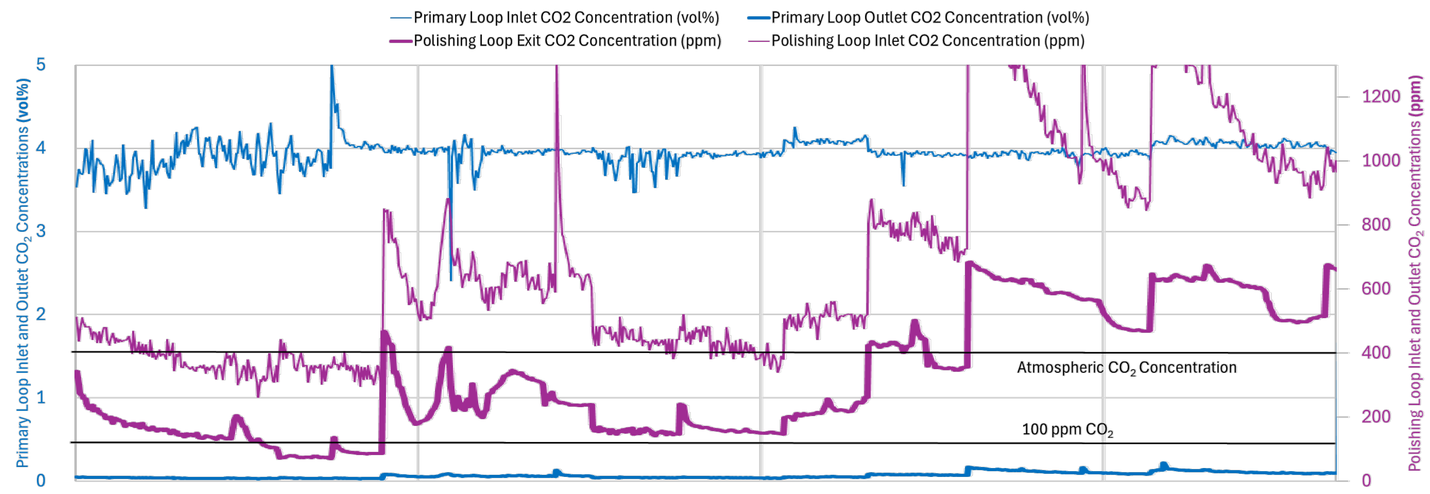


- 3/1/2022 to 11/30/2025
- Resulting TRL 4
- Existing UK CO_2 Capture Unit Applied and UK WLS Solvent as Primary Loop
- Polishing Loop Designed, Integrated, Operational and Being Tested
- Variable CO_2 Capture Efficiency in the Primary Loop
- TEA, LCA, EH&S Upcoming

Continuous Mode Operation with Electrochemical Regenerator



Demonstrated Treated Flue Gas with Lower CO_2 Than Air

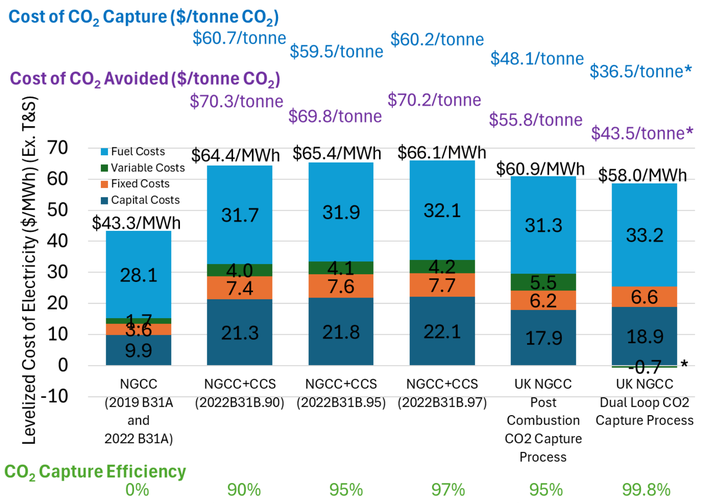


Economic Benefit

	RC B31B.95	UK IDEA Dual Loop CO_2 Capture Process Applied to NGCC	
Combustion Turbine Power, MWe	477	471	The UKy Process operates GT at high backpressure to eliminate the flue gas boost fan
Steam Turbine Power, MWe	212	220.7	Extra 5.34 MWe from lower steam extraction to the primary loop @1020 Btu/lb CO_2 Captured, and extra steam produced from high thermal energy from GTs operated at high back pressure
CO_2 Capture/Romval Auxiliaries, KWe	14400	6500	Less BOP from elimination of DCC and associated cooling duty, as well as the elimination of boost fan
CO_2 Compression, kWe	18900	17090	CO_2 produced from electro-regenerator will be purified and compressed separately
Balance of the Plant, kWe	16042	16372	Assume same
Electrochemical Regenerator, kWe	N/A	32301	Calculated based on CO_2 duty and electrolyzer efficiency
CO_2 Purification and Compression at Electro-generator Outlet, kWe	N/A	2907	Esimtaed for separating CO_2 (70%) and O_2 using 9% of Electrochemical Regeneration Power
H_2 Dehydronation and Compression, kWe	N/A	1615	Esimtaed using 5% of Electrochemical Regeneration Power
Net Power, MWe	640	615	
NGCC Plant Cost, in 1000$	610070	610070	Same base plant
CCS Island Cost, in 1000$	495733	311915	Reduction from UKy CCS process features
subtotal	1105803	921985	
Captial Cost per net kW	1729	1499	Total captial divided by the net power output, **a 13.3% reduction**
CO_2 Captured, kg/hr	223718	248073	10.8% increase
Hydrogen Produced, kg/hr	N/A	502	0.69 mole H_2/mole CO_2 based on the electro-regenerator efficiency
CO_2 Captured from Air, tonne/hr	N/A	1.96	99.8% capture efficieny is equivilant at 82 ppm CO_2 from NGCC
Natural Gas Cost, in 1000$	152160	152160	Same generating unit
Annual Operating Cost, in 1000$	27088	27088	Assume same for simplification
Credit from Hydrogen Sale, in 1000$	N/A	29913	H_2 sale price @ $8/kg for water eletrolysis grade and 85% capacity
Credit from CO_2 Negative Emission, in 1000$	N/A	1459	CO_2 price @ $100/tonne and 85% capacity
Subtotal of O&M Cost, Annually	179248	147876	**a 17.5% reduction**

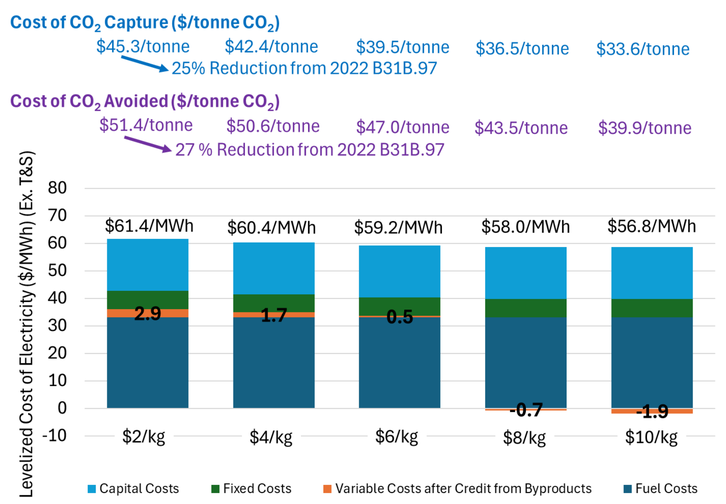
	RC B31B.95	UK IDEA Dual Loop CO_2 Capture Process Applied to NGCC	
Solvent	Cansolv	UK Hindered Primary Amine Solvent + KOH	
Capture Efficiency	95%	99.8% overall with ~85% being in the primary capture loop	
Major Equipment	DCC, Absorber, Stripper, EHX and BOP	Absorber, Stripper, Electroregenerator and CO_2 Purifier, EHX, and BOP	
Procss Intensification	Conventional Aquesous CCS with Absorber operated at 30°C	Increased GT backpressure to eliminate flue gas back pressure	
		In-duct cooling water spray to eliminate the standalone DCC	
		Absorber of the primary loop operated at temperature >45°C	
		Absorber of the primary loop temperature profile controlled by descretized packing	
		Stripper for the primiary loop with split rich feed to lower the exhaust temperature	
		Fine liquid droplet formation coupled with one-stage tray in the the polishing loop	
		Internal circulation of anode and cathode solution to reduce operating potentals	
Specific Reobier Duty	1205 Btu/lb CO_2 Capture	1020 Btu/lb CO_2 captured for the primary loop, and 2.12 kWh/kg CO_2 captured	
Capital Cost for CCS exluding compression and drying in $1000	431813	237497	Elimination of DCC and Boost Fan & Associated Duct Work
			Significant absorber size reduction: 10-15 ft. packing in the primary loop and open tower in the polishing loop
			Smaller stripper and BOP for reduced CO_2 capture duty in the primary loop
		8075	Electrolyzer and its associated BOP at $250/kW and the size required for proposed CO_2 capture is equivilant of 32.3 MW
		2423	Estimated CO_2 + H_2 purification and compression unit at the electro-regenerator exhaust, 30% of electrolyzer cost

Preliminary TEA



* Assuming a H_2 sales price of $8/kg and a credit for CO_2 capture from air of $100/tonne

Effect of H_2 Sales Price



Acknowledgements

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The UK IDEA Team