Piperazine Advanced Stripper (PZAS™) Front End Engineering Design (FEED) Study [on NGCC at Denver City , Tx]

DE-FE0031844
2020 CCUS Integrated Project Review Meeting
August 17-19, 2020

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Department of Chemical Engineering
The University of Texas at Austin

Takeaways

Objective: accurate FEED with benefits

PZAS: a superior capture technology

Mustang Station: space, EOR & cheap energy

Absorber: only 25 ft of solvent packing

Stripper: CO_2 product at 80 psia

Steam: gas-fired boilers with “free” fuel

Compression: 2 reciprocating machines

The Objective: *Accurate installed cost of PZAS™ on NGCC at GSEC Mustang Station*

Complementary Benefits:

- *Develop commercial project at Mustang Station*
- *Qualify PZAS for use on NGCC cogeneration*
- *Provide commercial cost detail*
  - *To optimize PZAS & other 2G capture processes*
  - *To guide R&D of capture technology*

Program Overview

- Funding (DOE and Cost Share)
  - 4.1 MM DOE
  - 1.1 MM cost sharing- ExxonMobil, Total, Chevron
  - 0.3 MM from Honeywell UOP outside DOE
- Performance Dates: 10/2019 – 9/2021
- Project Participants
  - Golden Spread Electric Cooperative (GSEC) - host
  - University of Texas at Austin (UT) - Modeling/ Technology
  - Trimeric – Process Engineering
  - AECOM - EPC

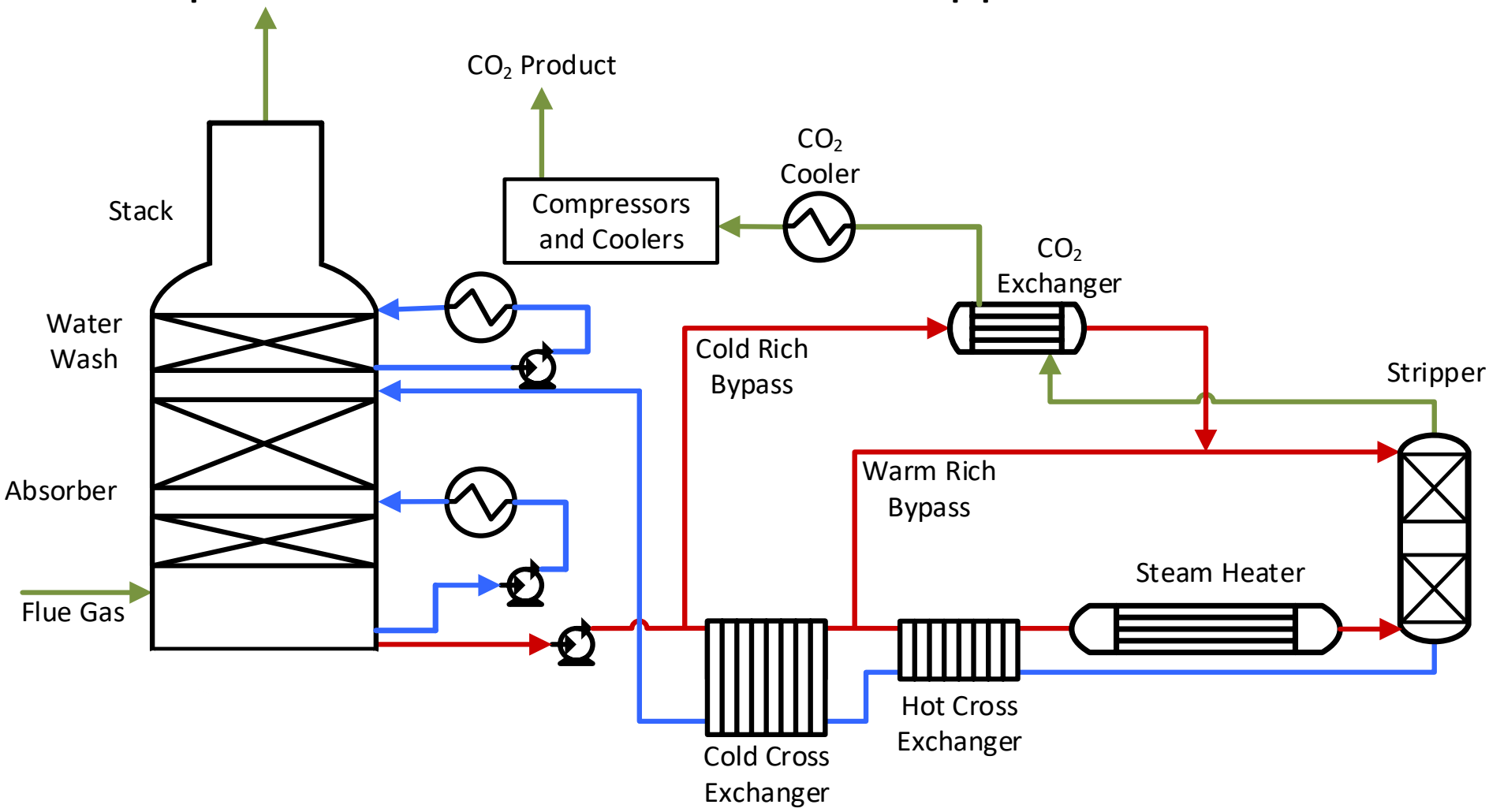
Milestones

2. Kick Off Meeting; DOE	Feb 3, 2020
3. Virtual Kick Off; Mustang Station	Mar 30, 2020
4. Project Design Basis	Aug 14, 2020
5. 2020 DOE-NETL Contractors Mtg	Aug 18, 2020
6. Baseline Process Design	Oct 2020
13. FEED Report	Sept 2021

Project team will request a no-cost extension to Dec 2021

PZAS for NGCC

5 m Piperazine with the Advanced Stripper



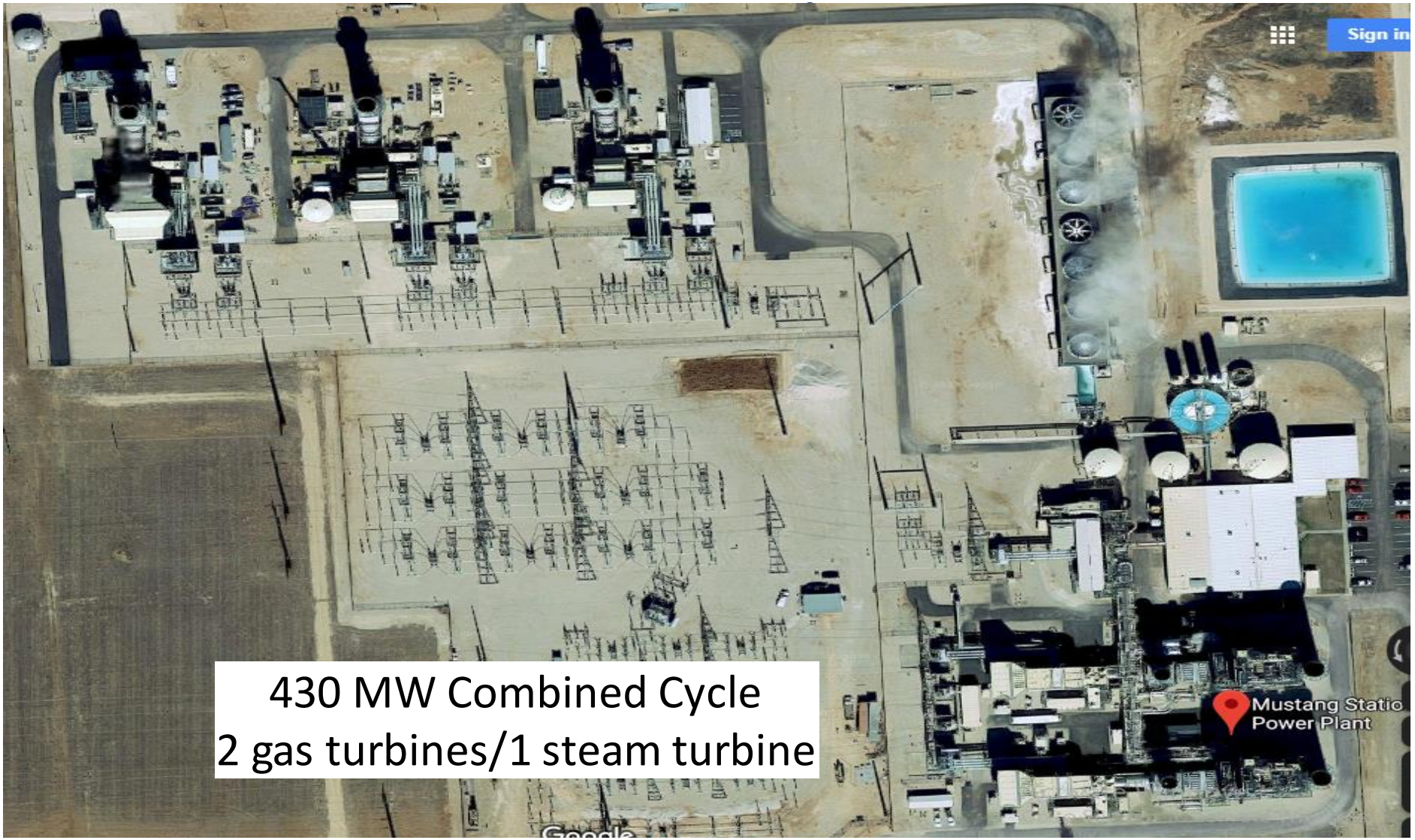
PZAS development includes comprehensive research & pilot plant demonstration

- (2000-20) Research by 43 graduate students
- (2006-09) UT Pilot of K_2CO_3/Piperazine (PZ)
- PZAS Pilot at 12% CO_2 for coal
  - (2010-18) UT Austin
  - (2018) at NCCC
- PZAS Pilot w 4% CO_2 For NGCC
  - (2016-18) UT Austin
  - (2019) NCCC

PZAS pilot at NCCC with CCP4 funding

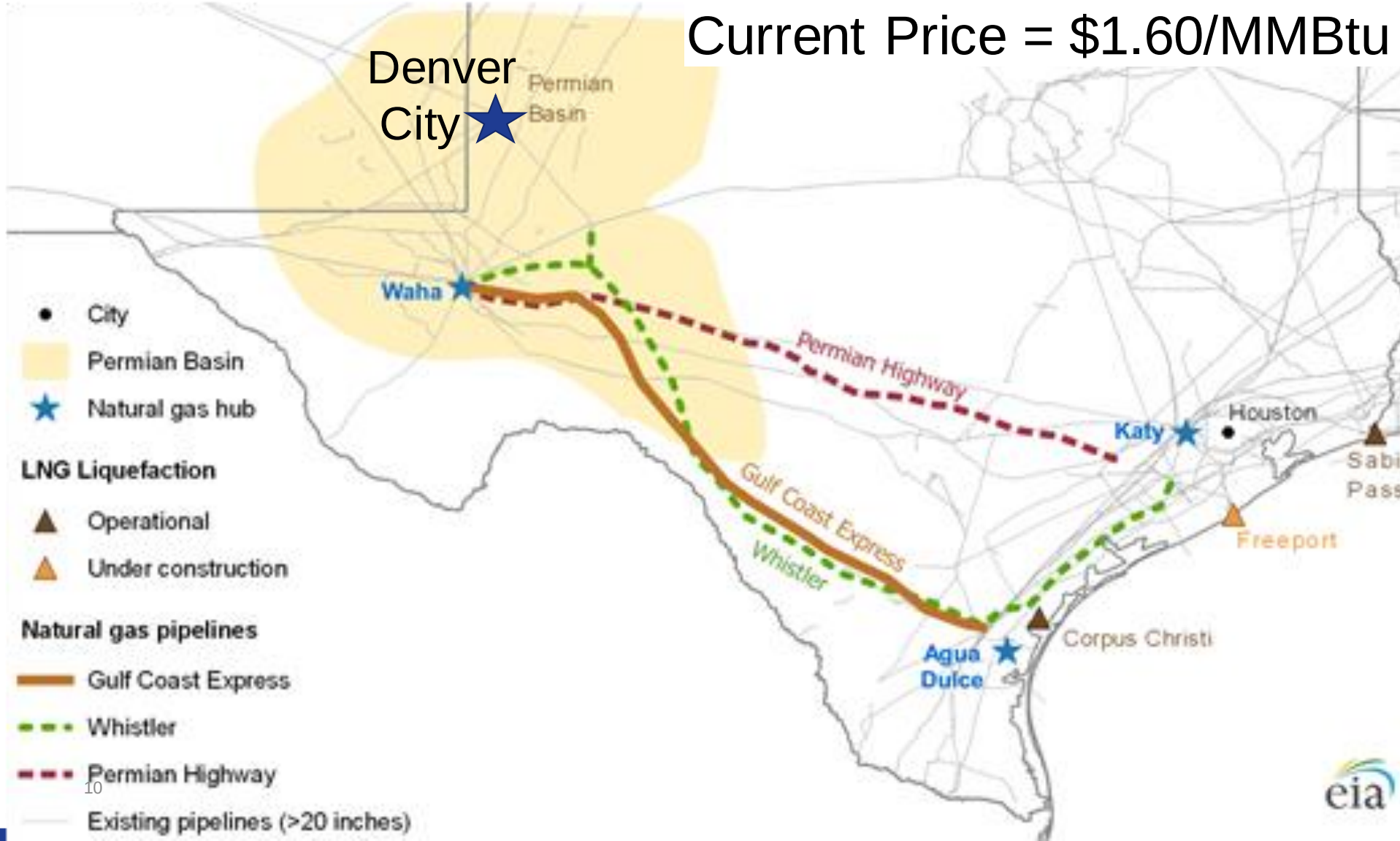
- Heat duty 2.4 GJ/t
- Stripping at 302 F/90 psia with little degradation
- 90-95% CO_2 removal with 2 x 20 ft packing
- Pump-around intercooling of hot inlet gas
- Low PZ oxidation, <0.3 kg/t CO_2
- 304 SS works up to 150°C
- PZ emissions < 1 ppm

Host Site - Mustang Station
Golden Spread Electric Cooperative, Denver City, TX

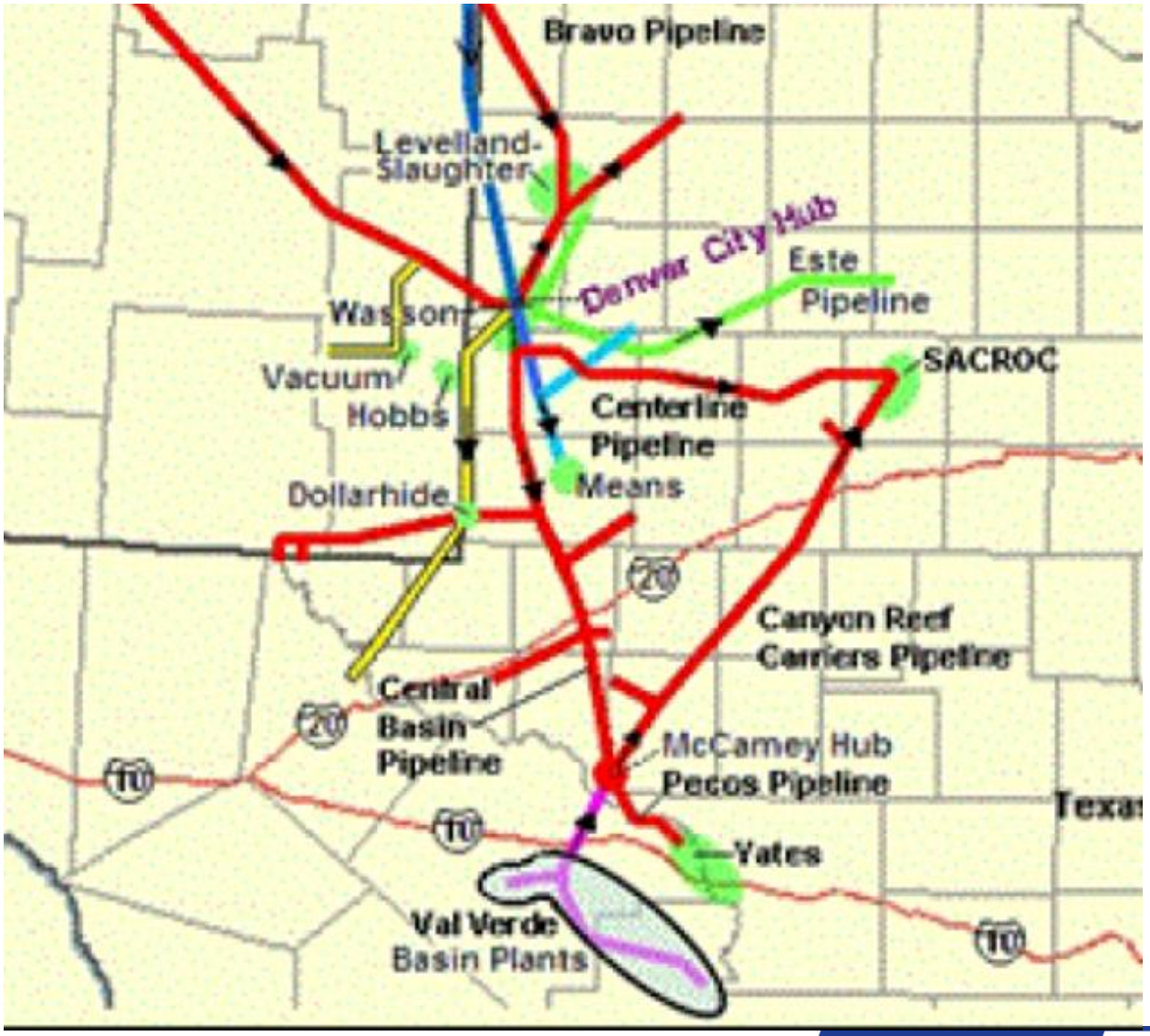


430 MW Combined Cycle
2 gas turbines/1 steam turbine

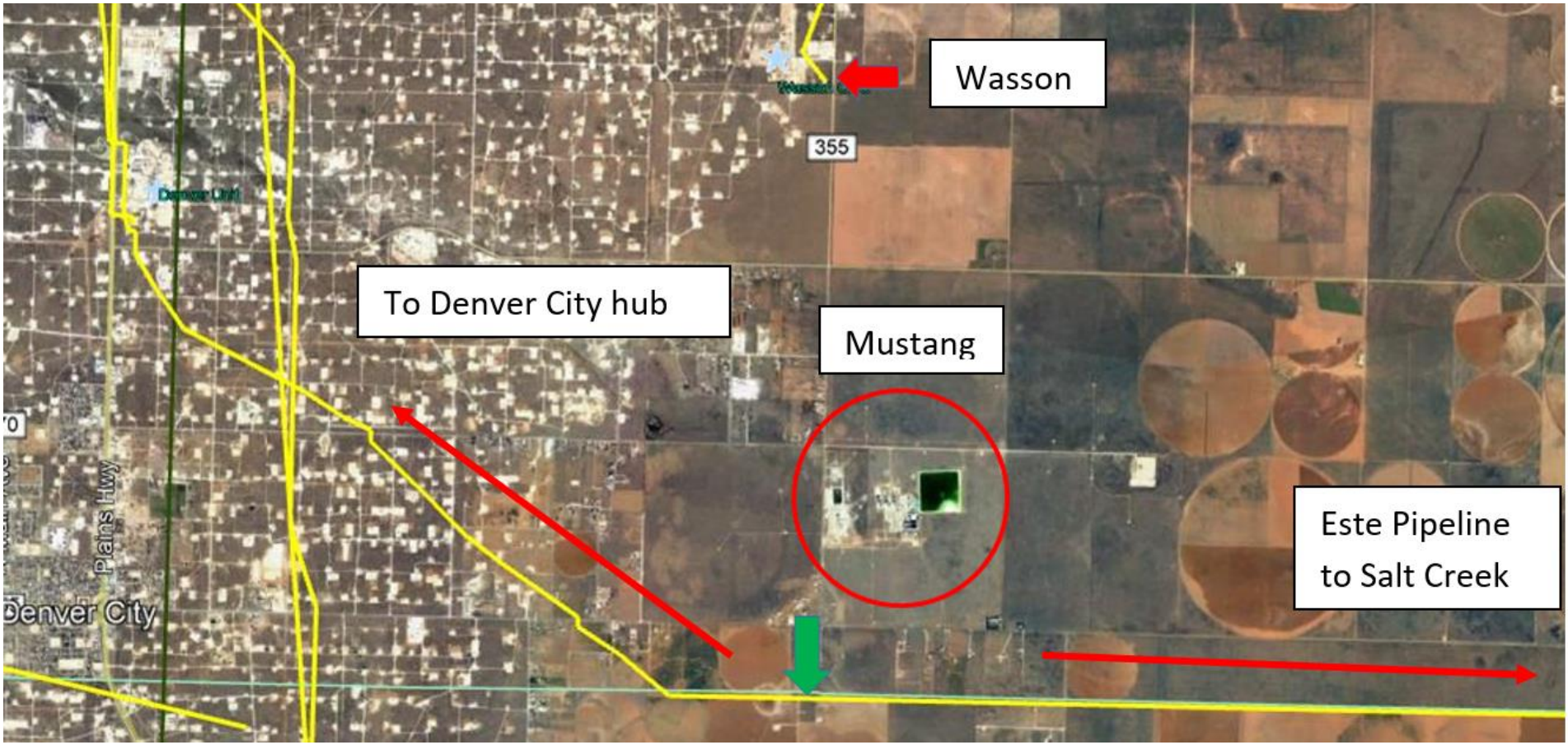
Cheap, Stranded Gas available from Waha Hub
Limited pipeline capacity from the Permian Basin



CO_2 pipelines converge on Denver City, TX

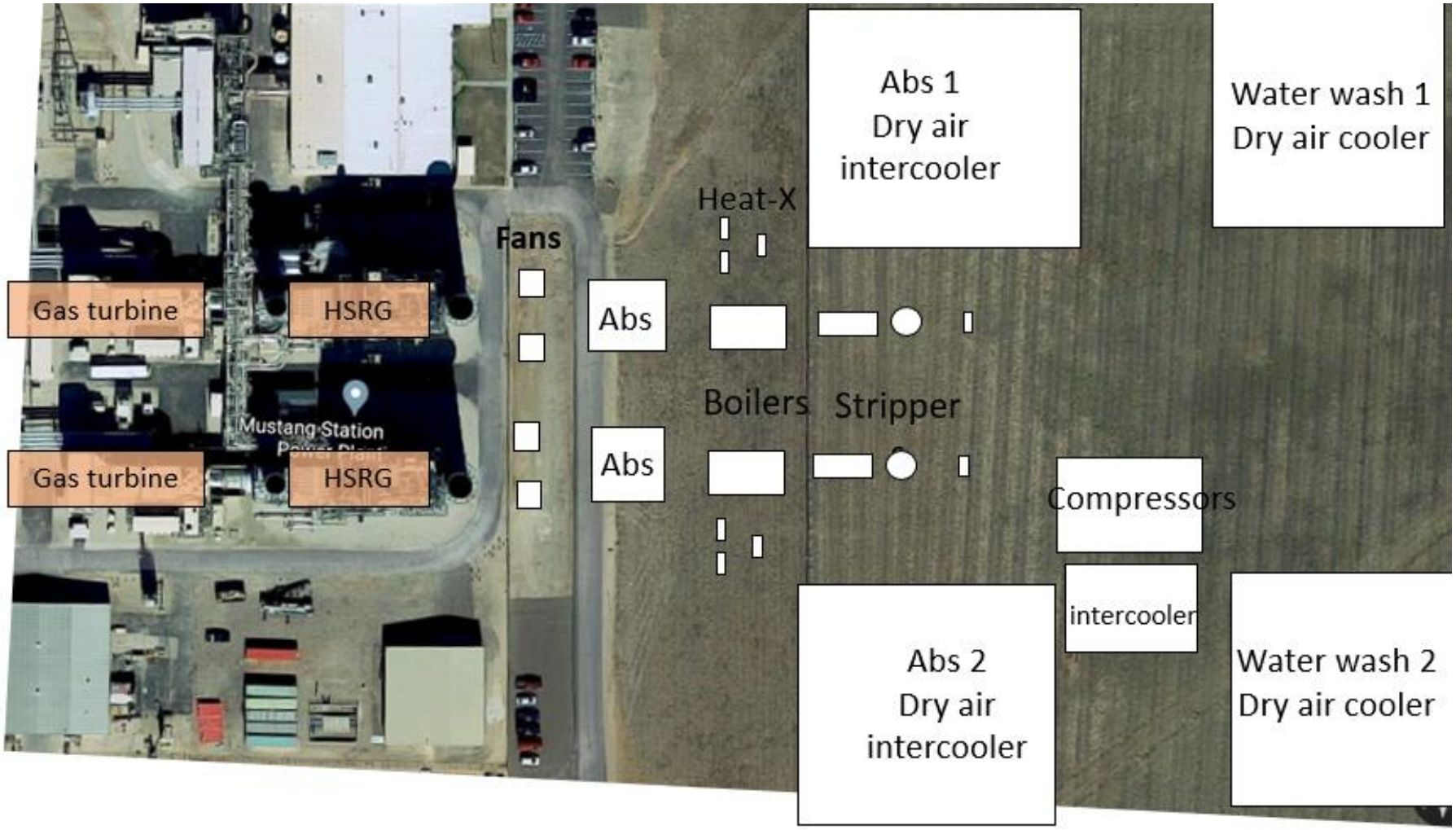


Ample open land
CO_2 to Este Pipeline for EOR



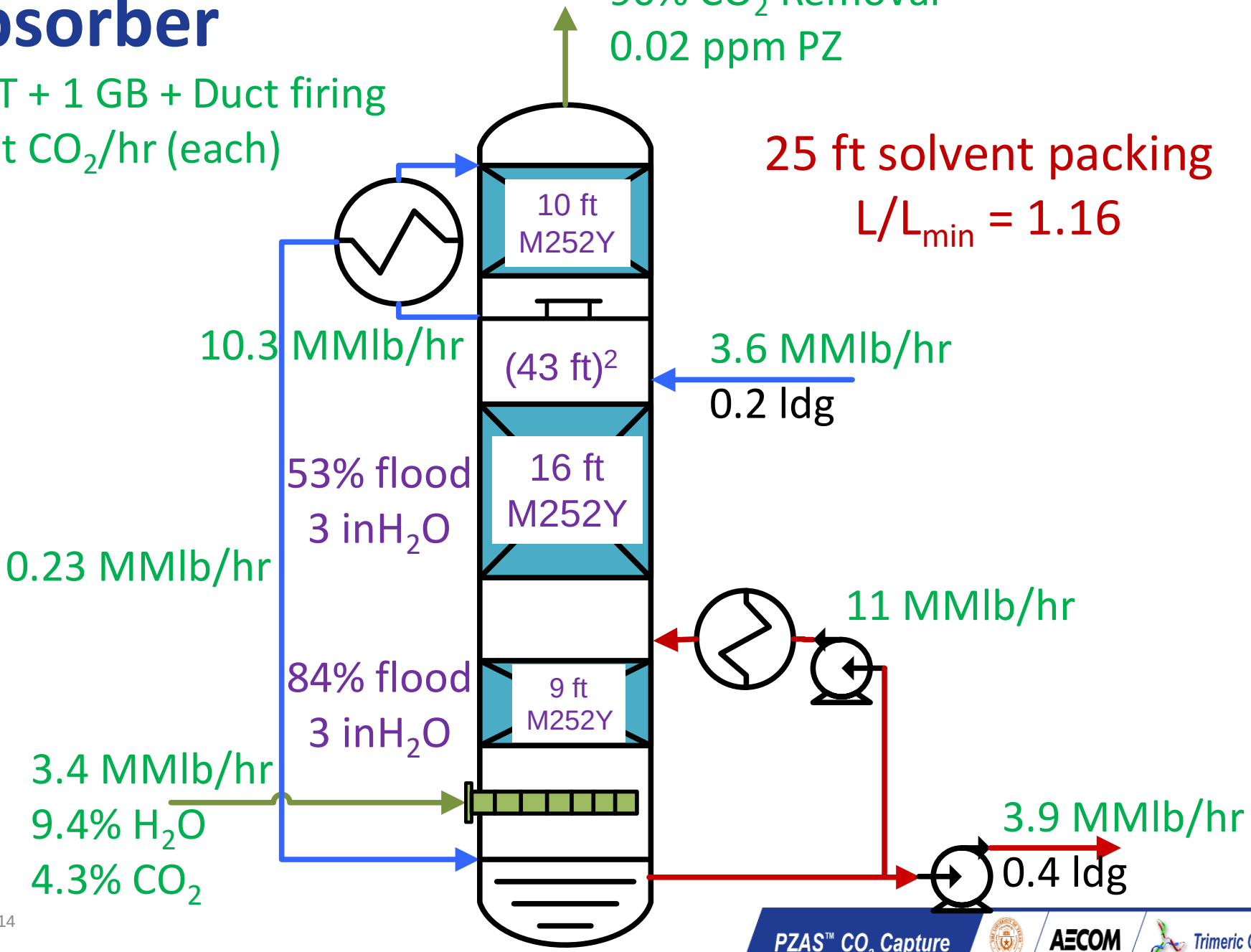
Two trains: Plot Space dominated by air coolers

[Preliminary unvetted layout by UT]



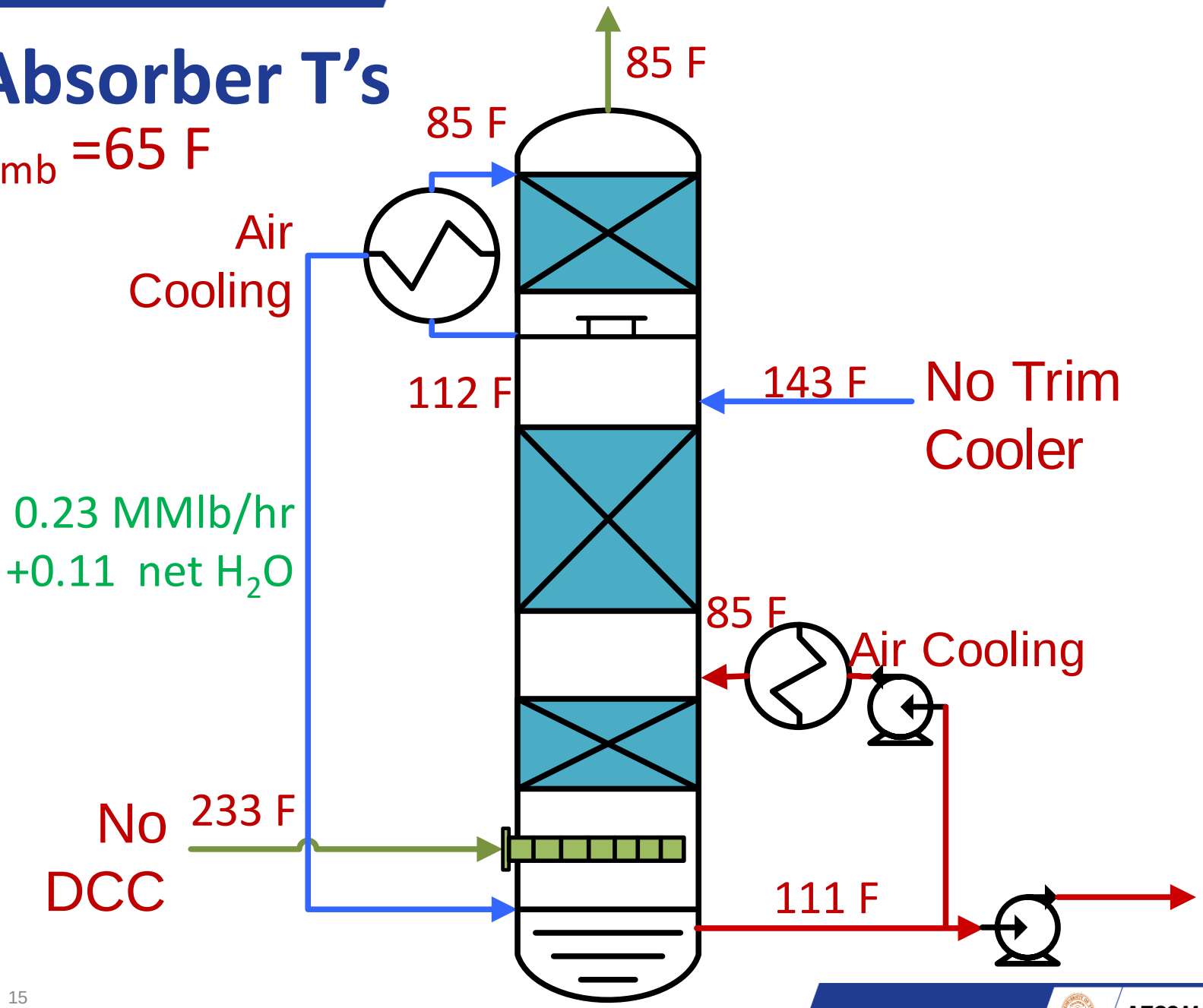
Absorber

1 GT + 1 GB + Duct firing
95 t CO_2/hr (each)



Absorber T's

T_{amb} =65 F

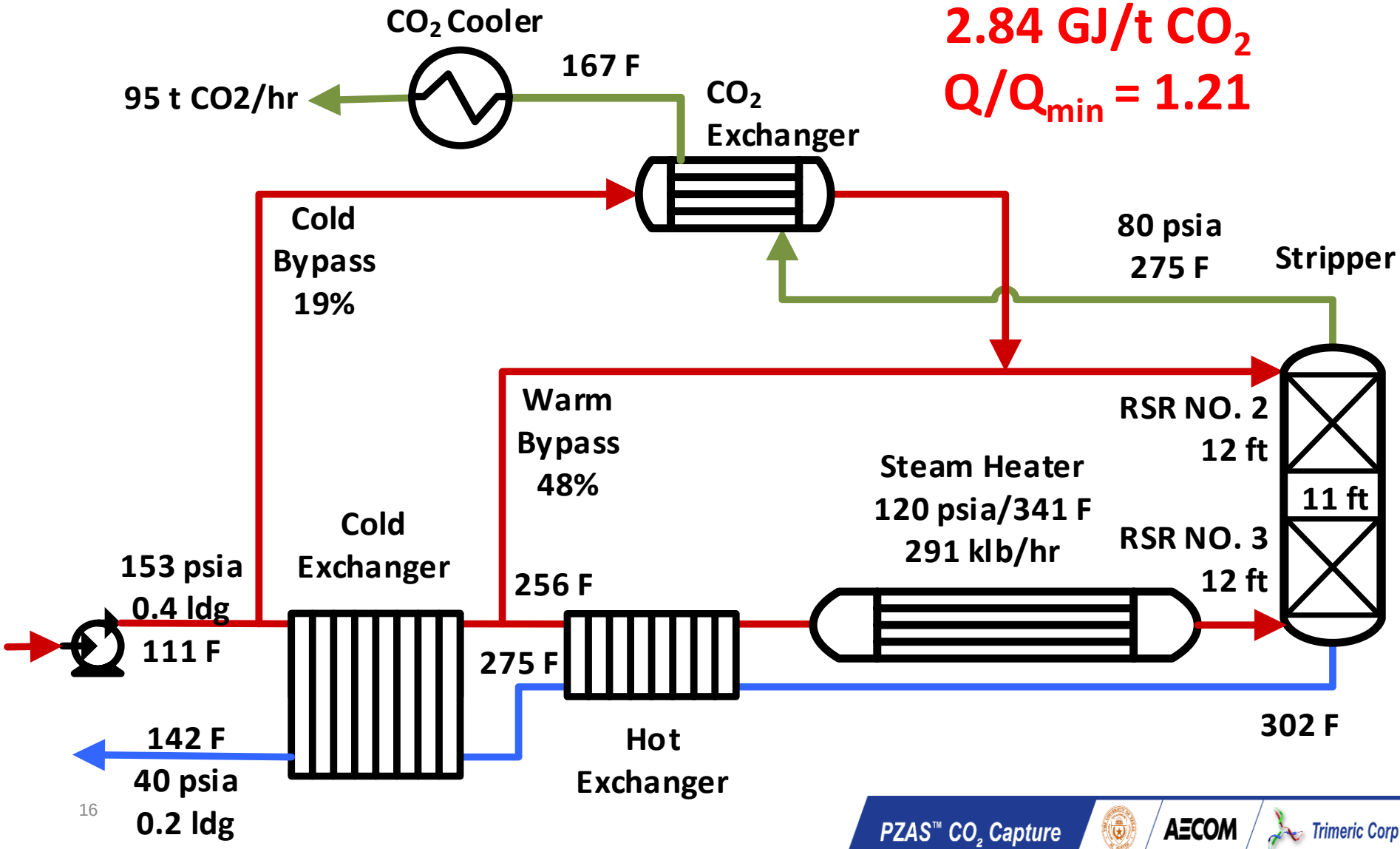


Advanced Stripper (for 1 GT+ 1 GB)

NTU = 8, 24 ft packing

2.84 GJ/t CO_2

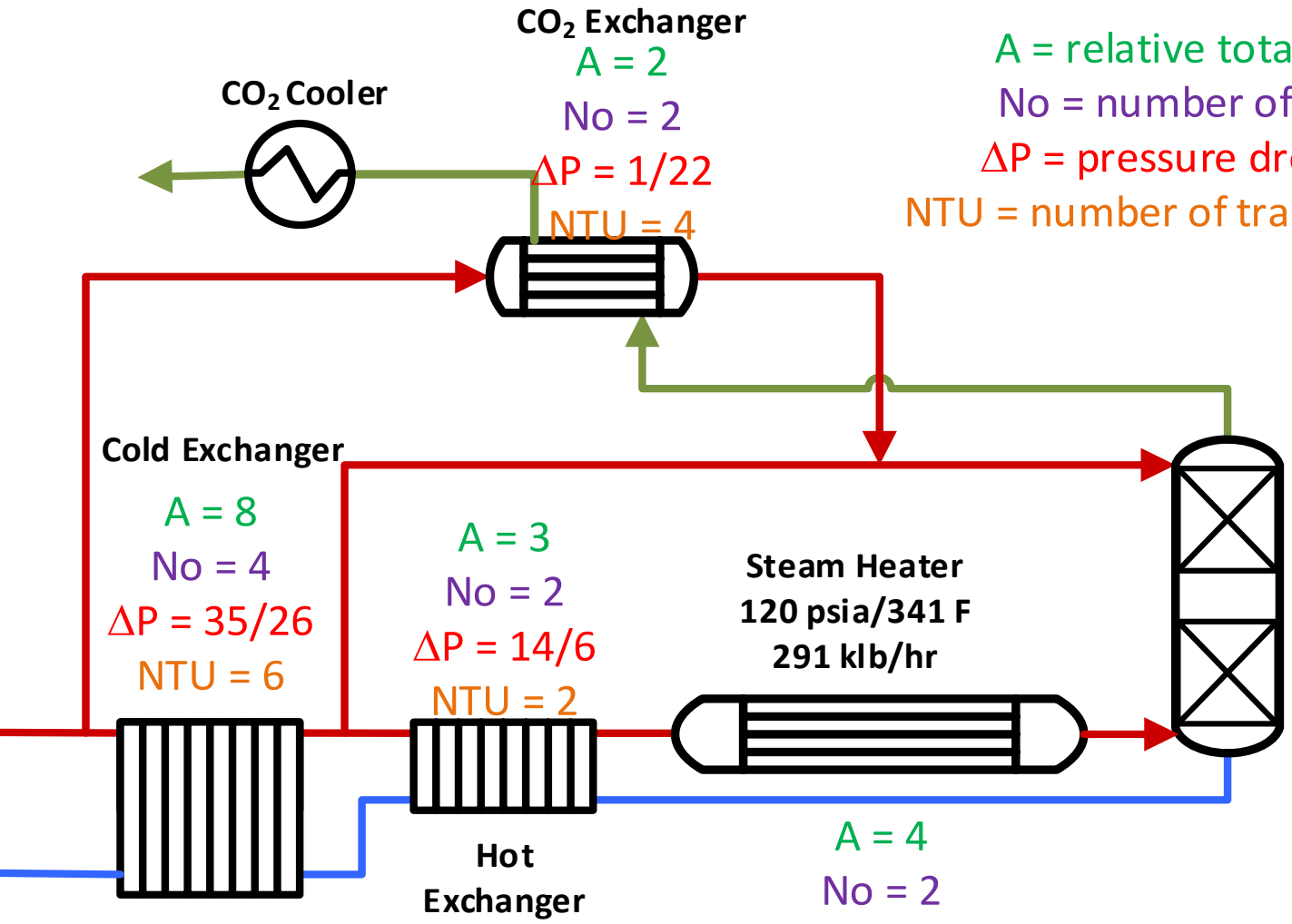
Q/Q_{min} = 1.21



Exchangers for both trains

low cost energy → less area, larger ΔP

Total Exchanger purchase cost = $3.6 MM



Steam provided by 2 gas-fired boilers

- 2 x 290,000 lbs/hr, one for each absorber
  - Saturated steam at 140 psia
  - Air preheater to reduce flue gas to 250 F
  - Flue gas fed to absorber for 90% removal
- @ \$50/t CO_2 for 45Q and EOR, the C in natural gas is worth \$2.66/MMBtu.
- @ 29 t CO_2/hr - \$13 MM/yr
- With 90% removal the incr fuel cost < zero if gas< \$2.4/MMBtu.
  - Current gas price is 1.2 – 2 \$/MMBtu

Design: One Reciprocating Compressor/Absorber

- Recip consistent with high inlet P
- Recip provides better turndown than centrifugal
- Purchase Cost about $700/hp
- Cost Comparison with 1 machine per absorber

	Reciprocating	Integrally Geared Centrifugal
Power per machine, HP	9,075	8,708
Relative Cost	1.0	1.3

1 IGC machine for 2 absorbers: relative total cost = 0.85

Profitability

- Cash Flow w capture, $65 MM/yr
  - Fuel cost, $2/MMBtu, $18/MWh
  - Variable maintenance & operating, $5/MWH
  - 45Q tax credit, $35/t CO_2, $14/MWh
  - EOR value, $15/t CO_2, $6/MWh
  - Electricity sales price, $18/MWh
  - Annual load factor, 75%
- Total cash flow w/o capture, $15 MM/yr
  - 50% annual load factor
- Net cash flow created by capture, $50 MM/yr
- With $300 MM investment, 6 yr payout

Conclusions

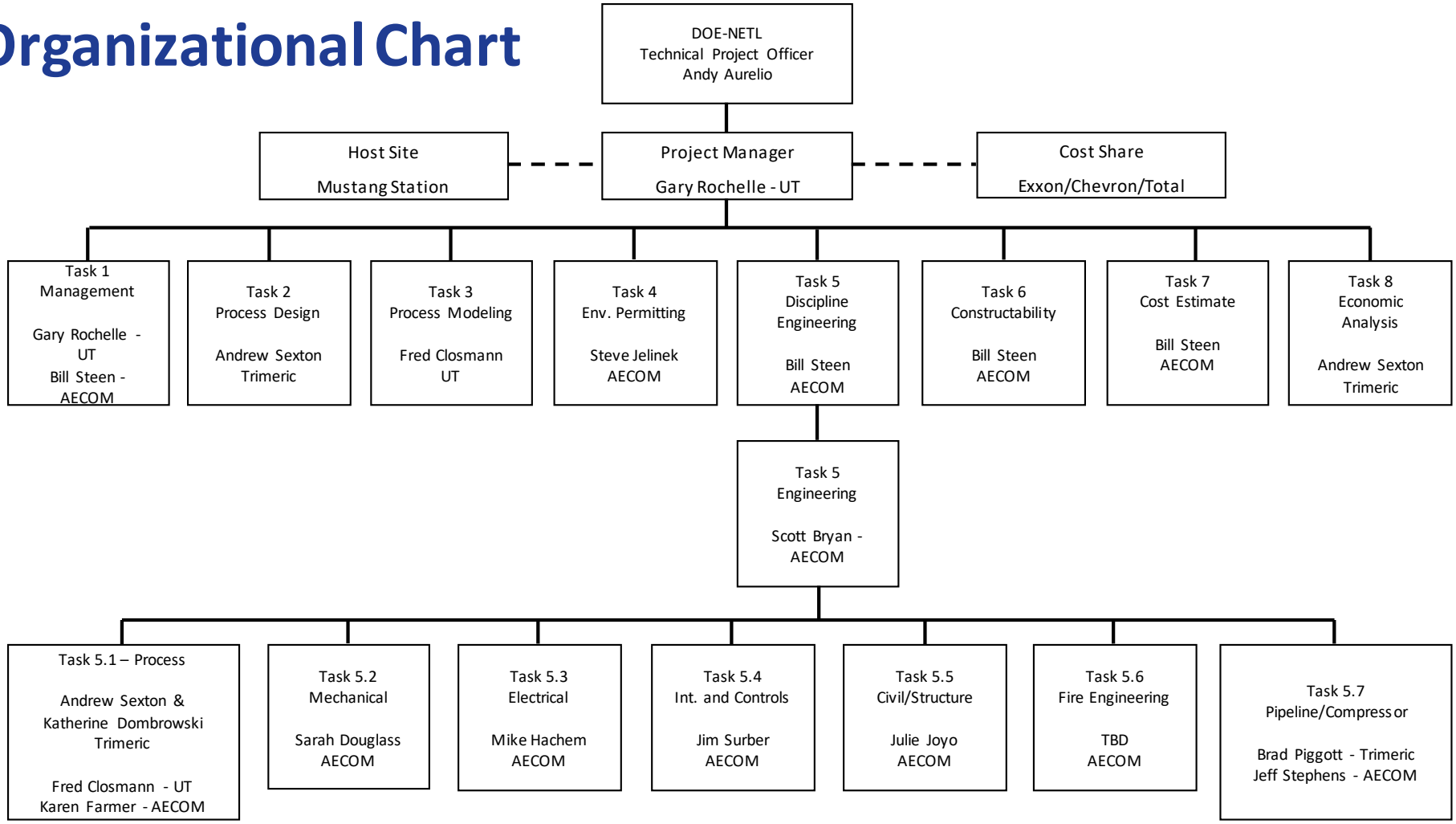
- PZAS uses 25 ft of absorber packing even w no DCC
- Air cooling feasible, even with swings in T_{amb}
- 80 psia stripper permits reciprocating compressors
- With cheap energy, PZAS uses 2.84 GJ/t CO2
- With cheap gas, gas boiler provides zero incr fuel cost
- 6 year payout expected
- Detailed FEED on schedule for Fall 2021

Appendix

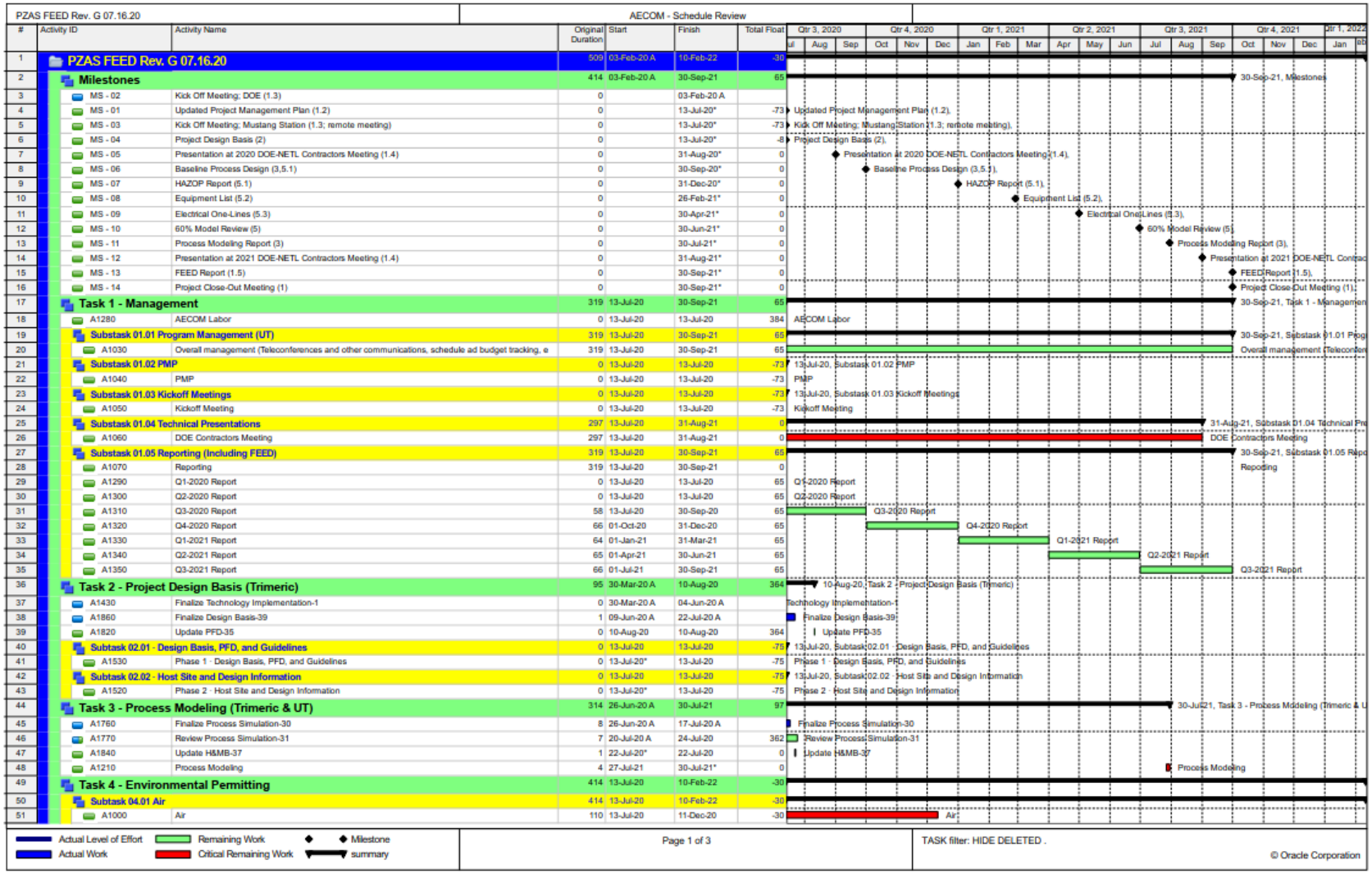
Project Team and Key Personnel

Party	Person	Role
NETL	Isaac Aurelio	Technical Project Officer
UT-Austin	Dr. Gary Rochelle	Principal Investigator
	Dr. Fred Closmann	Technical Proj Manager
AECOM	Dr. Bill Steen	AECOM Proj Manager
	Scott Bryan	Project Engineer
	Karen Farmer	AECOM Process Lead / Dept Project Manager
Trimeric	Dr. Andrew Sexton	Trimeric PjM
	Katherine Dombrowski	Process Lead

Organizational Chart

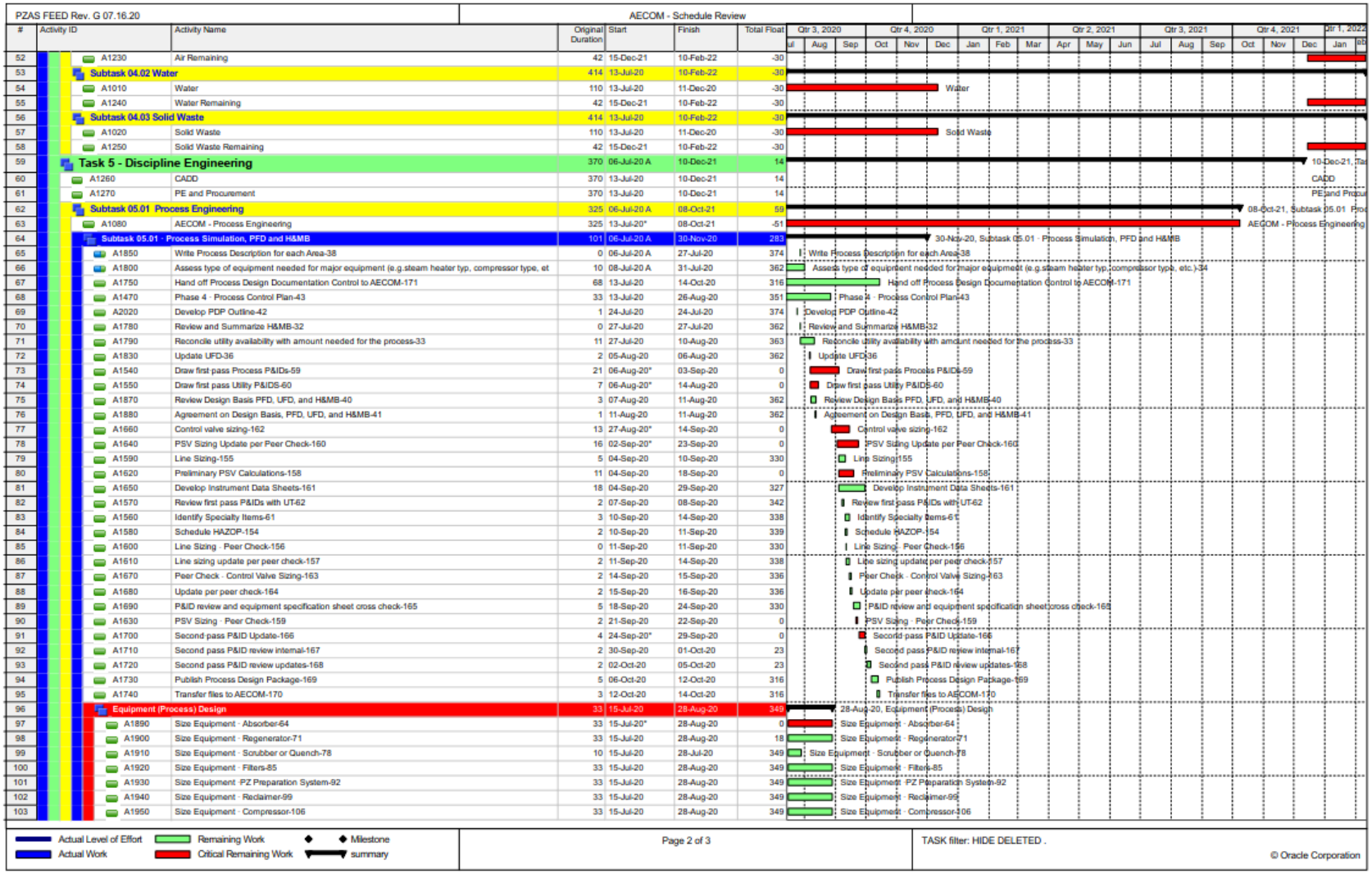


Gantt Chart



#	Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
1	PZAS FEED Rev. G 07.16.20		509	03-Feb-20 A	10-Feb-22	-30
2	Milestones		414	03-Feb-20 A	30-Sep-21	65
3	MS - 02	Kick Off Meeting; DOE (1.3)	0		03-Feb-20 A	
4	MS - 01	Updated Project Management Plan (1.2)	0		13-Jul-20*	-73
5	MS - 03	Kick Off Meeting; Mustang Station (1.3; remote meeting)	0		13-Jul-20*	-73
6	MS - 04	Project Design Basis (2)	0		13-Jul-20*	-8
7	MS - 05	Presentation at 2020 DOE-NETL Contractors Meeting (1.4)	0		31-Aug-20*	0
8	MS - 06	Baseline Process Design (3,5.1)	0		30-Sep-20*	0
9	MS - 07	HAZOP Report (5.1)	0		31-Dec-20*	0
10	MS - 08	Equipment List (5.2)	0		26-Feb-21*	0
11	MS - 09	Electrical One-Lines (5.3)	0		30-Apr-21*	0
12	MS - 10	60% Model Review (5)	0		30-Jun-21*	0
13	MS - 11	Process Modeling Report (3)	0		30-Jul-21*	0
14	MS - 12	Presentation at 2021 DOE-NETL Contractors Meeting (1.4)	0		31-Aug-21*	0
15	MS - 13	FEED Report (1.5)	0		30-Sep-21*	0
16	MS - 14	Project Close-Out Meeting (1)	0		30-Sep-21*	0
17	Task 1 - Management		319	13-Jul-20	30-Sep-21	65
18	A1280	AECOM Labor	0	13-Jul-20	13-Jul-20	384
19	Substask 01.01 Program Management (UT)		319	13-Jul-20	30-Sep-21	65
20	A1030	Overall management (Teleconferences and other communications, schedule ad budget tracking, e	319	13-Jul-20	30-Sep-21	65
21	Substask 01.02 PMP		0	13-Jul-20	13-Jul-20	-73
22	A1040	PMP	0	13-Jul-20	13-Jul-20	-73
23	Substask 01.03 Kickoff Meetings		0	13-Jul-20	13-Jul-20	-73
24	A1050	Kickoff Meeting	0	13-Jul-20	13-Jul-20	-73
25	Substask 01.04 Technical Presentations		297	13-Jul-20	31-Aug-21	0
26	A1060	DOE Contractors Meeting	297	13-Jul-20	31-Aug-21	0
27	Substask 01.05 Reporting (Including FEED)		319	13-Jul-20	30-Sep-21	65
28	A1070	Reporting	319	13-Jul-20	30-Sep-21	0
29	A1290	Q1-2020 Report	0	13-Jul-20	13-Jul-20	65
30	A1300	Q2-2020 Report	0	13-Jul-20	13-Jul-20	65
31	A1310	Q3-2020 Report	58	13-Jul-20	30-Sep-20	65
32	A1320	Q4-2020 Report	66	01-Oct-20	31-Dec-20	65
33	A1330	Q1-2021 Report	64	01-Jan-21	31-Mar-21	65
34	A1340	Q2-2021 Report	65	01-Apr-21	30-Jun-21	65
35	A1350	Q3-2021 Report	66	01-Jul-21	30-Sep-21	65
36	Task 2 - Project Design Basis (Trimeric)		95	30-Mar-20 A	10-Aug-20	364
37	A1430	Finalize Technology Implementation-1	0	30-Mar-20 A	04-Jun-20 A	
38	A1860	Finalize Design Basis-39	1	09-Jun-20 A	22-Jul-20 A	
39	A1820	Update PFD-35	0	10-Aug-20	10-Aug-20	364
40	Subtask 02.01 - Design Basis, PFD, and Guidelines		0	13-Jul-20	13-Jul-20	-75
41	A1530	Phase 1 - Design Basis, PFD, and Guidelines	0	13-Jul-20*	13-Jul-20	-75
42	Subtask 02.02 - Host Site and Design Information		0	13-Jul-20	13-Jul-20	-75
43	A1520	Phase 2 - Host Site and Design Information	0	13-Jul-20*	13-Jul-20	-75
44	Task 3 - Process Modeling (Trimeric & UT)		314	26-Jun-20 A	30-Jul-21	97
45	A1760	Finalize Process Simulation-30	8	26-Jun-20 A	17-Jul-20 A	
46	A1770	Review Process Simulation-31	7	20-Jul-20 A	24-Jul-20	362
47	A1840	Update H&MB-37	1	22-Jul-20*	22-Jul-20	0
48	A1210	Process Modeling	4	27-Jul-21	30-Jul-21*	0
49	Task 4 - Environmental Permitting		414	13-Jul-20	10-Feb-22	-30
50	Subtask 04.01 Air		414	13-Jul-20	10-Feb-22	-30
51	A1000	Air	110	13-Jul-20	11-Dec-20	-30

Gantt Chart


PZAS FEED Rev. G 07.16.20
AECOM - Schedule Review
| Activity ID | Activity Name | Original Duration | Start | Finish | Total Float
Qtr 3, 2020 | Qtr 4, 2020 | Qtr 1, 2021 | Qtr 2, 2021 | Qtr 3, 2021 | Qtr 4, 2021 | Qtr 1, 2022
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
52 A1230 Air Remaining 42 15-Dec-21 10-Feb-22 -30
53 Subtask 04.02 Water 414 13-Jul-20 10-Feb-22 -30
54 A1010 Water 110 13-Jul-20 11-Dec-20 -30
55 A1240 Water Remaining 42 15-Dec-21 10-Feb-22 -30
56 Subtask 04.03 Solid Waste 414 13-Jul-20 10-Feb-22 -30
57 A1020 Solid Waste 110 13-Jul-20 11-Dec-20 -30
58 A1250 Solid Waste Remaining 42 15-Dec-21 10-Feb-22 -30
59 Task 5 - Discipline Engineering 370 06-Jul-20 A 10-Dec-21 14
60 A1260 CADD 370 13-Jul-20 10-Dec-21 14
61 A1270 PE and Procurement 370 13-Jul-20 10-Dec-21 14
62 Subtask 05.01 Process Engineering 325 06-Jul-20 A 08-Oct-21 59
63 A1080 AECOM - Process Engineering 325 13-Jul-20* 08-Oct-21 -51
64 Subtask 05.01 - Process Simulation, PFD and H&MB 101 06-Jul-20 A 30-Nov-20 283
65 A1850 Write Process Description for each Area-38 0 06-Jul-20 A 27-Jul-20 374
66 A1800 Assess type of equipment needed for major equipment (e.g.steam heater typ, compressor type, et 10 08-Jul-20 A 31-Jul-20 362
67 A1750 Hand off Process Design Documentation Control to AECOM-171 68 13-Jul-20 14-Oct-20 316
68 A1470 Phase 4 - Process Control Plan-43 33 13-Jul-20 26-Aug-20 351
69 A2020 Develop PDP Outline-42 1 24-Jul-20 24-Jul-20 374
70 A1780 Review and Summarize H&MB-32 0 27-Jul-20 27-Jul-20 362
71 A1790 Reconcile utility availability with amount needed for the process-33 11 27-Jul-20 10-Aug-20 363
72 A1830 Update UFD-36 2 05-Aug-20 06-Aug-20 362
73 A1540 Draw first pass Process P&IDs-59 21 06-Aug-20* 03-Sep-20 0
74 A1550 Draw first pass Utility P&IDS-60 7 06-Aug-20* 14-Aug-20 0
75 A1870 Review Design Basis PFD, UFD, and H&MB-40 3 07-Aug-20 11-Aug-20 362
76 A1880 Agreement on Design Basis, PFD, UFD, and H&MB-41 1 11-Aug-20 11-Aug-20 362
77 A1660 Control valve sizing-162 13 27-Aug-20* 14-Sep-20 0
78 A1640 PSV Sizing Update per Peer Check-160 16 02-Sep-20* 23-Sep-20 0
79 A1590 Line Sizing-155 5 04-Sep-20 10-Sep-20 330
80 A1620 Preliminary PSV Calculations-158 11 04-Sep-20 18-Sep-20 0
81 A1650 Develop Instrument Data Sheets-161 18 04-Sep-20 29-Sep-20 327
82 A1570 Review first pass P&IDs with UT-62 2 07-Sep-20 08-Sep-20 342
83 A1560 Identify Specialty Items-61 3 10-Sep-20 14-Sep-20 338
84 A1580 Schedule HAZOP-154 2 10-Sep-20 11-Sep-20 339
85 A1600 Line Sizing - Peer Check-156 0 11-Sep-20 11-Sep-20 330
86 A1610 Line sizing update per peer check-157 2 11-Sep-20 14-Sep-20 338
87 A1670 Peer Check - Control Valve Sizing-163 2 14-Sep-20 15-Sep-20 336
88 A1680 Update per peer check-164 2 15-Sep-20 16-Sep-20 336
89 A1690 P&ID review and equipment specification sheet cross check-165 5 18-Sep-20 24-Sep-20 330
90 A1630 PSV Sizing - Peer Check-159 2 21-Sep-20 22-Sep-20 0
91 A1700 Second pass P&ID Update-166 4 24-Sep-20* 29-Sep-20 0
92 A1710 Second pass P&ID review internal-167 2 30-Sep-20 01-Oct-20 23
93 A1720 Second pass P&ID review updates-168 2 02-Oct-20 05-Oct-20 23
94 A1730 Publish Process Design Package-169 5 06-Oct-20 12-Oct-20 316
95 A1740 Transfer files to AECOM-170 3 12-Oct-20 14-Oct-20 316
96 Equipment (Process) Design 33 15-Jul-20 28-Aug-20 349
97 A1890 Size Equipment - Absorber-64 33 15-Jul-20* 28-Aug-20 0
98 A1900 Size Equipment - Regenerator-71 33 15-Jul-20 28-Aug-20 18
99 A1910 Size Equipment - Scrubber or Quench-78 10 15-Jul-20 28-Jul-20 349
100 A1920 Size Equipment - Filters-85 33 15-Jul-20 28-Aug-20 349
101 A1930 Size Equipment - PZ Preparation System-92 33 15-Jul-20 28-Aug-20 349
102 A1940 Size Equipment - Reclaimer-99 33 15-Jul-20 28-Aug-20 349
103 A1950 Size Equipment - Compressor-106 33 15-Jul-20 28-Aug-20 349
30-Nov-20, Subtask 05.01 - Process Simulation, PFD and H&MB
08-Oct-21, Subtask 05.01 Proc
AECOM - Process Engineering
10-Dec-21, Ta
CADD
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Actual Level of Effort
Actual Work
Remaining Work
Critical Remaining Work
Milestone
summary
Page 2 of 3
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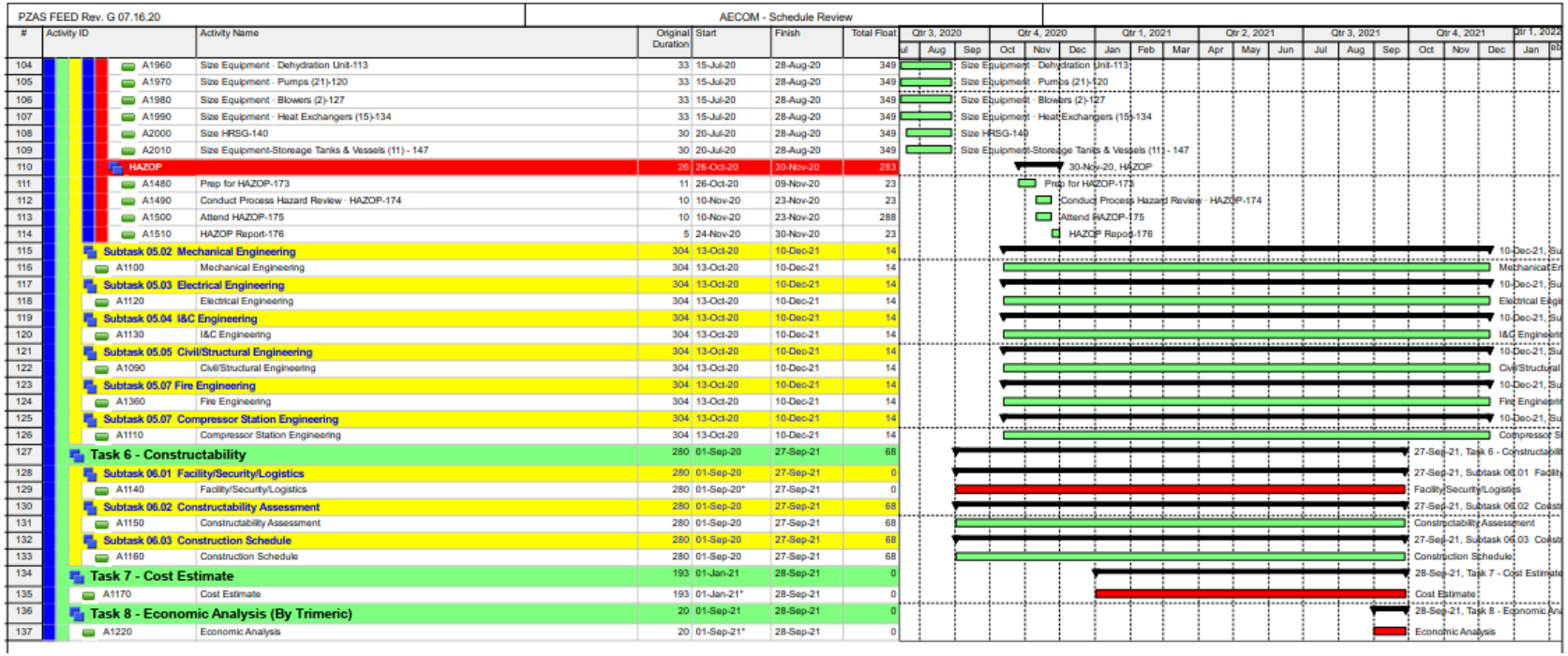
Gantt Chart



PZAS FEED Rev. G 07.16.20 — AECOM - Schedule Review

#	Activity ID	Activity Name	Original Duration	Start	Finish	Total Float
104	A1960	Size Equipment - Dehydration Unit-113	33	15-Jul-20	28-Aug-20	349
105	A1970	Size Equipment - Pumps (21)-120	33	15-Jul-20	28-Aug-20	349
106	A1980	Size Equipment - Blowers (2)-127	33	15-Jul-20	28-Aug-20	349
107	A1990	Size Equipment - Heat Exchangers (15)-134	33	15-Jul-20	28-Aug-20	349
108	A2000	Size HRSG-140	30	20-Jul-20	28-Aug-20	349
109	A2010	Size Equipment-Storeage Tanks & Vessels (11) - 147	30	20-Jul-20	28-Aug-20	349
110	HAZOP		26	26-Oct-20	30-Nov-20	283
111	A1480	Prep for HAZOP-173	11	26-Oct-20	09-Nov-20	23
112	A1490	Conduct Process Hazard Review - HAZOP-174	10	10-Nov-20	23-Nov-20	23
113	A1500	Attend HAZOP-175	10	10-Nov-20	23-Nov-20	288
114	A1510	HAZOP Report-176	5	24-Nov-20	30-Nov-20	23
115	Subtask 05.02	Mechanical Engineering	304	13-Oct-20	10-Dec-21	14
116	A1100	Mechanical Engineering	304	13-Oct-20	10-Dec-21	14
117	Subtask 05.03	Electrical Engineering	304	13-Oct-20	10-Dec-21	14
118	A1120	Electrical Engineering	304	13-Oct-20	10-Dec-21	14
119	Subtask 05.04	I&C Engineering	304	13-Oct-20	10-Dec-21	14
120	A1130	I&C Engineering	304	13-Oct-20	10-Dec-21	14
121	Subtask 05.05	Civil/Structural Engineering	304	13-Oct-20	10-Dec-21	14
122	A1090	Civil/Structural Engineering	304	13-Oct-20	10-Dec-21	14
123	Subtask 05.07	Fire Engineering	304	13-Oct-20	10-Dec-21	14
124	A1360	Fire Engineering	304	13-Oct-20	10-Dec-21	14
125	Subtask 05.07	Compressor Station Engineering	304	13-Oct-20	10-Dec-21	14
126	A1110	Compressor Station Engineering	304	13-Oct-20	10-Dec-21	14
127	Task 6 - Constructability		280	01-Sep-20	27-Sep-21	68
128	Subtask 06.01	Facility/Security/Logistics	280	01-Sep-20	27-Sep-21	0
129	A1140	Facility/Security/Logistics	280	01-Sep-20*	27-Sep-21	0
130	Subtask 06.02	Constructability Assessment	280	01-Sep-20	27-Sep-21	68
131	A1150	Constructability Assessment	280	01-Sep-20	27-Sep-21	68
132	Subtask 06.03	Construction Schedule	280	01-Sep-20	27-Sep-21	68
133	A1160	Construction Schedule	280	01-Sep-20	27-Sep-21	68
134	Task 7 - Cost Estimate		193	01-Jan-21	28-Sep-21	0
135	A1170	Cost Estimate	193	01-Jan-21*	28-Sep-21	0
136	Task 8 - Economic Analysis (By Trimeric)		20	01-Sep-21	28-Sep-21	0
137	A1220	Economic Analysis	20	01-Sep-21*	28-Sep-21	0

Still working to add fragments & detail to discipline engineering tasks