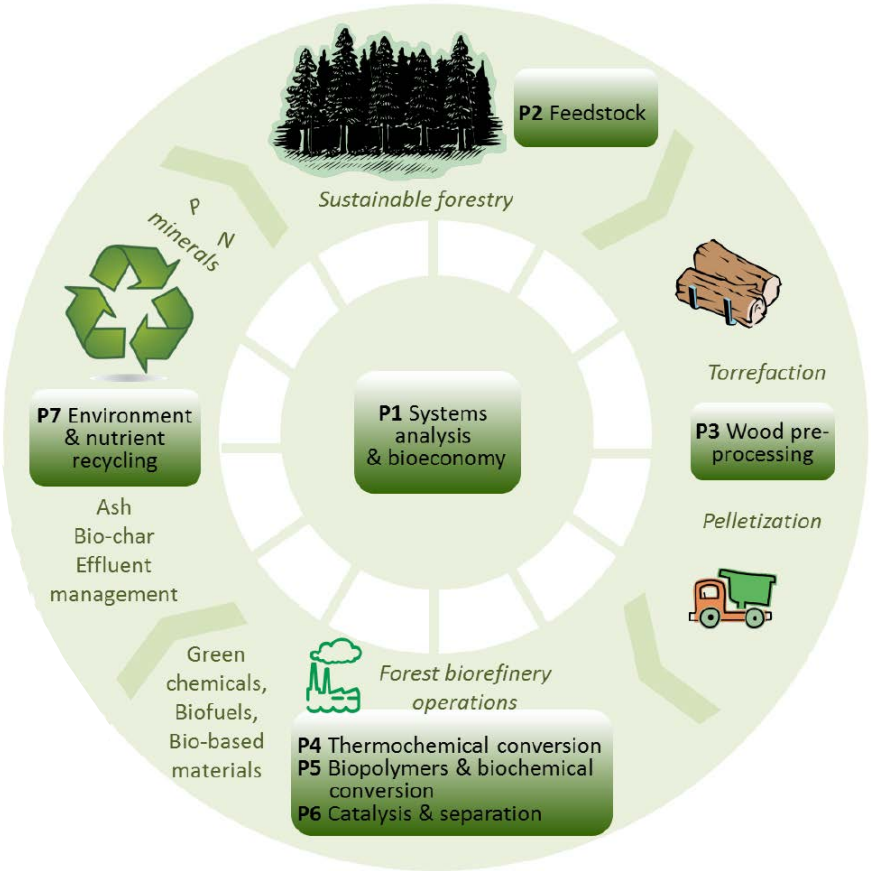
BIO4ENERGY

Annual report 2020



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Introduction – overview of 2020

As for the rest of the world, the year of 2020 was a both different and challenging year. Due to the global covid pandemic, all physical meetings were cancelled already early in the spring. On the positive side, we learnt how to plan and perform digital meetings in a meaningful way, and actually got to see each other at least as often as during a "regular" year, albeit through the screen.

Within Bio4Energy, 2020 marked the official end of the second program period. Christoffer Boman and Leif Jönsson at UmU took over from Dan Boström as managers, and Elisabeth Wetterlund at LTU took over from Ulrika Rova as deputy manager.

During the year, we have not only continued with the research from the program of the second program period – we have also worked industriously with the preparations for a third program period. We closed the year with an inspiring and inspired match-making event where ideas for new collaborative projects were pitched and discussed, thus laying a solid foundation for new strategic projects for 2021.

The year in numbers

Figure 1 summarises a few of Bio4Energy's output and achievements of 2020 in numbers.

People are our most valuable assets! After a few initial ramp-up years when Bio4Energy started in 2010, the number of researchers involved in Bio4Energy has been relatively stable at around 200 persons.

Publications is how most our research is disseminated. The 163 peer-reviewed journal publications of 2020 marks the second highest number since the start of Bio4Energy. Of those, at least 12% are a direct result of cross-platform collaboration, involving researchers from two or more of the seven Bio4Energy research platforms.

Patents represents another second program period record, with the highest number of new patents since 2013.

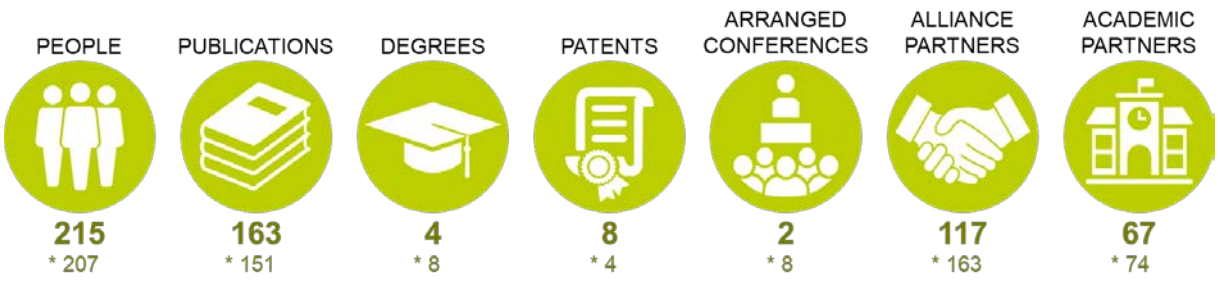

*Figure 1. Key numbers for Bio4Energy 2020. Numbers marked with * are average values for the second program period (2016-2020). 'Degrees' here represent PhD degrees. 'Alliance partners' represents our external collaboration partners from industry, society and institutes, and 'Academic partners' our external collaborations with academic departments outside Bio4Energy.*

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P1 Systems analysis and bioeconomy

- Impact assessments were performed of increasing forest bioenergy, versus forest conservation. It was concluded that market impacts of bioenergy promotion and forest conservation tend to have opposite effects on forest product prices.
- Trade-offs between timber production and carbon sequestration (and other ecosystem services) were investigated. By internalising the benefits of carbon sequestration with the optimal decision-making of forest-owners the forest rotation can be increased significantly, but different forest types are affected with different intensity. In addition, thinning operations would be rendered non-optimal, which reduces the supply of harvesting residues.
- Researchers from the platform participated in developing the official regional forestry program for Norrbotten county.
- A comparative environmental assessment of end-of-life carbonaceous water treatment adsorbents was performed in collaboration with P7.
- A methodological framework for technology assessments was developed and applied to examine a selection of emerging technologies in biomass and waste gasification, for IEA Bioenergy.
- Involvement in developing a synthesis brief from f3 (the Swedish Knowledge Centre for Renewable Transportation Fuels) with key conclusions regarding renewable fuels for transportation, based on the knowledge of researchers and experts in the f3 network.
- Combination of expansion in kraft pulp mill production capacity with production of black liquor-based drop-in biofuels via either gasification and synthesis, or lignin separation and upgrading, was examined. Substantial synergy effects, which can be allocated to either the biofuel production or the expanded pulp production, were identified and quantified.
- A pathway integrating pyrolysis and gasification of biomass for the flexible production of transportation fuels through light olefins was found to offer considerably higher carbon efficiencies compared to standalone gasification of biomass.
- Expanding on previous collaborative research by researchers within P1, P4 and P6, the environmental impacts and environmental costs of a novel methanol production route based on alkali enhanced biomass gasification were assessed.

Platform description

Biorefineries are inherently interconnected with existing industrial infrastructures and other sectors of the economy, and the related scientific-technological challenges are multifaceted and requires a multi-disciplinary perspective. In this platform, holistic and comprehensive methodological systems analysis approaches are used to address technological, economic and social changes challenges related to the development of biorefineries.

In the loop

New research initiatives have started based on collaborative efforts and external funding. The topics include forest based biofuels for marine shipping, negative emissions from sustainable forestry, and impacts of improved conversion processes for biofuel production. External grants include approved applications to, e.g., Formas and the Swedish Energy Agency.

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P2 Feedstock

- A metabolite roadmap was constructed for wood formation, allowing identification of interesting chemicals in wood and targeted modification of the chemical composition in forest feedstocks.
- Wood properties that influence processing, structure, and properties of cellulose nanofibrils were identified.
- The molecular mechanism that finalises lignification in the water-transporting vessels was identified, providing tools and methods for modification of lignin content and composition in specific cell types of wood.
- Climate models were created for wood formation and tree biomass production.
- Novel methods were identified to detect hydraulic vulnerability in Norway spruce sapwood.
- A method was established to test the effect of inoculation of pine seedlings with ectomycorrhizal fungi on drought resistance and plant performance.
- NIR-models were created for high resolution chemical characterisation of Norway spruce wood samples. In addition to increased understanding on the links between the physical and chemical properties of wood, this allows rapid screening of wood chemistry in large numbers of tree samples with high spatial resolution.
- Improved sample preparation methods were established for efficient physical and chemical characterisation of samples from small trees with SilviScan and a NIR-camera. This is crucial to predict adult tree properties already at an early stage.
- Root tannin levels were discovered to have a negative effect on ectomycorrhizal symbiosis in hybrid aspen, urging breeding towards low-tannin trees.
- It was demonstrated that bioprocessing properties of wood can be enhanced in *Populus* trees by reducing the degree of wood xylan acetylation without a negative effect on tree growth in the field.
- Pipelines were created to perform GWAS (genome wide association study) on spruce genotypes by machine learning methods. This will advance our understanding on genetics behind wood traits and identification of genetic markers for future tree breeding.
- An atomic force microscope (AFM) was acquired and set up for the mechanical study of plant samples. Several smaller instruments have been constructed, including 1) an automated confocal micro extensometer for cell adhesion strength quantification and mechanical study of plant samples, and 2) construction of a low cost 3D printed microscope incubator for long term microfluidic studies.

Platform description

Feedstock is the basis of all other platforms, and optimised feedstock will influence the whole value chain. Research on feedstock production systems contributes to increased wood yield and allows engineering of wood characteristics. Within this platform, genetic and molecular control of properties that are important for feedstock biorefining are investigated, as well as how these properties are governed by environment and management practices.

In the loop

One of the most significant new initiatives is studies into the mechanical properties of plant tissues such as wood. Other new research initiatives include studies into the effect of nitrogen fertilisation on wood properties, establishment of novel methods for tannin extraction and characterization for future applications, and analysis of wood mechanical properties by x-ray imaging of living aspen trees.

P3 Wood pre-processing

- Activated carbons with a very large surface area (equivalent to carbon nanotubes) produced from spruce bark with cheap and straightforward methods.
- A ground-breaking concept with one-step milling of raw wood to fine powder was systematically developed in collaboration with a manufacturing SME.
- Nutrients from algae were successfully utilised as a biofertiliser component for forest seedlings.
- Contrary to what has generally been assumed, industrially applied mechanical screening of forest fuels were shown to have no or minor effect on the fuels' ash chemistry and slagging tendencies.
- Hydrothermal liquefaction (HTL) of wet micro-algae was recovered as oil with high energy content and yields (80 %).
- With a maintained lignin degradation and production of edible mushrooms, optimisation of the substrate composition can reduce the fungal degradation of glucan by 20-30%, thus enabling higher yields in subsequent bioethanol production.
- Hot-air pasteurisation of hardwood substrate for fungal delignification was shown to reduce both energy demand and CO_2 emissions, when compared to conventional steam sterilisation.
- Cellulose fibre reject from the pulp and paper industry and Norway spruce stemwood were proven as possible substrates for a combined production of edible mushroom (*Pleurotus pulmonarius*) and biofuels.
- The energy demand of a typical Swedish pellet mill (100,000 tons/year) can be reduced by 4.1 GWh by injection of steam at a later stage in the process, compared to conventional steam conditioning. The method has been patented by Bio4Energy researchers.
- A review of using sustainable biomass activated carbons showed that, from different biomass residues, it is possible to obtain high-quality carbon electrodes with different electrochemical properties for end-use in modern high-performance batteries and supercapacitors.
- A method was developed to separate fresh pine needles from forest residues successfully.
- Installation of new instruments and equipment at the Biomass Technology Centre (BTC): Pulsed Fast Thermal Neutron Activation (PFTNA) for online elemental analysis of whole industrial bulk streams (financed by the Kempe Foundation), and granulation equipment (financed by Treesearch).

Platform description

Forest-based lignocelluloses are characterised by their structural and chemical diversity. Expertise in advanced feedstock characterisation and design and evaluation of tailored pre-processing technologies is critical for accelerating the development of biorefinery processes and products. This platform addresses challenges and opportunities caused by biomass heterogeneity, through research on characterisation, separation, and modification of bio-based materials.

In the loop

The platform has an established a position in Treesearch with two PIs, one as coordinator for SLU's participation and one as representative in the scientific committee. Bio4Energy has enabled participation in a Mistra Digital Forest project with KTH, and enabled and enhanced collaborations within, e.g., Bothnia-Atlantica, Horizon 2020 and Swedish Energy Agency funded projects.

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P4 Thermochemical conversion technologies

- Bio4Gasification (B4G) is a node of the large competence centre SFC (Swedish Gasification Centre) in which many researchers from the platform have participated and contributed during the last 10 years. SFC is coming to an end in its present form, and in this late stage many interesting results are being published.
- A large B4G intra-platform collaboration resulted in a successful experimental campaign using pilot-scale reactor at RISE ETC for gasification of forest residues and wheat straw. Research topics spanned corrosion, slag and aerosol formation, and gas composition monitored with newly developed diagnostic tools.
- New detailed knowledge and information on formation and transformation of silicate slags was published. This new knowledge is of high relevance for both combustion and gasification processes.
- Advanced analysis methods (Raman spectroscopy, x-ray microtomograph) were applied to analyse detailed structures of biomass, biocarbon, and fluidized bed materials, and used to predict their behaviour in thermochemical conversion.
- In-situ high speed imaging of reacting fuel particles in entrained-flow reactors revealed many previously unknown behaviours of biomass particle flows, and was used to develop a new burner design.
- First time in situ detection of K(g), KOH an KCl was done in laboratory flames and entrained-flow reactors up to pilot-scale during biomass combustion and gasification, using the previously developed TDLAS-based UV photofragmentation spectroscopy technique.
- Fundamental reactor simulating CFD (computational fluid dynamics) modelling for heterogeneous reacting particle-laden flows was improved for better prediction of flow dynamics in large scale simulations. Better predictions will assist design of industrial processes involving reactive particle-laden flows, and contribute to increased efficiency and decreased energy-intensiveness.
- Two patents were published that describe integrated thermochemical systems of high interest; one for thermochemical fuel conversion, and one for thermal treatment of acid sulphate soil.
- Showed how to convert phosphorus in sewage sludge ashes from calcium-phosphates into potentially more plant-available potassium-bearing phosphates by co-combustion/gasification with potassium-rich biomass fuels directly in the conversion process. Considerable amounts of heavy metals can also be separated from the coarse phosphorus rich ash directly in the process.

Platform description

Through thermochemical conversion processes, widely different types of biomass can be converted into advanced fuels and chemicals. The overall challenge for this platform involves generating the fundamental understanding needed to support the technical development of thermochemical conversion of forest-based biomass, side streams, recycled fibres, underutilised fractions, and to make the corresponding technologies competitive to those for fossil fuels.

In the loop

Bio4Energy enables several PhD student projects within the platform, supported by Swedish Research Council, Formas, and Vinnova and others. The platform also continues to strategically further strengthen the connections between its research and industrial sectors to promote the transformation to fossil-free and sustainable production systems; the main focus areas are the steel, cement and quicklime industries where several new projects have been initiated.

P5 Biopolymers and biochemical conversion technologies

- Recently initiated research within the platform addresses the potential use of lignin and nanocellulose as precursors for high-quality carbon materials and aerogels for new applications, such as energy storage and CO_2 capture. During 2020, this research resulted in publications related to green carbon nanofiber networks for advanced energy storage, multifunctional carbon aerogels with hierarchical anisotropic structure derived from lignin and cellulose nanofibers for CO_2 capture and energy storage, and lightweight, flexible and multifunctional anisotropic nanocellulose-based aerogels for CO_2 adsorption.
- Cellulose-based nanofibers from wood and industrial residuals were also successfully demonstrated for new applications, such as water purification, where water purification ultrafiltration membranes using nanofibers from residues such as unbleached and bleached rice straw, were investigated.
- Launch of the new project "Utilization of industrial residues for an efficient geological BECCS" (INSURANCE), in collaboration with, among others, Billerud Korsnäs. The project is devoted to the capture of biogenic CO_2 from effluent gas streams using enzyme-based technology, and received considerable media attention.
- New wood-chipping technology was investigated for both the kraft and the sulphite process. The new technology was shown to typically result in higher fractions of accept chips, and has the potential to provide energy savings and higher pulp yields.
- Other new research includes one project on production of advanced biofuels from softwood using a novel γ-valerolactone-based pretreatment, and one on polyhydroxyalkanoates from marine bacteria in the Norwegian Sea.
- An important new initiative involves collaboration with Södra within a new project focused on chipping and processing of wood damaged by the European spruce bark beetle, which has affected relatively large areas of Swedish forests during the past few years. The new alliance complements the existing collaborations within the wood chipping area, with e.g. MoRe Research, Multi Channel Sweden AB, and RISE Processum.
- RISE Processum and SEKAB continue to be important collaborators with the platform, and during 2020, a new joint patent application was submitted regarding new technology for making more efficient use of the capacity of enzymes and microorganisms in biochemical conversion of lignocellulosic materials.

Platform description

This platform focuses on bio-based polymers for advanced and sustainable materials and conversion processes that involve microorganisms and enzymes. Both conventional forest-industrial processes and products, e.g. cellulose and cellulose derivatives, and novel polymeric bio-based materials are included. Exploitation of the inherent characteristics of the raw materials is central, incorporating the sustainability aspect to reduce, recycle, and reuse.

In the loop

Also this platform participates in Treesearch, as well as in several other large programs and projects (KAW/ WWSC program on Biocomposites, SSF Medical HEALiX project, BBI Horizon 2020 program NEWPACK, and BIOMAC, a new Horizon 2020 project that includes biomass pretreatment and fractionation using a continuous organosolv process, as a part of a European pilot line).

P6 Chemical catalysis and separation technologies

- By combination of advanced membrane experiments and mathematical modelling, researchers within the platform have for the first time been able to unravel the origin of the so called "surface barrier", that limits the mass transfer in small particles of nanoporous materials. The research showed that the surface barrier actually is a surface diffusion process, with higher activation energy than the corresponding process inside the pores. The higher activation energy is thought to be an effect of the obvious difference in geometry between the pore mouth and the geometry within the pores. This observation and the new and simple hypothesis that explains the phenomena are of both high scientific and practical importance. The scientific importance rests on that the origin of the surface barrier has hitherto been unknown. The practical importance is related to the current widespread industrial use of small zeolite crystals in various processes, and that many of these processes are controlled by the surface barrier.
- A new collaborative project with the University of Oulu to develop novel "mechanical energy to electricity" –devices (e.g., wearable electronics and sensors) was initiated.
- On the commercialisation side, major companies have continued to show significant interest in the membranes for separation that are under development within the platform, and are now testing them for separation of both CO_2 and other substances.
- The renewable diesel project (ECO-OIL) has also advanced and a patent is expected to be public at the end of 2021. Letters of intent have been signed with a few companies to advance the commercialisation of the ECO-OIL gasoline and diesel processes, and the gasoline pilot plant has been transported to an engineering company in Luleå for up-scaling studies. The endeavour is now to scale-up the process to the sea container scale.

Platform description

In order to make biorefineries successful, it is essential to develop suitable catalysts and energy lean separation technologies. The focus of this platform is fundamental research on novel integrated catalysis and separation processes designed for application in forest and other lignocellulosic-based biorefineries, encompassing both thermochemical and biochemical routes to fuels and chemicals.

In the loop

The competence of preparing zeolite membranes with very high flux enabled participation in an EU project on water desalination, where Bio4Energy's researchers will prepare high flux ceramic membranes for desalination by membrane distillation. As membrane distillation is a very electricity-lean technology, compared to the current highly electricity-intensive desalination practices, the concept will have a large potential to reduce the global electricity consumption and thereby reduce emissions of greenhouse gases.

P7 Environment and nutrient recycling

- New investment in commercial production system for arginine phosphate secured and production system established at Dåva outside Umeå. Tillväxtverket approved partial financing of the production system. Research over several years has shown that arginine phosphate stimulates establishment and growth of tree seedlings. Rapidly growing interest for this product from forest companies and private forest owners in Sweden and Finland underpins the large investment. The new production system has the capacity to deliver arginine phosphate for the Nordic market of c. 550 million tree seedlings per annum.
- Discovery of a spontaneously forming solid product in the filtrate from hydrothermal carbonisation (HTC) of biomass and bio-based residues and waste streams. This new product, referred to as self-generated carbon (SGC), has not been previously described in the literature, and has very promising surface and morphological properties of relevance for environmental and technical applications, even when produced from sludge materials.
- New data on atmospheric properties, here focusing on ice-nucleating ability, of particulate emissions from solid-biomass-fired cook stoves, was obtained and published in a collaboration between Bio4Energy researchers and researchers from University of Kuopio and Lund University.
- The research within this platform has during the year also expanded to the area of fertilisation of pit lakes with wood ash. Pit lakes are often limited in nutrients which in turn restricts their biological productivity. By stimulation of algal growth in pit lakes by addition of different types of ash as natural fertiliser, the assimilation/ adsorption capacity of algae with regard to metals can be utilised. Combining fertilisation and metal remediation/ immobilisation measures will contribute to reducing the toxicity of pit lakes and promoting sustainability in industrial processes.

Platform description

One of the key challenges when introducing new biorefinery concepts is to develop sustainable and resource-efficient utilisation routes of forestry biomass, industrial residues and organic waste streams, including closing the loops of nutrients and minerals, as well as minimising the potential environmental and health impacts. This platform aims at advancing the understanding related to critical research questions on the environmental aspects of sustainable forestry, bioenergy and biorefinery processes.

In the loop

Bio4Energy has also enabled the establishment of a new collaboration between Department of Chemistry at UmU and Örebro University on method development related to analysis of per- and polyfluoroalkyl substances (PFAS), and reliable sampling of this challenging group of compounds in incineration flue gases.

New strategic projects

In the 2020 call for **free strategic funds (2021-2022)**, six new 2-year projects were granted (2025 kSEK per project):

Synthesis of jet fuel from wood by fast pyrolysis, steam cracking and conversion on ZSM-5 catalysts with optimal morphology. Jonas Hedlund (LTU), Linn Berglund (LTU), Hoda Shafaghat (RISE-ETC).

Two strategies for preparation of carbon materials from well-defined hydrolysis lignins for energy storage and their life-cycle assessment and life-cycle cost evaluation. Shiyu Geng (LTU), Venkata Krishna Kumar Upadhyayula (UmU), Carlos Martín (UmU), Leif Jönsson (UmU), David Blomberg (RISE-Processum), Rabia Ayub (RISE-Processum).

The effect of drought on spruce wood chemistry and feedstock utilisation. Gerhard Scheepers (RISE), Rosario García Gil (SLU), Robert Lundmark (LTU).

Economic and environmental assessment of integrated phosphorus recycling from sludge ash in thermochemical biorefinery processes – impacts of metal mobility and ash particle morphology (ReAsh). Nils Skoglund (UmU), Elisabeth Wetterlund (LTU), Marcus Öhman (LTU), Fredrik Weiland (RISE-ETC).

Activated and non-activated biochars and hydrochars from forestry-related waste streams for removal of environmental contaminants from sediments. Stina Jansson (UmU), Christoffer Boman (UmU), Robert Lindgren (UmU), Eleonora Borén (UmU), Eva Weidemann (UmU), Magnus Rudolfsson (SLU), Mirva Niinipuu (RISE-ETC), Gunnar Westin (RISE-Processum).

Efficient production of biomethane from wood by pressurized anaerobic digestion and upgrading by DDR zeolite membranes. Liang Yu (LTU), Charis Xiros (RISE-Processum), Io Antonopoulou (LTU), Leonidas Matsakas (LTU).

In the 2020 call for **targeted strategic funds (2021)**, nine 1-year projects were granted:

Bioethylene purification through energy efficient technology. Naser Tavajohi (UmU), Liang Yu (LTU), Jyri-Pekka Mikkola (UmU), 623 kSEK tot.

Increasing the use of renewable energy carriers in Swedish mineral processing industries. Markus Broström (UmU), Mirva Niinipuu (RISE-ETC), Matias Eriksson (UmU), Charlie Ma (UmU), Per Holmgren (UmU), Muhammad Aqib Chishty (LTU), 708 kSEK tot.

Utilizing the natural composition of industrial bio-based residues for efficient separation of functional nanofibers. Linn Berglund (LTU), Io Antonopoulou (LTU), Carlos Martín (UmU), Ola Sundman (UmU), Shaojun Xiong (SLU), 755 kSEK tot.

Bio-methanol to jetfuel. Elisabeth Wetterlund (LTU), Jonas Hedlund (LTU), Rikard Gebart (LTU), Fredrik Granberg (LTU), 415 kSEK tot.

Mixtures of wood ashes and algal biomass as novel bio-based fertilizer for sustainable forestry seedlings. Sarah Conrad (LTU), Johan Ingri (LTU), Francesco Gentili (SLU), Stina Jansson (UmU), Nils Skoglund (UmU), Christoffer Boman (UmU), 445 kSEK tot.

Investigating the electrochemical functionality of Norway spruce bark biochar and polymer composites. Sylvia Larsson (SLU), Gunnar Westin (RISE-Processum), Leif Jönsson (UmU), Kristina Oksman (LTU), Henrik Wiinikka (RISE-ETC), 622 kSEK tot.

Wood x-ray morphodynamics: Revealing the dynamics of cell rearrangement and the contribution of cell adhesion during wood formation through timelapse x-ray imaging in live aspen. Stéphane Verger (SLU), Fredrik Forsberg (LTU), 212 kSEK tot.

Detecting and quantifying resin canals in spruce. Rosario García-Gil (SLU), Thomas Grahn (RISE), Mikael Thyrel (SLU), 363 kSEK tot.

Effects of mechanical stress on wood formation in hardwood model species aspen. Ewa Mellerowicz (SLU), Sandra Winestrand (UmU), Totte Niittylä (SLU), Gerhard Scheepers (RISE), Nathaniel Street (UmU), 760 kSEK tot.

B4E graduate school

In the context of 2020's many challenges, we are proud to be able to state that B4E students have delivered four doctoral, four licentiates, and eleven MSc degrees this year.

The pandemic made it impossible to give the "Biorefinery Pilot Research" B4E course in autumn 2020 as planned. On-site teaching is an absolute prerequisite to reach several of the course's primary objectives of tangible interaction with B4E's large-scale infrastructures, relationship building with active researchers and technical personnel, and the provision of inspiration and tools for upscaling and industrial implementation of the students' scientific progress.

We are eagerly awaiting that the severe disturbance of our educational duties is alleviated and will do our best to address our students' pent-up needs of a context by our joint B4E activities and courses.

PhD theses

- Jessica Gard-Timmerfors, Dept. of Chemistry UmU (Biopolymers and biochemical conversion technologies): *"Wood chips for kraft and sulfite pulping - Evaluation of novel forest-industrial drum-chipping technology"*
- Shikha Singh, Dept. of Engineering Sciences and Mathematics LTU (Biopolymers and biochemical conversion technologies): "*Properties of poly(lactic acid) in presence of cellulose and chitin nanocrystals"*
- Bernadette Sztojka, Dept. of Plant Physiology UmU (Feedstock): "*New regulators of xylem lignification in Arabidopsis"*
- Linghua Zhou, Dept. of Forest Genetics and Plant Physiology SLU (Feedstock): "*Towards genomic-based breeding in Norway spruce"*

Licentiate theses

- Ali Hedayati, Dept. of Engineering Sciences and Mathematics LTU (Thermochemical conversion technologies): *"Ash transformation in single-pellet combustion and gasification of biomass with special focus on phosphorus"*
- Gustav Häggström, Dept. of Engineering Sciences and Mathematics LTU (Thermochemical conversion technologies): "*Experimental studies of ash transformation processes in thermochemical conversion of P-rich biomass and sludge"*
- Thomas Karl Hannl, Dept. of Engineering Sciences and Mathematics LTU (Thermochemical conversion technologies): "*Phosphorus recovery from sewage sludge fluidized bed gasification processes"*
- Thamali Rajika Jayawickrama, Dept. of Engineering Sciences and Mathematics LTU (Thermochemical conversion technologies): *"Particle-fluid interactions under heterogeneous reactions"*

Awards and commissions of trust

The Government appointed Bio4Energy researcher Patrik Söderholm (Systems analysis and bioeconomy), as a new member of the Climate Policy Council, an independent expert council whose task it is to evaluate whether the government's overall climate policy will meet the national target of net zero emissions in 2045.

Two of the projects on IVA's 100 list 2020 have connection to Bio4Energy: *Sustainable Innovation and Business Metrics (SIB Metrics)*, involving Krishna Upadhyayula and Mats Tysklind (Systems analysis and bioeconomy), aims to quantify short and long term sustainability benefits of and risks associated with emerging technologies for making investment decisions. *MicroBioRefine*, involving, among others, Francesco Gentili (Wood pre-processing), aims to investigate environmental and economic sustainability of biomass production by Nordic microalgae grown on local flue gases and wastewaters in Sweden.

Ulrika Rova (Biopolymers and biochemical conversion technologies) received the Innovator of the Year 2020, Employee award for her research on prebiotics from forests and the sea, which focuses on developing sustainable food products from forest residues.

Bio4Energy's younger researchers have also continued to excel, as evidenced by, e.g., Linn Berglund and Leonidas Matsakas (both Biopolymers and biochemical conversion technologies).

Linn Berglund was awarded the 2020 Prize for the best doctoral dissertation at Luleå University of Technology by Vattenfall. In their motivation, the jury highlights, among other things, how Linn in her work has shown that cellulose nanofibers can be separated in an environmentally friendly and energy-efficient way from industrial residues, and that her research has led to the development of a new bio-based ink, which can be 3D-printed into hydrogels that can, e.g. be used for biomedicine products.

Leonidas Matsakas was awarded Kungliga Skytteanska Samfundet's prize for a young well-deserving researcher at Luleå University of Technology. From the jury's motivation: *"By using residual materials from the forestry sector, [Leonidas'] research can not only deliver a solution to reduce our environmental impact, but also has the potential to provide economic added value to the forest industry and thus promote the development of a bio-based circular economy."*

Bio4Energy's researchers also hold a large number of commissions of trust, and act as members on various boards and committees. As a recent example, Christoffer Boman became engaged as steering board member for Umeå Transformation Research Initiative (UTRI), a new initiative established during 2020 as a grass-root initiative at Umeå University to support interdisciplinary research collaboration in the transition to sustainable development. Other examples include the Scientific Council of Centre for Business and Policy Studies (SNS), the European Federation of Chemical Engineering (EFCE), IEA Bioenergy, the prestigious Selection Committee for the Marcus Wallenberg Price, the MAX IV reference group, the European Federation of Chemical Engineering (EFCE), the European Union COST action EUAlgae, and several of the program counsels and boards for the Swedish Energy Agency's research programs.

Media and outreach

The research and collaborations enabled by Bio4Energy have continued to generate substantial outreach and visibility during the year. A few examples are outlined here.

Shaojun Xiong together with collaborators Carlos Martín och Feng Chen continued to attract headlines regarding their cross-platform research on combined production of mushrooms and biofuels (Comush). The project was also highlighted at the BioInnovation Yearly Conference.

Ulrika Rova attracted media attention for the above-mentioned award Innovator of the year, for her research on prebiotics from forests and the sea.

The *Bioenergy Insight Magazine* featured an article on the research by Christoffer Boman and colleagues on the development of clean-burning biomass gasification technology for household cooking and medium-scale electricity production for sub-Saharan Africa.

Ewa Mellerowicz was highlighted in the media after publication of her research results on field trials with transgenic hybrid aspen lines. The five-year trials demonstrated that forest feedstocks with modifications in wood chemistry and bioprocessing properties can grow as well as trees that have not been modified, meaning that there is not necessarily a negative trade-off between wood chemical modifications and biomass production. The work was done in collaboration with Leif Jönsson.

Bio4Energy news have also been addressed by both specialist press within our sector and general press. A few examples are Dagens miljöteknik, Bioenergitidningen, Skogsindustriernas magasin, Energinyheter, Industripress, Tänk och Västerbotten-Kuriren.

Meetings and events

Despite the challenging and extraordinary conditions in 2020, Bio4Energy researchers have during the year co-organised or participated in a number of digital conferences, workshops and webinars – both scientific such, and those organised in collaboration with and targeting industry and society. During 2020, we all learnt that we don't necessarily need to travel to participate – the north of Sweden was no longer more distant than any other place in Sweden, Europe, or the rest of the world.

Also our internal meetings went digital. In addition to two researchers' meetings, we took the opportunity to organise a digital pitch and match-making event in conjunction with the opening of the winter's call for strategic projects. The event was in particular targeted at younger researchers and researchers new in the Bio4Energy environment. The digital format turned out to work well, and the event was well attended. During the event, 15 different project ideas were pitched, many of which later were materialised in proposals for new strategic projects within Bio4Energy.

Bio4Energy Advisory Board

The spring's meeting with Bio4Energy's Advisory Board was centred around the theme *Towards commercialisation of bio-based innovations*. It took place at Arlanda in March and marked the end of travelling for most of us, for the rest of the year. The meeting contained discussions related to system changing technologies in the "valley of death", as well as presentations from three Bio4Energy researchers who all have one foot in research and the other in innovation and commercialisation.

The digital autumn's meeting was more introspective in character and focused on how we can continue to develop Bio4Energy's role in and collaboration with industry and society.

At the last meeting of 2020, we also thanked several Advisory Board members for their contribution to the board during the last years of the second program period, and wished them good luck in their continued endeavours.

Bio4Energy Advisory Board 2018-2020

Peter Axegård, C-Green
Charlotte Bengtsson, Skogforsk
Jörg Brücher, Holmen
Ann-Britt Edfast, Sveaskog
Sonja Enestam, Valmet
Rune Hillström, Hillstrom Pulp Management
Johanna Mossberg, RISE
Lars Stigsson, Suncarbon
Malin Strand, Fossilfritt Sverige
Björn Sundberg, Stora Enso