

The logo for Rambøll, featuring the company name in a bold, sans-serif font with a stylized checkmark integrated into the letter 'O'.

RAMBØLL

Bright ideas.
Sustainable change.

Amine Sludge

Problem or new business

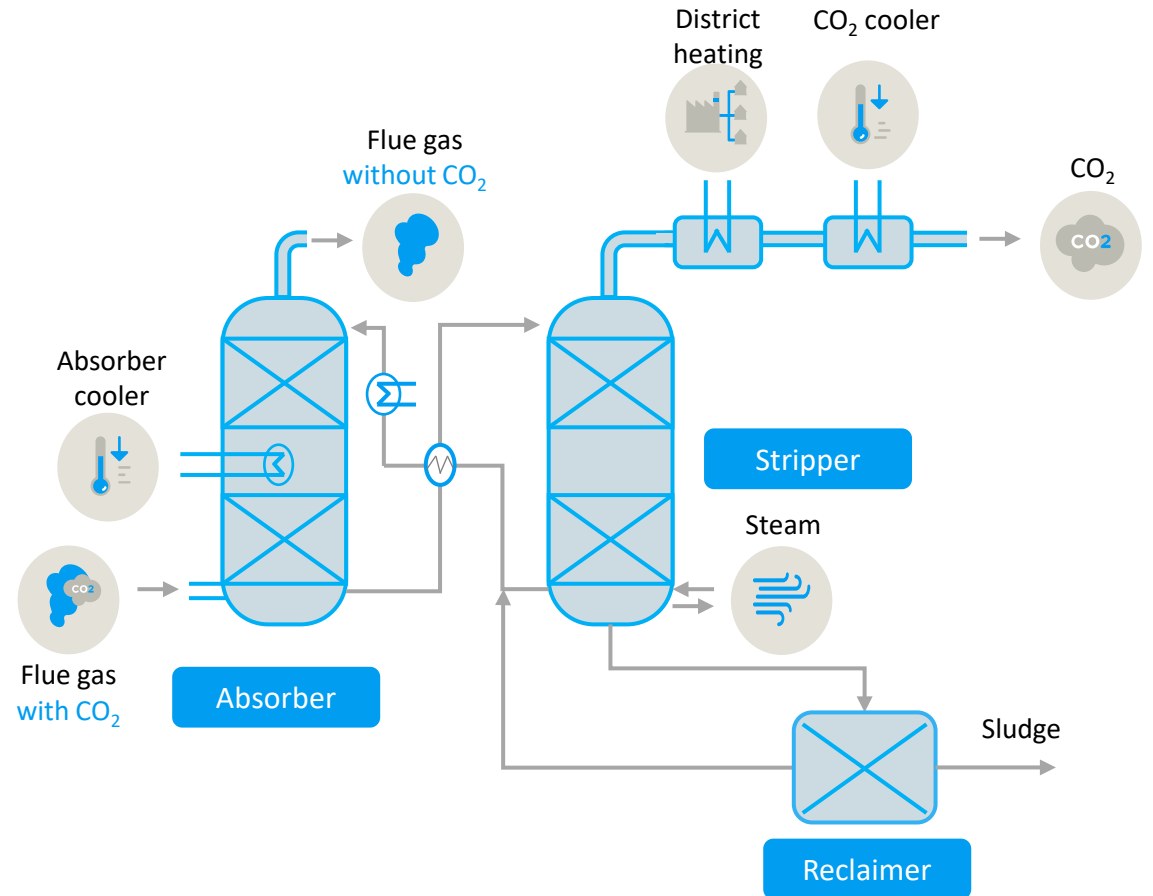
Restproduktsamarbejdet, Januar 2024

Christian Riber & Jens Jørsboe

Rambøll Carbon Capture

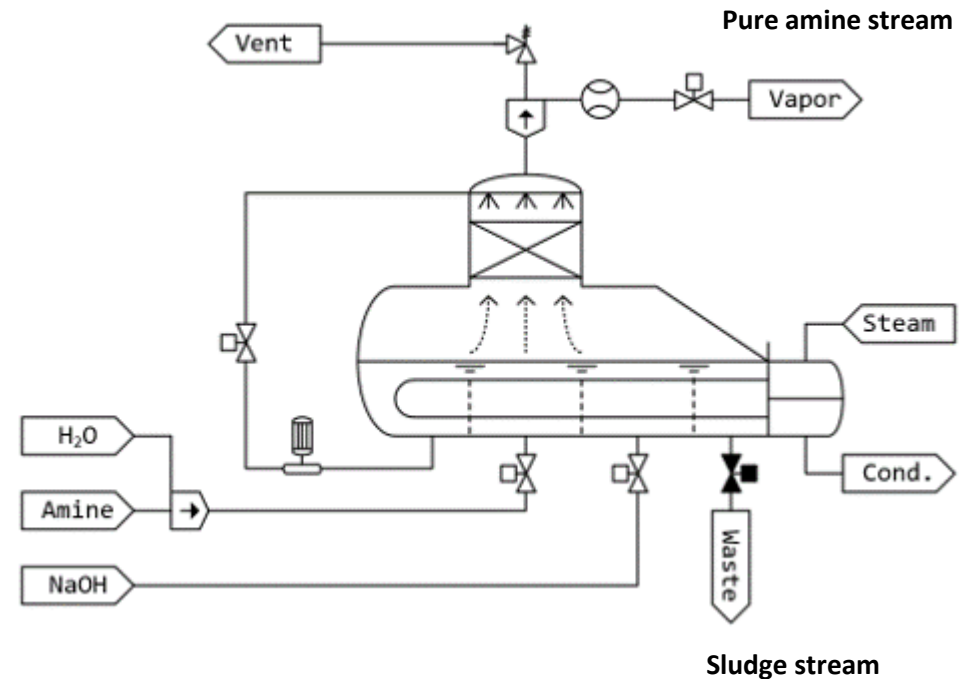
Amine sludge, what is it ?

- Amine-based carbon capture is currently the most mature carbon capture technology especially using MEA or PZ+AMP (CESAR1)
- Amines degrade in the presence of oxygen, temperature and impurities in the flue gas such as NO_x, SO_x and HCl
- Some degradation products are heat stable and will not be regenerated under stripper conditions. These compounds are called heat stable salts and abbreviated HSS
- HSS can be removed using a reclaimer-system where the HSS are separated from the amine solvent
- HSS leaves the reclaimer system in a sludge based product, which must be treated



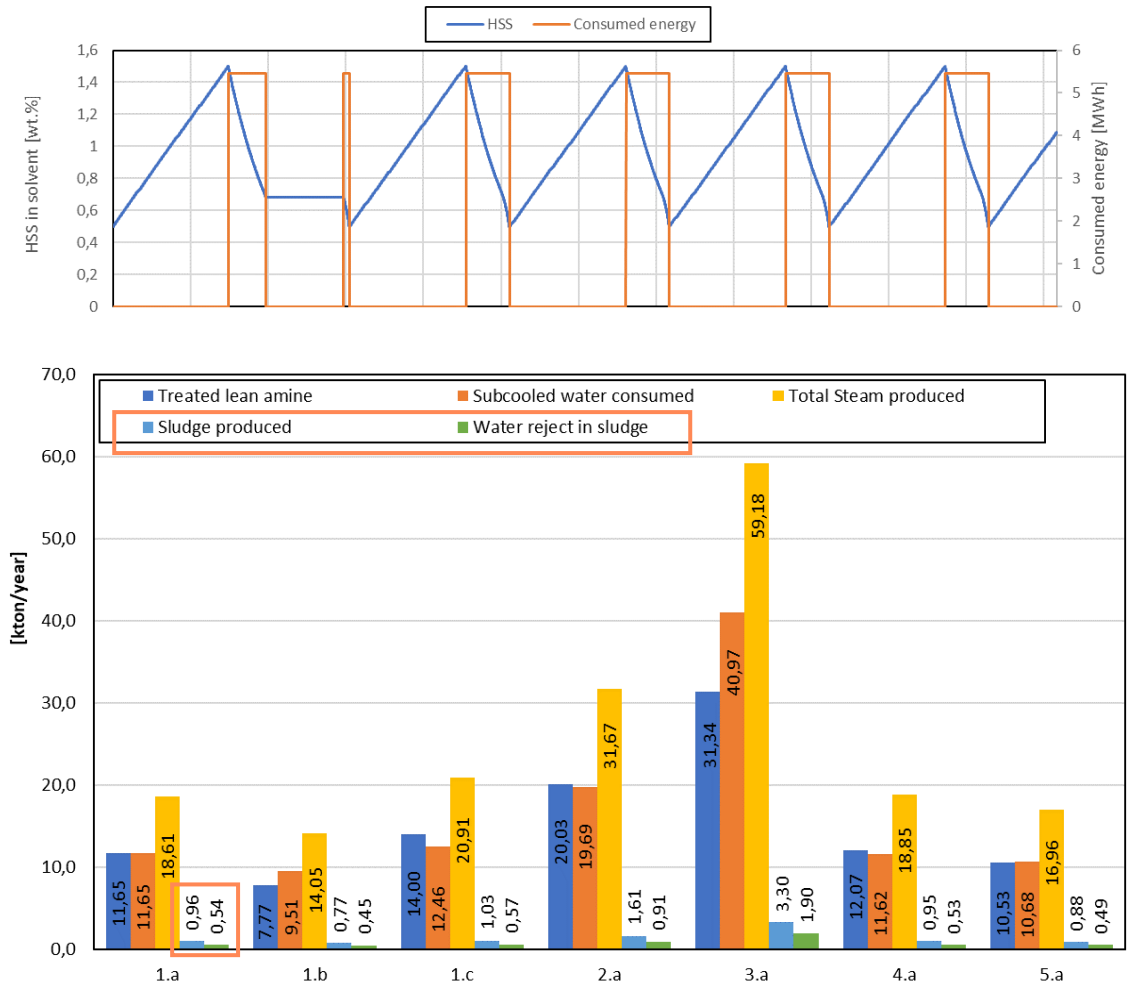
Reclaimer: A method to remove HSS

- Different process designs exist. A mature process is thermal reclaiming.
- Operation pressure 2 [bara]
- Operation temperature range: 130-150 [°C]
- Batch process:
 - NaOH is added to displace amines bound to HSS
 - HSS reacts with Na^+ to form sodium salts
 - Amines partial pressure increases with pH and can be boiled off
 - Sodium salts and amine leftovers remain in the reclaimer and must be removed



Reclaimer modelling

- Composition and amounts of sludge can be modelled:
 - Batch process is divided into many steps of continuous process
 - Temperature is controlled by:
 - 130 -> 140 [°C]: lean amine added
 - 140 -> 130 [°C]: sub-cooled water added
- Sludge amounts depend on:
 - HSS formation rate (kg/ton CO₂)
 - HSS threshold values (wt%)
 - Reclaimer duty (MW)
 - Recovery of amines (%)



Sludge and solvent: Amounts of sludge

- Amine sludge waste is produced from
 - Reclaiming (HSS formation)
 - Solvent bleed stream (Other degradation products)
- Sludge produced from amine plant:
 - 30 wt% MEA: 4.3-15.3 kg/ton CO₂
 - 32 wt% CESAR1: 1.3-4.6 kg/ton CO₂

Above is examples of some modelling results



Sludge and solvent: Case study

- Sludge produced from amine plant (Example)
 - 30 wt% MEA: 6 kg/ton CO₂ on average
 - 32 wt% CESAR1: 2 kg/ton CO₂ on average
 - Advanced solvent: Down to 0.15 kg/ton CO₂
- Example plant of 250.000 ton waste = 250.000 ton CO₂ could result in:
 - 1600 ton sludge using 30 wt% MEA or
 - 500 ton sludge using 32 % CESAR1 or
 - 100 ton sludge using advanced solvent
- Sludge amount equals the amount of chemicals that must be purchased to maintain CC operation



ARC Demo reclaimer unit

Sludge production: Predictions (based on guestimates)

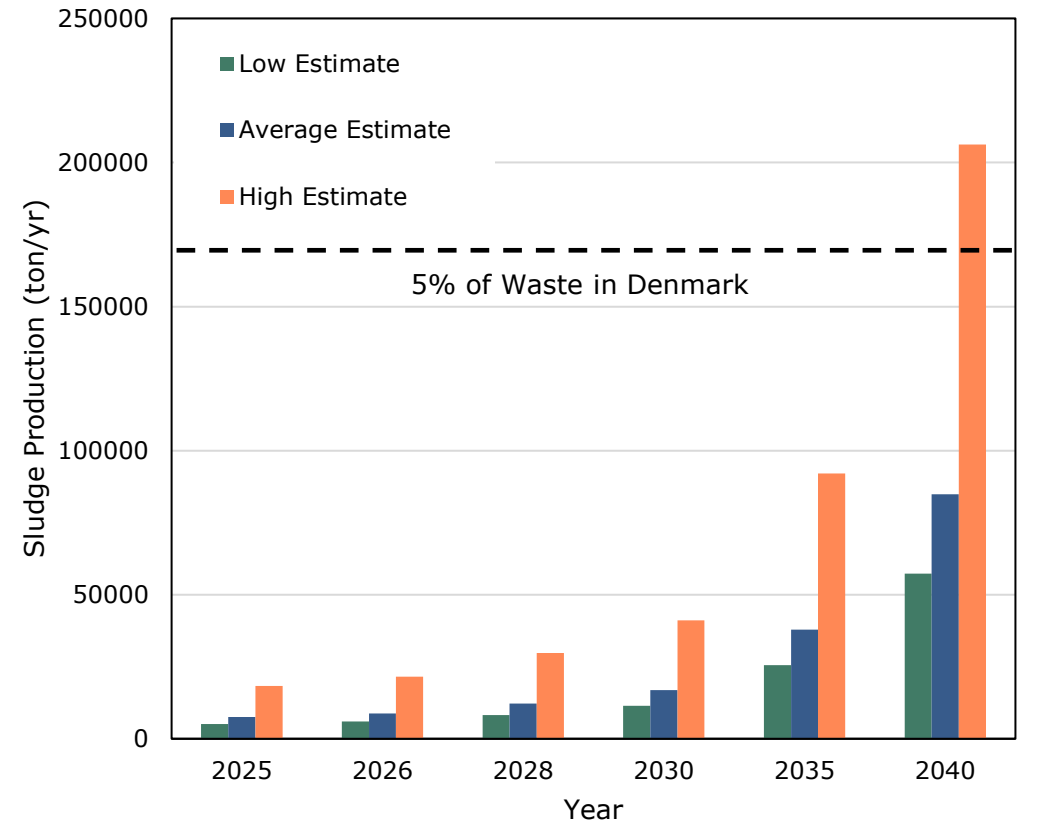
2025

- 24 mil. ton CO₂ yearly emissions in DK
- 5% carbon capture implementation
= 7,500 ton/yr with 30 wt% MEA or
= 2,250 ton/yr with 32 wt% CESAR1

2040

- 15 mil. ton CO₂ yearly emission in DK
- 90% carbon capture implementation
= 85,000 ton/yr with 30 wt% MEA or
= 25,000 ton/yr with 32 wt% CESAR1

WtE treatment capacity could be 5% of thermal treated waste in Denmark: 170,000 ton/yr (2022)



*Estimates based on simulations

Amine Sludge Facts

Two waste streams (Examples)

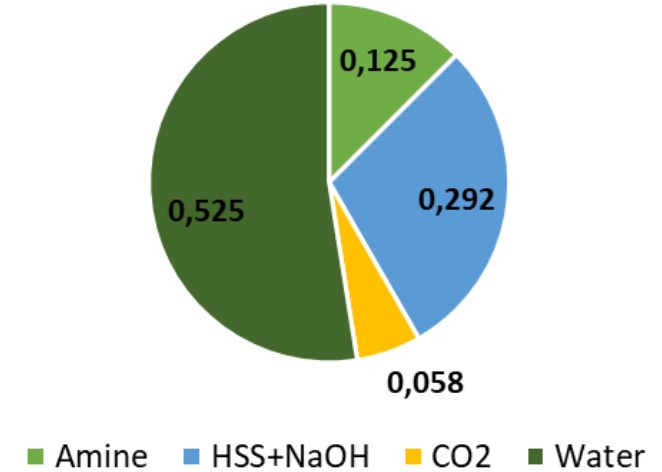
Reclaimer Sludge (CESAR1)

- 13 % amine, 29 % NaOH+HSS, 6 % CO₂, 52 % water
- Lower Heating Value up to 2.4 MJ/kg sludge

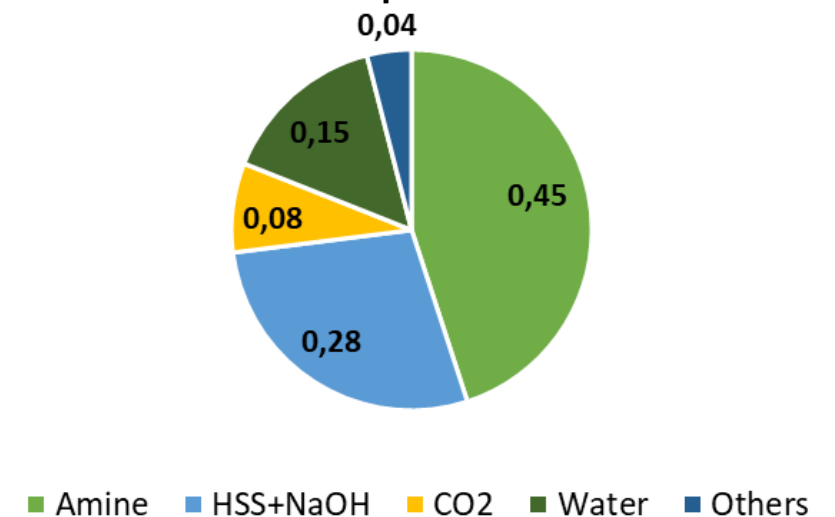
Amine bleed (Spent MEA)

- 31 % amine, 0% NaOH+HSS , 2 % CO₂, 67 % water
 - Lower Heating Value up to 5.2 MJ/kg amine
-
- Composition of reclaimer sludge depends on many parameters

Sludge
Example CESAR1



Sludge
Example MEA



Energy from waste treatment

Handling/Transport

- Personal Safety (Equipment)
- Environmental Spill (Handling)

Combustion emissions

- Complete combustion (Feeding control)
- Normal Combustion Products (CO₂, H₂O)
- No harmful emissions (Heavy metals, Acid products, Organic compounds)
- NO_x suppression (MEA sludge) can result in reduced emissions of NO_x at 850 – 900 °C (proven in lab scale)

Other emissions/Environmental impacts

- CO₂ emissions from sludge storage (can be handled without emissions)

Selected amines and amino alcohols Evaluation of health hazards and proposal of health-based quality criteria and C-values for ambient air

2.1.3 Regulation

An overview on the CLP-classification of all eight amines are shown in Table 2. Danish occupational exposure levels and current C-values are presented if available.

TABLE 2. Regulatory overview, CLP-classification, Danish OEL and Danish C-value

	CLP-classification Annex VI of Regulation (EC) No 1272/2008 (CLP Regulation) + REACH reg. classification	Danish OEL AT (2022)	Danish C-value* 2016
MEA CAS: 141-43-5 (Appendix A)	Acute tox. 4; H302 + H312 + H332 Harmful if swallowed, in contact with skin or if inhaled Skin Corr. 1B; H314 Causes severe skin burns and eye damage + STOT SE 3; H335 May cause respiratory irritation	2.5 mg/m ³ (value from 2022)	0.01 mg/m ³ (value from 1991)
MDEA CAS: 105-59-9 (Appendix B)	Eye Irrit. 2; H319 Causes serious eye irritation	Not listed	Not listed
AMP CAS: 124-68-5 (Appendix C)	Eye Irrit. 2; H319 Causes serious eye irritation Skin Irrit. 2; H315 Causes skin irritation Aquatic Chronic 3; H412 Harmful to aquatic life with long lasting effects	Not listed	Not listed
PZ CAS: 110-85-0 (Appendix D)	Skin Corr. 1B; H314 Causes severe skin burns and eye damage Resp. Sens. 1; H334 May cause allergy or asthma symptoms or breathing difficulties if inhaled Skin Sens. 1; H317 May cause and allergic skin reaction Repr. 2; H361fd Suspected of damaging fertility	0.1 mg/m ³ (value from 2022)	Not listed
MAPA CAS: 6291-84-5 (Appendix E)	No harmonized classification + Skin Corr. 1; H314 Causes severe skin burns and eye damage	Not listed	Not listed
TEA			

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