BioCarb+ Enabling the biocarbon value chain for energy

Newsletter 2-2017

Progress in 2017

In **2017**, the last year of the project, focus is on selected specific studies and concluding and summarizing studies connected to the resource base and biocarbon production, properties and end use, also in a value chain perspective.

In **2016** focus was 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+ handbook

A handbook is being made in BioCarb+, summing up the main results and giving recommendations. The handbook will be made available at the BioCarb+ website.

BioCarb+ Workshop and Steering Committee meeting in Trondheim

An open BioCarb+ workshop was arranged 9th November in Trondheim, and was a great success. The workshop focused on providing an overview of ongoing biocarbon related research and development (R&D) projects in Norway connected to the metallurgical industry, and discussing the R&D needs for this biocarbon value chain. More than 30 representatives from industry, academia and research institutes attended the workshop. At the workshop nine interesting presentations were given covering: 1) national strategies for increasing sustainability of process industries in Norway, 2) industry directly involved in biocarbon related projects aiming for production of different metals, 3) biocarbon related research projects and educational activities. The following issues were also discussed during the workshop: 1) enhancement of communication and integration between ongoing research projects and activities, 2) policies for biocarbon deployment, 3) guidelines for sustainable biocarbon deployment, 4) Norwegian forest resources for biocarbon production.

- a Knowledge-building Project for Industry (KPN) co-funded by the Research Council of Norway through the ENERGIX-programme.
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SINTEF

Sten Yngve Larsen giving a presentation from Eramet Norway at the BioCarb+ open workshop

Participants at the BioCarb+ open workshop

Biocarbon session at the SFI metal Production autumn meeting in Trondheim

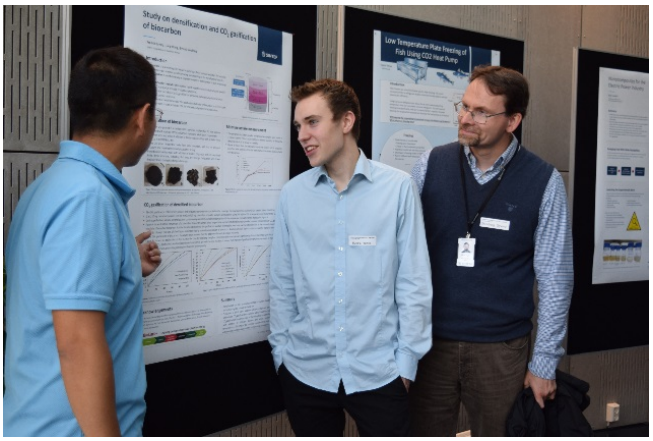
BioCarb+ co-organized an open session on biocarbon for metallurgical industries at the SFI Metal Production autumn meeting in Trondheim 8th November 2017, with presentations from BioCarb+ activities as well as from SINTEF Materials and Chemistry and NTNU Materials Science and Engineering.

Øyvind Skreiberg (SINTEF Energy Research), Liang Wang (SINTEF Energy Research), Eli Ringdalen (SINTEF Materials and Chemistry) and Scott Turn (Hawaii Natural Energy Institute) all gave presentations about biocarbon in metal producing industries.

Summer students in BioCarb+

BioCarb+ has for three years offered an undergraduate student a unique opportunity to participate in the project research work through the SINTEF summer job program. The three students have mainly worked in the thermal energy laboratory of SINTEF Energy Research in Trondheim, focusing on gasification reactivity of different biocarbons. Two of the students also had the opportunity to visit the Elkem Carbon laboratory in Kristiansand to carry out experimental studies using their unique furnace setup. Research results with high scientific value have been obtained from the summer student work, and have been published and disseminated, including several journal articles and conference presentations/posters. Each of the summer students also attended the summer student program conference organized by SINTEF Energy Research to present their work and findings. The three summer students have enjoyed working on biocarbon related tasks in a multidisciplinary and multicultural environment.

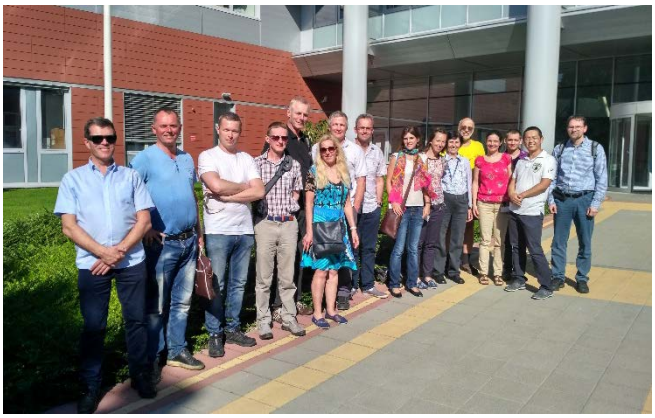
The summer students and SINTEF personnel



The 2017 summer student, Fredrik Buvarp, next to his poster at the summer student program conference

BioCarb+ Steering Committee meeting at the Hungarian Academy of Sciences in Budapest

The 9th BioCarb+ Steering Committee meeting was arranged 2 June at the Hungarian Academy of Sciences in Budapest. The project leader, Øyvind Skreiberg, reported status of the project and progress of deliverables. The Steering Committee members are in general satisfied with what have been achieved in the project and provides constructive feedback regarding the project activities, which is especially important in this the last year of the project. At the end of the meeting, all participants discussed a possible follow-up project after BioCarb+, and there is still a great researcher and industry interest in terms of R&D activities related to biocarbon production and utilization. The steering committee meeting was hosted by the BioCarb+ collaborative research partner the Hungarian Academy of Sciences. The day before the steering committee meeting, a laboratory visit was arranged for the participants to know more about the extensive experimental facilities and competences of the Hungarian Academy of Sciences.



Participants at the BioCarb+ Steering Committee meeting in Budapest, in front of the meeting location at the Hungarian Academy of Sciences

BioCarb+ at the upcoming IConBM 2018

Four BioCarb+ or connected abstracts have been accepted for presentation at the IConBM 2018 in Bologna, Italy, 17-20 June, 2018:

1) Liang Wang, Fredrik Buvarp, Pietro Bartocci, Øyvind Skreiberg. A study on densification and CO_2 gasification of biocarbon.

2) Liang Wang, Fredrik Buvarp, Øyvind Skreiberg, Roger Khalil. Impact of storage time and conditions on properties and reactivity of biocarbon.

3) Øyvind Skreiberg, Liang Wang, Quang-Vu Bach, Morten Grønli. Carbonization pressure influence on biocarbon yield and quality.

4) P. Bartocci, M. Barbanera, F. Liberti, G. Bidini, Ø. Skreiberg, L. Wang, F. Fantozzi. Biocarbon pellet production: Optimization of pelletizing process.

BioCarb+ at the upcoming EUBCE 2018

Three BioCarb+ abstracts have been accepted for presentation at EUBCE 2018 in Copenhagen, Denmark, 14-17 May, 2018:

1) Øyvind Skreiberg, Liang Wang, Roger Khalil, Simen Gjølsjø, Scott Turn. Enabling the biocarbon value chains for energy and metallurgical industries.

2) Liang Wang, Øyvind Skreiberg, Sam Van Wesenbeeck, Maider Legarra, Morten Grønli, Michael Jerry Antal, Jr. Characterization of biocarbon produced under different carbonization conditions.

3) Maider Legarra Arizaleta, Trevor Morgan, Scott Turn, Øyvind Skreiberg, Liang Wang, Morten Grønli. Constant-Volume Carbonization of Biomass.

BioCarb+ at 255th American Chemical Society National Meeting & Exposition

Maider Legarra Arizaleta will give a presentation at the 255th American Chemical Society National Meeting & Exposition in New Orleans, USA, 18-22 March 2018. The title of the presentation is "Constant-Volume Carbonization of Biomass".

BioCarb+ at 2nd International Workshop on Oxy-Fuel Combustion

Kathrin Weber, the BioCarb+ PhD candidate, will give a presentation with the title "CO_2 Gasification kinetics of Biomass Chars Derived from Flash Pyrolysis of Birch Bark and Forest Residue" at this workshop that is arranged in Bochum, Germany, 14-15 February, 2018.

BioCarb+ at ICAE 2017

Three BioCarb+ works were presented at the 9th International Conference on Applied Energy in Cardiff, UK, 21-24 August 2017:

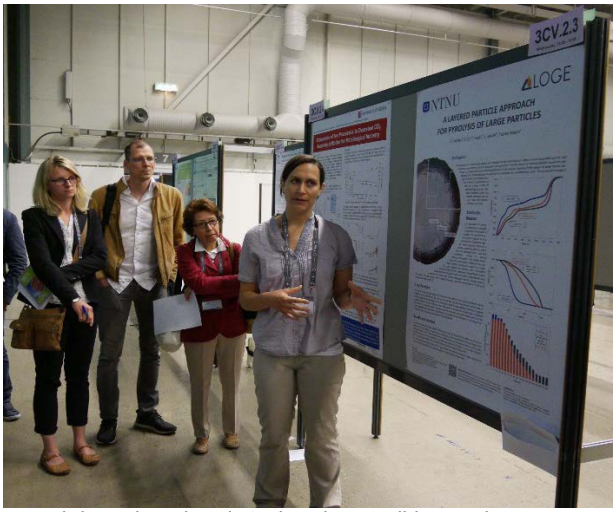
1) Alexis Sevault, Roger Khalil, Bjørn Christian Enger, Øyvind Skreiberg, Franziska Goile, Liang Wang, Morten Seljeskog, Rajesh Kempegowda. Performance evaluation of a modern wood stove using charcoal.

2) Liang Wang, Przmeysław Maziarka, Øyvind Skreiberg, Terese Løvås, Mariusz Wądrzyk, Alexis

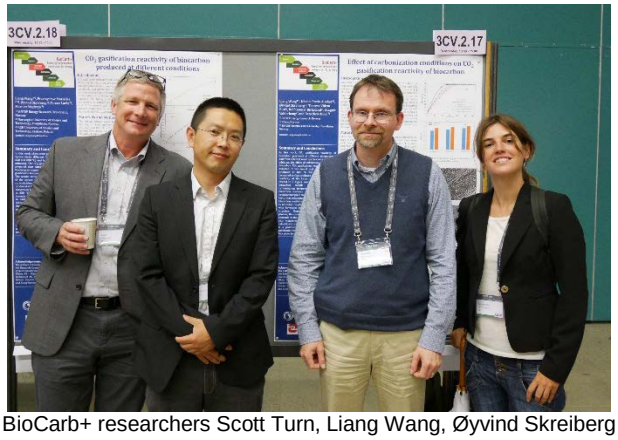
Sevault. Study of CO_2 gasification reactivity of biocarbon produced at different conditions.
3) Liang Wang, Nicolai Alsaker, Øyvind Skreiberg, Benedicte Hovd. Effect of carbonization conditions on CO_2 gasification reactivity of biocarbon.
These works have been accepted for publication in Energy Procedia.

BioCarb+ at 25th European Biomass Conference & Exhibition

Seven BioCarb+ works were presented at the 25th EUBCE conference in Stockholm, Sweden, 12-15 June 2017:
1) The pressure influence on biocarbon yield and quality, presented by Øyvind Skreiberg
2) Gasification behaviours of different biomass charcoals under CO_2 atmosphere, presented by Liang Wang
3) CO_2 gasification reactivity of biocarbon produced at different conditions, presented by Liang Wang
4) Technical and economic feasibility of combusting biocarbon in small scale pellet boilers, presented by Pietro Bartocci. Published in proceedings, pp. 1128-1134. See also BEsustainable article
5) A Layered Particle Approach to Model the Conversion of Thermally Thick Particles, presented by Kathrin Weber
6) Constant Volume Pyrolysis of Biomass for the Production of Char with High Fixed-Carbon Content, presented by Maider Legarra Arizaleta
7) Performance evaluation of a modern wood stove when using charcoal, presented by Alexis Sevault



Kathrin Weber, the BioCarb+ PhD candidate, at her poster.



BioCarb+ researchers Scott Turn, Liang Wang, Øyvind Skreiberg and Maider Legarra Arizaleta at Liang's BioCarb+ posters

BioCarb+ at 1st Journal of Thermal Analysis and Calorimetry Conference

Two BioCarb+ presentations were given at the 1st Journal of Thermal Analysis and Calorimetry Conference in Budapest, Hungary, 6-9 June 2017:
1) Towards a Meaningful Non-isothermal Kinetics for Biomass Materials and Other Complex Organic Samples, presented by Gábor Várhegyi
2) Thermoanalytical characterisation of torrefied stem wood, stump and bark of Norway spruce, presented by Zsuzsanna Czégény

BioCarb+ at 2nd International Bioenergy (Shanghai) Conference and Exhibition

Liang Wang gave a plenary lecture at the 2nd International Bioenergy (Shanghai) Conference and Exhibition in Shanghai, China, 19-21 April 2017. The title of the presentation was "Biocarbon production and utilization".


BioCarb+ researcher Liang Wang giving his plenary lecture at the 2nd International Bioenergy (Shanghai) Conference and Exhibition

BioCarb+ at INFUB 2017. Papers now published in Energy Procedia

Two BioCarb+ presentations were given at the 11th European Conference on Industrial Furnaces and Boilers (INFUB) in Algarve, Portugal, 18-21 April 2017:
1) A kinetic study on simultaneously boosting the mass and fixed-carbon yield of charcoal production via atmospheric carbonization, presented by Khanh-Quang Tran
2) Techno-economic assessment of integrated hydrochar and high-grade activated carbon production for electricity generation and storage, presented by Khanh-Quang Tran
These works have been published in Energy Procedia.

BioCarb+ at 253rd American Chemical Society National Meeting & Exposition

Maider Legarra Arizaleta gave a presentation at the 253rd American Chemical Society National Meeting & Exposition - Advanced Materials, Technologies, Systems & Processes in San Francisco, USA, 2-6 April 2017. The title of the presentation was "The manufacturing of charcoal in sealed vessels".

BioCarb+ at CenBio Final Conference

Øyvind Skreiberg gave a presentation at the CenBio Final Conference in Ås, Norway, 13-14 March 2017. The title of the presentation was "Biomass upgrading for improved combustion processes".

BioCarb+ at 2016 IEEE International Conference on Sustainable Energy Technologies

Khanh-Quang Tran presented a paper at the 2016 IEEE International Conference on Sustainable Energy Technologies (ICSET) in Hanoi, Vietnam, November 14-16. The title of the presentation was "Hydrochar slurry fuels and high-grade activated carbon for electricity production and storage - Conceptual process design and analysis." The paper has now been published in IEEE proceedings.

BioCarb+ at ICAE 2016. Papers now published in Energy Procedia

Five BioCarb+ papers were presented at the 8th International Conference on Applied Energy in Beijing, China, 8-11 October 2016. The papers have now been published in Energy Procedia. The paper titles are:

1) CO_2 Gasification of Charcoals in the Context of Metallurgical Application
2) Techno-economic assessment of thermal co-pretreatment and co-digestion of food wastes and sewage sludge for heat, power and biochar production
3) Simultaneously boosting the mass and fixed-carbon yields of charcoal from forest residue via atmospheric carbonization
4) Biocarbonization process for high quality energy carriers: Techno-economics
5) Biomass Charcoal Properties Changes during Storage

BioCarb+ in EERA Bioenergy Newsletter

BioCarb+ will be featured in the upcoming EERA Bioenergy Newsletter 8, December 2017.

BioCarb+ in Energy & Fuels

A manuscript entitled "CO_2 Gasification of Chars Prepared by Fast and Slow Pyrolysis from Wood and Forest Residue" has been accepted for publication in Energy & Fuels. The abstract is given below.

"The CO_2 gasification of chars was investigated by thermogravimetry (TGA). The chars were prepared from spruce and its forest residue. Prior to the gasification the raw materials were pelletized and pulverized. Part of the samples was directly gasified in the TGA when the char was formed at low heating rates before the gasification. Another sort of char was prepared in a drop tube reactor (DTR) at a heating rate of around 1×104 °C/s and a residence time of 0.2 s at 1200°C. The kinetic evaluation was based on TGA experiments with linear, modulated, and constant-reaction rate (CRR) temperature programs. The gasification of the DTR chars took place at temperatures 80–100°C lower than the chars formed at low heating rates. The chars formed at low heating rates exhibited a side reaction that occurred 80–100 °C below the main peak of the mass-loss rate curves during the gasification. Accordingly the gasification kinetics of these chars was described by assuming two pseudo-components. The thermal annealing (thermal deactivation) of the chars during the gasification experiments was taken into account by the pre-exponential factors which were allowed to have different values at different temperature programs. A strong compensation effect was observed between the activation energy (E) and the rest of the kinetic

parameters. Nevertheless, the obtained E values varied in a narrow interval (from 219 till 227 kJ/mol) and were very close to the ones obtained for other chars with similar kinetic evaluation procedures (Wang et al., Energy & Fuels 2013, 27, 6098-6107 and 2014, 28, 7582-7590.)"

BioCarb+ in Energy & Fuels

A manuscript entitled "Carbonization of biomass in constant-volume reactors" has been accepted for publication in Energy & Fuels. The abstract is given below.

"A novel carbonization process that realizes near-theoretical fixed-carbon yields in ~3 h is presented. Norwegian spruce and birch sawdusts were carbonized in a hermetically-sealed reactor at an initial nitrogen pressure of 0.1 MPa. During a carbonization test, the reactor vessel retained all pyrolytic products inside the hot reaction zone invoking high pressures as the temperature was raised. Given the elevated partial pressures of volatiles and their extended residence times, secondary, heterogeneous, char-forming reactions between the hot solid and the tarry vapors appeared to be promoted. This resulted in charcoals with a remarkably high fixed-carbon yield, non-condensable gases mainly composed of CO_2 and negligible amount of free tars.

This work presents a reproducibility study on the experimental method and explores the effects of heat treatment temperature, particle size, mass loading and immersion time on product distributions and charcoal properties. Proximate and elemental analyses, heating values and scanning electron microscope images of charcoal are presented. Higher heat treatment temperatures (from 300 to 400°C), smaller grains (from <2 to <0.2 mm), longer immersion times (from 30 to 190 min) and greater mass loadings (from 130 to 165 g of biomass per liter of reactor) intensified wood devolatilization without losing charcoal fixed-carbon yields. Final charcoal products had lower volatile matter contents and improved fixed-carbon contents. Temperature produced the strongest effect transforming the virgin spruce with a fixed-carbon content of 15% to charcoals with fixed carbon contents of 52% at 300°C and 73% at 400°C. The increase in temperature resulted in a transient plastic phase that changed the char appearance from loose, particulate matter to a smooth, shiny solid product with the appearance of coke."

BioCarb+ in Journal of Thermal Analysis and Calorimetry

A manuscript entitled "Towards a meaningful non-isothermal kinetics for biomass materials and other complex organic samples" has been accepted for publication in Journal of Thermal Analysis and Calorimetry. The abstract is given below.

"The literature of the kinetics in thermal analysis deals mainly with models that consist of a single reaction equation. However most samples with practical importance are too complex for such an oversimplified description. There is no universal way to overcome the difficulties, though there are well-established models that can express the complexity of the studied reactions for several important types of samples. The assumption of more than one reaction increases the number of unknown parameters. Their reliable estimation requests the evaluation of a series of experiments. The various linearization techniques cannot be employed in such cases, while the method of least squares can be carried out at any complexity of the models by proper numerical methods. It is advantageous to evaluate simultaneously experiments with linear and non-linear temperature programs because a set of constant heating rate experiments is frequently not sufficient to distinguish between different models or model variants. It is well worth including modulated and CRR (constant reaction rate) temperature programs into the evaluated series whenever they are obtainable. Sometimes different samples share some common features. In such cases one can try to describe their reactions by assuming parts of the kinetic parameters to be common for the samples. One should base the obtained models and parameter values on a sufficiently large amount of experimental information, in a reliable way. This article is based on the authors' experience in the indicated directions from 1979 till the present. Though the examples shown are taken from biomass research, the models and methods shown in the article are also hoped to be relevant for other materials that have complicated structure or exhibit complicated thermal reactions, or both."

BioCarb+ in Energy & Fuels

A manuscript entitled "Techno-economics of biocarbon production processes under Norwegian conditions" has been accepted for publication in Energy & Fuels. The abstract is given below.

"This work deals with techno-economic analysis studies in the context of production of various grade biocarbon for utilization as reducing agents in metallurgical industries. A detailed process design was developed for wood handling, debarking, chipping, drying, carbonization, and combined heat and power

production using Aspen Plus for 10 ton per day (TPD) biocarbon output. A Fortran based user defined function was developed for the carbonization process by considering pressure, temperature and particle size effects using a Box – Behnken approach. The empirical correlation indicates a strong influence of temperature as well as a significant influence of pressure and particle size on the biocarbon yield and its fixed carbon content. Fixed carbon content increases with temperature, pressure and particle size. Mass and energy balance results from Aspen Plus provided necessary results for cost parametrization considering three influencing parameters; temperature, pressure and plant scale on the equipment costs, operating expenses and production cost of biocarbon. Four scenarios are compared i.e. logwood supply, woodchips supply, co-production of biooil and replacing the carbonization agent from nitrogen to air. The results indicate that logwood supply is more economical than supplying woodchips to the plant gate. Economic benefits in terms of cost is ~5% (at 1 bar and 450-500ºC, 55-60 TPD) and ~4% (at 10 bar, 450-500ºC, 55-60 TPD). Co-production of biooil decreased the production cost of biocarbon ($/GJ) by 40-44% (at 1 bar, 450-500ºC, 40-60 TPD) and 30-36% (at 10 bar, 450-500ºC, 40-60 TPD), respectively. Finally, the economic return based on IRR suggests that highest IRR is achieved for scenario C, where biooil is a co-product, it is due to high market price of woody tar at 500 $/ton. Transportation of forest biomass (logwood) from 20 to 220 km increased the cost of logwood from 4.75 $/GJ to 7.15 $/GJ, which is significant in terms of operating cost."

BioCarb+ in Applied Energy

A manuscript entitled "Effect of torrefaction on physiochemical characteristics and grindability of stem wood, stump and bark" has been accepted for publication in Applied Energy. The abstract is given below.

"In this work, Norway spruce stem wood, stump and bark were torrefied in a bench scale tubular reactor at 225, 275 and 300 °C with two residence times (30 and 60 minutes). Effect of torrefaction on general properties, chemical composition, grindability and microstructure and morphology of biomass samples were studied. An increase in heating value and fixed carbon content of the torrefied biomass was observed for increasing torrefaction temperature and residence time. Chemical compositions of torrefied biomass samples considerably changed with increase of torrefaction severity. For the stem wood and stump, the relative hemicellulose content significantly decreased from 42.3% and 29.8% to less than 1% after torrefaction at 300 °C for 60 minutes, respectively. The hemicellulose content of untreated bark decreased from 27.5% to 0.14% after torrefaction at the same conditions. Additionally, the cellulose content of the torrefied bark drastically decreased already to half the initial value at a torrefaction temperature of 275 °C, with only trace amounts left in the 300 °C torrefied products. The grindability of stem wood and stump were substantially improved after torrefaction treatment. The energy required for grinding stem wood and stump torrefied at 225 °C decreased to respectively 87 and 70 kwh/ton, which are less than 50% of the energy needed for grinding the untreated samples. For raw bark, much less grinding energy is required compared to those for raw stem wood and stump, and torrefaction has minor effects on the grindability of bark. The ground torrefied biomass samples have much smaller particles than those of the untreated ones. SEM analysis results show that particles from ground torrefied samples lose their fibrous structure with decrease of length-to-diameter ratios, compared to untreated biomass samples. It explains the shift in particle size distribution curves towards smaller particles as obtained from the sieving tests."

BioCarb+ in Applied Energy

A manuscript entitled "Comparative study on the thermal behavior of untreated and various torrefied bark, stem wood, and stump of Norway spruce" has been accepted for publication in Applied Energy. The abstract is given below.

"In this work, the torrefaction of different parts of Norway spruce (stem wood, bark, and stump) was studied. Three different torrefaction temperatures were applied: 225, 275, and 300 °C with 30 and 60 min isothermal periods. The thermal stability as well as the evolutions of the decomposition products of the untreated and torrefied samples were measured by thermogravimetry/mass spectrometry (TG/MS). The TG/MS results are interpreted in terms of the chemical composition, namely the cellulose, hemicellulose and Klason lignin content. The inorganic components of the samples were measured by inductively coupled plasma-optical emission spectroscopy (ICP-OES) technique. It was found that the effect of torrefaction temperature was greater than the effect of residence time up to 275 °C, while at 300 °C the residence time had a significant influence on the composition of the torrefied samples due to the intensive decomposition of cellulose. Principal component analysis has been applied to find statistical correlations between the torrefaction temperature, the residence time, the chemical composition and the thermal parameters of the samples. The results of the principal component analysis confirmed that the chemical composition and

hence the thermal properties of the studied samples changed to a greater extent at higher torrefaction temperature than at lower torrefaction temperature."

BioCarb+ in Energy & Fuels

A manuscript entitled "Thermal Decomposition Kinetics of Wood and Bark and their Torrefied Products" has been published in Energy & Fuels. The abstract is given below.

"The pyrolysis kinetics of Norway spruce, its bark, and their torrefied products was studied. Thermogravimetry (TGA) was employed with linear and stepwise heating programs. Altogether 36 TGA experiments were evaluated simultaneously by the method of least-squares. Part of the kinetic parameters could be assumed common for the studied samples without a considerable worsening of the fit quality. This process results in better defined parameters and emphasizes the similarities between the studied materials. Three pseudocomponents were assumed. Two of them were described by distributed activation energy models (DAEM), while a simpler kinetics was assumed for the pyrolysis of the cellulose content of the samples. The pyrolysis kinetics of the wood and the torrefied wood showed remarkable similarities to the bark and torrefied bark, though essential differences were also observed."

BioCarb+ in Journal of Analytical and Applied Pyrolysis

A manuscript entitled "Stochastic reactor modeling of biomass pyrolysis and gasification" has been published in Energy & Fuels. The abstract is given below.

"In this paper, a partially stirred stochastic reactor model is presented as an alternative for the modeling of biomass pyrolysis and gasification. Instead of solving transport equations in all spatial dimensions as in CFD simulations, the description of state variables and mixing processes is based on a probability density function, making this approach computationally efficient. The virtual stochastic particles, an ensemble of flow elements consisting of porous solid biomass particles and surrounding gas, mimic the turbulent exchange of heat and mass in practical systems without the computationally expensive resolution of spatial dimensions. Each stochastic particle includes solid phase, pore gas and bulk gas interaction. The reactor model is coupled with a chemical mechanism for both surface and gas phase reactions. A Monte Carlo algorithm with operator splitting is employed to obtain the numerical solution. Modeling an entrained flow gasification reactor demonstrates the applicability of the model for biomass fast pyrolysis and gasification. The results are compared with published experiments and detailed CFD simulations. The stochastic reactor model is able to predict all major species in the product gas composition very well for only a fraction of the computational time as needed for comprehensive CFD."

Book publication by the BioCarb+ PhD candidate

Kathrin Weber, the BioCarb+ PhD candidate has co-authored a book in German language with the title "Biokohle - Herstellung, Eigenchaften und Verwendung von Biomassekarbonisaten", or in English: Charcoal - Production, properties and applications of biomass carbonization.

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, as did **Sophie Kloepfer** from Germany before him. Finally, in 2017 a summer student from Norway, **Fredrik**

Buvarp, was financed by BioCarb+, continuing the work on CO_2 reactivity of densified biocarbon. Hence, a very significant educational activity is connected to BioCarb+.

Publications

Liang Wang, Tian Li, Gábor Várhegyi, Øyvind Skreiberg, Terese Løvås. CO_2 Gasification of Chars Prepared by Fast and Slow Pyrolysis from Wood and Forest Residue. A Kinetic Study. Accepted for publication in Energy & Fuels.

Maider Legarra, Trevor Morgan, Scott Turn, Liang Wang, Øyvind Skreiberg, Michael Jerry Antal Jr. Carbonization of biomass in constant-volume reactors. Accepted for publication in Energy & Fuels.

Gábor Várhegyi, Liang Wang, Øyvind Skreiberg. Towards a meaningful non-isothermal kinetics for biomass materials and other complex organic samples. Accepted for publication in Journal of Thermal Analysis and Calorimetry.

Maciej Olszewski, Rajesh S. Kempegowda, Øyvind Skreiberg, Liang Wang, Terese Løvås. Techno-economics of biocarbon production processes under Norwegian conditions. Accepted for publication in Energy & Fuels.

Øyvind Skreiberg (2017). BioCarb+ and biocarbon research at SINTEF Energy Research and NTNU. BioCarb+ open workshop, 9 November 2017, Trondheim, Norway.

Øyvind Skreiberg (2017). The BioCarb+ project. SFI Metal Production Autumn Meeting, 7-8 November 2017, Trondheim, Norway.

Liang Wang, Øyvind Skreiberg, Morten Grønli (2017). Biocarbon production and utilization. SFI Metal Production Autumn Meeting, 7-8 November 2017, Trondheim, Norway.

Liang Wang, Øyvind Skreiberg (2017). Biocarbon properties and how to influence them. SFI Metal Production Autumn Meeting, 7-8 November 2017, Trondheim, Norway.

Maider Legarra Arizaleta, Trevor Morgan, Scott Turn, Michael J. Antal, Jr., Øyvind Skreiberg, Liang Wang, Morten Grønli (2017). Pressurized Biocarbon Production: Constant-Volume Carbonization of Biomass. SFI Metal Production Autumn Meeting, 7-8 November 2017, Trondheim, Norway.

Øyvind Skreiberg (2017). Biocarbon research needs, for the metallurgical industry. SFI Metal Production Autumn Meeting, 7-8 November 2017, Trondheim, Norway.

Øyvind Skreiberg (2017). Biokarbon. SINTEF Energy Research leader group meeting, 6 November 2017, Trondheim, Norway.

Fredrik Buvarp (2017). CO_2 gasification reactivity of densified biocarbon. SINTEF Summer Job Project report. Supervisors: Liang Wang, Øyvind Skreiberg

Alexis Sevault, Roger Khalil, Bjørn Christian Enger, Øyvind Skreiberg, Franziska Goile, Liang Wang, Morten Seljeskog, Rajesh Kempegowda. Performance evaluation of a modern wood stove using charcoal. Accepted for publication in Energy Procedia.

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Other news

IEA Task 32 Biomass Combustion and Co-firing

The last IEA Bioenergy Task 32 meeting of the year was arranged in September in Ottawa, Canada. The meeting was combined with field trips and two workshops arranged at the Wood Pellet Association conference, on 1) biomass co-firing and dedicated firing in PC boilers and 2) wood pellet heating markets. An IEA Bioenergy Task 32 meeting was arranged in connection with the 25th European Biomass Conference and Exhibition in Stockholm, Sweden, 12-15 June 2017. For information about IEA Bioenergy Task 32 activities, see the webpage and newsletters, 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 – SP5 Stationary Bioenergy

The effort this year has been focused on revising the SP focus and the description of work. For more info on EERA Bioenergy, visit the brand new website, and see the newsletters. Berta Matas Güell from SINTEF

Energy Research is leading SP5 Stationary Bioenergy in EERA Bioenergy.

RHC technology platform

The activity level of the RHC platform picked up after a period where new financing solutions were sought and the originally planned strategy documents had 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.

Previously 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.

This work continues through different efforts, whereof a Biomass Panel steering committee meeting was arranged 20 June in Brussels.

Øyvind Skreiberg from SINTEF Energy Research is a member of the Biomass Panel Steering Committee and the leader of Issue group 2: Residential/small scale heating devices and building integration.

As a continuation of the SET-plan work, workgroups were established to provide specific input to the SET-plan work, e.g. Action 5 Energy Efficiency in Buildings with the sub-action 5.2 Heating and Cooling Technologies for Buildings and Action 8 Renewable Fuels and Bioenergy. The work is still ongoing, and Øyvind Skreiberg has been involved in the Action 5 work, representing the Biomass Panel.

See the RHC newsletters for other news.

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

BioCarb+
SKOG22
Energi21
Renewable Heating and Cooling ETIP

EERA Bioenergy
IEA Task32 Biomass Combustion and Cofiring