Final report

1. Project details

Project title	**Demonstration of enhanced methane production from ammonia-pretreated biomasses in biogas plants (DEMONIAGAS)**
File no.	**64018-0070**
Name of the funding scheme	Energiteknologisk Udviklings- og Demonstrationsprogram (EUDP), 2018–I, Programområde: Biomasse
Project managing company / institution	**Dansk Gasteknisk Center**
CVR number (central business register)	12105045
Project partners	Lundsby Biogas A/S DTU Madsen Bioenergi I/S EnviDan A/S
Submission date	xx December 2021

2. Summary

- *English version*

The objective was to further optimize the Aqueous Ammonia Soaking (AAS) as a technology for the pretreatment of biomasses used as additional feedstocks (e.g. lignocellulosic biomasses) to manure based biogas plants. The aim of the pretreatment is to improve the methane yield in biogas plants. The idea was to use NH3 for performing AAS pretreatment of biomasses and after the AAS to recover the NH3 for continuous use in the process. Furthermore, and given the fact that manure comes with excess of NH3 the pretreatment process could result to a small net NH3 production.

The effect of AAS on several biomasses' methane potential was defined as a function of their composition. Different innovative laboratory scale configurations for NH3 recovery were also tested and the resulting NH3 recovery efficiencies were high enough. However, after simulations with Aspen HYSYS, it was concluded that these configurations could not result in financial viability when in full scale. In parallel, examining the commercially available equipment, different alternatives for extracting the NH3 from the slurry were suggested: Superheated steam, Gravity filter belt, Extraction tower, Screw compressor, and a Decanter centrifuge. Then, calculations and Aspen HYSYS simulations were done to find the best NH3 extraction method.

Our studies showed that while the AAS pretreatment can be profitable, the calculated profitability does not make this method competitive enough to replace already available alternative approaches for increasing methane yield, mainly because the existing alternatives (e.g. applying longer residence time in the digester) are less complicated for operators. For the time being, AAS treatment could be a well-suited method for biogas plants where available space for expansion is limited or expensive. Further investigations are required to develop simpler and cheaper technical solutions for AAS and thus render it a suitable and competitive addition to manure-based biogas plants in Denmark.

- *Danish version*

Målet var yderligere at optimere Aqueous Ammonia Soaking (AAS) som en teknologi til forbehandling af biomasser, der anvendes som yderligere råmaterialer (f.eks. lignocelluloseholdige biomasser) til gyllebaserede biogasanlæg. Formålet med forbehandlingen er at forbedre metanudbyttet i biogasanlæg. Ideen var at bruge NH3 til at udføre AAS-forbehandling af biomasser og efter AAS at genvinde NH3 til kontinuerlig brug i processen. Ydermere og i betragtning af, at gylle kommer med overskud af NH3, kan forbehandlingsprocessen resultere i en lille netto NH3-produktion.

Effekten af AAS på flere biomassers metanpotentiale blev defineret som en funktion af deres sammensætning. Forskellige innovative laboratorieskalakonfigurationer til NH3-genvinding blev også testet, og den resulterende NH3-genvindingseffektivitet var høj nok. Men efter simuleringer med Aspen HYSYS blev det konkluderet, at disse konfigurationer ikke kunne resultere i økonomisk levedygtighed i fuld skala. Sideløbende, ved at undersøge det kommercielt tilgængelige udstyr, blev forskellige alternativer til at udvinde NH3 fra gyllen foreslået: Overophedet damp, Gravity-filterbælte, Ekstraktionstårn, Skruekompressor og en Dekanter-centrifuge. Derefter blev der foretaget beregninger og Aspen HYSYS-simuleringer for at finde den bedste NH3-ekstraktionsmetode.

Vores undersøgelser viste, at mens AAS-forbehandlingen kan være rentabel, gør den beregnede rentabilitet ikke denne metode konkurrencedygtig nok til at erstatte allerede tilgængelige alternative tilgange til at øge metanudbyttet, primært fordi de eksisterende alternativer (f.eks. anvendelse af længere opholdstider i biogasreaktoren) er mindre komplicerede for operatørerne. Foreløbig kan AAS-behandling være en velegnet metode til biogasanlæg, hvor den tilgængelige plads til udvidelse er begrænset eller dyr. Der er behov for yderligere undersøgelser for at udvikle enklere og billigere tekniske løsninger til AAS og dermed gøre det til et egnet og konkurrencedygtigt supplement til gyllebaserede biogasanlæg i Danmark.

3. Project objectives

The main objective of the project was to pretreat lignocellulosic biomasses, e.g. straw or separated fibers from manure to improve the possible methane yield from biogas plants utilizing these biomasses in the production.

The main idea was to use the ammonia, which is present in the manure from the start and concentrate that to a level ready for the Aqueous Ammonia Soaking (AAS) pretreatment. In an earlier project, AMMONOX, the AAS pretreatment has proven to increase the yield of biogas (methane) considerably in the biogas process.

After the AAS the purpose was to extract the ammonia and recirculate it for continuous use in the process. It would be too expensive to add new ammonia continuously and it would not be sustainable. Furthermore, it is necessary to remove the ammonia and reduce the concentration to an acceptable level before the biogas reactor, as the fermentation process would be inhibited by high concentrations of ammonia.

So, the continuous extraction after the AAS process and recirculation of the ammonia would fulfil these requirements.

There were five main tasks to be done in the project:

1) To test develop and optimize further the AAS-technology at DTU for different kinds of feedstock relevant for biogas plants generally. This was related to WP4 of the project application.
2) To test at laboratory scale different technical solutions to the AAS extraction and continuous recirculation. This was from the start a technical challenge. It was related to WP1 and WP2 of the project application.
3) To model in HYSYS the total biogas plant system including the AAS pretreatment and ammonia recirculation to secure the balances of mass energy in such a system. This was related to WP1, WP2 and WP5 of the project application.
4) To demonstrate the process in reduced scale in a pilot plant erected close to the existing biogas plant of Madsen Bioenergy and in this way to proof the feasibility of the AAS pretreatment process. This was related to WP1, WP2 and WP3 of the project application.
5) To perform a scaling-up engineering and design and describe a full-scale plant utilizing the AAS technology developed in the project. Furthermore, a competition analysis and marketing plan were to be done. This was related to WP5 of the project application.

4. Project implementation

The first three tasks in the “Project Objectives” list above were completed in full. This work will be described in the next section 5.

However, the last two task were not done as the demonstration part of the project was abandoned. The reason will be explained below. As stated in the revised project description of July 2018, a new work package WP2 was added with the STOP/GO condition that the technique of recycling ammonia from the AAS process should be successful. The technical solution to this process has proven to be more difficult than expected in the project application.

A number of different technical solutions have been proposed, analyzed and calculated via the HYSYS program. A number of different solutions for extraction of the ammonia from the pre-treated biomass followed by a distillation for concentrating the ammonia were tested at DTU.

A number of suppliers of various equipment have been contacted, including suppliers of screw presses, decanter centrifuges, distillation units and belt filters - in addition to biogas plants, which may be able to make some equipment available for testing.

This work of finding a technical solution to the ammonia recycling process has taken more time than first assumed, but it was important to be done to be able to determine with certainty whether the process was feasible or not.

Our studies show that a solution with a decanter centrifuge combined with a distillation plant can probably be used for recycling the ammonia from the AAS pre-treatment. Economic calculations based on obtained market prices for the equipment showed that the solution is in general profitable. However, applied at Madsen Bioenergi, which is a partner in the project, the solution will probably generate a profit, but not at a level that is sufficient for making the technology attractive enough under the conditions Madsen Bioenergi perform their business.

At Madsen Bioenergi, the process would have to be used to pre-treat straw, where the process does not have the same high effect as with other biomasses. Therefore, Madsen Bioenergi and Lundsby Biogas withdrew regarding the implementation of the demonstration project. That we omitted the demonstration part of the project is in accordance with the STOP/GO condition in WP2.

However, we wanted to end the project considering all possibilities because our experimental results indicated that for other plants, e.g. biogas plants which use separated manure fibers, the process will be more profitable. This was evident from the results that DTU has obtained with experiments on these biomasses.

Therefore, we performed final calculations including financial estimates, so we could get a complete description of the possibilities of the AAS process with the technical solutions found in the project. In this way, the project and our final project report will have the greatest value.

The conclusion is that while the AAS pretreatment can be profitable, the calculated profitability does not make this method competitive enough to replace already available alternative approaches for increasing methane yield mainly because the existing alternatives (for example applying longer biomass treatment times by increasing the volume of digestion tanks) are less complicated to be applied by the biogas plant operators. For the time being, AAS treatment could be a well-suited method for increasing methane yield in biogas plants with short retention time and where available space for expansion is limited or expensive. Further investigations are required to develop simpler and cheaper technical solutions for AAS pretreatment and thus render this method a suitable and competitive addition to a larger part of the existing manure-based biogas plants in Denmark.

5. Project results

The project results will be presented by including the yearly reports from the three years of the project with reference to the corresponding Appendices.

Results achieved in the year 16/July/2018 until 30/June/2019

WP1:

A number of calculations have been made to support the construction of the unit for ammonia extraction from the liquid ammonia mixture used for the AAS pre-treatment of the biomass.

Originally, it was planned to use superheated steam for supplying heat to the evaporator. As an alternative to this, calculations were made on a plant without steam supply, but with a deeper vacuum for ammonia extraction. After a meeting with the consultant Ammongas, a simpler idea for solving the task has emerged.

The three alternatives will be thoroughly calculated and tested by laboratory experiments before deciding on the choice of method. See

*Appendix 1 to annual report July **2019** - DEMONIAGAS report - work done at DGC*

WP2:

Due to the Anna Lymperatou being on maternity leave only preliminary work has been done at DTU. Anna is coming back at work the 1st of July 2019 and the work will be fully resumed from this point.

The preliminary work was performed by DTU students in the frame of their final projects (Diplom or Master). The work was focused on workpackage 2 “Ammonia stripping and recovery, pilot plant start-up” and concerned the preliminary test of the ammonia stripping and recovery method in a batch reactor system already constructed at DTU. The tests were performed in two steps. During the first step, the ability of the batch unit to efficiently remove ammonia from aqueous ammonia solutions was tested. During the second step, the ability of the batch unit to efficiently remove ammonia from aqueous ammonia solutions mixed with lignocellulosic biomass was also tested. In both steps, the results were very encouraging and demonstrated the ability of the batch system to efficiently remove ammonia (stripping) with negligible ammonia loses and producing a concentrated ammonia solution that was suitable for the pretreatment of fresh biomass as is the plan for DemoniaGas project.

A schematic representation of the batch reactor system with a description of the different parts is presented in the attached Appendix.

*Appendix 2 to annual report July **2019** - DEMONIAGAS report - work done at DTU*

Results achieved in the year 1/July/2019 until 30/June/2020

WP1:

At the start of this period, we were at the stage of planning the technology for taking the slurry into vacuum at about 0.1 bar and boiling the slurry at about 50℃ to extract the ammonia. DTU and DGC had a meeting with Ammongas in June 2019 and a new solution without vacuum was suggested. The suggested solution includes ammonia diffusion through atmospheric air or an inert gas. Different solutions on this idea was brought up and tested by DTU. The tests were rather promising and DTU has made a short status on these tests (see appendix 2 on the work done at DTU). The results achieved at DTU suggest that the “Ammongas”-solution would work for the pilot scale unit. However, for a full-scale plant the “Ammongas”-solution would not work according to estimations made on the results from DTU and from heat transfer assumptions made by DGC. These estimates conclude that the system for this ammonia mass transfer should be about 1-10 km in length and 0.3 m in diameter. This, of course, is not realistic in a real plant and alternative solutions have to be found.

Different alternative solutions for extracting the ammonia from the slurry were suggested, Gravity filtering belt, Extraction towers, Screw compressors, etc. Finally, Anker Jacobsen from Ammongas mentioned a decanter centrifuge as a possible solution. After studying this technology, two experts were contacted who knows everything about decanter centrifuges and about ammonia distillation. They confirmed this solution as a possible way to go. This system with a decanter centrifuge and a distillation tower includes only well-known technologies except for an extra detail in the centrifuge. It is a very elegant solution, which will be tested in full scale to prove the concept. A large number of system calculations and modelling have been done with the Aspen HYSYS code in the resent year to find the best ammonia extraction method. This work will be continued along with the tests of the solids and ammonia separation methods mentioned.

Further details on the work in WP1 can be found in Appendix 1.

*Appendix 1 to annual report July **2020** - DEMONIAGAS report - work done at DGC*

WP2:

Experiments were conducted with two new devices that were designed specifically for removing and recovering NH3 from pretreated biomasses. The first device was used for NH3 diffusion from one warm compartment with

highly concentrated solution (7% w/w NH3) to a cold compartment with low initial concentration through a common headspace by means of heat. The second device was designed so that the NH3 of pretreated biomass could be evaporated from a warm compartment and collected after condensation on a cold surface as a concentrated solution. The results showed that both devices could be used for NH3 removal of AAS-pretreated biomass by reducing the NH3 concentration in less than 24 hours to a level that permits their subsequent anaerobic digestion for biogas production. Optimization of the experimenting conditions are expected to improve further the results.

WP4:

Eight different biomasses were collected and analyzed for their composition in sugars, lignin, extractives and ash. The biomasses were all subjected to AAS under mild conditions and their CH4 production was assessed by batch anaerobic digestion tests. Most biomasses presented an increase of the CH4 yield with some exceptions though. The composition of the biomasses after the AAS pretreatment was also analyzed for giving an insight on the effects of the pretreatment. AAS resulted mainly in the solubilization of the hemicellulose fraction of the biomasses, and in most of them in the solubilization of cellulose as well. Statistical software was used for searching for correlation between the increase of CH4 yield after AAS pretreatment with respect to the CH4 yield of the biomasses and their main compositional groups (cellulose, hemicellulose, lignin, ash, etc.). Based on a preliminary analysis it was found that the biomasses that respond better to AAS (with an increase of the CH4 yield) presented a high structural sugar content (cellulose and hemi-cellulose) and a low content in extractives.

More detail on the results obtained in the frame of WP2 and WP4 can be found in the Appendix 2.

*Appendix 2 to annual report July **2020** - DEMONIAGAS report - work done at DTU*

Results achieved in the year 1/July/2020 until 30/June/2021

WP1:

As stated in the revised project description of July 2018, a new work package WP2 was inserted with the STOP/GO condition that the technique of recycling ammonia from the AAS process should be successful.

The technical solution to this process has proven to be more difficult than expected in the project application.

A number of different technical solutions have been proposed, analyzed and calculated via the HYSYS program. A number of suppliers of various equipment have been contacted, including suppliers of screw presses, decanter centrifuges, distillation units and belt filters - in addition to biogas plants, which may be able to make some equipment available for testing.

This work of finding a technical solution to this process has taken more time than first assumed, but it was important to be done to be able to determine with certainty whether the process is feasible or not.

Our studies show that a solution with a decanter centrifuge combined with a distillation plant can probably be used for recycling the ammonia from the AAS pre-treatment. Economic calculations based on obtained market prices for the equipment showed that the solution is in general profitable. However, applied at Madsen Bioenergi which is a partner in the project, the solution will probably generate a profit, but not at a level that is sufficient for making the technology attractive enough under the conditions Madsen Bioenergi perform their business

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regarding the implementation of the demonstration project. That we omitted the demonstration part of the project is in accordance with the STOP/GO condition in WP2.

However, we wanted to end the project considering all possibilities because our experimental results indicated that for other plants, e.g. biogas plants which use separated manure fibers, the process will be more profitable. This was evident from the results that DTU has obtained with experiments on these biomasses.

Therefore, we performed final calculations including financial estimates, so we could get a complete description of the possibilities of the AAS process with the technical solutions found in the project. In this way, the project and our final project report will have the greatest value.

More detail on the results obtained in the frame of WP1 can be found in the Appendix 1.

*Appendix 1 to annual report July **2021** - DEMONIAGAS report - work done at DGC*

WP4:

In the frame of WP4, three independent research activities took place.

Initially, a study evaluating the performance of a continuous anaerobic digestion process of manure incorporating optimally AAS-treated swine manure fibers (AAS digester) in comparison to co-digestion of manure with raw swine manure fibers (NP digester) was finalized. The processes were compared in regard to their methane yield and digestate quality characteristics. Additionally, a preliminary techno-economic assessment was carried out for evaluating the viability and increase of revenue of a manure-based continuous anaerobic digestion process incorporating AAS coupled to NH3 recovery, based on a HYSYS simulation and by using experimental data. The results showed that the AAS digester resulted to a 38% increase of methane yield compared to the NP digester, and the digestate of the AAS digester presented an increased stability due to the higher conversion of organic matter. Furthermore, it was found that by digesting manure with AAS-treated manure fibers (including NH3 recovery), a 72% and a 135% increase of revenue from the biogas output is possible, as compared to digesting manure with raw manure fibers and manure alone, respectively.

In a second series of experiments, two manure-based digesters were operated; one fed sequentially with raw biomasses (RAW digester) and one fed sequentially with AAS-treated biomasses (AAS digester). Both processes were run smoothly and the biogas productivity was more variable in the AAS digester compared to the RAW digester. The processes will be further assessed for their stability performance by analyzing the microbial community shifts in each digester through a metagenomics analysis of collected samples (ongoing activities).

Finally, beach-cast seaweed was subjected to AAS for evaluating the effect of the pretreatment on the bioconversion to CH4 through anaerobic digestion tests, and furthermore to acids and alcohols through fermentation by mixed microbial cultures. Two additional pretreatments were applied on seaweed (hydrothermal, thermo-acidic) for comparison of the pretreatment efficiency. In the anaerobic digestion tests, the thermo-acidic pretreatment resulted to the highest increase of the CH4 yield (78%) of seaweed, followed by the AAS (36%), while the hydrothermal pretreatment had a negative effect. On the other hand, in the fermentation experiments, the hydrothermal pretreatment resulted to the highest yield of sugars and acids, while the thermo-acidic and AAS pretreatments resulted to a negative effect on the overall fermentation yield. In conclusion, AAS was shown to be very efficient on the anaerobic digestion process but exerted a poor result in improving seaweed fermentation. A preliminary CH4 production cost estimation between the thermo-acidic, the AAS pretreatment and no pretreatment of seaweed, showed that AAS application may be the most economically viable option.

More detail on the results obtained in the frame of WP4 can be found in Appendix 2.

*Appendix 2 to annual report July **2021** - DEMONIAGAS report - work done at DTU_final*

Results achieved in the period July/2021 until 30/November/2021

Results on estimation of different cases of the biogas plant at Madsen Bioenergi.

These are the results from economic calculations of different cases at the biogas plant at Madsen Bioenergi.

The base case is the existing case with 70 days retention time and converting 140,000 tons of manure plus 10,000 tons of straw each year to biogas, which is upgraded to natural gas quality and delivered to the local natural gas grid. This is the actual future case to be established at Madsen Bionergi. Calculations are made with possible added AAS pretreatment.

The second case has the same input, but the retention time is reduced to 20 days. The pretreatment with the AAS-process has a higher efficiency with shorter retention time and to simulate biogas plants with short retention time the example from Madsen Bioenergi has been used with the retention time as the only difference.

The third case is exactly as the second case, only straw with a humidity of 15 % has been exchanged with separated manure fibers with a humidity of 70%. The reason for this case is that the efficiency of the AAS process for manure fibers is even higher than for straw. At 20 days retention time, the yield of AAS pretreated fibers could increase with almost 200 % from 51 to 151 L-CH4/kgTS, while the pretreated straw would have an increased yield of about 38 % from 181 to 250 L-CH4/kgTS.

In the table below the main results have been summarized.

Tabel 1. Economic comparison with different biomasses and different retention time.

Retention time	Biomass	Base income	AAS profit	AAS Investment	ROI
Days		Mill DKK/y	Mill DKK/y	Mill DKK	%/y
70	Straw	33.1	1.85	13.2	14
20	Straw	22.9	2.78	13.2	21
20	Manure fibers	16.0	3.30	13.2	25
			Extra reactors Profit	Extra reactors Investment	
55	Manure fibers	16.0	4.14	15.5	27

The results show that in the base case with 70 days retention time and straw as additional pretreated biomass the profit of the AAS technology would be about 1,85 mill DKK/y with all CAPEX and OPEX subtracted based on an investment of 13.2 mill DKK. This is considered a relatively small profit compared to the risk of the investment, which is based on a 10-year period.

If instead the retention time had been 20 days in the biogas plant and pretreated manure fibers were intended to be added, the return would be about 3,3 mill DKK/y, which is about 25 %/y based on the same investment. This return on the investment would be acceptable. However, the increased yield from the biogas plant in this case could have been achieved also in a different way, i.e. by a longer retention time.

Based on the data from DTU, it could be achieved by increasing the retention time to 55 days. The price of extra biogas reactors, which could bring the yield to the same level as the increase based on the AAS treatment would be about 15.5 mill DKK (according to Lundsby Biogas). Such a solution would only involve the extra

investment (CAPEX) but no extra OPEX of noteworthy size. This would give space for an investment of about 16-17 mill DKK compared to the investment of 13.2 mill DKK in the AAS technology.

So even with the return on investment of 25 % for the AAS in the most beneficial case, other solutions would give an even higher return on the investment for the same case. This of course would not be possible in case of the necessary land to expand the plant would not be available or too expensive.

The conclusion is that while the AAS pretreatment can be profitable, the calculated profitability does not make this method competitive enough to replace already available alternative approaches for increasing methane yield mainly because the existing alternatives (for example applying longer biomass treatment times by increasing the volume of digestion tanks) are less complicated to be applied by the biogas plant operators. For the time being, AAS treatment could be a well-suited method for increasing methane yield in biogas plants with short retention time and where available space for expansion is limited or expensive. Further investigations are required to develop simpler and cheaper technical solutions for AAS pretreatment and thus render this method a suitable and competitive addition to a larger part of the existing manure-based biogas plants in Denmark.

6. Utilisation of project results

The results of this project have shown that the AAS treatment can result in increasing the methane yield of biogas plants and thus their profitability. However, the calculated profitability does not make this method competitive enough to replace already available alternative approaches for increasing methane yield mainly because the existing alternatives (for example applying longer biomass treatment times by increasing the volume of digestion tanks) are less complicated to be applied by the biogas plant operators, For the time being, AAS treatment could be a well suited method for increasing methane yield in biogas plants with short retention time and where available space for expansion is limited or expensive. Further investigations are required to develop simpler and cheaper technical solutions for AAS pretreatment and thus render this method a suitable and competitive addition to a larger part of the existing manure based biogas plants in Denmark.

The results of this project will be used as a background knowledge for establishing project consortia to work on the development of more cost efficient methods for ammonia recovery and recirculation, which is required for a more competitive AAS treatment as an affordable add-on process in existing biogas plants.

7. Project conclusion and perspective

The conclusion is that while the AAS pretreatment can be profitable, the calculated profitability does not make this method competitive enough to replace already available alternative approaches for increasing methane yield mainly because the existing alternatives (for example applying longer biomass treatment times by increasing the volume of digestion tanks) are less complicated to be applied by the biogas plant operators, For the time being, AAS treatment could be a well suited method for increasing methane yield in biogas plants with short retention time and where available space for expansion is limited or expensive. Further investigations are required to develop simpler and cheaper technical solutions for AAS pretreatment and thus render this method suitable and competitive addition to a larger part of the existing manure-based biogas plants in Denmark.

DTU and DGC will keep trying to attract the necessary funding to support the required investigations for optimizing the AAS treatment as a method for increasing the methane yield in biogas plants. So far, it has been clearly documented that AAS treatment can result in impressive increase of methane yield. However, this must be accompanied by more practical, easier to operate and cheaper methods for ammonia recovery than those tested and analyzed in this project, and this is where emphasis will be given in our future research and development efforts.

8. Appendices

- Add link to relevant documents, publications, home pages etc.

Three articles have been published in popular magazines or webpages on the DemoniaGas project:

GAS energi • Nr. 4 • 2018, s. 30-31. Link: https://www.danskgasforening.dk/sites/default/files/inline-files/Metanpotentiale%20unders%C3%B8ges%20i%20nyt%20projekt.pdf

Nyhedsbrev FiB nr. 78 • januar 2019, s. 5 - Ammoniak skal booste produktionen af biogas, Link: not available

DTU Chemical Engineering News: Boosting the efficiency of biogas plants

https://www.kt.dtu.dk/english/about-us/news/nyhed?id=84806B26-A347-4324-AE46-ECAE1540DA03

Manuscripts published, submitted or in preparation:

Lymperatou A, Rasmussen NB, Gavala HN and Skiadas IV (2021) Improving the anaerobic digestion of swine manure through optimized ammonia treatment: process performance, digestate and techno-economic aspects, Energies, 14, 787. https://doi.org/10.3390/en14030787 .

Manuscript submitted for publication: “Different pretreatments of seaweed for biogas production”. A. Lymperatou, T.K. Engelsen, I.V. Skiadas, H.N. Gavala. (submitted to Journal of Cleaner Production).

Manuscript in preparation: A. Lymperatou, T.K. Engelsen, I.V. Skiadas, H.N. Gavala. “Prediction of methane yield and pretreatment efficiency based on the main composition of lignocellulosic biomasses”

Manuscript in preparation: A. Lymperatou, M. Lezyk, I.V. Skiadas, H.N. Gavala. “Microbial population shift of anaerobic co-digestion during sequential feeding changes”

Manuscript in preparation: A. Lymperatou, M. Lezyk, I.V. Skiadas, H.N. Gavala. “Microbial community shifts in anaerobic co-digestion receiving different biomasses after a common pretreatment”

Conference presentations:

Oral Presentation: “Correlating methane yield increase after ammonia pretreatment to biomass compositional characteristics”. A. Lymperatou, T.K. Engelsen, I.V. Skiadas, H.N. Gavala. 29th European Biomass Conference and Exhibition, EUBCE21, (26-29 April 2021, online).

Abstract submitted for presentation in WASTEENG2022 conference: Predicting the efficiency of pretreatment of lignocellulosic biomasses based on their composition - A. Lymperatou, T.K. Engelsen, I.V. Skiadas, H.N. Gavala

Abstract submitted for presentation in WASTEENG2022 conference: Population dynamics in anaerobic digesters upon sequential changes of feedstock with and without pretreatment. A. Lymperatou, M. Kężyk, I.V. Skiadas, H.N. Gavala

Master and Bachelor Thesis:

Master Thesis: Recovery of ammonia from aqueous ammonia soaked biomass (2020) Mohammad Balkiss, DTU

Master Thesis: Processing of seaweed for biological production of bulk chemicals (2020) Carlos Alfonso Gonz´alez L´opez de Lerma, DTU

Master Thesis: Continuous anaerobic co-digestion of swine manure with pre-treated and raw carbon-rich biomasses (2020) Sotirios Efstathios Antonoudis, DTU

Master Thesis: Biomass composition effects on the efficiency of Aqueous Ammonia Soaking as a method to enhancing the methane potential (2019) Thor Kell Engelsen, DTU

Master Thesis: Aqueous Ammonia Soaking, AAS for pre-treatment of lignocellulosic biomasses: potential for methane enhancement and ammonia recovery (2019) Karen Saavedra Rubio, DTU

Bachelor in Engineering Thesis: Optimising the recovery of ammonia from aqueous ammonia soaked biomass in a pilot scale test unit (2018) Mariam Nickseresht Funder, DTU

Bachelor in Engineering Thesis: Recovery of ammonia from aqueous ammonia soaked biomass as a method to increase the methane productivity in biogas plants (2018) Thomas Nexø Holm, DTU