PROJECT CCS
CARBON
CAPTURE
OSLO

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FOV Design Basis for CC Plant

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1 INTRODUCTION

This document provides the basis of design (BoD) for the planned CO_2 capture operations at Klemetsrud and Oslo harbour. The CO_2 capture operations at Klemetsrud, referred to as *CC Plant*, include:

- The CO_2 capturing facility
- The CO_2 conditioning, liquefaction and storage equipment
- The CO_2 to truck loading facilities

The CO_2 capture operations at Oslo harbour, referred to as *Harbour facilities*, include:

- The CO_2 from truck unloading facilities
- The CO_2 storage and re-liquefaction equipment
- The CO_2 to ship loading equipment

<u>Definitions and abbreviations</u>

BoD	Basis of design
CC Plant	Future CO_2 capture plant at Klemetsrud including CO_2 conditioning and liquefaction
CCS	Carbon capture and storage
Company	Fortum Oslo Varme (FOV)
Contractor	Technip E&C Limited
DH	District heat
FEED	Front end engineering and design
FG	Flue gas
Harbour facilities	All CO_2 handling facilities (storage, piping, loading, etc.) at Oslo Harbour
HMI	Human machine interface
K1, K2, K3	Incineration line 1, 2 and 3 at Klemetsrud WtE plant
NIPH	Norwegian Institute of Public health
PLC	Programmable logic controller
TOC	Total organic carbon
TRU	Thermal reclaimer unit
VOC	Volatile organic compound
WtE	Waste to energy

1.1 HOLD List

HOLD No	Requirement	To be resolved by
1	DELETED	
2	DELETED	
3	Metocean Data, Oslo Harbour	FOV

2 BACKGROUND

The Klemetsrud waste to energy (WtE) plant (subsequently referred to as Company or FOV WtE plant), located in Oslo, Norway, converts municipal and industrial waste to heat and power. The conversion takes place in three incineration lines and results in significant amounts of flue gases. While the flue gases are cleaned to meet the stringent requirements set for waste incineration in Norway, the emitted CO_2 amount remains unaffected. However, the target for the plants future operation is to capture as much of the CO_2 as possible, while minimizing the impact on the existing plant operation (district heat (DH) - and electricity production).

Originally the Company WtE plant was taken into operation in 1985, but in 2011 it was expanded with a new independent line (K3) for waste incineration. Today the plant consists of three separate waste incineration lines and two steam turbines. The plant provides district heating to the Oslo district heating networks, Sentrum, Holmlia and Bjørndalen in addition to electric power from the steam turbines.

3 CC PLANT DESIGN INPUT DATA

3.1 Gassnova design basis requirements

Gassnova has prepared the document "Design Basis for the CCS Chain" that is intended for all parties involved in planning and realization of the Norwegian Full-scale carbon capture and storage (CCS) project. All applicable sections from this document have been included below (Gassnova Design Basis ver. 5.2).

3.2 Incinerated waste type

The source of the waste incinerated at the Company WtE plant has different origins, but due to effective (largely automated) waste handling systems, the quality (composition, humidity and dry heating value) of the incinerated waste remains fairly homogenous throughout the year. (Based on historical data, for a simplified estimation, one can consider that 1 ton of incinerated waste generates 1,14 tons of $CO_{2,}$)

The waste received at Company WtE plant consists of municipal- and industrial waste. The household waste from Oslo is treated so that plastics and food waste are sorted out from the waste stream by source separation and treated elsewhere. The remaining fraction is incinerated at the plant. The plant also receives hospital waste (around 750 tons in 2016). This waste represents only a small fraction (less than 0,2%) of the total amount incinerated and is fed directly in the hopper of Line 1 (K1).

3.3 Flue gas description

The flue gas source (composition, contaminants and emission limits) is described in detail below.

3.3.1 General design principles for the CC plant

The design principles shall be as follows:

- Normal operation and process design shall be based on Table 3-1 and Table 3-2.
- Process design shall also allow for the values in Table 3-3 (in combination with Table 3-1) including all the design flue gas parameter combinations. These conditions shall not cause any process upsets, short- or long term damage, excessive degradation etc. In addition, the CC Plant should be able to handle occasional peaks above the permit values.
- Mechanical design shall be based on both Table 3-1, Table 3-2 and Table 3-3 (all the design flue gas parameter combinations).

3.3.2 Flue gas volume flow, composition and operational parameters

Below are tables with design data and operational parameters for the Company WtE plant.

Table 3-1. Company WtE plant design data[1]

Description	Sum K1 & K2	K3	Total
CO_2 amount (t/y)	201 900	258 300	460 200
FG amount (Nm^3/h) [2, 3, 4]	157 600	199 200	356 800
FG minimum (Nm^3/h) [2]	151 600	-	151 600
FG O_2 target level (dry)	7% vol	6%-vol	-
FG CO_2 content (11% O_2, dry)	8,1% vol	8,1%-vol	-
FG H_2O content			-
Winter	18,1% vol	5 - 10% vol	-
Summer	18,1% vol	14,5% vol	-
FG temperature (°C)			
Winter	80 - 85	85 - 100	
Summer	110	85 - 100	-
FG pressure (bara)	0,95 - 1,05	0,95 - 1,05	-
Operational time (hours)	8 050	8 150	-

1) All yearly data accounts for operational hours, while hourly data represents momentary values
2) Nm^3/h: dry gas, 0°C, 101,3 kPa, 11 vol% O_2
3) Oxygen margin accounted for in FG amount (not to be added on top)
4) Plant base case is the simultaneous operation of all 3 lines using a flue gas flow rate based on the CO_2 mass flow and concentration

3.3.3 Flue gas contaminants

Table 3-2 provides information about the concentration of various contaminants separately for all three lines and all three lines combined. .

Table 3-3 provides information about the limit values (in accordance with current emission permit). For contaminants that are not regulated by the current emission permit, the design values have been provided in Table 3-3.

The online measured flue gas components are: NO_x, SO_2, NH_3, HCl, H_2O, CO, HF, O_2, and dust for lines 1 and 2, In addition, the total organic carbon (TOC) emissions are measured for lines 1 and 2, while volatile organic compounds (VOC) are measured for line 3,

Table 3-2. Design FG composition (at 11 % O_2 unless otherwise indicated)

Component	Concentration (mg/Nm³)			Combined (mg/Nm³) [3]
	K1 (Avg.)	K2 (Avg.)	K3 (Avg.)	Average
Dust	2,2	5,2	0,7	2,0
TOC/VOC	1,2	1,3	0,4	0,8
HCl	1,4	1,2	0,1	0,6
HF	0,05	0,05	0,08	0,07
CO	31,9	34,6	7,4	18,4
SO_2	14,5	8,7	1,9	6,0
NOx	117,7	111,2	14,4	57,0
NH_3	1,9	N/A	1,3	2
Acid mist (SO_3)	10,7	8,7	1,3	4,9
Nuclei/cm³ [(1]	858	513	31500	18 000
H_2S	0,5	0,5	0,4	0,4
Cd+Tl	0,00011	0,00010	0,00087	0,0005
Hg	0,0010	0,0001	0,0022	0,001
Heavy metals[2]	0,0019	0,0025	0,0181	0,01
Di+Fu (ng/Nm³)	0,009	0,002	0,026	0,02
NO	109	98	11	50
NO_2	1,90 (0,93 ppmv)	1,45 (0,71 ppmv)	0,85 (0,42 ppmv)	1,2 (0,59 ppmv)

[1)] Representing submicron particles
[2)] Consisting of Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V (+ Sn in more recent campaigns)
[3)] Combined data has been calculated based on flue gas flow provided in Table 3-1

Table 3-3. FG composition (avg. of all lines), permit limit values (at 11 % O_2 unless otherwise indicated)

Component	Limit values, average and peaks (mg/Nm³)		
	24 h	A- 100 % [1,3]	B- 97 % [2]
Dust	10	30	10
TOC/VOC	10	20	10
HCl	10	60	10
HF	1	4	2
CO	50	100	150 [4]
SO_2	50	200	50
NOx	200	400	200
NH_3	10	-	-
Acid mist (SO_3)	-	-	-
Nuclei/cm³ [5]	-	-	-
H_2S	-	-	-
Cd+Tl	0,05	-	-
Hg	0,05	-	-
Heavy metals[6]	0,5	-	-
Di+Fu (ng/Nm³)	0,1	-	-
NO	-	-	-
NO_2	-	-	-

1) 100 % of all half-hour average values have to be within the value A
2) 97 % of all half-hour average values have to be within the value B
3) Limit value A can be exceeded for four consecutive hours before incineration plant must shut down
4) This CO value (of 150 mg/Nm³) is a ten-minute average value
5) Representing submicron particles
6) Consisting of Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V (+ Sn in more recent campaigns)
7) Combined data has been calculated based on flue gas flow provided in Table 3-1

3.4 WtE Plant operational modes

All three incinerators are normally operated at full load, except during periods of scheduled or unscheduled maintenance. Typically maintenance is performed so that all three lines are out of operation for a period of four weeks every year. Below is an example of a typical maintenance cycle:

- K1 is shut down 3 weeks (typically weeks 27-29), after 2 weeks, K2 shuts down for 3 weeks (typically weeks 29-31). This means that both K1 and K2 are shut down for maintenance of common systems for one week (typically week 29).
- K3 is shut down 3 separate weeks (typically weeks 23-25)

The impact of the above maintenance breaks on the emitted CO_2 amount has been visualized below (Figure 1). The left axis represents the (momentary) CO_2 generation rate, while the right axis indicates the CO_2 emissions as a fraction of full capacity. Note that the CO_2 fraction is not equal to the flue gas flow rate fraction.

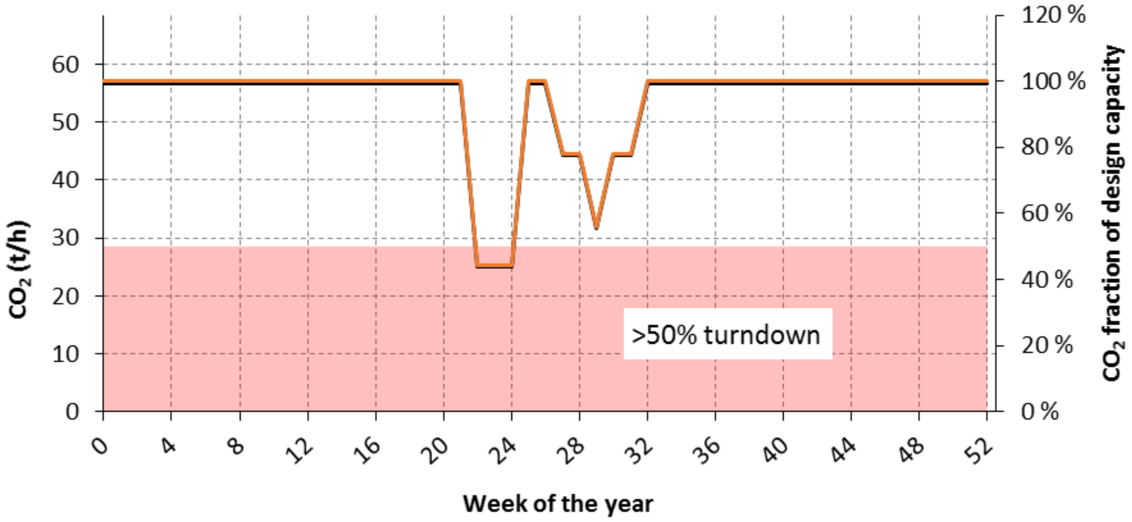

Figure 1. Typical yearly variation of CO_2 emitted from Klemetsrud WtE plant (not including unplanned service breaks).

4 CC PLANT PERFORMANCE

4.1 Key Process and Design Data

Table 4-1 Key Process and Design Data

Parameter	Design Value
Design lifetime	≥ 25 years
CO2 capture efficiency across absorber	≥ 95%
Amount of CO2 delivered to intermediate storage at KEA	≥ 400 000 tons CO_2 per year
Amount of CO2 delivered to ship	≥ 400 000 tons CO_2 per year
Yearly average production availability	≥ 95% (Target value)
LP Steam Consumption	≤ 67 000 kg/h (daily average) [1)]
MP Steam Consumption	≤ 1000 kg/h (daily average) [1)]
LP+MP Condensate Return	≥ 99% of LP + MP Steam consumption (incl. demineralised water make-up)
Energy consumption, thermal, ref. ISO 27919-1	≤ 3,0 GJ/t CO2 captured [1)]
Energy consumption, electric, ref. ISO 27919-1	≤ 442 kWh/t CO2 captured (average excl. heat pump) [1)] ≤ 23,9 MW (average excl. heat pump) [1)]
Solvent consumption (50/50% solvent/water)	≤ 134 t/y [1)]
Chemicals consumption (Caustic 47% solution)	≤ 74 t/y [1)]
Amine emissions from stack	≤ 0,2 ppmv, ref. Ch. 7.2 [1)]
Solvent waste	≤ 134 t/y [1)] ≤ 35 kg/h (TRU outlet batch flow rate) [1)]
Note 1: Additional 2% may be accepted subject to Company approval	

4.2 Design Operational Cases

The following two cases are defined as operation design cases:

- Summer Case – Based on summer operating conditions of the WtE plant. Cooling provided by cooling system only;
- Winter Case – Based on winter operating conditions of the WtE plant. Cooling provided by heat pump / cooling system.

The CC Plant should be capable of operating normally around the year, noting that the flue gas composition varies depending on season (winter/summer), see Chapter 3.3, Table 3-1.

The following two cases are defined as rating cases:

- Turndown Case – Based on lines 1 and 2 in operation during summer conditions and 90% flow rate. Cooling provided by cooling system only. The plant will not be optimised to operate at turndown for long periods of time;
- Max Contaminants Case – Based on design maximum concentration of impurities in the flue gas. Cooling provided by cooling system only. Cooling is possible up to 45°C. This case will not to be used to optimise the plant to operate for long periods of time, but to estimate the maximum amine degradation rate.

The CC Plant shall be able to operate with flue gas from WtE incineration lines 1 and 2 only (e.g. when line 3 is down for maintenance) and vice versa.

4.3 CO_2 product specification

The CO_2 product to be shipped shall meet the specifications provided in Table 4-2.

Table 4-2. CO_2 specification

Component	Concentration, ppm (mol)	Remarks / Comments
Water, H_2O	≤ 30	Required to avoid formation of hydrates (blockage) and free water (corrosion) in the pressure vessels and process systems used for interim and onshore storage and transportation.
Oxygen, O_2	≤ 10	Required to avoid formation of corrosive species in the lower well completion where the CO_2 mixes with reservoir brine containing chlorides.
Sulphur oxides, SOx	≤ 10	Required to avoid accelerated corrosion in presence of water. Value set conservatively to allow wider range of materials.
Nitric oxide/Nitrogen dioxide, NOx	≤ 10	Required to avoid accelerated corrosion in presence of water. Value set conservatively to allow wider range of materials.
Hydrogen sulfide, H_2S	≤ 9	Toxic to personnel in case of accidental release.
Carbon monoxide, CO	≤ 100	Toxic to personnel in case of accidental release.
Amine	≤ 10	May react with and degrade several non-metallic materials.
Ammonia, NH_3	≤ 10	Effects unknown.
Hydrogen, H_2	≤ 50	May cause embrittlement of metals.
Formaldehyde	≤ 20	May react with oxygen to form acetic acid. Other effects are unknown.
Acetaldehyde	≤ 20	May react with oxygen to form acetic acid. Other effects are unknown.
Mercury, Hg	≤ 0,03	Toxic to personnel entering vessels, replacing filters, etc. May cause embrittlement of metals.
Cadmium, Cd Thallium, Tl	≤ 0,03 (sum)	Toxic to personnel entering vessels, replacing filters, etc. May cause embrittlement of metals.

4.4 Modelling of thermodynamic properties of CO_2

Calculations of phase equilibria and thermodynamic properties for CO_2 must be carefully compared to measured data from e.g. NIST (http://webbook.nist.gov/chemistry/fluid). Using typical equations of state like Peng-Robinson, SRK, and PRSV will give calculated values that deviate significantly from measured properties:

- Density of liquid/dense phase CO_2 at temperatures approaching the critical temperature of 31,1 °C. The error may easily be greater than 10%.
- Solubility of water in liquid CO_2 at any pressure, where the equations of state may predict values that are orders of magnitude too low or too high.

4.5 Design Allowances

The following flue gas design margins on Company data shall be applied:

- Flue gas max/min flow: +7,5% / -10%;
- Oxygen concentration in flue gas: +35%;
- CO_2 concentration in flue gas: +6%.

Flue gas max flowrate margin shall be included in the rated flowrate. Flue gas min flowrate negative margin shall be applied in the Turndown Case.

The Oxygen concentration margin shall be considered in the Max Contaminants Case. The CO2 concentration margin shall be included in the rated flow. It shall also be considered when calculating degradation rate of the amine.

The normal design flowrate will correspond to the Summer or Winter case operation, whichever higher.

For the Pre-Treatment Section rated flowrate will be equal to the normal design flowrate plus a 7,5% margin. For the TRU, rated flowrate will be based on the Maximum Contaminants Case plus 20% design margins on equipment.

For the rest of the plant (carbon capture, compression, conditioning, liquefaction, transportation and storage) rated flowrate will be equal to the normal design flowrate plus a 6% margin, and with an additional extra 7,5% margin.

For equipment and systems, the following design sizing margins will be applied:

- Booster Fan: 5% on flow;
- Pre-scrubber tower: 10% on gas flow;
- Absorber: 10% on gas flow, 6% on liquid flow (including water wash);
- Stripper: 10% on gas flow, 5% on liquid flow;
- CO_2 Capture plant pumps: 10% on flow;
- Compressor: 10% on flow;
- Instrument Air System: 10% on maximum flow;
- Utility Water System: Size for start-up with no additional margin;
- Steam System: 10% on maximum flow/consumption. Licensor to confirm margin;
- Waste Water Treatment/Demineralisation water system: size for total flow of Waste Water with no additional margin;
- Plate Heat Exchangers: 10% on flow and duty (or manufacturer's margin, whichever is greater);
- Shell &Tube Heat Exchangers: 10% on flow and duty;
- Centrifugal pumps 10% on flow;
- Dosing pumps & reflux pumps 20% on flow.

4.6 CO_2 Intermediate Storage and Transportation

4.6.1 At Klemetsrud

An intermediate storage for CO_2 shall be included in connection with the CO_2 transport facility.

- The intermediate storage volume shall as a minimum account for one day of full production of CO_2.

The CO_2 shall be transported in liquid state using tanker trucks between Klemetsrud and the CO_2 export harbour. The truck loading operations shall as far as possible be automated in order to minimize failures due to human errors.

- The transport condition for the CO_2 is as for design basis purposes set to 15 bar(g) and -30°C

4.6.2 At Oslo harbour

Intermediate storage of CO_2 is needed at Oslo Harbour facilities.

- The interim storage tanks shall be sized to account for four days maximum CO_2 production

The CO_2 loaded onto the ship from the intermediate storage tanks shall be single-phase liquid.

- The operating pressure (at steady state) at the top of the interim storage tanks shall be kept above 13 bar(g) and shall not exceed 15 bar(g).
- The CO2 triple point shall be calculated and made available to the ship transportation contractor prior to each shipment

Loading of CO_2 to the cargo tanks on the transport ship shall be performed by pumping liquid CO_2 from the interim storage tanks onshore using a pumping arrangement onshore. The nominal loading rate should be approximately 800 t/h.

Dedicated pipeline(s) for transfer of gas phase CO_2 from the cargo tanks on the ship back to the interim storage tanks shall be used to balance the pressure between the cargo tanks and interim storage tanks onshore.

Custody transfer metering of CO_2 volumes/rates shall be performed when CO_2 is transferred from one operator to another, i.e. at loading of the transport ship.

The concentration (on mass or molar basis) of water and oxygen in the liquid CO_2 shall be accurately measured online during ship loading of CO_2 from the interim storage tank(s) at the harbour. These concentrations shall be lower than the limiting values given in Table 4-2.

The concentration of other impurities than water and oxygen may be excluded from online measurements if it can be documented that the concentration is inherently below the limiting values given in Table 4-2.

4.7 Normal Operation

Operation philosophy shall be based on a high automation level to minimize plant manning.

Main operation tasks will be:

- Supervision and monitoring of the terminal
- Handling and supervision of ship export
- Measurement of selected chemical components
- Handling gaseous CO_2 displaced from cargo tank(s) on ship during loading

At the harbour, it should be noted that during loading of liquid CO_2, gaseous CO_2 be returned from the ship at the same (or slightly higher) pressure. This CO2 gas/vapour will be transferred back to the storage tanks at the harbour. The effect of gas return shall be included in the design capacities where relevant.

4.8 Instrumentation and control design

Control system and integration with existing system is included in Contractor´s scope.

- CC plant shall be operated from the WtE plant existing common central control room. Any civil works and necessary extension of existing central control room is in Companies scope.
- The CC plant will have an independent control system. The control system will be placed in dedicated LCR/PLC room implemented in the CC plant. Only signal exchange will be required between the WtE plant and the CC plant. If required, Contractor will supply uninterruptible power supply (UPS).

The Contractor shall allow for standardization of the control system at Klemetsrud WtE plant. The following requirements exist:

- Object-oriented programming based on FOV object standard (consisting of about 20 standard objects based on NORSOK)
    - PLS library containing the FOV standard library.
    - Human machine interface (HMI) library containing FOV's default library that has full compatibility with the PLS library.
    - The library can be expanded if there is a need for new object types, must be coordinated with FOV.
- SCD form as documentation for PLS programming (program drawing)
- Compatibility with wall display in operating centre (integrated solution in Wonderware).
- Use of today's journal system as an integrated solution in Wonderware.
- Use of today's alarm system (integrated solution in Wonderware).
- Possibility of collecting calculated environmental data for Wonderware and further reporting.
- Historic data shall be recorded and stored

4.9 Civil/mechanical design interface

FOV will perform all underground civil works and provide a concrete slab at levelled ground for the installation of the CC Plant. A typical scope split for ground works and foundation are given in Figure 2.

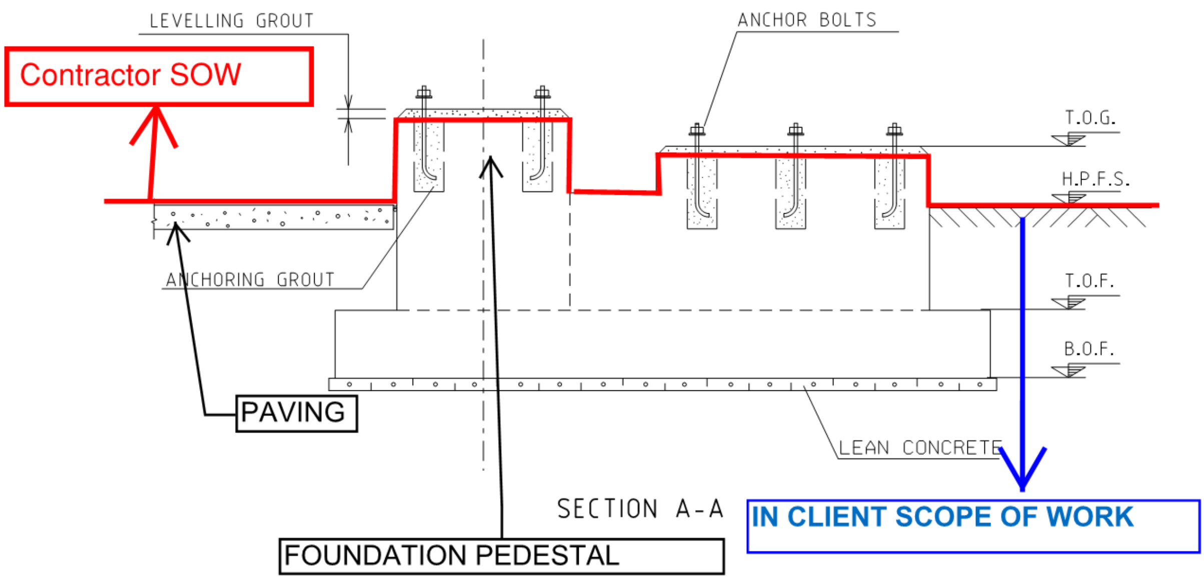

Figure 2. Typical scope split for foundation/ground work

4.10 Design Loads

All construction work shall be carried out in accordance with the current editions of the: Planning and Building Act, fire regulations, health regulations, labour regulations and municipal regulations. The construction works are classified as industrial plant and therefore placed in reliability class (CC/RC) 2 in accordance with NS-EN 1990, Table NA.A1 (901).

The structures shall be designed and dimensioned for loads in accordance with the current versions of NS-EN 1990, NS-EN 1991 and NS-EN 1998-1 (Eurocode), typically:

- Permanent loads (G), based on NS-EN 1991-1-1
- Payloads (Q), based on NS-EN 1991-1-1
- Snow loads (Q), based on NS-EN 1991-1-3
- Wind loads (Q), based on NS-EN 1991-1-4
- Temperature loads (Q), based on NS-EN 1991-1-5
- Loads imposed dring construction (Q), based on NS-EN 1991-1-6
- Accidental loads (A), based on NS-EN 1991-1-7
- Seismic loads (A), based on NS-EN 1998-1

Standard requirements for tolerances are specified in the current version of NS 3420 (Beskrivelsestekster for bygg, anlegg og installasjoner). In addition, the standard requirements for tolerances for concrete structures are specified in NS-EN 13670 and tolerances for steel structures are specified in NS-EN 1090-2,

5 SITE INFORMATION

5.1 Site location and description

5.1.1 Klemetsrud

Due to the fact that the CC Plant is being planned for an existing WtE plant (at Klemetsrud), the size of the planned CC Plant and location of the existing plant needs to be carefully considered.

An overview of the Company WtE plant and its location can be seen in Figure 3. The available locations for the CO_2 capture facilities and liquefaction, storage and truck loading facilities are marked as areas 1 and 2 respectively.

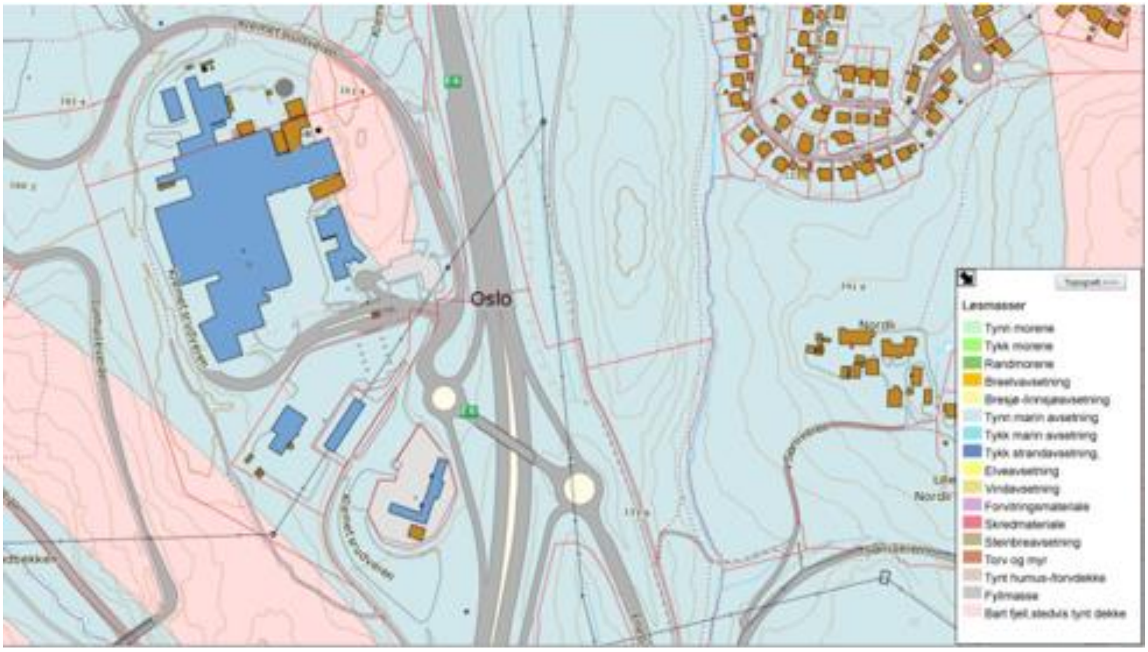

Figure 3. Company WtE plant site

The area available for CO_2 capture (excluding liquefaction, intermediate storage and truck loading) is less than 5 000 $m^{2,}$ Similarly, the additional area for liquefaction, intermediate storage and truck loading stations shall cover an area of not more than 5000 m² regardless of selected location.

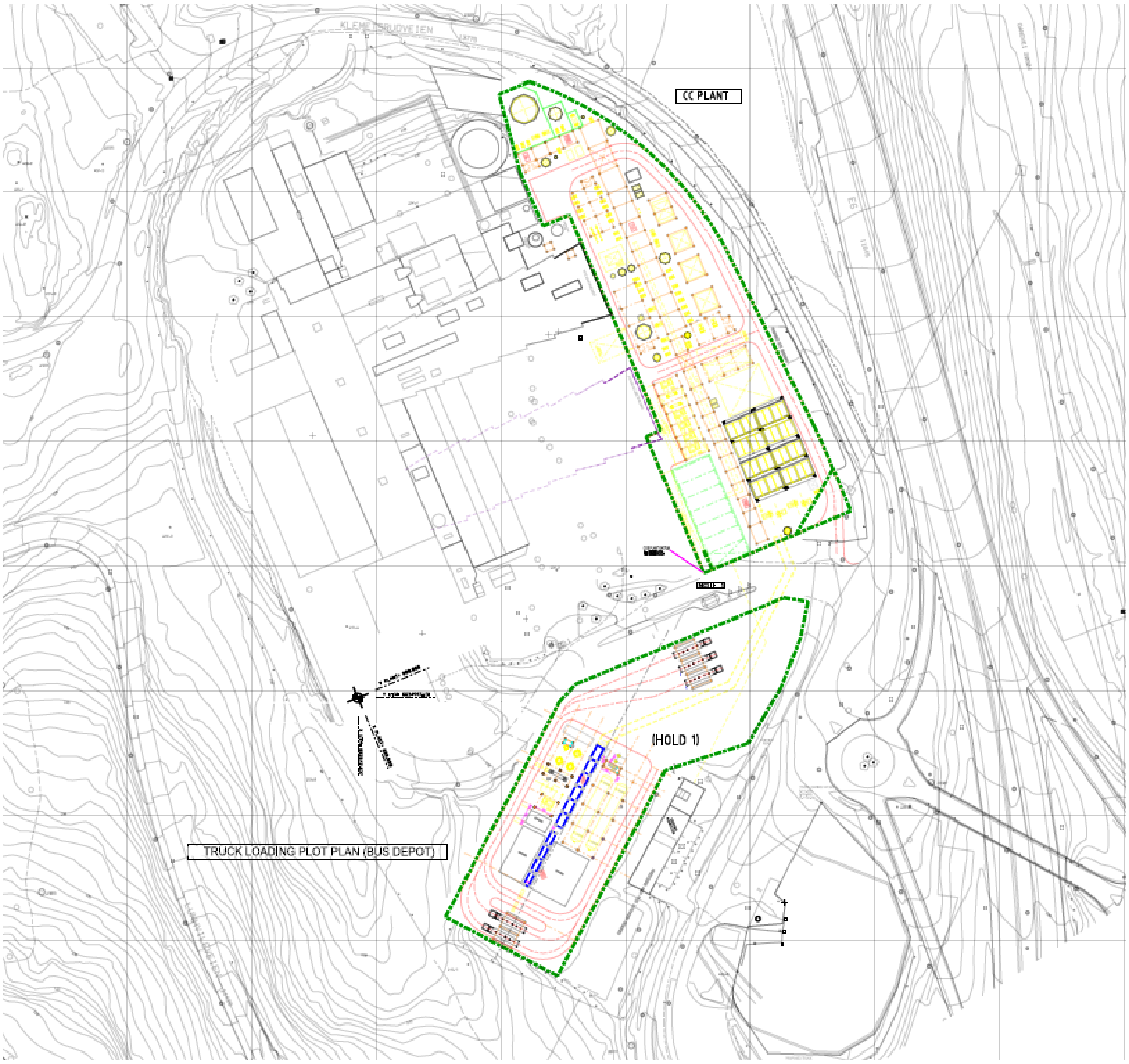

Figure 4. Location of CC Plant relating to WtE Plant

Table 5-1. Information on the location of the Company WtE plant

Location data	Site details
Country, city, location	Norway, Oslo, Klemetsrud
Nearby housing	Close (<300 m)
Land available for the CC plant	11,300 m2
Land available for intermediate storage, truck-loading etc.	< 5000 m2
Overview map of the proposed CC plant	Figure 3
Meteorological data	Figure 7
Source of water for the plant	Municipal/tap water (and ground water?)
Source of cooling	Ambient air (incl. wet coolers)
Harbour facilities, distance to the plant	~7 km
Tallest building at site (above ground)	~43 m
Stack height (above ground)	~80 m
General site elevation (above sea level)	+134 m

5.1.2 Oslo harbour

CO_2 is planned captured and liquefied at Klemetsrud WtE plant, transported by truck from Klemetsrud to a new CO_2 export terminal and exported by ships and subsea pipeline to the final storage site in the North Sea.

As can be seen from Figure 5, Klemetsrud is located southeast of Oslo city; approximately 7 km from Oslo harbour which is the base case for the terminal for storage and shipment export facilities. The actual terminal location is at Kneppeskjær in Oslo Harbour area, refer Figure 6.

The location for the CC terminal will be at an established harbour area with access to an existing jetty/berth. Basic infrastructure as roads, electricity, fresh water system and waste water systems will be available at/near the site. Beyond that, the terminal project is considered as a "greenfield" project, but the size of the CC activities should be minimized (< 5 000 m^2).

Figure 5. Map showing the location of the Klemetsrud WtE plant in comparison to Oslo harbour (storage and ship loading facilities).

Figure 6. Photo showing overview of Oslo harbour and the selected location south part of Kneppeskjær.

5.2 Environmental conditions

5.2.1 Meteorological data

Applicable to both Klemetsrud and Oslo harbour.

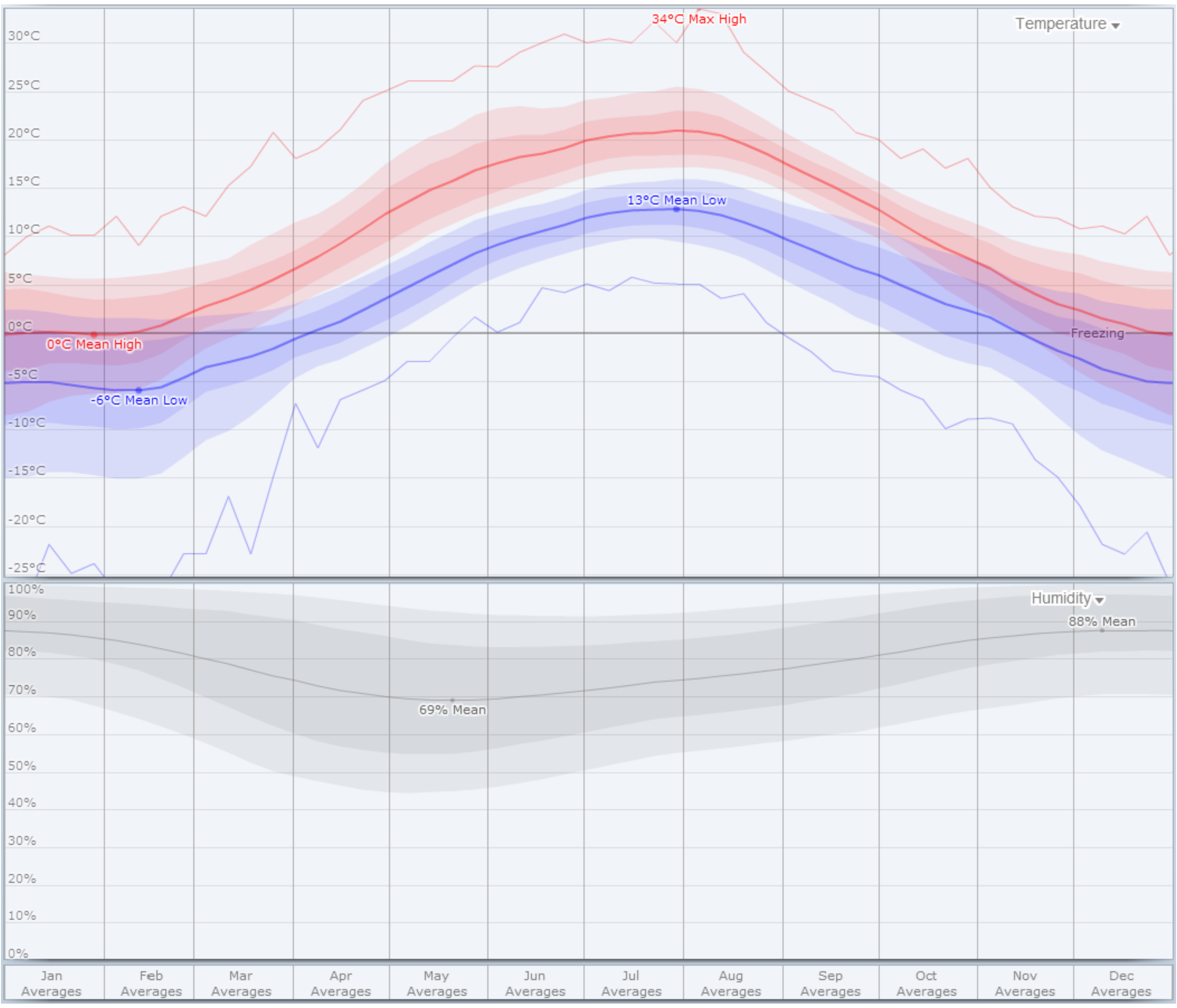

Figure 7. Klemetsrud (Norway) daily average low (blue) and high (red) temperature and humidity with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile) (https://weatherspark.com)

Table 5-2. Environmental design data for CC plant at Klemetsrud

Parameter	Value
Design ambient temperatures, max/min	+30 / -30 °C
Ambient relative humidity [%RH], max/min	100% (July – September) - 9% (May)
Design ambient temperature and humidity [%RH] for air coolers (summer)	+21 °C / 50% RH
Precipitation, rain	Design rainfall: Max 4,4mm in 5 minutes duration. See Ch. 4.10. Run Off: 100% from paved area
Precipitation, design snow load	See Ch. 4.10
Wind speed	See Ch. 4.10

5.2.2 Metocean conditions (Oslo harbour)

HOLD 3, To be completed

6 WTE AND CC PLANT INTEGRATION

This chapter provides details related to the design basis concepts of the interface between the existing WtE plant and the CC Plant. Relevant sections also include design requirements for the CO_2 activities at Oslo Harbour facilities.

6.1 General integration principles

The CC Plant shall be integrated with the existing 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 CC Plant is not allowed to reduce the operability, maintainability, availability nor capacity of any of the incineration lines.

Thus, the CC Plant shall be designed to be self-sufficient in order to minimize dependencies with the existing WtE plant. Exceptions to this general principle have been outlined below.

6.2 Automation and manning

The automation system at the CC Plant including the activities at Oslo harbour should be designed to minimize the manning requirements.

6.3 Heat integration

6.3.1 Heat transfer to district heating and heat pump design

There are two district heating lines going out from Company WtE plant and the temperature to and from the DH network varies depending on the seasonal requirements. The highest demand coinciding with the coldest months.

The CC Plant shall be designed to maintain or improve on the current district heating capacity of the WtE plant through inclusion of a heat pump package. Functional requirements for the Heat Pump package is outlined in the document "FOV Specification for CC plant Heat pump", doc no. NC03i-KEA-P-SA-0002,

6.3.2 Cooling of excess heat

No specific requirements for cooling exists, aside from the limited cooling water availability at the Klemetsrud site (see Chapter 6.4.1).

The CC plant shall have sufficient cooling capacity to cool off all excess heat received by and generated from the CC plant.

6.4 Water balance

6.4.1 Process water

All process water from CC plant to be utilized within CC plant.

A surplus of process water from Company WtE plant to be utilized in CC plant for the replacement of condensate loss and cooling water make-up to the extent possible.

Process water available from incineration plant to CC plant:

- Summer: 12 m³/h
- Winter (Heat pump line 3 in operation): 20 m³/h
- Quality of process water from incineration plant: As is from source
- Temperature of process water from incineration plant: < 50 °C

6.4.2 Demineralized water

The CC Plant shall be self-sufficient with and produce demineralized water to replace lost steam and condensate used internally in the process.

6.4.3 Waste water

Water that cannot be utilized at site should be disposed of to the existing sewage system.

6.4.4 Fire water

Water for fire protection purposes is not available from WtE plant and an active fire protection system is part of Contractor scope.

Note, fire detection system to be integrated in existing system by Contractor.

6.5 Disposal of Thermal Reclaimer Waste

Company will handle Thermal Reclaimer Waste after TRU discharge. The options will be further discussed and agreed with the Contractor during the project.

6.6 Battery limits / interconnection points

The principal interconnection points (battery limits) between the Company plant, the CO_2 capture plant and the CO_2 receiving and ship loading terminal at Oslo harbour are described in Contract Appendix A "Scope of Work".

7 HEALTH, SAFETY AND THE ENVIRONMENT

7.1 General

All existing regulatory requirements shall be met also after the addition of a CC Plant.

The main objective with regards to waste handling is to avoid emissions (zero discharge plant) from the entire Klemetsrud site as a total. All effluent streams (e.g. thermal reclaimer waste) should primarily be utilized/handled within the Klemetsrud site. In addition:

- Noise from the CC Plant will add up with the noise from the existing plant, i.e. the total noise level must not exceed the existing regulations.

For civil works, all parties shall focus on using secondary materials to the extent practically and financially reasonable to contribute to a circular economy. In addition, the building site shall, as far as possible, utilize fossil free energy sources.

Company has to apply for a new emission permit for the CC Plant and until such a permit is obtained, the exact requirements of "new" parameters are not known. Thus, in general, the CC Plant shall be designed to meet stringent requirements taking into consideration the location close to urban areas in the capital of Norway.

7.2 Emissions requirements

7.2.1 Emissions to air

The possible atmospheric degradation of amines to nitrosamines and nitramines and the resulting concentrations of nitrosamines and nitramines in surrounding air and fresh water is the primary concern. Due to the uncertainty of carcinogenic effects, the Norwegian Institute of Public health (NIPH) have therefore provided the following guideline values:

- total amount of nitrosamines and nitramines in air: 0,3 ng/m^3
- total amount of nitrosamines and nitramines in water 4 ng/l

The maximum amine emissions from the CC plant is found in Table 4-1.

7.2.2 Waste and waste water treatment

Process wastewater from CC Plant shall not be disposed of, instead primarily utilized as process water in the WtE plant, secondarily as cooling water (in wet or hybrid coolers). Planned discharges of cooling water (closed loop) is not allowed.

Disposal of surface water from paved areas shall not harm the local environment.

The existing emission permit for waste water to sewage shall not be exceeded. Table 7-1 presents the requirements and the maximum values for emission to sewer (as defined in the emission permit).

Table 7-1. Requirements for emission limits to sewer

Parameter/Substance	Limit Value
Suspended matter, total	7 mg/l
Arsenic and Arsenic compounds (As)	0,05 mg/l
Lead and Lead compounds (Pb)	0,05 mg/l
Cadmium and Cadmium compounds (Cd)	0,005 mg/l
Copper and Copper compounds (Cu)	0,2 mg/l
Chromium and Chromium compounds (Cr)	0,05 mg/l
Mercury and Mercury compounds (Hg)	0,002 mg/l
Nickel and Nickel compounds (Ni)	0,1 mg/l
Zinc and Zinc compounds (Zn)	0,3 mg/l
Thallium and Thallium compounds (Th)	0,01 mg/l
Dioxins (definition found in MDir emission permit)	0,03 ng/l
Temperature (max)	50 ^oC
Sulphate (SO_4^{2-})	300 mg/l
Chloride (Cl^-)	2500 mg/l
Ammonium (NH_4^+)	60 mg/l
pH	6 - 10

The chemical emissions and effluents from the planned CC plant are restricted by the same rules and regulations as for the existing WtE plant. Where a new emission/ effluent stream is introduced and not covered by the existing limitations, necessary actions need to be considered/taken.

The above requirements are based on the following two permits:

- Permit from Oslo Kommune Agency for Water and Sewage Works (VAV)
- Emission permit from Norwegian Environment Agency (MDir)

7.2.3 Diffuse emissions

Diffuse emissions (vapours and liquids) from the process systems and outdoor areas which may have a negative environmental impact shall be minimised.

7.3 Chemicals

Handling and storage of chemicals shall be in such a way to minimise the risk of personnel exposure and acute pollution.

Where better alternatives to the selected chemicals/substances exist, Contractor shall implement these unless unreasonably high cost or other negative impact.

7.4 Requirements for noise emissions to the surroundings

Noise emissions from the planned CC plant are restricted by the same rules and regulations as from the existing WtE plant and for the plant as a total, refer page 7 in the emission permit (see chapter 7.2.2). Noise from the CC plant will add up with the noise from the existing plant, i.e. the total noise level must not exceed the regulations.

The noise limits for Klemetsrudanlegget are as shown in Table 7-2 (Sound Pressure Level measured at the most exposed public or private housing). The noise requirements include all planned activities during normal operation, for instance truck transport, loading/unloading, maintenance work, etc.

Table 7-2 Noise requirements (SPL) to the surroundings

Period	Requirement
Monday - Saturday, L_{den}	55 dB(A)
Evening (19:00 - 23:00), $L_{evening}$	50 dB(A)
Night all days (23:00 - 07:00), L_{night}	45 dB(A)
Sundays, public holidays, L_{den}	50 dB(A)

The following noise exposure limit values for occupational noise shall not be exceeded (The Norwegian Working Environmental Act, Arbeidsmiljøloven):

- Exposure limit values LEX = 85 dB(A)
- Exposure limit values for impulse sounds LC,peak = 130 dB(C)

Additional exposure action values are specified for three different categories of working conditions. The "group III" category is defined as working conditions for personnel dealing with high noise machinery and noisy equipment. The lower action values for this group is defined as:

- Lower exposure action value, Group III: LEX = 80 dB(A)

Hearing protection shall be regarded as a secondary measure only. However, when applying the exposure limit value the actual attenuation from personnel hearing protection shall be considered. For the lower exposure action value, on the other hand, this attenuation shall not be taken into consideration.