Editorial thematic issue BCAB

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Solid, liquid, and gaseous fuels, produced from biomass in a sustainable way, can help to mitigate global warming and to reduce our dependency on fossil fuels. To improve the possibilities of biomass to be used within our energy system, new approaches and innovative technological solutions are needed. The great challenge is to use even very unfavorable organic matter—e.g., waste streams—in a technically sound, environmentally reasonable, and economically viable manner. Hydrothermal processes, the focus of this topical issue, are such an option. These thermo-chemical conversion processes are very similar to geochemical and geophysical processes responsible for the formation of fossil fuels.

What we are presenting in this issue may thus actually be termed as “geomimetic”—mimicking geochemical and geophysical processes in a technical setting. To be useful for our society, these natural geo-processes need to be accelerated from millions of years to minutes or a few hours at the longest. This acceleration can be achieved by using higher temperatures, pressures, and/or catalysts. The products from hydrothermally treating biomass are very similar, although not identical, to their fossil analogs:

- Hydrothermal carbonization (HTC) leads to a solid bio-char resembling lignite.
- Hydrothermal liquefaction (HTL) yields a biocrude oil. Its properties are closer to fossil crude oil than pyrolysis oil.

- Hydrothermal gasification (HTG) converts organic material into a combustible gas rich in methane or hydrogen, depending on the process conditions.

Interestingly, molecular hydrogen is the only product of hydrothermal (geo-)processes that has not accumulated in a reservoir on Earth. Why? The answer to this question is left to other disciplines.

In the paper of Theliander and colleagues, the stability of bio-oils, obtained from lignin conversion in subcritical water, is studied. They find that only a small amount of higher molecular weight products is formed after 1 week at 80 °C. Several papers deal with the hydrothermal liquefaction of biomass. Sintamarean and colleagues have developed a novel method for the two-stage liquefaction of wood under alkaline conditions in a continuous system. They were able to prepare and process pumpable slurries with up to 25 wt% total solids. Billing and colleagues have performed a liquefaction study with grape pomace. Using the leftovers from wine production (Cabernet Sauvignon and Montepulciano), they produced high yields of a gravity-separable biocrude. The residual process water from HTL was further converted to a methane-rich gas by catalytic HTG. Brilman and coworkers show that the co-liquefaction of wood, micro-algae, and sugar beet pulp can be beneficial for using also dry feedstocks in wet processing such as HTL. However, the biocrude yield was lower in the case of co-liquefaction when compared to the sum of the yields from the individual feedstocks. Lawson and colleagues assess agricultural crops and natural vegetation in Scotland for energy production by anaerobic digestion (AD) and hydrothermal liquefaction. Their study reveals that anaerobic digestion has the potential to yield more energy per mass than HTL alone. Treatment of the HTL water would further increase the total energy yield per mass of feedstock. Jensen and colleagues report about a commercial process for liquefying

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biomass to renewable crude oil. The Hydrofaction™ process is carried out in high-density supercritical water with a homogeneous alkali catalyst. This is one of the rare contributions reporting on total mass and elemental balances of a reasonably large-sized facility. And finally, Savage and coworkers have studied the conversion of different natural oils into hydrocarbon chemicals using a zeolite catalyst under hydrothermal conditions. A yield of up to 50 wt% of aromatic hydrocarbons highlights the potential for such a reaction to produce renewable aromatic building blocks and fuels. Matsumura and colleagues have studied how the amino acid histidine and its building block 4-methyl imidazole react under supercritical water conditions. This kinetic study is important for fostering the understanding of protein conversion to gases. Niceno and colleagues have performed a numerical study of sulfur adsorption on a sorbent material to protect a gasification catalyst located downstream. They find a distinct influence of the geometry of the adsorbent material on the saturation time with sulfur. Boukis and colleagues report on a pilot scale experiment with digestate from a biogas plant applying a catalytic hydrothermal gasification process. A sulfur trap material was placed upstream of the catalyst, which proved effective to

retain most of the sulfur from the biomass. Furthermore, 81% of the phosphorus contained in the digestate could be separated and recovered from the process with a proprietary salt separator device. Another interesting extension of the catalytic HTG is the addition of pressurized hydrogen to boost the production of methane, as reported by Müller and colleagues. Up to 86 vol% of methane were obtained in the raw gas. With this contribution, we close the circle of papers of this thematic issue.

I would like to thank all authors for their valuable contributions to this thematic issue. It nicely highlights the state of knowledge about hydrothermal processing of biomass. A personal hope for this compilation of papers is to become aware of the similarities in the different approaches and to strengthen the ties within our research community.

Such a special issue would not have been possible without the support of our editors Martin Kaltschmitt and Hermann Hofbauer. I would like to thank both colleagues for their confidence and advice. Many thanks also to the editorial team for their support. It has been a real pleasure to guest-edit this thematic issue on hydrothermal processing.