Optimization of algae cultivation using AI to significantly reduce methane emission from cattle

Public Report

20 January 2024

Introduction

Methane is a powerful greenhouse gas with 28 times higher climate impact compared to carbon dioxide, per kilogram of emitted gas. According to the UN environmental program, UNEP, methane accounts for approximately one-third of the average global warming that has occurred since pre-industrial times.

Due to its strength and impact, support to reduce greenhouse emissions from methane are growing in the EU. In 2021, the UN climate summit in Glasgow (COP26) resulted in the Global Methane Pledge, with a common goal of reducing methane emissions by 30 percent by 2030 compared to 2020 levels.[1]

One sector that contributes more than any other is agriculture.[2] In Sweden greenhouse gas emissions from the agricultural sector were 6.7 million tons carbon dioxide equivalents in 2021. Of which just over half consisted of methane (3.6 million tons), corresponding to 72 percent of the total methane emissions in Sweden.

With the agricultural sector contributing nearly three-quarters of methane emissions in Sweden it is not surprising, but imperative, that there is a focus on reducing these emissions. This in combination with the focus to increase productivity and self-resilience in the food sector, demands increased innovation and development of new technologies with methane reduction potential.

One such technology, that has been shown to reduce methane emissions from cows by between 80-90 percent, is a red macroalgae (seaweed: *Asparagopsis*) feed additive that reduces the formation of methane in cows' stomachs. The Swedish company Volta Greentech has a pilot production facility in Lysekil and have tested their product in the field with results suggesting upwards of 80 percent methane reductions. Although not the only company of its kind, they are the first to take their product to market, with Lome™ beef being sold in Sweden.

However, to scale up the production and adoption of their product, much work must be done to inform and incentivize producers, customers and policy makers. In addition, research and development is needed to optimize this macroalgae production, making it economically feasible to produce at scale.

Project

This Vinnova funded project brought together Volta Greentech, Chalmers Industriteknik (Chalmers Industrial Technology, CIT), IVL Svenska Miljöinstitutet (Swedish Environmental Research Institute), SLU (Swedish University of Agricultural Sciences) and Tre Bönder (Three Farmers) to explore how applied AI-based optimization methods can increase the yield and quality of macroalgae (seaweed: *Asparagopsis)* in large-scale cultivation systems with the mission to combat climate change. A biomass sensor was also developed to increase harvest efficiency and in-vitro and in-vivo studies were conducted to understand the impact growing conditions of algae have on their methane reduction potential.

1 Methane has contributed around 30% of all global warming to date.
2 The energy sector is second and contributes 40% of all methane emissions attributable to human activity.

Algae

Volta Greentech

Approximately **1 billion cows** on planet earth.

They produce over **4% of the world's greenhouse gas** emissions.

That's **two times more** emissions than the world's fleet of airplanes.

Volta Greentech (VGT) is on a mission to eliminate methane emissions from the world's cows and sheep by 2050. This includes ensuring that their production and operation facilities have as small an environmental footprint as possible. Thus, by providing farmers with a natural seaweed-based feed supplement (responsibly produced) that drastically reduces the methane emissions produced by bovines, the agriculture sector can take a massive leap in reducing its emissions.

For this project, VGT gathered data from its production facility for training AI models developed and assessed by the AI team at CIT; tested a biomass sensor developed by IVL to retrieve valuable input and data; and oversaw the in-vitro testing conducted at SLU and in-vivo studies at Tre Bönder farm.

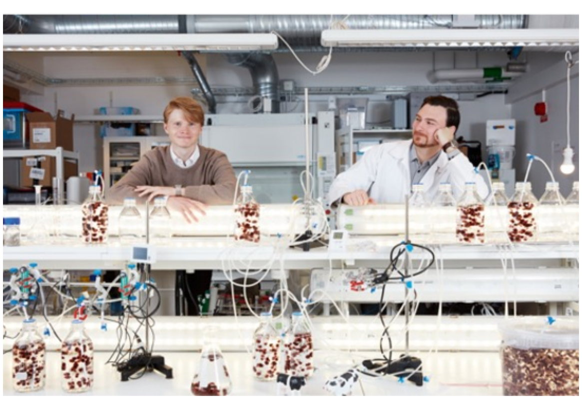


Image 1. Fredrik Åkerman (left) and Angelo Demeter (right) at VGT labs, Stockholm.

VGT is different from other companies that grow algae for cow feed additives because their production is land-based, which allows for quality control and potentially increased productivity due to monitoring.

Image 2. Red algae pom-poms at VGT labs (left) and freeze-dried Lome product (right).

Although they use seawater, the capacity to use recirculation and filters to partially disinfect the water, leads to a safer, cleaner product. This allows concerns of iodine or heavy metal accumulation to be put to rest, as can occur in open water production. They are also able to change parameters and use applied AI and sensors to optimize cultivation.

Algae

Volta Greentech

The algae that has been produced has been tested on small farms, supplementing the cows' diet with approximately 50 to 60g of algae additive. According to Fredrik Åkerman, CEO, the results exceeded expectations, with reductions of between 80 to 90 percent. With current production capacity, everything has been sold several years into the future, which highlights the need for a bigger facility and better understanding of cultivation parameters and optimization.

"Sweden is a good place to explore these technologies because there is an environmental awareness and support and educated consumers. However, there is also an urgent need to jump start projects like this through incentives that support farmers and producers before production is scaled up and the product widely recognized."

Ioannis Dogaris, VGT labs

"We don't want to convert those that are plant-based to go back, but instead want those that eat meat and dairy to have a better alternative."

Fredrik Åkerman, CEO Volta Greentech

Promising Results

A real-time online method was developed for quantifying biomass. Previously there was a time-consuming process that required first harvesting and then weighing the algae.

In addition, an analytical method was developed to rapidly estimate bromoform content, which indicates the quality of the algae and thus another parameter by which to judge the optimal time for harvest.

Also developed a list of the most important parameters to measure and use in the AI models for the prediction of algae optimization.

Image 3. Matt Hargrave at VGT production facility in Lysekil.

Biomass Sensor

IVL Svenska Miljöinstitutet

The Swedish Environmental Research Institute's (IVL) role in the project was to develop a biomass sensor to accurately measures algal biomass in VGT's tanks.

This research drew on previous experiments with using underwater acoustics to measure the biomass of fish in tanks as well as developing sensors for estimating turbidity in water. However, after testing three different techniques, IVL found a new combination of variables that were able to track the growth of algae and thus provide important information to the VGT production facility.

The sensor uses light to measure biomass and has been used by VGT in their outdoor raceways to detect algal biomass with promising results.

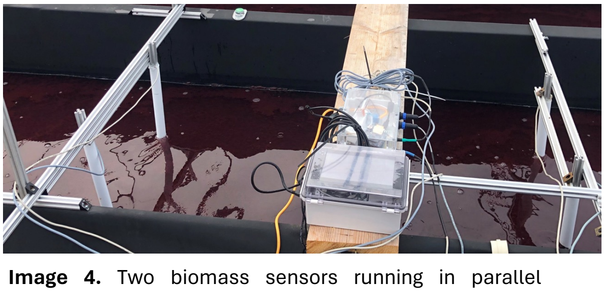


Image 4. Two biomass sensors running in parallel at VGT's production facility in Lysekil.

"We like to work with smaller companies that work with important issues and have the potential to make a big difference – for the climate – for example. They often do not have a technical unit themselves, so we can offer our services to help them have a greater impact."

Jacob Andrén , IVL

Figure 1 (below) maps one week of cultivation tests performed during the project and shows continuous biomass readings, in blue; the red dots show the daily average. This graph clearly depicts algal growth and can help VGT with harvesting schedules.

Figure 1. Continuous biomass readings (in blue) for one week of testing performed with the biomass sensor. Daily average shown in red.

This project awakened many questions and much curiosity in the IVL team, as they worked with VGT to develop the biomass sensor. Although much of the findings are confidential some of the areas for further research and development will be discussed in the 'What Comes Next' section of the report.

Promising Results

A biomass sensor was developed that can read and track the growth of algae in the tanks, providing valuable information about when to harvest. Indications are that you can measure biomass with very high accuracy, 3 percent error, in a cheap and simple way.

See Image 4 for an idea of how the installation of the biomass sensor may look in an outdoor raceway.

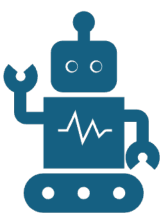
Applied AI

Chalmers Industriteknik

AI is increasingly a part of daily life, whether we are aware of it or not, and can be used in any number of contexts. In this project, AI modeling is applied with the goal of optimizing the production and quality of algae grown with the purpose of reducing methane emissions from the agricultural sector, cows specifically.

The target is to reach recipe production efficiency of 1:150 (meaning that for each kg of algae used, 150 kg CO_2 is reduced from cows). This can be reached through improvements to the recipe, with further AI development and modelling.

This application of AI relies on data points which train the various machine learning (ML) models, in search of a model that demonstrates the highest reliability.



Machine Learning is a branch of AI where the computer 'learns' something from past data to make predictions about the future.

VGT performed several cultivation tests where different cultivation parameters were considered (i.e., temperature, pH, light intensity, and start density), the data generated from these experiments were then used by the AI team in the ML models.

The AI team looked at five areas for model development:

1. Optimization for seaweed cultivation parameters
2. Nutrient consumption analysis
3. Culture depth optimization (tank depth)
4. Relationship of dissolved oxygen and biomass
5. Biomass forecasting

Findings: 1) Tested 4 models: best model was Artificial Neural Network; 2) Trained 3 models: Random Forest performed best, although it was not as good at predicting nitrogen as phosphorous; 3) Trained 3 models, Quadratic model best performing; 4) Found that dissolved oxygen and biomass are correlated; and 5) Found that biomass growth can be predicted well with a Ridge model.

Promising Results

An important AI observation, that helped move the project forward, was that the original tanks used at VGT production facility were too tall and did not let enough light through to the bottom. Therefore, new shallower raceway tanks were developed which are now in use in combination with the biomass sensor developed by IVL.

Although the findings pointed to models better suited to predicting the various areas of interest, the data sets were too small to have high confidence, which means further data and tests should be gathered and run.

"It is important to remember that the models and analysis are a 'proof of concept' – more tests must be done with larger data sets and broader cultivation parameters, to use the models confidently."

Berenice Gudino, CIT

Interesting Fact: *the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Germany is also exploring ML for the cultivation of algae and found two models for further validation: Support Vector Machines (SVM)-based model and a model with Monod kinetics.*

In Vitro & In Vivo

SLU and Tre Bönder

Researchers at SLU conducted in-vitro analysis of five different algae samples from VGT; simulating ruminant digestion. This was done in test tubes, combining buffered ruminant fluid, feed and algae (0.5% on organic matter basis) then measuring the total gas production and methane concentration for 48 hours (see Image 5, p.8). Each treatment was tested in triplicates within two runs, in total six replicates per treatment. The algae samples were grown in varying conditions and then compared to determine which conditions optimize the bromoform content, a bioactive compound that inhibits methane production during ruminant digestion. A control treatment (without inclusion of algae) was also used in addition to a wild harvested *Asparagopsis taxiformis*.

Promising Results

In-vitro testing demonstrated methane emission reductions of up to 83 percent, but this varied significantly between the different algae samples (Fig 2). For total gas production from the in-vitro system, no significant differences were observed between treatments, which indicates that there was no inhibition on feed fermentation, which is positive.

Although potential reductions are significant, SLU researcher Rebecca Danielsson, points out limitations and areas that need further research and longer-term studies. For example, how algae affects the feed intake over time, their meat and dairy quality and taste, and potential side-effects in humans. *(Continues on next page)*.

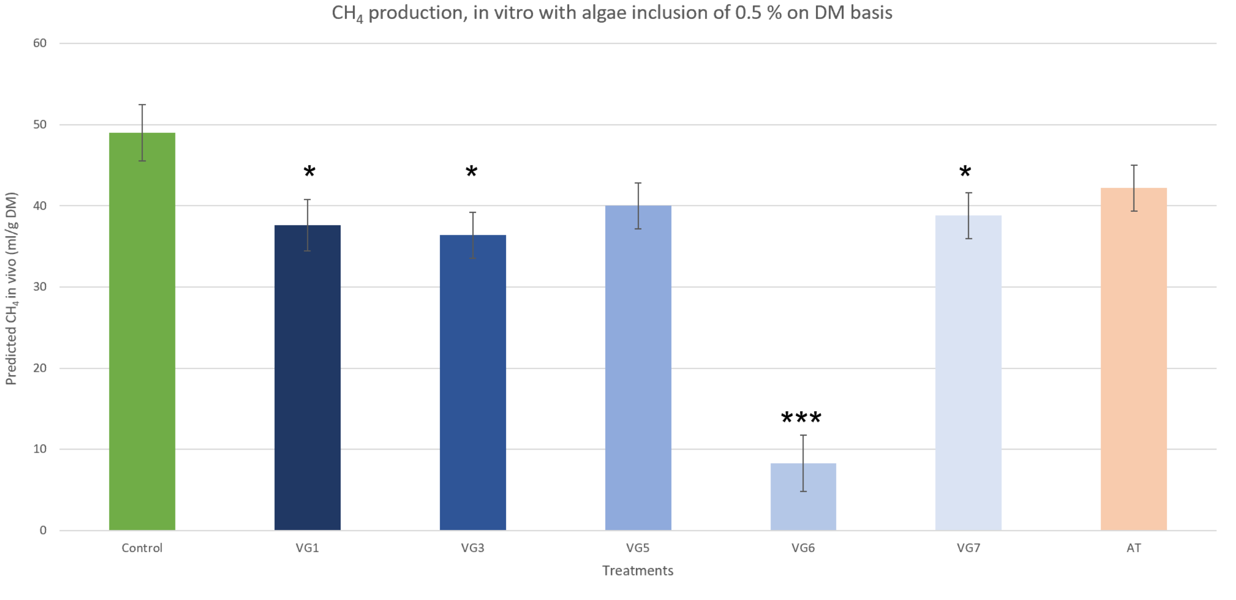


Figure 2. Figure 2. Effect of added algae at 0.5 % on organic matter basis on CH_4 production and total gas (mL/g of incubated DM)[1]. [2]Treatment: Control = no feed additive supplemented; VG1-VG6=inclusion of *Asparogopsis spp.* cultured during different conditions. AT= inclusion of wild harvested *Asparogopisis taxiforms*. Least squared means and statistical significance (*<0.05 and ***<0.001).

In Vitro & In Vivo

SLU and Tre Bönder

(Continued) In addition, there is a need to address the fact that many cows spend a large-portion of the year outside grazing in fields. However, she also sees the need for solutions now, and thinks there should be further in- vivo studies over longer periods.

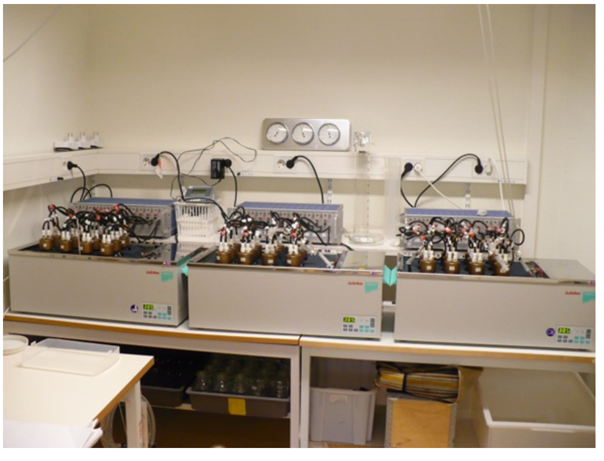


Image 5. Test tubes combining buffered ruminant fluid, feed and algae (0.5% on organic matter basis) at SLU labs.

Tre Bönder

VGT ran in-vivo trails at two farms, one of which was Tre Bönder (Three Farmers). The algae feed additive (Lome™) was dosed as 0.4-0.6 percent of the cows' diet over the course of three to four months.

Image 6. Feeding cows at Tre Bönder farm, Sweden.

Promising Results

These pilots resulted in an average methane reduction of around 80 percent. During the feeding period. Methane emissions were measured using a GreenFeed sensor system (shown below), which is considered the industry standard for methane measurements on the farm level.

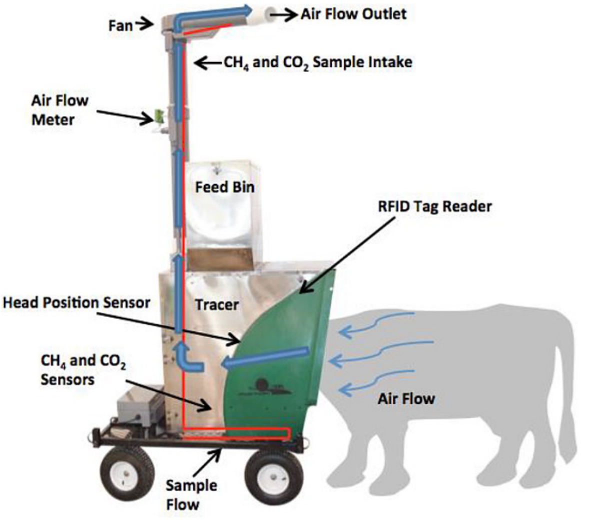


Image 7. GreenFeed sensor system, property of C-Loc Inc.

VGT has compiled the data in climate reports and got the reports verified by RISE as a 3rd party to build-up trust and transparency in the reporting. All climate reports are public and can be found at www.voltagreentech.com/lome.

Interesting Fact: *The unit used to measure reductions is kg CO2 per kg algae used. The pilot data estimates efficiency of 1:110, which means that for each kg of algae used (dry matter), 110 kg CO2 is reduced from cows.*

What Comes Next?

As with most exploratory research projects, this project has scratched the surface of what it means to use AI for the optimization of algae production when it comes to the reduction of methane emissions from cows; leading to many potential opportunities for further research and development.

When it comes to the biomass sensor, IVL has many areas they would like to continue to explore and develop, including more knowledge about algae pom-pom formations and growth variation, in addition to further development of the sensor to be able to take readings during the day (without daylight disruptions), sensor placement in the raceways and a business markets analysis.

CIT would like to see more data to train their AI models and thus achieve more confident predictions when it comes to optimal growth parameters.

In addition, longer term studies (as mentioned by SLU researcher) into how a diet supplement ed with algae affects bovine growth, meat and dairy quality and taste; and, importantly, if there are any side-effects in humans.

When it comes to the climate reduction potential, this project did explore co-location potential through an industrial symbiosis lens, in addition to a life cycle assessment (LCA) to understand the various environmental impacts of VGT's new production facility.

Next Steps: Co-location, industrial symbiosis and climate reduction potential

VGT plans to build a commercial-scale production facility, but the choice of site location is highly dependent on what impact this decision has on their overall climate emissions. As a purpose driven company with the goal to reduce methane emission from cows, all business decisions are made with impacts in mind; and the goal of climate neutral production.

This business model can lead to partnerships of industrial symbiosis, where one industry's by product (waste) becomes another industry's resource. VGT plans to build on site where waste heat or carbon dioxide are available. This will help minimize their impact through symbiotic relationships with other industries.

Optimization of algae growth in this new facility will be achieved through measures including applied AI and sensors.

Although there is further research to be done, Fredrik Åkerman is not dissuaded and believes the time is now to implement at scale. However, it is important to continue studies, both when it comes to how applied AI can contribute to the understanding of production parameters and optimization and how biomass sensors can improve harvest efficiency, but also into the long-term effect of algae supplements along with producer and consumer uptake.

Future work will also include conducting a LCA on VGT's production in Volta Factory 02 as well as continuously measuring, reporting and verifying the emission reduction levels of its products.

Challenges Ahead

Widespread adoption of methane-reducing products is the major challenge.

The Swedish Environmental Protection Agency (Naturvårdsverket) recognize the severity of the enteric methane problem and recommend that the government prioritize support for the development of methane reducing supplements. They specifically mention VGT's algae product as one of the most relevant technologies available. Promisingly, their report also suggests incentives could be made available to support scale up of these methane-reducing products.

In order to make rapid progress we need to cut enteric methane emissions, financial support for both R&D and early-stage deployment is essential. With methane reduction results as promising as these, it is hard to look in another direction.

Project Partners

VOLTA GREENTECH

ivl Swedish Environmental Research Institute

CHALMERS INDUSTRITEKNIK

SLU

TRE BÖNDER TORPS GÅRD NÄSHULTA

References

1. 2022 – Overview – Global Methane Tracker 2022 – Analysis - IEA
2. September 2023 – Naturvårdsverket – Minskade utsläpp av metan (naturvardsverket.se)
3. November 2023 – Dagens Nyheter – Algerna för klimatet: nu tar Volta Greentechsikte på världmarknad- DN.se
4. 2023 – Fraunhofer IGB – Machine learning for algae cultivation