BioCarbUp – Optimising the biocarbon value chain for a sustainable metallurgical industry

Newsletter 2-2020

Progress in 2020

In 2020 the focus on studies connected to the resource base in Norway for biocarbon production has continued, carbonization experiments are continuing in different experimental setups and the biocarbons and by-products are characterized. The characterization includes biocarbon CO_2 reactivity testing, and a summer job student has been working at SINTEF Energy Research connected to this topic and kinetics. Characterization methods and critical biocarbon characteristics with respect to the specific biocarbon end-uses have been evaluated and there is a focus on how to improve biocarbon characteristics by tuning biocarbon production processes and by biocarbon upgrading. The latter is also investigated by the BioCarbUp postdoc candidate. The BioCarbUp PhD student has now started, focusing on modelling related to the biocarbon production process. In general, the scientific activities are progressing rather well considering that the Covid-19 situation has inflicted on the ability to carry out experimental activities, where additional HSE regulations must be followed due to the pandemic.

BioCarbUp workshop and steering committee meeting by web

The second BioCarbUp workshop and steering committee meeting was arranged 13-14 October 2020 online. Results and progress were presented, and the program included ample time for first discussions with the industry partners regarding the content to be included in the annual work plan for 2021. The event went smooth, showing that it is possible to carry out such events online, if it is required.

BioCarbUp workshop and steering committee meeting in Trondheim

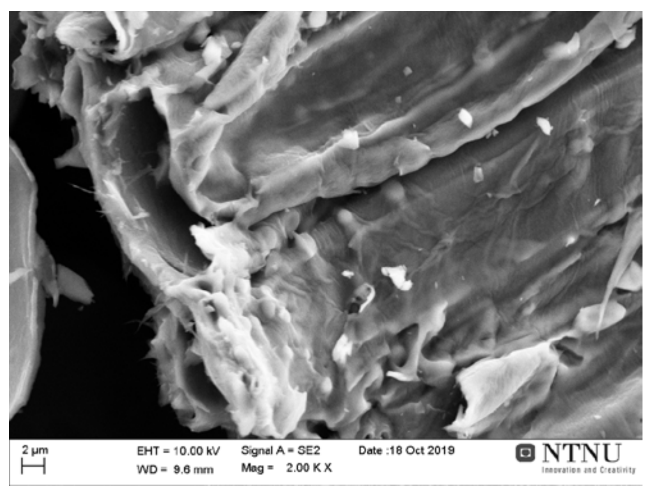
The first BioCarbUp workshop and steering committee meeting was arranged 12-13 February 2020 in Trondheim. Results and progress were presented, and the program included ample time for discussions with the industry partners regarding the final content to be included in the annual work plan for 2020.

PostDoc work

The BioCarbUp PostDoc work within composite agglomerates with biocarbon is progressing well. The PostDoc candidate, Hamideh Kaffash from Iran, started her work August 2019 at Department of Materials Science and Engineering, NTNU, with Professor Merete Tangstad as her supervisor.
Some very interesting recent results:
Three types of industrial charcoal have been densified using C from CH_4 and the C deposition was found to be 13-15%. The properties of the charcoals before and after densification by C deposition were investigated, with the following results:

1. Density increased by 3 times
2. Porosity decreased by 28-38%
3. Compressive strength increased by 7-15 times
4. CO_2 reactivity decreased by 28-40%

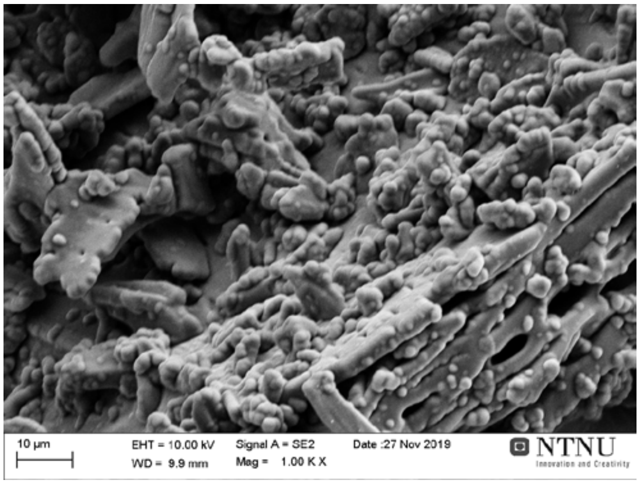
These are promising results, making charcoal more suitable for use in some metallurgical industries. Below are pictures showing a charcoal surface before and after deposition of C from CH_4.



Charcoal before deposition of C from CH_4

- a Knowledge-building Project for Industry (KPN) co-funded by the Research Council of Norway through the ENERGIX-programme.
Contact: oyvind.skreiberg@sintef.no

SINTEF



Charcoal after deposition of C from CH_4

Charcoals have also been impregnated with K to see how the CO_2 reactivity changes and it was found that with increasing K content in the charcoal of up to 2%, the CO_2 reactivity increased slightly, by a factor of 2, while we know from other works that for coke it increased by a factor of 10.

PhD work

The BioCarbUp PhD position within Modelling and CFD simulation of pyrolysis reactors has been filled. The candidate, Boyao Wang from China, is employed at Department of Energy and Process Engineering, NTNU, with Professor Terese Løvås as supervisor and Adjunct Associate Professor Tian Li as co-supervisor.

The candidate will focus on numerical modeling and simulation for efficient biocarbon production. Mandatory course work, literature review and initial research activities are ongoing.

BioCarbUp at MIT A+B Applied Energy Symposium

One BioCarbUp associated work was presented at the 2020 MIT A+B Applied Energy Symposium - e-conference, 13-14 August:

Pietro Bartocci, Lorenzo Riva, Henrik Kofoed Nielsen, Qing Yang, Haiping Yang, Øyvind Skreiberg, Liang Wang, Giulio Sorbini, Eid Gul, Marco Barbanera, Francesco Fantozzi (2020). How to produce green coke?

BioCarbUp at EUBCE 2020

One BioCarbUp work was presented at the 28th European Biomass Conference & Exhibition, originally planned for 27-30 April 2020, Marseille, France, but which was changed to an e-conference 6-9 July due to Covid-19:

Liang Wang, Lorenzo Riva, Øyvind Skreiberg, Pietro Bartocci, Henrik Kofoed Nilsen, Francesco Fantozzi (2020). Effect of Pyrolysis Conditions and Use of Condensates as Binder on Densification of Biocarbon.

BioCarbUp in Energy & Fuels

One BioCarbUp work has been published in Energy & Fuels:

Gábor Várhegyi, Liang Wang, Øyvind Skreiberg (2020). Empirical Kinetic Models for the Combustion of Charcoals and Biomasses in the Kinetic Regime. The abstract is given below.

"An empirical kinetic model was proposed in 2019 and tested extensively on biomass pyrolysis (Várhegyi, G., Energy Fuels 2019, 33, 2348−2358). The model was based on an isoconversional kinetic equation. The functions in the kinetic equation were approximated by mathematical formulas with adjustable parameters, and the parameters were determined by the method of least squares. This procedure ensures that the data calculated from the model would be close to the experimental data. In the present work, this way of modeling was adapted for the combustion of charcoals and lignocellulosic biomasses. The performance of the model was tested by the reevaluation of TGA experiments from earlier publications. In total, 18 experiments belonged to a study of charcoals, while 20 experiments were carried out on wheat straw and willow samples. The corresponding temperature programs included linear, modulated, stepwise, and constant reaction rate (CRR) temperature–time functions. The adjustable parameters of the model were determined by the method of least squares by evaluating groups of experiments together. The procedure aimed at finding best-fitting models for the derivative of the measured reacted fraction. The activation energy, E, was regarded as constant for the whole process. The change of the reactivity during the progress of the reaction was described by the rest of the isoconversional kinetic equation. Model variants with different numbers of adjustable parameters resulted in practically identical E values. It was possible to determine common E values for different samples with only a slight worsening of the fit quality. This procedure allowed an easy comparison of the reactivities of the samples as functions of the reacted fraction."

BioCarbUp in Energy & Fuels

One BioCarbUp associated work has been published in Energy & Fuels:

Liang Wang, Lorenzo Riva, Øyvind Skreiberg, Roger Khalil, Pietro Bartocci, Qing Yang, Haiping Yang, Xuebin Wang, Dengyu Chen, Magnus Rudolfsson, Henrik Kofoed Nielsen (2020). Effect of Torrefaction on Properties of Pellets Produced from Woody Biomass. The abstract is given below.

"Torrefaction has been recognized as a promising strategy to improve handling and storage properties of wood-based pellets, thus producing a uniform-quality commodity with high energy density and hydrophobicity. In this work, pellets produced from spruce stem wood, bark, and forest residues were torrefied in a bench-scale tubular reactor at 225 and 275 °C with two residence times (30 and 60 min). The effects of torrefaction on general properties, grindability, mechanical properties, hydrophobicity, and microstructure of the studied pellets were investigated. The increase of torrefaction severity reduced mass yields, but the heating values and the fixed carbon content of the torrefied pellets considerably increased. The grindability of raw pellets was substantially improved after torrefaction treatment. The energy required for grinding torrefied pellets is less than 50% of the energy needed for grinding the untreated pellets. In comparison to untreated pellets, the particles from ground torrefied pellets have clearly smaller sizes in a narrower size range. The increase of torrefaction severity improved hydrophobicity of the pellets, which have high resistance to water uptake and maintain their integrity after immersion testing. Upon torrefaction treatment, the durability and tensile strength of the pellets slightly decreased. Scanning electron microscopy analysis results show that particles from wood pellets torrefied at 275 °C lost their fibrous structure with an evident decrease of length/diameter ratios compared to untreated wood pellets. The particles from ground torrefied pellets are more uniform in terms of shape and size. Torrefaction can considerably improve grindability and uniformity of wood-based pellets and make them more acceptable in pulverized fuel applications."

BioCarbUp in Energy & Fuels

One BioCarbUp associated work has been published in Energy & Fuels:

Aekjuthon Phounglamcheik, Liang Wang, Henrik Romar, Norbert Kienzl, Markus Broström, Kerstin Ramser, Øyvind Skreiberg, Kentaro Umeki (2020). Effects of Pyrolysis Conditions and Feedstocks on the Properties and Gasification Reactivity of Charcoal from Woodchips. The abstract is given below.

"Pyrolysis conditions in charcoal production affect yields, properties, and further use of charcoal. Reactivity is a critical property when using charcoal as an alternative to fossil coal and coke, as fuel or reductant, in different industrial processes. This work aimed to obtain a holistic understanding of the effects of pyrolysis conditions on the reactivity of charcoal. Notably, this study focuses on the complex effects that appear when producing charcoal from large biomass particles in comparison with the literature on pulverized biomass. Charcoals were produced from woodchips under a variety of pyrolysis conditions (heating rate, temperature, reaction gas, type of biomass, and bio-oil embedding). Gasification reactivity of produced charcoal was determined through a thermogravimetric analysis at an isothermal condition of 850 °C and 20% of CO_2. The charcoals were characterized for the elemental composition, specific surface area, pore volume and distribution, Raman spectroscopy, and inductively coupled plasma optical emission spectrometry. The analysis results were used to elucidate the relationship between the pyrolysis conditions and the reactivity. Heating rate and temperature were the most influential pyrolysis parameters affecting charcoal reactivity, followed by reaction gas and bio-oil embedding. The effects of these pyrolysis conditions on charcoal reactivity could primarily be explained by the difference in meso- and macropore volume, and the size and structure order of aromatic clusters. The lower reactivity of slow pyrolysis charcoals also coincided with its lower catalytic inorganic content. The reactivity difference between spruce and birch charcoals appears to be mainly caused by the difference in catalytically active inorganic elements. Contrary to pyrolysis of pulverized biomass, low heating rate produced higher specific surface area compared with high heating rate. Furthermore, the porous structure and the reactivity of charcoal produced from woodchips were influenced when the secondary char formation was promoted, which cannot be observed in pyrolysis of pulverized biomass."

Other news

Elkem biocarbon production plant in Canada

Elkem has in an press release announced:

"Elkem has decided to invest in a new biocarbon pilot plant in Canada. The project aims to secure industrial verification of Elkem's technology for renewable biocarbon, with a long-term goal of contributing to climate-neutral metal production. The technology also has potential for application in other industry sectors, contributing to reduced CO_2 emissions. The total investment for the pilot plant amounts to NOK 180 million. The project has received financial support from the Canadian government, the Québec government and the city of Saguenay, reducing Elkem's net investment to NOK 60 million. The plant will be constructed near Elkem's production site in Chicoutimi, Quebec, Canada, with start of construction planned for the second half of 2020.

Based on conclusions from the pilot, Elkem will evaluate the basis for a full-scale plant."

Prosess21

Prosess21 is a forum established to strengthen the coordination between the competence environments in and connected to the process industry and the public actors. Prosess21 shall give strategic advices and recommendations on how to minimize emissions from the process industry while achieving sustainable growth. The metallurgical industry is a very important part of the Norwegian process industry. Prosess21 provided their input to the work with a Report to the Storting (white paper) regarding how to reach the national climate goals for 2030. An interesting report, with respect to possible future use and priorities regarding biomass based materials in the Norwegian process industry, Biobasert Prosessindustri, is now finalized by one of the Prosess21 expert groups.
For more info about Prosess21:
https://www.prosess21.no/

PhD thesis on Production and application of sustainable metallurgical biochar pellets

Lorenzo Riva, who was awarded the Elkem student prize for 2019 for his work within pyrolysis and pelletization of metallurgical biochar, and his networking abilities, defended his PhD thesis 7 September. He was in his work also collaborating with BioCarbUp. The thesis is available here.

Norsk Biokullnettverk

The "Norwegian Biochar Network" was founded in 2019. Its purpose is to gather actors from the biochar value chains in Norway. The network aims to promote biochar as an important part of the circular economy, and works towards Norwegian leadership in value creation connected to production and utilization of biochar. SINTEF Energy Research is a member in the network, and Øyvind Skreiberg is a member of its board. Also the BioCarbUp industry partners Elkem and Eramet Norway are members in the network. The network has now been in operation for more than one and a half year and has attracted great interest and many members. As a part of the network activities, seminars, workshops and webinars have been arranged on different biochar topics and for different industries (e.g. the metallurgical industry), and the network also are active in making the biochar voice heard in the society and towards authorities. All in all, the foundation of the network has been a timely one, serving its purpose. For more info about the network: https://www.biokull.info/ and the news page here.

Nordic Biochar Network

The Nordic Biochar Network was founded in 2019. It is a joint initiative of researchers in the Nordic countries to increase and spread knowledge about biochar. Research Scientist Kathrin Weber from SINTEF Energy Research was the main initiator of the Nordic Biochar Network. As a part of the network activities, a conference and webinars have been arranged. For more info about the network: https://www.nordicbiochar.org/

International Biochar Initiative

In addition to the Norwegian Biochar Network and the Nordic Biochar Network, the International Biochar Initiative (IBI) is a source of extensive information connected to the biochar field. Its mission is to provide a platform for fostering stakeholder collaboration, good industry practices, and environmental and ethical standards to support biochar systems that are safe and economically viable. The members of the Norwegian Biochar Network also become members of the international Biochar Initiative. IBI news are available here.

Recent events

28th European Biomass Conference & Exhibition, 27-30 April 2020, Marseille, France. - Changed to e-conference due to Covid-19, 6-9 July

TMS 2020 Annual Meeting & Exhibition, 23-27 February 2020, San Diego, California, USA.
https://www.tms.org/tms2020

Biochar + Soil workshop, 31 January 2020, Copenhagen, Denmark.
https://conferencemanager.events/biocharandsoil

Norsk Biokullnettverk workshop for metallurgical industry, 17 January 2020, Trondheim, Norway.

Upcoming events

Norsk Biokullnettverk seminar for metallurgical industry, 21 January 2021, Arendal, Norway. + virtual

International Symposium on Functional Biomass-derived Carbon Materials (GreenCarbon 2020). 9-11 March 2021, Zaragoza, Spain. e-conference
http://greencarbon-etn.eu/greencarbon2020/

TMS 2021 Annual Meeting & Exhibition, 15-18 March 2021. e-conference.
https://www.tms.org/tms2021

23rd International Conference on Analytical and Applied Pyrolysis (PYRO 2021), 26-30 April 2021, Ghent, Belgium.
http://www.pyro2020.org/

29th European Biomass Conference & Exhibition, 26-29 April 2021, Marseille, France. + e-conference
http://www.eubce.com/

Links (click on the links or logos to get there)
BioCarb+
KPN reduced CO_2
Prosess21
SKOG22
Energi21
Norsk Biokullnettverk
Nordic Biochar Network
International Biochar Initiative

Project information and past achievements

About the project

The overall objective of BioCarbUp is to optimise the biocarbon value chain for the metallurgical industry through:

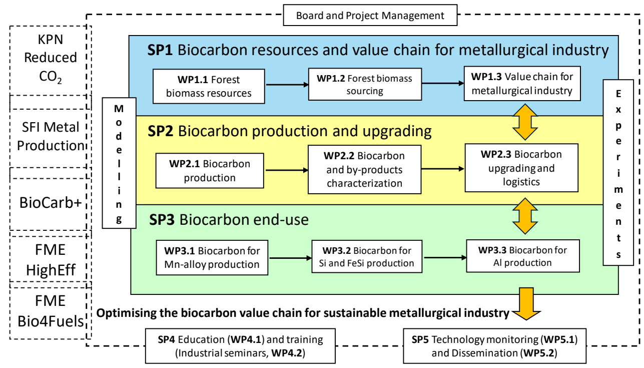
- **Production of biocarbon with sufficient quality** satisfying the end user quality requirements while ensuring optimum utilisation of the by-products
- **Optimised sourcing of Norwegian forest resources** for biocarbon production towards the specific metallurgical processes
- **Maximising the energy and cost efficiency** of the biocarbon value chain for metallurgical industry

The sub-objectives are:

- Identifying **optimum forest resources** for the specific metallurgical processes
- Identifying and **optimizing carbonisation processes and conditions** to produce optimum yields and qualities
- Developing methods for upgrading and **tuning biocarbon quality** to increase its suitability for the specific metallurgical processes, and methods for upgrading the by-product tar to higher value products
- Developing fundamental **knowledge of biocarbon behaviour** in and influence on the specific metallurgical processes and biocarbon impact on product quality
- Increasing expertise throughout the **biocarbon value chain for the metallurgical industry**
- **Educating** highly skilled candidates within this area and training of industry partners
- Monitoring activities and state-of-the-art practice within this area and **disseminating** knowledge to industry partners, and other interested parties where applicable

The anticipated results of the project are reduced harvesting and logistics costs for woody biomass resources, maximised BC yield and quality directly in the BC production process or via secondary upgrading and maximised utilisation in BC end-use applications, i.e. the metallurgical industry. Additionally, by-products utilisation and higher value products from tar are complementary foci.

The Work Breakdown Structure of BioCarbUp is:



BioCarbUP management and work break down structure and project links and information flow.
BioCarb+: Enabling the biocarbon value chain for energy, http://www.sintef.no/biocarb
SFI Metal Production, https://www.ntnu.edu/metpro
FME HighEFF: Centre for an Energy Efficient and Competitive Industry for the Future, http://www.higheff.no
KPN Reduced CO_2 emissions from metal production, https://www.sintef.no/en/projects/reduced-co2-reduced-co2-emissions-in-metal-production/
FME Bio4Fuels, https://www.nmbu.no/bio4fuels

BioCarbUp will run for four years (2019-2022) and has a total cash budget of 25 million NOK, which is 80% financed by the Research Council of Norway through the ENERGIX program and 20% financed by the industrial partners.

The BioCarbUp consortium

The project consortium covers all the necessary aspects, and includes large and central industrial players in the metallurgical and biomass utilization areas in Norway, complemented by recognized international research institutions.

SINTEF Energy Research leads the project and focus on biocarbon production and upgrading and the value chain for metallurgical industry. **NTNU** (Norwegian University of Science and Technology) supervise the PhD, the PostDoc and Master candidates. **SINTEF Industry** focus on biocarbon end-use and bio-based binder. **NIBIO** (Norwegian Institute of Bioeconomy Research) focus on biocarbon resources and value chain for metallurgical industry. **University of Hawaii** focus on biocarbon production at pressurised conditions, while **Hungarian Academy of Sciences** focus on biocarbon and by-products characterization.

The industrial partners contribute with finances as well as access to infrastructure and their extensive industrial knowledge generated through their commercial activities within the metallurgical areas: Elkem, Eramet Norway, Hydro Aluminium, Alcoa Norway, Eyde Cluster, and Norsk Biobrensel as a biomass supplier to metallurgical industry.

The constellation of project partners is very strong, bringing together leading research organisations within the field and major industrial players.

Project background

The ENERGIX program plan clearly states the importance of sustainability and sustainable value chains, including biomass based, contributing to reduced CO_2 emissions and a carbon neutral society in 2050. For biomass, there is an expectation of total biomass feedstock utilisation.

The metallurgical industry in Norway seeks to substitute large amounts of biocarbon for fossil reductants in their processes. The Norwegian Process Industry Roadmap - Combining growth and zero emissions by 2050, and Industrimeldingen lay the foundation for an accelerated utilization of Norwegian biomass resources that would reduce the CO_2 footprint of the metallurgical industry. The former document targets a 43% reduction of CO_2 by 2030 compared to 2005 levels. To enable this transformation, the whole biocarbon (BC) value chain for the metallurgical industry must be optimized to remove economic constraints, satisfy reductant quality demands, and develop predictable (amount, quality and price), long-term biomass resource demand.

This project responds to the national strategies and the goals of the metallurgical industry by analyzing and optimizing the BC value chain to produce suitable and affordable reductants in a sustainable manner. Producing BC, a renewable material from biomass resources, will have a twofold effect: (1) reduce CO_2 emissions by substituting for fossil reductants and (2) increase forest resource utilisation by creating higher value material and/or energy products. Due to the BC quality demanded by the metallurgical processes, woody biomass, especially stem wood, is the most suitable candidate for reductant feedstock.

The overall objective of this project is to optimise the biocarbon value chain for the metallurgical industry.

Project overview

The project is divided into 5 subprojects (SP), each subproject is itself divided into several work packages (WP).

- Biocarbon resources and value chain for metallurgical industry - SP1
- Biocarbon production and upgrading - SP2
- Biocarbon end-use - SP3
- Education and training - SP4
- Technology monitoring and dissemination - SP5

Biocarbon resources and value chain for metallurgical industry - SP1

The main objectives of SP1 are to identify optimum forest resources for the specific metallurgical processes, identify shortcomings in existing biomass quality monitoring systems, and increase the expertise throughout the biocarbon value chain for metallurgical industry.

SP1 leader: Senior Scientific Adviser Simen Gjølsjø, NIBIO

Biocarbon production and upgrading - SP2

The main objectives of SP2 are to develop novel (new) or improved solutions to produce and upgrade biocarbon dedicated for metallurgical processes with optimized logistics and maximize use of by-products.

SP2 leader: Research Scientist Liang Wang, SINTEF Energy Research

Biocarbon end-use - SP3

The main objective of SP3 is to identify biocarbon products that can be used in Mn, Si and Al industry to reduce fossil CO_2 emissions while having neutral or positive impacts on process performance and energy efficiency. SP3 will develop fundamental competence about effect on specific metallurgical processes of changes in properties of carbon sources. Sources currently in use will be compared with bio-based carbon sources.

SP3 leader: Senior Research Scientist Eli Ringdalen, SINTEF Industry

Education and training - SP4

The major objective of SP4 is to strengthen the education within this field through MSc and PhD students, and a postdoc candidate. The objective is also to increase the competence level in the industry. The long-term goal is competence building and strengthening of the education within the biocarbon value chain for metallurgical industry.

SP4 leader: Associate Professor Tian Li, NTNU

Technology monitoring and dissemination - SP5

The major objectives of SP5 are to monitor the latest research and technological developments and to disseminate research results.

SP5 leader: Chief Scientist Øyvind Skreiberg, SINTEF Energy Research, who also is the BioCarbUp project leader

Earlier progress

In 2019 the focus was on start-up of the project, studies connected to the resource base in Norway for biocarbon production, planning and execution of carbonisation experiments, characterisation of biocarbon, start-up of the postdoc work and dissemination from the project.

Earlier publications

BioCarbUp at TMS 2020

One BioCarbUp associated work was presented at TMS 2020 Annual Meeting & Exhibition, 23-27 February 2020, San Diego, California, USA:

Camilla Sommerseth, Ove Darell, Bjarte Øye, Anne Støre, Stein Rørvik (2020). Charcoal and use of Green Binder for use in Carbon Anodes in the Aluminium Industry.

A corresponding article has been published in [Light Metals 2020, pp. 1338-1347](). The abstract is given below.

"Carbon anodes for aluminium production are produced from calcined petroleum coke (CPC), recycled anode butts and coal tar pitch (CTP). The CO_2 produced during anode consumption contributes to a substantial amount of the CO_2 footprint of this industrial process. Charcoal from wood has been suggested to partly replace coke in anodes but high porosity, low electrical resistivity and high ash content contributes negatively to final anode properties. In this work, charcoal from Siberian larch and spruce was produced by heat treatment to 800, 1200 and 1400 ℃ and acid-washed with H_2SO_4. Acid-washing resulted in reduced metal impurity and the porosity decreased with increasing heat treatment. Pilot anodes were made from CTP, CPC with some additions of spruce and larch charcoal. Another set of pilot anodes were produced using a green binder. Compared to reference anodes, the CO_2 reactivity of anodes containing larch was less affected compared to anodes containing spruce. The green binder was found to be highly detrimental for the anodes' CO_2 reactivity properties. Electrochemical consumption increased for anodes containing both green binder, larch and spruce compared to the reference anode."

BioCarbUp in Journal of Thermal Analysis and Calorimetry

One BioCarbUp work has been published in Journal of Thermal Analysis and Calorimetry:

Gábor Várhegyi, Liang Wang, Øyvind Skreiberg (2019). [Non-isothermal kinetics: Best fitting empirical models instead of model-free methods](). The abstract is given below.

"The isoconversional (or model-free) methods cannot provide meaningful kinetic description for most samples in thermal analysis. Nevertheless, they can serve as empirical models. A usable empirical model should describe well the observed data and should be suitable for predictions, too. For this purpose, the functions in the isoconversional kinetic equation were parametrized, and the parameters were determined by the method of least squares. This procedure ensures that the data calculated from the model would be close to the experimental data. The present work supplemented a preceding work of Várhegyi (Energy and Fuels 33:2348–2358, 2019) by further considerations and by various evaluations on the TGA curves of a wood sample. The prediction capabilities of the models were also tested. It was found that an evaluation based on three experiments with constant heating rates could predict well two further experiments with stepwise temperature programs. Furthermore, a modification of the model was proposed and examined. The aim of this modification was to improve the fit quality without increasing the number of parameters in the least-squares procedure."

BioCarbUp in Applied Energy

One BioCarbUp associated work has been published in Applied Energy:

Lorenzo Riva, Henrik Kofoed Nielsen, Øyvind Skreiberg, Liang Wang, Pietro Bartocci, Marco Barbanera, Gianni Bidini, Francesco Fantozzi (2019). [Analysis of optimal temperature, pressure and binder quantity for the production of biocarbon pellet to be used as a substitute for coke](). The abstract is given below.

"In order to contribute to the decarbonization of the economy, efficient alternatives to coal and coke should be found not only in the power sector but also in the industrial sectors (like steel, silicon and manganese production) in which coal and coke are used as a reductant and for steel production also as a fuel. To this aim many research works have been focused on the development of a coke substitute based on woody biomass and known as "biocarbon". There are still barriers to overcome, among them: the biocarbon low density, poor mechanical strength and high reactivity. In this paper a new biocarbon production methodology is proposed, based on: pyrolysis at 600 °C, densification (using pyrolysis oil as binder), reheating of the obtained pellet. Response surface methodology with a Box-Behnken experimental design was utilized to evaluate the effects of the process conditions on the pellet's quality. Responses showed that densification was mainly affected by oil content and pelleting temperature, while pelleting pressure had a minor influence. The pelleting process has been finally optimized using Derringer's desired function methodology. Optimal pelletizing conditions are: temperature equal to 60 °C, pressure equal to 116.7 MPa, oil content concentration of 33.9 wt%. These results are relevant for metal production industries at a global level. The identified optimal parameters of the new biocarbon production process can contribute to replace coke with sustainable fuels and probably reduce great part of the related greenhouse gases emissions."

BioCarbUp at JTACC 2019

One BioCarbUp work was presented at 2nd Journal of Thermal Analysis and Calorimetry Conference (JTACC), 8-21 June 2019, Budapest, Hungary:
Gábor Várhegyi, Liang Wang, Øyvind Skreiberg (2019). Non-isothermal kinetics: best fitting empirical models instead of model-free methods.
A corresponding article has been published in Journal of Thermal Analysis and Calorimetry.

BioCarbUp at ISFR 2019

One BioCarbUp associated work was presented at 10th International Symposium on Feedstock Recycling of Polymeric Materials (ISFR), 26-29 May 2019, Budapest, Hungary:
Bence Babinszki, Viktor Terjék, Luca Kőhalmi, Eszter Barta-Rajnai, Zoltán Sebestyén, Zoltán May, Emma Jakab, Zsuzsanna Czégény (2019). Comparative study of torrefaction oils of rape straw and black locust waste.

BioCarbUp in EERA Bioenergy Newsletter

An article entitled "Optimising the biocarbon value chain for a sustainable metallurgical industry" presented BioCarbUp in an EERA (European Energy Research Alliance) Bioenergy newsletter.

Publication list

Gábor Várhegyi, Liang Wang, Øyvind Skreiberg (2020). Empirical Kinetic Models for the Combustion of Charcoals and Biomasses in the Kinetic Regime. Energy & Fuels 34(12):16302-16309.

Liang Wang, Lorenzo Riva, Øyvind Skreiberg, Roger Khalil, Pietro Bartocci, Qing Yang, Haiping Yang, Xuebin Wang, Dengyu Chen, Magnus Rudolfsson, Henrik Kofoed Nielsen (2020). Effect of Torrefaction on Properties of Pellets Produced from Woody Biomass. Energy & Fuels 34(12):15343-15354.

Pietro Bartocci, Lorenzo Riva, Henrik Kofoed Nielsen, Qing Yang, Haiping Yang, Øyvind Skreiberg, Liang Wang, Giulio Sorbini, Eid Gul, Marco Barbanera, Francesco Fantozzi (2020). How to produce green coke? 2020 MIT A+B Applied Energy Symposium - e-conference, 13-14 August.

Liang Wang, Lorenzo Riva, Øyvind Skreiberg, Pietro Bartocci, Henrik Kofoed Nielsen, Francesco Fantozzi (2020). Effect of Pyrolysis Conditions and Use of Condensates as Binder on Densification of Biocarbon. 28th European Biomass Conference & Exhibition - e-conference, 6-9 July.

Aekjuthon Phounglamcheik, Liang Wang, Henrik Romar, Norbert Kienzl, Markus Broström, Kerstin Ramser, Øyvind Skreiberg, Kentaro Umeki (2020). Effects of Pyrolysis Conditions and Feedstocks on the Properties and Gasification Reactivity of Charcoal from Woodchips. Energy & Fuels 34(7):8353-8365.

Camilla Sommerseth, Ove Darell, Bjarte Øye, Anne Støre, Stein Rørvik (2020). Charcoal and use of Green Binder for use in Carbon Anodes in the Aluminium Industry. Light Metals 2020, The Minerals, Metals & Materials Series, pp. 1338-1347.

Øyvind Skreiberg (2020). Ulike pyrolyseteknologier og teknikker. Norsk Biokullnettverk Fagseminar Metallindustri, 17 januar 2020, Trondheim.

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