UKy-CAER Heat-integrated Transformative CO_2 Capture Process in Pulverized Coal Power Plants (DE-FE00031583)

Kunlei Liu, Heather Nikolic and Jesse Thompson

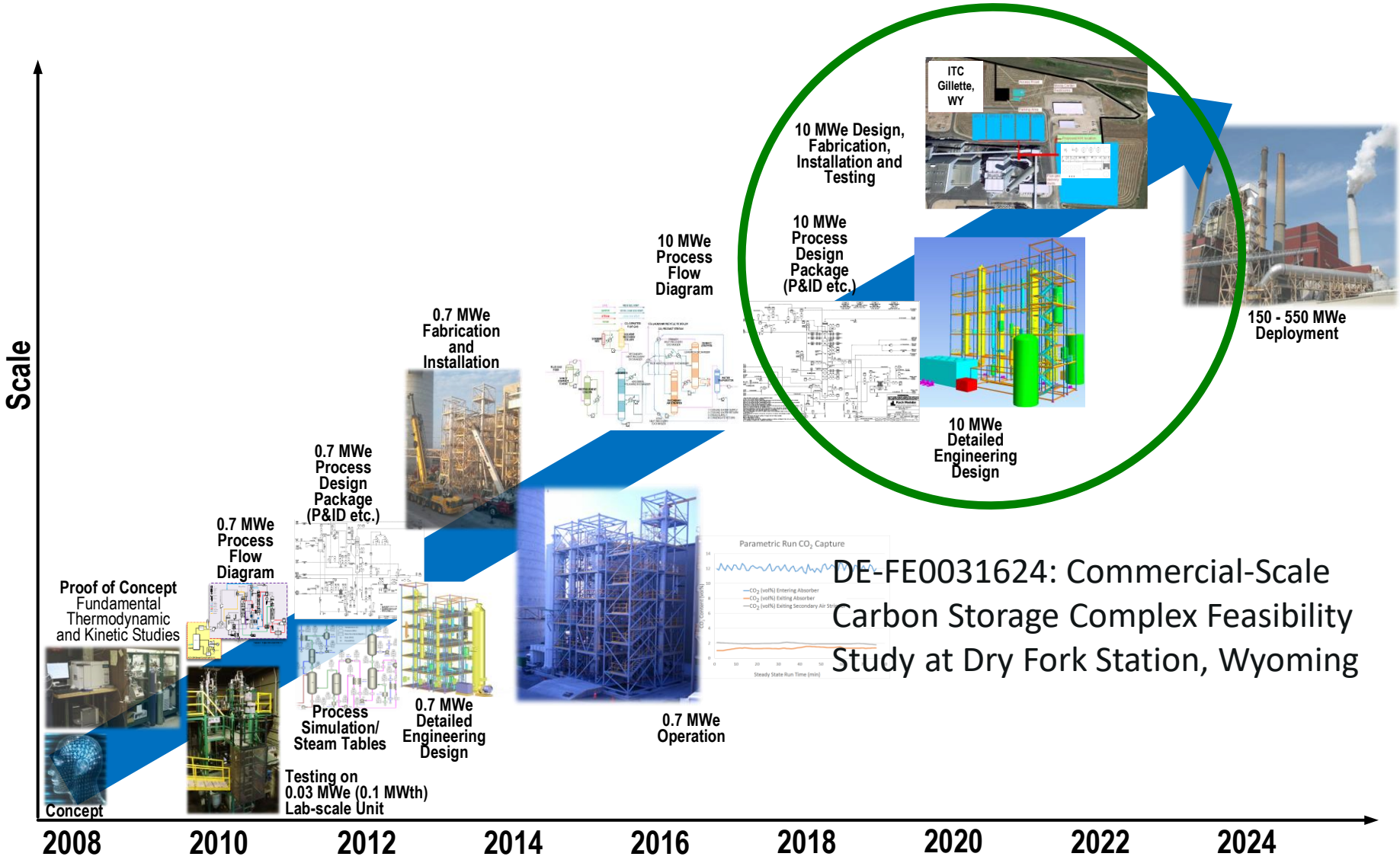
University of Kentucky

Center for Applied Energy Research

Lexington, KY

http://www.caer.uky.edu/powergen/home.shtml

Well-Investigated Technology



DE-FE0031624: Commercial-Scale Carbon Storage Complex Feasibility Study at Dry Fork Station, Wyoming

Executive Summary

- Process oriented technology, applicable with any 2nd generation solvent with short column and low operating cost
- Phase I complete, with all success criteria and milestones met
- Pre-FEED, EIV complete, Host Site Agreement in place and TAB established
- Team expertise covering every aspect – chemistry, engineering, fabrication, installation, operation, control, environment, health and safety, permit and waste management
- Phase II awarded for FEED study

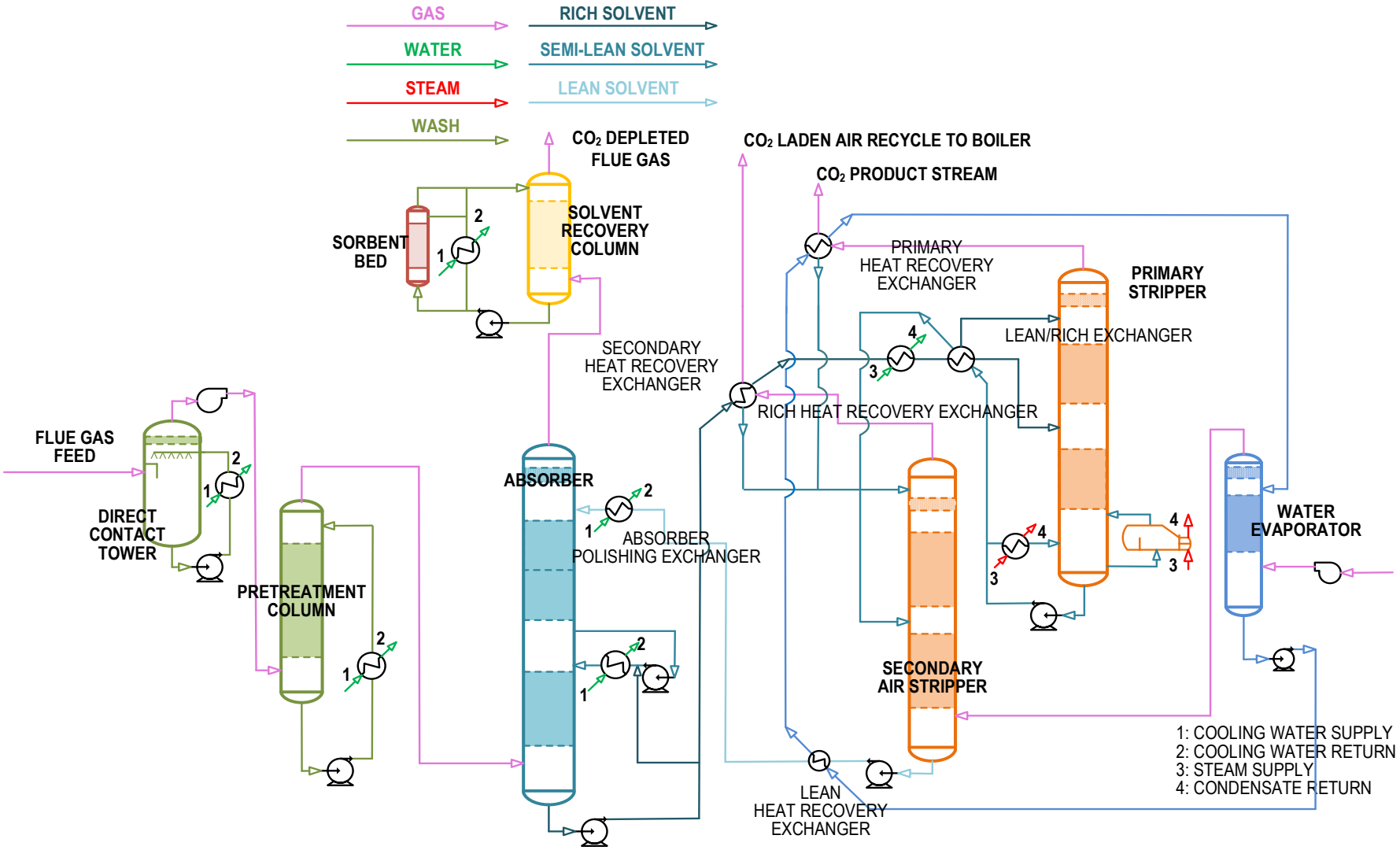
Project Team Member	Working Together Since	Significant Accomplishments Together
CCSUS	2016	Solvent campaigns conducted at large bench and small pilot scales
CMU	2018	New collaborator on advanced process control
EPRI	2008	CCS TEAs since 2012; 0.7 MWe small pilot CCS independent testing and calculation verification
ITC	2018	10 MWe large pilot CCS host site for design basis
KMPS	2009	0.7 MWe small pilot CCS ISBL process and equipment design and supply
Worley	2011	CCS TEA cost estimation and large-pilot OSBL
SMG	2009	EH&S assessments, NEPA and EIVs of CO_2 capture
Trimeric	2015	Cost estimation of CCS and gasification processes
UTA	2013	Aspen model and simulation development 0.7 MWe small pilot CCS emissions monitoring

Project Overview

Funding (DOE and Cost Share) and Project Performance Dates

Funding	Funding	Performance Dates
Phase I	$1,177,550	04/01/18 to 08/31/19
Phase II	$2,786,841	09/01/19 to 12/31/20

Technology Background



Performance

Integrated UKy-CAER CCS Power Summary.			
POWER SUMMARY	**RC B12B**	**UKy-CAER CCS**	**Percent Difference**
Steam Turbine Power (Gross at Generator Terminals, kWe)	642,000	632,779	-1%
AUXILIARY LOAD SUMMARY, kWe			
Coal Handling & Conveying	480	458	-4%
Pulverizers	3,370	3,219	-4%
Sorbent Handling & Reagent Preparation	1,070	1,022	-4%
Ash Handling	780	745	-4%
Primary Air Fans	1,670	1,595	-4%
Forced Draft Fans	2,130	2,035	-4%
Induced Draft Fans	8,350	7,976	-4%
SCR	60	57	-4%
Activated Carbon Injection (kW)	27	26	-4%
Dry Sorbent Injection (kW)	108	103	-4%
Baghouse	110	105	-4%
Wet FGD	3,550	3,391	-4%
CO_2 Capture System Auxiliaries	16,000	10,867	-32%
CO_2 Compression	35,690	34,086	-4%
Miscellaneous Balance of Plant[2,3]	2,000	1,910	-4%
Steam Turbine Auxiliaries	400	394	-1%
Condensate Pumps	640	611	-4%
Circulating Water Pump	7750	7,257	-6%
Ground Water Pumps	710	674	-5%
Cooling Tower Fans	4010	3,911	-2%
Transformer Losses	2380	2,153	-10%
TOTAL AUXILIARIES, kWe	**91,000**	**82,595**	**-9%**
NET POWER, kWe	550,000	550,000	0%
Net Plant Efficiency (HHV)	32.50%	33.97%	5%
As-Received Coal Feed (lb/hr)	495,578	473,362	-4%

Preliminary Economic Analysis

Economics of Integrated UKy-CAER CCS.			
UKy-CAER CCS Cost Estimate	**RC B12B[11]**	**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$/kW)	4940	4173	-16%
COE ($/MWh, 2011$) (including T&S)	142.8	125.2	-12%
COE ($/MWh, 2011$) (excluding T&S)	133.2	116.9	-12%
CO_2 T&S Costs	9.6	8.3	-13%
Fuel Costs	30.9	29.5	-5%
Variable Costs	12.3	12.4	1%
Fixed Costs	15.4	13.0	-16%
Capital Costs	72.2	61.9	-14%
Cost of CO_2 Captured ($/tonne CO_2) (including T&S)	67.8	51.4	-24%
Cost of CO_2 Captured ($/tonne CO_2) (excluding T&S)	58.2	41.4	-29%
Cost of CO_2 Avoided ($/tonne CO_2)	89.4	61.6	-31%

Progress and Current Status of the Project

Phase I Complete and Phase II Started

- ✓ Team Assembled
- ✓ Multi-party NDA in Place
- ✓ Host Site Agreement Negotiated and in Place
- ✓ ISBL Preliminary Design and Cost Estimate Complete
- ✓ OSBL Preliminary Design and Cost Estimate Complete
- ✓ TAB in Place
- ✓ EIV Complete
- ✓ FEED Underway

Host Site

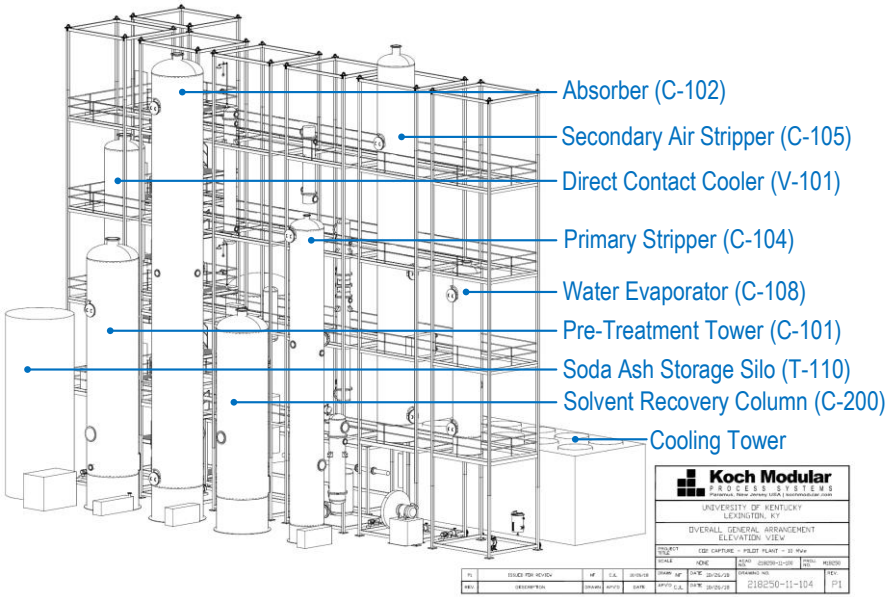
- ✓ Wyoming ITC
- ✓ BEPC Dry Fork Station 445 MW gross output coal-fired boiler, 96% capacity factor, PRB coal
- ✓ Ample space, flue gas and utilities supplied

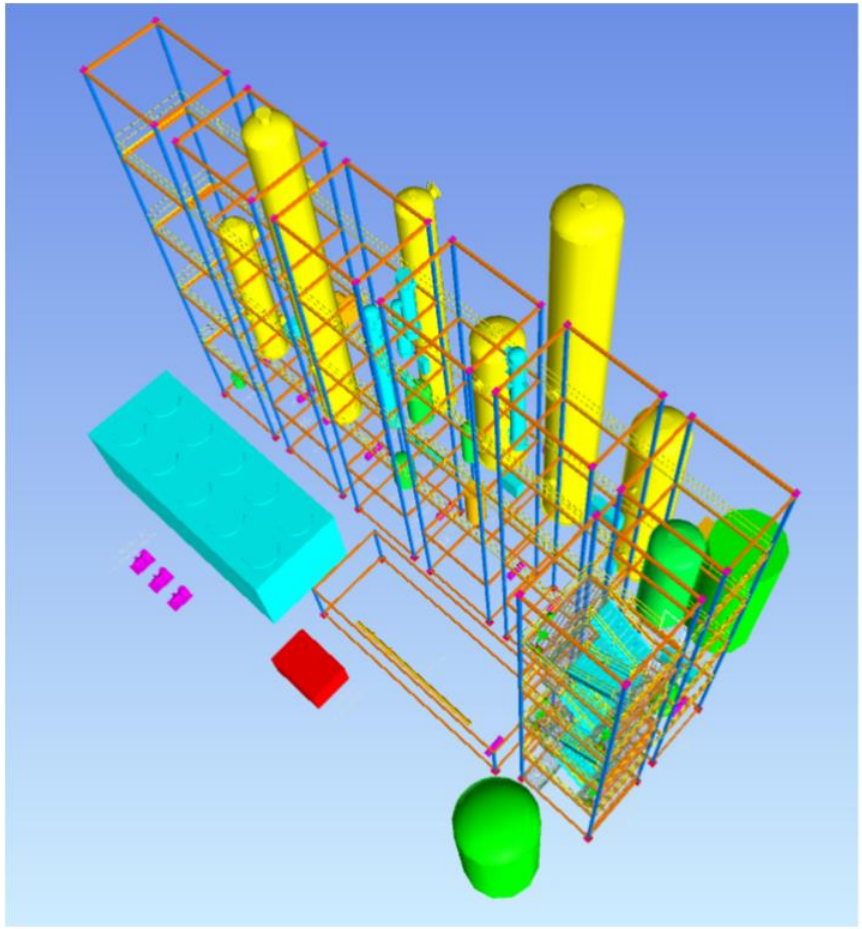
Site Characteristics and Ambient Conditions.

Characteristic	Units	Value
Location		~7 miles north of Gillette WY
Elevation	M	1295
Barometric Pressure	KPa abs	87
Average Temperature (Yearly)	°C (°F)	7 (46.3)
Maximum Temperature	°C (°F)	37 (99)
Minimum Temperature	°C (°F)	-40 (-40)
Relative Humidity	%	18-63
Prevailing Wind Direction		from the north
Rainfall Yearly Average	mm (in)	430 (16.9)
Rainfall Maximum Monthly Average	mm (in)	80 (3.15) / May
Design Rain Event (100-yr, 1-hour duration)	mm (in)	98.8 (3.89)
Snowfall – September to May	mm (in)	150 (59)
Frost Depth – Foundations	mm (in)	1067 (42)

ISBL Pre-FEED

- ✓ Identification of System Boundaries, Input and Output Streams, Site Characteristics and Ambient Conditions, Major Equipment and Operating Conditions and Environmental Controls
- ✓ Development of P&IDs, Gas, 3-D Model, Equipment List and Weights, Electrical Load Schedule and Solution Volumes





ISBL Pre-FEED

Streams Across Boundary

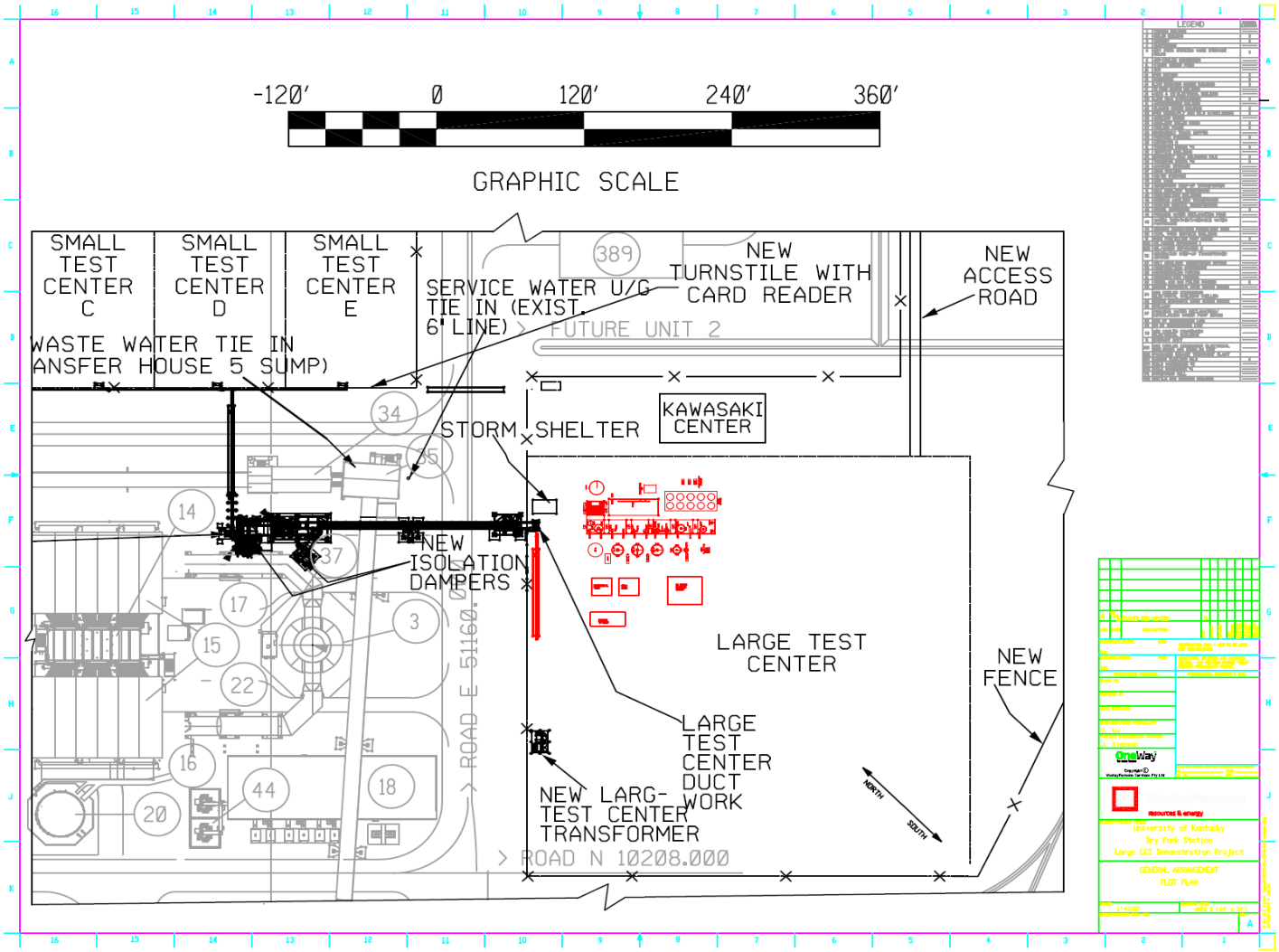
10 MWe CO_2 Capture System Requirements.		
Type	**Maximum Values to Meet Project Obligations**	**Units**
Required from DFS		
Land	0.5	acres
Flue Gas Feed	100,000	lb/hr
Plant Water	20	gpm
De-mineralization (DM) water	3	gpm
Plant Air (Flowrate Approved by Plant Prior to Use)	Leak Testing	
Potable Water (SS/EW Stations and Lab Use Only. No Process Use.)	200	gal/day
Natural Gas	1220	lb/hr
Instrument Air	May or may not be required	scfm
Electric Load	1500	kW
Returned to DFS		
Cooling Tower Blowdown	4	gpm
NG Boiler Blowdown	2	gpm
SO_2 Polisher Blowdown	0.13	gpm
Storm Water	152,000	gph
Supplied and Handled by UKy-CAER		
Steam System (NG Boiler)	22,000	lb/hr
Instrument Air	1450	scfm
Reclaimer Waste (Likely Hazardous)	300	gal
Solvent Waste (At End of Project)	19,000	gal
SO_2 Polisher Solution (At End of Project)	6,700	gal
Waste Lubricants	100	gal

OSBL FEED

- ✓ Identification of Utility Requirements, Major OSBL Equipment and Operating Conditions and Environmental Controls
- ✓ Development of Design Basis, PFDs, GAs, Equipment List, Electrical Load Schedule, Structural Design Criteria, Foundation Requirements, Buildings

Foundation and spill containment for the KMPS modules and equipment,
Foundations and spill containment for BOP systems
Natural Gas boiler and accessories and steam and condensate piping,
Pipe system supports,
Flue gas supply,
Duct support structures,
Process, potable and demineralized water service/piping,
Compressed and instrument air service/piping,
Cooling tower, NG boiler, pretreatment tower and storm water return service/piping,
Flue gas condensate collected OSBL to cooling tower service/piping,
Process materials loading dock,
Tie into electrical service and supporting electrical equipment
Electrical PDC Building,
CEMS equipment and Enclosure,
BOP systems process control system and integration with ISBL process control system,
Mobile control room/lab/maintenance area including washroom and washroom water collection tank
Fire water and hydrant and service to buildings

OSBL Facility Layout



EIV Completed

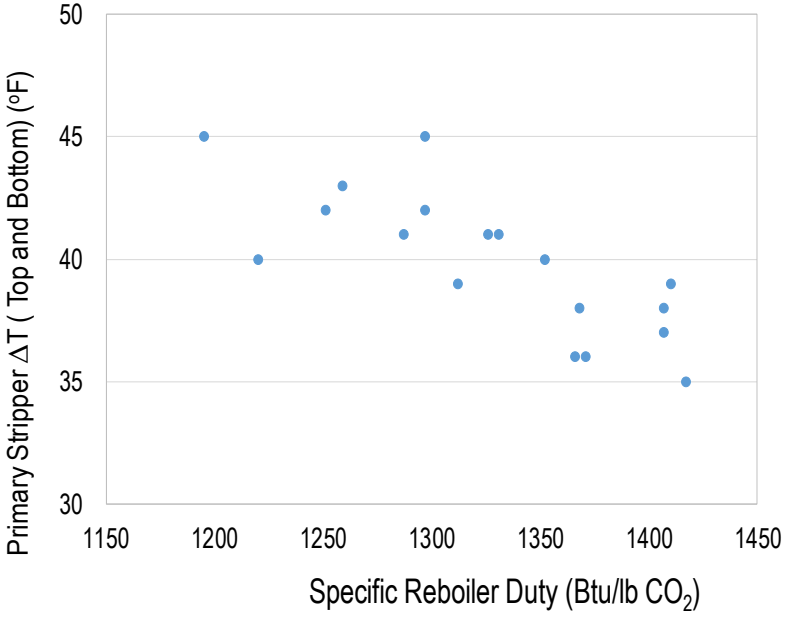
- ✓ No Significant EH&S Impacts Anticipated
- ✓ Phase II final National Environmental Protection Act (NEPA) documentation predicted to consist of a completed Categorical Exclusion (CX).

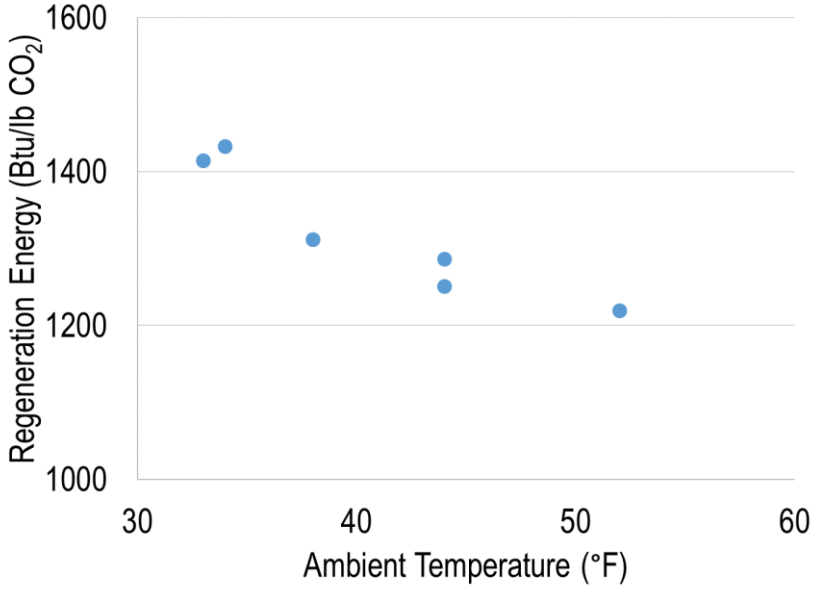
Environmental Information Volume completed
Nine areas considered

1. Land Use
2. Air Quality
3. Water Quality
4. Vegetation & Wildlife
5. Socioeconomic
6. Visual, Cultural & Historic
7. Health & Safety
8. Waste
9. Chemical Management

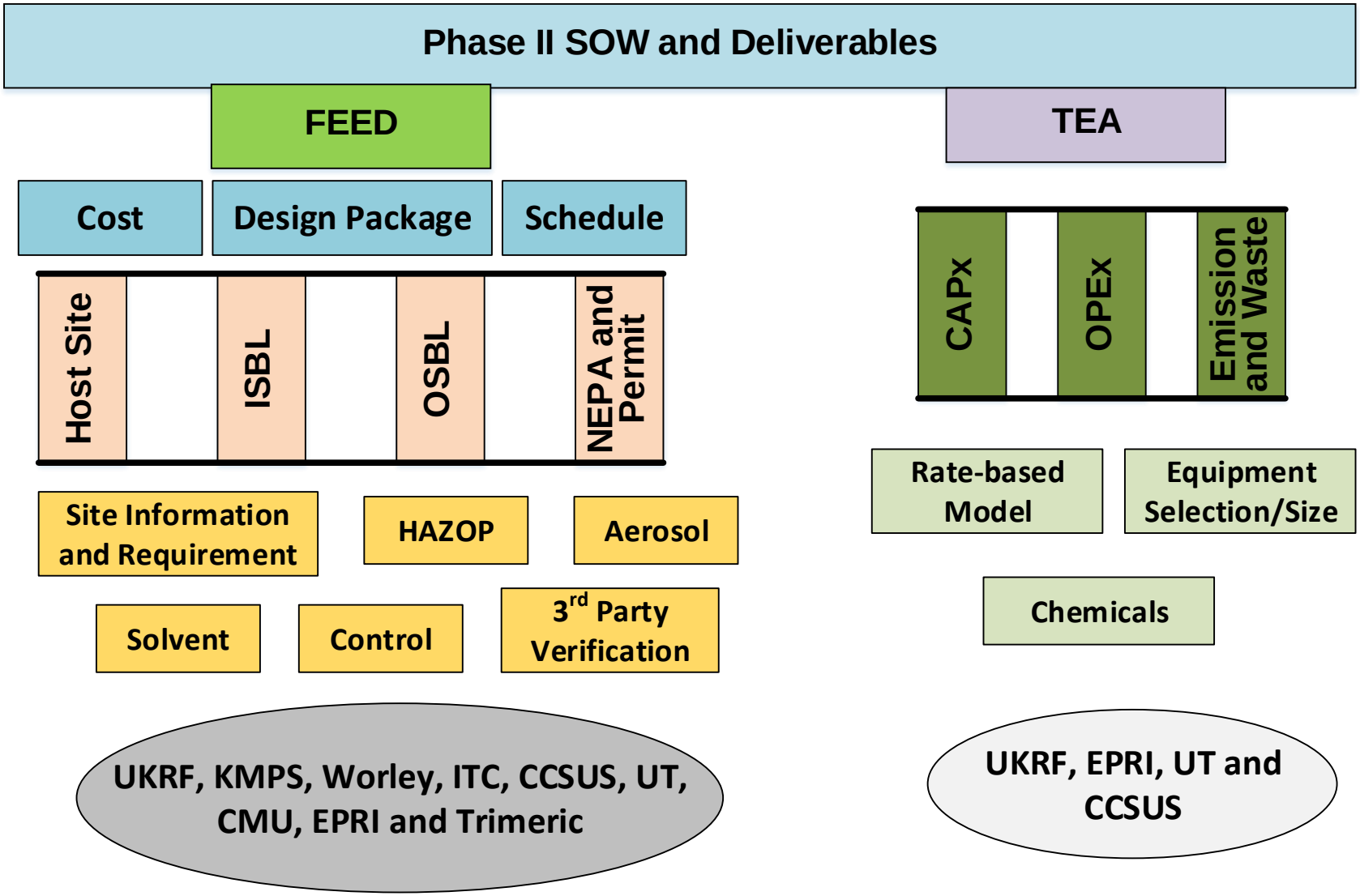
0.7 MWe Small Pilot CDRMax Campaign

- ✓ 225 hour campaign
- ✓ 90% CO_2 capture with a regeneration energy of 1200-1400 BTU/lb CO_2
- ✓ Secondary air stripper regenerated up to 17 wt% of the total CO_2 absorbed
- ✓ Increasing primary stripper ΔT Leads to Lower Solvent Regeneration Energy
- ✓ Lower Regeneration Energy Correlates to Higher Ambient Temperature.



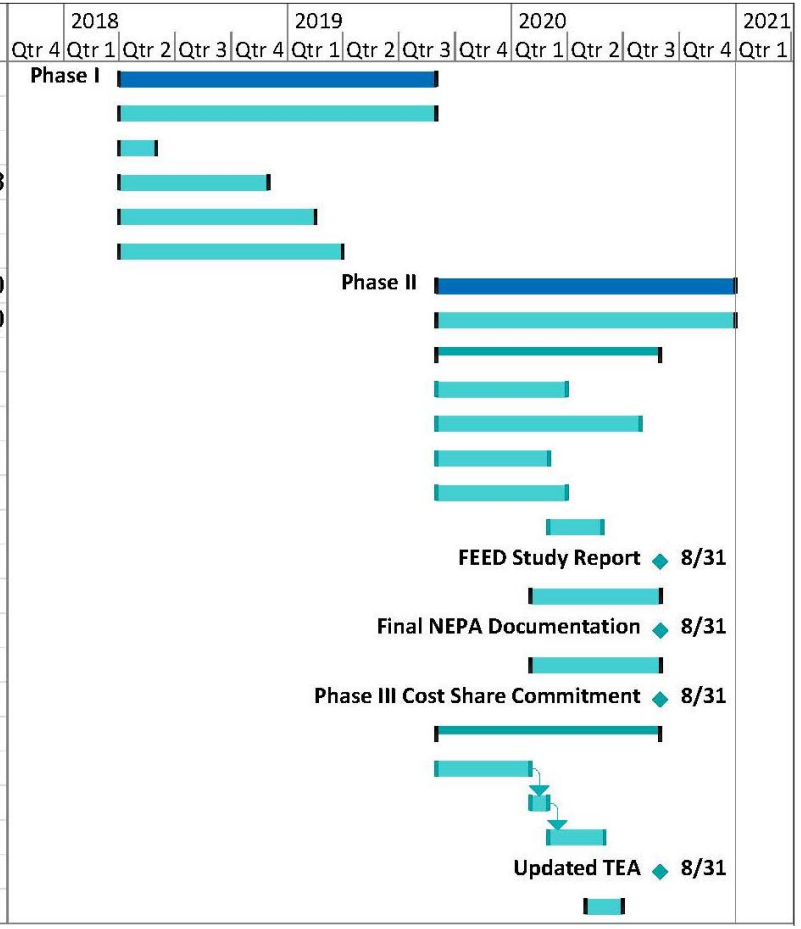


Phase II SOW and Team Integration

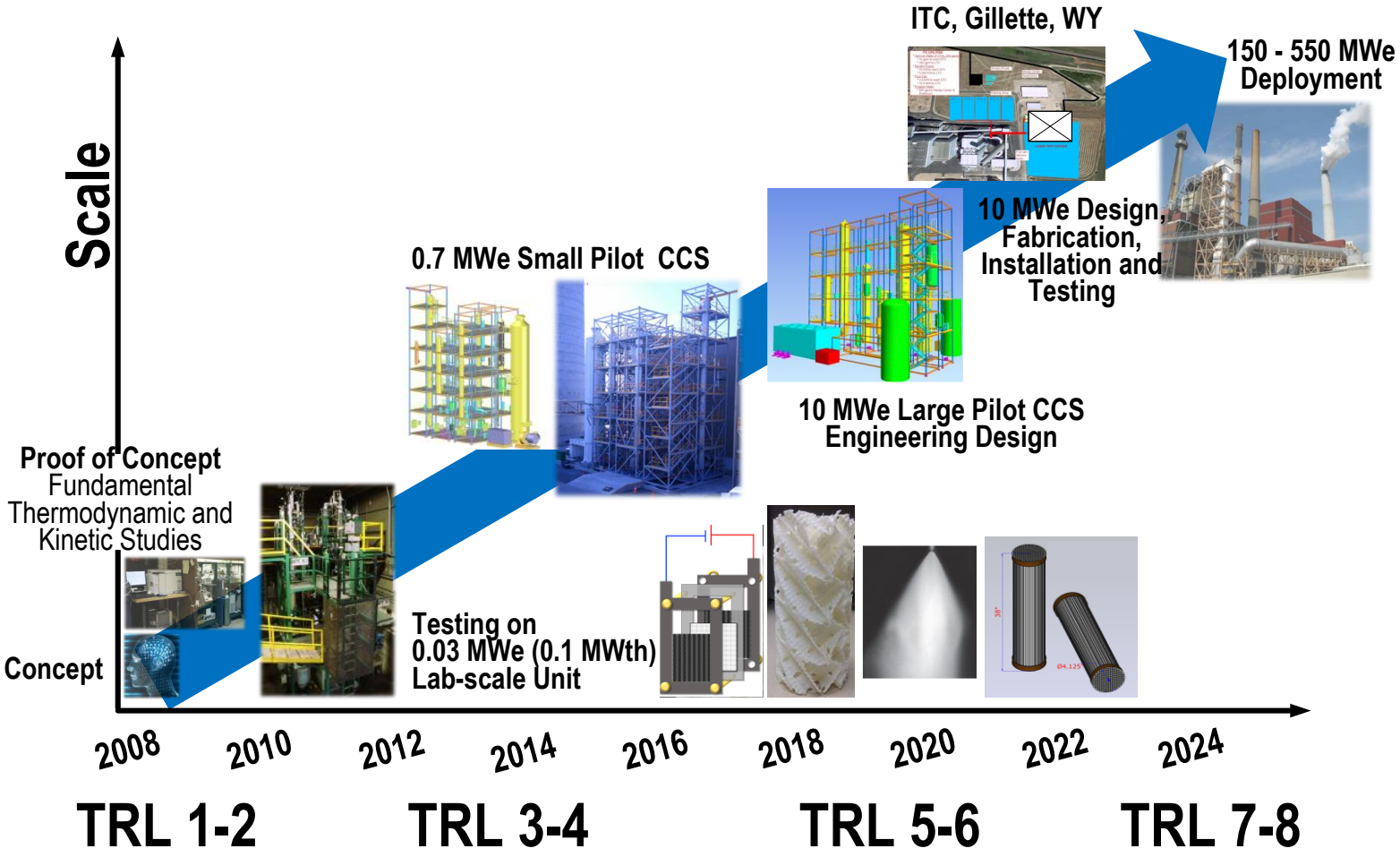


Project Schedule

Task Name	Start	Finish
Phase I	**4/1/18**	**8/31/19**
1.0 Project Management and Planning	**4/1/18**	**8/31/19**
2.0 Host Site Agreement Amendment	**4/1/18**	**5/31/18**
3.0 Aspen Plus®Model Simulation Creation and Update	**4/1/18**	**11/30/18**
4.0 Project Schedule and Cost Estimate	**4/1/18**	**2/15/19**
5.0 Environmental Information Volume	**4/1/18**	**3/31/19**
Phase II	**9/1/19**	**12/31/20**
1.0 Project Management and Planning	**9/1/19**	**12/31/20**
2.0 FEED Study	**9/1/19**	**8/31/20**
2.1 ISBL Feed Study	9/1/19	3/31/20
2.2 CCS Process Control Scheme	9/1/19	7/29/20
2.3 Aerosol Emissions Model Development	9/1/19	3/2/20
2.4 OSBL FEED Study	9/1/19	3/31/20
2.5 Process HAZOP	3/1/20	5/28/20
FEED Study Report	8/31/20	8/31/20
3.0 NEPA/Permitting at Host Site	**2/1/20**	**8/31/20**
Final NEPA Documentation	8/31/20	8/31/20
4.0 Team and Cost Share Commitments	**2/1/20**	**8/31/20**
Phase III Cost Share Commitment	8/31/20	8/31/20
5.0 Techno-Economic Analysis	**9/1/19**	**8/31/20**
5.1 Process Simulation	9/1/19	1/31/20
5.2 Equipment Sizing	2/1/20	2/29/20
5.3 Economic Analysis	3/1/20	5/31/20
Updated TEA	8/31/20	8/31/20
6.0 Project Schedule and Cost Estimate	**5/1/20**	**6/30/20**



Integrated/Crosslinked PCCC Research



Acknowledgements

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KMPS: Stan Lam and Terence Nish
Worley: James Simpson and Sandeep Jain
SMG: Clay Whitney and Stewart McCollam
Trimeric: Andrew Sexton
UTA: Gary Rochelle
UKy: Don Challman and Cliff Iler