

# Bio4Fuels

Norwegian Centre for Sustainable Bio-Based Fuel and Energy

HIGHLIGHTS  
FROM  
2019

Enabling sustainable biofuels production in Norway

BIO4  
FUELS

## Contents

Bio4Fuels value chains	3
What is Bio4Fuels	4
From the chair of the board and centre leader	5
Research activities	6
Bio4Fuels social benefits	10
Outreach	16
Bio4Fuels organization	18

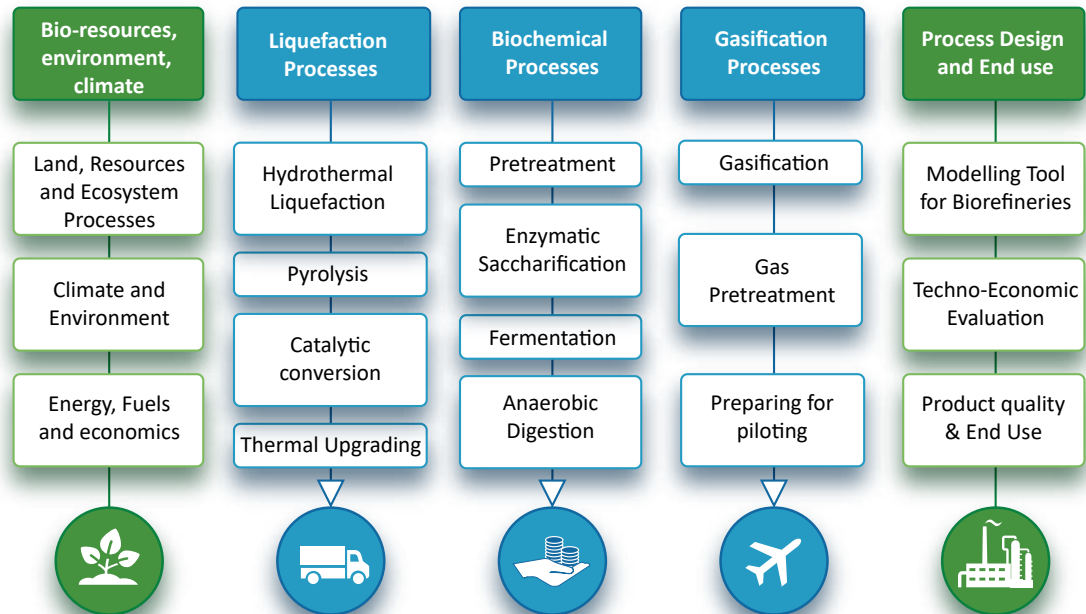


*Photo: Volvo Truck Corporation*



## Bio4Fuels value chains

*- From sustainable biomass resources to economic production of advanced biofuels*



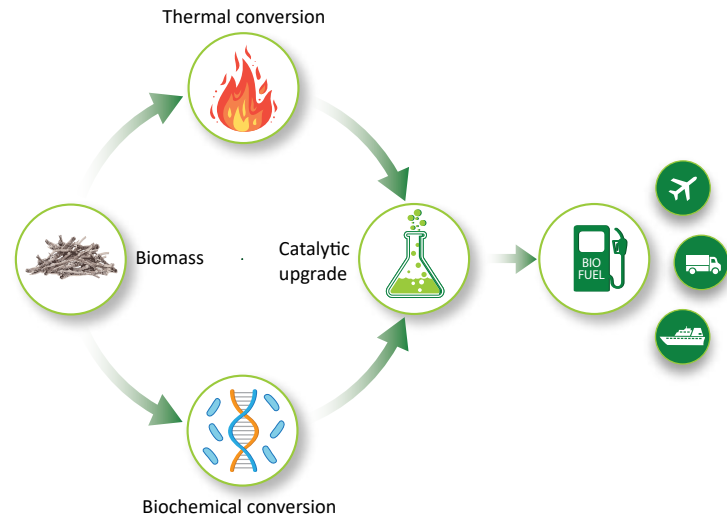


## What is Bio4Fuels?

The Bio4Fuels FME Centre's goal is to contribute to the reduction of climate gas emissions from the transport sector. We aim to enable a sustainable production of biofuels in Norway based on low-grade woody biomass and agricultural waste.

Bio4Fuels also addresses issues regarding viable commercial production of advanced biofuels from sustainable biomass, with the ambition to improve the technologies and economics of processes for converting biomass to advanced biofuels, investigate the sustainability and impact of large-scale use of low-grade biomass, and to evaluate and design the process concepts and testing quality of the biofuels for the engines used today.

The prospects for advanced biofuel production in Norway have increased significantly through the activities of key Bio4Fuels stakeholders since the establishment of Bio4Fuels in 2017.





## From the chair of the board and centre leader

In 2019, Bio4Fuels researchers continued to pursue their development efforts on the key technology platforms relevant for Norway, with experimental work on thermochemical conversion routes also gaining momentum. Feedstock sustainability and resource management are key aspects of a future bio-based society, thus the research in these is generating valuable insight for the debate on biofuels in Norway. Following a structural reorganization, new communication lines have been established along the major value chains in the Centre.

The Centre also continued its increasing international profile with the annual Bio4Fuels conference being held in Gothenburg as a joint event with the Swedish f3 Knowledge Centre for Renewable Transportation Fuels and the UK SuperGen Bioenergy Hub. This focus also included coordinating a landmark workshop in Brussels on the potential and future of HTL technology, bringing together the major technology providers worldwide.

The Centre's focus on supporting the industrial implementation in Norway has also been strengthened by the accession of Equinor with their interest in co-processing using existing refinery infrastructure. This will give valuable insights for activities in 2020 as key stakeholders come closer to fulfilling their plans of commercial scale production.



***Ingo Machenbach,***  
*Chair of the Board*



***Duncan Akporiaye,***  
*Centre leader*



## Research activities - Selected highlights

### Bio4Fuels contribution to IPCC Special report on Climate Change and Land

NTNU Professor Francesco Cherubini is the leader one of the sub projects in Bio4Fuels and was in 2019 one of the main authors of the IPCC's special report on Climate Change and Land, as the only author from a Norwegian-based institution.

The IPCC report addresses the links between climate change and land, including the role played by climate change mitigation alternatives, such as bioenergy.

The IPCC describes the report as an “assessment of the latest scientific knowledge about climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.” The report is an analysis of more than 7000 publications assessing many possible scenarios under various socioeconomic situations.

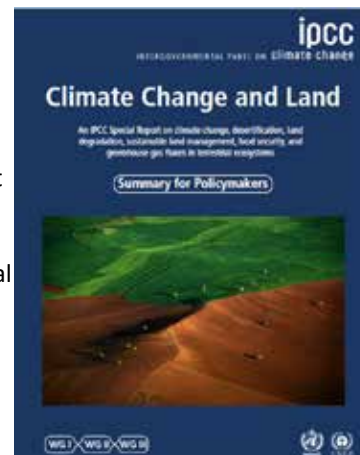
We need a lot of land in order to mitigate climate change. Even in the most sustainable possible scenarios, the amount of forest land needed to soak up CO<sub>2</sub> and to produce bioenergy -

either with or without carbon capture and storage - will by the end of this century top out at about 7.500.000 km<sup>2</sup>, or roughly the size of Australia. Bioenergy needs to be part of the climate change mitigation in order to achieve the goal of limiting global warming to 1.5 degrees.

Although these changes will cost money, the IPCC report emphasizes that the costs of inaction will exceed the costs of immediate action in many areas. They mean that money spent now is a sound investment to prevent even larger future costs from social and environmental damages and adaptation needs.

Reference: IPCC Special Report on Climate Change and Land at:

<https://www.ipcc.ch/srccl/>



## Successful enzymatic saccharification of spruce at demonstration scale

NMBU has worked in close collaboration with Borregaard and Lund University to develop an industrial setup to harness the action of oxidative enzymes called LPMOs (lytic polysaccharide monooxygenases) in commercial cellulase cocktails in a more efficient way.

The novel process is based on the recent scientific breakthrough at NMBU showing that LPMOs can utilize hydrogen peroxide much more efficiently than oxygen to break down cellulose. Based on processes developed at laboratory scale, a successful scale-up of the processes was carried out using Borregaard's demo unit. Using  $\text{H}_2\text{O}_2$  supply for the controlled activation of LPMOs in a commercial enzyme blend from Novozymes enabled faster and more complete saccharification of Borregaard's BALI-pretreated spruce feedstock.

With the new process setup at 2000 L scale, 15 per cent more glucose was released from the feedstock in 40 per cent less saccharification time than when using the current state of the

*Borregaard's demonstration plant in Sarpsborg, Norway. Phot by Martin Lersch, Borregaard.*

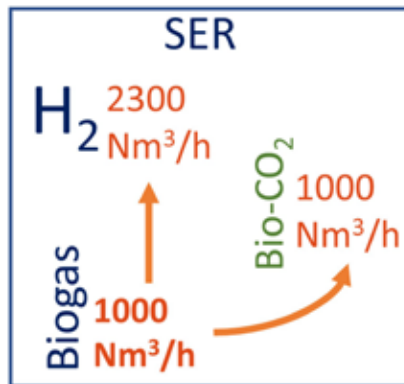


art. These wood sugars are excellent as feed in many types of fermentations processes for a range of chemicals and fuels. The data from the large scale saccharification process at Borregaard have been published in the scientific journal "Biofuels, Bioproducts and Biorefining". \*) Deputy leader of Bio4Fuels, Svein Jarle Horn, and Anikó Várnai, leader of one of the sub projects in Bio4Fuels, were involved in this work.

\*) Costa, T.H., Kadic', A., Chylenski, P., Várnai, A., Bengtsson, O., Lidén, G., Eijsink, V.G. and Horn, S.J., 2020, Demonstration-scale enzymatic saccharification of sulfite-pulped spruce with addition of hydrogen peroxide for LPMO activation. *Biofuels, Bioproducts and Biorefining*. <https://doi.org/10.1002/bbb.210>

## Sorption-Enhanced Reforming (SER) for H<sub>2</sub> production

SER (Sorption-Enhanced Reforming) is an emerging reforming technology that integrates H<sub>2</sub> production with CO<sub>2</sub> capture through the addition of a high temperature calcium-based CO<sub>2</sub> solid sorbent. In one single step higher H<sub>2</sub> yields can be obtained than with conventional reforming, as the capture of the CO<sub>2</sub> shifts the reaction equilibrium and enhances H<sub>2</sub> production. SER is suited to process natural gas feedstock, but the technology is also particularly attractive for reforming of biogas, as it simultaneously produces hydrogen and captures both the CO<sub>2</sub> contained in the feedstock, as well as the CO<sub>2</sub> formed in the reforming process. As a result, the biogas upgrading and water gas shift processing

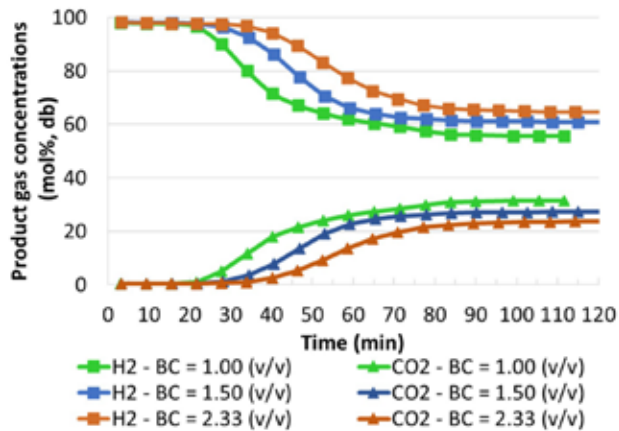


steps are removed, and the process is significantly simplified and intensified.

**SER Conversion Efficiency:** Within the Bio4Fuels framework, Bio4Fuels-partner IFE has carried out a series of SER experiments with synthetic biogas in a lab-scale fluidized bed reactor to optimize the SER process parameters towards this application area: 1) CH<sub>4</sub>/CO<sub>2</sub> ratio (see figure), 2) solid inventory, 3) steam to CH<sub>4</sub> ratio and 4) fluidization velocity. H<sub>2</sub> concentrations over 95 vol% and CO<sub>2</sub> concentrations lower than 2 vol% were obtained in the product gas for various operating conditions.

The process intensification has the potential to reduce investment costs by 20-30%, as it removes the need of a biogas upgrading unit and water-gas shift reactors. Additionally, the produced bio-CO<sub>2</sub> can be valorized after a purification step, for use in the food and beverage industry, greenhouses, bio-polymer synthesis, algae production, or for the production electrical fuels in a power-to-gas concept.



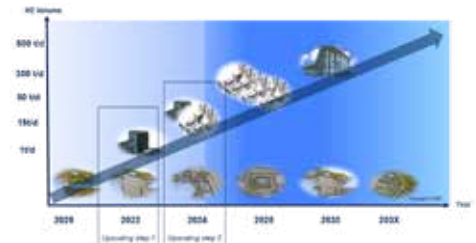


Product gas concentrations of SER carried out in a laboratory scale fluidized bed reactor, for different biogas compositions. Note: BC =  $\text{CH}_4/\text{CO}_2$  ratio.

## The first ZEG POWER hydrogen production plant with carbon capture

Bio4Fuels-partner ZEG Power is currently engineering its first upscaled SER plant for the production of clean, carbon-neutral hydrogen. The plant will have a hydrogen production capacity of 30 kg/h based on upgraded biogas as feedstock. The company has entered into a partnership with CCB (Coast Center Base AS) to realize the first plant at CCB Energy Park at Kollsnes in Hordaland by the end of 2021. The two companies have further plans to jointly further expand in order to supply land transport, maritime applications, and industrial players with clean, carbon-neutral hydrogen.

In addition, ZEG Power is also looking at the implementation of SER plants at biogas production locations, using clean biogas as feedstock.

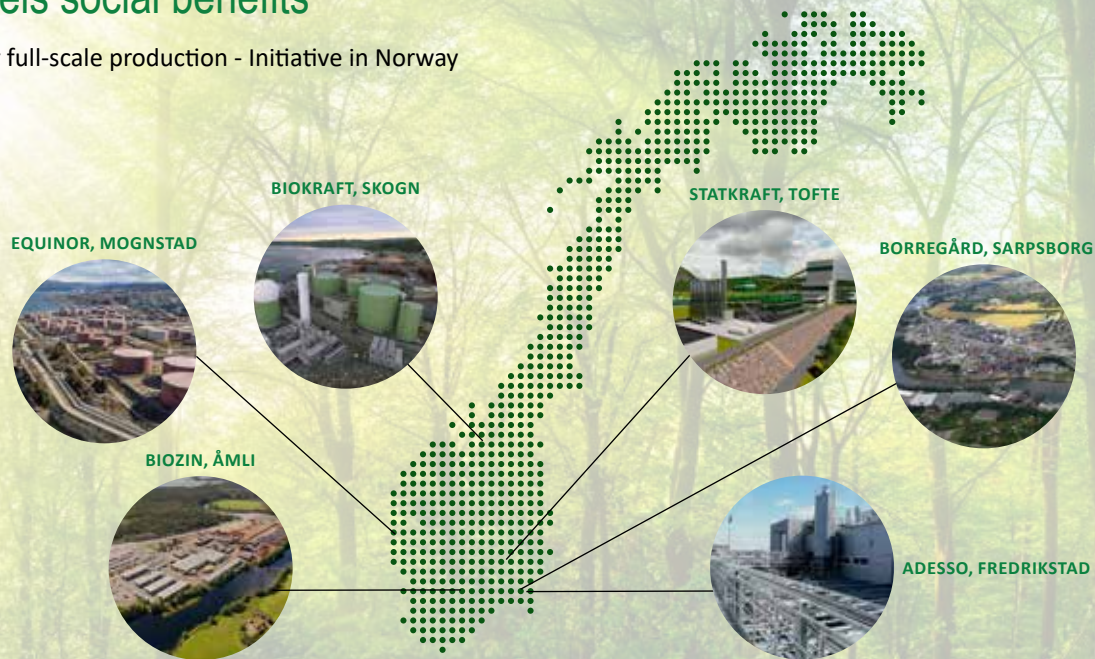






# Bio4Fuels social benefits

Heading for full-scale production - Initiative in Norway





*Helle Brit Mostad  
Advisor Innovation*



## Successful testing at Equinor's refineries

**We need new conversion technology to use more of the biomass we have at hand – and to produce advanced biofuels at scale. Energy company Equinor, welcomes dialogue with feedstock providers and conversion technology providers in order to reach this.**

- Our partnership with Bio4Fuels is an important meeting arena for us and an enabler for relevant research cooperation, says Helle Brit Mostad, Innovation Advisor for Equinor.

Equinor is committed to long term value creation in a low carbon future, and their strong technology base and ability to apply new technologies, gives them a competitive advantage, states Mostad.

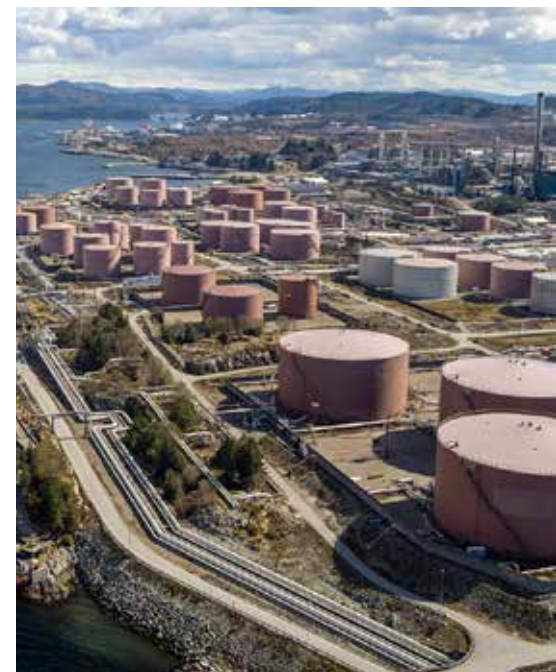
- Going forward we will prioritize a

portfolio towards renewables and low carbon activities. Sustainable and carbon neutral liquid fuels are not widely available today. That is one of the reasons why we work with advanced biofuels solutions, in order to provide viable alternatives to conventional fuels - particularly for means of transportation that are not easily electrified, she says.

During 2019, several successful tests were completed at Mongstad and Kalundborg refineries, co-processing bio-oil feedstocks. The objective is to test even more sustainable feedstocks with a lower supply chain CO<sub>2</sub> footprint compared with first generation biofuels.

- Our goal is to make our refineries at Mongstad and Kalundborg relevant for the energy transition by reducing the CO<sub>2</sub> footprint of our production and products, Helle Brit Mostad says.

*Mongstad facility. Photo: Equinor / Espen Rønnevik, Roar Lindefeld, Woldcam*



*Gerhard Muggen*  
*Managing director*



## High demand for Dutch biofuel technology in the Nordics

**Finland will invest 100 million euro in new sustainable technology in order to producing oil from various waste materials - including wood waste. The yearly capacity will be 20 million litres oil.**

The company BTG-BTL (Biomass to liquid) was established in 2008 to sell the BTG pyrolysis technology. The company has developed and upscaled commercial technology for producing pyrolysis oil from waste biomass.

In April 2019 managing director Gerhard Muggen could proudly announce a major order from Finnish company Green Fuel Nordic Oy – to first build a single production facility, and subsequently three more plants.

In September 2019 a new success was announced. The company Pyrocell (co-owned by Setra and Preem) ordered a pyrolysis plant to convert sawdust to pyrolysis oil. The plant will be built in Gävle in Sweden and the oil will be used by Preem in their refinery in Lysekil.

The BTG-BTL pyrolysis technology produces raw oil sustainably from natural waste materials. In pyrolysis, raw materials such as sawdust or grass clippings are heated to approximately 500 °C in the absence of oxygen, resulting in the formation of raw bio oil.

- In nature, this process takes millions of years, but our technology speeds up the process so that it takes only a few seconds, Gerhard Muggen explains. He continues:

- We can honestly say that we're talking about "non-fossil-non-food"-oil. Our oil is an excellent alternative for fossil fuels and does not require the exploitation of agricultural land or forests. It really is a sustainable form of energy.

*The Empyro plant in Hengelo (NL) (photo: BTG)*





Lars Lind  
Managing Director



## Adesso Bioproducts - bringing biofuels to market in Norway

**Adesso Bioproducts produced 260.000.000 liters of biofuel in 2019 in their factories in Norway and Sweden – corresponding to 52 per cent of Norwegians' consumption in 2018. Adesso is the only fully operational biofuel producer in Norway.**

Adesso Bioproducts' factory in Fredrikstad has been in operation since 2010, run by Adesso since 2016. Their biodiesel is sold to the Scandinavian market, and is used as mandatory blend-in with fossil fuels, as 100 per cent biofuels for trucks, buses and ferries, as well as a replacement for heating oil. Adesso fuels are documented to have good cold weather performance.

According to managing director of Adesso Bioproducts, Lars Lind, the

documentation of climate impact is very important. Every step in the production line, from growing rapeseed via processing to biofuels, all the way to the distribution to the end user, influences the total impact.

The feedstocks used by Adesso are mainly rapeseed from unused farmland in Europe, as the level of unsaturation is favorable for the Scandinavian climate. In order to meet the demand for advanced biofuels, cooking oil and fish oil has also been evaluated and included in the process.

Adesso are not involved with feedstocks from rainforests or deforestation,

meaning that they do not use palm oil or soy.

- One of Adesso's main objectives is to maximize the use of non-crop raw materials without jeopardizing the product quality and winter properties, and to utilise farmland not used for food production within Europe, to not put pressure on feedstock production outside of Europe, Lars Lind says.

*Adesso biodiesel plant in Fredrikstad  
(photo: Adesso Bioproducts)*



*Svein Guldal*  
Project leader



## Norwegian Farmers Union introduce strong CO<sub>2</sub>-cuts from the agriculture

**In June 2019 the Norwegian Farmers Union signed an agreement with the Norwegian government to reduce climate gas emission from agriculture by 5 million tons CO<sub>2</sub> equivalents annually within 2030.**

- Replacing fossil diesel with biodiesel and biogas is a prioritized action, says project leader on climate, energy and bioeconomy in Norwegian Farmers Union (Bondelaget), Svein Guldal.

In January 2020, the Norwegian Environment Agency released the vast report “Climate Cure”, evaluating several climate actions to be taken to meet a set 2030 target. Some of the actions with the highest impact include going from red beef production to plant production, as well as reducing the large losses in the

food chain from producer to consumer. Replacing fossil fuel with biofuel and biogas is also a prioritized action in the report.

Biodiesel-tests performed in 2018 and 2019 by Inland Norway University of Applied Sciences in collaboration with Norwegian Farmers Union conclude that the existing tractor park operates well when fueled with the biodiesel already on the market, also in cold weather. Biodiesel also reduces particle emission and keeps the vital parts of the motor cleaner.

- Status on Climate actions will be a central issue in the annual negotiations between The Farmers Union and the Norwegian Ministry of Agriculture and Food in the future, says Guldal.

- In the long-term perspective, the use

of electric machines and self-operating robots will be introduced in Norwegian farming, being an important factor, he says.

*Farmer fills up his tractor with biodiesel  
(photo: Norwegian Farmers Union)*





## Bio4Fuels outreach

### Bio4Fuels days

Date: 4-6 November

**Topics: The main objective of sustainable biofuel implementation prospects in Norway, Sweden and the UK.**

The intergovernmental organization Nordic Energy Research offered a back-to-back workshop to all participants.

The conference brought together researchers, industry specialists and policy-makers to review the status of bioenergy deployment, analyse the future of sustainable biofuel production and use in Europe, and connected sectorial expertise with a view to supporting sustainable biofuel production and greenhouse gas mitigation.

The conference cooperated with the international Elsevier journal Biomass & Bioenergy, and authors of scientific oral and poster presentations were invited to submit papers. These papers are currently going through a review process and selected papers will be published in a special issue of this journal in 2020.

This year's Bio4Fuels Days was a joint conference organized by three research centres:

- f3 Swedish Knowledge Centre for Renewable Transportation Fuels, SE
- Supergen Bioenergy Hub, UK
- Bio4Fuels, NO



## Bio4Fuels' webinar

Date: 26 November

**Topics: H2020 Bioenergy & Biofuels Proposals**

## European Expert Workshop

Date: November 19, Brussels, Belgium

**Topics: The potential of HTL for Biofuel production**

## National Breakfast meeting

Date: 14 November, Oslo, Norway

**Topics: Sustainable biomass in the Nordic region – how should we farm the ocean?**

For publications, see the Annual report

<https://www.nmbu.no/en/services/centers/bio4fuels/news/node/40424>

## Nordic Workshop co-organised with Nordic Energy Research

Date: 6 November 2019

**Topic: Biofuels strategy for the coming decade - The Nordic region at the forefront of technology and sustainability!**

## Summer school MOZEEs/Bio4Fuels

Date: 17-21 June

**Topics: NorRen summer school, Sustainable Transport**

## Bio4Fuels lunch meetings

Date: 1 February, 24 May, 11 October

**Topics: Scientific presentations within different fields of work.**



**Sustainable biomass in the Nordics – How should we farm the ocean?**

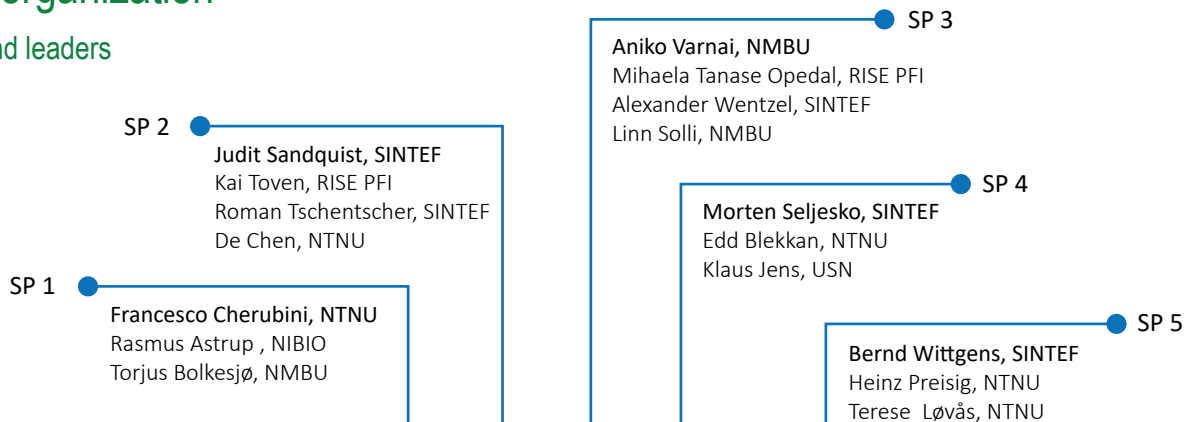
The Biltona Foundation and Nordic Energy Research invite you to join the discussion on bioenergy and seaweed aquaculture.





# Bio4Fuels organization

## Management and leaders

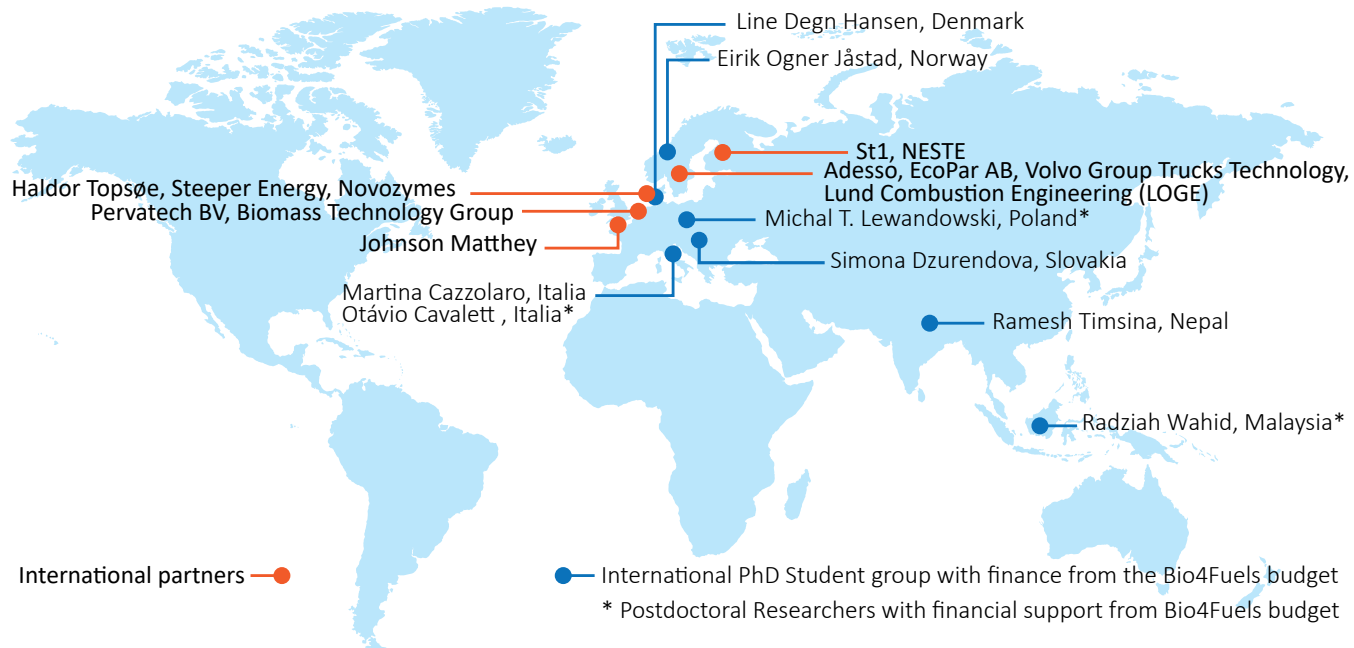


## Management & staff

Duncan Apkoriaye, SINTEF  
Svein Jarle Horn, NMBU  
Torjus Bolkesjøl, NMBU  
Odd Jarle Skjelhaugen, NMBU  
Janne Beate Utåker, NMBU  
Ann-Solveig Hofseth, NMBU  
Bente Paulson, NMBU







# Bio4Fuels Industrial and public stakeholders

## BIORESOURCE OWNERS



## BIOFUEL AND BIOCHEMICAL PRODUCERS



## TECH./KNOWLEDGE PROVIDERS, NORWEGIAN



## TECH./KNOWLEDGE PROVIDERS, INTERNATIONAL



## BIOFUELS DISTRIBUTORS AND END USERS



## TRADE ORGANIZATIONS

## GOVERNMENT AND STATE PARTNERS

