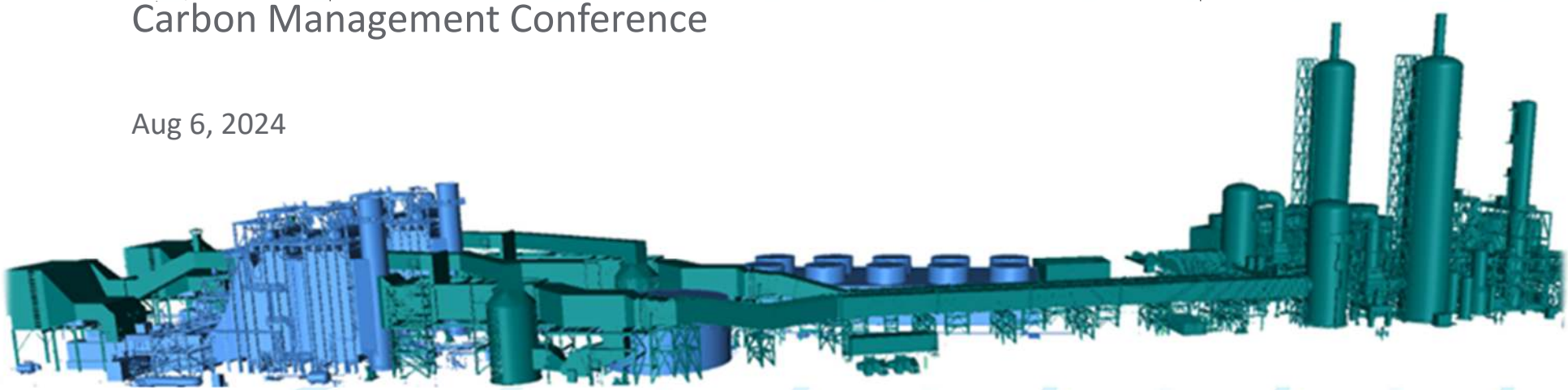
Retrofittable Advanced Combined Cycle Integration for Flexible Decarbonized Generation

Carbon Management Conference

Aug 6, 2024



Acknowledgment

This report was prepared by General Electric's Gas Power division with funding from the US Department of Energy, Office of Fossil Energy and Carbon Management, Carbon Capture R&D Program in collaboration with sub recipients Linde and Southern Company plus subcontractor Kiewit. This material is based upon work supported by the Department of Energy under Award Number DE-FE0032131.

Project Team

Contributors

- **General Electric Gas Power**

  John Sholes (Principal Investigator), Dennis Bowin, Tiffany Camp, Todd Denman, Harvey Dunning, Brian Gallagher, Patrick Gallagher, Xiaojun Gao, Parag Kulkarni, Peter Murphy, Ray Pang, Brian Whitright, Michelle York

- **Linde**

  Dirk Jarmus, Minish Shah, Torsten Stoffregen

- **Southern Company**

  John Carroll

- **Kiewit**

  Alan Donovan, Bryan Lofgreen, Bob Slettehaugh

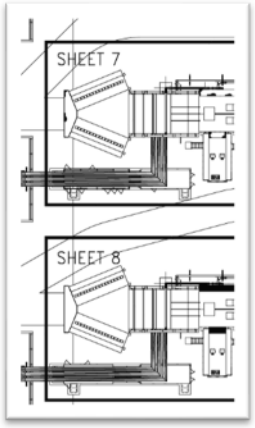
Agenda

Project Site
Results Summary
Lessons Learned
NGCC.CCS Performance
EGR Detailed Design
EGR Overview
CO_2 Capture Island (ISBL) Detailed Design
CCS Plant Integration (OSBL) Detailed Design
Plant model screenshot

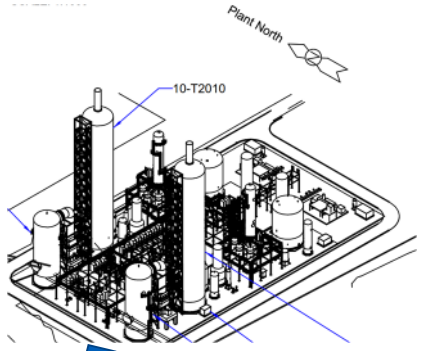
Project Site

Existing 2x1 7FA.03 (COD 2001)

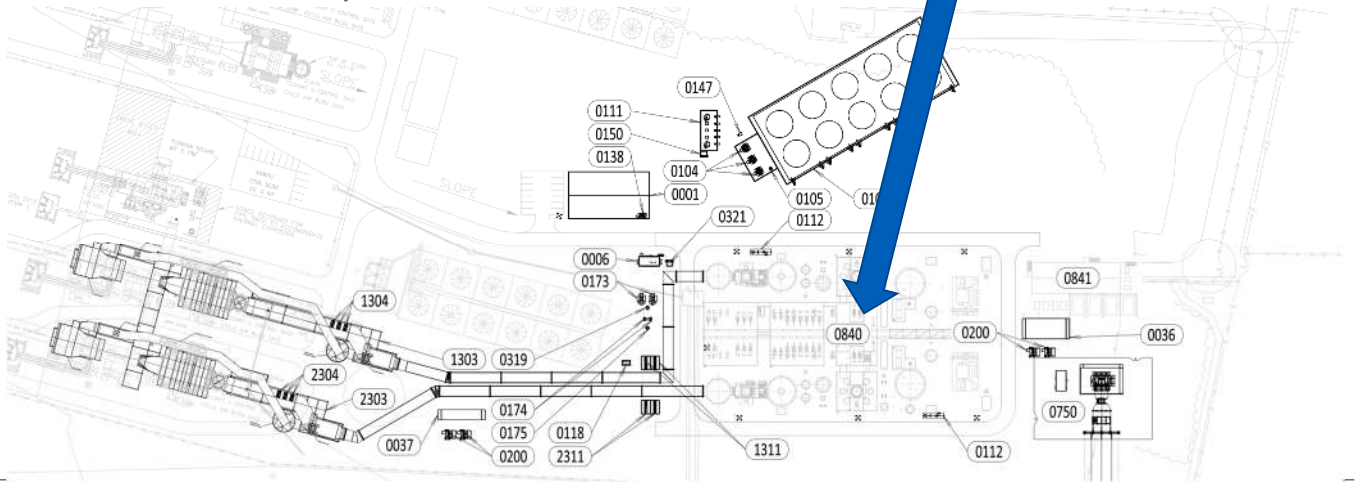
- "Arrowhead" Inlets w/ Evap Coolers
- Small Duct Burners
- Natural Gas Only
- Wet Cooling Tower
- GE D650 Steam Turbine
- Existing GT "Arrowhead" Inlets



New CCS Island



New NGCC Layout with CCS and EGR



Results Summary

Performance Summary

	Current NGCC Configuration (Pre-CCS)	NGCC + CCS Configurations (Post CCS)
Net NGCC HHV Performance	551.9 MW / 6,676 Btu/kWhr	556.9 MW / 7,660 Btu/kWhr
NGCC HHV Heat Consumption	3,684 MM Btu/hr	4,266 MM Btu/hr
CCS Aux Loads	---	39.2 MW
CO_2 Captured	---	482.7 kpph (5,255 tonne/day)
CCS Reboiler Specific Heat Duty	---	2.7 GJ/tonne CO_2 Captured

Cost Summary

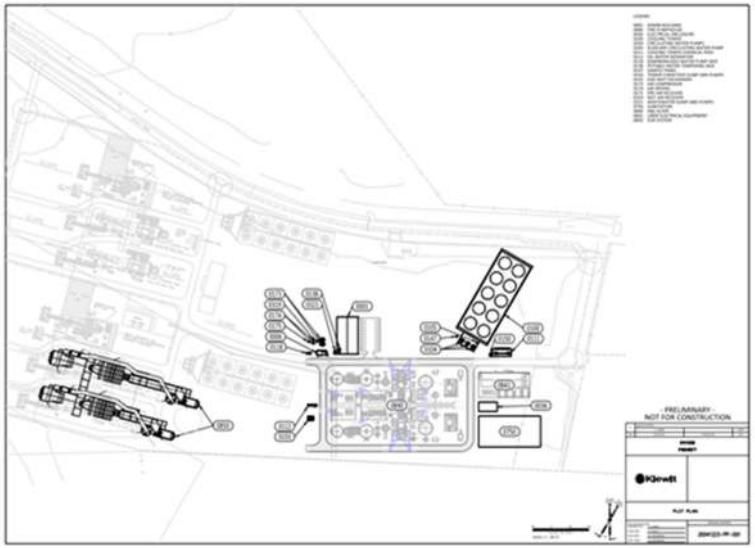
	2023 USD
CCS CapEx – Total Plant Cost	$ 1,083 MM
CCS Fixed OpEx	$ 3.3 MM
CCS Variable OpEx	$ 29.2 MM
Cost of CO_2 Captured – Excluding Transport and Storage	$ 100.2 / tonne CO_2
Levelized Cost of Electricity (LCOE) – Including Transport and Storage	$ 86.6 / MWhr

Results – Detailed Cost Breakdown

Detailed Cost Summary

Costs in Nov 2023 $MM USD (+30%/-20%)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
	Base Mods	EGR	GT Mods	CCS ISBL Capt	CCS ISBL Comp	CCS OSBL CW	CCS OSBL Other	CCS Initial Fill	Total
Equipment	23.03	41.58	47.34	169.19	60.90	27.18	46.81	29.94	446.0
Piping / Ducting	---	10.69	---	133.39	38.58	7.40	29.12	---	219.2
Foundations	---	3.95	1.46	17.24	5.60	4.43	17.35	---	50.0
Civil / Structural	---	12.28	3.64	76.44	15.11	8.54	41.67	---	157.7
Labor and Misc.	12.40	8.09	20.39	108.45	17.46	9.16	34.33	---	210.3
Sub-Total TPC	**35.43**	**76.59**	**72.83**	**504.70**	**137.65**	**56.70**	**169.28**	**29.94**	**1,083.1**
Contingency	1.39	9.53	2.23	100.74	27.49	11.31	39.75	---	192.4
Total Project Cost	**36.82**	**106.03**	**75.06**	**605.44**	**165.14**	**68.01**	**209.03**	**29.94**	**1,295.5**
Total Overnight Cost	---	---	---	---	---	---	---	---	1,574.6
Total As-Spent Cost	---	---	---	---	---	---	---	---	**1,716.4**

SoCo Barry FEED Results – Lessons Learned



EGR
- Large positive value added
- Reduces steam for CCS by 8%
- Reduces oxygen/oxidation in CCS Absorber
- Large reduction in footprint and cost of CCS Absorber
- Requires Flue Gas Clean-up to limit corrosion risk to GT
- Need to test with EGR ON and OFF

Steam Supply
- All Steam Supply for CCS requirements can be satisfied by NGCC
  - New ST crossover with control valves for primary supply point
- Multiple Steam sources are required for low loads
- Requires rigorous Steam Turbine protection
- Requires plan and controls mods for CCS trip – what to do with steam

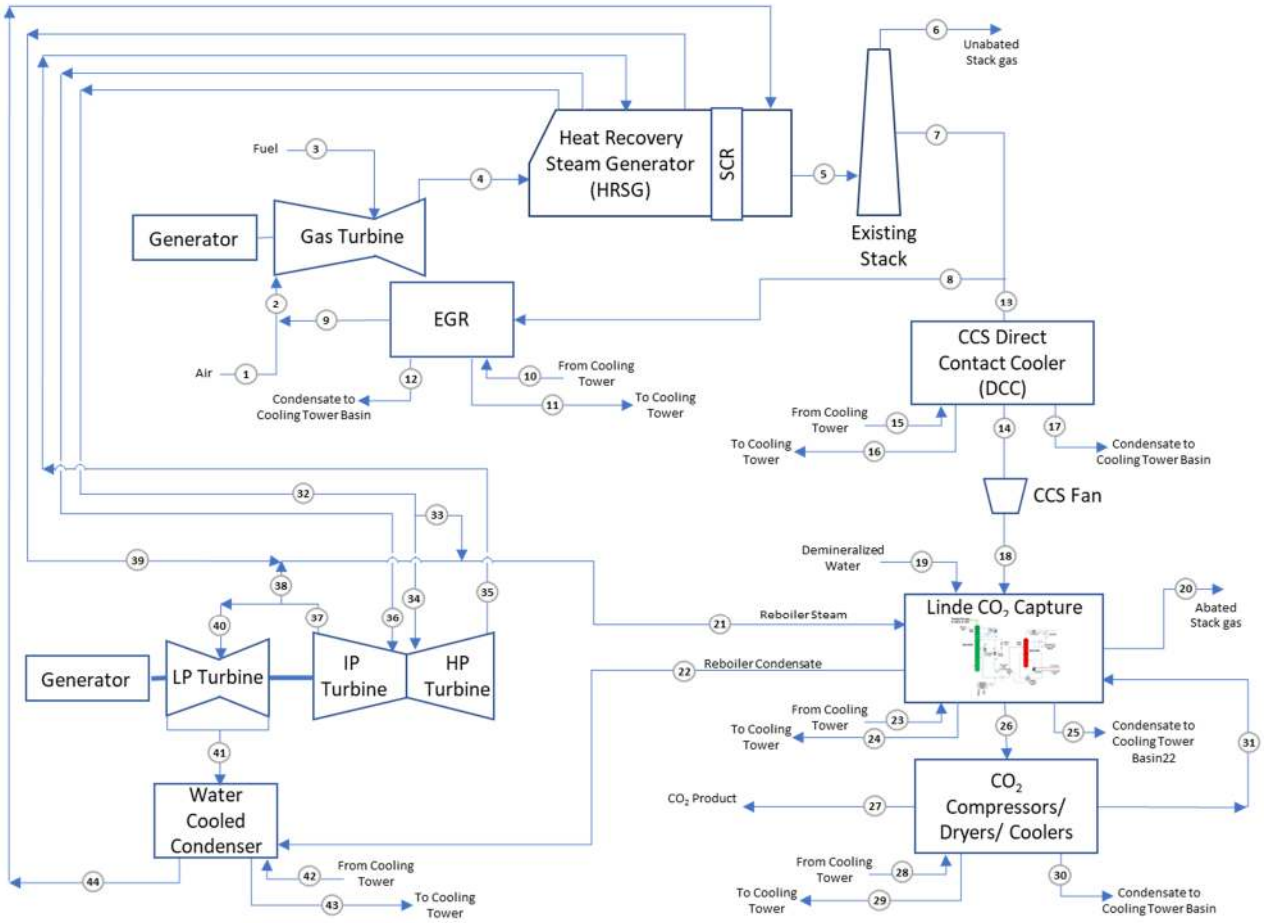
Flue Gas
- Dampers need seal air for zero leakage assurance
- Blow-out panels a strongly recommended to protect HRSG if CCS trip
- Ducting is very expensive – minimize lengths if possible

Cooling Water
- Requires plan for CCS trip – sudden increase in NGCC CW demand

Plant
- 7F GT has uprates that fully counters the CCS MW loss (~75MW)
- Cold start needs CCS to get steam early – modify GT startup
- Controls are critical, especially feed forward for trip & rapid loading

CCS
- Reduce number of trains to further save cost
- Limit containment area to further save cost
- Detailed constructability review early

NGCC Performance



Carbon In[A]		Carbon Out[A]	
	kg/hr (lb/hr)		kg/hr (lb/hr)
Pipeline Gas	229,044 (504,956)	Stack Gas	11,523 (25,404)
Air (CO_2)	1,416 (3,122)	CO2 Product	218,938 (482,674)
Total	**230,461 (508,078)**	**Total**	**230,461 (508,078)**

A Calculations based on an 85% capacity factor

Carbon Input to Cycle (total for 2x1 7FA plant):

Inlet Air: Standard Ambient Air @ 75% relative humidity
Fuel to GT's Pipeline Natural Gas (LHV = 20866.9 Btu/lb)

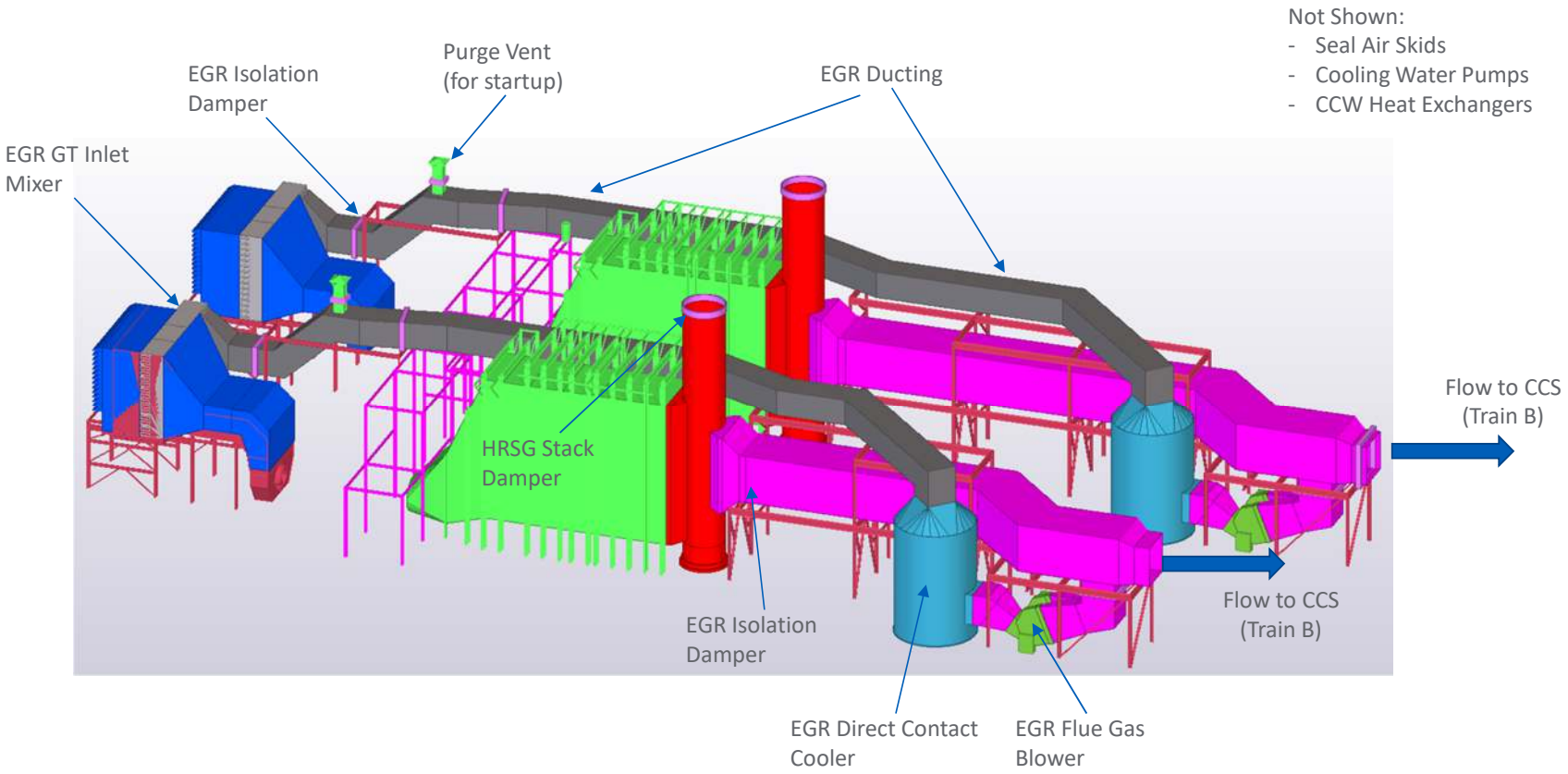
95.69%vol	Methane (CH_4)
2.14%vol	Ethane (C_2H_6)
0.80%vol	Carbone Dioxide (CO_2)
0.62%vol	Propane (C_3H_8)
0.29%vol	Butane (C_4H_{10})
0.28%vol	Nitrogen (N_2)
0.11%vol	Hexane (C_6H_{14})
0.07%vol	Pentane (C_5H_{12})

With 100% complete combustion, produces 2.73662 lb CO_2 per lb fuel

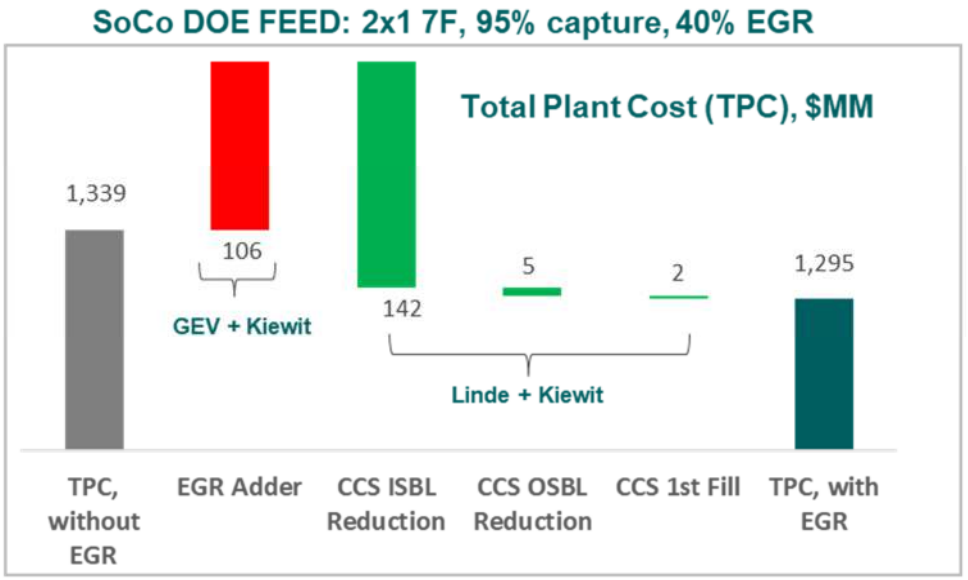
Air Flow to GT's	4,846,176 lb/hr	3,122 lb/hr CO_2
Fuel to GT's	184,518 lb/hr fuel	504,956 lb/hr CO_2
EGR Recirculation Flow (40%)	3,145,096 lb/hr	338,718 lb/hr CO_2
GT Exhaust Flow	8,175,790 lb/hr	846,796 lb/hr CO_2
HRSG Exhaust	8,175,790 lb/hr	846,796 lb/hr CO_2
Flow to EGR (40%)	3,270,316 lb/hr	338,718 lb/hr CO_2
Flow to CCS System	4,905,474 lb/hr	508,078 lb/hr CO_2
Captured CO2		482,674 lb/hr CO_2 (95% Capture)
CCS Absorber Exhaust	4,336,276 lb/hr	25,404 lb/hr CO_2

Net CO2 inlet	508,078 lb/hr CO_2
Net CO2 captured	482,674 lb/hr CO_2
Net CO2 exhaust	25,404 lb/hr CO_2
Annual CO_2 Capture (based on 7446 hr/yr operation)	1.6302 MM Metric tonnes/yr

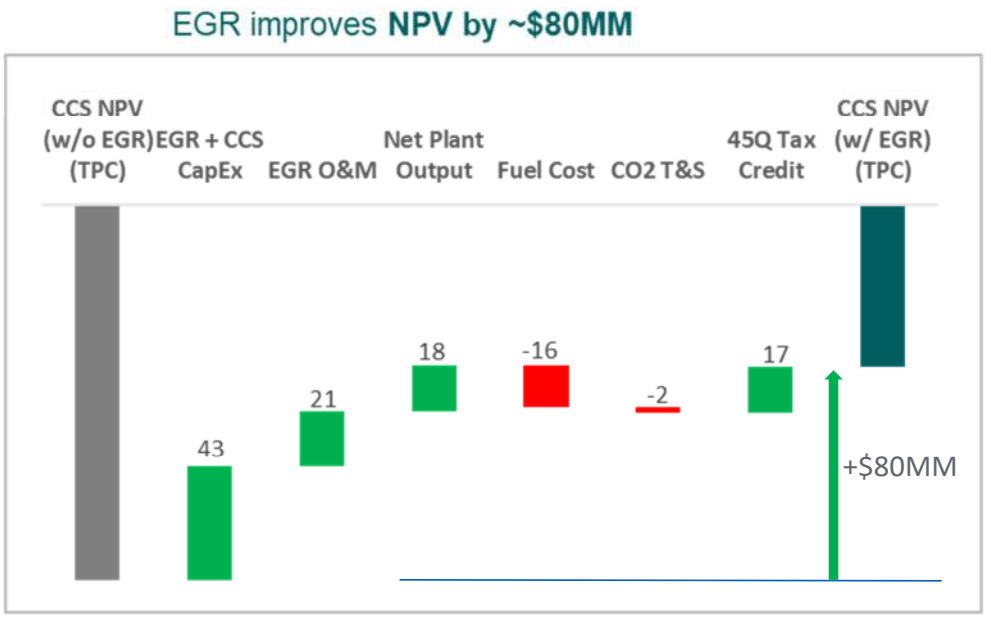
EGR – Detailed Design



EGR Overview



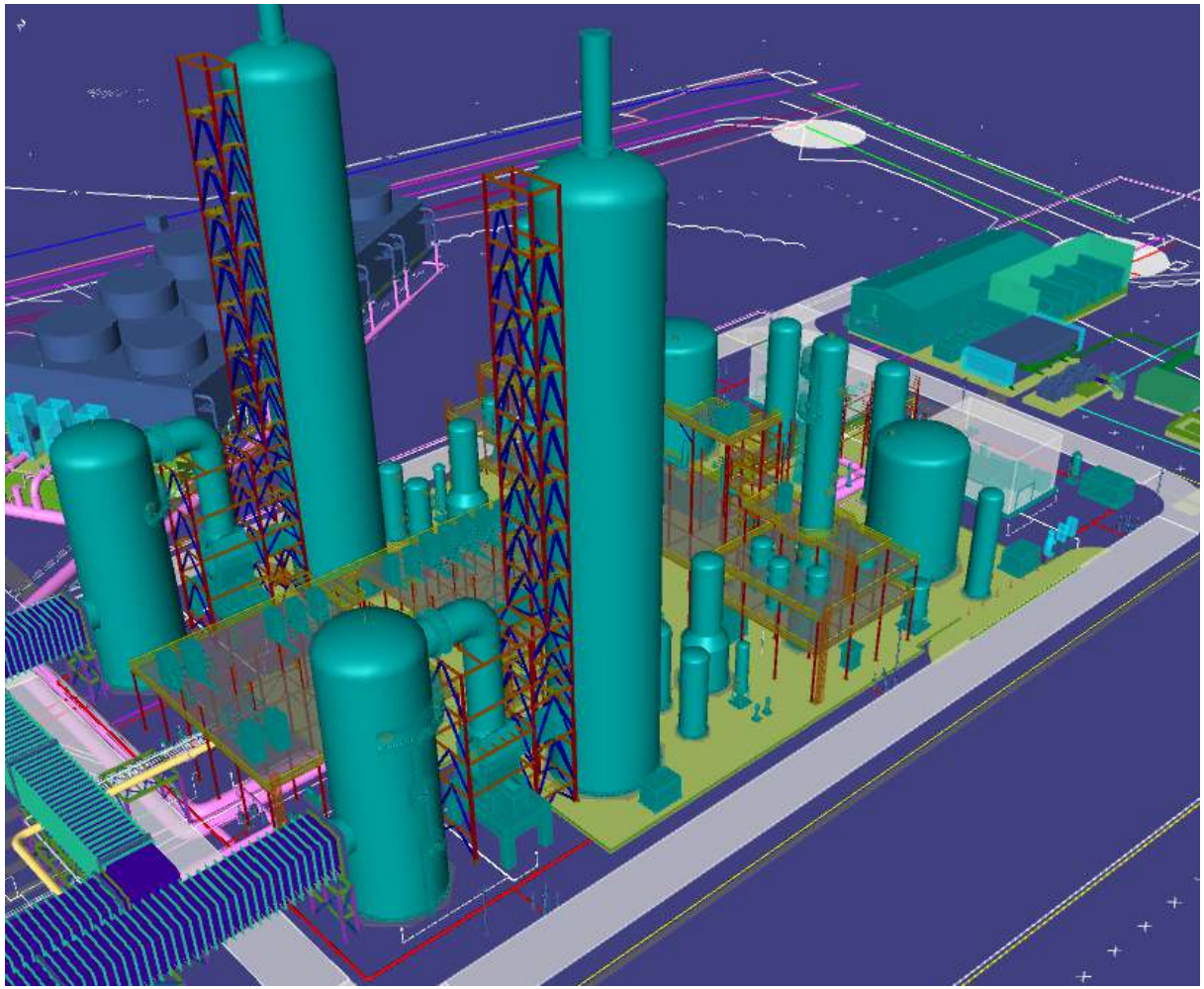
EGR delivers **$43MM TPC cost savings** (~3.3% of the TPC)



EGR assessment shows ~$80MM net NPV improvement with EGR applied

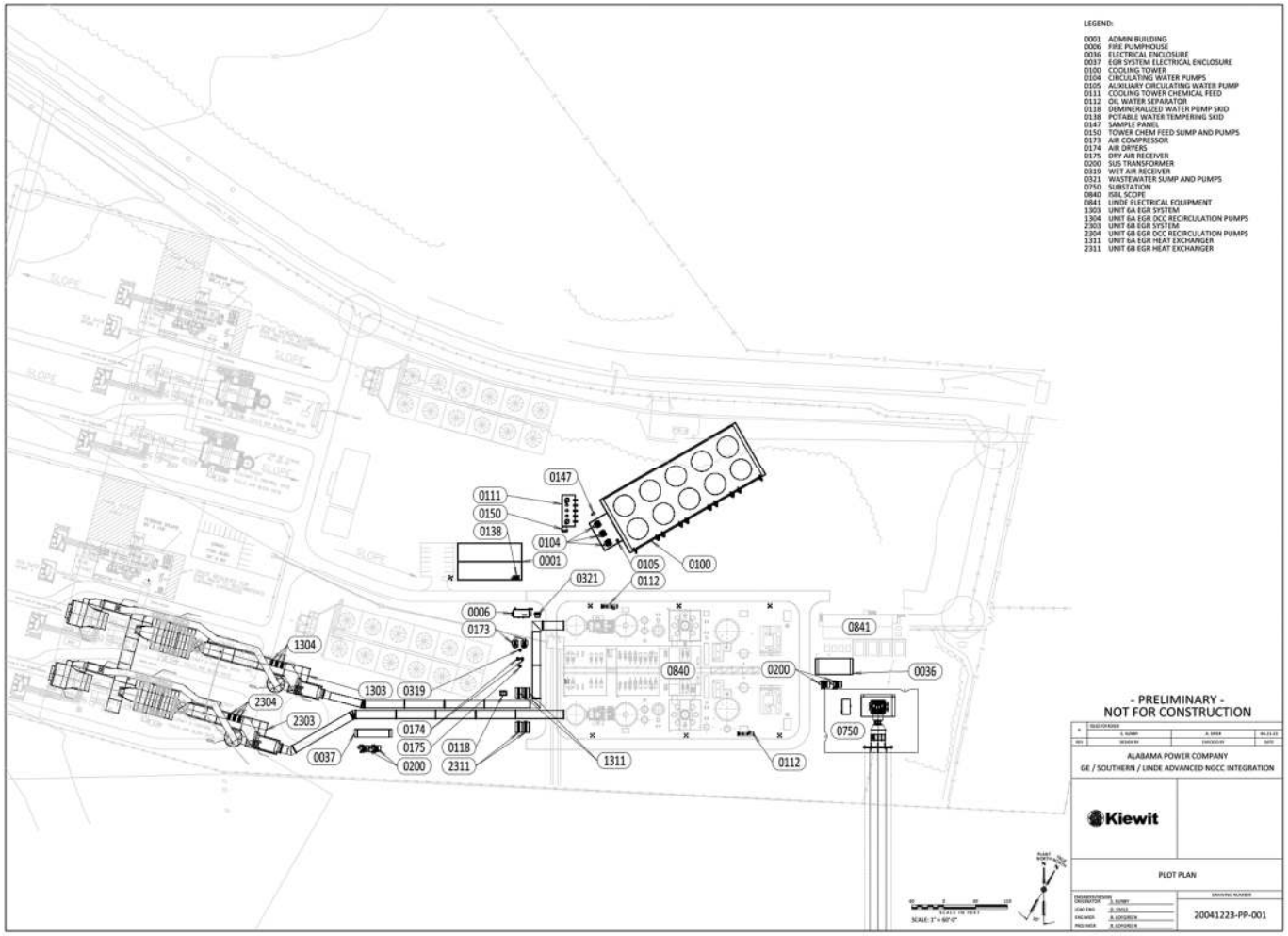
CO_2 Capture Island (ISBL)

- 2 Trains (1 for each GT)
- Common loading/unloading stations
- Common Cooling Water system

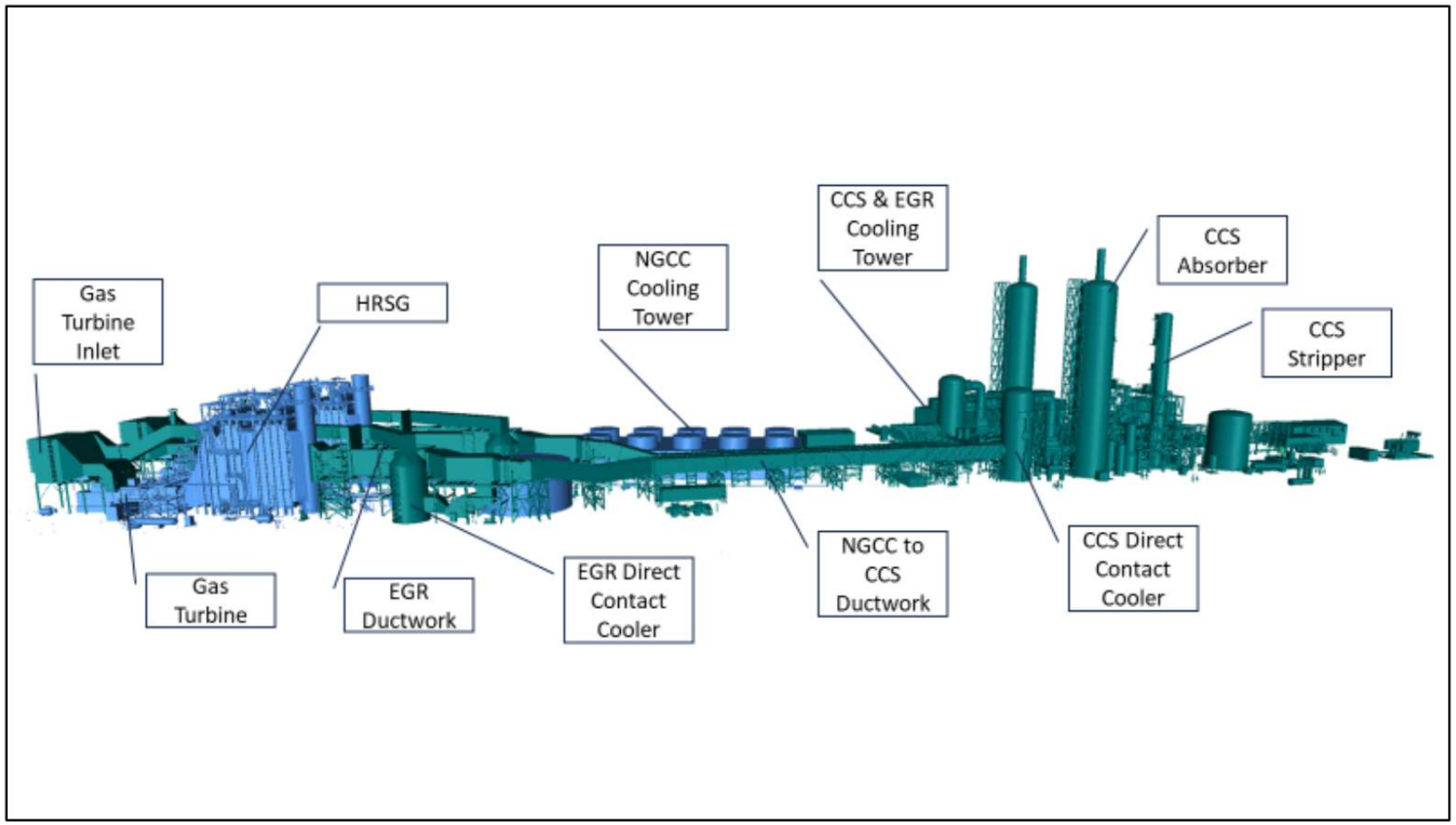


CCS Plant Integration (OSBL) Detailed Design

- 2 Trains (1 for each GT)
- Common loading/unloading stations
- Common Cooling Water system



CCS Plant Integration (OSBL) 3-D Model



Thank You

Questions?