Bio4Fuels Annual Report 2018

Norwegian Centre for Sustainable Bio-Based Fuels and Energy

Photo: St1 cellulosic ethanol plant in Kajaani, Finland

BIO4FUELS

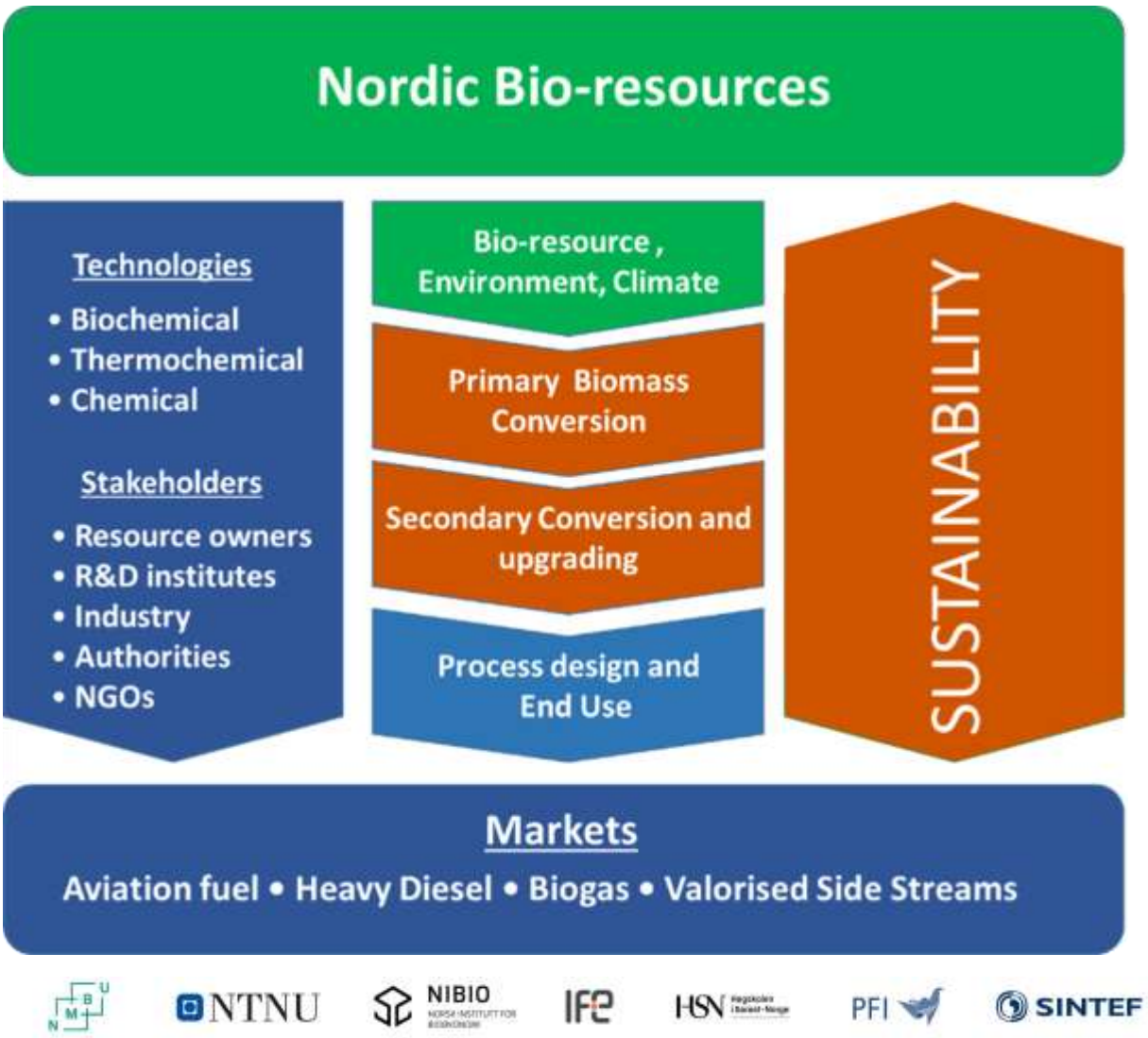
CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

The Research Council of Norway

VISION

Enabling sustainable biofuels production in Norway

Bio4Fuels aims to contribute to the reduction of emissions from the Norwegian transport sector through coordinated research efforts to establish the basis for sustainable routes to advanced biofuels.



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Picture from Avinor – delivery of Biojetfuel to Bergen airport

FROM THE CHAIR OF THE BOARD AND CENTRE LEADER

The focus of Bio4Fuels FME in 2018 has continued to address the building up of the Centre's activities within the major value chains that are considered most relevant for Norway. Looking forward, Bio4Fuels has initiated a Self-evaluation exercise required by the Research Council, aiming to provide the Board with the basis for reviewing and considering recommending adjustments of the operation and focus of the Centre.

The area of Biofuels has continued to be a matter of debate nationally and internationally, making the role of Bio4Fuels as a research-based Centre increasingly important. The need for viable routes to production of Biofuels was the topic of the annual Bio4Fuels days conference, which coincided nicely with the release of the report from the IPCC on the status of climate mitigating actions and IEA with respect to the role of Biofuels. In addition to this, other highlights from 2018 were the completion of the report on the effect of research in bioenergy, webinars and workshops addressing different aspects of the biofuels value chains, as well as the publication from Francesco Cherubini in the prestigious Nature journal.

Hans Aasnæs,
Chair of the Board

Duncan Akporiaye
Centre leader

SUMMARY

The ambition of the Bio4Fuels FME Centre is to reduce the impact of climate gas emissions from the transport sector through sustainable and economic production of Biofuels from low-grade fractions of wood from the forest and waste from agriculture.

There are four main routes identified for Bio4Fuels:

- Breaking down the biomass to separate out the sugars in the biomass for use in fermentation to produce "Bioethanol". This can be blended up to certain levels into existing fuels.
- Fermentation of the biomass in the absence of oxygen to produce a "Biogas". This Biogas can be upgraded to methane, liquified or converted to Hydrogen for use as fuels in transport.
- Treatment of the biomass at higher temperatures in the absence of oxygen to produce a liquid "Biooil", which is then upgraded to a substitute Biofuel.
- Treatment of the biomass at higher temperatures to convert to a gas, followed by upgrading of the gas to a substitute Biofuel.

In addition to the main routes from Biomass to Biofuels, it is also important to convert side streams and biproducts from the processes to products of higher value than fuels. This can be important to help the overall economics of the commercial process. The main issues being addressed for viable commercial production of Biofuels from Biomass are related to the economics and sustainability of the processes. The research activities in the Bio4Fuels Centre address these central issues through:

- Improving the technologies and economics of processes for converting Biomass to Biofuel
- Investigating the sustainability and impact of large scale use of low grade Biomass for Biofuels production,
- Evaluating and designing the process concepts and testing the quality of the Biofuels for existing engines.

Since the establishment of the Bio4Fuels, the prospects for production of biofuels in Norway based on the Bio4Fuels main value chains has increased significantly through the activities of key Stakeholders. This is illustrated in the insights from industrial stakeholders, showing activities ranging from the world's largest liquified biogas plant, through to maturing plans for pilot and demonstration units based on liquefaction technology. With this as background, there is an increased focus on the involvement and interaction of the researchers with stakeholders with the goal of contributing further to innovation within the field.

There have also been important changes in the Centre, with the welcoming of the Neste as partner in the Centre and changes in the membership of the board and leadership of the main subprojects.

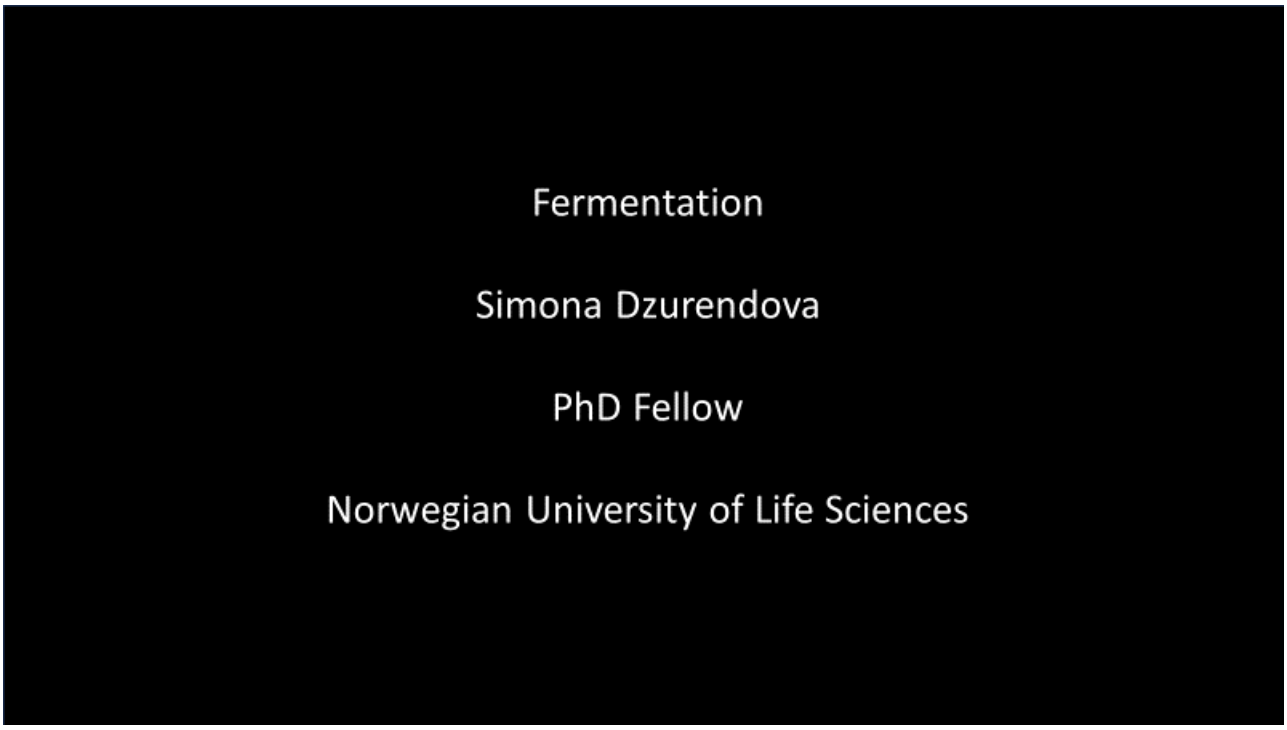
The second "Bio4Fuels" days annual meeting, was successfully organized at Gardermoen, following up the plans for establishing it as a significant event in the calendar. With the background of the release of the IPCC climate report, the plenary session had significant contributions from Adam Brown from IEA as well as European and Norwegian perspectives from EERA and the Environmental agency. The excursion to visit

Oslo Recycling Agency's biogas plant gave insight to the accelerating success of the implementation of commercial biogas units throughout Norway. Finally, Bio4Fuels has made special efforts of establishing its international links and associated projects. In particular, the portfolio of associated EU projects is now quite impressive, with research partners and stakeholders participating in an additional 4 new EU projects. In addition, Bio4Fuels has taken up a role in the in the Advanced Biofuels innovation challenge of Mission Innovation and has taken the initiative to become involved in the IEA Bioenergy Task 39 and 45, key activities related to commercialization and sustainability.

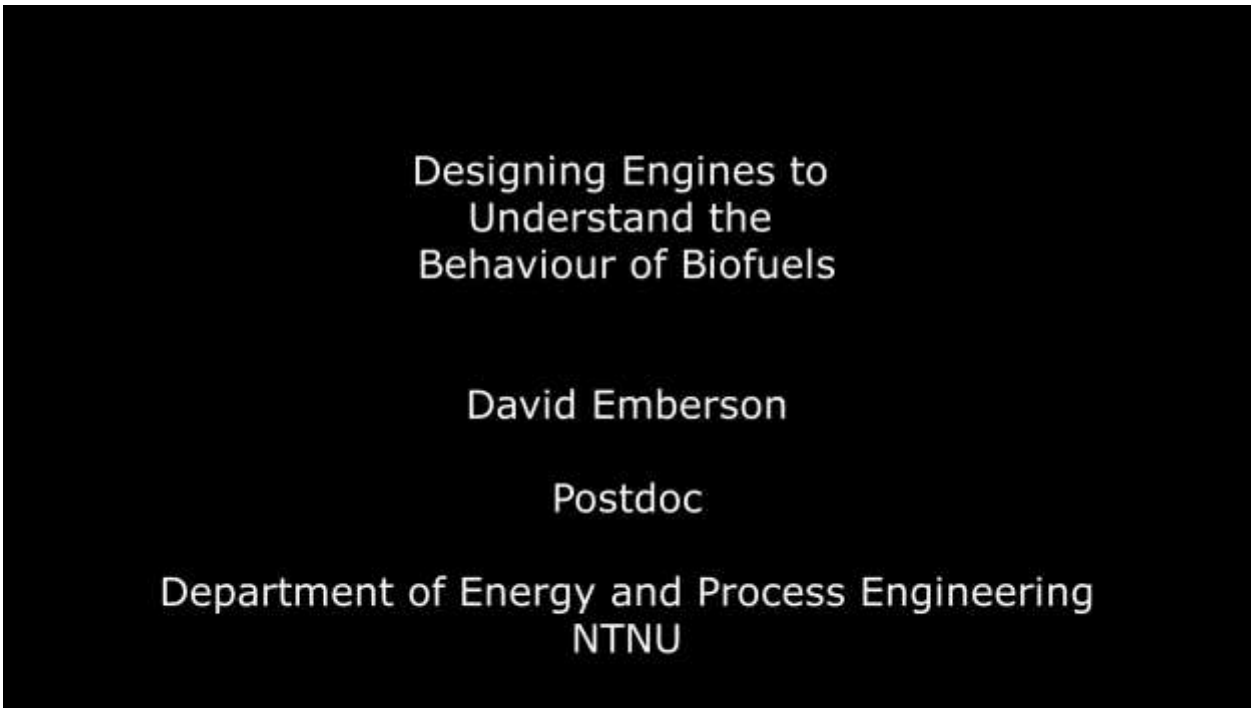
SHORT FILMS FROM STUDENTS AND POSTDOCS - UNDERSTANDING BIOFUELS

The Bio4Fuels Centre has has encouraged our PhD and Postdoctoral candidates to be active in promoting and explaining their research activities. Three candidates have been actively involved in creating a few short videos outlining the content and importance of their research within the whole context of Biofuels.

Picture LINK to Video.
https://www.nmbu.no/sites/default/files/wysiwyg_inserts/bio4fuels_short_film_l_d_hansen_enzymatic_saccharification.mp4

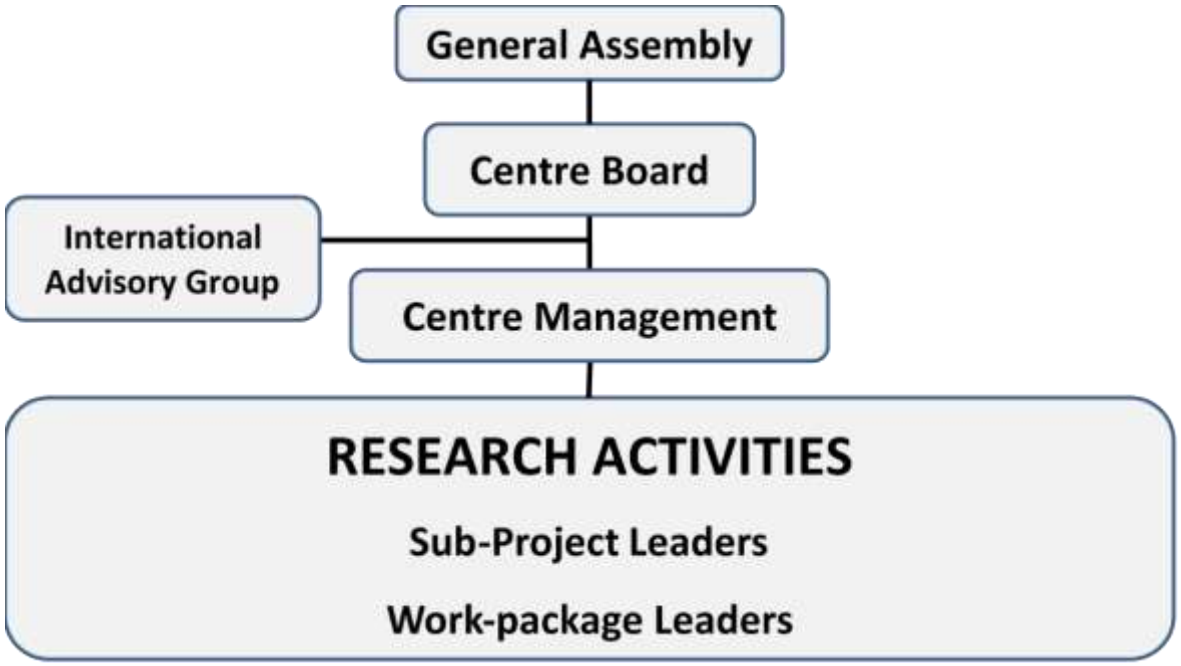


Picture LINK to video https://vimeo.com/326620989/137e501594



Picture LINK to video
https://www.nmbu.no/sites/default/files/wysiwyg_inserts/bio4fuels_short_film_d_emberson_designing_engines_to_understand_fuel_behaviour_1_0.mp4

BIO4FUELS ORGANIZATION



CENTRE BOARD AND MANAGEMENT

The Bio4Fuels' Board:

	**Hans Aasnæs**	**UMOE AS**	**Chair**
	Tyra Marie Risnes	Østfold County Council	Representing Stakeholders
	Erlend Grøner Krogstad	Norges skogeierforbund	Representing Resource partners
	Ingo Machenbach	Silva Green Fuel	Representing End Users
	Kine Svensson	CAMBI	Representing Technology partners
	Petter Røkke	SINTEF	Centre Leader Institute
	Ragnhild Solheim	NMBU	Host Institute
	Terese Løvås	NTNU	R&D partner
	Philip Andre Reme*	PFI	R&D partner
	*Per Arne Karlsen*	*Research Council of Norway*	*Observer*

**Rotation between PFI, USN, IFE, NIBIO*

THE BIO4FUELS' MANAGEMENT TEAM:

	Dr. Duncan Akporiaye	SINTEF	Centre Leader
	Prof. Svein Jarle Horn	NMBU	Deputy Centre Leader
	Dr. Odd Jarle Skjelhaugen	NMBU	Industrial Liaison
	Dr. Janne Beate Utåker	NMBU	Administrative Manager
	Christel Celine Nguyen	NMBU	Financial Officer (2017-2018)
	Ann-Solveig Hofseth	NMBU	Financial Officer (2018-)
	Frode Bjerkås	NMBU	Communication specialist (2018 – 2019)

THE INTERNATIONAL ADVISORY GROUP (IAG)

	Advisor	Affiliation	Area of expertise
	Prof. Patricia Thornley	Supergen Bioenergy Hub, University of Manchester, Tyndall, (UK)	Sustainability
	Prof. Kristiina Kruus	VTT Technical Research Centre of Finland (FI)	Biochemical Processes
	Dr. David Dayton	Research Triangle Institute (RTI), NC (USA)	Thermochemical Process

BIO4FUELS PARTNERS AND STAKEHOLDERS

Research partners in Norway

NMBU – The Norwegian University of Life Sciences
SINTEF – Applied research, technology and innovation
NTNU – The Norwegian University for Science and Technology
NIBIO – The Norwegian Institute of Bioeconomy,
IFE – Institute for Energy Technology
RISE PFI – Research Institutes of Sweden – Paper and Fiber Institute
USN – The University College of South East Norway

Bioresource owners	Main interest
The Norwegian Farmers Union	Biogas production from agricultural feedstocks
The Norwegian Forest Owners' Federation	Value from forest biomass
Ragn Cells AS	Value from organic waste
The City of Oslo, The energy recovery unit	Biogas production from food waste
Tech./knowledge providers, Norwegian	**Main interest**
Herøya Industry Park	Pilot plant construction
Cambi AS	Plants for biogas production from organic waste
Hyperthermix AS	High temperature biogas production from waste biomass
Norse Biotech AS	Consultancy on biofuels production plants
Zeg Power AS	Electricity and hydrogen production from hydrocarbons
UMOE AS	Biofuel plant investments and management
Tech./knowledge providers, International	**Main interest**
Biomass Technology Group (NL)	Biomass to liquid (btl) pyrolysis
Johnson Matthey (UK)	Chemical and catalytic processing of bio-feedstocks
Novozymes (DK)	Enzymes for forest based biorefineries
Pervatech (NL)	Membrane and separation systems for organic substrates
Haldor Topsøe (DK)	Chemical/catalytic processes for several bio feedstocks
Steeper ENERGY (DK)	Hydrothermal liquefaction
Lund Combustion Engineering as (SE)	Consultancy and software on combustion in motors
Biofuel and biochemical producers	**Main interest**
Silva Green Fuel AS	Biodiesel from forest biomass
Biozin AS	Forest based crude oil for biorefineries
Perstorp Bioproducts AB (SE)	High quality biodiesel
Borregaard	Forest-based high value chemicals and bioethanol
Biokraft	Biogas from paper mill side-streams and fish waste
Ecopro AS	Biogas from organic waste
Norske Skog Saugbrugs	Biogas from biorefinery side-streams
Solenis Norway AS	Industry chemicals from woody biomass

Neste (FI)	Biorefinery
Alginor ASA	Seaweed products from a multifunctional biorefinery
Biofuels distributors and end users	**Main interest**
Eco1 as	Biodiesel and biooil distribution in Norway
St1 Norge as	Bioethanol production and distribution in Norway
Preem (SE)	Biofuels production and distribution in Sweden/Norway
Volvo Group Trucks Technology (SE)	Truck engines powered by biofuels
Avinor	BioJetFuels for Norwegian airports
Government and State Partners	**Main interest**
Østfold Fylkeskommune	Sustainability, Resource Use, Transport policy, Technical Economics
Hedmark Fylkeskommune	Sustainability, Resource Use, Transport policy, Technical Economics
Akershus Fylkeskommune	Sustainability, Resource Use, Transport policy, Technical Economics
Oppland Fylkeskommune	Sustainability, Resource Use, Transport policy, Technical Economics
Trøndelag Fylkeskommune	Sustainability, Resource Use, Transport policy, Technical Economics
Follorådet	Sustainability, Resource Use, Transport policy, Technical Economics
Miljødirektoratet	Sustainability, Resource Use, Transport policy
Statens Vegvesen	Sustainability, Resource Use, Transport policy, Technical Economics
NVE	Sustainability, Resource Use, Transport policy, Technical Economics
Innovasjon Norge	Sustainability, Resource Use, Transport policy, Technical Economics

WORK PACKAGES AND SUB PROJECTS

	Name	institution	Main research area
	Sub Projects Leaders		
	Francesco Cherubini (leader SP1)	NTNU	Bio-resource, Environment and Climate
	Judith Sandquist (leader SP2)	SINTEF	Primary Biomass Conversion
	Aniko Varnai (leader SP3)	NMBU	Secondary Conversion and Upgrading
	Bernd Wittgens (leader SP4)	SINTEF	Process design and End Use
	WorkPackage Leaders		
	Rasmus Astrup (leader WP 1.1)	NIBIO	Resources and Ecosystem processes
	Francesco Cherubini (leader WP 1.2)	NTNU	Bio-Resources, Environment, Climate
	Torjus Bolkesjø (leaderWP 1.3)	NMBU	Energy, Fuels and Economics
	Morten Seljeskog (leader WP 2.1)	SINTEF	Gasification
	Kai Toven (leader WP 2.2)	RISE PFI	Pyrolysis
	Judit Sandquist (leader WP 2.3)	NTNU	Hydrothermal Liquefaction
	Øyvind Eriksen (leader WP 2.4)	RISE PFI	Pretreatment and Fractionation
	Aniko Varnai (leader WP 2.5)	NMBU	Enzymatic Saccharification
	Edd Blekkan (leader WP 3.1)	NTNU	Gas Conditioning
	Roman Tschentscher (leader WP 3.2)	SINTEF	Thermochemical upgrading of bio oils
	De Chen (leader WP 3.3)	NTNU	Chemo-catalytic conversion
	Alexander Wentzel (leader WP 3.4)	SINTEF	Fermentation
	Tormod Briseid (leader WP 3.5)	NIBIO	Anaerobic digestion and gas upgrading
	Heinz Preisig (leader WP 4.1)	NTNU	Modelling Tool for Biorefineries
	Bernd Wittgens (leader WP 4.2)	SINTEF	Techno-Economic Evaluation and Scale of Economy
	Klaus Jens (leader WP 4.3)	USN	Preparing for piloting and up-scale
	Terese Løvås (leader WP 4.4)	NTNU	Product quality and End Use

HIGHLIGHTS FROM 2018

BIO4FUELS' WEBINAR:
TRANSPORTATION BIOFUELS IN THE EU AFTER 2020: THE RED RECAST DIRECTIVE PROPOSAL

June 15 2018

Speakers:	Dr. Monica Padella and Dr. Laura Lonza, European Commission - Joint Research Centre
Title:	Transportation Biofuels in the EU after 2020: the RED Recast Directive Proposal
Moderator:	Prof. Francesco Cherubini, IndEcol - NTNU (Bio4Fuels lead SP1 and WP1.2)
When:	15th June 2018, 10:00 am (link will be distributed)
Duration:	1 hour (5' introduction, 40' presentation, 15' Q&As session)
Video link:	Skype for Business

Information about the speakers:
Monica Padella works as Researcher at the EC-JRC since 2012, and she is in charge of techno-economic assessment of GHG savings for a range of biofuels pathways currently, and expected to be, relevant to Europe.
Laura Lonza is a Scientific Officer at the EC-JRC since 2008, and she is in charge of coordinating and contributing to JRC research activities in the area of alternative transportation fuels.

Link to presentation (pdf) and Webinar (MP4) here:
https://www.nmbu.no/en/services/centers/bio4fuels/news/node/37072

FUELS OF THE FUTURE - A ONE-DAY OPEN WORKSHOP

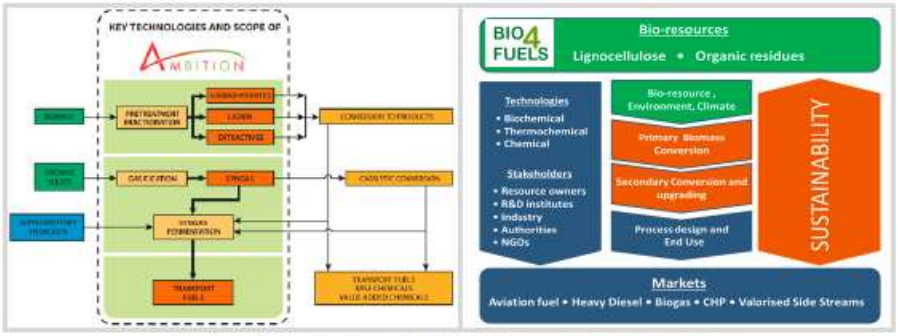
13 September 2018

OPEN WORKSHOP

Process Design and Up-Scaling for Renewable Energy Production

A joint open workshop is scheduled between the two complementary projects AMBITION and Bio4Fuels.

The workshop will provide the opportunity to exchange views, learn from each other and promote alignment in pursuit of high quality output from both projects.



Topics: Integration, Gasification and Fermentation

- ✓ Gasification of side streams (e.g. lignin) from lab scale to large scale
- ✓ Fermentation: the integration challenge
- ✓ Process design for scale up

Finalised programme and registration information coming soon.

Organising Committee: Bernd Wittgens (SINTEF); Francisco Girio (LNEG); Jaap Kiel (TNO/ECN) and Nicolaus Dahmen (KIT)

For more information, contact Bernd Wittgens: bernd.wittgens@sintef.no

Arranged by: the complementary projects AMBITION and Bio4Fuels
Responsible: Bernd Wittgens, SINTEF
Location: Radisson Blu Royal Garden Hotel, Trondheim

Energy System Integration of Bio-Based Fuels

- Energy products of the future - 2050
- Research and innovation needs
- Integration of fuel production into a European Energy System

Programme, Fuels of the Future:

9:00 Welcome / Introduction; Duncan Akporiaye - SINTEF, Leader of FME Bio4Fuels
9:10 Links between Ambition and Bio4Fuels; Bernd Wittgens - SINTEF, Ambition & Bio4Fuels
9:20 Future Ambitions for Liquid Transportation Fuels; Judit Sandquist - SINTEF, Bio4Fuels
9:40 Technical and Economical Evaluation of Biomass-to-Liquid, Power-to-Liquid and (Power & Biomass)-to-Liquid; Moritz Raab - German Aero Space Center
10:10 Hydrogen as Part of the Future (Transportation) Energy System; Torsten Buddenberg - Mitsubishi Hitachi Power Systems
11:00 Discussion Part 1
13:00 Gasification Beyond State of the art; Jaap Kiel - ECN part of TNO
13:20 Catalysis towards Oxygenated Compounds Beyond State of the Art; Armin Günther - Air Liquide
13:40 Biochemical Conversion Oxygenated Compounds Beyond State of the Art; Speaker from industry
14:00 A New Approach to Process Design; Heinz Preisig – NTNU
14:20 Discussions Part 2
15:30 Summary of Discussions

BIO4FUELS DAYS, 11 – 12 OCTOBER 2018

Thursday 11 October – Open Meeting

Theme	**Speaker**
Welcome	Duncan Akporiaye, Centre Leader
Biofuels in Norway	Audun Rosland, Director, the Norwegian Environmental Agency
The IEA's Bioenergy Roadmap	Adam Brown, IEA (Renewable Energy)
Biofuel Innovation and Technology Progress	Jaap Kiel, EERA Bioenergy
Coffee break /Poster Session	
Biofuels, climate change mitigation and sustainability	Francesco Cherubini, NTNU / UNEP
Refining the future - Lignofuels	Niilo Oikarinen, Neste
Sustainability in Elkem	Alf Tore Haug, ELKEM
Effects of the biofuel research in Norway	Odd Jarle Skjelhaugen
Lunch	
Visit to EGE Waste-to-Energy Agency's Biogas Plant	
Dinner at Quality Airport Hotel Gardermoen	

Friday 12 October – Closed Meeting

Theme	**Speaker (responsible)**
Introduction by Silva Green Fuels	Ingo Machenbach
Scientific Presentations - the Bio4Fuels Value Chains. Please see details below.	(SP Leaders)
Coffee / Poster Session	
International Advisory Group – evaluation of Annual Report 2017, Work Plan 2019, scientific presentations and posters	Bio4Fuels' IAG

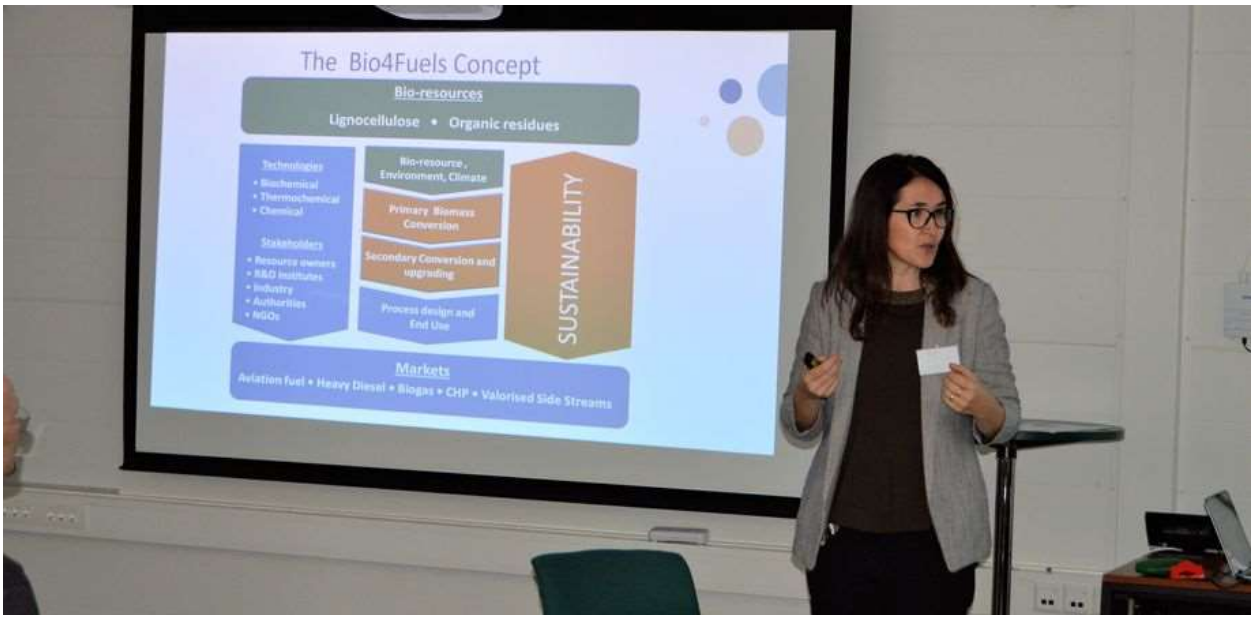
Lunch	
Bio4Fuels Cluster / SP Interactions – Work plans 2019	All / Lead by WP and SP leaders
Bio4Fuels General Assembly 2018 - information	Duncan Akporiaye

Scientific Presentations - the Bio4Fuels Value Chain (SP1, 2, 3, and 4)

SP1	Chair Francesco Cherubini
	NMBU Eirik Ogner Jåstad + **Norges Skogeierforbund** Erlend Grøner Krogstad
SP2	Chair Judit Sandquist
	NMBU Aniko Varnai + **St1** Minna Yamamoto
SP3	Chair Svein Jarle Horn
	NTNU De Chen + **Solenis** Are Wiberg
SP4	Chair Bernd Wittgens
	NTNU David Emberson + **SINTEF** Bernd Wittgens

THE BIO4FUELS 2018 AUTUMN WORKSHOP AT NTNU - THE NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY, TRONDHEIM, NORWAY

November the 5th.



As a stakeholder in the Bio4Fuels FME and with particular interest in the end use of the proposed fuels, the Department of Energy and Process Engineering NTNU, hosted a one day workshop on aspects of the end use of the fuels under development in the FME. The thematic title of the workshop is **Diesel engines for transport - present and future scenarios and their impact on the biofuel implementation.**

The FME mission statement
"The Centre aims to develop innovative technology and support industries to realize economic and sustainable conversion of lignocellulosic biomass and organic residues to **transportation fuels**, along with **added value chemicals**, heat and power"
The workshop will focus on the **transportation fuels** of the mission statement and introduce the current issues facing the diesel engine and some of the future legislative hurdles it will face. This will include an introduction the known public health issue around diesel engine usage. Trends in the internal combustion engine and the possible de-dieselation process will be presented. With these issues in mind the suitable response to the rapidly changing landscape by the Bio4Fuels FME will be discussed.

BIO4FUELS INDUSTRIAL STAKEHOLDERS INSIGHTS

SILVA GREEN FUEL DEMO-PLANT IN PROGRESS

Statkraft and the Swedish Sødra Cell established in 2015 the company Silva Green Fuel to develop a concept for large forest-based biofuel production plants. During two years, 30 processing technologies were tested. In parallel, Silva joined several R&D-projects relevant for this testing.

The winner was Hydrothermal Liquefaction, HTL, developed by the Danish company Steeper Energy. The technology is based on supercritical conversion of biomass, a process with high pressure and high heat. Silva collaborates with Steeper in finding technology- and process-varieties that do not put many restrictions on the feedstock quality. But at the same time, these varieties also cause the highest risk. In the demo-plant, near-full-scale tests will be conducted. However, at a lower cost than in a commercial plant.

Silva decided in 2017 to build this HTL-plant. It will be located at Tofte in Hurum, the same site as Sødra operated its cellulose factory some years ago. During 2018 the test facility has been planned in detail.

If good results from the demo-plant during 2019-2021, several full-scale factories will be planned, within and outside Norway. Each with a production capacity of 100-150 million liters drop-in quality biodiesel annually. As a comparison, the advanced biodiesel production-capacity in E28 was about 33 million liters in 2016.

ST1

St1 owns bioethanol plants in Finland and Sweden and is running an oil refinery in Gothenburg. The company operates retail station chains under the brand names of St1 and Shell in the Nordic countries. Thus, St1's main business and source of income is in the traditional oil industry, but the revenues are invested back into renewable energy like windmill parks, geothermal and biofuels. St1 is producing bioethanol from food industry side streams and lignocellulose waste.

In Kajaani in Finland, St1 has built a 10 million liter demonstration plant where advanced bioethanol is produced from softwood using an in-house developed process called Cellunolix™. Additional products from this biorefinery are lignin, turpentine, furfural, concentrated fermentation rank and CO_2. The process is based on steam explosion pretreatment, enzymatic hydrolysis, fermentation and distillation. St1 has made a letter of intent with Viken Skog to construct a similar Cellunolix® ethanol plant in the

industrial area of Follum in Hønefoss, utilizing the existing industrial infrastructure and equipment from the former paper-mill. The planned production capacity of the plant is 50 million liters of advanced cellulosic bioethanol for transportation, using local forest industry residues as feedstock.

In the Kajaani plant, the annual production volume of lignin side products is approximately double of the bioethanol volume. Therefore, the revenues from lignin is important for the cost effectiveness of the entire process. In solid form, lignin can be used for materials, biofuels or animal feed applications. Liquefied lignin streams may be upgraded and co-fed into oil refinery streams or potentially converted into jet fuel. From the industrial point of view, it is utmost important to create profitable business from lignin to promote the transformation from fossil energy resources to carbon free renewable energy production.

R&D is important for St1 and the company is an active partner in Bio4Fuels. In December 2018 researcher Timo Leskinen from St1 was visiting NMBU. Together with prof. Svein Horn and PhD student Line Hansen, both from NMBU, he carried out a range of novel steam explosion experiments on softwood samples. The effect of these pretreatments on enzymatic hydrolysis is being analyzed, and will help St1 improving their bioethanol process.

UMOE - RENEWABLE FUELS AS SEEN FROM AN INVESTOR

Umoe´s role in the green economy - Umoe's mission is "Building sustainable value", says founder and CEO Jens Ulltveit Moe. My contribution is basically leading by example. With Umoe, I can actually make a change by producing low carbon fuel, by reducing the cost of renewables and by running companies within that field as best as I can. That is tangible, meaningful, and I think also the longer term, profitable. I think this is a unique opportunity of making money and do the right thing at the same time. Those opportunities don't come around that often.

A long-term future for the green economy - For me the essence of the strategy is a concentration now on renewable energy in the economy. That is a big change and a long-term future in renewables. It is in my mind very promising. By going there, we are following a rising trend as opposed to that for the fossil industry, which is at a declining trend.

Invest in green energy now - In five years next to nothing will have happened. It will be a reduced cost in renewables, but the political actions will be very weak. Ten years ahead I think the crises will be very apparent, and there will be a very strong government action. That is the time when renewables will become truly profitable, when there will be stranded assets on the fossil side, and we will have a sharp reduction in CO_2-emissions. The combination of lower renewables cost and government actions means that we probably will solve the climate crises in the end. The big change, when renewables cost less than fossil fuels, is something that was kickstarted by the government, but really created by businesses. In Umoe we are very proud to be part of that trend. What we do is developing our companies and investing in other companies that can do their part of this important job.

Photo: In Brasil, **Umoe Bioenergy** produces sustainable bioethanol from sugar cane, a fuel costing less than fossil fuels.

AVINOR - NORWAY FIRST WITH MANDATORY DROP IN REQUIREMENT FOR JET BIOFUEL

Avinor owns, operates and develops a nationwide network of 45 airports for the civil sector and a combined air navigation service for the civil and military sectors. Sustainability is high on the agenda, and actions leading to lower carbon footprint from airport operations and aircraft have high priority.

Biodiesel for airport operation - Phasing in advanced biodiesel is an important action to reduce greenhouse gas emissions from the airport operations. About half of Avinor's own emissions arise from the airport vehicles. In 2018, 320 000 litres advanced biodiesel for the vehicles and 67 000 litres biooil for heating was phased in at the following airports: Oslo, Trondheim, Bergen, Ålesund, Molde and Kristiansand. Biodiesel consumed at Avinor's airports fulfills EU's sustainability criteria and does not contain palm-oil or palm-oil products.

Bergen Airport Flesland installed a 30 m^3 tank for biodiesel in September 2018, available to all partners operating at the airport. At Trondheim Airport Værnes, the biodiesel blend was about 28 %, and at Oslo Airport 20 %. The 2019 target is to further increase the biodiesel volumes for Avinor as a whole.

Mandatory drop in requirement for jet biofuel in aviation - In the National budget 2019 the Government decided a mandatory drop in requirement of 0,5 % advanced jet biofuel for aviation, starting in 2020. Norway is the first country in the world to introduce such a mandate. The blending has to be reported to the Norwegian product register, and biofuels from problematic feedstocks like palm-oil will not be accepted. Avinor and CAA Norway (Civil Aviation Authority of Norway) have, on behalf of the Ministry of Transport and communications, contributed to the background information and consultation documents. The Government's target for 2030 is 30 % advanced biojetfuel in the aviation fuel sold at Norwegian airports.

BIOZIN – INCLUDING CRUDE-OIL STEP IN THE BIOFUEL PRODUCTION

The company Biozin Holding AS, established in 2017, is owned by Bergene Holm AS, the second largest saw-mill company in Norway. Biozin targets to produce biocrude oil in several decentralised plants in Norway located near the forest feedstocks. The biocrude oil will be sold to Preem AB, the largest oil refinery in Scandinavia, for upgrading to advanced biofuel. Biozin and Preem have signed a long-term collaboration agreement, and both are Bio4Fuels-partners. The decentralised biocrude oil production will reduce transportation cost for the feedstock and open up for cheaper and smaller biocrude oil processing plants. The challenge has been to find the best processing technology.

Biozin conducted in 2018 a concept study to find the best technology and value chain. The outcome was positive. The reduced carbon footprint will be about 90 % compared to fossil fuel. The Biozin-owners have decided to go on to the next step; pre-engineering of a plant to be built near Bergene-Holms sawmill in Åmli in Agder county, a region with large forest resources. The facility will use the same feedstock supply chain as the sawmill, but will include forest residue, non-commercial and other types of softwood. Also, by-products from the sawmill will be utilized. The facility can be one of the first of its kind world-wide, and will be based on the Shell-owned IH^2 thermochemical processing technology.

In Bio4Fuels, Biozin and Preem mainly follow the value-chain initiatives to find if there are steps that can be addressed to improve profitability and/or climate impact. "When working at a full scale level we want to put all questions on the table to launch smooth roll out of the chain of facilities producing the second generation biofuels in Norway", Mikhail Tsypkin, Biozin CTO, states.

Biozin has decided to perform pre-engineering study for the facilitiy with location next to the Bergene Holm saw mill Nidarå in Åmli (Photo: Bergene Holm AS).

BIOKRAFT AS

Biokraft completed and commissioned the world´s largest production facility for LBG (liquid biogas), located at Skogn in central Norway, in the summer of 2018. The factory was officially opened by Prime Minister Erna Solberg on September 2nd 2018, in a ceremony attended by over a hundred dignitaries. The Prime Minister issued thanks to Biokraft for moving Norway towards a greener future.

The completion of the LBG facility coincide with the introduction of heavy-duty vehicles by Volvo, Scania and Iveco that are unique for renewable vehicles in combining long distance with maximum loads, making it possible to replace diesel trucks.

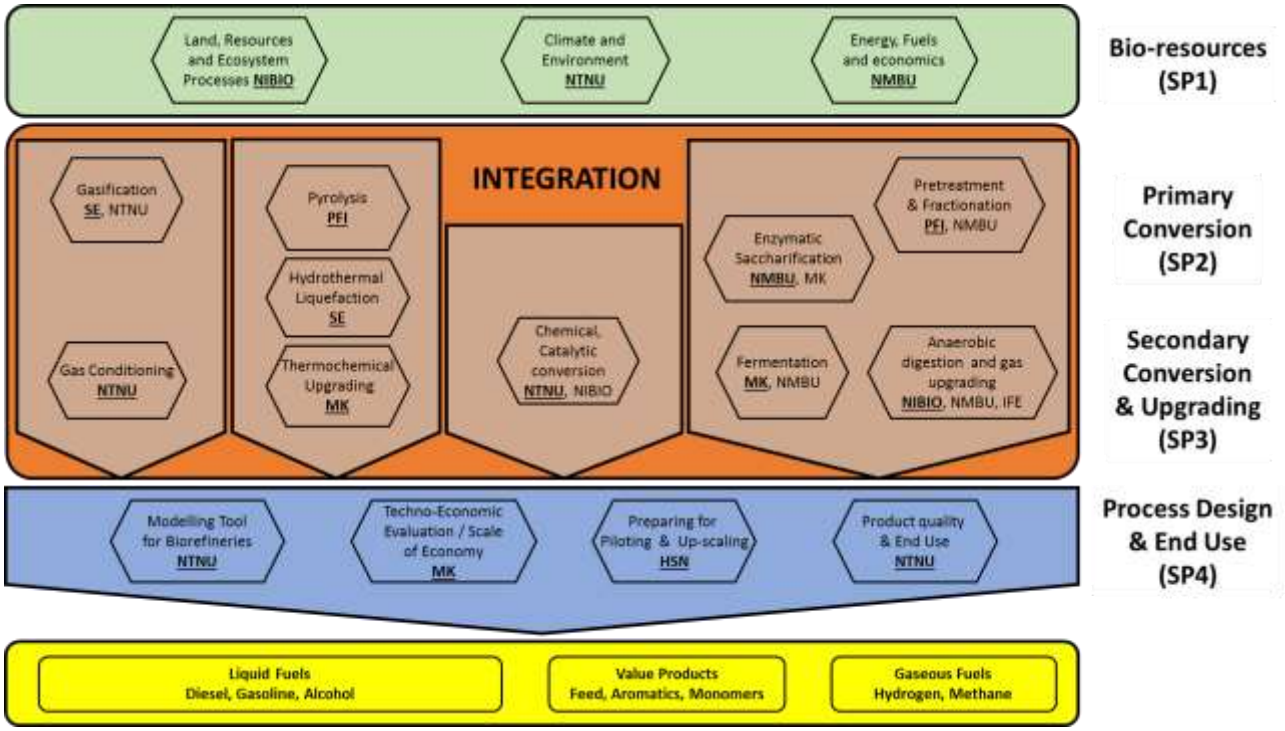
Biokraft´s factory uses a variety of substrates in their process including waste products from fish farming, poultry, industry and manure, as well as biproducts from paper production supplied by their neighbor Norske Skog. In addition to building the world´s largest LBG plant, Biokraft also set a speed record in getting it up to production capacity.

Biokraft is ever chasing profitability and, as such, Biokraft is involved in several projects with the aim of improving the process, use new substrates as well as looking at new ways of utilizing by-products of the plants in a more optimal way. Thus, R&D is important for Biokraft and they are involved in the biogas research in Bio4Fuels.Biokraft´s factory at Skogn will initially produce 12.5 million normal-cube-metres (Nm3) of LBG (biogas), with an energy contents of approximately 125 GWh per year. Biokraft intends to double this production capacity at Skogn shortly, and are currently working on several new projects.

Photo: Official opening of Biokraf factory at Skogn by Prime Minister Erna Solberg, September 2nd 2018

HIGHLIGHTS FROM SCIENTIFIC ACTIVITIES

The scientific activities in Bio4Fuels are structured according to the value chains going from accessibility and sustainability of bioresources through to the economics for production and end use.
As shown below, the high-level value chain (SP (sub project)) establishes interaction across focussed research activities (workpackages (WP)) addressing the four challenges of bioresources (SP1), Primary conversion (SP2), Upgrading (SP3) and end use. Within this organisation, Bio4Fuels has the flexibility to coordinate activities along focussed value chains looking at addressing specific challenges of the main technologies for conversion and upgrading. These include thermochemical, chemical and biochemical conversion approaches.



SP1: Bio-resource, Environment and Climate	
- Resource use and availability in Norway. - Climate change impacts and mitigation - Economic policies for sustainable biofuel economy	
SP Leader: Francesco Cherubini	
WP1.1	Land, Resources and Ecosystem Processes (Rasmus Aastrup, NIBIO)
WP1.2	Climate and Environment (Francesco Cherubini, NTNU)
WP1.3	Energy, Fuels and Economics (Torjus Bolkesjø, NMBU)

BACKGROUND AND APPROACHES

This subproject addresses important aspects related to bio-resources with a particular focus to Norway, their management, and the climate change mitigation of biofuel and co-product systems. This includes the availability and options for procurement under different management strategies; the physical attributes of ecosystem structure and processes resulting from different procurement and management strategies. With respect to resource availability, a suite of state of the art modelling tools will be applied to simulate forest state and structure. Biogeochemical (e.g., related to CO_2 and other greenhouse gases) and biogeophysical (e.g., surface albedo) changes induced by land management that, in addition to life cycle emissions along the value chain and subsequent use

The impacts on climate will be computed using up-to-date models and approaches and outcomes will in turn be used to inform policy makers of the best way to manage forestland and bioenergy options under the dual goal of renewable energy supply and climate change mitigation

The economy of biofuels and potential co-products will also be analysed including analysis of current and near term economic measures and policies governing the many aspects of Scandinavian biofuel economy with the view to outlining potential sound economic policies to enable a sustainable biofuel economy in Norway and Scandinavia.

NORDIC BIOFUELS RAW MATERIAL AVAILABILITY

Forest-based biofuel production in the Nordic countries is not constrained by raw material availability, Bio4Fuels researchers claim.

Norway and the other Nordic countries have set ambiguous targets for biofuel use. Currently, most of the raw materials are imported and the sustainability of some of them – e.g. palm and soy oil – is being questioned. An interesting question in this setting is the possibilities and costs of producing large quantities of biofuels based on forest resources in the Nordic countries. This is one of the key questions the research group at NMBU led by prof. Torjus F. Bolkesjø it trying to answer.

The good news is that there are quite large biomass volumes available from a pure resource viewpoint. Modellings results show that even a 40% biofuel share – equal to 11.6 billion liters– in the Nordic counties combined is possible without compromising sustainability. It would, however, have quite large impacts to the profitability in existing pulp and paper industries since the competition for wood fiber increases. According to the modelling assumptions, this production level will require about 100 million m^3 (solid) wood of different qualities. This is roughly 60% of the current harvest in the Nordic countries, and thus, a substantial amount of wood. However, only about 25% is sourced from increased harvest. The other sources

are increase in imports (15 %), increase in the utilization of harvest residues (38 %), and reduced pulp and paper production that frees up the rest of the necessary wood. Lower levels of biofuel production show similar patterns.

Pulpwood prices (delivered plant gate) increase up to 25 % in the 40 % biofuel scenario, according tot the model results performed in WP 1.3. This is what leads to the traditional pulp and paper industry being partly out-competed. Their profits reduce up to 23%. Forest owners, on the other hand, will be benefit greatly since harvest increase, prices increase and more sales of harvest residues increase.

It is not likely that the Nordic countries will aim at producing 40 % biofuels, but the price and competition effects are substantial also at lower levels of production. “Balancing the needs for change and needs of the existing industries is always a challenge when devising policies”, Bolkesjø replies to the results. As such the current study could inform those developing polices on some of such trade-offs.

Source: Jåstad, E. O., Bolkesjø, T. F., Trømborg, E. & Rørstad, P. K. (2019). Large-scale forest-based biofuel production in the Nordic forest sector: Effects on the economics of forestry and forest industries. *Energy Conversion and Management*, 184: 374-388. doi: https://doi.org/10.1016/j.enconman.2019.01.065.

BIOFUELS AND CLIMATE CHANGE: FOREST FOR SUSTAINABLE FLYING

Forests may offer us more than timber and ecosystems services; they may offer a more sustainable way of flying. This was proposed in a new paper published in Nature Sustainability by NTNU researchers Otavio Cavalett and Francesco Cherubini. Cherubini heads up the Bio4Fuels sub-project on Bio-resource, Environment and Climate.

The full paper is available here: **https://rdcu.be/bbB2K**.

In a post on Nature’s sustainability community blog, Cavalett, by taking a personal example, explains this further. Renewable jet fuels promotes sizeable climate mitigation benefits. Sometimes, though, this comes at a cost of unexpected implications to other Sustainable Development Goals. Yet, most of these adverse side effects are attenuated when improved conversion technologies and cleaner inputs are used for renewable jet fuel production.

nature sustainability
ANALYSIS
https://doi.org/10.1038/s41893-018-0181-2

Contribution of jet fuel from forest residues to multiple Sustainable Development Goals

Otavio Cavalett * and Francesco Cherubini

With limited decarbonization options in the aviation sector, renewable jet fuels produced from biomass resources represent a promising opportunity. However, potential implications of their deployment on the Sustainable Development Goals (SDGs) remain largely unexplored. We introduce an approach for SDG analysis based on life-cycle impact assessment methods. We show that climate action benefits of renewable jet fuels produced from forest residues available in Norway are larger in the medium/longer term than the shorter term, but they increase pressure on other SDGs—mainly SDGs 2, 3, 6, 11, 12 and 14—especially for alcohol-to-jet fuel technology. Most of these adverse side-effects are alleviated with technological and supply-chain improvements. Environmental sustainability analysis can identify both synergies (mitigation options that co-deliver across SDGs) and trade-offs between climate change mitigation and the SDGs, thereby supporting their early management and mitigation.

SP2: Primary Biomass Conversion
- Saccharification of softwood - Energy efficiency and feedstock flexibility
SP Leader: Berta Matas Güell

WP2.1	Gasification (Per Carlsson, SINTEF ER)
WP2.2	Pyrolysis (K. Toven, PFI)
WP2.3	Hydrothermal Liquefaction (Judit Sandquist, SINTEF ER)
WP2.4	Pretreatment and Fractionation (K. Øyaas, PFI)
WP2.5	Enzymatic Saccharification (A.Varnai, NMBU)

BACKGROUND AND APPROACHES

The activities in this subproject addresses the first difficult step in the breakdown of the biomass feedstock to an intermediate state using a variety of approaches.
Using thermochemical steps, gasification activities will be focused on process economy and feedstock flexibility, with the key challenge being in downscaling. Better heat integration and heat utilization aims to remove the dependency on low grade heat utilization such as district heating grids. The main research ambition is to have identified and improved a suitable gasification technology that can be integrated into a complete value chain, from feedstock to biofuels.

The pyrolysis approach for producing liquid bio-oils, gas and biochar will be based on fast pyrolysis technology, addressing the challenges of enhancing energy recovery from lignocellulosic feedstocks by linking fast pyrolysis with anaerobic digestion; and developing technology for direct conversion of lignocellulose feedstocks into gasoline range hydrocarbons by combining fast pyrolysis with direct vapour upgrading.

The alternative Hydrothermal Liquefaction approach aims to further development and establishment of HTL plants towards commercialization and deployment. This will include identification, evaluation and preparation of biomass feedstocks/blends, including side-streams from other value chains (e.g. lignin-rich streams), relevant for the production of biocrude through HTL. Process conditions for stable continuous operation, with goals of mitigation of the feedstock dependence on the biocrude quality and stability and minimization of the organic matter in aqueous phase.

With respect to biochemical approaches, pre-treatment, fractionation and enzymatic saccharification will be addressed. Focus of the pre-treatment and fractionation activities will be on pre-extraction of hemicelluloses, high lignin separation efficiency and effective breaking of the crystalline lignocellulose structure to make the carbohydrate fraction more accessible via optimization of steam pre-treatment technologies and water based hemicelluloses pre-extraction process and organosolv based lignin separation.
Focus on improvement of saccharification for wood processing will be directed to identify enzyme activities critical for softwood conversion, developing efficient processes for saccharification of softwood at high dry matter (DM) and development of new enzyme cocktails for commercially feasible softwood saccharification.

LIQUID BIOFUELS: CONVERTING WET BIOMASS

Hydrothermal liquefaction (HTL) and hydrothermal carbonization (HTC) are processes of particular interest to convert wet biomass to respectively primarily liquid biofuel and biochar. However, inorganics (ash) present in the biomass may cause operational challenges, e.g. corrosion and reactor clogging. It is therefore important to be able to predict and understand their fate (speciation and phase distribution) with the aim of mitigating any detrimental effect, especially when upscaling the process.

Thermodynamic equilibrium calculations (based on Gibb's free energy minimization and a Matlab-based model initially developed at Delft University of Technology) was used to simulate hydrothermal process conditions for a variety of feedstocks. The initial findings investigating the HTC conditions suggest that the ideal temperature with regards to minimize reactor clogging should be decided based on the feedstock composition.

Feedstocks high in Si, but low on other inorganic elements should be run on high temperatures. Feedstocks high in Ca, Mg and P, but low on Si should be run on low temperatures. As Cl chemistry is not affected by feedstock concentration nor temperature, the only thing one can do to minimize corrosion by Cl is to avoid feedstocks high in Cl.

BIOFUELS RESOURCES: NOVEL ENZYMATIC SACCHARIFICATION MECHANISM

In collaboration with industry partners, the Bio4Fuels research team has successfully applied a novel enzymatic mechanism for biomass saccharification.

By 2017, Bastien Bissaro, a guest researcher from INRA (France) and the NMBU team led by Prof. Vincent Eijsink discovered that oxidative enzymes called LPMOs (lytic polysaccharide monooxygenases) do not need oxygen but hydrogen peroxide to break down cellulose. To implement this ground-breaking discovery in industrial biorefining, the setups currently in use for enzymatic saccharification needed to be reconsidered.

In 2018, a team led by Profs. Svein Horn and Vincent Eijsink has been working in close collaboration with Bio4Fuels partners Novozymes and Borregaard to develop an industrial setup in order to harness LPMO action in a more efficient way. In a recent publication in the journal *Biotechnology for Biofuels*, the team showcased the successful application of hydrogen peroxide for improving saccharification of Borregaard's BALI-pretreated spruce (see Figure, next page). We believe that this is only a start and that there is still much more to be achieved.

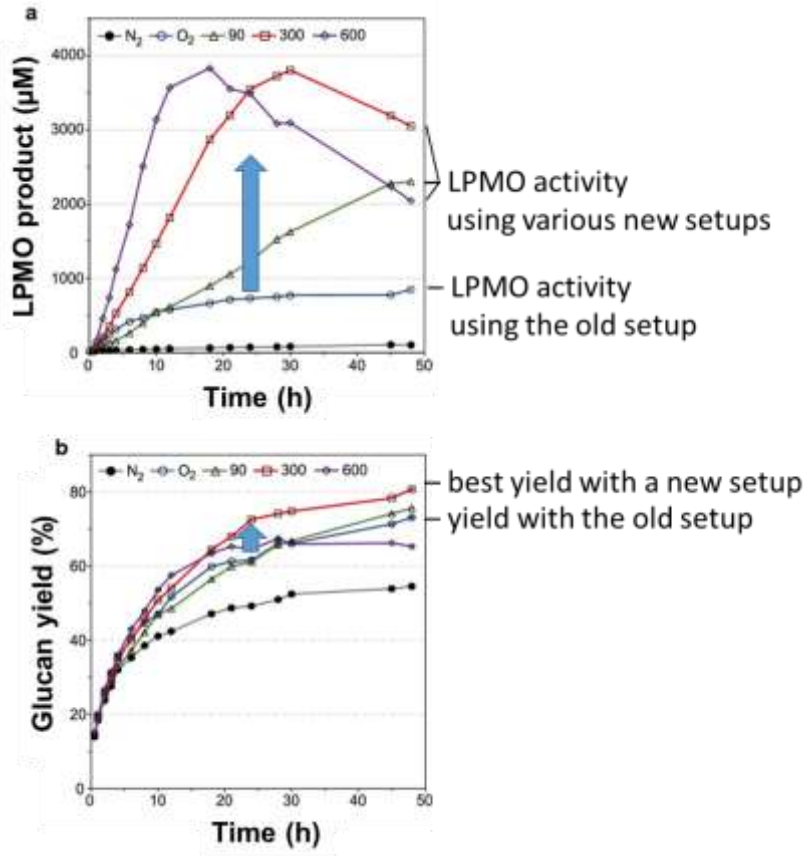


Figure showing how the action of LPMOs and, consequently, the total saccharification yield is boosted by changing to the new saccharification setup. The figure has been adapted from the publication by Müller, Chylenski et al. in Biotechnol Biofuels 11:209.

The NMBU team has been disseminating information about the recent developments at the most relevant conferences in the field worldwide, including the GRC (Gordon Research Conferences) on Cellulases and Other Carbohydrate-Active Enzymes (by Bastien Bissaro, July 2017), Symposium on Biotechnology for Fuels and Chemicals (by Svein Horn, May 2018), the Lignobiotech V Symposium (by Svein Horn, Aug 2018), an EMBO Workshop entitled Enzymes, biocatalysis and chemical biology (by Anikó Várnai, Sept 2018) and the GRC on Metals in Biology (by Vincent Eijsink, Jan 2019). The leading role of the NMBU team in this field has been also recognized through a number of recent invited review papers for prestigious journals, namely *Microbiology and Molecular Biology Reviews*, *Biotechnology for Biofuels*, *ACS Catalysis* and *Current Opinion in Structural Biology*.

In relation to Bio4Fuels, the add-on project Enzymes4Fuels, funded by the Research Council of Norway, has been started up in 2018. This project will work synergistically with Bio4Fuels to investigate the role of hemicellulases in biomass saccharification and to find ways for obtaining a lignin fraction with improved properties for lignin valorization.

SP3: Secondary Conversion and Upgrading
- Energy efficiency and high yields - Fermentation for novel fuels
SP Leader: Vincent Eijsink …

WP3.1	Gas Conditioning (Edd Blekken, NTNU)
WP3.2	Thermochemical Upgrading (R. Tschentscher, SINTEF MK)
WP3.3	Chemo-catalytic conversion (D. Chen, NTNU)
WP3.4	Fermentation (A. Wentzel, SINTEF MK)
WP3.5	Anaerobic digestion and gas upgrading (T. Briseid, NIBIO)

BACKGROUND AND APPROACHES

The subproject on secondary conversion is targeted to upgrading intermediates from the primary conversion including the potential of production direct from biomass. With respect to thermochemical routes; a main hurdle for the gasification is the thermal efficiency of the overall process, making gas cleaning and conditioning an important factor to investigate. This includes, removing volatile inorganic species as well as tars and lighter hydrocarbons that are formed in the processing of the biomass. For the liquefaction routes, the focus is towards the challenges in the development of suitable catalysts for upgrading of bio-oils to fuels, aiming to selectively remove oxygen while keeping the hydrogen consumption low. The upgraded oils and fuel blends will be characterized with regards to their suitability for further conversion to fuels and basic chemicals.

Additional options of catalytic chemical conversion are also being investigated. This will focus on conversion of the targeted components of biomass feedstock, such as separated carbohydrates, cellulose, hemicellulose and lignin to valuable products. This will be based on approaches by integrating advanced synthesis, characterization of catalysts and kinetic studies.

With respect to biochemical approaches, fermentation will focus on processes for production of higher alcohols and esters, and the production of oils. This will include development of high productivity, robust microorganisms and process intensification by integration of fermentation processes and in-situ product removal. Anaerobic digestion and gas upgrading, will provide pathways for converting residue fractions from lignocellulosic liquid and solid waste streams to methane as a biofuel. In addition to more efficient production, alternative routes to upgrading to hydrogen will be investigated

BIOMASS TO CHEMICALS

This project is a close collaboration with a leading Danish catalyst and process company Haldor Topsoe. They are developing a process to produce chemicals from sugars. Selective hydrogenation of

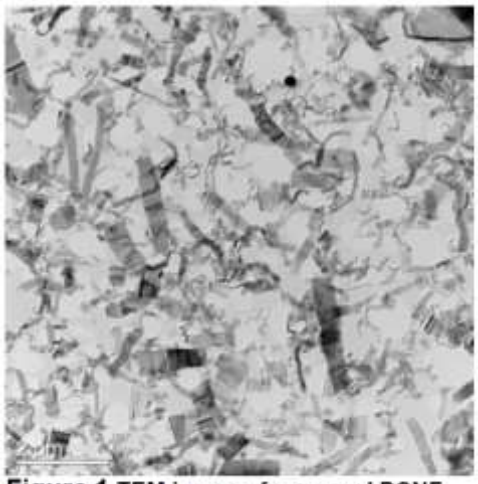
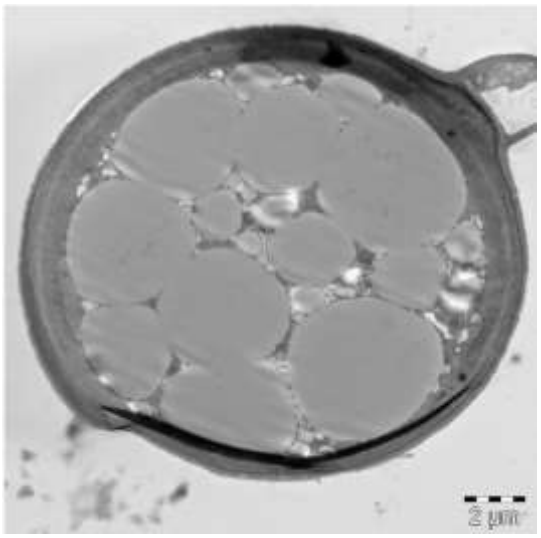


Figure 1 TEM image of prepared PCNF

hydroxyacetone to 1,2-propanediol represent a important step in this process as well as other processes in upgrading biomass to chemicals. Copper based catalyst shows high activity in this reaction, however catalyst deactivation through particle agglomeration, coke formation etc. could be problematic for commercial process. In this project, carbon nanofibers (CNF) interfaces are engineered to tune the interface interaction between metal and carbon surface, hence tuning the reactivity and stability of the supported metal catalyst. The CNFs are prepared by chemical vapor deposition. The effect of copper precursors and solvents will be investigated. The CNFs supported samples will be benchmarked with some commercial carbon supported catalyst.

FERMENTATION



Lignocellulose hydrolysates have been evaluated for the production of fungal lipids by oleaginous fungi *Mucor circinelloides* (Fig. 1). After optimization of macro- and micronutrients the biomass and lipid yield on liglocellulose hydrolysate media was higher than on the control synthetic medium. This is a promissing first results using Norwegian spruce lignocellulose hydrolysates for fungal lipid production.

Figure 1: Hyphae section of oleaginous fungi *Mucor circinelloides* showing accumulation of fungal lipids.

Five moderate thermophilic microorganisms have been selected as anaerobic thermophilic biorefinery candidate strains for further development in Bio4Fuels, i.e. *Clostridium thermocellum*, *C. thermobutyricum*, *C. thermopalmarium*, *Thermobacterium thermosaccharolyticum* and *T. saccharolyticum*. A systematic study of these strains with respect to the production of higher alcohols and organic acids on defined growth substrates and lignocellulose hydrolysates, as well as strain robustness, has been initiated. Microbioreactor technology (BioLector) with the possibility of monitoring 48 cultures in parallel under anaerobic conditions has been implemented as the basis for systematic bioprocess development, in comparison to standard fermentations in serum flasks and DasGip 1 L stirred tank bioreactors (Fig. 2).

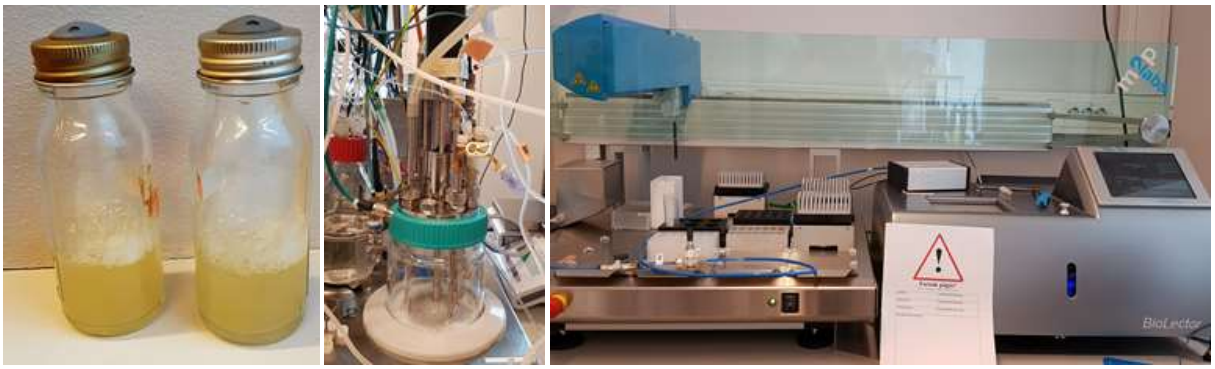


Figure 2: *Clostridium sp.* fermentations at different scale; serum flasks (left), DasGip bioreactors (middle), BioLector microbioreactor system (right).

SP4: Process design and End Use
- Identify most promising process configurations - Efficient and clean end use
SP Leader: Bernd Wittgens

WP4.1	Modelling Tool for Biorefineries (H. Preisig, NTNU)
WP4.2	Techno-Economic Eval. / Scale of Economy (B. Wittgens, SINTEF MK)
WP4.3	Preparing for Piloting and Up-scaling (K. Jens, HSN)
WP4.4	Product quality and End Use (T. Løvås, NTNU)

Background and approaches

The viability of processes and the quality of the products will be addressed using high level modelling tools for Biorefineries with an approach that requires biology, process technology, control and material properties to generate the predictive capabilities of the process models required for design and operations. Techno-Economic Evaluation will be applied to the initial crude process design giving an early phase cost estimation followed by in-depth analyses of the best candidate processes. A framework for process design analysis and optimization will be developed and jointly utilized for design and development of business cases for industrial implementation and thus generate insight into the framework needed for a successful commercialization of the most promising technologies.

With the view to the potentials for commercial implementation and piloting, process concepts will be analyzed and optimized using industrial flow sheeting software (e.g. ASPEN-HYSYS, ASPEN PLUS). The first generation process flowsheets will then be the basis for conceptual design of process instrumentation and control philosophy.

Finally, the activities related to product Quality and End Use will aim to use state-of-the-art simulation and diagnostic tools to develop a framework for optimizing operational cost, energy efficiency and minimizing emissions from biofuel combustion. Focus will include regulated emissions such as NOx, CO, UHC and particulate emissions (soot). Fundamental combustion studies will be performed to map the overall performance of these fuels and ensure safe, clean and durable utilization of biofuels, including studies of new biofuels as well as sn effects of blending into conventional fuels. Approaches will look to coupling state-of-the-art two-phase flow modelling and combustion chemistry with advanced engine and turbine measurements and optical diagnostics tools.

Biofuels End Use: In-Flame Combustion Processes

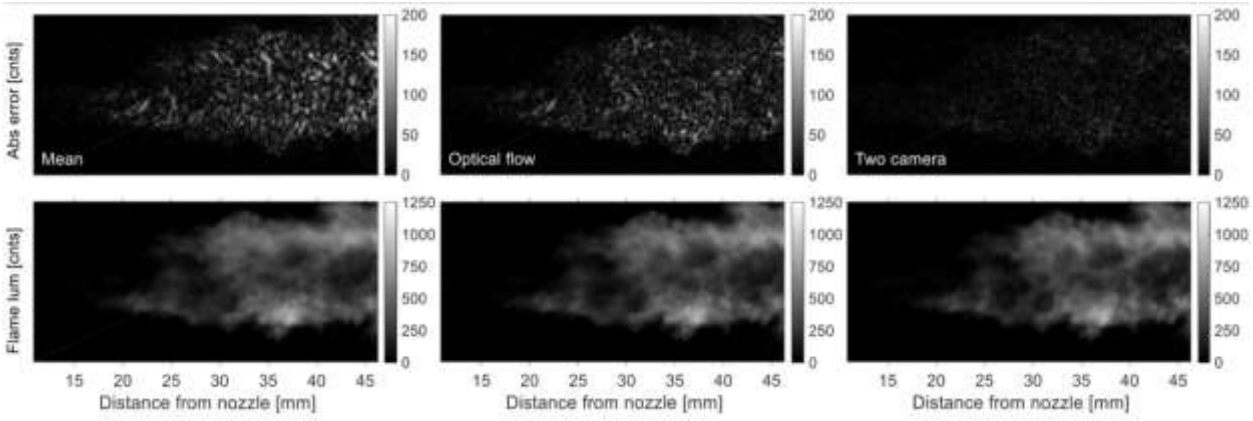
The understanding of in-flame combustion processes resulting in formation and oxidation of soot is of great importance since the underlying physical phenomena are not fully understood, especially for oxygenated fuels such as biofuels. Numerical simulations provide insight to complex processes that are hard to capture in physical experiments, but the models used for running the simulations require validation from experimental results. Temporally and spatially resolved in-flame soot measurements in engines are hard to perform since the process occurs over a few milliseconds, optical access is usually limited, and the

environment in the combustion chamber is harsh, i.e. large density gradients, high temperature and high concentrations of soot. The in-flame measurements are thus prone to large errors.

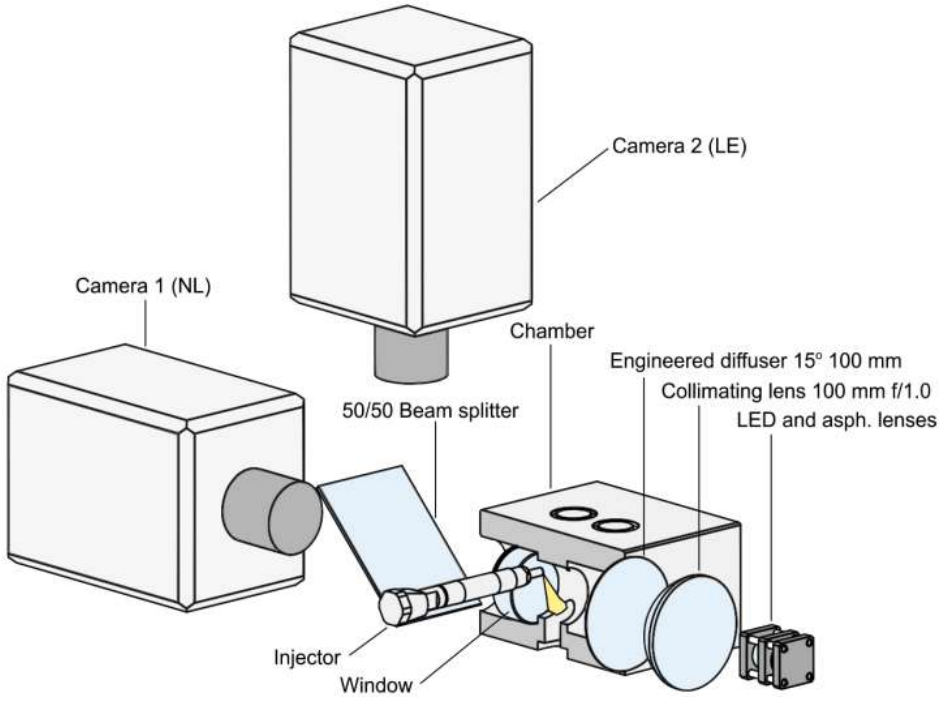
This study presents diagnostic development of diffuse back-illuminated extinction imaging of soot. The method provides high temporal and spatial resolution of the line-of-sight optical density of soot (KL) in compression-ignited fuel sprays relevant to automotive applications. The method is subjected to two major sources of error, beam
steering effects and broadband flame luminosity effects. These were investigated in detail in a direct injection combustion chamber with diesel fuel, under high and low sooting conditions. A new method for correcting flame luminosity effects is presented and involves measuring the flame luminosity using a separate high-speed camera via a beam splitter, i.e. a two-camera method. The new method yields 50% lower errors than the most promising method (optical flow method).

All experiments were performed using the Optical Accessible Compression Ignited Chamber (OACIC) at the Department of Energy and Process Engineering at the Norwegian University of Science and Technology (NTNU). The OACIC is a reciprocating rapid compression machine equipped with windows, enabling line-of-sight optical measurements of the reacting spray under CI engine conditions.

In order to access the errors associated with the estimated flame luminosity distribution (If) after applying the mean, the optical flow or the two-camera method, a sequence of flame only images was collected. The figure below clearly shows that the errors are largest for the mean method, where the turbulent flame structures are not estimated well enough. However, the novel two-camera method yields a much lower error, and will be used for subsequent studies of fuels and their sooting characteristics. Fuels that will be testes are various biofuels, and relevant soot reducing additives.



Experimental setup of the OACIC.



Reference:

Bjørgen, K.O.P., Emberson, D.R., and Lovas, T., "Diffuse Back-Illuminated Extinction Imaging of Soot: Effects of Beam Steering and Flame Luminosity," SAE Technical Paper 2019-01-0011, 2019, doi:10.4271/2019-01-0011.

INTERNATIONAL COOPERATION

Bio4Fuels has from the very start of the operation of the Centre had a significant level of international cooperation at all levels.

INTERNATIONAL AGENCIES AND POLICY FORUMS

IEA

The International Energy Agency has established an important role in collating, reporting within various aspects of Energy. The IEA Bioenergy Technology Collaboration Program is an important arena for collaboration with respect to tracking the status of technology within the Bioenergy area and recommending areas needing increased focus for research. As shown below, partners in Bio4fuels are already involved in key tasks of specific relevance to Norway and the Nordic countries. With respect to Bio4fuels activities, action has now been taken to involve Norwegian partners in the existing task 39, focussing on accelerating the transition of the production of Advanced Biofuels to commercial scale, as well as the newly established Task 45, focussing on the Climate and Sustainability aspects of bioenergy.

Mission Innovation

Mission Innovation was established as an action following up the historic Paris Agreement, with the explicit goal of significantly increasing the research focussed on mitigating climate change. With respect to thiis,Norway has joined the Innovation Challenge 4 (IC4), focussed on Advanced Biofuels. With the role

of taking part in particiipating in IC4 on behalf of Norway, Bio4Fuels attended and presented at the Internation Confernce on Sustainable Biofuels, organised jointly in New Dehli, India by Mission Innovation and Biofutures Platform.

INTERNATIONAL STAKEHOLDERS

With respect to the consortium of partners, the Centre has the strong involvement of a range of leading Nordic and European technology providers, given in Table below. This Nordic/European network is expanded through the involvement of associated partners, from the USA. These partners are active in the research activities and also had a significant role in the Bio4fuels kick-off, providing an international perspective with respect to the state of the art. These partners will in the future operation of the Centre, will also be active as hosts for short mobility tours of students and researchers from the centre to obtain experience in specific areas in an industry context.

International Stakeholders	Country	Main interest
Biomass Technology Group (NL)	NL	Biomass to liquid (btl) pyrolysis
Johnson Matthey (UK)	UK	Chemical and catalytic processing of bio-feedstocks
Novozymes (DK)	DK	Enzymes for forest based biorefineries
Pervatech (NL)	NL	Membrane and separation systems for organic substrates
Haldor Topsøe (DK)	DK	Chemical/catalytic processes for several bio feedstocks
Steeper ENERGY (DK)	DK	Hydrothermal liquefaction
Lund Combustion Engineering as (SE)	SE	Consultancy and software on combustion in motors
Preem (SE)	SE	Biofuels production and distribution in Sweden/Norway
Volvo Group Trucks Technology (SE)	SE	Truck engines powered by biofuels

International Advisory Group

As an important part of the governance of the Bio4Fuels Centre, an International Advisory group has been established with the role of providing an international perspective and evaluation of the scientific activities of the Centre. As outlined under the structure and organisation of the Centre, the members of the Advisory Group have been selected to represent perspectives from Nordic, European and USA, in addition to having deep scientific insight to some of the main pillars of the Centre.

Networks

Combined together in the Centre, most of the research partners have an extensive network of international contacts and collaboration. These include coordinating input to Mission Innovation, representation in EERA, involvement in mobilising input to the revision of the important SET plan for which the Bio4Fuels centre has been proposed as one of the Flagship projects in SET-Plan Action 8 (Renewable fuels and bioenergy) and participating and coordinating national input to the European Technology and Innovation Platform within Bioenergy (ETIP).

For Bio4Fuels, specific links are established with research groups and activities, as listed in the table below. at PNNL, Sandia and RTI in the USA. All partners were involved in the official kick-off of the Bio4Fuels centre and opportunities for collaboration within various international programs are being considered. Within the research topic of final end use of biofuels, Bio4Fuels partners are invited to receive information on the DOE funded project "Co-optima", through participation in the stakeholder Webinars.

Network of associated Research Partners outside Norway

North Carolina University (USA)

Sandia National Laboratories (USA)

Pacific Norwest National La – PNNL (USA)

f3 fossil free fuels (SE)

DTU Chemical Engineering (DK)

University of York (UK)

Abendgoa Research (ES)

EU Research Programs

Many of the research partners involved in the Centre have established a significant portfolio of European projects, both from FP7 and H2020. As shown in the table below, Bio4Fuels partners were involved in at

least 13 active EU projects, with at least 9 projects within H2020. As shown in the table, the projects cover different stages of the Bio4Fuels value chain towards biofuels production, with a total project volume of increasing to approximately 560 MNOK, in spite the completion of a number of projects. This, during 2018, the Bio4fuels partners were involved in securing at least four new projects: Waste2Road, NextGenRoadFuels, Pulp&Fuels and BESTER.

Overview of active EU research projects with involvement of Bio4Fuels research partners

Project	**Project owner**	**Financed by**	**Total budget [mNOK]**	**Platform(s) addressed**
AMBITION	SINTEF MC	H2020-ECRIA	22,5	Biochem./thermochem. platform
BioRaff	PFI	H2020/Interreg	8,1	Biochem./thermochem. platform
ERC starting grant to P. Pope	NMBU	ERC	14	Biochemical – Biogas
METAFLUIDICS	SINTEF Ind	EU - H2020	83,2	Biochemical – Sugar
DAFIA	Aimplas (Spain)	EU - H2020	58	Biochemical platform
Oxytrain	NMBU	MC-ITN	30	Biochemical platform
Prowood	INBIOTEC	ERA-IB; RCN and others	17,5	Biochemical platform
Thermofactories	SINTEF MC	ERA-MBT; RCN + abroad	22,3	Biochemical platform
4Refinery	SINTEF	EU - H2020	60	Chemical
LIBERATE	SINTEF	EU - H2020	60	Chemical
Waste2Road	SINTEF	EU - H2020	60	Chemical
ABC4Soil	NTNU	FACE/EEA	4,8	Thermochemical platform
NextGenRoadFuels	Aarhus (DK)	EU - H2020		Thermochemical platform
Pulp&Fuels	SINTEF	EU - H2020	49	Thermochemical platform
SelectiveLi	SINTEF Ind	EU - H2020	5	Thermochemical platform
BESTER	SINTEF Ind	ERA-CoBioTech Co-Fund; RCN and others	26,9	Biochemical - Sugar
C1Pro	NTNU	ERA-CoBiotech; RCN and others	17,1	Biochemical platform
OXYPOL	SINTEF Ind	ERA-IB; RCN and others	23,3	Biochemical platform

MOBILITY

In 2018, Prof Svein Jarle Horn, deputy leader of Bio4Fuels, spent 6 months on a sabbatical at the University of California, San Diego (UCSD). He worked in the group of Stephen Mayfield, which is a world-leading group in microalgae research. The main part of the research was focused on heterotrophic growth of microalgae, and in particular growth of *Chlamydomonas reinhardtii* on acetic acid. The algae was grown using a pH-stat system, and a novel repeated fed-batch strategy was developed for continuous production of microbial cells. Such oil-rich microalgae may be used for production of fuels, chemicals and food- and feed ingredients. Horn is now continuing the microalgae research at NMBU.

Horn in the laboratory at UCSD growing microalgae in a fermentor.

RECRUITMENTS AND EDUCATION

PhD Student Line Degn Hansen (WP2.5), NMBU

This PhD project is a part of the work package *Enzymatic saccharification* (WP2.5) and will focus on enzymatic saccharification of Norway spruce, with special attention on process optimization and integration. Biochemical biomass-to-liquid processes and the currently available commercial enzyme cocktails have been developed for grasses and hardwood materials and are not optimized for Norwegian biomass. In this project, we are going to identify enzyme components, such as redox and hemicellulolytic accessory enzymes, that are critical for efficient saccharification of softwood. Moreover, the recent discovery of the novel catalytic mechanism of lytic polysaccharide monooxygenases (LPMOs) creates an opportunity to considerably improve saccharification yields by optimizing process parameters including different feed strategies of H_2O_2, the enzyme's co-substrate. The obtained knowledge will be applied to allow better integration of the saccharification and fermentation steps. In addition, the effect of pretreatment type on saccharification and fermentation, regarding the composition of enzyme cocktail and process conditions, will also be assessed in order to achieve higher overall yields while minimizing process costs.

PhD Student Ramesh Timsina (WP4.3), USN

This PhD project is a part of the work package Preparing for Piloting and Up-scaling, WP4.3. The main objective is to establish computational fluid dynamics and process simulation models as basis for the preparation of the pilot plant for biofuel production. The models will include pre-treatment of feedstock, thermal treatment, as well as separation and extraction steps. The thermal conversion technologies gasification, pyrolysis and hydrothermal liquefaction will be studied and evaluated. Experiences from studies in the other work packages will be used to make the framework for the simulation models, and a process flow sheet will be generated.

An important part of the project is to find overall process with minimal waste and high-energy yield for such process plants. Based on existing data from experimental work and simulations, reliable process models will be developed. These models will be used to analyse the results of parameter variations to optimize the process design. The process flowsheets will then be the basis for conceptual design operations. A theoretically optimal solution will be chosen for a pilot plant design.

PhD student Eirik Ogner Jåstad (WP1.3), NMBU

This PhD project is a part of the work package Energy, Fuels and Economics, WP1.3. The aim of my PhD-project is to use economic models to find implication of forest biofuel production in the Nordic countries. In 2018, had I focus on two studies, one that focusing on implications in the traditional forest sector if large amount of biofuel is produced within the Nordic countries. The second study investigates which level of subsidy needed for making biofuel production competitive with the fossil fuel.

The results show that the fossil fuel price has to increase with 2-3x from today's level or the producers has to get an equivalent level of subsidy for making biofuel production competitive at today's raw material costs. Large investments of biofuel will give some structural changes in the traditional forest sector, the main findings is that harvest and utilizing of harvest residues will increase, similar will the net import to the Nordic countries increase simultaneously as the pulp and paper industry will reduce their production.

PhD student Simona Dzurendova (WP3.4), NMBU

The PhD project is part of the work package WP3.4, Fermentation, where one of the objectives is to develop utilization of lignocellulose hydrolysates as a source of carbon for production of microbial lipids by oleaginous fungi fermentation. Oleaginous fungi are able to produce lipids with fatty acids profile similar to vegetable or fish oils. Oleaginous fungi are able to perform concomitant production of lipids and other valuable components as for example chitin/chitosan and polyphosphate. Lignocellulose hydrolysates are liquid materials rich in saccharides, but as shown by our studies, it also contains possible inhibitors of fungal growth. Therefore, there is a need to perform high-throughput screening of different fungal strains and growth conditions in order to find the most suitable fungal producer and optimise composition of lignocellulose-based media for the scale up of the process. Currently we are using synthetic growth media for the bioprocess development that allows us to have full control over the effect of certain micro- and macronutrients on the production of lipids and other valuable co-products, such as chitin/chitosan and polyphosphates. For the process development, we are using a micro-cultivation system combined with vibrational spectroscopy.

PhD student Heidi Østby (WP2.5), NMBU

This PhD project is part of the Enzymes4Fuels project, an add-on project to Bio4Fuels, and is related to the work package Enzymatic Saccharification, WP2.5. There is still considerable potential to improve the efficiency of enzymatic conversion of lignocellulosic biomass, in particular when it comes to Nordic woody biomass. In this project, we will develop new thermostable enzyme cocktails for the conversion of Norwegian woody biomass, primarily softwood, to sugars and lignin fractions. The project will exploit the recent discovery of the hydrogen peroxide-based LPMO catalytic mechanism and hemicellulose-active LPMOs to improve the conversion efficiency.

Additional beneficial effects on efficiency may be achieved by tailoring enzyme cocktails specifically for Nordic woody biomass, with regard to the cellulase mixture and hemicellulases. The key goal of the project is to improve biomass saccharification by the optimal exploitation of LPMOs, and targeted removal of recalcitrant hemicellulose fractions.

Student profile Martina Cazzolaro (WP3.3), NTNU

This project is a part of the work package Catalysis for biomass conversion to chemicals, WP 3.3 and aims to develop a stable copper-based catalyst for selective hydrogenation of hydroxyacetone to 1,2-propanediol, a major commodity chemical. Hydroxyacetone is a by-product of various biomass-based processes: biomass pyrolysis, sugar hydrogenolysis, glycerol dehydration. The main challenge of the project is the catalyst stability towards deactivation. In order to achieve this goal, carbon supports are tested. Platelet carbon nanofibers (PCNF) were prepared via carbon vapor deposition of CO and H2 at 600°C over iron powdered nanoparticles. Various catalysts were prepared using PCNF and varying Cu precursors (nitrate, acetate and basic carbonate) and impregnation solvents (water, ethanol, isopropanol). Characterization of the catalysts and catalyst activity tests will follow.

Moreover, surface treatment of PCNF will be explored, as surface oxidation, foreign-ion doping or confinement effect can be used to tune the surface properties of the carbon nanofibers. She also spend 3 weeks in Haldor Topsoe in June 2018 to learn their experiences and I enjoyed a lot the stay there.

COURSES GIVEN BY BIO4FUELS RESEARCHERS

The researchers connected to the Bio4Fuels Centre are involved in a various courses at NTNU and NMBU. In this way, our research themes and results are present and made relevant for new students in Norway.

Courses at NTNU

Energi- og prosessteknikk, fordypningsprosjekt, 15 sp
Termodynamikk 1, 7,5 sp
Termisk energi, fordypningsprosjekt, 15 sp
Industriell økologi, 15 sp
Klimavern, 7,5 sp
Nanoteknologi, fordypningsprosjekt, 15 sp
Katalyse og petrokjemi, fordypningsemne, 7,5 sp
Kjemisk prosessteknologi, fordypningsprosjekt, 7,5 sp

Courses at NMBU

Bioenergi, 10 sp
Anvendt biokatalyse og bioraffinering, 5 sp

PERSONNEL AND RECRUITMENT

PERSONNEL

Name leader	institution	Main research area
Rasmus Astrup (WP 1.1)	**NIBIO**	Resources and Ecosystem processes
Francesco Cherubini (WP 1.2)	**NTNU**	Bio-Resources, Environment, Climate
Torjus Bolkesjø (WP1.3)	**NMBU**	Energy, Fuels and Economics
Morten Seljeskog (WP 2.1)	**SINTEF**	Gasification
Kai Toven (WP 2.2)	**RISE PFI**	Pyrolysis
Judit Sandquist (WP 2.3)	**NTNU**	Hydrothermal Liquefaction
Øyvind Eriksen (WP 2.4)	**RISE PFI**	Pretreatment and Fractionation
Aniko Varnai (WP 2.5)	**NMBU**	Enzymatic Saccharification
Svein Jarle Horn (WP 2.5)	**NMBU**	Enzymatic Saccharification
Edd Blekkan (WP 3.1)	**NTNU**	Gas Conditioning
Roman Tschentscher (WP 3.2)	**SINTEF**	Thermochemical upgrading of bio oils
De Chen (WP 3.3)	**NTNU**	Chemo-catalytic conversion
Alexander Wentzel (WP 3.4)	**SINTEF**	Fermentation
Tormod Briseid (WP 3.5)	**NIBIO**	Anaerobic digestion and gas upgrading
Heinz Preisig (WP 4.1)	**NTNU**	Modelling Tool for Biorefineries
Bernd Wittgens (WP 4.2)	**SINTEF**	Techno-Economic Evaluation and Scale of Economy
Klaus Jens (WP 4.3)	**USN**	Preparing for piloting and up-scale
Terese Løvås (WP 4.4)	**NTNU**	Product quality and End Use
Francesco Cherubini (SP1)	**NTNU**	Bio-resource, Environment and Climate
Judit Sandquist (SP2)	**SINTEF**	Primary Biomass Conversion
Aniko Varnai (SP3)	**NMBU**	Secondary Conversion and Upgrading
Bernd Wittgens (SP4)	**SINTEF**	Process design and End Use
Duncan Akporiaye	**SINTEF**	Centre Leader
Torjus Bolkesjø	**NMBU**	Vice Centre Leader
Odd Jarle Skjelhaugen	**NMBU**	Project Leader
Janne Beate Utåker	**NMBU**	Administrator

RECRUITMENT

PhD Students with finance from the Bio4Fuels budget:

Name	Nationality	Duration	Gender	Topic
Line Degn Hansen	Danish	01.06.2017 – 31.05.2021	F	Optimization of enzymatic conversion of biomass to platform chemicals (WP2.5).
Eirik Ogner Jåstad	Norwegian	01.02.2017 – 31.12.2020	M	Models for Economic Assessments of Second Generation Biofuel Production (WP1.3).
Martina Cazzolaro	Italian	01.08.2017 – 31.07.2020	F	Catalytic biomass conversion (WP3.3).
Vaibhav Sahu	Indian	01.03.2017 – 15.05.2018	M	Combustion and emission characteristics of low carbon biofuels (WP4.4). *Position terminated due to personal reasons.*
Simona Dzurendova	Slovakia	14.09.2017 – 13.09.2020	F	Bioconversion of lignocellulose materials into lipid rich fungal biomass (WP3.2).
Ramesh Timsina	Nepal	24.09.2018 – 24.09.2021	M	*Preparing for Piloting and Up-scale* (WP4.3)

Postdoctoral Researchers with financial support from Bio4Fuels budget

Name	Nationality	Duration	Gender	Topic
Radziah Wahid	Malaysia	01.01.2017 – 05.09.2019	M	Enzymatic Saccharification
Otávio Cavalett	Italian	18.08.2017 - 17.08.2019	M	LCA of biofuels in Norway

Other researchers

Name	Institution	Duration	WP
Boris Zimmermann	NMBU	01.02.2017 – 31.12.2023	3.4
Per Kristian Rørstad	NIBIO	01.01.2017 – 31.12.2020	1.3
Volha Shapaval	NMBU	01.02.2017 – 31.12.2023	3.4
Achim Kohler	NMBU	01.02.2017 – 31.12.2023	3.4
Jia Yang	NTNU	Permanent position	3.3
Liang Wang	SINTEF Energy		3.2

Michaël Becidan	SINTEF Energy		3.2
Øyvind Skreiberg	SINTEF Energy		3.2
David Emberson	NTNU		4.4
Roar Linjordet	NIBIO		1.3
Hege Bergheim	NBIO		1.3
Julien Meyer	IFE		

PhD students with financial support from other sources:

Name	Funding	Nationality	Duration	Gender	Topic
Kine Svensson	NIBIO	Norwegian	01.02.2015 – 31.01.2018	F	Pre-treatment, post-treatment and recirculation as strategy for improved biogas-yield in anaerobic digestion of food waste
Jianyu Ma	NRC "Chemical Looping Desulfurization"	Chinese	28.09.17-27.09.2020	M	Hot gas cleaning using solid sorbents, sorbent development, reactor development, kinetics and modelling.

MEDIA, PUBLICATIONS AND DISSEMINATION

COMMUNICATION AND OUTREACH

Data from Cristin https://app.cristin.no/

Eide, Kristine Bistrup.
Skattkammeret i skogen. Bondebladet [Avis] 2018-10-18 NMBU

Eijsink, Vincent.
Avfall blir gull verdt takket være enzymer. Forskning.no [Internett] 2018-10-15 NMBU

Eijsink, Vincent.
Enzymer skaper nytt fôr og ny gjødsel.. Nasjonen [Avis] 2018-10-16 NMBU

Sandquist, Judit.
Status biodrivstoff 2018 (i Norge og verden). #SINTEFblogg [Internett]
ENERGISINT SINTEF

Sandquist, Judit.
Status of biofuels in Norway and worldwide 2018. #SINTEFblog [Internett]
ENERGISINT SINTEF

PUBLICATIONS 2018

Data from Cristin https://app.cristin.no/

Birgen, Cansu; Markussen, Sidsel; Wentzel, Alexander; Preisig, Heinz A..
Response Surface Methodology for Understanding Glucose and Xylose Utilization by Clostridium beijerinckii NCIMB 8052. *Chemical Engineering Transactions* 2018 ; Volum 65. s.61-66
NTNU SINTEF

Birgen, Cansu; Markussen, Sidsel; Wentzel, Alexander; Preisig, Heinz A..
The Effect of Feeding Strategy on Butanol Production by Clostridium beijerinckii NCIMB 8052 Using Glucose and Xylose. *Chemical Engineering Transactions* 2018 ; Volum 65. s.283-288
NTNU SINTEF

Birgen, Cansu; Markussen, Sidsel; Wentzel, Alexander; Preisig, Heinz A.; Wittgens, Bernd.
Modeling the Growth of Clostridium beijerinckii NCIMB 8052 on Lignocellulosic Sugars. *Chemical Engineering Transactions* 2018 ; Volum 65. s.289-294
NTNU SINTEF

Cavalett, Otávio.
From political to climate crisis. *Nature Climate Change* 2018 s.663-664 NTNU

Cavalett, Otávio; Cherubini, Francesco.
Contribution of jet fuel from forest residues to multiple Sustainable Development Goals. *Nature Sustainability* 2018 ;Volum 1.(12) s.799-807 NTNU

Cavalett, Otávio; Slettmo, Sigurd Norem; Cherubini, Francesco.
Energy and Environmental Aspects of Using Eucalyptus from Brazil for Energy and Transportation Services in Europe. *Sustainability* 2018 ; Volum 10.(11) s.1-18
NTNU

Gavrilovic, Ljubisa; Brandin, Jan; Holmen, Anders; Venvik, Hilde Johnsen; Myrstad, Rune; Blekkan, Edd Anders.
Deactivation of Co-based Fischer-Tropsch Catalyst by Aerosol Deposition of Potassium Salts. *Industrial & Engineering Chemistry Research* 2018; Volum 57.(6) s.1935-1942
NTNU SINTEF

Gavrilovic, Ljubisa; Brandin, Jan; Holmen, Anders; Venvik, Hilde Johnsen; Myrstad, Rune; Blekkan, Edd Anders.
Fischer-Tropsch synthesis—Investigation of the deactivation of a Co catalyst by exposure to aerosol particles of potassium salt. *Applied Catalysis B: Environmental* 2018 ; Volum 230. s.203-209
NTNU SINTEF

Jåstad, Eirik Ogner; Mustapha, Walid Fayez; Bolkesjø, Torjus Folsland; Trømborg, Erik; Solberg, Birger.
Modelling of uncertainty in the economic development of the Norwegian forest sector. *Journal of Forest Economics* 2018 ;Volum 32. s.106-115
NMBU

Kòsa, Gergely; Vuoristo, Kiira; Horn, Svein Jarle; Zimmermann, Boris; Afseth, Nils Kristian; Kohler, Achim; Shapaval, Volha. Assessment of the scalability of a microtiter plate system for screening of oleaginous microorganisms. *Applied Microbiology and Biotechnology* 2018 ; Volum 102.(11) s.4915-4925
NOFIMA NMBU

Müller, Gerdt; Chylenski, Piotr; Bissaro, Bastien; Eijsink, Vincent; Horn, Svein Jarle.
The impact of hydrogen peroxide supply on LPMO activity and overall saccharification efficiency of a commercial cellulase cocktail. *Biotechnology for Biofuels* 2018 ; Volum 11.(209)
NMBU

Sandquist, Judit; Tschentscher, Roman; del Alamo Serrano, Gonzalo.
Hydrothermal liquefaction of organic resources in biotechnology: how does it work and what can be achieved?. *Applied Microbiology and Biotechnology* 2018 ;Volum 103.(2) s.673-684
ENERGISINT SINTEF

Svensson, Kine; Paruch, Lisa; Gaby, John Christian; Linjordet, Roar.
Feeding frequency influences process performance and microbial community composition in anaerobic digesters treating steam exploded food waste. *Bioresource Technology* 2018 ; Volum 269. s.276-284
NIBIO NMBU

CONFERENCES, LECTURES

Data from Cristin https://app.cristin.no/

Austad, Anna; Fredriksen, Lasse; Eijsink, Vincent; Vaaje-Kolstad, Gustav.
Enzymatic conversion of waste cotton textiles to glucose;. Norwegian Biochemical Society Contact meeting; 2018-01-18 - 2018-01-21 NMBU

Bissaro, Bastien; Isaksen, Ingvild; Eijsink, Vincent; Kjendseth, Åsmund Røhr.
The roles of H2O2 and lytic polysaccharide monooxygenases (LPMOs) in biomass conversion. Norwegian Biochemical Society Contact meeting; 2018-01-18 - 2018-01-21
NMBU

Blekkan, Edd Anders; Ma, Jianyu; Rout, Kumar Ranjan; Stavnes, Siri.
Zirconium promoted manganese-based solid sorbents for H2S capture. 10th Int, Conference on Environmental catalysis and 3rd EECAT; 2018- 09-22 - 2018-09-26
NTNU SINTEF

Cherubini, Francesco.
Biofuels: current status, climate effects, and resource availability. Biodrivstoffseminar med Klima- og miljøminister Ola Elvestuen; 2018-01-29 NTNU

Chytil, Svatopluk; Kure, Milly; Lødeng, Rune; Rout, Kumar Ranjan; Ma, Jianyu; Blekkan, Edd Anders.
Supported manganese sorbents for H2S capture. 25th Int. Symposium on Chemical Reaction Engineering (ISCRE); 2018-05-20 - 2018-05-23 NTNU SINTEF

Dzurendova, Simona; Zimmermann, Boris; Kohler, Achim; Hansen, Line Degn; Varnai, Aniko; Horn, Svein Jarle; Eijsink, Vincent; Marova, Ivana; Shapaval, Volha.
Evaluation of the lignocellulose hydrolysate materials as a substrate for the sustainable production of high-value single cell oils. Exploring lignocellulosic biomass: challenges and opportunity for bioeconomy" (ELB 2018); 2018-06-26 - 2018-06-29
NMBU

Dzurendova, Simona; Zimmermann, Boris; Kohler, Achim; Hansen, Line Degn; Varnai, Aniko; Horn, Svein Jarle; Eijsink, Vincent; Shapaval, Volha.
Evaluation of the lignocellulose hydrolysates as a substrate for the production of single cell oils by filamentous fungi. Bio4Fuels Days; 2018-10-11- 2018-10-12
NMBU

Dzurendova, Simona; Zimmermann, Boris; Kohler, Achim; Shapaval, Volha.
Bioconversion of lignocellulosic material into lipid rich fungal biomass. An interdisciplinary summer school on mining of biological data for master and PhD students; 2018-08-18 - 2018-08-18
NMBU

Dzurendova, Simona; Zimmermann, Boris; Kohler, Achim; Shapaval, Volha.
The role of phosphorus in the lipid accumulation of oleaginous fungi. Euro Fed Lipid; 2018-09-16 - 2018-09-19
NMBU

Eijsink, Vincent.
Biorefining and the Bio4Fuels project. Presentation for the board of Nordforsk; 2018-04-13 - 2018-04-13 NMBU

Eijsink, Vincent.
Examples of enzyme technology and biorefining at NMBU. Presentasjon for en delegasjon fra INRA og Lorraine Universitet (Frankrike); 2018-09- 13 - 2018-09-13
NMBU

Eijsink, Vincent.
Hva har Norge fått ut av NorZymeD (og hvorfor). Åpent avslutningsseminar i NorZymeD; 2018-10-18 - 2018-10-18
NMBU

Eijsink, Vincent.
Recent developments in enzymatic conversion of (hemi-)cellulose in lignocellulosic biomass. BioBoost symposium; 2018-03-13 - 2018-03-13
NMBU

Eijsink, Vincent.
Recent insights into determinants of LPMO functionality in biomass processing. 2nd LPMO symposium; 2018-11-07 - 2018-11-09
NMBU

Hansen, Line Degn; Varnai, Aniko; Eijsink, Vincent; Horn, Svein Jarle.
Optimization of enzyme cocktails and process conditions for efficient saccharification of Norway spruce. Lignobiotech 2018; 2018-08-29 - 2018- 09-01
NMBU

Horn, Svein Jarle.
Bio4Fuels - biodrivstoff og bioraffinering. Besøk av LMD; 2018-09-04 - 2018-09-04
NMBU

Jåstad, Eirik Ogner.
Biodrivstoff – muligheter og konsekvenser for norsk skogindustri. Treforedlinsforum 2018 – Trefiberens rolle i det grønne skiftet; 2018-11-21
NMBU

Jåstad, Eirik Ogner.
Large-scale forest-based biofuel deployment in the Nordic forest sector: Effects to the economics of forestry and forest industries. Bio4fuels days 2018; 2018-10-12
NMBU

Jåstad, Eirik Ogner.
Modelling impacts of policy schemes for increased forest-based biofuel production in the Nordic countries. Nordic wood biorefinery conference 2018; 2018-10-23
NMBU

Marova, Ivana; Szotkowski, M; Byrtusova, Dana; Rapta, Marek; Haronikova, A; Certik, Milan; Shapaval, Volha.
Pigmented yeasts as biotechnological factories for food and feed supplements. Eurobiotech Congress 2018; 2018-04-26 - 2018-04-28
NMBU

Marova, Ivana; Szotkowski, M; Vanek, M; Byrtusova, Dana; Rapta, M; Haronikova, A; Certik, Milan; Shapaval, Volha.
Pigmented yeasts as biotechnological factories. The 7th Meeting on Chemistry and Life; 2018-09-12 - 2018-09-14
NMBU

Marova, Ivana; Szotkowski, M; Vanek, M; Byrtusova, Dana; Rapta, Marek; Haronikova, A; Certik, Milan; Shapaval, Volha.
Pigmented yeasts as biotechnological factories for bioproducts and biofuels. 45th Annual Yeast Conference; 2018-05-15 - 2018-05-18
NMBU

Müller, Gerdt; Chylenski, Piotr; Bissaro, Bastien; Hansen, Line Degn; Varnai, Aniko; Eijsink, Vincent; Horn, Svein Jarle.
Activation of LPMOs in a commercial cellulase cocktail by controlled addition of hydrogen peroxide. The 5th Symposium of Biotechnology Applied to Lignocelluloses; 2018-08-29 - 2018-09-01
NMBU

Müller, Gerdt; Chylenski, Piotr; Bissaro, Bastien; Hansen, Line Degn; Varnai, Aniko; Eijsink, Vincent; Horn, Svein Jarle.
Increased saccharification efficiency of cellulose by using hydrogen peroxide to activate LPMOs in a commercial cellulase cocktail. 40th Symposium on Biotechnology for Fuels and Chemicals; 2018-04-28 - 2018-05-02
NMBU

Petrovic, Dejan; Bissaro, Bastien; Chylenski, Piotr; Skaugen, Morten; Sørlie, Morten; Jensen, Marianne Slang; Aachmann, Finn Lillelund.
Role of the N-terminal histidine methylation in fungal LPMOs. 2nd LPMO symposium; 2018-11-07 - 2018-11-09
NMBU NTNU

Rapta, Marek; Shapaval, Volha; Zimmermann, Boris; Tafintseva, Valeria; Kohler, Achim; Byrtusova, Dana; Marova, Ivana.
Vibrational spectroscopy as high-throughput tool for lipid accumulation in red yeasts. 45th Annual Yeast Conference; 2018-05-15 - 2018-05-18
NMBU

Rørstad, Per Kr..
Bioenergi som en del av klimaløsningen. Er bioenergi fra skog klimavennlig?. Fagdag for NVEs Energiavdeling; 2018-09-05
NMBU

Rørstad, Per Kr..
Biomasseressurser i skog. Preem Fagdag om biodrivstoff; 2018-02-15
NMBU

Rørstad, Per Kr..
Biomasseressurser i skog. Preem Forhandlerseminar; 2018-09-28
NMBU

Rørstad, Per Kr..
Hvor mye biomasse og til hvilken pris?. Skogbasert biodrivstoff- og biokullproduksjon i Agder; 2018-04-20
NMBU

Rørstad, Per Kr..
Hvordan bruke skog i klimasammenheng?. Hvordan bruke skog i klimasammenheng?; 2018-10-23
NMBU

Rørstad, Per Kr..
Kan skogen redde klimaet? Karbonkretsløp, karbonlager, bruk kontra vern av skog, osv. Åpent møte om skog og klima; 2018-03-07
NMBU

Vaaje-Kolstad, Gustav.
Substrate-binding protects lytic polysaccharide monooxygenases from self-destructive oxidative off-pathway processes. Kontaktmøte i Norsk Biokjemisk Selskap; 2018-01-18 - 2018-01-20
NMBU

Varnai, Aniko; Bissaro, Bastien; Petrovic, Dejan; Umezawa, Kiwamu; Chylenski, Piotr; Müller, Gerdt; Horn, Svein Jarle; Yoshida, Makoto; Eijsink, Vincent.
The role of Lytic Polysaccharide MonoOxygenases in polysaccharide depolymerization. EMBO Workshop – Enzymes, biocatalysis and chemical biology; 2018-09-09 - 2018-09-12
NMBU

Vysoka, Martin; Szotkowski, M; Bradacova, K; Matouskova, K; Holub, Jan; Simansky, S; Certik, Milan; Shapaval, Volha; Marova, Ivana.
Bioconversion of low-cost fat materiáls into high-value PUFA-carotenoid-rich biomass. 45th Annual Yeast Conference; 2018-05-15 - 2018-05-18
NMBU

Wahid, Radziah; Mulat, Daniel Girma; Horn, Svein Jarle.
In-situ biological biogas upgrading in anaerobic batch reactors: the influence of hydrogen to carbon ratio and temperature. International conference on anaerobic digestion: Biogas Science 2018; 2018-09-17 - 2018-09-19
NMBU

Østby, Heidi; Chylenski, Piotr; Costa, Thales; Horn, Svein Jarle; Singer, S; Eijsink, Vincent.
Optimizing process conditions for industrial lignocellulose degradation using a fungal enzymatic cocktail. Lignobiotech 2018; 2018-08-29 - 2018- 09-01
NMBU

ASSOCIATED PROJECTS

In addition to the research activities financed directly within Bio4Fuels, the partners and stakeholders in the centre aim to stimulate and coordinate additional research and demo activities. These associated projects are focussed towards EU funding as part of the internationalisation strategy, as well as nationally based funding in order to provide a larger platform for addressing the overall challenges within the field. The range of associated EU and Nationally funded projects are listed below.

EU FINANCED PROJECTS

Project	Project owner	Financed by	Total budget [mNOK]	Platform(s) addressed
AMBITION	SINTEF MC	H2020-ECRIA	22,5	Biochem./thermochem. platform
BioRaff	PFI	H2020/Interreg	8,1	Biochem./thermochem. platform
ERC starting grant to P. Pope	NMBU	ERC	14	Biochemical - Biogas
METAFLUIDICS	SINTEF Ind	EU - H2020	83,2	Biochemical - Sugar
DAFIA	Aimplas (Spain)	EU - H2020	58	Biochemical platform
Oxytrain	NMBU	MC-ITN	30	Biochemical platform
Prowood	INBIOTEC	ERA-IB; RCN and others	17,5	Biochemical platform
Thermofactories	SINTEF MC	ERA-MBT; RCN + abroad	22,3	Biochemical platform
4Refinery	SINTEF	EU - H2020	60	Chemical
LIBERATE	SINTEF	EU - H2020	60	Chemical
Waste2Road	SINTEF	EU - H2020	60	Chemical
ABC4Soil	NTNU	FACE/EEA	4,8	Thermochemical platform
NextGenRoadFuels	Aarhus (DK)	EU - H2020		Thermochemical platform
Pulp&Fuels	SINTEF	EU - H2020	49	Thermochemical platform
SelectiveLi	SINTEF Ind	EU - H2020	5	Thermochemical platform
BESTER	SINTEF Ind	ERA-CoBioTech Co-Fund; RCN and others	26,9	Biochemical - Sugar
C1Pro	NTNU	ERA-CoBiotech; RCN and others	17,1	Biochemical platform
OXYPOL	SINTEF Ind	ERA-IB; RCN and others	23,3	Biochemical platform

NATIONALLY FUNDED PROJECTS

Type project	Project	Project owner	Financed by	Total budget [mNOK]	Platform(s) addressed
Internal	Cat. conv. of biomass to fuels	NTNU	NTNU (N5T)	3,3	Chemical
National	Bio4Fuels	NMBU/SINTEF	RCN, FME	236,6	All platforms addressed
National	BioGasFuel	NMBU	RCN, ENERGIX	19	Biochemical - Biogas
National	BioLiGas	NMBU	RCN. ENERGIX	14	Biochemical - Biogas
National	Complete	Biokraft	RCN - Bionær	25	Biogas - Fertilizer
National	Rubiosa	NIBIO	RCN - SANCOOP	3	Biogas - Fertilizer
National	Hyperfermentan	Hyperthermics	RCN - EnergiX	7,5	Biogas - Pretreatment
National	BioFeed	NMBU	RCN, Biotek & Havbruk	14	Biochemical - Sugar
National	BioMim	Nibio	RCN, Bionær	28	Biochemical - Sugar
National	EcoLodge	NTNU	RCN, ENERGIX	6,6	Biochemical - Sugar
National	Enzymes4Fuels	NMBU	RCN, ENERGIX	10	Biochemical - Sugar
National	Foods of Norway	NMBU	RCN, SFI	218	Biochemical - Sugar
National	LipoFungi	NMBU	RCN, BIONÆR	10	Biochemical - Sugar
National	NorZymeD	NMBU	RCN, Biotek 2021	55	Biochemical - Sugar
National	OXYMOD	NMBU	RCN, Biotek2021	31,6	Biochemical - Sugar
National	Single Cell Oils	NMBU	RCN	7	Biochemical - Sugar
National	Value-added sugar platform	Borregaard	RCN, BIA	77	Biochemical - Sugar
National	WoodPrebiotics	NMBU	RCN, Bionær	20	Biochemical - Sugar
National	BioCoPro	PFI	RCN, SANCOOP	3	Biochemical platform
National	MIRA	NTNU	RCN-Havbruk/Biotek2021	13,3	Biochemical platform
National	Promac	Møreforskning	RCN-BIONÆR	35	Biochemical platform
National	Rocky	Borregaard	RCN	1	Biochemical platform
National	BarkCure	NIBIO	RCN, BIONÆR	10	Chemical/biochemical
National	Advanced Biofuels via Syngas	NTNU	RCN, ENERGIX	8,9	Thermochemical platform
National	BIOGREEN	RFFINNL; Moelven	RCN	6	Thermochemical platform
National	FLASH	SINTEF ER	RCN, ENERGIX	15,4	Thermochemical platform
National	GAFT	SINTEF ER	RCN, ENERGIX	20	Thermochemical platform
National	GasPro	NTNU	RCN, ENERGIX	16,7	Thermochemical platform
National	H2BioOil	NTNU	RCN, ENERGIX	11,8	Thermochemical platform

National	NanoCat4Fuels	SINTEF	RCN, ENERGIX	3,9	Thermochemical platform
National	PyroGas	Norske Skog	RCN, ENERGIX	4	Thermochemical platform
National	ReShip	PFI	RCN, ENERGIX	15	Thermochemical platform

ACCOUNTS 2018

An overview of the accounts for 2018 is given in the tables below. This provides a summarized overview of the costs and finance related to the research and support activities at the research partners and Stakeholders.

Cost specification	NOK	Finance specification	NOK
Payroll and indirect	8 005 202	In-Kind	4 377 530
Procurement of R&D services	18 469 446	Public	8 691 642
Equipement	733 800	Private	4 203 607
Other operating expences	2 787 601	International	1 280 243
		Research Council	14 767 744
Total	29 996 050	Total	33 320 766

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BIO4FUELS STAKEHOLDERS