Re- Issued for Detail Design	03	24.01.2025	TEAM	TEAM	CST/AB/JHR
Issued for Detail Design	02	10.01.2025	TEAM	TEAM	CSY/AB/JHR
Issued for Review	01	12.07.2024	TEAM	TEAM	CSY / AB
RELEASE PURPOSE	**REVISION**	**REV.DATE**	**PREP. BY**	**CHECKED**	**APPROVED**

Redacted version for publication	**PAGES**	**ENCLOSURE** -

PROJECT

Company: Hafslund Oslo Celsio

Client Ref.: -

Project: Oslo CCS

Project No.: HI2305

COMPANY LOGO:

DOCUMENT TITLE:

FEED STUDY REPORT

COMPANY DOCUMENT ID: HI2305-AKE-Z-RA-0001				03
SUPPLIER DOCUMENT ID: N/A				N/A
Project number	**Vendor code**	**Discipline & Doc. Type**	**Sequence number**	**Current Revision**

[redacted]

REVISION HISTORY

RELEASE PURPOSE	REV.:	DESCRIPTION OF CHANGES:
Issued for Review	01	First Issue
Issued for Design	02	Updated to reflect design as per end Pre-EPCIC phase

TABLE OF CONTENTS

[redacted]

1 EXECUTIVE SUMMARY

The FEED report Rev 03 has included response to comments from Company to the Rev 02 version. This is done to reflect design as per start of EPCIC contract.

The FEED report Rev 01 was submitted 12th July2024. In the period from then until end of 2024 Contractor continued the work through the pre-EPCIC phase. Main scope in the Pre-EPCIC phase has been to optimize layout of technical building and JC400 modules. The electrical system design is also optimized and partly redesigned since FEED. The heat pump system refrigerant has been changed from isobutane to HFO during Pre-EPCIC phase due to supplier market. Another major task during the Pre-EPCIC phase has been to seek solutions for transportation of oversized columns and pressure vessels.

The FEED CCP Klemetsrud project will install a modularized CO2 capture plant (Aker Carbon Capture JC400TM). designed to capture of up to 350 000 tonnes CO2/year from the Klemetsrud Waste to Energy (WtE) plant outside of Oslo, NorwayThe scope also includes a new electrical supply to the WtE plant including the CCP plant

nd new heat pumps (60 MW) to return the CCP “borrowed” steam energy back to the WtE Line 3 for district heating.

The captured CO2 is liquefied through compression and cooldown before transported by electric trucks to the Oslo harbor for further shipment to the Northern Lights terminal at Øygarden west of Bergen, Norway, and permanent stored in a subsurface reservoir. A one-day storagT buffer volume is included to cater for upsets in the logistics chain. Necessary utility systems for supporting the CO2 capture plant, as well as a new high voltage electrical supply system for the WtE plant is included as part of the

[redacted]

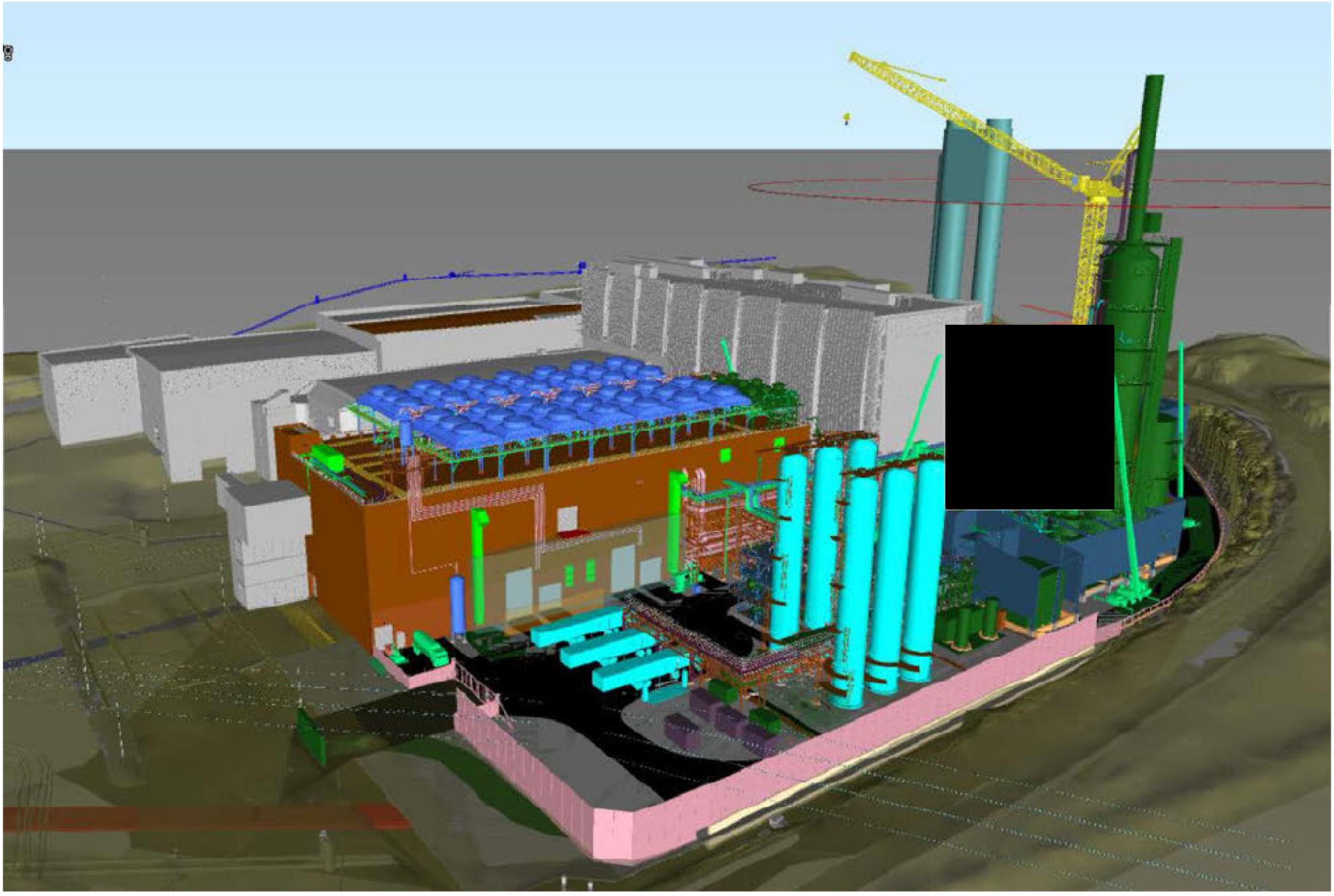

Figure 1-1 FEED CCP Klemetsrud - Overview

The overall strategy for the project has been to build upon Contractor`s experience from recently executed CCS-type projects to achieve the necessary maturity and quality within the time frame of the FEED, as well as a cost effective and lean design. To leverage competence both technically and historically from earlier phases of the Klemetsrud project, Contractor has utilized resources from both Aker Solutions, Aker Carbon Capture, Multiconsult and Norsk Energi for execution of the scope. Alignment across the project organization has been ensured through utilization of the project interface register, as well as frequent discipline meetings including representatives from all relevant parties.

Several review activities have been performed during the FEED to ensure HSSE and quality in the FEED design, including HAZID, HAZOP and LOPA being facilitated by an independent 3rd party. The reviews have resulted in almost 400 actions, whereof approximately 230 have been closed and 170 are closed for FEED but needs to be reviewed also in the EPCIC phase. Reference is made to Appendix A for further details (however, not updated for Pre-EPCIC phase).

To support the EPCIC cost and schedule estimates as well as the technical design, considerable procurement activities have been performed as part of the FEED. This has been further worked on during the Pre-EPCIC phase. The main focus has been on the critical priority 1 packages with direct link to the EPCIC schedule: The columns, large CO2 capture plant vessels, CO2 compressor and the heat pump, where budget quotes have been received and a recommended supplier list has been established. In addition, the wastewater treatment- and air cooler packages have had a special focus, being critical to the area development of the Technical Building.

The Klemetsrud site location introduces complexity both for transportation of oversized items to site due to being located inland, as well as for the construction and installation phase due to access to the construction site only from the South side and with limited laydown- and rigging areas nearby. Feasible preliminary solutions have been identified as part of the FEED work; however, further detailing and optimization of this phase is required during the next project phase.

Key risks for the project have been identified as:

- Site assembly of the Absorber and the DCC due to transport restrictions to the Klemetsrud site
- [redacted] piping requiring site run/stick-built, representing a congested area during installation and completion
- Limited laydown at the Klemetsrud area, as well as congested construction area only accessible from South

During the Pre-EPCIC phase emphasize on the following activities has been prioritized in addition to maturing the design towards the EPCIC phase.

- Layout of Technical Building – a cold eye review was initiated by Company in July to optimize the layout of the Technical Building. This has resulted in a relocation of the [redacted] and Wastewater Treatment room have been increased. Equipment has been relocated with aim to reduce pipe and cable lengths
- The JC 400 modules have been optimized and partly redesigned. The major change is that large plate and frame exchangers will be delivered directly to site such for installation instead of to module fabricators. Consequently, the number of heat exchangers was reduced. The FEED report reflects the status of the JC400 modules. The 3D model has been delivered as part of the interim phase work and the client has reviewed it and commented it after the modifications/changes made in November/December. SLBC has evaluated the client's comments and is preparing a reply to them. Stating that the model is not as per FEED level shall be done per the 1D gate review Excel list.
-
- [redacted]
- The risk analysis (QRA) has been updated in Pre-EPCIC phase and shows that the risk imposed on the surroundings due to operation of the facility. The inner consideration zone is slightly exposing the roundabout in connection with exiting and entering the main road E6, hence further risk reducing measures are being evaluated to avoid such exposure. The

QRA will be updated in the EPCIC phase with the late change from 3 to 6 storage tanks for liquid CO2.

- Transportation of the big columns and the CO2 intermediate storage tanks have been a major concern in the pre-EPCIC phase. The project are to conclude on a stick built approach for the columns operating at atmospheric pressure while the CO2 storage tanks will increase from 3 to 6 to have a diameter that can be transported in one piece on the roads. The desorber will be delivered in flanged pieces that can be installed at site to avoid site welding and hydrotests.
- The Heat pumps refrigerant is changed from isobutane to HFO as the market were not able to deliver isobutane per now.
- As part of EPCIC preparations, the construction installation methods, EPCIC plans and subcontracting strategy have been further matured.

2 INTRODUCTION

2.1 Interim/pre-EPCIC phase

Following the submission of the draft FEED report 12.7.24, Contractor has continued developing the project through an interim / pre-EPCIC phase in close collaboration with Company through four consecutive variations orders (VOs), ref Section 2.6. The main work for this period can be summarized as follows:

Further development of the technical design

At the time of delivery of the draft FEED report, there were several outstanding FEED issues, which during the interim/pre-EPCIC period have all been progressed up to end FEED level or beyond. The relevant sections of this FEED report are updated to reflect the new design, as applicable, and a brief summary is also included in Section **Error! Reference source not found.**.

Through a series of cold eye review reports, as well as a dedicated cold eye review full-day session in collaboration with Contactor, Company have provided comments and alternative design suggestions, mainly focused on the area design for the Technical Building and the CO2 capture- and liquefaction modules. Contractor has evaluated the comments and suggestions and presented its responses and recommendations typically in meetings with Company throughout the period. A summary of all the recorded actions from the cold eye review session, as well as the first set of cold eye reports, has been responded to and agreed with Company in writing, ref Appendix B. The design is generally updated accordingly, however, there may be some exceptions where implementation is ongoing at the time of issue of this report.

As revised supplier information has become available through dialogue with potential suppliers, the project design has also been updated accordingly. This is in particular relevant for the WWT treatment package, as well as the electrical system design including E-House.

For the CO2 capture plant modules, the end FEED design was subjected to a series of external and internal review sessions during the interim/pre-EPCIC period to optimize the design specifically for the Klemetsrud project. A cold eye review report was produced by the client with comments that were addressed by the contractor, although some remain open and are being considered/reviewed/implemented at the moment of issuing this report. The main outcome of the review sessions was the reduction of the number of equipment units (Mainly the heat Exchangers) to create space inside the modules that could be reserved for unforeseen needs that can appear during the EPCIC phase, to facilitate the material handling operations, correct pipe/structure clashes and to improve the layout of the modules in general. Additionally, to further increase confidence in the design, small bore pipe (drain and vent system) lines and items such as the noise enclosures for the pumps, etc. were included in the 3D-model.

Supporting procurement activities for LLI

Technical- and commercial package specifications for some procurement packages specified as LLI (CO2 compressor and heat pump, have been developed and issued officially to potential suppliers in the interim/pre-EPCIC period. No Official RFQ was issued for the Desorber/Absorber/DCC/CO2 tanks as there have been open questions related to the transportation and installation methods at Klemetsrud. However, the contractor has approached different suppliers for the columns and storage tanks for budgetary quotations since the FEED stage of the project and has sustained constant dialogue with many of them during the interim phase to prepare a solution that is either compliant with the transportation restrictions to the site or that can be built at the site. It is also noted that the open questions related to transportation/installation methods have been concluded and an agreement about the solutions was achieved.

For the heat pump RFQ, there was a surprising response from all nominated suppliers that neither of them was able/willing to offer an isobutane heat pump within the time frame of the project. Through intensive dialogue and collaboration with Company, the refrigerant selection was revised by Company to HFO, and the RFQ updated and re-issued accordingly.

The Desorber/Absorber/DCC/CO2 tanks package progress has been heavily impacted by re-iterations of the transportation to site and construction method resulting in changing the strategy from site assembly to stick-built for the Desorber, Absorber and DCC. The DCC, and Absorber Columns will be stick-built on Klemetsrud site. Pre-rolled sections of the cylindrical shell will be transported by road to site, then welded into complete rings inside tents. Nozzles and other welded attachments will also be finalised at this point. Then each ring section (height to be determined, but tentatively 6-10m) will be lifted to the final column foundation base and welded together one by one to form a complete column. After final dressing, surface protection and insulation works as required, columns will be ready for installation of internals.. For the CO2 tanks, the preference is to transport complete pressure vessels to site, requiring the tank diameter is reduced compared to the FEED design and number of tanks is increased from 3 to 6 tanks.

The Desorber will arrive in transportable pieces that are flanged and they will be mounted at site.

For the CO2 compressor, bids have been received from all nominated suppliers and bid evaluation is ongoing at the time of issue of this report.

Activities have also been performed for key high priority procurement packages not being LLI, but with high importance for the project design. This includes e.g. the WWT treatment package, the CM air coolers, E-house and CO2 capture- and liquefaction modules.

Mature Civil and interface design to support Civil 2 schedule

The Civil design has been further progressed in the period based on updated interface information and design development, as well as relevant supplier information received in the period..

Interface information towards the Civil design has generally been improved through the period, but some of the information needs to be revised once supplier information is received.

EPCIC execution preparations

Contractor has developed a comprehensive schedule that covers all phases of the project. Due to transportation restrictions, Contractor has concluded a construction-alternative with in-situ construction of Absorber and DCC. The schedule outlines key milestones and activities, highlighting critical dependencies and durations. The main project phases included are Engineering and Procurement, Civil Works, Construction and Installation, Mechanical Completion and Pre-Commissioning, and Final Start-Up.

Contractor is planning to establish one common organisation responsible for all construction / installation work carried out at Klemetsrud and Oslo Harbour (the Terminal) where lead personnel from Subcontractors will be integrated into to the organisation and together with AKSO Stord personnel in key positions. The Construction Manager will, via this common organisation, manage, coordinate and prioritise all activities at the Klemetsrud and Terminal construction sites, i.e. all direct- and indirect work including all service- and support functions such as warehousing, internal transport and rigging, craning including heavy lift campaign, scaffolding and other services necessary. Personnel from equipment suppliers will be brought in for necessary assistance and maybe also for larger portions of installation work for the SLB Capturis' module deliveries if evaluated beneficial. This will be concluded when designed and degree of trial fitting and testing etc at suppliers' premises have been more matured. Some discipline scope will be executed entirely with AKSO direct management and operator personnel with a combination of own employees and external resources. Other discipline work will be contracted based on a more regular subcontracting approach covering entire disciplines or part of disciplines scope. This is further detailed in a Revision 2 of the document Subcontracting Strategy HI2305-AKE-Z-RA-0002 and will be further developed in the EPCIC phase.

The Procurement Milestone Plan (PMP) has been further developed in collaboration with both engineering, procurement and construction in line with the latest design and construction method. Generally, combination of procurement packages between the Terminal and CCP scope has been implemented to reduce the number of procurement packages and support a lean and efficient EPCIC execution. Combination of procurement packages within the CCP scope is being investigated but is not yet concluded at the time of issue of this report.

Perform concept studies for potential changes to design

Two concept studies; 1) heating of the roads within the CCP area utilizing waste heat and 2) revised liquid CO_2 specification has been completed in the period and are documented in reference /57/ and /58/. Study nr 1 has been instructed by Company to be implemented and implementation is ongoing at the time of issue of this report.

A third concept study for an increased intermediate liquid CO2 storage capacity by 50% was initiated but put to a halt by Company as it is pending the conclusion on CO2 tank size determined by the transportation to site method.

2.2 FEED Study Approach

The WtE CCS feasibility study performed by Aker Solutions and Aker Carbon Capture through two separate study contracts in the period from June to August 2023 forms the starting point for the FEED, however, significant additions to Contractor scope was introduced as part of the SoW for the FEED with high voltage electrical supply to WtE- and CCP plants, as well as heat pump and district heating scope being transferred from Company to Contractor. No concept design was handed over to Contractor as basis for the scope previously handled by Company. A reduced bridging period between end of the concept study and the start of the FEED phase was spent investigating some agreed technical issues within the concept design, as well as preparing for the FEED through setting up IT-systems and initiating some FEED planning activities (FEED schedule, FEED MDR).

The maturity of the design at the beginning of the FEED was overall less mature than normal, due to lack of concept design for the new scope transferred from Company to Contractor at FEED CA, as well as the concept selection stage (C-study) being fully omitted. Due to the limited time available for the FEED execution, parallel activities were started for most disciplines already at FEED CA, meaning that some of the downstream disciplines, e.g., especially area disciplines, had to perform several iterations throughout the course of the FEED as design developed for the upstream disciplines. Procurement activities also had to be started early to allow for sufficient time for potential Vendors to assess and respond to requests for budget quotes.

The strategy for the FEED CCP Klemetsrud project has been to maximize re-use of lessons learned and standard design from Contractor`s other ongoing CCS projects, adjusted for the Klemetsrud plant as necessary (e.g., taking into account the inland location as well as Company technical requirements). Contractor`s Renewables Onshore Project Execution Model (PEM) has been utilized for the FEED, providing quality assurance activities, procedures and requirements for the work.

To utilize resources with the best available competence for the different parts of scope, Contractor has executed the work with resources from both Aker Solutions, Aker Carbon Capture, Multiconsult and Norsk Energi. Interdisciplinary meetings and workshops have been held throughout the FEED to ensure alignment between the teams, in addition to formalizing interface information through the project interface register. The work has been performed utilizing different engineering tools across the four contributors, however, with one central document handling system, regular exchange of data between the different 3D-model tools, and a common project SPS site.

There has been close co-operation with Company project team during the FEED both on management and discipline level with frequent status and discipline meetings being arranged. Minutes of Meeting are issued as correspondence in Company`s Interaxo system. In addition, a considerable number of interdisciplinary workshops and reviews have been undertaken in the period, ref Section 10 for details. Site visits to the existing WtE plant have been arranged for the majority of the project team.

2.3 Improvements

2.3.1 Standardisation, Synergies and Copy Effects from Other CCS Projects

Generally, when developing the concept design, lessons learned, and experience gained through execution of other recent and ongoing CO2-related projects by Contractor have been implemented where relevant.

Basis for the CO2 capture and liquefaction systems for the FEED CCP Klemetsrud scope is to utilize Aker Carbon Capture`s Just Catch™ standard design modules. This allows for a high degree of re-use of information from previous ACC projects.

Establishment of project specific design standards has been initiated during FEED based on documents developed for earlier CCS-projects, however, some additional work is required in the next project phase to completely align this work across the entire scope.

Contractor has manned up the project team with a large share of the resources having previous experience from CCS-projects, inherently bringing on board first-hand experience and lessons learned relevant to this type of projects. Resources from Norsk Energi have previous experience from the previous EPCIC phase with a different contractor, as well as from other modification projects to the WtE plant.

2.3.2 Value Improvement

A value improvement (VIP) workshop was held in January 2024 as a multidisciplinary session with participation from both Contractor and Company to evaluate a pre-defined selection of improvement proposals. 11 items were reviewed as part of the workshop, whereof 1 was dismissed, 2 agreed to be implemented in design and 8 to be evaluated further. After further evaluation, 4 additional ones were dismissed, whereas the remaining 4 were implemented. Reference is made to /26/ for additional information.

Some improvement items have also been identified outside of the VIP workshop:

Direct Air Cooling for CO2 Compressor Aftercooler

By having direct air cooling of the CO2 vapour discharged from the CO2 compressor, the amount of flash gas from the liquefaction system is reduced thus reducing the power consumption of the CO2 compressor. In addition, potential issues with having a high-pressure shell & tube heat exchanger in the low pressure Cooling Medium System is avoided.

Variable Frequency Drives for Cooling Medium Pumps

The Cooling Medium Pumps will require significantly less discharge pressure when the system is operated without the heat pumps, i.e., typically parts of the year with average temperatures above 10 deg C. Including VFDs for the pump motors allows for speeding down the pump when operating without the heat pumps, thus both reducing wear and tear on the pump, reducing electrical power consumption, as well as possible noise and vibrations from control valves within the system.

E-house for CO2 Capture Plant Electrical Consumers

Containerized electrical equipment modules (“E-house”) are included for serving most of the electrical consumers within the CO2 capture, liquefaction, temporary storage and offloading systems. This reduces cable lengths as well as freeing up space in the technical building by moving some of the electrical equipment into the E-house.

2.4 Definitions and Acronyms

Table 2-1 Definitions

Definitions	
Company	Hafslund Celsio
Contractor	SLB Capturi (formerly Aker Carbon Capture) and Aker Solutions

Table 2-2 Acronyms

Acronyms	
ACC	Aker Carbon Capture
ACF	Activated Carbon Filter
ACS	Access Control System
AKSO	Aker Solutions
ALARP	As Low As Reasonably Practicable
ATEX	ATmosphère EXplosibles
BAT	Best Available Technology
BDU	Brownian Demister Unit
BL	Blast Level
BOC	Bottom Of Concrete
CA	Contract Award
CCP	Carbon Capture Plant
CCS	Carbon Capture and Storage
CCTV	Closed Circuit Television
CEMS	Continuous Emission Monitoring System
CFC	ChloroFluoroCarbon
CHRA	Chemical Health Risk Assessment
CM	Cooling Medium
CO2	Carbon Dioxide
DAL	Design Accidental Loads
DB	Distribution Board
DCC	Direct Contact Cooler
DM	DeMineralized (Water)
DNV	Det Norske Veritas

Acronyms	
DP	Differential Pressure
DSB	Distribution Switch Board
EDI	Electro De-Ionization
EL	Elevation
FEED	Front End Engineering Design
FG	Finish Grade
FRP	Fiberglass Reinforced Plastic
FTIR	Fourier Transform Infrared
GA	General Alarm
GTS	General Technical Specifications
GWP	Global Warming Potential
HAZID	Hazard Identification
HAZOP	Hazard and Operability Analysis
HC	Hydrocarbon
HCFC	HydroChloroFluoroCarbon
HFC	HydroFluoroCarbon
HFO	HydroFluoroOlefine
HMI	Human Machine Interface
HSE	Health, Safety and Environment
HV	High Voltage
HVAC	Heating Ventilation and Air Conditioning
IGV	Inlet Guide Vane
IR	Infra-Red
JC400	Just Catch 400
K1, K2, K3	Klemetsrud WtE plant incineration lines 1, 2 and 3, respectively
KBF	Kraftberedskapsforskriften
KL1	Klemetsrud 1 transformer station (existing)
KL2	Klemetsrud 2 transformer station (new)
KNX	KONNEX
LCA	Life Cycle Assessment
LLI	Long Lead Item
LPL	Lightning Protection Level

Acronyms	
LPS	Lightning Protection System
LV	Low Voltage
MCC	Motor Control Centre
MDR	Master Document Register
MEA	Monoethanolamide
MEG	Monoethyleneglycol
MTU	Mobile Test Unit
O&M	Operation & Maintenance
ODP	Ozone Depletion Potential
OLH	Oslo Lokal Høyde
OLTC	On Load Tap Changer
OPEX	Operating Expenditure
OSBL	Outside Battery Limit
P&ID	Piping & Instrument Diagram
PED	Pressure Equipment Directive
PFD	Probability of Failure on Demand
PLC	Programmable Logic Controller
PMP	Procurement Milestone Plan
PMS	Piping Material Specification
PMS	Power Management System
PO	Purchase Order
PR	Pressure Reduction
PRDS	Pressure Reduction De-Superheating
PST	Package Specification Template
PSV	Pressure Safety Valve
PTR-ToF	Proton Transfer Reaction Time-of-Flight
QRA	Quantitative Risk Analysis
R&D	Research & Development
RAM	Reliability, Availability and Maintainability
RFI	Request for Information
RFQ	Request for Quotation
RIO	Remote Input/Output

Acronyms	
RO	Reverse Osmosis
RTD	Resistance Temperature Detector
SAS	Safety and Automation System
SCADA	Supervisory Control And Data Acquisition
SIL	Safety Integrity Level
SLBC	SLB Capturi
SLD	Single Line Diagram
SLS	Serviceability Limit State
SPL	Site Preparation Level
SRO	Styring, Regulering og Overvåking
SS	Substation
SSD	Soft Start Drive
SWB	Switch Board
TB	Technical Building
TCM	Technology Centre Mongstad
TFA	TriFluoroacetic Acid
TOC	Top Of Concrete
TPA	Tonnes Pro Annum
TSS	Total Suspended Solids
UDL	Universal Design Load
UF	UltraFiltration
UFD	Utility Flow Diagram
UG	Under Ground
ULS	Ultimate Limit State
VAV	Vann- og Avløpsetaten
VFD	Variable Frequency Drive
VIP	Value Improvement Process
VMS	Valve Material Specification
VO	Variation Order
VSD	Variable Speed Drive
WE	Working Environment
WEAL	Working Environment Area Limit

Acronyms	
WERA	Working Environment Risk Assessment
WtE	Waste to Energy
WWT	Waste Water Treatment

2.5 Scope of Work

Scope of Work for the FEED CCP Klemetsrud study has been to mature the WtE CCS study design to a +/-15% EPCIC cost level of confidence as outlined in Appendix A of Contract no C-2023-562984 in accordance with contractual requirements set out in Appendix E of the referenced contract. The starting point for the FEED has been the two feasibility studies performed by AKSO and ACC, respectively, in the period from June to August 2023.

In general, Contractors Scope of Work has covered the CCP CO2 capture and liquefaction plant, including necessary utility systems and associated civil design through all phases of the project from engineering, procurement, construction, assembly, transport, site installation, tie-in to final commissioning. The procurement work has been to develop procurement strategies and identify LLIs, as well as obtaining preliminary vendor technical information. For selected packages, information received from Suppliers has been incorporated in design. A larger than normal share of budget quotes has been requested to improve the basis for the EPCIC cost estimate.

Contractor has split the scope between resources in AKSO, ACC, Multiconsult and Norsk Energi to leverage the competence in the different organizations. Alignment in the team has been ensured through regular interdisciplinary meetings as well as interface handling. Regular discipline and management meetings, in addition to workshops and reviews, have also been conducted with Company during the FEED period to align on the FEED design.

Scope of work for the interim/pre-EPCIC phase has been defined by Company through VO1, VO2, VO3 and VO4 part 1. The main work in the period has been to further develop the FEED design to resolve outstanding design issues, reduce risk in the execution phase, as well as support procurement preparations for LLIs.

2.6 Basis Of Design

The starting point of the FEED CCP Klemetsrud work is based on Case B from the WtE CCS B-studies performed by AKSO and ACC from June to August 2023. In addition, as part of the scope of work for FEED, Contractor took over responsibility for high voltage electrical supply and heat pump and district heating scope previously covered by Company, where no concept design was made available to Contractor.

The basis of design for the execution of the FEED comprises authority laws, rules and regulations, design basis documents, functional requirements and technical requirements as listed in the FEED Appendix E. A project specific discipline design basis specification has been developed, ref /40/.

Clarifications and deviations have been discussed and agreed between Company and Contractor as described in the FEED tender clarification log (included as part of the FEED contract), as well as in letter HI2305-CEL-AKE-LE-0003 *FEED CCP Klemetsrud - Company confirmation of FEED clarification log*.

Interfaces between Contractor scope and the existing WtE plant have been agreed through the project interface register.

Table 2-3 Clarifications to Scope Received from Company During FEED

Reference	Title	Content
HI2305-CEL-AKE-EM-0016 11.03.24	FEED CCP Klemetsrud - Regarding the choice of refrigerant	Confirmation from Company that heat pump design is to be based on isobutane as refrigerant, disregarding other possible media (e.g., ammonia)
E-mail from Steffen Emil Birkeland 11.03.24	FEED CCP Klemetsrud - Control System Scope splitt	Company clarification on scope split for automation, HMI and hardware for control room
HI2305-CEL-AKE-LE-0003 28.06.24	FEED CCP Klemetsrud - Company confirmation of FEED clarification log	Company confirmation of FEED clarification log

The basis for design for the interim/pre-EPCIC phase is largely the same as for the FEED, with the exception of instructions and clarifications received from Company in the period, where the main items are summarized in the table below.

Table 2-4 Clarifications to Scope Received from Company During interim/pre-EPCIC

Reference	Title	Content
E-mail from Steffen Emil Birkeland 30.09.24	FEEED CCP Klemetsrud - No of truck chargers	Number of CO_2 truck chargers confirmed as 3 x 350 kW
E-mail from Steffen Emil Birkeland 30.09.24	SV: FEED CCP Klemetsrud - Vedr. rømningsveier på vestsiden av TB	Company approval of two emergency exits on the West side of the Technical Building with escape into the existing WtE area.
E-mail from Einar Hübert 16.10.24	Oppdaterte MTO'er	Instruction from Company to provide revised MTOs for Piping, Structural and Electrical (HV only).
E-mail from Einar Hübert 07.11.24	Clarification - Ventilation of transformer rooms in technical building	Celsio accept a solution with natural ventilation of transformer rooms in technical building following standard solutions in NEK 440 and REN. If a need of mechanical ventilation occurs during operation, fans can be installed later to mitigate.

Reference	Title	Content
E-mail from Einar Hübert 07.11.24	Clarification - Heating cable inlet grilles ventilation	Celsio accept a solution for inlet grilles without heating cables. If a need occurs during operation heating cables can be installed to mitigate.
HI2305-CEL-AKE-LE-0005 22.11.24	Heat Pump Refrigerant	Change of heat pump refrigerant from isobutane to HFO
E-mail from Steffen Emil Birkeland 05.12.24	CCP FEED Klemetsrud - Final decision on toilets in TB and road heating	Company requirement of having one toilet on level 2 and one toilet on level 3 in the north part of the Technical building. No toilet required on level 1. Contractor instructed to implement street heating within CCP area by use of process waste heat.
HI2305-CEL-AKE-LE-0007 09.12.2024	Investigation of consequence for HP rooms without columns	Instruction to perform high level study of avoiding columns inside heat pump rooms.
HI2305-CEL-AKE-LE-0009	Minimums krav til fysisk sikring CCP iht. KBF	Company summary of requirements to satisfy Kraftberedskapsforskrift (KBF)

Reference	Title	Content
E-mail from Steffen Emil Birkeland 16.09.24	FEED CCP Klemetsrud - Hafslund Celsio Krav og Prosedyre for Cyber Secutity	- Hafslund Celsio requirements and procedure for Cyber Security: 2024 – Celsio non-functional requirements for cybersecurity and information management.xlsx - Specific Cyber Security requirements for Operational Technology – Contract Appendix v3.1.pdf

3 SYSTEM DESIGN OVERVIEW

3.1 General

The sections below will present an overview of the system design for the CCP plant, including the necessary modifications and tie-ins to the existing WtE plant.

3.1.1 Aker Carbon Capture's Technology

The ACC's Advanced Carbon Capture™ (ACC™) technology is an energy and cost-efficient process with minimal environmental impact, based on the ACC™ proprietary solvents. Key features of the ACC™ technology include:

- Verified during two years of operation at the 80 000 tonnes CO2 per year plant at the Technology Centre Mongstad (TCM), Norway, by testing flue gas from a combined heat and power plant
- ACC™ technology, including CO2 conditioning, intermediate storage, and CO2 export has been qualified by DNV during Norcem's cement plant Front End Engineering Design (FEED) project in Brevik, Norway
- Verified for operating on flue gas from cement kilns, waste-to-energy plants, coal-fired power stations, gas boilers, gas power plants, and refinery applications, through campaigns with Aker Carbon Capture's Mobile Test Unit (MTU)

- Highly energy-efficient process with innovative heat integration solutions
- Extremely robust solvents for environmentally friendly operation. The solvents are characterized by low solvent degradation, which is associated with a low corrosion rate in the plant; low amine make-up requirement; low emissions of amine degradation products; low demand for amine reclamation, and thereby low production of reclaimer waste
- Proprietary advanced emission control system to prevent amine mist formation, which further reduces emissions of amine and amine degradation products
- No consumption of water in the CO2 capture processes, only cooling water needed
- No generation of wastewater contaminated with amine traces during normal operation, except during solvent reclaiming campaigns
- Currently, installing the world's first large-scale CO2 capture process from cement production at Heidelberg Materials' Norcem in Brevik, Norway, with a capacity of 400 000 tonnes of captured CO2 per year
- Currently, installing a standardized Just Catch™ 100 CO2 capture process from waste-to-energy at Twence in Hengelo, The Netherlands, with a capacity of 100 000 tonnes of captured CO2 per year. In Denmark, five more Just Catch™ 100 units are under construction for Ørsted's wood chip-fired Asnæs Power Station and the Avedøre Power Station's straw-fired boiler.

3.1.1.1 ACC™ Solvents

The ACC™ technology has demonstrated excellent performance during operation on flue gases from coal-fired utility boilers, gas-fired power plants, waste-to-energy plants, hydrogen production (from steam methane reforming), refinery gases (fluidized catalytic cracker), cement kilns, and char production, all with a variety of flue gas impurities.

The ACC™ proprietary solvents were developed over eight years in a comprehensive R&D program (SOLVit) together with industry players and Norwegian research partners. Numerous solvent mixtures have been tested and compared with regards to energy consumption, robustness, toxicity, material compatibility, and HSE performance.

The proprietary solvents in ACC's solvent portfolio have proved to be extremely robust, delivering low degradation rates and good energy efficiency. The low degradation rates are associated with other process benefits such as low corrosion rates, less need for solvent make-up, low emission rates of amine degradation products, reduced demand for solvent reclamation, and thereby minimized production of reclaimer waste.

A typical benchmark solvent for post-combustion CO2 absorption is monoethanolamine (MEA). Compared to MEA, the degradation rates of the ACC™ solvents can be up to one order of magnitude lower depending on the flue gas composition. As MEA is prone to oxidation, a range of products are formed during the degradation of MEA. Many of these products are volatile and will slip through the emission control systems to be released to the atmosphere. Other degradation products are known to increase corrosion rates, leading to an autocatalytic process where solvent degradation furthers the dissolution of metals in the solvent, upon which dissolved metals take part in solvent oxidation and further catalyze amine degradation rates. As a result, solvent losses when operating with MEA are typically seen to enter an exponential phase of uncontrollable degradation. The ACC™ solvents are resistant to oxidative degradation, thus the autocatalytic degradation reaction occurring in MEA systems does not apply to the ACC™ solvents. The degradation products of the ACC™ solvents are mostly nonvolatile and are not observed to increase corrosion rates. In effect, the few compounds formed during the degradation of the ACC™ solvents are seen to steadily reach an equilibrium concentration in the solvent.

Another advantage of the ACC™ solvents over MEA is their reduced formation of harmful compounds such as nitrosamines and nitramines. Nitrosamines are conventionally formed via the reaction of NOx and secondary amines. MEA is a primary amine, but it degrades into several compounds, many of which are secondary amines. These secondary amines form a range of nitrosamines when reacting with NOx in the flue gas. Since the ACC™ solvents demonstrate extremely low degradation rates, the formation of nitrosamines is also very low.

A benefit of operating a carbon capture system with stable solvents is the targeting of a consistent process performance both in terms of capture rates and energy efficiency. Degradation directly impacts the physical and chemical properties of the solvent, which again affects the CO2 absorption chemistry. Diminishing solvent alkalinities and increasing solvent viscosities will deteriorate CO2 capture rates and lead to an increase in energy consumption for solvent regeneration. Process reliability is more challenging for technologies relying on solvents that degrade quickly and unpredictably. The ACC™ solvents enable steady and consistently optimal process performances.

The low degradation rate of ACC™ solvents was demonstrated in test campaigns at the Technology Centre Mongstad (TCM) and the results indicate the low tendency of nitrosamine formation for one of the ACC™ solvents compared to MEA. This solvent is particularly designed to reduce the environmental and health impacts of carbon capture operations and is composed only of primary amines. During the test campaigns, both the ACC™ solvent and MEA were exposed to the same flue gas quality and operating conditions in the same test unit. During these tests, solvent reclamation was performed after around 3 300 operating hours purely for demonstration purposes, and not because of solvent degradation.

The amines used in the ACC™ solvents have low toxicity and are readily biodegradable. No degradation or corrosion inhibitors or other additives are used in the ACC™ solvents.

With respect to solvent handling, the properties of the ACC™ solvents are similar to those of MEA, hence similar precautions and design considerations apply. Personal protective equipment like safety goggles, face protection, chemical resistant gloves, etc. as specified in the material safety data sheet from the chemical suppliers and in the Aker Carbon Capture operating manual should always be utilized when handling the ACC™ solvents, concentrated amines for make-up, or caustic soda solutions. Because of the alkaline nature of amines, undiluted ACC™ solvents or concentrated amines are harmful to aquatic environments, and spillages must be contained and properly disposed of.

3.2 CO2 System Design

The objective of the Carbon Capture plant is to capture 90% or more of the CO2 from the flue gas generated by the three incineration lines in the Klemetsrud WtE, and minimize operation upset for the existing WtE plant.

On an annual basis, the CO2 carbon capture plant (CCP) is designed to capture 350 000 tonnes of CO2 per year (TPA) and are also designed to treat the entire flue gas flow produced by the WtE plant. The CO2 capture facility is designed as a single train (1x100%, no redundant equipment) for flue gas handling, solvent circulation, solvent regeneration, CO2 conditioning, storage and export facilities.

The storage facilities consist of three vertical CO2 tanks designed for intermittent storage of one-day production. In addition, three truck loading stations are planned to be installed at the CCS plant in Klemetsrud for loading and transportation of liquid CO2 to the CCS terminal storage facility located at Oslo harbor. From the terminal, further transport of CO2 is planned via ship to the Northern Lights terminal at Øygarden. The CO2 terminal at Oslo harbor is a separate FEED study and not further described in this report. Ref Figure 3-1 for an overview.

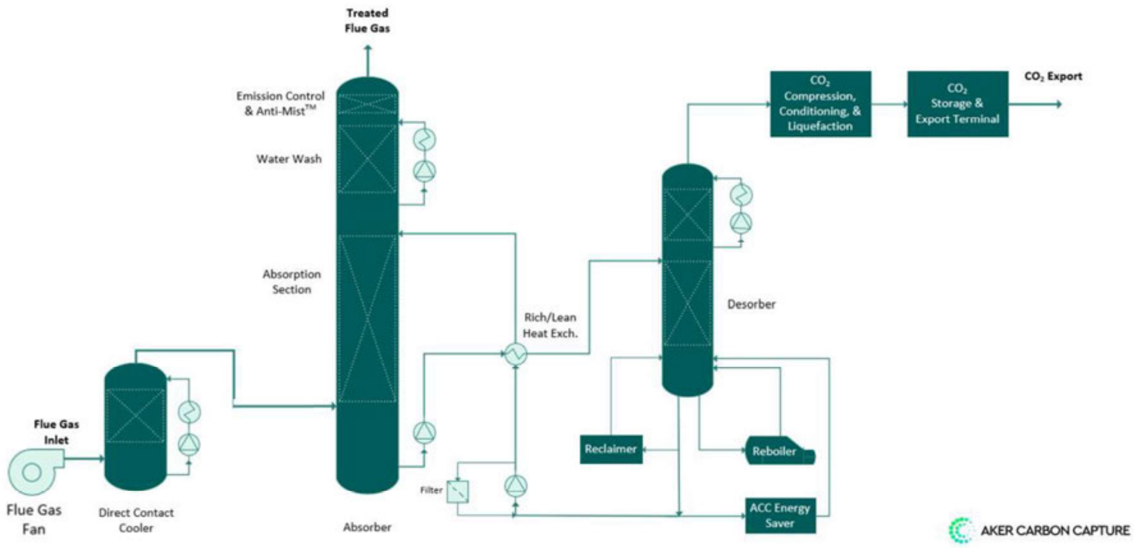

Figure 3-1 CO2 Capture and Liquefaction Process – Simplified Sketch

The following main systems are included in the CCP FEED design:

- Flue gas extraction and treatment
- CO2 absorption and emission control system
- Solvent handling and regeneration system
- Solvent reclamation system
- Chemical storage area
- CO2 compression and liquefaction
- CO2 storage and transport

A detailed description of the CCP is provided in the Process System Description, document number HI2305-AKE-P-RA-0001. For a complete understanding of the plant design, the process description shall be read in conjunction with the documentation below issued for the FEED:

- Heat and Mass balance - HI2305-AKE-P-CA-4001
- Line list - HI2305-AKE-P-LA-4001
- Equipment Process datasheets - HI2305-AKE-P-DS-4001 to 4030
- Vent & Drainage Philosophy - HI2305-AKE-P-FD-0001

- Overpressure, Vent, Relief & Blowdown Philosophy - HI2305-AKE-P-FD-0002
- P&IDs - HI2305-AKE-P-XB-0001 to 4035
- Process Flow Diagrams - HI2305-AKE-P-XA-4001 to 4009
- Isolation Philosophy - HI2305-AKE-Z-FD-0002
- Solvent and Chemical Consumption Summary - HI2305-AKE-P-LA-4003
- Waste and Effluent Summary - HI2305-AKE-P-LA-4004
- Dynamic Simulation Report - HI2305-AKE-P-RA-4002
- Sparing Philosophy - HI2305-AKE-R-FD-0001

3.2.1 CO2 Capture Plant

3.2.1.1 Flue Gas Extraction and Treatment

The CCP plant is designed with a capacity to treat the entire flue gas flow from the WtE.

The flue gas extracted from the WtE [redacted] is connected into one common duct header and routed to the CO2 capture plant. The tie-in connections are located [redacted]. The flue gas is routed through a new duct from the flue gas tie-in to the CO2 capture plant main process area where the new Flue Gas Fan is located.

[redacted]

[redacted]

The flue gas fan raises the flue gas pressure to overcome the pressure drop through the entire flue gas path including [redacted]. The centrifugal fan will be equipped with a VSD to accommodate start-up, shutdown and variations in flow and pressure.

Downstream of the Flue Gas fan, the flue gas enters the Direct Contact Cooler (DCC), where the flue gas flows counter-currently to water in a packed bed with structured packing. The DCC is a circular tower and water is circulated using a DCC pump via a DCC cooler. [redacted]

The flue gas is cooled beyond its dew point and the DCC is therefore a net water producer. Hence a water bleed is established to remove condensed water and/or maintain the quality of water by removing salts formed in the system. The bleed is sent to the Wastewater Treatment Plant (WWT) for further treatment.

[redacted]

[redacted]

3.2.1.2 CO_2 Absorption and Emission Control System

The CO2 Absorber is located downstream of the DCC. It comprises a CO2 absorption section and an Emission Control system that is designed with Aker Carbon Capture's ACC™ Anti-Mist design (patented) to prevent amine emissions in the form of mist.

The purpose of the CO2 absorption system is to absorb CO2 from the flue gas. The CO2 absorption section consists of beds with structured packing. Lean amine (lean with respect to CO2 content) is fed to the top of the CO2 absorption section through the liquid distribution system and flows downwards through the bed, counter-currently to the flue gas, and ends up as rich amine in the Absorber sump in the bottom of the Absorber tower. CO2-depleted gas exits through a stack located on top of the absorber.

The purpose of the water-wash sections is to minimize amine slip and to cool the flue gas. Water-wash section consists of a packed bed with structured packing.

The purpose of the acid-wash sections is to further minimize amine and ammonia slip. The acid-wash section consists of a packed bed with structured packing.

On the Absorber stack four different type of analyzers are provided:

- Continuous Emission Monitoring System (CEMS)
- CO2 analyzers
- FTIR gas analyzer
- Dedicated amine analyzer (PTR-ToF or equivalent) for lowest detection limit of amine and amine degradation products

3.2.1.3 Solvent Handling and Regeneration System

The rich amine solvent is regenerated in the Desorber and subsequently CO2 is released after heating. The Desorber column is a packed column equipped with an LP steam reboiler, overhead condenser, receiver vessel and reflux pump.

Heat required for the CO2 desorption is provided by:

- Low pressure (LP) steam (4bar) to the reboiler is supplied from [redacted] the WtE plant. The steam condensate is collected in an LP condensate vessel and pumped back to the WtE plant.
- The Energy Saver System is designed to reduce the LP steam flow requirement in the Reboiler [redacted].
- Vapor from the Reclaimer Package (when in operation)

The hot CO2 rich vapor is cooled in the overhead condenser, and the condensed water is further separated in the overhead receiver vessel before it is sent back to the Desorber. The pressure in the Desorber is controlled by the downstream CO2 compressor train. When the compressor is out of operation, a secondary pressure control vent line facilitates safe venting and pressure control. The amine solvent regenerated in the Desorber process and Energy

Saver is transferred by the Lean Amine Pump back to the Absorber via the Lean/Rich Amine Heat Exchanger.

3.2.1.4 Solvent Reclamation System

The solvent in a CO2 capture process will, over time, accumulate impurities absorbed from the flue gas and solvent degradation products. This may influence solvent characteristics such as density, viscosity, CO2 capture capacity, corrosivity, degradation rate, etc. The aim of the thermal reclaimer is to remove these impurities from the amine solvent [redacted]

[redacted]

[redacted]

3.2.1.5 Chemical Storage Area

The chemical storage area consists of a bunded area where the atmospheric tanks storing different chemicals used in the CCP plant are installed. The chemical storage area is provided with a truck unloading area and equipped with unloading pump to unload the chemical from each truck/isotainer to the respective chemical storage tank. The tanks are designed to have enough capacity to accommodate the volume of the transported chemical.

- [redacted]

  [redacted]

- [redacted]

- [redacted]

  [redacted]

- [redacted]

3.2.2 CO2 Compression and Liquefaction

The CO2 product flow from the CO2 capture plant is further treated to meet the downstream delivery requirements for the CO2 transport provider. CO2 is to be delivered from the intermediate storage as single-phase liquid at -30.5°C and approx. 14bara.

The CO2 from the Desorber overhead vessel is compressed in several stages (number of stages to be confirmed by vendor) via an integrally geared compressor train. The compressor stages are divided into several groups, where each group is equipped with an anti-surge loop and an inlet guide vane (IGV) for flow control blowdown valve to take down the pressure by releasing pressurized CO2 to safe location.

After the penultimate compressor stage, the CO2 stream enters the drying package [redacted]. The compressed CO2 is dried to water content below 15ppm (mol) to prevent hydrate formation in the downstream equipment. [redacted]

The CO2 gas is further cooled and condensed from gas to liquid [redacted]. Vapor phase CO2 generated [redacted] are recycled to appropriate compressor stages and recompressed/liquefied. Liquid CO2 is further pumped to the CO2 storage tanks for intermediate storage. Evaporated (due to heat ingress) and displaced CO2 gas from intermediate storage tanks head space are also recycled back to the compressor train and recompressed/liquefied.

The oxygen content of the final CO2 product needs to be reduced to < 10ppmv by inert stripping. The gas flows directly into an inert stripper column before it enters the inert stripper condenser where it is cooled.

3.2.2.1 CO_2 Storage and Transport

[redacted] Each storage tank is provided with internal top inlet spargers to be operated during the initial filling of the tank, as well as lower liquid CO2 connection for regular filling.

The CO2 storage tanks, and piping are insulated to reduce formation of CO2 vapor due to heat ingress. Displaced CO2 vapor together with any CO2 generated by heat ingress flows back to the compression system where it is re-liquefied.

A pressure control valve is provided for venting CO2 gas from the storage tanks to ambient in case the compression plant is out of service.

The CO2 tanks are connected through a single header to three identical truck loading stations, each designed for a loading capacity of 90m3/h. The three truck loading stations can be operated simultaneously and independently. The displaced vapor from the truck generated during the filling operation is routed back to the storage tanks.

To facilitate the loading operation, loading arms for liquid and vapor system are provided. After truck filling is completed, liquid CO2 from the liquid loading arm is drained and recovered back to the CCP plant via the CO2 drain system.

Protection against overfilling of the truck will be ensured by a truck to terminal connection link that will ensure that level signal in the truck is communicated to the CCP's control system with the possibility to stop the filling operation in case of high level.

3.3 Utility System Design

Utility System for the CCP plant comprises of Cooling Medium, Wastewater Treatment, Compressed Air, Fresh Water and Steam / Condensate Systems. These utilities are either supplied from the existing WtE plant headers or generated independently for use in the CCP. Each of the utility systems are further described in below sections.

3.3.1 Cooling Medium System

Cooling medium is used for removing the process heat in the CO_2 capture and liquefaction process, and as required, transfer the process heat to the district heating system via the heat pumps. In addition, cooling medium heat is used for heating the HVAC circulation air, street heating and cooling of compressed air in the air compressor inter stage coolers. The cooling medium system is a closed loop circuit with 43% Propylene Glycol (Dowcal 200E) / 57% Water mixture to prevent freezing during winter operation. Two centrifugal pumps operating at 2x50% capacity supply cooling medium to the consumers. No standby pump is considered for the system as per project philosophy. Pumps are provided with variable speed drive to regulate the cooling medium flow and pressure in the circuit based on the demand. Variable speed drive is primarily used for reducing the pump discharge pressure when the heat pumps are bypassed and not in operation.

The return cooling medium is cooled in the air coolers located on the roof of the Technical Building. During cold periods of the year, part of the heat load is cooled in heat pumps, however, air coolers are designed to cool the entire heat load of the cooling medium system to cater for summer operation. The air cooler consists of 14 bays, where each bay has two tube bundles and three air fans. One out of the three fans is driven by a variable speed drive to maintain outlet / supply temperature of the cooling medium during turndown operation. An open expansion vessel is installed at the highest point in the system to accommodate the change in volume of the cooling medium due to density changes with temperature.

In addition to the CCP and Heat Pump, the Emergency Steam Cooler is also one of the users of cooling medium. The Emergency Steam Cooler is not online during normal operation, but some flow of cooling medium is always passed through the cooler to ensure instant cooling of the steam when it is diverted from CCP in case of plant trip. Steam is condensed and sub cooled in the cooler using cooling medium. A flow control valve in the inlet line is used to supply the required quantity of cooling medium to the steam cooler when in operation.

Refer below system sketch for clarity.

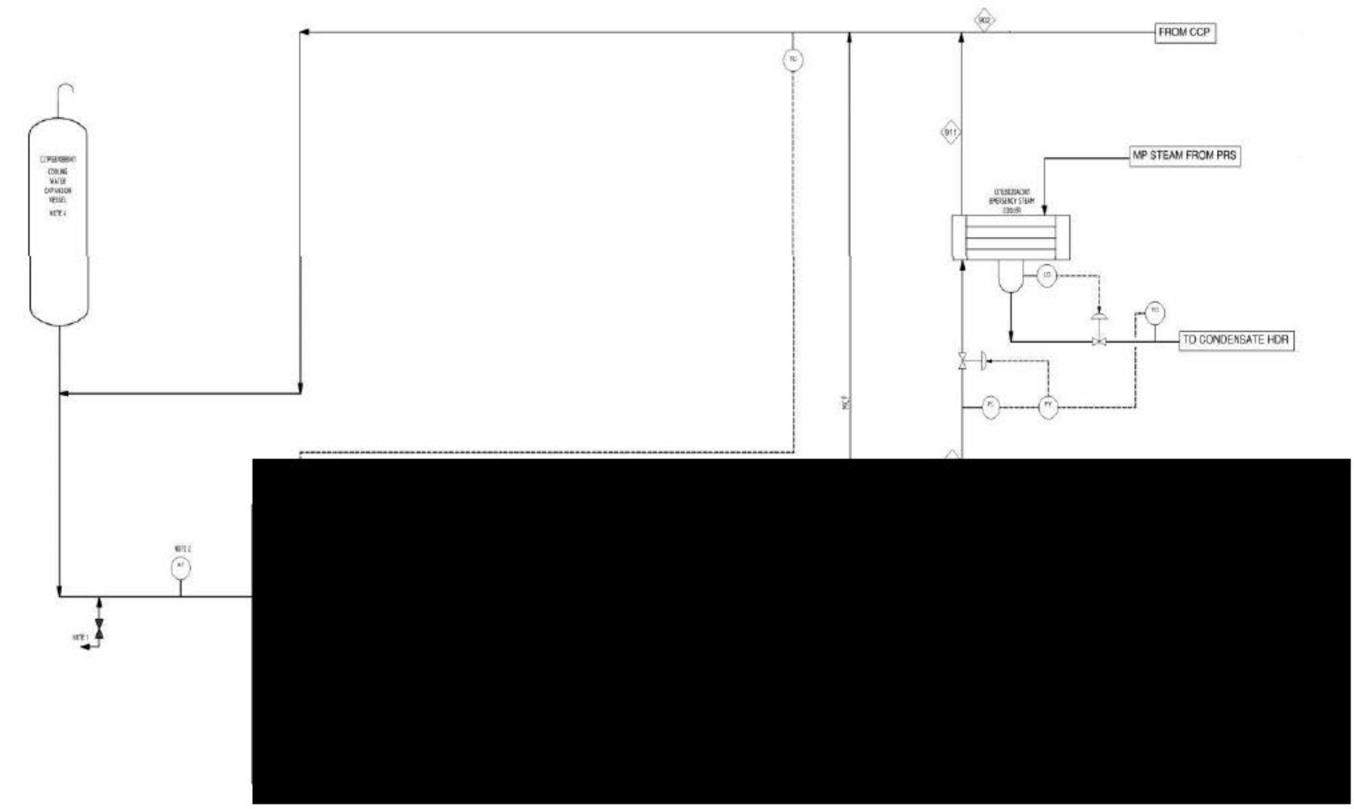

Figure 3-2 Cooling Medium System – Simplified Sketch

3.3.2 Waste Water Treatment System

The Wastewater Treatment System receives the condensed water from the DCC cooler during normal operation. It consists of two main parts: production of demineralized water from the clean side of the system for consumption in the WtE plant, and handling and removal of hazardous impurities from the separated waste streams to reach the allowable levels for discharge to the public sewer.

In addition to DCC cooler condensate, there are also streams from CCP and Technical building floor drains routed to the Wastewater Treatment System during maintenance. The technical building floor drains are collected in a drainpipe header and routed to an underground Oil-Water Separator. Oil gets separated from the top layer in the separator and is disposed to tote tank or truck. The contaminated water from the separator is transferred to the Drain Collection Tank by a pump. The contaminated water is analysed for the contaminants. Based on the analysis of the stream content, it is either routed to the Wastewater Treatment system or sent to truck to be transported away from plant.

The Wastewater Treatment system is planned to be arranged as a vendor package delivered by a specialized WWT Vendor. During FEED, dialogues with several eligible suppliers have been established and technical information received and incorporated in the FEED design and further described in this section.

The system is planned to be an automatic system with minimal manual intervention in normal operation. Manual make-up connection for start-up potable water and chemicals for neutralization, and periodic sampling of the streams at various section, may, however be required, subject to supplier recommendations. Sampler and analyzer shall be deployed to ensure the reject stream composition is within the regulatory limits.

Within the Wastewater Treatment system there are small chemical tanks for all the chemicals to be used. Two of the chemicals used in the Wastewater Treatment system (NaOH and H_2SO_4) are also used in other parts of the Carbon Capture Plant. There are two large storage vessels for these two chemicals in the Chemical Storage area. These two chemicals will be transferred by two dedicated pumps to the smaller tanks within the Wastewater Treatment system via the main pipe rack.

The system comprises of various treatment stages like Ultra Filtration filters, Reverse Osmosis, Electro deionization-, Metal / Mercury removal- and Ammonia removal modules. The system is designed with 1x100% configuration for all the sections, however, pumps are generally spared and for some sections the load is split across parallel equipment (e.g., 2x50%). A brief description of each section is given below.

DCC Condensate Collection

The DCC condensate is pumped from the CO_2 capture plant DCC cooler and collected in the DCC condensate tank. The tank both acts as a buffer in case of short-term unavailability of the WWT-plant, as well as evens out peak concentrations of impurities by mixing the incoming DCC condensate with the content of the tank prior to entering the first treatment stage. The level in the tank is monitored and an on/off valve is provided to close off the inlet in the event of high high level. DCC condensate flows by gravity to the first treatment stage in the demineralized water generation section.

Demineralized (DM) Water Generation Section

The DM water generation section consists of Ultra filtration (UF), Reverse Osmosis (RO) and electro deionization (EDI) treatment stages. The intent of the section is to separate out the impurities from the DCC condensate in separate waste / reject streams, as well as purify the clean stream to DM water specification [redacted]. Based on supplier recommendation, the UF, RO and EDI are currently sized to achieve recovery of 90%, 50% and 95% respectively from the inlet stream.

- The UF unit consist of feed pumps, UF membrane, backwash tank and pump. Suspended and colloidal particles are removed in this unit.
- The Activated Carbon Filter (ACF) unit consist of carbon media for removal of dioxins. Dedicated backwash pump is provided for periodic backwash of ACF.
- A two-stage RO system (RO-1 & RO-2) is envisaged to achieve the required quality. The RO unit consist of cartridge filters, RO-1 high pressure pump, RO-1 skid, permeate collection tank, RO-2 high pressure pump, RO-2 skid and Dosing systems (SMBS, Anti-scale, NaOH and H_2SO_4).
- The EDI unit is the final polishing unit which generates DM water quality as required by the WtE plant

Reject Treatment Section

Backwash from the ACF-filter stage and the RO reject is collected in the Concentrate Tank, which will both act as a buffer in case of short-term unavailability of reject treatment equipment, as well as even out peak concentrations of impurities by mixing the incoming reject and backwash with the content of the tank. The concentrate flows by gravity to feed pumps transferring the concentrate for further treatment for removal of heavy metals and ammonia to meet statutory requirements as specified in the WtE discharge permit. Ammonia is recovered as ammonium sulphate which is sent for disposal.

Solid Handling Section

UF reject consisting of high TSS is taken to a sludge thickener tank followed by a filter press. Dewatered sludge of approximately 50% sludge consistency is sent for disposal by truck.

Refer block diagram below from one of the suppliers for details of the package.

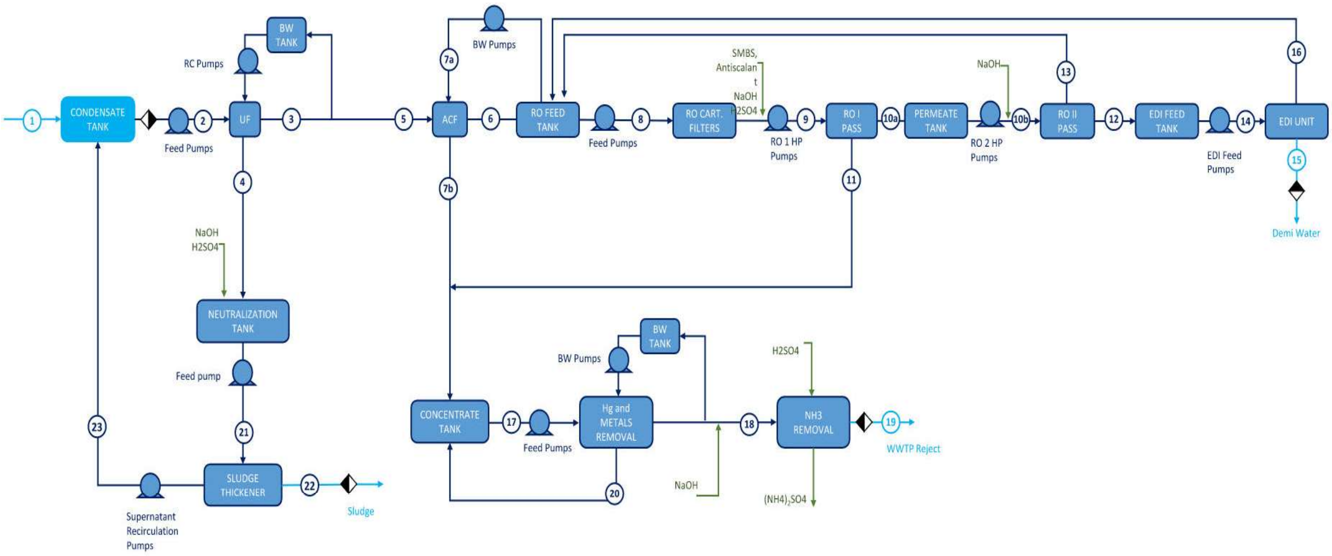

Figure 3-3 Waste Water Treatment System – Simplified Sketch

3.3.3 Compressed Air System

Compressed air is generated by installing a new compressor to supply instrument air to the CCP and associated facilities. A skid mounted air compressor is equipped with an air dryer to meet the required dew point for operation of control valves and on/off valves. An instrument air receiver is provided downstream of the dryer to provide buffer capacity as per supplier standard design. One working compressor is considered for the CCP and associated facilities, i.e., no standby compressor considered. For typical utility station use, compressed air is supplied using a portable air compressor.

3.3.4 Fresh Water System

Fresh water is supplied to CCP and associated facilities from the existing WtE plant. Tie-in point for the fresh water is located near the battery limit of the existing municipal supply line. A check valve is installed at the tie-in point to prevent reverse flow from the CCP facilities to the main header. A new fire water line for the CCP and associated facilities is taken from existing fire water header.

Fresh water is used for make-up in the WWT package and supply to utility stations in CCP and Technical Building. Use of fresh water in the process plant is intermittent and expected to be limited.

3.3.5 Steam and Condensate Systems

The main purpose of the Steam and Condensate System is to ensure that the steam has the correct conditions when supplied to the steam consumers in the CO2 capture plant, as well as safely transport the condensate back to the WtE plant at the correct water quality with respect to conductivity levels and temperature. The steam treatment is accomplished by using three pressure reduction valves, one valve for each of the steam users in the CCP; the reboiler, reclaimer and emergency steam cooler. The HP steam system will be EN piping standard AS100. The piping for LP- and MP-steam to reboiler, reclaimer and steam cooler will be ASME piping standard CA150 and CA300.

The emergency steam cooler is a heat exchanger to cool down and handle the steam supplied to the CCP plant in case of a trip in the CCP/reboiler. [redacted] the CCP. The steam from WtE shall be handled by the CCP in all cases not to influence the WtE plant.

The emergency steam cooler is placed in the same room as the steam pressure reduction valves. The steam cooler pressure reduction valve does not include cooling by condensate injection, as the steam cooler handles the high temperature from WtE superheated steam directly.

For the other steam PRDS valves (Pressure Reduction and De-Superheating), cooling of superheated steam is achieved by injection of warm condensate. The injected condensate evaporates to steam, resulting in a steam mixture with a lower degree of superheating. The condensate is extracted from the condensate return, with an operating temperature of 111°C, supplied by 2x100% capacity pumps placed in the same room as the pressure reduction valves and steam cooler.

A simplified sketch of the system is shown in Figure 3-4. For a more detailed description of the operation of the pressure reduction control valves, reference is made to /1/.

[redacted]

[redacted]

Steam traps are required to be placed along the steam lines to collect condensate. The condensate collected from these traps is led to the nearest of two condensate vessels operating at atmospheric pressure. One vessel is placed in the Technical Building, and one is in the outside area, just outside the technical building under the pipe rack. If the system is to be drained, there is a drain line in the main condensate return line, leading condensate to the outdoor condensate vessel. In addition, there is a drain line after the reclaimer, before the LP condensate vessel for startup of the reclaimer in normal operation.

The destination for the condensate outlet from these vessels is controlled by a conductivity measurement mounted in the vessel. A pump will return clean condensate to the WtE plant, while contaminated condensate is directed to the Waste Water Treatment System. If the condensate is led to WWT, the condensate is cooled by potable water. If the pump fails the tanks will overflow. If the tank inside the technical building overflows, the condensate is cooled by potable water and led to the closed drain network. If the tank outside the technical building overflows, the condensate is led to ground.

Before startups the LP condensate vessel and the reboiler bundle will be filled with condensate from the WtE plant. This will ensure that condensate is available before startup and shorten the duration of the reboiler startup.

3.4 Heat Pump and District Heating System Design

The WtE plant delivers up to 48MW of steam to the CCP, depending on the demand from the CO_2 capture plant. Today this thermal energy is used for electricity production in steam turbines and district heating to the Oslo area, hence utilizing the steam for heating purposes in the CCP introduces an energy penalty. To compensate for loss of thermal input in the district heating system, a heat pump system is installed. The heat pumps use cooling medium return from the CCP as heat source and deliver heat at approx. 80-90 °C to the district heating system by preheating the return line. The overall system design is shown in Figure 3-5 below.

[redacted]

[redacted]

3.4.1 Heat Pump System

3.4.1.1 Heat Pump Technology

The heat pump system for the CCP shall be capable of delivering 60MW thermal heat up to 90°C or higher into the existing district heating system. Currently, the best available technology to meet these requirements is an industrial heat pump utilizing centrifugal compressors and HFO-1234ze(E) as the refrigerant. This technology has proven to have high reliability and availability, and low maintenance need when delivering heat at 90°C or higher. Each heat pump unit can be designed with a high thermal output with one or two compressors per unit which simplifies system design and the number of interfaces. For the project specific process requirements each heat pump unit can be designed to deliver a thermal output of up to 30MW and should have a turndown of 15 MW unless otherwise agreed.

3.4.1.2 Refrigerant

This type of heat pump was originally designed for the synthetic refrigerant R12 (CFC) and has through the years been converted to other synthetic refrigerants such as R22 (HCFC), R134a (HFC) and most recently to R1234ze(E) (HFO). R1234ze(E) is currently considered BAT, however, the negative environmental impact from degradation products such as TFA is a concern.

If released to the atmosphere, synthetic refrigerants have short lifetime and tend to form TFA (typical TFA yield is 2-20% of leaked refrigerant, depending on refrigerant type and atmospheric conditions) as one of several degradation products. Once formed, TFA is associated with long environmental lifetime and negative impact on the environment and human health. In recent years environmental agencies and companies are focusing on finding possible substitutes for synthetic refrigerants. Currently environmental agencies are working on a PFAs restriction proposal which may lead to a ban on use of the abovementioned refrigerants. A final decision on which substances are affected by the restriction proposal is expected within the next few years.

Moving from synthetic to natural refrigerants with low GWP and ODP is the natural step, meaning different types of hydrocarbons may be used. Utilizing hydrocarbons require more consideration for a large heat pump system due to higher flammability of hydrocarbons compared to HFO refrigerants. Safety aspects and controlling the risk level is essential when utilizing heat pump with hydrocarbons as refrigerant.

Due to the uncertain prospects for HFO-1234ze, the projects main target during the FEED study was to focus on natural refrigerant and to mature a concept with isobutane as the base case refrigerant. During Pre-EPCIC an RfQ was prepared and sent to nominated suppliers Siemens Energy and Friotherm. However, the feedback was that neither of the suppliers could meet the project requirements and timeline of the project, hence, the Company decided to move from isobutane to HFO-1234ze.

3.4.1.3 Mechanical

This section describes the main components in the heat pump system. For further information, reference is made to the package specification and datasheet for the heat pump system, /44/ and /45/, respectively.

1. Evaporator heat exchanger: Transfers heat from the cooling medium return to the refrigerant cycle by evaporating the refrigerant at low pressure and temperature. Typically, shell&tube heat exchangers are applied.

2. Centrifugal compressor: Compressing the refrigerant to higher pressure and temperature in one or two compression stages. Depending on supplier, each heat pump unit may consist of one compressor, or two compressors working in parallel.
3. Condenser + subcooler heat exchangers: Transfers heat from the refrigerant cycle to the district heating water by condensing and subcooling the refrigerant at high pressure and temperature. Typically, shell&tube heat exchangers are applied for both condenser and subcooler.
4. Flash vessel: If a two-stage compressor is used the refrigerant cycle will have a flash vessel separating two-phase gas/liquid at an intermediate pressure.

In addition, the heat pump units consist of the following utility system:

1. Cooling water heat exchanger skids: For electrical motor and oil cooling
2. Service skid and storage tank: Used to transfer refrigerant between the heat pump units and an intermittent storage tank, e.g., during maintenance
3. Lube oil and seal oil skid: May be delivered as a separate skid or part of compressor skid

[redacted]

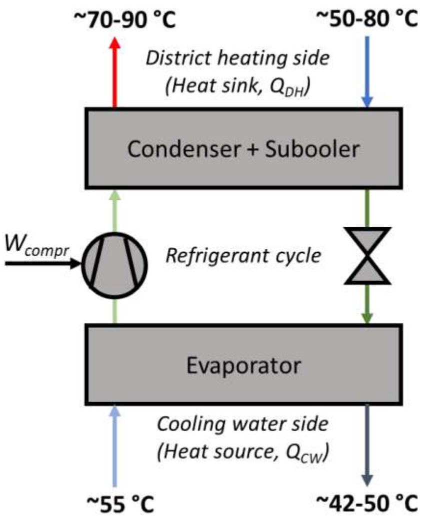

Figure 3-6 Simplified Heat Pump Schematic Including Refrigerant Cycle

3.4.1.4 Process

The existing district heating return line operating temperature typically varies between 54-70°C depending on the district heating demand and operation of the WtE plant. The heat pumps will raise the water temperature to 70-90°C, where the desired thermal output is set by the plant operator. 2x100% dedicated circulation pumps with VFD ensures the correct DH flow rate through the heat pump condensers to achieve the desired outlet temperature (DH set temperature). The heat pumps will provide heat to the district heating return system based on demand, typically high load and temperature in the wintertime, ref. Functional Description for more details, /1/. When there is no heating demand, the heat pumps are put in standby or stopped. The heat pumps are bypassed on both the DH and CM side when not in use.

The CCP cooling medium return will during normal operation have a temperature of approximately 55°C which will be cooled by the heat pump evaporators to approx. 42-50°C depending on the required thermal output from the heat pumps. The heat pumps are very sensitive to higher-than-normal temperatures of the cooling medium side, as this will cause elevated pressure in low-pressure part of the refrigerant cycle. If the refrigerant pressure rises, the heat pump trips and eventually the PSV's may lift and release refrigerant to the ambient. Hence, during detail design it is vital to ensure that the heat pump evaporator side is designed to handle the maximum temperature in the cooling water system. If this is not possible, measures need to be in place to ensure that the cooling water temperature cannot exceed the maximum acceptable temperature of the heat pump evaporator. In addition, the cooling medium flow rate shall be kept constant through the evaporator to ensure stable operation and avoid tripping the heat pump.

Table 3-1 shows the estimated thermal power extracted from the cooling medium and transferred to the district heating return line. In FEED, a system consisting of two heat pump units, each with a capacity of 30MW, has been used as base case. These would in total use approximately 12MW_{el} of electricity for their compressors at peak demand. The electrical input is converted to heat, hence the thermal output of the heat pump may be roughly estimated as $Q_{CM} + W_{compr} = Q_{DH}$.

Table 3-1 CCP Heat Pump System

CCP Heat Pump System (2x30MW units)		
Thermal output, Q_{DH}	MW_{th}	60
Thermal input, Q_{CM}	MW_{th}	48
Electrical input, W_{compr}	MW_{el}	12

3.4.1.5 Electrical

The heat pump utilizes 10.5kV high-voltage compressor motors. Due to the motors size (3-6 MW depending on supplier) the motors will require either soft starters or VSD's to ensure sufficiently low starting current to avoid large voltage dip when the heat pumps are put into operation. The base case in FEED study is heat pumps with VSD.

In addition, there will be 400VAC system to feed auxiliary consumers (pumps, etc.) on the heat pump skid as well as control system loads. The heat pump will have a 230VAC UPS system. UPS will be supplied from the projects UPS system.

3.4.2 District Heating System

The district heating system, also referred to as the heat sink of the heat pump, is shown in Figure 3-7. The scope related to the FEED CCP Klemetsrud project is highlighted in the figure, while the existing district heating plant is shadowed. [redacted]. The heat pump units can be designed to operate either in parallel or in series. The base case is that heat pumps are connected in parallel. The district heating design flow rate through the heat pump system will be between 500-2300 t/h depending on the heat demand in the district heating network.

[redacted]

3.5 HVAC System Design

The vital requirements of the HVAC system in the Technical Building are:

- Filtration and compliance of air quality in terms of salinity
- Maintaining room temperatures and comfort for maintenance personnel
- Maintaining room temperatures for safe operation of equipment
- Correct operation in case of gas/smoke/fire
- Pressurization

The operational and functional requirements of the HVAC systems in the Technical Building as well as heating of roads on the site is further described in document HI2305-AKE-H-RA-6001 /17/.

Further description of the HVAC system design is also found in Section 6.8.3.

3.6 Electrical Systems Design

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

3.7.2 Field Instrumentation

The Field Instrument design is based on the Field Instrument Specification: HI2305-AKE-J-SA-0003, which has been used as basis for instrument selection and process connections as indicated on the IFF P&IDs.

Instrument and instrumented valve types that are included in the FEED CCP design are as follows:

- Pneumatic control valves, globe or plug type
- Electric motor-driven and pneumatic actuated on-off valves, butterfly or ball type
- Conventional spring-operated pressure relief valves
- Flowmeters (depending on service): DP type, magnetic, ultrasonic, coriolis
- Flow Elements: Pitot tube, orifice plate
- Temperature Instrument: Head/Remote mounted temperature transmitter, RTD, thermowells
- Pressure Instruments: Pressure transmitter with/without remote diaphragm seal, pressure gauges
- Level Instruments (depending on service): DP type with or without chemical seal, radar type, magnetic level gauge
- Analyzers: pH, O_2, conductivity, O_2/H_2O, dust, sample probe for FTIR, CO_2, PTR-TOF, CEMS, O_2/H_2O
- Fire and Gas Detectors: CO_2 gas detectors, flammable gas (HC) detectors

The implementation of typical junction boxes, RIO cabinets, main trays and field trays has been done in the E3D-Model.

Instruments capable of handling fluids that may freeze at the minimum site ambient temperature will be equipped with electrical tracing. Electronic instruments located outdoors will be placed in a heated box.

The preferred method of protection will be intrinsically safe instruments mounted in the field with galvanically isolated safety barriers mounted in the safe area. If the instrument cannot be supplied with intrinsic safety, then Explosion-proof (EEx'd') protection will be provided instead.

[redacted]

[redacted]

4 AREA DESIGN OVERVIEW

4.1 E3D Model Development & Coordination

Throughout the FEED, AKSO has facilitated weekly E3D model collaboration workshops involving the Engineering area designers, Process, Safety and EIT system disciplines within ACC, Norsk Energi, Multiconsult and AKSO. Company have been invited to attend to the Bi-weekly multidiscipline 3D model workshops. The main purpose for these series of workshops has been to develop area design solutions complying with all relevant requirements in a lean and efficient manner as the FEED design has progressed, as well as efficiently resolve challenges. This has been particularly important for the FEED CCP Klemetsrud project, due to [redacted] with a large number of activities in parallel.

In the initial phase of the FEED, the main focus for the team was related to the Technical Building layout, as supplier responses and design development identified a need for additional space and a potential size increase for the building. Boundary limits were identified and discussed with Company, and the building footprint was defined based on the boundary limits not to exceed coordinates for the South, West and North side of the building. The East side, the building is limited by extensive logistics due to material handling for equipment located within the building, as well as the driving pattern for the CO2 trucks, charging of electrical trucks, and service logistics for the CO2 Carbon Capture plant area.

As the FEED progressed, the area design was further matured based on system design development, as well as in dialogue with the construction method team. Space was freed up inside the building by relocating the CO2 liquefaction module outside, and the pipe rack along the North side of the building was replaced with an East-West corridor within the building to allow for the building to span the entire available North-South direction within the plant area.

Considerable work was also spent together with Company to identify an acceptable CO2 truck driving pattern, both supporting the overall area layout of the plant, as well as not interfering with the existing logistics at the WtE plant.

Towards the end of the FEED, a combined layout- and WEHRA design review was held, identifying several issues with the electrical area design related to segregation of the WtE and CCP plant electrical systems, as well as conflict with Company`s scope outside of the CCP plant. Several dedicated workshops were held to look into this issue, searching for solutions which could both fulfill the requirements and be implemented within the timeframe of the FEED. [redacted] separate rooms, ending up requiring an increase in the Technical Building width of approximately 3m in East-West direction. Through good interdisciplinary collaboration including Company acceptable solutions were identified and implemented in the FEED design. However, opportunities for later optimizations were also recorded, ref Section **Error! Reference source not found.** for further details.

Some actions from FEED model review have not been incorporated in the 3D-model yet due to being related to detail design. These actions have been transferred to the Detail Engineering phase and can be found in Appendix A.

Regular E3D collaboration workshops also together with Company have continued during the interim/pre-EPCIC phase, in addition to specific workshops related to cold eye review comments received from Company. The Technical Building layout in particular has been substantially modified in the period, and the utilization of room height improved.

4.2 SGeneral

The location of the CCP plant at Klemetsrud, Oslo, Norway is shown in the figure below and constitutes approximately 12 850m2.

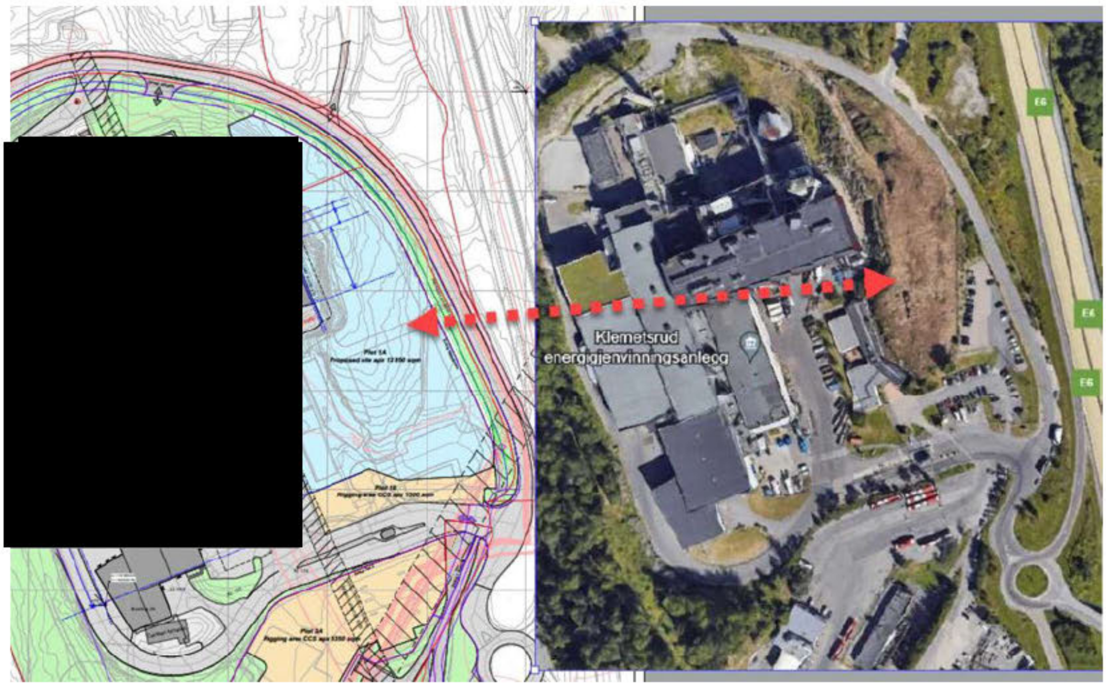

Figure 4-1 Available Area for the CCP Plant

The model, layout and piping design has been developed by use of local E3D CAD models. The piping design has been developed based on the available P&IDs and equipment/package information received during FEED. A Navisworks 3Dmodel has been extracted regularly and uploaded to the Project Collaboration site also available to Company. See figure below for an overview of the 3D model.

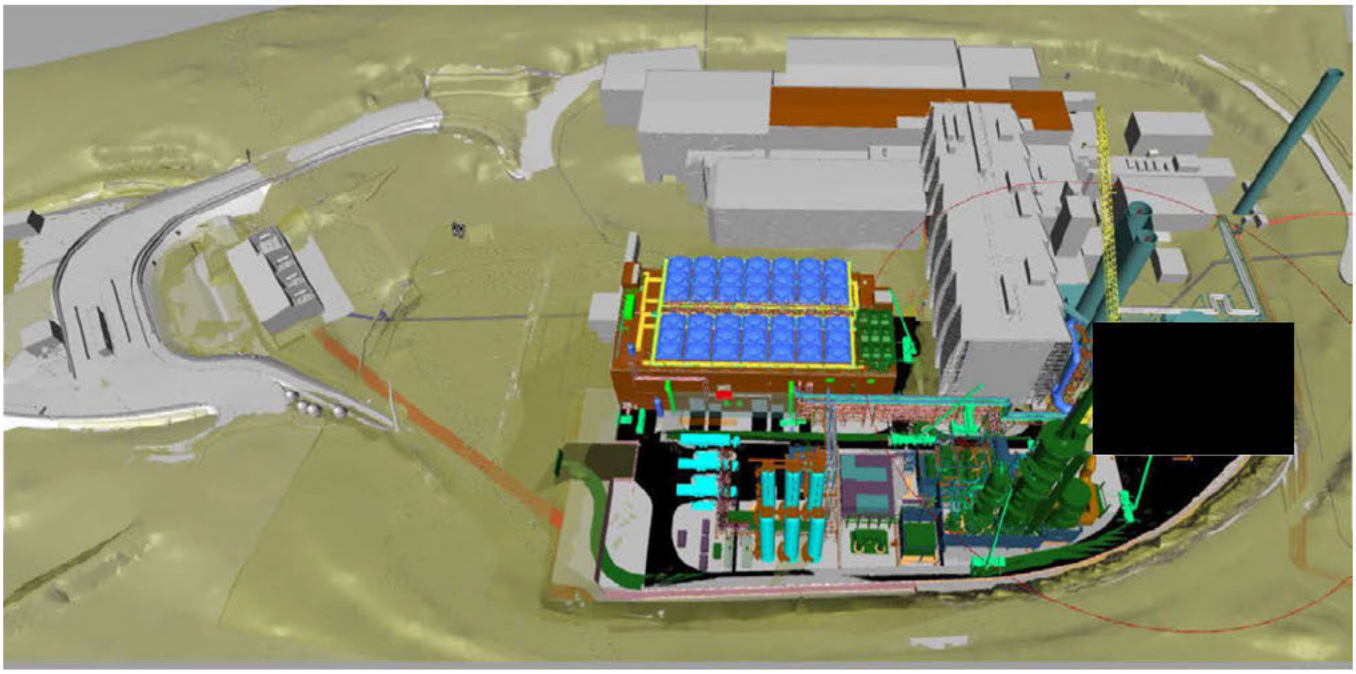

Figure 4-2 CCP Navisworks 3D-model

The overall philosophy for the area development has been to utilize space in the Technical Building in several levels to conserve the available plot, as well as locating the CO2 capture plant close to the WtE stacks to minimize the length of the large flue gas duct. The centrally located Technical Building provides acceptable conditions for [redacted] as well [redacted] reaching nearby neighbors. The CM air coolers are located on the Technical Building roof both providing favorable conditions for supply of fresh air, as well as utilizing shielding from the existing WtE plant buildings towards neighbors on the North and West side.

The liquid CO2 storage tanks and the truck loading station have been located in the South end of the plot to support the CO2 truck driving pattern in and out from the site. The trucks arriving at the CCP area have also been provided space allowing to stop in front of the CCP main gate without affecting the traffic into and out from the WtE facility, ref below figure. In current model some areas of terrain files can be seen obstruction part of plant roads. File adjustment have been agreed and Company will provide updated files for import.

[redacted]

4.2.1 Area Coding and Zoning

The basis for setup of the 3D CAD models for the CCP project are given in CCP FACILITY AREA CODING – KLEMETSRUD. /33/. Area coding and structure is based on the Company KKS manual and applies to all disciplines with input to the E3D model. Klemetsrud origin and coordinate reference system, in addition to Contractor`s 3D model plant elevation are also given in this document. The CCP area codes are listed in the table below and illustrated in Figure 4-4. Area Codes will during Detail phase be subject for development. This will take place in close collaboration with Method. The 3D model Hierarchical structure will be developed to reflect modularization principles for each module and its related control objects, e.g. Struct. Piping system, Equipment, EIT.

Table 4-1 CCP Area Codes

[redacted]

[redacted]

4.2.2 Material Handling

The material handling requirements have been developed and implemented in the design in accordance with relevant statutory regulations, and further detailed based on relevant concept document and requirements from NORSOK R-002 & R-003, serving as an informative reference. Where necessary, the material handling philosophy and proposed handling solutions in the report is expected to be optimized with leaner and more efficient alternatives during the later design stages, ensuring that the suggested alternatives comply with statutory regulations and meet the project's requirements. Developed material handling philosophy and material handling reports are introduced in the documents listed below.

- Material handling philosophy, HI2305-AKE-L-FD-0001
- Material handling report, HI2305-AKE-L-RA-0001

The Material Handling Report document will be assessed separately and document updated accordingly during early detail engineering.

[redacted]

4.2.3 [redacted]

4.3 [redacted]

[redacted]

The below image shows the plan view of the Carbon Capture facility in the 3D model.

[redacted]

4.3.1 Carbon Capture Unit

The following items are included in the Carbon Capture Unit:

1. Flue Gas Fan
2. DCC and BDU filter
3. Absorber

4. Desorber
5. Carbon Capture equipment modules
6. Closed drain vessel (UG)

In the current layout, the DCC, Flue gas fan and Absorber are located in such a way that the flue gas ducting from the main piperack to the Flue gas fan, DCC and then Absorber can be routed as short as possible, ref Figure 4-7.

[redacted]

[redacted]

The DCC column is located in a separate bunded area, whereas the Absorber, Desorber and Desorber overhead vessel are located in a common bunded area. A structural steel shed is considered around the DCC, Absorber, Desorber, and Desorber overhead vessel to provide partial weather protection against rain and snow to prevent ingress of rainwater/snowfall with the potentially spilled chemicals within the bunded area. A peripheral road is planned on the East side of the columns for allowing traffic to pass, and to allow for crane operation in case of material handling for maintenance for the items located around the columns.

On the West side of the columns, there is a technological structure where most Carbon Capture equipment is located. The structure consists of two levels of equipment modules and single level of pipe rack modules, ref Figure 4-8. On top of the second Equipment module, the Reboiler and Energy Saver fan are placed in the open area.

[redacted]

[redacted]

Each module will be prefabricated, painted, insulated and pressure tested at the fabrication yard prior to transportation to the Klemetsrud site where the modules will be installed and hooked up together. Same as the columns, there is a steel structure weather protection on top of the Carbon Capture modules to prevent rainwater/snowfall contamination with potential chemical spillages inside the modules. For more details about chemical spillages and collection pits refer to the Vent & Drainage Philosophy, /34/.

The closed drain vessel is located just by the Carbon Capture Modules on the South side. All Amine spillages will be routed to the closed drain vessel, ref Figure 4-9.

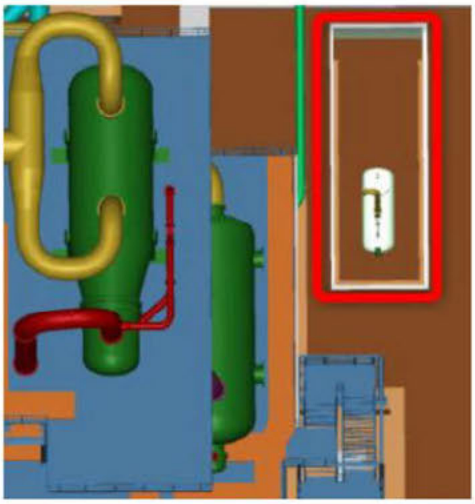

Figure 4-9 Closed Drain Vessel

[redacted]

4.3.3 Reclaimer Unit

The reclaimer skid is located on the South side of the columns in the Carbon Capture Unit (see figure 4.7). This unit will be in operation a few times per year when the solvent reclamation process is required. It is located in a bunded area to collect potential spillage. There is an adjacent road on the East side of the unit providing easy access for removing the reclaimer waste.

[redacted]

[redacted]

4.3.4 E-house

[redacted]

4.4 [redacted]

The compressor package (Number 1 in Figure 4-13) is located in the East part of the room, whereas the dryer package (Number 2 in Figure 4-13) is located in the Northwest part of the room. For material handling and maintenance, space is allocated on the North side of the compressor package and South side of the dryer package. Monorail beams are considered above the compressor package for lifting of compressor parts in case of maintenance.

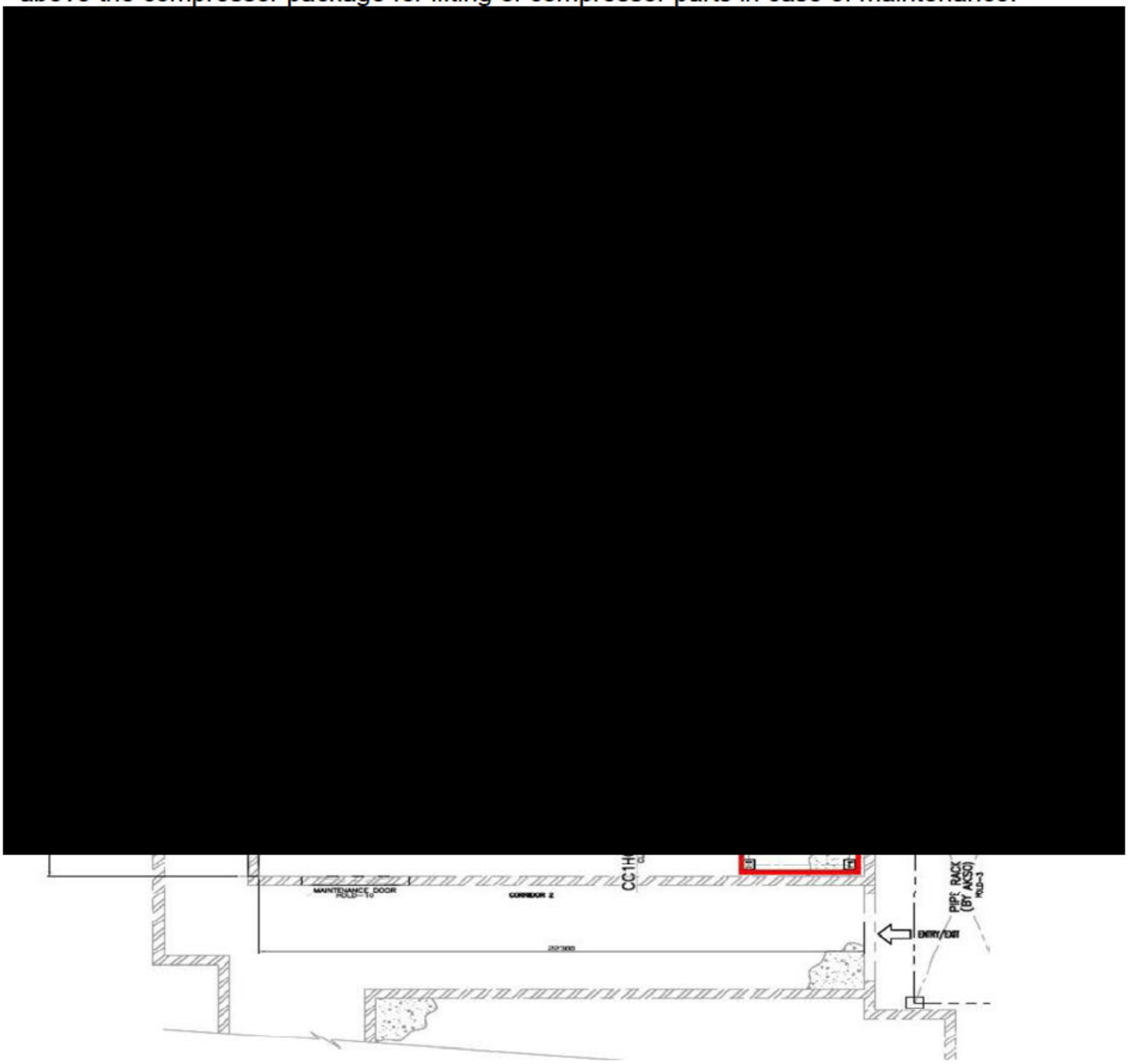

Figure 4-13 CO_2 Compressor Room Arrangement

4.5 CO_2 Liquefaction Module, CO_2 Storage Tanks and Truck Loading Station

4.5.1 CO_2 Liquefaction Module

The CO2 Liquefaction Module is located on the South side of the E-house and East side of the CO2 compressor room in the Technical Building. The location is considered to minimize the pipe routing, and corresponding pressure drop, between the compressor room and the Liquefaction Module.

The CO2 liquefaction Module has three levels where each level consists of two side-by-side modules. These modules will be prefabricated, painted, insulated and pressure tested at the fabrication yard, before they are transported to site and hooked up. The pipe rack on the North side of the module will connect all the pipes from the CO2 Compressor room to the CO2 Liquefaction Module, whereas the Eastern pipe rack will be used for connecting the pipes between the CO2 Liquefaction Module and The CO2 Storage Tanks. There is also cable tray routing from the E-house to the Liquefaction Unit for electrical power cables. See Figure 4-14 for the Liquefaction Module arrangement. There is a stair tower on the East side of the module which is shared between the Liquefaction Module and CO2 Storage Tanks.

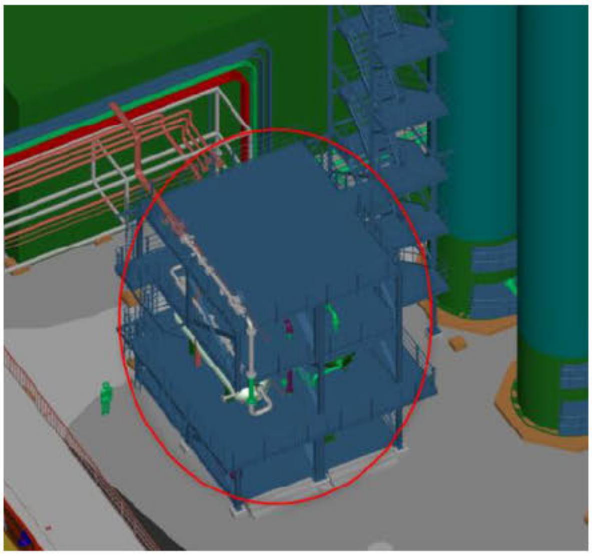

Figure 4-14 Liquefaction Module Arrangement

4.5.2 CO_2 Storage Tanks

Because of the challenges imposed by: 1) the transportation dimensions and weight restrictions in the roads to the plant and 2) the manufacturing/installation methods of the CO2 storage tanks, it has been agreed to install six vertical CO2 storage tanks with a total storage capacity of [redacted], which is equivalent to one day CO2 production at the WtE plant. The tanks are located on the East side of the Liquefaction module. There is a platform on top of the tanks which connects the CO2 storage tanks together. There is a shared stair tower between the Liquefaction Module and the CO2 storage tanks on the North side of the tanks (as primary escape route) and ladder arrangement for the CO2 storage tank located furthest South (as secondary escape). The CO2 export pump skids are located on the East side of the storage tanks and are accessible from the adjacent road for material handling and maintenance. A pipe rack on the East side of the storage tanks connects the pipes between the tanks and the Truck Loading Station on the South side of the tanks.

Figure 4-15 CO_2 Storage Tank Area

4.5.3 Truck Loading Station

The Truck Loading Station is located on the South side of the CO2 Storage Tanks and consists of three loading stations. Each loading station is equipped with a loading arm. A pipe rack from the CO2 Storage tank area will support the lines between the CO2 storage tanks and truck loading stations, and another pipe rack with East-West direction will further distribute the lines to each of the loading stations. There will be physical barriers around the loading stations to protect the stations from potential collision by trucks.

The CO2 trucks will enter the Carbon Capture plant on the South side of the plant. There is a sliding gate for the truck entrance, and it is enough space behind the gate for one truck to stand still and wait for the loading stations to be available/gate to open, without disturbing the traffic to the existing WtE facility. Figure 4.12 shows the Truck Loading Station arrangement.

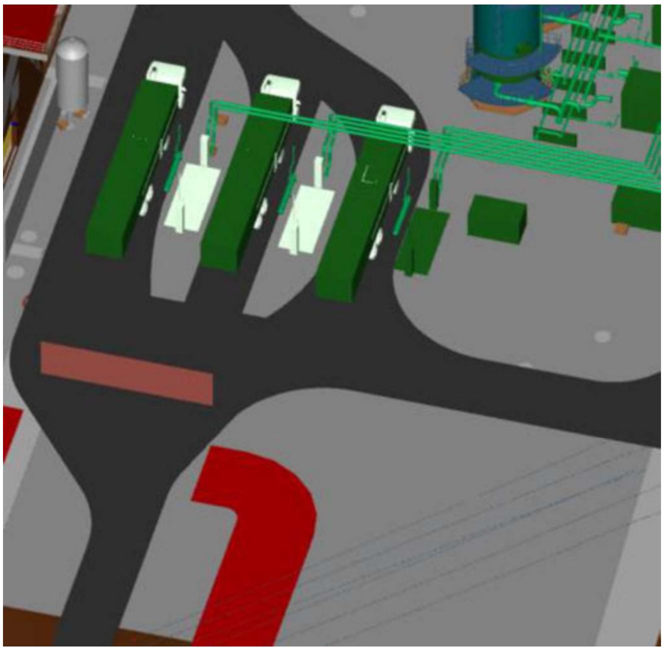

Figure 4-16 CO_2 Truck Loading Station Area

4.6 Technical Building

4.6.1 General

Ref Figure 4-17 the boundary area for the Technical Building as specified by Company during FEED indicated in red restricts the footprint size for the building for the South side, West side and North side. At the East side adjacent to the North half of the building the main pipe rack is located restricting the width in this direction.

In the North-South direction the Technical Building stretches approx. 83m. This is given by the [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

4.6.2 First Floor

[redacted]

[redacted]

View looking Down

Figure 4-21 Technical Building 1st Floor Layout

4.6.3 Second Floor

As part of the redevelopment of the Technical Building layout during the interim/pre-EPCIC [redacted]

[redacted]

View looking Down

Figure 4-22 Technical Building 2nd Floor Layout

4.6.4 Third Floor

[redacted]

[redacted]

Figure 4-23 Technical Building 3rd Floor Layout

4.6.5 Roof

Ref Figure 4-24 Technical Building Roof Layout

[redacted] shelter located at North side. CM expansion tank is located on elevated platform at Southeast side as it needs to be located above the highest CM consumer (air coolers).

Material handling cantilever platforms are currently implemented at east and west side of the CM air coolers, but the extent of platforms needs to be further developed during detail engineering phase in dialogue with the air cooler supplier.

[redacted]

Figure 4-24 Technical Building Roof Layout

Ref. Figure 4-25 Central elevated platform containing CM system valves arrangement.

[redacted]

[redacted]

Figure 4-25 CM Air Coolers with Access Platforms and Pipe Support Structures

4.7 Main Pipe Rack and Technical Building Pipe Modules

Piping systems have been modelled according to information given on piping and instrumentation diagrams (P&IDs). The number of pipe rack modules, module sizes, pipe expansion loops, pipe rack anchor bays etc. will be further studied in next phase of the project based on more information on pipes and process parameters.

As further described in Section 9, piping will be prefabricated and installed in pipe rack sections/modules at the fabrication yard which is then transported to site and installed. Flanges are considered between two modules for pipe connections. Evaluation regarding need for welded piping connections for some of the pipes must be performed during next phase of project (e.g., chemical lines). A typical module within the main pipe rack is shown in Figure 4-27.

[redacted]

[redacted]

As can be seen in Figure 4-27 below a section of the Main pipe rack have been designed according to agreed modularization principle with Method discipline and divided into three sub-modules with flanged connections planned to be assembled at side.

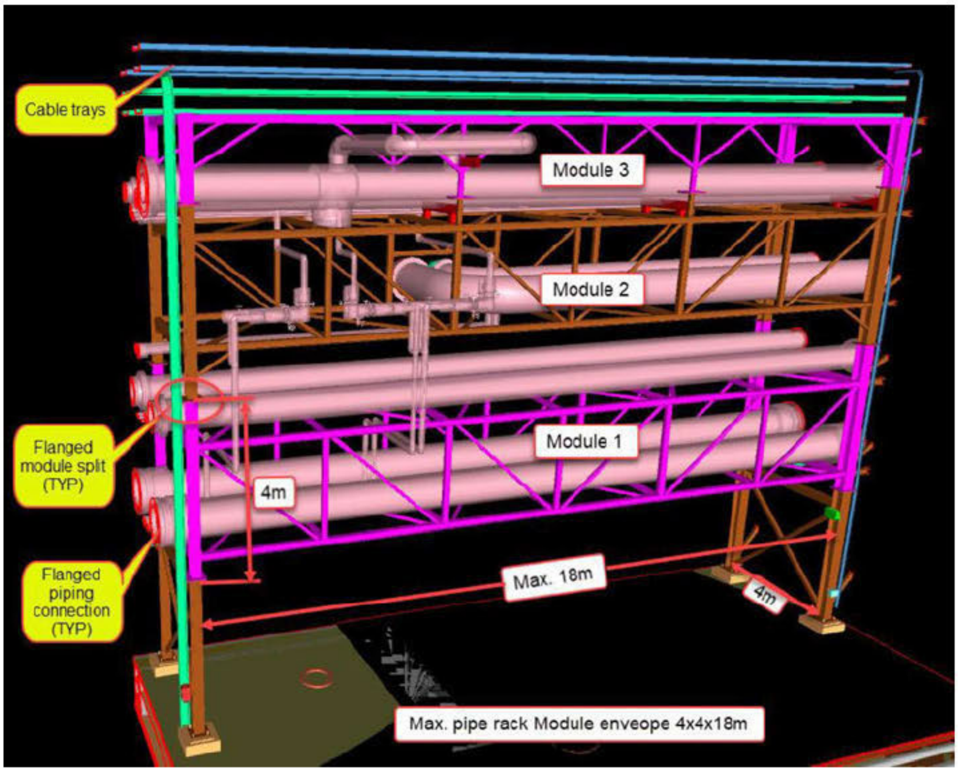

Figure 4-27 Typical Pipe Rack Module

Error! Reference source not found.

4.8 EIT Area Design

[redacted]

4.9 [redacted]

4.9.1 [redacted]

[redacted]

4.9.2 [redacted]

[redacted]

4.9.3 [redacted]

4.10 Piping Engineering and Pipe Stress

4.10.1 Piping Materials-, Valve- and Package Specs

A project specific Piping Material Specification (PMS), /37/, has been established mainly based on use of ASME B31.3, except for some of the steam system and all of the district heating piping where EN13480 is utilized as governing standard. The specification is used a basis for the P&IDs developed during FEED, as well as the Cats&Specs in the 3D-model.

A Valve Material Specification (Valve Datasheet) specification, /38/, has been established based on Contractor`s experience from earlier project, however, will need more refinement in the next project phase. Type of valves selected for the FEED design has been performed mainly based on Contractor`s best practice from earlier projects, except where specific requirements are included in Company`s governing documents (e.g., steam, condensate and district heating).

To provide input to the EPCIC cost estimate, as well as improve the quality in the technical design for the GRP flue gas duct, a simplified package specification has been established and used in dialogue with a possible GRP duct Vendor.

A Piping special items list has been developed based on the FEED design, /39/.

4.10.2 Pipe Stress

The 3D model has been matured using robust piping design principles and experience. Considerations have been made to incorporating flexible pipe routing with sufficient space for future dimensioning of supports following pipe stress calculations in later phases.

The ASME B31.3 standard is followed for pipe flexibility analysis. Pipe stress critical lines for detailed stress analysis are identified based on criteria defined in the Pipe Stress Analysis Procedure (HI2305-AKE-L-FD-0002). Pipe stress critical lines are listed in Pipe Stress Critical Line List (HI2305-AKE-L-LA-2001).

Piping flexibility is provided based on a visual check and Caesar II software analysis. Requirement for expansion loops in the pipe rack is checked based on the line temperature and pipe run on the pipe rack. For large bore lines on the pipe racks, a detailed stress analysis using Caesar II software is performed considering rest and four-way guide support near to battery limit and results are found ok. Preliminary stress analysis is also performed for the district heating pump- and emergency steam cooler piping to check the flexibility requirements and results are found ok. Piping load input is provided to Civil/Structural disciplines as UDL (KN/m2, KN/m). Horizontal loads for large bore lines on the pipe rack are provided based on Caesar II analysis results.

Furthermore, flexibility requirements should be checked based on OSBL piping layout, tie-in arrangements and equipment nozzle load allowable in the next phase of the project. Flue gas duct supporting and stress analysis will be done by the duct vendor.

4.10.3 PED Strategy

The CO_2 capture plant and associated utility system facilities shall be designed to comply with FOR-2017-10-10-1631 “Forskrift om Trykkpåkjent Utstyr” and Directive 2014/68/EC “Pressure Equipment Directive”, as applicable.

Responsibilities shall be identified for Contractor’s procurement scope, and Contractor shall obtain Declarations of Conformity and any relevant certificates from suppliers, as applicable.

The Pressure Equipment Directive applies for the manufacture, test and conformity assessment of pressure equipment/ pipe works with a maximum allowable pressure greater than 0.5barg. The PED strategy and requirements shall be verified by a Notified Body (No Bo) during detailed engineering phase and the verification report submitted to Company.

For more details, refer to document HI2305-AKE-L-SA-0005 - Declaration Of Conformity And CE Marking Including National Legislations Strategy.

4.11 Structural Engineering

4.11.1 Introduction

This section describes the structural scope for the FEED/Pre-EPCIC CCP Klemetsrud project. The structural design is based on the design basis as described in /40/. The structural analysis work has focused on the development of a concept which works satisfactorily in operational phase as well as for the temporary phases, to a FEED detailing level.

The purpose of the operational and temporary analyses is to demonstrate that the structure can safely support the design loads in accordance with requirements from Company and the applicable EN standards.

In the pre-EPCIC phase the structures geometry have been updated according to other disciplines requirements and structural strength. Structures have been added, deleted and/or modified.

In area CW50 three new pipe racks and stair tower for access to CO2 storage tanks have been transferred from SLBC scope to Aker. No analysis has been done for these structures due to late transfer.

4.11.2 Scope

The structural scope in FEED/Pre-EPCIC covers design and analysis of the outfitting structures on the Klemetsrud plant as shown in Figure 4-31 and Figure 4-32, and listed in Table 4-2. In addition to this it will also be miscellaneous structures such as equipment supports, lifting lugs and monorails in the structural scope.

Table 4-2 List of Structures

[redacted]

[redacted]

[redacted]

Figure 4-31 Structural Layout

[redacted]

Figure 4-32 Structures Inside Technical Building

4.11.3 Design Considerations

4.11.3.1 General

Structural analyses and calculations have been performed to demonstrate that the structures can safely support the design loads in accordance with regulatory and Company requirements. Further details can be found in the structural design reports, /41/ and /43/.

Access platform - 02 & 03 for damper access in the flue gas ducts are supported on existing structure K1 & K2, and corresponding support reactions are provided to Company during FEED. Checking of existing structures strength and stability is Company scope and has hence not been performed by Contractor.

The structures have been developed with the following criteria in mind:

- Reduce total cost
- Reduce weight compared to previous similar projects
- Easy installation
- Minimize stick-building at site
- Minimize/avoid welding, sandblasting, and painting at site

This has resulted in:

- Modularizing of pipe and equipment structure
- Modularizing of pipe rack
- Prefabricate pipe supports and pipe support frames in all areas

4.11.3.2 Material Selection

For selection of structural materials reference is made to the Material Selection Report, /42/.

S355MPa steel has been used for all structural steel. S275MPa steel has been used for Ladder and handrail, whereas grating will be of 355MPa steel and hot dipped galvanized. An alternative option for grating material as FRP was partially studied in the VIP workshop during FEED, but further evaluation and confirmation needs to be done in the detail engineering phase.

S420I Steel shall be used for lifting lugs.

Stainless steel joint will be used for the sliding / rest support.

Slotted holes shall be used at the interconnecting structure to structure/module.

4.11.3.3 Analysis Summary and Method

The structures are analyzed using STAAD-Pro software and hand calculations. Structural analysis for the following design conditions have been performed in FEED phase:

- ULS, SLS operation.

Analysis results confirm that the member framing arrangements and member sizes shown in the 3D-model are sufficient for the outfitting structures under operational and non-operational conditions.

During the Pre-EPCIC phase, no updates have been made to STAAD-Pro analysis models.

5 TECHNICAL DESCRIPTION

5.1 HSE in Design

The risk level at the CCP plant shall be reduced to a level which can be reasonably achieved. The criterion 'which can be reasonably achieved' expresses a principle (ALARP) where costs associated with risk reduction must be compared with the safety benefit that can be achieved.

The following HSE reviews have been performed throughout the FEED phase of the project, see Table 5-1.

Table 5-1 HSE reviews

HSE review name	Date	Objective / Scope of Work	[redacted]
HAZID	14.02.2024	The objective of the Hazard Identification (HAZID) was to identify hazards, evaluate the potential consequences and preventive and mitigating safeguards.	
HAZOP	18-22.03.2024	The objective of the Hazard and Operability (HAZOP) study was a structured and systematic examination of the planned process in order to identify and evaluate problems that may represent risks to personnel or equipment, or prevent efficient operation.	
LOPA	10-11.04.2024	The objective of the Layer of Protection Analysis (LOPA) was to estimate the risk associated with hazardous scenarios in a semi-quantitative way, to determine whether protection layers provide sufficient risk reduction to achieve a predefined tolerability criterion.	
Layout / Working environment review	23-24.04.2024	The objective of the Layout and Working environment review was to assess the layout with respect to working environment, access, operability, material handling and maintainability, as well as personnel safety.	
Constructability review - Civil	12.03.2024	The objective of the risk assessment was to identify hazards to be able to design good solutions and plan measures with respect to safety, health and working environment in the construction phase.	

HSE review name	Date	Objective / Scope of Work	[redacted]
Constructability review - Overall	07.05.2024	The objective of the constructability review was to identify issues with respect to HSE during construction phase to enhance good solutions and propose mitigating measures if found necessary.	
Chemical health risk assessment review	22.05.2024	The objective of the CHRA was to identify, evaluate and control chemical health risks to an acceptable level, to identify possible problem areas related to chemical handling, and to provide input to engineering based on findings in the workshop.	

Actions and recommendations were recorded throughout the reviews. Follow-[redacted] performed continuously throughout the FEED phase, and updated status is presented in Appendix A (not updated for Pre-EPCIC phase).

5.1.1 Technical Safety

[redacted]

[redacted]

5.1.2 Functional Safety

[redacted]

5.1.3 External Environment and Life Cycle Assessment (LCA)

For the external environment work emissions to air, energy consumption, liquid effluents, waste, and chemicals have been identified and described in the External Environment Report incl. Waste Handling, /49/. The report has been updated in the Pre-EPCIC Phase.

Emissions to Air

The cleaned flue gas is emitted from a stack on top of the Absorber, elevation 80m. A flue gas dispersion study has shown that the stack height and location are acceptable with respect to ground level concentration of pollutants.

The following techniques/equipment are included in design to reduce emissions to air from the Absorber:

- Selection of HSE friendly ACC™ S26 amine solvent for CO2 capture
- Flue gas pre-treatment in Direct Contact Cooler (DCC)
- Brownian Demister Unit (BDU) Filter
- Absorber wash sections
- Anti-mist design
- Acid wash

Energy Consumption

The CO2 capture process requires LP steam (19 (min.)/42 (normal)/48 (max.) MW) continuously for the Reboiler and MP steam (1.5 MW) intermittently for the Reclaimer, which are both provided by the existing WtE Plant. An Energy Saver System is included to reduce the steam requirement (approximately 10%) with a comparatively small electrical power consumption.

A Heat Pump System is installed to compensate for the steam routed from the WtE Plant to the CCP. The Heat Pump System uses low-grade heat from the Cooling Medium System and delivers heat (up to 60MW) to the WtE Plant District Heating (DH) system.

The CO2 dehydration unit is provided with an economizer to reduce the energy consumption.

[redacted]

The CCP uses air cooling, so there is no cooling water consumption or discharges.

Liquid Effluents and Waste

The Direct Contact Cooler (DCC) bleed is treated for production of demineralized water and removal of contaminants. The demineralized water is routed to the WtE Plant and in this way re-used. The cleaned reject from the Waste Water Treatment (WWT) System is discharged to the public sewer.

[redacted]

- Spent desiccants from the CO2 Dehydration Package

Chemicals

In the Pre-EPCIC Phase it was decided to change cooling medium from monoethylene glycol (MEG)/water mixture to a more HSE friendly DOWCAL 200E/water mixture. DOWCAL 200E is not a classified chemical, i.e. not a hazardous substance.

For the heat pump, it was late in the Pre-EPCIC Phase decided to change from isobutane to R1234ze(E), an hydrofluoroolefin (HFO), as refrigerant. HFOs degrade to produce trifluoroacetic acid (TFA). TFA is associated with long environmental lifetime and negative impact on the environment and human health, and the use of this refrigerant may be banned in the future. Refer to Chapter 3.4.1.2 Refrigerant for more information.

Life Cycle Assessment (LCA) for GWP / CO2 Footprint

An LCA for Global Warming Potential (GWP), also called CO2 footprint calculation, was performed for the FEED Phase. For the Pre-EPCIC Phase it was decided that this calculation will be performed by 3rd party (Carbon Limits) and updated input to the LCA has been given. This work is followed up by Company.

5.1.4 Working Environment (WE)

Working Environment (WE) analyses have been performed to identify and assess occupational safety and health risks and ensure that the design of the new CCP plant is in accordance with statutory and Company WE requirements. The following main activities have been performed:

- Establishment of Working Environment Area Limits (WEAL)
- Layout and Working Environment Review (including high level WERA)
- Chemical Health Risk Assessment (CHRA)
- Input of WE requirement to the Package Specification Template (PST) and individual equipment package specifications

These WE activities were primarily performed in FEED and are further described in the below subsections. The layout changes of the Pre-EPCIC phase during Autumn 2024 have not been reflected in an update of the WEAL document. However, no major impacts are foreseen as the general areas are similar and hence the same WEAL requirements will still apply despite changes to room/area locations.

Moreover, no formal update of layout/WE or chemical health risk reviews have been performed associated with the changes of the Pre-EPCIC phase. However, no major impacts are foreseen.

A summary of the noise control engineering activities is provided in Section 5.1.5 and further described in the Noise Prediction Report, /50/.

Working Environment Area Limits (WEAL)

WEALs have been established for the rooms and areas introduced as part of the new CCP plant, ref. the WEAL – Working Environment Area Limits document, /51/. The WEALs are based on applicable requirements and provide input to engineering on the area limits for illumination, noise (total and HVAC), temperature, and number of air changes for each room/work area. The WEALs also include the area manning levels. Furthermore, the main chemicals and hazardous substances of the various areas identified in FEED have been included.

Layout and Working Environment Review

As per agreement with Company it was concluded to include the Working Environment Risk Assessment (WERA) into the Layout and Working Environment Review, which is further described in Section 5.1.

Chemical Health Risk Assessment (CHRA)

A CHRA has been performed to identify, evaluate, and control chemical health risk to an acceptable level for activities where hazardous chemicals are planned used during operation, maintenance, transport and storage. Details are given in the Chemical Health Risk Assessment Report, /52/.

During normal operations the risk of occupational hazards due to exposure to hazardous chemicals is found to be relatively low. The majority of the chemicals and hazardous substances will be handled through closed, automated systems, giving no exposure to the operators. Sampling will also be fully automated or through closed systems.

The main source of chemical exposure will be during maintenance and cleaning of the systems, or when working on parts which are currently not fully enclosed and/or automated, [redacted] truck. The arrangement for flushing, draining and collection of spills and liquids throughout the new CCS plant must be further developed in Detail design to ensure solutions that minimizes the risk of chemical exposure.

Actions from the assessment have been transferred to the CHRA Action follow-up register (ref. Appendix A) for tracking and close-out.

5.1.5 Noise

The CCP has been evaluated with regards to acoustics and noise control in order to ensure that the statutory requirements for noise to surrounding areas and working environment requirements are met when the plant is in operation. Details are given in the project Noise Prediction Report, /50/.

The external third-party consultancy, Brekke & Strand, has evaluated noise emission from the complete plant at the specified neighboring addresses identified as governing by Company in the project Design Basis, and developed noise budgets for the CCP areas that will need to be met during the design development. Based on these, specific area limits have been applied and are summarized in the project Working Environment Area Limits document. The area limits have consequently been the basis for deriving equipment noise limits for the main noise emitting items, and these have been included in noise data sheets, submitted to prospective suppliers as part of preliminary enquiry documents, as applicable.

The Fin Fan Air Coolers have been regarded as the main external noise source on the CCP plant. The conclusion at this stage is that the supplier will be able to meet the budget noise limit for the roof of the Technical Building even given that the height is now increased compared to the concept phase. This will be closely followed up in the next phase.

The civil engineering contractor, Multiconsult, has worked on design of the Technical Building. This has included specifying internal wall surfaces with regard to need for acoustic absorption in the rooms with noise limits of 90 and 110dBA. Additionally, the need for specific requirements for noise insulation of blast panels and design of the HVAC system in order to minimize noise emission to the surrounding external environment has been evaluated. More details are given in Section 6.8.7.

5.2 Mechanical & Engineering for Procurement (EfP)

All mechanical equipment is defined within mechanical procurement packages. Procurement packages are defined as Priority 1, Priority 2 or Priority 3 packages, where Priority 1 is given to long lead equipment and equipment essential for system and area design.

For details of main equipment see Master Equipment List, ref /35/.

5.2.1 Mechanical and EfP FEED Deliverables

The following documents are defined as Mechanical deliverables in FEED:

- Package Specification Template (PST)
- Master Equipment List (MEL)
- Individual equipment package specifications

A Package Specification Template (PST) (HI2305-AKE-Z-SA-0002) is developed to include minimum of technical requirements for equipment packages in general, based on the FEED Contract requirements.

Individual package specifications will be made in the next phase and will be based on the PST. Focus in this process is given to defining industrialized equipment fit for purpose, where no “nice-to-have” additions are included.

Master Equipment List (MEL), ref /35/, lists all tagged mechanical equipment (AKSO, ACC, Norsk Energi and Multiconsult), reference to procurement packages and main technical attributes. Information in the MEL is best available information based on supplier input at this stage of the project. It shall be noted that no purchase orders have been placed and supplier info is non-binding. However, detailed clarifications with suppliers were conducted for the critical equipment packages and information given in Section 5.2.2 is based on actual supplier responses.

For mechanical equipment, package specifications have been established for the major equipment packages using the templates for the project. The specifications follow a common structure and is based on Contractor`s experience with already executed projects. However, each package specification is tailor-made for the applicable scope for any package. Equipment process data sheets are normally always attached to the technical specifications to convey all process parameters for the applicable equipment. In addition, surface protection specification (HI2305-AKE-M-SA-0001) and Insulation design specification (HI2305-AKE-M-SA-0002) are normally attached to package specifications. Other data, like mechanical design parameters, dimensions, layout and safety requirements etc. are all included in the package specification documents.

A list of all the package specifications prepared for the project are listed in the table below:

Table 5-2 Mechanical Package Specifications Prepared During FEED

[redacted]

Package specifications are also prepared for selected items that does not fall into the mechanical discipline such as Instrumentation (control valves, safety valves, etc.), electrical, piping, etc. and the scope of these documents is described in the respective chapter for each discipline.

An RFQ including equipment process datasheet, package specification and documentation requirements has been issued to various qualified suppliers for all major equipment. After bid receipt from suppliers, preliminary bid clarifications have been performed to short-listed bidders. The intention of this has been to establish a correct vendor scope for pricing and planning, as well as laying the foundation for a potential Purchase Order in the EPCIC phase. Need-to-have principles are followed for the specifications and negotiations with suppliers. Also, deviations to the given requirements will be thoroughly evaluated if they have the potential for savings in cost, schedule or other project parameters.

5.2.2 Main Mechanical Packages

Due to the relevance for the project in terms of design, construction and transportation complexity, cost, schedule, dimensions, etc. the following equipment was given priority by the mechanical team during the FEED stage:

Carbon Capture Plant Columns

The columns DCC, Absorber and Desorber are heavy and large mechanical items that require particular attention for transport, site works and installation. The Desorber is a pressure vessel and hence needs CE marking and PED approval. The intention is therefore to complete the fabrication at the supplier's works, and then transport the vessel in several flanged pieces to site for installation. The current flanged design is selected to avoid performing hydrotesting of the vessel at site.

The Absorber and DCC are larger in diameter and more difficult to transport as single items. It is therefore planned to build these columns at site. Plates will be pre-fabricated as far as possible at the supplier's works, and transport parts to site for final fabrication and installation. This procedure, however, requires large resources on site both for area, equipment and personnel and will need thorough preparation.

All columns will require installation of process packing after final erection. The reason for this is that such packing for the applicable dimensions is not designed for transport and lifting loads or loads in several directions.

CO2 Compressor

The CO2 Compressor [redacted] A multistage integral centrifugal compressor of considerable dimensions is foreseen. The compressor will be driven by an electrical motor and its capacity will be controlled by a VFD. In addition to the compressor unit itself, lube oil unit, coolers, CO2 dryer package and flash separators will be required for the complete compression and liquefaction process. The role of the compressor in the process as well as its location in the plant and the complexity inherent to the package makes it a key component in the project and therefore substantial attention is given to this package and the preparation for the documentation for RFQ and the evaluation of bidders.

CO2 Storage Tanks

The current proposed design requires several storage tanks for intermediate storage of liquid CO2 prior to export are planned. The maximum diameter of the vessel is limited such that these can be transported to site and as a result the number of tanks cannot be reduced. In connection with the tanks, truck loading stations will be installed for the filling of trucks for export to the terminal. Because of the dimensions of the tanks, the equipment requires special attention for selection of bidders.

Waste Water Treatment Package

For the Wastewater Treatment Package various vendors were approached to obtain an optimal technological solution for the package. Technical clarifications were also conducted to discuss and close open points. Vendors capable of delivering all the required treatment stages to fulfil the requirements in the discharge permit were prioritized to avoid splitting the WWT package scope on several Vendors. At the end of the FEED, three bidders are evaluated to be technically compliant, but due to having provided the best technical solution, the FEED design is based on the solution proposed by Cannon Artes.

In the next phase of the project, it is recommended that the technological solution is further developed preferably through a pilot study with short listed bidders.

Cooling Medium Air Coolers

A revised budget offer including technical details has been received from potential bidders for the Cooling Medium Air Coolers, adjusted for the revised roof layout of the Technical Building. The required height between the roof and the top of the fans has been significantly increased, however, it is expected that this may be further challenged in the next phase.

Air Compressor

For the Compressed Air Package, the technical description is based on a budget offer from Atlas Copco. The current layout is based a non-containerized solution, The package consists of Compressor skid, dryer skid and air receiver, [redacted]

Heat Pumps

The heat pump system will be based on large industrial heat pump units using centrifugal compressors. This technology is considered as BAT for process requirements and system design in the project. For further technical details, reference is made to Section 3.4.1.

The RFQ process for a heat pump system with HFO-1234ze as refrigerant was initiated during Pre-EPCIC and the RFQ has been sent to five suppliers. Preliminary discussion has been done with most suppliers and discussions regarding layout and space requirements within the [redacted]

5.3 Operations and Maintenance

5.3.1 RAM Analysis

RAM-analysis for the FEED CCP Klemetsrud, encompassing the CO2 capture and liquefaction plant, as well as main utility systems, has been performed by Norconsult Norge AS in close collaboration with Contractor. The purpose of the early RAM-analysis was to estimate the production availability of the FEED CCP Klemetsrud and corresponding equipment sparing and system design.

The major contributors to production unavailability are identified and presented in the RAM analysis Report, /31/, where the CO2 compressor is found to be the main contributor. In addition, sensitivities are assessed and described in the report.

The production availability for the CCP Klemetsrud plant is estimated to 94.8%. The assumptions for RAM analyses is in the RAM analyses Report (HI2305-AKE-K-RA-0001). The RAM analyses have not been updated; however no major changes are foreseen.

5.3.2 Operation and Maintenance Philosophy

The Operation and Maintenance (O&M) Philosophy is a collaborative document produced by Contractor and reviewed by Company. It is intended for use as a basis for achieving safe, efficient, and environmentally responsible operation and maintenance of the Klemetsrud CCP facility and should be updated based on maturity of the design.

General Philosophy:

- The CCP shall be integrated with the WtE Plant such that the primary task, incineration of waste and delivery of heat to the district heating network, is not negatively impacted during any phase of the project. The operation of the CCP is not allowed to affect the operability, maintainability, availability, or capacity of any of the incineration lines.
- Operations will be based on a philosophy of low manning and utilizing a high degree of automation. The CCP can be operated remotely from the existing WtE Plant central control room.
- Minimum maintenance or inspection intervention on equipment is required to achieve the required availability rate. For the same reason and when needed planned maintenance or inspection shall be planned as much as possible during the yearly maintenance stop.
- Calendar based maintenance shall be challenged by monitoring performance and be carried out where regulations dictate a calendar-based test regime
- Spare parts and warehousing strategy shall consider the balance between OPEX and plant availability

For further details, reference is made to the O&M philosophy /32/.

5.4 Materials, Surface Treatment and Insulation

During the FEED phase, the Material discipline has outlined the material selection for the equipment, piping, and structures for the CCP facility. The basis for the material selection has been based on Company`s design basis, experience, process data, and evaluations from previous similar installations.

Material selection is checked for all parties within Contractor’s organization. The selected materials shall when starting at the design phase be aiming for the best solution based on required corrosion resistance, cost involved, and production lead time.

Base material selected is carbon steel and stainless steel, grade 316SS. Higher alloyed corrosion resistant materials and plastic pipes are selected for systems and equipment with potential for higher corrosion rate.

The Material Selection Report, ref /42/, gives the current material selection for duct, piping and main equipment. A check versus Process has been made for materials on systems where acids are present. Use of non-metallic materials is preferred where found acceptable based on operational conditions and size, as carbon steel with internal lining for corrosive service has been found not to be the best solution for the specified design life.

Further evaluation of material selection will be done in the next phase based on suppliers' input/ bids, process data, and cost evaluation.

For surface protection, HI2305-AKE-M-SA-0001 Surface Protection Specification gives the current coating requirements for the fabrication yards. For procurement packages, the painting requirements will be based on ISO12944 and agreed with supplier for the individual package. Reducing painting requirements for piping is important during the fabrication period to avoid delays, therefore further checks of where painting is necessary and paint systems used will be done in the next phase.

Insulation requirements are described in HI2305-AKE-M-SA-0002 Insulation Design Specification. The insulation class build-up is based on insulation material normally used for the various temperatures and purposes. By standardization to fewer material alternatives, cost and time saving may be obtained. Further evaluation of insulation material will be made when detailed process data is available, which is planned to be in the next phase.

6 CIVIL

6.1 Civil Design Basis

The civil design for the CCP FEED has been developed based on the document HI2305-AKE-Q-RA-6001 /16/, and is further described in the sections below.

6.2 Ground Works and Site Conditions

The area intended for the process equipment and CO_2 storage tanks has as part of an earlier project phase been leveled and consists of a layer of compacted rock fill over bedrock. Foundations for the process equipment and CO_2 storage tanks will be established as direct foundations either on the gravel fill or directly on the bedrock. The basis for the FEED is that all foundations are direct foundations on gravel fill. The bedrock in the area is Gneiss.

The area where the Technical Building is to be established, the ground consists of gravel fill over dry crust over soft to medium firm clay. Accordingly, the Western side of the building is planned founded on steel core piles, while the Eastern side of the building will be founded on [redacted] the Southwest corner of the building, the size of the basement will have to be adapted to ensure room to install the sheet piles or alternatively perform open excavation. The details need to be reviewed in the next phase of the project.

The area required for the process equipment, access roads and handling of the surface water on the site, requires the site to have an extension to the East. The extension requires that parts of the existing support fill along the Klemetsrudveien road is removed. To compensate for the stability provided by this, an open culvert for the surface water acting as a support wall for the road will have to be established. The principles for establishing the culvert with retaining wall is shown in Figure 6-1 below. The stability of the road has been checked, and it will be required to close off the nearest lane if excavation is to be performed without installation of support structures (sheet piles etc.)

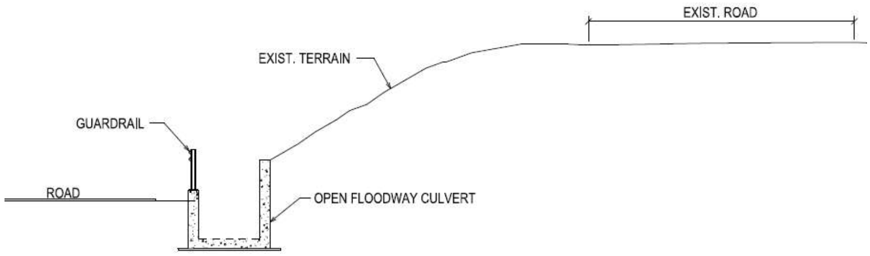

Figure 6-1: Open Floodway Culvert With Retaining Wall

6.2.1 Excavation and Site Preparation

As described in Section 6.2 the site has been leveled by use of rock blasting and filling to the site preparation level by others. The rock blasting has been performed to elevation 133.0 (OLH). The area has been backfilled by use of crushed rock 20/120mm, ref. HI2211-CWI-G-XF-3001, rev 4. Trenches for the underground systems such as firewater, drain and potable water need to be blasted at the site. The mases from this blasting need to be transported to a depot.

In total the required amount of excavated mases is estimated to approx. 13 090m^3, whereas the amount of backfilling is estimated to 10 370m^3. In addition, the top layer with crushed rock 8-32mm needs to be added approx. 2 510m^3.

The Klemetsrud site has limited space for storage of excavated mases, hence it is currently planned to transport the mases 20km to a depot. However, as a prat of the optimalisation is should be investigated finding a depot closer to the Klemetsrud site to reduce the transportation costs and the emissions to the environment.

6.2.2 Backfilling of Areas and Trenches

When installation in the trenches and on site is completed, the areas will be backfilled. The trenches will be backfilled with fine gravel 8-11mm around the pipes. The mases will be separated by use of fiber cloth. The general backfilling of the site after installation of foundation and trenches will be by reusing the excavated mases which then has to be transported back from the depot. As described in Section 6.2.1 the mases used is 20/120mm according to HI2211-CWI-G-XF-3001, rev 4. The site will be leveled by use of the existing mases to a level 300mm below FG (final grade). This layer will be compacted by means of a heavy vibration roller where applicable and smaller machinery towards the structures.

The top layer will be backfilled with 8/32mm crushed rock also with compaction.

6.3 Culverts, Underground Piping and Trenches

6.3.1 Firewater

Tie-in to the municipal water supply is into a dedicated underground pipe at the North end of the site, see also Section 4.9.3. From here, the pipe will go up into the nearby pipe rack to pass the existing equipment and buildings, before going back down underground for the rest of the CCP plant area. Firewater will be available from hydrant points in manholes located under the new road network (so that they will be kept free from snow). There is also a branch-off from this firewater pipe network into the Technical Building to supply the sprinkler system in the Heat Pump rooms. The firewater manholes will be designed according to requirements from Oslo municipality and Oslo Fire & Rescue.

6.3.2 Potable water

Most of the new potable water system will be up in the pipe rack from the tie-in point to the Technical Building and other end points. The extent of underground piping is limited to the few meters between the tie-in point, which is an underground pipe, to where the pipe goes up into the pipe rack.

6.3.3 Stormwater

The details of the stormwater system have been agreed with Oslo municipality who specify limitations on how the water is handled and how much can be discharged from the site.

Reference is made to the stormwater management report /22/ for further details.

The large Technical Building roof, and the ground conditions which make poor infiltration of water into the ground in the CCP area, present challenges to the prescribed way stormwater should be dealt with. Stormwater should be handled in three different ways:

- Stage 1 is infiltration of a certain amount of water into the top layer of the ground preventing it from ending up in the stormwater pipe system. This is not possible at the site due to the bedrock and clay ground conditions preventing adequate infiltration of water into the ground. The design allows for water falling onto the gravel surfaces to infiltrate into the rock fill, but there will be a set of drain pipes to collect up this water from the blasted rock surface (above the groundwater level) to ensure that the rock fill layer is properly drained. There will be a limited outflow from this drain system to the Ø1000mm culvert which is part of the total discharge limit from the CCP site set by Oslo municipality.
- Stage 2 is detention of the water collected in the stormwater pipe system and reduction to a prescribed maximum discharge rate set by Oslo municipality. It is proposed that buried large-diameter pipes will provide the necessary detention volume before the water is discharged in a controlled way into the existing Ø1000mm culvert below the WtE plant. Water from hard surfaces (roads and roofs) will be collected and sent to these detention basins.
- Stage 3 considers flood water. The Klemetsrud plant is located over a natural waterway, which has been laid in a Ø1000mm pipe culvert under the WtE plant. This means that it is a natural low point in the terrain and floodwater from surrounding areas will flow to the plant and the CCP area. It is proposed to route flood water two ways:
    - An open flood trench will be routed along the east side of the CCP plant area. At the southern end, there will be pipes under the main entrance road which convey the water further south out of the site.
    - Water that is not handled by the point above will flow south over the terrain surface. Attention needs to be given to the road level at the weigh-station area as this forms a local barrier to this surface water causing it to pool upstream.

/22/

6.3 [redacted]

6.3.5 Existing Stormwater Magazine

Between the existing ‘Line 3’ building and the Technical Building, there is an existing gravel-filled detention magazine for rainwater from the Line 3 building roof. The footprint of the new Technical Building is over a part of this magazine. In addition, it is proposed that the stormwater pipe from the CCP plant area will be laid under this magazine before it connects to the existing Ø1000mm stormwater culvert. Since the existing magazine has a watertight membrane surrounding the gravel fill, it will be difficult to excavate parts of it and restore it afterwards to its original integrity. It is therefore proposed to install large-diameter pipes as the detention volume here instead of the existing gravel magazine, keeping the existing discharge chamber as before. The discharge flow rate will therefore not be affected.

Gravel magazines are no longer recommended as a detention solution as experience shows that they will get blocked over time with silt.

6.4 [redacted]

6.5 Earthing and Bonding

The earthing systems are divided into sections which cover the Technical Building and each part of the process area. All sections have at least one connecting earthing wire between each other. Additionally, the new earthing system has a connecting point to the existing WtE plant earthing system.

The earthing system consists of foundation earth electrodes around all concrete foundations, mesh-grids beneath the concrete foundations, as well as earthing rods that are exothermic welded to the foundation earth electrodes. Down-conductor cables from the above ground lightning protection systems are exothermic welded to the foundation earth electrodes.

The earthing system also contains risers up to the earthing lugs on the foundations or equipment skids.

6.6 Foundations

The majority of foundations will follow the same general design principle, with concrete slabs supporting plinth/pedestals for bolting/fastening of equipment and structural

columns. Underneath the foundations slabs there will be a layer of approx. 50mm blinding atop approx. 100mm 8/32 crushed rock.

FG level at elevation +134.500m (OLH). TOC elevation of slabs will typically be 500mm-800mm below FG (EL. +133.700 to +134.000). BOC elevation for foundation slabs will generally be at EL. +133.200m, corresponding to 200mm above BL from the earlier executed site preparation contract. This BOC elevation is used for all major foundations except where stability, equipment requirements or ground conditions necessitate a deeper foundation. This general BOC elevation should minimize additional rock blasting while still ensuring space for potential underground installations like duct banks etc. to cross above foundations.

For plinths typically TOC level will be at EL. +134.760m (OLH) with a 40mm layer of expanding grouting between concrete plinths and steel baseplates. Meaning bottom of baseplate for equipment and steel columns is located 300mm above FG level corresponding to EL. +134.800m. Stability for overturning is the governing design constraint determining size of most foundations. With the exception of the tank foundations most equipment and columns will be fastened with bolts embedded in corrugated pipes cast in plinths (see Figure 6-2). The corrugated pipes are to be removed prior to grouting of bolts.

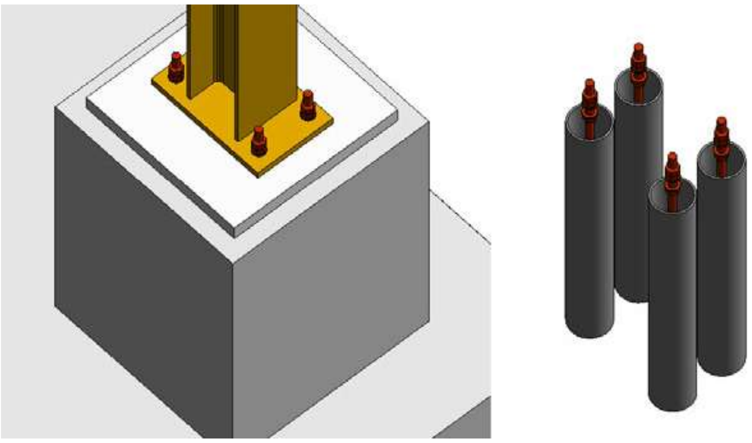

Figure 6-2 Typ. Bolts in Corrugated Pipes

6.6.1 Pipe Rack-, Platform- and Module Foundations

Several foundations are required at site to support various pipe racks and access platforms. Typical slab size for pipe rack foundation have been set to 5.4m x 4.0m x 0.8m (L x W x T) based on loads from previous projects. It is expected that more detailed load input in next phase will allow for reduction of foundations size for many of these foundations due to substantially reduced wind load in comparison with the reference project used for preliminary FEED calculations.

[redacted]

Figure 6-3 Pipe Rack Foundation

For pipe racks constructed close to the existing K3 building, additional work must be undertaken to ensure no differential settlement below the foundation. These foundations are located above sloping bedrock between old BL for the K3 structure and general BL at new site (see Figure 6-4). This work entails drilling/blasting “shelves” in sloping bedrock underneath foundations and casting lean concrete blocks up to BL for site at EL. +133.000m (OLH).

[redacted]

Figure 6-4 Bedrock Slope Towards K3 Basement

During the site preparation phase a small concrete retaining wall was cast along the site boundary towards the K3 building to avoid water draining into the basement of the K3 building. This temporary retaining wall needs to be demolished prior to construction of the new foundations. A new wall to be established.

Foundations for various access platforms will be designed similar to the pipe rack foundations with one plinth for each structural column.

Foundations for access platforms close to the existing WtE chimneys will need lean concrete filling to ensure no differential settlement similar to pipe rack foundations close to the K3 building (see Figure 6-5). The lean concrete should be cast so bottom of filling is at same depth as BOC for the existing chimney foundation. The foundation for the tallest access platform next to the chimney also needs a substantial slab with thickness (min. 1500mm based on FEED load input) in order to achieve sufficient stability.

[redacted]

Figure 6-5 Platforms Close to Existing Chimney

Figure 6-6 Liquefaction Module Foundation

Other prefabricated modules like pipe racks and platforms modules will be installed on foundations with plinths using bolts in corrugated pipes (see Figure 6-6).

6.6.2 Tank Foundations

Tank foundations including foundations for DCC, Absorber, Desorber, CO_2 storage tanks and chemical storage tanks will all be of a similar design (see Figure 6-7) with the tanks supported on octagonal plinth atop foundation slabs. The recommended fastening solution for tanks consists of embedded steel ring templates with threaded sleeves for anchor bolts and guiding pins for installation (see Figure 6-8).

[redacted]

Figure 6-7 Liquid CO_2 Storage Tank Foundations

[redacted]

6.6.3 Equipment Foundations

Foundations for minor equipment will consist of plinths on slab like most other foundations. Some of the larger equipment that is not part of prefabricated modules will however be bolted directly to the foundations slab. For these foundations the TOC of the slab needs to be above FG Level (see Figure 6-9).

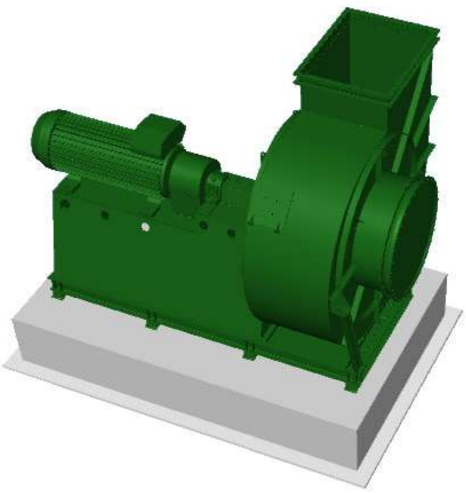

Figure 6-9 Flue Gas Fan Foundation

The closed drain amine tank foundation close to the reclaimer module will be constructed at an elevation below the general BL. As such, a pit for this foundation needs to be blasted in bedrock to the appropriate elevation. Additionally, walls will be constructed adequate to resist earth pressure and water ingress into the sump (see Figure 6-10). The sump will be closed with a removable concrete lid where TOC is flush with FG to avoid rainwater collection.

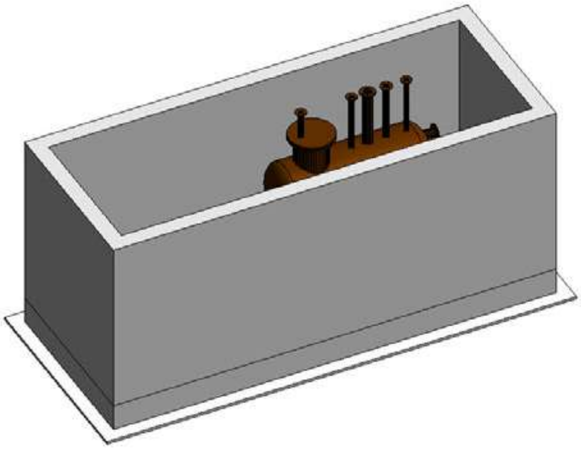

Figure 6-10 Amine Drain Tank Foundation

6.6.4 Paving, Bund Walls and Shed Foundations

Watertight bund walls and paving is required for several tanks and process equipment, where there is a risk of chemical spillage, in order to contain any liquids and prevent leakage into surrounding soil (see Figure 6-11). The paving will be constructed with slope (approx. 1:100) to facilitate drainage towards sumps. Paving thickness will be min. 200mm at the thinnest part around the sump, and a double membrane layer shall be used underneath the paving. Where paving is cast around plinths or against other concrete structures, a gap of approx. 20mm shall be maintained during casting of paving and later filled with flexible sealant to ensure independent contraction/expansion and movement of paving from surrounding structures.

[redacted]

Figure 6-11 Amin Reclaimer Unit Foundation

Bunding consist of typ. 300mm thick concrete walls with TOC elevation approx. 1m above FG. The final height of the bunds needs to be confirmed in the next project phase based on the required containment volume for each bund.

Where equipment does not have any shed or roof superstructure above paved area theses bund walls are to be cast directly atop paving and constructed as a continuous structure (see

Figure 6-11). Equipment that requires shed or roof structures may extend bund walls down below paving to a combined foundation supporting other equipment and/or plinths for superstructure columns. This is done in cases where space limitations or other constraints makes it unpractical to construct bund wall and paving as an unconnected structure from underlaying foundations. In such cases, the paving shall have a gap to the surrounding bunding similar to the gap towards other plinths and concrete elements penetrating paving (see Figure 6-12).

[redacted]

Tank and equipment modules where bunding and paving is required to contain chemical spill do in some instances need a shed/roof super-structure to limit rainwater collection inside the bunded area. Shed structural columns are supported on plinths with bolted connection above FG similar to most other equipment and structures. The interface between the baseplate of steel columns for shed structure and bolts atop plinths will be at a higher elevation than other equipment, approx. 1m above FG corresponding to height of the bund wall (see Figure 6-12).

6.6.5 Floodwater culvert, retaining wall and ground water barrier wall

An open floodway is planned along the eastern perimeter of the site mainly intended to handle stormwater inflow from surrounding areas. The floodway structure consists of a one-sided retaining wall that transitions into an open concrete culvert about halfway along the floodway.

A near vertical rock face encloses the northeastern part of the site. This rockface was created during site prep excavation and was secured with rock bolts and sprayed concrete slurry. This surface will function as a natural wall with the retaining wall running parallel to this rock face creating an enclosed floodway. The retaining wall will be cast on concrete paving directly atop BL and will be topped with a guard rail where it runs parallel to the road. Total length of the retaining wall approx. 144 m with prelim cross section and dimensions as shown in **Error! Reference source not found.**. A thin mesh reinforced concrete paving will be cast between the rock face and retaining wall to act as the base for the floodway. Top surface of this paving is to be flush with top of culvert slab at transition between retaining wall and open concrete culvert. This is done to ensure correct water flow and limit water infiltration to site.

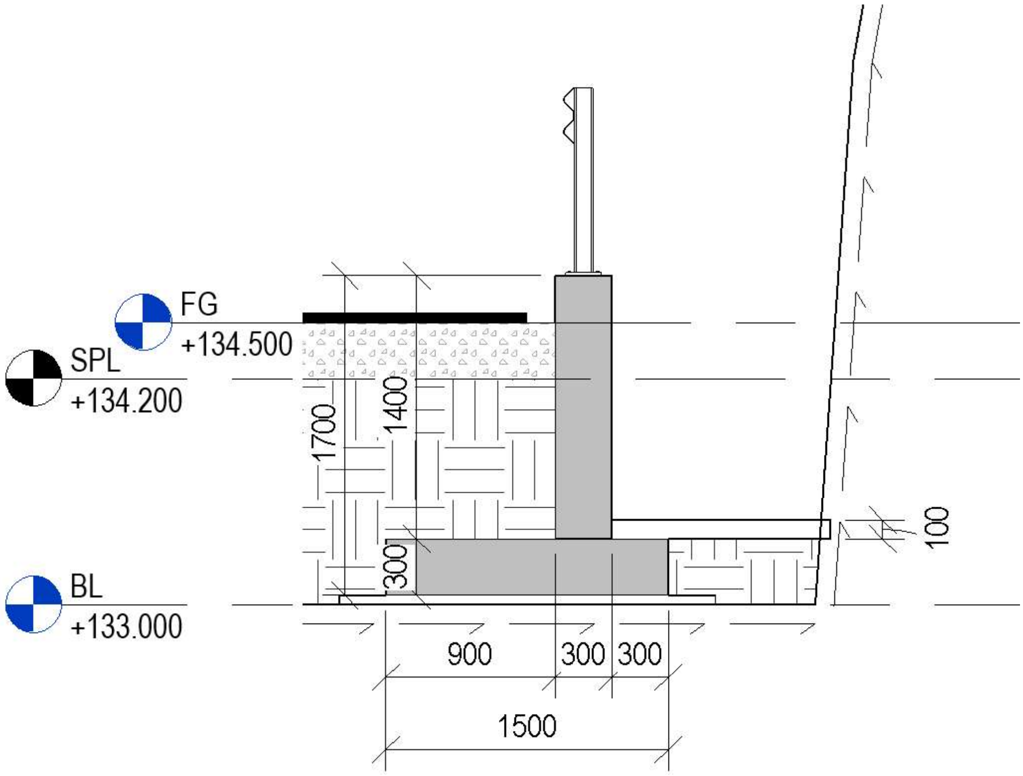

Figure 6-13 Preliminary design open floodway retaining wall cross section

The semi-impermeable rock face along the eastern perimeter transitions to a steeply sloped backfill further south along the floodway. The retaining wall is at this point replaced with an open concert culvert. The culvert runs for the remaining stretch of the floodway until it is terminated in pipes at the southern end of the site. This pipe termination is an interface point towards another project currently in design phase, but that will be completed before construction commences on CCP site. Total length of the culvert is approx. 73 m with a preliminary cross section as shown in **Error! Reference source not found.**. The culvert may b e cast in place or cast in smaller segments elsewhere on site before being lowered in place to limit work in construction pit adjacent to the sloped backfill. The stability of this backfill impacts the stability of a public road atop the slope. Excavation and construction that impacts the backfill must therefore be treated with special consideration. The culvert wall towards site along internal road will host guard rail similar to the retaining wall. The opposite culvert wall towards sloped backfill is currently intended to support a 5 m high fence that is meant to function as a barrier in the event of a CO^2 gas leak.

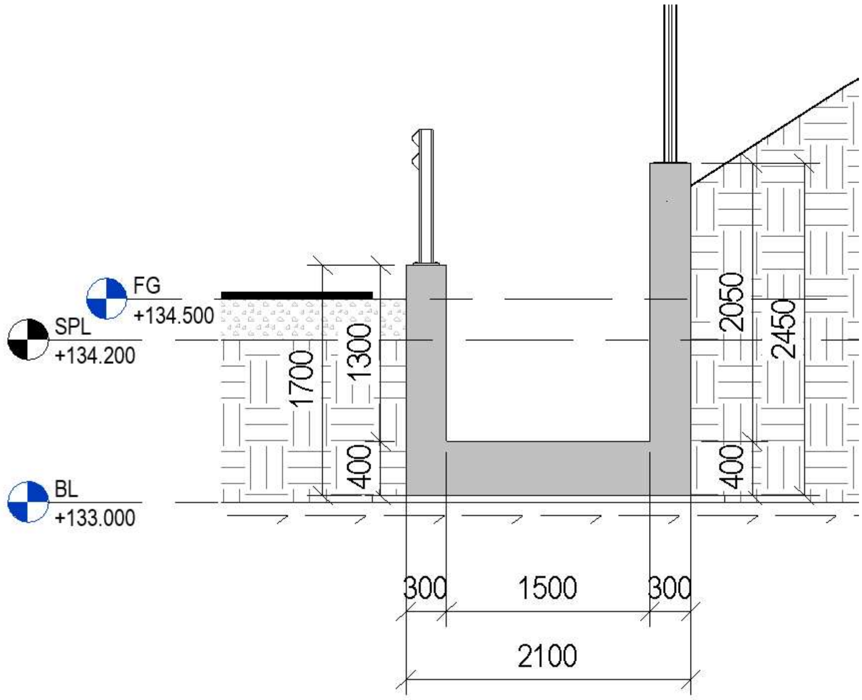

Figure 6-14 Preliminary design open floodway culvert cross section

During site prep a temporary concrete wall was constructed bordering much of the exciting plant toward the west. This low concrete structure was cast directly atop blasted rock surface and was intended to limit ingress of water in the existing L3 basement which is constructed approx. 5 m below the BL elevation of the new site (see Figure 6-4). The existing temporary wall will be demolished to enable construction of new foundations. Client concerns about flooding the L3 basement remain, even after considering the impact of the planned water drainage system for the new plant. The concrete barrier will therefore be reestablished along the west side of the plant after other concrete structures are completed.

6.6.6 Temporary foundations for assembly of tanks/ driers etc

Two sizes of temporary foundations for assembly of equipment is required:

Large tanks with a foundation load of 125 mT

Small tanks with a foundation load of 67.5 mT

For both foundations, the load is assumed taken in the center of the foundation, no moments from weight assumed.

Large foundation requirements:

2x2 m foundation, with mass exchange down to 0.75 meters. Replacement material to be quality blasted rock. Geotextile to be installed between soil and installed rock material.

3.2x3.2m foundation, no mass exchange required.

Small foundation requirements:

1.5x1.5 m foundation, with mass exchange down to 0.5 meters. Replacement material to be quality blasted rock. Geotextile to be installed between soil and installed rock material.

2x2m foundation, no mass exchange required.

Foundations for stick built units

Foundations for stick built units will be prepared as required for the applicable loads.

6.7 Roads and Tracing of Trucks

6.7.1 Driving Patterns

In connection with the Klemetsrud CCP project, driving patterns have been made to ensure accessibility for vehicles to the different parts of the CCP area. The driving patterns are made with AutoTURN version 11,

and includes the following vehicles:

- Semi-trailer for CO2 transport:
  - Maximum length: 17.5 meters.
  - Operates at a standard speed of 15 km/h, reduced to 10 km/h in tight areas.
  - Uses the designated sliding gate (12-meter width) for access to three filling stations.
- Mobile crane:
  - Used for handling and maintenance of heavy equipment.
  - Must be able to lift up to 50 tons and maneuver safely within designated areas.
- Chemical Truck:
  - Designed to carry 40-foot containers to the [redacted] side of the plant.
  - Maintains a speed of 15 km/h, with no requirement for full stops at turning points.
- Material Handling Truck:
  - Operates in the northwestern area to transport smaller objects up to 500 kg.
  - Driving paths are modeled for a 12-meter-long truck.
- Articulated Trucks (Vogntog):
  - Shares the same pathway as CO2 trucks, with the additional ability to circulate around the facility for material delivery or operational adjustments.
  - Designed for vehicles up to 22 meters long and 2.6 meters wide.
  - Speed limits and path alignments have been adjusted for safe maneuvering.

AutoTURN does not have standard vehicles for these tasks, hence Contactor has in collaboration with Company chosen vehicles from the AutoTURN library that fit the criteria. A clearance of 30cm has been added to both sides of the vehicles to ensure enough space.

As per interface agreement a standard speed of 15km/t has been used for the driving patterns all though the overall speed limit on WtE is 20km/t Some places the speed has been further reduced due to limited available space, and such exceptions are described in this chapter.

Vehicles enter the gate and turn left through the existing facility. Trucks from the chemical tank area follow a specific path before merging with CO2 transport trucks. A comprehensive logistics management plan ensures smooth coordination between different vehicle types, minimizing delays and ensuring operational safety. Future logistics report will cover for additional insights into traffic handling and peak time management.

6.7.1.1 CO2 Transport

CO2 transport trucks access one of three filling stations through the sliding gate, as illustrated in Figure 6-14. They exit via the north side of the technical building, following the established driving pattern.

Criteria:

- Semi-trailer with maximum length 17.5m
- The sliding gate is 12 meters wide, allowing uninterrupted entry.
- The semi-trailer must be able to stop in front of the gate without blocking external traffic.

The general speed limit is set to 15 km/h. In tighter areas where turns are necessary, the speed is reduced to 10 km/h to ensure safe maneuvering.

Safety measures, including clearly defined driving paths and reduced speed limits in tight areas, have been implemented to minimize the risk of collisions and ensure safe maneuvering. The AutoTURN model, as shown in Figure 6-14, illustrates the designated driving patterns for each path and highlights areas where extra caution is required.

The following vehicle has been chosen from AutoTURN, see Figure 6-15 below.

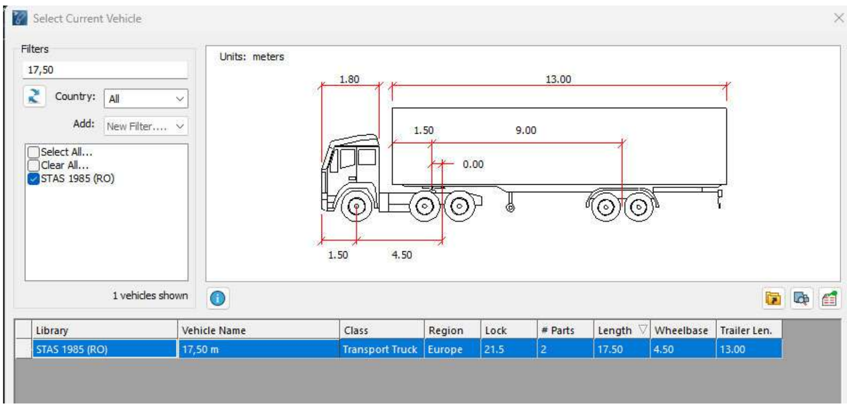

Figure 6-15 Semi-Trailer for CO2 Transport

The resulting driving patterns are show in Figure 6-16:

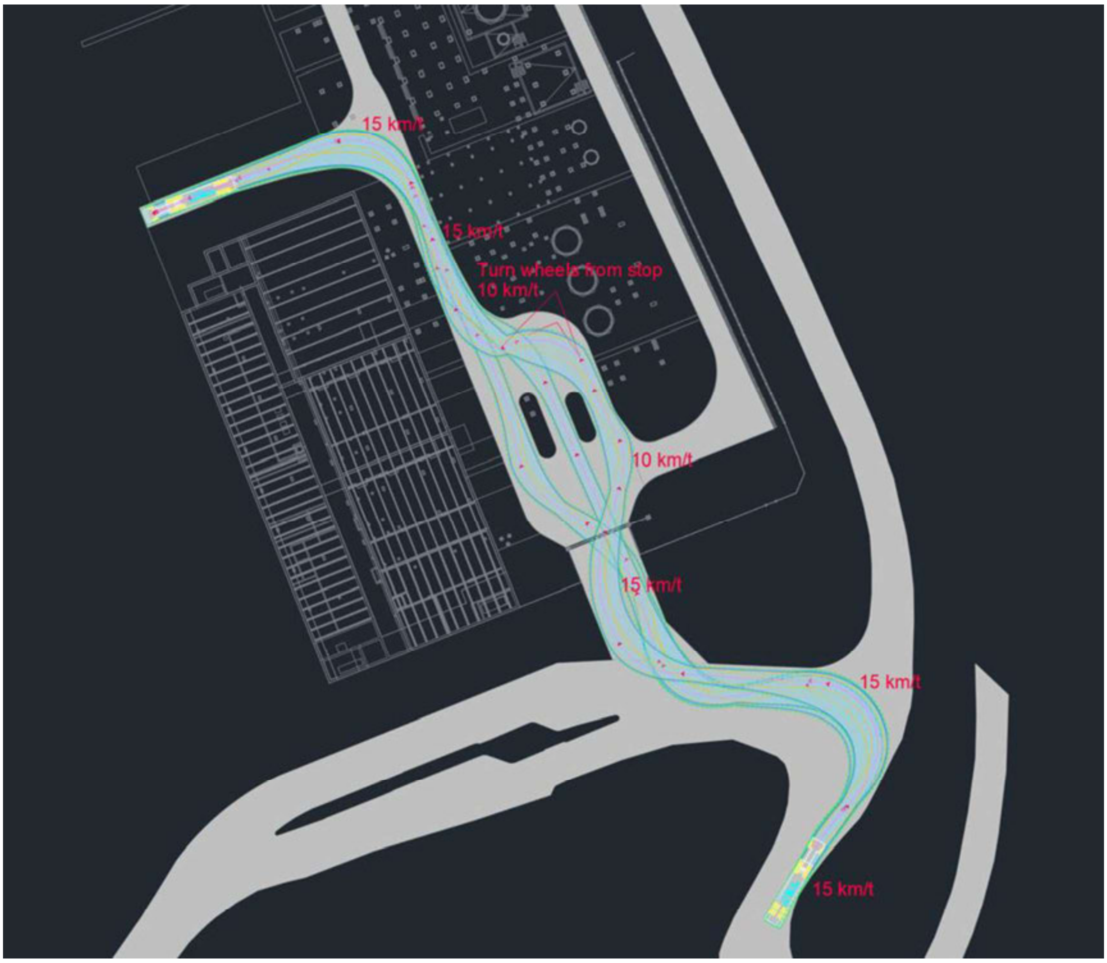

Figure 6-16 Driving Pattern Semi-trailer for CO2 Transport

6.7.1.2 Mobile Crane

A mobile crane must be able to drive according to the path shown in Figure 6-18 to support material handling and maintenance of items around the CCP plant.

Criteria:

- The crane must be able to lift 50T

The following vehicle has been chosen from AutoTURN, see Figure 6-17:

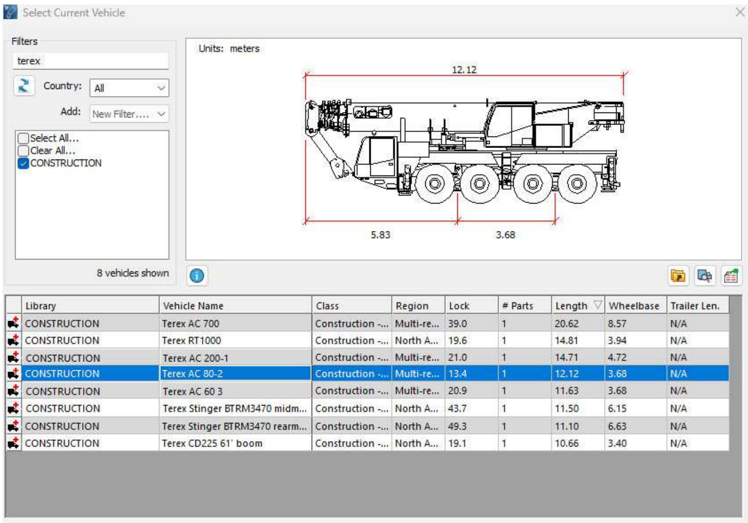

Figure 6-17 Mobile Crane for Material Handling

Driving patterns for the mobile crane is shown in Figure 6-18:

Figure 6-18 Driving Pattern Mobile Crane

As can be seen in the driving pattern, the speed limit is 15 km/h and the trucks do not require a full stop for turning.

6.7.1.3 Chemical Truck

A chemical truck must be able to access the same parts of the plant as the mobile crane, to allow for filling of the chemical tanks located in the chemical tank area on the North side of the plant.

Criteria:

- The truck must carry a 40 feet container

Driving patterns were made with a custom transport truck shown in Figure 6-19:

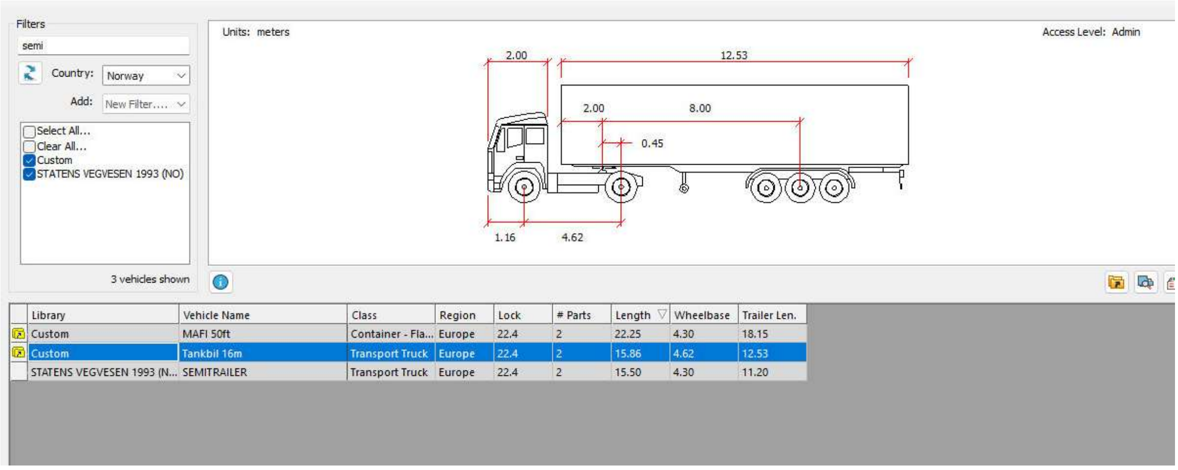

Figure 6-19 Chemical Transport Truck

The driving pattern for the chemical truck is shown in Figure 6-20.

Figure 6-20 Driving Pattern Chemical Transport Truck

As can be seen in the driving pattern, the speed limit is 15 km/h and the trucks do not require a full stop for turning.

6.7.1.4 <u>Material Handling Truck</u>

In the North-Western area of the plant, there is a need to transport and maintain smaller objects with a weight up to 500 kg. A driving path for this vehicle is shown in Figure 6-22 below.

Criteria:

- Vehicle must lift weight up to 500kg

Driving patterns were made with a standard 12m long truck, shown in Figure 6-21:

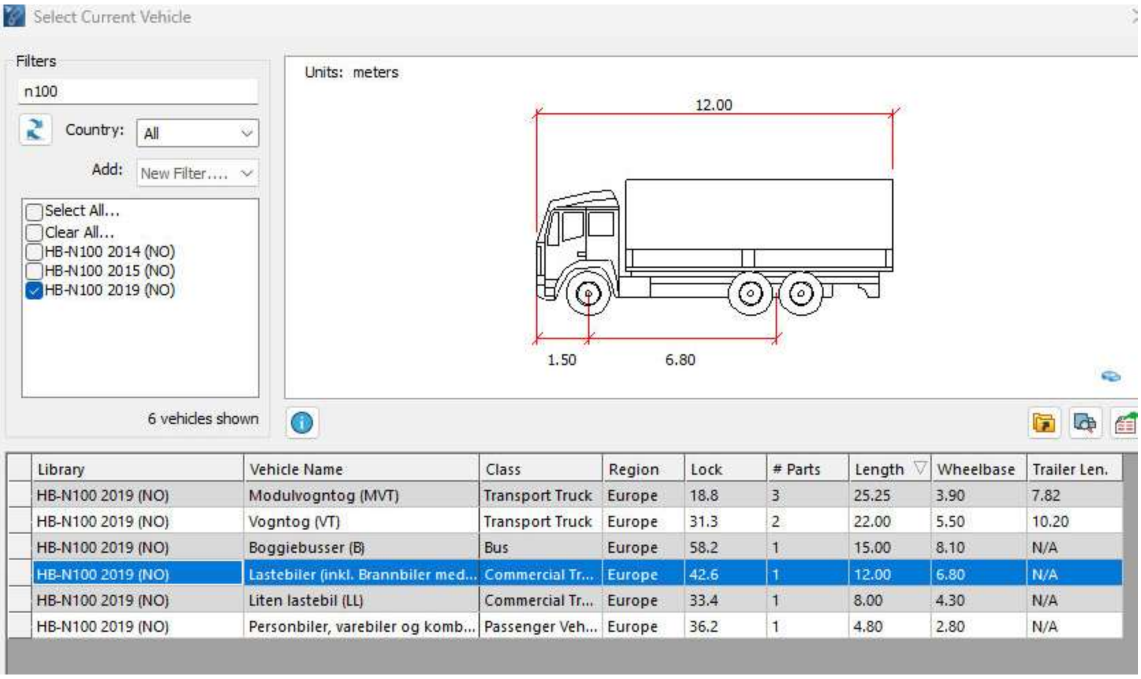

Figure 6-21 Material Handling Truck

The driving pattern for the material handling truck is shown in Figure 6-22:

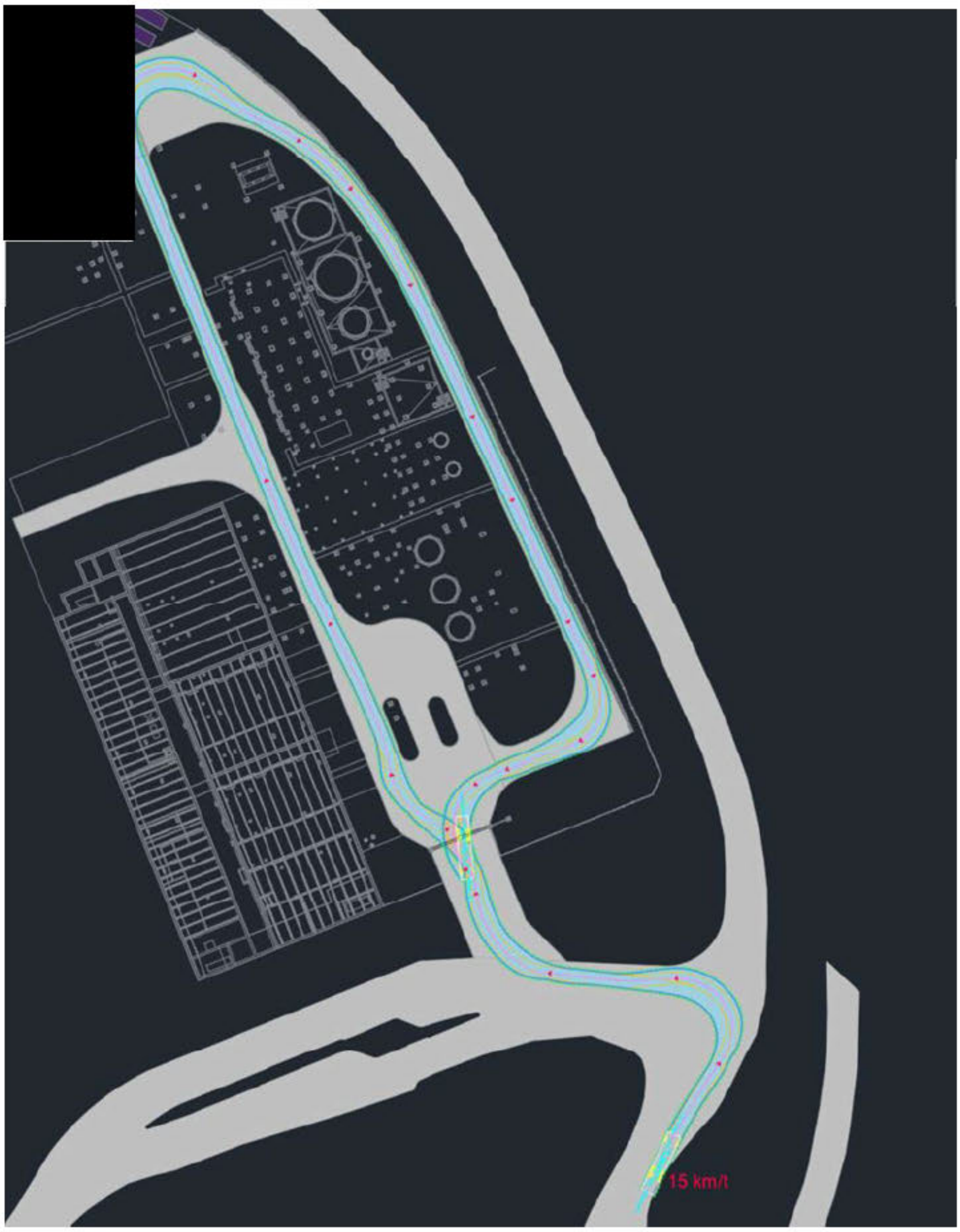

Figure 6-22 Driving Pattern Material Handling Truck

As can be seen from the driving pattern, the speed limit is 15 km/h and the trucks do not require a full stop for turning.

The project suggests that a forklift is used to access this area for material handling or maintenance operations.

6.7.1.5 Vogntog Track Pathways

Overview

The tracking pathways for vogntog (articulated trucks) are designed to follow the same route as CO2 trucks and ensure enough space for safe and efficient movement within the facility.

Specifications

- Speed Limit: The general speed limit is set to 15 km/h. In tighter areas where turns are necessary, the speed is reduced to 10 km/h to ensure safe maneuvering and to avoid any impact on nearby structures or surroundings.
- Path Alignment: Designed to follow the route of CO2 trucks to maximize shared space and streamline operations, ensuring compatibility with all internal facility roads.
- Vehicle Dimensions: Designed to accommodate trucks up to 22 meters in length and 2.6 meters in width.

Conclusion This design ensures that vogntog can move safely and efficiently, with adjustments made for critical areas to maintain safety and protect the surrounding environment.

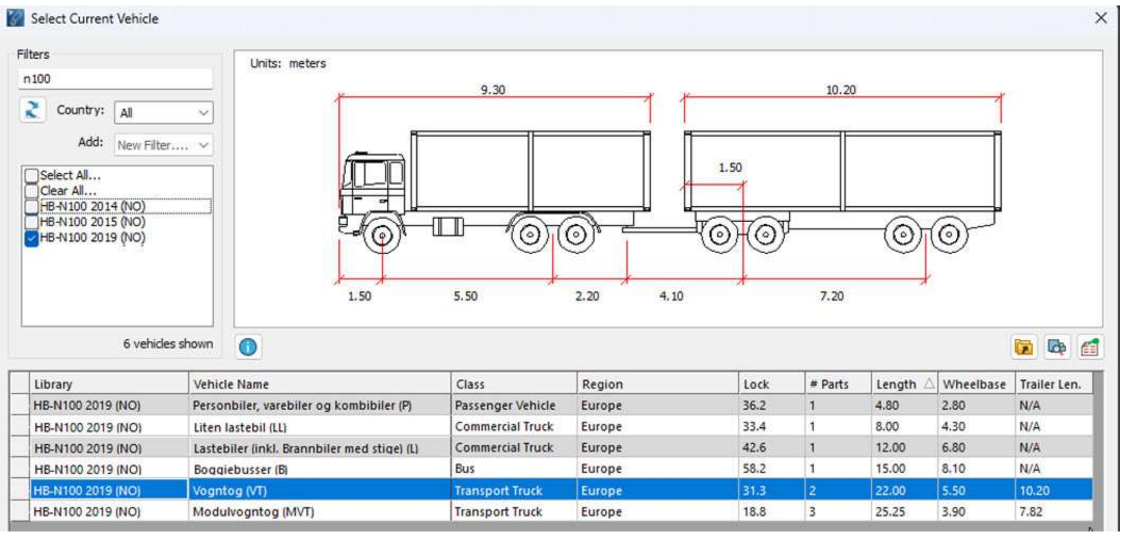

Figure 6-23 Vogntog Truck

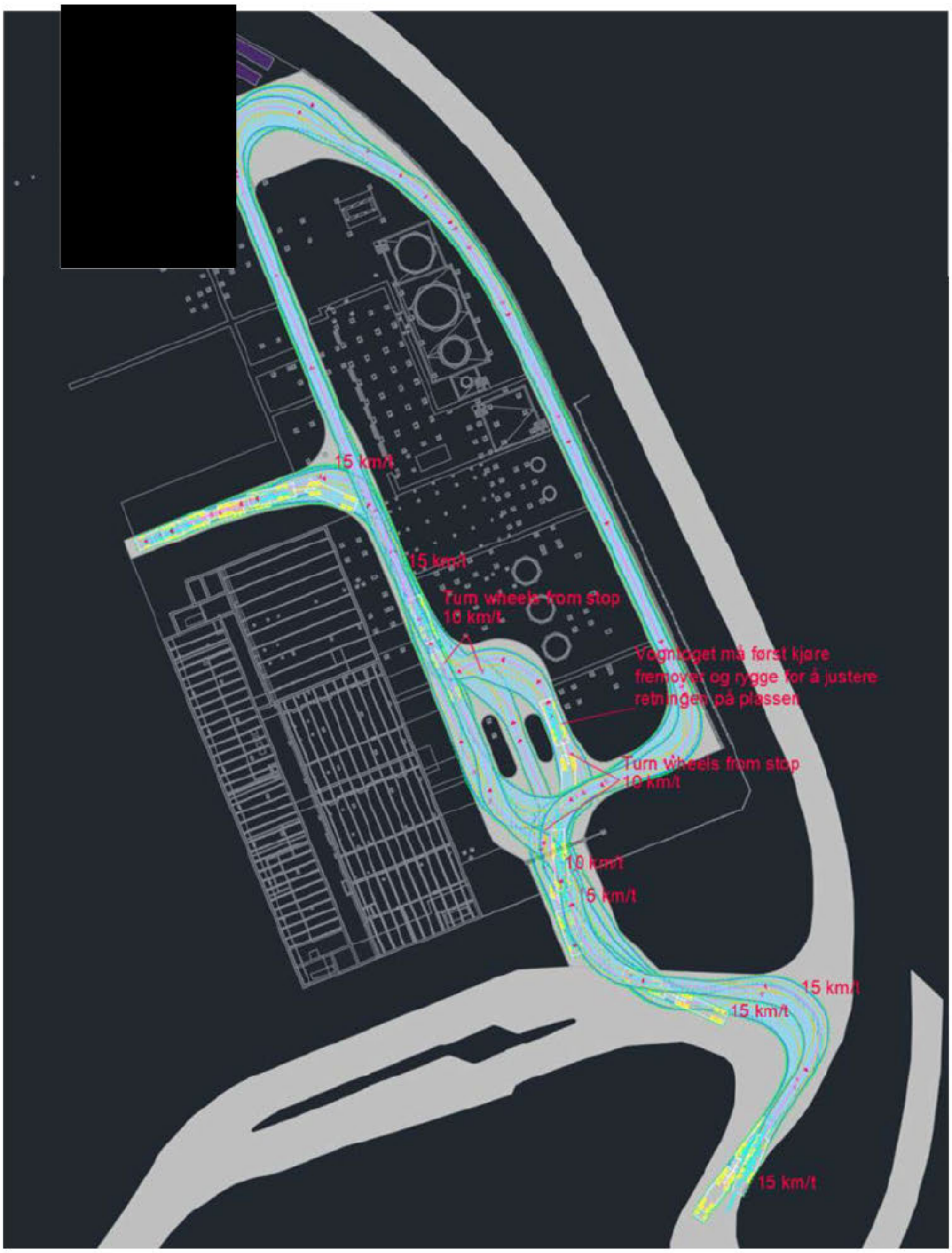

Figure 6-24 Driving Pattern Vogntog Truck

6.7.2 Superstructure

Standard section road and superstructures are show in document HI2305-AKE-Q-XS-6470 /23/.

The superstructure is calculated based on Statens Vegvesens handbook N200 with three semi-trailers every 30 minutes = 144 heavy vehicles passing through the CCP plant every day.

Documents HI2211-CWI-G-XF-3001 Plan Rock Excavation Rev4 and HI2211-CWC-C-XS-3002 StandardCross_Superstructure_-_Railing_Road_Klemetsrud Rev3 show the excavations and refilling of the site performed in an earlier phase by others. According to these drawings, there will be well graded crushed rock beneath the roadbed. Contractor`s design is based on the referenced document, hence, if the actual soil under the roadbed is later found to be of a poor quality, a thicker reinforcement layer must be considered. If there is frost susceptible soil under the roadbed, frost protection must be considered.

6.8 Technical Building

6.8.1 Architectural Design

The architectural SOW for the FEED phase, has consisted of developing a façade concept for the Technical Building, creating room and surfaces schedule based on the provided layout, and producing the necessary drawings for the building permit application, in accordance with TEK17 regulations.

During the process of developing the façade concept a series of workshops with Company and Astrup & Hellern were held. Over the course the workshops, Contractor presented our analysis of the existing plant, the projects impact on nearby communities, materiality, sustainability and approach to local regulations. Based on the discussions, use of expanded mesh panel modules as the decorative cladding for the Technical Building was proposed by Contractor.

Figure 6-25 Examples of the 2.4 x 2.4m Prefab Modules

Figure 6-26 Rendering of Proposed Technical Building Facade

The mesh panel modules are to be prefabricated and coated with a color from the color pallet developed by Astrup & Hellern, in collaboration with KOI.

The room schedule is developed based on layout input from the Piping&Layout, EIT and Structural design. The various surface treatments were developed in collaboration with the rest of the engineering team, reflecting the use of planned use of the different rooms.

6.8.2 Structural Design

6.8.2.1 General

The cable basement and the ground floor will be constructed with the use of reinforced concrete. For the structural elements above the first floor, steel columns and floor beams will in addition to reinforced concrete walls be used to support the floors and roof levels. Due to long spans required by the room layouts, floors and roof levels consists of cast in place concrete slabs supported by corrugated steel decking used as formwork and supported by the mentioned floor beams.

Some of the exterior and interior concrete walls will be used as shear walls to structurally maintain adequate horizontal stability.

The foundation consists of a concrete baseplate supported by steel core piles except a smaller section on the East side where the baseplate is founded directly on the rock level.

See additional discussions of recommended structural system later in this section.

6.8.2.2 Ground Conditions

The building site consist of a levelled rock filled area executed in earlier project phases by others. Depth to bedrock varies from approximately 2 meters at the East wall of the building and drops off to more than 20 meters at the West wall. This requires some rock blasting on the East and South side of the building.

6.8.2.3 Foundations

The building is founded on a thick concrete baseplate with bottom elevation approximately 1.4m below finished grade. At the cable basement the baseplate is lowered, and the bottom elevation is approximately 4.8m below finished grade. Due to limited space available, sheet piles must be introduced for the excavation of this lower basement. The West side of this basement may be recessed to avoid interference between the existing pipe culvert for “Gjersrudbekken” and the sheet pile.

A portion of the Technical Building along the East wall will be founded directly on partially blasted rock areas. The remaining portion of the baseplate will be supported by a multitude of steel core piles with varying length into the bedrock.

Technical installations, such as the CO_2 Compressor and the Heat Pumps, requires a separate foundation isolated from the building foundation. Evaluation and detailing of these foundations will be performed during the next phase when load data and footprint is made available by the vendors.

See Figure 6-27 for a typical view of the building foundation.

[redacted]

6.8.2.4 Load Bearing Philosophy

All vertical loads will be transferred via the roof and floor slabs supported by steel beams to concrete walls, steel columns and piles to bedrock.

Concrete roof and floor slabs are supported by steel beams to transfer the vertical load and allow for longer floor span.

The horizontal loads will be transferred to the baseplate section through the floor slabs and concrete walls to the bedrock by the section of the baseplate founded directly to bedrock. The piles will not transfer any horizontal loads.

6.8.2.5 Cable Basement

Reinforced concrete walls and a few concrete columns supported by the baseplate is chosen for this limited sized cable basement. Top of cable basement floor is located at elevation +130.300 m.

6.8.2.6 Level 1

All equipment and skids are assumed to be installed on top of plinths placed directly on the baseplate. To allow for “underground” pulling pipes and drain installations, a reinforced concrete slab on well-graded crushed rock is installed. See Figure 6-28 for additional information.

Top of concrete for floor level 1 is located at elevation +134.800 m.

6.8.2.7 Elevated Levels/Floors

The Technical Building has several elevated levels as follows:

- Level 2.
  Top of concrete at elevation +141.200 m

-
- Mezzanine Level at Waste Water Treatment Area.
  Top of concrete at elevation +141.800 m
- Level 3.
  Top of concrete at elevation +146.800 m
- Main Roof Level.
  Top of concrete at elevation +155.800 m
- Staircase Roof Level.
  Top of concrete at elevation +159.300 m

[redacted]

All levels are assumed constructed with a top of poured in place concrete slab. Due to heavy concentrated loads from technical installations, all floors are supported by steel floor beams to allow for longer floor spans. [redacted] floor beam installation allows for a high amount of floor penetrations for cables routed between the levels and cabinets/other equipment.

To avoid the use of traditional formwork and shoring due to the large floor to floor height, corrugated steel deck is used as formwork. See Figure 6-29 for the floor build-up.

[redacted]

Figure 6-29 Typical View of the Technical Building Structural System

All floors have a concrete slab finish to allow the use of concrete plinths to elevate and support equipment and equipment skids. Several rooms shall also receive an epoxy topping on the floor in addition to floor drains to ease maintenance and cleaning.

Placement of floor beams to be detailed when support information from the vendors is available in the detail phase of this project.

See the typical floor plan in Figure 6-30 below for the preliminary planned use of floor beams.

[redacted]

Figure 6-30 Typical Floor Plan Technical Building

6.8.3 HVAC

6.8.3.1 System Split

The following HVAC systems will be installed in the Technical Building:

- CC1SAA51 (General ventilation system for Technical Building)

[redacted]

- CC1SBA51 (Heating system for heating of ventilation air)

- CC1SBA60 (Heating of roads)
- CC1GKD51 and CC1GKC51 (Hot and cold tap water)
- CC1GMH51 (HVAC sanitary draining system)
- CC1GMB20 (Process draining system)

6.8.3.2 Ventilation

[redacted] ventilated. The ventilation systems shall operate with 100% fresh air.

The Technical Building will have several ventilation systems to fulfill the different system requirements, however, CC1SAA51 and CC1SAF51 are the primary ventilation systems. Both systems have an air handling unit that is located in the HVAC room on level 3.

The systems provide balanced ventilation with conditioned supply air to the building. CC1SAA51 serves as general ventilation for most of the Technical Building, except for the heat [redacted] The CC1SAA51 system is designed with a smoke extract strategy in case of a fire. Therefor the system has a dedicated bypass [redacted] the CC1SAF51 system is designed with a containment strategy and the system is therefore equipped with fire dampers.

[redacted]

The battery room is supplied with fresh air from system CC1SAA51, but has a separate extract system (CC1SAB51). The extract system is installed to make sure that any gas from a potential leakage will be extracted from the room and discharged to outside air without any risk of contamination to other rooms in the building. Equipment located in the battery room shall be classified according to the ATEX directive.

The compressor room will have mechanical extract ventilation (CC1SAA60) installed to make sure requirements for temperature and material emissions are met. Mechanical extract ventilation is chosen due to the high heat dissipation from equipment in the room.

The transformer rooms shall be naturally ventilated, and all ventilation louvers is to be designed and installed without heat tracing.

6.8.3.3 Heating and Cooling System

The building will have a HVAC cooling system (CC1QKA51) with a chiller and dry cooler located on the roof of the Technical Building. The system is providing central cooling (cooling of ventilation air and local cooling units). Main equipment such as stratification tank, pressure maintenance system and pump arrangements etc. will be located in the HVAC room on level 3.

The HVAC cooling system is installed to make sure room temperature is kept within acceptable levels for operation of installed equipment and working environment for operators.

The chiller will utilize R290 (propane) as refrigerant, and propylene glycol (40%) shall be used as cooling medium. The system is equipped with a dry cooler unit to utilize free cooling.

The basis for the FEED design is the use of local cooling units in rooms with high heat dissipation loads.

The building will have an HVAC heating system which utilizes waste heat from the building. Heat from CCP cooling medium system shall be utilized for heating of ventilation air in the building and heating of roads on the site.

[redacted]

The ventilation systems CC1SAA51 and CC1SAF51 will be equipped with a heating coil and an electrical heater will be installed as backup in case the CCP cooling medium system is not in operation in periods where heating of ventilation air is necessary. The Technical Building will rarely have any need for local heating due to high heat dissipation from the process and electrical equipment located inside the building. All rooms in the Technical Building will still be equipped with electric wall-mounted panel heaters or stationary fan heaters to ensure that the minimum temperature requirements are fulfilled.

6.8.3.4 Potable water systems, Draining Systems and Storm water from roof drains

The tap water systems consist of cold-water supply tap water (CC1GKC51), hot water supply tap water (CC1GKD51) and hot water circulation (CC1GKE51). The systems provide hot and cold water for emergency showers, toilets and washrooms in the building, as well as cold water for utility stations in process rooms.

The Technical Building is designed with two separate draining systems. One for process drains and one for sanitary drains.

Indoor draining system from process rooms (CC1GMB20) consists of floor drains located in all [redacted] and further pumped to a drain collection tank inside the Technical Building for analysis of potential pollutions.

Indoor sanitary draining system (CC1GMH51) is routed to a pump station located in washroom on level 1 and further pumped up to system CC1GNB40 located in pipe rack.

The Technical Building is designed with a stormwater system (CC1GUB51). The system is designed with roof drains located towards the centerline of the building, and drainpipes which are routed down to underground piping inside of the Technical Building.

6.8.3.5 Sprinkler system

At the end of the Pre-EPCIC phase it was decided to replace isobutane by HFO as refrigerant [redacted] supply water to a potential future sprinkler system shall be designed. The supply pipe for the future sprinkler system shall be [redacted] where it will be plugged.

The operational and functional requirements of the HVAC systems in the Technical Building is further described in document HI2305-AKE-H-RA-6001, /17/.

6.8.4 Building Electrical

[redacted]

[redacted]

Lighting

All rooms will be equipped with suitable light fixtures and will be designed according to Company GTS /18/. Typical industrial light fixtures with correct characteristics for the lighting task shall be installed in all rooms. In rooms with special needs or higher demands, like ATEX certified fixtures like at [redacted] etc. Light fixtures will be mounted onto walls, cable ladders or as high bay light fixtures suspended from the ceiling, if light calculations shows that this is needed during EPCIC phase.

Light fixtures will be controlled over a building automation field bus system and KNX control gear devices will be used. Large rooms will be equipped with regular KNX light switches. In more busy areas like corridors, stairs and smaller utility rooms, motion detectors will be used. Light fixtures on facade walls and outdoors will be controlled by illuminance detector or Astro timer relay.

The Technical Building will be equipped with emergency and escape light fixtures. The emergency light system will consist of electrical LED exit signs, escape route lighting and anti-panic light fixtures for voltage level 230V. Fixtures will automatically be monitored and operated from an autonomous emergency light control panel with internal battery supply for 60 minutes duration time and in addition, the control panel will be fed from a UPS source for greatly extending the duration time.

Fire Alarm System

The Technical Building will require a category 2 fire alarm system. A complete fully covering fire alarm system shall be installed for fire and smoke monitoring all indoor spaces. The fire alarm system shall be designed according to NS-3960 (Brannalarmanlegg- Prosjektering, Installasjon, drift og vedlikehold).

In rooms with large heights, lack of space and difficult accessibility for maintenances work, aspiration detectors will preferably be used. Smart aspiration detectors can be a great and versatile solution which requires little maintenance. Aspiration detectors are well suited for industry applications as they can have a pre- warning function to reduce false alarms.

In other rooms and areas, optic detectors will be used and in special hazardous areas, flame detectors with IR sensor might be used. As for alarm organs, standard warning sirens and flash beacons will be installed.

Manual call points shall strategically be installed in rooms and in escape routes with no less than 30m reach zone as according to NS 3960. The fire alarm system will be a standalone system, but alarms shall be integrated with the existing fire alarm system at the WtE plant.

Ventilation ducts at the Technical Building [redacted] will not require fire dampers as the fire strategy is to extract the smoke out and away when a fire and smoke occurs. [redacted] from the rest of the building. This system will require fire dampers to prevent smoke into the air system. Fire dampers are monitored and controlled by a local control panel and smoke detectors in the room and smoke detectors inside ventilations ducts will signalize the fire damper actuators to trigger when large concentrations of smoke are detected.

HVAC System Power and Automation

The HVAC instrument and automation systems comprises:

- Air handling unit (Technical building)

[redacted]

- Bypass axial fans
- Chiller unit and dry cooler
- Local room cooling units
- Room controllers for temperature and moisture monitoring and regulating

[redacted]

HVAC systems will be powered, operated and monitored by a combined HVAC switchboard and control center located in the HVAC room. The switchboard will be arranged with a touch panel (HMI) on the panel front for interfacing with the HVAC systems. The HVAC SRO system shall also be accessible remotely and operated through cloud connection. In addition, a selected range of critical alarms and signals shall be fully integrated into the Company`s own SCADA system in the WtE plant. Safety critical signals like HVAC shutdown shall be interconnected to Company`s SRO system.

The safety control class philosophy shall be class 3 for HVAC control systems.

A standardized building automation PLC logic controller unit from Siemens or equal supplier are desired for the HVAC SRO system. Analog signals and 24V digital signals will normally be hardwired to the PLC I/O-cards, mounted inside the switchboard panel.

Air handling units and chillers will have onboard automation- equipment, fans and VSD`s which requires a fieldbus protocol connection like MODbus or similar wired over to the HVAC control panel PLC MODbus gateway card.

The HVAC switchboard will include circuits breaker for power supplying field equipment, pumps and fans related to the HVAC systems. Due to the large cooling loads, the chiller unit will be supplied separately and directly from the 690V switchboard.

6.8.5 Earthing and Lightning Protection

The earthing system consist of foundation earth electrodes around all concrete foundations, mesh-grids beneath the concrete foundations, as well as earthing rods that are exothermic [redacted] has a connecting point to the existing earthing system.

The lightning protection system (LPS) has a lightning protection level (LPL) of 2. The LPS consists of several air terminal rods, with two down-conductor cables for each air terminal, and two earthing rods additionally, ref. /21/. The down-conductor cables are exothermic welded to the foundation earth electrodes. The air terminals masts shall be made from insulated material.

6.8.6 [redacted]

Manual fire extinguishers must be provided in the building in addition to a comprehensive automatic fire alarm system and guidance system.

There is drivable access for the fire service to and around the building, and there must be reserved space for parking for fire trucks. Manholes are established so that the building is covered with 50+100m of fire hose.

6.8.7 Internal Noise in the Technical Building

This chapter will outline the acoustic requirements for the various rooms in the Technical Building, relating to noise limits, partition walls, doors and acoustic absorption.

6.8.7.1 Requirements/Limits

The noise limits for the various rooms are defined in the Working Environment Area Limits-document /19/, and is presented together with estimated required noise reduction measures in Table 6-1.

Table 6-1 Room Types and Noise Requirements

[redacted]

6.8.7.2 Acoustic Absorption in Rooms With Noise Limit of 110dBA

For reduction of internal noise level and consequently noise emission from outer walls it is suggested to include acoustic absorption on 50% of wall area in all rooms with noise limit of 110dBA:

[redacted]

The absorption can be made by 50mm mineral wool directly mounted to the wall. Plates such as Rockphon Industrial can be used as described in https://www.rockfon.no/produkter/rockfon-industrial-black/#Sortiment. The suggested plates have an outer fabric layer that protects against dust and fibers.

6.8.7.3 Acoustic Absorption in Rooms With Noise Limit of 90dBA

For reduction of internal noise level, it is this suggested to include acoustic absorption on 25% of wall area in all rooms with noise limit of 90dBA:

[redacted]

For the instrument room it is suggested to also include 25% of wall area to be covered by acoustic absorption. As an alternative to acoustic absorption on the walls, the room can be equipped with an acoustic absorbing ceiling.

6.8.7.4 Sound Insulation

The main walls are designed with 400mm concrete and will fulfill all needed sound insulation requirements. The doors from corridor with 80dB to rooms with 110dB limit need doors with sound reduction of at least R'w = 30dB.

[redacted] have an external sound power level emission limit of 90dB. These rooms have explosion panels of around 110m^2. To meet the external sound power level, the sound pressure level outside the panels has to be 70dB or lower. This means that the panels themselves need to reduce the noise level by approximately 40dB.

A similar rough evaluation has been carried out for the compressor room, but as it has an external noise power level emission limit of 85dB, the explosion panel for this room needs to reduce the noise level by 45dB.

Explosion panels that aim to reduce noise by 40-45dB need to be double constructions with outside and inside panels with acoustic absorbing materials in between.

This evaluation is simplified as the information about the external noise limits was received very close to the project delivery date. Design of the explosion panels will therefore have to be further investigated in the next project phase.

6.8.8 Building Physics

The Technical Building will be designed to meet Norwegian building regulations (TEK17). Energy requirements, requirements for radon- and moisture protection and requirements for airtightness are given in §13 Inneklima og helse (Indoor climate and health), and §14 Energi (Energy), respectively. The functional requirements given in TEK17 can normally be met by using recognized and pre-accepted solutions, e.g., as shown in Byggforskserien from SINTEF Community.

There are requirements for independent control for building physics according to SAK10.

6.8.8.1 Energy and Thermal Insulation

The building shall be designed and constructed such that satisfactory energy performance is facilitated (TEK17, §14-1 and §14-2). The energy requirements apply to the building's heated area, and not to buildings or parts of buildings that are going to maintain at low indoor temperature, provided its energy needs are kept at a reasonable level. If heat gain from internal processes in the building is obviously sufficient to cover the heating needs, the area can be regarded as unheated.

[redacted]

The Technical Building will be designed with thermal insulation where the transmission heat loss at the current indoor temperature does not exceed what is permitted in a fully heated and fully insulated building.

Energy qualities for the Technical Building are shown in Table 6-2. With these qualities, the building satisfies the energy requirements in TEK17.

Table 6-2 Energy Qualities for the Technical Building

Component	Value	Preconditions
U-value Exterior wall	0.33 W/m²K	Concrete wall, 150mm continuous external insulation, λ=0.038 W/mK.
U-value Roof	0.14 W/m²K	Average thickness 280mm insulation, λ=0.038 W/mK.
U-value Floor – ground slab	0.10 W/m²K*	100 mm insulation, λ=0.038 W/mK.
U-value Floor - Basement	0.18 W/m²K	100 mm insulation, λ=0.038 W/mK.

U-value doors	2.0 W/m²K	The average U-value. Supplier need to document the U-value.
Normalized Thermal Bridge value	0.12 W/m²K	50 mm thermal bridge insulation. Acc. NS3031:2014, table A.4.
Air leakage number at 50Pa	$1.0h^{-1}$	

*Equivalent U-value, which includes heat contribution from the ground

6.8.8.2 Airtightness and Moisture

The building envelope must be airtight, both inside and outside. If there are leaks in the inner sealing layer, there is a risk that warm indoor air is pressed out into the construction leading to condensation.

The Technical Building is defined as normally unmanned with no permanent workplaces according to the WEAL- Working Environment Area Limits document. TEK17 *§13-5 Radon* specifies requirements to radon protection for buildings with rooms for permanent stay. There is therefore no requirement for radon membrane under the concrete slab or pressure-reducing actions in the ground (e.g., radon wells).

6.9 Authority Handling

The application to the local municipality for construction of the CCP plant has been sent and approved in previous phases of the project. However, since Contractor`s concept and number of buildings has changed compared to the earlier concept, an application of change has been issued by Company during the FEED CCP Klemetsrud project. Contractor has assisted Company by providing updated drawings and reports to support the application of change, as well as input to the application to VAV and the visual plan. The application of change has been sent to the municipality and was accepted during FEED.

Current approval lettes are received during the FEED:

- 08/02457-18 ; Påslipp av overvann
- 202011647 – 89 ; Tillatelse til endring – Klemetsrudveien 1 – 3
- 24/12398 – 2 ; 177/16 - Klemetsrudveien 1 - Endring av plassering av eksisterende fordrøyingingsbasseng

After submission of supporting documentation to Company, the Technical Building was subject to changes to accommodate design development in the area design. The application will therefore be updated in the EPCIC phase together with company.

7 INTERFACE

7.1 General

The nature of the FEED CCP Klemetsrud Project, with brownfield interfaces towards the existing WtE Plant and other external interfaces forms a break down in several contracts and necessitates a proper interface management system to ensure the overall integrity of the Project.

Changes in the existing plant may be needed or studied as a result of developing the new CO2 capture plant; hence the interface management system needs to ensure that such changes will be captured.

The sections below describe the interface management approach adopted in the FEED.

Based on information available in the FEED and pre-EPCIC phase, Contractor has established a procedure for the management of interfaces in the EPCIC phase, /55/.

7.2 Interfacing Parties

The interfacing scopes in the FEED and Pre-EPCIC phases are defined in the table below. The interfacing parties are identified by a unique code in the interface request register and system.

Table 7-1 FEED CCP Klemetsrud Interfacing Parties and Associated Codes

Interfacing Scope, FEED	Interfacing Party	Party code
Tech building and plant design/engineering	Aker Solutions	AS
CO2 capture process incl. temporary storage and truck loading	Aker Carbon Capture/ SLBC	AC
Civil design	Multiconsult	MC
Tech building architecture and HVAC system	Multiconsult	MC
Steam and condensate systems	Norsk Energi	NE
Heat pump and district heating	Norsk Energi	NE
E-House	Aker Carbon Capture / SLBC	AC
Existing plant and facilities	Celsio	CE
Interim/pre-EPCIC phase	**Interfacing Party**	**Party code**
Contractor's scope as above managed as the contracting party in interface with Celsio	Contractor	CO
Existing plant and facilities	Celsio	CE

7.3 Method and Tools

The interface management has been executed in accordance with the Contract requirements and governed by the Interface Management routines presented to all parties and stakeholders in the beginning of the FEED. Same routines did also apply to the Pre-EPCIC phase.

Contractor has coordinated all its interface relationships in accordance with the interface handling routines to ensure a holistic approach across the various contracts.

To exchange interface information and to develop and conclude on interface issues, numerous meetings at discipline levels have been conducted with the interfacing parties. Specific topics requiring special attention have been covered in dedicated meetings/workshops.

A Tie-in point index, /53/, has been developed to ensure common understanding of interfacing points and scope towards the existing plant and facilities.

An internal Interface Point index has been developed to ensure common understanding of interface points and scope split between Contractor's parties.

All interface requests have been recorded in an Interface Request Register, /54/. Requests and responses, with referenced documents and attachments, have been stored on the FEED collaboration SPS (/ Collaboration Externally Shared / Celsio / 6. FEED Interface Management /…) in folders corresponding with the interface request number. Counts of Interface Request statuses are summarized in Table 7-2.

Table 7-2 Interface Requests Raised During CCP FEED

FEED PHASE	Concluded and frozen for EPCIC	Not frozen for EPCIC. Transf. to pre-EPCIC		
Contractor to Celsio	14	6		
Celsio to Contractor	0	0		
Total:	14	6		
Pre-EPCIC PHASE	**Concluded and frozen for EPCIC**	**Awaiting conclusive response**	**Registered and transferred to EPCIC**	**Void**
Contractor to Celsio	29	21	12	2
Celsio to Contractor	0	1	1	0
Total:	29	22	13	2

Requests that have not been finally concluded in the FEED and pre-EPCIC phases are kept open and will be transferred to the EPCIC phase for conclusions. Interfaces and Interconnections to the WtE Plant

The CC Plant is designed to be interconnected to the existing WtE Plant technically and functionally. Contractor has managed all interfaces between the CC Plant, including the additional Technical Building and the plant surroundings.

The area or physical interface is defined as a common physical boundary between continuous elements of contract objects. The major physical external interfaces are given in the FEED 3D-model and further detailed in the Tie-in point index, /53/.

System interfaces have been identified and defined by the disciplines to the necessary level of details to support the overall FEED design. The interfaces are defined in relevant discipline deliverables like UFDs, P&IDs, SLDs, topology diagrams and interface documents.

Where necessary system engineering interface information has not been (sufficiently) specified in the FEED design basis documents, the interfaces have been discussed and agreed with the relevant interfacing party by Interface Requests, and/or documented in the Interface Request Register, /54/.

Reference is made to the discipline sections for further information and references.

7.4 Internal Interfaces

Internal interfaces are defined entirely within Contractor's (or within Contractor's joint venture or consortium) own scope, e.g., with its subcontractors or between different disciplines or departments within Contractor's organization or its partners. The responsibility for the coordination process between these parties has been entirely with Contractor.

Subcontracts established to complete the contractual work scope (e.g., civil scope) are regarded as an extension of Contractor's own disciplines and functions and as such regarded as being an internal interface.

Interface coordination between Contractor's own disciplines and functions is handled through regular interdisciplinary meetings and managed, documented and executed in accordance with Contractor's Project Execution Model (PEM). Coordination of internal interfaces is a line responsibility resting with the respective Managers and Discipline Leads and/or technical interface contacts.

8 PROCUREMENT

8.1 FEED Procurement Activities

The total identified procurement scope for the FEED CCP Klemetsrud Project, both equipment and bulk, has been broken down into around 100 procurement packages. These have been assigned a criticality level from 1 to 4 based on complexity, number of interfaces, lead time and impact on overall design. Reference is made to the Procurement Milestone Plan (PMP), /28/, for further details. Procurement activities have started on 50 procurement packages; this has included:

- Qualification of potential suppliers
- Issue of Requests for quotation / Requests for information
- Bid evaluations
- Establish a Procurement plan for the package

Budgetary RFQ's were issued to several suppliers for the most critical procurement packages, including technical and commercial requirements, as applicable. The technical information was typically contained in a Technical Specification, Process Datasheet, while the commercial information typically included General Terms and Conditions, Special Conditions, Price Summary and Clarification Logs, as applicable.

The information requested from bidders to be included in the budgetary quote was a technical description, price, lead time, delivery terms and place of manufacture. The received bids were evaluated technically and commercially and based on this, Contractor has made a list of shortlisted suppliers (typically 2-3 suppliers) per package. It is to be noted that initial commercial evaluations were made purely based on price, delivery, supplier competence and past performance.

In the EPCIC phase, more mature RFQ's will be issued to these shortlisted suppliers, and it is at this stage where in addition to price and delivery negotiations, the general terms and conditions will also be reviewed, and deviations, if any, will be negotiated.

In the pre-FID phase, Contractor has continued the design maturation for critical packages such as Columns and CO2 Compressor.

For some of the critical packages (CO2 Compressor, CO2 Dryer, Modules), Contractor prepared and issued the complete RFQ package, upon getting the Package procurement Strategies presented and approved by Company.

Contractor is exploring synergies between SLBC and AKSO for procurement of common bulk packages and certain identified equipment packages along with optimal use of procurement resources and systems. There are ongoing discussions between SLBC and AKSO Legal to use common standard T&Cs for establishing frame agreements for such packages.

8.2 Procurement Strategy

The main procurement strategy is to select suppliers for the procurement packages based on competitive bidding and subsequent negotiations. In some cases, a single source strategy may be established in dialogue with Company, and that also requires Company approval. The bid evaluation shall be based on package evaluation criteria as stated below:

- Technical know-how and product offerings (modularized construction)
- Price / Lead time
- Capacity
- Compliance with contract conditions and commercial requirements
- Compliance with general technical requirements
- Compliance with Company/Contractor's code of conduct (HSSE, Quality/business integrity)
- Project references
- Risk assessment

The weight of each criterion will be decided for each package by supply chain and engineering and will be included in the package procurement strategy. The bid recommendation will be presented to Company and PO will be placed upon Company approval of the recommendation.

Where it being technically possible and commercially beneficiary, merger of several procurement packages into one will be considered, introducing savings for administration and follow-up cost. Merger of procurement packages is planned to be evaluated both between the

Terminal and Klemetsrud plants, and the Aker Solutions and the Aker Carbon Capture scopes as part of the EPCIC tender activities.

For further details, refer to the Procurement Strategy document Rev 03.

8.3 Status of the Main Critical Procurement Packages

8.3.1 JC 400, Reclaimer and Liquefaction Modules

For the Modules, Contractor has issued a budgetary RFQ, in FEED, to 10 suppliers, worldwide. Based on the quotations received, Contractor made a preliminary shortlisting.

Preliminary selection was made on the basis of such **criteria** as:

a) previous **experience**

b) **diversification**, as to geographical location and expected competitive levels

c) **flexibility**, i.e. splitting or combining scopes (e.g. with respect to plant integration at Site)

[redacted]

SLB to procure standard bulk items such as valves and instruments thereby leaving fabricator to procure all remaining items.

8.3.2 E-house

For the E-house Contractor issued budgetary RFQ to 5 suppliers.

[redacted]

Combined procurement strategy between AKSO & SLBC scope for the E-House being investigated.

Complete RFQ package issued, technical discussions ongoing with both the suppliers.

Expect bid submission mid-February.

8.3.3 CL02 Absorber, Desorber and DCC Packages

The Absorber package is considered as a priority 1 package due to long lead time, material availability, interface information, cost and difficulties regarding transport and site assembly/erection.

Bids from the suppliers as stated in the below table were received in April-May 2024 and bid clarification meetings (BCM) held. The BCMs mainly focused on the manufacturing method and the amount of site work involved.

Table 8-1 Potential Suppliers for Absorber Package

[redacted]

Regarding the transport, Contractor has looked into different routes and scenarios together with logistic company [redacted] and input from column fabricators.

[redacted]

In EPCIC, Contractor will issue the complete RFQ package to these suppliers mentioned above and potentially to other suppliers on the market.

For the DCC Column, the same manufacturing method as for the Absorber will be considered.

[redacted]

8.3.4 CP01 CO2 Compressor Package

This is also a priority 1 package due to long lead time, material availability, interface information and cost.

Due to the technological and confidentiality/collaboration considerations, budgetary inquiry was issued to the following 3 suppliers who all have submitted their bids:

Table 8-2 Potential Suppliers for CO2 Compressor Package

[redacted]

[redacted]

[redacted]

8.3.5 ER276 Heat Pumps Package

This is considered a priority 1 package due to long lead time, complexity, requirements for early interface information and cost.

RFIs have been issued to six suppliers in January 2024. The bid evaluation process has highlighted five vendors which should be considered for the EPCIC phase.

Table 11 Potential Suppliers for Heat Pump Package

Supplier	Country
MAN Energy Solutions	Germany
Siemens Energy AS	Norway
Friotherm AG	Switzerland
Turboden S.p.A.	Italy
Heat Pump Alliance	Germany

The package has officially started in September 2024, and a strategy based on Isobutane has been approved by Celsio. Two vendors, Siemens and Frioterm have been enquired.

However, quoting on Isobutane has proved to be not possible for vendors at this stage, hence, a new package strategy has been approved by Company and issued based on HFO refrigerant.

Based on the new strategy, a new RFQ has been issued on Decemeber 9th to the following suppliers: Frioterm, Man, Turboden, Siemens (issued on 20.12) and The Heat Pump Alliance (Strabag and Atlas Copco). Due date for bidding: 14.02.2025.

8.3.6 ER285 Waste Water Treatment Package

This package is considered as a priority 2 package but with special focus during FEED, due to the technical criticality and impact on the layout of the Technical Building.

RFQs have been issued to several suppliers in February 2024. The bid evaluation process has highlighted three vendors which should be considered for the EPCIC phase, also considering they can deliver the Ammonia treatment equipment.

Table 12 Potential Suppliers for Waste Water Treatment Package

Supplier	Country
Canon Artes	Italy
Unidro SRL	Italy
Va Tech Wabag	Turkey

The package has officially started on January 6th, 2025, and the strategy has been issued to Celsio for approval on 09.01.2025.

9 CONSTRUCTION METHOD AND COMPLETION

9.1 General

Modularization is the guiding philosophy and method strategy for all project execution for the FEED CCP Klemetsrud project, since experience from earlier projects clearly shows that relocating as much of the work as possible to a pre-fabrication phase and deliver complete multidisciplinary modules (fabrication volumes) to the project site indicate several upsides. Not only does this reduce costs in direct disciplines, but also reduce resources for the indirect disciplines and improves HSSE.

To accomplish this, all modules must be designed as self-bearing structures. The design of the modules must be seen in conjunction with the different load conditions it is exposed to during the construction period. This could be conditions such as skidding, boat transport, land transport, temporary supporting and lifting. The various conditions can normally be identified in an early stage and frozen in time to be integrated into the design. For the CCP Klemetsrud project, transportation to site also needs to be taken into consideration when defining the module design.

Modularization will not only have a positive effect during execution due to limiting the number of on-site manhours, but also in conjunction with constructability, through construction friendly design, will greatly improve HSSE performance due to more of the work being performed in ideal facilities with all needed services during construction. This philosophy will also allow for more of the construction activities to be performed at ground level as opposed to at a higher level in a traditional stick-built installation scenario. In cases where modularization is not possible, stick-built installation is the alternative. The location of the construction site and nearby facilities are considered when choosing the most suitable methods for transport.

In the following sections Contractor`s proposal for the main execution method and installation sequence is described and explained on a high level, i.e., based upon the available information during this FEED phase. The execution method needs to be further detailed in the next phase of the project in close collaboration with the Engineering, Procurement and Planning disciplines.

9.2 Overall CCP Area

This section briefly describes the main installation sequence for the complete scope to be performed at the construction site, excluding the Technical Building. The installation sequence and methodology for the Technical Building is described in Section 9.3.

9.2.1 Location of Construction Site and Construction Restrictions

Since the location of the construction site at the Klemetsrud WtE plant has no access through waterways, all transportation of goods and materials will need to be by public roads. The standard allowed transportation dimensions are LxWxH = 18/22m x 4m x 4.5m, where the weight of the cargo as well as the location of the Center of Gravity also need to be considered. Typically accepted loads for road transports are max. 50-70T pending on number of axles of the carrier.

Contractor will keep the items to be transported as much as possible within the standard transportation window. Where this is not possible, special transports need to be planned and arranged for, e.g., permits, preparatory works (removal of obstructions, if required), transport escort etc. During the FEED, a transportation study has been performed by Sarens to identify possible routes, as well as maximum dimensions for each item, ref /30/ and document HI2305-AKE-Z-RA-0008 for details.

Extended transport studies were performed to evaluate various possibilities. The main routes investigated were:

- From Ormsundskaia via E18-Homlia
- From Ormsunskaia via Kongsveien-Ekeberg
- From Oppegård Båtforening via Homlia
- From Oppegård Båtforening via Herregårdsveien-Ljabruveien
- From Oppegård Båtforening via Ljabrudiagonalen tunnel

Technical solutions were found for each of the above routes. Details of each transport route will be in individual reports from the vendor. However, any selected route will require approval from the authorities which was not attained during FEED / interim phase.

Another restriction at site is that the only entrance is through the South part of the area. The complete North- and East side of the construction site is surrounded by a natural retaining rock wall, while the West side of the construction site is occupied by the Technical Building.

Installation sequence starts with the stickbuilt Absorber and DCC.The remaining installation sequence will mainly be from the North to the South, but deviations from this pattern can and/or might occur based on balancing the efficiency (parallel work), safety and control of the available installation spaceThe high voltage air spanned cables in close vicinity of the East side of the construction site also need to be taken into consideration during the execution period. The same goes for underground structures and existing cables.

The below figure illustrates the described restrictions.

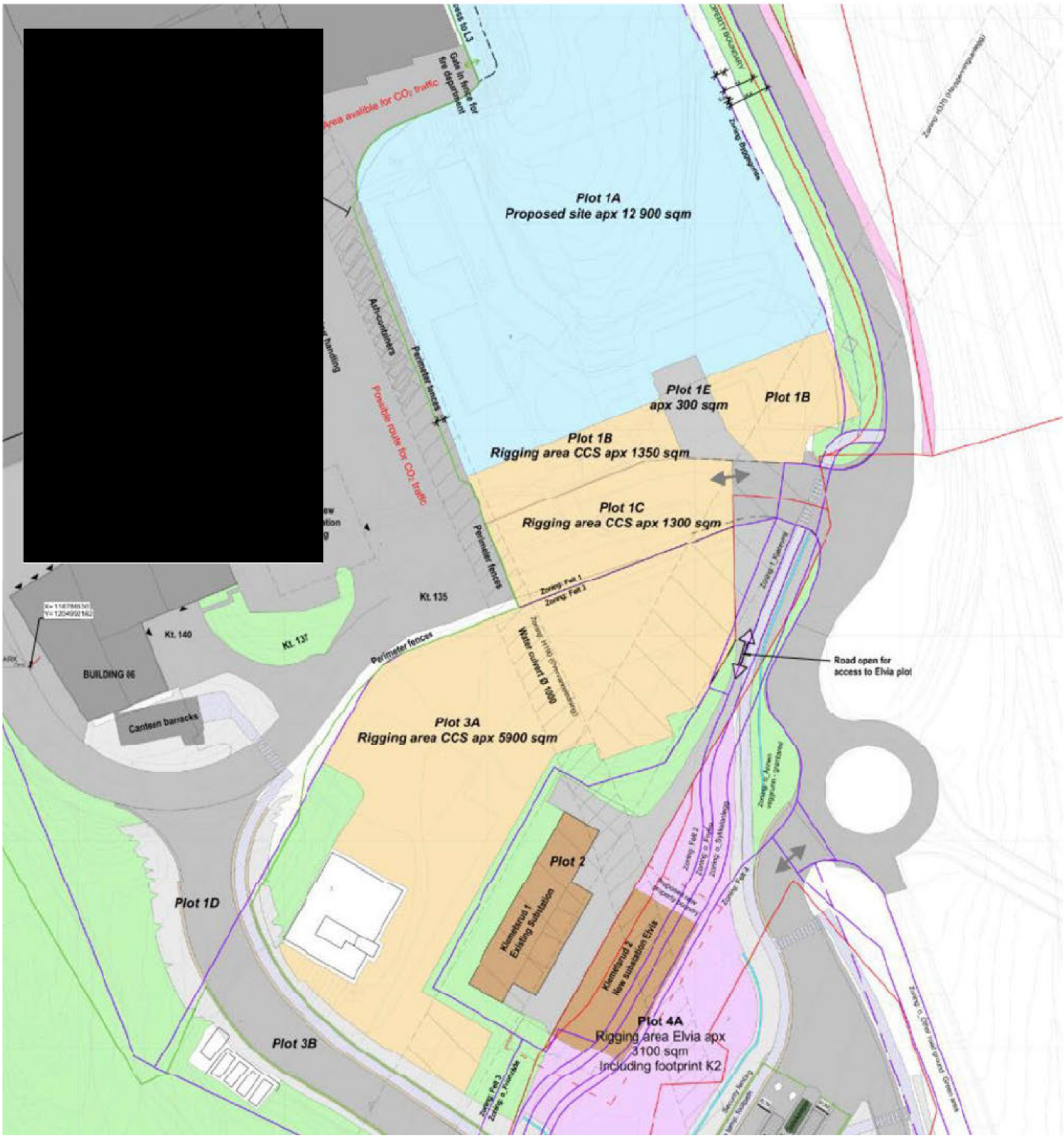

Figure 9-1 Site Restrictions – Retaining Wall, TB and Access from South Only

9.2.2 Installation Method for Large Equipment on Site

A short description of the defined large equipment to be installed at the Klemetsrud site is given below per item, including a high-level description of the installation method.

The proposed installation sequence is presented separately in Section 9.2.4.

Without going into the details, all other types of equipment such as the Flue Gas Fan and the elements [redacted] installed using standard methods (cranes, rigging) and therefore no specific description is given at this stage.

9.2.2.1 Absorber & Direct Contact Cooler (DCC)

Due to its large diameter and height, the Absorber and the DCC cannot be transported to site in one complete piece. Both columns will be prefabricated on the Klemetsrud site (Bus area).

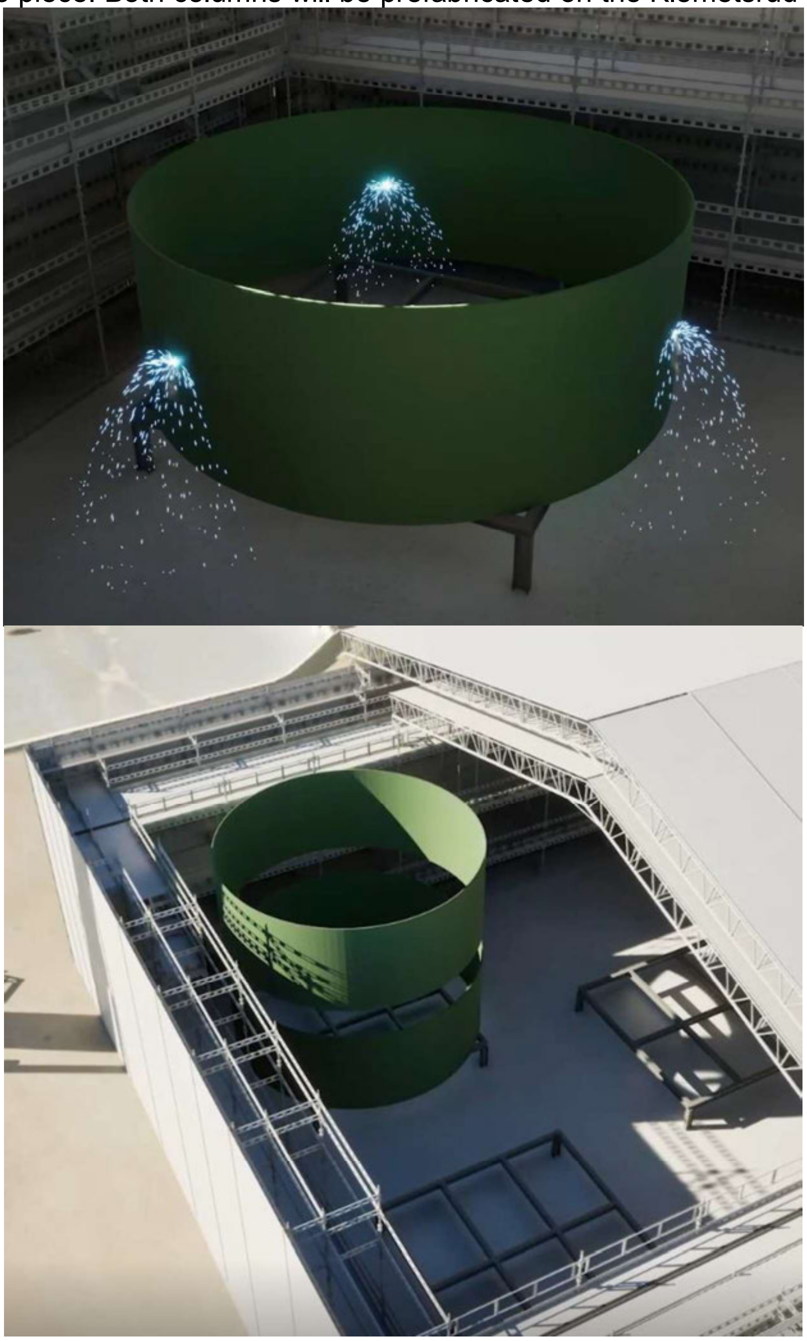

Figure 9-2 Typical Prefabrication of Absorber at Site

Prefabrication of the Absorber and DCC column, delivered in rolled sheets, is planned to be performed in the laydown area South of the construction site (Plot 3A), to avoid interfering with

Civil 2 work being executed in parallel, ref Figure 9-13. After the assembly period, time is required to dress / outfit the columns as much as possible, following the method principle of performing as much work as possible at prior to assembly on foundations. The dressing is planned at the same location as the assembly.

The completion of the dressing of both columns needs to be timed against the final installation of the columns. The Absorber and DCC will be assembled with a tower crane and mobile crane on their final foundations.

Figure 93 Assembly of Absorber / DCC

9.2.2.2 CO2 Storage Tanks and Desorber

The CO2 Storage Tanks, being pressure vessels, will be delivered as complete vessels using special transport by public road to site. This is possible due to the smaller diameter of the columns, compared to the Absorber and the DCC. The current design premise is that the desorber will be designed as flanged rings that will be hooked-up at site. Each section will be small enough for road transport.

A dedicated area for dressing the CO2 Storage Tanks and Desorber at the construction site is accounted for, ref Figure 9-13.

9.2.2.3 Just Catch^{TM} 400, Liquefaction Modules and E-House

The design of the JC400^{TM}, liquefaction modules and E-House is such that the whole module consists of building blocks, i.e., standard transport by road is possible. The modules will be installed by use of mobile crane or other means pending on the final installation weight. Site hook-up work will be required to connect the modules. Large equipment as plate and frame heat exchangers and the Reboiler will be installed at site. The modules will be trial fitted at module yard before shipment to site. Transport steel will be removed at site.

9.2.2.4 Pipe Racks

The pipe racks are designed to be transported by public road as standard transport. There are several pipe racks to be installed at the Klemetsrud site, but the installation principle is the same for all:

The pipe racks will be loaded onto multi-wheelers (SPMTs) and with aiding tools and temporary designed structures trailed onto their support columns.

9.2.2.5 The Reclaimer Package

The Reclaimer Package is a skid-based type of equipment, but due to its total size it will not be possible to transport as one piece, not even as special transport. Contractor will investigate designing the package in modules such that the package can be delivered as submodules and install at site.

Further maturation of the design of the Reclaimer Package in the next project phase will conclude the final installation method.

9.2.3 Construction Site Area Preparation

Prior to start of the construction activities in the overall area, which will start after all civil foundations and supports at ground level are completed, the construction site needs to be prepared. Specified areas need to be covered with gravel to protect the concrete foundations and provide correct load distribution to the ground, and hence provide safe and correct operational conditions for the cranes.

Site facilities are planned erected and prepared by the Civil2 subcontractor (e.g., office rigs, warehousing, fencing etc.), since the Civil 2 subcontractor is the first one to perform work at site. These functions are therefore assumed to be in place and operational when installation work at site commences.

9.2.4 Installation Sequence of the CO2 Plant Equipment

This section will briefly describe the main steps of the installation sequence. The full preliminary installation sequence is found in Appendix B.

The remaining installation sequence will mainly be from the North to the South, but deviations from this pattern can and/or might occur based on balancing the efficiency (parallel work), safety and control of the available installation space.

The figures below illustrate the installation of the pipe racks which arrive by truck to site and further loaded on multi-wheeler, driven into correct position and lowered onto their supports.

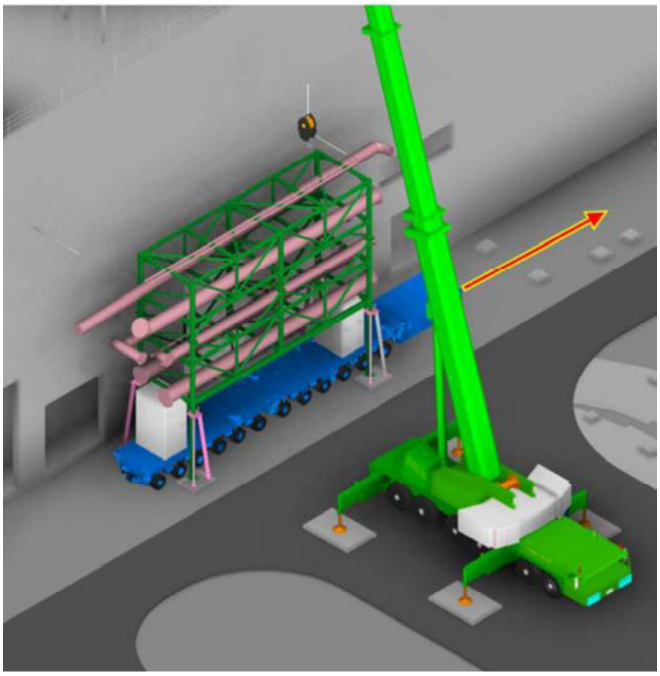

Figure 9-4: Pipe Rack Transport on Multiwheeler to Final Installation Location

During the installation phase, there will be parallel work in different sub-areas of the construction site and inside the Technical Building. The main part consists of hook-up work activities e.g. installation of piping, mechanical equipment, or E&I scope, as well as surface treatment and mechanical completion. Safety is always the decisive factor when planning for parallel works.

9.3 Technical Building

The installation of the main equipment inside and on top of the Technical Building is briefly described in this section. For the construction of the Technical Building itself reference is made to Section 6.

[redacted]

The installation sequence for the equipment in the Technical Building is reflected in the execution schedule, and also described in Appendix B. The following sub-sections will include a high-level description of the installation method and sequence for the most critical rooms.

9.3.1 [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Figure 9-10 Temporary Laydown by Use of Scaffolding

9.3.4 Air Coolers on the Roof

Installation of the air coolers on the roof of the Technical Building is planned by lifting pre-assembled cooler bays from the East and West side of the building by using a tower or mobile crane. The size of the cooler bays, as well as the amount of pre-outfitting needs to be further investigated in collaboration with the selected supplier in the next project phase, however, the below figure shows the principle.

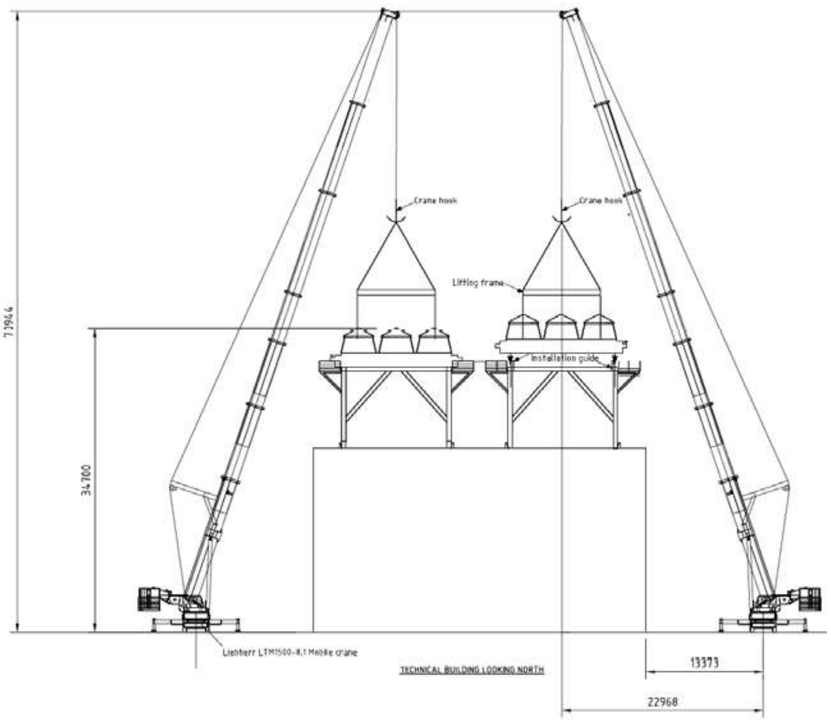

Figure 9-11 Lifting of Cooler Bays Onto the Technical Building Roof

9.4 Site Facilities, Rigging- and Laydown Areas

Available rigging- and laydown areas are defined by Company in HI2305-CEL-C-XE-0002, and as agreed with Company during FEED, constituting mainly the bus area on the South side of the construction site and Plot 14 on the North side, correspondingly indicated in Figure 9-12 below. The existing WtE plant entrance gate will be temporarily relocated by Company to allow for a continuous area under Contractor`s control from the bus area and into the construction area. Preparation of the rigging and laydown areas, including temporary services for construction (electricity, sewage, water) will be catered for by Company.

Contractor`s intention is to utilize the area on the South side for some offices inside the bus garage, scaffolding storage and for assembly and dressing of large vessels and columns avoiding conflict with the Civil2 laydown and rigging area. The area on the North side is primarily intended to be used for warehouses and storage of items arriving at site.. Figure 917 shows planned storage area, car parking and wardrobe barracks.

Further detailing on the use of the laydown areas has to be done in the next project phase along with maturing the construction and installation schedule, as well as in dialogue with the selected suppliers.

Figure 9-12 Available Rigging and Laydown Areas in yellow

Figure 9-13 Preliminary Sketch of use of Laydown Area South (Bus area)

Figure 9-17 Available Rigging and storage Areas Plot 14B-F

9.5 Completion

The purpose of developing a completion philosophy and completion strategy in the FEED phase is to present an overall methodology for the planning, preparation, and execution of all MC/Commissioning work to be carried out in the subsequent EPCIC phase, which in turn will ensure a safe start-up and operation of the entire CCP plant at Klemetsrud when it is ready.

The completion strategy outlines the principles of overall execution through the specific stages of engineering, procurement hereunder quality monitoring and inspections at suppliers, construction and hook-up with mechanical completion and dynamic testing, commissioning of all the installation work with equipment and systems and which will culminate in a reliability test prior to handover of the finished plant to Company.

The completion strategy document also provides an overview with division of systems to be tested that becomes the basis for interface definitions with boundary limits and further preparation of the sequential commissioning execution plan which will be established together with software, procedures, and guidelines during the EPCIC phase when the engineering work has achieved the required maturity.

The preservation methodology that is an integrated activity throughout all stages of the project is also briefly described in the philosophy.

The Completion Strategy and Philosophy for the CCP Plant is documented separately in /24/.

10 HSSEQ MANAGEMENT

To maintain a high level of quality throughout the whole project, Aker Solutions' Quality Management System has been utilized in the FEED. Aker Solutions` Quality Management System is certified by the international standard ISO 9001 and contains internal governing documents and working processes. Among others, the main quality management tools, utilized in the CCP FEED project, were quality plan and audits and verification schedule. It is described below how these tools were used in the project.

FEED Quality and HSSE Plan

This document has been issued for the FEED phase with the main objective to outline Contractor's company policies, organization, related procedures, and guidelines, which will be referred to manage quality and HSSE during the execution of the CCP FEED project, ref /25/ for details. The plan ensures, by setting systematic principles, work tasks and responsibilities, that the Project is executed in a consistent manner, according to quality policies, -objectives and according to project requirements. This plan acts as a management tool for ensuring compliance with Company project-specific requirements, Contractor's corporate, scope of work, contractual agreements, local laws, and regulations.

Project Audits and Verifications Schedule

Project audits and verifications schedule is an overview of the important project milestones and deliveries, where a project quality assurance function has a responsibility to follow up and control the key project deliveries. The schedule is a part of the FEED Quality plan.

Verifications schedule information is live data; therefore, an electronic version of the schedule was established on the project SPS, which has been maintained on a monthly basis. An overview as per end of FEED is presented in the table below.

All actions from FEED reviews have been evaluated and concluded for FEED level, however, a portion of the actions needs to be re-evaluated also in the next phase. Reference is made to Appendix A for a complete list of actions (not updated for Pre-EPCIC phase).

Table 10-1 FEED CCP Klemetsrud Verification Schedule

Activity	Planned dates	Responsible discipline	Facilitator	Status
Process System Design Review	16.01.2024	Process	Internal outside project	Completed
Coarse FEED HAZID	14.02.2024	HSE in Design	3rd party (ORS)	Completed
FEED Civil Constructability Review	12.03.2024	HSE in Design / Civil	Project internal	Completed
Coarse FEED HAZOP	18.03.2024 – 22.03.2024	Process	3rd party (ORS)	Completed
Coarse FEED LOPA	10.04.2024 - 11.04.2024	HSE in Design	3rd party (ORS)	Completed
FEED Layout Review / Coarse WEHRA	23.04.2024 - 24.04.2024	Piping & Layout / HSE in Design	Project internal	Completed
FEED Overall Constructability Review	07.05.2024	HSE in Design / Method Engineering	Project internal	Completed
FEED CHRA	22.05.2024	HSE in Design	Project internal	Completed

11 EPCIC SCHEDULE

This section provides a brief overview of the CCP EPCIC schedule, including a description of the identified critical path. For further details, please refer to the EPCIC Schedule Report, /36/.

11.1 Key Schedule Assumptions

- **Seamless Transition from FEED to EPCIC**
  - The project will maintain a high degree of resource allocation in both Contractor and Company project teams to ensure a smooth transition from the FEED into the EPCIC phase
- **EPCIC Contract Milestones**
  - **Contract Award Date**: February 3, 2025. This is a theoretical date only. Company will provide the actual date when the project is officially sanctioned. The durations in the schedule are still considered representative but may be subject to adjustments due to work being shifted into winter or holiday periods. The overall duration of the project from Contract Award (CA) to Project Complete Milestone M4 will be 47,5 months, with only minor adjustments expected.
  - **Interim Phase**: From July 12, 2024, to January 31, 2025, designated for further design maturation, procurement preparation activities, including those prior to the placement of priority 1 Purchase Orders (POs) and the Civil2 subcontract. It is important to note that no POs shall be placed before the contract award.
- **Civil2 Subcontract Milestones**
  - One Civil2 subcontract will cover the entire civil scope at Klemetsrud, and another will cover the scope of work at the Terminal.
  - Input to Civil2 RFQ issued for review is 17.03.2025 for Klemetsrud
  - The public announcement/final RFQ for Klemetsrud is scheduled for 11.4.2025
  - The subcontract award for Klemetsrud is targeted for 15.08.2025the date need to be agreed with Company. .
  - The first civil works at the site are expected to start 06.10.2025 (CA+8 months), focusing on general infrastructures, foundations for the Technical Building and SLBC equipment.
- **Detail Design**
  - Detail engineering starts at CA and to take 17 months until considered complete (PEM 3A stage gate – Main engineering deliverables released).
  - Release of first piperack IFC drawings from CA+13 months.
  - Civil IFC drawings to be released from mid-August 2025 (CA+6,5 months).
- **Construction, MC and Commissioning**

    - Prefabrication starts at Stord yard by CA+16 months, however cost competitiveness for the Stord Yard has to be documented. If Stord yard is not cost-efficient, external prefabrication yards will be chosen.
    - First SLB equipment start installation in north area by CA+21 months.
    - Project delivered mechanically complete: CA+43 months.
    - 2-month period for reliability test included at the end of the commissioning phase.
    - Temporary power from KL1 is assumed available from April-2027.
    - Permanent power from KL2 transformer station not available until KL2 is complete.
    - Temporary power is assumed available before Q1 2028 for construction and pre-commissioning activities.

- **Execution Strategy**
    - For the AKSO scope, the execution method will focus on modularizing the deliveries into Fabrication Assembly Volumes (FAVs). Contractor plans to perform all prefabrication at the Stord yard (if proven cost-competitive) and mechanically completed to the maximum extent possible before being shipped to the Klemetsrud site.
    - SLBC equipment will be delivered from suppliers according to the procurement and delivery plan and installed on-site.
    - Design development will prioritize the use of skid-mounted solutions to facilitate efficient equipment installation in the Technical Building, CO2 Capture Area, and CO2 Storage Area.

- **Procurement Plan**
    - Milestones for the placement of purchase orders (POs) for various packages are illustrated and aligned with the preliminary PMP. Further analysis will be conducted to adjust and balance PO dates to optimize execution with the project resources. Additionally, synergies in merging procurement packages common between the AKSO and ACC scopes will be considered.

11.2 CCP EPCIC Summary Schedule

Contractor has developed a comprehensive schedule that covers all phases of the project. Due to transportation restrictions, Contractor has concluded a construction-alternative with in-situ construction of Absorber and DCC. The schedule outlines key milestones and activities, highlighting critical dependencies and durations. The main project phases included are Engineering and Procurement, Civil Works, Construction and Installation, Mechanical Completion and Pre-Commissioning, and Final Start-Up.

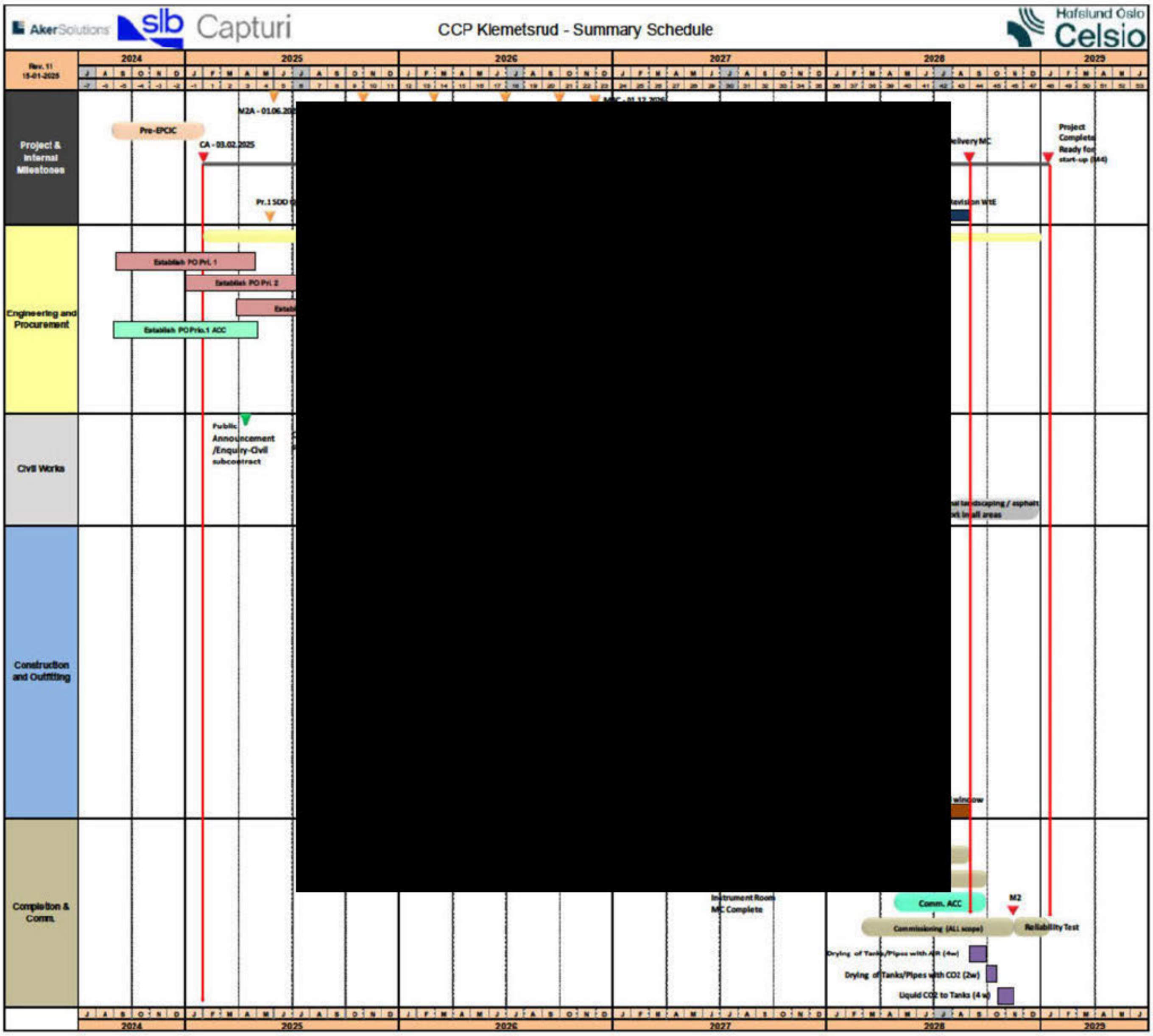

Figure 11-1 EPCIC Summary Execution Schedule

11.3 Critical Path

The critical path identified at this moment, based on the preliminary method statement and the longest path visible in the network, runs through several key stages:

Firstly, it begins with the detailed design and engineering for the procurement of critical equipment for the Technical Building. Following this, the placement of purchase orders for critical long lead items and other selected packages for the Technical Building is essential. Supplier interface information relevant to the Technical Building's civil design is also a crucial step.

Next, the Civil2 subcontractor contract award and the subsequent civil engineering design up to the first release of IFC are pivotal. The mobilization and work preparation of the Civil2 subcontractor follow, leading to the completion of the Technical Building's civil scope up until the roof is completed.

[redacted]

Finally, the subsequent pre-commissioning and commissioning activities of all relevant equipment to allow drying of pipes and tanks with air and CO_2 before the reliability test is also part of the critical path.

1. [redacted]
2. [redacted]
3. Supplier interface information relevant for Technical Building Civil design.
4. Civil 2 subcontractor contract award.
5. Civil design up to first release of IFC Technical Building.
6. Civil subcontractor mobilization and work preparation.
7. Establishing prefabrication facilities for in-situ stickbuilt columns and start-up of in-situ installation work

[redacted]

16. Columns, E-house and JC-Plant pre-commissioning and commissioning
17. Drying of tanks and pipes with CO_2
18. Reliability test

12 EPCIC COST ESTIMATE

The cost estimate is not updated, during Pre-EPCIC updated MTO for piping and structural disciplines have been submitted to Company.

The CCP FEED EPCIC cost estimate is described and documented in a separate report, ref /27/.

13 RISK MANAGEMENT

The main goal for the project Risk Management function during the FEED has been to identify risks or threats and opportunities that could affect the project outcome. The project has in turn managed the risks, aiming to reduce the potential harm of the risks through mitigating actions. The overall goal is to contribute to a controlled and successful FEED project execution and most importantly contribute to a controlled EPCIC project execution.

During the FEED, Contractor has executed several multidiscipline risk workshops to populate and maintain the project risk register, including establishing and closing out mitigating actions. In the early phases of the FEED, the main focus was related to risks in the FEED execution, whereas towards the end the main focus was shifted to risks for the EPCIC phase. For further details of the work performed for risk during the FEED, reference is made to the FEED risk management procedure, /56/, as well as the risk section included in each of the monthly management reports submitted to Company throughout the FEED.

A CCP Klemetsrud Top 10 risk list for the EPCIC phase as of end November 2024 is included in the below figure.

Risk Title	Cause	Consequence	Exposure	Min Cost NOK	Exp Cost NOK	Max Cost NOK	probability %	EMV
[redacted]								

Figure 13-1 CCP Top 10 Project Risks June 2024

14 OTHER ITEMS COVERED IN PRE-EPCIC PHASE

.

14.1.1 Tagging of Systems Spanning Across Several Parties

Contractor`s initial proposal for applying the Company KKS tagging manual to the CCP scope was rejected by Company, as claimed not to reflect the tagging practice in the existing WtE plant. Re-tagging of Contractor scope was partially performed, but not prioritized for systems spanning several parties (i.e., utility systems mainly). The principles for tagging have now been agreed with Company, however, not fully reflected in the issued FEED documents.

Tagging updated on Master documentation during interim phase. Some outstanding updates in Contractor engineering systems, but implementation is ongoing. As agreed with Company, the majority of the FEED documents have been kept as working copies and not officially re-issued during the interim phase.

14.1.2 Condensate Handling and Availability During Plant Start-up

A proposed system design for condensate drain has been developed and indicated on P&IDs HI2305-AKE-P-XB-8015 and HI2305-AKE-P-XB-8016, however, this is not fully incorporated in the area design.

In addition, handling of potentially larger quantities of contaminated condensate during start-up of the CCP plant needs to be further looked into, as return of off-spec condensate to the WtE plant is not accepted by Company.

During the interim phase the condensate handling system design has been developed further and agreed with the Company.

[redacted]

14.1.4 Heat Pump Safety Concept

The heat pump refrigerant selection was changed by Company from being either HFO or ammonia to isobutane after having received responses from potential suppliers to the initial RFI in March 2024. Heat pump solutions of the capacity required in this project are not common, even less so with isobutane as refrigerant. The amount of refrigerant is large, and the safety related to transport, filling and storing of the isobutane needs maturing.

Delivering a heat pump system that meets all regulatory requirements is the supplier's responsibility, however, it is important that the project group works in close cooperation with the nominated supplier to ensure all parts are compliant. Work with a safety concept to ensure that the complete heat pump installation meets all regulatory requirements is still ongoing by suppliers and needs further maturation. Certain safety aspects may also need to be solved as part of supplier's detail engineering. A critical part of the safety concept is to provide effective and reliable leakage detection systems [redacted] secondary water systems (cooling medium and district heating system, respectively).

During the pre-EPCIC phase, a heat pump RFQ based on isobutane was issued to potential suppliers in November 2024, however, as none of the suppliers were able to provide an offer within the timeframe of the project, Company again changed the refrigerant selection, this time to HFO. Although HFO has lower fire/explosion hazard compared to isobutane, feedback from the heat pump supplier is still required to finalize the heat pump safety concept.

The heat pump supplier will perform necessary risk assessments for their scope of supply and document that at hazardous area classification has been completed for their equipment.

All electrical equipment located within areas classified as hazardous zones must be ATEX compliant. This also applies for all other electrical equipment and motors which are not part of heat pump suppliers' scope (i.e. overhead crane, lighting, normal/emergency HVAC, electrical actuators, instrumentation, etc.). The design shall fulfill the requirements given in EN378-2 sec. 6.2.14.

[redacted]

Appropriate venting and dispersion of HFO from PSV discharge pipes needs to be evaluated, also with regards to proximity to potential ignition sources. Final solution and location will determined in the next phase.

Fire-fighting system/strategy in the machine rooms has been discussed during pre-EPCIC and it has been decided that a fixed fire-fighting system (i.e. sprinkler system) within the machine rooms is not required for HFO-1234ze. However, a pipe branch for fire water is established close to the machine rooms as well as necessary space for future installation of a sprinkler system in the rooms. .

The heat pump system contains a large amount of pressurized and hazardous substance which may cause over-pressure in the machine room in the event of a significant leak. The need for pressure relief panels is still under evaluation and will be determined based on a risk assessment during the next phase.

14.1. [redacted]

14.1.6 Heat Recovery from CO2 Capture Plant to District Heating System

As described in section 2.3.2, additional equipment will be required for additional heat recovery and OPEX reduction. The decision to proceed was concluded late by Company, hence, the FEED system and area design has not been completed. The additional equipment i.e. heat exchanger in the JC-modules has been included in the 3D model, however, the pipe rack and associated P&IDs etc have not been updated.

During the interim phase, it was discovered that the cost of implementing this solution is too high and the modifications required are too complex. This work was then stopped and will no longer be implemented.

14.1.7 Piping Specification for Steam Piping

As part of developing a project specific piping material specification, an evaluation between using ASME or EN for the steam piping has been performed. Initially, Contractor`s approach was to generally limit the use of EN piping due to negative experience from other ongoing CCS projects, however, after further evaluations and dialogue with potential suppliers, it was found beneficial to use EN for the CCP steam systems. T. The conclusion is that the HP steam piping will be EN standard Piping, while LP and MP steam piping will be ASME standard. Condensate piping will be EN and ASME standard.

14.1.8 Size of CO2 Compressor Aftercoolers not updated in 3D-model

The CO2 aftercoolers were changed during FEED from CM cooled to direct air cooled based on an improvement proposal from Contractor to allow for savings in both OPEX and motor sizing for the CO2 compressor. The size indicated by vendors is larger than the current cooler shown in the 3D model but is expected to fit in the available space on the roof.

The CO2 aftercoolers have been updated in the 3D-model during the interim/pre-EPCIC phase.

14.1.9 Charging Stations for CO2 Trucks

Charging stations for the CO2 trucks were covered by Company in the concept design. Due to lack of any stated capacity requirements, Contractor based the FEED design on typical and assumed required charging capacities considering the short distance between Klemetsrud and the Oslo harbor terminal. However, when later taking up the discussion with Company, [redacted] electrical load triggering knock-on consequences also for other parts of the electrical design. Due to coming up late, full implementation of this requirement in the design was not feasible.

Truck charging stations has been implemented in design during the interim phase.

[redacted]

14.2 Preparations for EPCIC Phase

This section lists some of the recommended preparational activities for the EPCIC phase identified at this stage. However, as agreed with Company, a complete list of the activities for the pre-EPCIC phase will be further discussed and agreed as part of the extended FEED work in August 2024.

.

[redacted]

[redacted]

16 APPENDIX

[redacted]