BREKKE STRAND

REPORT

KEA CCS Oslo

Noise Assessment Study Report

Client: Technip FMC

Summary:

Brekke & Strand Akustikk AS have been appointed by Technip E&C Limited to undertake a noise assessment study for the addition of a Carbon Capture facility at the Klemetsrud Waste-to-Energy plant in Oslo, Norway. The noise assessment has been made with the use of coarse estimations of sound level data for equipment and noise calculations have been made to predict the sound levels at the nearest residential areas.

Results show that extensive reductions/measures are needed to meet the noise limits both at Klemetsrud and Oslo Harbour.

Recommendations for the sites at Oslo harbour and CCS Klemetsrud are presented in the table 4 and table 5. For the CCS plant at Klemetsrud, a 2 dB reduction to the existing facility noise emissions is needed in combination with the given recommendations.

Project id:	26236-00
Report:	AKU – 01
Revision:	1
Date:	8.5.2019
Project manager:	Lars R. Nordin
Issued by:	Knut Haugen/Lars R Nordin/George Adams
Approved by:	Trond Blesvik

Revision History:

Rev No:	Issued by Name:	Date	Controlled by Name	Date	Comments
0	KH/LRN/GA	27.03.2019	TBL	27.3.2019	Draft Issue
1	LRN	8.5.2019	TBL	8.5.2019	Issue for final FEED (IFF)

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1 Introduction

Fortum Oslo Varme (FOV) has appointed Technip E&C Limited (TECL) to undertake a Front End Engineering Design (FEED) for the addition of a Carbon Capture facility at the Klemetsrud Waste-to-Energy (WtE) plant in Oslo, Norway.

The objective of this noise assessment study is to evaluate the impact of noise on neighbouring properties around the facility, as a basis to implement noise control actions necessary to meet the noise requirements in the discharge permit.

An existing model and results from previous assessments carried out by Brekke & Strand Akustikk have been used in this noise assessment.

1.1 Scope of work

The noise assessments include evaluations of noise from mechanic equipment at the Carbon Capture facility and the Oslo harbour offloading site.

Noise from piping, valves and restriction devices are not included at this stage of design. To account for the additions from these sources, as well as for the uncertainties in the given equipment noise data, a safety margin of 5 dB has been added to the resulting values. This safety margin will be reduced at a later stage of design when more detailed supplier information is known.

The main focus of this report is on environmental noise, occupational noise is only briefly commented.

1.2 Definitions and abbreviations

CCS	Carbon Capture & Storage
CO_2	Carbon Dioxide
DH	District Heating
WtE	Waste to Energy
FEED	Front End Engineering Design
FOV	Fortum Oslo Varme
KEA	Klemetsrudanlegget AS
TECL	Technip Energy & Chemicals Limited
L_{pA}	A-weighted Sound Pressure Level in decibels (dB) using a reference level of 20 µPa
L_{wA}	A-weighted Sound Power Level in decibels (dB) using a reference level of 10^{-12} Watt
L_{den}	A-weighted Sound Pressure Level in decibels (dB) using a reference level of 20 µPa with 10 dB/5 dB additions for night/ evening
L_{EX}	A-weighted Sound Exposure Level in decibels (dB) for a nominal 8 hour working day
Tonality	The presence of tonal components in noise, as determined by ISO 1996-2
FAT	Factory Acceptance Test

DEFINITIONS:

CLIENT:	Fortum Oslo Varme, Klemetsrudanlegget (KEA)
CONTRACTOR:	TechnipFMC, UK (TECL)
CONSULTANT:	Brekke & Strand Akustikk AS (BSA)

2 Criteria

2.1 Noise Limits for external areas in Discharge Permit

The noise requirements of the CCS project are governed by the limits as given in the discharge permit for the existing WtE plant (the Norwegian Environmental Agency, last revision 20. Dec. 2017). The CCS project will require a new discharge permit, but it is not expected that these regulations will be changed in the new permit. Limit values from the current WtE discharge permit are given in Table 1.

Table 1 - Noise Limits from discharge permit, last revision 20.12.2017. Free-field values in front of facade

Mon - sat L_{den}	Evening (7 pm – 11 pm) $L_{evening}$	Night (11 pm – 7 am) L_{night}	Sun-/ holidays L_{den}	Night (11 pm – 7 am) L_{5AF} *
55 dB	50 dB	45 dB	50 dB	60 dB

L_{den} is the A-weighted time average sound pressure level with 10 dB/5 dB additions for night/ evening.
$L_{evening}$ is the A-weighted time average sound pressure level for the evening period 7 pm – 11 pm.
L_{night} is the A-weighted time average sound pressure level for the night period 11 pm – 7 am.
**L_{5AF} is the A-weighted maximum sound pressure level measured with time constant «Fast» (125 ms) which is exceeded by 5 % of the noise events within a given time period*

The limit values apply to the total noise level from the ordinary operation of the plant, including internal transport within the property. All the limit values are to be fulfilled for every single day of operation.

Comment: Noise limits in the permit correspond for the most parts to the limit values given in the national guideline T-1442/2016 (*Retningslinje for behandling av støy i arealplanlegging*). Colours (yellow/red) in the noise contour maps is chosen according to these limits.

2.2 The Norwegian Working Environment Act

The Norwegian Working Environmental Act (Arbeidsmiljøloven) gives the following noise exposure limits values for occupational noise in Norway:

- Exposure limit values L_{EX} = 85 dB(A)
- Exposure limit values for impulse sounds $L_{C,peak}$ = 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: L_{EX} = 80 dB(A)

The Norwegian regulation states that 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 is not taken into consideration.

If the lower action value is exceeded, the employer shall perform a noise risk assessment and possible technical and/or administrative measures to reduce noise exposure shall be evaluated. Also, the employer shall ensure that all relevant personnel are informed of the health risks associated with noise exposure and of correct use and selection of suitable hearing protection. The employer shall also facilitate health tests including hearing examinations.

Rooms or areas where personnel may be exposed to noise levels of 85 dB(A) / 130 dB(C) ”peak” must be marked with a sign indicating mandatory hearing protection.

3 Facilities Descriptions

The Klemetsrud WtE plant converts municipal and industrial waste into power to provide heat and electricity to neighbouring communities. The conversion takes place in three incineration lines and results in significant amounts of flue gas. While the gases are cleaned to meet the requirements set for waste incineration in Norway, the emitted CO_2 amount remains unaffected. However, the target for future operation is to capture as much of the CO_2 as possible, while minimising the impact on the existing plant operation (district heating and electricity production).

3.1 Descriptions for new carbon capture plant

3.1.1 Klemetsrud WtE plant

Current operation produces 460 200 t/yr of CO_2. The aim of the Project is to develop an independent and self-sufficient full-scale unit for capture of CO_2 from the flue gas of the Klemetsrud WtE plant. The capture plant will be designed to capture 95% (in absorber) of produced CO_2. Any CO_2 produced will be compressed and conditioned for water and oxygen content. Following compression and conditioning, CO_2 will be liquefied and sent to intermediate storage at WtE site.

Figure 1 – Location of the Klemetsrud WtE facility, southeast of Oslo city.

3.1.2 Oslo Harbour

Liquid CO_2 will be transported to Oslo Harbour using truck transport where it will be stored in a tankage facility before being exported and shipped via a CO_2 Terminal located at the Jetty.

Figure 2 – Location of the harbour terminal for export of CO_2 (Preliminary location)

3.2 Existing noise situation

3.2.1 Descriptions of current noise situation at WtE Klemetsrud facility

Noise emission for the existing WtE plant, was calculated and reported in 2017 (Brekke & Strand Akustikk AS, *"AKU 06 230517 Klemetsrud energigjenvinningsanlegg - beregning av eksternstøy"*). The results in the report showed that the discharge permit limits were met at all points in the surrounding areas. The noise limit for Sundays/holidays is stated to be the most critical - dwellings at Blakkens vei, west of the facility, almost reached the limit value. A noise contour map corresponding to this limit is shown in Figure 3 (light yellow colour indicates this limit contour line). Dwellings situated east and northeast of the plant have noise levels well beneath the limits. In today's situation it is likely to assume that the noise from the E6 highway causes a larger impact on the residents in these areas than that of the WtE site.

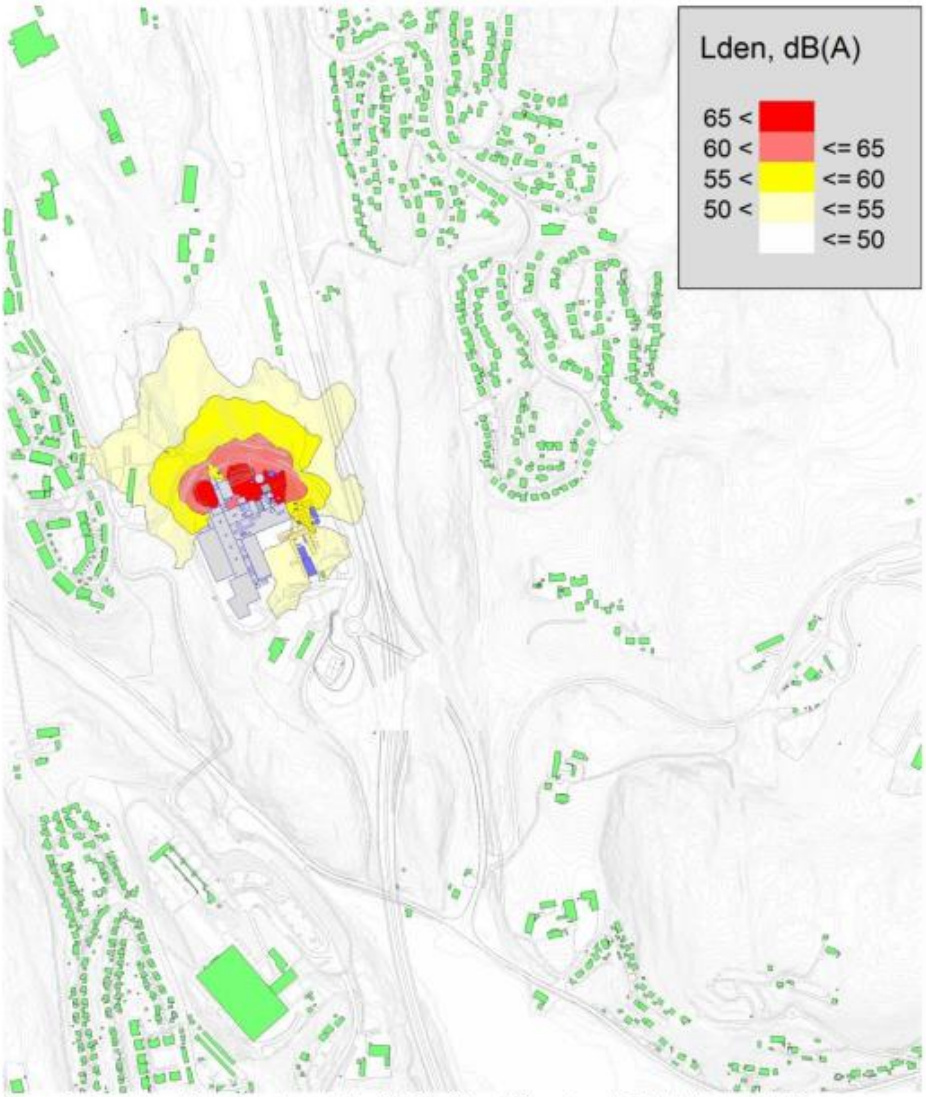

Figure 3 - Calculated L_{den} from the existing WtF facility at Klemetsrud. Calculation height 4 m.

3.2.2 Descriptions of existing noise situation at Oslo Harbour Ormsundkaia

There has been much focus on the noise situation around the Port of Oslo, with Oslo Havn developing a noise strategy to reduce noise to neighbouring areas as part of their environmental policy.

Ormsundkaia is the southernmost part of the port areas in Oslo. In recent years the container handling activities have been moved from Ormsundkaia to Sydhavna, where the distances to neighbouring residents are greater. In 2016 all container handling was stopped at Ormsundkaia. In the more recent years, the activites at Ormsundkaia have consisted of a small asphalt plant.

The noise from the port activities are constantly monitored and complaints from neighbours are filed via a noise complaint form on the internet. According the noise measurement report for 2017, there were ships located alongside the quay at Ormsundkaia in approx. 10 % of the evenings/nights of 2017 (Sweco *"Målestasjoner for støy fra Sydhavna Resultater for år 2017"*[1]).

The most recent available noise assessment for the Port of Oslo is from 2012 (*"Sweco Oslo Havn – Støysonekart etter T-1442"*[2]). This assessment was carried out by Oslo harbour showing an overview of external noise from the various harbour sites with noise contour maps results shown in Figure 4.

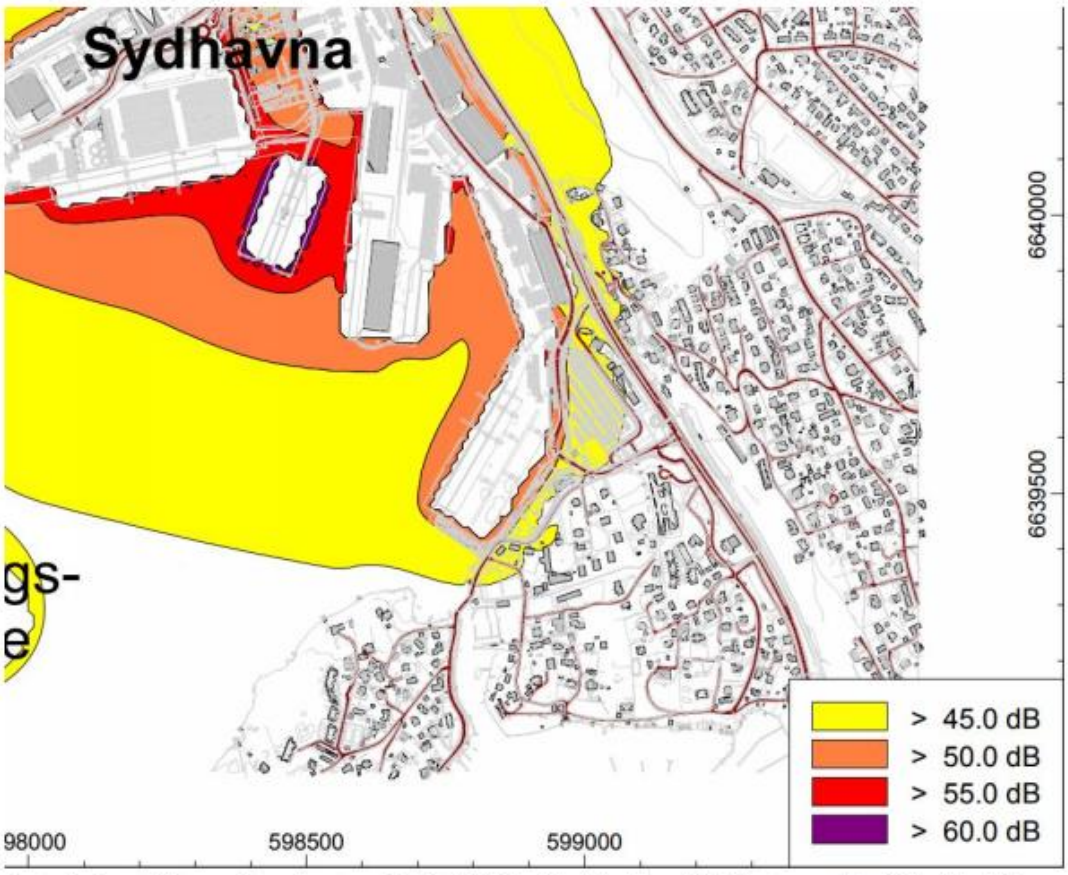

Figure 4 – Excerpt from noise contour map for Port of Oslo. Calculated L_{night}, 2010. Average port activity. Calculation height 4m. Detail for Ormsundkaia.

[1] https://www.oslohavn.no/filestore/Milj/Sty/2017rsrapport-StymlereSydhavna.pdf
[2] https://www.oslohavn.no/filestore/PDF/2014/2012StysonekartetterT-1442.pdf

4 Noise Equipment List

4.1 Mechanical Equipment

An overview of estimated noise values for the mechanical equipment was provided by TECL and is summarized in Table 2 and Table 3. Greyed out cells is not included in the noise prediction model (only A-pumps in operations).

To be used in the noise propagation model, the given sound pressure levels were calculated into sound power levels using the following equation:

$$Lw = \overline{Lp} + 10 * log10\ \frac{S}{S_0}$$

Where

Lw is the sound power level
Lp is the average sound pressure level at 1 metre distance
S is the area (m^2) of the circumscribed surface area at 1 m distance to the equipment
S_0 = 1 m^2

Frequency band vendor data was not available at this stage of the project so the noise sources in this assessment study have therefore been given a flat frequency spectrum with equal sound power in all frequency bands.

For some of the machinery the suggested sound levels were deemed unrealistic in comparison with prior experience. For these pieces of equipment 'best guess' estimates of sound power level have been made. These estimations can be seen marked in red in the L_{wA} columns in Table 2 and Table 3.

All limits refer to broadband noise without any distinct tonal characteristics. In case of clear tonal characteristics, the noise level limits shall be set 5 dB lower.

4.1.1 Carbon Capture Facility at WtE Klemetsrud plant

Table 2 – Calculated sound power levels of equipment for the new carbon capture facility at the WtE Klemetsrud plant

Tag no	Area	Description	Type	Rated Flow	Head	Driver power	Dimensions			net area	circ.area @1m	TECL estimate	Used in calc model		Comments
				m3/hr	m	kW	W	L	H	m2	m2	Lp(A @ 1m (dB))	Lp(A @ 1m (dB))	Lw(A (dB))	
C1HKG AP011	PR05	ABSORBER FEED PUMPS	Centrifugal	1049	61,6	227,6	1,5	3	1	13,5	51,5	80-89	85	102,1	No vendor data. Flat spectrum
C1HKG AP012	PR05	ABSORBER FEED PUMPS	Centrifugal	1049	61,6	227,6	1,5	3	1	13,5	51,5	80-89	85	102,1	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKJ AP001	PR05	ABSORBENT FEED PUMPS	Centrifugal	13	35,7	3,7	1	2	1	8,0	40,0	80-89	90	96,0	No vendor data. Flat spectrum
C1QCB AP011	PR05	47WT% CAUSTIC TRANSFER PUMPS	Centrifugal	0,14	42,3	0,1	1	2	1	8,0	40,0	80-89	90	96,0	No vendor data. Flat spectrum
C1QCB AP012	PR05	47WT% CAUSTIC TRANSFER PUMPS	Centrifugal	0,14	42,3	0,1	1	2	1	8,0	40,0	80-89	90	96,0	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKK AP001	PR05	ABSORBENT DRAIN PUMP	Centrifugal	18	39,9	5,4	1	2	1	8,0	40,0	80-89	85	101,0	No vendor data. Flat spectrum
C1HKF AP131	PR02	THERMAL RECLAIMER REFLUX PUMPS (LINE 1)	Centrifugal	1,3	31,4	0,5	1	2	1	8,0	40,0	80-89	90	96,0	No vendor data. Flat spectrum
C1HKF AP132	PR02	THERMAL RECLAIMER REFLUX PUMPS (LINE 1)	Centrifugal	1,3	31,4	0,5	1	2	1	8,0	40,0	80-89	90	96,0	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKF AP231	PR02	THERMAL RECLAIMER REFLUX PUMPS (LINE 2)	Centrifugal	1,3	31,4	0,5	1	2	1	8,0	40,0	80-89	90	96,0	No vendor data. Flat spectrum
C1HKF AP232	PR02	THERMAL RECLAIMER REFLUX PUMPS (LINE 2)	Centrifugal	1,3	31,4	0,5	1	2	1	8,0	40,0	80-89	90	96,0	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKF AP151	PR02	THERMAL RECLAIMER BOTTOMS PUMPS (LINE 1)	Centrifugal	5	17,3	1	1	2	1	8,0	40,0	80-89	90	96,0	No vendor data. Flat spectrum
C1HKF AP152	PR02	THERMAL RECLAIMER BOTTOMS PUMPS (LINE 1)	Centrifugal	5	17,3	1	1	2	1	8,0	40,0	80-89	90	96,0	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKF AP251	PR02	THERMAL RECLAIMER BOTTOMS PUMPS (LINE 2)	Centrifugal	5	17,3	1	1	2	1	8,0	40,0	80-89	90	96,0	No vendor data. Flat spectrum
C1HKF AP252	PR02	THERMAL RECLAIMER BOTTOMS PUMPS (LINE 2)	Centrifugal	5	17,3	1	1	2	1	8,0	40,0	80-89	90	96,0	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1GK AP001	PR02	TAP WATER PUMP	Centrifugal	15	40,4	4,4	1	2	1	8,0	40,0	80-89	85	101,0	NOTE 3. INTERMITTENT SERVICE. No vendor data. Flat spectrum
C1QFA AZ001	PR02	INSTRUMENT AIR COMPRESSOR PACKAGE	Air Compre	640			1,5	1,5	1	8,3	40,3	80-89	90	96,0	640 NM^3/H No vendor data. Flat spectrum
C1HKD AP013	PR01	RICH ABSORBENT PUMPS	Centrifugal	517	110	213,4	1	2	1	8,0	40,0	80-89	85	101,0	No vendor data. Flat spectrum
C1HKD AP012	PR01	RICH ABSORBENT PUMPS	Centrifugal	517	110	213,4	1	2	1	8,0	40,0	80-89	85	101,0	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKD AP011	PR01	RICH ABSORBENT PUMPS	Centrifugal	517	110	213,4	1	2	1	8,0	40,0	80-89	85	101,0	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKD AP032	PR01	WATER WASH PUMPS	Centrifugal	326	35,5	43,6	1	2	1	8,0	40,0	80-89	85	101,0	No vendor data. Flat spectrum
C1HKD AP031	PR01	WATER WASH PUMPS	Centrifugal	326	35,5	43,6	1	2	1	8,0	40,0	80-89	85	101,0	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKD AP023	PR01	CO2 ABSORBER INTERCOOLER PUMPS	Centrifugal	516	34,2	65,2	1	2	1	8,0	40,0	80-89	85	101,0	No vendor data. Flat spectrum
C1HKD AP022	PR01	CO2 ABSORBER INTERCOOLER PUMPS	Centrifugal	516	34,2	65,2	1	2	1	8,0	40,0	80-89	85	101,0	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKD AP021	PR01	CO2 ABSORBER INTERCOOLER PUMPS	Centrifugal	516	34,2	65,2	1	2	1	8,0	40,0	80-89	85	101,0	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKE AP012	PR01	PRE-SCRUBBER PUMPS	Centrifugal	1545	38,5	199,7	1,5	3	1	13,5	51,5	80-89	85	102,1	No vendor data. Flat spectrum
C1HKE AP011	PR01	PRE-SCRUBBER PUMPS	Centrifugal	1545	38,5	199,7	1,5	3	1	13,5	51,5	80-89	85	102,1	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKH AP012	PR01	STRIPPER REFLUX PUMPS	Centrifugal	17	64,6	7,7	1	2	1	8,0	40,0	80-89	90	96,0	No vendor data. Flat spectrum
C1HKH AP011	PR01	STRIPPER REFLUX PUMPS	Centrifugal	17	64,6	7,7	1	2	1	8,0	40,0	80-89	90	96,0	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKH AP042	PR01	STEAM CONDENSATE PUMPS	Centrifugal	74	70,9	24,6	1	2	1	8,0	40,0	80-89	90	96,0	No vendor data. Flat spectrum
C1HKH AP041	PR01	STEAM CONDENSATE PUMPS	Centrifugal	74	70,9	24,6	1	2	1	8,0	40,0	80-89	90	96,0	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKH AP032	PR01	LEAN ABSORBENT PUMPS	Centrifugal	1095	35,1	129,7	1,5	3	1	13,5	51,5	80-89	85	102,1	No vendor data. Flat spectrum
C1HKH AP031	PR01	LEAN ABSORBENT PUMPS	Centrifugal	1095	35,1	129,7	1,5	3	1	13,5	51,5	80-89	85	102,1	NOTE 1. ONLY A-PUMPS IN OPERATION. No vendor data. Flat spectrum.
C1HKE AN001	PR01	BOOSTER FAN	Fans				?	?	?	#VT	command failed	100-109		105	376,644 kg/h. No vendor data. Flat spectrum. Assumes LwA = 105 dB
C2HK AZ001	PR06	CO2 COMPRESSOR PACKAGE	Compressor				?	?	?	#VT	command failed	100-109		110	19,577 m3/hr. Located inside noise shelter. No vendor data. Flat spectrum.Assumes LwA = 110 dB
C2HK AN001	PR06	REGENERATION GAS COMPRESSOR	Compressor				2,25	4,5	2	37,1	92,1	80-89	85	104,6	19,577 m3/hr. Located inside noise shelter. No vendor data. Flat spectrum
C1SB AZ001	PR04	HEAT PUMP PACKAGE	Compressor				?	?	?	#VT	command failed	90-99		105	NOTE 5. PACKAGE CONTAINS 3 COMPRESSORS.No vendor data. Flat spectrum. Assumes LwA = 105 dB
C1P AZ001	PR03	COOLING SYSTEM AIR COOLER PACKAGE	Fan				?	?	?	#VT	command failed	80-89		100	NOTE 4. WET AIR COOLERS INCLUDE NOISE FROM FAN MOTOR AND A PUMP (MARKED INDIVIDUALL
C2HK AP002A/B		LIQUEFIED CO2 TRANSFER PUMPS	Centrifugal	75	20	7,9	1	2	1	8,0	40,0	80-89	90	96,0	No vendor data. Flat spectrum. Only A-pumps in operation

4.1.2 Oslo Harbour CO_2 offloading site

Table 3 - Calculated sound power levels of equipment at the Oslo Harbour CO_2 offloading site

Tag no	Area	Description	Type	Rated Flow	Head	Driver power	Dimensions			net area	circ.area @1m	TECL estimate	Used in calc model		Comments
				m3/hr	m	kW	W	L	H	m2	m2	Lp(A @ 1m (dB))	Lp(A @ 1m (dB))	Lw(A (dB))	
C3HK AP011		LIQUID CO2 TRANSFER PUMP	Centrifugal	375	43,5	65,3	1,1	2,2	1,5	12,3	49,5	80-89	85	101,9	No vendor data. Flat spectrum. Only A-pumps in operation
C3HK AP012		LIQUID CO2 TRANSFER PUMP	Centrifugal	375	43,5	65,3	1,1	2,2	1,5	12,3	49,5	80-89	85	101,9	No vendor data. Flat spectrum. Only A-pumps in operation
C3HK AP013		LIQUID CO2 TRANSFER PUMP	Centrifugal	375	43,5	65,3	1,1	2,2	1,5	12,3	49,5	80-89	85	101,9	No vendor data. Flat spectrum. Only A-pumps in operation
C3HK AP041		LIQUID CO2 UNLOADING PUMP	Centrifugal	75	27,1	10,7	1,1	2,2	1,5	12,3	49,5	80-89	85	101,9	No vendor data. Flat spectrum. Only A-pumps in operation
C3HK AP042		LIQUID CO2 UNLOADING PUMP	Centrifugal	75	27,1	10,7	1,1	2,2	1,5	12,3	49,5	80-89	85	101,9	No vendor data. Flat spectrum. Only A-pumps in operation
C3HK AZ001		CO2 RELIQUEFACATION PACKAGE					?	?	?	#VT	command failed	90-99		85	No vendor data. Flat spectrum. Assumes LwA = 85 dB
C3QF AZ001		INSTRUMENT AIR COMPRESSOR PACKA	Air Compressor				?	?	?	#VT	command failed	90-99		95	No vendor data. Flat spectrum. Assumes LwA = 95 dB

4.2 Transports

There will be 3 trucks in continuous operation transporting CO_2 from the WtE facility in Klemetsrud to the harbour offloading area at Ormsundkaia. The noise produced by these vehicles has been included in the noise propagation calculations. The following information about the transport trucks was provided by TECL.

- 3 transport trucks in continual operation 24 hours per day
- One operational event occurs approximately every 30 minutes

4.3 Noise from ships

Noise created from the CO_2 transport ships has not been included in this noise assessment survey. However, this could be a contributing source of noise from the harbour site and should be included in an assessment at a future stage when more details of operation on site are available.

4.4 Pipe Noise

Noise from piping is not included in the calculations at this stage of design. Acoustic pipe insulation may be required to reduce the emitted noise from piping and ducts. Noise from piping may be generated by the connected mechanical equipment (pumps, compressors) and can also be flow-generated in elements such as heat exchangers etc. Both evaluations of the extent of pipe insulation as well as evaluations of the insulation classes, ref ISO 15665, should be documented and indicated on the relevant P&Ids. For the piping identified to be on the borderline for required acoustic insulation, space for future installation shall be considered. HOLD 1

4.5 Noise from Valve and Restriction Devices

Noise from valves and any other restriction devices must be assessed and controlled. Acoustic pipe insulation may be required for pipelines if noise generated in the system is not controlled properly in the design. Valves with low-noise trim (multi-stage “whisper” trim) and orifices with low-noise design (multi-hole design) is the primary noise control measure. If the noise requirements to valves and restriction devices cannot be met, acoustic pipe insulation and noise control by location are the other options for noise control.

Noise from valves and restriction devices are not included in the noise calculations at this point. The first choice for noise reduction should be application of special purpose valve low-noise design i.e. whisper trim is recommended. Valve and orifice noise must be reviewed and included in the calculations in later stages of the design project. HOLD 2

Use of PSVs in upset/ emergency conditions. HOLD 3

4.6 Interface noise topics

In-duct noise from booster fan, tag no. C1HKE AN001, might influence the noise coming from top of the flue gas stack. Requirements for potential silencers will have to be assessed in a later stage of design. HOLD 4

5 Noise Calculations

5.1 Methodology for noise predictions

All calculations are performed in the noise propagation software SoundPlan. The noise prediction method applied for the calculations is the "*Nordic Prediction Method for Industrial Noise*".

The noise source sound power levels are implemented in the 3D noise calculation model. According to the method, the calculated sound level at receiver points depends on the propagation distance, screening from terrain or obstacles, air absorption and reflections.

All hard surfaces, including the sea surface, are treated as acoustically reflective according to the method.

At the Klemetsrud site, all new noise sources are placed on the ground. "Shelters" in the CCS area are assumed to be acoustically open and without any noise reducing effect in the calculations shown in this report. Reflections from the terrain cutting east of the site, making room for the new facility, are also included in the calculations.

At the Oslo harbour site an existing noise barrier spans the southwest and southeast sides of the site. The effect of this noise barrier has been included in the calculation models of the harbour site.

A safety margin of 5 dB is considered in the calculation results. This safety margin might be reduced at a later stage of design when more detailed supplier information is known.

All results are presented for receivers situated 4 meters over the terrain elevation.

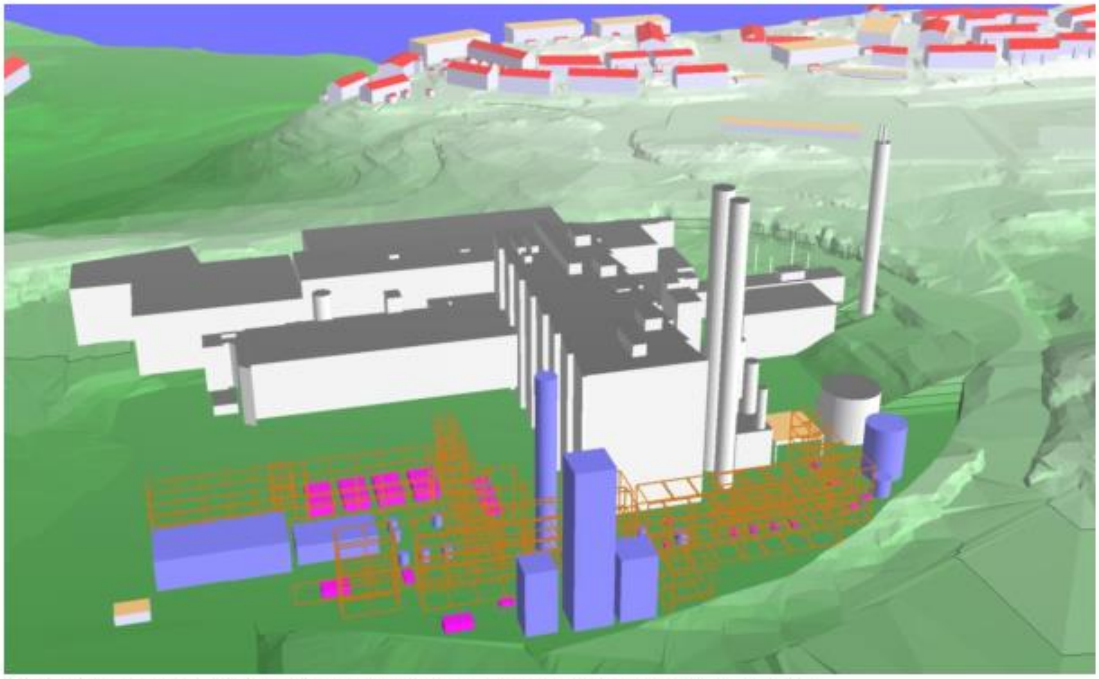

Figure 5 - 3D view of the noise propagation model for the CCS plant at the Klemetsrud site.

5.2 Noise prediction results

5.2.1 Klemetsrud

Since all noise sources at the CCS plant are 24-hour continuous, it follows that it is the noise limit for Sundays/holidays that will be the most critical, see chapter 2.1. Therefore, it is chosen to narrow the presentation of the results for Klemetsrud to those corresponding to this limit.

In this section, calculated results are shown based on assumed sound powers presented in Table 2. Figure 6 shows noise levels for the CCS facility alone, while Figure 7 represents the combined noise from the CCS plant and the WtE facility.

From the noise contour maps, it is obvious that without any noise mitigation measures carried out on the new facility, noise zones from the CCS plant will overshadow those from the existing plant in all directions. Also, the relevant noise limit (for Sunday/holidays) will be significantly exceeded in large areas. In the most exposed neighborhood at Pasoplia, east of the site, noise levels are expected up to 15 dBs over the noise limit. For the most exposed area in today's situation, at Blakkens vei west of the site, noise levels will exceed the limits by approximately 10 dB. The results also indicate that the new facility is well screened behind the existing plant as can be seen in the residential area to the west. Therefore, it can be said that the areas affected by noise from the CCS plant are quite different from that of the WtE facility: westbound for the existing WtE site and eastbound for the new CCS equipment.

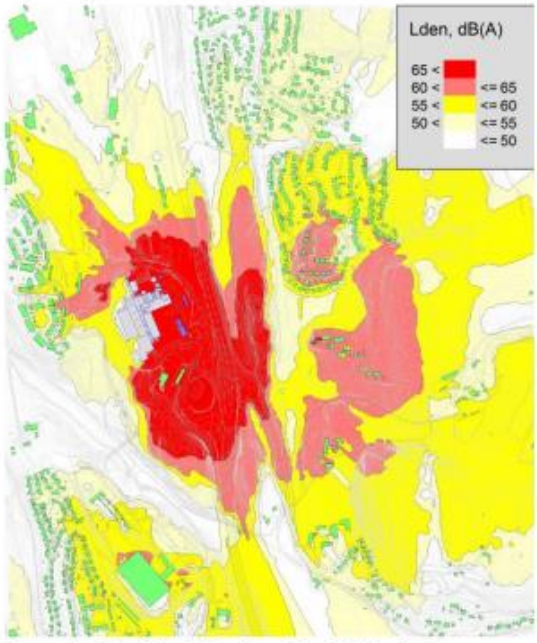

Figure 6 - Calculated Lden from the CCS plant at Klemetsrud alone. TECL estimations (no measures) Calculation height 4m.

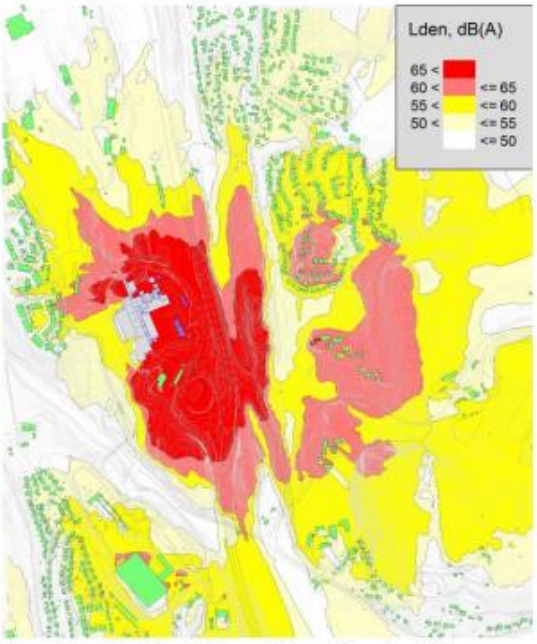

Figure 7 - Calculated Lden combined from the WtE facility and CCS plant at Klemetsrud. TECL estimations (no measures) Calculation height 4m.

5.2.2 Oslo harbour

Since there is no discharge permit for the export facility at the harbour site, the basic noise limits from the national guidelines T-1442/2016 have been applied. For 24-hours continuous activity, the equivalent night limit (L_{night} = 45 dB) is the most critical value.

The residential area to the southwest of the harbour site receives the highest levels of noise exposure, with calculated free field façade values up to L_{night} = 52 dB. Noise levels to the southwest of the site are calculated L_{night} = 45-47 dBA for the most exposed dwellings. Dwellings that lie to the north east of the site receive the lowest levels of noise with values between L_{night} = 40 - 43 dB.

Figure 8 shows a noise contour map for the planned harbour offloading site.

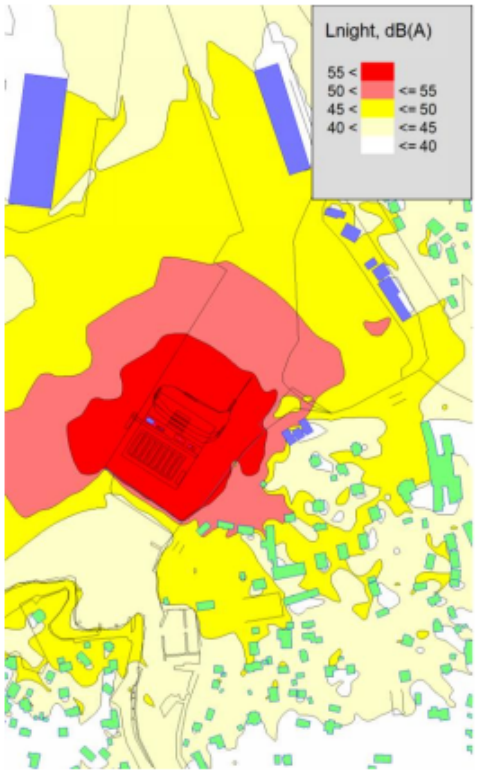

Figure 8 - Calculated Lnight for the harbour site. TECL estimations (no measures) Calculation height 4m.

6 Recommendations

In the following sections, recommendations for the noise sources as defined in Table 2 are given for both Klemetsrud and Oslo harbour. The recommendations can be seen as the highest admissible sound powers that must be met in order to satisfy the limits of the (expected) discharge permits.

It must yet be pointed out that, especially for the Klemetsrud site, where the number of noise sources are rather high, the task to find sensible recommendations has numerous solutions. Thus, the recommendations are to be considered as a first suggestion, based on information at hand at this stage.

6.1 Klemetsrud

To reduce the noise emission from the CCS facility enough to meet the noise limits, the single sound powers have been repeatedly lowered. In this iterative process, the type of the equipment and a rough degree of cost-benefit analysis has also been considered. The highest sound power is permitted for the booster fan.

As the noise impact to the neighbourhood decreases, the effect from further measures on the new facility also decreases for the combined noise emission from the CCS and WtE facilities. This suggests that any further measure should instead be directed to the existing WtE facility to be effective. The proposal that is suggested is thus a combination of:

- Recommendations for the new CCS facility
- An overall reduction of 2 dBs from the existing WtE facility

Recommendations for the CCS plant are shown in Table 4. In order to achieve this, high focus on low-noise design is necessary. Relevant measures might include one or several of the following:

- Low-noise equipment
- Enclosures/buildings
- Silencers
- Variable frequency drives (low rpm)
- Pipe insulation/cladding

Figure 9 shows the noise contour map combined for the CCS plant, with the set of recommendations implemented, and the WtE facility, the latter with an overall 2 dB reduction.

Table 4 - Recommendations for the noise sources at the CCS plant at Klemetsrud.

Description	Tag no	Estimated sound power L_{wA} (dB)	Recommended sound power L_{wA} (dB)
Small pumps	C1HKJ AP001, C1QCB AP011-12, C1HKF AP131-132, C1HKF AP231-232, C1HKF AP151-152, C1HKF AP251-252, C1HKH AP011-12, C1HKH AP041-42, C2HK AP002A/B	96	82
Large pumps	C1HKG AP011-12, C1HKK AP001, C1GK AP001, C1HKD AP011-13, C1HKD AP031-32, C1HKD AP021-23, C1HKE AP011-12, C1HKH AP031-32	101-102	87
Instrument air compressor package	C1QFA AZ001	96	82
Booster fan	C1HKE AN001	105	95
CO_2 compressor package	C2HK AZ001	110	92
Regeneration gas compressor	C2HK AN001	105	92
Heat pump package	C1SB AZ001	105	89
Cooling system air cooler package	C1P AZ001	100	89

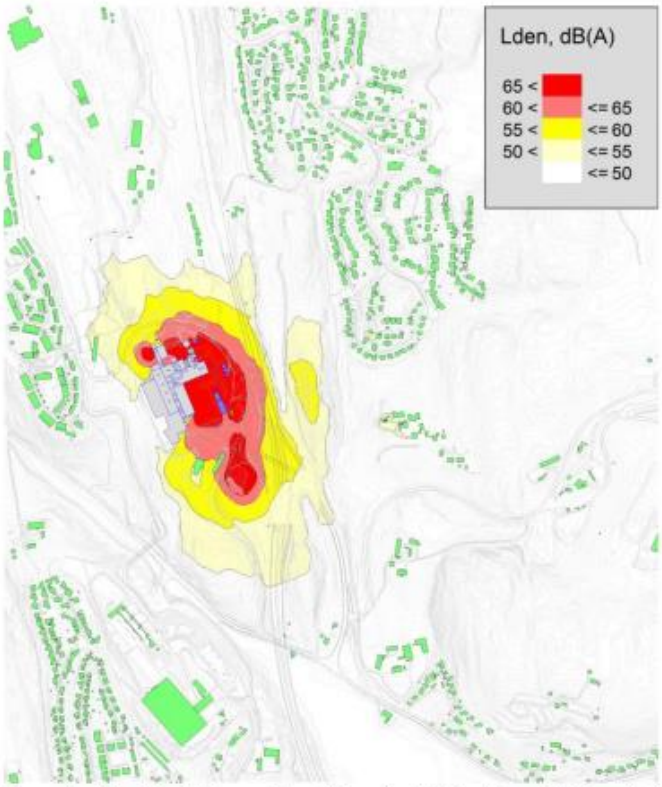

Figure 9 - Calculated Lden combined from the WtE facility, with the set of recommendations implemented, and CCS plant at Klemetsrud. Calculation height 4m.

6.2 Oslo harbour

To sufficiently reduce the noise emission from the Oslo harbour site to meet the national guidelines noise limits, the sound powers levels of almost all the machine equipment need to be significantly reduced. Recommendations for the Oslo harbour site equipment are shown in Table 5.

Figure 11 shows the noise contour map from Oslo harbour site with this set of recommendations implemented. With these recommendations, the highest calculated residential façade level is calculated at 40 dB(A).

Table 5 - Recommendations for the noise sources at the offloading area at Ormsundkaia, Oslo Harbour.

Description	Tag no	Estimated sound power LwA (dB)	Recommended sound power LwA (dB)
Liquid CO_2 transfer pump	C3HK AP011	102	88
Liquid CO_2 transfer pump	C3HK AP041	102	88
CO_2 Reliquefication package	C3HK AZ001	85	85
Instrument air compressor package	C3QF AZ001	95	88

The level of noise from transport trucks calculated to residential receivers in the surrounding area is comparatively low compared with that of the machine equipment. Therefore, calculations for the scenario with recommendations for the Oslo harbour model contain the same truck sound data that was used in the calculation with the estimated sound power levels.

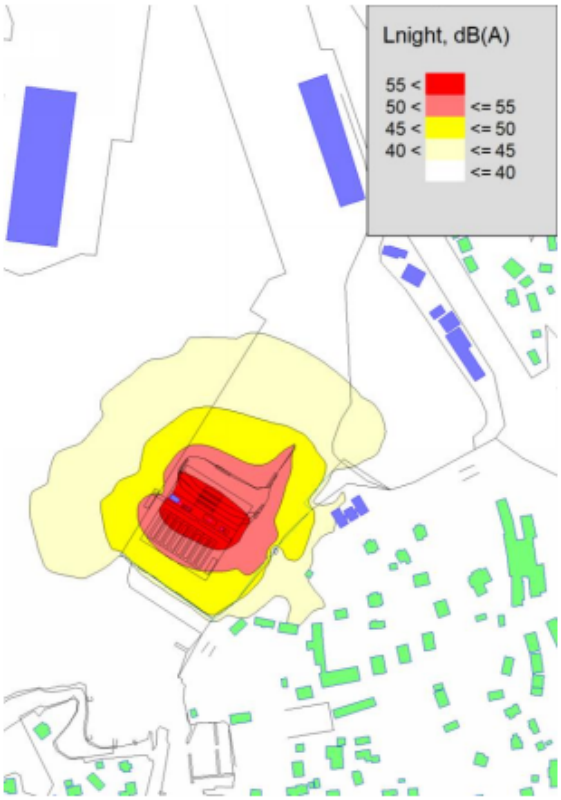

Figure 10 - Calculated Lnight for the harbour site with recommendations for equipment noise

7 Follow up in later phases of the project

In later stages of the project, the follow-up in noise engineering may require the following:

- Ensure that equipment noise recommendations are included in vendor documentation. This includes requirements to mechanic equipment, control valves, orifices, PSV's etc.
- Planning of noise shelters/ buildings. Requirements to walls and sound insulation properties of façade elements in the noise reducing screening elements.
- Follow up on vendor noise documentation and participation in FAT testing, if required. Evaluate mitigation measures included in any vendor documentation
- Give input to mitigation measures if it shows difficult for vendors to comply with specified equipment noise level limits. Mitigation measures might also be relevant for the existing sources of noise in the existing plant.
- Evaluate the need for acoustic pipe insulation on piping.
- Evaluate the need for silencers in stack downstream booster fan.