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SYSAV CARBON CAPTURE STORAGE (CCS)

DESIGN BASIS

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DESIGN BASIS

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CONTENTS

1. EXECUTIVE SUMMARY

Sysav is conducting a pre-feasibility study (Övergripande förstudie, Avfalls-CCS) to outline the possibilities for realizing a cost-effective solution for CO_2 capture and transport and storage of the captured CO_2 for the Waste-to-Energy (WtE) plant at Sysav in Malmö, Sweden. The study covers the entire value-chain from carbon capture (CC) at Sysav's site including transport and storage of CO_2.

The study aims at identifying the most favourable CC technology for Sysav, developing a basic CC concept for the most favourable technology and evaluating the overall economic consequences of implementing a CO_2 capture system including transport and storage.

The pre-feasibility study will cover two scenarios. A main scenario based on the existing boiler lines P3 and P4 as well as an alternative scenario based on the existing boiler lines P3, P4 and a new established boiler line, P5.

The purpose of this document is to provide a design basis for the pre-feasibility study, including design preconditions, assumptions and strategy for the possible future CC facility and basic design information about the existing (P3 and P4) and expected future (P5) Waste-to-Energy plant located at Sysav.

The document is authored by Ramboll and includes inputs from Sysav.

2. INTRODUCTION

2.1 Background for the CCS project

Sysav is conducting a Carbon Capture and Storage (CCS) project (Utredningsprojekt CCS) to study the possibilities for realizing a cost-effective solution for CO_2 capture and transport and storage of the captured CO_2 for the Waste-to-Energy (WtE) plant at Sysav in Malmö, Sweden. The project covers all aspects of Carbon Capture (CC) at Sysav's site and transport and storage of CO_2.

The total project is planned to be carried out through the following project phases:

- Phase 1: Övergripande förstudie
- Phase 2: Fördjupad förstudie
- Phase 3: Utformning av ett eventuellt genomförandeprojekt

This report relates to phase 1 "Övergripande förstudie", which is a pre-feasibility study.

Figure 1: Sysav implementation model for "Utredningsprojekt CCS"

The purpose of this pre-feasibility study is to:

- Develop the design basis.
- Identify the most favourable CC technology for Sysav through a technology screening.
- Develop a basic concept/solution for CO_2 capture, liquefaction and storage from a technical and economical perspective.
- Analysis of possibilities for transport and store/use captured CO_2 safely and at the cost as low as possible.
- Set out the legal conditions for capture of CO_2 at Sysav
- Identify a reasonable economic model for carrying out the investment and subsequent operation of the Carbon Capture facility and analyse options for providing a reasonable financial risk while delivering according to the ambitions of Sysav and the owners.

The pre-feasibility study covers two scenarios dependant on the realization of a future boiler line P5.

1) A main scenario based on the existing boiler lines P3 and P4.
2) An alternative scenario based on the existing boiler lines P3, P4 and a new established boiler line, P5.

2.2 Purpose of this document

The purpose of this document is to provide a common basis and understanding regarding the design basis of a possible future CC facility at Sysav and to provide basic information about the existing (and expected future) WtE plant located at Sysav.

The Design Basis provides a technical description of Sysav's requirements stipulating the technical framework conditions and scope of the project. It will be prepared in the earliest project phase and is to be revised in subsequent phases if assumptions and preconditions change.

3. SYSAV

This section provides information about Sysav's WtE facility, where the CC plant will be located.

Sysav is located at Spillepengsgatan 13, 211 24 Malmö in Sweden. The location is indicated in Figure 2.

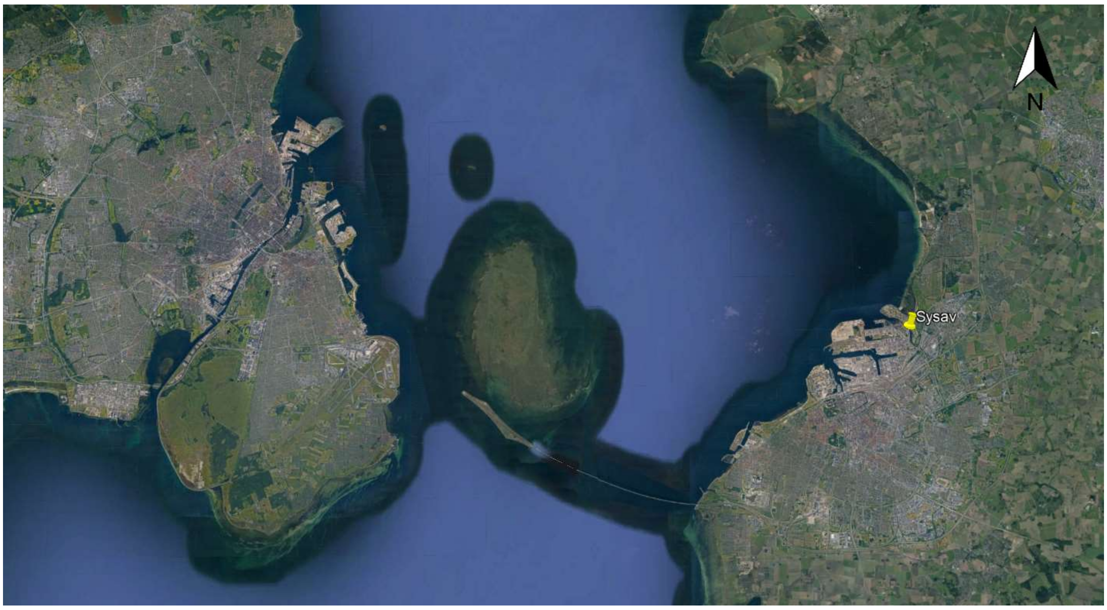

Figure 2: Satellite picture of Copenhagen-Malmö region

Today (as of August 2021) Sysav operate a WtE plant, consisting of four lines P1, P2, P3 and P4 as well as a biological waste pre-treatment facility.

Figure 3: Satellite picture of Sysav

The two oldest boiler lines, P1 and 2, were commissioned in 1972 and produce hot water. The boilers each have a capacity of about 11.5 tons of waste per hour, which corresponds to about 100,000 tons/year. P1 and P2 are expected to be decommissioned by 2030.

The two newest, P3 and P4, were commissioned in 2003 and 2008 respectively. Both lines are combined heat and power plants with separate turbine cycles, wet flue gas cleaning and flue gas condensation with heat pumps. The boilers have the capacity to process about 30-35 tonnes of waste per hour (LHV dependent), which corresponds to about 240,000 – 280,000 tons/year.

All heat produced goes out via the district heating network, as the plant has not established other cooling. It is currently considered to install summer coolers in order to maximize the boiler operation during periods with low district heating demand.

The CC plant shall capture CO_2 from P3+P4 or P3+P4+P5, respectively and will be designed according to the size, process, layout etc. of the WtE plant for the two scenarios. In addition, the CC plant will affect the WtE plant as flue gas and energy will be exchanged between the WtE and CC process. The CC plant is planned to be commissioned by 2030.

The two plants are therefore interconnected, and the two projects (P5 project and CCS project) will be conducted in parallel.

The introduction of a CC plant will be based on two scenarios:
- A main scenario consisting of the existing P3 and P4.
- An alternative scenario with realization of P5.

3.1 Waste-to-Energy lines

Table 1 below provides an overview of the size and technology used for P3 and P4.

Table 1: Overview of P3 and P4

Parameters	P3	P4
Commission year	2003	2008
Design lower heating value of waste	12.5 MJ/kg	12.5 MJ/kg
Design waste treatment capacity at design LHV	25 ton/h	26 ton/h
Design thermal input	86.8 MW	90 MW
Waste treatment capacity after upgrade at design LHV	27.6 ton/h	27.6 ton/h
Thermal input after capacity upgrade	96 MW	96 MW
Annual operational hours	8000 h	8000 h
Waste treatment technology	Incineration with reverse-acting grate	Incineration with reverse-acting grate

Parameters	P3	P4
Boiler	Steam boiler Steam parameters: 40 bar(a) / 400 °C	Steam boiler Steam parameters: 40 bar(a) / 400 °C
Flue Gas Treatment System	Electrostatic precipitator (ESP) system with wet scrubber and SCR. Wet scrubber is a polishing (HCl and SO_2) and condensing scrubber with heat pumps and venturi section for dust separation. Selective Catalytic Reduction (SCR) for deNOx.	Electrostatic precipitator (ESP) system with wet scrubber and SCR. Wet scrubber is a polishing (HCl and SO_2) and condensing scrubber with heat pumps and venturi section for dust separation. Selective Catalytic Reduction (SCR) for deNOx.
Energy system	Backpressure turbine with production of district heating. Low-temperature economizer for DH production Flue gas condensation with heat pumps	Backpressure turbine with production of district heating. Low-temperature economizer for DH production Flue gas condensation with heat pumps
District heating	Supply heat to E.ON district heating network in Malmö Further details in section 3.3 "Energy System and District Heating"	
Cooling system	No air coolers are currently installed. It is considered to install summer coolers and a pre-feasibility study for introducing summer coolers to P3 and P4 has been conducted by Sysav in 2020.	
Stack	P3 and P4 has individual stack pipes gathered in one common clustered stack.	
Additional information	Internal flue gas reheating after condensation as well as flue gas reheating by steam for SCR operation. Possibility of flue gas recirculation	Internal flue gas reheating after condensation as well as flue gas reheating by steam for SCR operation.

Figure 4 and Figure 5 show the original capacity diagrams (before capacity increase) for P3 and P4, respectively.

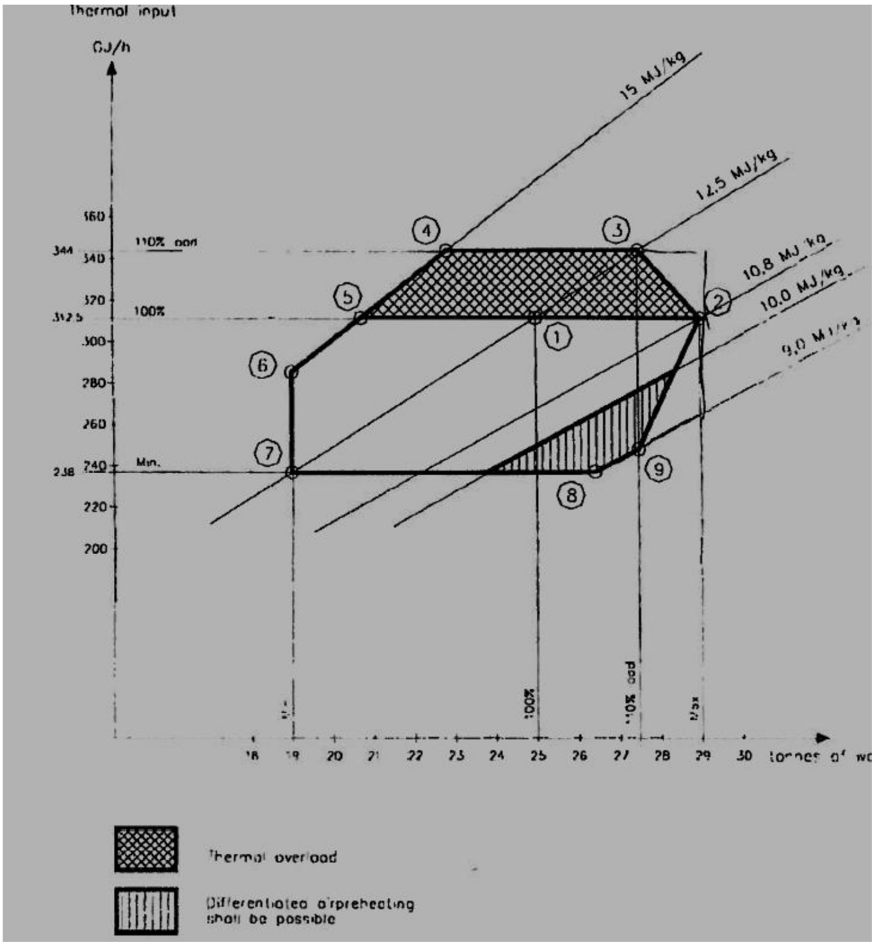

Figure 4: Capacity diagram for the existing P3.

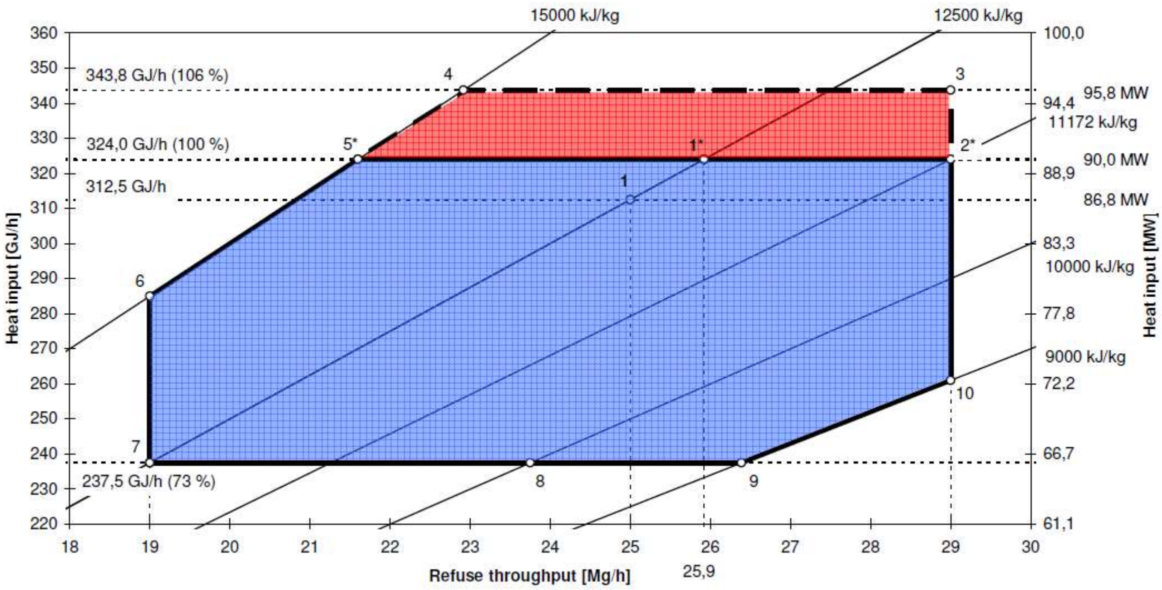

Figure 5: Capacity diagram for the existing P4.

P3 and P4 have the ability to operate at short peak thermal load variations of up to 110% and 106%, respectively.

3.1.1 Future P5

The production capacity of P1 and P2 is expected to be decommissioned in 2030 and an eventual P5 is planned to be put into operation the same year. Studies of a future P5 have previously been conducted by Sysav (please refer to the study "Sysav Alternativ för P1+P2", dated 2017). The study has been made before the plans of integrating CCS into Sysav. Introduction of a CC facility will likely lead to a significant demand for process heat at elevated temperatures to satisfy the CC process. This demand will most likely be supplied by the boiler lines. The introduction of a CC facility can therefore alter the optimal energy concept for a future line P5.

Different concepts for boiler plants are shown below, where the expected CC process heat demand at the required temperature can be fulfilled. It is recommended, as a separate study, to update the former P5 study also to incorporate the effects of establishment of a Carbon Capture plant into the overall energy system. Such optimization of a future boiler line P5 is not part of the scope of the current pre-feasibility study.

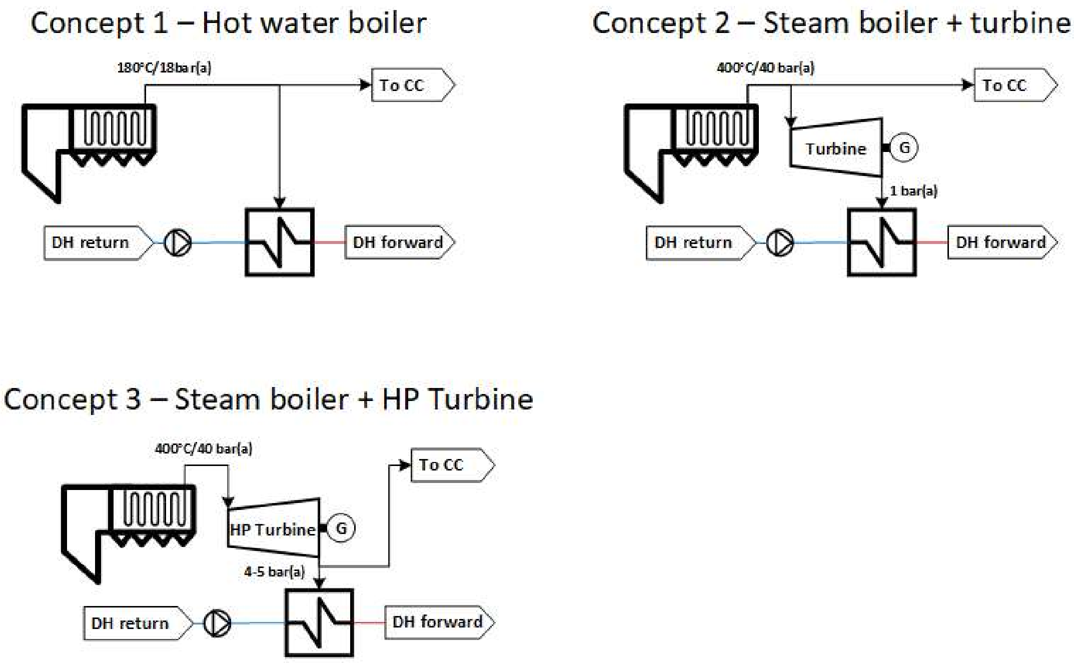

Figure 6: Concepts for boiler plants, which can fulfil the heat requirements for the CCS process.

Ramboll has in similar studies investigated the economic effects of incorporating a hot water boiler (Concept 1), Steam boiler + LP turbine (Concept 2) and Steam boiler + HP turbine (Concept 3) in connection with introducing carbon capture. In these cases Concept 1 and Concept 3 is generally the most attractive solutions. Indicative economical behaviour for CAPEX, OPEX and revenue is shown in Table 2 below for illustration:

Table 2: Indicative economical behaviour for different concepts.

	CAPEX	OPEX	Revenue
Concept 1	Low	Low	Low
Concept 2	High	Medium	Medium
Concept 3	Medium/High	Medium	High

The CAPEX for concept 1 is lower than for concept 3 as a hot water boiler is more simple than a steam boiler. Likewise, the OPEX for the hot water boiler in concept 1 is expected to be lower than OPEX for the steam boiler in concept 3 due to higher corrosion rates in a steam boiler. On the other hand, the revenue from energy sales in concept 1 is limited to heat supply, while concept 3 has the ability to produce both heat and electricity. Furthermore concept 3 will in periods with limited heat offtake have a higher waste throughput and thereby higher income from gate fees due to the more adaptive energy conversion in the concept.

In this pre-feasibility study, focussing on the CCS process, it is assumed that P5 will be realized based on Concept 3 consisting of a steam boiler and a high-pressure turbine designed with an exhaust pressure suited for the CC process. Concept 3 is considered advantageous as it has power production combined with a heat supply for the Carbon Capture process allowing for a total higher annual waste treatment capacity at Sysav.
The Concept 3 for P5 further has the ability to produce steam for reheating the flue gas before the expected tail-end SCR. It can therefore be operated as a stand-alone unit. The P5 size is based on the previous P5 study, where the base case suggests a thermal capacity at 100% load of 90 MW. Figure 7 shows an illustrative capacity diagram based on a LHV of 10.7 MJ/kg for the suggested plant capacity.

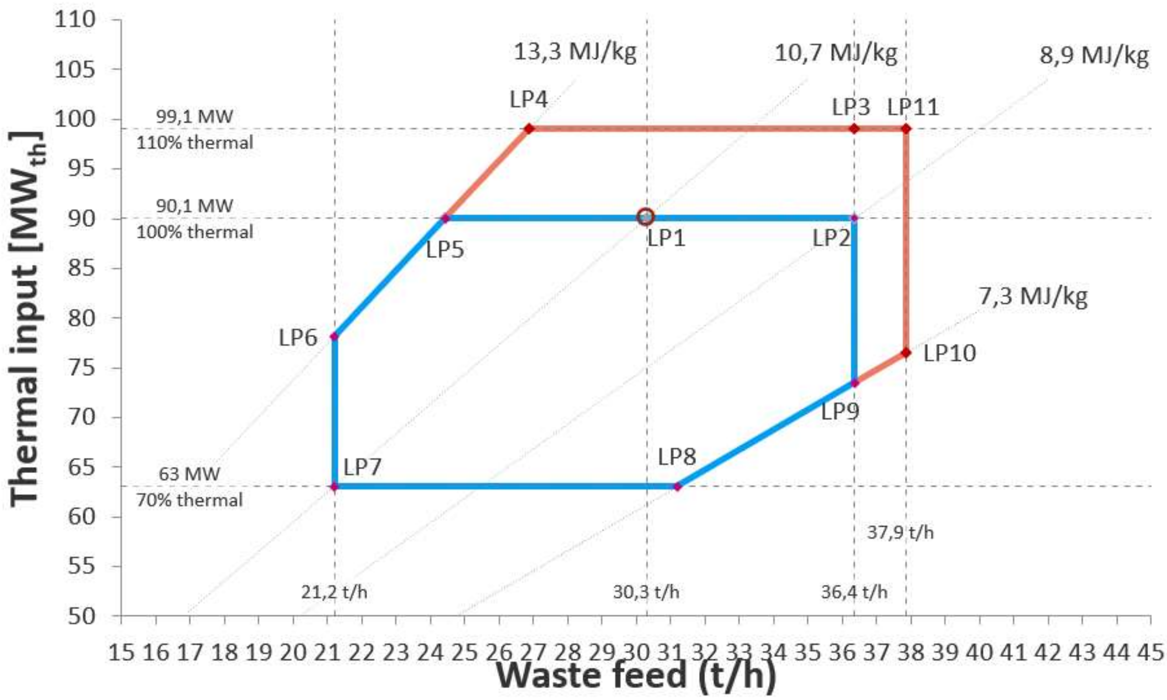

Figure 7: Illustrative capacity diagram for a future P5.

3.2 Environmental Performance

The following text is based on the current environmental permit valid for Sysav. Adjusted limits may be decided by the authorities when applying for new waste treatment capacity at Sysav. This must be carefully followed up in dialogue with the relevant authorities.

3.2.1 Air emissions

The current environmental permit for air emissions at stack for Sysav are presented in Table 3.

At present it is expected that the emission limits for the new line P5, as a minimum, shall meet or be better than the environmental performance of P3 and P4. It is therefore expected to be based on current emission limits for heavy metals and NOx as well as the upper limit for new plants of the Best Available Techniques Associated Emission Levels (BATAELs) of the latest Best Available Techniques (BAT) Conclusions under Directive 2010/75/EU of the European Parliament and the Council for waste incineration published in December 2019 in the so-called BAT reference note (BREF).

The expected emission limits for P5 are presented in Table 3 below. The limit values are primarily based on the upper limits for new plants from BREF 2019 and correspond to the expected performance of current flue gas treatment technology for WtE plants.

Table 3: Sysav emission permit and expected emission limits for P5. Values taken from "Sysav ersättning av P1+P2", dated 2017

Air emissions at stack		Sysav emission permit	Expected limits for environmental permit of P5	Expected performance of P5
Substance	**Unit (11% O2, dry)**	**Daily average**	**Daily average**	**Daily average**
Dust	mg/Nm^3	10	5	1
TVOC	mg/Nm^3	10	10	1
CO	mg/Nm^3	50	50	10
HCl	mg/Nm^3	10	6	1
HF	mg/Nm^3	1	<1	0
SO_2	mg/Nm^3	50	30	5
NO_x*	mg/Nm^3	50	50	20
NH_3**	mg/Nm^3	12	10	5
Hg	µg/Nm^3	20	20	3
PCDD/F	ng$_{I\text{-}TEQ}$/Nm^3	Dioxins: 0.1 ng/Nm^3	0.06	Dioxins: 0.01 ng/Nm^3
PCDD/F + PCB-D	ng$_{I\ \&\ HO\text{-}TEQ}$/Nm^3		0.08	
Cd+Tl	mg/Nm^3	0.02	0.02	0.04
Σ9 metals$^{2)}$	mg/Nm^3	0.4	0.3	0.1

*Yearly average in existing permit

**Monthly average in existing permit

Amine emissions

It is recommended that Sysav initiates a dialogue with the authorities regarding expected requirements for amine emissions. In this pre-feasibility study it is, however, assumed that amine emissions shall not contribute to higher values of the sum of nitrosamines and nitramines than 0.3 ng/Nm^3 in surrounding air and 4 ng/l in drinking water. These values are presently used by Norwegian authorities in on-going carbon capture projects.

Such values shall be confirmed through emission dispersion calculations using emission dispersion models with integrated amine chemistry. To estimate amine emission limits from the stack it is possible to back-calculate from the above-mentioned recipient values using the same amine chemistry dispersion model.

3.2.2 Process wastewater discharge

The current environmental permit prescribes that any process liquid effluents (wastewater) must be treated in a chemical wastewater treatment plant before discharge to Øresund.

P3 and P4 are today producing wastewater, which after treatment is sent to the recipient. Further the plants could in the future be enforced to follow the Best Available Techniques Associated Emission Levels (BATAELs) of the latest Best Available Techniques (BAT) Conclusions under Directive 2010/75/EU (BREF).

Table 4 presents the present current and possible future requirements to treated liquid effluents sent to the municipal effluent system from Sysav.

Table 4: Requirements to treated liquid effluent from Sysav as stated in the discharge permit.

Discharge parameter	Unit	Limits for unfiltered daily samples	Förordning (2013:253) om förbränning av avfall	BAT-AELs for direct emissions
Total amount suspended solids	mg/l	20	45	10 – 30
Total organic carbon	-	-	-	15 – 40
pH	-	6.5 – 9.5	-	-
Discharge temperature	°C	-	-	-
Mercury and Hg compounds	mg Hg/l	0.004	0.03	0.001 – 0.01
Cadmium and Cd compounds	mg Cd/l	0.007	0.05	0.005 – 0.03
Thallium and Tl compounds	mg Tl/l	0.05	0.05	0.005 – 0.03
Arsenic and As compounds	mg As/l	0.15	0.15	0.01 – 0.05
Lead and Pb compounds	mg Pb/l	0.05	0.2	0.02 – 0.06
Chromium and Cr compounds	mg Cr/l	0.04	0.5	0.01 – 0.1
Copper and Cu compounds	mg Cu/l	0.1	0.5	0.03 – 0.15
Nickel and Ni compounds	mg Ni/l	0.1	0.5	0.03 – 0.15
Zink and Zn compounds	mg Zn/l	0.5	1.5	0.01 – 0.5
Cobalt and Co compounds	mg Co/l	0.02	-	-
Sulphate	mg/l	-	-	400 – 1000
Dioxins and furans	ng/l	0.3	0.3	0.01 – 0.05

The requirements stated above must be expected to apply also after installation of P5 and the CC plant.

The CC plant may dependent on technology that generate continuous and discontinuous liquid effluents containing e.g. small amounts of ammonia, amines and nitrosamines/nitramines. There may also be limitations on such effluents to the effluent stream and internal collection and pre-treatment must therefore be expected and considered.

3.2.3 Noise

Swedish environmental noise regulation applies for Sysav and will apply for a future CC plant. Table 5.

The present environmental permit for Sysav states limits which must be adhered. The limit values are presented in Table 5.

Table 5: Maximum allowable noise limit at nearest dwelling of Sysav.

Period	Time	Limit value at nearest dwelling
Daytime (every day)	0700 – 1800	50 dB(A)
Evening (every day)	1800 – 2200	45 dB(A)
Night-time (every day)	2200 – 0700	40 dB(A)
Night-time, Instantaneous (every day)	2200 – 0700	55 dB(A)

The limit values shall be checked either by ambient measurements or by near field measurements and calculations. Control shall be carried out when the noise emission, due to changes in operations, increases by 1 dB (A), but at least in connection with each periodic inspection or when requested by the supervisory authority.

It must be expected these values will be valid also when the new installations at P5 and the CC plant are in place. Since noise contributions are logarithmic and additive and if no measures are taken in the existing part of the installations at Sysav, stricter noise emission values will apply for the new installations.

3.3 Energy System and District Heating

3.3.1 Energy System

P3 and P4 consist of steam boilers for production of steam for electricity and district heating. P3 and P4 produce steam with the parameters: 40 bar(a) / 400 ºC. The steam is used for:

- Preheating of primary combustion air
- Electricity production through turbine
- District heating production through condenser

It is, for the Carbon Capture pre-feasibility study, assumed that P5 is a steam boiler with high pressure exhaust.

In addition, P3 and P4 produce district heating by means of:

- Flue gas condensation via direct condensation and heat-pumps (two heat pumps with a total heating capacity of 19 MW) for each line.
- A separate low-temperature economizer for district heating production located downstream the ID fan preheating district heating return water on each line.
- Heat pumps connected to the ventilation system of P3 and P4 (total heating capacity if 5.2 MW per line – In practice only one is operated at a time)

P5 is currently planned with direct condensation. It is possible that P5 will be implemented with additional components or sub-systems to increase the energy production and increase energy efficiency.

Figure 8 provides a graphical overview of the existing DH producers at Sysav. Figure 9 provides a graphical overview of the expected future DH producers at Sysav once P1+2 have been demolished and P5 established.

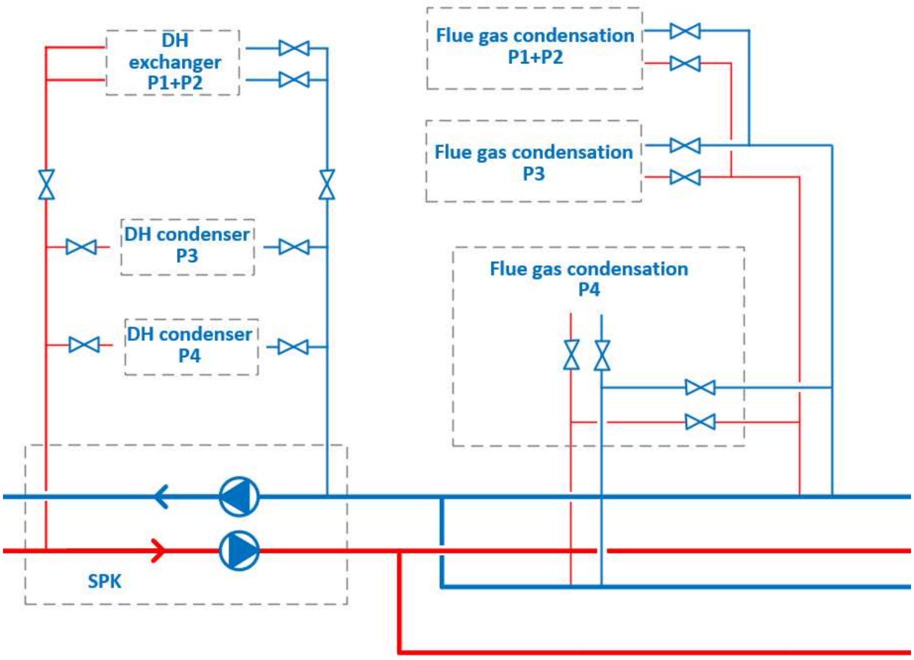

Figure 8: Simplified overview of existing DH producers at Sysav.

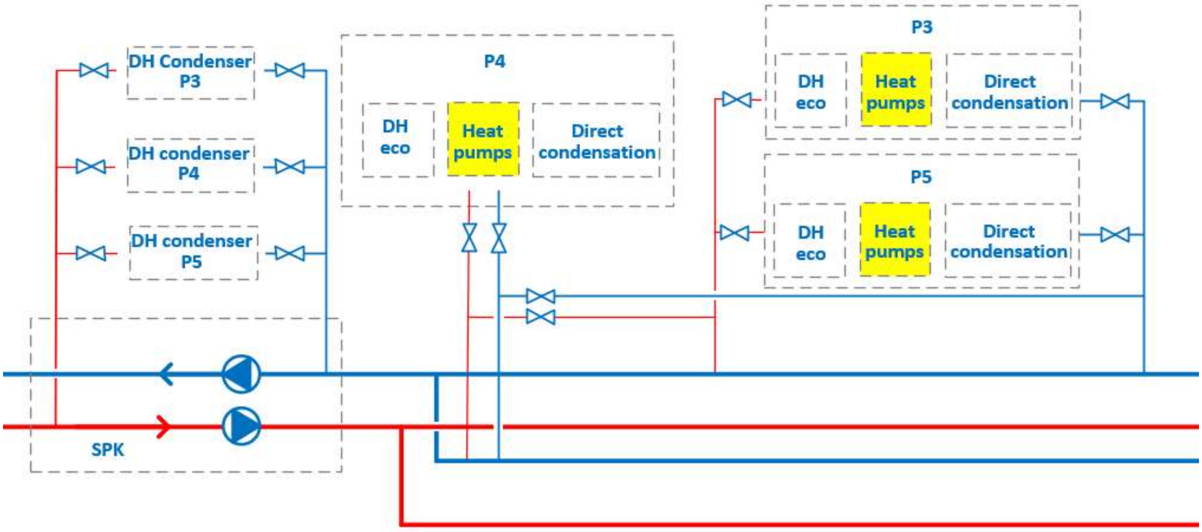

Figure 9: Simplified concept of expected future DH producers at Sysav. Energy modelling to identify optimal location of heat pumps in the WtE facility.

The nominal production capacity of each DH producer is presented in Table 6. The values are informed by Sysav and is based on typical operational data. The heat pumps for flue gas condensation have a capacity of 2x9 MW for each line.

Table 6: Nominal DH and gross power production of Sysav's WtE facility (excluding P1 and P2).

DH production	Nominal DH capacity [MW]	Nominal gross power capacity [MW]
P3		
P3, Turbine/DH condenser	60.5	21
P3, DH ECO	4.6	
P3, Direct condensation	7.6	
P3, Heat pump condensation (Heat delivered)	9.9	
P3, Civil heat pumps ("Fastighets VP", HP3+HP4)	0	
P4		
P4, Turbine/DH condenser	57.7	20
P4, DH ECO	7.5	
P4, Direct condensation	7.9	
P4, Heat pump condensation (Heat delivered)	10.8	
P4, Civil heat pumps ("Fastighets VP", HP3+HP4)	3.5	
P5		
P5, Turbine/DH condenser	59.6	
P5, Condensation	11	

3.3.2 District Heating

Sysav supplies district heating to the DH network in Malmö. The owner of the district heating network is E.ON. E.ON aims at having heat production in Malmö "100% Förnybar eller Återvunnen" by 2025. The overall district heating network currently has a peak load capacity at around 500 MW.

The first priority in the district heating network is held by the recycled heat from the Orion plant, which has a capacity reservation of 15-32 MW, depending on period of the year:

- 1. May – 30. September: 15 MW
- April and October: 22 MW
- 1. November – 31. March: 32 MW

After the Orion plant, it is prioritized that incineration of waste is supplied as baseload DH in the district heating network with a production obligation of 1,150 GWh per year. This demand shall be met with existing P3, P4 and possibly P5 once P1 and P2 are taken out of operation.

The Sjölunda heat pumps recover waste heat from the wastewater treatment plant located next to Sysav and is prioritized after Sysav in terms of DH delivery, however, the district heating connection means that when in operation the Sjölunda heat pumps raises the district heating temperature experienced by the turbine condensers at Sysav and therefore has an impact on DH recovery options at Sysav's facility.

Figure 10 presents Sysav's DH connection to the grid. The figure is based on available PID's and PFD's from Sysav and E.ON. Here the relative position of the different DH producers appears, and it is seen how the Sjölunda heat pumps affect the DH temperature at inlet of the turbine condensers of P3 and P4. P1 and P2 are omitted from the figure, but are located in parallel to the P3 and P4 turbine condensers.

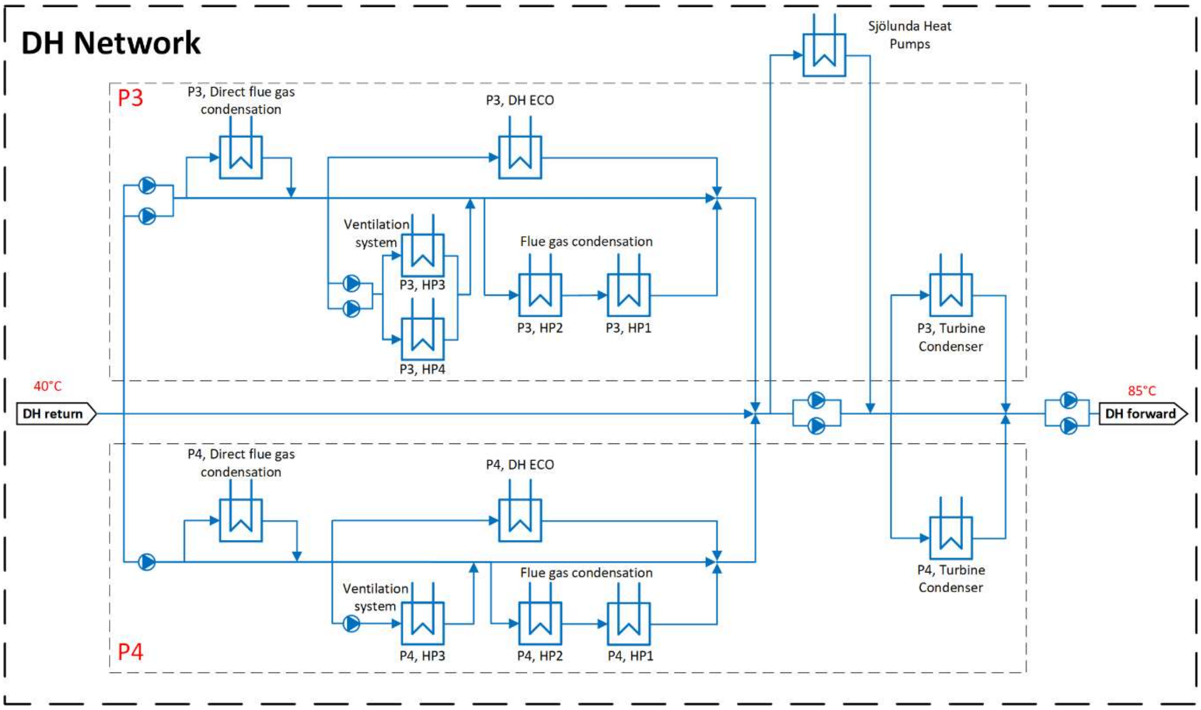

Figure 10, Simplified illustration of Sysav's DH connection. P1 and P2 are assumed decommissioned and not included in the sketch.

The DH demand is expected to vary based on season and climate. The variation for district heating demand is based on the average of 2011-2020. The average historical district heating demand is considered representative for the near-future district heating demand. A prognosis for the future DH demand from has not been made available.

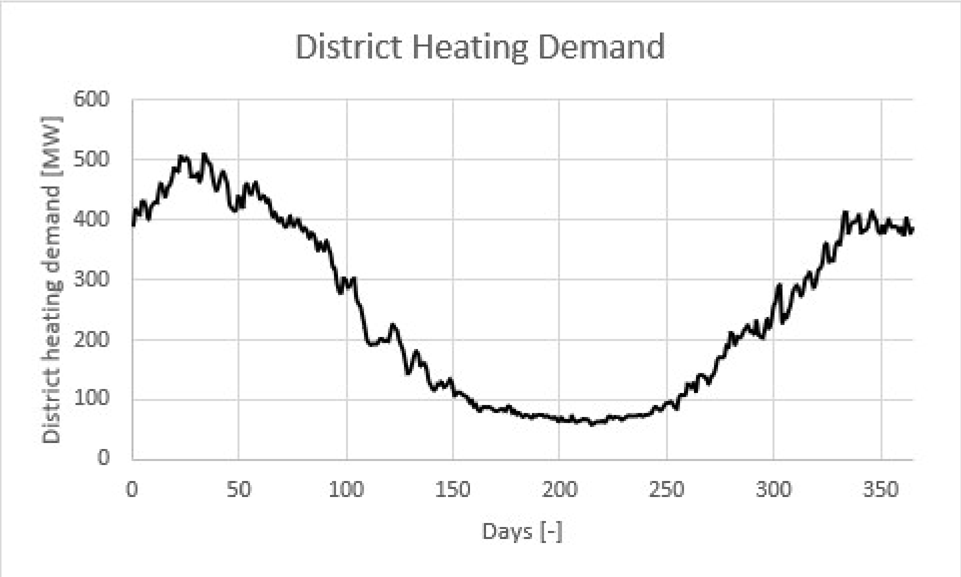

Figure 11: Average daily DH demand, 2011-2020.

Figure 12, Figure 13 and Figure 14 present the district heating temperatures measured at Sysav's WtE facility in 2020. The return temperature spans from 40 to 55 °C and the forward temperature span from 70 to 95°C.

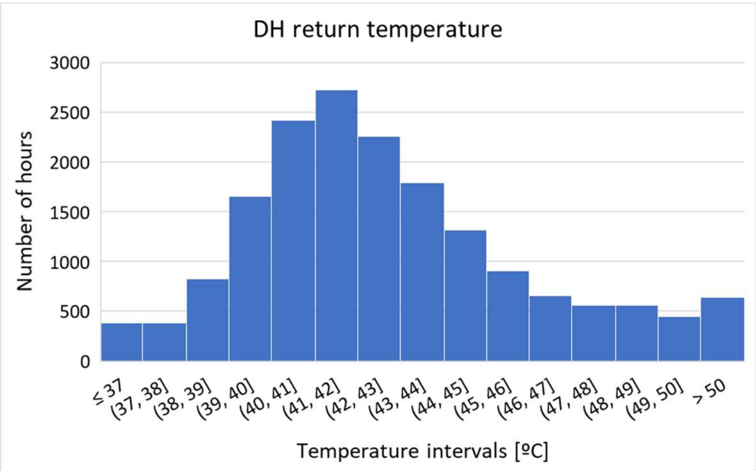

Figure 12, Temperature distribution of DH return water to Sysav's WtE plant in 2020

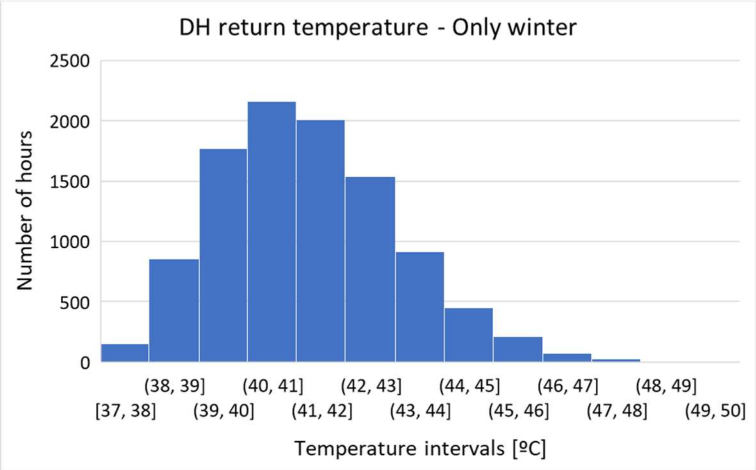

Figure 13, Temperature distribution of DH return water to Sysav's WtE plant in the winter of 2020 (January to April and October to December)

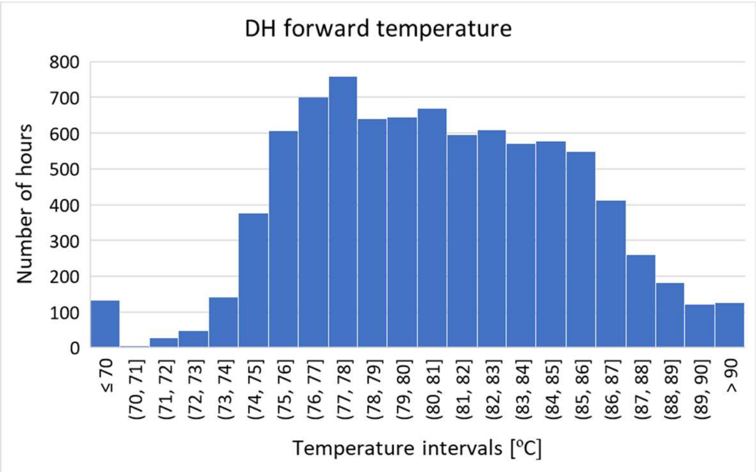

Figure 14, Temperature distribution of DH forward water from Sysav's WtE plant in 2020.

No prognosis for future DH temperatures at Sysav are available and the temperature ranges from 2020 is assumed to represent the future DH temperatures at Sysav.

Table 7 presents the 2020 temperature span and the typical temperature case of 40/85°C. The typical temperature case has been adopted for the current study.

Table 7: DH current forward and return temperatures.

DH Water Temperatures	Forward [°C]	Return [°C]
Temperature span	70-95	40-55
Typical temperature case	85	40

3.3.3 Cooling

There is currently not installed any air coolers at Sysav. During the summer period the energy production is limited by the district heating demand, as the backpressure turbines rely on the district heating (DH) network to provide the cooling of the turbine exhaust. If the DH off-take was higher the full power production potential of the turbines could be utilized. As an additional benefit the full waste treatment capacity could be sustained.

Ramboll have, in 2020, made a pre-feasibility study of introducing summer coolers for P3 and P4. Dry-air coolers have been found beneficial to maximize the fuel throughput and electricity production for periods with low DH demand. Capacity of the dry-air cooler is foreseen to be designed for P3 and P4 (and potentially P5) with no spare capacity for a potential carbon-capture plant.

3.4 Process Flow Diagrams, Heat and Mass Balance & Flue gas composition

Rough heat and mass balances are derived for P3, P4 and P5 based on the yearly average waste composition for 2020 based on inputs for the study "Estimates of consumption and generation for selected waste fraction".

Waste composition and actual operation can differ from the rough heat and mass balances presented and these shall only be considered indicative. The values presented in this section are indicative, only for information and not directly used for the present study. For flue gas composition and calculation assumptions used for the current CC study is referred to section 4.

Table 8: Average waste composition for 2020.

Parameter	Unit	Nominal load point 100% thermal input
Lower heating value	MJ/kg	10.7
Ash	%	22.7
Moisture	%	25.9
C	%	27.7
H	%	3.9
O	%	18.7
N	%	0.6
S	%	0.1
Cl	%	0.5
Metal content	%	1.1

Figure 15 shows a simplified process flow diagram for the existing P3 and P4.

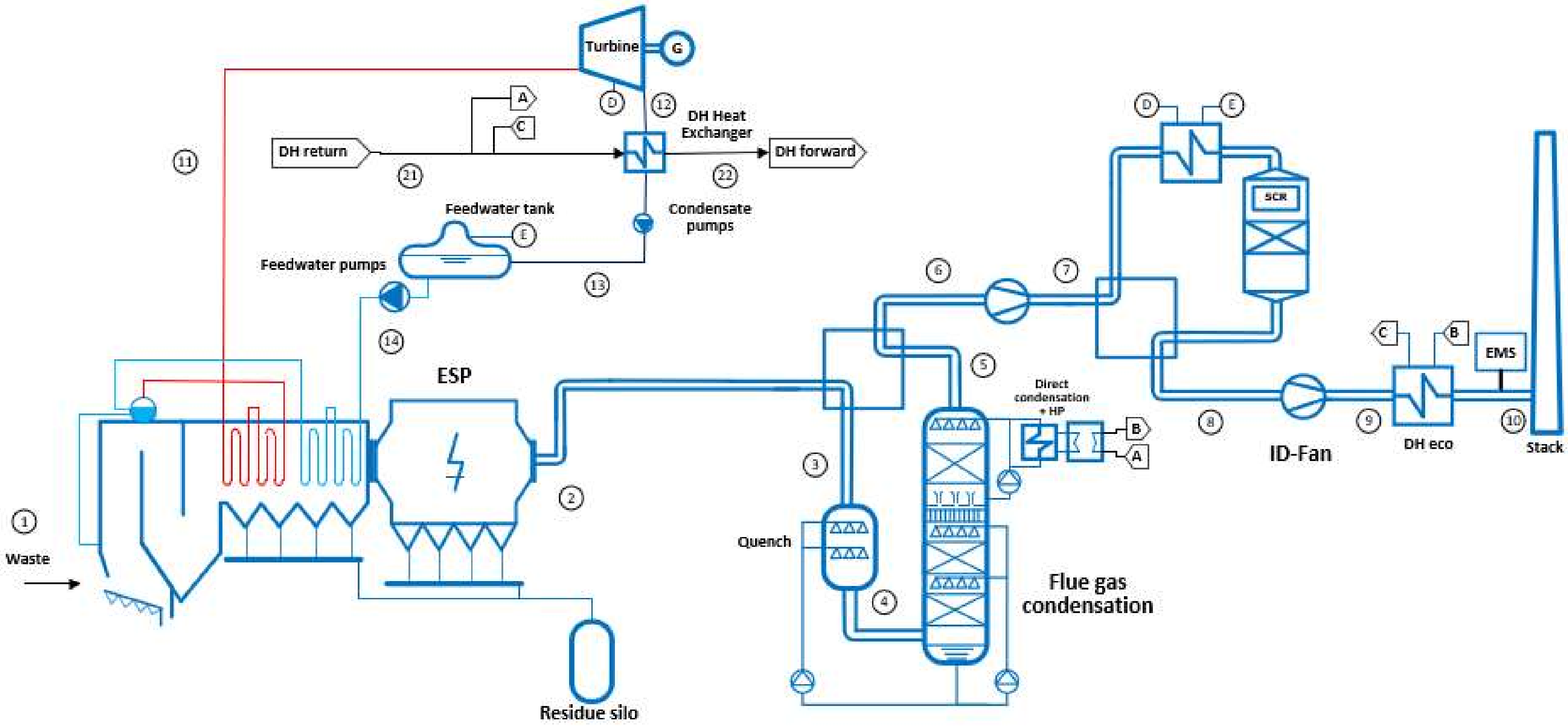

Figure 15: Simplified process flow diagram for P3 and P4.

A rough heat and mass balance for the main flows of P3 and P4 have been made and is provided as an example for illustration of the mass balance variation at a given operation point. The heat and mass balance is based on Ramboll's inhouse simulation tool RAMsteam and are indicative only. The flue gas composition at the stack may show deviations from actual operation at Sysav. Likewise operational conditions for P3 may be slightly different from P4. Such minor differences are considered not to affect the overall concept development of the Carbon Capture plant in this pre-feasibility study. Numbers in the table refer to the numbers in Figure 15.

Table 9: P3 and P4, Indicative heat and mass balance for main flows at nominal operation. The table is only indicative and is not tuned based on operational data.

No.	Media	Flow rate	Temperature	Pressure	Other parameters
1	Waste	32.3 ton/h	NA	NA	LHV: 10.7 MJ/kg Thermal input: 96 MW
2	Flue gas	Volume flow standard: 182,716 Nm3/h Volume flow actual: 335,507 m3/h	220 ºC	0.996 bar(a)	H_2O: 15% O_2, wet: 7.5% CO_2, wet: 9.1%
3	Flue gas	Volume flow standard: 182,716 Nm3/h Volume flow actual: 285,901 m3/h	145 ºC	0.991 bar(a)	H_2O: 15% O_2, wet: 7.5% CO_2, wet: 9.1%
4	Flue gas	Volume flow standard: 193,685 Nm3/h Volume flow actual: 242,309 m3/h	60 ºC	0.986 bar(a)	H_2O: 19.8% O_2, wet: 7% CO_2, wet: 8.6%
5	Flue gas	Volume flow standard: 178,261 Nm3/h Volume flow actual: 222,960 m3/h	50 ºC	0.958 bar(a)	H_2O: 12.9% O_2, wet: 7.6% CO_2, wet: 9.3%
6	Flue gas	Volume flow standard: 178,261 Nm3/h Volume flow actual: 278,746 m3/h	129 ºC	0.953 bar(a)	H_2O: 12.9% O_2, wet: 7.6% CO_2, wet: 9.3%
7	Flue gas	Volume flow standard: 178,261 Nm3/h Volume flow actual: 267,743 m3/h	137 ºC	1.013 bar(a)	H_2O: 12.9% O_2, wet: 7.6% CO_2, wet: 9.3%
8	Flue gas	Volume flow standard: 178,503 Nm3/h Volume flow actual: 288,727 m3/h	162 ºC	0.998 bar(a)	H_2O: 13% O_2, wet: 7.6% CO_2, wet: 9.3%
9	Flue gas	Volume flow standard: 178,503 Nm3/h Volume flow actual: 283,609 m3/h	166 ºC	1.025 bar(a)	H_2O: 13% O_2, wet: 7.6% CO_2, wet: 9.3%
10	Flue gas	Volume flow standard: 178,503 Nm3/h Volume flow actual: 222,672 m3/h	70 ºC	1.013 bar(a)	H_2O: 13 % O_2, wet: 7.6% CO_2, wet: 9.3%
11	Steam	30.7 kg/s	400 ºC	40 bar(a)	
12	Steam	26.8 kg/s	93 ºC	0.8 bar(a)	

No.	Media	Flow rate	Temperature	Pressure	Other parameters
13	Condensate	26.8 kg/s	92 ºC	0.7 bar(a)	
14	Feed water	32.2 kg/s	131 ºC	68 bar(a)	
21	District heating	438 kg/s	50 ºC	8 bar(a)	
22	District heating	438 kg/s	90 ºC	10 bar(a)	

Table 10 presents indicative flue gas flow and composition for P3 and P4 and the average thermal load point and the lowest and highest load point within the capacity diagram (refer to Figure 4). Estimates are made using Ramboll's inhouse simulation tool RAMsteam and are indicative only. The flue gas composition at the stack may differ from actual operation at Sysav.

Table 10: Indicative flue gas flow rate and composition for P3 and P4 at stack. The table is only indicative and is not tuned based on operational data.

Parameter	Unit	Nominal average load point	Lowest load	Highest load
		100% thermal input	70% thermal input	110% thermal input
Thermal input	MW	96.0	67.2	105.6
Flow rate	Nm3/h, wet	178,503	124,952	196,353
Temperature	ºC	70.0	70.0	70.0
Pressure	bar(a)	1.02	1.02	1.02
O_2	%, wet	7.6%	7.6%	7.6%
CO_2	%, wet	9.3%	9.3%	9.3%
N_2+Ar	%, wet	70.0%	70.0%	70.0%
H_2O	%	13.0%	13.0%	13.0%

Figure 16 shows a simplified process flow diagram for the possible future P5. Optimization of the overall process design for the future P5 is not part of this pre-feasibility study and the flue gas conceptual design is initially assumed as a semi-dry flue gas treatment with a polishing and condensing scrubber followed by a tail-end SCR. In the next project phases, it is recommended to update the existing P5 studies with an optimization of the total plant concept including the influence of the future Carbon Capture plant investigated in this pre-feasibility study.

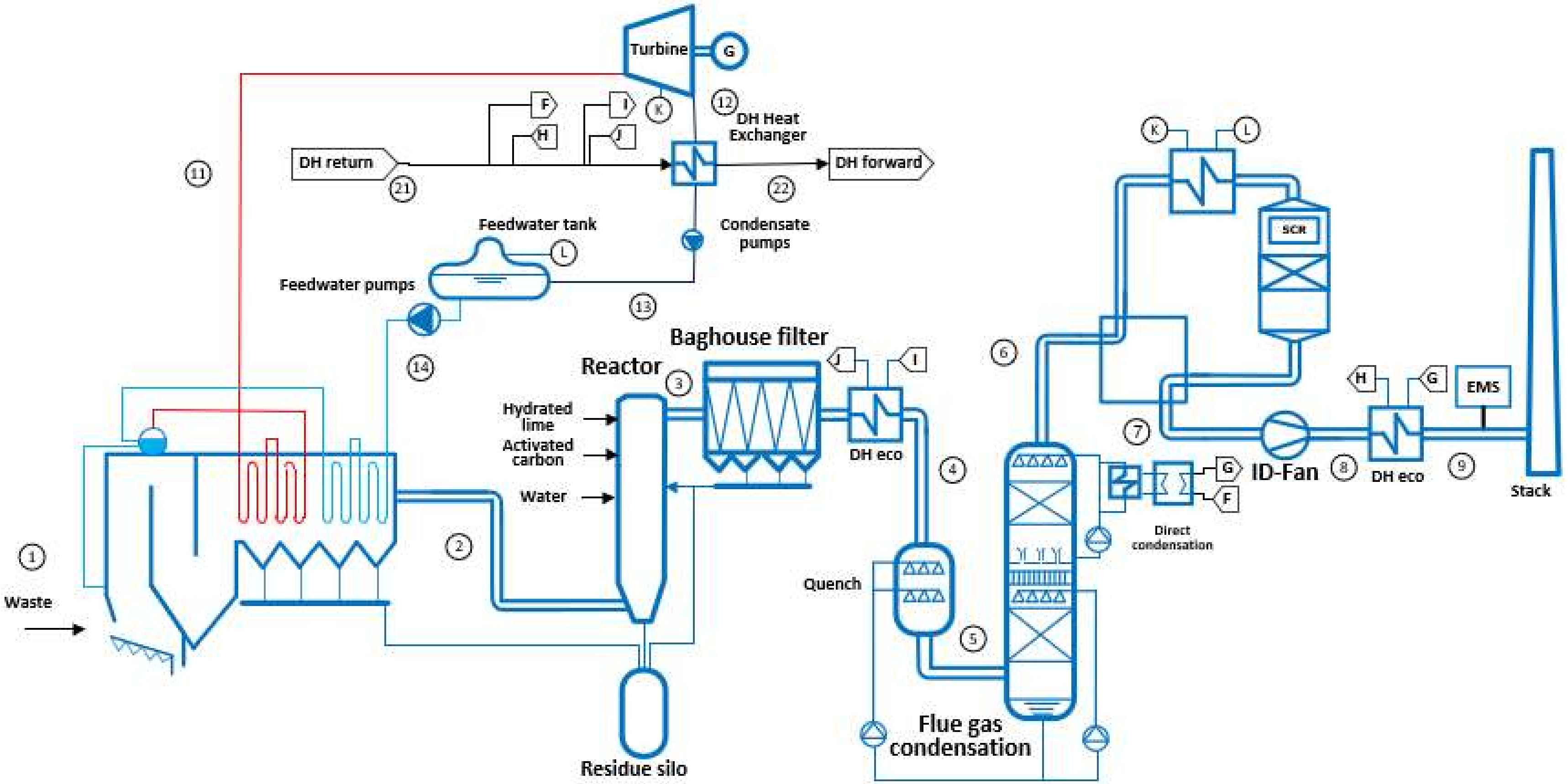

Figure 16: Simplified process flow diagram for P5.

A simple heat and mass balance for the main flows of the assumed P5 are provided in Table 11 as an example for illustration of the mass balance variation at a given operation point. The heat and mass balance is based on Ramboll's inhouse simulation tool RAMsteam and are indicative only. The waste composition from 2020 has been used. Numbers in the table refer to the numbers in Figure 16.

Table 11: P5, Indicative heat and mass balance for main flows at nominal operation. The table is only indicative and is not tuned based on operational data.

No.	Media	Flow rate	Temperature	Pressure	Other parameters
1	Waste	30.3 ton/h	NA	NA	LHV: 10.7 MJ/kg Thermal input: 90 MW
2	Flue gas	Volume flow standard: 171,037 Nm3/h Volume flow actual: 275,286 m3/h	160 ºC	0.998 bar(a)	H_2O: 14.8% O_2, wet: 7.5% CO_2, wet: 9.1%
3	Flue gas	Volume flow standard: 175,825 Nm3/h Volume flow actual: 281,679 m3/h	145 ºC	0.968 bar(a)	H_2O: 15.3% O_2, wet: 7.7% CO_2, wet: 8.9%
4	Flue gas	Volume flow standard: 178,853 Nm3/h Volume flow actual: 239,048 m3/h	70 ºC	0.952 bar(a)	H_2O: 15.1% O_2, wet: 7.9% CO_2, wet: 8.7%
5	Flue gas	Volume flow standard: 180,836 Nm3/h Volume flow actual: 231,757 m3/h	54 ºC	0.947 bar(a)	H_2O: 16% O_2, wet: 7.8% CO_2, wet: 8.6%
6	Flue gas	Volume flow standard: 160,134 Nm3/h Volume flow actual: 195,028 m3/h	32 ºC	0.929 bar(a)	H_2O: 5.1% O_2, wet: 8.8% CO_2, wet: 9.7%
7	Flue gas	Volume flow standard: 160,360 Nm3/h Volume flow actual: 275,307 m3/h	150 ºC	0.914 bar(a)	H_2O: 5.3% O_2, wet: 8.8% CO_2, wet: 9.7%
8	Flue gas	Volume flow standard: 160,360 Nm3/h Volume flow actual: 255,200 m3/h	167 ºC	1.025 bar(a)	H_2O: 5.3% O_2, wet: 8.8% CO_2, wet: 9.7%
9	Flue gas	Volume flow standard: 160,360 Nm3/h Volume flow actual: 200,100 m3/h	70 ºC	1.02 bar(a)	H_2O: 5.3% O_2, wet: 8.8% CO_2, wet: 9.7%
12	Steam	27.4 kg/s	400 ºC	40 bar(a)	
13	Steam	24.7 kg/s	77 ºC	0.8 bar(a)	
14	Condensate	24.7 kg/s	76 ºC	0.4 bar(a)	
15	Feed water	32.2 kg/s	131ºC	68 bar(a)	

No.	Media	Flow rate	Temperature	Pressure	Other parameters
16	District heating	467 kg/s	50 ºC	8 bar(a)	
18	District heating	467 kg/s	90 ºC	10 bar(a)	

Table 12 presents estimated flue gas flow and composition for P5 for the nominal thermal load point and the lowest and highest load point within the capacity diagram (refer to Figure 16). Estimates are made using Ramboll's inhouse simulation tool RAMsteam and are indicative only.

Table 12: Indicative flue gas flow rate and composition for P5 at stack. The table is only indicative and is not tuned based on operational data.

Parameter	Unit	LP1 Nominal load point 100% thermal input	LP7 Lowest load 70% thermal input	LP11 Highest load 110% thermal input
Thermal input	MW	90.0	63.0	99.0
Flow rate	Nm3/h, wet	160,360	112,252	176,395
Temperature	ºC	70.0	70.0	70.0
Pressure	bar(a)	1.02	1.02	1.02
O_2	%, wet	8.8%	8.8%	8.8%
CO_2	%, wet	9.7%	9.7%	9.7%
N_2+Ar	%, wet	76.2%	76.2%	76.2%
H_2O	%	5.3%	5.3%	5.2%

3.5 Layout & Site information

Sysav is located at Spillepengsgatan 13, 211 24 Malmö, Sweden. Figure 17 shows an image overview of Sysav

Trucks arrive at site by Spillepengsgatan south of the site and enters through the main access in the southern corner of the site. Waste-trucks enters the reception hall on the north-east side of the site, unloads the waste into the waste bunker before leaving the reception hall. Waste trucks are weighted at the weighbridges on both arrival and departure.

Trucks for consumables or residual products arrive through the same main access and drives to the relevant location on site for unloading or loading of consumables or residual products.

It is planned to decommission P1 and P2 in 2030 It is further considered to introduce a new P5. If P5 is established, it will most likely utilize the current area of P1 and P2.

Figure 17: Satellite picture of Sysav

4. DESIGN STRATEGY

4.1 Vision

The carbon capture plant shall be constructed as a stand-alone plant on the Waste-to-Energy plant site, Sysav or nearby. The overall pre-study will be conducted for two scenarios depending on the construction of P5. That will be a P3+P4 scenario and a P3+P4+P5 scenario.

The plant shall be able to capture CO_2 from the WtE plant based on the two scenarios. The CO_2 quality and pressure at the delivery point will be dependent on the transportation method. The overall vision and ambition are summarized by Table 13.

Table 13: Overall vision and ambition for the Carbon-Capture Facility

CAPTURE	High capture rate of CO_2 supported by proven technology and optimized for minimum CO_2 capture cost (SEK/ton CO_2)
CAPEX/OPEX	Balanced CAPEX/OPEX Approach Investment balanced during plant lifetime.
PLANT LIFETIME	Technical lifetime of the plant is expected to exceed 20 years. Period for depreciation calculations for economical evaluations is 20 years.
INNOVATION	Base case: Proven technology and commercial standard components by 2025. Alternative case: May be more novel and less proven technology. Solutions with easy and minimum maintenance. High level of automation Short start-up and shut-down time
EXPANDABILITY	Not prepared for expansions
AVAILABILITY	High availability
ENERGY PERFORMANCE	High but balanced degree of energy optimization. No negative impact on the operation of the district heating production or fuel throughput of WtE plant.
ENVIRONMENTAL PERFORMANCE	Low environmental impact with no negative effect on the emissions from the WtE plant.
OCCUPATIONAL HEALTH AND SAFETY	Best possible solutions for occupational safety and health.

4.2 Health, Safety and Environment (HSE)

The construction and operation of the plant shall comply with all statutory national laws, regulations, standards and permits within the area of health, safety and environment, as well as Sysav site specific requirements.

The overall goals for the project are to achieve:
- Zero harm to people, environment, and materials
- Zero accidents or losses
- Zero work related disease

The overall principle of good design in this project is to ensure that all risks on or associated with the site remain As Low As Reasonably Practicable (ALARP).

The daily operation shall ensure that the operating staff will have as little contact as possible with the flue gas, dust, dirt, liquids, moisture etc. The design of the plant shall ensure the best possible working conditions for the personnel.

4.3 Performance Criteria

The ambition of the Carbon Capture plant is to fulfil the performance criteria stated in Table 14. The parameters presented in Table 14 shall act as a guideline for the evaluation criteria of the CC Screening to be conducted as part of the current study

Table 14: Performance criteria for future Carbon Capture Facility

Parameter	Main Scenario P3+P4	Alternative Scenario: P3+P4+P5
Total generated[1] CO_2 from WtE The possible amount CO_2 generated at nominal WtE operation and 8000 hours of operation per year per WtE line. Currently generated CO_2 from P1, P2, P3 and P4: **~**600,000 ton/y.	~540,000 ton/y [2]	~790,000 ton/y
Total captured CO_2 – Target Corresponds to ~80% of total CO2 generated	>430,000 ton/y	>630,000 ton/y
Design Capacity Corresponds to WtE operation: P3, 96 MW thermal input (100% thermal load) P4, 96 MW thermal input (100% thermal load) P5, 90 MW thermal input (100% thermal load)	Flue gas flow: 378,600 Nm^3/h, dry @11% O_2 O_2 concentration: 8 %, dry CO_2 concentration: 11 %, dry	Flue gas flow: 556,178 Nm^3/h, dry @11% O_2 O_2 concentration: 8 %, dry CO_2 concentration: 11 %, dry
Operation range	Shall be able to handle all flue gas conditions that can occur due to operation of P3 and P4 covering: 1. Operation of the WtE lines within the Capacity Diagrams for P3 and P4 and any combinations hereof including one line being off-line. 2. Operation of the WtE lines within the environmental permit. <u>Maximum flue gas flow:</u> P3+P4 at 110% thermal input, short peak thermal load variation (half hour mean value) Flue gas flow: 416,500 Nm^3/h, dry @ 11% O2 <u>Minimum flue gas flow:</u> One line out of operation One line operating at minimum load Flue gas flow: 132,500 Nm^3/h, dry @ 11% O2	Shall be able to handle all flue gas conditions that can occur due to operation of P3, P4 and P5 covering: 1. Operation of the WtE lines within the Capacity Diagrams for P3, P4 and P5 and any combinations hereof including two lines being off-line. 2. Operation of the WtE lines within the environmental permit. <u>Maximum flue gas flow:</u> P3+P4+P5 at 110% thermal input, short peak thermal load variation (half hour mean value) Flue gas flow: 611,800 Nm^3/h, dry @ 11% O2 <u>Minimum flue gas flow:</u> Two lines out of operation One line (smallest) operating at minimum load Flue gas flow: 124,300 Nm^3/h, dry @ 11% O2
Capture rate[3], - Target at nominal operation: - Yearly average:	90% >85%	
CO_2 outlet parameters at interface towards external recipient of CO_2	Dependent on transportation method	
Target on-stream factor[4]	90%	
Target annual operation availability of CC plant	8000 h/year	
Annual planned outages	1	

Parameter	Main Scenario P3+P4	Alternative Scenario: P3+P4+P5
Plant lifetime	20 years	
Change in WtE plant DH production	0%	
Change in WtE waste throughput	0%	
Environmental Performance	Compliant with all existing environmental requirements for Sysav, refer to section 3.2 *"Environmental Performance"*	
1) The amount of generated CO_2 from waste depends on the amount of carbon in the waste. For the presented estimate a factor of 1.05 kg CO_2 per kg of waste is assumed. 2) Sysav reported a production of 450.000 ton CO_2 for P3 and P4 in 2020. 3) Capture rate defines the amount of CO_2 in the flue gas that shall be captured by the CC plant. 4) On-stream factor defines the fraction of time that the CC plant shall be available relative to the total amount of hours available in a year of 8760 h/y.		

4.4 Preconditions and Assumptions

The CC plant shall be able to receive flue gas and capture CO_2 from either one, two or all three of the WtE lines P3, P4 and possibly P5, depending on the scenario. Flue gas from the WtE plant is taken downstream the flue gas treatment system and shall be returned to the stack through suitable flue gas ducts. Bypass of the CC plant shall be possible as outage of the CC plant must not introduce reduced waste treatment.

The design, construction, testing and commissioning of the CC plant shall, to the extent possible, be planned and executed without disturbance of the operation of the existing Waste-to-Energy plant.

The CC plant shall be designed, manufactured, transported, checked, installed and tested according national and international standards and norms. Where applicable EN standards exist, these shall take preference.

The CC facility shall be designed with an optimized water balance to minimize the needed water supply and wastewater treatment requirements. Any water or wastewater treatment shall be part of the scope of the CC plant.

Equipment and components shall to the extent possible be covered by a climate screen providing necessary weather protection and minimizing noise emissions. Large components can be located outdoors if they can resist the ambient conditions.

Preconditions and assumptions for the future work on the present project including modelling of the Waste-to-Energy and CC plant is presented in Table 15 to Table 17 below:

Table 15: General preconditions and assumptions

Parameter	Value
Unit system	SI ("International System of Units")
Design ambient air temperature	25 °C [1)]
DH temperature	Return: 40 °C Forward: 85 °C
DH demand	Winter day with unlimited demand.
1) Max temperature for design of CC plant e.g. temperature for design of component coolers.	

Table 16: Preconditions and assumptions for modelling of Waste-to-Energy plant

Concept	P3	P4	P5
Waste CV [MJ/kg]	10.7	10.7	10.7
Waste input [ton/h]	32.3	32.3	30.3
Excess air ratio	λ=1.7	λ=1.7	λ=1.7
Flue gas temperature at boiler outlet [°C]	220	220	160
Air preheating [°C]	110	110	110
Ambient air [°C]	15	15	15
Feed water temperature [°C]	130	130	130
Steam parameters [bar/°C]	40/400	40/400	40/400

Table 17: Preconditions and assumptions for modelling of carbon capture plant

Parameter	P3+P4	P3+P4+P5
CO_2 in flue gas	63.5 ton/h	93.3 ton/h
Capture rate	90%	90%
Flue gas inlet conditions and composition	Refer to Table 18	Refer to Table 18
Heating media available from WtE plant	Steam: 40 bar(a) / 400°C	Steam: 40 bar(a) / 400°C or 6 bar(a) / 215°C

Table 18 presents estimated flue gas conditions at the inlet of the carbon capture plant. The flue gas conditions have been estimated based on based on available flue gas measurements for P3 and P4 for 2020. For the available data the typical O_2 content has been estimated to be 8% (dry), CO_2 to be 18% (0% O_2, dry), water content of 9% and flue gas temperature at the stack to be 80 ºC. The flue gas composition from P5 is assumed to be as the estimated flue gas composition of P3 and P4. The volume flow of the flue gas has been estimated using a dry stochiometric flow on 260 Nm^3 per GJ.

The figures presented in Table 18 shall be used as basis for the current study.

Table 18: Estimated typical flue gas conditions and composition at inlet of Carbon Capture plant for mixed flue gas stream of P3 and P4 operating at nominal thermal input for different inlet temperatures.

Parameter	Unit	Main scenario P3+P4	Alternative scenario P3+P4+P5
Primary composition			
Temperature	°C	80	80
Saturation temperature	°C	44	44
Pressure	bar(a)	1.01325	1.01325
H_2O	%	9	9
O_2	%, wet	7.3	7.3
CO_2	%, wet	10.1	10.1
Ar+N_2	%, wet	73.6	73.6
Sum	%	100	100
Flow			
Flow rate, P3	Nm3/h, wet	159,768	159,768
Flow rate, P4	Nm3/h, wet	159,768	159,768
Flow rate, P5	Nm3/h, wet	0	149,875
Total flow rate, main scenario	**Nm3/h, wet**	**319,536**	**469,411**
Density	g/Nm^3	1,3	1,3
Mass flow, total	kg/h	415,389	610,223
Estimated CO_2-flow	kg/h	63,498	93,281
The volume flow of the flue gas has been estimated using a dry stochiometric flow on 260 Nm^3 per GJ, which is based on strong empirical correlation. The correlation matches flow measured at Sysav's P3 and P4.			

Figure 18 provides a simplified process flow diagram for P4 with indication of the location of the estimated flue gas composition and flow. Refer to the red cross downstream the DH economizer. The location is similar for P3.

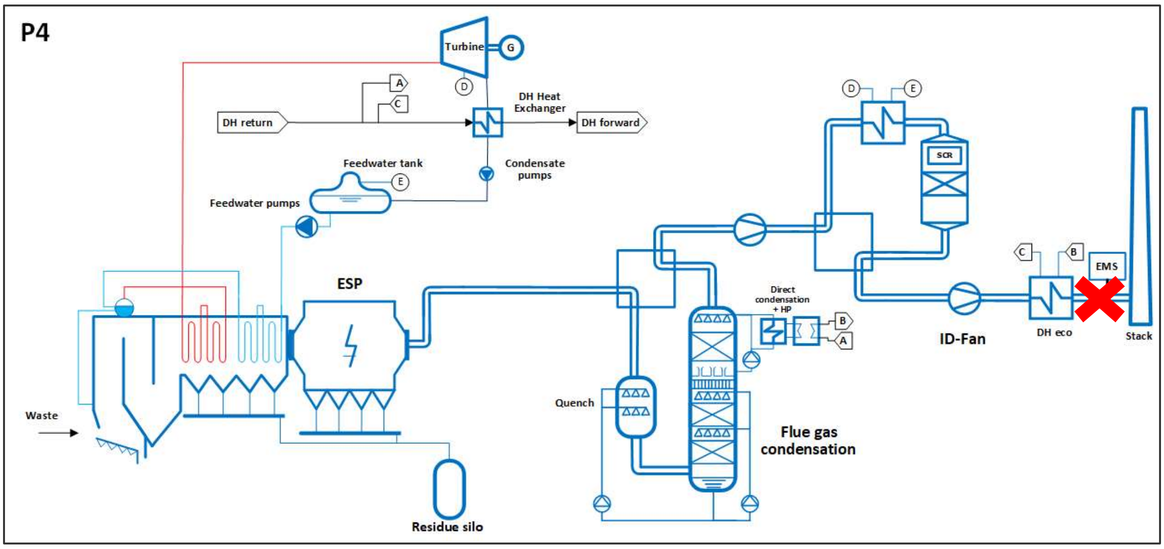

Figure 18: Illustration of P4 with indication of the location (red cross) of the estimated flue gas composition and amount.

4.5 Base Concept for Carbon Capture

The base concept for a carbon capture (CC) plant at Sysav for further development in the upcoming project phases is summarized in Table 19.

Table 19: Base Concept for Carbon Capture plant at Sysav

Parameter	Details
Technology	To be decided during CC screening.
Size	Main scenario: Designed for full flue gas amount originating from the two WtE lines (P3+P4). Alternative scenario: Designed for full flue gas amount originating from the three WtE lines (P3+P4+P5).
ID-fan	Each line has individual ID-fan. Booster-fan implemented in CC plant to overcome increased pressure loss.
Available heat source	Main Scenario: Steam (40 bara, 400°C) from the WtE plant available as heat source. Alternative Scenario: Primary heat source available is steam ~6 bara, ~215°C) from P5. Alternatively steam at 40 bara, 400°C from P3 and P4.
Cooling of CO_2	Implementation of air coolers if needed.
Stack	It is preferred to reuse the existing stack. New stack to be installed, if deemed necessary. For alternative, which includes P5, the existing stack for P1+P2 is replaced by a P5/CC stack.

Any waste streams produced by the CC plant shall be treated by the CC plant or redirected to the WtE plant for incineration and disposal. The primary waste stream from the CC plant is expected to be reclaimer waste (i.e. sludge), which is classified as hazardous waste. The preferred way is to incinerate it at the WtE plant. Sysav currently holds a permit for incineration of hazardous waste.

4.6 Transport and Logistics

After the capture process, CO_2 will be released in "pure" form and after being compressed and cooled CO_2 shall be transported and disposed. At Sysav the CO_2 shall either be temporarily stored on site for periodic transportation, or CO_2 compressors shall be connected to a pipeline. In case of the former, the storage at site acts as daily buffer for the discontinuous transportation during the day and to acts as buffer during night-time. With a pipeline connection such buffer is not necessary. The main scenarios regarding transport and logistics of the captured CO_2 from Sysav are considered to be as follows:

1) Intermediate storage of CO_2 at Sysav and subsequent road transport by tank-trailer of liquid CO_2 from Sysav to CO_2 Export terminal in Malmö port storage area.
2) Pipeline to Malmö port storage area with subsequent liquefaction on Harbour site.
3) Pipeline to near-shore storage in Denmark. The pipe from Sysav will be connected to a Danish CO_2 transmission pipeline with possible point of connection somewhere in Copenhagen.

As a variation of scenario 1, the transportation of liquid CO_2 could be made to Copenhagen instead of using an export terminal in Malmö. As the amount of CO_2 from Sysav is sufficient to ensure a cost-effective transportation from Sweden to the final destination, no significant scale of economy is expected if the CO_2 is transported to Copenhagen

Optimization of offshore transportation may be done by cooperation with partners in Copenhagen for ship loading, however this option is not assessed further in this report.

As a variation of scenario 3, transportation of the CO_2 to Copenhagen could be by truck, but in this case the CO_2 needs to be heated up and further compressed prior to injection to a Danish pipeline, hence this does not form a suitable scenario.

A high-level evaluation of the storage and transport for CO_2 to its final destination and disposal will be conducted based on the design basis and a high-level life cycle cost (LCC) for capture, transport and storage of CO".

The design basis for the transport and logistics of the captured CO_2 is summarized in Table 20 below. The design basis is the overall guidelines which will be used as basis for the storage and transport evaluation.

Table 20, Design basis for transport and storage

Parameter	Details
System capacity	Shall be able to handle the production of CO_2 and the total yearly captured amount of CO_2. Refer to Table 14.
CO_2 quality at export interface	State of liquified CO_2 for road transport is foreseen to be 15 bara/ -30 ºC or similar, and the expected quality requirements are assumed to be similar to the latest version of product specification issued by Equinor/Northern Lights Project. Refer to Table 21. Transport of CO_2 by pipeline: Expected distribution pressure of 150 bar(a).
Storage at Sysav	Temporary site storage capacity: Corresponding to 24 hours of nominal operation CO_2-loading to road transport: The following cases shall be investigated further: • Two working shifts of 8 hours (16 hours daily operation) • Three working shifts of 8 hours (24 hours daily operation) Expected truck loading rate: 40 ton CO_2/hour
Storage at export terminal	Storage capacity at the export terminal must be based on the transport time for a round trip of the carrier with sufficient buffer.
Location of intermediate storage	The siting of the storage, loading and unloading operations shall be according to estimated safety distances to neighbouring activities like populated areas, roads, rails, etc.
Trucks and Trailers	Expected maximum length truck and semitrailer: 25 m Expected payload: 25 tons CO_2 Expected unloading rate: 40 ton CO_2/hour. To be determined during study.
Harbour facility	A harbour facility taking up an area of approximately 50x50 m must be expected as a minimum. Depending on access and lay-out, the proportion of the area may change. For a scenario with pipeline transport to the harbour for liquefaction at the jetty, an additional area of approximately 25x50 m must be expected. The jetty must be able to handle ships with expected main parameters: • Length: 150 m • Width: 25 m • Draught: 9 m

Parameter	Details
	It is expected that Malmö Copenhagen Port will build and operate the harbour facility. Sysav will pay a fee for using the facility.
Metering	The volumes of CO_2 transferred in the transport system shall be measured to keep track of losses in the system. The following metering stations may be envisaged: • Volume and product analysis of product transferred to the road tanker or pipeline at CC capture plant. • Volume and product analysis of product transferred to the ship or near-shore storage.

Table 21:, Specification of CO_2-fluid at interface towards Northern Lights LCO_2 carrier. Source: Northern Lights Project FEED Report, 2020-03-27, Table 3-7 CO2 specification

Component	Concentration ppm (mol)
Water, H_2O	≤ 30
Oxygen, O_2	≤ 10
Sulphur oxides, SO_x	≤ 10
Nitric oxide/Nitrogen dioxide, NO_x	≤ 10
Hydrogen sulphide, H_2S	≤ 9
Carbon monoxide, CO	≤ 100
Amine	≤ 10
Ammonia, NH_3	≤ 10
Hydrogen, H_2	≤ 50
Formaldehyde	≤ 20
Acetaldehyde	≤ 20
Mercury, Hg	≤ 0.03
Cadmium, Cd / Thallium, Tl	≤ 0.03 (sum)

4.7 Layout Considerations

The WtE site is located approximately 5 km (on road) from the centre of Malmö and less than 1 km (on road) from the industrial harbour of Malmö.

Figure 19 shows an overview of Sysav. The red and yellow areas indicated on the figure show future available areas which potentially can be used for a Carbon Capture plant. It should be noted that the availability of the red area is depending on the realization of P5.

The area required for the Carbon Capture facility is highly dependent on the chosen scenario as well as a consideration regarding a common facility (mainly common absorber and stripper) for the boiler lines or separate CCS lines suitable for each of the boiler lines. It must further be considered, in case of a solution with road transport, how the logistics should be managed. Area requirements and site logistics for the Carbon Capture plant must be done at a later stage.

Area description:

P1+P2 (red):
Area currently occupied by P1+P2. The area will be available, when P1 and P2 are demolished. Area will however only be available in case P5 is not realized. The food waste facility is included in the highlighted area. It is noted that it is preferred to maintain the food waste facility in the current location and relocation is only to be suggested, if deemed necessary for the CC plant.

Administration (yellow):
Area currently occupied by Administration building for Sysav including parking spaces. In case of realization of P5, relocation of the administration building may be suggested, if necessary, for the CC plant.

Figure 19, Satellite picture of Sysav WtE site

5. PERMITTING REQUIREMENTS AND PROCESSES

The following authority processes connected to planning, construction and start-up of a CC plant must be adhered to under Swedish regulations. It is crucial to include authority processes when setting up the total schedule for a construction project such as this. Elements in the authority process to be considered may among others be:

- Zoning
- Environmental Impact Assessment
- Building permit and consents
- Emission and Discharge permit
- Consent on operation of plant

It must in the next project phase be clarified whether existing zoning is applicable for the installation of a CC plant at SYSAV. It is expected that the actual zoning in any case must be discussed with Malmö municipality and the pre-feasibility study therefore assumes that the layout proposal is to be based on optimal process layout and logistics for the Carbon Capture plant within Sysav's site boundary.

6. BASIS FOR ECONOMICAL EVALUATION

The key parameters for economical evaluation are summarized in Table 22. Table 23 presents the prognosis for the electricity prices experienced by Sysav.

Table 22, Key parameters for economical calculation

Parameter	Unit	Value
Price-level	[year]	2021
Planning period / Discounting period	[years]	20
Interest rate, real	[%]	XX[1)]
Availability	[hours]	8000
Gate fee	[SEK/ton]	XX[3)]
Incineration taxation	[SEK/ton]	XX[3)]
District heating price	[SEK/kWh]	XX[3)]
Electricity price	[SEK/kWh]	See prognosis below
Fresh water	[SEK/ m^3]	XX[1)]
Discharge of wastewater	[SEK/ m^3]	XX[1)]
Annual maintenance of CC plant in % of total investment	[%]	2
Exchange rate	[SEK/€]	10.15 [2)]
1) Excluded in open report 2) Sveriges Riksbank database 3) No impact as waste feed and district heating production are kept constant 4) It is assumed electricity for energy recovery from the CC-plant is taxed.		

Table 23, Electricity price prognosis

Electricity price prognosis	Unit	2025	2030	2040	2050
Base scenario	[EUR/MWh]	30	35	36	29
High scenario	[EUR/MWh]	40	44	47	45
Low scenario	[EUR/MWh]	22	24	28	22

A potential future CO_2-tax may be considered as a variation in the business model.

Electricity used for energy recovery (e.g., compression heat pumps) are taxed based on the applicable tax rate.