BioCarb+ Enabling the biocarbon value chain for energy

Newsletter 2-2016

Progress in 2016

In 2016 focus is on further studies connected to the resource base, carbonization experiments under different conditions, biocarbon combustion and gasification reactivity and techno-economic studies connected to biocarbon production and use. This is in sum extensive studies that contributes with significantly increased knowledge regarding how Norwegian biomass resources can be utilized in an optimum manner in the biocarbon value chain.

In 2015 focus was on further work connected to the resource base, biocarbon production and logistics, as well as biocarbon end use properties.

In 2014 focus was on startup of the project and the planned activities and deliverables for 2014. Various studies were started connected to the resource base and costs of these, fuel properties, feeding solutions, carbonization technologies and biocarbon conversion applications. The PhD position on modelling of biocarbon production was also announced, and filled.

BioCarb+ at ICAE 2016

Five BioCarb+ papers were presented at the 8th International Conference on Applied Energy in Beijing, China, 8-11 October 2016. The paper titles were "CO_2 Gasification of Charcoals in the Context of Metallurgical Application", "Techno-economic assessment of thermal co-pretreatment and co-digestion of food wastes and sewage sludge for heat, power and biochar production", "Simultaneously boosting the mass and fixed-carbon yields of charcoal from forest residue via atmospheric carbonization", "Biocarbonization process for high quality energy carriers: Techno-economics", and "Biomass Charcoal Properties Changes during Storage". The papers have been accepted for publication in Energy Procedia.

BioCarb+ at IConBM 2016

Two BioCarb+ abstracts were accepted for submission of full papers for presentation at the 2nd International Conference on Biomass, 19-22 June 2016, Giardini Naxos-Taormina, Sicily, Italy. The papers published in Chemical Engineering Transactions are:

1) CO_2 reactivity assessment of woody biomass biocarbons for metallurgical purposes, with the abstract:

"Replacing the use of fossil reductants with biocarbons in metallurgical industries has a great potential with respect to reducing CO_2 emissions and the contribution from this industry to the increasing greenhouse gas effect. However, biocarbons are significantly different from fossil reductants and the biocarbon properties vary in a wide range depending on the raw biomass properties and the biocarbon production process conditions. A key property of the biocarbons is their reactivity in the specific metallurgical process. The reactivity should be appropriate for the specific metallurgical process, to ensure an optimum reduction process. Especially important is the biocarbon reactivity towards CO_2, i.e. the CO_2 gasification of biocarbon fixed carbon. A standard method has earlier been developed by the metallurgical industry to test the CO_2 reactivity of coal and coke. This can be adopted also for biocarbons. However, a simpler and more cost-efficient reactivity test method is wished for. For the silicon industry, also SiO reactivity is important and a standard method has been developed. This is very expensive to carry out, and also here a simpler and more cost-efficient reactivity test method is wished for. If a qualitative correlation between SiO and CO_2 reactivity could be established as well, this would be very beneficial for this metallurgical industry. In this study, the main objectives were to assess the CO_2 reactivity of biocarbons produced from different woody biomass in two experimental setups, a standardized setup and a thermogravimetric analyser (TGA), and to compare with the reactivity of fossil reductants. Spruce and

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

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birch stem wood and in addition their forest residues were tested. The results show that even if quantitatively different results were found in the two experimental setups, the qualitative results were the same, and hence the TGA test provides the opportunity of a simplified and cost-efficient CO_2 reactivity test method. The biocarbon from the forest residues showed a higher reactivity than stem wood biocarbon, probably due to the higher ash content in the forest residues and their biocarbons, giving a catalytic effect. Compared to coke the biocarbons were more reactive."

2) Value chain analysis of biocarbon utilisation in residential pellet stoves, with the abstract:

"Biocarbon production is a thermochemical conversion process, which transfers biomass into solid fuels characterized with superior handling, grinding and combustion properties. Biocarbon can be potentially utilized as a high quality fuel in small-scale heating applications, as charcoal, powder, briquettes or pellets. However, there are only few studies on the use of biocarbon in residential stoves. Charcoal based modern residential stoves can achieve high thermal efficiency and low emissions. In this study, the main objectives were to assess the energy efficiency of the whole value chain for utilization of carbonized wood for small-scale biocarbon pellet based stoves and to evaluate the overall heat production cost of the whole value chain by a techno-economic approach, under Norwegian conditions. The carbonization temperature did not affect the stove thermal efficiency significantly. However, at higher carbonization temperatures higher biocarbon pellet production cost and higher overall heat production cost were obtained when standalone pellet production was considered. In the case of pellet and district heat coproduction, the pellet production cost was always lower than the corresponding one without district heat production."

BioCarb+ at 24th European Biomass Conference & Exhibition

Four BioCarb+ works were presented at the 24th EUBCE conference in Amsterdam, 6-9 June 2016:

1) Bio-carbonization process integration for high quality energy carriers: charcoal, biomethane, biocrude, and biofertilizer
2) Carbon Yield Predictions in Biochar Based on Stochastic Reactor Modelling
3) Reactivity assessment of biocarbons for metallurgical purposes
4) Energy efficiency, environmental aspects and cost-efficiency of small-scale biocarbon conversion applications – value chain analysis

BioCarb+ at Pyro 2016

Two BioCarb+ works were presented at the 21st International Symposium on Analytical and Applied Pyrolysis, 9-12 May 2016, Nancy, France.

1) Stochastic reactor modelling for biomass pyrolysis
2) Towards the maximum theoretical yields of charcoal from biomass pyrolysis

BioCarb+ in Energy & Fuels

A manuscript entitled "Experimental Study on Charcoal Production from Woody Biomass" has been published in Energy & Fuels. The abstract is given below.

"In the present work, effects of process conditions on char and fixed carbon yields from four woody biomasses were studied. The influence of the particle size, sample mass, and pressure on experimental values of char and fixed carbon yields from spruce stem wood, spruce forest residue, birch stem wood, and birch forest residue were examined in three thermogravimetric analyzers (TGAs) (two atmospheric and one pressurized) and a flash carbonizer. The obtained experimental fixed carbon yields were then compared to theoretical values calculated using the elemental composition of the studied woody biomasses. It was found that carbonization of small samples of small particles in atmospheric TGAs in an open crucible/pan offered the lowest fixed carbon yield. The yields were improved when following standard proximate analysis procedures employing closed crucibles. Further enhancement of the fixed carbon yields were obtained in the atmospheric TGAs using a crucible covered by a lid that restricts release of volatiles. Further, an increase of the pressure, particle size, and sample size gave more significant effects on char and fixed carbon yields. The largest gains were obtained as large particles were carbonized at elevated pressures. The highest char and fixed carbon yields were realized by a flash carbonizer at elevated pressure. Carbonization of spruce wood in the flash carbonizer at 2.2 MPa offered a fixed carbon yield of 28 wt %, which approaches 85% of the theoretical value. Scanning electron microscopy analyses revealed significant differences in morphology and microstructure of char particles produced under the different conditions. The spruce wood char particles produced in the flash carbonization reactor passed through a molten stage, showing a smooth and intact surface. Melting of the cell structure and recondensation/deposition of secondary carbon are more intensive at an elevated pressure. The findings presented in this work suggest that secondary reactions, involving the interaction of tarry vapors with char and conversion of them to

secondary char, play a key role in charcoal formation. Char and fixed carbon yields from biomass can be considerably enhanced under process conditions that extend contacts of vapor phases with the char matrix."

This is a key micro-scale experimental work in BioCarb+ connected to charcoal yield and quality.

BioCarb+ in Energy & Fuels

A manuscript entitled "Charcoal 'mines' in the Norwegian woods" has been published in Energy & Fuels. The abstract is given below.

"This paper presents lab-scale flash carbonization (FC) experiments under elevated pressure using Norwegian wood as a feedstock. The silicon and ferrosilicon industry of Norway has been urged to reduce fossil CO_2 emissions by increasing the use of charcoal as a substitute for coal and coke in the production process. Because charcoal is not produced in Norway, large amounts of it are imported from south Asia. Norway now intends to produce charcoal locally using optimum carbonization techniques from local biomass and forestry waste. That is where the pressurized FC experiments come in. Birch, spruce and corresponding forest residues (FRs) were carbonized, enabling the analysis of the impact of pressure and FC canister insulation on their respective fixed carbon yields. FRs proved to be proper to make charcoal, because fixed carbon contents of 80% could be achieved at moderate pressures. The fixed carbon yields of spruce and birch wood reached over 90% of their theoretical values. The high charcoal yields can result in remarkable cost savings for the metallurgical industry while, at the same time, making excessive deforestation unnecessary. The use of coal will soon be abandoned in the ferrosilicon industry, and charcoal “mines” could become an obvious choice."

This is a key bench-scale experimental work in BioCarb+ connected to charcoal yield and quality.

BioCarb+ in Energy & Fuels

A manuscript entitled "Comprehensive compositional study of torrefied wood and herbaceous materials by chemical analysis and thermoanalytical methods" has been published in Energy & Fuels. The abstract is given below.

"In this work, the torrefaction of three biomass materials, black locust wood, wheat, and rape straw, was studied at various temperatures: 200, 225, 250, 275, and 300 °C. The thermal stability and formation of the decomposition products of the untreated and treated samples were measured by the thermogravimetry/mass spectrometry method. The degree of hemicellulose and cellulose decomposition during torrefaction at different temperatures was characterized by compositional analysis of the torrefied and untreated samples. The cellulose, hemicellulose, and Klason lignin contents of the raw and torrefied biomass samples were determined by acidic hydrolysis and subsequent high-performance liquid chromatography analysis. The inorganic ion contents of the untreated samples were measured by the inductively coupled plasma optical emission spectrometry method. The joint evaluation of the results obtained by various analytical methods revealed that the acidic side groups of hemicellulose were partially split off, while the main mass of hemicellulose did not degrade at 225 °C torrefaction temperature. About 40% of hemicellulose degrades at 250 °C torrefaction temperature and the remainder decomposes at a higher temperature. Although hemicellulose has a different chemical structure in the hardwood and straws, no significant differences were observed in the thermal stability of hemicelluloses in the three studied samples. When the significantly higher alkali ion content of the straw samples is taken into consideration, it was concluded that the alkali ion content of the samples did not modify the thermal stability of hemicellulose. Statistical analysis [principal component analysis (PCA)] has been used to present correlations between the torrefaction temperature, chemical composition, and thermal parameters of the samples. The PCA calculations revealed substantial changes in the chemical composition and thermal properties of biomass materials as a result of torrefaction at 275–300 °C temperatures."

This is a key work connected to compositional changes of thermally upgraded biomass.

BioCarb+ in Energy & Fuels

A manuscript entitled "Combustion Characteristics of Biomass Charcoal Produced at Different Carbonization Conditions: A Kinetic Study" has been published in Energy & Fuels. The abstract is given below.

"The combustion properties of spruce chars and spruce forest residue chars were studied in the kinetic regime by a series of thermogravimetric analysis (TGA) experiments. The work aimed at establishing how the pressure of the char preparation affects the reactivity with oxygen. Parts of the chars were prepared from a thin layer of biomass in inert gas flow at atmospheric pressure and 0.8 MPa. Other chars were formed in a pressurized reactor by a flash carbonization method [Antal, M. J., Jr.; Mochidzuki, K.; Paredes, L. S. Flash carbonization of biomass. Ind. Eng. Chem. Res. 2003, 42 (16), 3690−3699, DOI:

10.1021/ie0301839]. Despite the differences in the preparation, remarkable similarities were observed in the combustion behavior of the samples. The kinetics of the char burnoff was described by assuming three partial reactions. A total of 18 experiments at three different temperature programs were evaluated by the method of least squares to obtain dependable kinetic model variants. A common activation energy of 150 kJ/mol gave a reasonable description for the three partial reactions in all experiments."

This is a key work on combustion characterization of biomass charcoal produced at different carbonization conditions.

BioCarb+ in Fuel Processing Technology

A manuscript entitled "CO_2 gasification of charcoals produced at various pressures" has been published in Fuel Processing Technology. The abstract is given below:

"In this work, stem wood and branches and tops of Norwegian spruce and birch were carbonized at different pressures, producing charcoals of which the CO_2 gasification reactivity was studied by means of a thermogravimetric analyzer operated isothermally at 850 °C. The results reveal that the gasification reaction rates of charcoals produced under higher pressures was lower than those produced at the atmospheric pressure. Clear correlations between the CO_2 gasification reactivity of the charcoals and their fuel and chemical properties, including the catalytic effect of the inorganic matter, were observed. The semi-empirical power law kinetic model described well the gasification behavior with high fit quality. The activation energy was found to be within 140–160 kJ/mol, whereas the reaction order varied in the range of 0.4–0.6."

This work contributes to the understanding of the effect of pressure and catalytic elements on the CO_2 reactivity of biocarbons.

BioCarb+ at the upcoming 25th European Biomass Conference & Exhibition

Four BioCarb+ works have been accepted for presentation at the 25th EUBCE conference in Stockholm, 12-15 June 2017:

1) The pressure influence on biocarbon yield and quality
2) Gasification behaviours of different biomass charcoals under CO_2 atmosphere
3) CO_2 gasification reactivity of biocarbon produced at different conditions
4) Technical and economical feasibility of combusting biocarbon in small scale pellet boilers

Remembering Michael Jerry Antal, Jr.

Prof. Michael Jerry Antal, Jr. sadly passed away October 21, 2015. He was a key research partner in BioCarb+ and a great colleague and friend through decades of many of us. His contribution to the scientific community really stood out from the crowd. He will be greatly missed, but never forgotten.

At the above mentioned Pyro 2016 conference, a Soirée in honor of Prof. Antal was arranged, and now an Energy & Fuels manuscript entitled "From “Sirups” to Biocarbons: A 30 Year Research Cooperation for Better Biomass Utilization with Michael J. Antal, Jr" has been published.

Presentations from the soirée are available at the Pyro 2016 website.

Also a special issue (In Honor of Michael J. Antal) in Energy & Fuels has been published, including an editorial. Three BioCarb+ manuscripts have been published in this special issue.

Scott Turn has joined the BioCarb+ team

Dr. Scott Turn from the University of Hawaii (UH) has joined the BioCarb+ team, as responsible for their contributions to the BioCarb+ project. The UH contributions are concentrated on high yield fixed carbon charcoal production at pressurized conditions. A PhD candidate, Maider Legarra, is part financed by BioCarb+.

BioCarb+ students

A number of students have been or are connected to BioCarb+. In 2014 two students (**Charissa Higashi** and **Kathryn Hu**) from Hawaii, **USA**, visited Trondheim during the summer. In 2015 a summer student from **Norway** (**Benedicte Hovd**) financed by BioCarb+ within the SINTEF summer job program was working with aspects connected to biocarbon CO_2 reactivity. This work was continued by a master student (**Hau-Huu Bui**) from **Vietnam** and a project student (**Maria Zabalo Alonso**) from **Spain**. Also in 2015, a PhD student from **Hungary** (**Eszter Barta-Rajnai**) visited Trondheim Aug-Sept, as well as an assistant professor (**Zsolt Barta**) from Hungary in September. A master student from **Belgium** (**Sam van Wesenbeeck**) at University of Hawaii worked in the BioCarb+ project and there is also a link to a PhD student from Spain (**Maider Legarra**) at University of

Hawaii, who now is part financed by BioCarb+. In 2016 Maria Zabalo Alonso continued and finished her master thesis within BioCarb+, **Przemyslaw Maziarka** from **Poland** carried out his master thesis work within BioCarb+, also connected to CO_2 reactivity of biocarbons, and **Maciej Olszewski** from Poland carried out his master thesis connected to techno-economics of biocarbon production. Also in 2016 a summer student from Norway, **Nicolai Alsaker**, was financed by BioCarb+, working with CO_2 reactivity of densified biocarbon. In addition the BioCarb+ PhD student from **Germany** (**Kathrin Weber**) is continuing her work. Connected to her work, **David Lüdecke** from Germany carried out his master thesis. Hence, a very significant educational activity is connected to BioCarb+.

Industrial charcoal production in Norway to become a reality?

Elkem, one of the industrial partners in BioCarb+, is together with Treklyngen, Avinor and Vardar now carrying out an innovation project called **Norwegian Wood**. The aim is to create an industrial value chain producing both biocarbon, biooil and heat. The first step is a feasibility study. More info is given here.

A new biocarbon project has received funding from the Research Council of Norway

Elkem has been running their Carbon Neutral Metal Production (CNMP) project for 2 years. At 15 December, a continuation project received funding from the EnergiX program at the Research Council of Norway. The new project, Pyrolysis of wood optimized for production of energy and tailor-made biochar for silicon production (PyrOpt), is also an innovation project for the industry.

Publications

Øyvind Skreiberg, Liang Wang, Morten Grønli. The pressure influence on biocarbon yield and quality. Accepted for presentation at the 25th European Biomass Conference & Exhibition (**EUBCE**), 12-15 June 2017, Stockholm, Sweden.

Liang Wang, Nicolai Alsaker, Øyvind Skreiberg, Therese Videm Buø, Rolf Gunnar Birkeland, Aasgeir Valderhaug, Benedicte Hovd. Gasification behaviours of different biomass charcoals under CO_2 atmosphere. Accepted for presentation at 25th EUBCE.

Liang Wang, Przmeysław Maziarka, Øyvind Skreiberg, Terese Løvås, Mariusz Wądrzyk. CO_2 gasification reactivity of biocarbon produced at different conditions. Accepted for presentation at 25th EUBCE.

R. S. Kempegowda, P. Bartocci, F. Liberti, G. Bidini, Ø. Skreiberg, F. Fantozzi. Technical and economical feasibility of combusting biocarbon in small scale pellet boilers. Accepted for presentation at 25th EUBCE.

Liang Wang, Øyvind Skreiberg, Sam Van Wesenbeeck, Morten Grønli, Michael Jerry Antal, Jr. (2016). Experimental Study on Charcoal Production from Woody Biomass. Energy & Fuels 30(10):7994-8008.

L. Wang, E. Barta-Rajnai, K. Hu, C. Higashi, Ø. Skreiberg, M. Grønli, Z. Czégény, E. Jakab, V. Myrvågnes, G. Várhegyi, M. J. Antal, Jr. Biomass Charcoal Properties Changes during Storage. Accepted for publication in Energy Procedia.

Rajesh S. Kempegowda, Øyvind Skreiberg, Khanh-Quang Tran. Biocarbonization process for high quality energy carriers: Techno-economics. Accepted for publication in Energy Procedia.

Khanh-Quang Tran, Maria Zabalo Alonso, Liang Wang, Øyvind Skreiberg. Simultaneously boosting the mass and fixed-carbon yields of charcoal from forest residue via atmospheric carbonization. Accepted for publication in Energy Procedia.

Rajesh S. Kempegowda, Øyvind Skreiberg, Khanh-Quang Tran, P.V. P. Selvam. Techno-economic assessment of thermal co-pretreatment and co-digestion of food wastes and sewage sludge for heat, power and biochar production. Accepted for publication in Energy Procedia.

Hau-Huu Bui, Liang Wang, Khanh-Quang Tran, Øyvind Skreiberg, Apanee Luengnaruemitchai. CO_2 Gasification of Charcoals in the Context of Metallurgical Application. Accepted for publication in Energy Procedia.

David Lüdecke (2016). Kinetic modelling of biomass pyrolysis. RWTH Aachen University Master thesis. Main supervisor: Terese Løvås, Co-supervisor: Kathrin Weber

Przemysław Maziarka (2016). Reactivity of biochar with CO_2 using thermogravimetric analysis. AGH University of Science and Technology Master thesis. Main supervisors: Mariusz Wądrzyk, Terese Løvås, Co-supervisors: Liang Wang, Øyvind Skreiberg

Maciej Pawel Olszewski (2016). The techno-economics of biocarbon production processes. AGH University of Science and Technology Master thesis. Main supervisors: Karol Sztekler, Terese Løvås, Co-supervisors: Rajesh S. Kempegowda, Øyvind Skreiberg

Nicolai E. Alsaker (2016). Biocarbon for use in metallurgic industry. SINTEF Summer Job Project report. Supervisors: Liang Wang, Øyvind Skreiberg

Eszter Barta-Rajnai, Emma Jakab, Zoltán Sebestyén, Zoltán May, Zsolt Barta, Liang Wang, Øyvind Skreiberg, Morten Grønli, János Bozi, Zsuzsanna Czégény (2016). Comprehensive compositional study of torrefied wood and herbaceous materials by chemical analysis and thermoanalytical methods. Energy & Fuels 30(10):8019-8030.

Maria Zabalo Alonso (2016). A thermogravimetric and kinetic study on devolatilization of woody biomass. NTNU Master thesis. Main supervisor: Khanh-Quang Tran, Co-supervisors: Liang Wang, Øyvind Skreiberg

Hau-Huu Bui, Liang Wang, Khanh-Quang Tran, Øyvind Skreiberg (2016). CO_2 gasification of charcoals produced at various pressures. Fuel Processing Technology 152:207-214.

Sam Van Wesenbeeck, Liang Wang, Frederik Ronsse, Wolter Prins, Øyvind Skreiberg, Michael J. Antal, Jr. (2016). Charcoal 'mines' in the Norwegian woods. Energy & Fuels 30(10):7959-7970.

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Rajesh S. Kempegowda, Zsolt Barta, Øyvind Skreiberg, Liang Wang (2016). Value chain analysis of biocarbon utilisation in residential pellet stoves. Chemical Engineering Transactions 50:7-12.

Rajesh S. Kempegowda, Øyvind Skreiberg, Khanh-Quang Tran, Pagandai V. Pannir Selvam (2016). Bio-carbonization process integration for high quality energy carriers: charcoal, biomethane, biocrude, and biofertilizer. 24th European Biomass Conference and Exhibition (**EUBCE**), 6-9 June 2016, Amsterdam, The Netherlands.

Kathrin Weber, Tian Li, Terese Løvås (2016). Carbon Yield Predictions in Biochar Based on Stochastic Reactor Modelling. 24th EUBCE.

Liang Wang, Hau-Huu Bui, Benedicte Hovd, Aasgeir Valderhaug, Therese Videm Buø, Rolf Gunnar Birkeland, Øyvind Skreiberg, Khanh-Quang Tran (2016). Reactivity assessment of biocarbons for metallurgical purposes. 24th EUBCE.

Rajesh S. Kempegowda, Zsolt Barta, Øyvind Skreiberg, Liang Wang (2016). Energy efficiency, environmental aspects and cost-efficiency of small-scale biocarbon conversion applications – value chain analysis. 24th EUBCE.

Hau-Huu Bui, Liang Wang, Khanh-Quang Tran, Øyvind Skreiberg, Apanee Luengnaruemitchai (2016). CO_2 Gasification of Norwegian Charcoals Prepared at Different Pressures. Proceedings of The Petroleum and Petrochemical College International Symposium, Chulalongkorn University, 24 May 2016, Bangkok, Thailand.

Khanh-Quang Tran, Hau-Huu Bui, Apanee Luengnaruemitchai, Liang Wang, Øyvind Skreiberg (2016). Isothermal and non-isothermal kinetic study on CO_2 gasification of torrefied forest residues. Biomass and Bioenergy 91(Aug 2016):175-185.

Kathrin Weber, Tian Li, Terese Løvås, Lars Seidel, Cathleen Perlman, Fabian Mauss (2016). Stochastic reactor modelling for biomass pyrolysis. **Pyro 2016** (21st International Symposium on Analytical and Applied Pyrolysis), 9-12 May 2016, Nancy, France.

Morten Grønli, Liang Wang, Øyvind Skreiberg (2016). Towards the maximum theoretical yields of charcoal from biomass pyrolysis. Pyro 2016.

Charissa Rachelle Mika Higashi (2016). A study on the theory, generation, and retention of charcoal quality by thermochemical equilibrium calculations, efficient microcrystalline celulose carbonization, thermogravimetry, and psychrometric experiments. University of Hawaii Master thesis. Supervisor: Michael J. Antal, Jr.

Liang Wang, Gábor Várhegyi, Øyvind Skreiberg, Tian Li, Morten Grønli, Michael J. Antal, Jr. (2016). Combustion Characteristics of Biomass Charcoal Produced at Different Carbonization Conditions: A Kinetic Study. Energy & Fuels 30(4):3186-3197.

Hau-Huu Bui (2016). CO_2 gasification of charcoals produced from Norwegian stem wood and forest residues. Chulalongkorn University Master Thesis. Main supervisor: Apanee Luengnaruemitchai, Co-supervisors: Khanh-Quang Tran, Liang Wang, Øyvind Skreiberg

Sam Van Wesenbeeck, Charissa Higashi, Maider Legarra, Liang Wang, Michael Jerry Antal Jr (2016). Biomass pyrolysis in sealed vessels. Fixed-carbon yields from Avicel cellulose that realize the theoretical "limit"!. Energy & Fuels 30(1):480-491.

Maria Zabalo Alonso (2015). Use of charcoal as reductant in metallurgical industry. NTNU Project thesis. Main supervisor: Khanh-Quang Tran, Co-supervisors: Liang Wang, Øyvind Skreiberg

Sam Van Wesenbeeck (2015). Charcoal in a nutshell: Biocarbon production from cellulose, Norwegian wood, Macademia nutshells and sewage sludge. University of Hawaii Master thesis. Supervisor: Michael J. Antal, Jr.

Benedicte Hovd (2015). Biocarbon for energy - Biocarbon CO_2 reactivity. SINTEF Summer Job Project report. Supervisors: Liang Wang, Øyvind Skreiberg

Øyvind Skreiberg (2015). BioCarb+ Verdikjeden for biokarbon: Fra biomasse til energi. Bioenergidagene 2015, 18-19 November 2015, Gardermoen, Norway.

Øyvind Skreiberg (2015). BioCarb+. Presented in the session "Grensesprengende forskning" at Energiforskningskonferansen, 21 May 2015, Oslo, Norway.

Liang Wang, Gábor Várhegyi, Øyvind Skreiberg, Morten G. Grønli, Michael J. Antal, Jr. (2015). Combustion Characteristics of Biomass Charcoal Produced at Different Carbonization Conditions. Proceedings of 23rd European Biomass Conference and Exhibition (**EUBCE**), 1-4 June 2015, Vienna, Austria, pp. 1196-1199.

Liang Wang, Charissa Higashi, Øyvind Skreiberg, Morten G. Grønli, Michael J. Antal, Jr. (2015). Charcoal Production from Forest Residues. Proceedings of 23rd EUBCE, pp. 1184-1187.

Liang Wang, Kathryn Hu, Charissa Higashi, Øyvind Skreiberg, Viktor Myrvågnes, Morten G. Grønli, Michael J. Antal, Jr., Gábor Várhegyi (2015). Effect of Storage Time and Conditions on Biomass Charcoal Properties. Proceedings of 23rd EUBCE, pp. 1180-1183.

Liang Wang, Øyvind Skreiberg, Morten G. Grønli, Michael J. Antal, Jr. (2014). Thermogravimetric studies of charcoal formation from cellulose under different pyrolysis conditions. AIChE Annual Meeting in Atlanta, GA, 16 - 21 November, 2014.

BioCarb+ in the media

Lars Martin Hjorthol, Øyvind Skreiberg (2014). Lopwood and brushwood make high-grade charcoal. Gemini.

Lars Martin Hjorthol, Øyvind Skreiberg (2014). Kvist og kvas blir edelt kull. Gemini. Reproduced on forskning.no, Aftenposten nett and Adresseavisen nett.

Other news

IEA Task 32 Biomass Combustion and Co-firing

An IEA Bioenergy Task 32 meeting was arranged in Switzerland in connection with the 20th ETH-Conference on Combustion Generated Nanoparticles, 13-16 June. This was the first meeting in the new triennium (2016-18). The second meeting in 2016 was arranged in Japan. For more information about IEA Bioenergy Task 32 activities, see this newsletter, and for IEA Bioenergy news, see this newsletter. Øyvind Skreiberg from SINTEF Energy Research is the Norwegian participant in IEA Bioenergy Task 32.

EERA Bioenergy - Stationary Bioenergy

The effort this year has been focused on arranging workshops in Brussels connected to issue papers, on bioenergy and biofuels, and coordination of efforts to establish joint EU proposals. The annual EERA conference was arranged 24-25 November in Birmingham, UK. More info is available here. For more info on EERA Bioenergy, visit the website, and see the newsletters.

RHC technology platform

The activity level of the RHC platform is picking up, after a period where new financing solutions have been sought and the originally planned strategy documents have been delivered. The "new" European Technology and **Innovation** Platform on Renewable Heating & Cooling (RHC-ETIP) brings together stakeholders from the biomass, geothermal and solar thermal sector - including related industries such as District Heating and Cooling, Thermal Energy Storage, Hybrid Systems and Heat Pumps - to define a common Research, Development and Innovation strategy for increasing the use of renewable energy technologies for heating and cooling. Two workshops were arranged 27 and 28 June. The first one was an industry workshop while the second one was a technology workshop. The aim was to support to key activities of the RHC-ETIP and to discuss the

successful contribution of the RHC-sector to the fifth dimension of the Energy Union.
Further concrete work has been carried out by the Biomass Panel in the RHC-ETIP connected to giving input to the SET-plan issues paper on renewable fuels and bioenergy, as well as work connected to the Implementation of the biomass technology roadmap of the Biomass Panel. The aim of the latter was to update the progress in R&I priorities identified by the Biomass technology roadmap.
Øyvind Skreiberg from SINTEF Energy Research is a member of the Biomass Panel Steering Committee.
See the RHC newsletters for other news.

Links (click on the links or logos to get there)

BioCarb+
SKOG22
Energi21
Renewable Heating and Cooling platform
EERA Bioenergy
IEA Task32 Biomass Combustion and Cofiring