AASS Pilot Summary

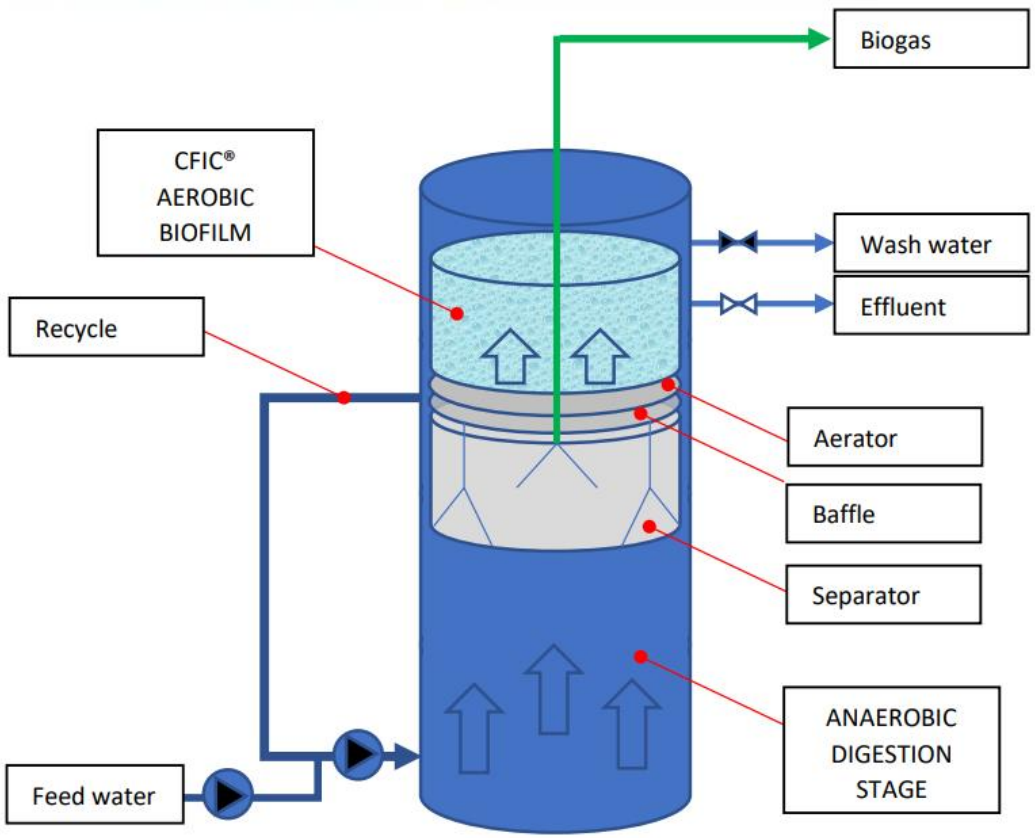
13.10.2021

Agenda

- Introductions
- HyVAB Technology
- Pilots Plant Operations at AASS
- Full Scale Sizing and Solution Options
- Further Steps
- Open to Discussion

Acknowledgement

Thank you to Christian, Rune, Ingun and also the electrical and maintenance department personal for a successful functioning of the pilot operations!



HyVAB

The Hybrid Vertical Anaerobic Bioreactor combines the anaerobic and aerobic wastewater treatment systems one over the other to achieve over 90% waste removal through a single compact reactor while producing energy in the form of Biogas.

Initial Observation

We understood that

- the wastewater is mostly collected in a cascading fashion throughout the plant.
- collecting wastewater from these different locations separately is physically challenging.
- there is quite random flow pattern and concentration variation during a particular day as well as week
- treating the wastewater from pump station would be the most representative of all.

Operational Phases

PARAMETER	RAMP-UP PHASE (MAY – JULY)	HIGH LOAD PHASE (AUG-SEP)
Number of operation days	60	30
Average feed TCOD (mg/L)	5700	10000 (18500)
Average feed SCOD (mg/L)	4850	8000 (14300)
Average COD load (kg/m3-d)	5.3	12 (21)

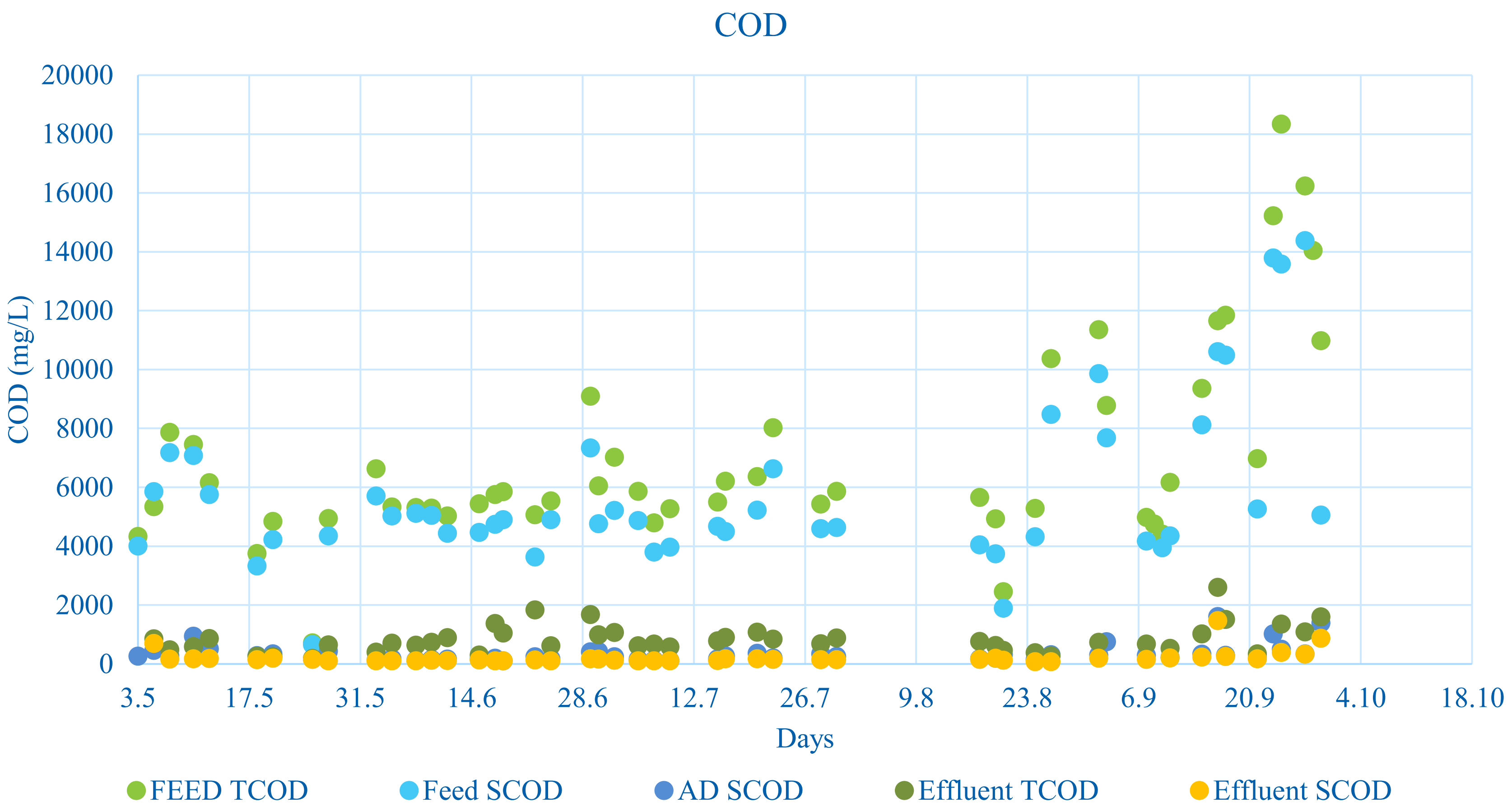
- We collected samples from different locations around the plant and analyzed them.
- We treated the wastewater from pump station where all of them combine.
- There were two phases of operations
- Analysis was carried out throughout the trial.
- Reports were published to understand what was happening the in the reactor

Results

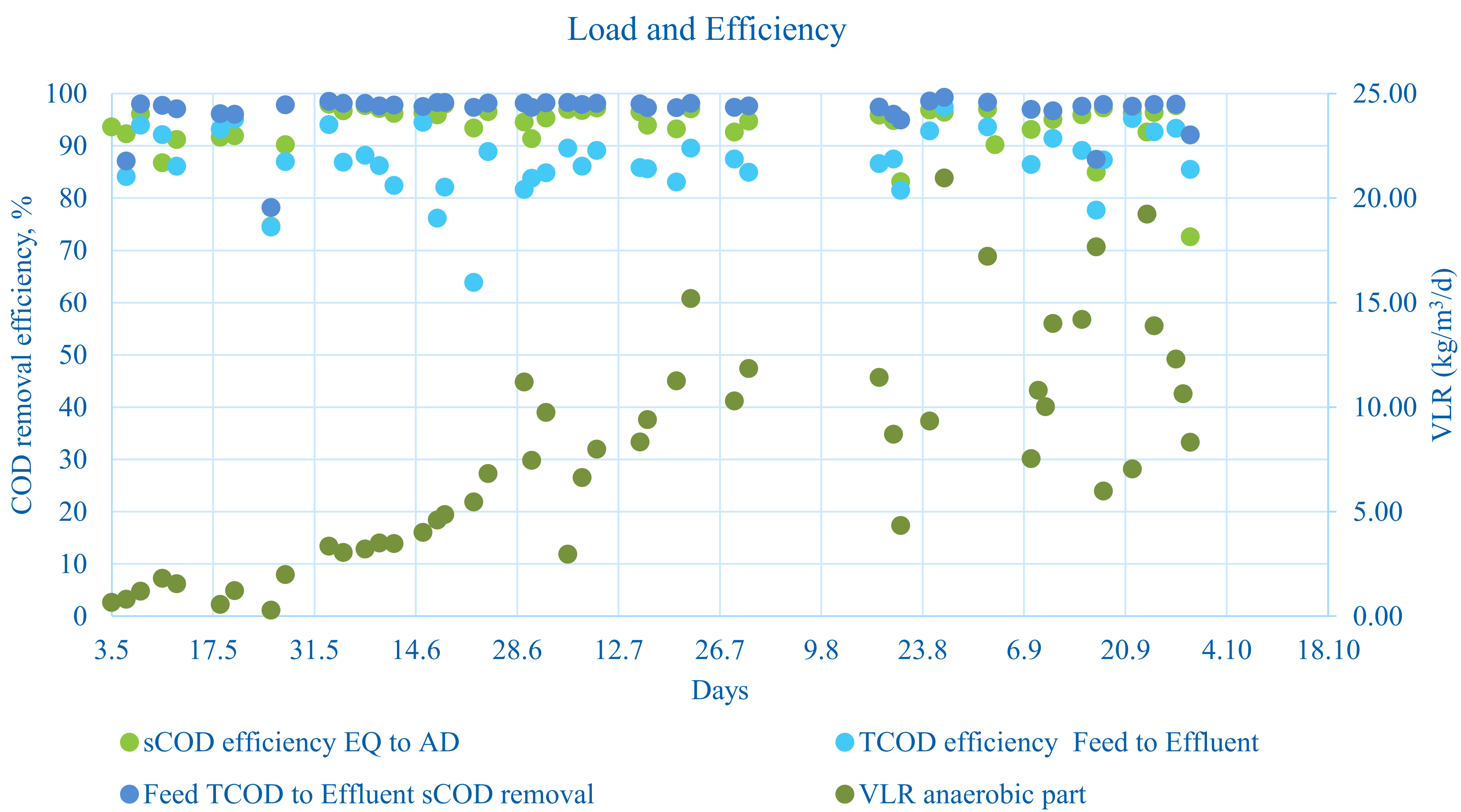
COD out of HyVAB	Ramp-up	High load
Total	776 mg/L (86% removal)	978 mg/L (89% removal)
Soluble	150 mg/L (97% removal)	286 mg/L (97% removal)

- Total COD represents COD including solids, soluble COD is representing COD of the filtrated sample
- The temperatures of operation during September was on average 7 °C less than June to Aug which affected the removal efficiency.
- Very strong biogas production capability.

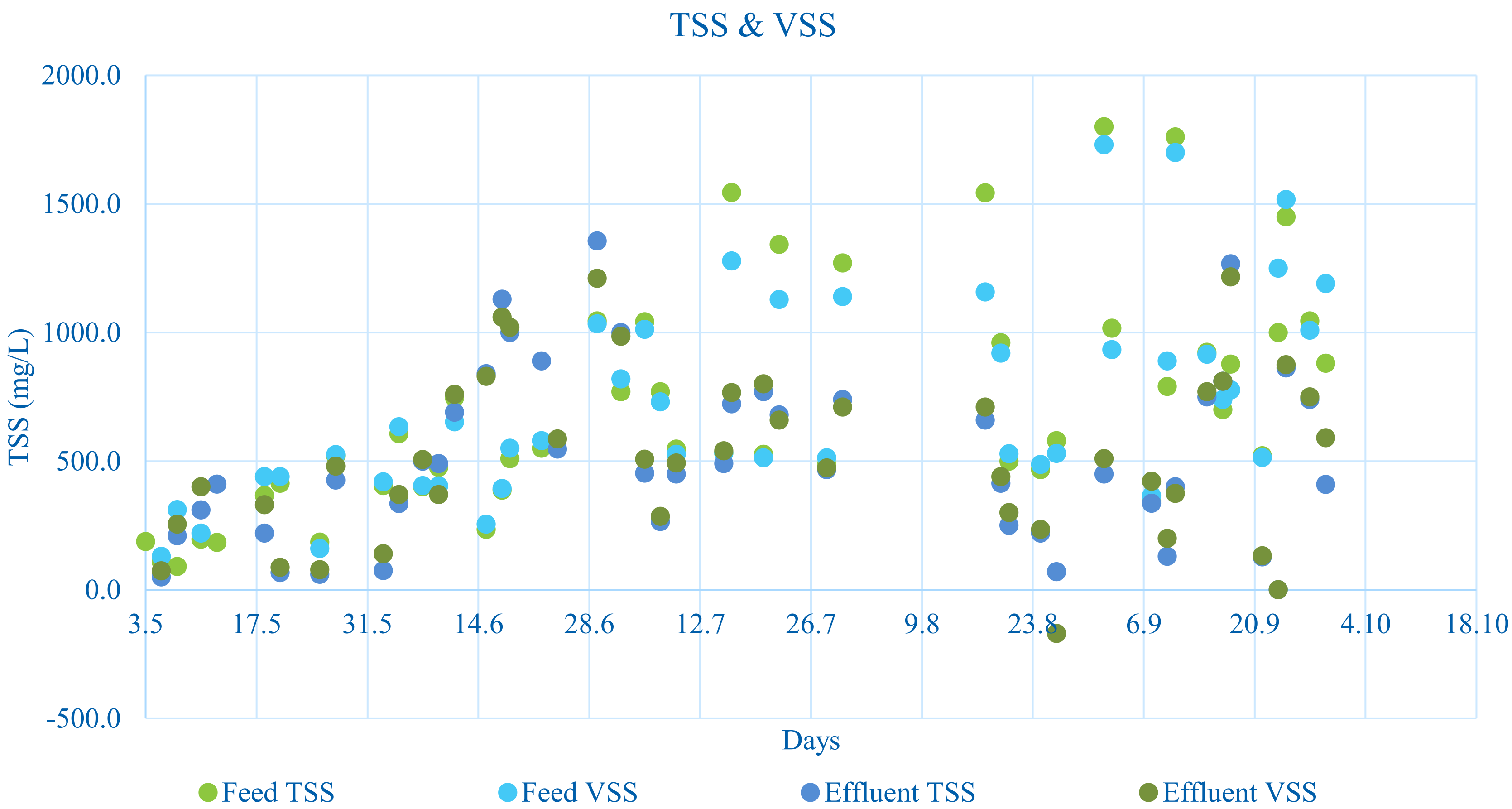
COD


COD
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
COD (mg/L)
3.5
17.5
31.5
14.6
28.6
12.7
26.7
9.8
23.8
6.9
20.9
4.10
18.10
Days
FEED TCOD
Feed SCOD
AD SCOD
Effluent TCOD
Effluent SCOD

Load vs Efficiency

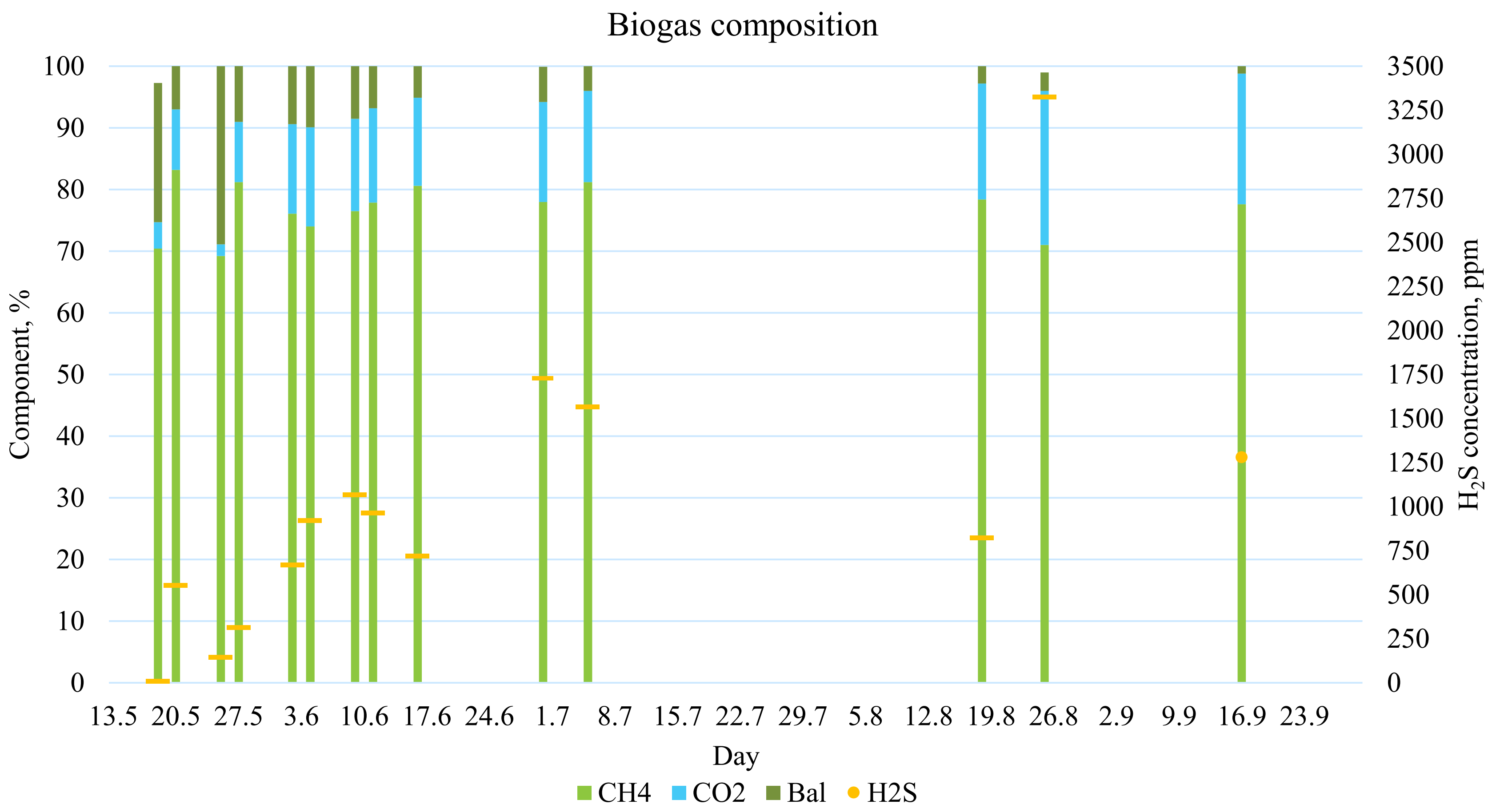


Solids



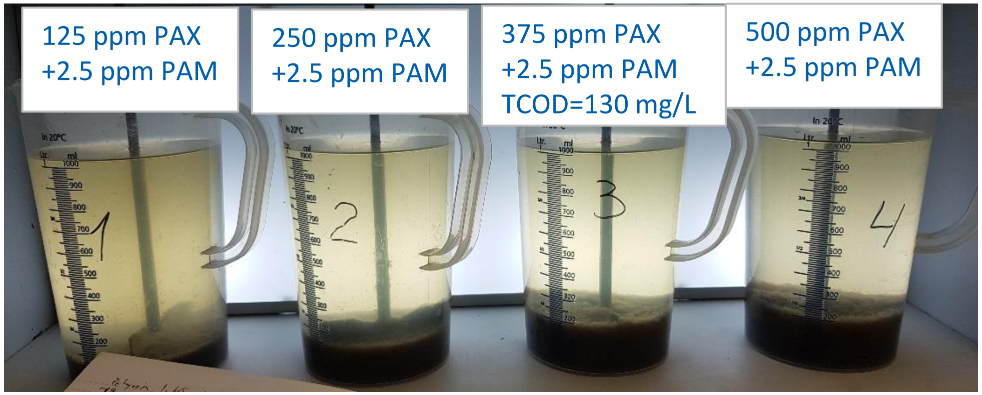
TSS & VSS
2000.0
1500.0
1000.0
500.0
0.0
-500.0
TSS (mg/L)
3.5
17.5
31.5
14.6
28.6
12.7
26.7
9.8
23.8
6.9
20.9
4.10
18.10
Days
Feed TSS
Feed VSS
Effluent TSS
Effluent VSS

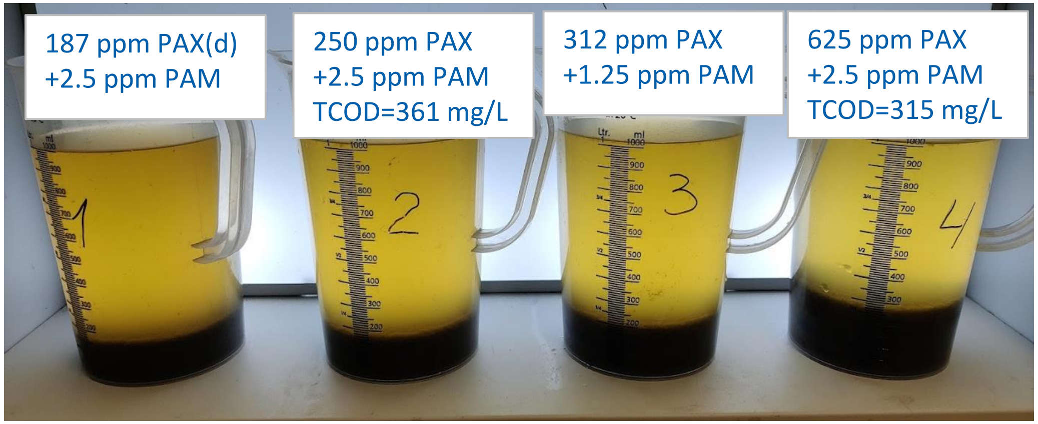
Biogas


Biogas composition
100
90
80
70
60
50
40
30
20
10
0
Component, %
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
H2S concentration, ppm
13.5 20.5 27.5 3.6 10.6 17.6 24.6 1.7 8.7 15.7 22.7 29.7 5.8 12.8 19.8 26.8 2.9 9.9 16.9 23.9
Day
CH4 CO2 Bal H2S

Results of Jar Tests

- The jar tests represent the solid removal steps in full scale
- We conducted 3 jar tests in September with different effluent waters and different chemical dosing.
- Over 90% of solids and around 65% of the TCOD were removed from the effluent .
- We expect to reach our target range of 150-350 mg/L on effluent COD and <50 mg/L on TSS.
- This COD level is equivalent to sewage water coming out of our households.





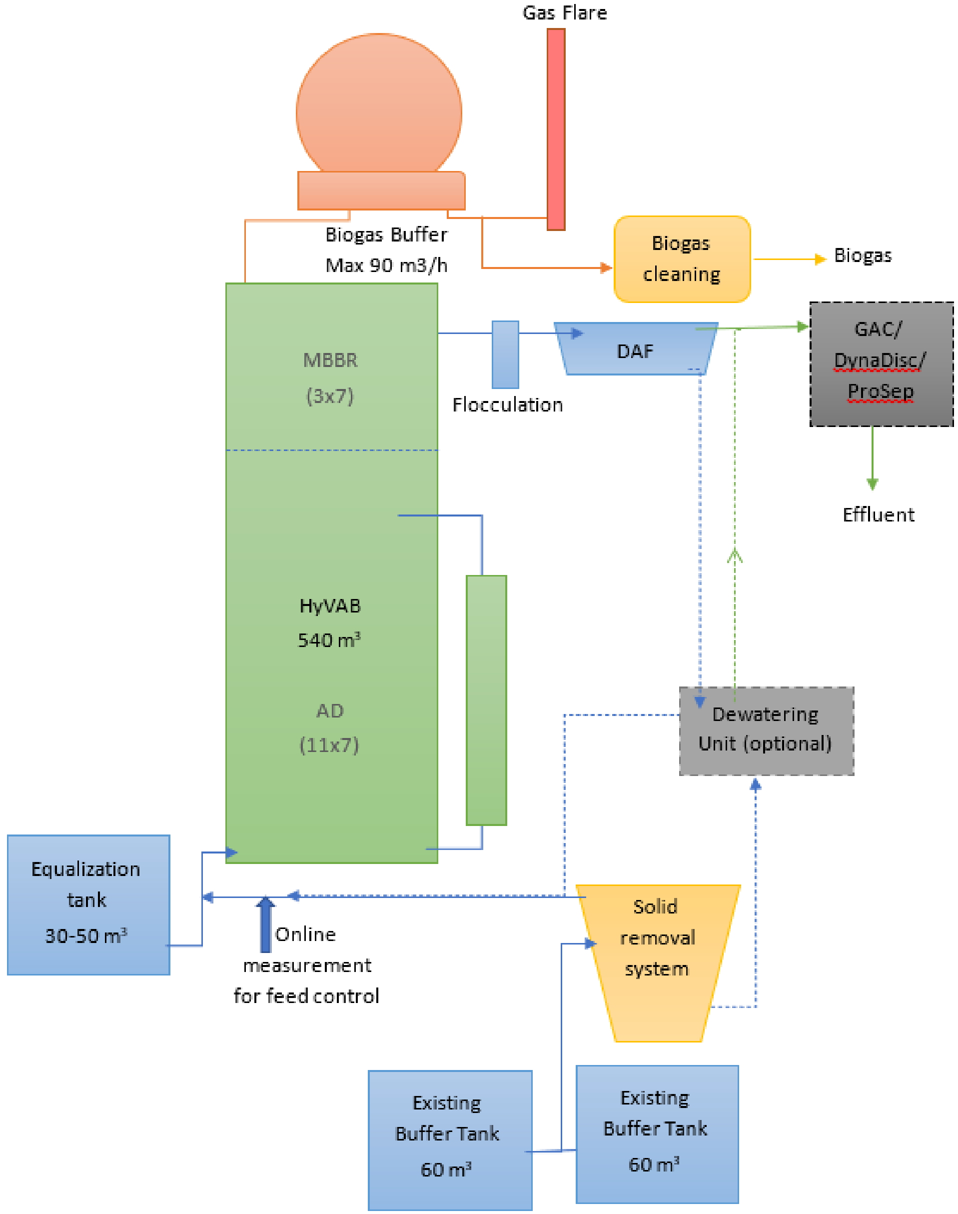
BIOWATER TECHNOLOGY

Observations

- Was not able to find a strong correlation between yeast/beer/diatomaceous earth dumping and COD.
- Only large volumes of about 20-60 m3 beer dumping showed some increase in CODs.
- Effect of yeast dumping could not be seen may be because of sedimentation in the IBCs/buffer tanks/sumps etc.
- CODs were relatively very high during the period the pump in the PST stopped working and the water level was very high.

Full Scale Proposal 1

Parameter	Value	Footprint
EQ tank	30-50 m^3	50
Solid removal	-	25
HyVAB height	15 m	
HyVAB diameter	7 m	100
Design Max Load	5200 kg/d	
Design Max COD Conc.	18000 mg/L @12m3/h 24 h	
Flocculation tank	10 m^3	10
DAF	-	50
Advanced cleaning	-	50
Dewatering unit	Optional	50
Biogas Buffer	45 m^3	50
Emergency Flare	-	50
Biogas Cleaning	-	50
Expected footprint		~ 500 m^2

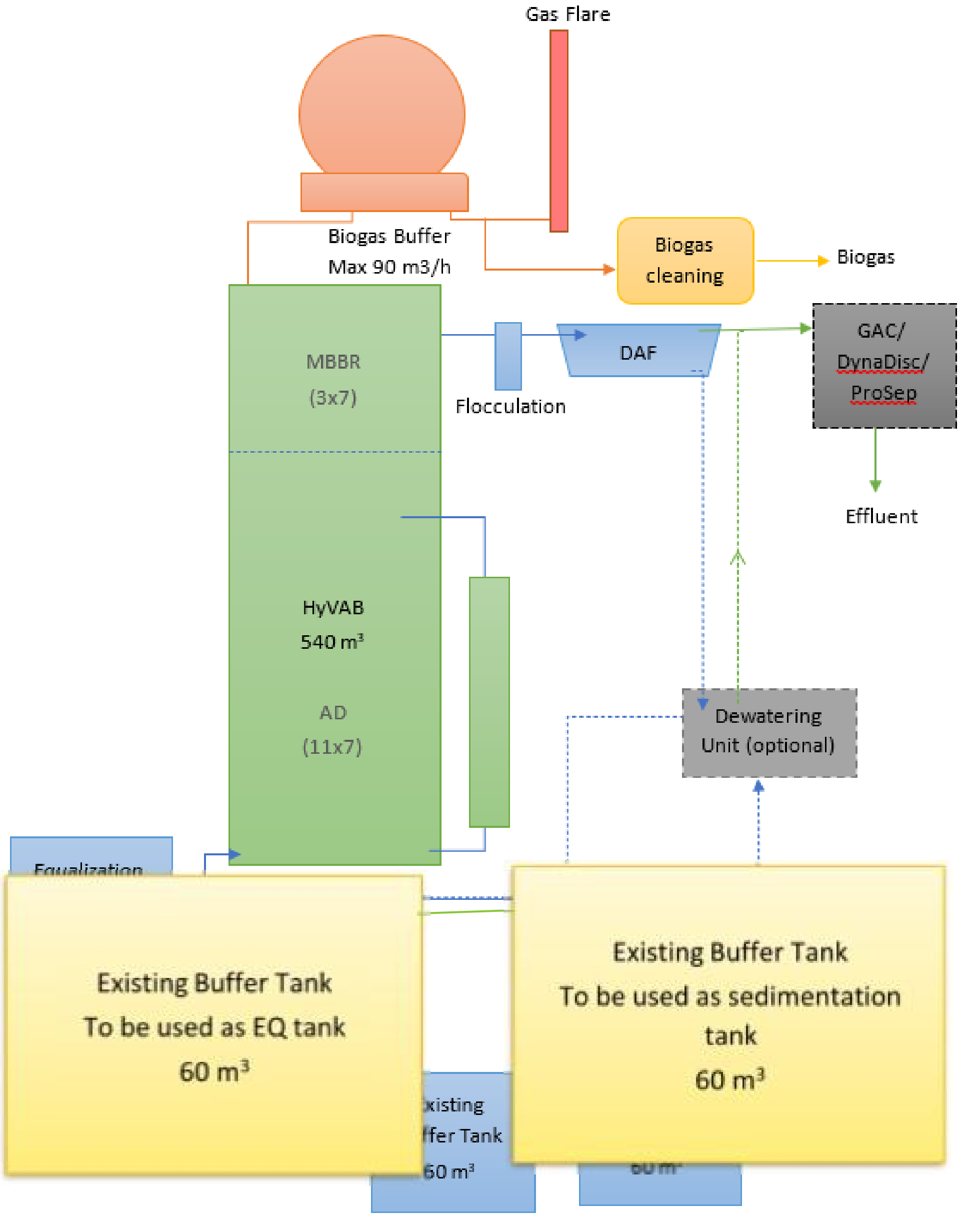


Balance of biogas value to sludge disposal value

Full Scale Proposal 2

Parameter	Value	Footprint
EQ tank	30-50 m^3	
HyVAB height	15 m	
HyVAB diameter	7 m	100
Design Max Load	5200 kg/d	
Design Max COD Conc.	18000 mg/L @12m3/h 24 h	
Flocculation tank	10 m^3	10
DAF	-	50
Advanced cleaning	-	50
Dewatering unit	Optional	50
Biogas Buffer	45 m^3	50
Emergency Flare	-	50
Biogas Cleaning	-	50
Expected footprint		~ 400 m^2

We can reduce the footprint by using one of the existing buffer tanks as a sedimentation tank or as main equalization tank.



Further treatment options

In order to meet the stricter restrictions on COD further down to 25-100 mg/L we will need to install advanced cleaning systems following the DAF that can be:

- DynaDisc + Granulated Activated Carbon
- Sand Filtration + Granulated Activated Carbon
- Sand Filtration + ProSep

Tabel 1: BAT-relaterede emissionsniveauer (BAT-AEL'er) for direkte udledning til en recipient

Parameter	BAT-AEL [1] [2] (døgnmiddelværdi)
Kemisk iltforbrug (COD) [3] [4]	25-100 mg/l [5]
Total suspenderet stof (TSS)	4-50 mg/l [6]
Totalt kvælstof (TN)	2-20 mg/l [7] [8]
Total fosfor (TP)	0,2-2 mg/l [9]

(1) BAT-AEL gælder ikke for emissioner fra kornmøller, fremstilling af grøntfoder og fremstilling af tørfoder, herunder foderblandinger til dyr.

(2) BAT-AEL gælder muligvis ikke ved produktion af citronsyre eller gær.

(3) Der er ikke fastlagt BAT-AEL for biokemisk iltforbrug (BOD). Som indikation vil det årlige gennemsnitlige BOD5-niveau i spildevandet fra et biologisk spildevandsrensningsanlæg normalt være ≤ 20 mg/l.

(4) BAT-AEL for COD kan erstattes af en BAT-AEL for TOC. Korrelationen mellem COD og TOC bestemmes fra gang til gang. BAT- AEL for TOC er den foretrukne løsning, da TOC-monitering ikke kræverpå brug af meget giftige forbindelser.

(5) Den øvre ende af intervallet er:
— 125 mg/l for mejerier
— 120 mg/l for anlæg til forarbejdning af frugt og grøntsager
— 200 mg/l for anlæg til forarbejdning af olieholdige frø og raffinering af vegetabilsk olie
— 185 mg/l for anlæg til fremstilling af stivelse
— 155 mg/l for sukkerfabrikkersom døgnmiddelværdi, hvis reduktionseffektiviteten er ≥ 95 % som årsgennemsnit eller som et gennemsnit for produktionsperioden.

(6) Den nedre ende af intervallet opnås typisk ved filtrering (f.eks. sandfiltrering, mikrofiltrering, membranbioreaktor), mens den øvre ende af intervallet typisk opnås udelukkende ved brug af sedimentering.

(7) Den øvre ende af intervallet er kun 30 mg/l som døgnmiddelværdi, hvis reduktionseffektiviteten er ≥ 80 % som et årsgennemsnit eller som et gennemsnit for produktionsperioden.

(8) BAT-AEL finder muligvis ikke anvendelse, når spildevandets temperatur er lav (f.eks. under 12 °C) i længere perioder.

(9) Den øvre ende af intervallet er:
— 4 mg/l for mejerier og stivelsesfabrikker, der producerer modificeret og/eller hydrolyseret stivelse
— 5 mg/l for anlæg til forarbejdning af frugt og grøntsager
—10 mg/l for anlæg til raffinering af vegetabilsk olie, der foretager sæbespaltning.som døgnmiddelværdi, hvis reduktionseffektiviteten er ≥ 95 % som årsgennemsnit eller som et gennemsnit for produktionsperioden.

Tilbage til BAT-tjeklisten

Limitations

- The HyVAB is designed for a maximum load of about 5200 kgCOD/d
  - If the COD is 6000 mg/L the maximum flow into the HyVAB can be 36 m^3 /h for 24 h
  - If the COD is 12000 mg/L then the maximum flow into the HyVAB can be 18 m^3 /h for 24 h
  - If the COD is 18000 mg/L the maximum flow into the HyVAB can be 12 m^3 /h for 24 h

- If AASS is expanding its production 3 times the expected flow as calculated is appx 30 m3/h. The current HyVAB design can still take those flow rates provided the concentration of wastewater doesn’t exceed 7200 mg/L

- The HyVAB has a limit of SS inlet at a concentration of 250 mg/L
  - This implies we have to remove the solids before entering the Equalization tank.
  - We cannot treat yeast, trub or spent grain with the HyVAB.

- The ideal temperature for HyVAB is in between 30-35 °C, so a temperature adjustment system has to be in place.

CAPEX

HyVAB

Particle Separation	1M NOK
EQ Tank	1.6 M NOK
Reactor	14.9M NOK
Biogas system	3M NOK
Chemical Dosing	1.8M NOK
Plant Rooms	0.7M NOK
Instrumentation	0.8M NOK
Automation	2.8M NOK
Odour Removal	0.5M NOK
DAF and chemical dosing system	2.7MNOK
Installation	1M NOK
Post Treatment (to direct river discharge)	3M NOK
Engineering and Project Management	4.4M NOK

Total HyVAB: 38.2M +/- 20% contingency

Footprint: 500 m2

Excluded: **Civil foundations on site.**
Any requirements for infrastructure for discharge to the Drammensfjord.

MBBR

Particle Separation	1M NOK
EQ Tank	1.6 MNOK
Civils (exc foundation)	2M NOK
Carriers	1M NOK
Blowers	0,3M NOK
Plant rooms	0.7M NOK
Instrumentation	0.5M NOK
Automation	2M NOK
Odour Removal	1M NOK
DAF and chemical dosing system	2.7MNOK
Installation	1M NOK
Post Treatment (to direct river discharge)	3M NOK
Engineering and Project Management	3.4MNok

Total MBBR : 20.2 M NOK +/- 20% contingency

Footprint: 1000 m2

HyVAB OPEX

Costs

2,5% Sludge from Pre-sedimentation tank (24 h operation) – 490 kg/d

2,5% Sludge from DAF – 280 kg/d

Total 2.5% sludge – 770 kg/d

1,4 MNOK per year assuming 24 h operation 5 days a week 45 weeks per year

Caustic (25%) – 400 kg/d

Nutrients **150.000 NOK/year**

PAX and Polymer **60.000 NOK/year**

Electricity usage for HyVAB system would cost appx. 20.000 NOK/year

TOTAL COST = 1,63 MNOK/yr

Savings

Biogas production – 1,6 GWh (assuming 16 hours per day 5 days per week 45 weeks per year)

(Minimum must be 1 GWh for ENOVA)

Biogas Value = **700.000 NOK/year**

(natural gas at 33,2 øre/KWh).

Potential savings from Municipal STP– **4 MNOK/year**

for reducing high concentration wastewater to household wastewater.

In future Drammen kommune might charge the disposal cost on <KOF> which can increase your costs 10 times and that can be saved.

TOTAL SAVING = 4.7MNOK / YEAR

NET OPEX = -3.07MNOK / YEAR (Saving)

MBBR OPEX

Costs

2,5% Sludge from Pre-sedimentation tank (24 h operation) – 490 kg/d

2,5% Sludge from DAF – 1380 kg/d

Total 2.5% sludge – 1870 kg/d

3,4 MNOK per year assuming 24 h operation 5 days a week 45 weeks per year

Caustic (25%) – 0 kg/d

Nutrients **400.000 NOK/year**

PAX and Polymer **40.000 NOK/year**

Electricity usage for MBBR system would cost appx. **80.000 NOK/year**

TOTAL COST = 3.92MNOK/year

Savings

No Biogas – No financing option

Potential savings from Municipal STP – **4M NOK/year**

for reducing high concentration wastewater to household wastewater.

In future Drammen kommune might charge the disposal cost on <KOF> which can increase your costs 10 times and that can be saved.

NET OPEX = -0.08MNOK (saving)

ENOVA

Maximum funding is 50 % of the difference between conventional treatment and the , biogas option

How much you can actually receive depends on the profitability of the project.

Maximum funding will be the amount, based on the models Enova uses, that makes the project profitable.

If it is profitable in itself, you cannot receive funding. It is too unprofitable, you cannot receive funding.

There are also additional requirements:

1. Minimum production: 1 GWh (ca 100 000 Mn3 CH4)
2. Project must be directly linked to the production of the fuel
3. Costs for handling waste is not included
4. Not related to production of food based biogas or biofuel
5. Uses the best commercially available technology
6. Only includes investments in physical installations/measures
7. Expected lifetime of more than 15 years
8. The project must be started within 2 years, and completed within 5 years of contract agreement with Enova.

ENOVA Funding

Enova, Biogass: Enova can support investments in new biogass production facilities. Minimum annual production is 1 GWh. The amount of funding is evaluated individually per project, and may not exceed what's required to make a positive investment decision.

	Year 1 build	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
HYVAB COST	38.2	-3.07	-3.07	-3.07	-3.07	-3.07	-3.07
HYVAB COST CUMULATIVE	38.2	35.13	32.06	28.99	25.92	22.85	19.78
CMFF COST	20.2	-0.08	-0.08	-0.08	-0.08	0.92	1.92
CMFF CUMULATIVE	20.2	20.12	20.04	19.96	19.88	20.8	22.72
	Year 1 build	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
HYVAB COST WITH FUNDING	29.2	-3.07	-3.07	-3.07	-3.07	-3.07	-3.07
HYVAB COST CUMULATIVE	29.2	26.13	23.06	19.99	16.92	13.85	10.78
ENOVA FUNDING POSSIBILITY							
- if the investment is paid back in e.g. three years (depends on type of investment etc) it is profitable in itself, and cannot be funded.							
- If it becomes profitable within the maximum funding available within five years, the project can receive enough funding to make it profitable.							
- If, with the maximum funding amount, it is still unprofitable after five years, it can't be funded.							
CAPEX difference between options		18	MNOK				
Max funding is 50%		9	MNOK				

Further Steps

Biowater propose a Front End Engineering and Design Study to:

- Produce a more detailed design and firm up CapEx and build programme.
- Secure firm quotations.
- Evaluate biogas safety aspects.
- Take a discussion on where to send the effluent water and what kind of discounts we can achieve from the kommune with this level of treatment.
- Evaluate the use of existing buffer tanks for sedimentation or equalization tanks.
- The HyVAB likes a steady load i.e. good balance of flow and concentration of the COD.
  - Real time flow data can help us size the tanks more accurately.
  - Flow vs Conc. data can help regulate the operation better.
- Produce ENOVA with IGAIDI to have confidence in funding.

End results – A fixed price with confirmation of grant funding ready for

Anticipated FEED price budget 700kNok – 1MNok.

End Comments

- Environmental impact
- Biogas quality for usage
- Source separation of solids and their value
- Reduction of acid usage in the plant beneficial
- Evaluate usage of waste caustic in HyVAB
- More details on soft loans