

# *2<sup>nd</sup> International Symposium on Hydrothermal Carbonization*

*Hydrothermal carbonization  
as a building block  
for a sustainable bioeconomy*



**HTC**  
**2019**

The logo for the HTC 2019 conference, featuring the letters 'HTC' in a bold, dark blue font above the year '2019' in a bold, green font. The background of the entire page is a light blue-tinted photograph of a classical building with columns and a tall tower with a spherical top, likely the Berlin TV Tower.

## IMPRINT

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# ***2<sup>nd</sup> International Symposium on Hydrothermal Carbonization***

*Hydrothermal carbonization as a building  
block for a sustainable bioeconomy*

May, 14<sup>th</sup> – 16<sup>th</sup> 2019 | Berlin

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# PROGRAM

## 1<sup>st</sup> DAY

2019-05-14

**08:00**  
**Registration**

**09:00**  
**Conference opening/ welcome**  
*Benjamin Wirth, DBFZ Leipzig, Germany*  
*Judy Libra, Leibniz Institute for Agricultural Engineering and Bioeconomy Potsdam, Germany*

**Session A.1**  
Fundamental insights into the HTC-process

**09:30 – 10:45**  
Speaker presentation 15' incl. Discussion per each

**Keynote:**  
1. *Andrea Kruse, University of Hohenheim, Germany*  
Hydrothermal Carbonization: Elimination reaction of water in water as solvent

**Speakers:**  
2. *Jillian Goldfarb, Cornell University, USA*  
Looking beyond routine characterizations to understand opportunities and limitations of HTC for carbon-based products and applications  
3. *Benjamin Keiller (TBC), University of Adelaide, Australia*  
Compositional analysis and kinetic modeling of the breakdown of lignocellulose during HTC

4. *Luca Fiori, University of Trento, Italy*  
Hydrothermal carbonization kinetics of lignocellulosic agro-wastes: Experimental data and modeling

**10:45 – 11:00**  
**Coffee break**

**Session A.2**  
Fundamental insights into the HTC-process

**11:00 – 11:45**  
Speaker presentation 15' incl. Discussion per each

**Speakers:**  
1. *Luke Higgins, University of Leeds, UK*  
Studying the fundamental properties of hydrochars using synchrotron radiation  
2. *Lynn Hansen, Technical University of Munich, Germany*  
Influence of hydrothermal carbonization on combustion properties of biomass  
3. *Toufiq Reza, Ohio University, USA*  
Fate of oxygen functional groups upon thermal activation of hydrochars



**Download the program**

**1<sup>st</sup> DAY**  
2019-05-14

**HTC**  
2019

**Poster Session I**  
Fundamentals/ material & energetic use

**11:45 – 12:15**

3 min poster presentations

I.1 *Andrés Álvarez-Murillo, University of Extremadura, Spain*

Good practices for a proper characterization of HTC liquid phase

I.2 *Gözde Duman Tac, Ege University, Turkey*

Comparative evaluation of hydrothermal carbonization and pyrolysis of olive wastes

I.3 *Iskender Gökalp, CNRS, France*

Characterization of solid and aqueous phase products from hydrothermal carbonization of orange pomace

I.4 *Jakob Köchermann, DBFZ Leipzig, Germany*

Hydrothermal conversion of D-xylose and organosolv hemicellulose catalyzed by a Keggin-type heteropoly acid under N<sub>2</sub> and CO<sub>2</sub> atmosphere

I.5 *Ivan Kozyatnyk (Kenneth Latham), Umeå University, Sweden*

Hydrothermal carbonization of humic acids: Physical and functional properties

I.6 *Nader Marzban, Leibniz Institute for Agricultural Engineering and Bioeconomy Potsdam, Germany*

Reaction kinetic modelling of the hydrothermal carbonization of plant-based feedstocks: Identification of reaction mechanisms

I.7 *Eduardo Sabio, University of Extremadura, Spain*

Kinetics of the hydrothermal carbonization of safflower cane

I.8 *Charles Coronella, University of Nevada, USA*

Nutrient solubilization by hydrothermal carbonization

I.9 *Pierpaolo Modugno, Queen Mary University of London, UK*

Influence of reaction conditions on hydrothermal conversion of biomass

I.10 *Daniela Moloeznik Paniagua, TU Berlin, Germany*

Partitioning of inorganics in the HTC process: The effect of process parameters

**12:15 – 13:45**

**Lunch break & poster exhibition/ discussion**

**Session A.3**

Fundamental insights into the HTC-process

**13:45 – 14:45**

Speaker presentation 15' incl. Discussion per each

**Speakers:**

1. *Matteo Pecchi, Free University of Bolzano, Italy*

Liquid-phase continuous analysis during hydrothermal carbonization (HTC) of model compounds using GC-FID

2. *Sunyoung Bae, Seoul Women's University, Korea*  
Is molecularly imprinted polymer effective to extract 5-HMF from heterogeneous bio-liquid?

3. *Pablo J. Arauzo Gimeno, University of Hohenheim, Germany*

Recirculation of process water during hydrothermal carbonization (HTC) influences secondary char formation

4. *Kenneth Latham Umeå University, Sweden*

Hydrothermal carbonization of organosolv and kraft lignin's: Physicochemical properties and water contaminate adsorption

**1<sup>st</sup> DAY**  
2019-05-15

**HTC**  
2019

## Poster Session II

Fundamentals/ material & energetic use

### 14:45 – 15:15

3 min poster presentations

II.1 *Hande Alptekin, Queen Mary University of London, UK*

Structure-performance correlations in hard carbons for Na-ion batteries

II. 2 *Heather Au, Queen Mary University of London, UK*

Development of hard carbon anodes for sodium-ion batteries

II. 3 *Daniele Basso, Free University of Bolzano, Italy*

Preliminary tests on the thermochemical conversion of hydrochar produced from AD digestate and sewage sludge

II. 4 *Richard Lobo (TBC), Queen Mary University of London, UK*

Properties and applications of size controlled HTC-derived carbon dots

II. 5 *Zhenyu Guo (TBC), Queen Mary University of London, UK*

Amorphous carbons as anodes for sodium ion batteries

II.6 *Beatriz Ledesma, University of Extremadura, Spain*

Effect of aluminum alloy shavings scraps on physical-chemical properties of hydrochars derived from several biomass wastes

II.7 *Sabina Alexandra Nicolae, Queen Mary University of London, UK*

Biomass based carbon materials for gas storage and separation

II.8 *Mo Qiao (TBC), Queen Mary University of London, UK*

Engineering the interface of carbon electrocatalysts at the triple point for enhanced oxygen reduction reaction

II.9 *Yahaya Balarabe Umar, University of Leeds, UK*

Hydrothermal carbonization of waste textile: Effect of reaction temperature and residence time

II.10 *ZZhen Xu (TBC), Queen Mary University of London, UK*

Carbon materials inspired by hierarchical forms of cellulose as electrodes for sodium-ion hybrid capacitors

### 15:15 – 16.15

Coffee break & poster exhibition/ discussion

**1<sup>st</sup> DAY**  
2019-05-14

**HTC**  
2019

### Session B.1

Innovative applications of HTC-  
technology

**16:15 – 18:00**

Speaker presentation 15´incl. Discussion per each

#### Speakers:

1. *Animesh Dutta, University of Guelph, Canada*  
A life cycle assessment (LCA) of integrated hydrothermal carbonization and anaerobic digestion systems for power generation from biomass
2. *Stéphane Bostyn, CNRS, France*  
Assessment of the global energy performances of hydrothermal carbonization of wet biomass
3. *José Daniel Marín Batista, Universidad Autonoma de Madrid, Spain*  
Energetic potential and nutrient recovery throughout hydrothermal carbonization of digested sewage sludge
4. *Kristian Melin, VTT Technical Research Centre of Finland, Finland*  
Techno-economic analysis of treatment of HTC effluent by wet oxidation
5. *Andrés Fullana, University of Alicante, Spain*  
Hydrothermal carbonization of marine plastic debris
6. *Yuriy Budyk, University of Alicante, Spain*  
Hydrothermal carbonization of disposable diapers
7. *Erik Marklund, Luleå University of Technology, Sweden*  
Influence of HTC process parameters on the fate of elements

### Networking dinner

**Brauhaus Lemke** am Hackeschen Markt  
Dircksenstraße, S-Bahnbogen 143, 10178 Berlin-Mitte

The 'Brauhaus Lemke am Hackeschen Markt' is situated within only 3 minutes walking distance from Alexanderplatz.



**19:30 – 23:00**

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# 2<sup>nd</sup> DAY

2019-05-15

# HTC

## 2019

**09:00**

**Welcome**

*Benjamin Wirth, DBFZ Leipzig, Germany*

**Session B.2**

*Innovative applications of HTC-technology*

**09:05 – 10:05**

Speaker presentation 15 min incl. Discussion per each

**Keynote:**

1. *Kyoung S. Ro, USDA-ARS Coastal Plain Soil, Water and Plant Conservation Research, USA*

Innovative agro-environmental applications of HTC

**Speakers:**

2. *Jürgen Kern (TBC), Leibniz Institute for Agricultural Engineering and Bioeconomy Potsdam, Germany*  
Post-treatments of HTC chars for use in agriculture

3. *Taina Lühmann DBFZ Leipzig, Germany*  
Hydrothermal conversion of landscape conservation material for the production of peat substitutes

**Poster Session III**

*Material & energetic use/ applications*

**10:05 – 10:35**

3 min poster presentations

III.1 *Chinnathan Areeprasert, Kasetsart University, Thailand*

Possibility of MSW and EFB pellets produced from hydrothermal carbonization in biomass pellet market

III.2 *Huyen Chau Dang (TBC), TU Dresden, Germany*

Reuse of spent coffee grounds to produce charcoal briquettes by using hydrothermal carbonization process

III.3 *Elisabeth Kleiber, Leibniz Institute for Agricultural Engineering and Bioeconomy Potsdam, Germany*

Experimental investigation of the drying kinetics of hydrochar derived from coffee grounds on the laboratory scale

III.4 *James Hammerton (TBC), University of Leeds, UK*

Utilization of hydrochar slurries as a fuel

III.5 *Jackie Massaya, University of Bath, UK*

Developing a biorefinery from spent coffee grounds: Using subcritical water and hydrothermal carbonization to derive value from a major by-product of the coffee processing industry

III.6 *Carla Pérez, Umeå University, Sweden*

Hydrothermal carbonization of biosludge from the pulp and paper industry

III.7 *Gabriel Gerner, Zurich University of Applied Sciences, Switzerland*

HTC-Innovation Campus in Switzerland

III.8 *Fabian Gievers, University of Applied Sciences and Arts Hildesheim, Germany*

Environmental impacts of sewage sludge treatment by hydrothermal carbonization

III.9 *Giulia Ischia, University of Trento, Italy*

Realization of a solar hydrothermal reactor: A hybrid solution to develop a zero-energy technology

III.10 *Vicky Shettigondahalli Ekanthalu, University of Rostock, Germany*

Hydrothermal carbonization: An emerging technology to effectively manage sewage sludge – Review

**10:35 – 11:15**

**Coffee break & poster exhibition/ discussion**

# 2<sup>nd</sup> DAY

2019-05-14

# HTC

## 2019

### Session B.3

Innovative applications of HTC-technology

**11:15 – 12:00**

Speaker presentation 15´incl. Discussion per each

#### Speakers:

1. *Thomas F. Ducey, USDA-ARS Coastal Plain Soil, Water and Plant Conservation Research, USA*  
The use of hydrothermal carbonization for the removal of pathogens and antibiotic resistance genes from animal waste
2. *Virpi Siipola, VTT Technical Research Centre of Finland, Finland*  
Utilization of hydrothermally carbonized brewery residues in high-value electrochemical applications
3. *Monika Bosilj, Fraunhofer Institute for Solar Energy Systems, Germany*  
Sustainable hydrothermal carbons for biorefinery-related catalysis

**12:00 – 13.30**

Lunch break

### Session C.1

Material and energetic use of HTC-products

**13:30 – 15:00**

Speaker presentation 15´incl. Discussion per each

#### Keynote:

1. *Maria-Magdalena Titirici, Imperial College London, UK*  
Black is the new green: Sustainable carbon energy materials

#### Speakers:

2. *Viola Hoffmann, University of Hohenheim, Germany*  
In-situ functionalizing of HTC chars for the production of biobased electrode materials for electromobility

3. *Kenneth Latham, Umeå University, Sweden*  
Ability of different nitrogen sources to dope hydrothermally carbonized pulp and paper mill black liquor: Physicochemical properties and supercapacitor performance

4. *Jingyu Feng, Queen Mary University of London, UK*  
Biomass derived freestanding electrode for oxygen reduction reaction applications

5. *Saskia Heumann, Max Planck Institute for Chemical Energy Conversion, Germany*  
Hydrothermal carbon as sacrificial electrode for solar fuel production

### Poster Session IV

Material & energetic use/ applications

**15:00 – 15:30**

3 min poster presentations

- IV.1 *Avery Brown (TBC), Worcester Polytechnic Institute, USA*  
Changes in the adsorption capacity of hydrothermal chars after thermal, chemical and mechanical activation

- IV.2 *Gareth Davies, University of Sheffield, UK*  
Effect of alcohol/water mixtures on hydrochar formation for use as adsorbents and catalysts

- IV.3 *Elena Díaz, Universidad Autonoma de Madrid, Spain*  
Application of activated hydrochar from grape seeds and olive stones for removal of emerging pollutants in aqueous phase

- IV.4 *Changyoon Jeong, Louisiana State University, USA*  
Effect of hydrochar amendment on tylosin adsorption-desorption and transport in agricultural soils

**2<sup>nd</sup> DAY**  
2019-05-15

**HTC**  
2019

IV.5 *Mikko Mäkelä, Aalto University, Finland*  
Hydrothermal carbonization in producing wood-based activated carbons for organic chlorine removal

IV.6 *Manuel Nowotny, Carl-von-Ossietzky-University Oldenburg, Germany*  
Activated biochar made from liquid-solid biomass mixtures

IV.7 *Silvia Román Suero, University of Extremadura, Spain*  
Magnetic porous carbon materials from almond shells by Fe assisted hydrothermal carbonization

IV.8 *Andrew Ross, University of Leeds, UK*  
Co-processing of digestate with lignocellulosic biomass: Influence of blending on bio-coal properties and biochemical methane potential

IV.9 *John A. Villamil Martínez, Universidad Autonoma de Madrid, Spain*  
Integral management of waste sludge by hydrothermal carbonization and anaerobic co-digestion of the process water with primary sewage sludge

IV.10 *Jale Yanik, Ege University, Turkey*  
Hydrothermal carbonization of food waste and its digestate

**15:30 – 16.30**

**Coffee break & poster exhibition/ discussion**

### Session C.2

Material and energetic use of HTC-products

**16:30– 18:00**

Speaker presentation 15 min incl. Discussion per each

#### Speakers:

1. *Vivian Mau, Ben Gurion University of the Negev, Israel*

Recirculation of HTC aqueous phase and use as fertilizer

2. *Reza Khoshbouy, Tokyo Institute of Technology, Japan*

Cd adsorption from aqueous solution by modified hydrochar: Effect of in-situ modification using HTC with acid and alkaline additive

3. *Aaron Brown, University of Leeds, UK*

Hydrothermal treatment of aquatic biomass: Potential for biomethane and biohydrogen generation from process waters

4. *Hui Luo, Queen Mary University of London, UK*

Platinum doped carbon dots and its hybridization with TiO<sub>2</sub> for enhanced visible light photocatalytic hydrogen evolution

5. *Yuxiao Ding, Max Planck Institute for Chemical Energy Conversion, Germany*

Hydrothermal carbon as support for water splitting

6. *Veronica Benavente, University of Alicante, Spain*  
Additives for ash related problems prevention in HTC fuels

**3<sup>rd</sup> DAY**  
2019-05-15

**HTC**  
2019

**09:00**

**Welcome**

*Judy Libra, Leibniz Institute for Agricultural Engineering and Bioeconomy Potsdam, Germany*

**Session D.1**

State-of-the-art in upscaling and commercialization

**09:05– 10:05**

Speaker presentation 15' incl. Discussion per each

**Speakers:**

1. *Marc Buttman TerraNova Energy GmbH, Germany*  
Industrial scale plant for sewage sludge treatment by hydrothermal carbonization in Jining/China and phosphate recovery by TerraNova® Ultra HTC process
2. *Timo Garrels (TBC), KS-VTCtech GmbH, Germany*  
Innovative applications of VTC technology in modern waste processing
3. *Alfons Kuhles, GRENOL GmbH, Germany*  
Hydrothermal carbonization and biogas - synergy effects. Example of the HTC Innovation Campus Rheinmühle, Switzerland
4. *Stepan Kusche, HTCycle, Germany* Presentation of the federal association „HTC“ and activities of HTCycle GmbH

**10:05 – 10:30**

**Coffee break**

**Session D.2**

State-of-the-art in upscaling and commercialization

**10:30– 11:30**

Speaker presentation 15' incl. Discussion per each

**Speakers:**

1. *Kunio Yoshikawa, Tokyo Institute of Technology, Japan*  
Commercial demonstration of solid fuel production from municipal solid waste employing the hydrothermal treatment
2. *Bryan Gooch Redd, ThermChem Corporation, USA*  
Combining HTC and gasifier systems for small scale to large scale deployments to convert complex wastes into valuable products
3. *Enrico Gribaudo, HBI Srl, Italy*  
Opportunities and limits regarding the diffusion of the HTC technology worldwide
4. *Kathleen Meisel, DBFZ Leipzig, Germany*  
CARBOWERT: Life cycle assessment of different hydrothermal carbonization concepts producing hydrochar for energetic and material use

**Farewell**

**11:30– 11:45**

1. *Judy Libra, Leibniz Institute for Agricultural Engineering and Bioeconomy Potsdam, Germany*
2. *Benjamin Wirth DBFZ Leipzig, Germany*
3. *Sunyoung Bae, Seoul Women's University, Korea*

**11:45 – 13.15**

**Lunch break**

**3<sup>rd</sup> DAY**  
2019-05-15

**HTC**  
2019

**Field Trip**  
Registration required!

**14:00 – 17:30**

The afternoon of the last day of the symposium will feature a field trip to a German-based HTC plant at demonstration scale. SunCoal Industries GmbH will open its doors for the symposium attendees!

Schedule:

14:00-14:45

Bus transfer to SunCoal Industries

15:00-16:30

Guided tour in 3 groups à 15 people

16:45-17:30

Bus transfer to Berlin main station

The tour will be held in English.



## Editorial – Ministry of State for Environment and Agriculture

*Dear attendees,*

Saxony is one of the most innovative economic and cultural regions in Europe. The free state of Saxony traditionally has an excellent research infrastructure in the fields of energy, as well as environmental and mechanical engineering. Interconnected municipal contractors and a solid base of small and medium-sized enterprises in chemical and plant engineering, agriculture and waste disposal offer ideal conditions for developing new technologies and sustainable value chains finally bringing them to market maturity.

Hydrothermal carbonization (HTC) is a field of research that promises a wide range of product and process solutions and focuses in particular on the fields of application as "energy carriers and fuels", "chemicals and fuels", "material applications" and "sewage sludge recycling and organic residues".

So far, hydrothermal processes can exploit potentials of highly wet biomass streams that are used only to a limited extent. These processes are suitable for the production of solid, liquid, or gaseous carbon carriers. They are also suitable for the recycling of nitrogen and phosphorus.

For the recycling of organic waste streams, fermentation residues, or sewage sludge, this technology opens up new product paths by means of a sustainable recycling economy. When sewage sludge is hydrothermally carbonized and thus becomes a dewatered, transportable, and phosphorus-depleted product, the high disposal pressure could be counteracted with increasing costs for sewage sludge recycling.

There is also great potential in the production of hydrochars. These have a higher energy density than the initial materials after dewatering and drying. A further advantage is that the final product can be tailored to the quality requirements of the customers by means of targeted control of the process parameters. If the corresponding admission requirements exist, hydrochars can be used in a wide variety of ap-



*Thomas Schmidt,  
Saxon Minister of State for Environment and Agriculture*

lications, ranging from co-incineration in coal-fired power plants to the use in cement industry, for the production of coarse ceramics, or used in road construction and as soil amendment.

The integration of these innovative processes into multi-output productions regarding a pioneering bioeconomy opens up a large field of activities for Saxon companies.

The symposium brings top international research to Germany and thus contributes to Saxony's profile as a region for innovation.

We are pleased to welcome you here in the Representation of the Free State of Saxony in Berlin and we wish you a successful event!

**Thomas Schmidt**

STAATSMINISTERIUM  
FÜR UMWELT UND  
LANDWIRTSCHAFT



Freistaat  
**SACHSEN**

## Editorial – Federal Ministry of Food and Agriculture

*Dear attendees,*

Increasing resource efficiency and independence from fossil resources are important challenges that we must face in order to achieve commitment to the United Nations sustainability goals and the Paris Climate Convention. Biomass already has an important role to play here today, and this role will continue to grow in the bio-economy to be developed. In the future, we will therefore need more sustainable forms of economic activity in order to secure our prosperity and handle our resources responsibly. On 17 July 2013, the Federal Government adopted the National Policy Strategy Bioeconomics in order to set the concrete course for biobased change in industry and society. Reliable and innovation-friendly framework conditions should help industry to exploit the potential of growth markets and innovative technologies.

One of these technologies is hydrothermal carbonization, which can play an important role in agriculture with regard to the recycling of inorganic nutrients and process coupling with biogas production. Hydrothermal processes provide the basis for a large number of new value chains that need to be developed. The integration of hydrothermal process streams into the material-energetic coupled production of the bioeconomy opens up a large market potential for products and corresponding process technologies.



*MinR Dr. Volker Niendieker  
Federal Ministry of Food  
and Agriculture, Ref. 524*

We are pleased that a large research community has gathered for the "2<sup>nd</sup> International Symposium on Hydrothermal Carbonization" in Berlin and hope that this event can contribute to keeping science and application in intensive exchange.

**Dr. Volker Niendieker**



Federal Ministry  
of Food  
and Agriculture

# HTC 2021

## 3<sup>RD</sup> INTERNATIONAL SYMPOSIUM ON HYDROTHERMAL CARBONIZATION

APRIL, 2021  
SEOUL, KOREA



CONTACT :  
HTC2021KOREA@GMAIL.COM

# *Oral Presentations*

*Prof. Dr. Andrea Kruse, University of Hohenheim*

## **Hydrothermal carbonization: Elimination reaction of water in water as solvent**

Andrea Kruse<sup>1</sup>, Dennis Jung<sup>1</sup>, Paul Körner<sup>1</sup>

<sup>1</sup> University of Hohenheim, Conversion Technologies of Biobased Products, Institute of Agricultural Engineering, Garbenstr. 9, 70593 Stuttgart, Germany

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Keywords: Kinetic modelling, HMF, HTC, acidic catalysis

A lot of papers are published in the last years dealing with hydrothermal carbonization (HTC). But what is hydrothermal carbonization? “Hydrothermal” means in water and “carbonization” is a (thermo-) chemical reaction increasing the carbon content of a material. This increase of carbon content could be reached via the elimination of water or carbon dioxide. Usually the carbon content increases with the temperature applied. At this point most of the papers about HTC stops.

A deeper look into the chemistry tells us a little bit more: The increase of carbon content is the consequence of water elimination. First cellulose hydrolyses to sugars, which forms hydroxymethylfurfural or furfural by elimination of water. This reaction is catalyzed by acids. The next step is the poly-condensation of HMF to hydrochar, the product of HTC. Also here, a lot of questions are still open, e.g. what happens with the complex structure of biomass? What is exactly the role of the acid as catalyst? And further more.

Here the goal is to model the formation of HMF and the HTC to get a deeper understanding of the reaction. These models are systems of ordinary differential equations describing the reaction rate of the different reaction steps. In addition, we want to quantify HTC in order to control the reaction network better.

### *References:*

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*Prof. Jillian Goldfarb, Cornell University*

## **Looking beyond routine characterizations to understand opportunities and limitations of HTC for carbon-based products and applications**

Jillian Goldfarb<sup>1</sup>, Luca Fiori<sup>2</sup>, Maurizio Volpe<sup>2</sup>, Lihui Gao<sup>3</sup>, Michela Lucian<sup>2</sup>, Giulia Ischia<sup>2</sup>, Giulia Severini<sup>2</sup>

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<sup>2</sup> University of Trento

<sup>3</sup> China University of Mining and Technology

**Keywords:** Hydrochars, solid fuel, adsorbent, nutrient recovery, applications

Hydrothermal carbonization (HTC) of wet biomass is touted as an economical method to produce carbon-condensed solid hydrochars from wet biomass. Hydrochars are hyped as potential solid fuels. While their combustion enthalpies and van Krevelen diagrams resemble bituminous coals, we recently demonstrated that a reactive amorphous secondary char forms during carbonization that may hamper the ability of some hydrochars to be used as drop-in fuels for combustion due to the drastically different reactivity of the secondary char. There is also a growing literature on the upgrading of hydrochars to advanced carbon materials such as adsorbents for water treatment, with evidence of high surface area and low ash materials. Yet, our results suggest that some hydrochars are not suitable for adsorption due to both mechanical and chemical limitations. While HTC is a promising thermochemical conversion method, we must temper our enthusiasm for using HTC as a “one size fits all” answer to biomass utilization by a critical analysis of the feedstock characteristics and processing conditions that lead to hydrochars with properties – beyond routine characterizations of proximate/ultimate analyses, HHV, and surface area – that are appropriate to given applications.

This presentation will provide a survey of an internationally collaborative effort to understand how to optimize selection of feedstocks and processing conditions for use of hydrochars as both solid fuels and adsorbents. For example, the carbonization of more sugar-intensive biomasses (e.g. prickly pear) as compared to a more lignocellulosic biomass (such as olive trimmings) leads to a more reactive secondary char, limiting the ability to co-combust hydrochars with coals of similar composition. However, the ability to easily remove such secondary chars yields adsorbents with higher surface areas and increased porosity, producing better adsorbents. On the other hand, carbonization of phosphorus-rich biomasses such as manure may help concentrate and sequester nutrients in the hydrochar, but after these nutrients are removed, the remaining hydrochar has a weakened mechanical structure with low surface area and minimal adsorption capacity. The potential applications of hydrochars are more than a function of elemental and proximate analyses; we are working to understand how physical and chemical properties are both functions of HTC conditions and drivers of potential downstream applications.

*Benjamin Keiller, University of Adelaide*

## **Compositional analysis and kinetic modeling of the breakdown of lignocellulose during HTC**

Benjamin Keiller<sup>1</sup>, Phoebe Chilman<sup>1</sup>, Matthew Potter<sup>1</sup>, Philip van Eyk<sup>1</sup>, Rachel Burton<sup>1</sup>

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**Keywords:** Compositional analysis, kinetics, hemicellulose, cellulose, lignin

The biochemical changes that occur during Hydrothermal Carbonisation (HTC) of lignocellulosic biomass, as well as the kinetics thereof, are poorly understood. Previous literature on the behaviour of the primary components of lignocellulose (crystalline cellulose, non-crystalline polysaccharides or hemicellulose, and lignin), have typically relied on experiments carried out using individual purified components as an idealised HTC feedstock, instead of whole biomass. While convenient, such studies fail to take into account the very complex interactions between the various components as they react in whole biomass. There is a need, therefore, to try to measure the behaviour of each lignocellulosic component as it reacts in whole biomass.

Australian saltbush, was subjected to HTC at three temperatures (200 °C, 230 °C, 260 °C) and four reaction times (0 minutes, 10 minutes, 30 minutes and 60 minutes at reaction temperature), and the resultant hydrochars were subjected to vigorous compositional analysis, including PMP-derivative HPLC, Updegraffe analysis, and acetyl bromide solubilisation, to determine the changes in hemicellulose, cellulose and lignin content respectively.

The degradation of each lignocellulosic component was then modeled as an Arrhenius reaction, and the reaction order  $n$  and key kinetic parameters  $k$  (reaction rate constant),  $E_a$  (Activation Energy), and  $A_0$  (pre-exponential factor) were calculated. Hemicellulose is the most highly susceptible to hydrolysis during HTC, completely disappearing within minutes at any temperature ( $n = 1$ ,  $E_a = 61 \text{ kJmol}^{-1}$ ). Cellulose, meanwhile, is the most resistant, with only mild losses at 200 °C and 230 °C ( $n = 0.5$ ,  $E_a = 127 \text{ kJmol}^{-1}$ ). Lignin, widely assumed to be inert under HTC conditions, was found to be only partially susceptible to HTC, with around 78 % of lignin undergoing rapid degradation, and the remainder being stable ( $n = 1$ ,  $E_a = 66 \text{ kJmol}^{-1}$ ). The kinetic parameters calculated were consistently lower than in purified component experiments found in the literature, demonstrating the effect of the complex interactions that occur during HTC of whole biomass.

*Prof. Luca Fiori, University of Trento*

## **Hydrothermal carbonization kinetics of lignocellulosic agro-wastes: Experimental data and modeling**

Luca Fiori<sup>1</sup>, Michela Lucian<sup>1</sup>, Maurizio Volpe<sup>1</sup>

<sup>1</sup>University of Trento, Department of Civil, Environmental and Mechanical Engineering, Via Mesiano 77, 38123 Trento, Italy

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**Keywords:** Hydrochars, solid fuel, adsorbent, nutrient recovery, applications

Olive trimming (OT), residual from olive trees maintenance, were used as feedstock for an in deep study on the reaction kinetics affecting hydrothermal carbonization (HTC). OT were hydrothermally carbonized for residence times up to 8 h at temperatures between 180 and 250 °C to systematically investigate the chemical and energy properties changes of hydrochars during the course of HTC. Additional experiments at 120 and 150 °C at 0 h residence time were carried out to collect data relevant to the thermal transient phase, i.e. the heat-up phase required to reach the set-point HTC reaction temperature.

In parallel with the experimental activity, an original HTC reaction kinetics model was developed which allows the prediction of the carbon distribution among the HTC products: solid phase, i.e. hydrochar, and liquid and gaseous phases. The HTC reaction pathway is described through a lumped model, in which biomass is converted into solid (distinguished between primary and secondary char), liquid and gaseous products. Primary char derives from a solid-to-solid reaction, while secondary char is due to the polymerization – and precipitation as a solid phase – of organic molecules previously dissolved in the liquid phase.

The kinetics model, written in MATLAB™, was used in best fitting routines with the HTC experimental data obtained using OT. The reliability of the model was also tested on HTC data previously obtained for two other lignocellulosic agro-wastes: grape marc (Basso et al. 2016) and *Opuntia Ficus Indica* cladodes

(VOLPE et al. 2018). The HTC kinetics model here developed effectively predicts the carbon distribution among HTC products versus time, thermal transient phase included. The reaction producing primary char results the key reaction during HTC, and the production of secondary char increases as the HTC temperature increases. Importantly, both the modeling and experimental data suggest that already during the transient heat up phase the feedstock greatly carbonizes, in particular at the highest HTC temperature tested: at 250 °C, around half of the initial carbon contained in the biomass moves to the other HTC products already during the thermal transient.

Complete information can be found in the full length article by the authors (LUCIAN et al. 2019).

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Luke Higgins, University of Leeds

## Studying the fundamental properties of hydrochars using synchrotron radiation

Luke J.R. Higgins<sup>1</sup>, Andrew P. Brown<sup>1</sup>, Andrew B. Ross<sup>1</sup>, Bhoopesh Mishra<sup>1</sup>

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**Keywords:** Synchrotron radiation, NEXAFS, formation mechanisms, X-ray raman spectroscopy (XRS), STXM

*In situ* measurement of hydrochar formation is extremely difficult; therefore reported mechanisms of formation involve a great deal of postulation. Current understanding of hydrochar formation has been built from FTIR, XPS and <sup>13</sup>C NMR spectroscopies. However, whilst these techniques have their benefits, they suffer from weaknesses such as high surface sensitivities and low signal to noise ratios. The application of synchrotron radiation to hydrothermal carbon now offers a route to study their fundamental carbon chemistry using X-ray spectroscopy (LATHAM et al. 2017). Here, two synchrotron X-ray techniques, X-ray Raman spectroscopy (XRS) and scanning transmission X-ray microscopy (STXM), have been applied in order to study the formation and bulk carbon chemistry of hydrochar produced from a model compound (glucose) and a complex forestry residue (oak wood). The current model of hydrochar formation involves a complex chain of condensation reactions occurring before polymerisation and nucleation of the monomer – hydroxymethylfurfural (HMF). This process is thought to result in the formation of a *core-shell* type spherical structure, with a condensed furan-type core and a less condensed shell (SEVILLA/FUERTES 2009). However the in-situ measurement of this process is challenging, and there are few direct methods for investigating this *core-shell* model. In this study, STXM was applied to thin cross-sections of hydrochars (glucose and oak) produced over temperatures of 200–250 °C. Spatially-resolved core X-ray spectra from STXM, complemented by high-resolution TEM images, show single HTC spheres with a clear shell-core structure as one would might expect from the

literature-proposed model – La Mer nucleation and growth. Further analysis of the carbon core K-edge spectroscopy shows small, but significant variations in the chemistry of the shell as compared to the core of the HTC spheres.

X-ray Raman spectroscopy, applied to the same materials, offers insight to the bulk carbon chemistry of these samples. At the carbon K-edge techniques such as NEXAFS or XPS are purely surface measurements, and only penetrate a few tens of nanometres. However, X-ray Raman spectroscopy offers the advantage of using highly penetrative hard X-rays (~10 KeV) to gain measurements analogous to core X-ray absorption spectra (SAHLE et al. 2015). Here, XRS is applied to complement the analysis of the shell carried out in the STXM experiment. The use of XRS is novel to this field, and future applications of the technique will be discussed.

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Lynn Hansen, TU Munich

## Influence of hydrothermal carbonisation on combustion properties of biomass

Lynn Hansen<sup>1</sup>, Sebastian Fendt<sup>1</sup>, Hartmut Spliethoff<sup>1,2</sup>

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**Keywords:** Hydrothermal carbonization, combustion, fuel indices, biomass pretreatment

Within the framework of the EU H2020 project *Bioefficiency* dealing with efficiency enhancement of biomass-fired CHP plants by handling ash-related problems, the Technical University of Munich investigates the pre-treatment via HTC in lab- and pilot-scale.

As a solid fuel, one of the key concerns in utilizing biomass feed stocks for energy generation is the occurrence of ash-related problems in boilers. Further, due to the inherent inhomogeneity and low energy content of biomass thermal use of biomass is problematic. This study focuses on the properties of HTC biocoal relevant for combustion. Seven high moisture, residual biomass types were treated in water in the temperature range from 50–270 °C, covering sole water leaching conditions, as well as a broad range of hydrothermal conditions. All samples were characterized by proximate, ultimate, and thermogravimetric analysis and bomb calorimetry. The ash composition was determined by XRF.

The influence of HTC on fuel properties with respect to problems that occur upon biomass-firing (i.e. ash

melting, corrosion, particulate emission, NO<sub>x</sub> emissions, reactivity) are assessed with aid of the fuel analysis data, fuel indices and experiments.

HTC proved to be effective in increasing the energy density of the material, as well as in removing problematic biomass constituents, such as chlorine and potassium. For example, the removal efficiencies for chlorine and potassium for hydrothermal conditions lay in the range of 60–80 % and 70–86 % respectively, depending on reaction conditions and biomass type. In comparison, sole water leaching at 50 °C also led to removal of chlorine and potassium; however the removal efficiencies were lower than for hydrothermal conditions. A positive effect of HTC was also observed on the expected particulate emission, ash melting temperatures and corrosion tendencies. On the other hand: Fuel-N content increased upon HTC treatment and the combustion performance assessed by TGA decreased with higher treatment temperature.

Dr. Toufiq Reza, Ohio University

## Fate of oxygen functional groups upon thermal activation of hydrochars

Toufiq Reza<sup>1</sup>, Nepu Saha<sup>1</sup>, Danhui Xin<sup>2</sup>, Nabiul Afrooz<sup>3</sup>, Pei Chiu<sup>2</sup>

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**Keywords:** HTC, pyrolysis, functional group, electron storage capacity, Boehm titration

Hydrothermal carbonization (HTC) a thermochemical process, where biomass is treated with high-pressure high-temperature water. Hydrochar is a carbon-dense solid product from HTC with various oxygen functional groups on the surface. Among other process parameters, HTC temperature is one of the most dominant for hydrochar functional properties.

The surface functional groups on the surface of chars play a vital role to use them as an adsorbent. We have performed acidic functional groups analysis for hydrochar at different HTC temperatures. Now, many of the functional groups could be submerged by the volatile material. Therefore, thermal activation or pyrolysis might be useful to further increase the concentration of functional group. However, dehydration is one of the major reactions for pyrolysis. As a result, there could be a competition between oxygen functional groups increase with dehydration.

Therefore, the objectives of this study were to quantification of oxygen functional groups and electron exchange capacities on activated hydrochars from model compounds (cellulose and wood). The hydrochars were pyrolyzed in a muffle furnace at three different temperatures (400 °C, 500 °C, and 600 °C) for 1 hour. The change in functional groups on activated hydrochar surface was evaluated by surface morphology analysis, pH, Boehm titration, PZC, and FTIR. As prepared hydrochar shows relatively low surface area, mostly because of the lack of pores/clogged pores with volatiles. An increase of surface area was observed but the oxygen functional groups were decreased with the increase of activation temperature as evident by the increase of pH, pKa, PZC. EAC values were in the range of 1.7–1.83 mmol e-/g activated hydrochar.

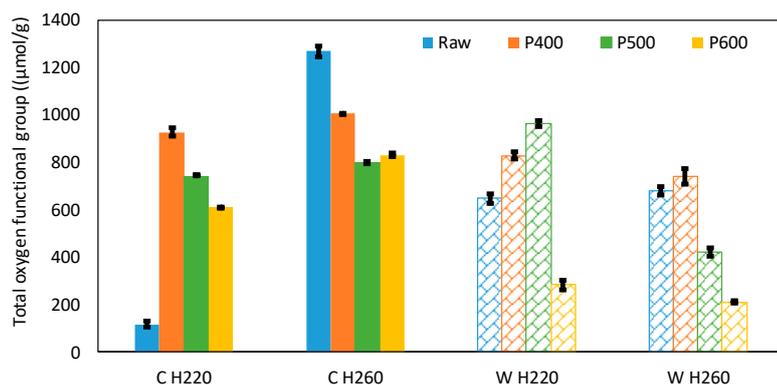


Figure 1. Total oxygen functional groups on raw, hydrochars, and thermally activated hydrochars at various temperatures. Note: C/W H220 stands for cellulose/wood hydrochar prepared at 220 °C

Matteo Pecchi, Free University of Bolzano

## Liquid-phase continuous analysis during hydrothermal carbonization (HTC) of model compounds

Matteo Pecchi<sup>1</sup>, Daniele Basso<sup>1,2</sup>, Francesco Patuzzia<sup>1</sup>, Vittoria Benedetti<sup>1</sup>, Silvia Celletti<sup>1</sup>, Tanja Mimmo<sup>1</sup>, Stefano Cesco<sup>1</sup>, Marco Baratieria<sup>1</sup>

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**Keywords:** Hydrothermal-carbonization, lab-scale reactor, continuous analyses, liquidphase, HPLC

The hydrothermal carbonization process has been modelled by several authors in the last years, both in terms of kinetics occurring during the process and of thermodynamics (BERGE et al., 2011; ÁLVAREZ-MURILLO et al., 2016). Among the others, a computational tool based on the direct application of the Hess's Law between the initial and final state of the HTC process for the evaluation of the process enthalpy, was recently developed by the authors. The script was run using the results of the tests performed by (BASSO et al., 2018), who worked on grape marc, i.e. a vinery industry residue.

A 4-litre lab-scale reactor for the HTC process has recently been installed in the Bioenergy and Biofuels Lab in the University of Bolzano, Italy. The system has been developed by the Italian company HBI Srl, and it has a specific design which allows a periodic sampling of small amounts of liquid during the process, for a subsequent characterization. Through this system, it is then possible to evaluate the evolution of the composition of the liquid phase in a semi-continuous way. For the purpose of the present work, the liquid compounds formed during the HTC process have been analyzed through a high-performance liquid chromatography (HPLC). The gaseous phase has been analyzed at the end of the run through a micro-gas chromatograph ( $\mu$ -GC), in terms of permanent gases, i.e. CO, CO<sub>2</sub>, CH<sub>4</sub> and H<sub>2</sub>.

Pure cellulose, as model compound, and selected wood sawdust have been used as feedstock. The substrates have been treated with a water-to-biomass ratio of 8 at 220 °C for 3 hours, while sampling of liquid was performed every 30 minutes. Preliminary results showed that the compositions of the liquid phases change during the HTC process. These data will be used for the development of a new improved model for the HTC process.

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*Dr. Sunyoung Bae, Seoul Women's University*

## **Is molecularly imprinted polymer effective to extract 5-HMF from heterogeneous bio-liquid?**

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**Keywords:** Bio-liquid, 5-HMF, molecularly imprinted polymer, extraction, gas-chromatography

Hydrothermal carbonization (HTC) is a thermal treatment for moisten organic waste at relatively low temperature. After the HTC reaction, hydrochar, bio-gas, and bio-liquid are produced. In bio-liquid 5-Hydroxymethyl-2-furaldehyde (5-HMF), a value-added product that is used as an intermediate substance in various field such as fuel, medicine, and polymer was generated during the reaction. A common method for extracting 5-HMF in bio-liquid is liquid-liquid extraction (LLE). However, LLE requires a lot of solvent and labor. It demands selective extraction of target compounds from bio-liquid without interference in the heterogeneous matrix. Our research team synthesized the 5-HMF molecularly imprinted polymer (5-HMF MIP) and conducted the various experiments. In this study, selective adsorption of 5-HMF on synthesized MIP was performed using Gas Chromatography-Flame Ionization Detector (GC-FID) with internal standard. The adsorption isotherm was conducted at a solid:solution ratio of 1:90.

The selectivity test was performed using 5-methyl-2-furaldehyde and methyl 5-methyl-2-furoate, which are similar in structure to 5-HMF. The developed method using MIP was validated and showed the selective extraction of 5-HMF from the bio-liquid obtained from HTC reaction of food waste. In conclusion, the tailored 5-HMF MIP was successfully synthesized, characterized, and shown the excellent extraction efficiency.

Pablo J. Arauzo Gimeno, University of Hohenheim

## Recirculation of process water during hydrothermal carbonization (HTC) influences secondary char formation

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**Keywords:** Hydrothermal carbonization, hydrochar, water recirculation, secondary char, 5-hydroxymethylfurfural

HTC is a promising technology for the conversion of wet waste biomass into carbonaceous materials, termed hydrochar, with different characteristics depending on the feedstock; however, it is still necessary to have a deeper knowledge about the complex reactions within the aqueous environment, e.g. in view of process optimization.

Instead of using fresh water, some studies propose to recirculate the process water (PW), which increase the yield to hydrochar and reduce the cost of wastewater treatment (UDDIN et al. 2013). In this case, the PW includes degradation products of biomass. It is also demonstrated that recirculation of PW produces an increase of carboxylic acids (acetic, formic, levulinic or lactic acid) and rather reactive intermediates of the HTC (HMF, furfural, glucose) in the PW, which makes it interesting for further recirculation cycles but also as a source for the chemical basic chemicals (STEINBACH et al. 2017).

The increase of the hydrochar yield and the carbon content by recirculation is due to the “secondary char” formation. HMF as well as its derivatives have been proven to enhance secondary char formation, because these compounds can polymerize to secondary char. The increase of acetic acid provides an acidic milieu for further recirculation and positively influences the solvolysis of the cellulosic fraction in wast biomass, which result also in a more stable primary char (LUCIAN et al. 2018).

This study was focused on the study of second char reaction after water recirculation. Figure 1 shows that hydrochar from brewer’s spent grains produced after 2<sup>nd</sup> recirculation of PW at 240 °C and 2 h reaction time has a peak at 421 °C, typically associated to secondary char reactions.

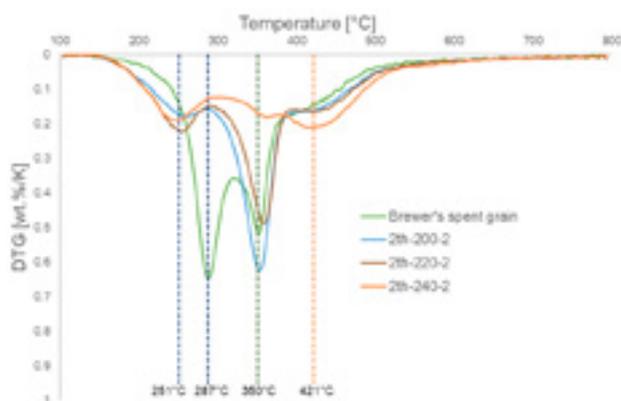


Figure 1. Hydrothermal thermal stability of hydrochars after 2 recirculation.

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*Dr. Kenneth Latham, Umeå University*

## **Hydrothermal carbonization of Organosolv and Kraft lignin's: physicochemical properties and water contaminate adsorption**

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**Keywords:** XPS, FTIR, SEM, methylene blue, kinetics

Lignin has become a hot topic in the field of sustainable materials and biofuels due to its naturally occurring aromatic structure, abundance in lignocellulosic biomass (15–30 wt%, 40 % by energy), and an annual production of 70–100 million tons. However, lignin remains relatively underutilized in industry with only a small fraction of the lignin produced from the pulp and paper mill industry used commercially. This is due to the lignin being intermixed with inorganic materials (i.e, sodium and sulfates) in liquors and sludge's from the Kraft pulping process. These materials are either burnt in low-level energy recovery boilers or disposed of in landfill. To address this issue, there is growing support for the organosolv pulping method that utilizes recyclable organic solvents instead of NaOH and Na<sub>2</sub>S. Furthermore, the lignin that is extracted from Organosolv is considerably cleaner than after the Kraft process.

In this work, we have examined the impact of time and temperature on the physicochemical properties of hydrothermal carbon produced from Kraft and Or-

ganosolv lignin. We found that the extraction method was the predominate factor in determining the final properties of the carbon material. For instance, the surface area for three different Kraft lignin's was 51.9 m<sup>2</sup> g<sup>-1</sup>, 155.5 m<sup>2</sup> g<sup>-1</sup> and 0.9 m<sup>2</sup> g<sup>-1</sup> after undergoing the same treatment time and temperature. We also found that the hydrophobicity, determined by the surface chemistry and morphology of the lignin precursor, played an influential role in shaping the final carbon product. There was also a significant difference between carbons produced from Kraft and Organosolv lignin, especially in yield, with Kraft lignin's producing between 40–60 wt%, while Organosolv was around 10–25 %. Thus, we will discuss how each of the factors influence the final product, challenges in hydrothermally carbonizing lignin and their ability to adsorb contaminants from water.

*Dr. Animesh Dutta, University of Guelph*

## **A life cycle assessment (LCA) of integrated hydrothermal carbonization and anaerobic digestion systems for power generation from biomass**

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**Keywords:** LCA, biomass, HTC, emission, bioenergy, AD

Greenhouse gas emissions due to daily increasing fossil fuel consumption are threatening the planet by climate change and its potentially serious dangers to human being. Alternative resources like biomass can play a significant role to tackle these issues. Two methods for converting biomass to fuel are hydrothermal carbonization (HTC) and anaerobic digestion (AD). This study is aimed at comparing two scenarios for bioenergy production from undervalued biomass (sawdust). In the first scenario, raw biomass is burned in a combustor to provide the heat required by power cycles to generate electricity. In the second scenario, firstly the raw biomass goes under HTC treatment,

while the solid product (hydrochar) is used to produce power by a Rankin cycle, the liquid by-product undergoes to an AD process. This results in fuel gas production and can be used in a Bryton cycle to generate more power. Energy and mass balance of both scenarios were developed for each unit process by using Engineering Equation Solver (EES) and used to evaluate the life cycle of bioenergy. The life cycle assessment (LCA) methodologies (ISO 14040) were adopted to evaluate the life cycle of bioenergy. The functional unit of this study was selected to be 1 MJ electricity. In this process, environmental impacts of bioenergy were determined with TRACI 2.1 as an impact assessment method of SimaPro (LCA software).

*Dr. Stéphane Bostyn, Institut de Combustion, Aérodynamique, Réactivité et Environnement*

## **Assessment of the global energy performances of hydrothermal carbonization of wet biomass**

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**Keywords:** Energy valorization, hydrochar, olive pomace, TGA, design of experiments

Hydrothermal carbonization (HTC) allows pre-treating wet biomass in subcritical water, under temperatures of 180–250 °C and pressures between 10–40 bars. It produces a carbonaceous solid material, called "hydrochar", with an attractive potential for energy production. The aim of this work is to provide a global energy performance assessment of the HTC process applied to solid residues from olive oil production. Olive pomace (OP) contains water, residual oil, olive skin, olive pulp, and olive stones (with 70% moisture content). A Design of Experiments and Response Surface Methodology (DoE/RSM) approach was applied to analyze the effects of temperature and heating time. The results show that the hydrochar mass yield (~66–86%) and its fuel properties significantly depend on the process temperature. Hydrochars have much less oxygen and higher carbon contents than untreated OP.

HTC treatment increased by 4–26% the high heating value of hydrochar when compared to untreated OP (20.3 MJ.kg<sup>-1</sup>). Furthermore, the results revealed that a flash treatment (0 min) at 197 °C with an OP/water weight ratio of 1/3 maximizes the energy yield (94%)

of the HTC process. The thermal degradation (TGA) by oxidation behavior of hydrochar is also investigated using thermogravimetric analysis. The characteristic temperatures ( $T_{\text{ignition}}$ ,  $T_{\text{maximal combustion}}$ ,  $T_{\text{combustion}}$ ) and combustion parameters (ignition index, reactivity) depend essentially on hydrochar's proximate composition (volatile matter, fixed carbon). The HTC process requires energy to generate the hydrochar and also to treat the liquid phase. The energy balance of the global process is determined from mass and energy balance calculations. A system of linear equations dependent on temperature and OP/water weight ratio is established to represent the three energy-consuming operations: ( $E_1$ ) heating of the HTC system, ( $E_2$ ) drying of wet hydrochar, and ( $E_3$ ) process water treatment. To evaluate the energy balance, it is necessary to calculate the global energy consumption ( $E_1 + E_2 + E_3$ ) and to estimate the amount of energy that could be recovered from HTC products (hydrochar, gas and oil). It is demonstrated that the biomass/water ratio is the most influential factor on the energy balance of the HTC process. The appropriate control of this parameter would be necessary to achieve a satisfactory energy balance.

*José Daniel Marín Batista, Autonomous University of Madrid*

## **Energetic potential and nutrient recovery throughout hydrothermal carbonisation of digested sewage sludge**

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**Keywords:** Anaerobic digestion, biogas, phosphate recovery, sewage sludge digestate, soil amendment

Anaerobic digestion (AD) has become the most common alternative for sewage sludge valorization due to the added benefit of energy generation from biogas, which has helped to reduce the net energy consumption in urban wastewater-treatment facilities. Nevertheless, with the vast implementation of AD, digestate creates a waste disposal problem that requires to be addressed as its direct application into the land (as fertilizer) arises potential risks of ammonia and greenhouse-gases emissions, and lead to accumulation of heavy metals in the soils (e.g., Cu, Zn, and Mn). An interesting alternative to overcome this issue is to upgrade digestate by hydrothermal carbonization (HTC) to obtain hydrochar as a precursor material for solid amendment after acid leaching. In the meantime, obtaining additional methane recovery by AD of the HTC liquid-fraction (HTCLF).

This study evaluated the energetic potential and nutrient recovery throughout hydrothermal carbonisation of digested sewage sludge. Three temperatures (180, 210 and 240 °C) were checked to optimize the characteristics of the hydrochar and LF produced. The carbonization yields ranged from 64.2 to 74.2 % for all HTC conditions. Phosphate recovery in hydrochar raised up to 82.1 % by means of HTC at

the lowest temperature tested (180 °C). The carbon recovery, and atomic C/O and C/H ratios in all the hydrochars were increased after washing ashes out with HCl 0.1 N. Therefore, hydrochar was suggested as a potential solid amendment.

The specific methane potentials (SMP) achieved in AD of HTCLF obtained at 180, 210, and 240 °C were  $313 \pm 3$ ,  $269 \pm 2$  and  $45 \pm 5$  mL CH<sub>4</sub> g<sup>-1</sup> VS<sub>added</sub>, respectively. The runs carried out with HTCLF 180 and HTCLF 210 showed COD removal of 93 % indicating a feasible digestion process. However, run performed with HTCLF 240 showed COD accumulation in form of VFA. As TAN kept under 1800 mg/L, ammonia inhibition was discarded. The analysis of chemical species suggested the presence of refractory compounds such as pyrazine, 2-ethyl-5-methyl- and 1-H-indole. These chemical species were derived from the thermal processing and might limited efficiency of the AD. Therefore, HTC at 180 °C presented the optimal condition for upgrading digested sewage sludge. The low HTC temperature favored the phosphate recovery in hydrochar and methane production from HTCLF.

*Dr. Kristian Melin, VTT Technical Research Centre of Finland*

## **Techno-economic analysis of treatment of HTC effluent by wet oxidation**

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**Keywords:** Wet liquids, wet oxidation, techno-economic analysis, water water treatment

The liquid effluent from hydrothermal carbonization process is often seen problematic to handle. Typically these effluents contains high amount of dissolved organic carbon and both biodegradable and non-biodegradable components. Components such as phenol, HMF, furfural and short chain carboxylic acids are present in the HTC effluent.

Wet oxidation is a technology based on treatment of aqueous stream at high temperature and elevated pressure, which oxidizes the non-biodegradable and toxic compounds into non-hazardous products such as CO<sub>2</sub> and short chain carboxylic acids. The short chain carboxylic acids found in the effluent after the wet oxidation (e.g. formic, acetic, succinic, propionic and glycolic acid) are not considered toxic for the environment. In addition a considerable part the energy content of the waste water can be converted into heat which is needed in the HTC process.

In earlier work a high reduction of more than 80 % of the chemical oxygen demand and total organic content for HTC effluent was observed. Also the treated effluent contained only biodegradable substances such as acetic and formic acid.

In this presentation the previous analysis is extended to include the techno-economic performance of the wet oxidation treatment is both in a mobile small scale unit and at a bigger production plant. The analysis also shows that all the heat needed for the HTC process could be supplied by the wet oxidation treatment.

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*Dr. Andres Fullana, University of Alicante*

## **Hydrothermal carbonization of marine plastic debris**

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**Keywords:** Plastics, HTC, hydrochar, HTC-liquor, seawater

Between 4.8 and 12.7 million tons of plastic debris reaches the sea every year (JAMBECK et al., 2015). Once removed from the sea, most plastics cannot be recycled or reused. These plastics are good fuels, but they can contain chlorine and other compounds which are necessary to eliminate before the combustion process. In this way, a hydrothermal carbonization treatment is the best option to improve the properties of these materials as fuels (Lu et al., 2003; YAO and MA, 2017).

In this work, hydrothermal carbonization (HTC) of a mixture of the four plastics most frequently found in the sea (PE, PP, PET and Nylon) and seawater was performed at three different temperatures (200, 250 and 300 °C) to examine the characteristics of the final products obtained and to test the feasibility in converting marine plastic debris to fuel.

Results showed that the inorganic anions content in the solid residue was lower after the treatment. The nitrogen content in the hydrochar also decreases, it is important to avoid the formation of nitrogen oxides (NO<sub>x</sub>) during the subsequent combustion process. In addition, the NCV increases, reaching a maximum value of 39.08 MJ/kg in the solid at 300 °C.

Evolution of the thermal behavior of the original mix (before HTC process) and the solid residue (after HTC process) was followed by thermogravimetry at

different heating rates (5, 10 and 20 °C/min). The material prepared at 200 °C shows small differences respect to the original mix, and solid residue obtained at 300 °C presented a greater degradation. Chloride was the most abundant compound founds in the HTC-liquor. The content of fluoride, bromide and sulfate increase as the process temperature grows. This is expected since during the HTC, the inorganic anions of the solid material pass into the liquid. The organic compounds were also identified, being amides, alcohols and alkanes the major compounds. This liquid could be used again in another HTC process.

Additionally, the gases emissions during the process were analyzed. Low emissions of CO were founded and the main gas emitted was nitrogen. Taking into account the high hydrocarbons and other non-condensable products, the higher emissions were detected during the treatment at 300 °C, reaching a value of 822 mg/kg sample. This gas would not be a problem because it could be subsequently burned.

Taking into account the results, it can be said that from 250 °C the HTC treatment to this mixture of marine plastic debris would be effective.

*Yuriy Budyk, University of Alicante*

## **Hydrothermal carbonization of disposable diapers**

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**Keywords:** Disposable diaper, hygienic waste, hydrothermal carbonization, waste diaper treatment

There was generated more than 4 million tons of waste diapers in Europe, during 2007. The main part of those diapers ends up in the landfill due to the absence of specific treatment. Since water represents more than 80 % of the total weight of these wastes, the aim of this work is to remove the water from waste diapers and produce a compact and high calorific value hydrochar for numerous applications. In addition, synthetic faeces and urine were used to simulate waste diaper conditions.

The mass yields after performing HTC showed 10% of hydrochar, around 90 % of liquid phase and scant gas generation (approximately 1 %). The carbonaceous nature of the originated hydrochar during the HTC, promote liquid-solid separation. Moreover, the Thermogravimetry, High calorific value and Elemental analyses of hydrochars showed greater properties in comparison with those of dry diaper: chiefly

better combustion characteristics (40 MJ/kg) and high carbon content (75 %). The liquid phase characterization showed important conductivity increase (13–15 mS/cm) and high chemical oxygen demand (DQO, 46–52 g<sub>O<sub>2</sub></sub>/L) while the pH was close to neutral (5.6–6.6 pH).

The results of the experiments with simulated waste diapers showed slightly lower yields in hydrochar, but also lower hydrochar humidity, which indicated higher water elimination. The liquid phase conductivity, pH and DQO evolved up to 41 mS/cm, 7 and 100 g<sub>O<sub>2</sub></sub>/L respectively. However, the hydrochar characterization showed slightly greater high calorific values and similar carbon content values compared to that hydrochar from diaper plus water mixture.

This research provides useful information for the design of HTC system for diapers treatment.

*Erik Marklund, Luleå University of Technology*

## **Influence of HTC process parameters on the fate of elements**

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**Keywords:** Hydrothermal carbonization, waste treatment, trace elements, construction and demolition waste

Hydrothermal carbonization (HTC) is a process used for upgrading waste streams into higher value products such as biochars. Typical waste streams are sludges, lignocellulosic and agricultural residues. The increased demand for waste recycling leads to growing amounts of rejects. One example is the organic fraction of mixed construction and demolition waste (CDW) fines. These fines contain significant amounts of wood and other organics. However, as it is often mixed with other types of materials or contaminants, it is only suitable for incineration together with other mixed wastes. HTC is investigated as a waste treatment method to upgrade the CDW-fines to find potential uses. Moreover, the influence of different factors on the fate of elements is investigated. During HTC organic material is heated to 180–260 °C at pressures of 10–50 atm. The process affects the material in many ways as different constituents of the waste become distributed differently in the resulting phases (solid, liquid, gaseous) in the course of the treatment. This influence of process parameters on the fate of elements is largely unknown. Therefore, the influence of temperature, liquid-solid ratio (L/S) and particle size on the fate

of elements is investigated, using a full factorial experimental design with temperature settings of 180 and 260 °C, and liquid/solid ratio of 4 and 10, and two different particle sizes (1–10 mm and a finely ground sample), and a center point setting. Chemical analyses include the content of heavy metals and metalloids, alkali and alkaline earth metals and non-metals, as well as pH, electric conductivity, organic content etc. Results are analyzed using multivariate data analysis. Results shows that higher temperature increases the severity of the reaction. The dry mass of the char is 20–60% of the dry mass of the ingoing material. There was no significant difference regarding the concentration of heavy metals in the solid phase before and after treatment, and a tendency that more metals will dissolve at higher temperatures. Particle size shows the lowest correlation to the observed responses. Temperature shows generally the highest correlation to the fate of metals. While the treatment didn't result in an improvement regarding a potential use of the fines due to the content of heavy metals, the treated CDW fines can be incinerated in a waste incinerator, with an increase in heating value.

*Dr. Kyoung S. Ro, USDA-ARS*

## **Innovative agro-environmental applications of HTC**

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### Keywords:

The increase in concentrated animal feeding operations (CAFOs) calls for innovative manure and mortality management options with minimal environmental impacts. Without appropriate management practices, surplus manure and livestock mortality from CAFOs may pose a potential threat to surrounding environments with emissions of nutrients, organic matter, fugitive gases, and pathogens - affecting air, surface and groundwater, and soil. Recently, hydrothermal carbonization (HTC) has attracted global attention of researchers as an innovative technique to convert biomass to a carbonaceous byproduct called hydrochar. For the last decade, we have investigated the potential of HTC as an alternative manure and livestock mortality management technology.

We also compared the ability of manure-based hydrochar, pyrochar (biochar), and compost in improving soil fertility. While all amendments improved soil fertility, only the hydrochar amended soil had the ability to retain environmentally sensitive nutrients within soil matrix. We also found that HTC could eliminate both pathogens and antibiotic resistance genes from mortality. We investigated the potential of using manure-based hydrochar as an environmental sorbent. Because of its complex surface functionalities as evidenced by <sup>13</sup>C NMR spectra, manure-based hydrochar showed unusually high sorption capacity toward both polar and non-polar organic pollutants. Brief summaries of these findings along with shortcomings and suggested areas for future research will be presented at the meeting.

*Dr. Jürgen Kern, Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB)*

## **Post-treatments of HTC chars for use in agriculture**

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**Keywords:** Inorganics, nutrients, phases, mass balance, quality of products

Currently, interest in char substrates as a component in growing media is growing, since they may become one option for the replacement of peat. Among the different thermal conversion processes for biomass, hydrothermal carbonization (HTC) has been found to produce chars with acidic pH values similar to peat. However, due to the conditions of the HTC process, the char products often contain toxic phenolic compounds that can inhibit plant growth. An overview will be given of the recent literature on the effect of hydrochars on plant growth. The possibility of inhibition from chemicals associated with the process water raises the question, if a post-treatment can be used to get rid of undesirable compounds in the fresh HTC

chars. In this study three different post-treatments (1. Degassing at 20 °C, 2. Thermal treatment and 3. Washing) of fresh HTC chars have been tested in terms of reducing the contents of phenols and furfurals. In addition to evaluating the success of the post-treatments for chemical removal, the effects of the fresh hydrochars on the germination rate and the root length of cress salad (*Lepidium sativum*) were studied. The unusual positive effects of non-treated HTC chars on the germination rate will be discussed. Further studies will show, which kind of HTC process and which post-treatment is necessary to get high quality amendments for growing media with tailor-made properties for different plant species.

*Taina Lühmann, DBFZ*

## **Hydrothermal conversion of landscape conservation material for the production of peat substitutes**

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**Keywords:** Peat substitute, cultivation trials, hydrothermal carbonization

Due to the negative impact of peat use on the carbon balance of ecosystems and the landscape, the demand for peat substitutes is rising. Therefore, the aim of growing media producers is to substitute bog peat in horticulture by using regional, ecologically advantageous substrates. Concurrently, hydrothermal conversion is providing a process to convert biomass to obtain peat-like properties. This process was investigated with landscape conservation material as input material with the goal to apply the produced peat substitute in cultivation trials. Hydrothermal carbonization of the landscape conservation material was first carried out in preliminary tests on a laboratory scale by varying temperature and holding time. Based on the results, the three temperatures 150, 170, 190 °C with an average holding time of 60 min were selected for the conversion at larger scale to obtain the required quantities of carbonized material. This was performed in 12 runs in a 500L

vessel. The pre and post processing by chopping and dewatering was thereby found to be of great importance for the subsequent application. Afterwards, an admixture of 10, 20 and 30% of carbonized material was applied to a pure peat substrate. These mixtures, the pure peat substrate and a peat substrate mixed with wood fiber were used in substrate hydraulic and phytotoxic experiments. Moreover, extensive cultivation and storage trials of the described admixtures of the different produced grades were carried out with tomato, pepper, Chinese cabbage, impatiens and daisies. For some of the tested qualities, comparable plant growth could be observed, but issues with fungus and smell leave room for improvement, especially regarding post processing. In the end, a techno-economic evaluation for the dimension of a demonstration plant was prepared and concluded with the development of recommendations for action.

*Dr. Thomas F. Ducey, USDA-ARS*

## **The use of hydrothermal carbonization for the removal of pathogens and antibiotic resistance genes from animal waste**

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**Keywords:** Pathogens, antibiotic resistance, antibiotic resistance genes

Hydrothermal carbonization (HTC) treatment processes provide a biosecure treatment option for animal waste, including animal mortality. For animal mortality current methods involve pit burial, composting, incineration and rendering. Pit burial and composting both run the risk of pathogen survival and contamination of ground-water and soil, while incineration is expensive, and rendering is species dependent. Therefore, HTC treatments provide a more efficient, cheaper, and potentially more thorough treatment alternative. Along with pathogen reduction, the fate of microbial DNA after treatment remains an area of active research. While these treatments may be sufficient to kill pathogens, their ability to degrade DNA to the point where the genetic information encoded is unusable remains a poorly studied area. This raises the potential of significant amounts of cell-free, microbially-derived DNA carrying pathogenic factors such as antibiotic resistance genes (ARGs), being introduced to agricultural environments, or into public lands. In turn, this DNA can then be transformed directly into pathogenic organisms which can pose health risks to animals and humans, or into non-pathogenic organisms which may then serve as a vector for future transfer into pathogenic microbes. Our research has focused on

the ability of HTC treatments and its ability to reduce pathogens and eliminate ARGs from animal waste streams. At temperatures at or above 150 °C, and residence times as little as 15 minutes, HTC provides complete pathogen kill, and results in the inability to detect microbially-derived in the remaining residue. These results demonstrate the capability of hydrothermal carbonization methods to effectively eliminate pathogens, while also destroying their DNA. This holds promise as a treatment method to not only produce pathogen-free byproducts, but also help reduce microbial DNA – in particular antibiotic resistance genes – from being introduced back into the environment post-treatment. Additional research focused on the use of these treatment byproducts for downstream, economically viable projects will also be discussed.

*Dr. Virpi Siipola, VTT Technical Research Centre of Finland Ltd*

## **Utilization of hydrothermally carbonized brewery residues in high-value electrochemical applications**

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**Keywords:** Brewer's spent grain, hydrothermal carbonization, activated carbon, cyclic voltammetry, supercapacitors

Brewer's spent grains (BSG) is an abundant waste material that is commonly used as an animal feed, fermented to produce biogas or dried and burned to produce energy. As a wet material, BSG can also be easily converted into carbonaceous material using hydrothermal carbonization (HTC). This HTC-BSG can be further pyrolyzed into activated carbon (AC), which expands its usability to other, high value applications. As a protein rich raw material, BSG contains abundantly nitrogen, which makes it an interesting source material for activated carbons used in electrochemical applications, e.g. solar cells and supercapacitors, where nitrogen has been found very beneficial. In our recent studies, we have found that HTC preserved both oxygen and nitrogen in the produced BSG biochar. This HTC-BSG biochar was then

chemically activated into high surface area AC. The produced AC, which also contained high amounts of nitrogen and oxygen groups, was evaluated in view of potential electrochemical applications using e.g. cyclic voltammetry. These test results will be presented at the symposium.

Monika Bosilj, Fraunhofer Institute for Solar Energy Systems

## Sustainable hydrothermal carbons for biorefinery-related catalysis

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**Keywords:** –

Catalysed chemical transformations in the liquid phase are a critical component of the continuing elaboration of Power-to-X and Biorefinery concepts. Due to a variety of challenges regarding homogeneous catalysts use and recycling, and with regards to the principles of Green Chemistry, it would be desirable to substitute homogeneous with heterogeneous catalysts. Hydrothermal Carbonization (HTC) (TITIRICI et al. 2015) is a sustainable technique that has potential to synthesize tailorable and functional nanomaterials that can be applied as catalyst supports in catalysed chemical transformations (e.g. biorefinery-related catalysis). HTC materials can be prepared from biomass-derived sugars in the presence of identified additives such as sodium borate (FELLINGER et al. 2012) and albumin (WHITE et al. 2011) known to generate promisingly structured porous carbons and opening the possibility of structural heteroatom (e.g. nitrogen) doping. Carbonaceous gels can be synthesized in this manner, typically presenting high surface areas (SBET > 250 m<sup>2</sup>g<sup>-1</sup> and pore volumes (V<sub>meso</sub> > 0.4 cm<sup>3</sup>g<sup>-1</sup>), the nanostructures of which are very attractive with regard to layered porosity in tandem with functional surfaces. In this context, our work focuses on the production of porous HTC carbon materials and the introduction of catalytic entities (e.g. metal nanoparticles). As an example of our investigations, N-doped carbon supports (NDC) were prepared via HTC and then thermally carbonized at different temperatures (i.e. to direct surface chemistry/nitrogen-containing surface motifs). The prepared supports were then subsequently impregnated with Pd nanoparticles. These Pd/NDC catalysts were

compared against commercial catalyst for the hydrogenation of phenol to cyclohexanone (e.g. as basis for lignin-to-nylon production). Post-carbonisation at elevated temperature alters the support chemistry and nitrogen bonding motif(s) which controls the size distribution and electronic structures of the loaded Pd nanoparticles. Consequently, this affects catalyst selectivity, activity and stability for the hydrogenation of phenol to cyclohexanone.

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*Prof. Maria-Magdalena Titirici, Queen Mary University of London*

## **Black is the new green: Sustainable carbon energy materials**

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**Keywords:** Hydrothermal carbonization, lignin, biomass conversion, ORR/OER, Na-ion batteries, supercapacitors

One of the grand challenges facing humanity today is access to sustainable materials and chemicals which are at the heart of sustainable technologies. The production of materials, chemicals and fuels from abundant and renewable resources will eliminate our dependence on petroleum/critical metal-based supplies and will provide access to a new economy based on available reserves.

Carbon is the most versatile element known. It combines with other (carbon) atoms giving rise to new carbon materials with astonishing properties. The versatility and potential of carbon has attracted top recognition in the last decade for the work in fullerenes (1996 Nobel Prize in Chemistry), CNTs (2008 Kavli Prize in Nanoscience) and grapheme (2010 Nobel Prize in Physics). However, the mystery and wonder of carbon offers more to discover.

While carbon is widespread on Earth, it has been mainly synthesised from fossil fuel based precursors with sophisticated and energy consuming methodologies that generate toxic gases and chemicals. The preparation of carbon materials from renewable resources is a key research challenge in terms of sustainability, climate change and economics. Since the beginning Nature created carbon from biomass.

We have demonstrated that it is possible to mimicking the natural process of carbon formation and prepare carbon nanomaterials from biomass using mild hydrothermal processes. Along with amorphous carbon materials (denoted HTC), this procedure also enables biomass transformation into useful chemicals such as 5-hydroxymethylfurfural (5-HMF) or levulinic acid (LA). Recently, we have discovered a third product of Hydrothermal Carbonisation – a crystalline form of carbon – arising at the interface between the amorphous HTC microspheres and the aqueous phase containing the biomass-derived chemicals. In this talk I will present some of the fundamentals governing the production of carbon nanomaterials and chemicals. We will also discuss the application of HTC materials in electrocatalytic reactions such as Oxygen Reduction Reaction and Oxygen Evolution Reaction.

Finally, some of the photo-physics governing the optoelectronic properties of the new family of fluorescent hydrothermal carbon nanocrystals and their applications as sensitizers in solar cells will be presented.

*Viola Hoffmann, University of Hohenheim*

## **In-situ functionalizing of HTC chars for the production of biobased electrode materials for electromobility**

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**Keywords:** Electromobility, energy storage, functional carbon materials, hydrothermal carbonization, coffee grounds

Electromobility is one of the most promising solutions for the establishment of a sustainable and future-oriented economic system based on the principles of bioeconomy. Nevertheless, sustainable energy storage technologies are still lacking due to the fact that most of the materials currently used in energy storage devices are fossil-based. Via Hydrothermal Carbonization (HTC) of coffee grounds in the presence of a nitrogen source such as urea, promising N-enriched carbon materials can be produced in a one-step process. The activation of these carbons via pyrolysis leads to increased specific surface areas and hence interesting, highly functional materials for the use as electrode materials in e.g. supercapacitors. Nitrogen-containing hydrochars (N-Hydrochar) were prepared via Hydrothermal carbonization of coffee grounds with urea as a nitrogen precursor. The syn-

thesis of N-Hydrochar was conducted at 220 °C for five hours. The molar ratios of Urea were varied to achieve the highest nitrogen content in the Hydrochar. After pyrolysis of N-Hydrochar at 600 °C for two hours, elementary analysis of the hydrochars showed that nitrogen contents between 7 and 10 wt % were obtained. This means an increase of nitrogen of up to 3 times compared to hydrochars obtained via the hydrothermal carbonization of coffee grounds under the same conditions in the absence of urea. Further analysis was conducted with the nitrogen-rich hydrochars regarding specific surface area, electric conductivity and capacitative behaviour in order to assess their suitability as electrode materials in energy storage devices for electromobility.

*Dr. Kenneth Latham, Umeå University*

## **Ability of different nitrogen sources to dope hydrothermally carbonized pulp and paper mill black liquor: Physicochemical properties and supercapacitor performance**

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Keywords: SPECS, XPS, FTIR, electrochemical capacitors

Black liquor is an environmentally problematic waste product that is produced in the Kraft pulping processing at pulp and paper mills. It contains mixture of water, hemicellulose, lignin residues and inorganic chemicals and is currently incinerated in recovery boilers for low grade energy recovery. Due to organic content and high level of water, black liquor has been shown to be an ideal candidate to produce carbon materials via hydrothermal carbonization. As black liquor is susceptible to hydrothermal treatment, additional elements can be doped into the carbon structure potentially enhancing the performance of the final carbon material.

In this work, we have examined the impact of different nitrogen dopants (i.e, melamine,  $(\text{NH}_4)_2\text{SO}_4$ ,  $(\text{NH}_4)_2\text{HPO}_4$ ,  $\text{NH}_4\text{Cl}$ , urea, chitosan) have on physicochemical properties of the resultant carbonaceous material. Furthermore, the performance of these

materials as electrode materials in supercapacitors was also assessed. This was done using standard electrochemical methods (i.e., cyclic voltammetry) but also using step potential electrochemical spectroscopy (SPECS). SPECS allows the separation of capacitance contributions from double layer capacitance (surface area) and pseudocapacitance (nitrogen/oxygen groups). Thus, the electrochemical impact that each nitrogen dopant had could be assessed independently.

*Jingyu Feng, Imperial College London*

## **Biomass derived freestanding electrode for oxygen reduction reaction applications**

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**Keywords:** Freestanding electrode, HTC, N-doped carbon, ORR

The oxygen reduction reaction is a critical step that determines the performance and stability of the electrocatalysts at the cathode side of fuel cells and metal-air batteries. By carefully designing the catalysts, progress has been made in powdered catalysts with excellent oxygen reduction reaction performance. Recently, freestanding electrodes are becoming popular for oxygen reduction reaction due to their large amount exposed active sites, interconnected structure, and high conductivity.

In this work, nitrogen doped freestanding electrode was synthesized by firstly converting biomass into carbonaceous materials via hydrothermal process followed by pelleting process and further carbonization process. The obtained electrode showed 3D freestanding structure with preferred pore structure, nitrogen content, and conductivity.

Furthermore, we evaluate its oxygen reduction reaction performance with special designed tip which screw the working electrode on rotating disk. The obtained freestanding structure shows superior oxygen reduction reaction performance than powdered catalysts. Moreover, the freestanding electrode also shows superior long-term stability. This work introduces a new platform for energy conversion devices application.

Dr. Saskia Heumann, Max Planck Institute for Chemical Energy Conversion

## Hydrothermal carbon as sacrificial electrode for solar fuel production

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**Keywords:** Sacrificial electrode, water splitting, large scale, gas analysis, carbon oxidation

Several energy scenarios have been considered for storing the electrical energy, derived from renewable sources, in the form of chemical energy. One potential way to achieve this is by electrochemical splitting of water into hydrogen and oxygen. The main challenge of electrolytic water splitting is the lack of a sustainable anode material. The high electrical potentials used in the process lead to electrode instability, and dissolution. This is especially the case for the metal materials that experience valence change during the electrochemical process. Sustainability, eco-friendliness and the economy of energy systems require closed material cycles to save rare resources and to avoid the release of harmful substances. By applying hydrothermal carbon as sacrificial electrode derived from biomass a closed carbon cycle to produce hydrogen is fulfilled.

Here we present the chemical and technical feasibility of carbon based electrode materials. To mimic industrially relevant conditions high current densities up to 360 mA/cm<sup>2</sup> were applied. The impact of different electrolytes was also investigated (Yi et al. 2017). Apart from the technical feasibility of carbon electrodes, the flexibility for chemical modification presents many possibilities to tune their per-

formance characteristics (REICHE et al. 2015, STRATEN et al. 2018). A simple and scalable modification of the carbon material by incorporation of nitrogen was performed to examine the effect of functionalizing carbon based electrodes.

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Vivian Mau, Ben Gurion University of the Negev

## Recirculation of HTC aqueous phase and use as fertilizer

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**Keywords:** Recirculation, poultry litter, nutrients, fertilizer, agriculture

As HTC research advances, the need to improve process efficiency has become clear. To date, the liquid phase is still considered a byproduct requiring treatment. Liquid phase recirculation has been considered as a method to reduce water inputs, wastewater outputs, heating energy, and possibly improve hydrochar properties. The liquid phase has also been considered a possible liquid fertilizer due to its high nutrient concentration, though sufficient research is still lacking. For the first time, we analyzed liquid phase recirculation as a method to increase nutrient concentration in the liquid phase, and then apply it as a fertilizer to plants.

HTC of poultry litter was conducted at a 1:3 solid-to-liquid ratio, at 200 and 250 °C in laboratory scale reactors. Five recirculation cycles were conducted for each temperature in triplicates. The generated hydrochar and liquid phase were characterized.

Concentrations of C, N, P and macro and micro-nutrients increased significantly with liquid phase recirculation. The concentration increase reached steady-state around cycle 3 for most nutrients. Concentrations of major nutrients by cycle 3 ranged from 40–44 g/l for C, 5.0–5.1 g/l for N, 0.7–0.9 g/l for  $\text{NH}_4^+$ , 0.3–0.4 g/l for P and 0.1–0.4 g/l for  $\text{PO}_4^{3-}$ . Recirculation did not affect hydrochar caloric value, and caused only minor decrease in O/C ratio.

Following the laboratory scale results, liquid phase that underwent 3 recirculation cycles was prepared in a 30 L pilot HTC reactor and investigated as a liquid fertilizer. Lettuce (*Lactuca sativa*) seedlings were grown in pots in a randomized block design receiving daily fertilizing treatments of 100 mg/L TN originating from either recirculated liquid phase, non-recirculated liquid phase, or commercial fertilizer. Plant growth was assessed to determine the liquid phase agronomic efficiency.

Recirculated and non-recirculated liquid phase successfully supported plant growth, achieving similar results to commercial fertilizer, despite an initial growth delay. The lettuce dry weight was statistically similar in all fertilizing treatments. Moreover, the liquid phase could be stored for long periods of time without degradation due to its microbial toxicity, but once diluted N degradation became significant.

This experiment has demonstrated that liquid phase recirculation can be an effective method to concentrate nutrients in the liquid phase, and then be used as a liquid fertilizer to recycle nutrients back into agriculture.

*Reza Khoshbouy, Tokyo Institute of Technology*

## **Cd adsorption from aqueous solution by modified hydrochar: Effect of in-situ modification using HTC with acid and alkaline additive**

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**Keywords:** Cd<sup>2+</sup> removal, adsorption mechanism, hydrothermal carbonization, modified hydrochar

Hydrothermal carbonization (HTC) is being emerging as a promising thermo-chemical biomass waste conversion technology into innovative carbon products such as hydrochar. It can be used as an adsorbent for removing inorganic and organic contaminants from aqueous solutions. Based on literature study, amongst the effective parameters on the mechanism of heavy metal adsorption, the surface oxygen-containing functional group (OFG) and the cation exchange capacity (CEC) of adsorbent might play the main act. Therefore, in this study, acid- and basic-assisted HTC of woody waste materials (trimmed tree branches and bamboo waste) using HNO<sub>3</sub> (0.0 to 5.0 %) and KOH (0.0 to 30 %), respectively, were performed under different operating conditions (200–260 °C and 0.5–3 h) to prepare the modified hydrochars (MHCs). The physio-chemical properties of obtained MHCs and their adsorption performance toward Cd removal were evaluated by SEM, BET, XPS, FTIR, Boehm titration and ICP. The results presented that increasing the temperature of HTC and the acid concentration had negative influence on the mass yield of MHCs. The optimal condition of acid-assisted HTC for the highest Cd adsorption (4.3 mg/g) was achieved at the high acid concentration (200 °C, 0.5 h and 5.0 % of acid), which was 48.1 % more than that at the same condition without the pres-

ence of acid. Although the OFG values were generally raised with increasing the acid concentration, the trend of Cd adsorption capacity did not follow completely the increase of OFG. The results indicated that the exchangeable cations concentration (CEC) might be the predominant adsorption mechanism as shown by good consistency of trend of the CEC with Cd uptake capacity. It also can be inferred that exchangeable cations interaction plays important role in the Cd adsorption due to the surface complexation reaction with MHC. Moreover, this finding was also confirmed by MHCs obtained from KOH-assisted HTC which showed much higher Cd uptake capacity (9.11 to 20 mg/g) compared to MHC with acid modification. The highest value of Cd ion was adsorbed by KOH-MHC prepared at 200 °C, 1 h and 15 % concentration of KOH solution. The commercial activated carbons (CAC) were also compared with our materials and found that produced KOH-MHCs showed superior results for Cd removal. In conclusion, MHC obtained from in-site HTC with alkaline additive has the potential application to produce cost-effective alternative adsorbents to current CACs in removal of heavy metal from wastewater streams.

Aaron Brown, University of Leeds

## Hydrothermal treatment of aquatic biomass: Potential for biometane and biohydrogen generation from process waters

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**Keywords:** Biomethane, biohydrogen, process water, aquatic biomass

Marine and aquatic biomass such as water hyacinth, have the potential to be utilised as a bioenergy feedstock; eliminating land-use management issues associated with terrestrial biomass. Hydrothermal carbonisation (HTC) of these feedstocks at temperatures ranging from 200–250 °C results in a carbon rich solid hydrochar and a process water rich in solubilised organic and inorganic compounds. HTC can upgrade macroalgae into a bio-coal with low slagging and fouling tendency, despite the high levels of ash in the original feedstock (SMITH et al. 2016). The process waters contain considerable amounts of organic carbon however there is limited knowledge on the most efficient method of extracting the energetic value from the solubilised organics.

Biological conversion technologies allows for the production of gaseous fuels from organic-rich waste streams. Methane can be produced through conventional anaerobic digestion (AD) or alternatively, by inhibiting methanogenesis, biohydrogen can be produced through dark fermentation (DF). Both methane and hydrogen are multifunctional fuels and can be used for generating heat, electricity or as a transport fuel.

This study compares the biomethane and biohydrogen yields from the process waters of three different aquatic feedstocks: macroalgae species: *Saccharina latissima* and *Fucus serratus* as well as the

fresh water macrophyte; water hyacinth (*Eichhornia crassipes*). Hydrothermal conversion of each biomass was conducted over the temperature range of 150 °C, 200 °C and 250 °C using a 600 mL Parr reactor. The residual biomass and solid hydrochars produced were analysed to determine their combustion properties.

Batch mesophilic (37 °C) digestions were conducted on the resultant process waters using an Automatic Methane Potential Test System (AMPTS II). Inoculum from a waste water treatment plant was used 'as received' for biomethane tests, and 'heat treated' at 115 °C for 30 minutes for use in biohydrogen tests to inhibit methanogen activity. The energy recovery from the different integration strategies were compared for each of the feedstocks.

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Hui Luo, Queen Mary University of London

## Platinum doped carbon dots and its hybridization with TiO<sub>2</sub> for enhanced visible light photocatalytic hydrogen evolution

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**Keywords:** Carbon dots, hydrothermal carbonization, photocatalysis, hydrogen evolution, mechanism

To address the challenge of pushing forward sustainable energy technologies to achieve low-cost solar fuels derived from abundant materials, it is essential to explore new types of materials with desirable properties that meet these criteria. Due to the unique photoluminescence behavior, photo-induced electron transfer property, electron donor/acceptor role in hybridizing with other photoactive materials, carbon dots (CDs) are potentially considered to be an efficient component in the construction of high-performance photocatalysts, as well as a photosensitizer or a spectral converter along with other semiconductor materials in the photocatalytic processes.

Here we report that nitrogen-doped carbon dots (NCDs) produced via hydrothermal carbonization can act as photocatalyst. Structural and optical characterizations such as TEM, XRD, XPS, FTIR and

photoluminescence were conducted (Fig 1), which revealed that the NCDs show a mixture of crystalline and amorphous structure with a topological disorder, with N atoms exist on the surface as well as in the core structure. The heteroatom doping brings remarkable improvement to optoelectronic property. Their photoactivity increases after hybridization with the well-known semiconductor material, TiO<sub>2</sub>.

Techniques such as UV-Vis DRS, EIS, EPR and femto-second TAS were employed to develop a fundamental understanding of the intimate relationships governing the interactions between CDs and TiO<sub>2</sub>, and further improve the photocatalytic performance in terms of efficiency and selectivity.

The aim is to divulge how the excited states can affect the parameters that are critical for a photocatalytic reaction, such as carriers/radicals generation, recombination paths, carriers' lifetime, Fermi level and band position shifting.

Furthermore, plasmonic metal is reduced onto the CD surface in single atom or nanocluster form to tune their optoelectronic properties, and its hybridization with TiO<sub>2</sub> showed a significant improvement in H<sub>2</sub> production compared to bare TiO<sub>2</sub> under visible light irradiation.

Atomic level analysis such as X-ray absorption spectroscopy is conducted to investigate the Pt speciation and the relationship between the Pt-CD-TiO<sub>2</sub> systems by providing information about local atomic arrangements (from EXAFS) and electronic state of Pt (from XANES). We believe this would shed light on the photocatalytic mechanism, providing a guideline for future structural modification.

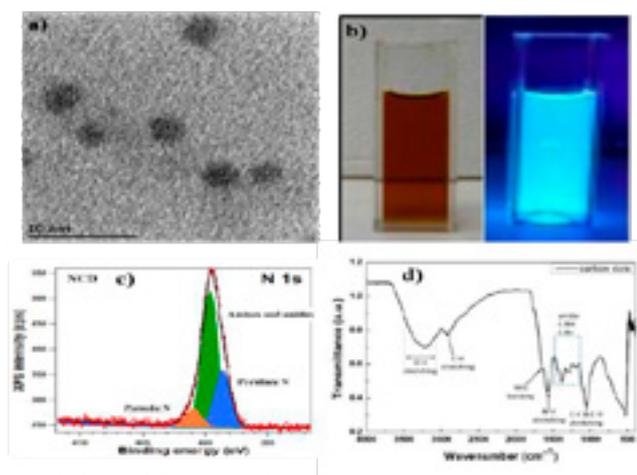


Figure 1. TEM image of the NCDs in ethanol with 365nm excitation; XPS N 1s spectra (c) and FTIR (d) showing the existence of N.

*Dr. Yuxiao Ding, Max Planck Institute for Chemical Energy Conversion*

## **Hydrothermal carbon as support for water splitting**

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**Keywords:** Hydrothermal carbon, water splitting, carbon oxidation, oxygen evolution

Water splitting to produce hydrogen is a critical process for the conversion of electricity into chemical energy. In water splitting, the oxygen evolution reaction at the anode is critical due to the high overpotential, and the associated instability of the anode materials under these harsh conditions. Therefore, developing scalable and sustainable anode materials is of urgently challenging for the industry scale application of water splitting.

Plant biomass has been used to produce functional carbonaceous materials, encompassing economic, environmental and social issues. The materials starting from cheap natural precursors are becoming an important role in the carbon circulation. Herein, we

developed a series of hydrothermal carbon-based materials with different metals as dopants, by using glucose as representative for biomass for a knowledge-based synthesis, which were operated in the water splitting process. The hydrothermal carbon supported metal materials are scalable and desirably dynamical. During the synthesis, some metals could improve the carbon structures, while during the water splitting the metal active sites catalyze not only oxygen evolution, but also carbon oxidation. Therefore, biomass derived carbon can be applied as sacrificial electrode producing oxygen and carbon oxides at the anode side, while hydrogen can be gained from the cathode side at an acceptable rate.

Dr. Veronica Benavente, University of Alicante

## Aditives for ash related problems prevention in HTC fuels

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**Keywords:** Energy conversion, hydrochar, ashes, additives, ash fusion temperature

Hydrochar produced from agroindustrial wastes contains significant amounts of alkali metals and other inorganic elements that lead to different ash related operational problems during energy conversion processes. Hydrothermal carbonization (HTC) is reported as a beneficial pretreatment to mitigate ash related problems and it could be even more beneficial if it was coupled with the use of additives to improve the ash fusion behavior. The aim of this work was to prevent ash related problems during hydrochar combustion by adding Si-rich wastes (rice hulls (RH)) and mineral additives (lime (L), bentonite (B) and kaolin (K)) to improve the hydrochar ash fusibility characteristics.

Two sets of samples were prepared by using additives before (S1) or after (S2) the HTC process to evaluate which would be the optimal addition procedure. Temperature and residence time of the HTC process were established at 225 °C and 2 hours and olive mill wastes (OMW) were used as raw materials. Afterwards, samples were ashed in agreement with UNE-EN 18122:2016 and the resulting ashes were characterized through XRF and ash fusion tests according to the standard ASTM 1857-87D to determine, respectively, their composition and ash characteristic fusion temperatures (AFTs, Figure 1).

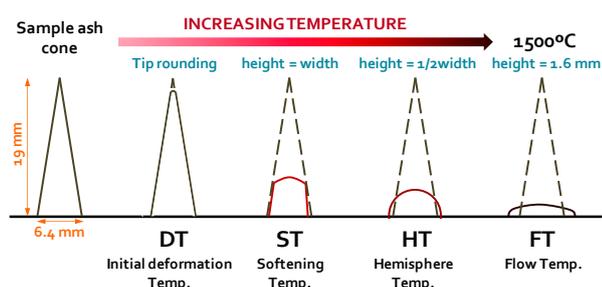


Figure 1. Schematic of the AFTs determination procedure.

The best results, in this study, were found when using RH and K, which were able to increase the initial ash deformation temperature (DT) to >1500 °C. Among them, RH, consisting of a waste, would be the most interesting option in terms of economic and sustainability criteria, and also because lead to the lowest total hydrochar ash content.

On the other hand, no significant differences were found in ash composition by adding RH before or after the HTC process. However, the order in which additives were used did affect the hydrochar properties: the joint carbonization of RH and OMW in series 1 led to a less carbonized solid with higher moisture content, whereas the addition of RH to the hydrochar in series 2 decreased its energy density. Therefore, although further economic and environmental assessment would be advantageous to reach the best compromise solution, it is recommended that RH should be used as received before the HTC process or in the form of hydrochar by mixing it with OMW-hydrochar to maintain the benefits of HTC as possible.

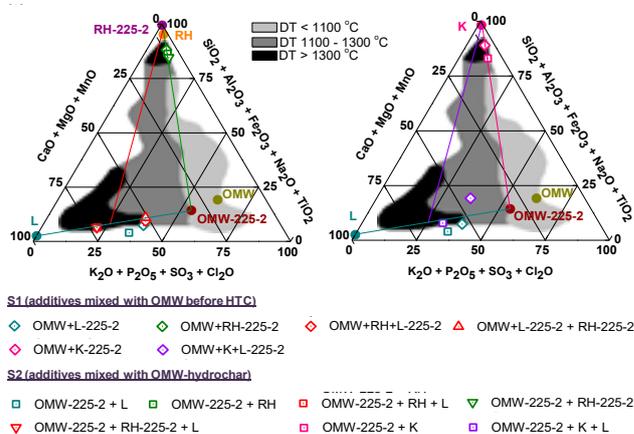


Figure 2. Multicomponent phase diagram illustrating the DT of the samples as a function of ash composition.

*Marc Buttmann, TerraNova Energy GmbH*

## **Industrial scale plant for sewage sludge treatment by hydrothermal carbonization in Jining/China and phosphate recovery by TerraNova® Ultra HTC Process**

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**Keywords:** Sludge dewatering, thermal conditioning, hydrothermal carbonization, phosphorous recovery

In Jining/China 14.000 t of dewatered sewage sludge are treated by TerraNova® Ultra Hydrothermal Carbonization (HTC) technology per year to generate a solid fuel for energy production.

The technology is economically attractive as the sewage sludge is considerably reduced in mass due to the loss of dry matter (DM) during HTC and subsequent purely mechanical dewatering of up to 70 % DM.

Furthermore, TerraNova® Ultra enables the recovery of Phosphorous from sewage sludge. By adjusting the pH level during the HTC process, Phosphorous

is leached into the liquid phase and transferred into the filtrate. By adding CSH minerals to the filtrate >80 % of the Phosphorous is recovered as fertilizer product. The moderate use of reagents and the one-step process allow for low specific cost.

In the lecture the energy- and mass- balance of TerraNova® Ultra, the Phosphorous recycling process and the fertilizer specification as well as typical project economics for an installation in Europe will be presented.

*Dr. Peter Axegård, C-Green Technology AB*

## **C-Green`s HTC-solution for conversion of biosludge to hydrochar**

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**Keywords:** HTC, wet-oxidation, biosludge

C-Green has recently developed a continuous hydrothermal carbonization (HTC) technology that transforms bio-sludge into a solid carbonaceous product, at the same time enabling WWTPs to increase their biogas production by using the water separated from the bio-sludge. The process combines three well established processes: HTC, flash steam recovery and wet oxidation. The key innovation lies in the technical design: all the heat necessary to run the process is extracted from the organic substances in the bio-sludge. This means that all heat required is generated internally within the process, a unique feature, which makes the C-Green HTC Zero-Energy process completely energy sufficient with regard to heat-energy.

The process has been evaluated in batch laboratory trials and in continuous pilot trials, see table below. Different types of sludges from municipal and pulp/paper mill WWTPs and have been tested. A typical result of C-Green`s HTC Zero-Energy treatment of bio-sludge from municipal and pulp/paper mill WWTPs

is an increase in the dry solid content from 15–30 % in the incoming bio-sludge to 55–70 % in the hydrochar. The calorific heat value is 10–15 GJ per tonne of hydrochar. It is also possible to extract more than 90 % of the phosphorous from the hydrochar.

C-Green`s HTC Zero-Energy process is not restricted to WWTP sludge. Sludge from food processing sludge and other low value sludge residues are also of interest.

C-Green is currently in the process of building a full-scale commercial HTC-plant with a capacity of 20.000 tonnes bio-sludge per year at the Stora Enso`s pulp and paper mill in Heinola, Finland, which is expected to be operational mid-2019.

This presentation shares the results obtained from C-Green`s HTC Zero-Energy treatment of different types of bio-sludge in laboratory, continuous pilot and mill demo trials. Results from the leaching of phosphorous will also be presented.

<b>Milestones and TRL achieved until Q2, 2019</b>	<b>Year</b>	<b>TRL</b>
Basic principles observed, current HTC processes reviewed and areas for improvements identified. Resulted in the founding of C-Green.	2014	TRL1
Technology concept formulated and developed, including mass- and energy balances.	2014	TRL2
Technology validated in laboratory: The different process steps were verified on laboratory scale with over 200 trials using 15 different types of sludges.	2015–2016	TRL4
Technology validated in pilot plant: Principles for critical process steps verified in trials using several different types of sludge.	2016–2018	TRL5
20,000 tonnes per year C-Green HTC Zero-Energy Demo plant fully designed, engineering completed, construction of equipment on-going with planned production start-up mid-2019.	2019–Q1–Q2	TRL6

*Alfons Kuhles, GRENOL GmbH*

## **Hydrothermal carbonization and biogas – synergy effects. Example of the HTC Innovation Campus Rheinmühle, Switzerland**

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Keywords: Biogas digester, HTC, reduction of CO<sub>2</sub>, hygienisation, heat & power generation

The aim was to develop a process that converts organic residues in an environmentally friendly, climate-friendly and hygienic way and enables both the energetic use and the recycling of plant nutrients for agriculture. The core of the project is a continuously operating plant for hydrothermal carbonization (HTC) at the Innovationscampus Rheinmühle. Biogas digestate and cattle manure are used and processed as input materials in the HTC plant (10–15 t/d input) at the site. In the HTC process, the input materials used are separated to HTC biochar (Hydrochar) and HTC process water without emissions. The coal is then converted into synthesis gas in a wood/carbon gasifier. At the same time, the process water can be fermented in a downstream compact fixed-bed fermenter in the anaerobic phase. The methane gas produced can be combined with the synthesis gas from coal gasification in a CHP plant to produce electricity and heat. The operation of hydrothermal carbonization is integrated in a closed regional cycle consisting of hydrothermal carbonization, fermentation, fertilizer production and the generation of electrical and thermal energy by means of a wood/coal gasifier and CHP.

The example of biogas digestate will be used to show how hydrothermal carbonization can represent a sensible supplement and added value to an existing biogas plant. Depending on the region in Germany, the disposal costs for digestate amount to between 10–25 euros per ton. These costs are saved when the fermentation residue is recycled using hydrothermal carbonation. To refine the input materials, approximately 100 MWh/a of electricity and approx. 600 MWh/a of heat must be fed into the HTC reactor including peripheral equipment (coal/water separation, wood/coal gasifier, water treatment, etc.).

Due to the specified process parameters of hydrothermal carbonization, the fermentation residues are hygienized and CO<sub>2</sub> emissions are reduced by 60% in relation to the status quo. From the assumed 5,000 t/a with a dry matter content of 22–27%, approx. 750 t/a of coal with a calorific value of approx. 5 kWh/kg can be produced. About 1,125 MWh of electricity and 2,250 MWh of heat can be produced per year from CO<sub>2</sub>-neutral biochar using a wood/coal gasification. In addition to energy generation, also produced the process water can be used to optimize the methane production in a fermenter. By using a compact fixed-bed fermenter, the methane yield can be increased by 60%.

*Stepan Kusche, Bundesverband Hydrothermale Carbonisierung e.V. / HTCycle AG*

## **Bundesverband Hydrothermale Carbonisierung e.V. / HTCycle AG**

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**Keywords:** publication, coordination HTC activities / environmental commitment, batch technology and P- and N-recycling

**Bundesverband Hydrothermale Carbonisierung e.V.** founded in 2011 as a registered association. The association currently has 18 members and represents the following goals and purpose:

Publication and coordination of HTC activities at federal and state level/Platform for all interested companies, associations and other institutions Opportunities to promote hydrothermal processes (HTP)/ Support of association members in the development of new resources and environmentally friendly applications based on HTP technology

### **Most important goals:**

End of waste status/Development of overall environmental concepts according to AbfKlärV, DüV and BImSchG/Presentation of the high energy efficiency of hydrothermal processes as an alternative to drying processes/Presentation of the efficient recycling of phosphorus and nitrogen from carbonised sewage sludge after hydrothermal processes in the conformity according to AbfKlärV (Waste Disposal Ordinance).

### **Results:**

Since the foundation the individual members have participated in the drafting of VDI Guideline 3933 "Emission Reduction - Production of Biocarbinates" of the VDI/DIN Commission on Air Quality Control (KRdL), thus creating legal certainty for the approval and construction of HTC plants.

**HTCycle AG** founded in 2009 is also located in the Vorpommern Innovation Park and is an SME with 10 employees that carries out R&D on a pilot plant and an HTC demonstration plant on an industrial scale. With a capacity of 16,000 tons per year, the large plant can produce large quantities of HTC coal for interested parties for project planning or research at any time. HTCycle has set itself the goal of closing the nutrient and resource cycles based on the HTC batch technology in accordance with the Closed Substance Cycle Act (Kreislaufwirtschaftsgesetz). Since 2014, HTCycle has been perfecting an overall environmental concept for the treatment of municipal sewage sludge and can now offer a recycling or recovery solution for every material flow in the form of marketable products or limit values.

In 2018, HTCycle received the award for the best alternative sewage sludge concept from the European Commission. HTCycle is planning the construction of the HTCycle concept at the wastewater treatment plant in Wolgast. Here, the amount of sewage sludge from 6 associations is converted into high-quality products such as activated carbon for water treatment, recycled phosphorus and ammonia as fertilizer. The HTCycle process reverses the previous practice of sewage sludge disposal from a costly disposal process to a lucrative business model.

*Prof. Kunio Yoshikawa, Tokyo Institute of Technology*

## **Commercial demonstration of solid fuel production from municipal solid waste employing the hydrothermal treatment**

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**Keywords:** Hydrothermal treatment, municipal solid waste, solid fuel production, commercial plant, coal alternative fuel

Up to now, the only commercialized ways of municipal solid waste (MSW) treatment are mass land-filling and mass burning. In Japan, most of burnable wastes are incinerated, but not in other countries, and still land-filling is the most popular way of waste treatment all over the world. But the world recent trend is to prohibit or limit land-filling of wastes while citizens do not want to increase waste incineration in developed countries as well as developing countries. On the other hand, major part of the world is discharging non-segregated municipal solid wastes. Thus we have to find out the utilization ways alternative to incineration for non-segregated MSW. Pre-treatment of wastes requires crushing, drying and deodorizing, which are normally different processes. But we have developed innovative hydrothermal treatment technology (HTT) which can perform these three pre-treatment functions in one process utilizing high pressure saturated steam. Figure 1 shows the operating principle of HTT. Non-segregated MSW are fed into the reactor, and then, 220 °C, 2.5 MPa saturated steam is supplied into the reactor for about 30 minutes and the blades installed inside the reactor rotates to mix MSW and steam for about 10 minutes. Then the product is discharged after extracting steam. The product is powder-like substance and the moisture content is almost the same as the raw material, but is easily dried by natural drying. The inert material such as metal, glass and stones can be easily sieved out after drying. There is almost

no bad smell in the solid products, and the products can be used as solid fuels which can be easily mixed with coal for power generation or cement production. Only 10-15% of the product is enough for steam production in a boiler. HTT has already commercialized in Japan, China and Indonesia.

*Bryan Gooch Redd, ThermChem Corporation*

## **Combining HTC and gasifier systems for small scale to large scale deployments to convert complex wastes into valuable products**

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Keywords: Hydrothermal carbonization, gasifier, MSW, medical waste, syngas

Over the past few years, both Hydrothermal Carbonization (HTC) and gasification have made significant progress towards commercialization. Most of that progress has been with wastes/residues that are relatively homogenous and either are small in size or require pre-processing size reduction. Moreover, most HTC and gasification systems in commercial use appear to depend on relatively large volumes of feedstock to be commercially viable. Furthermore, even though researchers around the globe have published encouraging findings regarding upgrading outputs from HTC to higher value uses other than BioCoal, there has been little reported commercial progress in linking HTC with the downstream systems necessary to convert HTC outputs into higher value products.

Our presentation will focus on the marriage of two proprietary, commercial scale systems: ThermChem's HTC system and Cogent Energy System's HelioStorm™ Gasifier. This combined system can convert complex wastes, with no pre-processing, into a clean syngas to be used for heat and power, and high value products such as chemicals, Hydrogen, and liquid transportation fuels. Both of these proprietary technologies are modular and scalable, thus they can be combined for small scale or large scale deployments.

We will present two examples of the marriage of our two technologies: Processing Medical Wastes; and, (2) Processing Municipal Solid Waste (MSW). In each case, the respective wastes will be processed directly into the HTC system without pre-processing, and the resulting HTC Hydrochar will be processed directly into the HelioStorm™ Gasifier. Among the data we will present will be the composition of the Syngas produced. We will also provide an overview of the energy balance for our combined systems.

Both the ThermChem HTC system and the HelioStorm™ Gasifier are at commercial scale. The HTC system has been in commercial operation for multiple years, including the processing of Medical Wastes and MSW. The HelioStorm™ Gasifier, while not yet in commercial operation, has operated at commercial scale to convert a wide range of feedstocks into syngas comprised solely of CO and H<sub>2</sub>, at temperatures reaching 10,000 °C.

*Dr. Enrico Gribaudo, HBI Srl*

## **Opportunities and limits regarding the diffusion of the HTC technology worldwide**

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Keywords: Legal limits, incentives, opportunities, diffusion

In the last years, the hydrothermal carbonization process has been implemented by some companies, which have designed and developed their systems, although at different readiness levels. This effort on trying to introduce this interesting process on the market demonstrate that this solution can represent a sustainable alternative to extract value (i.e., both energy and materials) from wet organic residues. However, when analyzing the potentialities related to the diffusion of this technology worldwide, several incentives and limits are encountered. The incentives are strictly connected to the opportunity to solve a global problem, represented by the effective management and treatment of organic waste and residues with high humidity content. As a matter of fact, the technologies commonly used are not too efficient or their efficiency is gained only with public incentives.

Moreover, the most valuable product extractable from organic waste is energy, that is a product still in the lower part of the pyramid of the circular economy. Furthermore, the possibility to exploit the HTC process to extract valuable materials and chemicals represents a very strong driver to move towards sustainability.

On the other hand, some limiting factors for the diffusion of this solution can be highlighted and analyzed. In this work, the authors focused on regulatory issues and economic evaluations. In fact, depending on the final use of the hydrochar, for example for energy production or as a soil improver, the legislation is not completely mature, thus HTC plants can undergo to stiff authorization procedures. Moreover, the hydrochar in order to be exploited in both the two ways previously mentioned, must fit narrow legal limits and this can strongly obstacle the application of this technology. Another important factor considered in this work is the availability of feedstock. In fact, because of the high average CAPEX at the moment, the economic sustainability can be reached only when medium to big scale plants are realized. This implies requires a high availability of feedstock, in terms of volumes to be treated, or there must be implemented a strong logistic system, capable to collect the residues from different locations and bring them to a centralized system. Furthermore, seasonality of several feedstocks can represent a strong limiting factor. In this work, all these aspects are reviewed and analyzed.

*Dr. Kathleen Meisel, DBFZ*

## **CARBOWERT: Life cycle assessment of different hydrothermal carbonization concepts producing hydrochar for energetic and material use**

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Keywords: LCA, sewage sludge, hydrochar, agricultural and energetic use

The CARBOWERT project aims at contributing to resource and climate protection by developing innovative and sustainable concepts of hydrothermal carbonization (HTC) of municipal sewage sludge producing hydrochar. The HTC technology provides different opportunities for the valorisation of sewage sludge streams in new applications. Within CARBOWERT two applications have been investigated in detail: Firstly, hydrochar can be used in the energy sector where it contributes to the substitution of fossil based electricity and heat. Secondly, the application of hydrochar in agricultural systems potentially leads to improved soil fertility and increased yields.

The different HTC concepts including both applications are assessed and compared to conventional agricultural and energy production systems by means of life cycle assessments (LCA). One of the scoping questions for the application of the LCA methodology was to identify the concept with the highest greenhouse gas (GHG) saving and thus with the highest contribution to climate protection compared to its conventional system. The conducted LCAs based on mass- and energy balances considering actual data.

The scientific innovation is to compare two completely different application options of hydrochar and to solve the methodical challenge behind.

The LCAs conducted are based firstly on system- and technology –specific data from the technology owner and secondly on field experiments in agricultural systems. So the scientific relevance is to present case specific results instead of comparisons of standard values presented in other studies.

After the LCAs of the HTC concepts including the different applications of the hydrochar are conducted, the concept with the highest GHG saving compared to its conventional systems is identified. Furthermore, optimisation potentials for reducing GHG emissions to a minimum in each concept are shown. This is done in order to increase the contribution of the concepts to climate protection and to increase their chances for an implementation in the energy and agricultural market.

# *Poster Presentations*

*Dr. Andrés Álvarez-Murillo, University of Extremadura*

## **Good practices for a proper characterization of HTC liquid phase**

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Keywords: Hydrothermal, biomass, analytical chemistry, liquid phase

The knowledge on the reaction chemistry of HTC and how it is affected by process conditions is essential to size equipments and find optimal conditions to get targeted properties on both liquid phase or hydrochars (HCs). With this goal, the study on the changes of the composition of the liquid phase during the process can help understanding how the formation of particular interest compounds is promoted, at the same time that can provide information about the causes influencing the composition and surface chemistry of the HCs. The experimental study is, however, quite complex because while the examination of the HC, a stable material, can be performed easily by several techniques, the analysis of the liquid phase, a very inestable solution, can yield very different results depending on the methodology followed during its isolation and characterization.

This work aimed to study the changes induced on walnut shells as a result of HTC processes, varying the mass load and the particle size, and the changes on the liquid phase composition along the reaction (including heating and cooling steps). The runs were performed several times and the procedure followed for collecting, storing and analyzing the liquid phase was modified. It was found that, while the reproducibility on the solid yield and typical HC properties of interest (proximate and immediate analysis, surface chemistry, porosity, point of zero charge...) were almost identical, the liquid phase composition of each sample and also their trend along a given reaction changed significantly, because of the reactivity of the compounds in the liquid phase. The authors demonstrate how a fast sample recovery, dilution, freezing, and just-before-analysis defreezing is essential to get reproducibility in the results.

*Dr. Gözde Duman Tac, Ege University*

## **Comparative evaluation of hydrothermal carbonization and pyrolysis of olive wastes**

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**Keywords:** Hydrothermal carbonization, pyrolysis, biochar, hydrochar, olive wastes

In this work, we aimed to investigate effects of process variables on the yields and properties of hydrochar by varying the process temperatures (200 °C–260 °C) and reaction times (0–240 min.) with a constant olive tree pruning (OTP): water ratio (1/5 by weight). For comparison, biochars were obtained by slow pyrolysis at different temperatures (200 °C–600 °C) for 60 min. and 120 min. The HTC results showed that temperature had an impact on the mass yield of hydrochar while mass yield did not significantly change with the reaction time higher than 60 min. Increasing the reaction severity enhanced the fixed carbon and energy density of hydrochar in expense of the mass yield. Thermogravimetric analysis proved that cellulose still remained even in the hydrochar obtained at 260 °C and 240 min. In case of pyrolysis, duration had almost no effect on both the fuel properties and the yield of biochars. In contrast to hydrochar, cellulose in the OTP structure was decomposed at and above the temperature of 350 °C.

Hydrochar had lower ash content than biochar due to dissolution of inorganic content in biomass during the HTC. FTIR spectrum also revealed the differences in functional groups of biochar and hydrochar. Hydrochars contained number of oxygenated functional groups including carbonyl groups, alcohol groups. However, in case of biochar, new bonds related to aromatic structures were appeared, particularly in biochars obtained at higher temperatures. SEM images of chars indicated that biochar at 500 °C was more porous structure having small pores, whereas the surface of hydrochars obtained at a duration of 60 min. were smoother, probably due to secondary char formation on the surface. As a conclusion, this study gives insights to produce chars from olive wastes with desired properties by varying the reaction conditions as well as process types.

**Acknowledgement:** The financial supports from TUBITAK (Project Contract No: 117M570) under the Eranet-Med2 Programme (Project Acronym: MEDWASTE) of the EU are gratefully acknowledged.

*Prof. Iskender Gökalp, ICARE*

## **Characterization of solid and aqueous phase products from hydrothermal carbonization of orange pomace**

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**Keywords:** Hydrothermal conversion, orange pomace, hydrochar, solid biofuel, HTC process liquid

Waste generation is increasing everyday with the increase of world population affecting therefore the environment and the economy. In order to offer a solution for waste management and reduce waste management costs, utilization of biomass waste for producing hydrochars via the hydrothermal carbonization process (HTC) is considered in recent years.

Although one of the most important parameters affecting the thermal decomposition processes is particle size of the sample, there is no much studies of particle size effect on hydrochar yield and characteristics of hydrothermal carbonization products in the literature. So, this study was especially focussed on investigating the particle size effect on HTC treatment of orange pomace wastes. HTC experiments were conducted in a 300 mL batch reactor (Top Industrie, France) made of a nickel base alloy. Hydrochars and HTC process liquids were characterized, combustion characteristics of orange pomace and hydrochars were also investigated using thermogravimetric analysis in detail. The combustion kinetic parameters and best fitting model were determined by using different calculation methods and model equations. It was concluded that the Arrhenius Parameters ( $E$  and  $\log A$ ) were changed depending on the particle size of biomass and the method of calculation.

It was found that the yield of hydrochars decreased from 46.02 % to 39.98 % when the particle size of biomass sample was decreased, while the fixed carbon value of hydrochars increased from 34 % to 38 % for particle size of  $d < 1$  mm and  $d > 1$  cm, respectively.

Both the orange pomace and the hydrochar were characterized by ultimate, proximate and thermogravimetric analyses. The orange pomace waste under the HTC process showed significantly improved physicochemical properties. The ultimate and thermogravimetric analyses showed that the hydrochar is more carbonaceous and more thermally stable than untreated orange pomace. The proximate analysis showed that hydrochars contained lower ash and volatile matter compared to the raw orange pomace. Particle size of biomass samples also affected HTC Liquid characteristics such as acidity, conductivity, TOC and COD values, the amounts of formic acid, lactic acid, acetic acid and furfural. Acidity, conductivity and TOC values of HTC Liquids increased while the particle size of biomass samples decreased. And also formic acid, lactic acid and acetic acid amounts of HTC Liquids increased with decreasing sample size. In conclusion, this study showed that HTC has great potential as an environmentally friendly process to convert orange pomace wastes to added-value products.

*Jakob Köchermann, DBFZ*

## **Hydrothermal conversion of D-xylose and organosolv hemicellulose catalyzed by a keggin-type heteropoly acid under N<sub>2</sub> and CO<sub>2</sub> atmosphere**

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**Keywords:** Heteropoly acids, furfural, CO<sub>2</sub>, D-xylose, organosolv hemicellulose

Furfural is commercially produced by acid catalyzed conversion of hemicellulose rich agricultural waste. As catalyst sulfuric acid is used, which is highly corrosive, not reusable for the reaction, and responsible for large amounts of contaminated salt waste. In contrast, heteropoly acids (HPAs) are known as useful homogeneous acid catalysts. The advantages of HPAs are their strong Brønsted acidity (more than mineral acids like H<sub>2</sub>SO<sub>4</sub>), reusability, easy handling and removal as well as the low corrosiveness. Furthermore, it could be shown in recent years that the presence of Lewis acids leads to higher furfural yields. Therefore, an easy to handle combination of a Brønsted/Lewis acid system consisting of a HPA (Brønsted acid) and CO<sub>2</sub> (Lewis acid) was chosen for our examination.

Experiments were conducted in a stirred tank reactor at different temperatures and CO<sub>2</sub> pressures. To avoid the heat up phase, the reactants (D-xylose or organosolv hemicellulose) were added to the reactor after the desired reaction temperature was reached. Samples were taken immediately after adding the reactant and at 5, 15, 30, 60 and 180 min. By liquid chromatography (HPLC-DAD), the samples were analyzed.

HPAs are promising acid catalysts, but their use for furfural synthesis has not been studied intensively until now. An extensive examination under use of a model substance (D-xylose) and a real substrate (organosolv hemicellulose) in combination with and without a Lewis acid was conducted. This approach offers a number of interesting perspectives for further investigation, such as catalyst recycling or the development of heterogeneous HPA salts.

Preliminary results of this ongoing study will be presented at the conference. First results indicate fast xylose conversion rates but not associated with high furfural yields. Whether the addition of CO<sub>2</sub> as Lewis acid can increase furfural selectivity and yield will be the subject of discussion.

*Dr. Ivan Kozyatnyk, Umeå University*

## **Hydrothermal carbonization of humic acids: Physical and functional properties**

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### Keywords:

Humic acids (HA) represent an economic and environmental challenge in water treatment, as they have the propensity to foul membranes and create toxic by-products when interacting with chlorine. To overcome this, HA were submitted to hydrothermal carbonization to convert them into an easy to remove, valuable carbon material. The result was a carbonaceous material with a yield of  $49 \pm 1.8$  wt%, which was easy to filter/dewater compared to HA. Physicochemical analysis of the material via X-ray photoelectron spectroscopy (XPS), diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) and solid-state nuclear magnetic resonance (NMR) indicated that under hydrothermal carbonization the aromatic structure of HA condensed.

Carboxylic acids groups were also lost from the surface of HA, with ether and alcohols increasing because of their loss. The morphology of the obtained material had a cotton-like structure consisting of many smaller carbon fragments. Finally, the hydrothermal treatment increased the surface area from 0.41 to  $102.99 \text{ m}^2 \text{ g}^{-1}$ . The porosity is located in the mesoporous range of 10–80 nm with a maximum peak at 50 nm.

*Nader Marzban, Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB)*

## **Reaction kinetic modelling of the hydrothermal carbonization of plant-based feedstocks: Identification of reaction mechanisms**

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**Keywords:** Hydrothermal carbonization, reaction mechanism, kinetic, modeling, upscaling

Hydrothermal carbonization (HTC) can transform wet agricultural residues into a variety of value-added solid and liquid products. Although plant-based feedstocks are mainly made of lignin, cellulose, hemicellulose, sugars, proteins, their concentrations and additional components in each feedstock can vary widely. Hydrolysis, dehydration, decarboxylation, polymerization, and aromatization reactions all play a role in product formation. Understanding the complex reaction kinetics of the transformation process is necessary for reactor design and optimization. However, knowledge of the rate-limiting steps in most HTC reaction systems is still unknown.

Previous modelling work has varied from detailed statistical models of the solid products for single feedstocks over kinetic models for liquid components to general statistical models based on literature results from hundreds of publications. The focus has been on describing changes in lumped parameters such as the higher heating value or solid yield.

This presentation will give an overview of the current status of the modelling work on hydrothermal carbonization and an outlook on potential pathways for further work on determining reaction kinetics for modeling the HTC process.

*Dr. Eduardo Sabio, University of Extremadura*

## **Kinetics of the hydrothermal carbonization of safflower cane**

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**Keywords:** Hydrothermal, biomass, process chemistry, multiphysics modeling

The lignocellulosic biomass is the most abundant biological material on earth and the most economical to produce. In this study, a lignocellulosic residue of agricultural origin (safflower cane) was employed to obtain a second-generation solid biofuel using the hydrocarbonization technique. The kinetics of the process was studied by carrying out four experimental runs at 180 °C, 200 °C, 22 °C, and 240 °C under autogenous conditions during processing times in the range 15-180 min. In order to reduce the pre-heating period, small columns with 17 mL volume were used. The biomass/water ratio used was 0.3 (%wt./wt.). Once the experiments ended, the corresponding solid residues were dried, the solid yields (SY) determined, and the elemental analyses carried out. The evolution of temperatures inside the column and the kinetics of the SY were modeled by using the COMSOL Multiphysics software. Selected hydrochar samples were subjected to thermogravimetric analyses under both N<sub>2</sub> and O<sub>2</sub> atmospheres,

and their FTIR spectra were recorded as well.

The experimental conditions induced a different energy densification of the samples. Solid yields in the range 50.7% and 98.7%, with corresponding high heating values of 18.97–23.24 MJ kg<sup>-1</sup>, were obtained. There was a negative correlation of time with SY and pH, and a positive one, with conductivity and refraction index of the liquid phase. Temperature followed the same pattern than time, but the level of correlation was lower.

Dr. Charles Coronella, University of Nevada

## Nutrient Solubilization by Hydrothermal Carbonization

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**Keywords:** Nutrient recovery, HTC, manure, biomass, waste valorization

The hydrothermal carbonization (HTC) process has shown potential to densify the carbon content of diverse biomass by removing water and producing a solid product with increased energy value. Several waste biomass (e.g., manure, municipal sludge) contain a sizeable amount of nutrients, and numerous investigators have evaluated use of HTC for nutrient recovery. We propose to use HTC to separate fuel value and nutrient content from waste biomass to the solid and aqueous phases, respectively. In order to understand the factors affecting the nitrogen and phosphorous solubilization, HTC of cow manure has been conducted at two different temperatures (170 °C and 230 °C), at reaction times of 5 min, 30 min and 2 h. The effect of an acidic hydrothermal environment has been studied by addition of either hydrochloric acid or citric acid. The liquid samples were analyzed for nitrogen and phosphorous by spectrophotometric technique. The fractionation of nitrogen including TKN and NO<sub>2</sub> – NO<sub>3</sub> were measured.

The HTC process successfully solubilizes about 20% – 30% of the nitrogen from the biomass, and the presence of nitrogen oxides is relatively small compared to that of TKN.

The effects of reaction time is less significant than that of temperature, while acid addition is even more significant to nitrogen solubilization, although the trends are complex. For example, in some cases TKN increases with reaction time, and in other cases it decreases. The highest TKN result was observed with addition of 0.5M HCl, 230 °C, and at 2 h. Results are presented regarding a mass balance of nitrogen and phosphorous during HTC, and future directions of research are indicated.

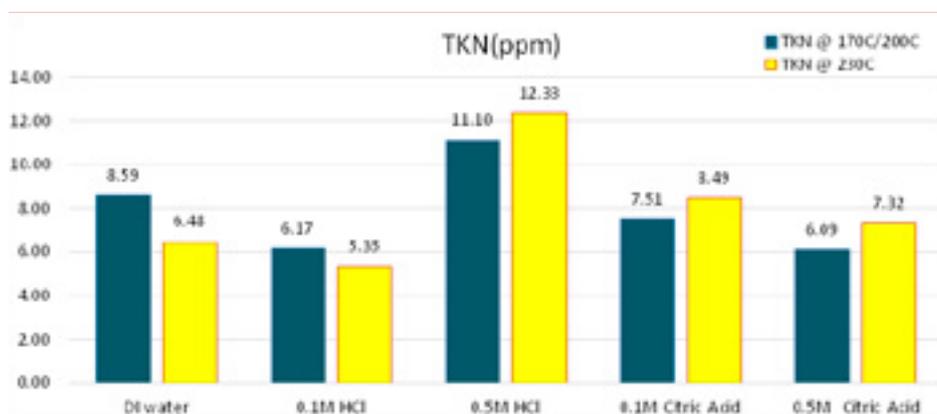


Figure 1 TKN in the aqueous phase at low and high temperature with and without acid addition. Low temperature is 200 °C for DI water and 170 °C for all other cases

*Pierpaolo Modugno, Queen Mary University of London*

## **Influence of reaction conditions on hydrothermal conversion of biomass**

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**Keywords:** Biomass conversion, hydrothermal carbonization, sugars

Hydrothermal carbonization is regarded as a very promising method to convert agricultural waste into a source of chemicals and carbon materials, due to the relative easiness of the process, which involves mild operating conditions and little to no pretreatment. Among the various products of hydrothermal treatment of biomass, there are water soluble organic compounds and insoluble and solid amorphous carbonaceous materials.

The reaction paths which lead to the formation of these two kinds of products run in parallel; so, depending on which one is the product of interest, the other is regarded as a byproduct and vice versa.

5-hydroxymethyl furfural and levulinic acid are two of the several soluble organic compounds which result from dehydration of cellulosic biomass under hydrothermal conditions; their use as building blocks for the synthesis of a vast number of chemicals has been demonstrated.

Although the general conditions required for the conversion from cellulose to dehydration products are known, reaction parameters such as pH, catalyst, temperature and residence time still need to be optimized, in order to achieve the best yield of the desired product and the scalability of the process.

Hydrothermal carbon results from the polymerization and condensation of the aforementioned molecules. It has proven to be a very versatile material and its application in batteries, electrochemical devices or in catalysis is being deeply explored.

The aim of this work is to study the influence of reaction condition (substrate, residence time, temperature, initial pH and catalyst) on the yield of solid and dissolved products and on the morphology of hydrochar.

Fructose, glucose and 5-hydroxymethylfurfural have served as model substrates to mimic the behavior of real biomass in hydrothermal condition. Several mineral acids have been employed as homogenous catalysts to evaluate the effect of both acid strength and related anion on the yields of the products. Hydrothermal process has been performed in static and stirred reactors.

Fructose has demonstrated to be much more active towards dehydration compared to glucose, reaching highest yield of HMF after 2 hours only, whereas conversion from glucose to HMF reaches its peak at 4 hours in static reactors. In both cases this maximum is followed by a decline in favour of its degradation products. Lower pH conditions and longer reaction times again largely favour levulinic acid and hydrochar yield at the expenses of HMF.

*Daniela Moloeznik Paniagua, TU Berlin*

## **Partitioning of inorganics in the HTC process: the effect of process parameters**

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**Keywords:** Inorganics, nutrients, phases, mass balance, quality of products

Hydrothermal carbonization can lead to different products: a high calorific fuel, a soil amendment, an adsorption material for the treatment of waste water, a carbon-based catalyst or even a raw material for the production of batteries, among others. The required product characteristics vary widely. The main focus up to now has been describing the transformation of the organic compounds, as well as the mass and energetic properties of the hydrochar, e.g. solid yield and higher heating value. However, inorganic compounds can play an important role in the quality of the desired product(s) (i.e. nitrogen and phosphorus for the soil amendment, or chloride for the fuel usage). Then, it is important to know how the HTC process affects the distribution of these key compounds between the solid, liquid, and gas phase during carbonization. While complete mass balances for the selected compounds in the 3 phases would be necessary to determine the fate and concentration of these compounds in the products, it is rarely reported in the literature. Predictions cannot be made on the potential behavior of inorganics in the HTC process.

This study summarizes the knowledge on the distribution of inorganics (nutrients, halogens, heavy metals) based on past research. It compares the fate of different measured compounds (Cl, N, P etc.), considering the methods (ICP-AES, MS), feedstocks types (sewage sludge, biomass type), the phases taken into account (solid, liquid) and the operational parameters (temperature, residence time) in each run. The presentation will also discuss potential correlations between typical process parameters (temperature, residence time, feedstock mass/volume input) and the distribution of the inorganics (heavy metals, nutrients), in order to predict the optimal operational conditions for the desired products.

*Hande Alptekin, Imperial College London*

## **Structure-performance correlations in hard carbons for Na-ion batteries**

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**Keywords:** HTC, sodium-ion battery, carbon, anode, energy storage

Inexpensive, efficient energy storage systems are essential for the wide-scale successful implementation of renewable energy technologies. Among the various available energy storage technologies, Li-ion batteries (LIB) have been have received considerable attention. However, in terms of largescale application they are not suitable because their price is very high, which is resulting from the uneven distribution of lithium reserve around the world and increasing consumption. Hence, it is crucial to research low-cost secondary batteries for energy storage technologies. Sodium is located below Li in the periodic table, so it possesses similar chemical and physical properties to Li in many aspects. First of all, regarding availability sodium is fourth most abundant element in the Earth's crust, making sodium relatively inexpensive. Namely, sodium-based batteries could provide an alternative chemistry to lithium batteries, and might become competitive to lithium-ion batteries.

However, there are still inevitable drawbacks related to discovery of suitable anode materials. Optimizing the porous and graphitic structure of the anode materials is important to achieve electrochemically elevated Na-ion battery technology. In this study, we will present the preparation of a series of hard carbon anode materials prepared via the Hydrothermal Carbonisation (HTC) followed by high temperature carbonisation. Applying various carbon precursors, carbonization temperatures, templating agents and dopants results in materials with different pore morphologies, functional groups and graphitisation degrees which were characterised by HRTEM, XPS, Raman and SAXS. The influence of material morphology, type of the dopant and change microstructure on electrochemical performance and Na-storage mechanism were investigated.

*Dr. Heather Au, Imperial College London*

## **Development of hard carbon anodes for sodium-ion batteries**

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**Keywords:** Sodium-ion batteries, hard carbon, hydrothermal carbonisation, anode

Sodium-ion batteries have shown potential as a cost-effective successor to lithium-ion batteries, but the performance is still limited by their low energy density and poor cycleability compared with lithium-ion analogues. The development of suitable electrode materials is crucial for the realisation of sodium-ion batteries as a feasible replacement. Disordered carbons, also known as 'hard carbons' (i.e. those with some degree of graphitisation but randomly oriented graphitic domains) are considered promising anode materials due to negligible volume change during the sodiation/desodiation cycles, essential for achieving a long cycle life.

A range of materials were prepared via hydrothermal carbonisation of various biomass precursors followed by further heat treatment; by tuning the carbon source, the nature and amount of dopant, the templating agent and the treatment temperature, carbon anodes with varying degrees of graphitisation and tailored pore size, wall thickness and heteroatom functionalities were obtained. The pore structure, particle size, nature of defects and degree of doping were found to have a significant effect on the storage capacity and cycleability of the batteries. The ability to tailor these hierarchical nanostructures therefore makes this process a promising route to achieving new electrode materials.

*Dr. Daniele Basso, Free University of Bolzano*

## **Preliminary tests on the thermochemical conversion of hydrochar produced from AD digestate and sewage sludge**

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**Keywords:** Digestate, sewage sludge, hydrochar, energy, HBI

The possibility to exploit the hydrothermal carbonization process to treat anaerobic digestion digestate and sewage sludge has risen the interest of the community operating on the HTC sector, mainly because the common alternatives to treat and/or manage these two by-products are encountering more and more problems, because of both regulatory restrictions and sustainability issues. As a matter of fact, at least in Europe, the possibility to spread these by-products in field as liquid fertilizers is becoming more and more restricted, because of pollutants (such as, nitrates and heavy metals) and/or harmful compounds (hormones and drugs) that can be diffuse in the territories, through this practice. Within this context, the HTC process can effectively act as a sustainable alternative. In fact, the hydrochar produced can be exploited for renewable energy production, while from the liquid phase can be extracted fertilizers concentrates that can be used in a more controlled way in agriculture. In this work, the potentialities to couple a pyrolytic or combustion system to HTC are investigated. Hydrochar has been produced under specific conditions, with a lab scale reactor owned by the company HBI Srl and placed in the labs of the Free University of Bolzano.

The process parameters were: 180 °C for 3 h, and 220 °C for 3 h. Proximate and ultimate analyses and calorific values of the hydrochars were then performed. In order to get preliminary insights on the behaviour of these hydrochars during a gasification process, thermogravimetric (TGA) tests were performed and, the quality of the produced gas were evaluated by coupling the TGA to a Fourier-transform infrared spectroscopy (F-TIR) analyzer. Thus, the preliminary results indicate that the energy production from hydrochar produced from digestate or sewage sludge can be a viable alternative, although the calorific value of this material is averagely lower than that of the materials commonly used for energy production. This preliminary results suggest that some precautions should be foresaw, for example mixing the feedstock with other interesting by-products (for example, saw dust) or evaluating an adequate plant scale, in order to guarantee an appropriate economic sustainability of the entire system.

*Richard Lobo, Imperial College London*

## **Properties and applications of size controlled HTC-derived carbon dots**

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**Keywords:** Carbon dots, size, optoelectronic

Carbon dots derived through hydrothermal synthesis have the potential to be a sustainable nanomaterial with facile upscaling routes. However, the polydispersity of the resultant nanomaterial poses a challenge as the properties can be significantly size-dependent. This uncontrolled variable can obscure characterisation of their optoelectronic and structural properties and therefore potential applications.

Harnessing various methods to control or select for size can help elucidate mechanistic insights and help optimise for different applications. Notably, the quantum confinement effect exhibited by the  $\pi$ -conjugated core can make size a useful tool to tune optoelectronic properties, in fields such as photocatalysis and photovoltaics. In these systems the ability to align specific HOMO and LUMO band levels with energy levels in different substrates when used as sensitizing or passivating additions is highly desirable.

*Zhenyu Guo, Imperial College London*

## **Amorphous carbons as anodes for batteries**

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**Keywords:** HTC hard carbon, sodium battery, anodes

As the price of lithium resources has been climbing these years, it is of great significance to investigate alternative batteries at a lower cost. Sodium-ion batteries (SIBs) are ideal alternatives due to the abundance and low-cost of sodium resources. One bottleneck of SIBs is anode materials as graphite which has been dominant for decades as anodes in lithium-ion batteries (LIBs) cannot be directly applied in SIBs. Among all proposed anode materials, amorphous carbon materials with a decent capability and stable dimensions are regarded as the most promising alternatives, replacing the graphite in LIBs. Hydrothermal carbonisation (HTC) is an efficient and facile method to produce amorphous carbons that can be easily nanostructured or functionalised and used for further at low-temperature under self-generated pressure. The resulting amorphous carbons followed by high-temperature carbonisation can be used as anodes in SIBs, exhibiting competitive electrochemical performances with high-capacity, good cycling stability, high initial Coulombic efficiency (ICE). To further improve the capability and ICE of nonporous amorphous carbon, mesophase pitch (MP) is selected as a low-cost and high carbon yield precursor to enclose the pores of amorphous carbon at an elaborated temperature. MP can be melt at high temperature and covers the open pores of activated carbons and, in turn, decreases the specific surface area and irreversible capacity.

HTC amorphous carbons can also be used as anodes in dual-ion batteries (DIBs). All-carbon batteries can be achieved that amorphous carbon and graphite as electrodes sandwich a mix of  $\text{LiPF}_6$  and  $\text{NaPF}_6$  electrolyte. DIBs exhibit safety, sustainability, high working voltage (ca.4.5v) and high energy/power density. BET, SEM, electrochemical characterisation techniques will be carried out to both investigate the SIBs and DIBs.

*Dr. Beatriz Ledesma, University of Extremadura*

## **Effect of aluminum alloy shavings scraps on physical-chemical properties of hydrochars derived from several biomass wastes**

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**Keywords:** Aluminum alloy, biomass, hydrothermal, porosity

In this work, the hydrocarbonization process of three different biomass wastes (e.g. water hyacinth leaves [WH], potatoes peels [PP] and almond shells [AS]) was modified by introducing different amounts of aluminum alloy (AA201) shaving scraps during the reaction. By means of different characterization techniques such as thermogravimetry (TG-DTG), physical adsorption/desorption of N<sub>2</sub> at 77 K, infrared spectroscopy (FT-IR) and scanning electron microscopy (SEM), the variations in textural, morphological and chemical surface properties of the obtained products were examined.

The methodology and experimental conditions employed during HTC were based on those proposed by other authors. Particularly, the process was carried out in a stainless steel autoclave (Berghof, Germany) using a volume of 100 mL of deionized water and 3 g of biomass. The mixture was sealed into a teflon vessel and then inserted in the autoclave, which was subjected to 230 °C for 20 h.

The results obtained indicated that the presence of this metal waste in the liquid phase during the hydrothermal experiments has originated certain degree of porosity development in the hydrochars obtained. Specifically, and regarding a reference sample, the development of an extra porosity in the meso and macroporosity range as well as significant changes in the outermost surface morphology was found. This fact suggests that, in some extent, the presence of this alloy in the liquid phase ( $2\text{Al} + 6\text{H}_2\text{O} \rightleftharpoons 2\text{Al}(\text{OH})_3 + 3\text{H}_2$ ) could favor the hydrogasification of the amorphous carbon of the hydrochar.

The creation of porosity with this method may considered an interesting starting point in order to assess the basis of future research.

*Sabina Alexandra Nicolae, Queen Mary University of London*

## **Biomass based carbon materials for gas storage and separation**

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**Keywords:** Hydrothermal carbonization, CO<sub>2</sub> adsorption, separation, activation

Global warming is a matter of great concern around the world. With an increase of about 40% in the atmospheric concentration since the industrial revolution, CO<sub>2</sub> represents the primary cause of the greenhouse effect. The main sources of CO<sub>2</sub> are represented by human activities, contributing with more than 80% of the atmospheric CO<sub>2</sub> in urban areas (HOUGHTON et al. 2001). Over the time, several technologies have been developed to decrease the CO<sub>2</sub> concentration, such as absorption using alkaline solvents, membrane-separation, conversion/adsorption using a wide range of adsorbents, like zeolites, metal organic frameworks and activated carbons (WANG et al. 2011). But despite all the efforts devoted to minimize it, recent studies reported an increase of CO<sub>2</sub> emission from 280 ppm, in 1750, up to 406 ppm in 2017. Therefore, finding new ways to diminish the CO<sub>2</sub> content in the atmosphere is still a topic of great interest. Porous carbon materials have attracted a lot of attention, due to their multiple applications, such as catalysis, adsorption processes for water and air depollution, energy storage and production. In particular, CO<sub>2</sub> capture via physical adsorption represents an eco-friendly alternative to the traditional amine-based absorption processes (SEVILLA et al. 2017). Herein we present the synthesis of porous carbon materials starting from different biomass precursors, such as palm date, guava seeds and winged beans. The bio-inspired adsorbents have been prepared via hydrothermal carbonisation (HTC) and have been used for CO<sub>2</sub> capture. Following the HTC, different activation methods have been employed in order to boost the porosity of the pristine carbons.

The resulted materials have been characterized via different characterization techniques and have been tested for CO<sub>2</sub> adsorption. The N<sub>2</sub> sorption isotherms revealed the presence of porous carbons with large pore volume and considerable high surface area, in between 950 m<sup>2</sup>/g and 2800 m<sup>2</sup>/g. SEM micrographs were in good agreement with surface area measurements, showing the formation of porous carbon spheres. The preliminary tests, for CO<sub>2</sub> uptake, presented good adsorption capacities in STP (0 °C and 1 bar), reaching a maximum of about 5.63 m<sub>mol</sub>/g. Overall, the experimental results showed that HTC is a useful tool for the development of porous carbon materials derived from sustainable resources, such as biomass feedstock. The resulted hydrochar presented high potential for gas storage applications, with an increase in the adsorption activity after chemical activation.

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## Engineering the interface of carbon electrocatalysts at the triple point for enhanced oxygen reduction reaction

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**Keywords:** Non-precious metal catalysts, electrocatalysis, triple-phase boundary, interface reaction, oxygen reduction reaction

Oxygen reduction reaction (ORR) has recently received increasing attention due to its critical role in clean and sustainable energy generation technologies, such as PEM fuel cells, alkaline fuel cells and Zn-air batteries. The sluggish kinetics of ORR resulting from multistep electron transfer process is the main challenge to address in this field. The kinetics are partially related to the O<sub>2</sub> adsorption process onto the catalyst, which happens on the triple-phase boundary (TPB) of electrocatalyst-electrolyte-oxygen interface. In addition, tremendous efforts that have been devoted to improving the intrinsic properties of a catalyst such as electrical conductivity and porosity.

Engineering the electrocatalyst's interfacial properties is another critical issue in ORR, however less encountered and described in the literature.

The catalyst's surface provides the microenvironment for the triple boundary interface reaction, which directly influence the electrocatalytic activity and the kinetics for gas-involving energy electrocatalysis.

In this work we present a new concept to improve the ORR performance by engineering the interface reaction at the electrocatalyst-electrolyte-oxygen triple-phase boundary (TPB) using a protic and hydrophobic ionic liquid and demonstrate the wide and general applicability of this concept to several Pt-free catalysts. Two catalysts, a Fe-N co-doped and a metal-free N-doped carbon electrocatalysts are used as proof of concept. The ionic liquid layer grafted at

the nanocarbon surface creates a water-equilibrated secondary reaction medium with a higher O<sub>2</sub> affinity towards oxygen adsorption, promoting the diffusion towards the catalytic active site, while its protic character provides sufficient H<sup>+</sup>/H<sub>3</sub>O<sup>+</sup> conductivity, and the hydrophobic nature prevents the resulting reaction product water from accumulating and blocking the interface. Our strategy brings obvious improvements in the ORR performance in both acid and alkaline electrolytes, while the catalytic activity of FeNC-nanocarbon outperforms commercial Pt-C in alkaline electrolyte. We believe that this research will pave new routes towards the development of high-performance ORR catalysts free of noble-metals via careful interface engineering at the triple point.

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*Yahaya Balarabe Umar, University of Leeds*

## **Hydrothermal carbonization of waste textile: Effect of reaction temperature and residence time**

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**Keywords:** Hydrothermal carbonization, waste textile, hydrochar, physicochemical properties

Textile waste is a significant component of municipal waste streams and includes both natural and synthetic fibres. Municipal waste is often landfilled or incinerated depending on local waste management strategies. The use of alternative routes such as hydrothermal carbonisation (HTC) is gaining interest due to its simplicity and low-cost and has potential for producing higher value materials. The behaviour of complex municipal waste, including textiles, during HTC is unclear. Previous studies have concentrated on the HTC of individual components of municipal waste such as paper, food waste and cardboard but have spent less attention to waste textiles. The feedstock and process conditions have a significant influence on the physicochemical properties of the resulting hydrochar.

This study investigates the behaviour of waste textiles such as cotton and polyester during HTC at different reaction conditions in a high pressure batch reactor. Samples of textile have been carbonized in the temperatures range of 180–280 °C at different residence times. The resulting hydrochar has been characterised for its calorific value and its physicochemical characteristics. The implications of processing municipal wastes containing significant levels of textile wastes by HTC is discussed.

*Zhen Xu, Imperial College London*

## **Carbon Materials Inspired by Hierarchical Forms of Cellulose as Electrodes for Sodium-ion Hybrid Capacitors**

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**Keywords:** Nature-inspired carbon, sodium-ion hybrid capacitors, hierarchical forms of cellulose

Because of the abundance and the low cost of sodium resources, sodium-ion energy storage technology is an emerging alternative to the current commercial lithium-ion systems. Among this, sodium-ion capacitor composed of a battery-style anode and a capacitor-style positive cathode is attracting increasing attention due to its potential to become a tradeoff between batteries and supercapacitors. Nature-inspired carbon materials derived from different building blocks of cellulose, one of the most abundant and renewable resources on the plant, have been applied to the anodes of batteries or the electrodes of electrical double-layer electrochemical capacitors separately, whereas there is not much research on applying these two different styles of biomass-derived carbons into one sodium-ion capacitor.

In our study, carbon materials with hierarchical pore structures as the capacitor-type cathode are prepared by the hydrothermal carbonisation and activation of cellulose microfibers, while the battery-type disordered carbon anode is obtained through thermal pyrolysis of cellulose nanocrystals.

Full sodium-ion capacitor are assembled by combining the two different carbon electrodes. The discharging capacitance of cathodes tested in half cells can reach  $212 \text{ F g}^{-1}$  at the current density of  $0.1 \text{ A g}^{-1}$ , and the charging capacity of anodes can stand at  $257 \text{ mAh g}^{-1}$  at  $0.1 \text{ A g}^{-1}$ . The discharge capacity of the full-cell configuration is  $73 \text{ mAh g}^{-1}$  at  $0.1 \text{ A g}^{-1}$ . Moreover, the influence on electrochemical performance resulting from the structures of materials and the kinetic of the electrochemical reaction inside the capacitors have been studied so as to help understand the working mechanism of sodium-ion capacitors.

*Dr. Chinnathan Areeprasert, Kasetsart University*

## **Possibility of MSW and EFB pellets produced from hydrothermal carbonization in biomass pellet market**

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**Keywords:** Hydrothermal carbonization, biomass pellet, EFB, MSW

Biomass pellet becomes very important resource in energy sector around the world. This first generation fuel is produced from wood-based material. It passes through conventional shredding, drying, and pelleting processes. However, these production methods can be applied to woody biomass only. Other abundant agricultural residues and low-grade biomass are not yet utilized. This work presents a pilot-scale testing of alternative pellet fuel produced from municipal solid waste (MSW) and empty fruit bunch (EFB) via hydrothermal carbonization (HTC). MSW and EFB were provided from local municipal area and palm oil mill in Thailand, respectively. HTC pilot-scale equipment with the reactor volume of 1 m<sup>3</sup> was utilized. The treatment temperature was 160–200 °C with the holding time of 30 min. The HTC products were naturally dried. A 5.5-kW pelleting machine is used to pelletize the HTC products.

Results showed that the MSW and EFB pellet produced from HTC have a significant improvement on fuel property such as calorific value and physical characteristic. HTC facilitated fuel pellet production process because it can homogenize and carbonize the raw material. Moreover, potassium content in EFB that can generate slagging and fouling problem in boiler was significantly removed. Chlorine content in MSW pellet product was lower than the standard of RDF fuel in Thailand. This work showed possibility of the second generation fuel pellet produced from the HTC.

*Huyen Chau Dang, TU Dresden*

## **Reuse of spent coffee grounds to produce charcoal briquettes by using hydrothermal carbonization process**

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Keywords: –

Coffee drinks play an important role in society, and coffee consumption continues to grow. World coffee consumption was reported to be about 7 million tons of coffee beans in 2016 (EUROMONITOR INTERNATIONAL, 2017). Coffee grounds (or spent coffee grounds-SCG) are one of leftover by-products from coffee production process. The two main sources are from the manufacturing process of instant coffee, and from cafés and cafeterias. Disposal methods for the spent coffee grounds depend on the region, and can cause environmental problems in regions without processes to treat organic solids. Sustainable reuse as a renewable fuel is an interesting option for this high organic-containing waste. The question is what type of processing is necessary to convert the SCG into a fuel suitable for use in households or industry.

This study examines whether the HTC process can convert wet coffee grounds into carbon-rich char for use as charcoal briquettes. SCG were collected from 7 different sizes of coffee shops in Dresden with the SCG amount of 3–20 Kg/day. After collecting, SCG with 16,9% of moisture are treated at different temperatures ranging from 200–250 °C in a 18.5 L HTC reactor.

The ultimate analysis shows that higher heating value of SCG hydrochar can be up to 32,11 MJ/Kg as high as that of wood/coconut charcoal. The presentation will show the effect of the process parameters on the solid yield, higher heating value, and relevant combustion properties.

Regarding to pelletizing tests for SCG-hydrochar, the results of the two trials will also be shown. In the first trial test, pressing force levels of 1000 N and 2500 N were used in order to form 8 mm diameter pellets. The second tests were made with a hydraulic pressing machine, where hydrochars with 12–15% of moisture were mixed with swelling starch at different ratios. The hydraulic pressing forces were chosen from 25–75 bar. Pellets were formed without binder at 50 bar. More detail about bulk density, mixing ratio and mass and size of char will be discussed on the poster.

The final aim of this study is to investigate on ignition, burning time and burning performance of SCG hydrochar pellets as a charcoal that can be used in life activities such as: cooking, heating, BBQ, etc..

*Elisabeth Kleiber, Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB)*

## **Experimental investigation of the drying kinetics of hydrochar derived from coffee grounds on the laboratory scale**

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**Keywords:** Drying Kinetics, Hydrochar

In order to meet international climate protection goals, the utilization of unused biomass and organic residues is becoming progressively important due to the constantly increasing energy consumption and its resulting increase of CO<sub>2</sub> emissions. Precise knowledge about the conversion of organic residues into biochar and their treatment is necessary for a comprehensive use of biomass and intermediates derived from them in order to increase their value. For example, in cities large amounts of coffee grounds arise, which could be treated by hydrothermal carbonization into hydrochar and thus be used for energy supply. However, the energetic use of hydrochar requires drying the product. Grindability, pelletizing and combustion properties are improved by reducing the water content. This reduction cannot be achieved by mechanical dewatering alone. Therefore, it is necessary to thermally after-dry the hydrochar. Since the thermic drying process is accompanied by high energy consumption, it is important to make the process as energy efficient as possible. For the design of a product-specific drying technique, it is necessary to know the drying kinetics of the hydrochar. The aim is to develop energy-efficient techniques and processes which provide biogenic recyclables and energy sources from agriculture for a sustainable, bio-based material and energy industry.

In this work, the drying behavior of hydrochar prepared from coffee grounds was investigated. If temperatures rise above 100 °C, there is the danger of self-heating and, hence, of spontaneous combustion of the material. Thus, temperatures of 50 °C, 70 °C and 90 °C were used for the laboratory experiments conducted at the thermogravimetry. The absolute humidity, as another drying parameter, varied between 0g/kg and 10g/kg. Furthermore, the thermal stability of the material during the drying process was investigated by means of the gas chromatography – mass spectroscopy. For this purpose, the volatiles of the hydrochar were detected at different drying times. To determine the final moisture content for storage and transport, the equilibrium moisture content values of the char was measured in form of sorption isotherms.

The results of the drying experiments showed that, as expected, the drying time decreases with increasing temperature. The drying time at 50 °C was about three times as long as at 70 °C. Most volatile components are detected on undried coal and after passing 15% of the drying progress. By determining the sorption isotherms, the hydrochar can be classified as hygrophobic material.

*Dr. James Hammerton, University of Leeds*

## **Utilization of hydrochar slurries as a fuel**

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**Keywords:** Slurry, gasification, milling

One of the key features of hydrothermal upgrading of biomass is the improved grindability. This improvement makes it possible to convert the treated biomass into a slurry which can be used like a liquid fuel. Using hydrochar in a slurry has a number of advantages including transportation and accurate control of flow rate.

Two applications for hydrochar slurries were investigated: as a fuel for a diesel engine and for gasification. The hydrochar slurry used to power a diesel engine consisted of 10% by weight of hydrochar mixed into diesel. This slurry was used successfully to run a 6 kW, 3000 rpm diesel generator. The hydrochar particles in the slurry had a median size of 3.93  $\mu\text{m}$  after using a wet milling process. The slurry could be used at high powers at a similar efficiency to diesel, but at low powers had a severe efficiency penalty. The reason for the poor efficiency at low powers was the low combustion temperature.

In terms of emissions, particle number increased when using the slurry compared to diesel, but total hydrocarbons and carbon monoxide were similar at high powers.

Gasification was another application for slurries tested. In this case hydrochar was mixed with water instead of diesel. Slurries were produced from a number of types of biomass treated through hydrothermal carbonization.

*Jackie Massaya, University of Bath*

## **Developing a biorefinery from spent coffee grounds: Using subcritical water and hydrothermal carbonization to derive value from a major by-product of the coffee processing industry**

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**Keywords:** Spent coffee grounds, biorefinery, hydrochar, waste valorisation, NO<sub>x</sub>

Spent Coffee Grounds (SCG), the residual solids from brew preparation, are a major by-product of the coffee processing industry. Comprised of lignin, proteins, lipids, carbohydrates and secondary metabolites, SCGs are a viable 2<sup>nd</sup> generation lignocellulosic biomass for conversion into renewable fuels, energy, composite materials, and specialty chemicals.

This work utilised SCGs as a feedstock within a biorefinery concept, valorising the biomass through integrated sustainable technologies, namely subcritical water extraction (SWE) and hydrothermal carbonisation (HTC). First, 2<sup>4</sup> central composite design (SWE) and 2<sup>3</sup> full factorial (HTC) DOE determined the influence of process parameters on the response variable. SWE (110–200 °C, 10–50 min, 5–30 mL water/g SCG) isolated an aqueous stream containing chlorogenic acid (1–6 mg/g SCG) with associated antioxidant activity. Conversion of the residual solids into an energy dense carbonaceous material through HTC (160–250 °C, 1–4 h, 10–15 mL water/g SCG) yielded a hydrochar with improved calorific value relative to the raw feedstock (21–33 vs 20 MJ/kg HHV).

Presence of nitrogen containing components in SCGs (e.g. alkaloids and proteins), confer high N/C ratios in corresponding hydrochars, potentially exceeding NO<sub>x</sub> emission limits when burnt as solid fuels. To this end, this study explored the reduction of nitrogen content in the raw feedstock through a protein extraction pretreatment. Isolation of a higher value protein extract and lower N/C ratios were observed in the pretreated solid residue and corresponding hydrochar relative to the untreated control. This work goes towards the complete utilisation of SCGs in a biorefinery, highlighting the potential of HTC for the production of a commercially viable SCG derived solid fuel product.

*Carla Pérez, Umeå University*

## **Hydrothermal carbonization of biosludge from the pulp and paper industry**

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Keywords: HTC, hydrochar, biosludge, pulp and paper industry, solid fuel

Hydrothermal carbonization (HTC) of biosludge generated from the pulp and paper industry was studied using a 350 ml batch reactor. The resulting hydrochar has a great potential for use as solid fuel for combustion purposes. However, the HTC process is highly dependent on operational conditions and the characteristics of the starting material. Therefore, the purpose of this work was to compare two different biosludges generated in the effluent treatment facility of two pulp and paper industry mills in Sweden. The work conducted includes determination of the optimal temperature for reaching the favorable hydrochar properties with regard to their performance in combustion applications, and thereby improve their fuel properties compared to the starting biosludge.

To achieve this objective, HTC experiments were conducted at different temperatures with a constant reaction time for each run. The characterization of the resulting hydrochar

showed an increase in carbon content and heating value, and decreased slagging and fouling indexes. In addition, the dewatering properties were improved. Therefore, observations made from results obtained strongly indicate that HTC is suitable for upgrading this type of high-moisture waste materials. However, further investigation is required for efficient application of hydrochar as a solid fuel as well as for achieving a complete understanding of the whole reaction process.

*Dr. Gabriel Gerner, Zurich University of Applied Sciences*

## **HTC-Innovation Campus in Switzerland**

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**Keywords:** Sewage sludge, cow manure, digestate from cow manure, briquette, bio-fuel

HTC-Innovation Campus Rheinmühle is a project, which aim it is the optimization of a plant utilizing the process hydrothermal carbonization (HTC) for the production of briquette bio-coal as well as the utilization of produced process-water. Each year, approx. 1000 m<sup>3</sup> cow manure of a livestock farm and approx. 100 t sewage sludge from a close-by water treatment plant (ARA Chur) will be processed and HTC products used as alternative fuel and substrate for biogas production.

The HTC hydrochar is converted to a storable feed fuel for gasification and combustion systems. The separated process water is used as a co-substrate in the biogas plant Halbmil. The pilot plant is intended to show a power- and heat-generating processing pathway for manure and sewage sludge in Switzerland, leading to its industrial development.

*Fabian Gievers, HAWK University of Applied Sciences and Arts*

## **Environmental impacts of sewage sludge treatment by hydrothermal carbonization**

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**Keywords:** Hydrochar application, life cycle assessment, hydrothermal carbonization, sewage sludge

Considering the current developments of sewage sludge management by incineration, away from the material recycling in agriculture, a Life Cycle Assessment (LCA) was carried out to investigate whether hydrothermal carbonization (HTC) represents a more sustainable form of sewage sludge treatment. The research is based on the material and energetic modelling of the HTC as well as subsequent utilization paths of the hydrochars. The lifecycle assessment is generally focused on the HTC process chain of anaerobically pretreated and dewatered sewage sludge compared to the currently practiced process chain of incineration and ash disposal. For the life cycle assessment various application routes for hydrochars with energy and material balances were investigated: On the one hand, co-incineration in existing combustion capacities of waste and lignite power plants. By substituting municipal waste and lignite, balanced according to their energy content, credits could be generated. On the other hand, its use as a soil improver in agriculture and as a peat substitute in horticulture was modelled, since nutrients are more available for the plants in hydrochar than in sewage sludge ash. Therefore, mineral and fossil-based fertilizers and peat can be replaced by hydrochar.

Beside energetically aspects the concentration and accumulation of pollutants such as PCDD / PCDF, PCB and heavy metals were taken into account in order to quantify the environmental impacts and determine possible uses of the hydrochar. The LCA was carried out with the professional software GaBi based on Life Cycle Inventory (LCI) data sets from GaBi and ecoinvent (v3.3) as well as own unit processes. The environmental impacts were analyzed using lifecycle inventory analysis (LCIA) according to ReCiPe-Midpoint methodology. The system boundary covers the production of dewatered sludge, the HTC-process and dewatering of HTC slurry, treatment of process water, possible transports, electricity and heat production and subsequent utilization of the generated hydrochar. The Results indicate a positive overall balance for the HTC itself with certain negative outcomes in some impact categories for different hydrochar applications.

*Giulia Ischia, University of Trento*

## **Realization of a solar hydrothermal reactor: A hybrid solution to develop a zero-energy technology**

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**Keywords:** Hydrothermal carbonization, solar concentrator, biomass, solar reactor, parabolic solar dish

Hydrothermal carbonization has acquired a rising interest in last years and an increasing number of small to medium enterprises are developing HTC pilot to industrial scale facilities for the production of carbonaceous materials starting from residual biomasses. Even though hydrothermal carbonization itself is slightly exothermic, the overall process entails energy consumptions to reach the HTC operating conditions and tackle heat losses. With the aim of facing this issue and developing a technology with zero energy consumptions, a completely innovative configuration is proposed: the coupling of a HTC reactor with a solar concentrator. The project is currently under development and this work focuses mainly on the design of an experimental apparatus, i.e. a prototype.

Our system consists of a stainless steel HTC reactor positioned on the focus of a parabolic dish concentrator. This configuration was chosen for its versatility and ability to achieve high concentration ratios, necessary to sustain thermal duty of the hydrothermal conversion. The parabolic dish can accommodate a total of 24 mirror modules for an overall diameter of 5 m and is mounted on a two axis tracking support.

The HTC reactor was built specifically for this project; it has an internal volume of 300 ml and is placed on the focus of the solar concentrator at 2.5 m height. The system is designed to work with three mirrors, able to concentrate the sunlight up to a ratio of 870X on the HTC reactor bottom flange, which is properly treated with a functional coating to maximize light absorption. During operations, the direct solar radiation is focused by mirrors on the HTC reactor bottom flange, which warms up and ensures to achieve the desired HTC reaction temperature. The tracking device maintains the apparatus towards the sun direction, enabling the exploitation of the solar radiation through all the day. Besides, the internal reactor temperature is kept to the desired value by means of a variable cooling water flow rate passing through a jacket realized around the HTC reactor walls.

Therefore, this work reports first steps towards the realization of a zero-energy HTC system, through which the energy needs for the production of carbon-enriched materials and chemicals are completely met by solar energy.

*Vicky Shettigondahalli Ekanthalu, University of Rostock*

## **Hydrothermal carbonization: An emerging technology to effectively manage sewage sludge – Review**

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**Keywords:** Hydrothermal carbonization, nutrients recovery, sewage ludge management, environmental sustainability

The global sewage sludge production is steadily increasing. This situation not only makes it difficult to handle the excessively produced sewage sludge but also triggers a new problem associated with storage of sewage sludge. Further, the stringent regulations placed on sewage sludge management is making it even more difficult to handle. Since 2017, the new regulation is in force in Germany, makes it mandatory to recover nutrients(P) from sewage sludge. Even though sewage sludge is rich in macronutrients (NPK), the lack of environmentally and economical benign processes are hindering the use of nutrients from wastes.

Hydrothermal carbonization (HTC) is emerging as the most promising technology that effectively converts various underutilized wet feed-stocks viz., dairy manure and sewage sludge into high energy density hydrochar and simultaneously aids the recovery of all available micro and macronutrients. Compared to the initial feedstock, the produced hydrochar is highly hydrophobic and has a biologically inert characteristic, which significantly favors dewatering potential and also the production of the value-added product. The hydrochar produced by HTC is proved to have higher H/C and O/C ratio similar to that of natural coal making it an effective fuel alternative.

Further, hydrochar also shows the relatively higher adsorption characteristic in term of iodine number making it highly effective in the production of adsorbent as a value-added product. Considering the finiteness of essential life-giving nutrients (NPK), this comprehensive review analyses the effectiveness of HTC as a technology to recover macronutrients combination (NPK) from sewage sludge. Together with emphasizing the state-of-art HTC technology to recover nutrient combinations, this review analysis the production of various value-added product from the produced hydrochar. Further, the analysis of the effectiveness of HTC in term of environmental sustainability are made considering the existing legislation (European and national level). Besides updating the knowledge on the effectiveness of HTC as a technology to manage sewage sludge, this review briefly summarises some of the most appropriate future research prospects for the technical development of HTC in sewage sludge management.

*Avery Brown, Worcester Polytechnic Institute*

## **Changes in the adsorption capacity of hydrothermal chars after thermal, chemical and mechanical activation**

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Keywords: Raman, spectroscopy, copper, lead, adsorption

Hydrothermal chars (hydrochars) are carbonaceous solids derived from the thermal degradation of biomass under liquid water conditions. The resulting material is oxygen rich, aromatic, and possesses carboxylic acid sites. These materials have been linked to a variety of applications, such as gas storage, metal adsorption and soil amendment. Hydrothermal carbonization is advantageous as a one-step method for producing materials with range of properties, chemistry and potential applications.

Previous literature has shown that chemical activation by either acid or base can change the surface area and surface structure of the hydrothermal char. Mechanical activation via ball-milling has previously shown to produce greater surface area, and improve the aromatic content of the materials. While thermal activation has often been used to remove side chains and increase aromaticity. In this work we examine hydrochar synthesized from glucose and activated under various chemical, mechanical and thermal treatments under Raman spectroscopy to elucidate their structure. We then test the capacity of these chars for copper nitrate.

Gareth Davies, University of Sheffield

## Biomass based carbon materials for gas storage and separation

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**Keywords:** Hydrochar, alcohol:water, adsorbent, lignocellulose

Hydrothermal carbonization (HTC) is used to produce hydrochars for application in soil amendment, energy production, and synthesis of low cost environmentally friendly adsorbents (FANG et al. 2018). Lignocellulosic materials are widely used as the carbon source (KAMBO AND DUTTA 2015). In contrast with such previous studies, mixed water/alcohol solvents at sub-critical conditions have been used herein as the synthesis medium. Alcohol:water mixtures were chosen because their non-ideal behavior results in enhanced liquid-phase structuring at the mesoscopic scale (BYE et al. 2017). This research shows that the ratio of alcohol:water has a direct impact on the physical and chemical characteristics of the hydrochar produced.

The post-treatment of the produced chars via metal impregnation and thermal conditioning; and the characterization of the porous chars produced. Scanning electron microscopy and in situ adsorption test have been employed to characterize adsorption capacity of the hydrochars, whilst bomb calorimetry, elemental analysis, and thermogravimetric analysis have been used for further characterization of the effect that the synthesis medium has on the hydrochar.

In order to correlate the differences in hydrochar structure and efficacy for adsorption applications with the composition of the solvent, in situ Fourier transform infrared (FTIR) spectroscopy studies of the alcohol:water mixtures have been conducted in a specialized cell.

Two-dimensional correlation spectroscopy was used to gain further understanding of the alcohol:water system (NODA 2015). This reveals direct information on the physical and chemical characteristics of the synthesis medium, which is in turn linked to the nature of the carbons formed.

The understanding gained from this work facilitates a more intelligent design of synthesis conditions in order to produce chars with differing and tailored properties for specific applications, in particular in the area of adsorption.

### References:

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Fang, J.; Lu Zhan, L.; Ok, Y. Z.; Gao, B. (2018): Minireview of potential applications of hydrochar derived from hydrothermal carbonization of biomass. *Journal of Industrial and Engineering Chemistry* 57: 15–21.

Kambo, H. S.; Dutta, A. (2015): Renewable and Sustainable Energy Reviews. Elsevier, 45: 359–378.

Noda, I. (2015): Techniques of two-dimensional ( 2D ) correlation spectroscopy useful in life Biomedical Spectroscopy and Imaging 4 (2015) 109–127.

*Dr. Elena Diaz, Autonomous University of Madrid*

## **Application of activated hydrochar from grape seeds and olive stones for removal of emerging pollutants in aqueous phase**

Elena Diaz<sup>1</sup>, Javier Manzano<sup>1</sup>, John Villamil<sup>1</sup>, Juan Jose Rodriguez<sup>1</sup>, Angel F. Mohedano<sup>1</sup>

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**Keywords:** Hydrothermal carbonization, hydrochar, adsorption, chemical activation, sulfamethoxazole.

Hydrothermal carbonization (HTC) is becoming an increasingly attractive process for biomass conversion. The resulting solid product, hydrochar (HC), presents high carbon content and a relatively higher heating heat value (HHV). This material can be used in contaminant remediation, soil amelioration, carbon sequestration, energy storage, and also as a low-cost catalyst support and adsorbent. For this purpose, the HC can be activated by physical, using CO<sub>2</sub> or steam, or chemical (KOH, FeCl<sub>3</sub> or H<sub>3</sub>PO<sub>4</sub>). The aim of this work is to study the potential of grape seeds (GS) and olive stones (OS) as precursors for the production of carbonaceous adsorbents via HTC and chemical activation, analyzing the influence of water content (40–90% wt.) and reaction temperature (180–300 °C) in HTC process and the role of KOH, H<sub>3</sub>PO<sub>4</sub> and FeCl<sub>3</sub> as activating agents.

Grape seed and olive stone HCs are characterized by a high carbon content (64–73% wt.) and HHV within 26 and 31 MJ/kg. In both cases, the materials resulting from HC activation developed BET surface areas between 400 and 2000 m<sup>2</sup>/g, being the highest values associated to the HC activation with KOH. The viability of activated HCs as adsorbents has been studied for the removal of the pharmaceutical pollutant sulfamethoxazole at 20 °C. Experimental data fitted the Langmuir equation, being the maximum adsorption capacity 650 and 500 mg/g for GS-HC-KOH and OS-HC-KOH, respectively.

**Acknowledgments:** The financial support by MINECO (CTM2016-76564-R), CM (BIOTRES-CM S2018/EMT-4344) and UAM-SANTANDER-EEUU (2017/EEUU/07). Javier Manzano wishes to thank to Madrid Community (PEJ16/AMB/AI-1327).

*Dr. Changyoon Jeong, Louisiana State University*

## **Effect of hydrochar amendment on tylosin adsorption-desorption and transport in agricultural soils**

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**Keywords:** Hydrochar amendment, adsorption-desorption, transport, tylosin, breakthrough curves

Hydrothermal carbonization (HTC) technology is significantly reducing energy use for drying and solid product yield compared to thermally processed biochar (pyrochar). However, researches regarding on the role of hydrothermal biochar as a soil amendment on the adsorption-desorption and transport of tylosin, a macrolide class of veterinary antibiotic, is little known. In this study, batch and column experiments will be conducted to investigate the adsorption kinetics and transport of tylosin in agricultural field soils amended with hydrochar and pyrochar made of swine manure. The trend of tylosin adsorption will be characterized through the adsorption stages, and the biochar amendment rate will be determined. Pyrochar amendment on tylosin adsorption will be compared with the effect of the hydrochar amendment. The trends of desorption under two different types of biochar will be presented to understand the remaining amount of tylosin in agricultural soils.

The transport patterns of tylosin under the application of hydrochar and pyrochar to soils will be presented to understand the potential leaching to groundwater for the environmental assessment. The modified miscible displacement method will be used for this study. The method is soil columns under soil water saturated conditions with constant flow velocity will be maintained. The extent of tylosin mobility is presented by quantifying the concentration in the effluent solution versus time via breakthrough curves (BTC). The CXTFIT model for the miscible displacement column study will use to explain the peak arrival time as well as the maximum concentration of tylosin breakthrough curves. The results from both adsorption-desorption and transport of tylosin will be described by the use of a multi-reaction and transport model based on the classical convection-dispersion equation (CDE) for reactive solutes through porous media. The expected results are enhancing retention and mitigating transport of tylosin under the application of hydrochar in agricultural soils.

*Dr. Mikko Mäkelä, Aalto University*

## **Hydrothermal carbonization in producing wood-based activated carbons for organic chlorine removal**

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Keywords: Activation, adsorption, chlorine removal, filtrate treatment

Modern biorefineries deal with several biomass streams that can be efficiently utilized for replacing current fossil alternatives in a wide variety of material and energy applications. One such example is currently being developed in Northern Finland. This biorefinery aims at utilising softwood for manufacturing biomaterials and chemicals and hardwood for the production of activated carbon for organic chlorine removal from industrial wastewater. The advantage of hydrothermal carbonization (HTC) for wood modification is that the decomposed hemicellulose fractions of wood can be recovered as monomeric sugars or acids in the HTC filtrate. Thus, no separate extraction phase is required and hemicellulose removal and char production can be performed simultaneously in a single process step.

The recovered filtrate can then be used as an auxiliary energy source for the entire system. Our recent results illustrate that wood-based activated carbons can be produced in relatively high yields coupled with a sorption performance that is comparable to commercial fossil-based analytical reagents in organic chlorine removal. In this contribution we present our current activities in the field of wood-based activated carbons, discuss the role of HTC, and the effects of HTC and activation conditions on properties and performance of the HTC filtrate and the final activated carbons.

*Manuel Nowotny, Carl-von-Ossietzky-University Oldenburg*

## **Activated biochar made from liquid-solid biomass mixtures**

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**Keywords:** Manure-coconut shell-mixture, mesoporosity, fuel cell, pore-size engineering

Typically, the process of hydrothermal carbonization (HTC) converts biomasses to hydrochars with low specific surface areas of  $< 10 \text{ m}^2/\text{g}$ . But the hydrophilicity of the surfaces is retained due to the high density of oxygen-containing functional groups of the raw materials. An increase of the surface area under conservation of the oxygen-containing polar surface group could enable the hydrochars to be used as substitute for peat in the gardening industry, in sewage and/or waste gas purification, as a growth medium for microorganisms or as support for catalysts. In a recent study we successfully used hydrochars after an additional step of gentle pyrolysis as a catalyst carrier in fuel cells. However, the conductivity of the chars has still to be optimized.

There are several ways to increase the porosity of hydrochars such as in-situ activation with  $\text{ZnCl}_2$  and / or a subsequent steam activation. A subsequent physical activation of the chars in steam at different temperatures and times resulted in a strong increase of the surface area, mainly due to micropore formation, however, this is coupled with a partial loss of the polar surface groups.

One promising route to substitute the corrosive  $\text{ZnCl}_2$  is to treat optimized liquid-solid biomass mixtures, e.g. of manure and coconut shells, under hydrothermal conditions. After subsequent steam activation of hydrochars made from such manure/coconut shell mixtures hierarchical pore structures of micro- and mesopores with pore sizes up to 10 nm and BET surface areas of up to  $470 \text{ m}^2/\text{g}$  were found. Next to the improved pore-size engineering the use of coconut shells as additive allows to reduce the reaction time from 12 to 4 hours, thus saving energy. In addition to that a cascade use is supported, since it's possible to convert in parallel two different complex biomasses to hydrochars. The obtained hydrochars are still rich in functional groups after a subsequent steam activation and thus have similar properties to those prepared in saline solutions.

*Dr. Silvia Román Suero, University of Extremadura*

## **Magnetic porous carbon materials from almond shells by Fe assisted hydrothermal carbonization**

Silvia Román<sup>1</sup>, Mara Olivares<sup>1</sup>, Beatriz Ledesma<sup>1</sup>, Andrés Álvarez-Murillo<sup>1</sup>

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**Keywords:** Hydrothermal, adsorbent, magnetism, porosity, biomass

Besides the adsorption performance, other physico-chemical properties can be designed to improve their further use as adsorbents, for example, in waste water decontamination processes. This is the case of properties such as magnetism, durability, resistance to erosion or ageing, etc..

In the frame of hydrothermal preparation of adsorbents, problems such as the scant porosity of the hydrochars (HCs) have been tackled successfully, for example, by adding chemicals or including additional posttreatments such as physical activation. However, the modification of HTC processes to provide magnetic properties on the HCs has been scarcely studied.

In this work, almond shell was subjected to HTC and iron, in different forms, was included as reactant to the process following different methods in order to find the best way to infer magnetic properties to the resultant HCs. In particular, the metal was added as Fe<sub>3</sub>Cl (prior or during HTC), as pure Fe particles or as magnetic ferrofluid, followed or not by pyrolysis. The results indicated that the way in which the process is designed improves barely or significantly the structure and surface chemistry of the material, as well as the magnetization effect induced on the hydrochar.

*Andrew Ross, University of Leeds*

## **Co-processing of digestate with lignocellulosic biomass: Influence of blending on bio-coal properties and biochemical methane potential**

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**Keywords:** Digestate, BMP, hydrochar, energetics, ash

Hydrothermal carbonisation is a useful digestate enhancement technology with opportunities to increase biogas yields and produce a solid biofuel. The properties of digestate however do not lend themselves to producing high quality bio-coal and the blending of other lignocellulosic feedstocks is often required to improve bio-coal properties. This study has investigated a range of digestate from anaerobic digestion of different feedstock and shown the resulting bio-coal to be of low quality. Biochemical methane potential (BMP) of process waters demonstrate the potential for enhanced biogas generation. The co-processing of digestate with different lignocellulosic waste (grass clippings, hedge clippings and wood chippings) has been investigated to enhance bio-coal properties.

Co-processing results in significant increases in energy density of the bio-coal with improved ash chemistry, however this also effects the composition of the process waters and affects the potential for enhanced biogas production. Experimental BMP tests have compared the properties of process water with and without co-processing to study inhibitory behaviour. HTC temperature is critical in optimising the properties of the bio-coal and enhancing the biodegradability of process waters.

*John A. Villamil Martínez, Autonomous University of Madrid*

## **Integral management of waste sludge by hydrothermal carbonization and anaerobic co-digestion of the process water with primary sewage sludge**

John A. Villamil Martínez<sup>1</sup>, Elena Diaz<sup>1</sup>, Jose Daniel Marin-Batista<sup>1</sup>, Juan Jose Rodriguez<sup>1</sup>, Angel Fernandez Mohedano<sup>1</sup>, Maria de los Angeles de la Rubia<sup>1</sup>

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**Keywords:** Waste activated sludge, hydrochar, anaerobic digestion, valuable products, carbon-rich solids

The work studies the valorization of waste activated sludge (WAS) by hydrothermal carbonization (HTC) and the production of activated carbon from hydrochars by physical and chemical activation. We also study the anaerobic co-digestion of the liquid fraction from HTC (LFHTC) of WAS with primary sewage sludge (PSS) in order to develop an integral approach for sewage sludge management. WAS (15% dry matter) was collected from a cosmetic factory full-scale membrane bioreactor. A central composite rotatable design was applied to analyze the effect of temperature (152–220 °C) and reaction time (0.5–4 h) on the physical and chemical characteristics of hydrochars. The higher heating value of hydrochars varied from 19.1 to 22.3 MJ/kg and the BET area reached values up to 24 m<sup>2</sup>/g. Air activation (325 °C) allowed increasing 5-fold the BET area. Chemical activation (650 and 850 °C) with K<sub>2</sub>CO<sub>3</sub>, KOH, FeCl<sub>3</sub>, and ZnCl<sub>2</sub> increased BET surface areas in the range of 411 to 1030 m<sup>2</sup>/g with an important contribution of meso (0.079–0.271 cm<sup>3</sup>/g) and microporosity (0.136–0.398 cm<sup>3</sup>/g). The results obtained support the potential application of HTC process of dewatered WAS for the production of a solid fuel and a precursor of inexpensive adsorbents with tunable porous structure.

On the other hand, mesophilic co-digestion of the liquid fraction from HTC of WAS with primary sewage sludge (PSS) has been studied in batch and semicontinuous experiments. Mixtures of different composition (25, 50 and 75% of LFHTC on a chemical oxygen demand (COD) basis), as well as the individual substrates, have been tested using a granular sludge. Methane production decreased as the LFHTC/PSS ratio increased, which could be related to the presence of recalcitrant compounds in the LFHTC, such as alkenes, phenolics, and other oxygen- and nitrogen-bearing aromatics. Methane yield reached 248 mL CH<sub>4</sub> STP/g COD<sub>added</sub> with the 75% PSS/25% LFHTC mixture. Anaerobic co-digestion was optimized by performing mesophilic semi-continuous experiments with a 90% PSS/10% LFHTC mixture, on a COD basis and an organic loading rate of 1.5 g COD/L-d. Low concentrations of total volatile fatty acids (TVFA < 400 mg COD/L) and ammonium (< 1.2 g N/L) were achieved. In addition, a fairly good methane yield (172 mL CH<sub>4</sub>/g COD<sub>added</sub>) was obtained, 1.15 times the value for the control test with 100% PSS.

The results obtained support the potential application of HTC process of dewatered WAS in wastewater treatment plants, including the production of a solid fuel and a precursor of inexpensive adsorbents.

*Jale Yanik, Ege University*

## **Hydrothermal carbonization of food waste and its digestate**

Koray Akarsu<sup>1</sup>, Gozde Duman Tac<sup>2</sup>, Alper Yilmazer<sup>2</sup>, [Jale Yanik](mailto:jale.yanik@ege.edu.tr)<sup>2</sup>

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**Keywords:** Hydrothermal carbonization, food waste, digestate, biochar

Hydrothermal carbonization is an easy and sustainable method to convert the wastes having high moisture content into value added solid product. In our study, we performed hydrothermal carbonization (HTC) to obtain biochar from fruit and vegetable wastes (FVW) and its digestate from anaerobic digestion. HTC process was conducted at different temperatures (175–250 °C) and duration (15–120 minutes). The effect of temperature and duration on mass yield and fuel characteristic were investigated. 200 °C was found to be optimum temperature for both two types of wastes, whereas optimum duration was 30 and 60 minutes for digestate and FVW, respectively. According to Van Krevelen Diagram, most of the biochars was in the similar range of lignite area.

Biochars had lower ash content than the raw wastes. The selected biochars were then gasified at 850 °C under steam/N<sub>2</sub> atmosphere in vertical fixed bed reactor. The obtained H<sub>2</sub> yields were 1588 and 1227 mL H<sub>2</sub>/g biochar from the FVW and digestate biochars, respectively. This study proposed a new concept for both solid fuel and hydrogen production from wet biomass.

**Acknowledgement:** The financial support from TUBITAK-MAG under contract 2015-M-314 and Ege University under contract 16-ÇSUAM-004 are gratefully acknowledged.

# *Speaker Profiles*



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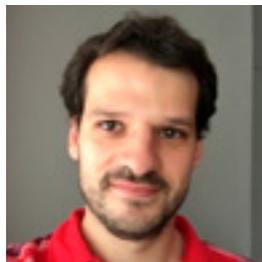
## Alptekin, Hande

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### Current position:

PhD Student at Chemical Engineering



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## Dr. Álvarez-Murillo, Andrés

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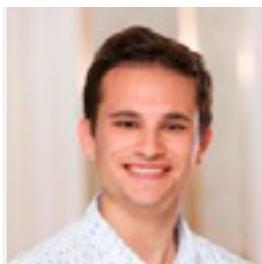
### Biographic keypoints:

- Formed as Industrial Engineer (University of Extremadura, UEX, 2011)
- Master of Research in engineering (2012)
- Experience as teaching assistant and research in the field of thermal engineering and thermal facilities
- Experience in research projects applied to industry in several sectors: biomass boilers, hybrid power generation, nuclear plants, boiler manufacturers, gasification plants
- Several papers published about characterization of solid materials as fuel, valorizing biomasses by different techniques, gasification, hydrothermal carbonization and pyrolysis
- Awarded with the “PhD excellence recognition” and final degree project recognition as supervisor by the University of Extremadura

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### Current position:

Researcher at the Applied Physics Department (University of Extremadura, Spain)



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### Biographic keypoints:

- 2008–2014 Chemical Engineering degree, Zaragoza University, Spain
- 2015–2017 Internship, Hawaii Natural Energy Institute, USA
- 2017–today PhD candidate at Hohenheim University, Germany

### Current position:

PhD Candidate



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## Dr. Areeprasert, Chinnathan

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### Biographic keypoints:

- Graduate from Tokyo Institute of Technology 2015
- Main research topic: Hydrothermal carbonization
- Previous research work: HTC of paper sludge, sewage sludge, MSW, EFB, sugarcane bagasse, etc. Combustion/Co-combustion of hydrothermally treated paper sludge.
- Current research work: HTC and steam activation of agricultural residues for activated carbon production. Scaling-up of HTC. Biogas production from HTC liquid products.

### Current position:

Assistant Professor



## Dr. Au, Heather

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### Biographic keypoints:

- BA & MSci in Natural Sciences (Chemistry) from the University of Cambridge (2007–2011)
- PhD from Imperial College London on the 'Development of grafting strategies for the polymer functionalisation of graphene' (2013–2017)
- PDRA at Imperial College London, investigating grafting mechanisms on nanocarbons (2017)
- PDRA at Queen Mary University of London and Imperial College London with Magda Titirici, working on the development of hydrothermal carbon materials as anodes for sodium-ion batteries (Jan 2018–)

### Current position:

PDRA



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### Biographic keypoints:

- 1982–1988, Eka Chemicals. Implementation of ECF-bleaching. One major outcome was that the formation of chlorinated dioxins/furans was eliminated by replacing chlorine with chlorine dioxide.
- 1996–2002, Program director Swedish research program "The Eco-cyclic Pulp Mill". Several aspects of increased resource efficiency of kraft pulp mills were developed. The program gave birth to technologies which are essential for bio-refining such as closed water loops, Ligno-Boost, and chip leaching.
- 2002–2017, Vice President Biorefining at STFI/Innventia.
- Recognized by RISI 2008 and 2009 awarded the Swedish Ekman medal as one of the pioneers in developing the biorefinery concept.
- 2017–2018, Vice President RISE Bioeconomy.
- 2018–, President Axegård Consulting AB and CMO including market development at C-Green, a Swedish start-up company, developing technology for converting wet biosludge into hydrochar.

### Current position:

CMO



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## Dr. Bae, Sunyoung

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### Biographic keypoints:

- Assistant professor, North Carolina A&T State University
- Visiting research scholar, USDA, USA
- Board member, Korea Society Analytical Science

### Current position:

Associate professor



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### Biographic keypoints:

- 2007: M.Sc. in environmental engineering
- 2016: Ph.D. in environmental engineering (Thesis title: “Hydrothermal carbonization of waste biomass”)
- 2016: CEO and co-founder of HBI Srl, innovative startup which develop HTC systems
- 2016: Post-doc position at the Free University of Bolzano

### Current position:

CEO



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## Dr. Benavente, Verónica

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### Biographic keypoints:

- PhD in Chemical Engineering from University of Alicante in 2017.
- Research first focused on the upgrading of agro-industrial wastes via torrefaction and hydrothermal carbonization to make them suitable for energy generation.
- Interests: Operational parameters, raw material composition, hydrochar-ash fusibility and life cycle analysis of those thermal pretreatments
- Getting into the field of biorefinery and circular bioeconomy

### Current position:

Post-doctoral researcher



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## Dr. Berge, Nicole

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### Biographic keypoints:

- BS and MS in Civil Engineering from the University of South Carolina
- PhD in Environmental Engineering from the University of Central Florida
- Associate Editor of the journal Waste Management
- Member of the Managing Board and Science Advisory Board of the IWWG
- Research interests include developing and evaluating sustainable solid waste treatment techniques, resource recovery from solid and liquid wastes, hydrothermal carbonization, and fate and transport of emerging contaminants in waste environments

### Current position:

Associate Professor



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## Bosilj, Monika

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### Biographic keypoints:

- Fraunhofer Institute for Solar Energy Systems (Scientific Assistant/PhD Student, Sustainable hydrothermal carbons for biorefinery-related catalysis)
- Fraunhofer Institute for Solar Energy Systems (Scientific Assistant, Catalytic conversion of lignocellulosic biomass)
- Chair of Technical Chemistry, University of Bochum (Internship, SCR catalyst synthesis and SCR reduction of NO)

### Current position:

PhD Student



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## Dr. Bostyn, Stéphane

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### Biographic keypoints:

- The main theme: valorization of biomass
- In the first part of the career, it focused on the isolation of compounds that have an interest in cosmetic, pharmaceutical industries
- Now, it is biomass conversion into energy using hydrothermal process in order to produce solid fuels (hydrochar) and to study combustion of these

### Current position:

Researcher



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## Brown, Aaron

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### Biographic keypoints:

- BSc Biology, University of Leeds, (2011–2014)
- PhD, University of Leeds, CDT Bioenergy, (2016–ongoing)

### Current position:

PhD Student



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### Biographic keypoints:

- B.S Chemical Engineering, Illinois Institute of technology
- Ph.D Candidate Chemical Engineering, Worcester Polytechnic institute.

### Current position:

PhD Candidate



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### Biographic keypoints:

- Master's Degree in Chemical Engineering at the University of Alicante
- Currently, a Ph.D. student in the University of Alicante
- Working in the investigation of the HTC technique application for different types of organic waste

### Current position:

Ph.D. student in Chemical Engineering



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## Buttmann, Marc

TerraNova Energy GmbH,  
Königsberger Str. 100, 40231 Düsseldorf, Germany  
Tel.: +49 21154413096  
E-Mail: [marc.buttman@terranova-energy.com](mailto:marc.buttman@terranova-energy.com)

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### Biographic keypoints:

- Several leading positions in the Endress + Hauser group
- Member of the Executive Board of Krohne Water Solutions GmbH
- 2009 founder and CEO of TerraNova Energy GmbH

### Current position:

CEO of TerraNova Energy GmbH



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### Dr. Coronella, Charles

University of Nevada,  
Chemical and Materials engineering department /  
170, Reno, NV 89557 USA  
Tel.: +1 775 7844253  
E-Mail: [coronella@unr.edu](mailto:coronella@unr.edu)

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#### Biographic keypoints:

- Assistant, associate professor of chemical engineering at University of Nevada since 1993.
- PhD from University of Utah.
- Research interests include application of hydrothermal processing and waste valorization.

#### Current position:

Associate professor



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### Dang, Huyen Chau

TU Dresden, Institute of Waste Management und  
Circular Economy, Pratzschwitzer Str. 15, 01796  
Pirna, Germany  
Tel.: +49 35146344121  
E-Mail: [huyenchau.dang@mailbox.tu-dresden.de](mailto:huyenchau.dang@mailbox.tu-dresden.de)

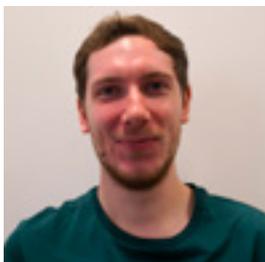
---

#### Biographic keypoints:

- Bachelor of Environmental Management and technology
- Master of Hydro Science and Engineering
- Currently I am a member of biochar research group at ATB, Potsdam, Germany
- Additionally, I am working on my PhD thesis about hydrothermal carbonization process.

#### Current position:

PhD Student



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## Davies, Gareth

University of Sheffield, Department of Chemical and Biological Engineering, Mappin Street, Sheffield S1 3JD, UK  
Tel.: +44 1142227521  
E-Mail: [gdavies4@sheffield.ac.uk](mailto:gdavies4@sheffield.ac.uk)

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### Biographic keypoints:

- 2017-present: PhD student, University of Sheffield, UK
- 2012-2016: 1st class MChem (Hons) in Chemistry, Nottingham Trent University, Nottingham, UK

### Current position:

PhD Student



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## Dr. Diaz, Elena

Universidad Autonoma de Madrid (UAM), Chemical Engineering Department, c/Francisco Tomas y Valiente, 7, 28049 Madrid, Spain  
Tel.: +34 914978035  
E-Mail: [elena.diaz@uam.es](mailto:elena.diaz@uam.es)

---

### Biographic keypoints:

- Environmental Science Grade (2004) and PhD on Chemical Engineering (2009) from University Autonoma de Madrid and joined to the Chemical Engineering Department in 2005
- Associate Professor in 2012
- Working in areas of environmental technologies focused on the wastewater treatment by means of advanced catalytic and biological processes and waste recovery
- Research stays in Heriot-Watt University (Edinburgh), Penn State University (Pennsylvania) and Universidad Autonoma de Mexico (Mexico)
- Involved in 22 research projects from different entities, co-authored around 20 referred papers in scientific journals and presented more than 60 communications in national and international conferences.
- Orcid ID: 0000-0003-1020-6240. Research ID: M-4740-2013.

### Current position:

Associate Professor



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## Dr. Ding, Yuxiao

Max Planck Institute for Chemical Energy Conversion,  
Stiftstraße 34-36, 45470 Mülheim an der Ruhr  
Germany  
Tel.: +49 2083063742  
E-Mail: [yuxiao.ding@cec.mpg.de](mailto:yuxiao.ding@cec.mpg.de)

### Biographic keypoints:

- Doctorate in 2015 from Institute of metal research, Chinese Academy of Science, with a focus on surface engineering of nanocarbon surface and carbon catalysis
- working as a postdoc. researcher in MPI for chemical energy conversion with a focus on hydrothermal carbon synthesis and applications

### Current position:

Post doc



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## Dr. Ducey, Thomas F.

Coastal Plains Soil, Water, and Plant Research  
Center, Agricultural Research Service, USDA  
2611 West Lucas Street, Florence SC, USA  
Tel.: +1 8432457020  
E-Mail: [thomas.ducey@ars.usda.gov](mailto:thomas.ducey@ars.usda.gov)

### Biographic keypoints:

- Research Microbiologist with ARS-USDA, at the Coastal Plain Soil, Water, and Plant Research Center in Florence, SC
- has served in this role for the past 12 years, during which he has led interdisciplinary research on a variety of agricultural issues focused on antibiotic resistance and animal wastewater treatment

### Current position:

Research Microbiologist



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### Dr. Duman Tac, Gozde

Ege University, Faculty of Science, Chemistry Department, 35100 Bornova Izmir, Turkey  
Tel.: +90 5363233400  
E-Mail: [gozdeduman@gmail.com](mailto:gozdeduman@gmail.com)

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#### Biographic keypoints:

- PhD in Organic Chemistry in 2015 at the Ege University, Izmir, Turkey.
- Focusing on various thermochemical conversion of biomass; namely fast and slow pyrolysis, catalytic pyrolysis, steam gasification and hydrothermal processes
- national and international projects as researcher
- various international universities and research centers for short terms (1-6 months) and published 15 articles indexed in JCR (H-index: 10).

#### Current position:

Researcher



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### Dr. Dutta, Animesh

Bio-Renewable Innovation Lab (BRIL),  
School of Engineering, RICH 3509,  
50 Stone Road East, University of Guelph,  
Guelph, Ontario, N1G 2W1  
Tel.: +1 5198244120  
E-Mail: [adutta@uoguelph.ca](mailto:adutta@uoguelph.ca)

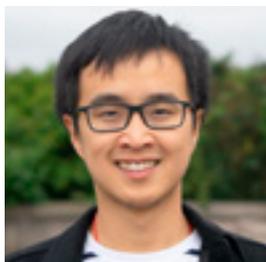
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#### Biographic keypoints:

- Professor and Director of Bio-renewable Innovation Lab (BRIL) with the School of Engineering at the University of Guelph
- His research focuses on energy, primarily on clean and sustainable-renewable energy technologies in the changing global context
- has built an international stature in the field of biorefinery, particularly in the production of bio-energy, bio-fuels, bio-based chemicals and materials from feedstocks originated from forestry and agricultural sectors.

#### Current position:

Professor



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## Feng, Jingyu

Imperial College London,  
South Kensington Campus, London, SW7 2AZ  
Tel.: +44 7459723888  
E-Mail: [j.feng19@imperial.ac.uk](mailto:j.feng19@imperial.ac.uk)

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### Biographic keypoints:

- doing his 3rd year PhD study in Imperial College London in Titirici's group
- received his BSc degree in Composite Materials and Engineering from Northwestern Polytechnical University
- received his MEng degree in Materials Science in Queen Mary University of London
- research focus on synthesizing carbon-based materials in the application of the electrocatalysis

### Current position:

PhD Student



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## Prof. Fiori, Luca

University of Trento, Department of Civil,  
Environmental and Mechanical Engineering  
via Mesiano 77, 38123 Trento, Italy  
Tel.: +39 0461282692  
E-Mail: [luca.fiori@unitn.it](mailto:luca.fiori@unitn.it)

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### Biographic keypoints:

- Leader of the Green Process Engineering Group at the University of Trento
- Expert on processes based on high-pressure fluids, such as hydrothermal processes (SCWG, HTC) and supercritical CO<sub>2</sub> extraction and fractionation
- Bioenergy expert

### Current position:

Associate Professor of Chemical Engineering Fundamentals



## Dr. Fullana, Andres

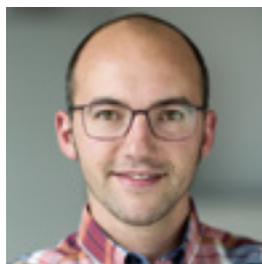
Department of Chemical Engineering,  
University of Alicante, Campus de San Vicente,  
San Vicente del Raspeig, 03690, Spain  
Tel.: +34 600948787  
E-Mail: [andres.fullana@ua.es](mailto:andres.fullana@ua.es)

### Biographic keypoints:

- Associate Professor of Chemical Engineering Department at University of Alicante (Spain)
- current research topics: Energy from biomass, waste recycling, water treatment using nanoparticles
- 2001: PhD in Chemical Engineering at University of Alicante; topic: 'Pyrolysis of tire wastes and sewage sludge'.
- After the PhD: a 2 years Fulbright postdoctoral scholarship at Dayton University (USA); research related to mechanism of pollutant formations in waste incineration process
- 2004: academic career as lecturer at department of Chemical Engineering at University of Alicante; since 2010: full time professor
- research interest includes: energy from biomass, pyrolysis/gasification, torrefaction, hydrothermal carbonization (HTC), waste treatments, water treatment, nanoparticles applications
- authored or co-authored around 50 publications on those topics

### Current position:

Associate Professor of Chemical Engineering



## Gerner, Gabriel

Zurich University of Applied Sciences  
Grüntalstrasse 14, Postfach  
8820 Wädenswil, Switzerland  
Tel.: +41 589345588  
E-Mail: [gabriel.gerner@zhaw.ch](mailto:gabriel.gerner@zhaw.ch)

### Biographic keypoints:

- 2007–2010: Bachelor of Science in Natural Resource Sciences; Zurich University of Applied Sciences
- 2012–2015: Master of Science in Life Sciences; Specialisation in Natural Resource Sciences; Zurich University of Applied Sciences
- 2015–2017: Research associate at the University of Minnesota; Research project in hydrothermal carbonization of animal manure and agricultural by-products
- 2018–now: Research associate at the Zurich University of Applied Sciences

### Current position:

Research Associate



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## Gievers, Fabian

HAWK- University of Applied Sciences and Arts  
Hildesheim/Holzminden/Göttingen  
Rudolf-Diesel-Straße 12, 37075 Göttingen  
Tel.: +49 5515032184  
E-Mail: [fabian.gievers@hawk.de](mailto:fabian.gievers@hawk.de)

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### Biographic keypoints:

- Student: Environmental Engineering (2009–2015), TU Braunschweig
- Since 2016: Research Associate HAWK and PhD-Student University of Rostock

### Current position:

Research Associate, PhD-Student



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## Prof. Gökalp, İskender

ICARE-CNRS UPR3021,  
1C avenue de la recherche scientifique,  
45071, Orléans Cedex 2, France  
Tel.: +33 238255463  
E-Mail: [iskender.gokalp@cnrs-orleans.fr](mailto:iskender.gokalp@cnrs-orleans.fr)

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### Current position:

Research director at the CNRS-ICARE, Orléans, France



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## Prof. Goldfarb, Jillian

Cornell University,  
226 Riley Robb Hall, Ithaca, NY 14850 USA  
Tel.: +1 6072555789  
E-Mail: [jlg459@cornell.edu](mailto:jlg459@cornell.edu)

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### Biographic keypoints:

- Program Chair, American Chemical Society Division of Environmental Chemistry
- 2017 Fulbright Scholar at University of Trento, Italy
- 2017 American Chemical Society Green Chemistry Institute GreenX: Rising Star Award
- 2016 National Science Foundation Award to present work at the AIChE International Congress on Sustainability Science and Engineering, Suzhou, China
- Funded by U.S. National Science Foundation, Proctor & Gamble Corporate Sustainability Program, the Eppley Foundation
- Member of the American Chemical Society National Committee on Environmental Improvement
- Past-President of New England Institute of Chemists

### Current position:

Assistant Professor of Biological and Environmental Engineering



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## Dr. Gribaudo, Enrico

HBI Srl  
Via A. Volta 13/A, 39100 – Bolzano (IT)  
Tel.: +39 3463626 200  
E-Mail: [e.gribaudo@hbigroup.it](mailto:e.gribaudo@hbigroup.it)

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### Biographic keypoints:

- 2014: Master on Management and business success at SDA Bocconi
- since 1997: business general manager
- since 2018: Executive board advisor
- 2018: COO at HBI Srl

### Current position:

COO



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## Guo, Zhenyu

Department of Chemical Engineering, Imperial College London, South Kensington Campus, London SW7 2AZ, UK  
Tel.: +44 7529147280  
E-Mail: [zhenyu.guo@qmul.ac.uk](mailto:zhenyu.guo@qmul.ac.uk)

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### Biographic keypoints:

- 2018–2022 Ph.D. in Materials Science at Queen Mary University of London, UK
- 2016–2017 M.Sc. in Advanced Materials Science at University College London, UK
- 2012–2016 B.Eng. in Wood Science and Engineering at Northeast Forestry University, China

### Current position:

PhD student



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## Hammerton, James

School of Chemical and Process Engineering, University of Leeds, Woodhouse Lane, Leeds, LS2 9JT, UK.  
Tel.: +44 7982031707  
E-Mail: [j.m.hammerton@leeds.ac.uk](mailto:j.m.hammerton@leeds.ac.uk)

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### Biographic keypoints:

- Research Fellow at the University of Leeds
- investigating innovative biofuels, particularly for developing countries
- expertise lies in producing alternative fuels for diesel engines, such as carbon slurries and thermochemically converted biomass wastes

### Current position:

Research Fellow in Biofuels and Solar Resource



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## Hansen, Lynn

Technical University of Munich, Chair of Energy Systems  
Boltzmannstr. 15, 85748 Garching b. München  
Tel.: +49 8928916266  
E-Mail: [lynn.hansen@tum.de](mailto:lynn.hansen@tum.de)

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### Biographic keypoints:

- 2010-2015: Studies in Chemical Engineering at ETH Zürich
- 2015-2016: Research Assistant at Swiss Federal Laboratories for Materials Science and Technology
- Since 2016: Research Assistant at Chair of Energy Systems at Technical University of Munich

### Current position:

Research Assistant



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## Dr. Heumann, Saskia

Max Planck Institute for Chemical Energy Conversion (MPI-CEC)  
Stiftstrasse 34-36, 45470 Mülheim an der Ruhr  
Tel.: +49 2083063701  
E-Mail: [saskia.heumann@cec.mpg.de](mailto:saskia.heumann@cec.mpg.de)

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### Biographic keypoints:

- Diploma: Christian-Albrechts-Universität zu Kiel, Dipl. Chem. (2003-2008)
- Diploma thesis: IFM-GEOMAR, Leibnitz Institute, Marine Chemistry (2009)
- Dr. rer. nat.: Christian-Albrechts-Universität zu Kiel, Inorganic Chemistry (Prof. Dr. W. Bensch) (2012)
- Group leader: MPI CEC (since 2012)

### Current position:

Group Leader



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## Higgins, Luke

School of Chemical and Process Engineering,  
University of Leeds, Clarendon Road, Leeds LS2 9JT  
Tel.: +44 1133 436737  
E-Mail: [pmljrh@leeds.ac.uk](mailto:pmljrh@leeds.ac.uk)

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### Biographic keypoints:

- Master of Physics (MPhys), University of Kent, 2012–2016
- PhD, University of Leeds, CDT Bioenergy, 2016–(ongoing)

### Current position:

PhD Student



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## Hoffmann, Viola

University of Hohenheim,  
Garbenstr. 9, Stuttgart Hohenheim, Germany  
Tel.: +49 (0)711 459 23393  
E-Mail: [viola.hoffmann@uni-hohenheim.de](mailto:viola.hoffmann@uni-hohenheim.de)

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### Biographic keypoints:

- Bachelor and Master studies in Heidelberg, Bogota und Weimar
- PhD Candidate and part of the BBW ForWerts Graduate Program at the University of Hohenheim, Department of Conversion Technologies of biobased resources (current)

### Current position:

PhD Candidate



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## Ischia, Giulia

University of Trento, Department of Civil,  
Environmental and Mechanical Engineering,  
via Mesiano 77, 38123 Trento, Italy  
Tel.: +39 3663717893  
E-Mail: [giulia.ischia-1@unitn.it](mailto:giulia.ischia-1@unitn.it)

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### Biographic keypoints:

- MSc in Energy Engineering (joint program between University of Trento and Free University of Bolzano)
- Thesis title “Biofuels production from organic fraction of municipal solid waste through hydrothermal carbonization and pyrolysis”, carried out at University of Trento (Italy) and Boston University (USA).

### Current position:

PhD student



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## Dr. Jeong, Changyoon

Louisiana State University, Agricultural Center,  
Red River Research Station, 262 Research Station,  
Bossier City, LA 71112  
Tel.: +1 3187417430  
E-Mail: [cjeong@agcenter.lsu.edu](mailto:cjeong@agcenter.lsu.edu)

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### Biographic keypoints:

- expertise in water quality, soil chemistry, soil and water conservation, and carbon and nitrogen cycles

### Current position:

Assistant Professor



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## Keiller, Benjamin

University of Adelaide  
Adelaide, South Australia 5005

E-Mail: [benjamin.keiller@adelaide.edu.au](mailto:benjamin.keiller@adelaide.edu.au)

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### Biographic keypoints:

- International Baccalaureate Diploma at Pembroke School in 2010
- Bachelor of Science (Biotechnology), majors in Chemistry and Biochemistry at University of Adelaide in 2013
- First Class Honours Degree of Bachelor of Science in Biochemistry at University of Adelaide in 2014

### Current position:

PhD Student



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## Dr. Kern, Jürgen

Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB),  
Max-Eyth-Allee 100, 14469 Potsdam, Germany  
Tel.: +49 3315699123  
E-Mail: [jkern@atb-potsdam.de](mailto:jkern@atb-potsdam.de)

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### Current position:

Senior scientist



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## Khoshbouy, Reza

Tokyo Institute of Technology, 4259 Nagatsuta,  
Midori-ku, Yokohama 226-8502, Japan  
Tel.: +81 8099874746  
E-Mail: [khoshbouy.r.aa@m.titech.ac.jp](mailto:khoshbouy.r.aa@m.titech.ac.jp)

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### Biographic keypoints:

- final year PhD student at Tokyo Institute of Technology (Tokyo Tech), Japan
- B.Sc. and M.Sc. degree from Department of Chemical Engineering from Sahand university of Technology, Iran
- His research interests are focused on the removal of organic and inorganic pollutants from aqueous and gaseous area by adsorption technology on hydrochars and modified hydrochars prepared from hydrothermal carbonization of bioresource wastes
- Currently doing research on the development of cost-effective functionalized adsorbent for removing of heavy metal ions from water and wastewater streams

### Current position:

Doctoral student



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## Kleiber, Elisabeth

Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB),  
Max-Eyth-Allee 100, 14469 Potsdam, Germany  
Tel.: +49 3315699336  
E-Mail: [ekleiber@atb-potsdam.de](mailto:ekleiber@atb-potsdam.de)

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### Biographic keypoints:

- 2013–2016, DHBW Mosbach: Bachelor of Engineering (Maschinenbau-Verfahrenstechnik)
- 2016–2018, TH Wildau: Master of Engineering (Maschinenbau)
- 03/2018–03/2019: Research Assistant at ATB

### Current position:

Doctoral candidate at Anhalt University of Applied Sciences, Köthen (Anhalt)



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## Köchermann, Jakob

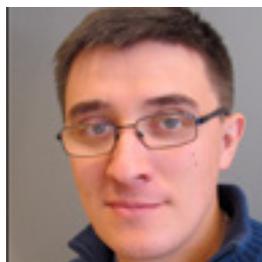
DBFZ - Deutsches Biomasseforschungszentrum  
gemeinnützige GmbH,  
Torgauer Straße 116, 04347 Leipzig, Germany  
Tel.: +49 3412434359  
E-Mail: [jakob.koechermann@dbfz.de](mailto:jakob.koechermann@dbfz.de)

### Biographic keypoints:

- 2016–present: PhD student DBFZ
- 2015–2016: research fellow DBFZ
- 2007–2014: Studies in chemical engineering at Karlsruhe Institute of Technology and Dresden University of Technology

### Current position:

PhD Student



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## Dr. Kozyatnyk, Ivan

Umeå University, Department of Chemistry,  
SE-901 87 Umeå, Sweden  
Tel.: +46 767976960  
E-Mail: [ivan.kozyatnyk@umu.se](mailto:ivan.kozyatnyk@umu.se)

### Biographic keypoints:

- graduated from National Technical University of Ukraine "Kiev Polytechnic Institute" in 2005
- 2009: PhD thesis on "Natural organic matters transformation in the processes of water purification and treatment" in A.V. Dumansky Institute of Colloid and Water Chemistry National Academy of Science of Ukraine.
- Post-doc in Department of Chemistry, Umeå University, Sweden.
- Topic of study is focusing on after-treatment of end-of-life biochar adsorbents and comparative evaluation with regard to both environmental and economical sustainability

### Current position:

Senior research engineer



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## Prof. Kruse, Andrea

University of Hohenheim, Institute of Agricultural Engineering, Depart. Conversion Technologies of Biobased Resources (440f), Garbenstrasse 9, 70599 Stuttgart, Germany  
Tel.: +49 71145924700  
E-Mail: [andrea.kruse@uni-hohenheim.de](mailto:andrea.kruse@uni-hohenheim.de)

### Biographic keypoints:

- Study of Chemistry (University of Heidelberg)
- Doctorate of Applied Physical Chemistry (University of Heidelberg, Research Center Karlsruhe)
- Habilitation in Chemical Engineering
- Junior and later senior scientist in the Karlsruhe Institute of Technology
- Since 2012 full professor at the University of Hohenheim

### Current position:

Professor



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## Kuhles, Alfons

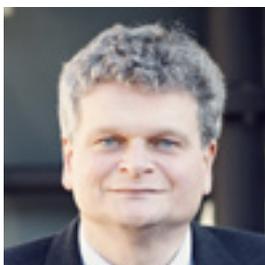
GRENOL GmbH & Co.KG  
Artzbergweg 6, 40882 Ratingen/Meiersberg  
Tel.: +49 21042145153  
E-Mail: [alfons.kuhles@grenol.de](mailto:alfons.kuhles@grenol.de)

### Biographic keypoints:

- Farmer
- Politician
- Founder of the GRENOL company

### Current position:

CEO



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## Kusche, Stepan

Bundesverband Hydrothermale Carbonisierung e.V.  
HTCycle AG, Libnower Landstraße 1  
17390 Murchin-Relzow, Germany  
Tel.: +49 39718769024  
E-Mail: [stepan.kusche@bv-htc.de](mailto:stepan.kusche@bv-htc.de) / [s.kusche@ipi.ag](mailto:s.kusche@ipi.ag)

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### Biographic keypoints:

- Seaborne ERL Environmental Research Laboratory GmbH, Owschlag
- Ader Abwasser Anlagen AG, Bruchsal
- CWG/PWT, Mannheim/Hockenheim
- VESCON Systems AG, Frankenthal
- AVA - CO<sub>2</sub> - Forschung, Karlsruhe
- HTCycle AG

### Current position:

Technical director



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## Dr. Latham, Kenneth

Umeå University, Department of Chemistry,  
SE-90 1 87, Umeå, Sweden

E-Mail: [kenneth.latham@umu.se](mailto:kenneth.latham@umu.se)

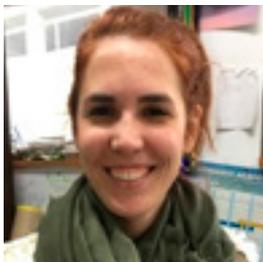
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### Biographic keypoints:

- postdoctoral research fellow at Umeå University,
- examining the hydrothermal carbonization of lignin and lignin containing waste materials for use as adsorbents and electrochemical capacitors
- experience in the doping of hydrothermal carbons, electrochemical capacitors and advanced synchrotron characterization methods

### Current position:

Postdoctoral Research Fellow



## Dr. Ledesma, Beatriz

University of Extremadura, Department of Applied Physics, Avda. Elvas, s/n, 06006, Badajoz (Spain).  
Tel.: +34 924289600  
E-Mail: [beatrizlc@unex.es](mailto:beatrizlc@unex.es)

### Biographic keypoints:

- Degree in Chemical Engineering (University of Extremadura, UEX, 2008)
- Other academic Masters as the Master of Preventional Risks (3 specialities, 2010), and official titles (B2) of English
- PhD on the regeneration of activated carbons by means of thermal treatment (with and without the addition of an activating agent) and wet oxygen regeneration
- Teaching experience in different areas (Applied Physics and Thermal engines)
- Field of research: use of wastes for energy via thermochemical processes as well as the production of porous materials for several applications, with a scientific production of more than 30 scientific papers on these topics.

### Current position:

Researcher at the Applied Physics Department (University of Extremadura, Spain)



## Dr. Libra, Judy

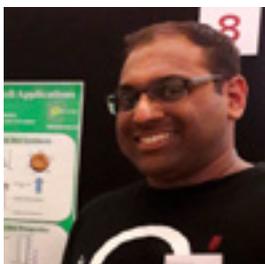
Leibniz-Institut für Agrartechnik und Bioökonomie e.V. Max-Eyth-Allee 100 14469 Potsdam, Germany  
Tel.: +49 3315699856  
E-Mail: [jlibra@atb-potsdam.de](mailto:jlibra@atb-potsdam.de)

### Biographic keypoints:

- started her career as a chemical engineer in the petrochemical industry before getting her Ph.D. in Civil and Environmental Engineering at UCLA, Los Angeles
- received her habilitation in environmental process engineering from the Technische Universität Berlin (TUB), lecturing at both the TUB and the Brandenburg Technical University Cottbus senior researcher at the Leibniz Institute of Agricultural Engineering and Bioeconomy e.V. (ATB) since 2011
- research in biochar focusses on understanding how the conversion processes (hydrothermal carbonization, pyrolysis) affect product characteristics as well as impacts the use of biochar materials on soil and in environmental applications
- her work at the German Federal Environment Agency and the German Academy of Science and Engineering (acatech) focussed on the sustainable management of water resources

### Current position:

Senior researcher



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## Lobo, Richard

Department of Chemical Engineering  
Imperial College, Imperial College Rd  
Kensington, London SW7 2AZ  
Tel.: +44 20 75895111  
E-Mail: [r.lobo19@imperial.ac.uk](mailto:r.lobo19@imperial.ac.uk)

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### Biographic keypoints:

- Master of Engineering from Trinity College, Oxford in Materials Science
- Worked as a design engineer on lyophilization analytical instruments

### Current position:

PhD Student



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## Lühmann, Taina

DBFZ - Deutsches Biomasseforschungszentrum  
gemeinnützige GmbH,  
Torgauer Straße 116, 04347 Leipzig, Germany  
Tel.: +49 341 2434357  
E-Mail: [taina.luehmann@dbfz.de](mailto:taina.luehmann@dbfz.de)

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### Biographic keypoints:

- Studied chemical engineering in Merseburg (Germany) and Göteborg (Sweden)
- M.Sc. in Chemical Engineering, Chalmers University of Technology
- Since 2017: Researcher at the DBFZ
- Focus area: Hydrothermal carbonization of fibrous materials

### Current position:

Research Associate



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## Luo, Hui

Queen Mary University of London, School of Engineering and Materials Science,  
Mile End Road, E14NS, London, UK  
Tel.: +44 7762258871  
E-Mail: [hui.luo@qmul.ac.uk](mailto:hui.luo@qmul.ac.uk)

### Biographic keypoints:

- currently doing a PhD at Queen Mary University of London, United Kingdom in Prof. Magdalena Titirici's group
- Her research project is about investigating the optical properties of hydrothermally prepared carbon dots and using it as photocatalyst for hydrogen evolution applications

### Current position:

PhD student



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## Dr. Mäkelä, Mikko

Aalto University, School of Chemical Engineering  
Vuorimiehentie 1, 02150 Espoo, Finland  
Tel.: +35 8505980361  
E-Mail: [mikko.makela@aalto.fi](mailto:mikko.makela@aalto.fi)

### Biographic keypoints:

- Doctorate in Environmental Technology within the Process Industry from Aalto University, Finland in 2012
- Postdoctoral researcher on sludge treatment at the Swedish University of Agricultural Sciences, Sweden during 2013-2015, researcher at the same institution since 2015
- Postdoctoral researcher on hydrothermal carbonization of sludge at the Tokyo Institute of Technology, Japan during 2015-2016
- Postdoctoral researcher at Aalto University since 2017
- Main research areas include biomass and waste conversion for fuel and material applications, experimental design, spectral imaging and chemometrics.

### Current position:

Postdoctoral researcher



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## Marín Batista, José Daniel

Autonomous University of Madrid,  
Department of Chemical Engineering,  
Campus de Cantoblanco, 28049 Madrid, Spain  
Tel.: +34 914975012  
E-Mail: [josed.marin@estudiante.uam.es](mailto:josed.marin@estudiante.uam.es)

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### Biographic keypoints:

- Chemical engineer with expertise in biological treatment of wastewater and waste management
- Relevant experience in the start-up of laboratory and pilot scale biological reactors
- Skills in modelling and control/simulation of biological processes using SIMULINK/MATLAB, ASPEN PLUS, MINITAB

### Current position:

Doctoral student



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## Marklund, Erik

Luleå University of Technology, Waste Science & Technology, SE 971 87 Luleå, Sweden  
Tel.: +46 920 491287  
E-Mail: [erik.1.marklund@ltu.se](mailto:erik.1.marklund@ltu.se)

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### Biographic keypoints:

- 2011–2013 Masters degree in Industrial Ecology at the Royal Institute of Technology, Stockholm Sweden
- 2016–current, PhD student in Waste Science & Technology, Luleå Sweden
- 2019/01 Defense of licentiate thesis, “Treatment oriented waste characterization”, Luleå Sweden

### Current position:

PhD-student



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## Marzban, Nader

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Leibniz Institute of Agricultural Engineering and Bio-economy e.V. (ATB),  
Max-Eyth-Allee 100, 14469 Potsdam, Germany  
Tel.: +49 1788038864  
E-Mail: [nmarzban@atb-potsdam.de](mailto:nmarzban@atb-potsdam.de)

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### Biographic keypoints:

- Phd student at Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Potsdam, Germany

### Current position:

PhD student



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## Massaya, Jackie

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University of Bath,  
Department of Chemical Engineering,  
9 West 2.04c, Bath, BA2 7AY, UK  
Tel.: +44 7380196304  
E-Mail: [j.massaya@bath.ac.uk](mailto:j.massaya@bath.ac.uk)

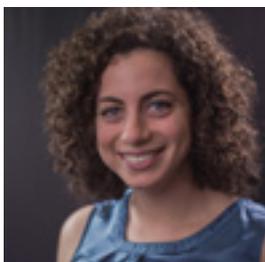
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### Biographic keypoints:

- MChem: University of Edinburgh 2015
- Began postgraduate research at the University of Bath in October 2017

### Current position:

Postgraduate researcher (2<sup>nd</sup> year)



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## Mau, Vivian

Ben Gurion University of the Negev,  
Zuckerberg Institute for Water Research,  
Midreshet Ben Gurion 84900, Israel  
Tel.: +97 2544952645  
E-Mail: [vivimau@gmail.com](mailto:vivimau@gmail.com)

---

### Biographic keypoints:

- Bachelor's degree in Bioresource Engineering from McGill University, Canada
- Master's degree in Hydrology from Ben Gurion University of the Negev, Israel
- Currently in 3<sup>rd</sup> year of Ph.D. studies at Ben Gurion University researching HTC of poultry litter
- has published 3 papers from her HTC research in leading journals
- Volunteered with Engineers Without Borders Canada, including a 4-month placement in Malawi working on sanitation issues

### Current position:

PhD-student



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## Dr. Meisel, Kathleen

DBFZ - Deutsches Biomasseforschungszentrum  
gemeinnützige GmbH,  
Torgauer Straße 116, 04347 Leipzig, Germany  
Tel.: +49 3412434472  
E-Mail: [kathleen.meisel@dbfz.de](mailto:kathleen.meisel@dbfz.de)

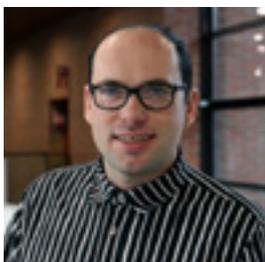
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### Biographic keypoints:

- holds a Diploma in Geography and obtained a doctorate in the field of environmental assessments
- research scientist at DBFZ she primarily conducts life cycle assessments of biofuel-, bioenergy- and biomaterial production systems.

### Current position:

Research Fellow



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## Melin, Kristian

VTT Technical Research Centre of Finland  
Tietotie 4C, Espoo, Finland  
Tel.: +358 403575489  
E-Mail: [kristian.melin@vtt.fi](mailto:kristian.melin@vtt.fi)

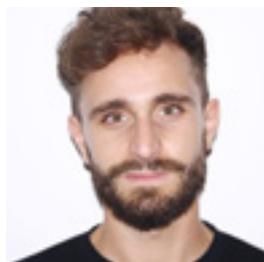
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### Biographic keypoints:

- 2015–2018: Senior Scientist VTT Technical Research Centre of Finland
- Techno-economical analysis, simulation, and process development of novel technologies related to biomass or waste utilization for material products, chemicals and fuels.
- 2009–2015: Teaching, doctoral studies and multiple research project in the field biofuels and wet oxidation of black liquor at Aalto University
- 2004–2009: work in oil& petrochemical industry Perstorp, Neste and Borealis as a process development engineers and process design engineer

### Current position:

Senior Scientist



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## Modugno, Pierpaolo

Queen Mary University of London, School of Engineering and Materials Science, Mile End Road, London E1 4NS, UK  
Tel.: +44 7456709395  
E-Mail: [p.modugno@qmul.ac.uk](mailto:p.modugno@qmul.ac.uk)

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### Biographic keypoints:

- 2014: Master's Degree in Chemical Science at Università di Bari Aldo Moro
- 2011: Bachelor's Degree in Chemistry at Università di Bari Aldo Moro

### Current position:

PhD candidate



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## Moloeznik Paniagua, Daniela

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Straße des 17.Juni 135, 10623 Berlin  
Tel.: +49 3031425087  
E-Mail: [d.moloeznikpaniagua@tu-berlin.de](mailto:d.moloeznikpaniagua@tu-berlin.de)

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**Current position:**  
Scientific Assistant



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## Nicolae, Sabina Alexandra

Queen Mary University of London, School of Engineering and Materials Science, Mile End Road  
London E1 4NS, UK

E-Mail: [sabina.nicolae@qmul.ac.uk](mailto:sabina.nicolae@qmul.ac.uk)

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**Biographic keypoints:**

- BSc in General Chemistry – Faculty of Chemistry, University of Bucharest
- MSc in Chemistry of Advanced Materials - Faculty of Chemistry, University of Bucharest
- PhD Student at Queen Mary University of London, School of Engineering and Material Science

**Current position:**  
PhD student



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## Nowotny, Manuel

Carl-von-Ossietzky-University Oldenburg  
Carl von Ossietzky Straße 9-11, 26129 Oldenburg  
Tel.: +49 441 7983829  
E-Mail: [manuel.nowotny@uni-oldenburg.de](mailto:manuel.nowotny@uni-oldenburg.de)

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### Biographic keypoints:

- 2016–today: Carl-von-Ossietzky-Universität, Oldenburg, Ph.D. Student  
Thesis: Production of activated biochars made from agricultural waste by Hydrothermal Carbonization
- 2013–2016: TU Dortmund, chair of technical chemistry, M.Sc. Chemistry  
Thesis: Ruthenium-catalyzed hydrogenation of carbon dioxide to N, N-dimethylformamide and other formamides with subsequent catalyst recovery
- 2010–2013: Westfälische Hochschule, Recklinghausen, B.Sc. Chemistry  
Thesis: Chain-extended cellulose acetate - melt processability of chains-extended cellulose acetate in the extruder
- 2013–2015: Fraunhofer UMSICHT, Oberhausen, Student assistant
- 2014–2015: TU Dortmund, chair of technical chemistry, student assistant

### Current position:

PhD student



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## Pecchi, Matteo

Faculty of Science and Technology,  
Free University of Bolzano,  
Piazza Università 5, 39100 Bolzano, Italy  
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E-Mail: [matteo.pecchi@natec.unibz.it](mailto:matteo.pecchi@natec.unibz.it)

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### Biographic keypoints:

- Bachelor Degree in Environmental Engineering (University of Modena, Italy)
- Erasmus at NTNU, Norway
- Master Thesis at DLR, Stuttgart, Germany
- Master Degree in Energy Engineering (University of Trento and University of Bolzano, Italy)
- PhD student in Energy Engineering in Bioenergy and Thermodynamics (University of Bolzano, Italy)

### Current position:

PhD Student



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## Pérez, Carla

Processum Biorefinery Initiative AB/ Umeå  
University, Department of Chemistry, SE-90187  
Umeå, Sweden  
Tel.: +46 728490873  
E-Mail: [carla.perez@umu.se](mailto:carla.perez@umu.se)

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### Biographic keypoints:

- Chemical engineer graduate at the University of Gran Canaria, Spain.
- Master in Chemical Engineering for energy and environment at the Royal Institute of Technology in Stockholm, Sweden

### Current position:

PhD Candidate



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## Qiao, Mo

Department of Chemical Engineering, Imperial Col-  
lege London, South Kensington Campus, London,  
SW7 2AZ, UK  
Tel.: +44 7842244340  
E-Mail: [m.qiao@imperial.ac.uk](mailto:m.qiao@imperial.ac.uk)

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### Biographic keypoints:

- Research focuses on targeted design and synthesis of carbon-based electrode materials for energy storage and conversion devices
- Research experiences include graphene-based and biomass-derived carbon hybrids, and extended studied materials includes ionic liquids and polymers
- Capable of independently design, synthesis and characterise nano-scale composites
- Familiar with electrochemistry analysis such as cyclic voltammetry, electrochemical impedance spectroscopy, etc.
- highly motivated scientific researcher as well as good communicator bridging the collaborations between UK and Chinese scientific researchers
- Keen and enthusiastic to work in the field of energy storage, energy conversion, and other related fields.

### Current position:

PhD student

Postdoctoral Research Associate



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## Redd, Bryan Gooch

ThermChem Corporation  
330 NW Royal Blvd., Portland, Oregon 97210, USA  
Tel.: +1 5033147632  
E-Mail: [bryan.redd@thermchem.com](mailto:bryan.redd@thermchem.com)

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### Key points of the biography:

- Research scientist in Estuarine Ecology.
- Owner and Founder of Environmental Consulting firm
- Lawyer, with focus on Environmental and Business Law
- CEO of Environmental Technology/Hazardous Waste Remediation company with 300+ employees
- Co-founder and CEO of a holding company with a portfolio of small businesses.

### Current position:

President and Founder



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## Dr. Reza, Toufiq

Ohio University, Mechanical Engineering  
Athens, OH 45701

E-Mail: [reza@ohio.edu](mailto:reza@ohio.edu)

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### Key points of the biography:

- Assistant Professor of Mechanical Engineering at the Ohio University
- Ph.D. and M.S. in Chemical Engineering at University of Nevada, Reno in 2013 and 2011
- Published 39 peer-reviewed journal articles, 3 patent applications, 2 book chapters, and numerous oral and poster presentations in Europe and USA
- Primary research interests: thermochemical and biochemical conversion processes including hydrothermal carbonization, hydrothermal liquefaction, torrefaction, pyrolysis, anaerobic digestion, wet air oxidation, and pelletization
- His research covers the fundamentals of mass and energy balance, reaction engineering, mass and heat transfer, separations, particle technology, process design, and safety analysis

### Current position:

Assistant professor



## Dr. Ro, Kyoung S.

USDA-ARS Coastal Plain Soil, Water and Plant Conservation Research, Florence, SC, USA  
 Tel.: +1 8436695203  
 E-Mail: [kyoung.ro@usda.gov](mailto:kyoung.ro@usda.gov)

### Biographic keypoints:

- Research environmental engineer for the USDA Agricultural Research Service (USDA-ARS), Florence, SC
- His educational training includes BS in Chemical Engineering and Ph.D. in Civil Engineering from University of California at Berkeley (UCB) and Los Angeles (UCLA)
- Before joining the USDA-ARS, Dr. Ro worked as a faculty for the Louisiana State University (LSU) and the City University of New York (CUNY)
- current research interests are: assessment of fugitive gas emission from animal feeding operations and development of innovative thermochemical techniques in converting agricultural and livestock wastes to value-added products

### Current position:

Research Environmental Engineer



## Dr. Román, Silvia

Department of Applied Physics, University of Extremadura. Avda. Elvas, s/n, 06006, Badajoz (Spain)  
 Tel. +34 924289600  
 E-Mail: [sroman@unex.es](mailto:sroman@unex.es)

### Biographic keypoints:

- Degree in Applied Chemistry (University of Central Lancashire, UK, 2001) and Chemical Engineering (University of Extremadura, UEX, 2003)
- Other academic Masters as the Master of Science (2008), Teaching Skills Master (2004), International Cooperation and Development Master (2008), Preventional Risks (3 specialities, 2010), and official titles (C1) of English, French (B2) and Portuguese (B2)
- PhD on the production of activated carbons from biomass and their applicability in radioiodine adsorption in Nuclear Plants
- Teaching experience in different areas (Applied Physics, Thermal engines, Materials and Metallurgical Engineering)
- Field of research: use of wastes for energy via thermochemical processes as well as the production of porous materials for several applications

### Current position:

Professor at the Applied Physics Department



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## Dr. Ross, Andrew

University of Leeds, School of Chemical & Process Engineering, Leeds, West Yorkshire, LS2 9JT, UK

E-Mail: [a.b.ross@leeds.ac.uk](mailto:a.b.ross@leeds.ac.uk)

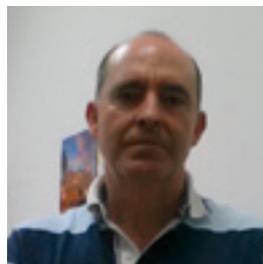
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### Biographic keypoints:

- Dr Andrew Ross is an Associate Professor within the School of Chemical and Process Engineering at Leeds University and has research interests in Bioenergy, Biorefining and Industrial Biotechnology
- He has a background in Energy and Environmental Engineering and has particular expertise in hydrothermal conversion of biomass and waste.
- Current projects within his research group include integration of hydrothermal conversion with anaerobic digestion, hydrothermal conversion of algal biomass, combustion and gasification of biocoal from hydrothermal carbonisation, extraction and recovery of nutrients from biomass and advanced characterisation of carbonaceous materials.

### Current position:

Associate Professor



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## Prof. Sabio, Eduardo

University of Extremadura,  
Department of Applied Physics,  
Avda. Elvas, s/n, 06006, Badajoz, Spain  
Tel.: +34 924289600

E-Mail: [esabio@unex.es](mailto:esabio@unex.es)

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### Biographic keypoints:

- Degree in Chemistry (University of Extremadura, UEX, 1985)
- University lecturer since 2000
- Teaching experience in different areas: (Applied Physics, Thermal engines, currently teaching subjects like technical thermodynamics and energy efficiency)
- Field of research: Multiphysics modeling, use of wastes for energy via thermochemical processes as well as the production of porous materials for several applications, with a scientific production of more than 50 scientific papers on these topics
- Recently awarded with research recognition prizes such as “teaching excellence”, and “Vector for technical engineers” given by the University of Extremadura

### Current position:

Professor at the Applied Physics Department



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## Ekenthalu, Vicky Shettigondahalli

University Rostock,  
Tannenweg 22/Halle 1, 18059 Rostock  
Tel.: +49 3814034994  
E-Mail: [vicky.ekenthalu@uni-rostock.de](mailto:vicky.ekenthalu@uni-rostock.de)

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### Biographic keypoints:

- Master in Environmental resource management from Brandenburg Technical University, Cottbus
- currently working as a scientific assistant at University Rostock
- previous experience working in lab in the field viz., wastewater treatment, water purification, preparation of adsorbent
- anticipating to start my PhD within next few months in the field of sewage sludge management using Hydrothermal Carbonization as a key technology.

### Current position:

Scientific assistant



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## Dr. Siipola, Virpi

VTT Technical Research Centre of Finland Ltd  
P.O.Box 1000, FI-02044 VTT, Espoo, Finland  
Tel.: +358 40 823 7143  
E-Mail: [virpi.siipola@vtt.fi](mailto:virpi.siipola@vtt.fi)

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### Biographic keypoints:

- MSc in Inorganic chemistry
- PhD in Environmental soil science

### Current position:

Research Scientist



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## Prof. Titirici, Maria-Magdalena

---

Department of Chemical Engineering  
Imperial College, Imperial College Rd  
Kensington, London SW7 2AZ, UK  
Tel.: +44 20 7594 5601  
E-Mail: [m.titirici@imperial.ac.uk](mailto:m.titirici@imperial.ac.uk)

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### Biographic keypoints:

- PhD at the Technical University of Dortmund in 2005
- working on molecularly imprinted polymers for her postgraduate studies at the Johannes Gutenberg University Mainz
- completed a postdoc at the Max Planck Institute of Colloids and Interfaces
- joined Queen Mary University of London in 2013 as a Reader,
- Professor in 2014
- moved to Imperial College in the Chemical Engineering Department in 2019
- interested in how carbon nanomaterials produced in hydrothermal processes (HTC) can be used in electrocatalytic reactions, including oxygen reduction and oxygen evolution.
- leads a large research group who work on several projects focussed on sustainable materials
- published over 130 publications in peer-reviewed scientific journals. She contributed to the book *Global Sustainability: A Nobel Cause*.

### Current position:

Professor of Sustainable Energy Materials at Imperial College London



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## Umar, Yahaya Balarabe

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University of Leeds, LS2 9JT, Leeds, UK  
Tel.: +44 7741916955  
E-Mail: [pm10ybu@leeds.ac.uk](mailto:pm10ybu@leeds.ac.uk)

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### Biographic keypoints:

- MSc. Energy and Environment, UK,
- BEng. Chemical Engineering, Nigeria.

### Current position:

Postgraduate Researcher (PhD Student)



## Villamil Martínez, John A.

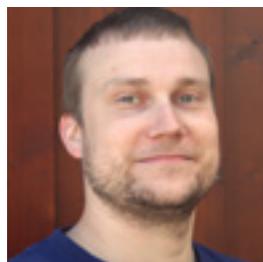
Autonomous University of Madrid,  
Chemical Engineering Department,  
Campus de Cantoblanco, 28049 Madrid, Spain  
Tel.: +34 914973525  
E-Mail: [john.villamil@uam.es](mailto:john.villamil@uam.es)

### Biographic keypoints:

- Master degree in Engineering focused on environmental management from Andes University (Colombia) and a Master degree in Environmental Engineering from the University of Santiago de Compostela (Spain)
- skilled in aspects of chemical engineering including a solid foundation in engineering principles and environmental aspects
- currently a Ph.D. student at Autonomous University of Madrid (Spain)
- particularly interested in the topics of technologies for waste and wastewater treatments such as hydrothermal carbonization (HTC) and anaerobic digestion
- current research centers around the valorization of different biomass (algae, manure, sewage sludge) by the integration of HTC and anaerobic digestion as well as nutrients recovery from hydrochar and aqueous phase from HTC.
- research stays in the University of Reno, Nevada (EE.UU.)
- co-author of 6 referred papers in scientific journals

### Current position:

PhD student



## Wirth, Benjamin

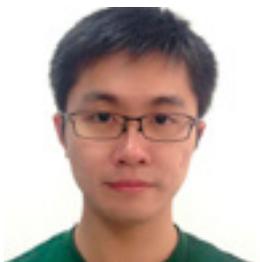
DBFZ Deutsches Biomasseforschungszentrum  
gemeinnützige GmbH,  
Torgauer Straße 116, 04347 Leipzig, Germany  
Tel.: +49 341 2434-449  
E-Mail: [benjamin.wirth@dbfz.de](mailto:benjamin.wirth@dbfz.de)

### Biographic keypoints:

- 2012–2016 Research Fellow at Leibniz Institute for Agricultural Engineering and Bioeconomy Potsdam
- since 2016 Research Fellow at DBFZ Leipzig

### Current position:

Research Fellow



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## Xu, Zhen

Imperial College London,  
South Kensington Campus, London SW7 2AZ  
Tel.: +44 7422927533  
E-Mail: [z.xu19@imperial.ac.uk](mailto:z.xu19@imperial.ac.uk)

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### Biographic keypoints:

- 2019–2022: Ph.D. in Chemical Engineering at Imperial College London, UK
- 2017–2018: Ph.D. in Advanced Materials Science at Queen Mary University of London, UK
- 2013–2017: B.Eng. in Polymer Materials and Engineering at Donghua University, China

### Current position:

PhD student



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## Prof. Yanik, Jale

Ege University, Faculty of Science,  
Chemistry Department, 35100 Bornova Izmir  
Tel. +90 3233112386  
E-Mail: [jale.yanik@ege.edu.tr](mailto:jale.yanik@ege.edu.tr)

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### Biographic keypoints:

- Jale Yanik (F) is Professor in Chemistry Department. She has more than 70 papers in scientific journals and an h-index of 29 (web of science, December 2018). Her research activities include conversion of solid wastes, such as biomass, sludges and plastics, into fuels and chemicals. She is expert in thermochemical processes, namely pyrolysis, hydrothermal processes and characterization of process products. Recently, she is focusing on production of biochar/hydrochar production to use as soil amendment and solid fuel.
- She has been coordinating and involving a number of research projects (both national and EU) and supervises numerous MSc. and PhD.

### Current position:

Professor



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## Prof. Yoshikawa, Kunio

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Tokyo Institute of Technology, 4259 Nagatsuta,  
Midori-ku, Yokohama 226-8503, Japan  
Tel.: +81 45 9245507  
E-Mail: [yoshikawa.k.aa@m.titech.ac.jp](mailto:yoshikawa.k.aa@m.titech.ac.jp)

---

### Biographic keypoints:

- graduated from Tokyo Institute of Technology and obtained PhD in 1986.
- worked for Mitsubishi Heavy Industries for one year, and then went back to his home university to become a research associate, associate professor and professor
- major research areas are energy conversion, thermal engineering, combustion, gasification, waste treatment technologies and atmospheric environmental engineering
- wrote more than 200 papers
- main awards are AIAA (American Institute of Aeronautics and Astronautics) Best Paper Award in 1999, ASME (American Society of Mechanical Engineers) James Harry Potter Gold Medal in 2001, JSME (Japan Society of Mechanical Engineers) Environmental Technology Achievement Award in 2006, Fellow of JSME in 2008 and Best Educator Award of Tokyo Institute of Technology in 2014.

### Current position:

Professor

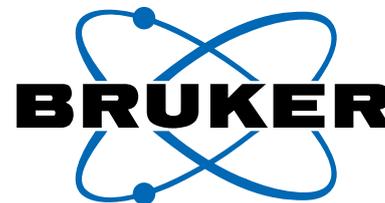
# *Annex*

## Exhibitor – Bruker Optik GmbH

Bruker Optik GmbH  
Permoserstraße 15  
D-04318 Leipzig

Dr. Rayk Hassert  
Applied Spectroscopy  
Sales & Application NIR

Tel.: +49 341 2410945  
E-Mail: Rayk.Hassert@bruker.com  
[www.bruker.com/optics](http://www.bruker.com/optics)



Bruker Optics, part of Bruker Corporation is one of the world's leading manufacturer and supplier of Fourier Transform Infrared, Near Infrared and Raman spectrometers for various industries and applications. Bruker systems made in Germany cover a broad spectrum of applications in all fields of research and development and are used in industrial production processes for the purpose of ensuring quality and process reliability.

Innovation with Integrity

[www.brukeroptics.com](http://www.brukeroptics.com)

## Organizer

DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH  
Benjamin Wirth (Scientific contact)  
Torgauer Straße 116  
04347 Leipzig  
Tel.: +49 341 2434-449  
E-Mail: benjamin.wirth@dbfz.de  
www.dbfz.de



### Our Mission

The DBFZ was established by the former German Federal Ministry of Food and Agriculture (BMEL) with the aim of establishing a central scientific research institution covering all the fields relevant to bioenergy, to bring together the findings of the highly diverse German research community in the sector. The scientific mission of the DBFZ is to support the efficient integration of biomass as a valuable resource for sustainable energy supply based on wide-ranging applied research. The mission incorporates technical, ecological, economic, social policy and energy

business aspects all along the process chain, from production, through supply, to use. The DBFZ drives and supports the development of new processes, methodologies and concepts in close cooperation with industrial partners. It also maintains close links with public-sector research bodies in Germany in the agricultural, forestry and environmental sectors, as well as with European and global institutions. Working from this broad research base, the DBFZ is also tasked to devise scientifically sound decision-making aids for government policy-makers.

### With support by

Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB)  
Max-Eyth-Allee 100  
14469 Potsdam  
Tel.: +49 331 56990  
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www.atb-potsdam.de



SunCoal Industries GmbH  
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14974 Ludwigsfelde  
Tel.: +49 3378 88122  
E-Mail: info@suncoal.com  
www.suncoal.com



## List of participants

<b>Nr.</b>	<b>Name, surname</b>	<b>Institution</b>
1	Alptekin, Hande	Imperial College London
2	Dr. Álvarez-Murillo, Andrés	University of Extremadura
3	Prof. Andreas, Lale	Luleå University of Technology
4	Arauzo Gimeno, Pablo José	University of Hohenheim
5	Dr. Areeprasert, Chinnathan	Kasetsart University
6	Ashour, Radwa	Biokol Sverige AB
7	Dr. Au, Heather	Imperial College London
8	Dr. Axegård, Peter	C-Green technology AB
9	Dr. Bae, Sunyoung	Seoul Women's University
10	Dr. Basso, Daniele	HBI
11	Benavente, Verónica	University of Alicante
12	Bosilj, Monika	Fraunhofer Institute for Solar Energy Systems ISE
13	Dr. Bostyn, Stéphane	ICARE – CNRS
14	Brown, Aaron	University of Leeds
15	Brown, Avery	Worcester Polytechnic Institute
16	Budyk, Yuriy	University of Alicante
17	Buttmann, Marc	TerraNova Energy GmbH
18	Campbell, Bethany	University of Surrey
19	Clay, Lewis	University of Nottingham
20	Coronella, Charles	University of Nevada, Reno
21	Crossley, Oliver	University of Surrey
22	Dang, Huyen Chau	Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB)
23	Dr. Dautzenberg, Geertje	SunCoal Industries
24	Davies, Gareth	University of Sheffield
25	Dr. Diaz, Elena	Universidad Autónoma de Madrid
26	Diestel, Michael	Agrokraft GmbH
27	Dr. Ding, Yuxiao	MPI for Chemical Energy Conversion
28	Dr. Ducey, Thomas F.	USDA – United States Department of Agricultural
29	Dr. Duman Tac, Gözde	Ege University
30	Dr. Dutta, Animesh	University of Guelph
31	Etzold, Hendrik	Deutsches Biomasseforschungszentrum
32	Farru, Gianluigi	PhD student
33	Farthing, Sarah	University of Nottingham
34	Feng, Jingyu	Imperial College London
35	Finnerty, Gillian	The University of Leeds
36	Prof. Fiori, Luca	Università degli Studi di Trento
37	Dr. Fullana, Andres	University of Alicante
38	Dr. Gerner, Gabriel	ZHAW (Zurich University of Applied Sciences)
39	Gievers, Fabian	HAWK (University of Applied Sciences and Arts)
40	Prof. Gokalp, Iskender	ICARE–CNRS

<b>Nr.</b>	<b>Name</b>	<b>Institution</b>
41	Prof. Goldfarb, Jillian	Cornell University
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43	Dr. Gribaudo, Enrico	HBI
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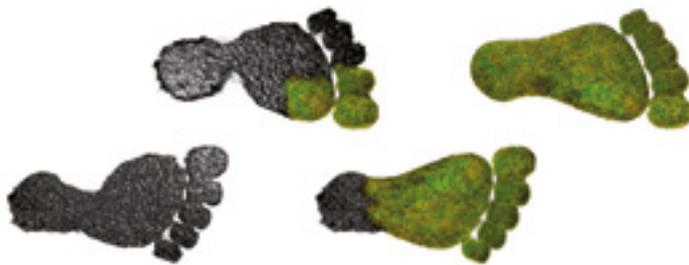
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117	Xu, Zhen	Queen Mary University of London
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