CO_2 Capture Facility at Kårstø, Norway

Front-End Engineering and Design (FEED) Study Report

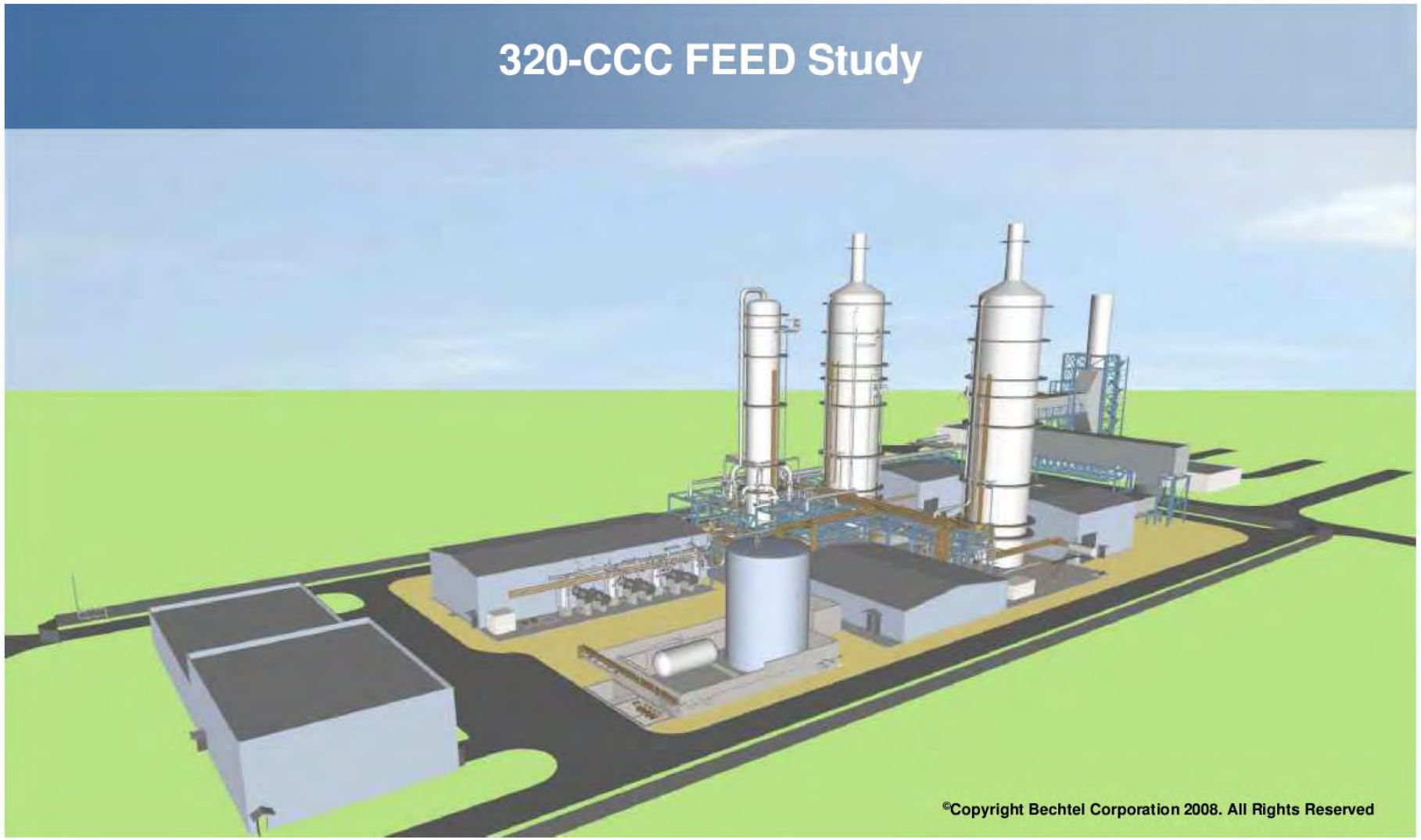
Submittal to GASSNOVA

13 January 2009, Revision 1

Redacted for Distribution as per Gassnova Instructions 3 April 2019

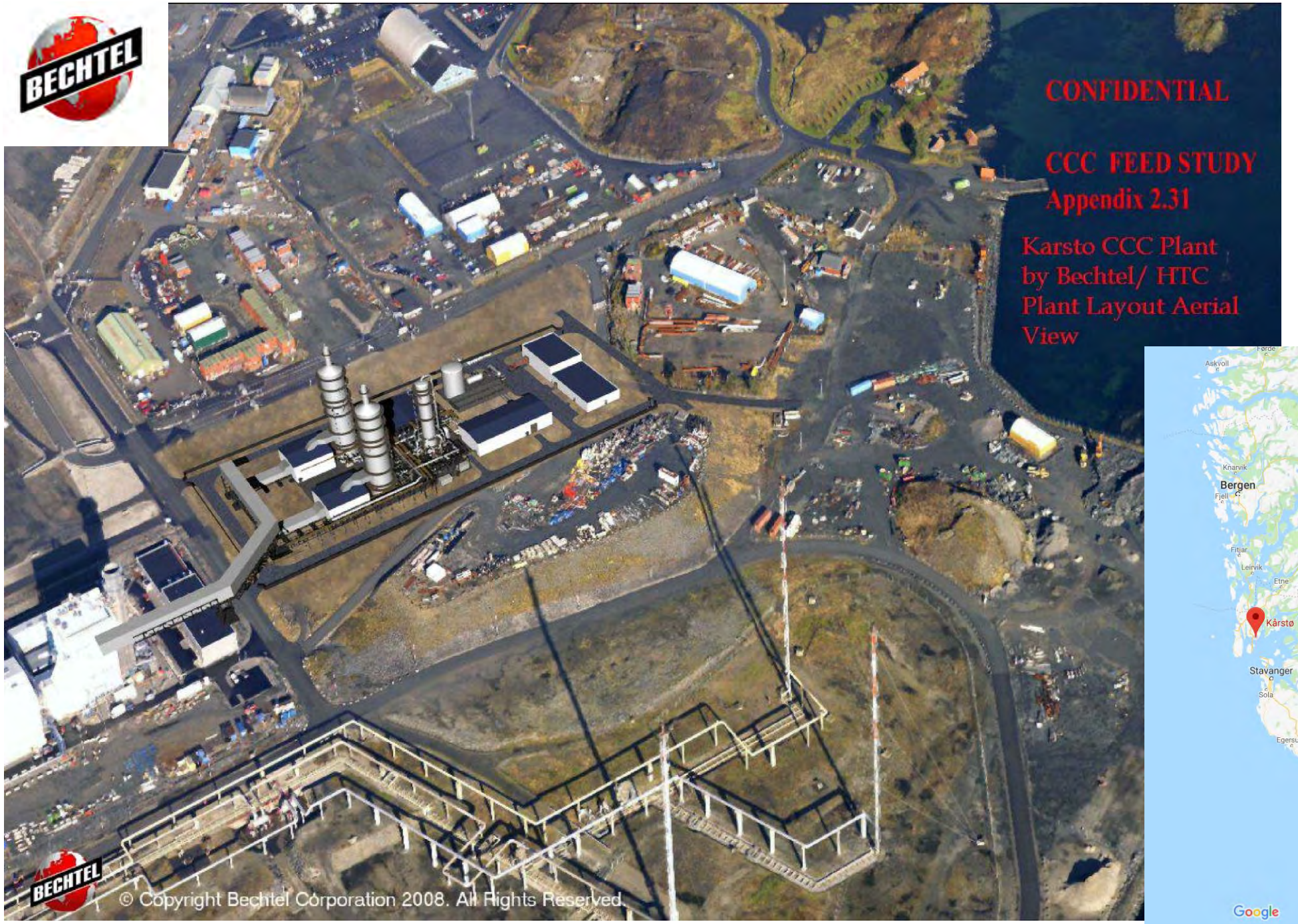
25474-000-30R-G04G-00001

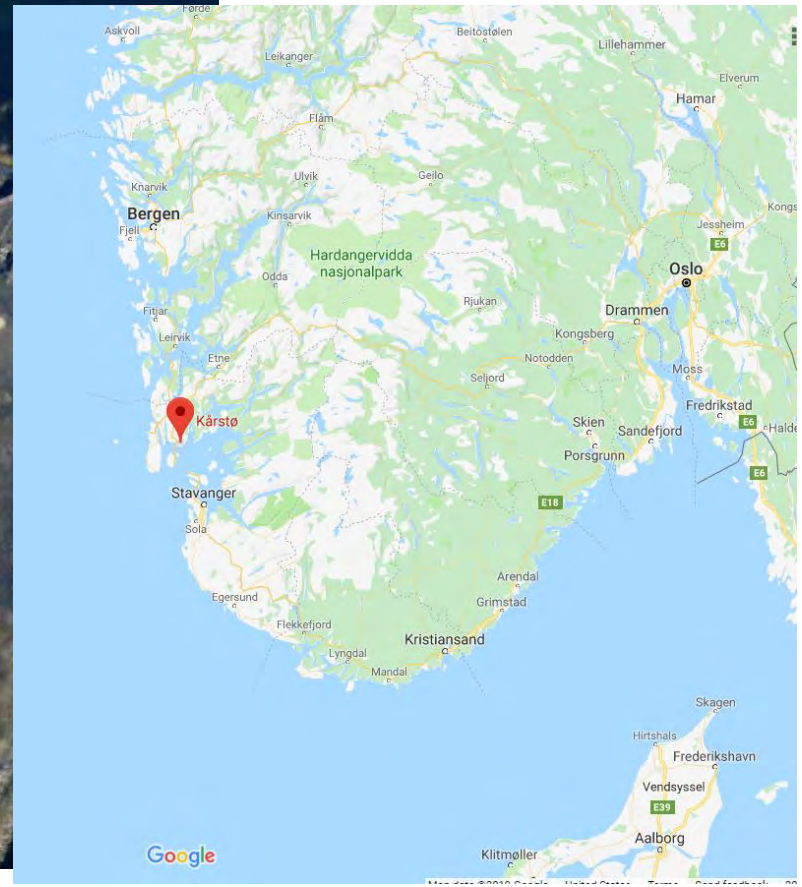
10112936-PB-G-DOC-0005

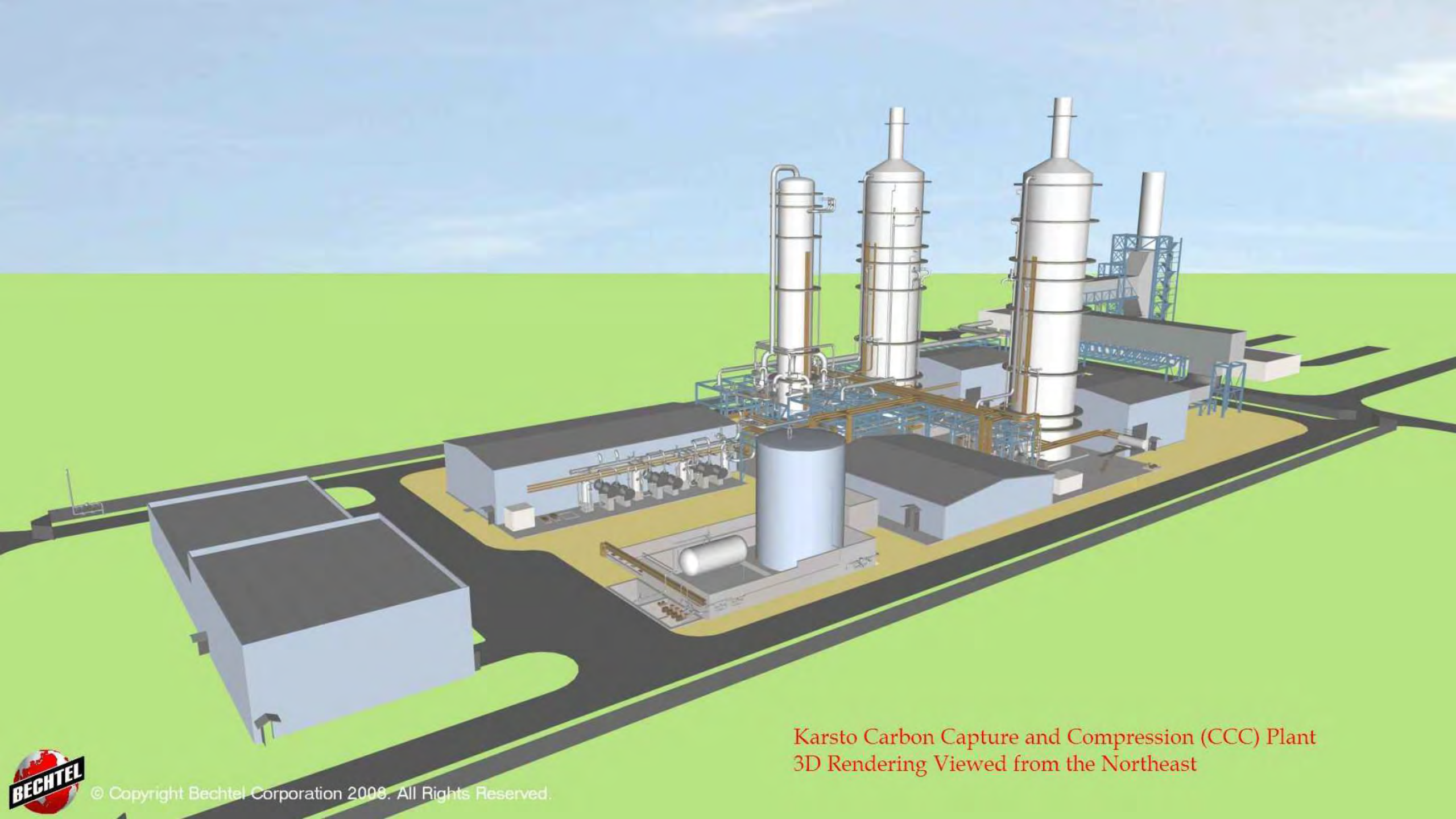


https://ukccsrc.ac.uk/sites/default/files/documents/news/Karsto-FEED-Study-Report-Redacted-Updated-comp.pdf

PLANT AERIAL VIEW AND LOCATION

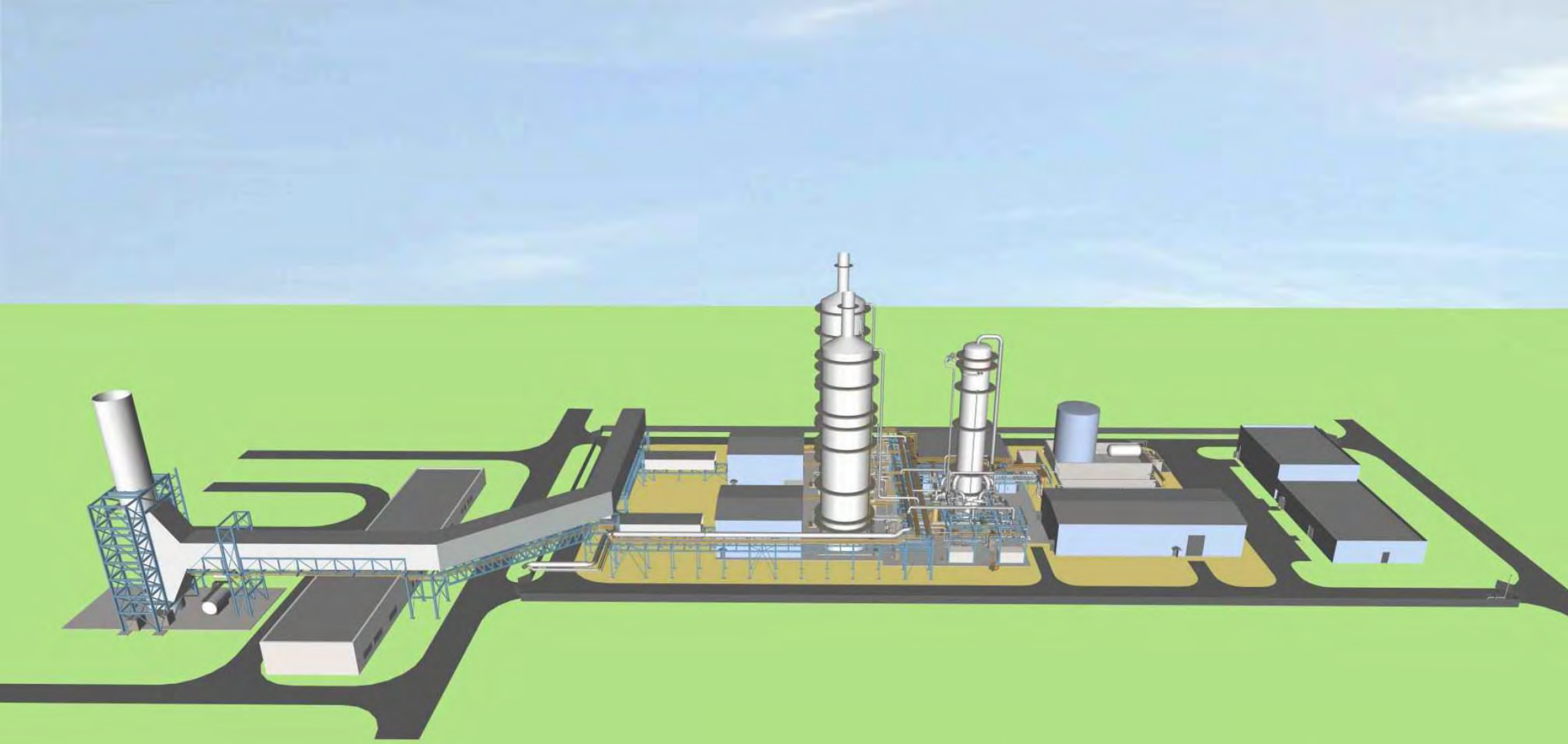






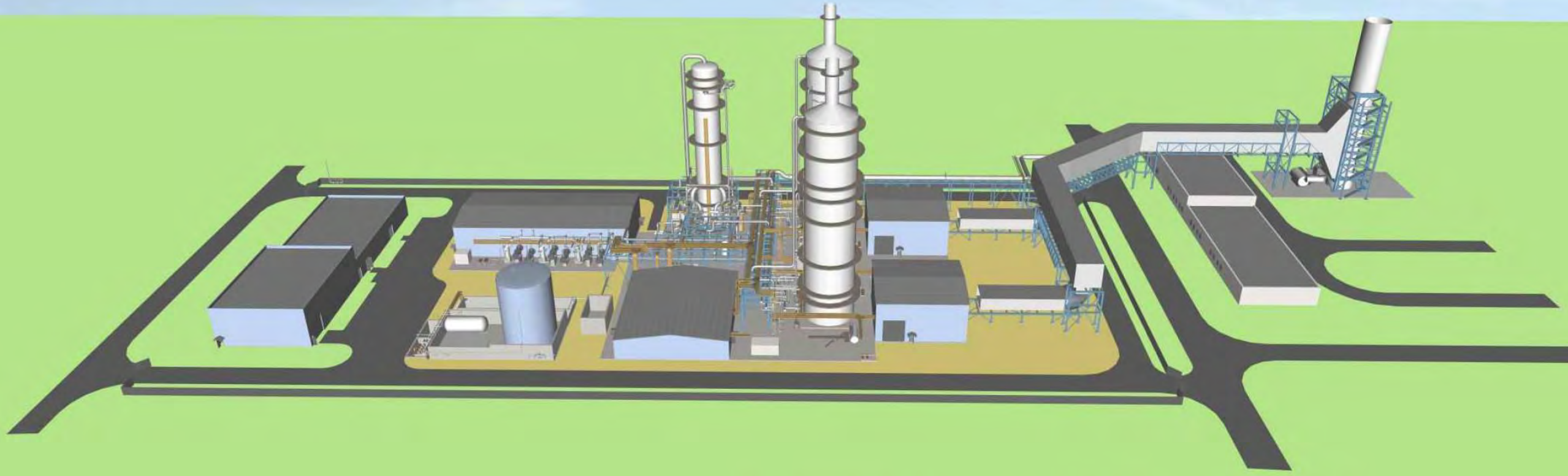
Karsto Carbon Capture and Compression (CCC) Plant
3D Rendering Viewed from the Northeast

© Copyright Bechtel Corporation 2008. All Rights Reserved.



Karsto CCC Plant Arrangement Aerial View - from the North

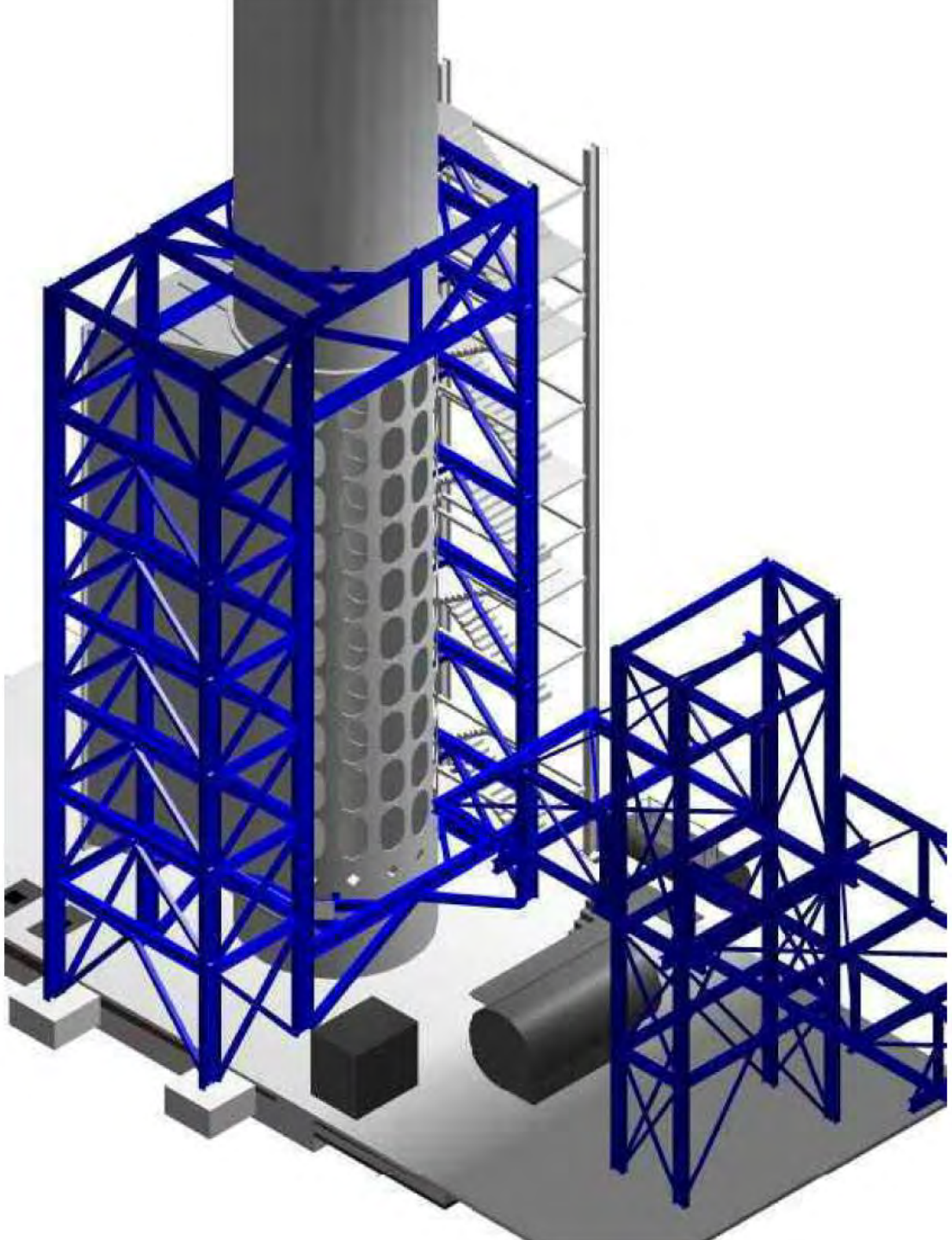
© Copyright Bechtel Corporation 2008. All Rights Reserved.



Karsto CCC Plant Arrangement Aerial View - from the South

© Copyright Bechtel Corporation 2008. All Rights Reserved.

TIE-IN TO EXISTING STACK



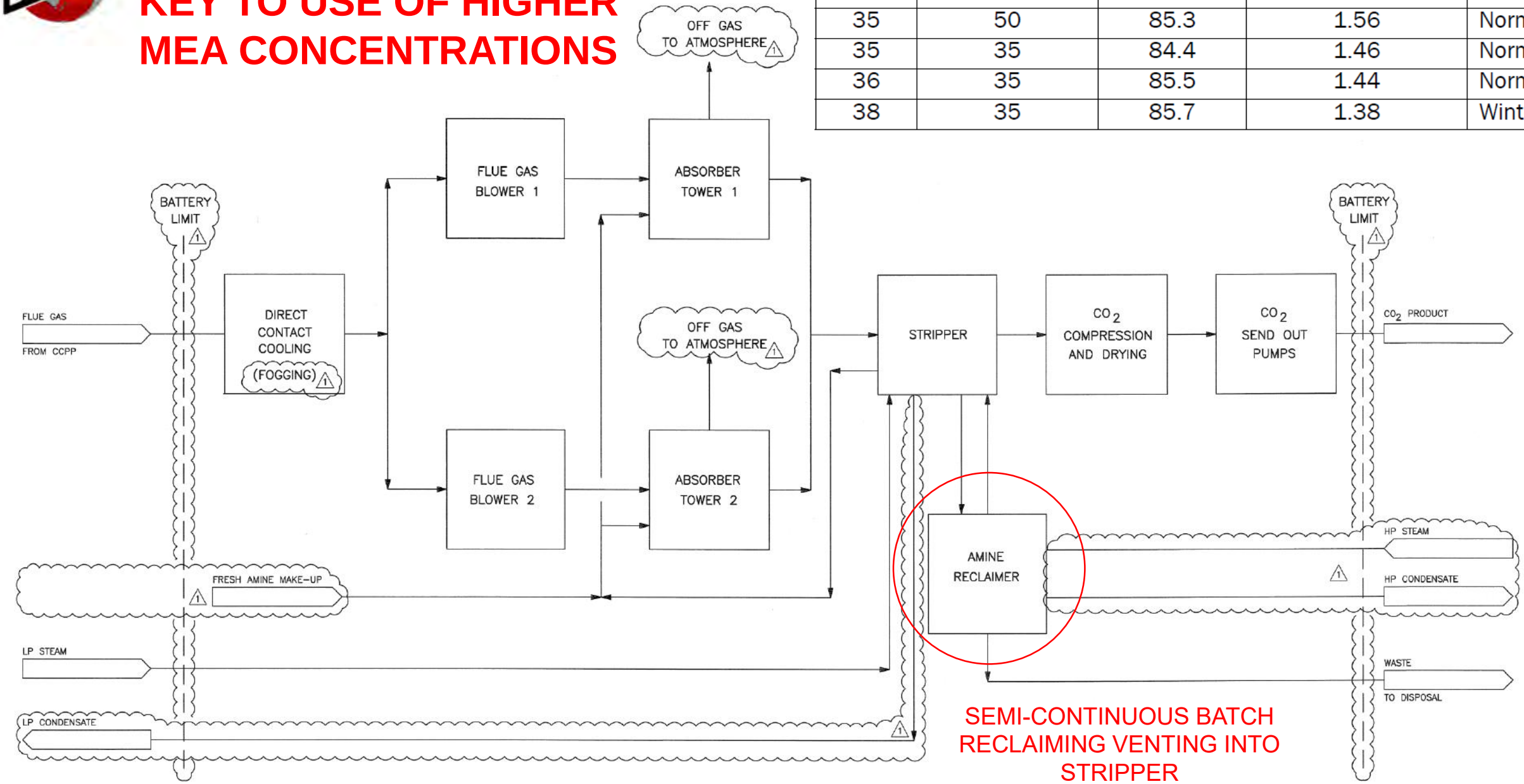
TECHNICAL & COMMERCIAL ASPECTS OF THE PROJECT

	Base Case: Open-art MEA with split flow
Capture rate	85.3%
LP steam required (tons/hr)	198.4
Electricity requirements (MW/hr)	32MW
Capital Cost (excluding contingency)	NOK 2.24billion
Operating cost (yearly avg)	NOK 388million
NPV of cost per tonne of CO2 Capture	199NOK/t

- For the Kårstø case of relatively low concentrations of CO2 in the flue gas stream, the use of relatively high flue gas temperatures in the absorber is economical.
- Use of MEA @ 35% to 40% concentration is viable with use of 100% stainless steel materials of construction.
- The use of two absorbers of known industry size and geometry reduces the risk of poor flow distribution in the columns
- Use of stainless steel materials for the amine circuit allows greater flexibility in future use and solvent selection.
- Use of two absorbers of maximum 12m diameter allows for maximum pre-assembly in the fabrication shops and also allows for shipping in one piece.
- Significant cost savings can be realized through competitive purchase in the world wide market, especially when maintaining flexibility in suppliers to optimize exchange rate fluctuations.
- Release of engineering prior to financial close can reduce the schedule risk by allowing immediate issue of request for bids for long lead items

SOLVENT MANAGEMENT KEY TO USE OF HIGHER MEA CONCENTRATIONS

MEA (%)	Flue Gas Temperature (°C)	CO_2 Capture Efficiency (%)	Steam Rate - Gross (kg steam per kg CO_2)	Case
35	50	85.3	1.56	Normal
35	35	84.4	1.46	Normal
36	35	85.5	1.44	Normal
38	35	85.7	1.38	Winter



SEMI-CONTINUOUS BATCH RECLAIMING VENTING INTO STRIPPER

STEAM SUPPLY & USE OF AUXILIARY BOILER

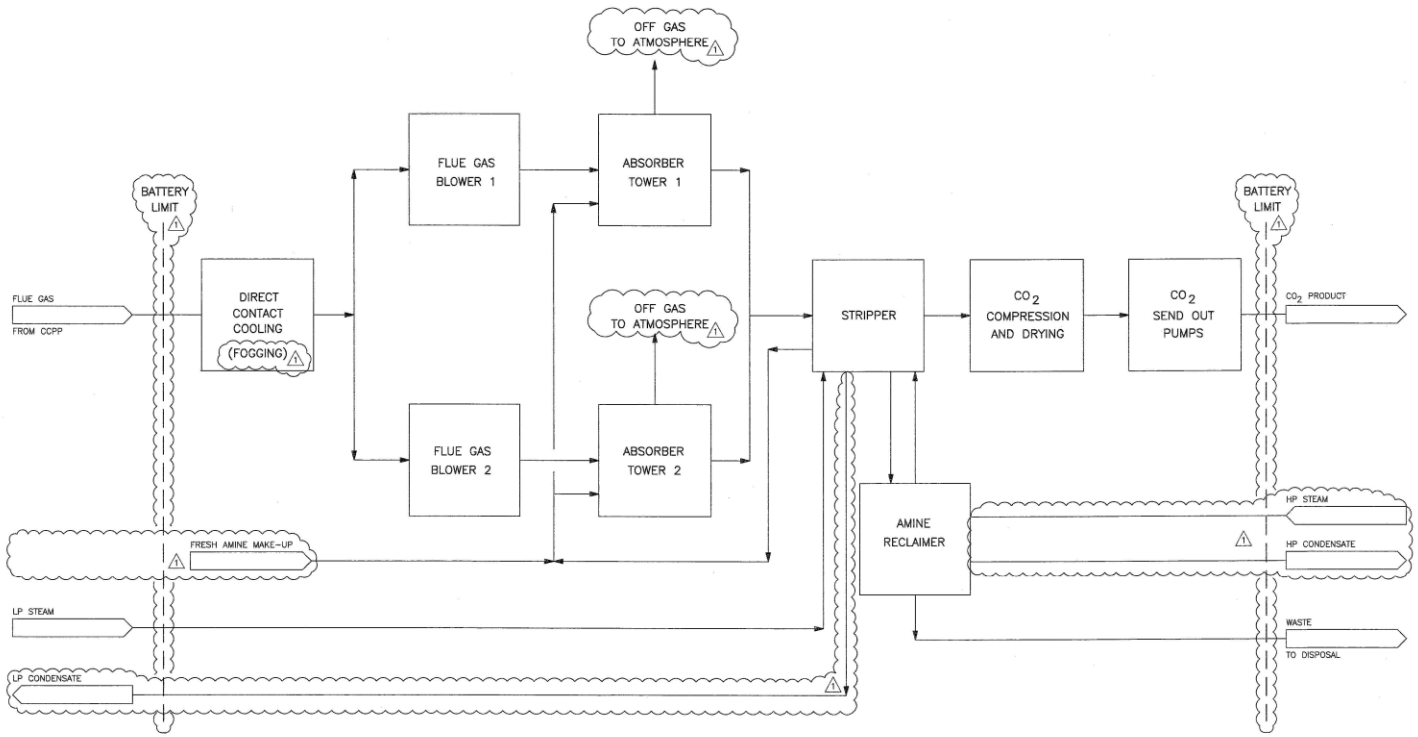
The CCC Plant design includes low pressure (LP) steam, auxiliary boiler steam, high pressure (HP) steam, and LP and HP condensate systems for plant operations.

The LP steam supply is from the adjacent NaturKraft combined cycle power plant (CCPP) LP steam turbine crossover piping to an interface at the CCC Plant battery limit (B/L). The LP steam conditions at the B/L are 2.2 barg and 270 °C, and the maximum quantity of steam available from the CCPP is 165 tonnes/hr. The LP steam is desuperheated using LP condensate to reduce its temperature to approximately 135 °C for use in the reboilers and at the seven CCC Plant utility stations, thereby increasing its volume by about 20 tonnes.

During certain CCC Plant operating scenarios, the quantity of LP steam required exceeds the 165 tonnes/hr available from the CCPP. During these operating scenarios, the CCC Plant auxiliary boiler is used to supplement the LP steam demands to the stripper reboilers. The auxiliary boiler is sized for approximately 20 tonnes/hr of saturated steam to meet the LP steam conditions.

©Bechtel Corporation 2008. All rights reserved. Bechtel Confidential. Contains information that is confidential and proprietary to Bechtel and may not be used, reproduced, or disclosed in any format without Bechtel's prior written permission. This document is prepared exclusively for Gassnova in connection with the preparation of the FEED study for the CO2 Capture Facility at Karsto, Norway, and is not to be relied upon by others or used in connection with any other project.

NOTES:
1.



NO.	DATE	REVISIONS	BY	CHK	DES	ENGR.	PROJ	APPR.
2	12 MAR 09	RE-ISSUED FOR APPROVAL	DM	GR	-	RS	[illegible]
1	10/10/08	ISSUED FOR APPROVAL	GR	DM	-	RS	-	[illegible]

Owner: GASSNOVA
Owner Drawing No.: 10112936-PB-P-FLD-0001
Contractor: BECHTEL POWER CORPORATION FREDERICK, MARYLAND

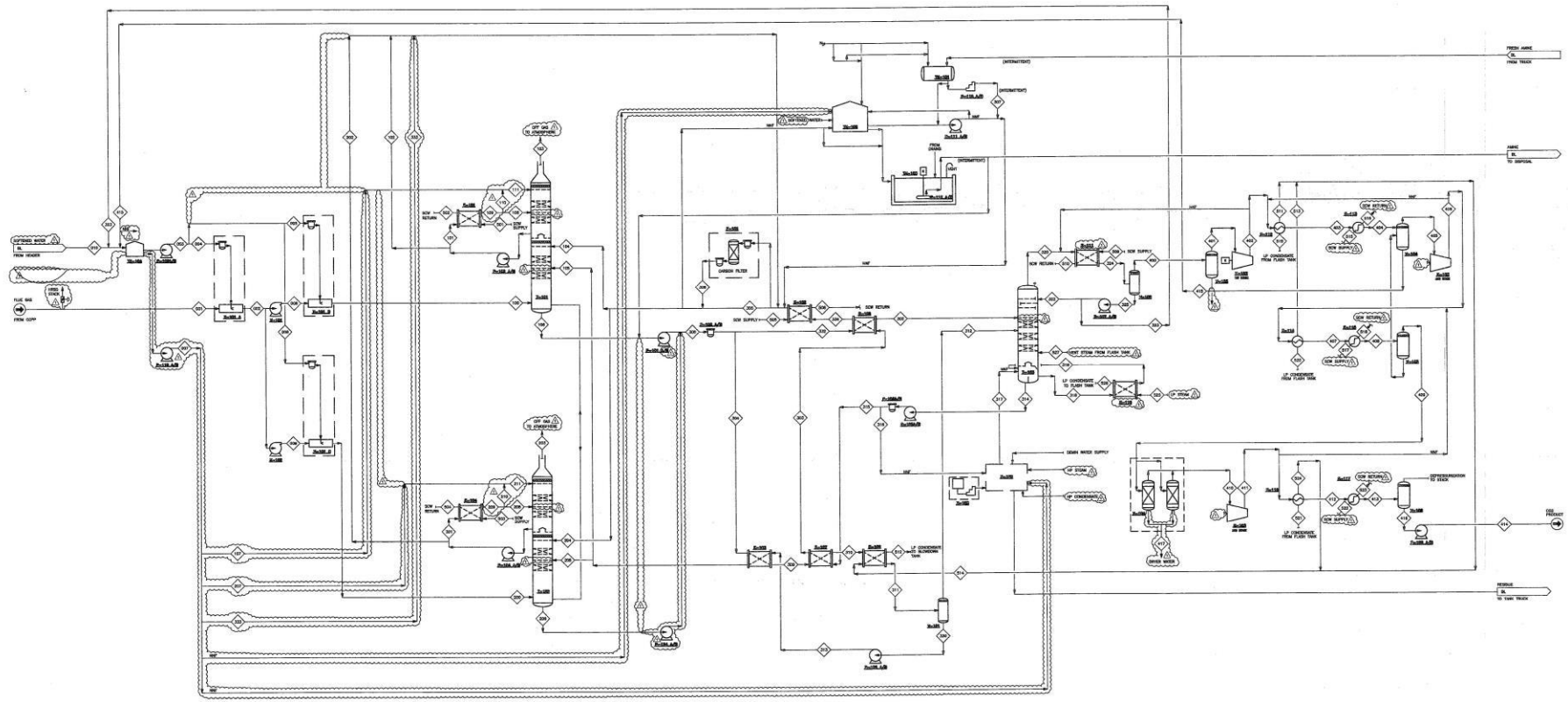
CO2 KARSTO PROJECT

BLOCK FLOW DIAGRAM

Sheet Size: S94x841 "A1" | Scale: N.T.S.

JOB NO.	DRAWING NO.	REV.
25474	000-M5-YA-00001	1

©Bechtel Corporation 2008. All rights reserved. Bechtel Confidential. Contains information that is confidential and proprietary to Bechtel and may not be used, reproduced or disclosed to others without the written permission of Bechtel. Gassnova is authorized to use this information in connection with the preparation of the FEED study for the CO2 Capture Facility at Karsto, Norway, and is not to be relied upon by others or used in connection with any other project.



REV.	DESCRIPTION	BY	CHK	ENGR.	PROJ	APPR.
1	RE-ISSUED FOR COMMENT	OR	DM	–	RS	
0	ISSUED FOR COMMENT	KJ	DM	–	RS	–

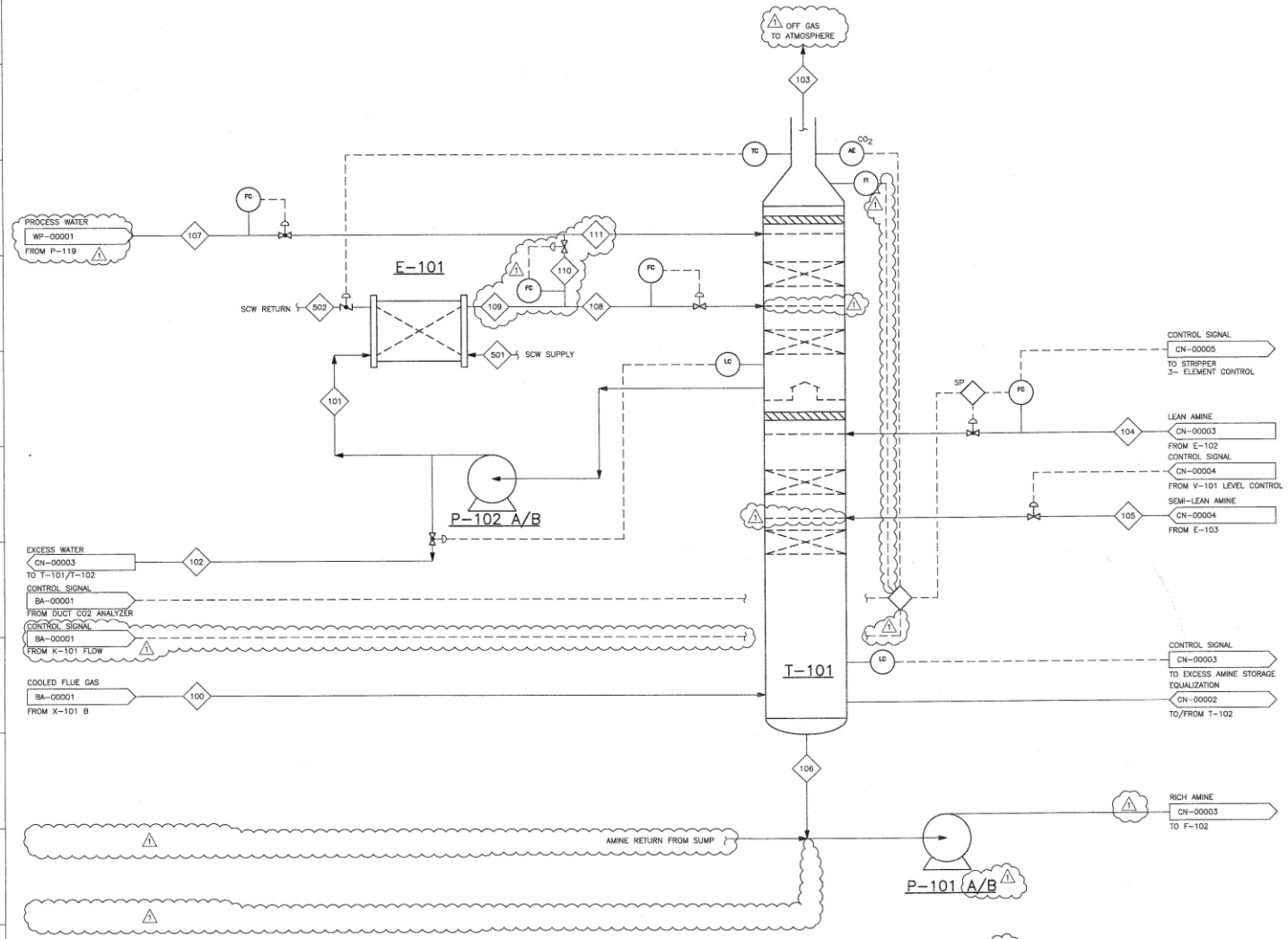
Owner	GASSNOVA
	CO2 KARSTO PROJECT
Owner Drawing No.	101129J6-PB-P-HMB-0002
	PROCESS HEAT & MASS BALANCE DIAGRAM
Contractor	BECHTEL POWER CORPORATION FREDERICK, MARYLAND
Sheet Size	594x841 "A1"
Scale	N.T.S.
JOB NO.	25474
DRAWING NO.	000-M4-CN-00002
REV.	1

©Bechtel Corporation 2008. All rights reserved. Bechtel Confidential: Contains information that is confidential and proprietary to Bechtel and may not be used, disclosed or duplicated in any form without Bechtel's prior written permission. Unless otherwise agreed to in writing by Bechtel, any use of this drawing shall be limited to preparation of the FEED study for the CO2 Capture Facility at Karsto, Norway, and is not to be relied upon by others or used in connection with any other project.

NOTES:
1. –

E–101
WASH WATER COOLER (ABSORBER 1)
NORMAL DUTY: 52.7 x 10^3 kW

T–101
CO2 ABSORBER
INTERNAL DIAM: 11.8 m
LENGTH T/T: 43.4 m
PACKING TYPE: STRUCTURED PACKING
PACKING MATERIAL: SS



P–102 A/B
WASH WATER RECIRCULATION PUMP (ABSORBER 1)
NORMAL CAPACITY: 1.46 x 10^3 Am^3/h

P–101 A/B
RICH AMINE PUMPS (ABSORBER 1)
NORMAL CAPACITY: 1.21 x 10^3 Am^3/h

NO.	DATE	REVISIONS	BY	CHK	DES	ENGR.	PROJ.	APPR.
2	IFC Issue 2B	RE-ISSUED FOR APPROVAL	DM	UP	–	RS		
1	10/19/09	ISSUED FOR APPROVAL	GR	DM	–	RS	–	–

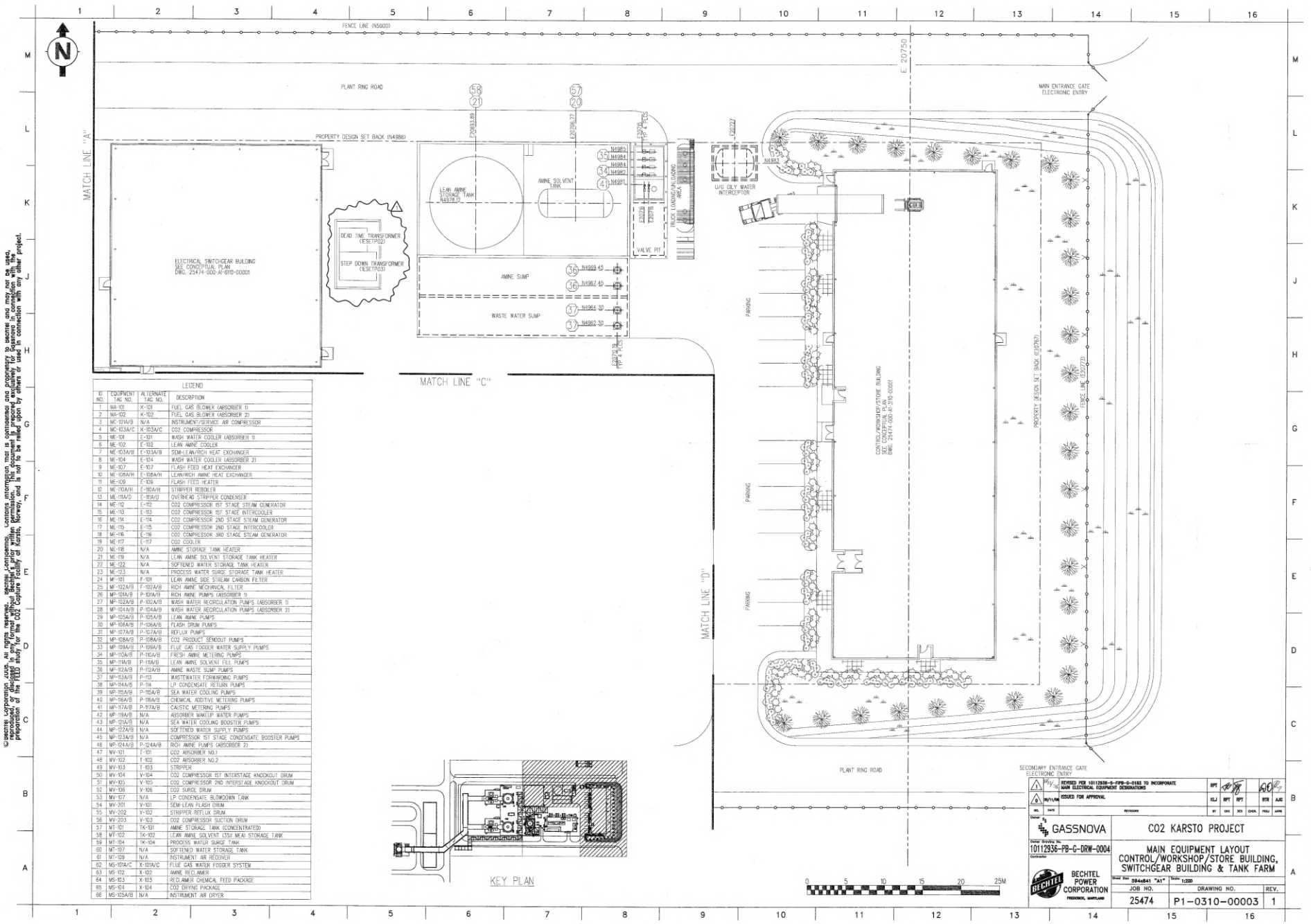
Owner: GASSNOVA
Owner Drawing No.: 10112936–PB–P–FLD–0004
Contractor: BECHTEL POWER CORPORATION FREDERICK, MARYLAND

CO2 KARSTO PROJECT

PROCESS FLOW DIAGRAM
ABSORBER T–101

Sheet Size: 594x841 "A1" | Scale: N.T.S.

JOB NO.	DRAWING NO.	REV.
25474	000–M5–CN–00001	1



LEGEND			
ID NO.	EQUIPMENT TAG NO.	ALTERNATE TAG NO.	DESCRIPTION
1	MA-101	K-101	FUEL GAS BLOWER (ABSORBER 1)
2	MA-102	K-102	FUEL GAS BLOWER (ABSORBER 2)
3	MC-101A/B	N/A	INSTRUMENT/SERVICE AIR COMPRESSOR
4	MC-103A/C	K-103A/C	CO2 COMPRESSOR
5	ME-101	E-101	WASH WATER COOLER (ABSORBER 1)
6	ME-102	E-102	LEAN AMINE COOLER
7	ME-103A/B	E-103A/B	SEMI-LEAN/RICH HEAT EXCHANGER
8	ME-104	E-104	WASH WATER COOLER (ABSORBER 2)
9	ME-107	E-107	FLASH FEED HEAT EXCHANGER
10	ME-108A/H	E-108A/H	LEAN/RICH AMINE HEAT EXCHANGER
11	ME-109	E-109	FLASH FEED HEATER
12	ME-110A/H	E-110A/H	STRIPPER REBOILER
13	ME-111A/D	E-111A/D	OVERHEAD STRIPPER CONDENSER
14	ME-112	E-112	CO2 COMPRESSOR 1ST STAGE STEAM GENERATOR
15	ME-113	E-113	CO2 COMPRESSOR 1ST STAGE INTERCOOLER
16	ME-114	E-114	CO2 COMPRESSOR 2ND STAGE STEAM GENERATOR
17	ME-115	E-115	CO2 COMPRESSOR 2ND STAGE INTERCOOLER
18	ME-116	E-116	CO2 COMPRESSOR 3RD STAGE STEAM GENERATOR
19	ME-117	E-117	CO2 COOLER
20	ME-118	N/A	AMINE STORAGE TANK HEATER
21	ME-119	N/A	LEAN AMINE SOLVENT STORAGE TANK HEATER
22	ME-122	N/A	SOFTENED WATER STORAGE TANK HEATER
23	ME-123	N/A	PROCESS WATER SURGE STORAGE TANK HEATER
24	MF-101	F-101	LEAN AMINE SIDE STREAM CARBON FILTER
25	MF-102A/B	F-102A/B	RICH AMINE MECHANICAL FILTER
26	MP-101A/B	P-101A/B	RICH AMINE PUMPS (ABSORBER 1)
27	MP-102A/B	P-102A/B	WASH WATER RECIRCULATION PUMPS (ABSORBER 1)
28	MP-104A/B	P-104A/B	WASH WATER RECIRCULATION PUMPS (ABSORBER 2)
29	MP-105A/B	P-105A/B	LEAN AMINE PUMPS
30	MP-106A/B	P-106A/B	FLASH DRUM PUMPS
31	MP-107A/B	P-107A/B	REFLUX PUMPS
32	MP-108A/B	P-108A/B	CO2 PRODUCT SENDOUT PUMPS
33	MP-109A/B	P-109A/B	FLUE GAS FOGGER WATER SUPPLY PUMPS
34	MP-110A/B	P-110A/B	FRESH AMINE METERING PUMPS
35	MP-111A/B	P-111A/B	LEAN AMINE SOLVENT FILL PUMPS
36	MP-112A/B	P-112A/B	AMINE WASTE SUMP PUMPS
37	MP-113A/B	P-113	WASTEWATER FORWARDING PUMPS
38	MP-114A/B	P-114	LP CONDENSATE RETURN PUMPS
39	MP-115A/B	P-115A/B	SEA WATER COOLING PUMPS
40	MP-116A/B	P-116A/B	CHEMICAL ADDITIVE METERING PUMPS
41	MP-117A/B	P-117A/B	CAUSTIC METERING PUMPS
42	MP-119A/B	N/A	ABSORBER MAKEUP WATER PUMPS
43	MP-121A/B	N/A	SEA WATER COOLING BOOSTER PUMPS
44	MP-122A/B	N/A	SOFTENED WATER SUPPLY PUMPS
45	MP-123A/B	N/A	COMPRESSOR 1ST STAGE CONDENSATE BOOSTER PUMPS
46	MP-124A/B	P-124A/B	RICH AMINE PUMPS (ABSORBER 2)
47	MV-101	T-101	CO2 ABSORBER NO.1
48	MV-102	T-102	CO2 ABSORBER NO.2
49	MV-103	T-103	STRIPPER
50	MV-104	V-104	CO2 COMPRESSOR 1ST INTERSTAGE KNOCKOUT DRUM
51	MV-105	V-105	CO2 COMPRESSOR 2ND INTERSTAGE KNOCKOUT DRUM
52	MV-106	V-106	CO2 SURGE DRUM
53	MV-107	N/A	LP CONDENSATE BLOWDOWN TANK
54	MV-201	V-101	SEMI-LEAN FLASH DRUM
55	MV-202	V-102	STRIPPER REFLUX DRUM
56	MV-203	V-103	CO2 COMPRESSOR SUCTION DRUM
57	MT-101	TK-101	AMINE STORAGE TANK (CONCENTRATED)
58	MT-102	TK-102	LEAN AMINE SOLVENT (35% MEA) STORAGE TANK
59	MT-104	TK-104	PROCESS WATER SURGE TANK
60	MT-107	N/A	SOFTENED WATER STORAGE TANK
61	MT-109	N/A	INSTRUMENT AIR RECEIVER
62	MS-101A/C	X-101A/C	FLUE GAS WATER FOGGER SYSTEM
63	MS-102	X-102	AMINE RECLAIMER
64	MS-103	X-103	RECLAIMER CHEMICAL FEED PACKAGE
65	MS-104	X-104	CO2 DRYING PACKAGE
66	MS-105A/B	N/A	INSTRUMENT AIR DRYER

©bechtel corporation 2005. all rights reserved. bechtel confidential. contains information that is confidential and proprietary to bechtel and may not be used, reproduced, or disclosed in any form except with prior written permission. this document is made available solely for discussion in connection with the purpose for which it was prepared and may not be relied upon by others or used in connection with any other project.

1	09/11/06	REVISED PER 10112936-S-FVP-G-0103 TO INCORPORATE MAIN ELECTRICAL EQUIPMENT DESIGNATIONS	RPT				
0	08/11/06	ISSUED FOR APPROVAL	SLJ	RPT	RPT	BTR	AJG
NO.	DATE	REVISIONS	BY	CHK	DES	CHKR	PROJ APPR

Owner: GASSNOVA

Contractor: BECHTEL POWER CORPORATION, FREDERICK, MARYLAND

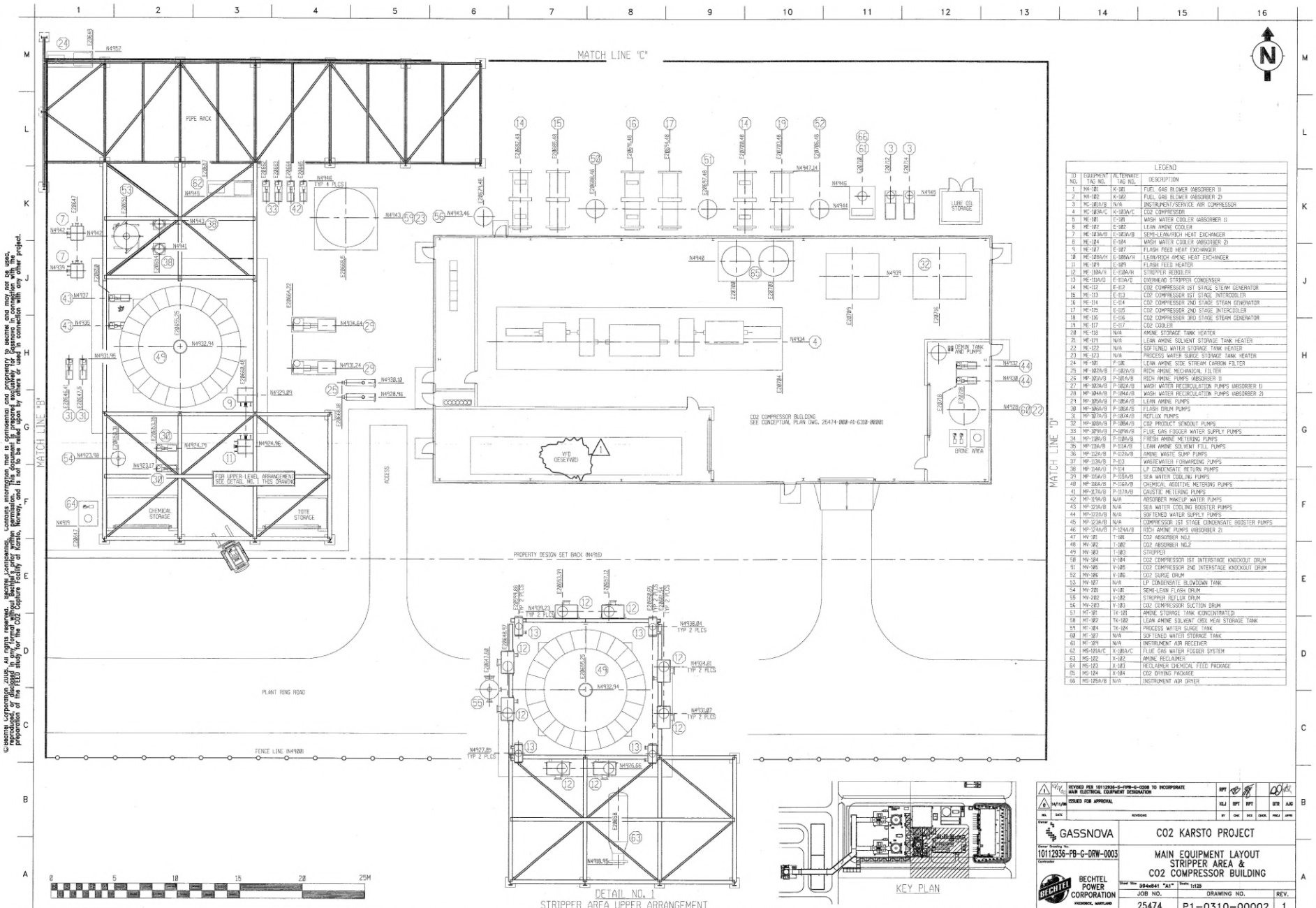
Owner Drawing No.: 10112936-PB-G-DRW-0004

Sheet Size: 594x841 "A1" | Scale: 1:200

JOB NO.	DRAWING NO.	REV.
25474	P1-0310-00003	1

CO2 KARSTO PROJECT

MAIN EQUIPMENT LAYOUT CONTROL/WORKSHOP/STORE BUILDING, SWITCHGEAR BUILDING & TANK FARM



LEGEND			
ID NO.	EQUIPMENT TAG NO.	ALTERNATE TAG NO.	DESCRIPTION
1	MG-101	K-101	FUEL GAS BLOWER (ABSORBER 1)
2	MG-102	K-102	FUEL GAS BLOWER (ABSORBER 2)
3	MC-101A/B	N/A	INSTRUMENT/SERVICE AIR COMPRESSOR
4	MC-103A/C	K-103A/C	CO2 COMPRESSOR
5	ME-101	E-101	WASH WATER COOLER (ABSORBER 1)
6	ME-102	E-102	LEAN AMINE COOLER
7	ME-103A/B	E-103A/B	SEMI-LEAN/RICH HEAT EXCHANGER
8	ME-104	E-104	WASH WATER COOLER (ABSORBER 2)
9	ME-107	E-107	FLASH FEED HEAT EXCHANGER
10	ME-108A/H	E-108A/H	LEAN/RICH AMINE HEAT EXCHANGER
11	ME-109	E-109	FLASH FEED HEATER
12	ME-110A/H	E-110A/H	STRIPPER REBOILER
13	ME-111A/D	E-111A/D	OVERHEAD STRIPPER CONDENSER
14	ME-112	E-112	CO2 COMPRESSOR 1ST STAGE STEAM GENERATOR
15	ME-113	E-113	CO2 COMPRESSOR 1ST STAGE INTERCOOLER
16	ME-114	E-114	CO2 COMPRESSOR 2ND STAGE STEAM GENERATOR
17	ME-115	E-115	CO2 COMPRESSOR 2ND STAGE INTERCOOLER
18	ME-116	E-116	CO2 COMPRESSOR 3RD STAGE STEAM GENERATOR
19	ME-117	E-117	CO2 COOLER
20	ME-118	N/A	AMINE STORAGE TANK HEATER
21	ME-119	N/A	LEAN AMINE SOLVENT STORAGE TANK HEATER
22	ME-122	N/A	SOFTENED WATER STORAGE TANK HEATER
23	ME-123	N/A	PROCESS WATER SURGE STORAGE TANK HEATER
24	ME-101	F-101	LEAN AMINE SIDE STREAM CARBON FILTER
25	ME-102A/B	F-102A/B	RICH AMINE MECHANICAL FILTER
26	MP-101A/B	P-101A/B	RICH AMINE PUMPS (ABSORBER 1)
27	MP-102A/B	P-102A/B	WASH WATER RECIRCULATION PUMPS (ABSORBER 1)
28	MP-104A/B	P-104A/B	WASH WATER RECIRCULATION PUMPS (ABSORBER 2)
29	MP-105A/B	P-105A/B	LEAN AMINE PUMPS
30	MP-106A/B	P-106A/B	FLASH DRUM PUMPS
31	MP-107A/B	P-107A/B	REFLUX PUMPS
32	MP-108A/B	P-108A/B	CO2 PRODUCT SENDOUT PUMPS
33	MP-109A/B	P-109A/B	FLUE GAS FOGGER WATER SUPPLY PUMPS
34	MP-110A/B	P-110A/B	FRESH AMINE METERING PUMPS
35	MP-111A/B	P-111A/B	LEAN AMINE SOLVENT FILL PUMPS
36	MP-112A/B	P-112A/B	AMINE WASTE SUMP PUMPS
37	MP-113A/B	P-113	WASTEWATER FORWARDING PUMPS
38	MP-114A/B	P-114	LP CONDENSATE RETURN PUMPS
39	MP-115A/B	P-115A/B	SEA WATER COOLING PUMPS
40	MP-116A/B	P-116A/B	CHEMICAL ADDITIVE METERING PUMPS
41	MP-117A/B	P-117A/B	CAUSTIC METERING PUMPS
42	MP-119A/B	N/A	ABSORBER MAKEUP WATER PUMPS
43	MP-123A/B	N/A	SEA WATER COOLING BOOSTER PUMPS
44	MP-122A/B	N/A	SOFTENED WATER SUPPLY PUMPS
45	MP-123A/B	N/A	COMPRESSOR 1ST STAGE CONDENSATE BOOSTER PUMPS
46	MP-124A/B	P-124A/B	RICH AMINE PUMPS (ABSORBER 2)
47	MV-101	T-101	CO2 ABSORBER NO.1
48	MV-102	T-102	CO2 ABSORBER NO.2
49	MV-103	T-103	STRIPPER
50	MV-104	V-104	CO2 COMPRESSOR 1ST INTERSTAGE KNOCKOUT DRUM
51	MV-105	V-105	CO2 COMPRESSOR 2ND INTERSTAGE KNOCKOUT DRUM
52	MV-106	V-106	CO2 SURGE DRUM
53	MV-107	N/A	LP CONDENSATE BLOWDOWN TANK
54	MV-201	V-201	SEMI-LEAN FLASH DRUM
55	MV-202	V-202	STRIPPER REFLUX DRUM
56	MV-203	V-203	CO2 COMPRESSOR SUCTION DRUM
57	MT-101	TK-101	AMINE STORAGE TANK (CONCENTRATED)
58	MT-102	TK-102	LEAN AMINE SOLVENT CRSE MEAS STORAGE TANK
59	MT-104	TK-104	PROCESS WATER SURGE TANK
60	MT-107	N/A	SOFTENED WATER STORAGE TANK
61	MT-109	N/A	INSTRUMENT AIR RECEIVER
62	MG-101A/C	X-101A/C	FLUE GAS WATER FOGGER SYSTEM
63	MG-102	X-102	AMINE RECLAIMER
64	MG-103	X-103	RECLAIMER CHEMICAL FEED PACKAGE
65	MG-104	X-104	CO2 DRYING PACKAGE
66	MG-105A/B	N/A	INSTRUMENT AIR DRYER

NO.	DATE	REVISIONS	BY	CHK	DES	CHKR.	PROJ	APPR
2	14/11/08	REVISED PER 10112936-S-PPM-G-0008 TO INCORPORATE MAIN ELECTRICAL EQUIPMENT DESIGNATION	RPT	KD				
1	14/11/08	ISSUED FOR APPROVAL	KLJ	RPT	RPT		UTB	AJG

Owner: GASSNOVA
Owner Drawing No.: 10112936-PB-G-DRW-0003
Contractor: BECHTEL POWER CORPORATION FREDERICK, MARYLAND

CO2 KARSTO PROJECT

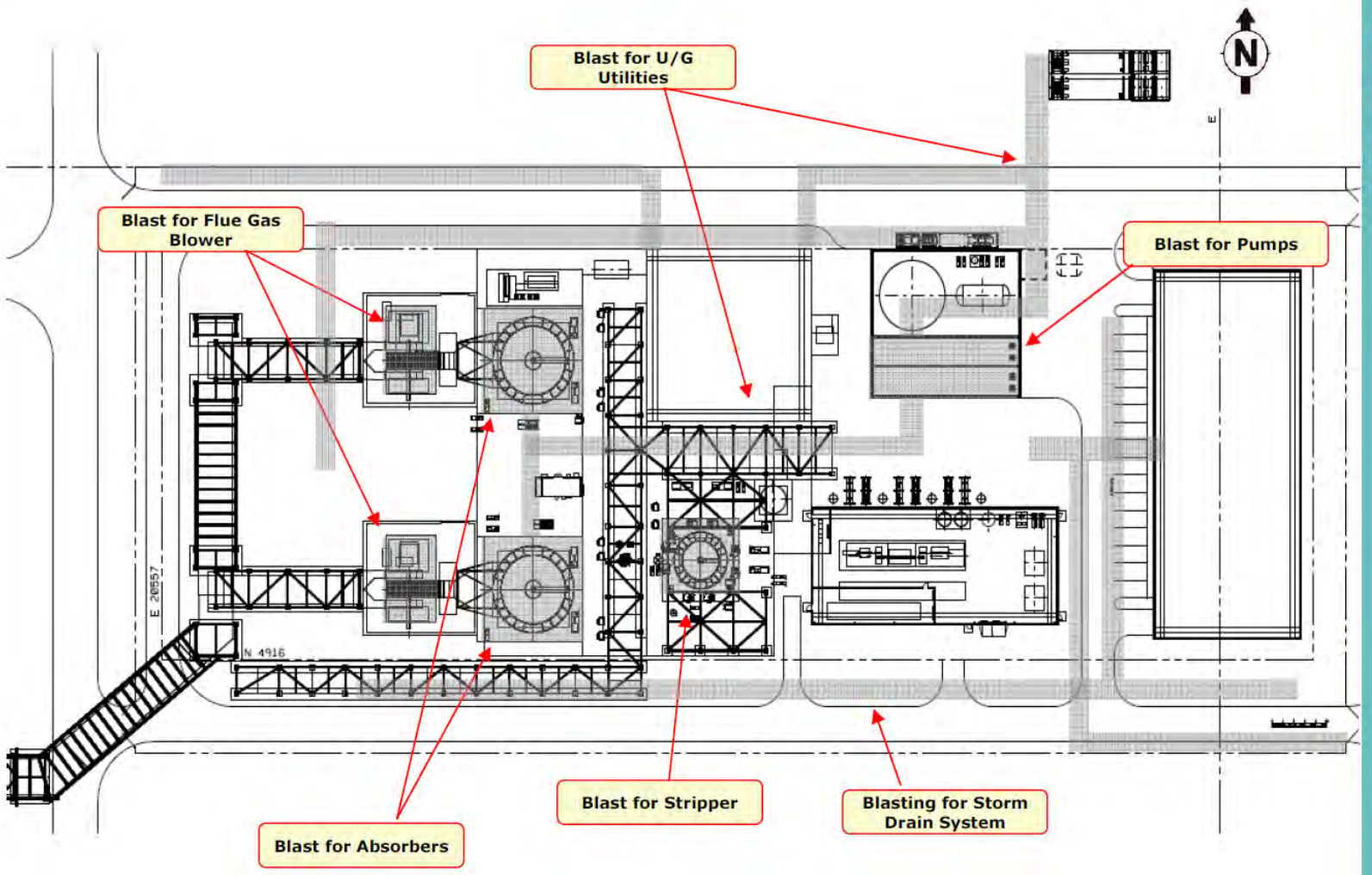
MAIN EQUIPMENT LAYOUT
STRIPPER AREA &
CO2 COMPRESSOR BUILDING

Sheet Size: 594x841 "A1" Scale: 1:125
JOB NO.: 25474
DRAWING NO.: P1-0310-00002
REV.: 1

©bechtel corporation 2008. all rights reserved. bechtel confidential. contains information that is confidential and proprietary to bechtel and may not be used, reproduced or disclosed to others without prior written permission. this document is intended only for classroom use in connection with the capture facility at the karsto ccs project and is not to be used for any other purpose by students or used in connection with any other project.

Karsto Facility

Month 10



Construction Activities

- Site Mobilization
- Blasting Plan
- Setup Site Offices
- Establish Laydown
- Establish Parking Lots
- Start Site Grading

Color Legend:

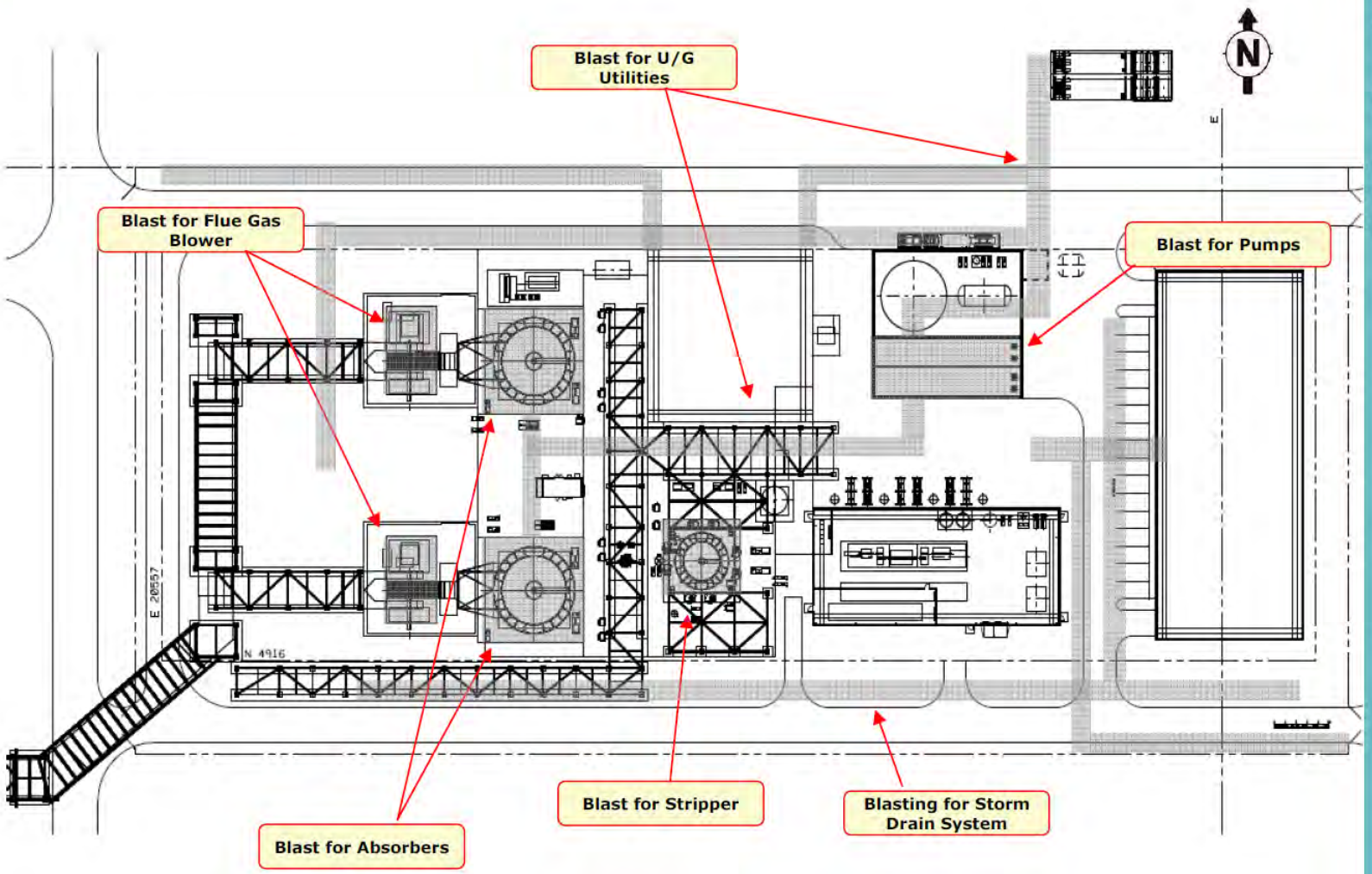
Concrete	Electrical Equipment
Underground Utilities	Blasting
Mechanical Equipment	Crane
Steel	

Karsto Facility

Month 11

Construction Activities

- Site Mobilization
- Blasting Plan
- Setup Site Offices
- Establish Laydown
- Establish Parking Lots
- Start Site Grading



Color Legend:

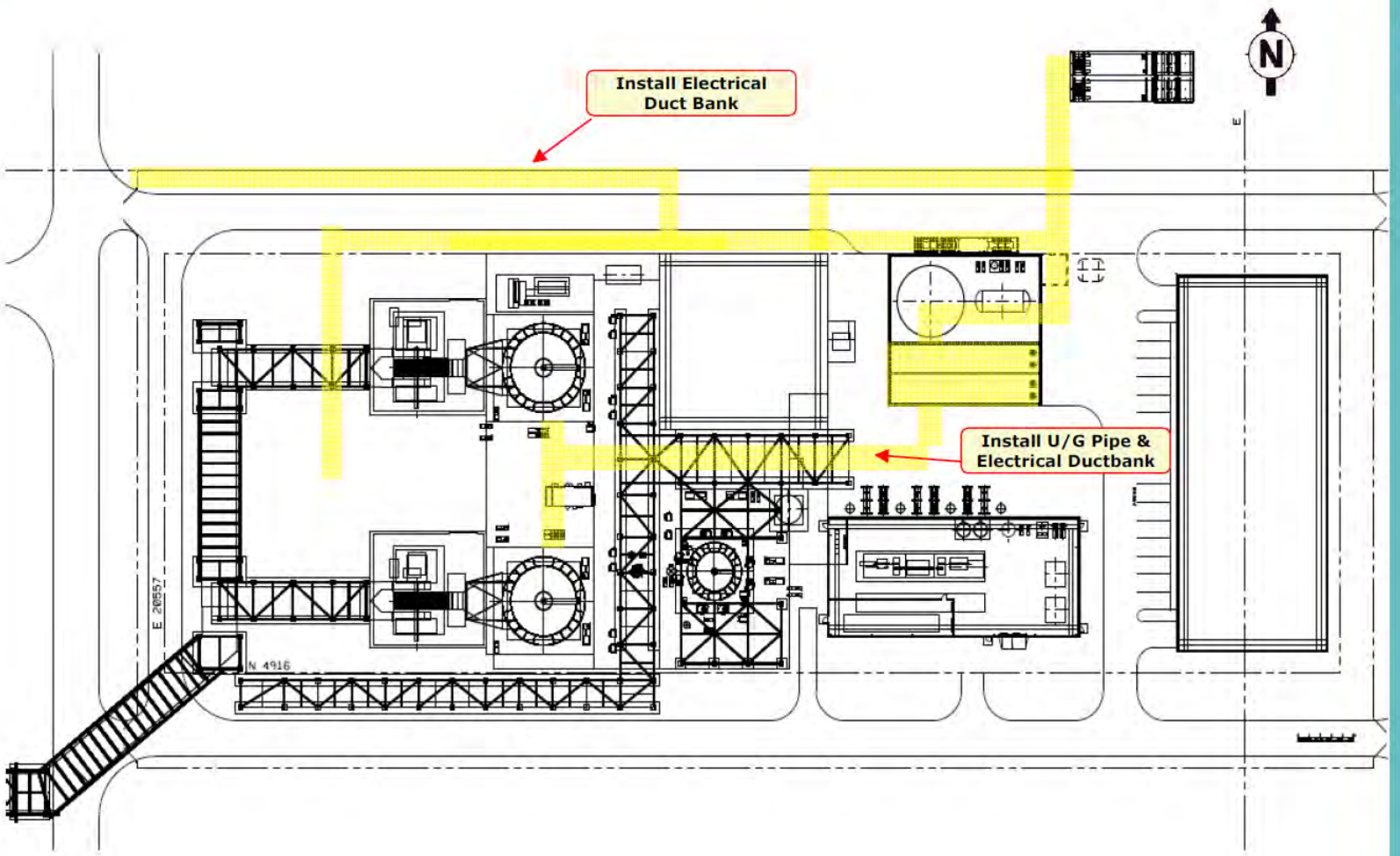
Concrete	Electrical Equipment
Underground Utilities	Blasting
Mechanical Equipment	Crane
Steel	

Karsto Facility

Month 12

Construction Activities

- Start Installation at Processor Area for Circulating Water Pipe
- Install Underground Utilities.



Color Legend:

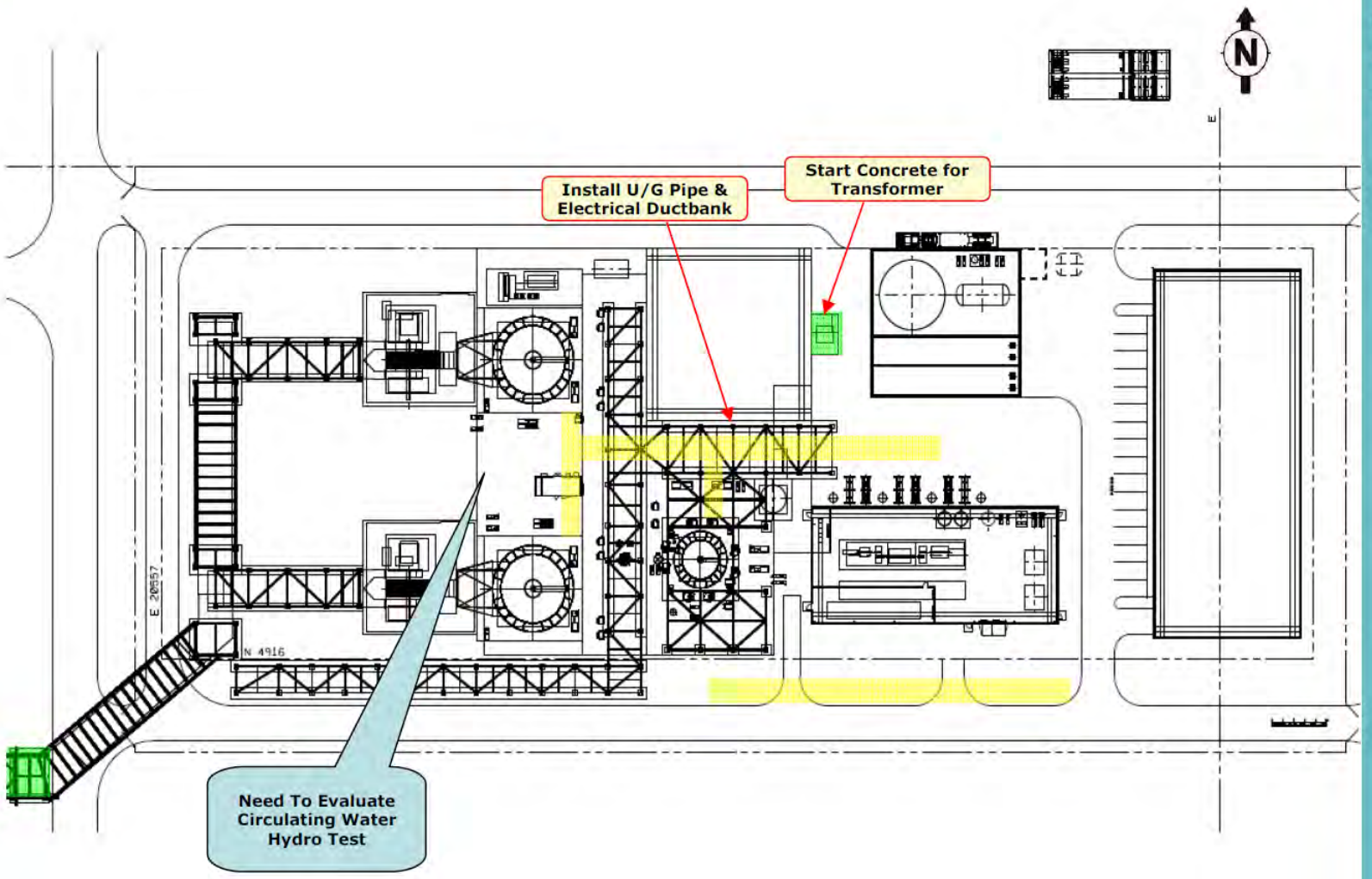
- Concrete
- Electrical Equipment
- Underground Utilities
- Blasting
- Mechanical Equipment
- Crane
- Steel

Karsto Facility

Month 13

Construction Activities

- Continue Installation of Circulating Water Pipe
- Continue Installation of Underground Utilities
- Start Concrete for Transformer

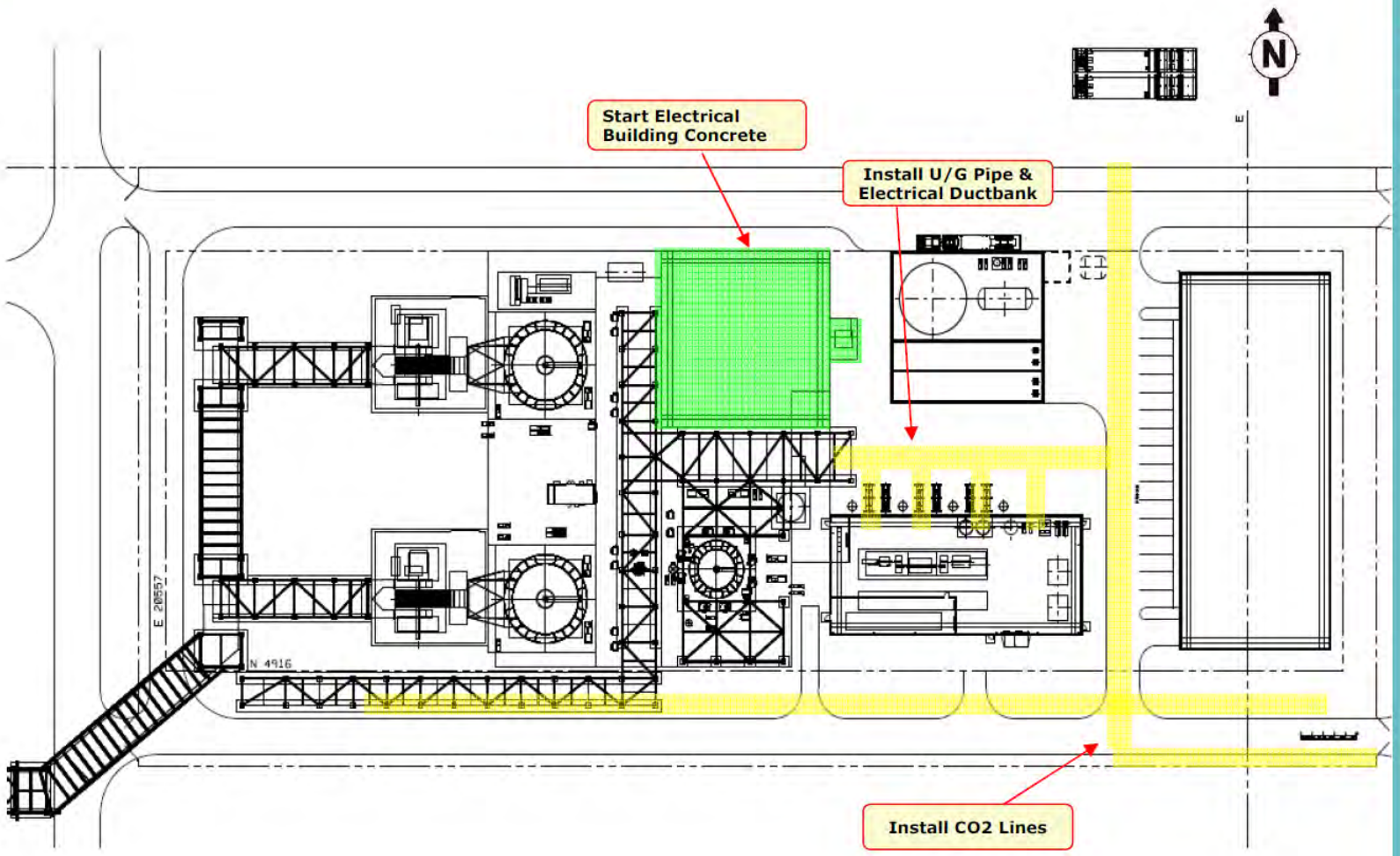


Color Legend:

- Concrete
- Electrical Equipment
- Underground Utilities
- Blasting
- Mechanical Equipment
- Crane
- Steel

Karsto Facility

Month 14



Construction Activities

- Install Circulating Water Pipe
- Install Underground Utilities
- Install CO2 Lines
- Start Electrical Building Concrete
- Continue Transformer Foundation

Color Legend:

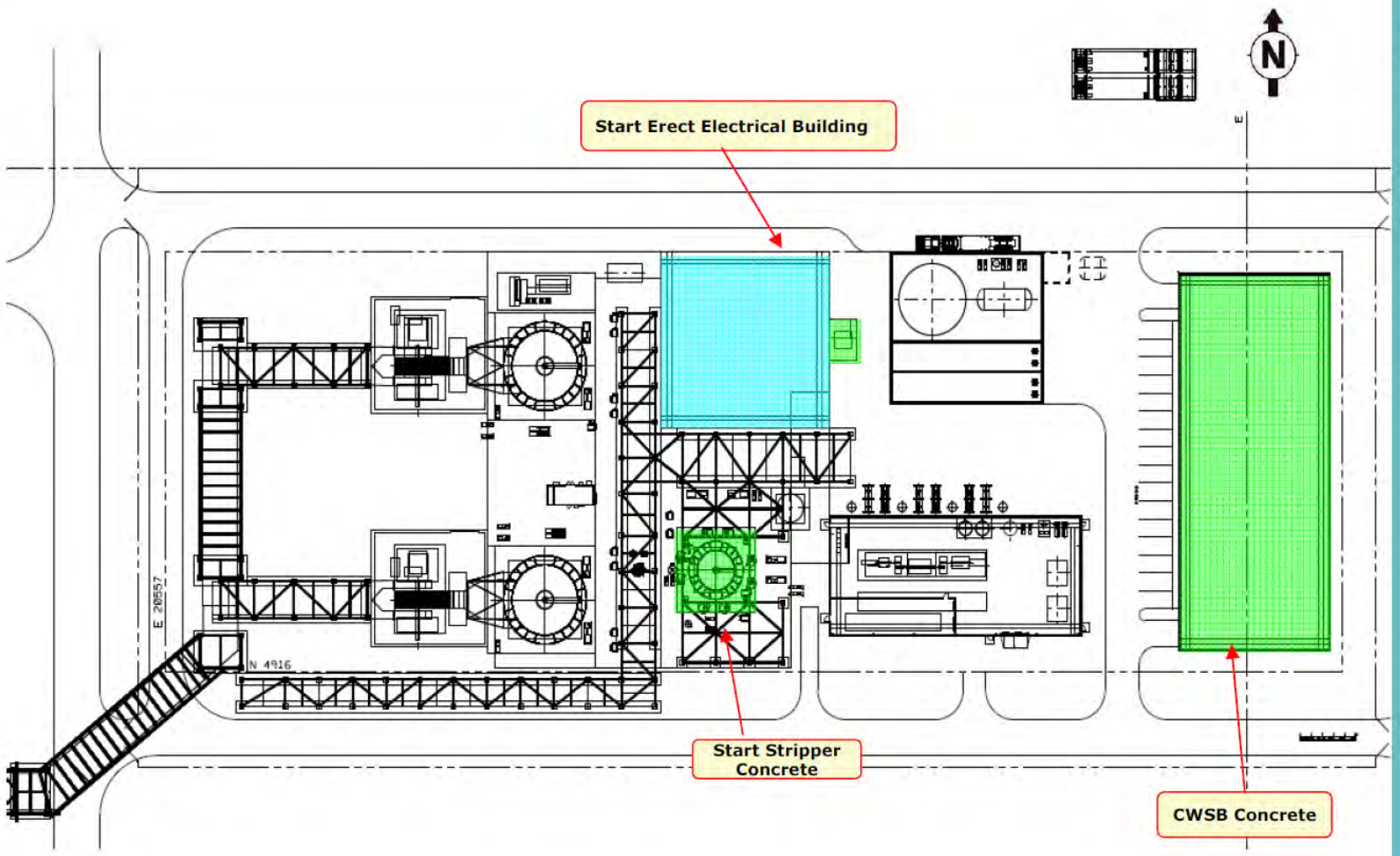
- Concrete
- Electrical Equipment
- Underground Utilities
- Blasting
- Mechanical Equipment
- Crane
- Steel

Karsto Facility

Month 15

Construction Activities

- Start Stripper Concrete
- Start Electrical Building Steel Work
- Concrete work for the Control, Workshop, Store building
- Finish Concrete Work for the Transformer



Color Legend:

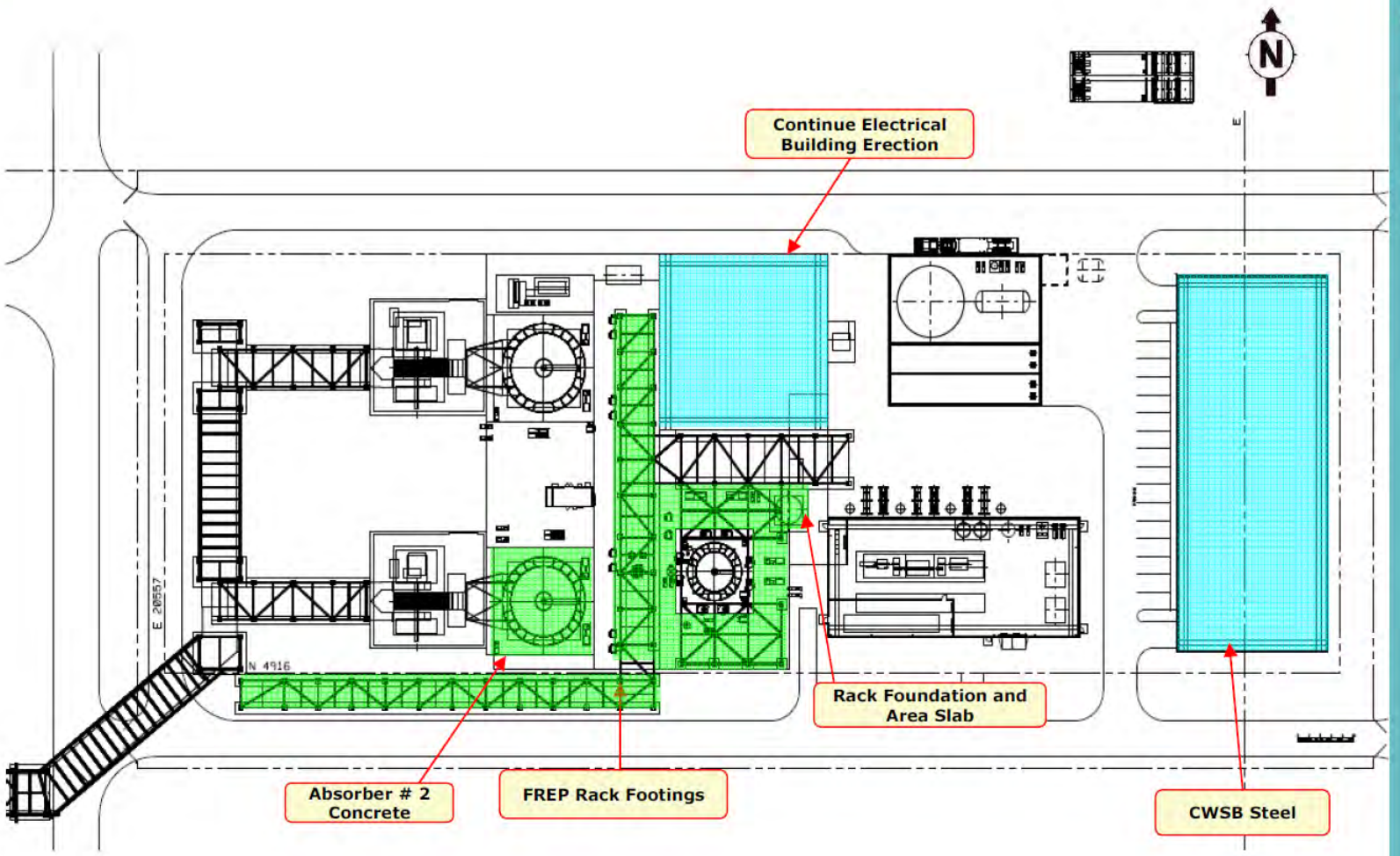
- Concrete
- Electrical Equipment
- Underground Utilities
- Blasting
- Mechanical Equipment
- Crane
- Steel

Karsto Facility

Month 16

Construction Activities

- Absorber #2 Concrete
- FREP Rack Footings
- Start Steel work for the Control/ Workshop Building
- Place Area Slab (Area around the stripper
- Continue Electrical Building Steel work

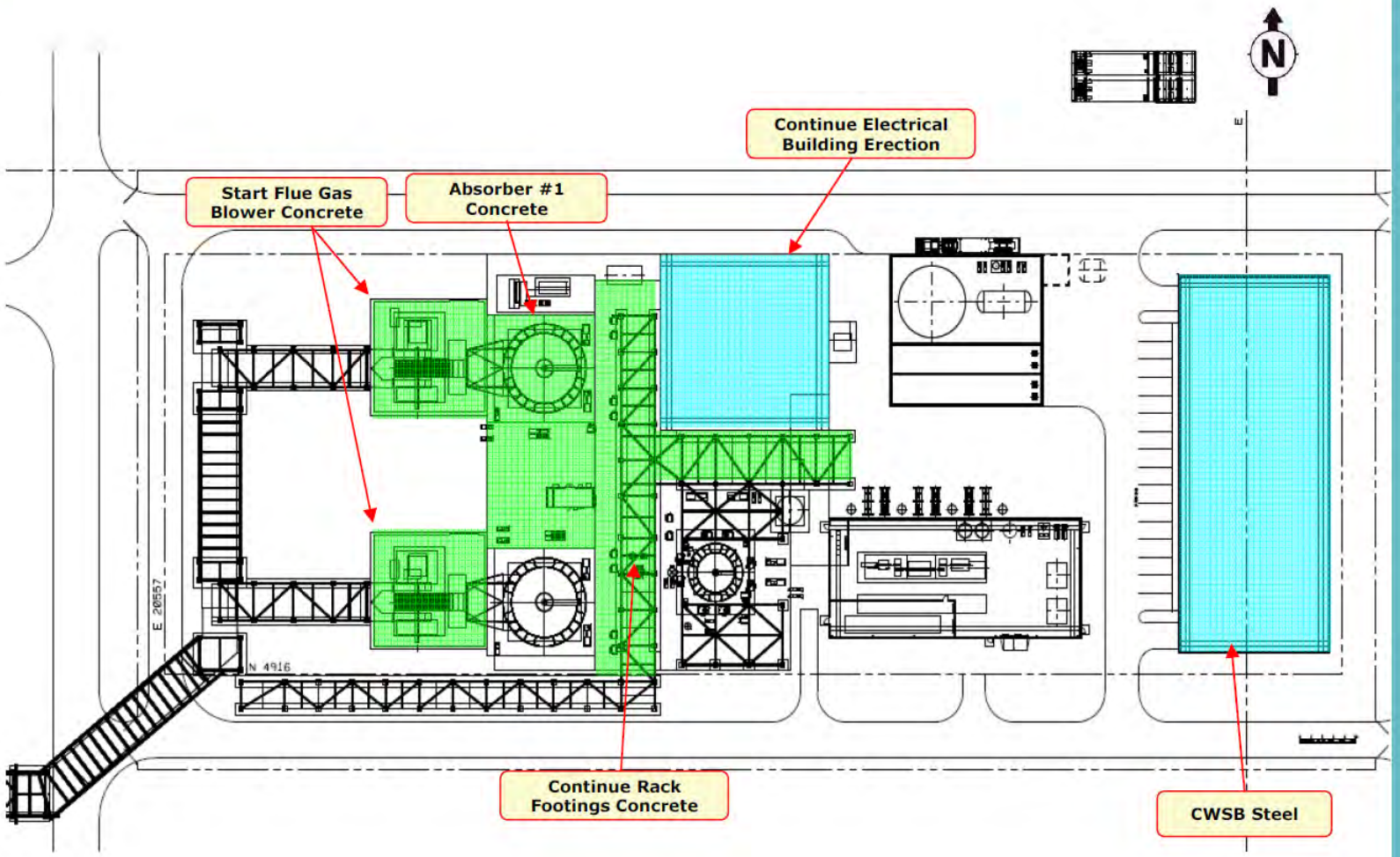


Color Legend:

- Concrete
- Electrical Equipment
- Underground Utilities
- Blasting
- Mechanical Equipment
- Crane
- Steel

Karsto Facility

Month 17



Construction Activities

- Continue Electrical Building Steel work
- Concrete for Flue Gas Blower #1 & 2
- Continue Control Building / Workshop steel erection
- Continue Area Concrete to Allow Rack Setting
- Concrete for the Absorber #1

Color Legend:

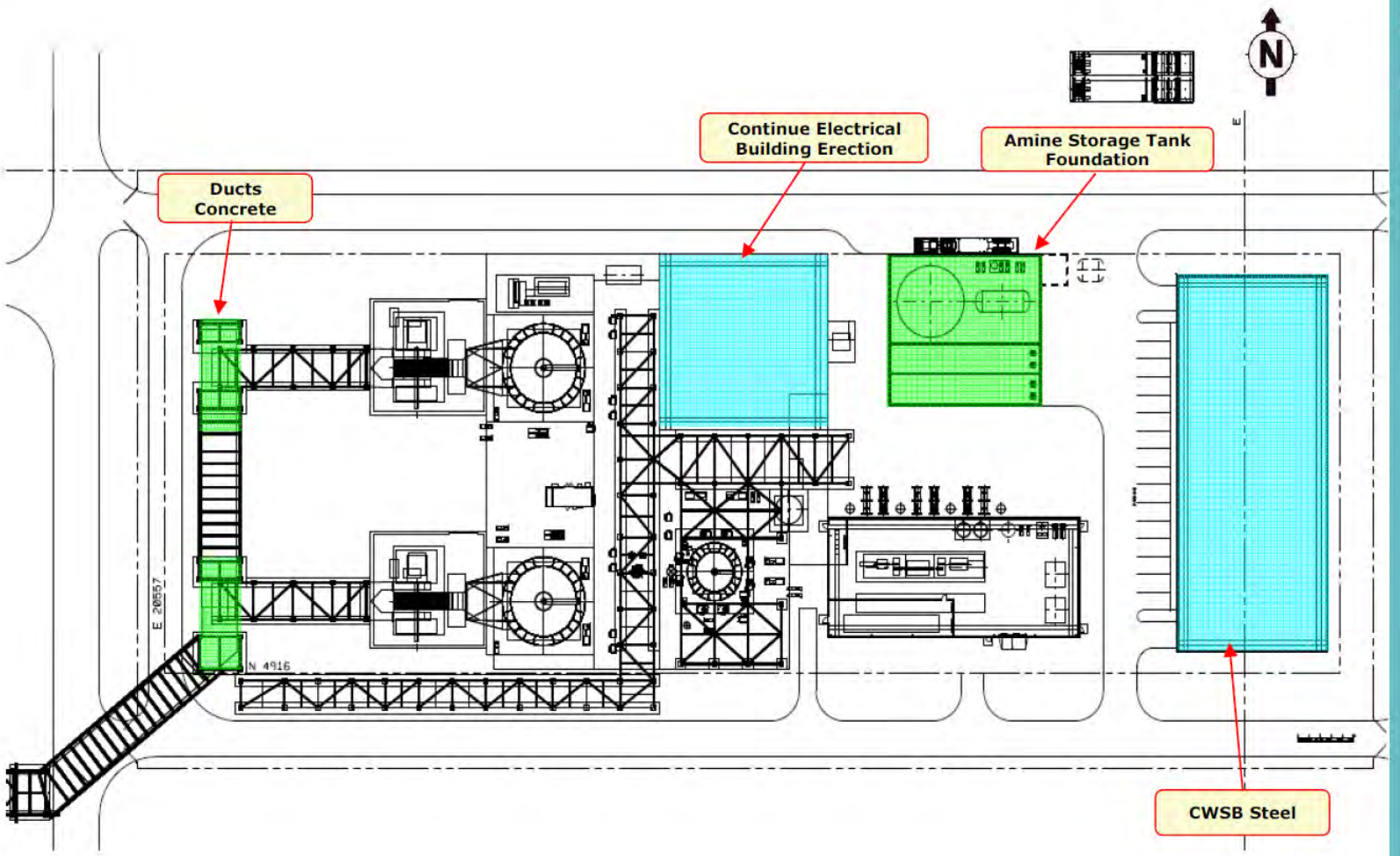
- Concrete
- Electrical Equipment
- Underground Utilities
- Blasting
- Mechanical Equipment
- Crane
- Steel

Karsto Facility

Month 18

Construction Activities

- Continue steel work for the CWSB & Electrical Building
- Concrete foundation for the Duct Towers
- Concrete for the Amine Building



Color Legend:

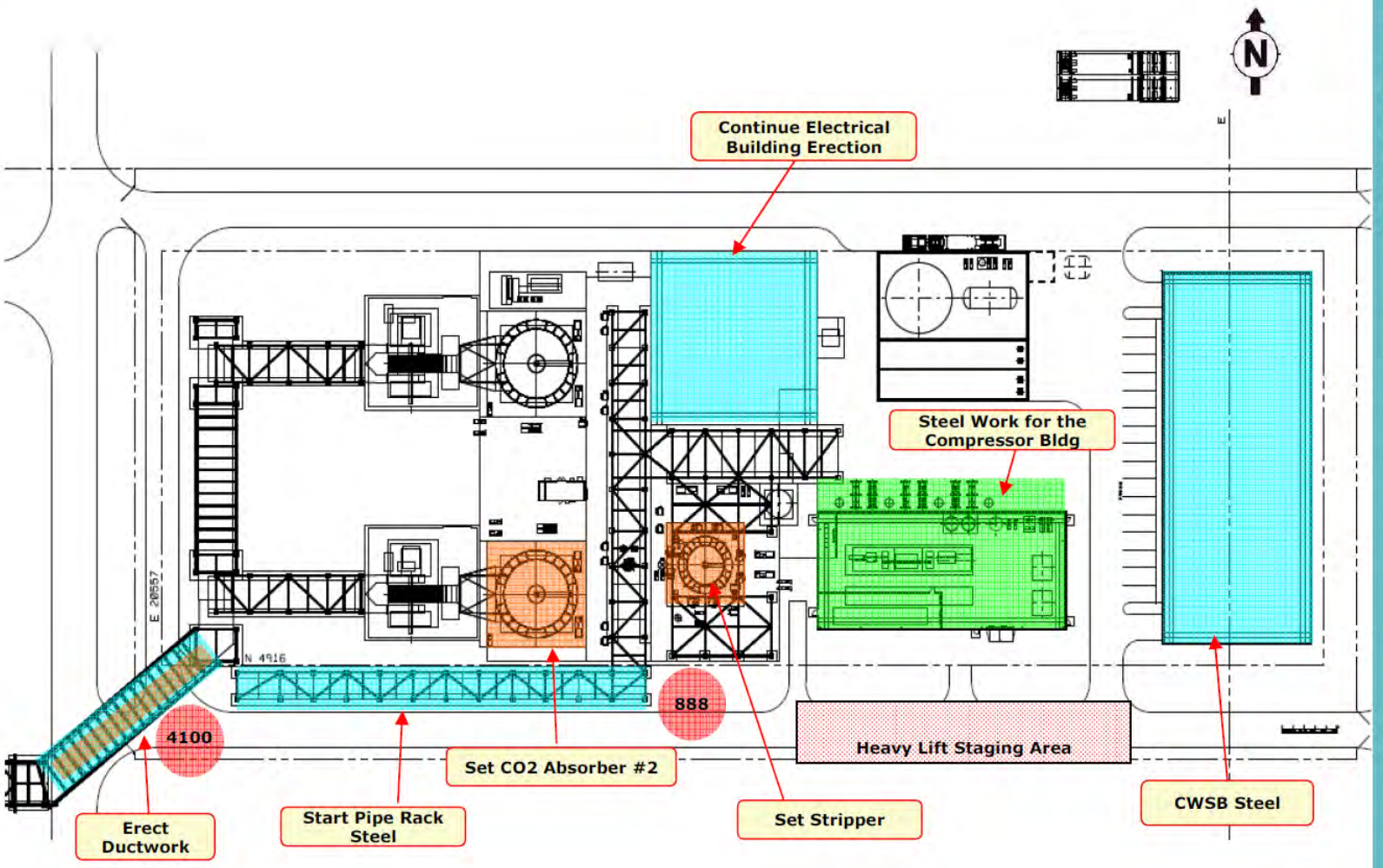
- Concrete
- Electrical Equipment
- Underground Utilities
- Blasting
- Mechanical Equipment
- Crane
- Steel

Karsto Facility

Month 19

Construction Activities

- Start Pipe Rack Steel (South Side)
- Set south side Ductwork
- Finish Electrical Building Steel Work
- Continue Control Room / Workshop Building Steel
- Set the Absorber #2
- Set The Stripper
- Concrete for the Compressor Building



Color Legend:

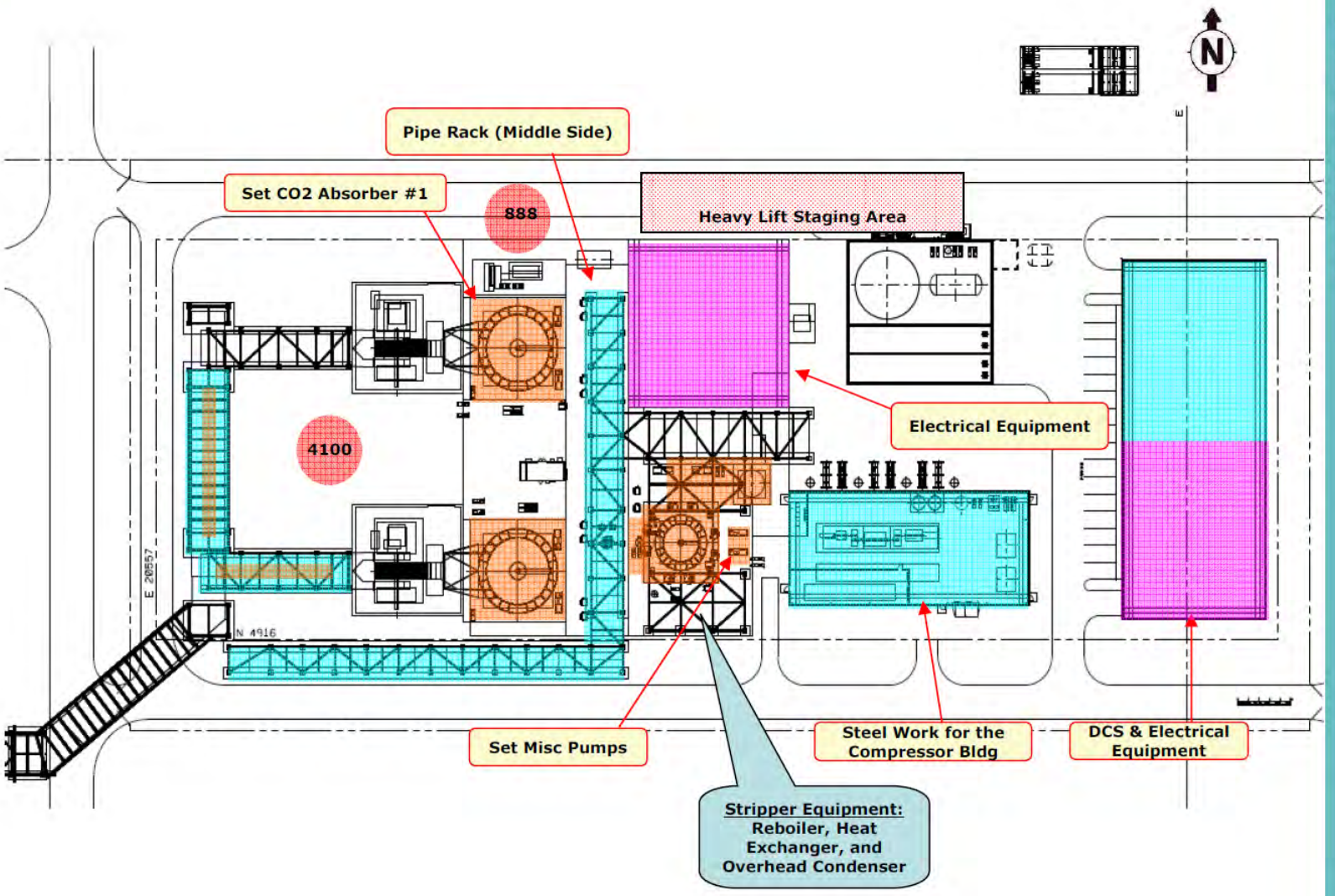
- Concrete
- Electrical Equipment
- Underground Utilities
- Blasting
- Mechanical Equipment
- Crane
- Steel

Karsto Facility

Month 20

Construction Activities

- Set Miscellaneous Pumps
- Relocate the 888 Crane from the East side
- Start Erect Compressor Building
- DCS & Electrical Equipment for Control Room / Workshop Building
- Finish Steel Work for the CWSB
- Start Pipe Rack Steel (Middle Side)
- Set Ductworks
- Set The Absorber #1
- Setting Absorbers Equipments & Pipes

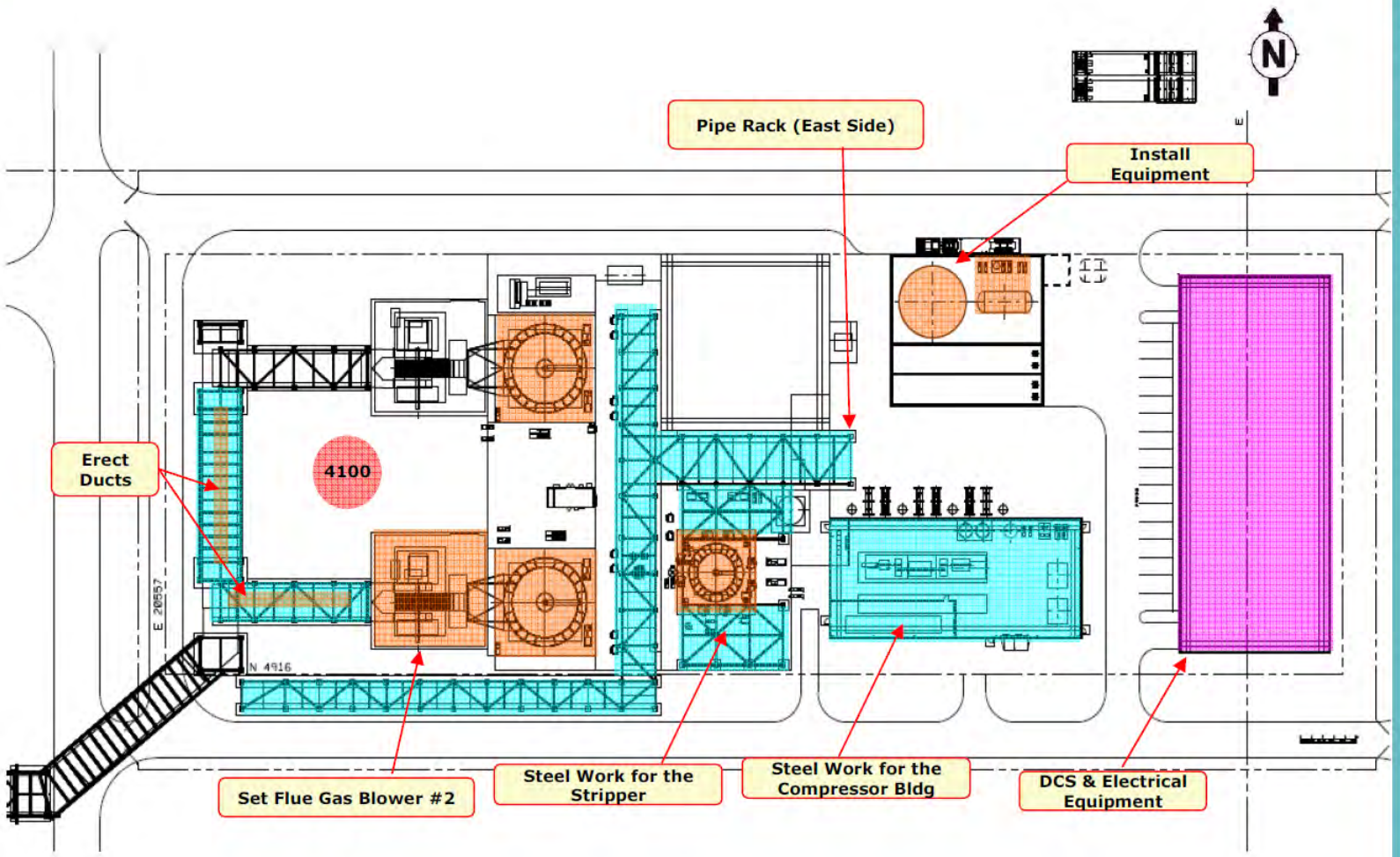


Color Legend:

Concrete	Electrical Equipment
Underground Utilities	Blasting
Mechanical Equipment	Crane
Steel	

Karsto Facility

Month 21



Construction Activities

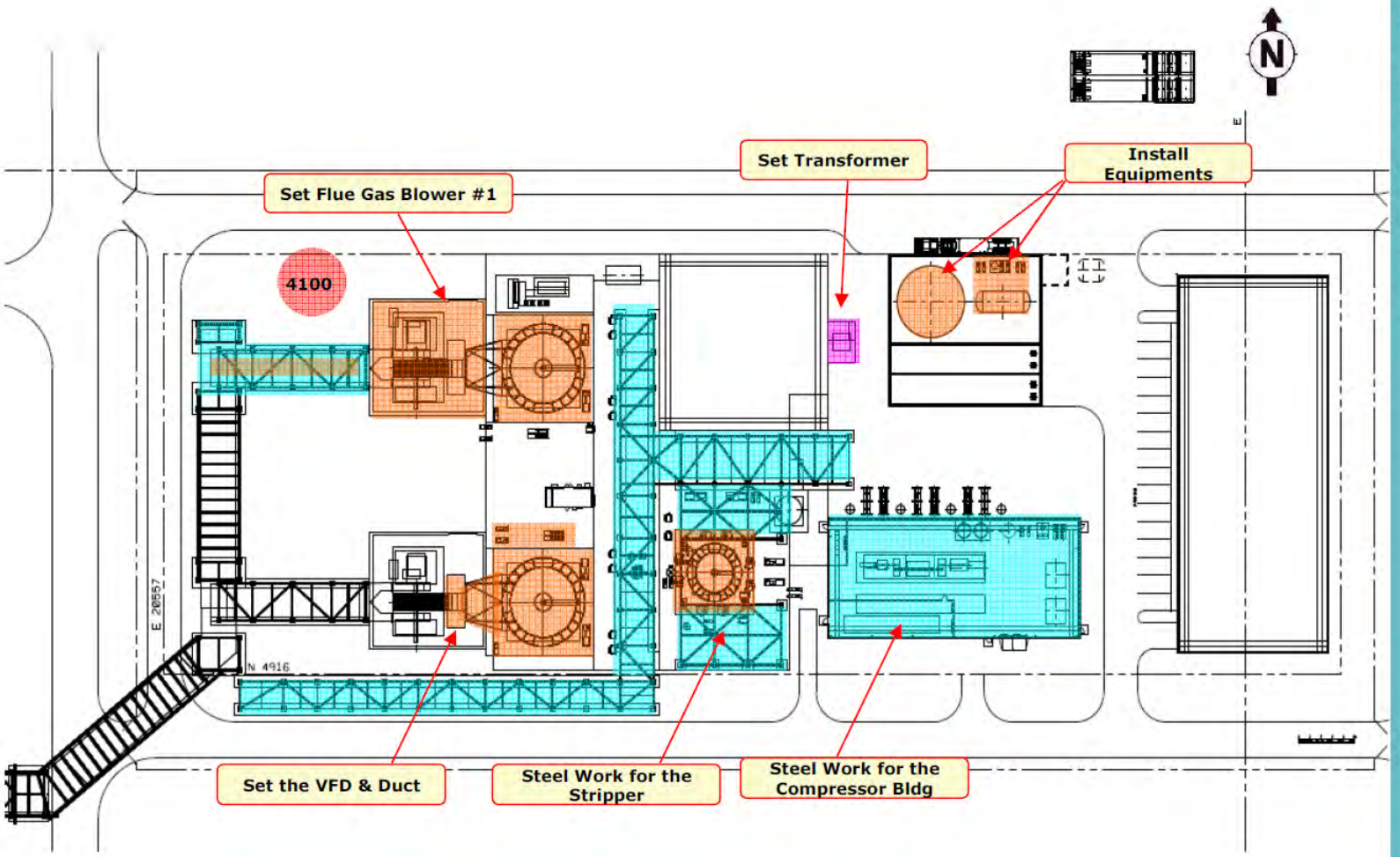
- Start Cable Pulling
- Finish Setting Electrical Equipment for Control Room / Workshop Building
- Set Equipment for the Amine Building
- Start Pipe Rack Steel (East Side)
- Set The Blower #2
- Continue Setting the Ducts
- Continue Setting Absorbers Equipments & Pipes
- Start Stripper Steel work

Color Legend:

Concrete	Electrical Equipment
Underground Utilities	Blasting
Mechanical Equipment	Crane
Steel	

Karsto Facility

Month 22



Construction Activities

- Start Set the Transformer
- Relocate the 4100 Crane
- Continue Pipe Rack Steel.
- Continue Setting Absorbers Equipments & Pipes
- Setting the Ducts
- Continue Setting the Equipments for the Amine Building
- Setting The Duct Between The Blower And Absorber #2
- Setting The VFD for the Blower #2
- Continue Stripper Steel work

Color Legend:

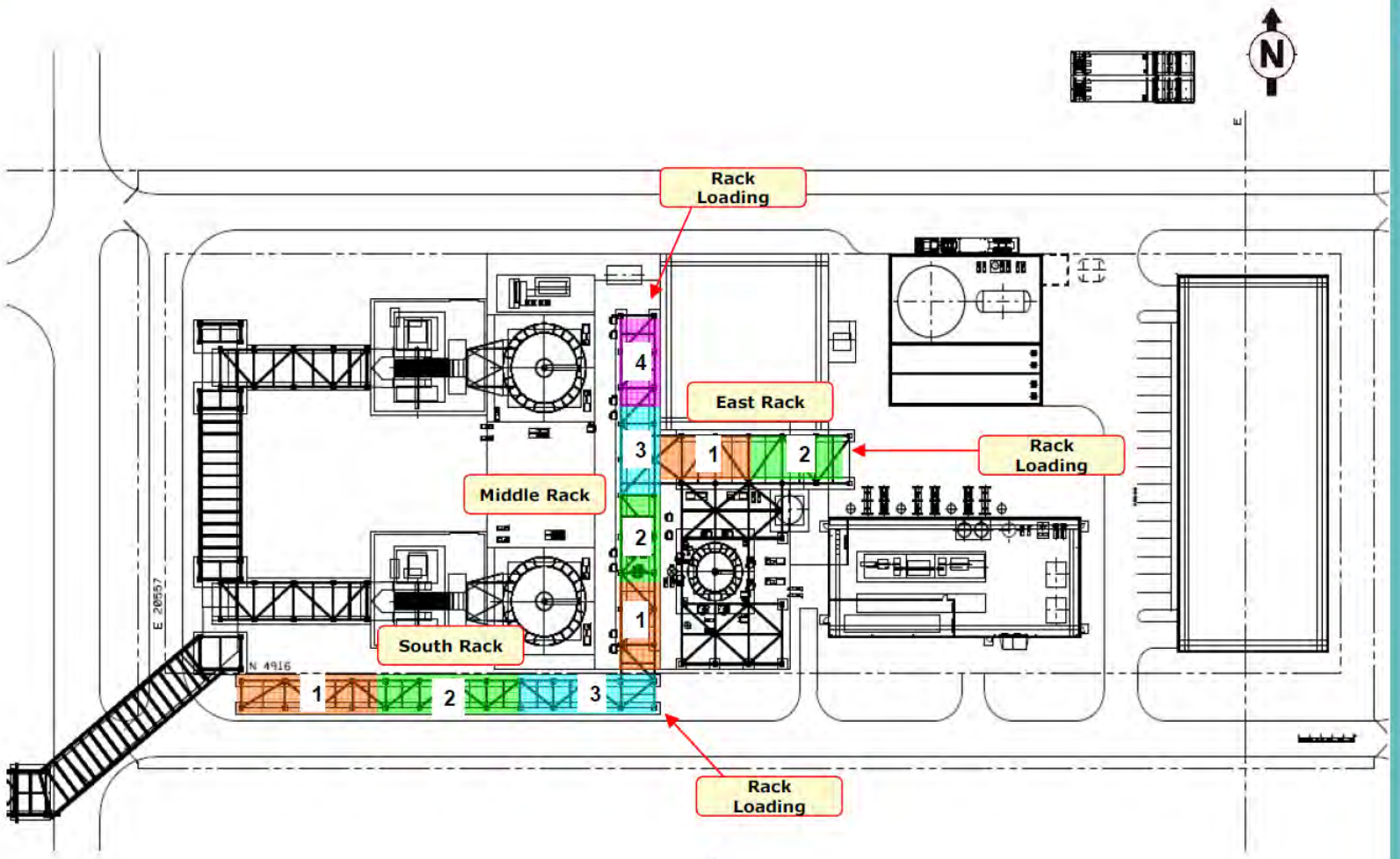
Concrete	Electrical Equipment
Underground Utilities	Blasting
Mechanical Equipment	Crane
Steel	

Karsto Facility

Pipe Rack Sequence

Notes:

- Go to Month 19 for Rack Sequencing

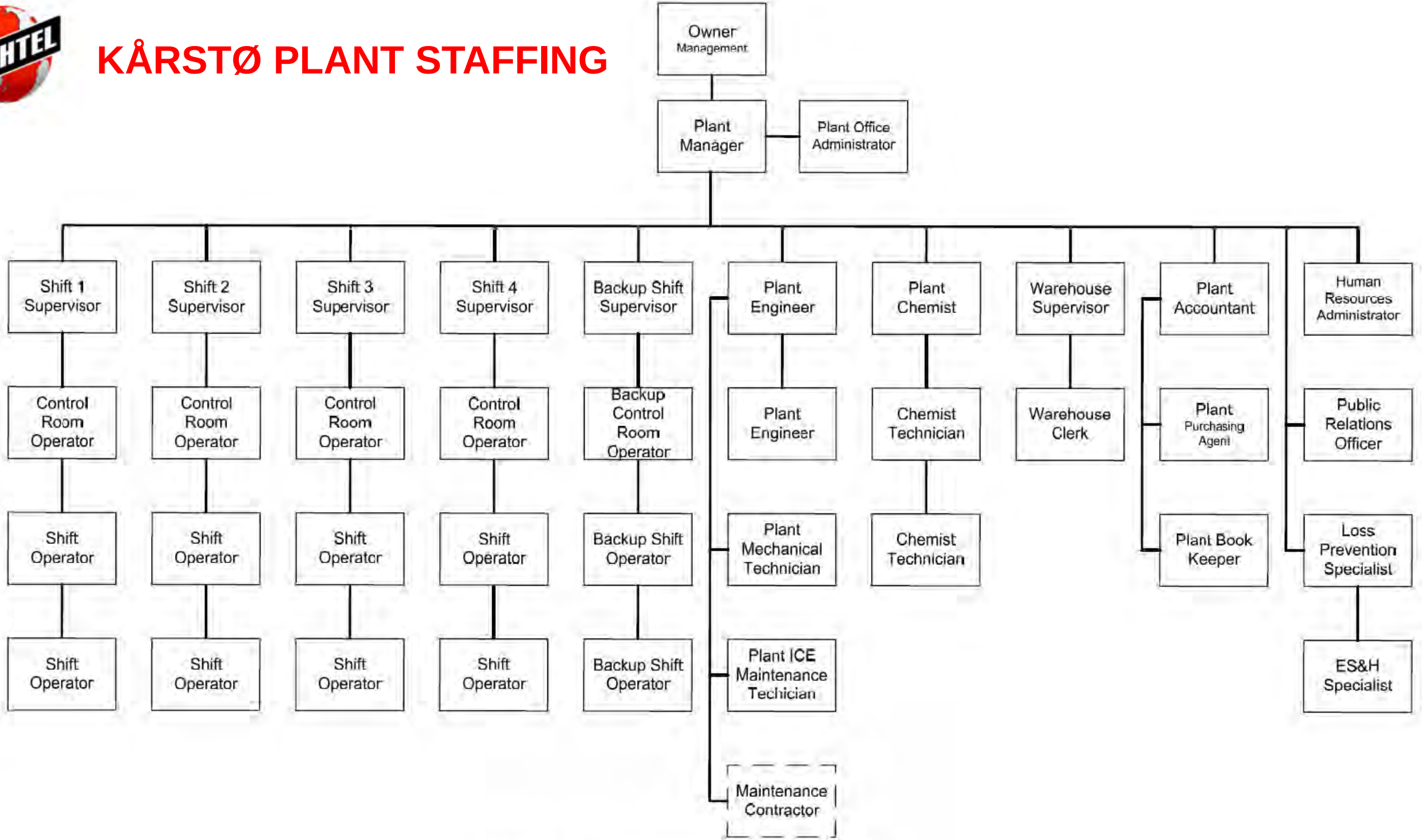


1

Rack Module Sequence:

1) SR1
2) SR2
3) SR3
4) MR1
5) MR2
6) MR3
7) MR4
8) ER1
9) ER2

KÅRSTØ PLANT STAFFING

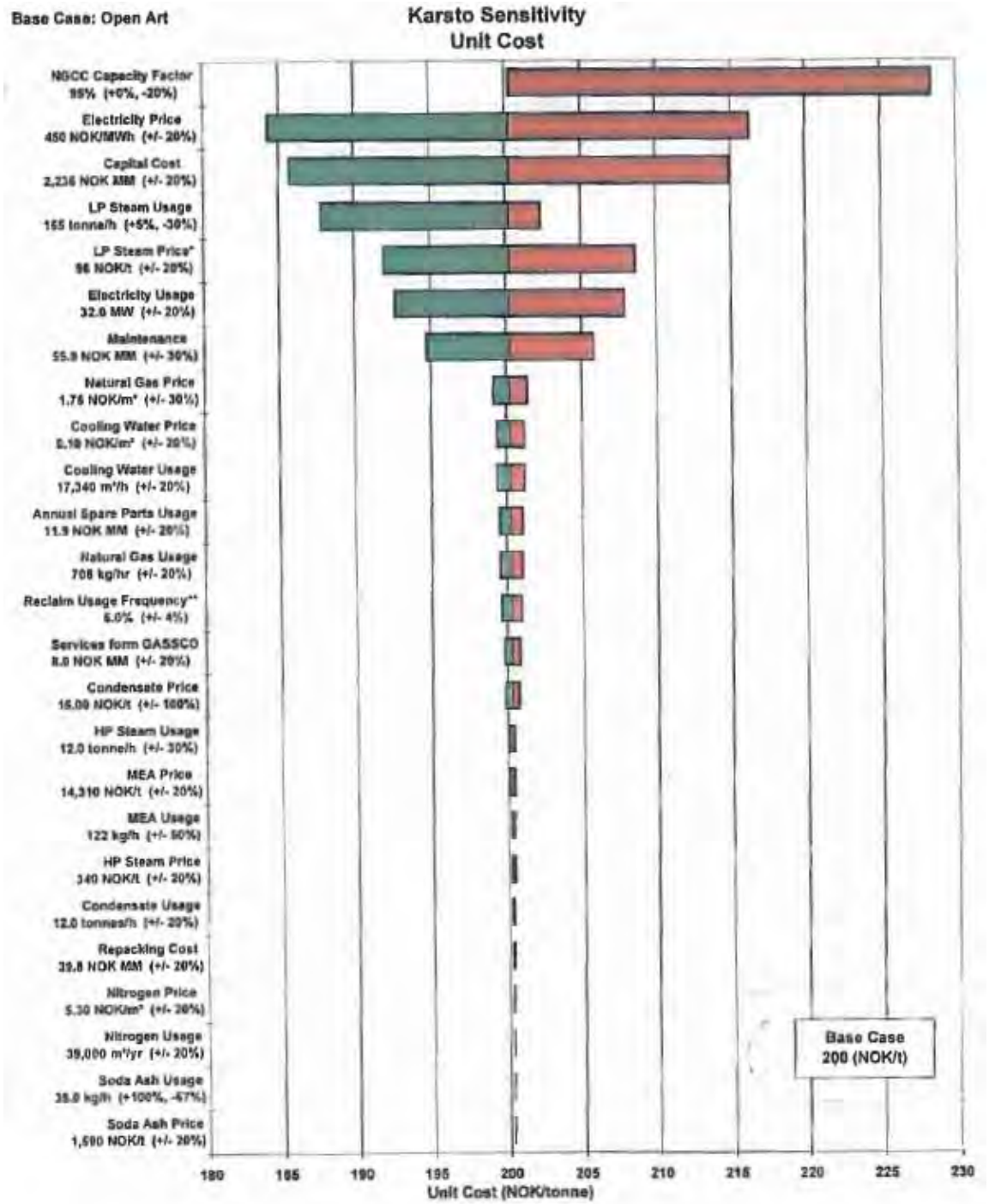


The following assumptions were used in creating the model:

- Project lifetime of 25 years
- Data provided in Exhibit E1.1 to determine the level of planned and unplanned outages for the Naturkraft CCPP. These vary year by year, and this is reflected in the model (for information, the availability averages 95.4% over the 25 year period).
- A capture plant on-stream factor of 97% for the design case (100% load of power plant) relative to the CCPP availability
- A production year of 8760 hours. Actual operation hours are calculated using CCPP availability and the CCC Plant on-stream factor for each year.
- Exchange rate of NOK/USD: 5.3 (per Exhibit E1.1)
- Discount rate (NPV) of 8%
- For simplicity, a construction schedule done on an annual basis. Because the NPV calculation is done on an annual basis, little is gained by splitting construction numbers into a monthly level of detail.
- Changes in working capital added to operating expenses to get a more accurate representation of cash flows. Working capital includes changes in operating cash and changes in accounts payable.

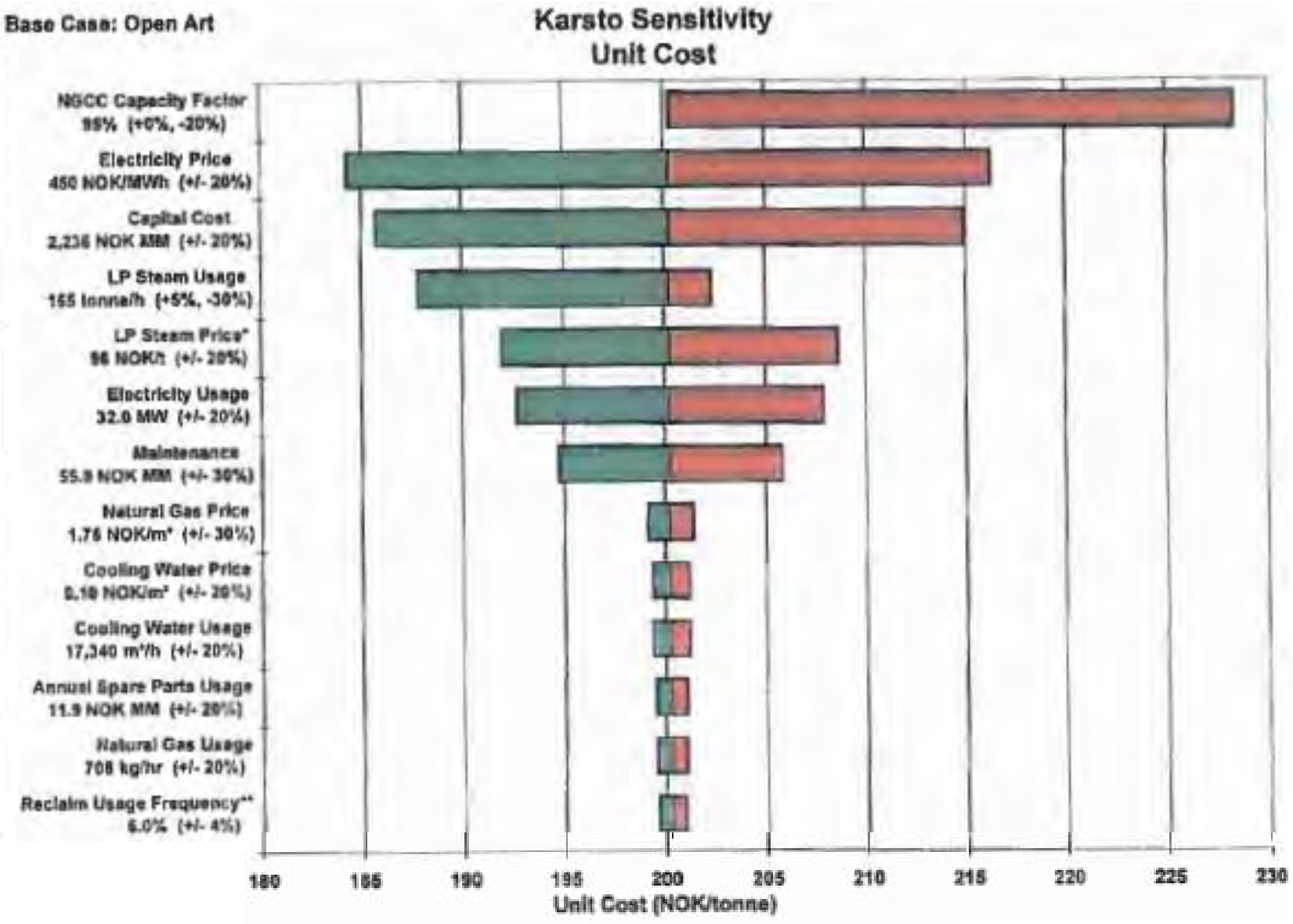
COST SENSITIVITY FOR CO_2 CAPTURED

	Base Case: Open-art MEA with split flow
Capture rate	85.3%
LP steam required (tons/hr)	198.4
Electricity requirements (MW/hr)	32MW
Capital Cost (excluding contingency)	NOK 2.24billion
Operating cost (yearly avg)	NOK 388million
NPV of cost per tonne of CO2 Capture	199NOK/t



COST SENSITIVITY FOR CO_2 CAPTURED

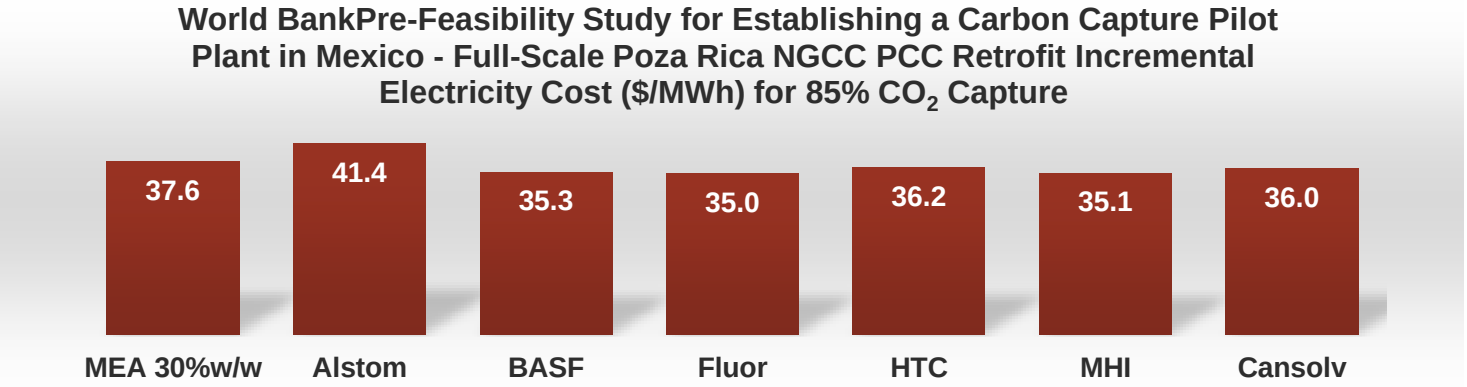
	Base Case: Open-art MEA with split flow
Capture rate	85.3%
LP steam required (tons/hr)	198.4
Electricity requirements (MW/hr)	32MW
Capital Cost (excluding contingency)	NOK 2.24billion
Operating cost (yearly avg)	NOK 388million
NPV of cost per tonne of CO2 Capture	199NOK/t



BRINGING THE KÅRSTØ FEED STUDY CONCEPTS UP TO DATE

- Engineering is engineering and thermodynamics is still thermodynamics – basic approach still very relevant, although site-specific factors must be used for effective detailed design.

- Recent solvent comparisons for natural gas power plants suggests concentrated MEA will be competitive with proprietary solvents



- Open-technology and open-access post-combustion capture plants offer a route to maximise competition, standardize designs based on shared development of best practices and allow investors to make a clear, unbiased assessment of what is available.
- Concentrated MEA is currently the best initial solvent to use, but plants can be expected to upgrade to other solvents, generic and/or proprietary, if they offer benefits and to be able to build on the experience of an open-access user community for a range of other in-service improvements.