CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH
The Research Council of Norway

Bio4Fuels

Norwegian Centre for Sustainable Bio-Based Fuel and Energy

HIGHLIGHTS FROM 2021

Enabling sustainable biofuels production in Norway

BIO4 FUELS

Contents

Front page photo: CAMBI, China Gaobeidian B12

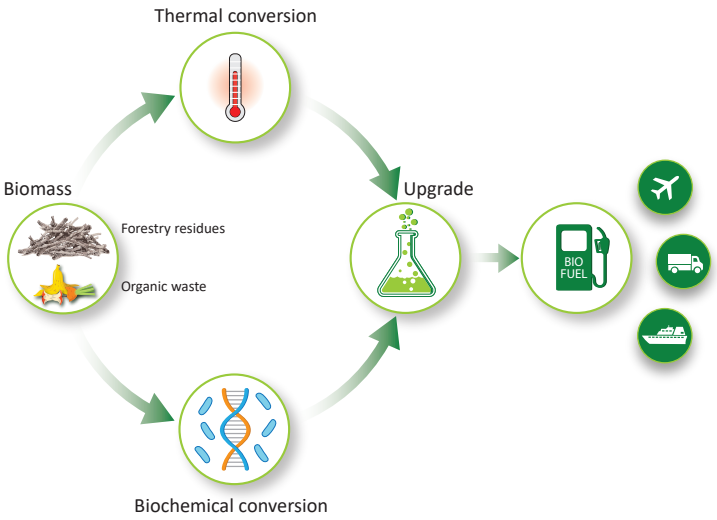
Photo: shutterstock

What is Bio4Fuels?

The goal of the FME Centre Bio4Fuels 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, organic and agricultural waste.

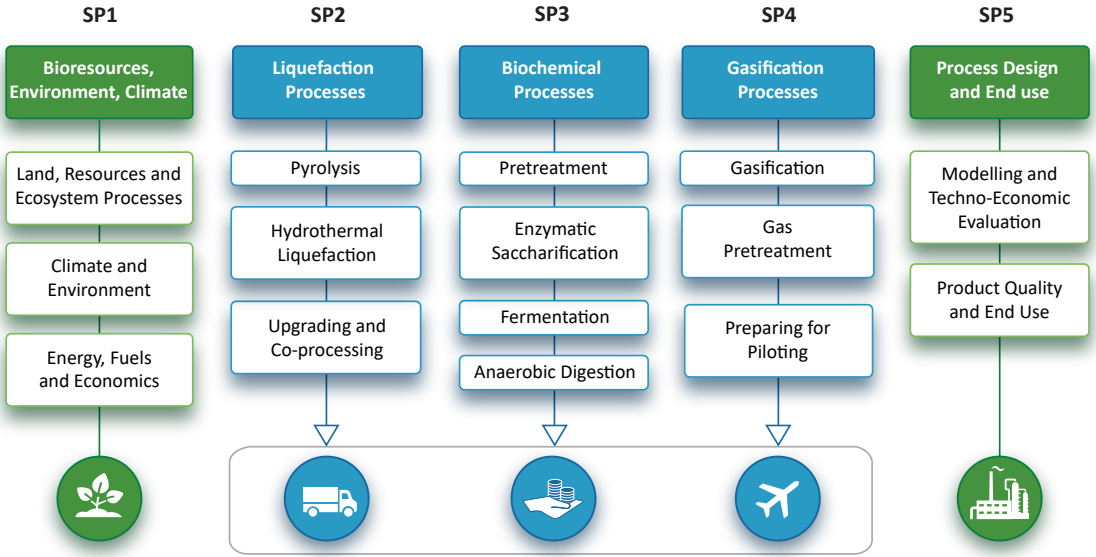
Bio4Fuels also addresses issues regarding viable commercial production of advanced biofuels from sustainable biomass. The ambition is to improve the technologies and economics of processes for converting biomass to advanced biofuels, investigate the sustainability and impact of large-scale use of low-grade 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 stakeholders since the establishment of Bio4Fuels in 2017.



Value chains and research

From sustainable biomass resources to economic production of advanced biofuels



From the Chair of the Board and Centre Leader

In 2021, FME Bio4Fuels achieved a major milestone as the centre was given the green light from the Norwegian Research Council to complete the final period of the centre's eight years. This was the result of a valuable and constructive mid-term evaluation, and the process gave us insights into where to improve.

With the backdrop of 2021 being yet another challenging year, in terms of meeting in person, it was particularly enjoyable that the centre was able to arrange the annual Bio4Fuels Days as a physical meeting again. The visit to Silva Green Fuels HTL Demo unit was an additional highlight of the event.

The timing of the annual meeting also coincided with the end of COP26, and with the sobering IEA "Net Zero" report in mind, we are reminded of the importance of the centre in fostering research within renewable energy and the clear role of advanced biofuels as part of the ambitions to reach Net Zero.

We acknowledge again the continued support of the Bio4Fuels stakeholders, both industrial and public sector, and the dedication of the research partners.

Ingo Machenbach, Statkraft
Chair of the Board

Duncan Akporiaye, SINTEF
Centre Leader

Reseach activities - Selected highlights

Special Issue in Biomass and Bioenergy

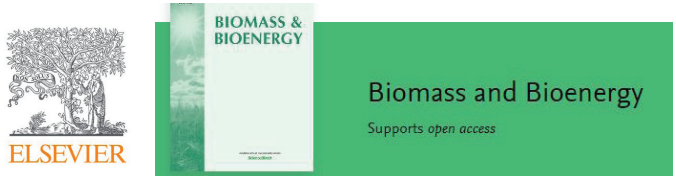
A special issue of Biomass and Bioenergy was published in July 2021, containing a selection of work presented at the conference "Building a sustainable biofuels industry" in Gothenburg (4–6 November 2019).

This special issue presents research on the effect of bioenergy on climate change, the effect of policy incentives on establishing biogas transport systems and a comparison of effectiveness of support policies for sustainable development of the bioenergy sector in UK and the Nordic countries. Moreover, it covers work on biochemical processing to produce biogas or bioethanol, and H2S capture in gasification processes.

Research on biofuels is facilitated by centres such as Bio4Fuels, and industrial projects for biofuel deployment are moving forward in many countries. At the same time there is a lot of interest in other energy carriers like hydrogen and ammonia, and the move towards electrification of the transport factor is ongoing.

So, what is the role of biofuels in the coming decades?

Read the full report here: https://www.sciencedirect.com/journal/biomass-and-bioenergy/special-issue/10ZCG8VXS6H



In May 2021 the International Energy Agency (IEA) released the report **Net Zero by 2050** which describes a roadmap to reach net-zero CO2 emissions in 2050 and the needed deployment of renewables to reach this goal. The report describes the phaseout of fossil fuels and installment of a range of renewables. Biomass and biofuels have a clear role in this energy transition, where biofuels will be important in heavy trucks and gradually also in shipping and aviation. The papers in this special issue frame this energy transition by exploring the greenhouse gas impacts of biofuels, policy and particular technical challenges and their solutions.

Publication in Nature Sustainability: The land–energy–water nexus of global bioenergy potentials from abandoned cropland

Authors: Jan Sandstad Næss, Otavio Cavalett and Francesco Cherubini

More biofuels are needed to counteract climate change. But producing them should not diminish food production or wilderness areas. The solution may be to grow more grass on recently abandoned cropland. Bioenergy is a key option in climate change mitigation scenarios. Growing perennial grasses on recently abandoned cropland is a near-term strategy for gradual bioenergy deployment with reduced risks for food security and the environment.

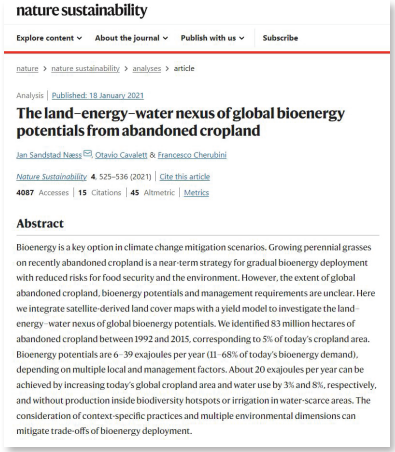
Biofuels come in several varieties. Common to all is that plants are broken down and transformed into a product we can take advantage of in vehicles and machines, for example.

But corn, wheat, rapeseed and soybeans that become biofuels instead of food affect people's ability to feed themselves, making the choice for biofuels ethically questionable. Wild areas cleared to grow biofuels can compromise biodiversity.

In many of the scenarios that the researchers explore, the production of biofuels would not compete with food production or wilderness, but would use cropland that has been abandoned due to more efficient food production or because plant foods replace more land-intensive meat production.

The least controversial option for producing biofuels is the use of waste from industry, agriculture and forestry, but this does not generate nearly enough.

If we use areas that already have limited value for other purposes, the cultivation of biofuels will become more attractive for more people.



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Analysis | Published: 18 January 2021

The land–energy–water nexus of global bioenergy potentials from abandoned cropland

Jan Sandstad Næss, Otavio Cavalett & Francesco Cherubini

Nature Sustainability **4**, 525–536 (2021) | Cite this article

4087 Accesses | **15** Citations | **45** Altmetric | Metrics

Abstract

Bioenergy is a key option in climate change mitigation scenarios. Growing perennial grasses on recently abandoned cropland is a near-term strategy for gradual bioenergy deployment with reduced risks for food security and the environment. However, the extent of global abandoned cropland, bioenergy potentials and management requirements are unclear. Here we integrate satellite-derived land cover maps with a yield model to investigate the land–energy–water nexus of global bioenergy potentials. We identified 83 million hectares of abandoned cropland between 1992 and 2015, corresponding to 5% of today's cropland area. Bioenergy potentials are 6–39 exajoules per year (11–68% of today's bioenergy demand), depending on multiple local and management factors. About 20 exajoules per year can be achieved by increasing today's global cropland area and water use by 3% and 8%, respectively, and without production inside biodiversity hotspots or irrigation in water-scarce areas. The consideration of context-specific practices and multiple environmental dimensions can mitigate trade-offs of bioenergy deployment.

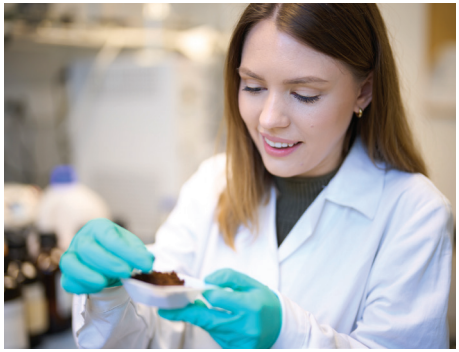
Enzymatic Saccharification

NMBU researchers have worked in close collaboration with the centre's partners Novozymes, Borregaard and St1 towards improving the efficiency of today's state-of-the-art enzyme blends in depolymerizing softwood-type feedstocks, which we have in abundance in Norway. One of the key components of these enzyme blends is lytic polysaccharide monooxygenases (LPMOs), and the Bio4Fuels research team aims to develop industrial setups to improve the efficiency of commercial cellulase blends by harnessing the action of oxidative enzymes called LPMOs (lytic polysaccharide monooxygenases) in a more efficient way than it is done in current industrial processes.

In early 2021, NMBU published a collaborative work with Lund University in the journal of Biotechnology for Biofuels. In this research paper, researchers measured the oxidation–reduction potential and hydrogen peroxide concentration in situ during cellulose saccharification with Novozymes' state-of-the-art LPMO.

In addition, the research team published a method paper describing the analysis of oxidized sugar oligosaccharides generated by the action of LPMOs, with simplified operation and increased sensitivity for low abundant LPMO products, in the Journal of Chromatography A. This work was the result of a joint effort of Bio4Fuels and Enzymes4Fuels, an NFR-funded project that is associated with Bio4Fuels.

In a joint effort within Bio4Fuels researchers have established a combined biochemical and thermochemical conversion route that enables the recovery of a sugar-rich hydrolysate and the concomitant generation of a quasi-pure lignin-rich saccharification residue for pyrolysis. The process is based on the modification of steam explosion, a biomass pre-treatment used by St1, with carbocation scavengers to improve lignin reactivity after pre-treatment.



Line Degn Hansen in the lab / Photo: Alexander Benjaminsen, NMBU

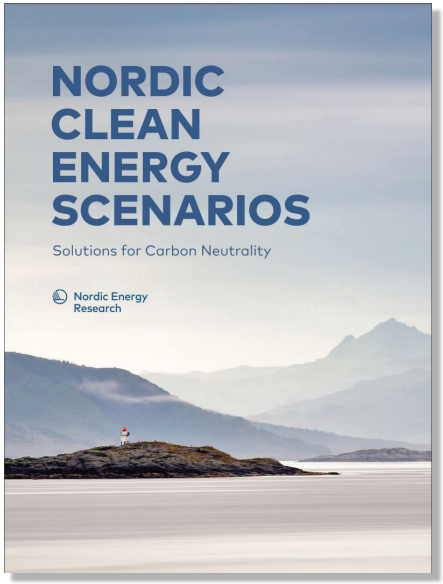
Contributing to Nordic Energy Research report

The cooperation and interaction with Nordic Energy Research continues via Bio4Fuels' Torjus Bolkesjø and his contribution to the report Nordic Clean Energy Scenarios. The report focuses on the Nordic vision and five different ways to a carbon neutral future.

"The Nordic countries have a unique and longstanding cooperation on energy, which has created a solid foundation for a sustainable and secure energy supply in the region. Now, it is time to further Nordic energy cooperation with the green transition as a new framework", the report states.

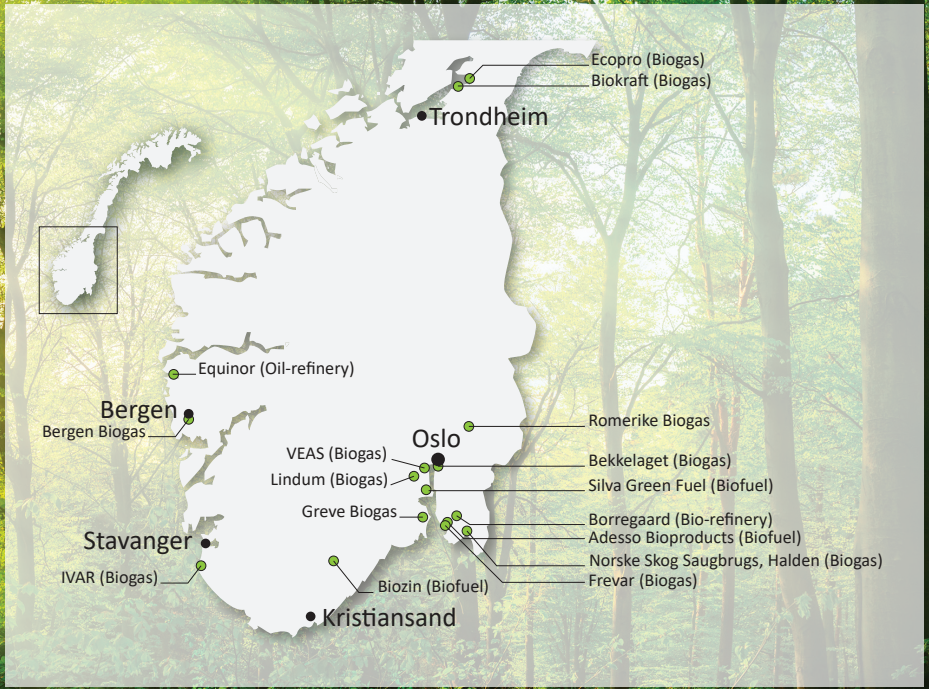
"Nordic Clean Energy Scenarios aim to identify and help prioritise – through scenario modelling – the necessary actions up to 2030 and map potential long-term pathways to carbon neutrality, and thereby support the joint Declaration on Carbon Neutrality. This work is both timely and important, considering that energy-related emissions make up almost four-fifths of Nordic emissions today".

The report focuses on ten areas, and the Nordic Clean Energy Scenarios analysis reveals strong results, identifying actions that can be implemented in the near-term to set a strong foundation for achieving carbon neutrality.



Nordic Clean Energy Scenarios – Solutions for carbon neutrality report

Industrial activities in Norway



Some of our partners

Cambi

Cambi's work with the Bio4Fuels program supports its vision of securing greater understanding and strengthening of the biogas market in Norway and around the world. The company has been a supporter of biofuel market efforts since its start-up in 1992.

In parts of the world where wastewater is treated, a by-product called sludge is typically produced. This is a mix of mostly organic substances, often thought of as costly to dispose of, store, incinerate, or sanitise. Cambi's thermal hydrolysis process (THP), when used with anaerobic digestion, transforms sludge from a waste item to a resource. THP allows utilities to extract more biogas from sludge, reduce biosolids volumes, and produce a pathogen-free biosolids product.

Over 75 medium and large wastewater treatment plants worldwide now use or are planning to use Cambi's THP systems, servicing about 110 million people across 24 countries as of 2022. Cambi understands just how important biogas can be for the green energy transition. In fact, it is estimated by Global Water Intelligence that about 87 per cent of the energy needed by wastewater utilities worldwide could be provided by sewage sludge. Cambi is an inseparable part of that opportunity.

An example of the THP technology at work is seen at the Oslo Romerike Biogas Plant, which treats household food waste and industrial biowaste. The plant upgrades the methane produced to liquefied biogas fuel, used to run over 130 public commuter buses in Oslo. As a result, carbon dioxide emissions are reduced by approximately 10,000 tonnes each year.

Cambi - THP at Davyhulme wwtp Manchester UK Photo: Cambi

Hydrothermal Liquefaction (HTL) at Silva Green Fuel

Silva Green Fuel is a collaboration between Statkraft and Sødra, formed in 2015 to develop and produce advanced biofuel to replace fossil fuels.

After a two-year validation period, the long-term goal is to benefit from the biomass value chain and build and operate a commercial biofuel facility. This plant could be ready for operations in 2025 and would form the centre of the future Tofte industry cluster.

The demonstration Plant Silva Green Fuel's plant at Tofte, Norway is now running and soon finished.

- Feedline: All instrumentation connected to biomass processing are installed, tested and in operation
- HTL core system: The HTL high-pressure system, including reactors, heat exchangers and accessories, are installed and tested
- Downstream systems: Equipment for oil separation and chemical recycling are installed and tested.

The remaining equipment, including process gas treatment and laboratory facilities, were installed in parallel with the above-mentioned systems. Silva Green Fuel's plant was mechanically completed in the summer 2021, and the whole plant was finished in November 2021.

Hydrothermal Liquefaction (HTL) Biomass Conversion: Silva Green Fuels demonstration plant, Tofte, Norway. Photo: Silva Green Fuel

Norwegian-owned biofuel production in Brazil

The Brazilian bioethanol production company 'Foundation of the Paranapanema Distillery' was established 1980. The company was acquired by UMOE in 2009 and was, after substantial investments, renamed Umoe Bioenergy (UBE).

UBE grow and harvest sugar cane in the State of Sao Paulo in Brazil and produce large volumes of sustainable bioethanol and electricity. The soil in this area is among the highest productive in the world. UBE grow the sugar cane on 40,000 hectares leased arable land and process it in its own state-of-the art mill. Alcoholic fermentation is a complex biochemical process during which yeasts convert sugars to ethanol, carbon dioxide and other metabolic by-products. The process is being operated by skilled staff, helped by advanced sensor technology. The biofuel is mixed with fossil gasoline or used as a stand-alone low-carbon fuel. Bioethanol powers 70 per cent of Brazilian cars.

The annual production is 170.000 m^3 ethanol and 151 GWh electricity. It takes 2.5 million tons crushed sugarcane to produce this volume, and about 900.000 seedlings are planted every year.

The biofuel is being produced about 2.000 km from the Amazon. The production occupies less than 1% of arable land in Brazil, and is not competing with the national food production.

The UMOE Bioenergy (UBE) plant in Brazil producing bio-gasoline and electricity from sugar cane. Photo: UMOE

Simona Dzurendova

PhD degree

Making the most of forestry waste

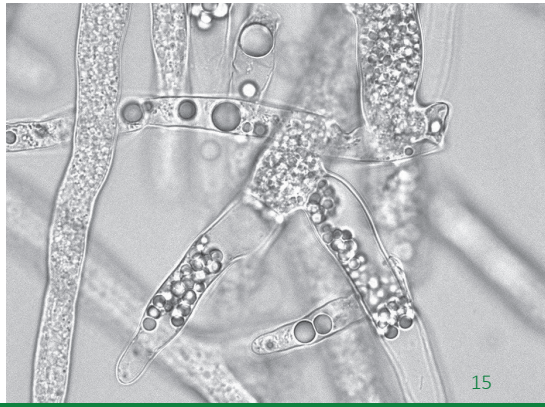
Fungi growing on waste from the forest industry can produce oil which can be used for our food and animals' feed, as well as for biofuels. However, the production of such oil is costly. Producing additional valuable bioproducts in the same process may solve this challenge.

Fungi is more than mushrooms, mildew and mould. With the right tools we can use it as food, medicine, and biofuels – and numerous other things. Part of Bio4Fuel's research is using lignocellulose from woody biomass to grow fungi, in order to produce oils that can be used as biofuels or a part of human and animal nutrition.

However, this bioproduction is costly. Any process solely producing lipids is not economically viable, and NMBU researchers see the need for making more use of the process, producing more valuable components at the same time. Now, they have discovered that co-production may be a solution, as other high value components can be produced in the same fermentation process.

23 April 2021, Simona Dzurendova successfully defended her thesis with the title "Sustainable Fungal Biorefineries: Optimizing production of valuable metabolites in oleaginous Mucoromycota". The main objective of the PhD research work was to investigate growth conditions that could improve the production of valuable metabolites in fungal biorefineries based on Mucoromycota fungi. The PhD work resulted in six publications and after an interesting and comprehensive discussion with the opponents, the committee concluded the PhD defense approved.

Photo: Hyphae of Mucor circinelloides containing lipid bodies



Outreach in 2021

Bio4Fuels days 17-18 November

Bio4Fuels Days is a yearly meeting for all partners in the Centre, spanning over three days:

- Day one: Young Researchers' Forum, for PhD students and post docs in Bio4Fuels
- Day two: International scientific meeting open to all + Site visit to a biofuel facility
- Day three: Meeting for Bio4Fuels' partners with focus on research status and plans for the coming year

Bio4Fuels Days 2021 was organized as a physical meeting in Drammen, Norway, also including some digital presentations. A highlight was a site visit to Silva Green Fuel's new demonstration plant at Tofte, Hurum.

The 2021 Meeting covered the following topics:

- Young researcher Forum focusing on communication related to biofuels
- The role of Biofuels in IEA's Report "Net Zero by 2050"
- Communicating Sustainability – Chellenges and Opportunities
- Commercial Roll-Out of Pyrolysis Technology in Europe
- Working Towards a Mass Balance Standard for Co-Processing
- Challenges with Aviation Fuels

Presentations given at Bio4Fuels Days 2021 can be downloaded from Bio4Fuels' webpages: https://www.nmbu.no/en/services/centers/bio4fuels/news/node/43987

Bio4Fuels webinars

Date: 10 March
Topic: Integrating the Gasification Value Chain in Bio4Fuels into an Industry Cluster

Date: 14 April
Topic: Co-Processing as route to deployment of advanced biofuels production

Workshops and events

Date: 14 April
Joint European workshop organised by project consortia: 4REFINERY, WASTE2ROAD and Bio4Fuels

Date: 20 April
European workshop for Master's and Doctoral Students organized by 4REFINERY and WASTE2ROAD

Date: 26-29 April
EUBCE - 29th European Biomass Conference & Exhibition 2021

Date: 17 August
Arendalsuka

Date: 27 September
CONCAWE

Date: 13 October
13 Oil Forum of the Energy Community of Europe

Date: 14-15 October
European Climate, Infrastructure and Environment Executive Agency (CINEA)

Date: 26 October
NFR Energiforskningskonferansen

Scientific publications 2021: https://www.nmbu.no/en/services/centers/bio4fuels/key-research/scientific-publications

Organization 2022

Management and leaders

SP 1 Bio-resources, Environment and Climate

Francesco Cherubini, NTNU
Rasmus Astrup, NIBIO
Per Kristian Rørstad, NMBU

SP 2 Liquefaction Processes

Judit Sandquist, SINTEF
Kai Toven, RISE PFI
Roman Tschentscher, SINTEF

SP 3 Biochemical Processes

Aniko Varnai, NMBU
Mihaela Tanase Opedal, RISE PFI
Alexander Wentzel, SINTEF
Lu Feng, NIBIO

SP 4 Gasification Processes

Morten Seljesko, SINTEF
Edd Blekkan, NTNU
Klaus Jens, USN

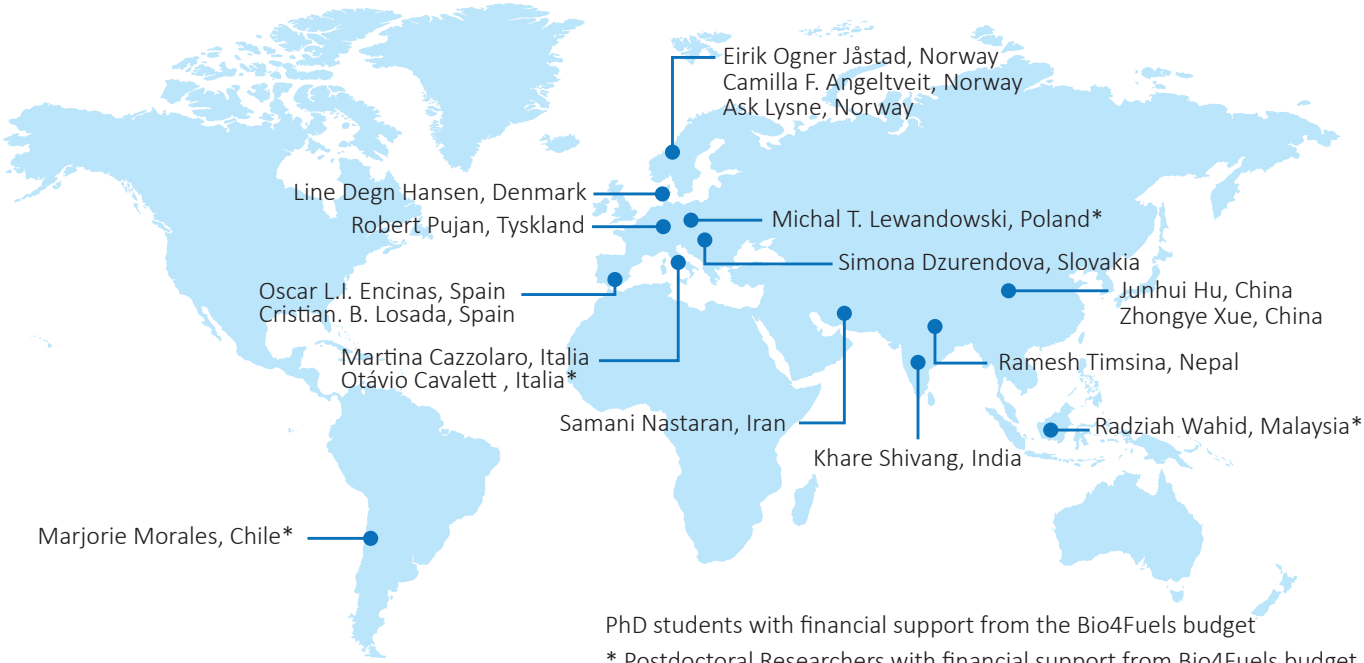
SP 5 Process Design and End Use

Bernd Wittgens, SINTEF
Terese Løvås, NTNU

Management and Staff

Duncan Akporiaye, SINTEF
Svein Jarle Horn, NMBU
Odd Jarle Skjelhaugen, NMBU
Janne Beate Utåker, NMBU
Ann-Solveig Hofseth, NMBU
Camilla Fløien Angeltveit, NMBU
Haldis Bjerva Watson, SINTEF

PhD Students and Post docs in Bio4Fuels



PhD students with financial support from the Bio4Fuels budget

* Postdoctoral Researchers with financial support from Bio4Fuels budget

Bio4Fuels Industrial and public stakeholders

BIORESOURCE OWNERS

NORGES BONDELAG

Norges Skogeierforbund

BIOFUEL AND BIOCHEMICAL PRODUCERS

Silva Green Fuel

BIOZIN AS – Circular energy solutions –

equinor

Adesso BioProducts

Borregaard

BIOKRAFT

ecopro ecologic bioproducts

Norske Skog

alginor

NESTE

TECH./KNOWLEDGE PROVIDERS, NORWEGIAN

HERØYA INDUSTRIPARK

CAMBI

UMOE

Hyperthermics™ THE GREEN SHIFT REVOLUTION

ZEG Power

TECH./KNOWLEDGE PROVIDERS, INTERNATIONAL

btg biomass technology group

JM

novozymes

PERVATECH

steeper ENERGY

LOGE

BIOFUEL DISTRIBUTERS AND END USERS

st1

AVINOR

TRADE ORGANIZATIONS

nobio Norsk Bioenergiforening

ZERO

GOVERNMENT AND STATE PARTNERS

VIKEN FYLKESKOMMUNE

Innlandet fylkeskommune

Trøndelag fylkeskommune Trøndelagen fylkenntjelte

folkeradet

MILJØDIREKTORATET

Statens vegvesen

Innovasjon Norge

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