Application of a Heat Integrated Post-Combustion Carbon Dioxide Capture System with Hitachi Advanced Solvent into Existing Coal-Fired Power Plant (DE-FE0007395)

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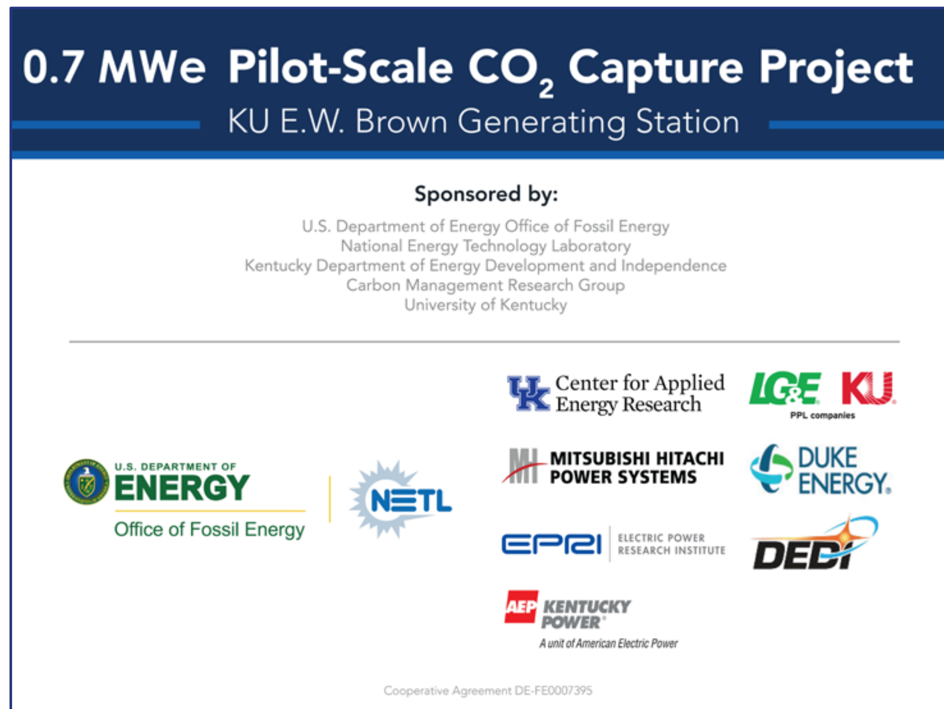
https://caer.uky.edu/power-generation/

Current Accomplishments

- Additional advanced solvent campaign complete
- Intensified process modification design and construction complete
- Commissioning and startup complete
- Initial evaluation on modified process complete

Team Members



Funding

Federal – \$16,291,967

Cost Share – \$5,932,902

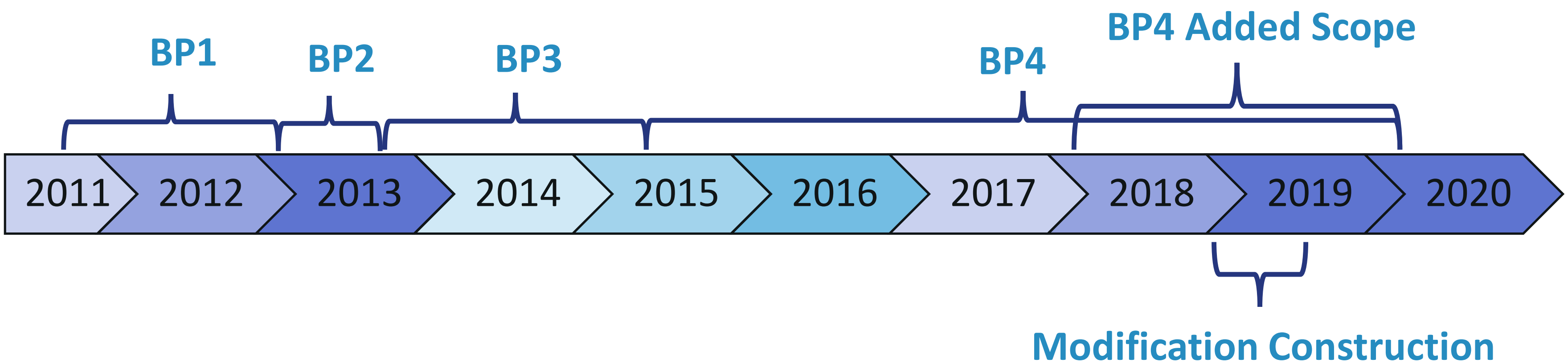
Project Performance Dates

BP1: October 1, 2011 to January 31, 2013 (16 months)

BP2: February 1, 2013 to August 31, 2013 (7 months)

BP3: September 1, 2013 to March 31, 2015 (19 months)

BP4: April 1, 2015 to March 31, 2020 (60 months)



Added Scope:

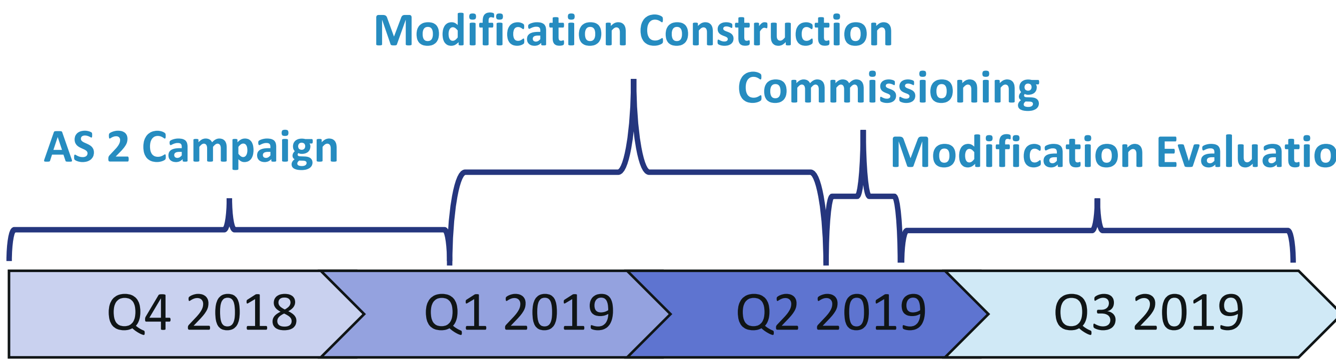
- Testing of additional advanced solvents
- Process modification to include pre-concentrating membrane and solid-assisted water washing

BP4 Milestones

- ✓ Advanced solvent campaign and degradation study – 12/31/2018
- ✓ Fabrication of process modification equipment complete – 1/4/2019
- ✓ Modified pilot unit commissioning complete – 7/16/2019

BP4 Success Criteria

- ✓ Documented delivery of equipment onto plant site according to design and construction specifications – 4/30/2019
- ✓ Certification that the completed process modification system meets the design performance specifications – 7/16/2019



UK Blend Solvent Campaign: June to November 2018
Construction: February 2018 to May 2019
Commissioning: June 2019
Membrane and Water Wash Preliminary Evaluation: Since July 2019

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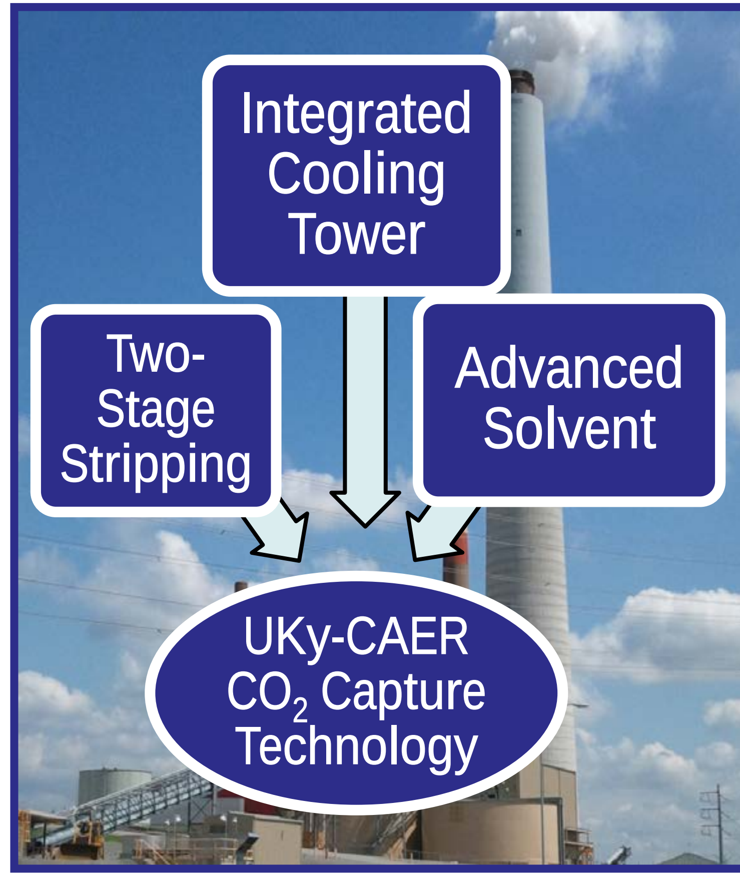
Project Overview

- 0.7 MWe advanced post-combustion CO_2 capture small pilot
- Modular design
- Installed at Kentucky Utilities E.W. Brown Generating Station in Harrodsburg, KY, approximately 30 miles from UKy-CAER
- Includes several UKy-CAER developed technologies
- Over 4500 hours of operation
- Five solvents tested: 30 wt% MEA baseline, H3-1, AS 1, 6M MEA, AS 2
- Installation of process modification including a CO_2 preconcentrating membrane and water wash system

UKy-CAER Advanced CO_2 Capture Technology

Motivation

- Reduced energy penalty and costs
- Utilization of low grade heat via internal heat pump
  - Secondary air stripper
  - Liquid desiccant for cooling tower
- Near-zero makeup water for amine loop to save operation costs
- Advanced Solvents



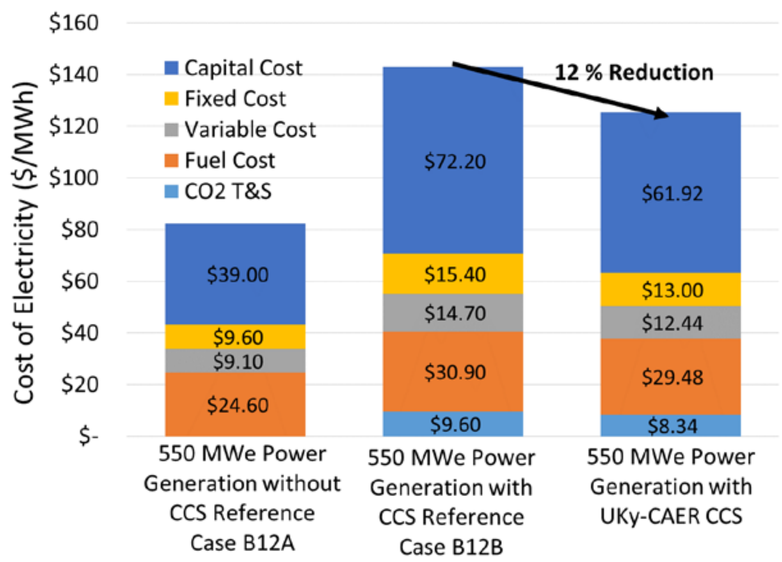
Performance Metrics Obtained

- ✓ Mass Transfer Intensification: increase in absorption rate, 5-11% increase in rich loading, absorber with 40 ft packing with near equilibrium loading achievable
- ✓ Two-Stage Solvent Regeneration: leading to 8% less energy compared to conventional with >10% of regeneration in secondary air stripper demonstrated, 15-17% vol% CO_2 at absorber inlet due to recycling
- ✓ Robust Process Performance proven for various solvents: ≥80% trouble free startups, capable of both daily startups and shutdowns and 24/7 operations
- ✓ Process Stability: Generally ≤5% variation of key process parameters
- ✓ Solvent Quality: Low makeup rate required due to low primary stripper bottom T <245 ^oF and negligible effect of secondary stripper on solvent degradation
- ✓ Amine Loop Water Makeup: No DI water system needed with the application of water evaporator for air stripper

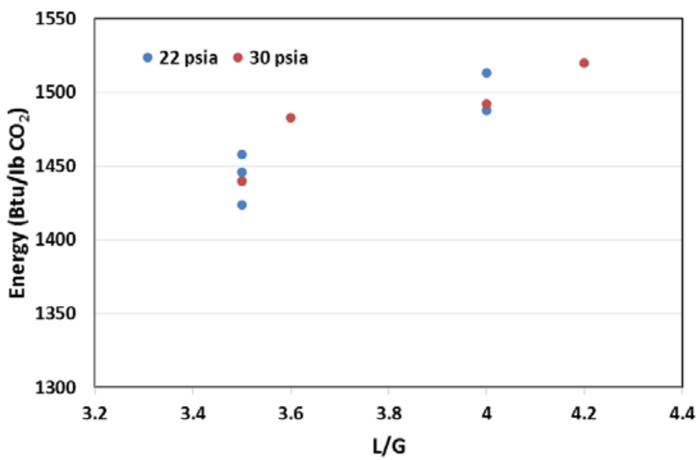
Costs of UKy-CAER CCS

- ✓ Plant Efficiency (HHV basis) of 34.0%, a 5% increase compared to RC B12B
- ✓ Capital Cost of \$61.90/MWh, a 14% reduction compared to RC B12B
- ✓ Cost of Electricity of \$117/MWh, a 12% reduction compared to RC B12B
- ✓ CO_2 Capture Cost of \$41.40/tonne CO_2, excluding T&S, a 29% reduction compared to RC B12B

	RC B12B	UKy-CAER CCS	Percent Difference
Net Power, Mwe	550	550	0%
Total Plant Cost (2011 \$/kW)	3524	2977	-16%
Total Overnight Cost (2011\$/kW)	4333	3660	-16%
Total As-Spent Cost (2011\$/kW)	4940	4173	-16%
Cost of Electricity (\$/MWh, 2011\$)	133.2	116.9	-12%
CO_2 T&S Costs	9.6	8.3	-13%
Fuel Costs	30.9	29.5	-5%
Variable Costs	12.3	12.4	1%
Fixed Costs	15.4	13.0	-16%
Capital Costs	72.2	61.9	-14%
Cost of CO_2 Captured (\$/tonne CO_2)	58.2	41.4	-29%



Advanced Solvent 2 Campaign – Regeneration Energy

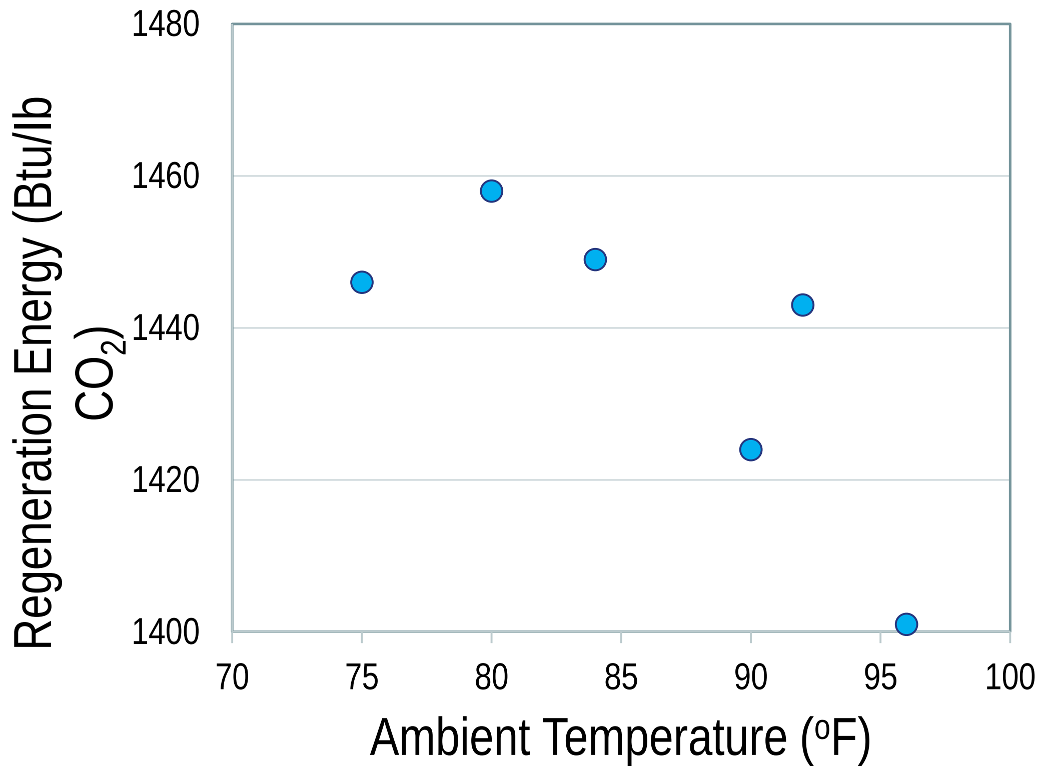


Performance Compared to 30 wt% MEA	Hitachi H3-1	Advanced Solvent 1	Advanced Solvent 2
Energy Penalty	33% savings	30% savings	14% savings
Solvent Circulation Rate	~35-45% reduction	~30% reduction	~same
Cyclic Capacity	~1.5X	~1.5X	~1.0X
Viscosity	2.5 – 3X	~1.5X	~1.0X
Surface Tension	~0.6X	~1.0X	~0.8X
Degradation Products	Low	Low	Low
Solvent Regeneration Energy Measured at UKy-CAER 0.7 MWe CCS	1022 Btu/lb CO_2	1070 BTU/lb CO_2	1315 BTU/lb CO_2

Despite differences in chemistry and physical properties, advanced solvents tested perform similarly.

Advanced Solvent 2 Campaign – Effect of Ambient T

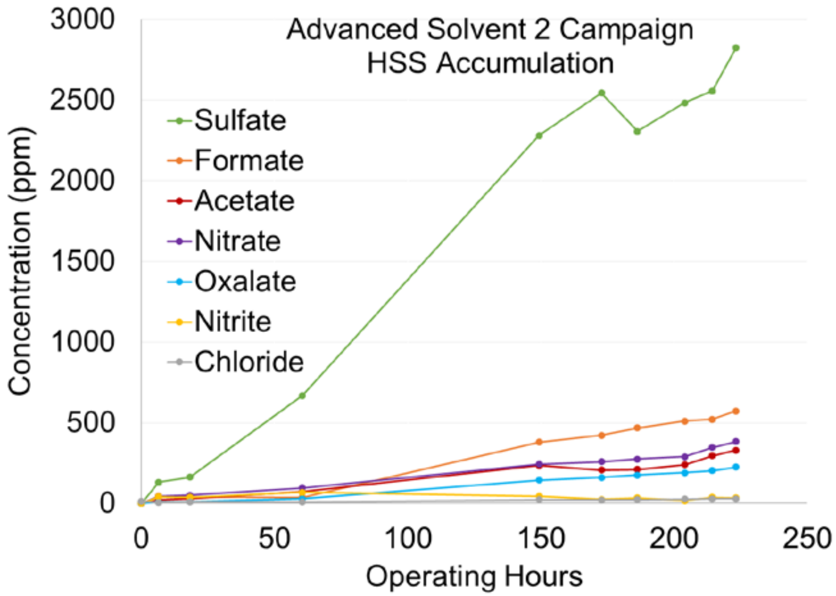
~50 BTU/lb CO_2 captured decrease in regeneration energy with 20 ºF increase in ambient temperature

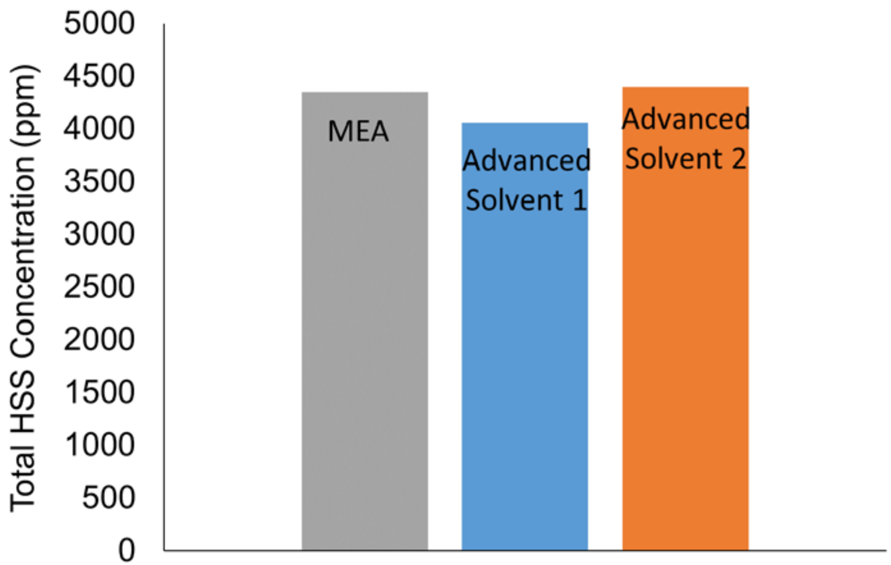


Same L/G = 3.5, Stripper pressure = 22 psia

Advanced Solvent 2 Campaign – Solvent Stability

Total HSS levels are similar for the three campaigns conducted at similar run hours.

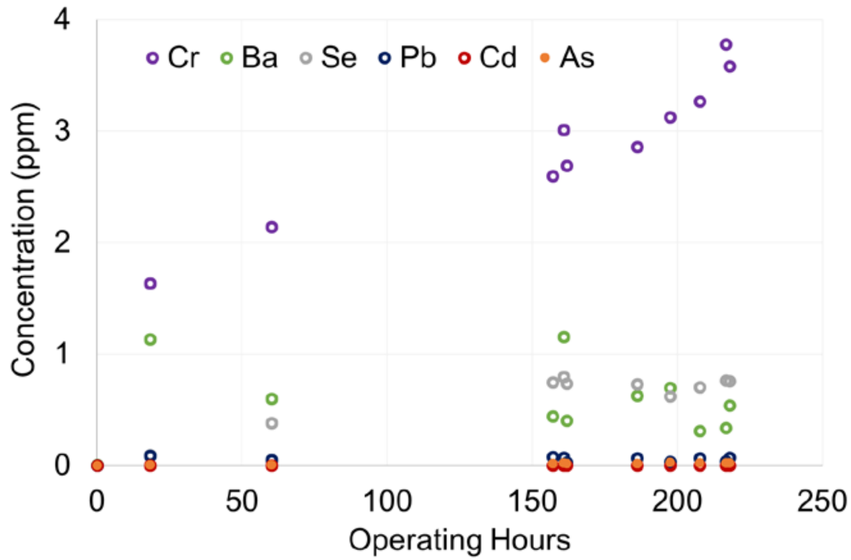


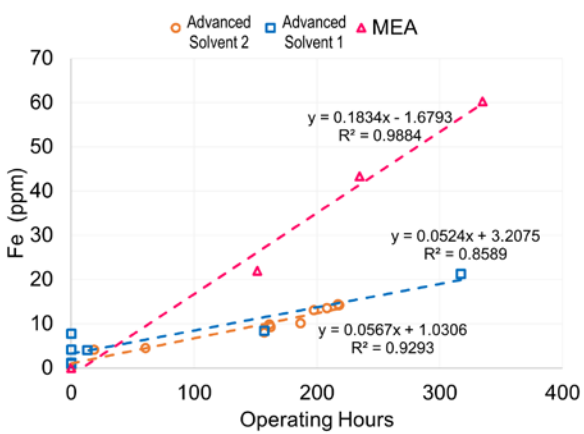


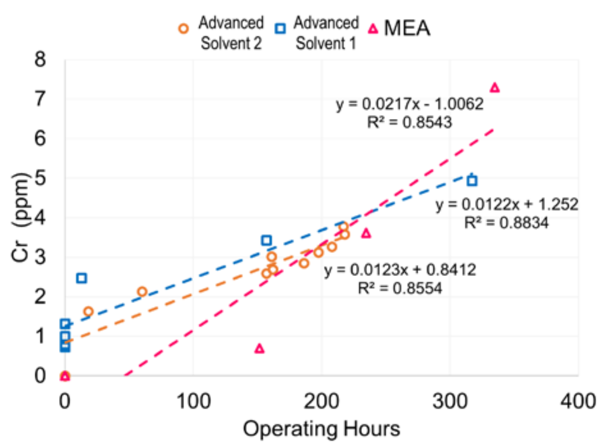
Advanced Solvent 2 Campaign – RCRA Elements

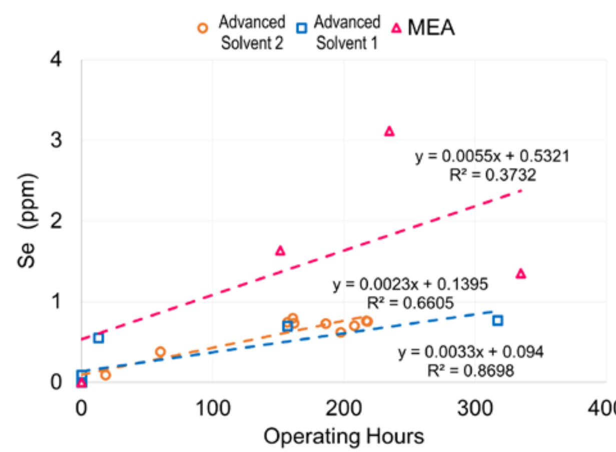
RCRA regulated metals all under limits.

Similar Fe, Cr and Se accumulation rates for advanced solvents.

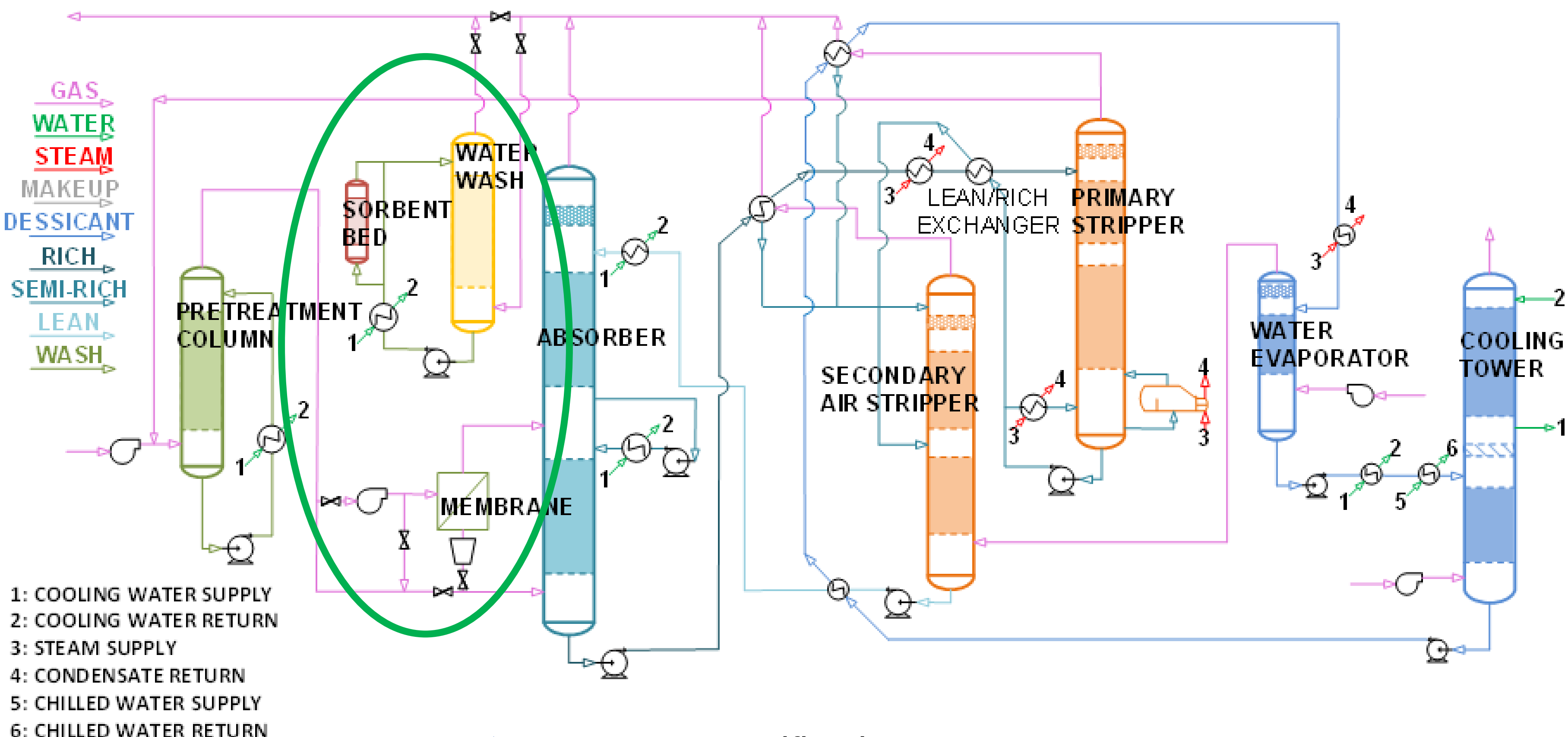








Modification of UKy-CAER 0.7 MWe CCS



- Process Intensification
- Two-Stage Solvent Regeneration
- System Integration and Heat Recovery
- Advanced Solvent

Process Modification Construction

- Blau Mechanical contracted for the installation of new equipment
- New level/grating added at top of module for membrane skid
- Structural modifications made
- Water wash column and circulation pump
- Membrane, vacuum pump and blower
- Piping modifications
- Electrical modifications
- Control system modifications

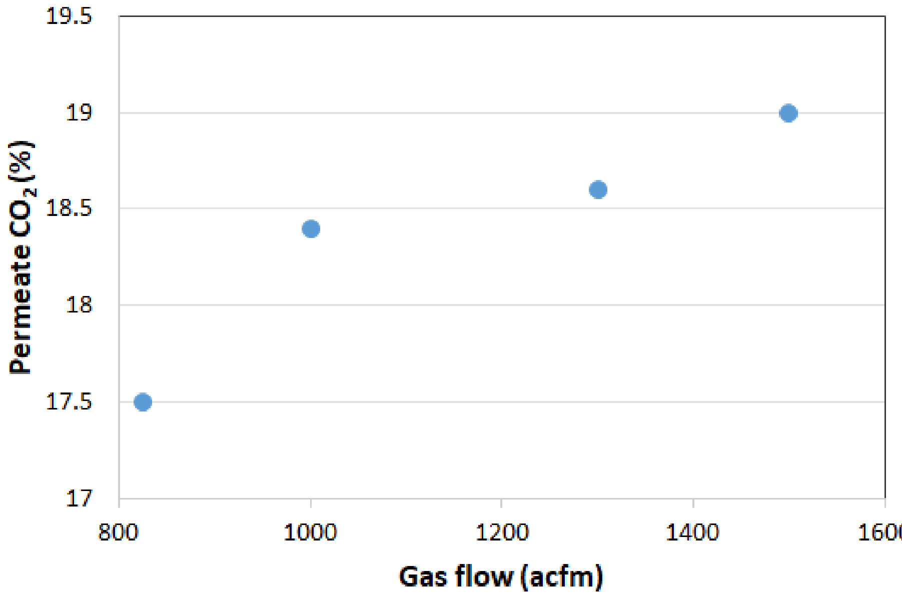
CO_2 Preconcentrating Membrane

Vacuum Pump

Water Wash Column

Preliminary Membrane Results with Fixed Vacuum Pump Intake

Permeate concentration of 19 vol% CO_2 achievable with inlet feed CO_2 concentration of 12 vol%.



	Pressure		Temperature
Gas flow (acfm)	Membrane Inlet (psia)	Vacuum (psia)	Membrane Inlet (°F)
825	14.8	4.6	101
1000	15.1	4.7	107.5
1300	15.7	5	120
1500	16.2	5.4	134

New Knowledge Gained

- Despite differences in chemistry and physical properties, 2nd generation advanced solvents have similar performance

- Decrease in regeneration energy with increase in ambient temperature

- 19% CO_2 in permeate achievable with preconcentrating membrane

Remaining Tasks

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1) Complete pre-concentrating membrane performance evaluation

2) Complete water wash system evaluation

3) Update TEA and EH&S assessment

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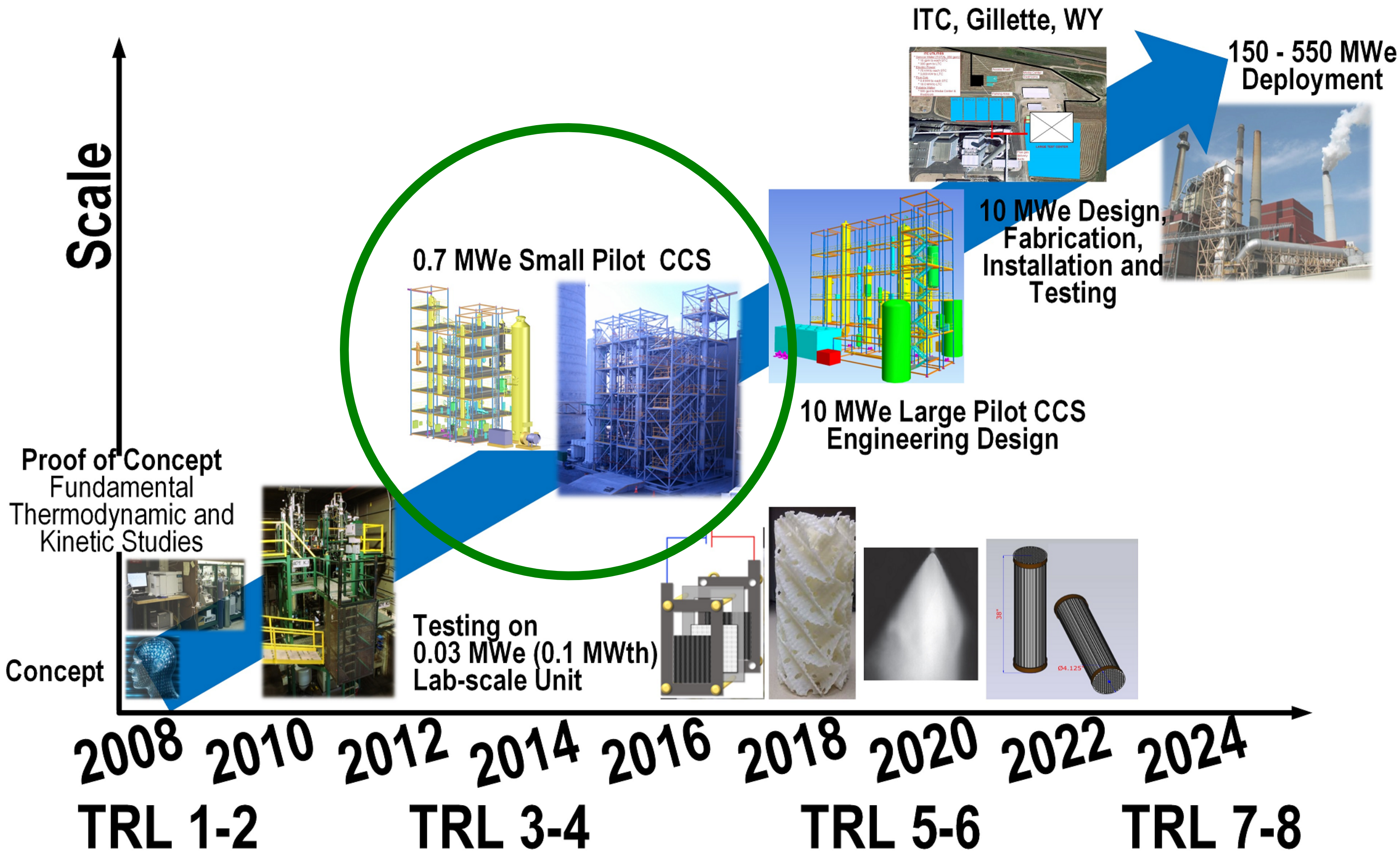
Technology Development Plan



Acknowledgements

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