PRO MAN CONSULTING RESEARCH AND INNOVATION

SCCER BIOSWEET CONFERENCE 2020

Biomass to Energy in Switzerland - Achievements and Perspectives

SUMMARY

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The virtual SCCER BIOSWEET Conference 2020, 10th September 2020, was followed by up to 67 attendees and moderated by **Markus Zeifang (PSI)**.

Oliver Kröcher (PSI) welcomed the audience and announced a summary of achievements from seven years research. The Swiss Competence Center of Energy Research (SCCER) teamed with IEA Task 37 and united the Swiss bioenergy research community (PSI, ETH, EPFL, FHNW, ZHAW, HSLU, WSL and SUPSI), while mobilizing 26 full time researchers performing 145 research and technology development projects with 150 collaboration partners. 29 innovations were validated by 47 prototypes, 17 patent applications, 4 licenses, 4 spin-off companies, 192 peer reviewed publications, 111 master and 45 PhD theses, 60 new education and training modules and 39 conferences. The vision of 100 PJ Swiss sustainable biomass potential has been confirmed. Bioenergy is considered the joker in the Swiss energy transition.

Urs Baier (ZHAW) started his review with looking back to the first SCCER BIOSWEET funding period from 2014 to 2016. In this phase research focused on: a) biomethane from wet residues, manure, and algae and b) liquid biofuels from wood, agricultural residues, and algae, both based on pre-treatment, enzymatic hydrolysis, and fermentation. In Phase 2 (2017-2020) work package 1 focused on biomass to biomethane organized in 4 tasks: pre-treatment, high efficiency anaerobic digestion (AD), hydrothermal gasification (HTG), and advanced, high end analytics. Four new technologies were developed: 1) Hydrothermal Gasification (from TRL4 to TRL7) achieving 100% carbon conversion with a net thermal efficiency of 66%. A new, stable ruthenium catalyst has enabled continuous gasification to be soon demonstrated in a 110 kg/h (sewage sludge with 20% dry matter) pilot plant. 2) ManuMax, the acronym for heat integrated steam explosion (from TRL4 to TRL6), an economically promising pretreatment to enhance biogas yields in AD of cow manure and reduce fermentation time by up to 50% to be validated in a pilot starting from October 2020. 3) Scenario analysis of agricultural nutrient and energy hubs in response to decentralized agricultural structures in Switzerland. Installing on-site solid/liquid separation plus liquid digestion while pre-treating and fermenting solids in a larger, centralized unit can mobilize the full manure potential. 4) Lipid extraction from sewage sludge in a liquid/liquid extraction reactor, using butane as extraction agent produced 11 wt.% / dry matter lipids at 5 bar and 60 °C. In addition, hydrothermal carbonization (HTC) was investigated for use of biochar as a non-energy carbon source and new analytical tools were developed. Promising projects will be continued beyond BIOSWEET.

Peter Kornatz (DBFZ Germany) provided an overview of the German climate protection program 2030. While biogas may be a solution to reduce CO_2 emissions, the current and future Renewable Energy Acts (EEG2017 / draft EEG2021) do not provide a supportive economic framework for biogas plant investments – only plants with less than 75 kW installed power capacity have access to a guaranteed feed-in tariff. From a total potential 146 Mt fresh matter (FM) cattle and pig manure only 43 Mt FM are currently converted to biogas, 75% of it in 36% of the AD plants. Economy of scale is highly important. Doubling the use of manure for biogas conversion would cost 2 billion €/year and full use almost 4 billion €/year compared to current expenses of 0.82 billion €/year. However, manure conversion to biomethane and use of biomethane in industry has a significant greenhouse gas reduction potential, up to 6.3 million tons CO_2-equivalents in the agricultural sector and up to 3.8 million tons CO_2-equivalents in the industry sector.

Serge Biollaz (PSI) gave an overview of thermal biomass to biomethane conversion plants, gasification and gas cleaning systems and the continued research for the best combination. While coal gasification is typically large scale (>1 GW), biomass gasification was only implemented at scales from 1-10 MW. The Swiss vision is using 30% of renewable gas in industry, an increase by a factor 10 or 4,500 GWh compared to current supplies. The 2020 Gas Decarbonization Study "Gas for climate – A path to 2050" (Guidehouse) forecasts 1,170 TWh biomethane and 1,710 TWh hydrogen supply for use in buildings (230 TWh), industry (700 TWh), power (1,105 TWh) and heavy transport (845 TWh) in the 2050 net zero emission scenario. The SCCER innovation roadmap has focused on the tasks 1) gas cleaning, 2) biogas to biomethane and 3) conversion of wood-gas to biomethane. The tasks include field sampling, lab tests, field tests and diagnostics. The high content of "nasty" stuff in biowaste, particularly trace S compounds makes the selection of gas cleaning systems difficult. Methanation poses similar challenges and the question if catalytic (at PSI) or biological processes shall be chosen have to answered before the specific process equipment can be selected. A multi-track approach was chosen for methanation of CO_2 and H_2. A study on small-scale – 30-250 m^3 biogas/h - agricultural biomass to biomethane conversion targeted at the Swiss context resulted in a cost range for biomethane from manure in the order of 0.09 – 0.11 CHF/kWh. A smart carbon and sulfur management and investments in large scale commercial biomethane plants are considered as potential development accelerators.

Jerry D. Murphy (University College Cork) presented numerous case studies including: GHG negative milk from a 140 cattle farm in Denmark, a carbon neutral brewery in Austria and biomethane as fuel from grass cuttings of a 400 ha campus in Brazil. The unique position of biogas as a multi-facetted solution for organic waste management, renewable energy, biobased fertilizers and (air + water) pollution prevention was emphasized. The California Air Resources Board awarded a Carbon Intensity Score of -255 g CO_2-equivalents/MJ for a dairy waste-based vehicle fuel. A very high conversion and carbon sequestration efficiency was achieved for eGas: in a testbed of 80 : 20 grass : slurry, with 2% fugitive CH_4 losses and 41% green electricity 2.2 t CO_2-equivalents/ha/year were sequestered. Similar scenarios are conceivable in Ireland planning for 12 GW_{el} offshore wind by 2030: assuming 40% capacity factor, peak power production will be 175% of average demand. Additives to increase the gas yield in biogas plants were investigated, showing similar results for pyrochar and graphene. Denmark plans a fully decarbonized gas in the grid by 2035, corresponding to 72 PJ.

Timothy Griffin (FHNW) summarized WP3 including its tasks, solid biomass fuels for combustion and gasification, burner optimization, process integration of biomass combustion systems, energy system integration to avoid fossil fuel peak supply and thermal recovery of phosphorus from waste biomass – aiming at the development of clean and efficient heating systems with wood, as well as alternative solid biomasses to increase the substitution of fossil energy carriers. In cooperation with the public sector (e.g. BAFU), advanced measurement techniques were developed. Task 1 covered different low quality, high ash, and high moisture fuels and derivates (e.g. HTC and pyrochar), in task 2 a screw burner was developed and optimized for high ash fuels, task 3 focused on particle removal and oxidative pyrolysis and task 4 on energy storage in biomass plants. Task 5 investigated thermal P recovery aiming at producing elementary P for use in P chemistry. Recovery rates of 20% - 95% were achieved depending on the feedstock. Beyond 2020, staged combustion and secondary improvements will be developed in several application-oriented projects with industrial partners.

Jan Liebetrau (Rytec Germany) talked about biogas production in Germany showing that in 2018 close to 10,500 plants were converting biomass, including energy crops, to almost 35,000 GWh electricity, but almost no new capacities were installed since 2012 due to the lack of an attractive support scheme. 203 plants were upgrading biogas to biomethane, mainly used for conversion to power. Fuel traders are legally bound to a GHG reduction by 6% and face high penalties of 470 €/t CO_2-equivalents if not achieved. Natural gas is not yet a popular fuel in Germany but new incentives to establish an advanced fuel sector may offer an opportunity for biomethane as a transportation fuel. A quota for biowaste-based fuels (“Biokraftstoffquote”) leads to a cost of >200 €/per ton of CO_2 avoided and a price range of 40-54 € /MWh biomethane. Flexible operation of biogas plants converting biomass to biomethane or electricity on demand is subsidized but requires investments in gas storage and conversion overcapacity. Case studies investigated different scenarios and conclude that biomethane production for fuel may have a future in Germany.

Jeremy Luterbacher (EPFL) presented his research on conversion of lignin, cellulose and hemicellulose, i.e. high-quality biofuels. Treatment included fractionation to xylose, cellulose, and highly accessible lignin, enzymatic hydrolysis, and fermentation. Modified pathways were developed: 1) The acetal-facilitated deconstruction of biomass resulted in a simple process for the production of a new set of plastic precursors from plants in one single step. 2) The integrated depolymerization of lignin with formaldehyde is able to produce aromatic monomers with 47-90% yield. A spin-off company was founded, attracting 1.3 million CHF in dilutive investments including from a major process company. 3) Use of stabilization group chemistry, particularly the reversible stabilization of xylose and glucose by acetal formation with formaldehyde resulted in a carbohydrate yield of >70% and a final product concentration of ~5 wt.% compared to only 28% yield without formaldehyde. 4) Consolidated bioprocessing (CBP) using optimized steam explosion and oxygen extraction by a biofilm on a membrane produced via catalytic processing (Cu/ZrO_2) mixed fatty acids and a mixture of aromatics, which are possibly used as jet-fuel. CBP applied to bioethanol can save up to 27% of total production cost but needs to be combined with cheap waste feedstock and lower ROI expectations. New and exciting chemical routes can be developed to produce bio-based fuels and chemicals, among others bio-degradable and recyclable PET replacements. Companies are interested to see a diversified pathway, starting with high-value products, and eventually ending up with fuels.

Timo Kikas (Estonian University of Life Sciences) outlined options for pre-treatment to open the lignocellulosic structure of biomass: chemical or physical methods or both methods combined could be used, usually pressure and temperature. Whereas steam explosion, SO_2 explosion, CO_2 explosion and ammonia fiber expansion (AFEX) are available options, the group investigated Nitrogen Explosives Decompression (NED), using nitrogen to pressurize biomass and water. Experiments have shown that optimal glucose yields of up to 120 g/kg can be achieved at 150 °C with >70% hydrolysis efficiency. NED is effectively breaking the biomass structure, at lower temperatures more effective than steam explosion, allowing hemicellulose to remain in the biomass. Planned future work: testing nitrogen mixtures with soluble gas, explosion from the bottom and catching volatiles from explosion.

Oliver Thees (WSL) presented an analysis of 10 types of biomass to be considered for calculating the Swiss biomass potential. Hotspots and cold spots were identified and compared regarding local socio-economic aspects. Cold spots preferred the biomass-to-energy strategy, while hotspots did not. The theoretical Swiss potential is 200 PJ but only 100 PJ could be considered as sustainable and stable resource. Wood supply can respond to demand depending on different management practices, resulting in 3-6 Mm^3 per year. Anaerobic digestion of 65% of Swiss manure can save 159 kt CO_2-equivalents. By digesting 100% manure, 346 kt CO_2-equivalents can be saved corresponding to 7% of the Kyoto target and 1.6% of the Paris Agreement. In addition, sustainable transport distances were evaluated. The symbiotic use of manure needs to be considered: its use reduces GHG emissions, can serve as heater for greenhouses and provides better fertilizer use efficiency. The full use of the biomass potential will require up to 17 km^2 of additional land in Switzerland. A case study in Aargau has shown that a maximum of 13% of energy demand could be supplied by biomass.

Francois Maréchal (EPFL) emphasized the important role of EPFL in the project, contributing to biogas, biomethane and power-to-gas, combustion / combined heat, and power (CHP) and liquid fuels – serving for scenarios for the Swiss energy system. Conversion systems were modelled and designed. The potential for wood was calculated at 50.2 PJ = 14 TWh at 30.1 CHF/MWh (420 MCHF/y) creating 5.43 Mt/y biogenic CO_2 comparing to 46.8 PJ = 13 TWh at 0 CHF/MWh for wet biomass creating 4.89 Mt/y biogenic CO_2. Integrating biomass in district energy systems (DES): the national potential of biomass-based DES needs investments of 31.4 CHF/m^2/y, reducing CO_2 emissions from 61.0 kg CO_2-equivalents/m^2/ y to 6.2 kg CO_2-equivalents/m^2/y. The combined heat and fuel concept from wood-based energy biomass could achieve a fossil carbon substitution between 1.6 and 3.0, up to three times more than the district concept. Carbon flow modelling: avoiding accumulation of CO_2 can be achieved by two options: the decarbonization of the Swiss energy system will cost 16.10 billion CHF/y, sequestrating 1.1 tons CO_2/cap/y. Including the decarbonized bio-jet fuel option would require 19.23 billion CHF/y. The range of biomass technology system costs is 1570 – 2250 CHF/cap/y with total conversion costs of 48-90 CHF/cap/y (20-25 years amortization). In conclusion, a cascade use of biomass is needed, and waste biomass is a key resource. Power to gas is competing with hydropower dams, CO_2 sequestration and hydrogen. If carbon-based fuels are used, CO_2 needs to be captured and separated.

Kari-Anne Lyng (Norsus) called biogas plants "The Magic Factory". In Norway, food waste and sewage sludge are converted to 500 GWh biogas of which 40% is upgraded and used in the transport sector. The grid infrastructure is limited, hence conversion to biomethane fuel is a viable solution. The national objective of livestock manure conversion is 30% but unlikely to be achieved, as the status is only 1% use. The Norwegian focus is on developing circular value chains. Food waste and manure should be fed to AD, digestate used as fertilizer, biogas upgraded to biomethane and used as transport fuel. The impact on climate was measured with the additional objective to better understand the LCA methodology which was adapted to fit the purpose of the study. If several products are produced by a defined process, LCA is a multifunctional system (as is AD), and the different products are assessed using allocation keys, commonly used in Environmental Production Declarations (EPDs) to avoid double accounting of environmental benefits. The impact of an AD plant is assessed by comparing its footprint with a typical reference scenario. The effect is highly positive due to avoiding the typical emissions of the reference scenario: Business as usual emits 72 kg CO_2-equivalents, composting reduces emissions by 98 kg CO_2-equivalents and AD further reduces emissions by 285 kg CO_2-equivalents (AD of food waste) and by 354 kg CO_2-equivalents (AD of food waste and manure). If biomethane is used as a fuel, GHG emissions from AD are 0.25 kg CO_2-equivalents compared to >1 kg CO_2-equivalents for diesel and about 0.10 kg CO_2-equivalents for hydropower electricity. The current AD practice saves more than 14,000 t CO_2-equivalents per year in Norway.

Laura Lang (Innosuisse) presented Switzerland as one of the most innovative countries and with some of the highest GDP related R&D expenses in the world. Innosuisse is part of the Swiss Innovation Agency promoting innovation in four areas: 1) Preliminary studies with an innovation cheque of up to 250 full time equivalents for research partners and up to 15,000 CHF for SMEs, 2) innovation projects funded by grants for 50% of the expenses (40% can be contributed in-kind, 10% in cash), 3) the BRIDGE program with up to 100% grant based funding by the Swiss Science Foundation and Innosuisse and, coming soon, 4) The Flagship Initiative for consortia of more than 2 research partners and 2 implementation partners following the funding rules of innovation projects but invited by dedicated calls. Beyond financial contributions, innovators can ask for coaching, mentoring, and networking support. Project proposals are checked for formal compliance, evaluated, and reviewed in regular evaluation meetings, the whole process taking only 6-8 weeks depending on the dates of evaluation meetings. More information on www.Innosuisse.ch.

Wrapping-up the event, **Oliver Kröcher (PSI)** thanked all contributors, speakers, authors, and Markus Zeifang for his excellent moderation. He emphasized his believe that the future of biomass is still to come. Currently, many people shy away from biomass, but will reconsider and acknowledge its valuable contribution later in the transition to a climate friendly energy mix. **Fréderic Vogel (PSI)** expressed his special thanks to Oliver Kröcher as leader of the SCCER BIOSWEET.