

Piperazine Advanced Stripper (PZAS™) Front End Engineering Design (FEED) Study

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Carbon Management and Natural Gas & Oil Research Project Review Meeting
Virtual Meetings August 2 through August 31, 2021

Agenda

- Overview and Objectives
- Site Info
- Technology Details and Layout
- Purchased Equipment Costs
- Schedule
- Takeaways

Program Overview

- Funding (\$5.4 MM)
 - 4.1 MM DOE
 - 1.1 MM cost sharing- ExxonMobil, Total, Chevron
 - 0.3 MM from Honeywell UOP outside DOE
- Expected Performance Dates: 10/2019 – 3/2022
- Project Participants
 - Golden Spread Electric Cooperative (GSEC) – Host
 - University of Texas at Austin (UT) – Modeling/ Technology
 - Trimeric – Process Engineering
 - AECOM – EPC

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

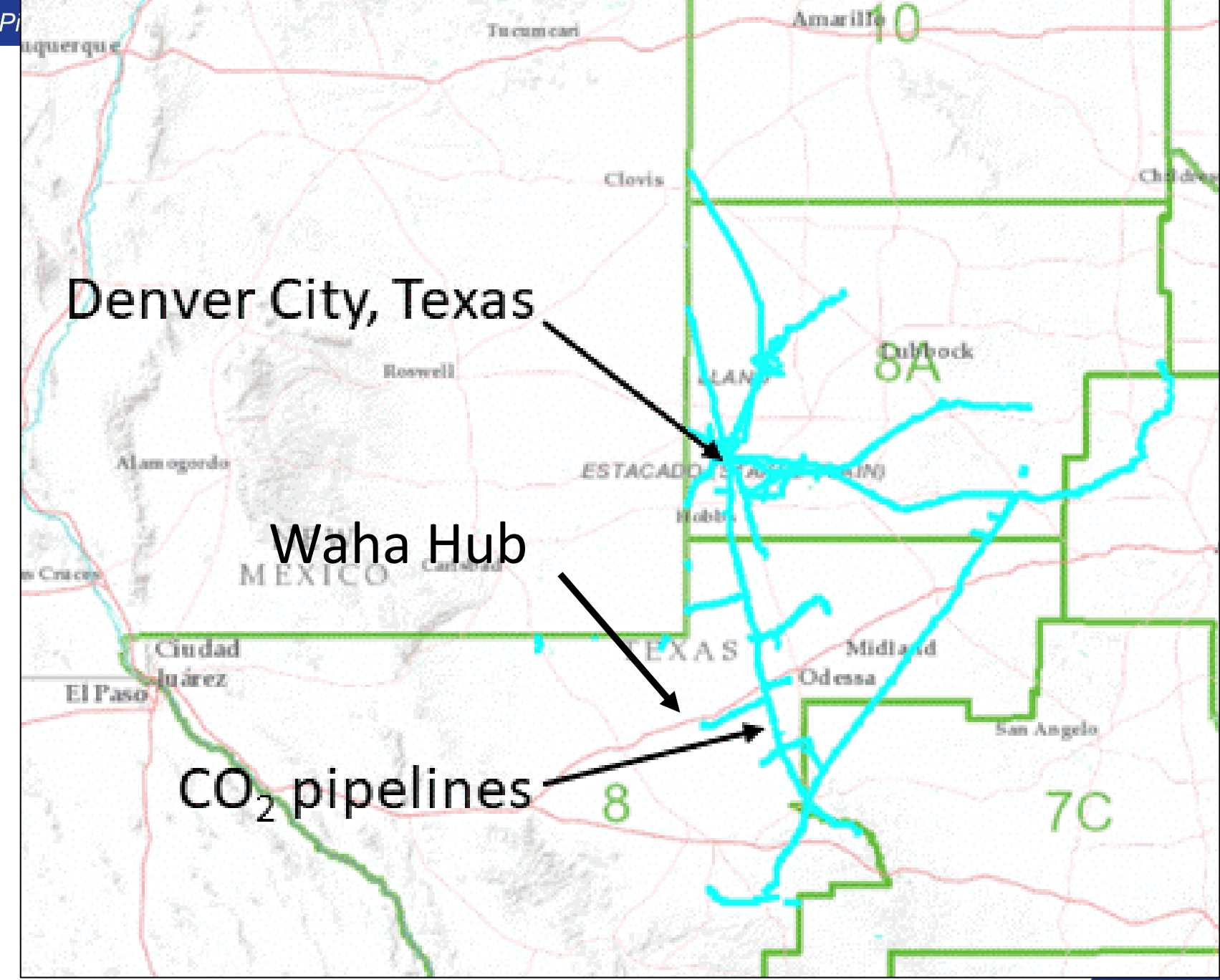
Complementary Benefits:

- Develop commercial project at Mustang Station
- Qualify PZAS for use on NGCC cogen
- Provide commercial cost detail
- Optimize PZAS & other 2G capture processes
- Guide R&D of capture technology



Mustang Station
Power Plant

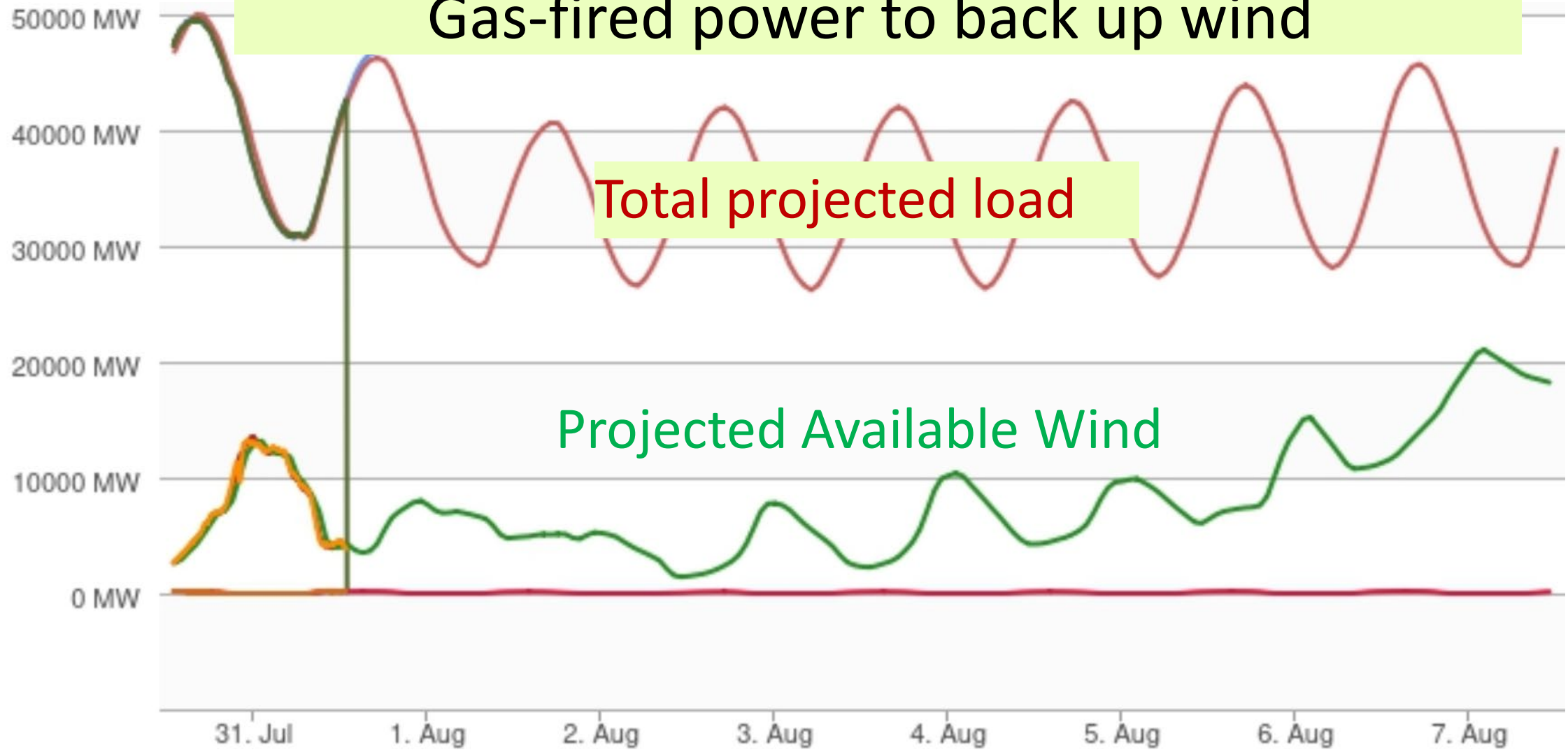
Host Site - Mustang Station
Golden Spread Electric Cooperative
Denver City, TX Cooperative
Southwest Power Pool
460 MW NGCC
2 GT/1 ST



- West Texas Permian Basin
- Available land
- Cheap Gas from Waha
- CO₂ sales for EOR
- CO₂ pipeline one mile south
- No cooling water for Capture

Southwest Power Pool, August 2021

Gas-fired power to back up wind

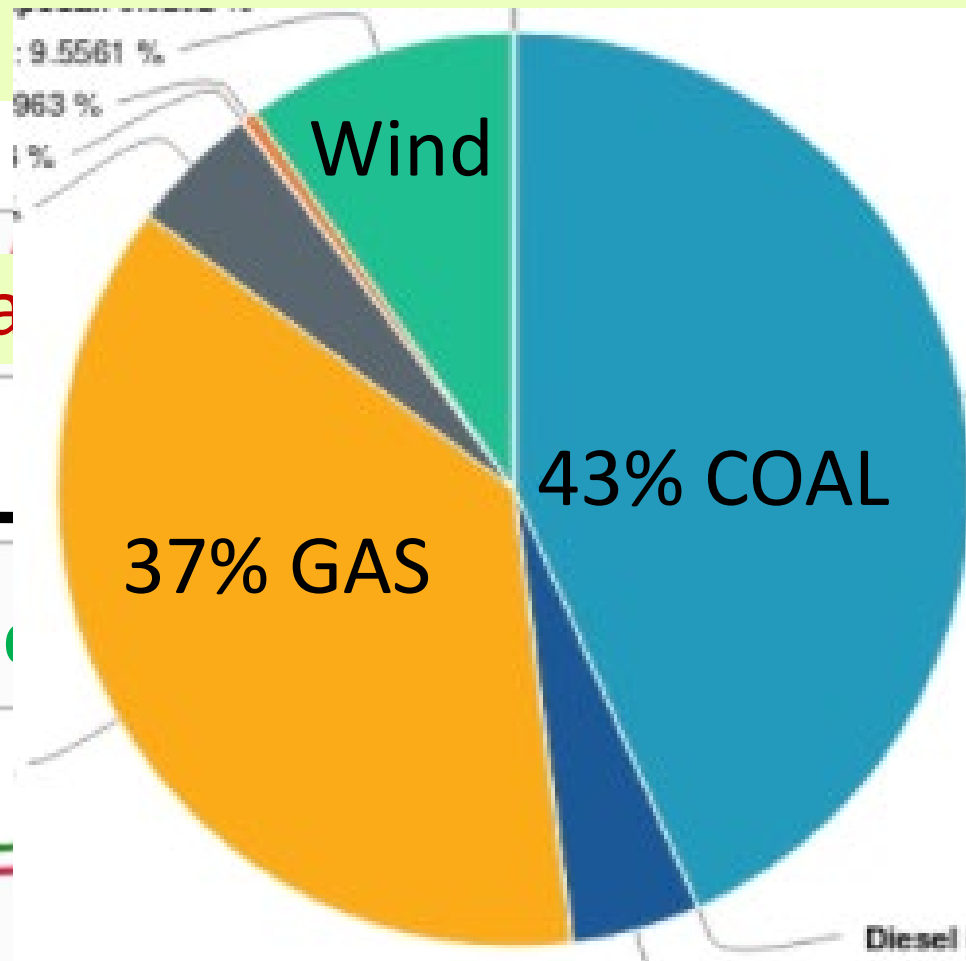


Southwest Power Pool, August 2021

Gas-fired

Total

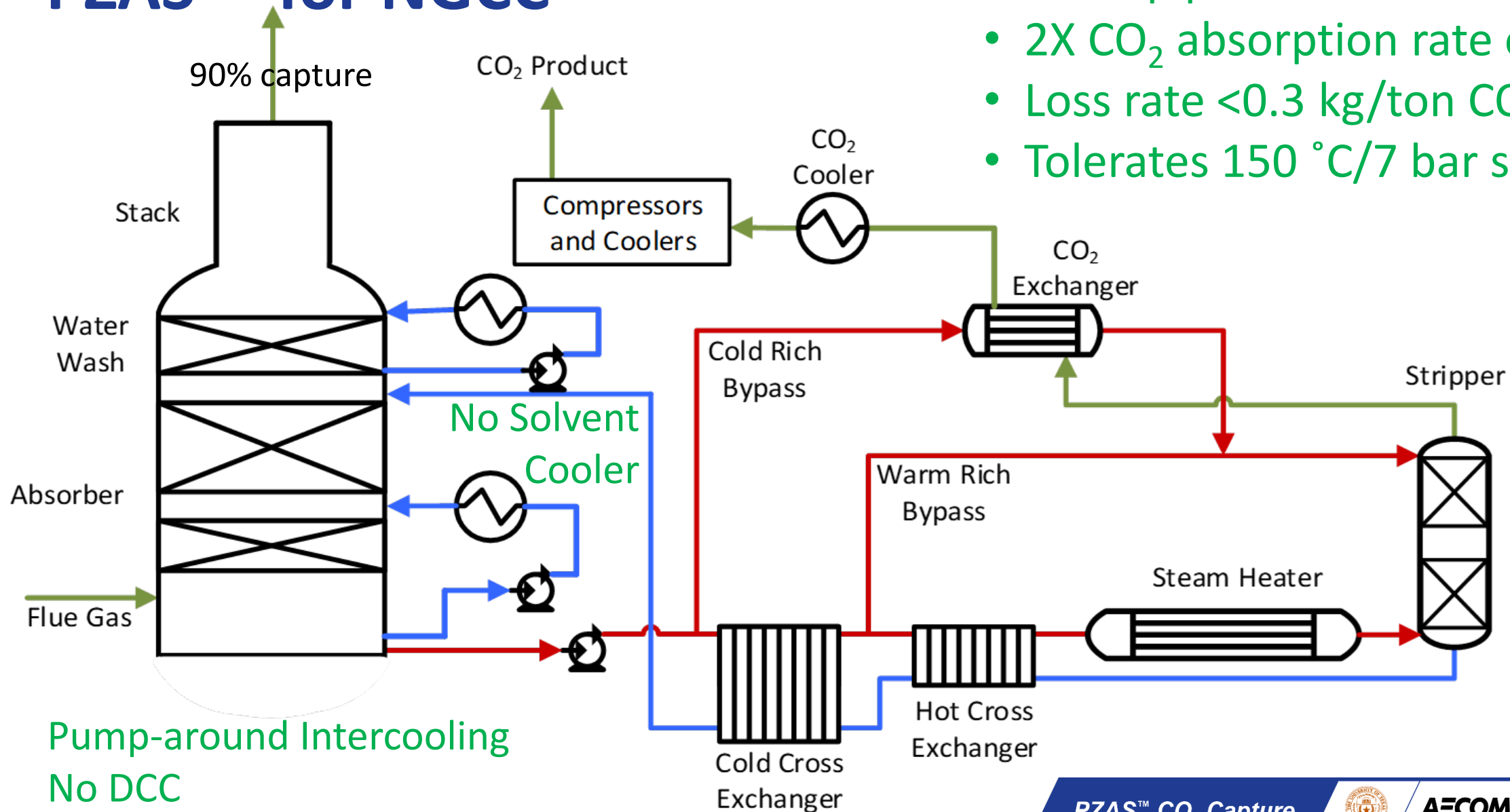
Projected



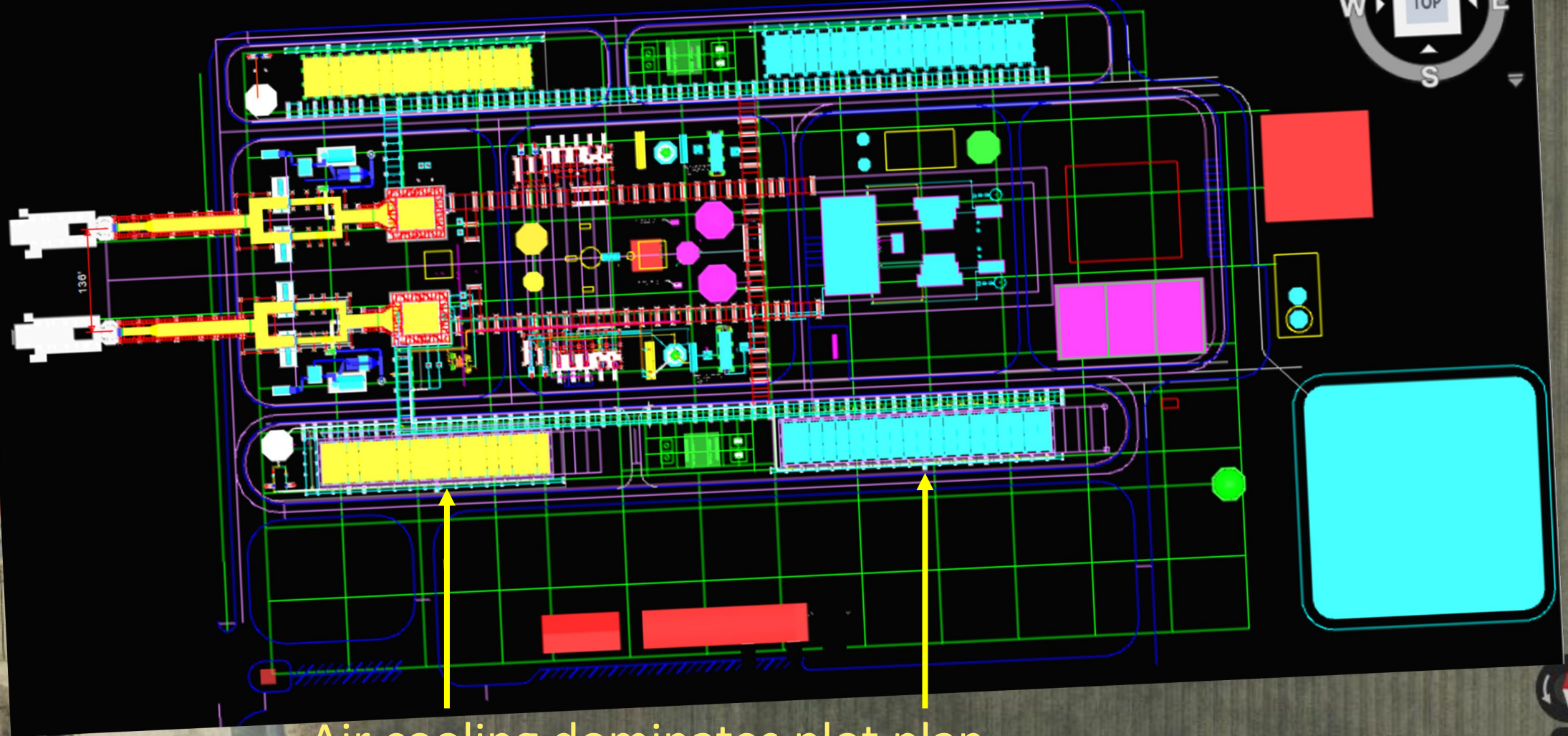
PZAS™ for NGCC

5 molal piperazine:

- 2X CO₂ absorption rate of MEA
- Loss rate <0.3 kg/ton CO₂
- Tolerates 150 °C/7 bar stripper

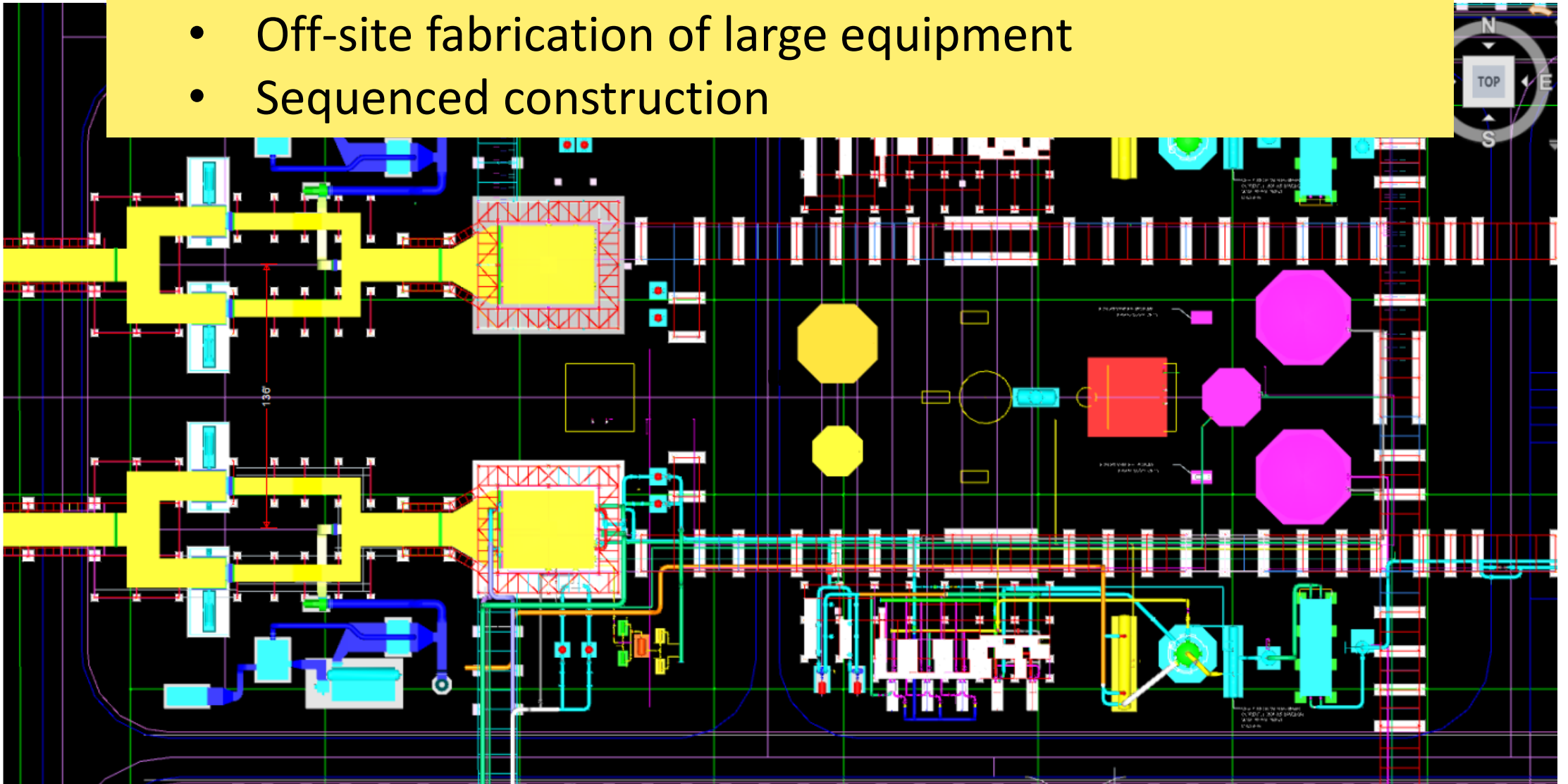


Two Gas Turbines w HRSGs and Stacks
90% Capture (190 tonne/hr) in Two Absorbers

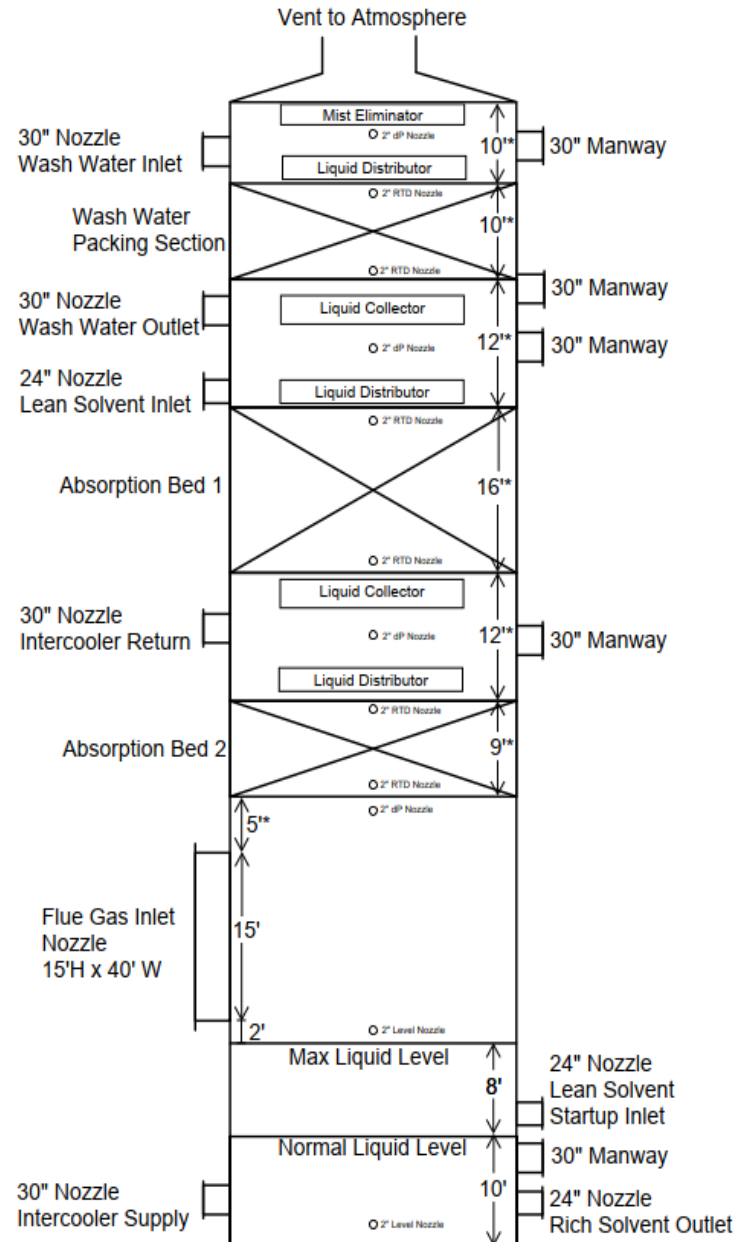


Air cooling dominates plot plan
25% of purchased equipment cost

- Each train treats all flue gas from 1 GT and one new boiler
 - Turndown to match Mustang Station operation
 - Off-site fabrication of large equipment
 - Sequenced construction

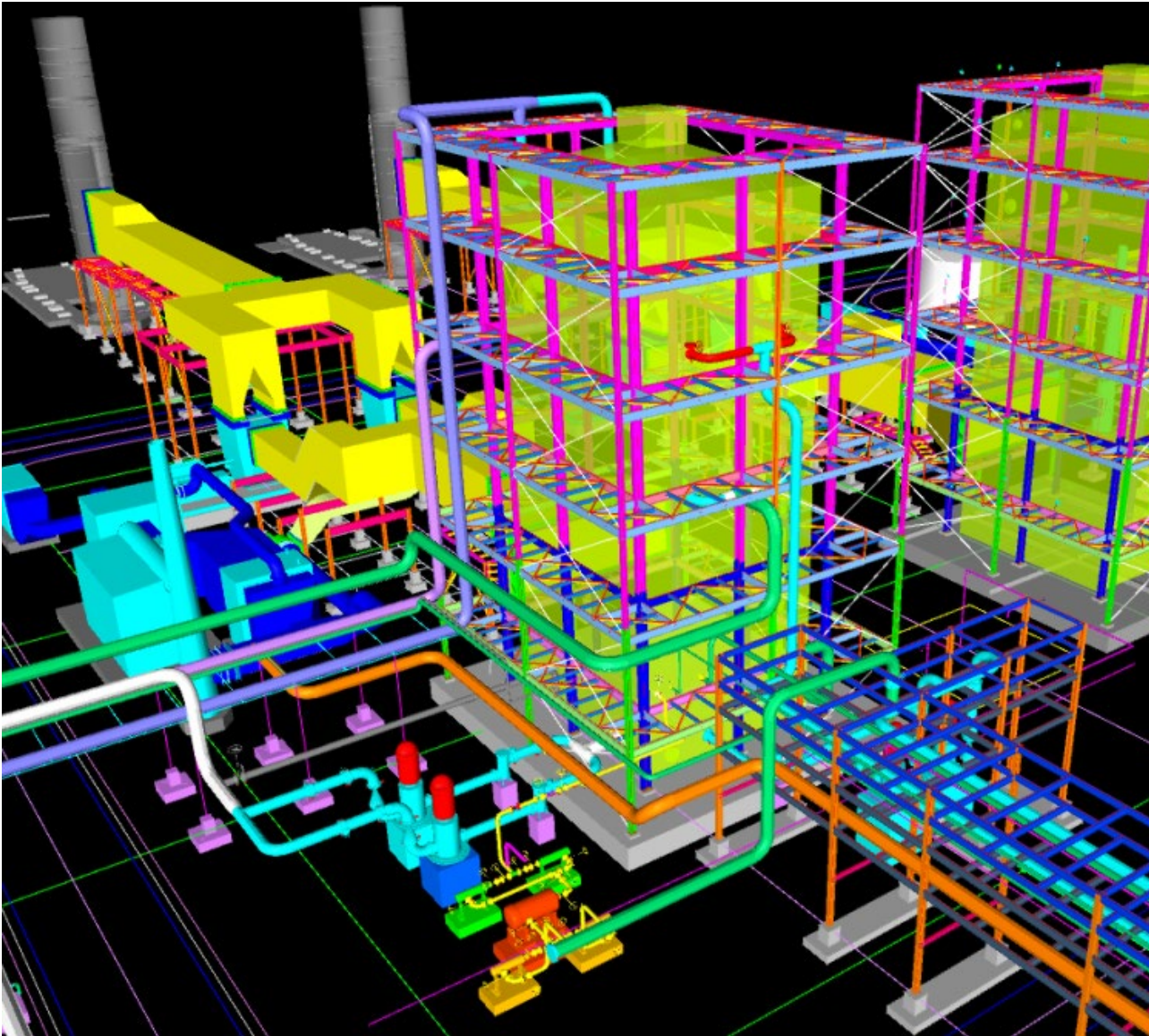


Absorber Design

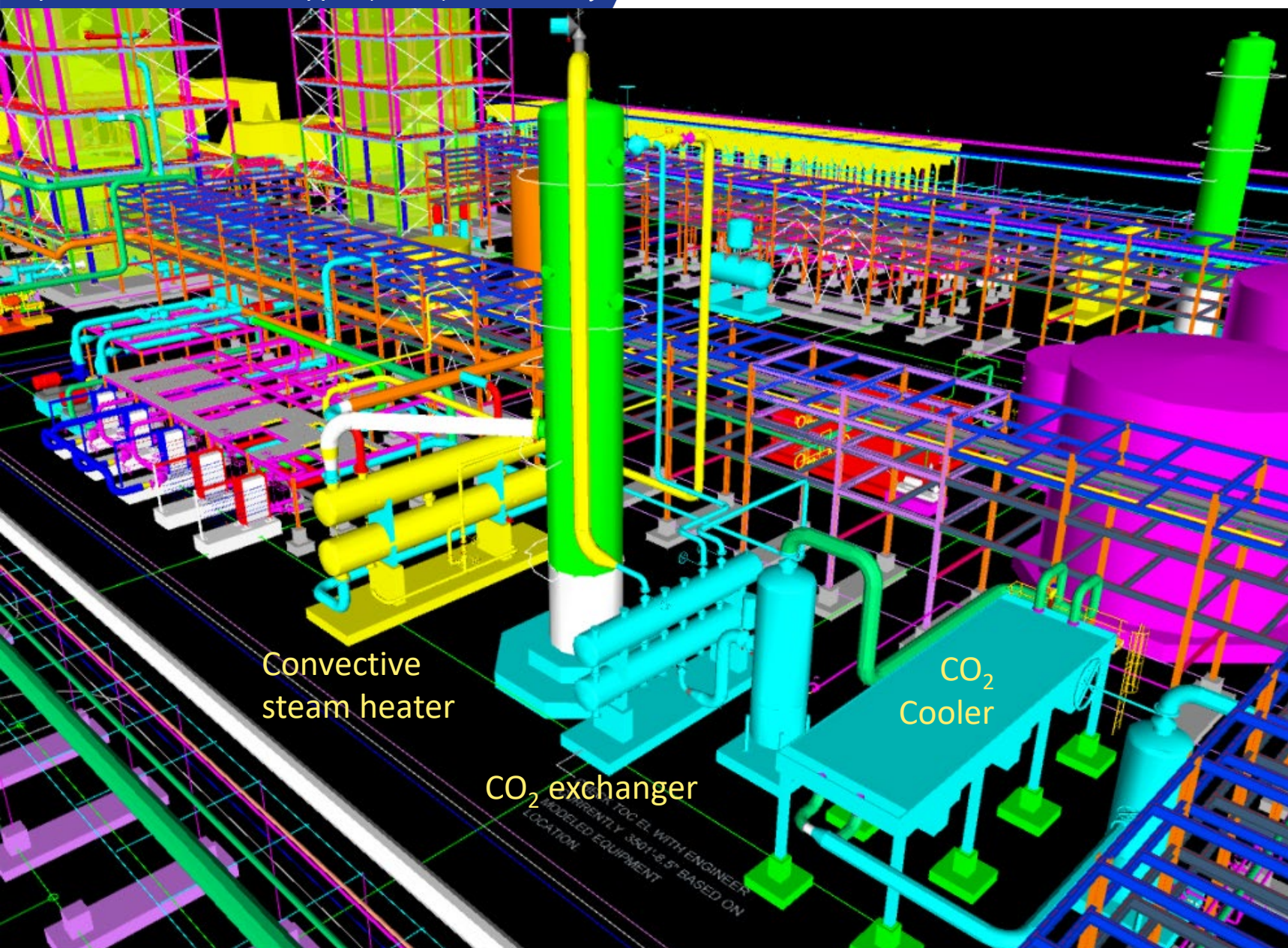


- Two 40 x 47 ft rectangular absorbers
- Two absorber beds and one water wash section, with pump-around intercooling
 - Total packing height = 35 ft
 - Total absorber height = 117 ft
- Max sump depth = 18 ft with Vertical sump pump to reduce NPSH
- 40 ft cylindrical stack on top of absorber dictated by CEMS

Absorber Cost dominated by Shell, not Packing



- Shop and field-construction costs in progress
- Costs for materials and shop fabrication estimated to be ~\$20M
- Shell costs ~80% of total (including internals but not foundations and platforming)



Advanced Stripper

11-ft diameter stripper
Shop fabricated

Convective
steam heater

CO₂ exchanger

CO₂
Cooler

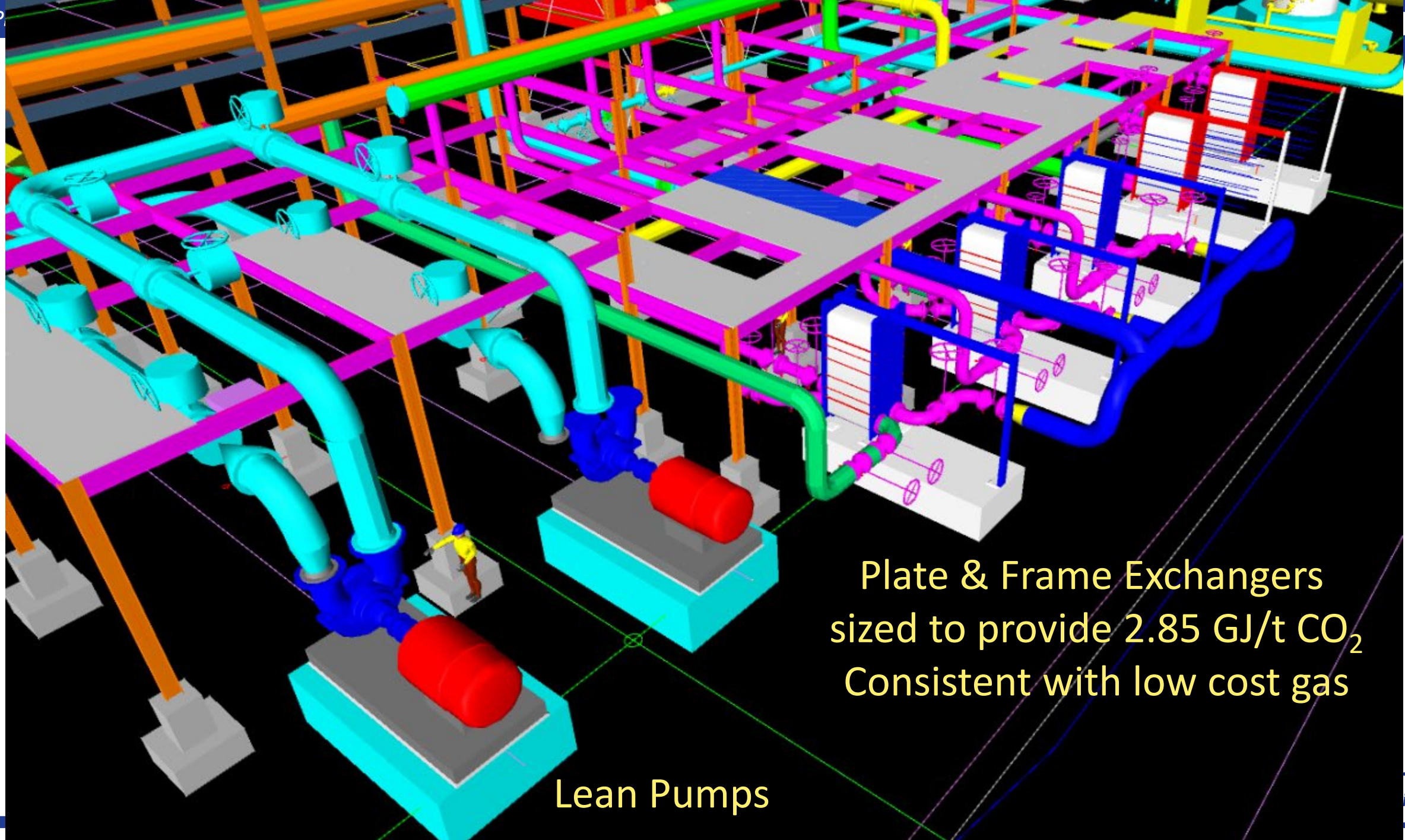


Plate & Frame Exchangers
sized to provide 2.85 GJ/t CO₂
Consistent with low cost gas

Lean Pumps

Ductwork and Boilers

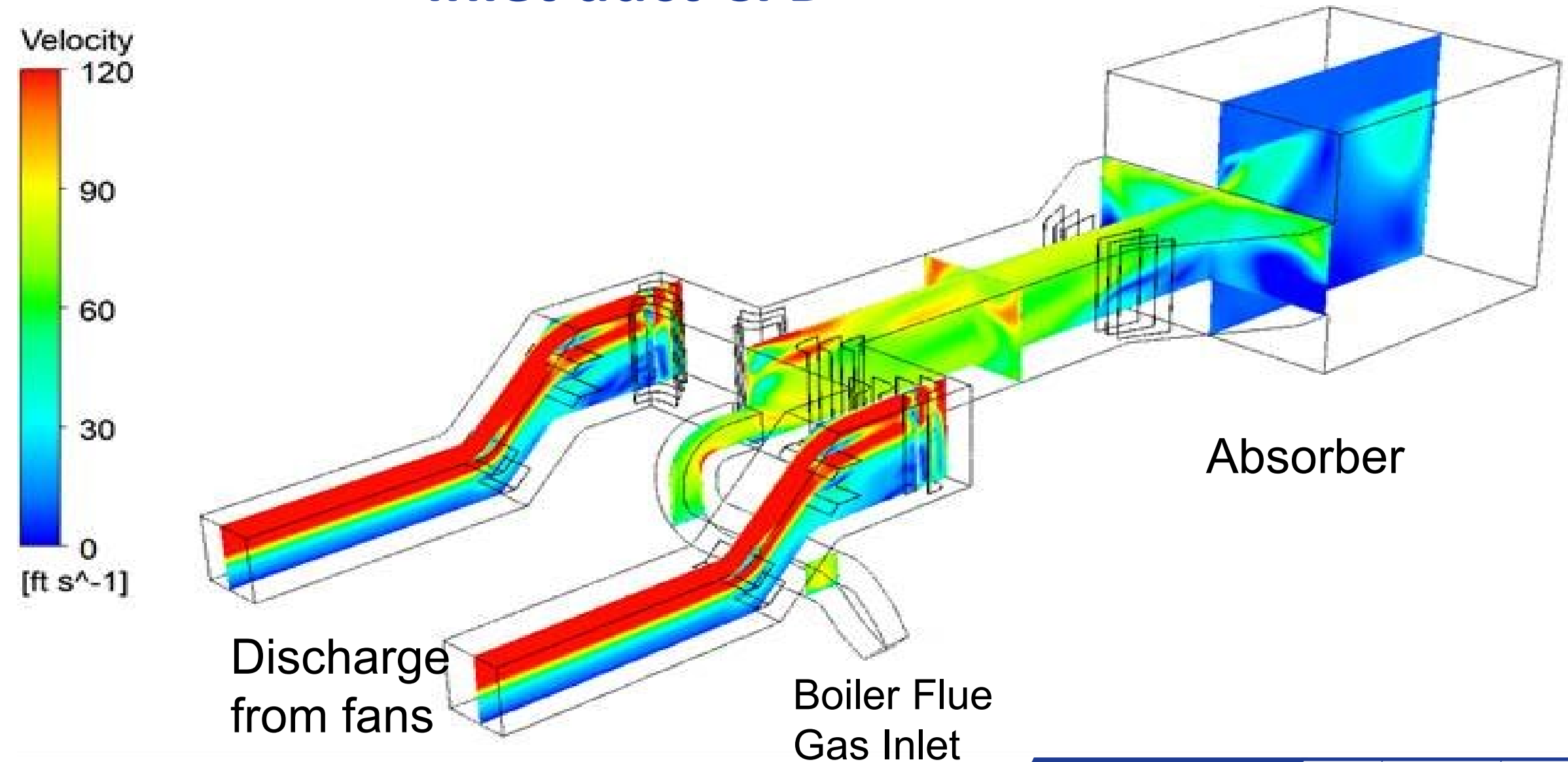
2 package boilers to provide steam
increases gas rate by 7%, CO₂ by 20%

Tie in to
Existing
stacks

2 Fans/Abs

Gas
Boiler

Inlet duct CFD

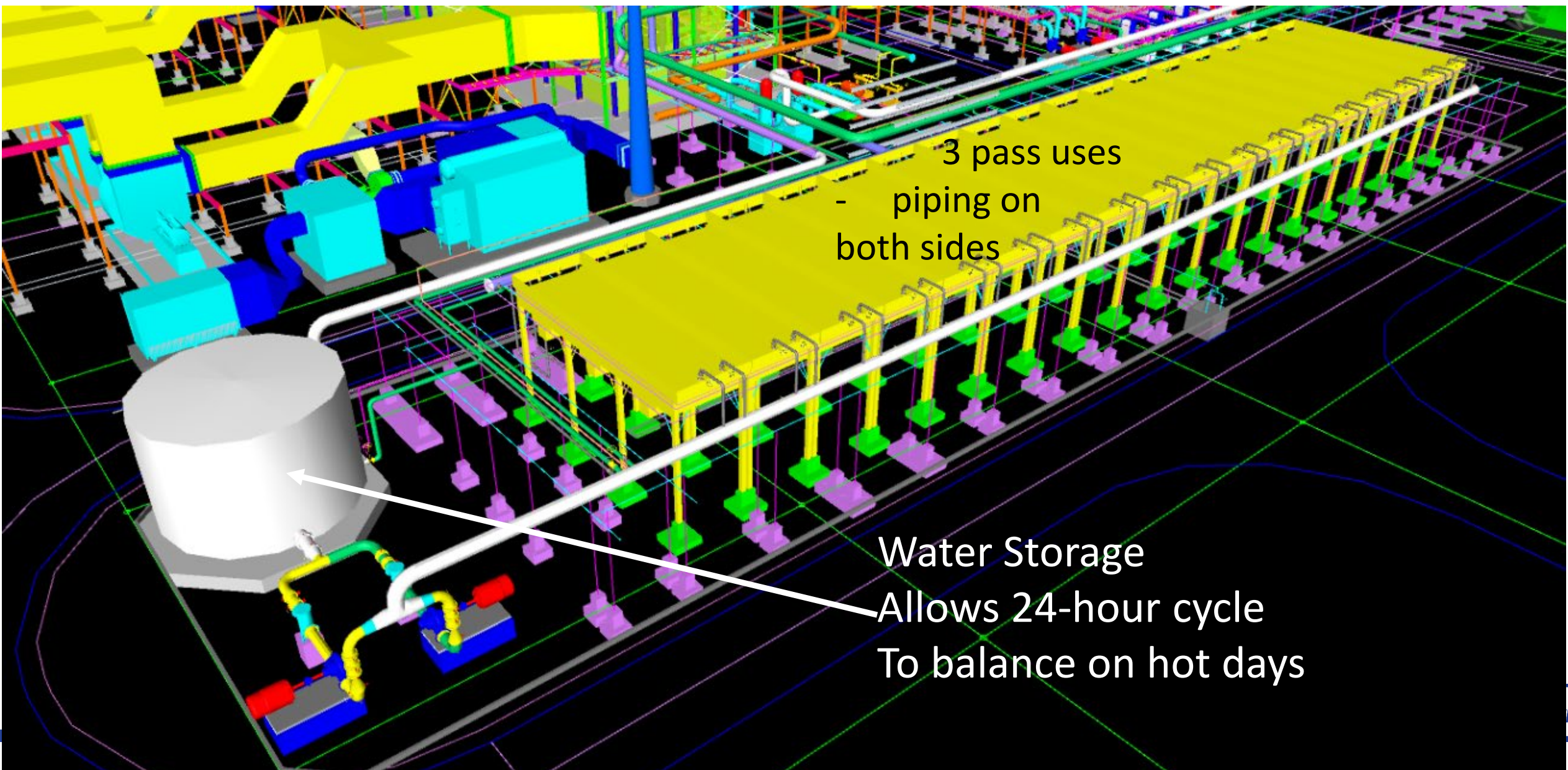


All cooling by air

- API 661 standard
- Materials of Construction – 304SS with aluminum fins
- Nominal approach temperature 11°C

Air Coolers	% of Total Air Cooler Cost
Absorber Intercoolers	~52%
Wash Water Coolers	~45%
CO ₂ Coolers	~3%

Wash Water Air Cooling, 18 bays for each train



Compressors

- Low-speed reciprocating machine w automatic load reduction
 - One 9,100 hp compressor/process train
 - Better turndown than integrally-gearred centrifugal design
 - Higher stripper P of PZASTM (5 -6 bar) reduces power & capital
- Interstage cooling by air
- TEG Dehydration around 14% of total compressor package cost

Equipment	Purchase Cost (\$ X 10 ⁶)
Air coolers	33
Absorber	28
Compressors	19
Reclaiming/Solvent treatment	15
Packaged boilers	10
Exchangers	8
Stripper	5.5
Fans	2.8
Utilities	0.9
Process BOP	0.1
Total PEC	122

Schedule

Kick Off Meeting; DOE	Feb 2020
Virtual Kick Off; Mustang Station	Mar 2020
Project Design Basis	Aug 2020
Baseline Process Design	Aug 2020
Equipment Lists	April 2021
Electrical One-Lines	July 2021
CapEx	Oct 2021
Process Modeling Report	Dec 2021
FEED Report	Mar 2022

Takeaways

- 90% CO₂ capture (190 tonne/hr)
- Total cost of purchased equipment is \$122 million
 - Absorbers and air coolers are 50% of the total
- Available land provides easily accessible general arrangement
- Two parallel trains provide flexibility during construction and operation
- 80% of absorber cost is the shell
 - Packing is only 30% of total absorber height
- Dry air cooling is suited to provide all cooling duties
- Reciprocating compressors used with 6 bar stripper and 50% turndown

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Organizational Chart

