BECOOL
Brazil-EU Cooperation for Development of Advanced Lignocellulosic Biofuels

SUSTAINABLE VALUE CHAINS FOR LIGNOCELLULOSIC ADVANCED BIOFUELS

Newsletter February 2021

Integrated Crop Rotations - Sugarcane Straw Recovery - Bio-oil from Lignin Residues - Gasification - Gas cleaning

BECOOL is a Horizon 2020 research and innovation project to foster the cooperation between the European Union and Brazil, for the development of advanced lignocellulosic biofuels, from sustainable agricultural value chains. Launched in June 2017 and ending in 2022, the project is carried out by a consortium of twelve partners from seven countries, coordinated by the University of Bologna.

We are glad to share with you some of the latest results and activities of the project.

Growing lignocellulosic crops in rotation with food crops

The sequential cultivation of food crops and lignocellulosic crops can increase the beneficial effects of rotations on soil fertility, without reducing the land available for food production.
Annual lignocellulosic crops can be introduced in multiannual rotations alongside conventional food crops and grown as summer cover crops, thus increasing the period of utilization per unit of land. A paper by Andrea Parenti et al. 2020, University of Bologna, describes the preliminary assessment of the effect of four lignocellulosic crops (sunn hemp, fiber sorghum, kenaf, and hemp) on a subsequent cereal crop. The lignocellulosic crops were tested within conventional sequential maize - wheat crop rotations, established between 2018 and 2019 at the experimental farm of the University of Bologna. Biomass sorghum, hemp, sunn hemp and kenaf obtained average yields of 31, 19, 15 and 10 tons/ha (dry matter) respectively.
The grain productivity of the subsequent winter crop (wheat) was unaffected by the precedent crops. Interestingly, the rotation of sunn hemp and wheat obtained high biomass yields with the least use of nitrogen fertilizers than the other rotations, as sunn hemp is a nitrogen-fixating legume species.

Read the full paper
Lignocellulosic Crops in Rotation with Food Crops.
(A.Parenti, W. Zegada-Lizarazu, A. Borghesi, A.Monti)

Slides

Learn more in this video

Sunn hemp: a valid crop for sustainable biomass feedstock in temperate climates

The large-scale deployment of advanced biofuels is a fundamental tool to reach the objectives of the REDII for the decarbonization of the transport sector by 2030, as well as for the EU long term goal of net-zero emissions by 2050. In addition, the EU Green Deal puts the agricultural sector at the centre of the green transition and urge it to find solutions to supply large volumes of lignocellulosic biomass for the circular bioeconomy, while increasing soil health, and developing environmentally friendly food systems.

An effective way to achieve this is by developing integrated cropping systems, where innovative annual lignocellulosic crops can be introduced within crop rotations gaps, alongside traditional food crops.

Sunn hemp (*Crotalaria juncea L.*), is a fast-growing, high lignocellulose, multipurpose leguminous crop of Indian origin. In tropical areas it is traditionally used as a forage crop or as green manure and is normally grown in rotation with rice, wheat, tobacco, and sugarcane. However, little is known so far about its suitability as a crop for temperate climates. To investigate this aspect, between 2016 and 2017 researchers at Department of Agricultural and Food Science of the University of Bologna, conducted three independent one-year field trials at the experimental farm of the University. The tests aimed at evaluating the performance of a series of sunn hemp cultivars at different harvesting times, in addition to the effects of different planting densities and soil tillage methods.

Results showed that regardless of the cultivar used, sunn hemp can produce acceptable biomass yields up to **11.5 tons/ha dm**, under no-tillage conditions and with sowing at 45 cm row distance, in as little as 90 days between sowing and harvesting (at the flowering stage).
These preliminary results indicate that introducing sunn hemp as a lignocellulosic biomass crop within traditional cropping systems in temperate climate can be feasibile, by growing it as a summer cover crop and leaving the land available in time for a subsequent winter crop.

Besides representing a potential source of biomass for advanced biofuels, compliant with the criteria for low- ILUC risk feedstocks, sunn hemp as a leguminous species has positive effects on soil fertility in terms of nitrogen fixation, and is also effective in contrasting root nematodes and weeds. Thanks to the combination of all these features, the cultivation of sunn hemp as a cover crop can then represent an interesting solution to support the goals of the REDII for low-ILUC risk advanced biofuels, as well as those of the EU Farm-to-fork strategy and ultimately of the EU Green Deal.

Learn more in this video

SunnGro: A new crop model for the simulation of sunn hemp grown under alternative management practices

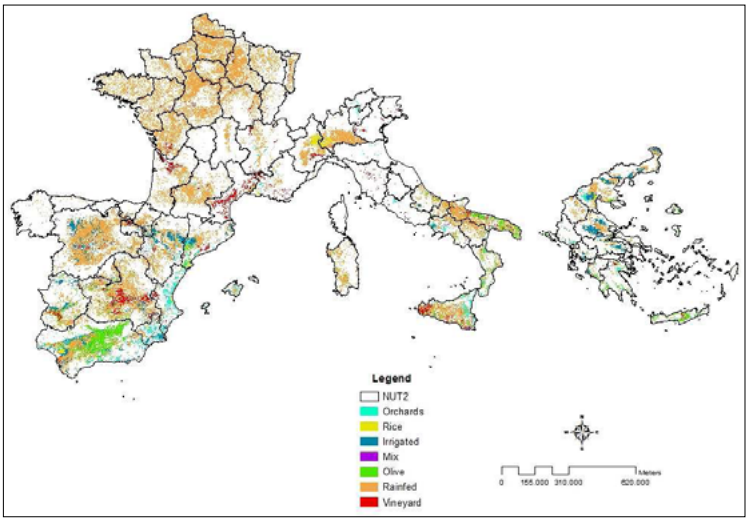
A study by Parenti et al. presenting a new simulation model which reproduces sunn hemp growth and productivity, was recently published in Biomass and Bioenergy. The model, SunnGro, demonstrated to be an effective tool to predict sunn hemp yields used whether as main or double crop in different European climatic conditions (explaining 67–82% of aboveground biomass variability). SunnGro was calibrated and validates using 20 different datasets collected from 2016 to 2018 in Greece, Spain and Italy. This tool could be used to plan new cropping systems integrating food crops (main crop) with sunn hemp (double crop for energy purpose) with several benefits in terms of crop diversification, reducing GHG emissions, improved soil structure and fertility.

Read the full paper

Harvesting of Crotalaria in Italy.

A review of sustainable biomass potentials for advanced biofuels

In 2020 a review of existing literature on biomass availability assessments was conducted as part of the work package "biomass production and feedstock diversification for advanced biofuels" of BECOOL. The results were published in September 2020 in a report by M. Chirstou (CRES), Paloma Perez Ortiz, Carlos Martín Sastre and Pilar Ciria (CIEMAT), which provides a comprehensive assessment of the available agricultural, forest and industrial lignocellulosic residues of potential interest for advanced biofuels in both EU and in Brazil. The literature review was supplemented by a spatial analysis using the BIORAISE model.



Agricultural areas of crops which produce residues for NUTS 2 regions of Spain, France, Italy and Greece.

The report finds that estimations can be diverse and wide-ranging depending on the targets, models and assumptions used. In Europe, agricultural residues that are available and that meet the sustainability criteria are reported to range between 139 to 182 Mt in 2030 and could reach 286 to 567 Mt dm in 2050. In all the studies considered, straw is the dominant agricultural residue available.

Forest residues that are available and that meet the sustainability criteria are reported to range from 44 tons to 500 Mt dry matter in 2010, to 584 Mt in 2020, and they could reach more than 600 Mt dm in 2050.The potential of sustainable biomass production from forests consists of stem wood, primary forestry residues, e.g., logging residues, early thinnings and extracted stumps, as well as secondary forest residues from wood processing industries. Optimized logistics could significantly increase the availability of residual biomass for energy and fuels. Energy crops can be a significant asset to increase biomass feedstock, supplementing the biomass from agricultural and forest residues. In Brazil, sugarcane production represents the 15.2% of the total agricultural production value, with the respective soybean production representing more than 37%. Soybean, sugar cane and corn made up approximately 63% of the country's agricultural production value that year. Agricultural residues are reported to reach 597 million tons per year.

Read the report

Learn more in this video

Innovative solutions for the recovery of sugarcane straw as a lignocellulosic feedstock for bioenergy

Brazil is a major sugarcane producer and its production more than doubled over the last decades. With the progressive shift from a burned to a non-burned harvest system, most of the straw presently retained on the soil surface has become economically viable residual feedstock for bioenergy production. Large-scale bioenergy demand has triggered new approaches to the field management of sugarcane straw management, as a promising feedstock for bioelectricity and for cellulosic ethanol in Brazil. However, the recovery and use of sugarcane straw is still limited by logistical constraints related to harvesting.

In December 2019 on the occasion of the first BECOOL-BIOVALUE joint meeting, researchers from Italian CREA-IT had the opportunity to visit sugarcane plantations in the North of Brazil, together with BIOVALUE partners from LNBR (Brazilian Biorenewables National Laboratory). The mission aimed at studying the existing value chain of sugarcane straw harvesting and to improve it by reducing the ash content of straw bales, used to produce bioenergy (both power and ethanol). Following the mission, two innovative solutions were considered, which were described in a paper by Luigi Pari et al.

Sugarcane harvesting in Brazil.

The first solution is the replacement of the traditional windrowers used to gather the straw with innovative belt windrowers. The second solution is the baling of the straw biomass directly from the harvesting machine, directing one fan of the cleaning system into the baler that follows the harvesting machine. The two proposed harvesting systems can tackle the problem providing a solution at the present bottlenecks. Although further studies and field tests will be needed, the outcomes of this work represent a solid base to build an international scientific cooperation, leveraging on the synergies and the complementarities between BECOOL and BIOVALUE for the development of advanced lignocellulosic biofuels.

Windrowers used for sugarcane straw harvesting in Brazil.

Read the paper

Slides

Learn more in this video

Production of Fast Pyrolysis Biooil from Lignin Rich Residues

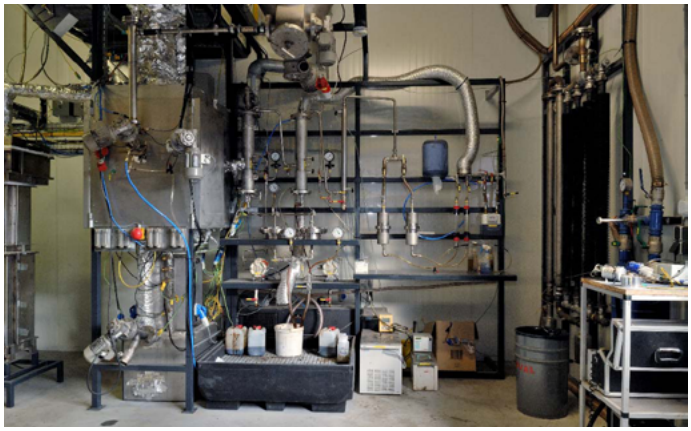
The industrial processes for the production of cellulosic ethanol generate significant volumes of a lignin-rich residue stream, which is normally combusted to produce heat and power, both for the plant's needs and for grid injection.
In BECOOL, an alternative solution to valorise the lignin-rich residue is being evaluated, by converting it into bio-oil, a liquid intermediate energy carrier, via fast pyrolysis (Fast Pyrolysis Bio-Oil or FPBO).

During the fast pyrolysis process, gaseous and solid (char) by-products are generated in addition to the FPBO. In commercial scale fast pyrolysis plants, these by-products are combusted to generate heat and power for the pyrolysis plant while the surplus is exported as renewable energy. The concept evaluated within BECOOL is to replace the lignin combustor in ethanol plants with a fast pyrolysis process.

The lignin-rich residue during outdoor drying.

Instead of excess electricity, lignin oil is produced as additional product. The FPBO can then be used for the production of biofuel through gasification or hydrotreating, or alternatively, as source of bio-based chemicals and materials. By applying this conversion pathway the lignin rich residues could potentially generate a much higher added value compared to the business as usual of combustion for combined heat and power.

In 2020, experimental trials for the conversion of the lignin-rich residue of cellulosic ethanol plants into FPBO, were performed in the Netherlands by BTG. Due to the specific nature of the feedstock, some modifications to the standard process conditions of fast pyrolysis had to be elaborated and tested. As a result of the tests, the chemical pre-treatment of the lignin-rich residue with calcium hydroxide proved to be a suitable solution to prevent any operational issues. The yield of pyrolysis oil was relatively high and with low water content, although this solution implies additional costs for the pre-treatment of the feedstock, compared to standard fast pyrolysis.
Further techno-economic evaluations and different modelling of process option will be carried out this year, to obtain a complete overview of the possible integration of fast pyrolysis in the bioethanol production process.



The bench-scale pyrolysis setup 'MPP' in the BTG laboratory.

Producing biochar and pyrolysis oils with eucalyptus wood

Slow oxidative pyrolysis is a versatile thermal conversion technology which produces a range of products: a solid (char), a mixture of non-condensable gases (CO, H2, CO2, CH4 and higher C2+) and condensable vapours resulting from the thermal fragmentation of the feedstock constituents, which, once condensed, form the bio-oil.
Char is the main product that allows organic carbon sequestration in the soil and improves its properties as amendment, whereas the co-products are generally burned to provide heat, losing a consistent fraction of high-value compounds still available in their gaseous form.
In BECOOL, an alternative strategy to valorise the total outputs from slow oxidative pyrolysis is being evaluated.
In Italy, RE-CORD (Renewable Energy Consortium for Research and Demonstration) performed slow oxidative pyrolysis trials of several lignocellulosic biomass, including eucalyptus wood, producing biochar, bio-oils and other liquid fractions and investigating how each feedstock affects the quality and yields of the products.
The experimental tests were carried out in the CarbON unit, an innovative continuous biomass carbonization system based on open top, downdraft technology,

operating in oxidative pyrolysis in the temperature range of 500 – 650°C and equivalence ratio (ER) between 0.1-0.2.
While the feedstock is an ordinary lignocellulosic biomass, it can be noticed that the produced charcoal features some unique properties, i.e. very high fixed carbon (85 wt%) and elemental carbon content (88 wt%) and finally a significant surface area (>100 m2/g). The amount of fixed carbon is of prominent interest for metallurgical applications and for carbon sequestration purposes, whereas the surface area is suitable for activation.
Furthermore, a fractional condensation unit has been realized in the framework of H2020 BECOOL project. The unit is an auxiliary system designed to condense pyrolysis vapours in different fractions, corresponding to different boiling points of the chemical compounds constituting the pyrolysis oil.
The system includes two bubbler condensers and an electrostatic precipitator and can condensate 3 bio-oil fractions up to 3 different temperatures respectively, from 180°C to 20°C in the first steps (1st bubbler + ESP) and from 20 to -15 in the 2nd bubbler.
The main aim is to provide a pyrolysis oil with reduced water content, suitable for gasification and downstream conversion to advanced biofuels for transports.

Learn more in this video

Towards advanced biofuels from energy crops – Gasification and gas cleaning

An important outcome of the BECOOL project is the development of a competitive business case for biofuel production in Europe. To accomplish this, demonstration and the accompanied process development are vital. In this video, Evert Boymans, TNO Netherlands present the results of gasification tests of fiber sorghum, giant reed and Eucalyptus, obtained from experiments at mini-pilot scale, including the tar removal, BTX recovery and sulphur removal. The presentation also explains the methodologies used to remove trace sulphur components such as mercaptans and thiophenes using HDS/ZnO combinations.
For all the three types of biomass the gasification tests were successful, with typical carbon conversion rates between 70% and 80% at 800°C. although sorghum and giant reed resulted more challenging than eucalyptus for what concerns downstream syngas cleaning, due to their higher content of sulphur and nitrogen.

Slides

Learn more in this video

Gasification of liquid intermediates to syngas

One of the routes to produce advanced biofuels from biomass under investigation in the BECOOL project involves the fast pyrolysis of biomass to a liquid intermediate energy carrier, followed by gasification of the liquid to form syngas from which the biofuel is synthesized. This route gives advantages in solving logistical challenges associated with biofuel production from biomass, as well as providing some technological advantages like separating the inorganic (ash forming) elements prior to the gasification stage and making it easier to enable pressurized operation of the gasifier to avoid syngas compression.

In 2020, as part of the thermochemical experimental activities of BECOOL project, samples of giant reed, fibre sorghum and eucalyptus were converted to fast pyrolysis bio-oil (FPBO) by VTT in Finland and the bio-oil was then sent to BTG in the Netherlands for bench scale gasification tests.

The three types of FPBO were gasified in an autothermal catalytic reformer, at a temperature of around 900 ˚C in the partial oxidation zone and around 800 ˚C in the catalytic reforming zone. For each of the feedstocks, a good quality syngas was obtained, containing roughly 50 vol.% H_2, and the remainder almost equally distributed between CO and CO_2. The H_2/CO ratio was near 2:1, which is a good parameter for subsequent Fischer Tropsch synthesis. The average syngas production was around 50 mol (H_2+CO)/kg FPBO, which corresponds well with the theoretical maximum.

These promising results indicate that the final gas composition is almost independent of the original biomass used and therefore confirms the possibility to design feedstock flexible advanced biofuels value chains, which is one of the research goals of BECOOL.

Read the full report

New BECOOL results will be featured at the European Biomass Conference and Exhibition 2021

The BECOOL project will present its results at the European Biomass Conference and Exhibition, which will be held online from 26 to 29 April. The following abstracts were selected for presentations:

Growing Selected Industrial Crops on Marginal Lands for Bioenergy and Biobased Products
E. Alexopoulou CRES, Pikermi, Greece

Biomass from Non-Food Land: Long Term Giant Reed and Switchgrass Evaluation as Feedstock for Advanced Biofuel
Parenti, W. Zegada-Lizarazu, A. Monti, Unibo, Bologna, Italy

Relay Cropping for Enhanced Food and Dedicated Lignocelulosic Feedstock Availability
W. Zegada-Lizarazu, A. Parenti, A. Borghesi, A. Monti, University of Bologna, Bologna, Italy

Sunn Hemp (Crotolaria Juncea L.) A Novel Multi-Purpose Crop for Alternative Cropping Systems
E. Alexopoulou, M. Christou CRES, Pikermi, Greece

Separation and Condensation of Hot Vapours from Oxidative Slow Pyrolysis in Different Fractions
Buffi M., Salimbeni A., Lombardi G, Lotti G., Chiaramonti D.

More information at eubce.com

EUBCE 2021
29th European Biomass Conference & Exhibition | 26 - 29 April Online

Further Reading – BECOOL open access publications

Life Cycle Assessment of Kenaf Grown as Feedstock for Bio-Products and Power Generation within a Crop Rotation with Food Crops in South-West Spain
Sastre, C.M., Carrasco, J.E., Barro, R., Cabanillas, J., Royano, L., Parralejo, A., González, J., Esteban, L.S., Ciria, P.

Tall wheatgrass (Thinopyrum ponticum (Podp)) in a real farm context, a sustainable perennial alternative to rye (Secale cereale L.) cultivation in marginal lands
Ciria C., Sastre, C.M., Carrasco J., Ciria P.

SunnGro: A new crop model for the simulation of sunn hemp grown under alternative management practices
Parenti A., Cappelli G., Zegada-Lizarazu W., Sastre C.M., Christou M., Monti A., Ginaldi F.

Spatio-temporal assessment of integrating intermittent electricity in the EU and Western Balkans power sector under ambitious CO2 emission policies
(Mesfun, S., Leduc, S., Patrizio, P., Wetterlund. E., Mendoza-Poncea, A., Lammensc, T., Staritsky, I., Elbersen, B., Lundgren, J., Kraxner, F.)

Biomass Production and Feedstock Diversification for Advanced Biofuels: the BECOOL Project
(Christou, M., Alexopoulou, E., Monti, A., Zegada-Lizarazu, W., Parenti, A., Carrasco, J., Ciria, C.S., Pari, L., Suardi, A.)

Perennial Grasses as feedstock for Bioenergy and Bio-Products
(Alexopoulou, E., Christou, M., Zegada-Lizarazu, W., Monti, A., Parenti, A., Carrasco, J., Ciria, C.S.)

Evaluation of Sunn Hemp Productivity after Wheat under No Tillage Conditions
(Parenti, A., Zegada-Lizarazu, W., Monti, A.)

Sunn Hemp, a Promising Leguminous Energy Crop as Inter-Cropping System: Preliminary Results for Spain
(Sastre, C.M., Royano, L., Ciria, C.S., Parralejo, A.I., González, J., Ciria, P., Carrasco, J.)

Sowing Dates Effect on Camelina Growth in Different EU Climatic Zones
(Christou, M., Alexopoulou, E., Zanetti, F., Krzyżaniak, M., Stolarski, M.J., Righini, D., Monti, A.)

Maize Cob Harvesting: first assessment of an innovative system
(Pari, L., Bergonzoli, S., Suardi, A., Alfano, V., Scarfone, A., Lazar, S.)

Intercropping Dedicated Grass and Legume Crops for Advanced Biofuel Production
(A.Parenti, W. Zegada-Lizarazu, A. Monti)

Building Value Chains for Large Scale Ft Production
(B.J. Vreugdenhil, E.H. Boymans, P.M.R. Abelha, M. Buffi, D. Chiaramonti)

Sustainable Biomass Feedstock Options for Advanced Biofuels
(M. Christou, E. Alexopoulou, A. Monti, W. Zegada-Lizarazu, A. Parenti, J. Carrasco, C.M. Sastre)

Comparable studies on four annual herbaceous lignocellulosic crops as feedstock for advanced biofuels
(E. Alexopoulou, W.Zegada-Lizarazu, M.Christou, A.Monti)

Innovative Lignocellulosic Crop Rotation Systems as a Source of Feedstock for Biofuels Production
(W. Zegada-Lizarazu, A. Parenti, C. Martin-Sastre, J. Carrasco, M. Cristou, E. Alexopoulou, A. Monti)

Fractional Condensation of Slow Oxidative and Intermediate Pyrolysis Vapors from Lignocellulosic Biomass: Pilot Unit Design and Testing
(M. Buffi, S. Dell'Orco, A. M. Rizzo, D. Chiaramonti)

Investigation of Slurries Made of Char-In-Pyrolysis Oil in Terms of Formulations, Stability, and Rheological Properties
(Buffi, M.)

A Value Chain for Large Scale FT Production: the Case of Pyrolysis Oil-char Slurry Gasification
(Boymans, E., Vreugdenhil, B., Abelha, P., Buffi, M., Chiaramonti, D.)

Discover all project publications and deliverables here

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