Delivering Sustainable Solutions - The future of R&D - How do we assess and ensure technological innovation gives optimal impact?

SUSTAIN 2018 Kgs.Lyngby
29th Nov - 30th Nov

Table of contents

For updated program and locations see
www.sustain.dtu.dk

Abstract book editors:
Carlos Melero
Kristian Mølhave

Sponsors 2018

Sponsor support

miljø-og energifonden

GRØN DYST™

Sustain

Session

A

Oral Presentations

See session details and schedule on
www.sustain.dtu.dk

Construction transformation

Christian Thuesen*[1], Nina Koch-Ørvad[1]

1: DTU Management Engineering, Engineering Systems, building 424, Kgs Lyngby
*Corresponding author email: chth@dtu.dk

The world relies on our ability to construct. Construction has been the key sector in creating the modern societies of the developed countries, a position for which developing countries also strive. With the future population growth and urbanization, we see increasing requests for housing, schools, transport and energy infrastructure. However, our modern lives and current construction practices is inherently unsustainable and shouldn't be considered as an example for imitation.

In a planetary boundary perspective, an average citizen in the developed countries like Denmark spends 4 times of the world resources. Compared to this, a citizen in Sri Lanka only spends 0.5 times (O'Neill, Fanning, Lamb, & Steinberger, 2018). Construction represents one of the most resource-intensive sectors, accounting for 40% of material consumption, 40% of energy consumption, 33% of water consumption and 30% of the production of waste (Energistyrelsen, 2015).

Recent simulations from the Stockholm Resilience Centre finds that only bold transformative change will allow us to create a sustainable society beyond 2050 (Randers et al., 2018). This has significant implications for construction. The presentation combines various research findings over the last 10 years regarding sustainable innovations within construction. The research finds that we are on the verge of a new construction reality where the request for sustainability and new disruptive technologies transforms the products, processes and organizations of construction. Moving forward, we must identify and evaluate the transformative power of construction, and support the needed transformation of construction practices. This requires systems perspectives that connect the various levels of the built environment from the components to the city and regional level.

References:

Energistyrelsen. (2015). *Bæredygtigt byggeri [Sustainable construction]*. Energistyrelsen.

O'Neill, D. W., Fanning, A. L., Lamb, W. F., & Steinberger, J. K. (2018). A good life for all within planetary boundaries. *Nature Sustainability*, *1*(2), 88–95. http://doi.org/10.1038/s41893-018-0021-4

Randers, J., Rockström, J., Stoknes, E., Golüke, U., Collste, D., & Cornell, S. (2018). *Transformation is feasible*. Stockholm Resilience Centre.

Supporting sustainable construction with sustainable business models

Jakob Brinkø Berg*[1], Per Anker Jensen[1], Christian Thuesen[1]

1: Technical University of Denmark, Department of Management Engineering
*Corresponding author email: jajoh@dtu.dk

In the construction industry, we see a clear trend in the focus on sustainable construction.[1] This is especially apparent in government sustainable procurement program and this leads to the industry developing new capabilities.[2] There is however, a gap between the good practices used in experimental and government supported building projects and the day-to-day reality of normal construction.

To make the leap from a development project to an actual profitable business process requires that the experiments are translated into a sustainable business model. Being sustainable is both a matter of keeping the original sustainability parameters in the project, as well as in an economic sustainability. It requires the mobilization of talent, collaborators and resources, which in the construction industry typically comes from a very fragmented supply chain. A market and target customers have to be identified and viable sales and communication channels have to be put in place. Finally the product or service the company provides has to add value and be desired by the customer, within the constraints of cost and revenue.[3]

In the research conducted with sustainable business models in the construction industry we have relied on workshops, interviews and business model analysis. Through this we have identified key challenges, and forms of collaboration and changed business relationships are proposed. Long-term strategic partnerships can support the creation of social sustainable housing development, use of certification can enable ambitious environmental targets and digital platforms can create new customer-contractor relationships.

[1] B. Xia, J. Zuo, P. Wu, and Y. Ke, “Sustainable construction trends in journal papers,” 2015.
[2] K. Haugbølle *et al.*, *Sustainable refurbishment by public clients: innovation and procurement strategies and practices*. 2013.
[3] A. Osterwalder, “The Business Model Ontology” UNIVERSITE DE LAUSANNE, 2004.

Disrupting the ecosystem: The challenges of circular construction

Nina Koch-Ørvad*[1], Christian Thuesen[1]

1: DTU Management Engineering, Engineering Systems, building 424, Kgs. Lyngby
*Corresponding author email: ninko@dtu.dk

The world is facing a significant transition from a fossil-fuel driven, linear economy to a closed-loop, circular economy. The circular economy (CE) represents a change of paradigm in the way that human society is interrelated with nature and aims to prevent the depletion of resources, close energy and materials loops, and facilitate sustainable development (Prieto-Sandoval, Jaca, & Ormazabal, 2018). For such a transition to happen, completely new configurations of industrial sectors, technologies, consumer practices, as well as multiple radical innovations are needed (Geels, 2002).

In the construction industry, the sustainability agenda is critically urgent, and opportunities for CE business models are particularly promising. In Denmark, the construction industry generates one third of the total amount of waste and as prices on raw materials are currently rising, there is a significant potential for reusing waste as resources. An increasing focus from both the government and companies is on innovative solutions that support the so-called *circular construction.* The founding principles of circular construction lie in the better management of resources (Pomponi & Moncaster, 2017). This can be achieved, for example, by designing buildings for disassembling, planning the deconstruction of the building upfront and by reusing old construction materials.

We have studied a circular economy innovation that is based on the aim of reusing construction materials, namely old bricks. The value proposition of this innovation is rather simple and clear: to avoid waste and depreciation by reusing old bricks, a valuable construction material that brings aesthetics and history into new buildings. However, the innovation's journey towards the market has been remarkable challenging, as it requires a significant change of procedures and relationships between partners in the existing ecosystem (Adner, 2012). Based on this case, we analyse and discuss the challenges of implementing circular economy innovations, and emphasise the importance of adding a systemic, management-oriented lens to the current discussions on circular construction.

References:

Adner, R. (2012). *The wide lens: A new strategy for innovation*. New York, NY: Portfolio/Penguin.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274. http://doi.org/10.1016/S0048-7333(02)00062-8

Pomponi, F., & Moncaster, A. (2017). Circular economy for the built environment: A research framework. *Journal of Cleaner Production*, *143*, 710–718. http://doi.org/10.1016/j.jclepro.2016.12.055

Prieto-Sandoval, V., Jaca, C., & Ormazabal, M. (2018). Towards a consensus on the circular economy. *Journal of Cleaner Production*, *179*, 605–615. http://doi.org/10.1016/j.jclepro.2017.12.224

Recycling Concrete Aggregates in New Concrete: Investigations of Quality and Origin of the Concrete Waste

L.G. Pedersen*[1], K.N. Jensen[2], M.E. Herløv[3], G.M. Kirkelund[4], L.M. Ottosen[5]

Department of Civil Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark.
*logrep@byg.dtu.dk

This study investigates recycled concrete aggregates (RCA), RCA has gained interest the last years[1]. The RCA investigated is in the fractions 4-8 and 8-16 mm of unknown sources, as partial replacement of natural aggregates (NA) in new concrete. The mix designs of the new concrete has been investigated without admixtures or increasing the amount of cement.

The RCA was obtained from concrete waste from four different construction sites in the area around Copenhagen. Three of the construction sites had RCA of unknown sources and the fourth RCA was from Copenhagen airport, which was concrete from a known source with a compressive strength of 45 MPa without contamination from the demolition. The unknown sources of the RCA gave a picture of the average concrete waste around Copenhagen, the quality and level of sorting at the demolition.

A total of 83 concrete mixtures were produced throughout this study, this includes 24 different mix designs and types of concrete curing for 28 days and 59 mix designs curing for 7 days. The amount of cement in the different mix designs was kept equivalent to the references in order to not increase the CO2 emission due to the amount of cement. The constant amount of cement meant that the workability of the new concrete was very dry. This problem was met by investigating different processing procedures of the RCA together with the results from the characterization of the RCA.

Characteristics of the RCA showed that the aggregates had a lower density than NA and a higher water absorption due to the attached mortar. The RCA's high water absorption was encountered by saturating the aggregates, which ensured the amount of free water for the water/cement-ratio (w/c) and thereby also the workability of the concrete.

The proposed mix design methodology demonstrates that the deviation of the compressive strength and the workability of RAC could be met by RCA being saturated by pre-soaking, with the compressive strength at 25.48 - 37.01 MPa depending on the percentages of RCA in relation to the references at 30 MPa for 0.6 w/c-ratio.

The compressive strength and characterization of the RCA of unknown sources show that the maximum requirement according to DS/EN 206 can be used and even exceeded, especially when applying concrete of a known source. Thus, there is a potential for using RCA in new concrete, even without knowing which sources the RCA came from.

[1] Safiuddin, M. et al. (2013). *Use of Recycled Concrete Aggregates in Concrete: A Review.* Journal of Civil Engineering and Management, pp 796-810.

Wood Ashes for Possible Utilisation in Cement-based Materials Evaluated by Multivariate Models

Nina Marie Sigvardsen[1], Lisbeth M. Ottosen[1]

1: Technical University of Denmark

As a result of the necessity to mitigate the pressure on the global environment several actions have been taken. In April 2017, 26 of the 28 EU nations, stated they would not invest in new coal-fired power plants after 2020, in close accordance to the Paris Agreement and the goal to provide 100 % carbon neutral fuel by 2050 [1]. The Paris Agreement leads to an increase in the demand for renewable energy and a reorganisation of the existing energy sector, e.g. from the use of coal to alternative, sustainable fuels for energy production by transforming existing plants. Wood is considered an alternative, sustainable fuel for energy production. Coal fly ash (CFA) is utilised in the production of cement or as a cement replacement, reducing the consumption of cement and the associated CO_2 emission. However, the withdrawal of coal-fired power plants results in a decrease in the availability of CFA. Opposite the availability of new types of ashes will increase, such as wood ash (WA) from wood combustion. These new types of ashes are often landfilled, which is both uneconomical and contaminating, making utilisation of alternative ashes, such as WA, in cement-based materials of interest.

Utilisation of WA in cement-based materials depends on the physiochemical characteristics of WA, which again depends on the parameters of production such as the utilised wood fuel, e.g. wood chips or pellet, and on the combustion process, e.g. temperature, and technology [2]. Multivariate modelling was used to identify the link between production parameters and the physicochemical characteristics of WA and to determine which production parameters result in the WAs most suitable for utilisation in cement-based materials. Based on the multivariate model partial least square, WA originating from circulating fluidised bed combustion of wood chips made from whole trees is the optimal type of WA when utilised as a supplementary cementing material with pozzolanic activity. WA originating from the combustion of wood chips made from whole trees is the optimal type of WA when utilised as a supplementary cementing material with hydraulic activity. The combustion method and type of ash (bottom, fly or mix of bottom and fly ash) were seen to have the largest influence on the physiochemical characteristics of WAs compared to the other production parameters included in this study.

Literature

[1] A. Neslen, The end of coal: EU energy companies pledge no new plants from 2020, Guard. (2017). https://www.theguardian.com/environment/2017/apr/05/the-end-of-coal-eu-energy-companies-pledge-no-new-plants-from-2020.

[2] R. Siddique, Waste Materials and By-Products in Concrete, Springer Berlin Heidelberg, Berlin, Heidelberg, 2008.

Mining sewage sludge ash by electrodialytic separation

Lisbeth M. Ottosen*, Gunvor M. Kirkelund & Pernille E. Jensen

DTU Civil Engineering
*lo@byg.dtu.dk

Ashes are produced in vast amounts worldwide from incineration processes for heat and power production. Examples of materials incinerated are waste, wood or sewage sludge. The ashes are most often residual waste. They are landfilled and are lost from the overall material cycle. The ashes contain valuable, scarce elements, and should be considered as secondary resources; however, to recover the different resources retained in the ashes, it is necessary to develop separation technologies. This work focus on one such technology, namely electrodialytic separation[1], where the ash is suspended in water and an electric DC field is applied. Hereby ions are transported towards the electrode of opposite polarity. During treatment, pH and redox conditions are optimized for desorption of target elements, and ion exchange membranes are used to separate heavy metals ions from the suspension.

This work is on electrodialytic separation of sewage sludge ash (SSA) into resources. Sewage sludge incineration is practiced extensively in many European countries. The produced SSAs have high concentrations of phosphorous, which is a chemical element essential to all life. Phosphate rock is listed as EU critical raw material based on two indicators: high supply risk and equally high economic importance. Currently most P-fertilizers originate from mining of sedimentary phosphate rock deposits, but this source is finite and non-renewable. A better alternative is mining from secondary resources such as SSA. During the electrodialytic separation of SSA two major resources are produced: Phosphorous for the fertilizer industry and a mineral fraction for use as partly cement replacement in concrete. The ratio of heavy metals to phosphorous in the produced crystals is comparable to the very low end in phosphorous fertilizers at the market today2, which is a major environmental benefit in relation to the final fertilizer product. When using the mineral fraction of the SSA after recovery of phosphorous as partly cement replacement, the resulting concrete has an interesting aesthetical expression because of a warm red colour, and the material properties were highly encouraging3. As cement production is a major anthropogenic CO2 emitting process, replacement of cement in concrete with SSA could also give a major environmental benefit, in addition to resulting in a new interesting concrete type.

1. Ottosen, L.M.; Jensen, P.E.; Kirkelund, G.M.; Ebbers, B. (2013) Electrodialytic separation of heavy metals from particulate material. Patent WO 2015032903 A1

2. Ottosen, L. M.; Jensen, P.E.; Kirkelund, G.M (2016) Phosphorous recovery from sewage sludge ash suspended in water in a two-compartment electrodialytic cell. Waste Management 51, 142-148

3. Kappel, A.; Viader, R.P.; Kowalski, K.P.; Kirkelund, G.M.; Ottosen, L.M. (2018) Utilization of electrodialytically treated sewage sludge ash in mortar. Waste and Biomass Valorization, 9(12), 2503-2515

Phase-change humidity control material and its application in energy-efficient green buildings

Menghao Qin*

Department of Civil Engineering, Technical University of Denmark
*Corresponding author email: menqin@byg.dtu.dk

A novel phase-change humidity control material (PCHCM) was prepared by using organic PCMs (based on waste fats or oils) and different hygroscopic porous materials. The PCHCM composite can regulate the indoor hygrothermal environment by absorbing or releasing both heat and moisture. The PCMs were microencapsulated by the sol–gel method. The diatomite, vesuvianite, sepiolite and zeolite were used as hygroscopic materials. The scanning electron microscopy (SEM) was used to measure the morphology profiles of the microcapsules and PCHCM. The differential scanning calorimetry (DSC) and the thermal gravimetric analysis (TGA) were used to determine the thermal properties and thermal stability. Both the moisture transfer coefficient and moisture buffer value (MBV) of different PCHCMs were measured by the improved cup method. The DSC results showed that the SiO_2 shell can reduce the super-cooling degree of PCM. The super-cooling degrees of microcapsules and PCHCM are lower than that of the pure PCM.

In this research, a novel model for analyzing the hygrothermal performance of the PCHCM in built environment is also developed and validated by experiments. The new model is then applied to investigate the impact of PCHCM on indoor hygrothermal conditions and building energy consumption in an office building under different climates (Beijing, Paris, Atlanta, and Guangzhou). The simulation results show that PCHCM has a great impact on the building energy performance in Paris and Atlanta climates, which have a large temperature and humidity difference between day and night. The maximal potential energy saving rate could be up to 19.57% in Paris. The model and analysis will provide a guidance for the application of PCHCM in different climate conditions.

Session

A

Laptop Presentations

See session details and schedule on
www.sustain.dtu.dk

Reduction of climate impact from concrete by incorporation of mine tailings

Pernille Erland Jensen*, Anne Mette Simonsen, Lisbeth M. Ottosen

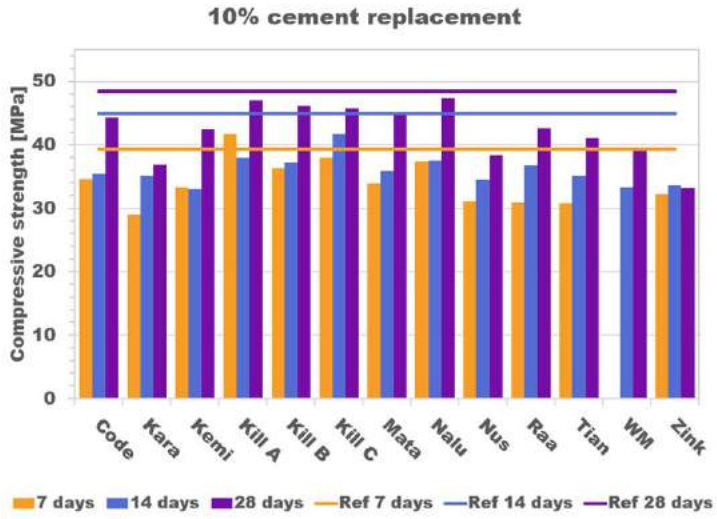
DTU Civil Engineering
* Corresponding author pej@byg.dtu.dk

According to EU's BREF document on "Management of Tailings and Waste-Rock in Mining Activities" [1], the primary Best Available Technology (BAT) principles to reduce footprints from mining are to prevent and/or reduce the generation of tailings/waste-rock by: a) minimizing the volume generated in the first place; or b) maximizing opportunities for the alternative use. Despite "use as aggregates" is highlighted [1], this is rarely done.

Further, high value uses, for instance as active components in construction materials, are not considered in practice though such use would contribute significantly to sustainability. The cement industry is responsible for 5-10 % of the anthropogenic global CO2-emission, and substituting cement for mine waste will pay off on the CO2-accounting even if the waste has to be shipped long distances.

Thus a structured approach covering a broad range of wastes is needed to reveal critical characteristics, and be able to generalize results. At DTU Byg, Bachelor and Master projects were made during the past years investigating valorization of mine tailings from twelve different mines around the globe as a substitute of cement and sand in concrete mortar.

Mineralogical results suggest that tailings have some, but not significant potential for partial cement replacement, while mechanical tests of mortar specimens show good potential for most tailings. Further studies are needed on the chemical performance.



[1] EUROPEAN COMMISSION, Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities, 2009.

Pre-treatment of Greenlandic municipal solid waste incineration residues before use in mortar or bricks

Gunvor M. Kirkelund[1*], Cosmin Florian[1], Lorena Skevi[1/2], Benjamin A.R. Ebert[1]

[1]DTU Civil Engineering, Brovej, Building 118, Technical University of Denmark, 2800 Kgs. Lyngby
[2] School of Physics, Faculty of Sciences, Aristotle University of Thessaloniki, 54124 Thessaloniki
*Corresponding author email: gunki@byg.dtu.dk

Greenland implemented six small municipal solid waste incineration (MSWI) plants from the 1990'ties to substitute unsanitary landfills. Annually, approximately 900 tons fly ash is shipped and deposited in Norway from these plants, since disposal in Greenland is prohibited. About 15,000 tons MSWI bottom ash is produced annually in Greenland and is disposed of at the open disposal sites without leachate collection or encapsulation. The MSWI ashes could have value as a secondary resource in construction work, as most construction materials are imported, however the ashes need pre-treatment to be upgraded to valuable secondary resources. An example of pre-treatment is electrodialytic treatment to remove heavy metals and reduce heavy metal leaching from fly ash [1] before use in bricks [2] or mortars [3].

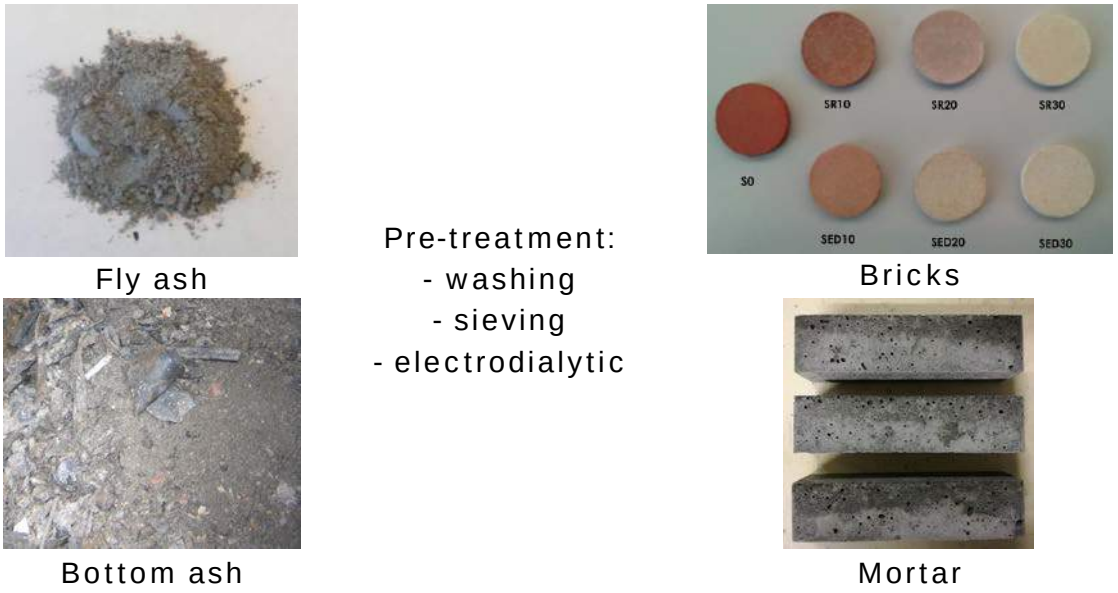


Figure 1: Municipal solid waste incineration ashes: from residue to secondary resource in construction

[1] Kirkelund, G.M., Jensen, P.E., (2018): Electrodialytic treatment of Greenlandic municipal solid waste incineration fly ash. Waste Management, 80, 241-251.
[2] Belmonte L.J., Ottosen L.M., Kirkelund G.M., Jensen P.E., Vestbø A.P. (in press) Screening of heavy metal containing waste types for use as raw material in Arctic clay-based bricks. Environmental Science and Pollution Research
[3] Kirkelund G.M., Ottosen L.M., Jensen P.E., Goltermann P. (2016): Greenlandic waste incineration fly and bottom ash as secondary resource in mortar. J. Sus. Dev. Plann., 11(5): 719-728.

Session

A

Poster Presentations

See session details and schedule on
www.sustain.dtu.dk

Valorization of MSWI Fly Ash for Use in Cement Based Materials

Benjamin Ebert*[1], Gunvor Kirkelund[1], Britt-marie Steenari[2], Mette R. Geiker[3]

1: Department of Civil Engineering, Technical University of Denmark

2: Chemistry and Chemical Engineering, Chalmers University of Technology

3: Department of Structural Engineering, Norwegian University of Science and Technology
*Corresponding author email: bareb@byg.dtu.dk

Abstract

The European Union trends in municipal solid waste management has changed in the last couple of decades, with recycling, recovery and incineration being the major waste management methods in several member states [1]. Municipal solid waste incineration (MSWI) is the common practise of burning waste for heat and energy recovery, at combined heat and power plants. This results in a waste volume reduction of up to 90% [2] and bi-products of bottom and fly ash. The fly ash contains heavy metals, salts and organic toxins and is regarded as a hazardous material, that remains underused and are dumped in secure landfills [2].

It could potentially be utilized as a resource for making cement based materials, similarly to fly ash from coal incineration. Pre-treating the fly ash could be required, in order to remove the salts and heavy metals, reducing the hazardousness. Possible methods of treatment could be the extraction of metals from the ash using electrodialytic remediation [3] or solvent extraction [4]. Minimal research in to the feasibility of utilizing the subsequent treated residue of these methods have been done. The purpose of this PhD project is to treat MSWI fly ash using remediation and extraction and analysing the viability of using the treated ash in cement based materials.

Keywords: MSWI fly ash, Pre-treatment, Cement, Electrodialytic remediation,Solvent extraction

References

[1] EC, Being wise with waste : the EU' s approach to waste management, Publ. Off. Eur. Union. (2010) 20. doi:10.2779/93543.

[2] K.L. Lin, K.S. Wang, C.Y. Lin, C.H. Lin, The hydration properties of pastes containing municipal solid waste incinerator fly ash slag, J. Hazard. Mater. 109 (2004) 173–181. doi:10.1016/j.jhazmat.2004.03.014.

[3] G.M. Kirkelund, C. Magro, P. Guedes, P.E. Jensen, A.B. Ribeiro, L.M. Ottosen, Electrodialytic removal of heavy metals and chloride from municipal solid waste incineration fly ash and air pollution control residue in suspension - Test of a new two compartment experimental cell, Electrochim. Acta. 181 (2015) 73–81. doi:10.1016/j.electacta.2015.03.192.

[4] J. Tang, Removal and Recovery of Metals from Municipal Solid Waste Incineration Ashes by a Hydrometallurgical Process Department of Chemistry and Chemical Engineering, 2017.

Session

C

Oral Presentations

See session details and schedule on
www.sustain.dtu.dk

Direct conversion of methane to methanol

Pablo Beato[1]

1: Haldor Topsøe A/S, Research and Development, Atomic Scale Analysis Group, email: pabb@topsoe.com

Abstract

The direct low-temperature conversion of methane to methanol is currently a heavily investigated field, due to its enormous potential for the energy and chemicals sector. However, the high energy required for cleavage of the C–H bond in CH_4 combined with the facile over-oxidation to CO_x pose great challenges for the realization of such a process. In nature, mono-oxygenase enzymes in methanotrophic bacteria are able to transform methane to methanol. These enzymes have inspired researchers in the field of heterogeneous catalysis to mimic such a unique reactivity. Metal-exchanged zeolites are able to stabilize well-defined metal-oxo sites: different zeolite topologies have been demonstrated to stabilize copper, iron, and other metal-oxo clusters and all of them have shown activity for stoichiometric transformation of methane to methanol.

Most reaction approaches found in the literature are based on a multi-step process, with an activation of the catalyst as the first step in order to generate the active sites. For the activation, H_2O_2, N_2O, NO, and O_2 have led to the formation of Cu centers that were able to convert me-thane. Generally, a relatively low activation temperature (500 °C) combined with a cheap and available oxidant (i.e. air) would be preferred for forming the methane-converting centers in the zeolite. After this activation, methane is reacted over the material at different conditions (partial pressure, reaction time, and temperature) in order to cleave one C–H bond on the active sites. Finally, the product (methanol) is extracted using a polar solvent or by passing steam through the reactor. Recently, an alternative approach to this step-wise process was reported for Cu-MOR such that methane is fed at 7 bar and H_2O is utilized to partially oxidize methane and simultaneously regenerate the active sites while facilitating the product desorption.

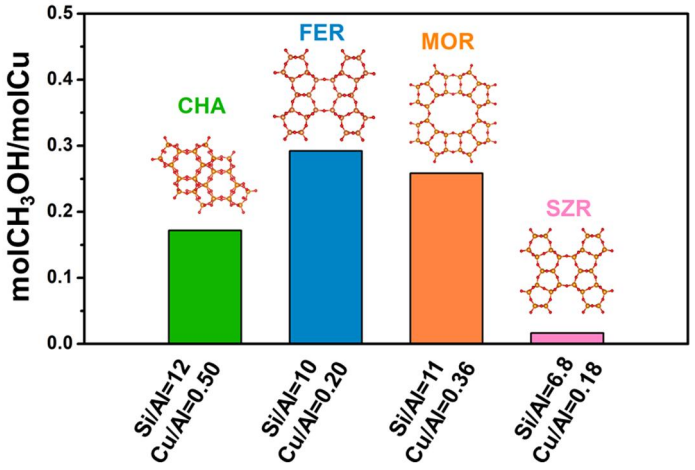


Figure: Productivity of different Cu-exchanged zeolite topologies for the direct conversion of methane to methanol

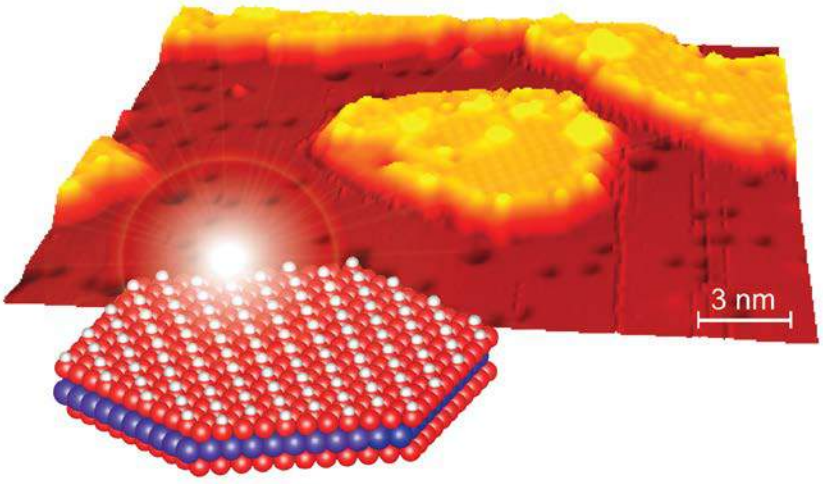
Imaging Atomic-scale Structure and Dynamics on Catalyst Materials using Scanning Probe Microscopy

Jeppe V. Lauritsen[1]

1: Interdisciplinary Nanoscience Center, Aarhus University, Denmark

Corresponding author email: jvang@inano.au.dk

The development of new materials for catalysis is seen as a crucial progress for securing sustainable energy resources and for better protection of the environment. Obtaining detailed control of materials on the nanoscale is of essence in catalyst development, but often a lack of insight into the fundamental physical and chemical processes occurring on catalytically active surfaces hampers the progress. We pursue the goal of understanding catalytic processes on surfaces by focusing on what happens on the atomic level. Scanning Probe Microscopy techniques (SPMs) are particularly strong techniques in this regard, since they allow us to visualize the atomic structure of surfaces and sometimes directly see the outcome of catalytic reactions. In my presentation, I will give short examples on how we successfully use the scanning tunneling microscope (STM) in interplay with other surface science techniques, e.g. at the MAX-IV synchrotron and other synchrotron facilities, to investigate industrially used catalysts for e.g. NOx pollution abatement[1], hydrodesulphurization of crude oil [2] and electrocatalysts for water splitting [3].



[1] S. Koust, B. N. Reinecke, K. C. Adamsen, et al., J. Catal. **360**, 118 (2018).
[2] S. S. Grønborg, N. Salazar, A. Bruix, et al., Nat. Commun. **9**, 2211 (2018).
[3] J. Fester, A. Makoveev, D. Grumelli, et al., Angewandte Chemie International Edition **57**, 11893 (2018).

The quest for simple and scalable routes to synthesizing nanoalloy catalysts

Yang Hu,* Jens Oluf Jensen, Lars Nilausen Cleemann, Benedikt Axel Brandes, Qingfeng Li

Department of Energy Conversion and Storage, Technical University of Denmark, Kemitorvet 207, DK-2800 Kgs. Lyngby, Denmark
*Corresponding author email: yanhu@dtu.dk

Alloy nanoparticles have found widespread application in the fields of catalysis, medicine, and nanoelectronics.(*1*) As investigated via theoretical calculations and experimental studies, the enhanced performance of is due to the geometrical (or ensemble) effects or/and electronic (or ligand) effects.(*2*) A number of approaches have been developed to produce nanoalloys, such as physical gas aggregation techniques, wet chemistry-based processes, and electrochemical methods, etc. However, many important nanoalloys are still hard to synthesize, especially on a large scale.(*3*) Here we report a simple, scalable and versatile approach to synthesizing Pt-Rare earth metal nanoalloys and other types of nanoalloys. By pyrolysis of selected precursors, metal ions are embedded atomically into the in-situ formed carbon-nitrogen network. A subsequent heat treatment of this compound in hydrogen leads to the decomposition of the carbon-nitrogen network and the formation of nanoalloys from the released metal ions.

1. R. Ferrando, J. Jellinek, R. L. Johnston, Nanoalloys: From theory to applications of alloy clusters and nanoparticles. *Chem. Rev.* **108**, 845-910 (2008).
2. J. K. Norskov, T. Bligaard, J. Rossmeisl, C. H. Christensen, Towards the computational design of solid catalysts. *Nature Chemistry* **1**, 37-46 (2009).
3. C. Roy *et al.*, Scalable Synthesis of Carbon-Supported Platinum–Lanthanide and −Rare-Earth Alloys for Oxygen Reduction. *ACS Catalysis*, 2071-2080 (2018).

The Co4Cat™ technology: a novel surfactant-free synthesis of precious metal nanoparticles providing colloidal solutions for supported catalysts with superior performances

Jonathan Quinson*[1], Sarah Neumann[2], Francesco Bizzotto[3], Jan Bucher[3], Sebastian Kunz[2], Matthias Arenz[3]*

1: Department of Chemistry, University of Copenhagen, 5 Universitetsparken 2100 Copenhagen, Denmark
2: Institute of Applied and Physical Chemistry, University of Bremen, Leobenerstraße 28359 Bremen, Germany
3: Department of Chemistry and Biochemistry, University of Bern, Freiestrasse 3CH-3012 Bern, Switzerland
*Corresponding authors email: jonathan.quinson@chem.ku.dk; matthias.arenz@dcb.unibe.ch

Catalysts are required to produce 80-90 % of the chemicals needed in our modern societies. In particular **precious metal catalysts** are used for various chemical transformations, energy conversion, automotive and energy-related applications, for a global market of ca. 9 billions €/year. Precious metals are however limited resources so they need to be used and produced efficiently. This is first achieved by using **nanoparticles** with high surface to volume ratio. State-of-the-art production of precious metal nanoparticles catalysts are typically performed by impregnation-calcination methods[1] with several drawbacks: (i) limited control over size and distribution of the nanoparticles on a support material, (ii) strong dependence of the synthesis to the nature of the support, (iii) formation of the nanoparticles on part of the support - typically porous - that are not accessible during catalysis. It overall leads to a use of the precious and expensive resources and design of catalysts that is not fully optimized.

A more **sustainable approach to develop catalysts** is to separate the optimization of the catalyst synthesis, to control properties like size or composition, and the immobilization of the catalyst on a given support. This can be achieved with **colloidal syntheses**.[2] The later are not fully exploited at industrial scale due to several limitations:[1] (i) use of surfactants (that needs to be removed by energy and cost intensive steps), (ii) use of high boiling point solvents (time, energy and cost consuming to process) and (iii) limited scalability. A new colloidal approach that successfully addresses the main drawbacks of colloidal syntheses is presented.[3,4] **The 'Colloids for catalysts' (Co4Cat™) process introduced is a surfactant-free colloidal synthesis in low boiling point solvents**.

This new process is a synthesis of colloidal nanoparticles bearing **economic and ecological benefits over state-of the art syntheses**. The catalysts obtained by the Co4Cat™ technology are compared with industrial and commercial catalysts and **show superior catalytic properties** not only for the production of chemicals (hydrogenation reaction by platinum nanoparticles) but also electrochemical reaction for energy-conversion (oxygen evolution reaction catalyzed by iridium nanoparticles).

References *

1- P. T. Witte et al., *T. Catal.* **2012**, *55*, 505.
2- J. Quinson et al., *ACS Catal.* **2018**, *8*, 6627.
3- J. Quinson et al., *Angew. Chem. Int. Ed.* **2018**, *57*, 12338.
4- J. Quinson, M. Arenz, S. Kunz. *PCT Patent pending*. **2017**.

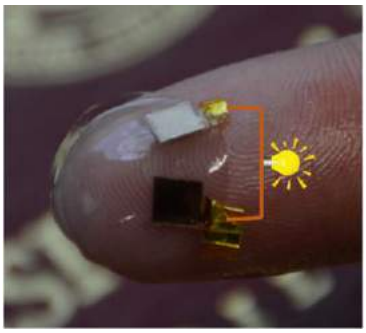
Immobilization of enzymatic catalysts on flexible nanoporous gold for wearable power suppliers

Xinxin Xiao*[1,2], Edmond Magner[2], Jingdong Zhang*[1]

1: Department of Chemistry, Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark

2: Department of Chemical Sciences and Bernal Institute, University of Limerick, Limerick, Ireland
*Corresponding author email: xixiao@kemi.dtu.dk; jz@kemi.dtu.dk.

Enzymes are natural catalysts that harness metabolic reactions with high activities and selectivity. Oxidoreductase that are redox active can be immobilized onto inorganic electrodes and studied by electrochemistry. The electron communication between the electrode surfaces and the redox centers of enzymes during the biocatalytic reactions is the basis for electrochemical biosensors and enzymatic biofuel cells (EBFCs). Nowadays, there is growing interest in fabrication of wearable biosensors for personal healthcare. Wearable EBFCs using sugars in tears or sweat are potential, miniaturized power sources for wearable microelectronics. Those applications require flexible, biocompatible and high-surface-area electrodes. Nanoporous gold (NPG) can be an excellent candidate meeting all the requirements [1]. We fabricated a mechanically stable and flexible NPG by electrochemically dealloying Au/Ag alloy films that are sputtered on plastic membranes [2]. The NPG has been biofunctionalized for EBFC applications.



Flexible NPG based lactate/O_2 EBFCs on commercial contact lenses register 1.7 ± 0.1 µW cm^{-2} in air-equilibrated artificial tear solutions, which is slightly lower than those obtained in PBS (2.4 ± 0.2 µW cm^{-2}) (See Figure) [2]. A quasi-solid-state and flexible EBFC can be skin-worn consuming the stocking fuel in a hydrogel electrolyte, avoiding the constrain of the required sweat sugars [3]. The device can also function as a self-powered biosupercapacitor delivering pulses for over 600 cycles, with a power density over 10 times higher than that from the EBFC alone.

At DTU Kemi, we focus on the development of a new-type photobiobattery. The photobiobattery is a device that converts chemical energy stored in fuels into electricity using dioxygen-reducing biocathodes and lactate-oxidising photocatalysts on the anodes.

References

[1] X. Xiao, J. Ulstrup, H. Li, J. Zhang, P. Si, *Electrochimica Acta* **2014**, *130*, 559-567.
[2] X. Xiao, T. Siepenkoetter, P. Ó. Conghaile, D. Leech, E. Magner, *ACS Appl. Mater. Interfaces* **2018**, *10*, 7107-7116.
[3] X. Xiao, E. Magner, *Chem. Commun.* **2018**, *54*, 5823-5826.

Magnetic mesoporous nitrogen-doped carbon as catalyst for enhancing electricity production in microbial fuel cell

Huihui Zhou[1], Mingyi Xu [2], Defeng Xing*[1]

1: School of Environment, State Key Laboratory of Urban Water Resources and Environment, Harbin Institute of Technology, Harbin 150090, China

2: Department of Environmental Engineering, Technical University of Denmark, DK-2800 Lyngby, Denmark

Abstract

To explore efficient and cost-effective cathode material for microbial fuel cells (MFCs), a new type of magnetic mesoporous nitrogen-doped carbon (Fe_3O_4@N-mC) was developed. Fe_3O_4@N-mC was the product of the carbonization of magnetic mesoporous polyaniline composite (Fe_3O_4@mPANI), which was obtained from aniline polymerization in the surface of PVP-modified Fe_3O_4 particles (Fe_3O_4-PVP). Surface modification and magnetic property were successfully introduced into the mesoporous carbon material with core–shell structure according to X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and X-ray photoelectron spectroscopy (XPS) measurements. The resulting hybrid electrocatalyst (Fe3O4@N-mC) showed higher limiting current density (2.94 mA cm^{-2}), lower H_2O_2 yield (7.2–12.7%), and a higher electron transfer number (3.74–3.85) for ORR activity than its intermediates, indicating good electrocatalytic activity of Fe_3O_4@N-mC. The maximum power density of Fe_3O_4@N-mC was 0.73 W/m^2, which was much higher than that obtained from Fe_3O_4, PANI, N-mC and Fe_3O_4@mPANI. Illumina sequencing of 16S rRNA gene amplicons and non-metric multi-dimensional scaling (NMDS) indicated distinct separation of the cathode biofilm bacterial communities between MFCs with different cathodic catalysts. This study provides further understanding of the composition-structure-ORR catalytic activity relationship of Fe-N-C catalysts and reveals the microbial response of Fe-N-C catalysts for the first time.

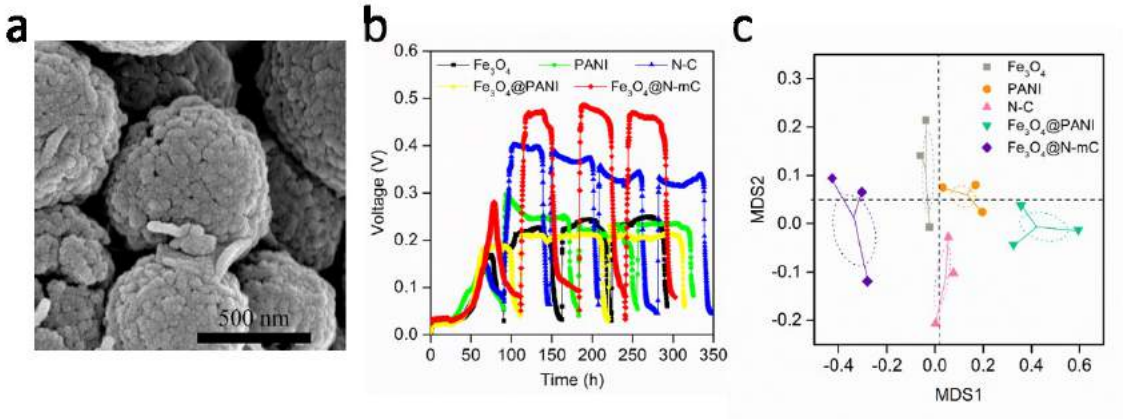


Figure 1 SEM images of Fe_3O_4@N-mC (a); comparison of voltage generation of MFCs with different cathode catalysts at an external resistance of 1,000 Ω (b); NNMDS of the cathode biofilms of MFCs with different cathodes based on bacterial OTUs (c).

Session

C

Poster Presentations

See session details and schedule on
www.sustain.dtu.dk

Electrocatalytic oxidation of $K_4[Fe(CN)_6]$ by metal-reducing bacterium *Shewanella oneidensis* MR-1

Zhiyong Zheng[1], Yong Xiao[1], Ranran Wu[1], Hans Erik Mølager Christensen[1], Feng Zhao[2], and Jingdong Zhang[1]*

[1]*Technical University of Denmark, Department of Chemistry, 2800 Lyngby, Denmark*
[2]Chinese Academy of Sciences, Institute of Urban Environment, 361021 Xiamen, China
*Corresponding author email: jz@kemi.dtu.dk

The microbial metabolic activities between minerals and bacteria play a role on biogeochemical cycling of metal compounds[1]. One of these activities is extracellular electron transfer (EET), in which some microbes exchange electrons with external redox minerals, electrodes or even other microorganisms[2, 3].
In this study, we observed that *Shewanella oneidensis* MR-1 (MR-1) selectively catalyzed the electrooxidation of $K_4[Fe(CN)_6]$ to $K_3[Fe(CN)_6]$. A surprising asymmetric pair of voltammetric peaks is found in cyclic voltammetry (CV) of $K_4[Fe(CN)_6]$ on a MR-1 coated glassy carbon electrode (GCE). The oxidation catalysis is obvious under slow scan rate and low $K_4[Fe(CN)_6]$ concentration. The uniqueness is validated by the exclusion of other microbes and other redox compounds. Extracellular polymer substance (EPS), cytochrome *c*, and riboflavin are not responsible to the asymmetrical redox phenomenon. The antagonistic relationship between the electrooxidation of $K_4[Fe(CN)_6]$ and the formation of Pd nanoparticles by MR-1 indicates that the nanoparticles blocked the pathways of MR-1 to react with $K_4[Fe(CN)_6]$. This study suggests the ability of MR-1 to selectively electrocatalyticly oxidize $[Fe(CN)_6]^{4-}$ and its versatile role in biogeochemical cycle.

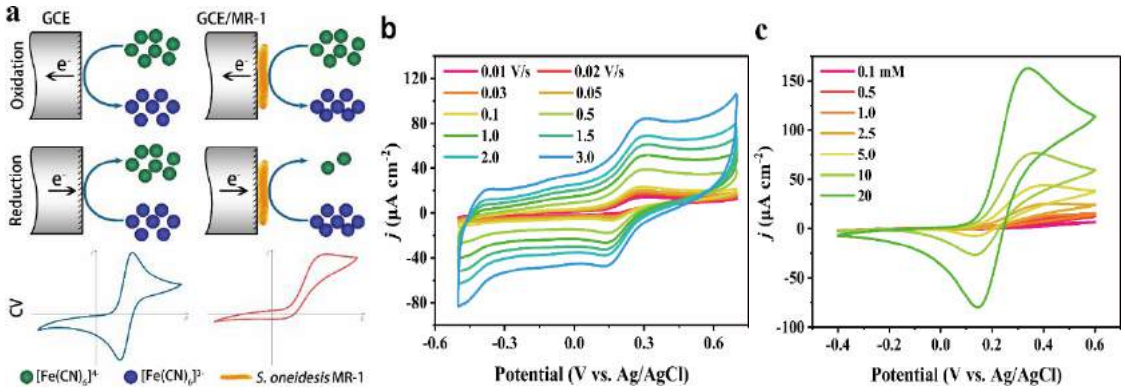


Fig. 1. (a) Reversible conversion of $[Fe(CN)_6]^{4-/3-}$ on GCE (left) and electrocatalytic oxidation of $[Fe(CN)_6]^{4-}$ to $[Fe(CN)_6]^{3-}$ by GCE/MR-1 (right). (b) Scan rate dependenct CVs and (c) concentration-dependent CVs of $[Fe(CN)_6]^{4-/3-}$ conversion. The scan rate is 10 mV/s unless otherwise stated.

Acknowledgments
Supported from the China Scholarship Council (CSC) (No. [2016]3100) is appreciated.

References

[1] C. R. Myers and K. H. Nealson, *Science*. **240**, 1319 (1988).
[2] Y. Xiao, E. Zhang, J. Zhang, Y. Dai, Z. Yang, H. E. M. Christensen, J. Ulstrup, and F. Zhao, *Sci. Adv*. **3**, e1700623 (2017).
[3] X. Tian, F. Zhao, L. You, X. Wu, Z. Zheng, R. Wu, Y. Jiang, and S. Sun, *Phys. Chem. Chem. Phys*. **19**, 1746 (2017).

Microwave-assisted morphology evolution of iron doped birnessite hierarchical nanosheets

Wei Huang[1], Hongyu Sun[2], Kristian Mølhave[2] and Jingdong Zhang*[1]

[1]*Department of Chemistry, Technical University of Denmark, Kongens Lyngby 2800, Denmark*

[2]Department of Micro- and Nanotechnology, Technical University of Denmark, Kongens Lyngby 2800, Denmark.

*Corresponding author email: jz@kemi.dtu.dk

Electrochemical water splitting to generate oxygen and hydrogen is a promising way for the clean energy conversion technology. The oxygen evolution reaction (OER) is core reaction in water splitting with four-electrons transfered. Layered manganese oxide, for example, birnessite have been widely investigated as a potential candidate for OER [1, 2]. In this work, iron doped birnessite is successfully developed for this application based on the reaction and a facile, simple and low-cost synthesis strategy using microwave heating. The morphology evolution of the iron birnessite is investigated. The OER performance and electrochemical performance will be further explored in the near future.

$$KMnO_4 + 3\ Fe^{2+} + 4\ H^+ \rightarrow MnO_2 + 3Fe^{3+} + K^+ + 2\ H_2O$$

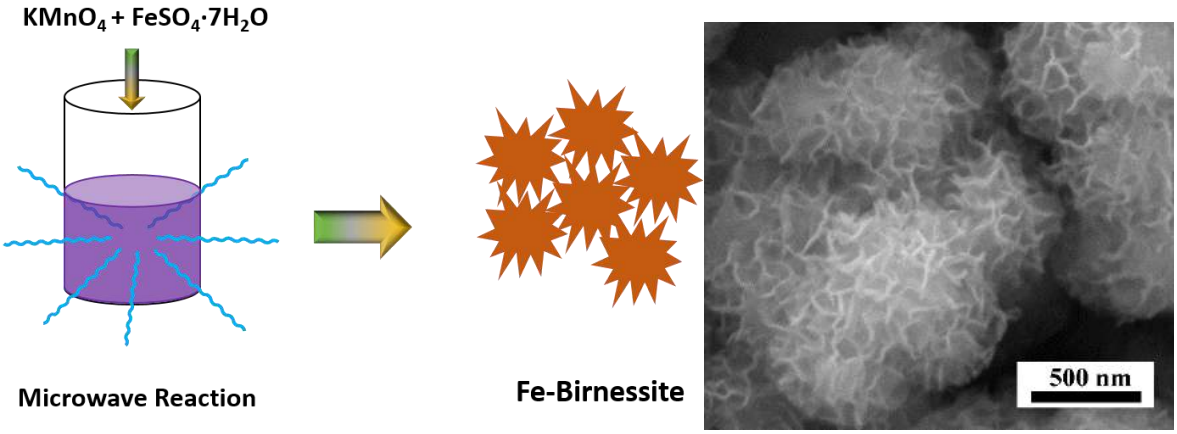


Fig.1 Schematic illustration of the synthesis process of Fe-Birnessite.

Acknowledgments
Wei Huang acknowledges the China Scholarship Council for a PhD scholarship (201706220080).

References

[1] Wiechen, M.; Zaharieva, I.; Dau, H.; Kurz, P. Chem. Sci. 2012, 3, 2330.
[2] Kang, Q.; Vernisse, L.; Remsing, R. C.; Thenuwara, A. C.;Shumlas, S. L.; McKendry, I. G.; Klein, M. L.; Borguet, E.; Zdilla, M. J.; Strongin, D. R. J. Am. Chem. Soc. 2017, 139, 1863.

Graphene-sulfite oxidase bioanodes for enzymatic biofuel cells

Jing Tang[1], Rebecka Maria Larsen Werchmeister[1], Loredana Preda[2], Wei Huang[1], Zhiyong Zheng[1], Silke Leimkühler[2], Ulla Wollenberger[2], Xinxin Xiao[1] and Jingdong Zhang[1,*]

1: Technical University of Denmark, Department of Chemistry, Kemitorvet 207, 2800 Kgs. Lyngby, Denmark
2: University of Potsdam, Institute of Biochemistry and Biology, Karl-Liebknecht Strasse 24-25, 14476 Golm, Germany
*Corresponding author email: jz@kemi.dtu.dk

Enzymatic biofuel cells (EBFCs) are electrochemical devices that produce electricity using enzyme catalysts, Fig. 1a. An EBFC consists of a bioanode in which enzymes catalyze the oxidation of fuels such as sugars, ethanol and sulfite, and/or a biocathode using oxygen-reducing enzymes. Most of EBFCs are capable of generating energy from abundant fuels without using noble metals. However, EBFCs still are not sufficiently stable and be hampered by the limited power density. Here, we have developed a bioanode using graphene[1] as a supporting material, polyethyleneimine (PEI) as a binder and human sulfite oxidase (HSO), Fig. 1b. HSO can catalyze the oxidation of sulfite to sulfate, and facilitated direct electron exchange with electrodes can be obtained when it is appropriately immobilized[2]. In this study, HSO is immobilized on the electrodes with PEI via electrostatic forces. The architecture and composition of the graphene-HSO bioanode are shown in Fig. 1b. Electrocatalytic performance of the bioanode has been enhanced by electrochemically reducing graphene oxides, Fig. 1c, indicating the electron-transfer from enzyme to electrode becomes more efficient after the electrochemical reduction. The bioanode is further optimized by systematic variation of experimental parameters such as the ratio of components and pH.

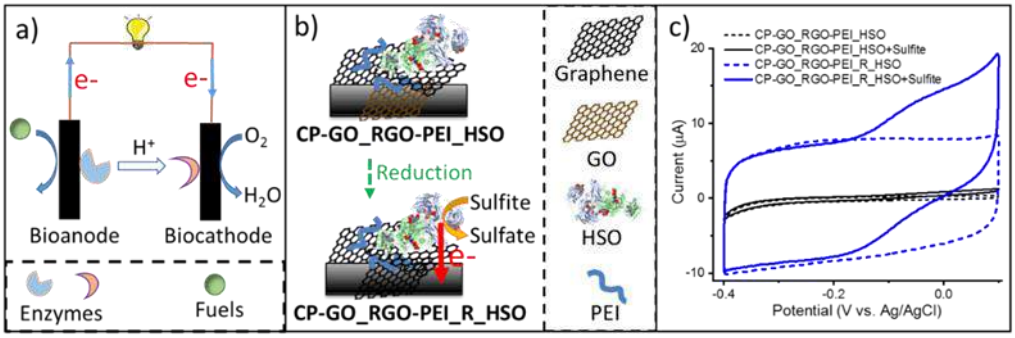


Fig. 1. Illustration of (a) an enzymatic biofuel cell and (b) the graphene-SO bioanode. (c) Cyclic voltammetry (CV) of the graphene-HSO electrodes with (blue) or without (black) reduction in the absence (dot) and presence (solid) of 1.0 mM sulfite in 750 mM Tris-acetate buffer, pH 8.4, scan rate 5 mV/s. The graphene-HSO electrode was prepared by dropcasting 16 µL reduced graphene oxide-PEI (RGO-PEI) solution on carbon paper electrodes coated with graphene oxide (CP-GO, active surface area: 0.25 cm^2), and 10 µL of 10 µM HSO (pH 7.0, 0.5 mM Tris-acetate buffer) on the dried electrode. The RGO-PEI solution is synthesized by mixing 20 mL of aqueous solution containing 2.0 mg GO and 40 mg PEI (25000 g/mol) for 60 min at 95 °C and concentrating to 4.0 mL. Electrochemical reduction is carried out before enzyme immobilization under N_2 by CV from -1.1 to 0.2 V vs. Ag/AgCl for 10 cycles, scan rate 50 mV/s.

Acknowledgments

Finance support from Danish Research Council (FTP-YDUN) is greatly appreciated.

References

[1] M. A. Raj and S. A. John, J. Phys. Chem. C. 4326, 117 (2013).
[2] T. Zeng, S. Leimkühler, U. Wollenberger and V. Fourmond, JACS 139, 11559 (2017).

Development of novel electrode materials for high temperature electrochemical water splitting

Nicola Mazzanti[1], Peter Vang Hendriksen[1*], Christodoulos Chatzichristodoulou[1], Mogens Bjerg Mogensen[1]

1: DTU Energy, Frederiksborgvej 399, 4000 Roskilde

* pvhe@dtu.dk

The human race is currently enjoying an arguably unprecedented level of wealth and abundance, much of which can be traced back to fossil fuels, that gives us most of the energy we consume and are essential to produce many of the chemicals that we depend on, such as plastics and fertilizers [1]. As the hidden costs of relying on fossil resources become evident, renewable sources of energy such as the wind and the sun are receiving more and more attention, to the point where they are commonly spoken of in main stream media. Unfortunately, they are ill suited to form the backbone of our energy supply, as their intermittent nature means they are hard to implement at a grid level without a cheap, efficient and scalable form of energy storage, that would allow us to match their output to society's energy demand [2]. Electrocatalysis stands out among the solutions being developed, as it allows the storage of energy in chemical bonds, creating "solar fuels" with high energy density suitable for applications as diverse as grid level storage and air transportation [2].
High temperature Solid Oxide Electrolyser Cells (SOECs) are particularly interesting, as a portion of the energy needed for the electrocatalytic reaction is provided as heat, resulting in very high efficiencies [3]. State-of-the-art SOEC use yttria-stabilized zirconia (YSZ) as an oxide-ion conducting electrolyte, a porous Ni-YSZ cermet as cathode and a Lanthanum strontium manganite (LSM) anode, but are still held back from various degradation mechanisms [4].
The development of novel materials holds the key for substantial improvements in the current densities and long term stability of SOEC, bringing them closer to market and increasing their financial viability.
Ceria, in particular, is regarded as very promising, because of its high electrocatalytic activity for water splitting and its nature as a mixed ionic and electronic conductivity, that could expand the active area to the entire catalyst surface [5]. Surface orientation and strain have been indicated as possible routes to controlling the properties of ceria, tailoring them for use as an electrode in SOEC [6].
Nanostructured ceria electrodes can be synthetized with techniques, such as Hydrothermal Synthesis and Pulsed Laser Deposition, that allow a close control on parameters like composition, orientation and strain in order to assess their influence on cell performance. Electrochemical and structural analysis can then be used to the mechanism of high temperature water-electrolysis and to develop better, more stable and efficient catalysts to increase the performance and stability of SOEC.

References

[1]. Key energy statistics. www.iea.org/publications/freepublications/publication/KeyWorld2016.pdf
[2]. Lewis N.S., Nocera D.G. . Powering the planet: chemical challenges in solar energy utilization. PNAS, 2006
[3]. Annabelle Brisse, Josef Schefold and Mohsine Zahid. High temperature water electrolysis in solid oxide cells. International Journal of Hydrogen Energy, 2008
[4]. Muhammad Shirjeel Khana et al.Fundamental mechanisms involved in the degradation of nickelyttria stabilized zirconia (NiYSZ) anode during solid oxide fuel cells operation: A review. Ceramics International, vol 42 issue 1. 2016
[5]. Chueh and Haile. Electrochemistry of Mixed Ion and Electron Conducting ELectrodes in Solid Electrolyte Cells. Annual Review of Chemical and Biomololecular Engineering. 2012
[6]. Trovarelli et al. Ceria Catalysts at Nanoscale: How Do Crystal Shapes Shape. ACS Catalysis. 2017 Catalysis

Session

E

Oral Presentations

See session details and schedule on
www.sustain.dtu.dk

Needs and means for assessing environmental sustainability of energy technologies and systems

Alexis Laurent*[1]

1: Division for Quantitative Sustainability Assessment, Department of Management Engineering, Technical University of Denmark, Denmark

* Corresponding author email: alau@dtu.dk

Energy technologies and systems are key to support and further develop modern societies. However, they remain associated with important environmental impacts, for example on climate change or fossils depletion. This has led to renewable energy sources being increasingly viewed as means to move towards sustainability. However, switching from fossils-based sources to renewables is not a silver bullet solution to environmental sustainability challenges, and even renewable energy technologies carry environmental impacts through their life cycle, for example during their production. Quantifying these impacts and keeping them in check is essential to actually move towards sustainable societies. Means to perform such assessments exist. In this presentation, the conduct and use of life cycle assessment (LCA), which adopts a holistic perspective in taking all life cycle stages of energy systems and all relevant environmental impacts, will be introduced to showcase how ecoefficiency of newly-developed technologies and systems can be gauged and how environmental improvement potentials can be identified. Examples in the energy sector will be used to illustrate the utilization of results from LCA application. This will contribute describing the potentials of the LCA methodology in ensuring environmental sustainable development and implementation of technologies and systems within the energy sector –which is one of the key dimensions of UN Sustainable Development Goal SDG no. 7.

Syngas production using straw pellet gasification

Nabin Aryal[1,2]*, Niels B. K. Rasmussen[1]*

[1]Danish Gas Technology Centre, Dr. Neergaards Vej 5B, DK-2970, Horsholm Denmark,
[2]Biological and Chemical Engineering, Aarhus University, Hangovej 2, DK-8200 Aarhus N, Denmark
*Correspondence: aryalnabin@eng.au.dk & nbr@dgc.dk

Syngas is a key energy carrier and intermediate to synthesis of liquid fuels and chemicals. Syngas is primarily produced from fossil-based fuels thus an alternative approach must be adopted due to environmental concern. Biomass is a widely applied alternative feedstock for syngas production using gasifier. Recently, alternative feedstocks in particular waste materials, agriculture residue, forest residues are being researched intensively. Nevertheless, there are several challenges concerning feedstock such as efficiency, technological barriers, and economical cheap material for commercial application. Interestingly, straw is one of the commonly available economical agriculture waste material in Denmark, which needs to be utilized as a resource. However, recent studies reported that straw is not an ideal feedstock for gasification creating problems in most of the existing combustion due to high moisture content, high alkali, which perhaps causes slagging, fouling and agglomeration resulting gasification. Therefore, current study tested the straw pellet in an allothermal laboratory-scale fluidized bed gasifier for syngas production in different temperature profiling and then compared with the ideal feedstock wood pellet. During the gasification, allothermal temperature was selected starting from 750 ^{o}C to 950 ^{o}C using olivine (Mg^{2+}, Fe^{2+})$_2$SiO) as a fluidized bed material acting as catalysis. The result showed that agglomeration of ash and bed material is probably possible at higher temperatures where at lower temperate agglomeration was not observed. In parallel, hydrocarbons such as Ethylene (C_2H_4)/Propane (C_3H_6) and Ethane (C_2H_6)/Propane (C_3H_8)/Butane (C_4H_{10}) were also produced.

Anode fuel recirculation on solid oxide fuel cells (SOFCs) fueled with landfill gas

Hendrik Langnickel*[1], Daniele Reschiotto[1], Christopher Graves[1], Anke Hagen[1]

1: DTU Energy, Technical University of Denmark
*Corresponding author email: henlan@dtu.dk

Landfill gas, consisting of methane, carbon dioxide and nitrogen as well as impurities like sulfur, is formed over time from landfill, e.g. domestic waste. Only landfill gas with a high share of methane can be converted into electricity and heat by standard combustion engines. This is a challenge as the methane content is declining over time. Solid oxide fuels cells (SOFCs) are an option for a highly efficient transformation of landfill gas with a low heating value into electricity and heat.

For a stable operation of the SOFC the prevention of degradation caused by carbon formation is of great importance. For avoiding carbon formation, a reforming agent like steam or carbon dioxide is needed. A certain amount of the needed reforming agent can be covered by the carbon dioxide present in the landfill gas. The idea is to obtain the remaining part from recirculating a certain amount of the anode exhaust gas, which contains steam and carbon dioxide. This has the advantage that an external reforming agent source is only needed for the initial phase, but not for the continuous operation.

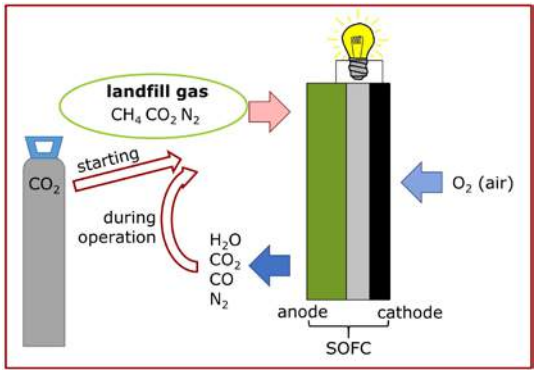


Figure 1: Principle of anode fuel recirculation for landfill gas fueled SOFCs.

The presented work consists of two parts. In the first part a semi 1D model was developed to find suitable operation conditions for landfill gas fueled SOFCs, using fuel recirculation to avoid carbon formation. In the second part different anode fuel recirculation rates were tested based on the results of the first part of the study. For this purpose a planar 16 cm^2 cell was operated at 750 ˚C, fueled with pre-mixed and real landfill gas from one of the largest Danish landfill sites in Odense.

The theoretical analysis showed that the recirculation rate has to be proportional to the amount of methane present in the landfill gas to ensure an avoidance of carbon formation. A SOFC cell fueled with real landfill gas and an anode fuel recirculation rate of 30% was successfully operated for around 150 hours. It was observed that the electric efficiency could be increased by around 4-5% using fuel recirculation instead of extra carbon dioxide as a reforming agent.

Advanced functional coatings for smart windows

Eugen Stamate*[1], Kion Norrman[1], Poul Norby[1]

1: DTU Energy, Technical University of Denmark, Frederiksborgvej 399, Roskilde – 4000, Denmark
*eust@dtu.dk

Windows are part of our daily life and making them smarter can have a tremendous impact on the CO_2 emission reduction strategy. The flat glass market reached over 9 billion m^2 in 2017 and this incommensurable surface is connected to a fraction of primary energy above 30% spent in buildings for human comfort (heating, cooling and lighting). Smart windows can tune themselves depending on the working hours, occupancy, daytime and season by an independent control of their transmittance in visible and infrared, in direct correlation with the energy management of the whole building. The radiation selectivity can be controlled by chromogenic effects, realized in a multilayer structure [1]. One of the important layers is the transparent and conductive electrode (TCE) that needs to have very good optoelectronic properties at affordable price. So far, indium tin oxide is the most used TCE, not only for smart windows but also for other large-market applications, such as solar cells, displays and OLED. However, the limited abundance of indium requires a timely replacement with alternative materials. This work presents our results on the development of a thin film deposition process for a TCE based on aluminum-doped zinc oxide (AZO) using magnetron plasma sputtering. AZO thin films show promising properties for limited zones on the substrate surface while the implementation to large-area needs basic understanding about the role of oxygen negative-ions on the film growth mechanism. For example, the radial distribution of the resistivity for four AZO samples (10x50 cm glass substrate) deposited at different pressures is presented in Fig. 1, where one can see variations with more than one order or magnitude over 10 mm. This behavior correlates with the erosion track on the deposition target, location that releases a large amount of energetic negative ions that are assisting the oxygen doping of the film. A proper understanding of this mechanism can lead to a deposition process able to provide AZO thin films of about 150 nm in thickness with resistivity below 10^{-3} Ωcm and a transmittance above 88%, as required by most applications.

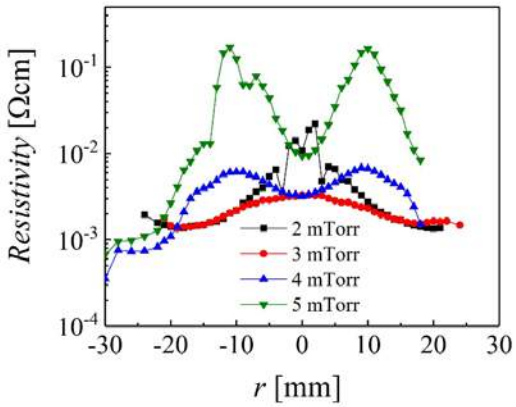


Fig. 1 Radial distribution of resistivity for different deposition pressures.

[1] C. G. Granqvist, Electrochromics for smart windows: oxide-based films and devices, Thin Solid Films 564 (2014) 1-38.

Engineered Biogenic Materials (EBMs) for Catalysis and Clean Energy

Sarvesh Kumar Srivastava*
Department of Micro- and Nanotechnology, Technical University of Denmark, Denmark

*Corresponding author email: sarvesh.kumar@nanotech.dtu.dk

Bio/molecular materials facilitate nature's design of 'things' towards material fabrication and organization. Living cells routinely exhibit autonomous structuring of matter at nano and microscale, by controlling reactions and self-organization in space (which nano/chemical engineering has largely mastered), as well as in time.[1] This talk will be an overview of my research in the area of bio/molecular materials highlightening multidisciplinary applications: in drug delivery, catalysis, clean energy and environmental remediation. To this end, I will present my recent research in the area of genetically engineered biogenic photovoltaic materials towards fabrication of a solar cell (DSSC). [2] The unique supramolecular interfaces and inherent biological membrane properties of these materials have been demonstrated to have interesting applications in heterogeneous catalysis [3], heavy-metal recovery/mining [4] and cleaner production [5]. We will critically examine the role of biogenic materials (mainly microbial, owing to easy scale-up) towards heterogeneous catalysis and clean energy (photovoltaics), based upon the following parameters: **i**) Hierarchical, molecular self-assembly of inorganic components; **ii**) Membrane mediated surface properties and; **iii**) Genetic engineering of host cells towards novel structural/chemical advancements. Interestingly, all of these are all inter-related phenomenon in living systems, which in turn, make engineered biogenic materials (EBMs) as a promising candidate for environmentally sustainable applications.

Bibliography: (*- corresponding author; Click here to download PDF copies)
[1] *S. K. Srivastava, V. G. Yadav, *Trends Biotechnol.* **2018**, *36*, 483.
[2] *S. K. Srivastava, P. Piwek, S. R. Ayakar, A. Bonakdarpour, D. P. Wilkinson, V. G. Yadav, *Small* **2018**, *14*, DOI 10.1002/smll.201800729.
[3] S. K. Srivastava, R. Yamada, C. Ogino, A. Kondo, *Nanoscale Res. Lett.* **2013**, *8*, 70.
[4] *S. K. Srivastava, M. Medina-Sanchez, O. G. Schmidt, *Chem. Commun.* **2017**, *53*, 8140.
[5] *S. K. Srivastava, O. G. Schmidt, *Chem. - A Eur. J.* **2016**, *22*, 9072.

The ACES Project - Large-scale Integration of Electric Vehicles into the Electric Power System

Mattia Marinelli

CEE – Center for Electric Power and Energy, Department of Electrical Engineering, DTU Risø Campus
Corresponding author email: matm@elektro.dtu.dk

In the quest for sustainable development and integration of renewable energy sources, electric vehicles (EVs) can play a pivotal role. EVs, however, are not primarily designed and utilized for supporting the electrical grid: it is necessary to close the gap between power system needs and cars' properties. With this in mind, the ACES (Across Continents Electric Vehicle Services) project, a Danish funded research project, was started as collaboration between DTU, Nissan, Bornholm Energi og Forsyning and NUVVE. The project investigates techno-economic system benefits of large-scale electric vehicles integration in Bornholm, augmented by real usage patterns, grid data and field-testing for across continents replicability. This abstract gives a brief overview of the mid-term results on EVs providing both system wide and local grid services. The indicated references and the project website report further details: www.aces-bornholm.eu

When looking at the system level, EVs bidding into the ancillary services market, specifically frequency control, can be very remunerative, up to 10000 DKK/y. However, the need for extra equipment such as a bidirectional charger, the cost for associated losses and need to fulfill bid requirements can drastically reduce the profit [1]. The work in [2] proves that EVs can effectively replace conventional power plants for supporting more renewables into the power system. On the other hand, at the distribution grid level, by considering pseudo-real Japanese and Danish driving and charging patterns, it is highlighted how a 100% EV penetration would determine an evening peak concurrency factor equal to 40% for a 3.7 kW charge level [3]. The average distribution grid in Denmark would be able to handle a 50% EV scenario, though safety margins are reduced. Smart charging options can, however, increase the hosting capacity and avoid grid reinforcements [5].

References

[1] A. Thingvad, C. Ziras, J. Hu, M. Marinelli, "Assessing the Energy Content of System Frequency and Electric Vehicle Charging Efficiency for Ancillary Service Provision," *Universities Power Engineering Conference (UPEC), 2017 Proceedings of the 52nd International,* Heraklion, 29 Aug. – 1 Sep. 2017.

[2] A. Zecchino, A. M. Prostejovsky, C. Ziras, M. Marinelli, "Large-scale Provision of Frequency Control via V2G: the Bornholm Power System Case," *Electric power system research,* under review.

[3] L. Calearo, A. Thingvad, K. Suzuki, M. Marinelli, "Grid Loading due to EV Charging Profiles Based on Pseudo-Real Driving Pattern and User Behaviour," *Energy,* under review.

[4] A. Gadea, M. Marinelli, A. Zecchino, "A Market Framework for Enabling Electric Vehicles Flexibility Procurement at the Distribution Level Considering Grid Constraints," *20th Power System Computation Conference (PSCC)*, Dublin, 11-15 Jun. 2018.

[5] K. Knezović, M. Marinelli, A. Zecchino, P. B. Andersen, C. Træholt, "Supporting involvement of electric vehicles in distribution grids: Lowering the barriers for a proactive integration," *Energy,* vol. 134, 2017.

Session

E

Poster Presentations

See session details and schedule on
www.sustain.dtu.dk

Image Processing for Advanced Drone-Based Electroluminescence Characterization of PV Power Plants

Gisele A. dos Reis Benatto*[1], Claire Mantel[1], Adrian A. Santamaria Lancia[1], Michael Graversen[1]; Nicholas Riedel[1], Sune Thorsteinsson[1], Peter B. Poulsen[1], Søren Forchhammer[1], Harsh Parikh[2], Sergiu Spataru[2] and Dezso Sera[2]

[1]Department of Photonics Engineering, Technical University of Denmark, Frederiksborgvej 399, 4000, Roskilde, Denmark.
[2]Department of Energy Technology, Aalborg University, Pontoppidanstraede 101, 9220, Aalborg, Denmark.
*Corresponding author email: garb@fotonik.dtu.dk

Solar energy produced by photovoltaic (PV) devices is a renewable source of energy that differently from wind and hydropower do not affect the environment the same way. For instance, PV modules do not have moving parts and do not required infrastructure in a scale that prevent single owners or buildings to generate its own electricity and secure is sustainability. Present day PV panels are designed to operate for 25-30 years, however field experience shows that after 11-12 years of operation, 2% or more of all PV panels fail [1]. Particular failures occurring in key sections of the PV module or array can provoke high or low power loss, making advanced techniques for accurate characterization of PV plants a need for efficient maintenance and warranty claims. However, inspection in PV array scale are commonly inaccurate and time demanding.

Figure 1- Drone equiped with an InGaAs camera for EL inspections

Image characterization techniques performed using drones, such as visual, thermographic, and more recently electroluminescence (EL), can be a viable solution for large and house hold scale PV inspections. The accuracy of thermographic fault detection though, presents limitations, which can be surpassed when performed in combination with EL imaging of the panels. EL can be used to rapidly and accurately detect a large range of major and minor faults in PV modules such as cell cracks, broken interconnections, potential induced degradation (PID) among others [1], [2]. While night time EL imaging presents few acquisition challenges, applying high power to PV strings can pose a safety risk to the operators and drone flights can be restricted by national and local laws for UAV night flights. To perform advanced daylight EL in movement, the capability to acquire many images per scene, with high frame rates is essential, as well as the ability to obtain background images to remove ambient light even with the use of filters. Together with the current efforts to build up a full automated solar plant inspection, here we describe and perform EL image processing on modules with different faults to assure quality of the EL images acquired in daylight and in movement.

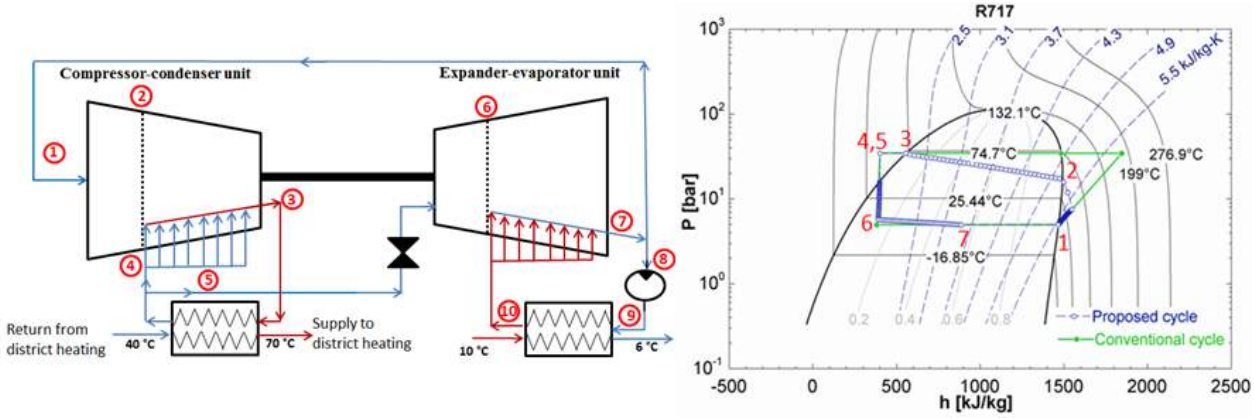
[1] M. Köntges *et al.*, "Review of Failures of Photovoltaic Modules," *IEA-Photovoltaic Power Syst. Program.*, pp. 1–140, 2014.

[2] J. B. S. Koch, T. Weber, C. Sobottka, A. Fladung, P. Clemens, "Outdoor Electroluminescence Imaging of Crystalline Photovoltaic Modules: Comparative Study between Manual Ground-Level Inspections and Drone-Based Aerial Surveys," *32nd Eur. Photovolt. Sol. Energy Conf. Exhib.*, pp. 1736–1740, 2016.

Cooled compression and heated expansion –A new system configuration for vapor compression heat pumps

Nasrin Arjomand Kermani[1], John Terpollari Madsen[2] , Christian Heerup[3], Brian Elmegaard[*1]
1: Technical University of Denmark, Lyngby, 2800, Denmark
2: Joma Tech, Årslev, 5792, Denmark, Taastrup, 2630, Denmark,
3: Danish Technological Institute,
*Corresponding author email: be@mek.dtu.dk

Improving the efficiency of vapor compression heat pumps is essential to provide energy efficient heat supply in domestic and industrial applications. Modifications to the basic cycle configuration can offer an alternative approach for providing better heat pump performance in a broad range of applications. The present work proposed and evaluated a performance of a new heat pump cycle configuration combining compression and condensation in one single unit and evaporation and expansion in another separate unit while benefiting from the advantages of liquid refrigerant injection into both units at proper time with appropriate temperature glides matches with district heating system.



(Left) System configuration for the proposed vapor compression heat pump cycle, (Right) P-h diagram for the proposed cycle compared to conventional cycle for R717

A cooled compression and heated expansion characteristics of vapor-liquid two phase mixture was analyzed by numerical modeling of the complete cycle using R717 and R134a as working fluids. The model was completed by a dynamic analysis of a compressor-condenser unit to evaluate the influence of the injection conditions and effective heat transfer between the gas and liquid phase in order to achieve the conditions suggested by the proposed cycle model. Furthermore, a pilot system was built as a proof of concept and preliminarily tested.

The proposed cycle model reached COP of 4.1 and 59 % Lorenz efficiency for a case related to R717 and COP of 4.4 and 63 % Lorenz efficiency for a case related to R134a as a working fluid and district heating production. The obtained results show that the performance improvement depends on the choice of working fluid, heat sink and heat source temperature and isentropic efficiency; thus the assumptions used in the model. The configuration and corresponding working conditions should be optimized based on the obtained results from the model and experiment to identify the applications that can provide the most potential for improved performance.

Electrification of processes in the manufacturing industry

Fabian Bühler*[1], Benjamin Zühsldorf[1], Fridolin Müller Holm[2], Lars Reinholdt[3] and Brian Elmegaard[1]

1: Department of Mechanical Engineering, Technical University of Denmark
2: Viegand Maagøe A/S, Copenhagen
3: Energi og Klima, Teknologisk Institut, Aarhus
*fabuhl@mek.dtu.dk

With the recent plans for Denmark becoming independent of fossil fuels by the year 2050, an increasing amount of energy will be supplied by electricity from renewable energy sources. This development poses challenges to the Danish industry sector, which in 2016 received more than half of its energy from fossil sources. Electrifying processes in the manufacturing industry, which use a majority of the fuels for heating, would allow considerable reductions in primary energy use and CO_2 emissions. This electrification requires new integrated strategies to provide process heat efficiently and has to consider the complete industrial site. Electrification scenarios for different industries in Denmark are studied, which include industrial laundries, dairy factories, slaughterhouses and aluminum processing plants. The electrification is reached by integrating energy efficiency measures, heat pumps and other electricity-based technologies into the production. Different electrification scenarios are compared by thermodynamic, economic and environmental methods. Based on the findings, the potential for electrification and its impact on the Danish energy system will be assessed. For heat pumps, which play a major role in reaching an efficient electrification, a comparison of the economic framework is shown in Figure 1 and the obtainable coefficient of performance (COP) of heat pumps in industrial processes in Figure 2. With the 2020 energy prices a minimum COP of 2 will be required, which will be obtainable in many industrial applications.

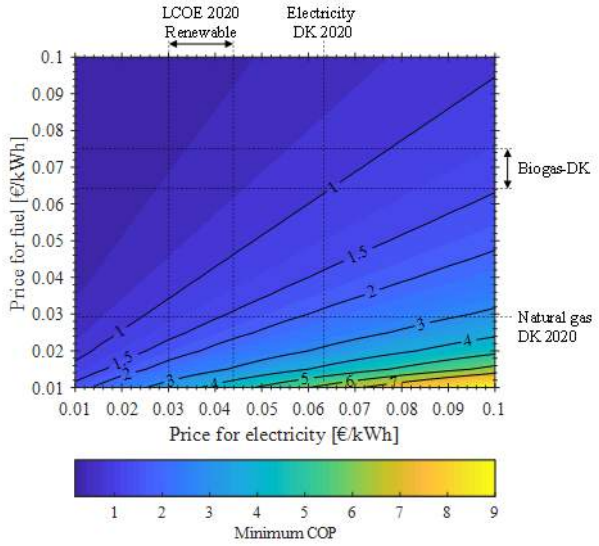


Figure 1: Required minimum COP of a heat pump system replacing a fuel based one for combinations of electricity and fuel prices (specific HP costs 1000 €/kW, fuel efficiency 86 %, 7000 operating hours).

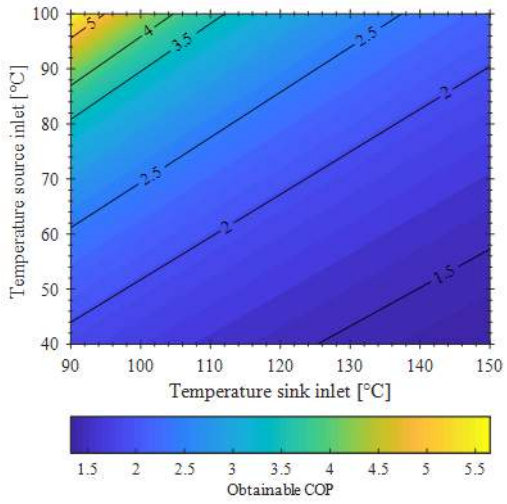


Figure 2: Obtainable COP of heat pump systems based on the Lorentz COP with a 45 % system efficiency and with a 40 K temperature glide at the source and sink.

Fast and facile synthesis of highly-porous 1D/2D $CuCo_2O_4$ nanohybrids for flexible energy storage

Xianyi Cao, Jens Øllgaard Duus, Qijin Chi*

DTU Chemistry, Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark.
*Corresponding author. E-mail: cq@kemi.dtu.dk

Flexible energy storage systems are of great importance as power supply components for next-generation portable/wearable electronics. Mixed transition metal oxides such as $NiCo_2O_4$, $FeCo_2O_4$ and $MnCo_2O_4$ have received increasing attention as high-performance supercapacitive materials due to their improved conductivity and superior electrochemical activity compared to conventional pseudocapacitive materials. In this work, a fast and facile microwave synthetic method combined with a post-annealing process is developed to synthesis a $CuCo_2O_4$ nanohybrid with a hierarchical highly-porous structure constructed by 1D nanorods and 2D nanoflakes. Acid-activated graphite papers are used as flexible substrates and current collectors. Structural, morphological and electrochemical performances of the as-synthesized $CuCo_2O_4$ nanohybrid are comprehensively studied. Benefiting from its abundant hierarchical pores and enhanced electrochemical activity, the $CuCo_2O_4$ nanohybrid can deliver excellent electrochemical performance: high mass specific capacity (1437 F g^{-1} at 1 A g^{-1}), good cyclic stability (93% retention at 5 A g^{-1} after 10000 cycles) and good rate performance (894 F g^{-1} at 10 A g^{-1}). A flexible solid-state asymmetric supercapacitor device was further fabricated, which could achieve a superior areal specific capacitance, as well as enhanced rate capability and cyclic stability, compared to most of reported transition metal oxide based supercapacitor devices. The results suggest that the highly-porous 1D/2D $CuCo_2O_4$ nanohybrids are a promising electrode material for flexible energy storage applications.

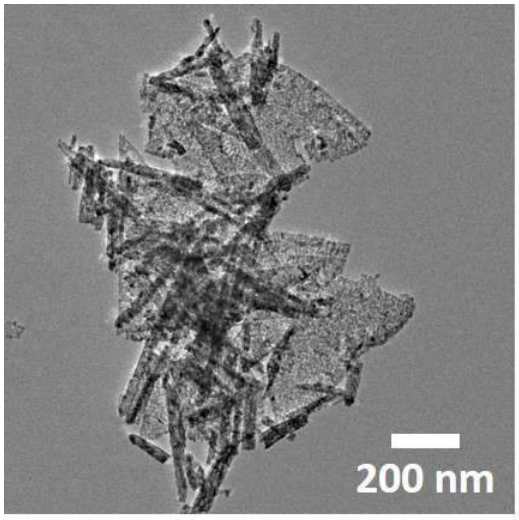


Fig.1 A transmission electron microscopy image of the highly-porous 1D/2D $CuCo_2O_4$ nanohybrids.

Acknowledgments

This work was supported by DFF-FTP, the Danish Research Council for Technology and Product Science (to Q.C., Project No. 12-127447). X.C. is grateful for the support from the Chinese Scholarship Council (PhD scholarship No. 201406170040).

References

[1] D. P. Dubal, N. R. Chodankar, D-H. Kim & P. Gomez-Romero, *Chem. Soc. Rev.*, 2018, **47**, 2065-2129.
[2] X. Lu, M. Yu, G. Wang, Y. Tong & Y. Li, *Energy Environ. Sci.,* 2014, **7**, 2160-2181.
[3] D. Chen, Q. Wang, R. Wang & G. Shen, *J. Mater. Chem. A*, 2015, **3**, 10158-10173.
[4] Z. Lu, X. Wu, M. Jiang, J. Wang, J. Liu, X. Lei & X. Sun, *Sci. China Mater.*, 2014, **1**, 59-69.

Shape-controlled synthesis of Zinc Vanadate and its supercapacitor performance

Huili Cao[1], Susanne Mossin[1], Poul Norby[2], Qijin Chi*[1]

1: Department of Chemistry, Technical University of Denmark,2800 Kgs. Lyngby, Denmark.

2: Department of Energy Conversion and Storage, Technical University of Denmark, 4000 Roskilde, Denmark.

*Corresponding author email: cq@kemi.dtu.dk

The design and fabrication of supercapacitors have become research hotspots in energy storage due to their fast charge and discharge, outstanding cycling behavior and relatively high energy density.[1] Electrode materials are the most important components in supercapacitors for storing and delivering electrical current. General electrode materials mainly focused on metal oxides, carbon, and conductive polymer materials.[2] And they can be assembled into two types of supercapacitors, electric double layer capacitors with carbon materials and pseudocapacitors with the others materials having superior energy densities and capacitance values compared to the former one. However, the pseudocapacitors materials is limited by low electron transportation due to lower ions accessibility.[3] To overcome this limitation, fabrication of various nano-morphologies will facilitate the accessibility of electrolyte ions with the shortest transportation path and improve the diffusion kinetics.

Herein, we report a facile route to fabricate highly ordered lawn-like Zinc vanadate ($Zn_3V_2O_8$) assembled from nano-plates (Figure 1). The unique structure was controlled by the addition of different surfactants. The possible mechanism for the formation of the morphologies is investigated and discussed. Furthermore, the supercapacitor performance will be studied.

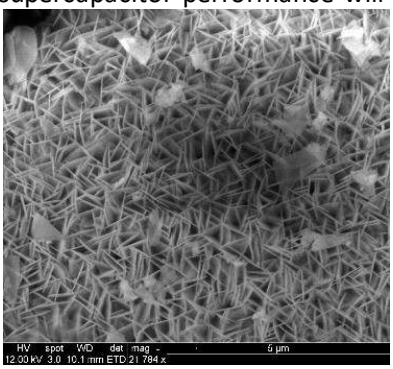


Figure 1. Morphology of $Zn_3V_2O_8$.

Acknowledgments

H.C. acknowledges the China Scholarship Council for a PhD scholarship (No. 201706220078)

References

1. Bera, A., A. Kumar Das, A. Maitra, R. Bera, S. Kumar Karan, S. Paria, L. Halder, S. Kumar Si, and B. Bhusan Khatua, *Chemical Engineering Journal* **343**, 44 (2018).
2. Gao, Z., C. Chen, J. Chang, L. Chen, P. Wang, D. Wu, F. Xu, and K. Jiang, *Chemical Engineering Journal* **343**, (2018).
3. Sun, W., G. Gao, K. Zhang, Y. Liu, and G. Wu, *Carbon* **132**, (2018).

Session

F

Oral Presentations

See session details and schedule on
www.sustain.dtu.dk

Sustainability of diets – challenges of developing sustainable food based dietary guidelines

Ellen Trolle*[1] and Anne Dahl Lassen[1]

[1]: Division for Risk Assessment and Nutrition, National Food Institute, DTU Technical University of Denmark
*Corresponding author email: eltr@food.dtu.dk

Background. Greenhouse gas (GHG) emissions (CO2 equivalents) from food consumption are estimated to be around 25% of total GHG emissions (1). In order to increase the chance of reaching the goal of temperature increase of max 1.5 ˚C, and thereby mitigate climate changes, GHG emission from human consumption, including from the diet need to be reduced (1). Only few countries so far (e.g. Sweden, Brazil, Qatar and Germany) have developed Food based dietary guidelines (FBDG) that take climate impact into account (2,3). In an earlier study we developed additional guidance to the official Danish FBDG based on overall estimates of GHG emissions from different scenarios of Danish diets (4). Since then, the Danish FDDG were updated and knowledge about the complexity of sustainability has increased (5). Sustainable FBDG have the potential to address the UN Sustainable Development Goals on malnutrition and climate changes.

Objective. To provide an overall view of the potential and challenges of developing new sustainable FBDG, including key method considerations and data requirements.

Method. Based on literature and experiences from earlier projects in the division, the complexity of estimating the combination of nutritional impact and GHG emission from food consumption with additional environmental metrics are illustrated. Moreover, it is demonstrated how available national dietary survey data can be used for estimation of environmental impact of different healthy diets.

Results and conclusion. Sustainable FBDG should combine nutritional and environmental issues as well as toxicological considerations. Data requirements include dietary intake data as well as environmental impact data of individual foods. National dietary surveys provide intake data on individual level, and a relative detailed food level. Data modelling based on intake data has the potential to combine health and nutrient data with other metrics on environmental outcomes such as GHG emission, land use, fresh water use, biodiversity etc. and compare estimated effect of different healthy dietary patterns and impact from waste, transportation, cold storage and cooking at home. Challenges include that adjustment for under-reporting is required, data level is limited to ability of dietary survey participants and values on other metrics are present only on a limited number of foods. Prerequisites of estimates need to be thorough scrutinized before comparison to avoid fruitless and futile FBDG.

References

1 Ritchie H, Ray DS, Higgins P 2018 The impact of global dietary guidelines on climate change. *Global Environmental Change* https://doi.org/10.1016/j.gloenvcha.2018.02.005
2 Fischer CG, Garnett T. 2016. Plates, Pyramids, Planet: Developments in National Healthy and Sustainable Dietary Guidelines: A State of Play Assessment. http://www.fao.org/3/a-i5640e.pdf
3 Hyland JJ, Henchion M, McCarthy M, McCarthy SN. 2017. The role of meat in strategies to achieve a sustainable diet lower in greenhouse gas emissions: A review. *Meat Science, 132,* 189-195.
4Thorsen, Mogensen, Jørgensen, & Trolle 2012. Klimaorienterede Kostråd. Søborg DTU Fødevareinstituttet.
5 Mertens E, van't Veer P, Hiddink GJ, Steijns JMJM. Kuijsten A. 2017. Operationalising the health aspects of sustainable diets: a review. *Public Health Nutrition, 20,* 739-757.

AnOxPe-pred: Using deep learning for the prediction of antioxidative properties of peptides.

Tobias Hegelund Olsen*[1], Margarita Pertseva[1], Pedro Jesús García Moreno[1], Charlotte Jacobsen[1], Ole Lund[1], Egon Bech Hansen[1], Paolo Marcatili[2]

1 National Food Institute, Technical University of Denmark
2 Department of Bio and Health Informatics, Technical University of Denmark
* Corresponding author email: tobhe@food.dtu.dk

Dietary antioxidants are used as preservatives in food[1] and have been suggested to help in disease prevention[2,3]. With consumer demands for less synthetic and more safe additives in food products, the food industry is searching for antioxidants that can be marketed as natural. Peptides derived from natural proteins show promise, as they are generally regarded as safe and might additionally contain other bioactive properties[1,4]. Antioxidative peptides are usually obtained from hydrolysates, derived from proteins hydrolyzed by a selection of proteolytic enzymes[4]. Unfortunately, this trial and error approach is exhaustive. Introducing some insight with a computational approach, which predicts antioxidant peptides and thereby reduces laboratory work, is therefore highly sought. A few previous predictors have been made for proteins and non-peptides[3,5,6], but no web-server predicting the antioxidative properties of peptides is currently available according to our knowledge.

We here present the AnOxPe-pred web-server that uses deep learning algorithms to predict a peptide's free radical scavenging and chelating properties from its sequence. A convolutional neural network was trained on a self-curated database consisting of scavengers and chelators, and on experimentally-tested non-antioxidants and random peptides as negatives. Both in a cross-validation setup, and on an external validation set, the method displays a prediction performance significantly better than a sequence-similarity based approach. This pipeline therefore represents a good standard for future predictors of antioxidant properties of peptides.

1. Santos-Sánchez, Norma F. et al., "Natural antioxidant extracts as food preservatives." Acta Sci. Pol. Technol. Aliment., vol. 16, no. 4, 2017, pp. 361-370. DOI: 10.17306/J.AFS.2017.0530.
2. Nimse, Satish Balasaheb et al., "Free radicals, natural antioxidants, and their reaction mechanisms." RSC Advances, vol. 5, 2015, pp. 27986-28006. DOI: 10.1039/C4RA13315C
3. Zhang, Lina et al., "Sequence Based Prediction of Antioxidant Proteins Using a Classifier Selection Strategy." PLoS One, vol. 11, no. 9, 2016, pp. e0163274. DOI: 10.1371/journal.pone.0163274
4. Sarmadi, Bahareh H. et al., "Antioxidative peptides from food proteins: A review." Peptides, vol. 31, no. 10, 2010, pp. 1949-1956. DOI: 10.1016/j.peptides.2010.06.020
5. Xu, Lei et al. "SeqSVM: A Sequence-Based Support Vector Machine Method for Identifying Antioxidant Proteins." International Journal of Molecular Sciences, vol. 19, no. 6, 2018, pp. E1773. DOI: 10.1007/s12539-015-0124-9
6. Fatemi, Mohammad H. et al., "Prediction of the Radical Scavenging Activities of Some Antioxidant from Their Molecular Structure" Industrial & Engineering Chemistry Research, vol. 52, no. 28, 2013, pp 9525-9531. DOI: 10.1021/ie4001426

Eating Meat: Current Challenges and the Road Forward

Alex Felman[1]

[1]Felman Family Office

*Corresponding author email: alrangers@gmail.com

Meat consumption is an increasing global trend that is not going away anytime soon. Unfortunately, meat consumption is one of the most resource intensive forms of food production and a significant contributor to the worsening of global climate change. This presentation gives an overview of the current trends in food consumption and the associated resource cost. Additionally, it summarizes how the new discipline of synthetic biology is trying decrease the resources necessary to produce meat using the current methods.

From coffee grounds to umami proteins

By Tobias Lau, board chairman, Beyond Coffee

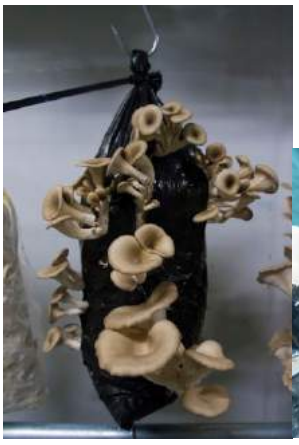
The project is realised in collaboration with prof. Lene Lange and Amass (restaurant)
Email: tobias@beyondcoffee.dk

In 2015, Beyond Coffee started to grow mushrooms in collected coffee grounds from Copenhagen. Not long after, we made a collaboration with a farmer to pick-up our own waste after we had harvested the mushrooms. The farmer used the waste as fertilizer.

We thought about whether or not this was the best use of our waste. We knew the substrate contained proteins but we didn't know how to use it for anything ambitiously purposeful without diversifying the company all at once within a relatively small organization.

We contacted prof. Lene Lange and together we submitted an application to Innobooster to figure out how to use our double spent coffee grounds (the mushroom biomass substrate) – possibly as a future food supplement in the human consumption cycle. We got the grant and after a year we have discovered a process by which we can boost the protein level by 40%. Turning the mushrooms biomass substrate into a powder, we can take the first steps to make a umami-tasting protein powder. The powder could be used in doughs, drinks or snacks. We have submitted yet another application for MUDP – this time together with the restaurant Amass (that is focusing on creative use of waste streams in their kitchen). We have just gotten this grant as well, and we have just started on the new phase: to understand the different uses and applications for the umami protein powder.

We would love to meet collaborators and curious people during Sustain 2018 to bring ideas and inputs to the endeavor going forward!



The impact of gastronomic innovation in the Nordic Region

Roberto Flore[1]*

1:DTU Skylab Food Lab, Diplomsvej 373A Lyngby Dk
*Corresponding author email: roflo@dtu.dk

Over the last 15 years the Nordic region has experienced exponential growth in food entrepreneurship and has become increasingly more oriented towards sustainable food production.

The relationship between research and the exploration of the food potential of the regional foodscape has generated a large impact both locally and internationally, placing Denmark and Nordic countries in on the global gastronomic map and transforming cities like Copenhagen into culinary meccas.

Many of the principals and initiatives generated over past years have been used as sources of inspiration for the development of new sustainable food businesses around the world.

This presentation will highlight the future steps required to keep this momentum alive.

The hunt for alternative sustainable food sources

Michael Krag Nielsen*

Affiliation: Aliga Microalgae

*Corresponding author email: mkn@aliga.dk

A steady growing population raises the demand for alternative food sources. Traditional production of meat proteins contributes to raising the level of CO2 emission. The major challenge in producing alternative food sources is providing cost effective nutritious products. Through thorough analysis of nutritious values in different microalgae strains and the ability to produce in larger scale, we have found multiple suitable candidates from the Chlorella Vulgaris family. Several of these strains contains a good protein composition including all essential amino acids. Compared to meat, the protein level is significant higher (50-70%). In addition to protein, Chlorella also contains high levels of beneficial vitamins and antioxidants. Depending on method, producing microalgae leaves a small CO2 footprint compared to producing meat products. The CO2 emission ranges between 1Kg CO2/1Kg Biomass to a negative value (during photosynthesis algae absorb CO2), this makes the CO2 footprint 28x smaller compared to beef, 20x smaller compared to shrimps and 11x smaller compared to pork, at worst case. Given the nutritional value, ability to produce in large volume and low CO2 emissions, we consider microalgae as a good alternative to traditional food sources produced in a sustainable way.

What is the role of food policy in a rapidly changing world?

Afton Halloran[1], Mads Frederik Fischer-Møller[1*], Marie Persson*, Elisabet Skylare

1: Nordic Food Policy Lab, Nordic Council of Ministers, Ved Stranden 18, Copenhagen K, Denmark
*Corresponding author email: afthal@norden.org

What is the best way to make sure that all children have equal access to nutritional food? What are the best ways to instil a greater sense of food culture and identity and what societal benefits can it bring? What is the best way to transition to diets that are better for us and for the health of the planet?

One approach is through food policy.

For the first time, the most innovative food policy solutions in the Nordic Region have been collated in a single document. This Solutions Menu covers nutrition, food culture and identity, public food and meals, food waste and sustainable diets. It includes 24 policy examples – from local, national and regional levels – designed to trigger new conversations and inspire new policies in other parts of the world. Each solution represents a tangible step to address a specific issue; together they represent a new and holistic approach to food policy. They are also testament to the fact that soft policies can deliver solutions and play a significant role in pursuing ambitious national and international goals.

This presentation will discuss the importance of soft food policy in tackling the greatest global challenges of our time. The main point of departure will be the *Solutions Menu: A Nordic Guide to Sustainable Food Policy*, a 2018 publication produced the Nordic Food Policy Lab, one of six flagship projects under the Nordic prime ministers' Nordic Solutions to Global Challenges initiative at the Nordic Council of Ministers.

Session

F

Laptop Presentations

See session details and schedule on
www.sustain.dtu.dk

Toxic effect of H_2S on methanotrophic single cell protein production by *Methylocapsa Acidiphila*

Mingyi Xu [1], Huihui Zhou [1, 2], Irini Angelidaki [1], Yifeng Zhang [1, *]

1: Department of Environmental Engineering, Technical University of Denmark, DK-2800 Lyngby, Denmark

2: School of Environment, State Key Laboratory of Urban Water Resources and Environment, Harbin Institute of Technology, Harbin 150090, China

*Corresponding author email: yifz@env.dtu.dk

Abstract

Methane oxidation bacteria (MOB) show a wide prospect in utilizing biogas for value-added biocommodities production, such as single cell protein (SCP). However, biogas usually contains H_2S with a range of 5000 ~ 10000 ppm but the effects and the mechanism of sulfide on the growth of MOB are not widely investigated[1]. In this study, pure culture *Methylocapsa Acidiphila* B2 (DSM 13967^T) was cultivated and enriched as the objective MOB. It is termed as the α-subclass of the *Proteobacteria*, Gram-negative, curved coccoids and acidophilic (optimum pH range 4.5~5.8), which has a meaningful potential for SCP production in acid environment [2]. This experiment was conducted in serum bottles at a batch mode and in triplicate. Four concentrations of sodium sulfide (5, 10, 15, 20 mg/L) were added to the medium to study the effect on optical density growing with simulated biogas (80%CH_4 and 20%CO_2) supplied. Results show that the existence of sulfide in the medium has a negative effect on the growth of *M. Acidiphila* and such inhibitory phenomenon is more obvious when the sulfide concentration is higher. The inhibition presents a longer lag phase and a lower growth rate. The highest OD_{410} of control group S1 (no sulfide added) can reach to 1.28 and the experimental groups were 1.11 (S2), 1.22 (S3), 1.00 (S4), 0.96 (S5). The concentration of oxygen was a key factor that limited the performance in the early stage. But the impact of sulfide cannot be recovered though the methane and oxygen were sufficient in the end.

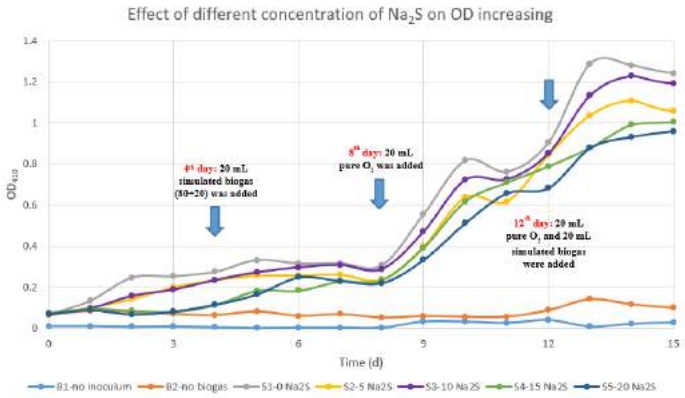


Fig 1 Effect of different concentration of Na_2S on OD increasing

1. Al Mamun, M.R. and S. Torii, *Removal of hydrogen sulfide (H2S) from biogas using zero-valent iron.* Journal of Clean Energy Technologies, 2015. **3**(6): p. 428-432.
2. Dedysh, S.N., et al., *Methylocapsa acidiphila gen. nov., sp. nov., a novel methane-oxidizing and dinitrogen-fixing acidophilic bacterium from Sphagnum bog.* International Journal of Systematic and Evolutionary Microbiology, 2002. **52**(1): p. 251-261.

Seaweeds – a sustainable food resource from Greenland

Katharina Johanna Kreissig*[1], Lisbeth Truelstrup Hansen[1], Pernille Erland Jensen[2], Jens Jørgen Sloth[1]

[1] DTU Food

[2] DTU Civil Engineering

*Corresponding author email: kjkr@food.dtu.dk

Greenland has many of the prerequisites to make seaweed harvesting and cultivation a viable and sustainable business: 44,087 km coastline, low water pollution, and a diverse native seaweed population. Seaweed could provide an environmentally friendly income source with little investment requirements, making use of already existing infrastructure of the fishing industry.

However, seaweeds have a highly variable chemical and nutritional composition, depending, amongst others factors, on species and location. While the current intensive research effort is rapidly increasing our knowledge of edible seaweed, very little is known about Greenland seaweeds. The PhD project "Greenland seaweeds for human consumption" provides this knowledge base for Greenlandic seaweed species, combined with an evaluation of chemical and microbial risks. This presentation addresses the project in general and presents the newest results from the analysis of 16 different chemical elements in ten seaweed species, including toxic metals.

Session

F

Poster Presentations

See session details and schedule on
www.sustain.dtu.dk

The use of cod frames from the cod filleting for value-creation

Ann-Dorit Moltke Sørensen[1]*, Rocio Maciel Gomez[1], Ali Jafarpour[1,2] and Charlotte Jacobsen[1]

1: Technical University of Denmark, National Food Institute, Research group for Bioactives – Analysis and Application, Kgs. Lyngby, Denmark

2: Sari Agricultural Sciences and Natural Resources University, Department of Fisheries – Seafood Science and Technology, P.O. Box 578, Sari-Iran

*Corresponding author email: adms@food.dtu.dk

Cod frames are a side-stream from the cod filleting in the fish industry. These cod frames are bones with a substantial amount of meat attached to them. The aims of this project are to identify valuable compounds in this side-stream and to evaluate their possible applications without generating new side-streams.

In order to identify valuable compounds, the cod frames were characterized with respect to dry matter, ash, lipid protein and phosphorous content, total amino acids composition and fatty acid composition. Cod frames were sampled every third month over a year, March 2017 – March 2018 (five sampling points). The different sampling time will show if there is any seasonal variation in the different parameters analyzed. From the early sampling points (March 2017, June 2017), the following values were obtained: 13.2 – 14.7 % Protein, 0.98 – 1.18 % Oil, 19.4 – 21.2 % Dry matter, 4.8 – 6.0 % Ash and 2.7 – 3.1 % PO_4 (phosphate).

Assuming that the side-stream amounts to 2,000 tons cod frames from a fish factory yearly, the amount of protein and phosphate extracted could be 132,500 and 30,000 kg / year if we have 50% recovery.

Due to the content of protein and the interest in the phosphate, the aim is to combine two approaches and generate peptides (protein hydrolysates) to be used as emulsifiers, antioxidants or both and phosphate rich powder if possible.

One approach to obtain peptide and phosphate is grinding the sample, followed by enzyme treatment, heat inactivation, separation in liquid (hydrolysates) and solid (bone including phosphate) fraction. Another approach is separating the bones from the fish meat by boiling. Thereafter, fish meat and bones were treated separately to obtain hydrolysates and phosphate rich powder, respectively. Again, the hydrolysates were generated by the use of enzymes. The phosphate rich powder was produced by drying and grinding. Three different enzyme treatments were used for the two approaches (Alcalase, Neutrase and a combination hereof). Functional properties of the obtained peptides and phosphate content in the bone powder are currently being analyzed. The newly generated results will be presented on the poster.

What Really Killed the Sugar Kelp?

Effects of simulated heat wave scenarios on *Saccharina latissima*

Jacob Nepper-Davidsen*[1], Daniel Tveen Andersen, Morten Foldager Pedersen[1]

[1]*Roskilde University, Department of Science and Environment, Universitetsvej 1, 4000 Roskilde*

**Jacob.nepper@gmail.com*, *www.linkedin.com/in/Jacob-Nepper-Davidsen*

Abstract

Kelps are important foundation species in coastal cold-water ecosystems, and loss of these organisms are a threat to global biodiversity. *Saccharina latissima* is one of the most promising species of kelp for commercial cultivation in Europe and North America, with applications including; animal feed supplements, human consumption, biofuels and extraction of bioactive compounds. However, severe reduction in the abundance of the kelp has been observed in Northern Europe during recent decades, likely caused by increasing water temperature. To test the heat tolerance of *S. latissima* we exposed the kelp to simulated heat wave scenarios of 15, 18, 21 and 24°C followed by a recovery period at 15°C. While growth rate and photosynthesis decreased significantly with increasing temperature, mortality remained low among treatments, except at 24°C where >90% died halfway through the heat wave. Although 21°C had limited effect on mortality of *S. latissima*, the kelp exposed to this heat wave temperature lost weight and started to dissolve during the subsequent recovery period. It seems that the observed mortality and loss of biomass was mainly due to heat related damage (e.g. oxidative stress) rather than carbon starvation, as net photosynthesis remained positive throughout the experiment (except at 24°C) and mannitol storage levels were similar among treatments. Oxidative stress may have been caused by discrepancy between photosynthetic electron transfer rate and photosynthetic capacity at high temperatures. Overall, our results indicate that extreme heat events pose a serious threat to the Danish populations of *S. latissima*.

References

Müller, Ruth, Thomas Laepple, Inka Bartsch, and Christian Wiencke. 2009. "Impact of Oceanic Warming on the Distribution of Seaweeds in Polar and Cold-Temperate Waters." *Botanica Marina* 52 (6): 617–638.

Moy, Frithjof E., and Hartvig Christie. 2012. "Large-Scale Shift from Sugar Kelp (Saccharina Latissima) to Ephemeral Algae along the South and West Coast of Norway." *Marine Biology Research* 8 (4): 309–321.

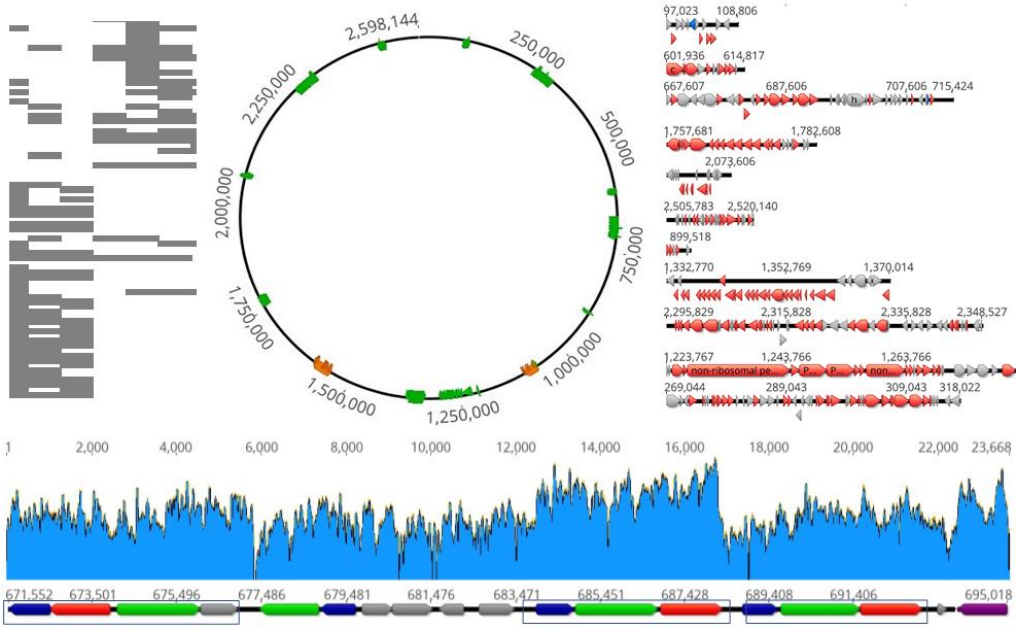
Kim, J. K., C. Yarish, E. K. Hwang, M. Park, and Y. Kim. 2017. "Seaweed Aquaculture: Cultivation Technologies, Challenges and Its Ecosystem Services." *ALGAE* 32 (1): 1–13.

Omics based comparative analysis of Mobile Genetic Elements in *Lactococcus lactis*

Joakim Mark Andersen*, Christine Møller Pedersen, Claus Heiner Bang-Berthelsen

National Food Institute, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark

*Corresponding author email: joakm@food.dtu.dk



Lactococcus lactis is globally used in dairy fermentation. However dairy based fermented foods are becoming a burden in terms of its carbon footprint whereas plant based dairy alternatives is emerging. Yet traditional starter cultures are not selected or targeted towards the more complex and diverse plant nurients. Therefore we are establishing a biobank of plant associated *L. lactis* and otherstrains to be characterized *in silico* and tested in plant fermentation applications.

Genomics of food fermenting strains is useful in investigations of speciation, key functions and differential occurrence of (un)desired gene functions related to safety, in connection to mobile DNA.

This study investigates *L. lactis* for putative mobile genetic elements through comparative genomics, and to analyse how they contribute to strain variation. Our work identified 111 loci ranging up to 10.8% of the genome size and the loci display a marked differential occurrence in the analysed strains. Analysis of differential transcriptomics data revealed how mobile genetic elements may impact the host physiology in response to conditional changes.

The insight in the genetic variation of mobile genetic elements in *L. lactis* holds potential to further identify important functions related to food and biotechnology application within this important species.

Electrospun phospholipids fibers: making and applications

Ana C. Mendes*[1], Ioannis S. Chronakis[1]

1: Nano-Bio Science Research Group, DTU-Food, Technical University of Denmark, Kemitorvet 202, 2800 Kongens Lyngby, Denmark
*Corresponding author email: anac@food.dtu.dk

Natural phospholipids are often isolated from renewable sources (e.g. soybean, rapeseed, and sunflower seed) and manufactured with more ecologically friendly processes in larger scale at relatively low cost comparatively to synthetic phospholipids. Therefore, we have been exploring the potential of using natural phospholipids to create functional asolectin phospholipid nano-microfibers by electrospinning (Figure 1) [123]. Fibers production and morphology is dependent on the phospholipid concentration and the solvents used[1]. Moreover, the diameter of the fibers can be tuned by using co-axial electrospinning. Their mechanical properties were evaluated by nanoindentation using Atomic Force Microscopy, and their elastic modulus was found to be approximately 17.3 MPa[2]. Furthermore, electrospun phospholipid microfibers were found to have the potential to be used as antioxidants and encapsulation matrices for bioactive compounds such a curcumin and vanillin[3].

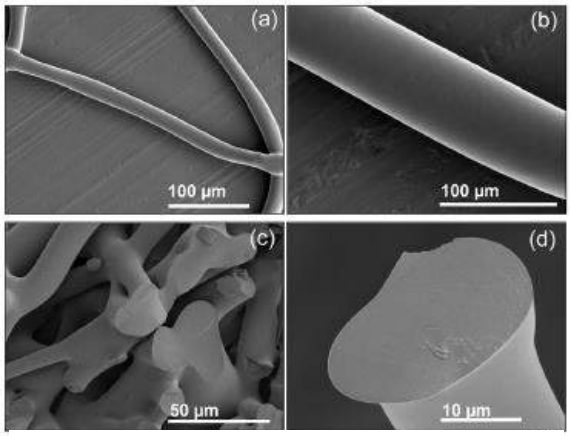


***Figure 1**. SEM images of (a) electrospun asolectin microfibers, (b) a single fiber at a higher magnification showing the smooth surface of the fiber, (c) cross-section of several and (d) single fiber at higher magnification (Image adapted from[2]).*

References

1. Jørgensen, L., Qvortrup, K. & Chronakis, I. S. Phospholipid electrospun nanofibers: effect of solvents and co-axial processing on morphology and fiber diameter. *RSC Adv.* **5**, 53644–53652 (2015).
2. Mendes, A. C., Nikogeorgos, N., Lee, S. & Chronakis, I. S. Nanomechanics of electrospun phospholipid fiber. *Appl. Phys. Lett.* **106**, (2015).
3. Shekarforoush, E., Mendes, A., Baj, V., Beeren, S. & Chronakis, I. Electrospun Phospholipid Fibers as Micro-Encapsulation and Antioxidant Matrices. *Molecules* **22**, 1708 (2017).

Nano fibrous polysaccharide food matrices for the delivery of anti-oxidants

Elhamalsadat Shekarforoush, Adele Faralli, Ioannis S. Chronakis, Ana C. Mendes*

1: Nano-Bio Science Research Group, DTU-Food, Technical University of Denmark, Kemitorvet 202, 2800 Kongens Lyngby, Denmark
*Corresponding author email: anac@food.dtu.dk

Polysaccharides are a class of sustainable and renewable polymers that can be used in a broad range of food applications, including encapsulation and delivery of anti-oxidants. Electrospinning, as encapsulation technology, allows the production of nano-microfibers using a broad range of shell materials and bioactives encapsulated with high encapsulation efficiency. In addition, the high surface area, tunable diameter and surface functionality of nano-microfibers offers the possibility to control the release of bioactives[1,2]. Therefore, this work aimed to blend Chitosan (Ch), a biocompatible and mucoadhesive polysaccharide with ability to enhance gastrointestinal drug absorption, with xanthan (X) gum polyssacharide to produce Ch-X electrospun fibers for encapsulation and improved delivery of Curcumin. Fiber creation required the formation of a viscoelastic gel network, shear-thinning behavior and specific viscosity values of X-Ch solutions that were achieved for mixtures X-Ch containing minimum 0.75% xanthan. The encapsulation of curcumin (aprox 69%) led to a slightly increase in fiber diameter, as result of the increase of viscosity of the solution, although no interactions between the biopolymer matrix and curcumin were detected. The release of curcumin from X-Ch electrospun fibers in pH 1.2; 6.5 and 7.5 was observed to be similar within 8h of release study. However, after 120h, the release of curcumin at pH 1.2 was partially hindered, whereas a neutral pH, 5 times more curcumin was released. Caco-2 cells exposed to X-Ch-Cu exhibited 80% of viability. Enhanced *in vitro* absorption of curcumin across Caco-2 cell monolayers was observed when curcumin was encapsulated and released from the fibers comparatively to free curcumin[3]. The results obtained revealed that X-Ch nanofibers can be used for the delivery of poorly water-soluble anti-oxidants, e.g. curcumin, at the gastrointestinal tract.

References

1. Mendes, A. C., Stephansen, K. & Chronakis, I. S. Electrospinning of food proteins and polysaccharides. *Food Hydrocoll.* **68**, 53–68 (2017).
2. Jacobsen, C., Garcia-Moreno, P. J., Mendes, A. C., Mateiu, R. V & Chronakis, I. S. Use of Electrospinning for Encapsulation of Sensitive Bioactive Compounds and Applications in Food. *Annu. Rev. Food Sci. Technol.* **9**, 1–25 (2018).
3. Faralli, A., Elhamalsadat Shekarforoush, Mendes, A. C. & Chronakis, I. S. In vitro permeability enhancement of curcumin across Caco-2 cells monolayers using electrospun xanthan-chitosan nanofibers. *Carbohydr. Polym.* (2018).

Oxidative stability of omega-3 emulsions stabilized by potato peptides

P.J. García-Moreno[1], E.B. Hansen[1], M.L. Andersen[2], P. Marcatili[1], A.-D. M. Sørensen[1], C. Jacobsen[1]

1: Technical University of Denmark, Lyngby, Denmark; 2: University of Copenhagen, Copenhagen, Denmark

*Corresponding author email: pejeg@food.dtu.dk

Many food products are oil-in-water emulsions (e.g. mayonnaise, milk, dressings, and beverages). Proteins are commonly used as emulsifiers to stabilize oil-in-water emulsions due to their amphiphilic properties, which permit them to unfold at the interface, stabilizing oil droplets via steric and/or electrostatic repulsion. In the last years, there is an increasing trend to replace animal proteins (e.g. casein and whey protein) by plant proteins in vegetarian or vegan products, as well as to enhance food sustainability. Several plant proteins have been reported to show emulsifying properties. Additionally, enzymatic hydrolysis of plant proteins may release embedded peptides with improved functional (e.g. emulsifying) or bioactive (e.g. antioxidant) properties. Particularly interesting is the production of added-value ingredients from by-products streams. In this regard, the potato industry produces a considerably volume of side-streams rich in proteins. These potato proteins may have the potential to be used as cheap raw material for the production of high-added value products such as plant-based emulsifiers.

In this study, the physical and oxidative stability of 5% fish oil-in-water emulsions stabilized with synthetic potato peptides was investigated. Six different peptides with potential different conformation at the interface (e.g. α-helix, β-sheet or random coil) and predicted to have emulsifying activity by bioinformatics were assayed. First, the physical stability of the emulsions was monitored by measuring droplet size, zeta potential and interfacial tension. Secondly, oxidative stability of the emulsions was evaluated by: i) electron paramagnetic resonance (EPR) (e.g. to determine trapped radicals formed from lipid oxidation), and ii) measuring the oxygen consumption rate in the emulsions by using Oxygraph.

These results provide new insights into the production of emulsifying peptides from potato protein.

Oxidative stability and oxygen permeability of fish oil-loaded electrosprayed capsules

D.M.W. Boerekamp[1], C. Jacobsen[1], M.L. Andersen[2], I.S. Chronakis[1], P.J. García-Moreno[1]

1: Technical University of Denmark, Lyngby, Denmark; 2: University of Copenhagen, Copenhagen, Denmark

*Corresponding author email: pejeg@food.dtu.dk

Lipid oxidation (rancidity) is one of the main causes of food deterioration and off-flavour formation. Moreover, oxidation of lipids can result in the generation of harmful compounds (e.g. toxic aldehydes). Food industry is interested in the production of food enriched with omega-3 fatty acids (due to their beneficial health effects) (e.g. infant formula). Encapsulation of omega-3 polyunsaturated fatty acids is a common strategy to protect them against oxidation (e.g. by creating a barrier between lipids and prooxidants) when incorporation them into food matrices. Electrospraying is a promising encapsulation technique since it does not require heat, allowing to dry omega-3 emulsions at room temperature. This is of special importance to avoid degradation of thermosensitive bioactive compounds such as long-chain omega-3 fatty acids.

This work aimed at investigating the oxygen permeability and oxidative stability of fish oil-loaded electrosprayed capsules by using electron spin resonance (ESR). Two different types of capsules were produced by employing either dextran or glucose syrup as main shell materials. Electrosprayed capsules with dextran as main biopolymer showed a significantly faster broadening (ΔH_{pp}) of 16-doxyl-stearate ESR spectrum when compared to glucose syrup capsules, which indicates a higher oxygen permeability for dextran capsules. This is explained by the lower free volume of the glucose syrup-capsule shell, which limited oxygen diffusivity to a higher extent than the dextran wall. Moreover, glucose syrup capsules showed a significantly lower increase in the peak-to-peak amplitude of N-tert-Butyl-α-phenylnitrone ESR spectrum during storage when compared to dextran capsules. This implies a higher oxidative stability of glucose syrup capsules than dextran capsules, which correlates well with the lower oxygen permeability of the former.

These results indicated the importance of the oxygen barrier properties of the wall materials when encapsulating long chain omega-3 polyunsaturated fatty acids by electrospraying.

Antioxidants characterizations and cosmetics applications of extracts from brown algas *Saccharina latissimas*

Ditte B. Hermund[1*], Niruja Sivasubramaniam[1], Randi Neerup[2], Birgitte R. Thomsen[1] & Charlotte Jacobsen[1]

1: National Food Institute, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark
2: Danish Technological Institute, DK-2630 Taastrup, Denmark
*Corresponding author email: dbala@food.dtu.dk

Studies have shown that brown seaweed contains a wide range of bioactive compounds. Hence, brown algae extracts may potentially be applied in facial cream formulations as a functional ingredient e.g. contributing with antioxidant activity. Moreover, the antioxidant activity of brown algae extract can also increase the oxidative stability, and thereby, protect lipids in the facial cream formulations, which are prone to oxidation.

Our ongoing work aims to extract highly antioxidative compounds from brown alga *Saccharina latissima* (sugarkelp) and find application for these extracts in facial cream. Hence, more than thirty *S. latissima* extracts were screened for total phenolic content (TPC) and *in vitro* antioxidant properties. Based on the screening, three extracts were chosen for full characterization, and the antioxidants, such as phenolic compounds and pigments were identified. Furthermore, formulation trials were conducted in which the extracts were added to facial cream and the antioxidant efficacy and stability are under evaluation.

It was found that the antioxidant composition and properties *in vitro* were highly dependent on the extraction media. The water extract contained higher amounts of phenolic compounds compared to ethanol extracts, and also showed the highest metal chelating ability and radical scavenging capacity in vitro. Moreover, whereas ethanol extracted pigments, such as chlorophylls and fucoxanthin, only ß-carotene was identified in the water extract.

These results will be presented on the poster together with preliminary results of the stability studies.

Session

G

Laptop Presentations

See session details and schedule on
www.sustain.dtu.dk

AquaGreen and DTU, projects and collaboration

Claus Dalsgaard Jensen

1: Former student of DTU. Holds a M.Sc.Eng. from the Department of Sustastainable Energy DTU, within the field of Biofuels. Currently employed as a Project Engineer in AquaGreen ApS.

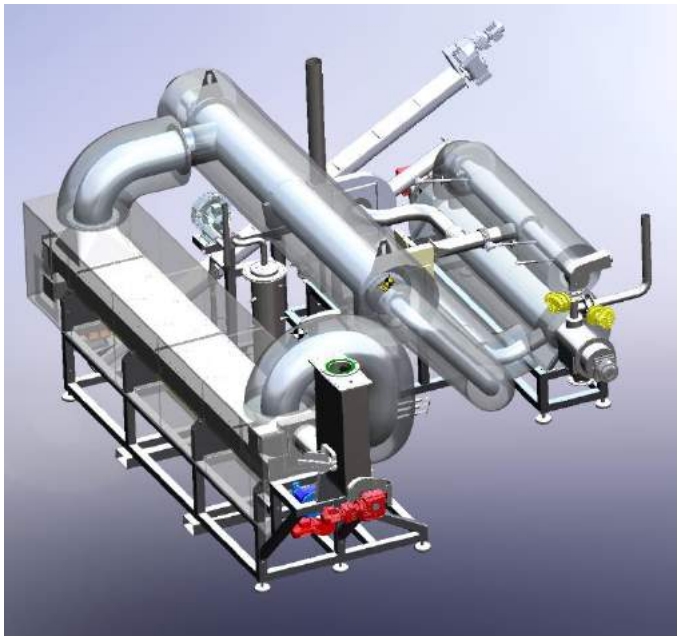
*Corresponding author email: cdj@aquagreen.dk

AquaGreen is a company that since 2014 has been developing technology for thermal processing and handling of sludge-biomass from waste water treatment plants or the aquaculture industry. We use steam drying and pyrolysis and has developed our technology in close corporation with the Chemical & Biological Engineering Department at DTU campus Risø.

AquaGreen and their partners have received around 22 million DKK in funding over the years in the development and demonstration of our technologies, in which DTU has been a very important partner. We currently have two patents pending on our technology that is partly owned by DTU and AquaGreen in a 2:1 configuration.

AquaGreen's technology have the potential of becoming a worldwide success and is currently rolled out in the waste water treatment industry in Denmark and the aquaculture industry in Norway.

The presentation will be about the benefits of our collaboration with DTU and on sharing the experiences we have on funding opportunities.



Session

H

Laptop Presentations

See session details and schedule on
www.sustain.dtu.dk

Wound Diagnostics

Susan Ibi Preus[1], Maria Dimaki[2], Winnie E. Svendsen[3*]

DTU Nanotech
Contact: Winnie.svendsen@nanotech.dtu.dk

Infections in clinical wounds covers approximately 2% of the hospital expenses in DK, corresponding to more than 1 billion DKK/year. An intelligent wound dressing that can monitor a wound and warn about a rising infection can be one way to lower expenses. The intelligent wound dressing will allow the doctor, or home-care nurse, to monitor the wound without opening the wound dressing thus preventing exposing the wound to pathogens. Current standard methods for diagnosis rely on visual inspection of the wound by physicians, swab, growth and MALDI-TOF analysis, which is time consuming (days to weeks). During this time the patient is administered broad spectrum antibiotics. The intelligent wound dressing will allow the doctor to initiate pathogen-specific treatment and, consequently, reduce the development of multiresistent bacteria.

The sensor will initially screen for the most prevalent pathogens found in clinical and diabetic wounds. The sensor readout will be digitalized and adapted into current cloud-based solutions. The sensor will also contain a QR code such that each wound dressing sensor is linked directly to the patient journal.

Susan Ibi Preus, Maria Dimaki and Winnie E. Svendsen (Technical team) from DTU Nanotech, Lars Jelsbak (Bioassay) from DTU BioEngineering, Jan Madsen (digitalization) from DTU Compute, Dianova (commercialization), Dan Høgdall (clinical adviser) from Herlev hospital and POC solutions.

Session

H

Poster Presentations

See session details and schedule on
www.sustain.dtu.dk

Development of Polymeric Nanobiocatalysts for Diagnosis and Treatment of Atherosclerosis Disease

Jong Hyun Lee[1], Andreas Hadjistylli[1], Sergey Chernyy[1], Salime Bazban-Shotorbani[1], Suman Basak[1], Philip Charlie Johansen[2], Nazila Kamaly[*1]

[1]: Department of Micro- and Nanotechnology, Denmark Technical University, Produktionstorvet Kgs, Lyngby 2800, Denmark.
[2]: Department of Chemistry, Denmark Technical University, Kemiorvet Kgs, Lyngby 2800, Denmark.
*Corresponding author email: nazk@nanotech.dtu.dk

Atherosclerosis is a systemic and chronic inflammatory condition in which plaques build up inside the arteries. Accumulation of cholesterol in early lesions leads to the formation of macrophage foam cells that ingest free cholesterol, eventually resulting in the presence of intra- and extracellular cholesterol crystal (CC) in advanced atherosclerotic plaques. Over time, growth of the necrotic core leads to plaque destabilization and vessel narrowing, which in turn increases the risk of rupture and thrombosis, leading to heart attacks and strokes. The formation of sharp-edged CC can result in piercing of biological membranes, an effect that was previously confirmed by scanning electron microscopy (SEM) of clinical coronary artery samples from patients, that showed evidence of CC perforating arterial walls, an observation that was evident only in patients who had died of acute coronary syndrome (and not observed in patients with advanced atherosclerosis who were not suffering from acute cardiac events). These studies demonstrated a link between CC, plaque disruption and vascular injury. CC is present in all stages of atherogenesis and can be phagocytosed by macrophages. The abundant uptake of CC by macrophages induces lysosomal damage that leads to the activation of the NLRP3 inflammasome, which subsequently activates caspase-1 and the secretion of IL-1β cytokines.

In this work we have developed novel catalytic and anti-inflammatory polymeric nanomedicines that are capable of directly diminishing a major detrimental effect of atherosclerosis; the formation of CCs within plaques. We present the development and characterisation of targeted polymeric nanobiocatalysts capable of selectively targeting atherosclerotic plaques and 'dissolving' CCs via a bioinspired catalytic approach based on innate cholesterol catabolic pathways. Given the recent results of the CANTOS trial by Novartis on raising hopes for anti-inflammatory therapies for patients with atherosclerosis, the approach of delivering anti-inflammatory biologics to the plaque in a targeted manner is highly timely.

Dysfunctional Endothelium-on-a-chip, The Next Generation of Drug-screening Systems for Cardiovascular Disorders

Salime Bazban-Shotorbani[1], Jong Hyun Lee[1], Krishna Kant[2], Janko Kajtez[1], Martin Dufva[1], Nazila Kamaly*[1]
[1] Department of Micro- and Nanotechnology, Technical University of Denmark, Lyngby, Denmark
[2] INL-International Iberian Nanotechnology Laboratory, Braga, Portugal
*Corresponding author email: nazk@nanotech.dtu.dk

Among various diseases, cardiovascular disorders (CVD) are the world's leading killer. These diseases cause an estimated 18 million deaths every year, which is 31% of all mortality worldwide [1]. Therefore, there is an enormous need for new cardiovascular medicines. Despite such a demand, Food and Drug Administration (FDA) approvals for new CVD medicines decreased by 33% during the last decade [2]. The reason behind this decline is absence of effective drug-testing systems for CVD medicines prior to their marketing stages [3]. Generally, drug-testing systems can be categorized into two groups, *in vitro* testing (*i.e.* traditional cell- and tissue-cultures) and *in vivo* testing (*i.e.* animal models). *In vitro* tests cannot recapitulate the complex environment of the body. On the other hand, *in vivo* tests are expensive, time-consuming, ethically controversial, and poor predictors of human responses because of physiological differences between humans and animals. To overcome these shortcomings, vessel-on-a-chip systems have recently achieved wide attention as a suitable alternative for traditional tests. Vessel-on-a-chip systems are microfluidic cell culture systems engineered to mimic the physiological function and environment of a vessel on a small chip.

The developed chip in this project consists of two polydimethylsiloxane (PDMS) layers separated by a porous polyethylene terephthalate (PET) membrane (Figure 1). Each PDMS layer has a microfluidic channel with an inlet and outlet. Endothelial cells were cultured on the membrane. Therefore, the upper channel can simulate the lumen, where blood flows. The fabrication process of the proposed chip consists of three main steps. The first step is fabrication of silicon molds by photolithography of SU-8 (Figure 2,a). Then, these molds were used to make PDMS layers based on standard soft lithography process (Figure 2,b). Finally, the surface of the membrane and PDMS layers were chemically treated in APTES solution and physically treated in oxygen plasma, respectively. The activated PDMS layers and the membrane were brought into contact in order to attach the layers and make a three-layered microfluidic chip. As can be seen in figure 1, various drugs and drug-loaded nanoparticles can be injected into the upper microchannel. Then, their translocation through endothelial cells can be studied by collecting the samples from the lower microchannel.

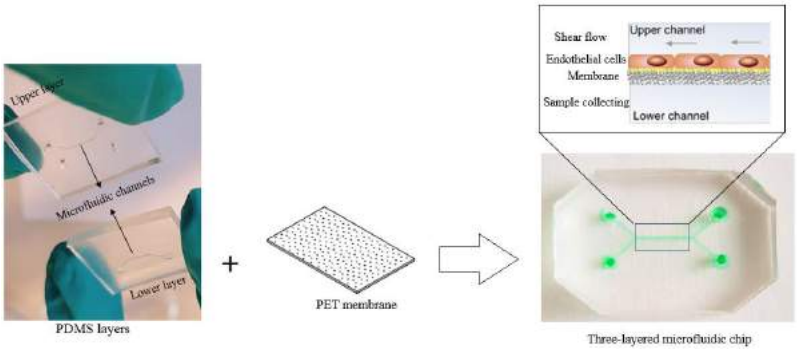


Figure 1. Developed microfluidic chip in this project.

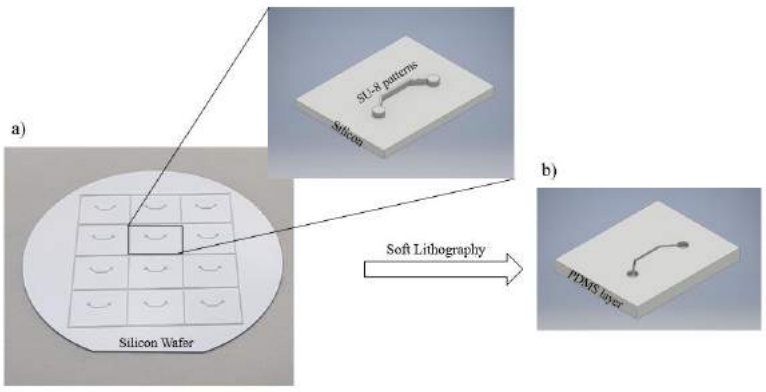


Figure 2. Schematic representation of a master mold (a), and a PDMS layer (b).

1. World Health Organization (WHO), *Heart disease statistics*, 2017.
2. Fordyce, Christopher B., et al. *Journal of the American College of Cardiology* 65.15 (2015): 1567-1582.
3. Ribas, João, et al. *Applied in vitro toxicology* 2.2 (2016): 82-96.

Session

L

Oral Presentations

See session details and schedule on
www.sustain.dtu.dk

Planning For The future: a 50-year wastewater strategy for Greater Copenhagen Utility

Ida Marie Knudsen[1]*, Jonas Smit Andersen[2]

1, 2: HOFOR Greater Copenhagen Utility
*Corresponding author email: idkn@hofor.dk

Greater Copenhagen Utility (HOFOR) had the goal of developing a strategy for the future wastewater system that supports the vision of creating sustainable and resilient towns for future generations. A long-term strategy for the transition of the system into a sustainable and resilient structure is difficult to define. However, without a clear strategy we are in high risk of investing in an inadequate system. With this strategy, the existing wastewater infrastructure is placed in a context of a 50-year planning period with the goal of balancing investment plans, climate change, cloudburst mitigation, environmental goals and the unpredictability of the future. The 50-year strategy points to the optimized use of the existing structure by combining it with the parallel strategic decision of a separate system for stormwater, both underground and integrated in the urban landscape. The scale of which a separate stormwater system is employed is weighted against the risk of reinvestment and the consequent effects of a separate stormwater system, such as environmental and financial cost of an increasingly more decentralized system.

A review of current work with social sustainability in the built environment

Nanna Brøgger Larsen[1], Lotte Marianne Bjerregaard Jensen[1]

1: Department of Civil Engineering, Technical University of Denmark, Kongens Lyngby, Denmark

Abstract. Sustainability is based on the United Nation' (UN) Brundtland Report, which defines economic, social and environmental factors that can ensure long-term economic viability while maintaining an environmental balance and showing commitment to socially desirable practices. Great focus has been on integrating environmental and economic factors into the project processes. There is substantial potential in developing a strategic process to ensure that social sustainability is systematically incorporated into a project equally with economic and environmental factors. Research in the field is scarce and suggests that social sustainability is a secondary parameter even though it is integrated in building projects today. There is a tendency that decisions made regarding which social sustainability aspects is to be integrated in a project is based on experience from previous projects. There is a need of a strategic approach on how to handle and work with social sustainability that is based on more than experience. Can decisions be informed by quantifiable information about social sustainability as is the case with economic and environmental sustainability?

References

Shirazi MR, Keivani R. Critical reflections on the theory and practice of social sustainability in the built environment – a. Local Environ. 2017;9839.

Littig B, Griessler E. Social sustainability: a catchword between political pragmatism and social theory. Int J Sustain Dev [Internet]. 2005;8(1/2):65. Available from: http://www.inderscience.com/link.php?id=7375

Dempsey N, Bramley G, Power S, Brown C. The Social Dimension of Sustainable Development: Defi ning Urban Social Sustainability. Sustain Dev [Internet]. 2011;19(May 2009):289–300. Available from: http://onlinelibrary.wiley.com/doi/10.1002/sd.417/pdf

Vallance, S., Perkins, H.C, Dixon, J.E. What is social sustainability, a clarification of concept. Geoforum. 2011;42:342–8.

Cuthill M. Strengthening the 'social'in sustainable development: Developing a conceptual framework for social sustainability in a rapid urban growth region in Australia. Sustain Dev. 2010;18(6):362–73.

Weingaertner C, Moberg Å. Exploring social sustainability: Learning from perspectives on urban development and companies and products. Sustain Dev. 2014;22(2):122–33.

Åhman H. Social sustainability - society at the intersection of development and maintenance. Local Environ. 2013;18(10):1153–66.

Is green infrastructure more sustainable? Environmental life cycle assessment of four different stormwater management systems

Sarah Brudler*[1,2], Karsten Arnbjerg-Nielsen[1], Michael Zwicky Hauschild[3], Christian Ammitsøe[4], Martin Rygaard[1]

1: DTU Environment, 2: VCS Denmark, 3: DTU Management Engineering, 4: HOFOR
*Corresponding author email: sabr@env.dtu.dk

Green infrastructure is increasingly used in to manage stormwater, as it is expected to add additional aesthetic and recreational benefits that traditional infrastructure like pipes and basins can not provide. It is often assumed that it is also more environmentally sustainable, but this assumption is rarely substantiated. We used life cycle assessment to compare the environmental sustainability of different four stormwater management systems for a Danish catchment. This allowed us to quantify the tradeoff between resource consumption for infrastructure and treatment, and point source emissions caused by discharges of polluted stormwater (Figure 1). Traditional subsurface systems require significantly more non-renewable resources than green infrastructure systems. At the same time, the latter are less efficient in removing pollutants from stormwater than central wastewater treatment, leading to higher ecosystem damage. These findings highlight the need for holistic and quantitative sustainability assessment in order to minimize the environmental damage of stormwater management.

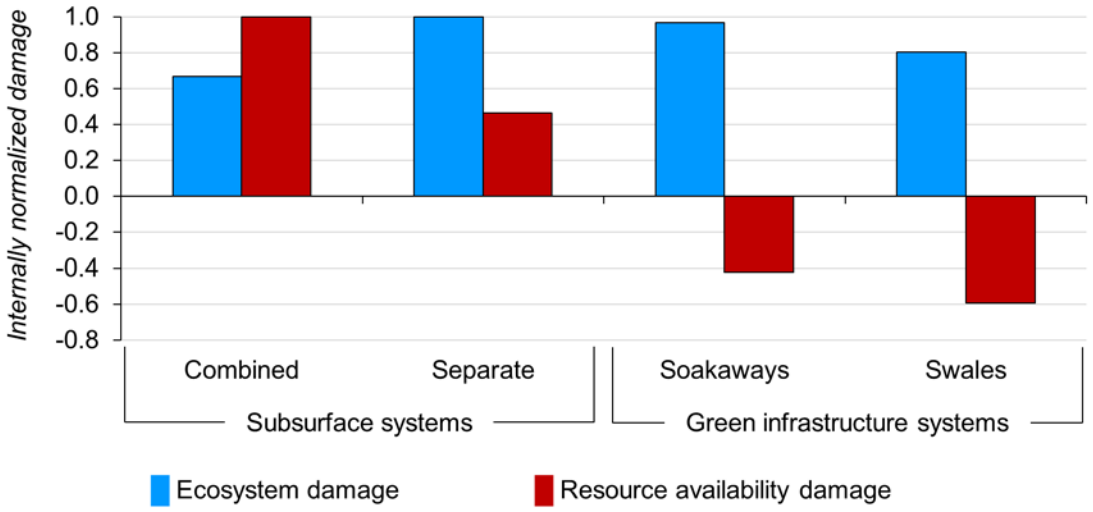


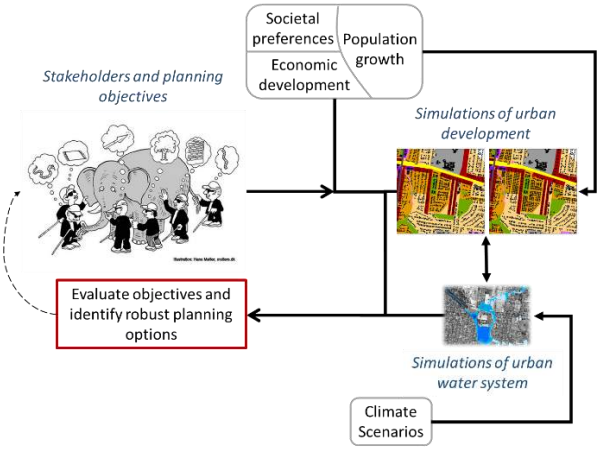
Figure 1. Internally normalised ecosystem and resource availability damage for four different stormwater management systems for the Skibhus catchment (Brudler, S., 2019. Life Cycle Assessment of Stormwater Management Systems – Quantification of environmental impacts for decision support. PhD thesis, DTU Environment, Lyngby)

Evaluation and Simulation of Urban Water Management from a Multi-Stakeholder Perspective

Roland Löwe[1],*, Julie Skrydstrup[1], Herle M. Madsen[1], Agnethe N. Pedersen[2], Ida B. Gregersen[3], Karsten Arnbjerg-Nielsen[1]

1: DTU Environment; 2: Vandcenter Syd (VCS); 3: Rambøll Denmark
*Corresponding author email: rolo@env.dtu.dk

Multi-stakeholder approaches to urban water management are likely to consider water in earlier stages of the planning process. This can contribute to reduced risk of flooding (SDT1.5, 13.1), and promote the usage of urban infrastructures for multiple purpose. The latter leads to a reduced environmental footprint (SDT 11.6) and economic cost, as well as improved air quality if the implementation of green areas in urban spaces is promoted. However, in many countries the collaboration amongst stakeholders requires a re-negotiation of existing legal frameworks, and discussions on who benefits and who pays the bill will arise.



To facilitate discussions, it is necessary to know which stakeholders interact with urban water management and what their various objectives are. Based on a stakeholder analysis in Danish literature, as well as a series of workshops with relevant actors, we have condensed this information into a structured overview similar to Lienert et al. (2015), which can be used to identify which stakeholder should be involved in a planning decision. As a next step, we aim to quantify the objectives in simulations to assess the impact of planning decisions on various stakeholders preferences.

The quantification of planning objectives requires a modelling setup, which can link the effects of urban water management on various city planning parameters and vice versa. In addition, investments into water infrastructure as well as urban planning decisions can have consequences over time horizons of several decades and more, and need to be considered in a context of uncertain socio-economic and climate developments. For the city of Odense we extend the framework described by (Löwe et al., 2017) to perform assessment of a wide range of urban water management indicators for a variety of user-defined scenarios of climate and socio-economic developments.
Our framework enables collaborative efforts linking, for example, design of water management to aspects of urban mobility, recreation and health. Challenges arise from quantifying intangible objectives and the lack of experience with making decisions under uncertainty. These are the subject of on-going work.

Lienert, J., Scholten, L., Egger, C., Maurer, M., 2015. Structured decision-making for sustainable water infrastructure planning and four future scenarios. EURO J. Decis. Process. 3, 107–140.
Löwe, R., Urich, C., Sto. Domingo, N., Mark, O., Deletic, A., Arnbjerg-Nielsen, K., 2017. Assessment of Urban Pluvial Flood Risk and Efficiency of Adaptation Options Through Simulations – A New Generation of Urban Planning Tools. J. Hydrol. 550, 355–367.

Operationalizing the SDGs to help evaluate the sustainability of climate adaptation measures

HJD Sørup[1]*, K Arnbjerg-Nielsen[1], M Feilberg[2], L Liu[3], O Fryd[3], K Ulbak[4], MB Jensen[3]

[1] DTU Environment, [2] DANVA, [3] University of Copenhagen, [4] Teknologisk Institut

* Presenting author

Water is the only resource to have received a goal of its own in the UN SDGs, SDG6. Hence, SDG6 is often the main focus for water professionals. However, the purpose of urban water management is much broader than what is covered by SDG6 and is reaching far into other targets as for instance SDG11 on resilient cities and SDG13 on climate change.

Climate change adaptation of cities should ideally, on top of handling water, deliver a multitude of other services to society; it is often seen used as a levee for transforming cities in a more livable, green, and resilient direction and these measures should be acknowledged as part of the services delivered.

In this study we identify a range of services that climate change measures can deliver within four overall domains: stormwater management, resources management, livability for people, and transition and innovation. For each service we identify relevant targets from all SDGs and their associated indicators. Based on the targets and indicators we then assess what would be the most relevant target(s)/indicator(s) to measure the sustainability of a given service function at project/planning level and we formulate indicators that reflect the intention with the global targets and indicators.

We demonstrate through Danish examples from lot to city scale that the proposed methodology can help inform decision makers about the sustainability of climate adaptation measures through provision of quantitative measures relating to relevant UN SDG targets. This should, ideally, lead to more focused and informed work towards achieving the UN SDGs.

Session

L

Laptop Presentations

See session details and schedule on
www.sustain.dtu.dk

Data analysis on ventilation systems for energy screening

Ole Schultz[1], Per Christensen[1], Michael Dahl Knudsen*[2], Jakob Nørby*[3] ,Bo Eskerod Madsen*[3]

1: Associate Professor, DTU Diplom – EIT osch@dtu.dk, 2: Associate Professor Per Christensen, DTU Diplom -DMP 2*Engineering Århus Universitet, mdk@eng.au.dk. 3*Danish Energy Management,jny@dem.dk, REMONI, bem@remoni.dk.

When energy consultants perform energy screening, they spend many hours inspecting the specific building and collecting data and specifications on installed equipment and the building envelope. Based on this information the consultant advises the building owner about energy saving measures and their savings potential.

By using clamp on temperature and power sensors (Figure 1) (1), it is possible to detect in detail how building systems actually operate without spending hours on inspection and without connecting to the BMS (Building management system). This data can help answer the questions “Is the system operated in accordance with the actual usage?” or “is the performance of the building components as expected?” (2)

The presentation discuss and shows some results from the ESNAP project (3) externally funded by the Danish Energy Agency. We will present some evaluation of the performance – and modeling of the system and its components by using one airflow measurement together with-non-intrusive power and temperature measurement of a ventilation system. An ex. in Figure 2 on power dynamics

Figure 1

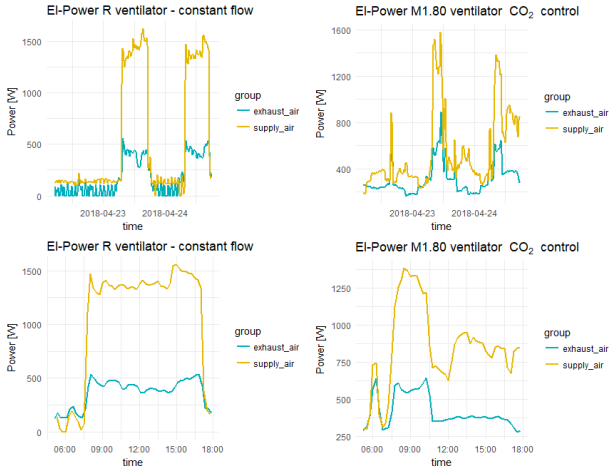


Figure 2

References:

1: https://www.remoni.com/media/1422/data-sheet_powermonispot_ver_200.pdf

2: A review of Methods to match building simulation models to measured data. Authors: Daniel Coakly, Paul Raftery, Marcus Keane, Journal Renewable and Sustainable Energy Reviews p 123 – 141 2014

3. ESNAP Bo Eskerod Madsen (REMONI), Ole Schultz, Per Christensen)(DTU Diplom),Michael Dahl Knudsen (AU),Jakob Nørby (Danish Energy Management) 2018-2019.

Improving urban energy system operation with flexible heat and power coupling

Hanmin Cai[1], Shi You[1]

1: Department of Electrical engineering, Technical University of Denmark
*Corresponding author email: hacai@elektro.dtu.dk

Low-temperature district heating (LTDH) has been proposed to reduce heat loss and facilitate renewable energy integration. Yet, LTDH alone is insufficient for domestic water heating, which requires 50 °C for circulation and 60 °C as set point temperature for the storage tank due to hygiene concern. The engineering solution to address this is to complement existing system with heat booster. It is expected to be a widespread coupling across power system and district heating system and represents the flexibility to support integrated energy system operation. Our work is based on this paradigm shift in the research of integrated energy system and this abstract presents partly the results from reference [1]. We based our work on real system in Copenhagen's Nordhavn area, as a part of the large demonstration project - EnergyLab Nordhavn.

The analysis on fuel shift technology shows substantial benefits and the potential to provide more services in an integrated energy system. It was based on a district terraced single-family houses supplied by both a low-temperature district heating (LTDH) network and a low-voltage network (LVN). A real example is illustrated in Fig. 1. It was shown that district heating network (DHN) losses could be reduced by 35% if the supply temperature is reduced from 70 °C to 50 °C, but the LVN peak power will have to be increased by up to 2% using heat boosting. It further aggregated EHBs to provide a fuel shift (FS) service for the DHN. The results show that while LVN peak power was increased by up to 4.3%, the basic power production and peak boiler usage for DHN could be reduced by as much as 15% and 48%, respectively. In summary, lower supply temperatures and intelligent components can improve system efficiency and turn the DHN into an integrated part of a SES.

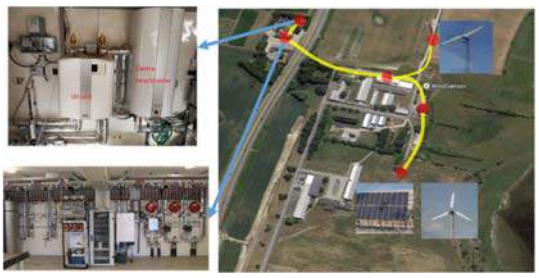


Fig 1. Building's connection to heat and power system

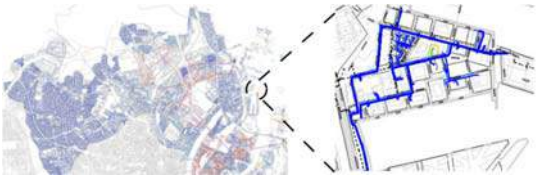


Fig 2. Field demonstration

[1] Cai, H., You, S., Wang, J., Bindner, H.W. and Klyapovskiy, S., 2018. Technical assessment of electric heat boosters in low-temperature district heating based on combined heat and power analysis. Energy, 150, pp.938-949.

Session

P

Oral Presentations

See session details and schedule on
www.sustain.dtu.dk

The Regional Nordic Hub: Alternative protein production in the Nordic Bioeconomy.

Jesica Murcia López[1], Morten Gylling[1]

[1]University of Copenhagen, Department of Food and Resource Economics
jaml@ifro.ku.dk

The Nordic Bioeconomy in regards to the protein potentials for higher value products for feed and food as well as the need for new alternative protein solutions is capable of contributing with advanced bio-industries, international recognized research in bioprocesses, biobased products and biological solutions with strong competences and skills from the preferred partners. In the present, there is no international EU strategy for a sustainable protein shift, which opens up an opportunity for the creation of a Regional Nordic Hub to establish Nordic initiatives as pioneers in the protein solution innovation and the co-benefits in the Bioeconomy of the region and in Europe. The latest update in terms of the EU Protein strategy, it will be launched in late November 2018 by the European Commission.

The Regional Nordic Hub (RNHub) in the Nordic Bioeconomy, focuses to increase and strength a Nordic public private partnership model to collaborate in beneficial market opportunities in the fields of production patterns, bioprocessing and breeding techniques of alternative-based proteins innovation (e.g.: Green protein: Lupins, Faba beans, Field pea, Field beans, Spring turnip rape, Spring oil seed rape, Ryegrass, Red clover, White clover, Lucerne (alfalfa); Blue protein: seaweed, mussels, starfish, macro-microalgae, and possibly Yellow protein: insects) in the region. Therefore, the Hub is aiming on the establishment of key networks to understand the regional development in terms of the bioeconomy strategies that focus on the opportunities of this uprising protein industry.

The RNHub aims at empowering a cross-regional Nordic innovation network to stimulate and implement climate smart solutions with focus on the production of alternative proteins (plant-based, algae- based, insect-based, fungi-based) value chains. The RNHub activities are divided into five objectives, i) to gather key academic and industrial partners to build community; ii) to organize events and facilitate networking with stakeholders; iii) to accelerate innovative projects based on the sustainable development of alternative proteins used in the food and feed sectors, and iv) to coordinate Regional Nordic Hub Governance meetings for its long-term impact in the protein industry; and v) the elaboration of impactful communication material to create awareness of the opportunities for the Bioeconomy of alternative proteins.

The Climate Smart Agriculture booster a flagship programme of the Climate-KIC Sustainable Land Use Theme supports this project.

Protein from green biomass as a food resource

Daniel Stender Nørgaard, Mikkel Duvier Stærmose and Peter Ruhdal Jensen

Research Group for Microbial Biotechnology and Biorefining
National Food Institute, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
*Corresponding author email: perj@food.dtu.dk

The world population growth and the protein demand that follows, requires new alternatives to meat. We are adjusting to fully utilise our planets resources and in this context biorefining plays a critical role. Danish agricultural scientists has established methods for utilisation of protein from green biomass, as an alternative to soy protein in poultry and pigs feed. The prior research has shown that protein extracts that are derived from green biomass, has a very favourable amino acid profile, similar to that of milk and meat. Compared to other protein resources, grass is much more sustainable, and in a food ingredient perspective, it is also a very cheap resource. The nutritional properties, sustainability and availability perspectives, makes the green protein a good candidate as future alternative protein resource, but there are challenges related to off flavours and other properties when used as food ingredient. We have very promising results on how we can utilise a fraction from the green biomass feedstock production, as a food ingredient. By making a few adjustments to the protein extraction process, and implementing a few additional processing steps, such as solvent extraction, the protein extracts can be used successfully for protein enrichment in e.g. bread, energy rich snack products, plant based meat substitutes etc.

Our research group collaborate with several relevant industrial partners, to develop a cost-effective and sustainable production of high quality grass protein extracts, that can be used as protein supplement in a wide range of food products.

Seaweed for ruminants- a Climate KIC project

Hanne H. Hansen*[1], Prabhat Khanal[2], Kristine Engel Arendt[3], Edvard Bergiton Iversen[4], Jarmo Valaja[5] , Anni I.K. Halmemies-Beauchet-Filleau[5] , Mette Olaf Nielsen[1]

1: University of Copenhagen , Faculty of Health and Medical Sciences, Depart. of Veterinary and Animal Sciences
2: Nord University, Nord
3: University of Copenhagen, SCIENCE, Private and Public Sector Services
4: AgricTech Nordic, T-lab
5: University of Helsinki, Department of Agricultural Sciences
*Corresponding author email: Hanne Helene Hansen hhh@sund.ku.dk

New and refined techniques have been developed for cultivation of marine plant biomass (macroalgae, also called seaweed), and the future production potential is expected to exceed that of terrestrial plants by 10-fold or more. Macroalgae species are categorized into brown, green and red macroalgae, which contain carbohydrate and protein fractions that are distinctly different from those of terrestrial plants. Within these three main categories, it is possible to find species that have sufficiently high protein contents and organic matter digestibility to make them interesting as alternative, new protein feeds for ruminant livestock – provided they can be marketed at competitive prices in the future. Seaweeds and seaweed extracts have been shown to reduce methane and increase feed degradation in ruminants. Additionally, they can be a valuable source of protein. Specific Nordic species have been tested in the lab at the University of Copenhagen, Department of Veterinary and Animal Sciences, showing promising results. In this way, seaweed as ruminant feed addresses two challenges of ruminant production: methane mitigation and protein supplementation. However, there is a distance from scientific lab results to marketable, validated products and we will address this in a CLIMATE KIC ideation project together with 2-3 Norwegian seaweed producers. During this project, we will focus on the challenges facing nutritional and feeding validation as well as product development and formation.

Microbial protein as an alternative protein source enabling circular bio-economy

Borja Valverde-Pérez*[1], Irini Angelidaki[1], Barth F. Smets[1]

1: Department of Environmental Engineering, Technical University of Denmark, Building 115, DK – 2800, Kgs. Lyngby, Denmark
*Corresponding author email: bvape@env.dtu.dk

Conventional water treatment technologies remove nutrients via resource intensive processes. Similarly, bio-waste is digested in best case scenarios and seldom nutrients are reused as fertilizers. Thus, new approaches for residual nutrient recycling are needed. The increasing meat demand by a growing global population puts higher demands on protein supply. However, vegetable protein production is inefficient, generates large amounts of waste, has a high land and water footprint and is energy intensive. Moreover, the agricultural soils are limited and if more protein should be produced to secure food supply, new and lower-footprint modes to produce protein-rich feed or food ingredients are needed. Production of microbial protein from residual streams not only reduces the demand of vegetable protein, but also reducing the burden of anthropogenic activities by treating waste with more resource and cost efficient processes. Despite its potential, several barriers exist when introducing microbial protein produced from residual resources. For organic wastes which may be polluted with heavy metals, pharmaceuticals and other recalcitrant components or pathogens, several barriers should be put in place when extracting nutrients. We have successfully applied electro-dialysis for nutrient extraction from bio-pulp or urine as a means to recover ammonia free of pollutants. Furthermore, extracted nutrients have been successfully fed to a methanotrophic microbial culture that accumulated protein suitable for substitution of soy or fish meal proteins. When residual streams are byproducts from industry which are safe for reuse, e.g. byproducts from food industry, microbes can be grown without pretreatment. As example, we have cultivated green microalgae and methanotrophs in effluents from potato processing industries and produced biomass with high quality protein (Rasouli et al., 2018). Thus, we have successfully demonstrated that microbial protein can be produced from recovered resources as a promising alternative to traditional protein sources or microbial protein produced with first generation strategies (i.e., relying on fossil fuels).

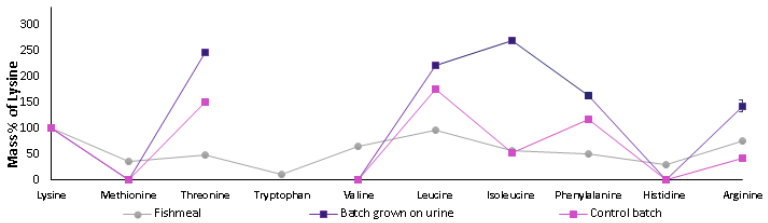


Fig.1 Amino acid profile of microbial protein grown on recovered residual nitrogen from urine and control batch.

Rasouli, Z., Valverde-Pérez, B., D'Este, M., De Francisci, D., Angelidaki, I., 2018. Nutrient recovery from industrial wastewater as single cell protein by a co-culture of green microalgae and methanotrophs. Biochem. Eng. J. 134, 129–135.

Session

R

Oral Presentations

See session details and schedule on
www.sustain.dtu.dk

Sustainable concepts of biorefineries in arid regions

Jens Ejbye Schmidt [1]

1: Department of Chemical Eng., Biotechnology and Environmental Tech. University of Southern Denmark

Implementation of sustainable biorefineries in arid/semi-arid regions can be problematic due to the reduced sustainable resources, e.g. fresh water and biomass. However, the regions still have significantly amounts of biomasses like palm tree residues, seawater biomass-based residues (coastal arid/semiarid regions), and the organic fraction of municipal solid waste. These biomasses can be converted using sustainable biorefinery concepts to added-value products and biofuels using concepts used in non-arid regions. However, due to the limited amount of fresh water, the use of seawater is advisable and can reduce the consumption of fresh water. These seawater-based concepts can also be used for seawater biomass-based residues, minimizing the use of fresh water in the step removing the salt for the biomasses.

Life Cycle Assessment of biorefineries: how robust are the results?

V. Bisinella*[1], K. Conradsen[2], T.H. Christensen, T.F. Astrup

1: Technical University of Denmark, Department of Environmental Engineering, Bygningstorvet, Building 115, 2800 Kgs. Lyngby, Denmark
2: Technical University of Denmark, Department of Applied Mathematics and Computer Science, Richard Petersens Plads, Building 321, 2800 Kgs. Lyngby, Denmark

*Corresponding author email: valenb@env.dtu.dk

Life Cycle Assessment (LCA) studies that aim at supporting decisions usually compare a number of technologies (or technological systems) within a number of framework conditions in which they might operate. Both technologies and framework conditions are subject to uncertainty, due to the data used for the model and to the assumptions taken. LCA studies should quantify and communicate this uncertainty to decision-makers. In particular, when input- and process-specific models are used (e.g. EASETECH LCA model, Clavreul et al., 2014), knowledge of influence of data and model structure allow highlighting strengths and weaknesses of the assessed technologies. However, formal guidance on how to quantify and communicate the results of comparative LCAs subject to data and framework uncertainty is currently missing in the ISO standard (Gregory et al., 2013).

The aim of this presentation is to illustrate a method that combines uncertainty analysis on model data and scenario analysis on framework conditions. The method complements and extends existing step-wise uncertainty quantification methods (Bisinella et al., 2016; Clavreul et al., 2012) using discernibility analysis, Null Hypothesis Significance Testing (NHST) and modified NHST (Mendoza Beltran et al., 2018). The method aims at providing a quantitative indication of the most robust technology within the framework conditions assessed, in a manner simply conveyable to decision-makers. The presentation shows the application of the method to a hypothetical case study that compared waste biorefinery and anaerobic digestion. The study was carried out with the LCA model EASETECH, which allowed detailed input-specific and process-specific modelling of the technologies involved.

Bisinella, V., Conradsen, K., Christensen, T.H., Astrup, T., 2016. A global approach for sparse representation of uncertainty in Life Cycle Assessments of waste management systems. Int. J. Life Cycle Assess. 21, 378–394. doi:10.1007/s11367-015-1014-4

Clavreul, J., Baumeister, H., Christensen, T.H., Damgaard, A., 2014. An environmental assessment system for environmental technologies. Environ. Model. Softw. 60, 18–30. doi:10.1016/j.envsoft.2014.06.007

Clavreul, J., Guyonnet, D., Christensen, T.H., 2012. Quantifying uncertainty in LCA-modelling of waste management systems. Waste Manag. 32, 2482–2495.

Mendoza Beltran, A., Prado, V., Font Vivanco, D., Henriksson, P.J.G., Guinée, J.B., Heijungs, R., 2018. Quantified Uncertainties in Comparative Life Cycle Assessment: What Can Be Concluded? Environ. Sci. Technol. 52, 2152–2161.

Ammonia inhibition threshold during continuous biomethanation process

M.Yan[1], H. Tian[2], I. A. Fotidis[2], B. Khoshnevisana[2], P. Tsapekos[2] and I. Angelidaki[3]

* Department of Environmental Engineering, Technical University of Denmark, Bygningstorvet Bygning 115, DK-2800 Kgs. Lyngby, DK

(E-mail: ioanf@env.dtu.dk)

Abstract

The protein-rich organic waste is widely used as substrate for anaerobic digestion due to its high methane potential. However, the high ammonia levels formed from the protein-rich substrate degradation inhibit anaerobic digestion process and consequently result in the methane production loss. In the present study, the ability of microbial community to acclimatize to extremely high total ammonia levels (7 g NH_4^+-N/L) through stepwise acclimatization was assessed in two mesophilic continuous stirred tank reactors, fed with the organic fraction of municipal solid waste. To understand how the digesters respond to the different ammonia levels (from 1.2 to 7 g NH_4^+-N/L), the methane production and the volatile fatty acids (VFA) levels were monitored throughout the experimental period. The results showed that the stepwise acclimatization was successful up to 7 g NH_4^+-N/L; where the methane production fluctuated less than 10% compared to the reactors' methane yield in phase 1 and VFA was less than 4000 mg/L (no extra ammonia addition).

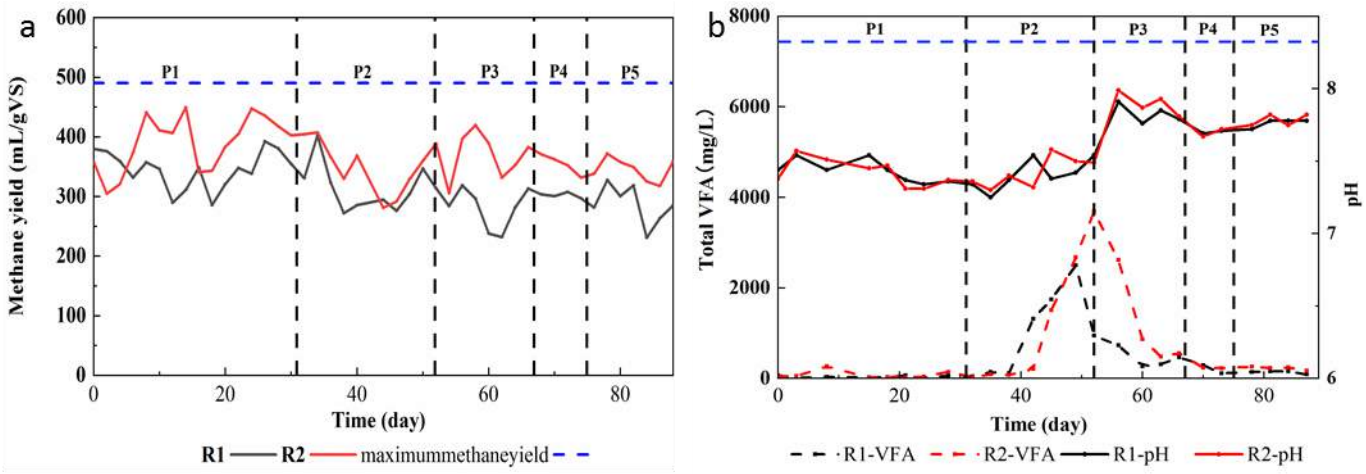


Figure 1.1 a) Methane yield and TAN change, b) VFA and pH variation throughout the experimental period

Session

R

Laptop Presentations

See session details and schedule on
www.sustain.dtu.dk

Seaweed biorefinery: where are we standing now, and then? – with a focus on the seasonal and spatial trends in biomolecular composition

Xueqian Zhang[1,*], Marianne Thomsen[1]

1: Eco-industrial System Analysis (EISA) Research Group, Department of Environmental Science, Aarhus University, Frederiksborgvej 399, DK-4000 Roskilde, Denmark
*Email: xqzh@envs.au.dk

Seaweed is a previously untapped resource in western world and gaining increasing attention for its potential use as feedstock for biorefinery. In the newly emerging field of seaweed biorefinery, scientific production started in 2010 and has been rising at a fast pace with an annual percentage growth rate of 43.51, as revealed by our science mapping analysis[1]. To analyze the evolution of topics in this research field over time, we conducted co-word analysis through keyword co-occurrence by using the same bibliographic collection but dividing the whole timespan in different time slices. Graphs of co-work networks illustrated that the research interest, which was originally aroused by seaweed's potential role as the 3rd generation feedstock for biofuel production, appears to shift the focus onto the bioactive molecules that possess unique nutritional and pharmacological properties.

Saccharina latissima is one native Kelp species in North Atlantic and North Pacific. It has received a growing interest due to its potential for high biomass production and rich content in valuable biochemical compounds. Fractioning *S. latissima* biomass into different constituents and then upgrading the valuable compounds separately to extract products seems economically promising. Among others, alginate, mannitol, fucoidans, laminarin, protein and lipid are top value-added extract products with the potential to improve profitability of all actors in the macroalgal bioeconomy, estimating from their market prices. However, spatial and seasonal variations in the biomolecular composition of *S. latissima* play crucial roles in determining the quantity and quality of extract products and thus the economic viability of biorefinery.

To obtain a better picture of how and to which degree the seasonal and spatial trends in biomolecular composition influence associated revenues, a systematic review was conducted based on a collection of 34 currently available scientific studies with primary measurements. It is found that the maxima and minima of different components' content seldom coincide at the same time, though there exist similarities in the seasonal patterns shown by some of them. Therefore, phase II biorefinery (i.e. single raw material is utilized for producing one major product and several co-products) seems to be most applicable for business in practice in pursuit of high revenues from seaweed extracts. Optimization of net revenues of all actors along the value chains can be realized by careful selection of intended application and cultivation site, flexible management of production system regarding harvest time, effective communication between upstream and downstream actors, and broad expansion of sales channels or biorefinery pathways.

[1] Bibliographic data were retrieved from a query on Web of Science (WoS) by using generic key words ("macroalgae*"OR"seaweed*")AND"biorefinery*" and processed with Bibliometrix R-package (http:\\www.bibliometrix.org).

Session

R

Poster Presentations

See session details and schedule on
www.sustain.dtu.dk

An advanced biorefinery LCA model with a process oriented approach

Concetta Lodato*[1], Davide Tonini[2], Anders Damgaard[1], Thomas Fruergaard Astrup[1]

1: Department of Environmental Engineering, Technical University of Denmark, Bygningstorvet, 115 2800 Kgs. Lyngby, Denmark

2: European Commission, Joint Research Centre (JRC), Edificio Expo, Calle Inca Garcilaso, 3, 41092 Sevilla, Spain
*Corresponding author email: conlod@env.dtu.dk

The quantification of environmental impacts of biotechnologies is generally done through the standardised methodology of life cycle assessment, LCA (ISO 14040 series, 2006). Biotechnologies, such as biorefineries, in an LCA analysis have an added challenge due to the complex reproducibility of the system to be analysed and different streams involved. Biological biomass conversion to bio-based materials and energy within a biorefinery are not generally integrated in traditional LCA software tools (e.g. SimaPro, Thinkstep Gabi). In addition, a biorefinery is modelled by following a black-box approach with no relationship between each input and output of the modelled process. With this study, we provide a biorefinery model in EASETECH (Clavreul et al., 2014), an LCA software tool developed at the Technical University of Denmark, specific for waste and environmental technologies. The biorefinery model in EASETECH follows a process-oriented modelling approach where the technology is broken down until its single operator unit-processes such as pre-treatment, hydrolysis, fermentation and distillation, and recovery. Equations reproducing these single unit-processes are identified based on results given by specific studies on this field (e.g. Tonini et al., 2016). Variable parameters (e.g. cellulose conversion efficiency to simple sugars) are included in these equations in order to adapt the modelled processes to particular case-studies. Therefore, advanced LCAs with a higher level of details supporting a more realistic reproducibility of the technology itself are feasible. For this reason, firstly, it is possible to optimize technologies in terms of emission and production, from lab scale to full scale, delivering renewable energy, improving its efficiency, making them affordable, reliable and modern. Secondly, by using for example a second generation biomass, it is possible to reduce the waste generation, since agro-industrial residues and organic waste are suitable biomasses for biorefineries, and biotechnologies in general.
The second-generation biorefinery model presented in this study keeps track of each feedstock component throughout each process within the biorefinery. Additionally, it provides accurate results that better reflect the system analysed useful to strengthen the decisions especially in the bioenergy field.

Clavreul, J., Baumeister, H., Christensen, T.H., Damgaard, A., 2014. An environmental assessment system for environmental technologies. Environ. Model. Softw. 60, 18–30. https://doi.org/10.1016/j.envsoft.2014.06.007

ISO 14040, 2006. Environmental Management - Life Cycle Assessment - Principles and Framework. 2nd edn, ISO, Geneva, Switzerland.

ISO 14044, 2006. Environmental Management - Life cycle assessment - Requirements and guidelines. 1st edn. ISO, Geneva, Switzerland.

Tonini, D., Hamelin, L., Astrup, T.F., 2016a. Environmental implications of the use of agro-industrial residues for biorefineries: application of a deterministic model for indirect land-use changes. GCB Bioenergy 8, 690–706. https://doi.org/10.1111/gcbb.12290

Characterization of rare-cutting xylanases for extraction of hemicellulosic polysaccharides

Jan Muschiol*[1], Line Munk[1], Claire Holland[2], Bodil Jørgensen[2], Peter Ulvskov[2], Anne S. Meyer[1]

1: Section of Protein Chemistry and Enzyme Technology, DTU Bioengineering, Technical University of Denmark; 2: Section for Plant Glycobiology, University of Copenhagen
*Corresponding author email: jmus@dtu.dk

Traditionally xylanases have been used for conversion of plant biomass into biofuel or other organic compounds. Therefore, the plant cell wall hemicelluloses are generally digested completely to the monomers. Recently also the use of xylooligosaccharides for food, feed and material science applications gained some interest. For extraction of these oligomers “rare-cutting” xylanases from the GH families 5, 30 and 98 can be applied. We studied a unique set of such xylanases from different bacterial and metagenomic origins, which have not been characterized yet. All enzymes were biochemically characterized and their hydrolytic products from certain industrial waste biomasses were identified using size exclusion chromatography and MALDI-MS. Preliminary data show that most of the studied enzymes indeed produce the desired xylooligosaccharides. Future efforts will validate their application in an industrial context.

Control of anaerobic reactor treating cattle manure for maximal biogas production under dynamic conditions

Parisa Ghofrani Isfahani[1,2], Borja Valverde-Pérez[1], Merlin Alvarado-Morales[1], Mohammad Shahrokhi[2,*], Manouchehr vossoughi [2], Irini Angelidaki[1,*]

[1] Department of Environmental Engineering, Technical University of Denmark, Kgs. Lyngby, DK-2800, Denmark

[2] Department of Chemical and Petroleum Engineering, Sharif University of Technology, Tehran, Iran

*Corresponding authors email: iria@env.dtu.dk, shahrokhi@sharif.edu

Anaerobic digestion (AD) is a friendly environmental technology that relies on metabolic activity of a diverse group of microorganisms for degradation of bio-wastes. Efficient and stable operation of AD process it is feasible only by proper control and monitoring. Recently, several indicators have been used for monitoring, and several control strategies have been proposed to control AD [1]. For systems with high buffer capacity (i.e., treating manure), volatile fatty acids (VFA) concentration is more sensitive and reliable than other parameters (pH, alkalinity, etc.) as an imbalance indicator in AD [2]. The control aim is maximizing methane production and keeping the reactor stable in presence of disturbances (e.g., overloading by addition of glucose).

The experiment was carried out in a 9 L total volume (7.5 L working volume) CSTR at thermophilic conditions (54 ± 1 °C). Control strategy was programmed in LabVIEW2016 software. In order to prevent wash out of microorganisms the minimum hydraulic retention time (HRT) is set at 5 days. The control strategy consists of a supervisory structure where the inner loop is a proportional controller that manipulates the feed flow rate in order to achieve the desired gas flow rate. The outer loop is a supervisory controller that defines the set point for the inner loop according to methane production and VFA content and pH in the digester. The digester was fed only with diluted cattle manure, 2% volatile solids (V.S.), for 39 days (Fig. 1). The feed V.S. content was increased from 2% to 6% by addition of glucose to the feed at 39th day. Methane production increased instantly and VFA accumulated in the reactor due to the acidification as a result of quick glucose fermentation. The controller manipulated the loading rate to set back VFA to the same level as before glucose addition, while methane production was maximized and tracked the set point.

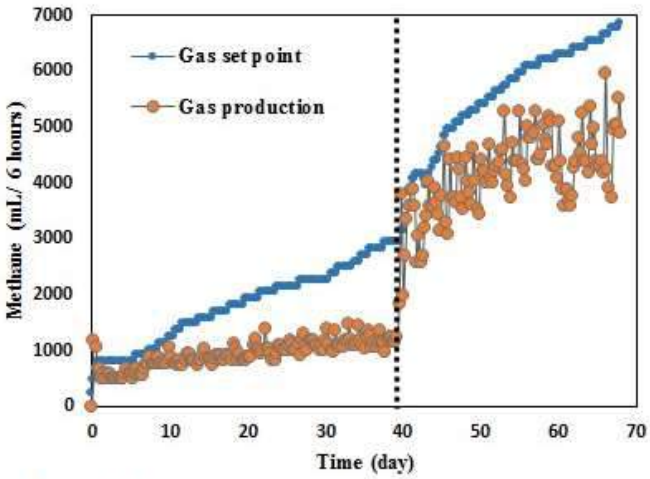


Figure 1. Methane production and set point during reactor operation. Vertical line indicates glucose addition (change from 2 to 6 % V.S.)

References:

[1] D. Nguyen, V. Gadhamshetty, S. Nitayavardhana, S.K. Khanal, Automatic process control in anaerobic digestion technology: A critical review, Bioresour. Technol. 193 (2015) 513–522.

[2] K. Boe, D.J. Batstone, J.-P. Steyer, I. Angelidaki, State indicators for monitoring the anaerobic digestion process, Water Res. 44 (2010) 5973–5980.

Role of nano-sized compounds in anaerobic digestion of wheat straw

Parisa Ghofrani Isfahani[1,2], Hamed Baniamerian[1,3], Panagiotis Tsapekos[1], Merlin Alvarado-Morales[1], Mohammad Shahrokhi[2,*], Manouchehr Vossoughi[2], Irini Angelidaki[1,*]

1: Department of Environmental Engineering, Technical University of Denmark, Kgs. Lyngby, DK-2800, Denmark
2: Department of Chemical and Petroleum Engineering, Sharif University of Technology, Tehran, Iran
3: Department of Chemical Technologies, Iranian Research Organization for Science and Technology, Tehran, Iran
*Corresponding authors email: iria@env.dtu.dk, shahrokhi@sharif.edu

Anaerobic digestion (AD) of bio-waste is an attractive area that can contribute on reaching the worldwide demands for energy and waste management. AD processes of agricultural residues have often low efficiency, because of limited degradation of refractory components [1]. Many methods such as co-digestion , chemical or physical pre-treatments and/or combination of them have been tested to facilitate the bioconversion of lignocellulosic substrate [2].

Nanotechnology has been a growing technology in environmental, medical, and chemical industries. Due to the unique thermal, mechanical, structural properties and high specific area, nano-sized materials (1-100 nm) could have positive effect on AD process.

This study investigated the effect of Fe_2O_3-TiO_2 and NiO-TiO_2 nano-composites and corresponding $FeCl_3$ and $NiCl_2$ salts, on the AD of wheat straw, as lignocellulosic substrate in batch assays. Metal oxide-TiO_2 NPs were synthesized and fully characterized. Results showed that addition of different concentrations of TiO_2-based nanoparticles to batch assays, i.e. 0.252 mg of NiO-TiO_2/gTS, resulted in up to 13% increased soluble chemical oxygen demand) and up to 67% increase of volatile fatty acids concentration in comparison with control experiments during the first 4 days of experiments, indicating a positive effect on hydrolysis and acidogenesis rates (Fig. 1). The results indicate coating high surface area TiO_2 NPs with trace metals, gives promising prospects to promote AD process of lignocellulosic feedstocks.

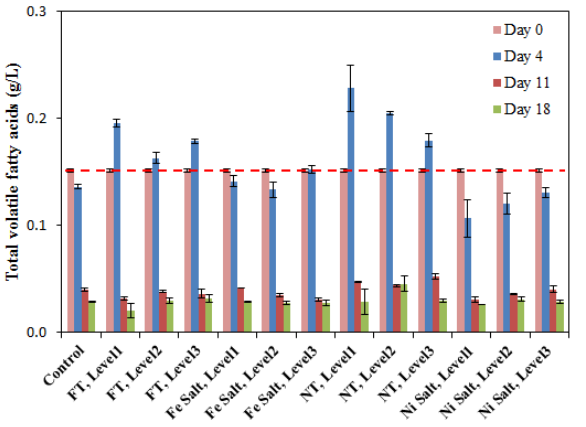


Fig. 1: Effect of different concentrations of trace elements (in form of TiO_2-based NPs and metal salts) on VFAs variations

Refrences

[1] S.R. Paudel, S.P. Banjara, O.K. Choi, K.Y. Park, Y.M. Kim, J.W. Lee, Pretreatment of agricultural biomass for anaerobic digestion: current state and challenges, Bioresour. Technol. 245 (2017) 1194–1205.

[2] G. Mancini, S. Papirio, P.N.L. Lens, G. Esposito, Increased biogas production from wheat straw by chemical pretreatments, Renew. Energy. 119 (2018) 608–614. doi:10.1016/j.renene.2017.12.045.

LyGo: simple one-step cloning of LPMO expression vectors: from in silico design to lab-ready construct in one week!

Cristina Hernández Rollán[1], Kristoffer Bach Falkenberg[1], Maja Rennig[1] and Morten H. H. Nørholm*

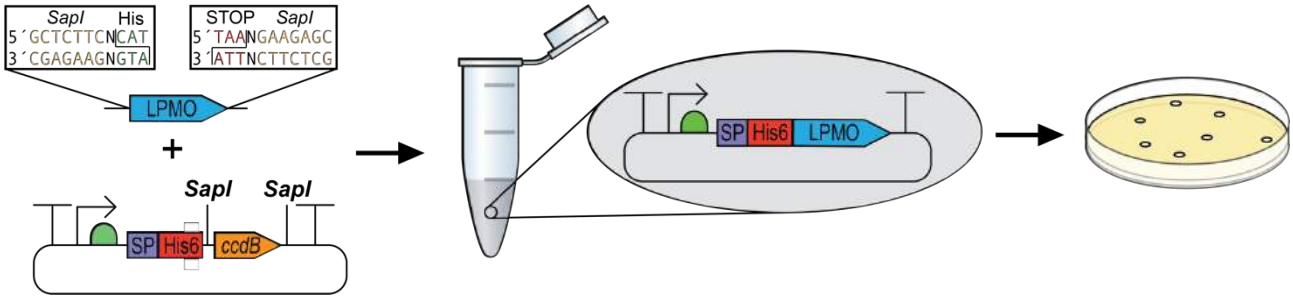
1The Novo Nordisk Foundation Center for Biosustainability, Technical University of Denmark, Lyngby, Denmark

*Corresponding author email: morno@biosustain.dtu.dk

Lytic Polysaccharide Monooxygenases (LPMOs) are a newly discovered, carbohydrate-active class of enzymes. They have been found to significantly increase depolymerization of certain biomass polymers and are currently subject to high amounts of scientific and industrial interest[1].

Construction of expression vectors for LPMO production can be a tedious and time-consuming task. A typical cloning workflow requires several reaction steps, including PCRs, which are prone to introducing errors or suffer from design limitations due to the specific DNA sequences at hand. Furthermore, many DNA assembly workflows rely on DNA purification steps which are slow and often result in loss of considerable amounts of DNA.

To address these challenges, we have developed the LyGo, **Ly**tic polysaccharide monooxygenase **Go**lden gate cloning platform. It involves a 15 minute, one-step Golden Gate assembly reaction, compatible with both PCR products and inexpensive synthetic DNA fragments. This means that the time spend from *in silico* design to ready expression clone is less than one week – independently of the availability of the original source of the LPMO-encoding gene. LyGo relies on the type-IIS restriction endonuclease *SapI*. *SapI*-digestion removes the recognition site and creates three-nucleotide overhangs of any choice. This characteristic is exploited to generate overhangs corresponding to the codon of the conserved LPMO N-terminal histidine and the stop codon, allowing for any LPMO to be inserted in compatible vectors using this method. We have developed several LyGo plasmids prepared with different modules (e.g. promoters, optimized translation initiation sites, terminators, signal peptides, reporters and purification tags). This allows us to quickly insert the gene of any LPMO of interest in standardized vector backbones, without the need to re-sequence the backbone after every assembly reaction.



Overview of the LyGo workflow. The PCR or synthetic DNA fragment, and the backbone is digested with SapI and ligated in the same 15 minute reaction. Afterwards, the reaction mix is transformed directly, yielding the desired transformants.

References

[1] Hemsworth, G. R., Johnston, E. M., Davies, G. J., & Walton, P. H. (2015). Lytic Polysaccharide Monooxygenases in Biomass Conversion. *Trends in Biotechnology*, *33*(12), 747–761. https://doi.org/10.1016/j.tibtech.2015.09.006

Recovery of acetic, succinic and lactic acid through Forward Osmosis – a novel down-streaming approach

Jon García-Aguirre[1], Ioannis Fotidis*[2], Merlín Alvarado Morales[2], Carina Schneider[2], Irini Angelidaki[2]

1: Ceit, Manuel de Lardizabal 15, 20018 Donostia/San Sebastian, Spain.
2: Department of Environmental Engineering, Technical University of Denmark, Bygningstorvet Bygning 115, DK-2800 Kgs. Lyngby, DK
*ioanf@env.dtu.dk

Waste management rethinking will open new opportunities for the business sector, by exploiting green solutions that will boost the resource recovery from linear production systems. Organic waste streams offer a cost-effective biomass source for the production of marketable chemicals in biorefineries. Recent studies have shown the potential of food waste for volatile fatty acid (VFA) and lactic acid production (Garcia-Aguirre *et al.*, 2017, Zhang *et al.*, 2017). Additionally, promising results were obtained from macroalgae feedstock for succinic acid production (Marinho *et al.,* 2016).

The objective of this study was to assess the potential of Forward Osmosis (FO) (Figure 1a) as a novel downstream technology for the up-grading of acetic acid, succinic acid and lactic acid. Different membrane configurations i.e. flat sheet and hollow fibre membranes, were assessed with synthetic mixtures at pH 3 and pH 7, and with different draw solutes, such as NaCl and CH_3COONa.

The results showed a clear influence of the pH of the feed solution on the water flux passing through the membrane (Figure 1b), which ranged within 2.89 and 5.71 L/m^2 h and was overall higher at pH 3 during 24 hours FO tests. The highest feed recovery rate was obtained at acidic pH, where the target acids are in the free acid form and the recovery values were between 67 – 94%.

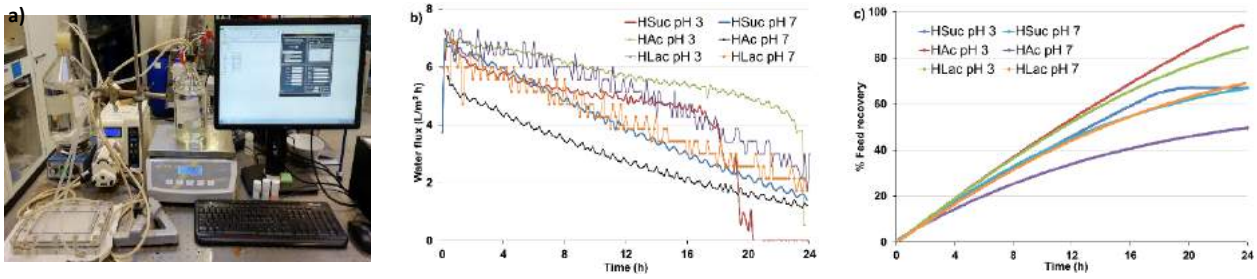


Figure 1. FO set-up (a). Water flux (L/m^2 h) (b) and % Feed recovery (c) for flat sheet membranes.

Further studies were performed with real fermentation broths to analyse the feasibility of FO as a downstream technology for target chemical upgrading.

References

- Garcia-Aguirre, J., Aymerich, E., González-Mtenz de Goñi, J., Esteban-Gutierrez, M. 2017. Selective VFA production potential from organic waste streams: assessing temperature and pH influence. Bioresource Technology 244, 1083-1088.
- Marinho, G.S., Alvarado-Morales, M., Angelidaki, I. 2016. Valorization of macroalga *Saccharina lattisima* as novel feedstock for fermentation-based succinic acid production in a biorefinery approach and economic aspects. Algal Research 16, 102-109.
- Zhang, W., Li, X., Zhang, T., Li, J., Lai, S., Chen, H., Gao, P, Xue, G. 2017. High-rate lactic acid production form food waste and waste activated sludge via interactive control of pH adjustment and fermentation temperature. Chemical Engineering Journal 328, 197-206.

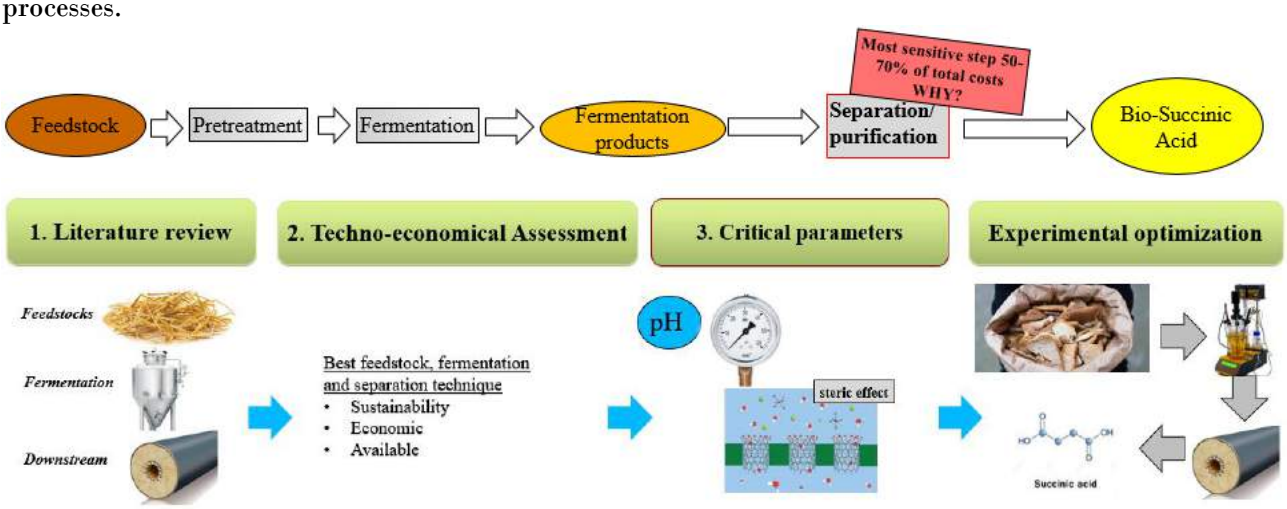
Sustainable downstream routes for bio-manufacturing processes

E. Mancini[1], Seyed Soheil Mansouri[1], Krist V. Gernaey[1], Manuel Pinelo*[1]

1: Department of Chemical Engineering, PROSYS division, Technical University of Denmark, Søltofts Plads 229, DK-2800 Kgs. Lyngby, Denmark

*Corresponding author email: mp@kt.dtu.dk

Biorefinery is a promising concept that can contribute overcoming the petrol-era, especially with respect to sustainable fine chemical production, addressing at the same time several problems: the depletion of petroleum resources (with the associated consequences), human sustainability, waste management and political concerns [1,2]. Production and separation of valuable products from biomass have indeed been successfully achieved and implemented at full scale[3]. However, the lack of cost-effective downstream processes is largely preventing biorefinery products to become economically competitive, and membranes are one of the fundamental technologies for separation of fermentation products such as succinic acid[4] (SA). Therefore, key factors such as pH, pressure, steric effect etc. in downstream processes must be identified for a technological breakthrough. Data collection about different feedstocks, fermentation and downstream techniques for bio-SA production will highlight the most relevant for large-scale application. These, will be then study trough a techno-economical analysis, which will be focused on membrane separation techniques. Thus, a computer-aided framework will be used to assess and rank the critical parameters in downstream technologies, which will be subsequently tested trough an experimental validation of bio-SA production. The interest for bio-SA production have been constantly increasing[3,5], since more than 30 commercially valuable products can be currently synthetized from it, including solvents and lubricants, synthetic resins and biodegradable polymers such as PBS and polyamides, cosmetics, food and pharmaceuticals [3,5]. Finally, a defined and interactive operation range for each studied variable is intended to be provided, which can be virtually extrapolated to other similar separation processes. The feasibility of potential alternatives will be evaluated experimentally on other similar processes.



1 F. Cherubini, *Energy Convers. Manag.*, 2010, 51, 1412–1421.
2 A. K. Chandel, V. K. Garlapati, A. K. Singh, F. A. F. Antunes and S. S. da Silva, *Bioresour. Technol.*, 2018.
3 R. K. Saxena, S. Saran, J. Isar and R. Kaushik, *Curr. Dev. Biotechnol. Bioeng. Prod. Isol. Purif. Ind. Prod.*, 2016, 601–630.
4 Pacific Northwest National Laboratory (PNNL), National Renewable Energy Laboratory (NREL), T. Werpy and G. Petersen, *US Dep. Energy*, 2004, 36–38.
5 F. Deswarte, *Introduction to Chemicals from Biomass*, York, UK, 2008.

Evaluation of enzymatic hydrolysis effects on fermentative production of lactic acid from municipal bio-waste

Samin Baladi[1,3], Panagiotis Tsapekos[1], Merlin Alvarado-Morales [1], Elleke F. Bosma[2], Irini Angelidaki*[1]

1: Department of Environmental Engineering, Technical University of Denmark, Kgs. Lyngby, DK-2800, Denmark
2: The Novo Nordisk Foundation Center for Biosustainability, Technical University of Denmark, Kgs. Lyngby, DK-2800, Denmark
3: Department of Biosystem engineering, Faculty of agriculture, Shahid Chamran university of Ahvaz, Khouzestan, Iran
*Corresponding author email: iria@env.dtu.dk

Annually, one third of the edible parts of food generated for human consumption gets wasted worldwide. Therefore, discovering a suitable and environmentally favorable method for managing the enormous amounts of the organic fraction of municipal waste is an urgent need. Typical treatment solutions for managing municipal bio-waste are landfilling, incineration and biomethanation through anaerobic digestion [1]. Although methane generation from bio-waste is considered an environmentally friendly approach, the fermentative lactic acid production lately appears as a viable alternative for the reuse and valorisation of organic wastes. Lactic acid has an extensive application in different industries such as food, pharmacology and cosmetic. Furthermore, lactic acid has a broad diversity of applications and is used as a platform chemical to form biodegradable polymers, green solvents etc [1,2]. As municipal bio-wastes are recalcitrant in degradation specific pre-treatments such as enzymatic hydrolysis (EH) are needed in order to release the soluble sugars.

The aim of this study was to evaluate the effects of (EH) using β/glucosidase and cellulase to boost lactic acid production using municipal bio-waste and *Lactobacilus delbrueckii* as bioaugmentation inoculum.

The results showed that applying the (EH) was quite effective on hydrolysing the glycosidic bonds and releasing sugars for the bacterial microcosm os. In addition, the injection of *L. delbrueckii* along with (EH), in comparison with control experiments (i.e. without applying EH), could produce a higher titer of lactic acid equal to 19.73 g/l compared to 18.4g/l, respectively, after 48 hours of fermentation (Fig. 1). Adding enzymes compared to the control could increase the concentration of produced lactate by 9%.

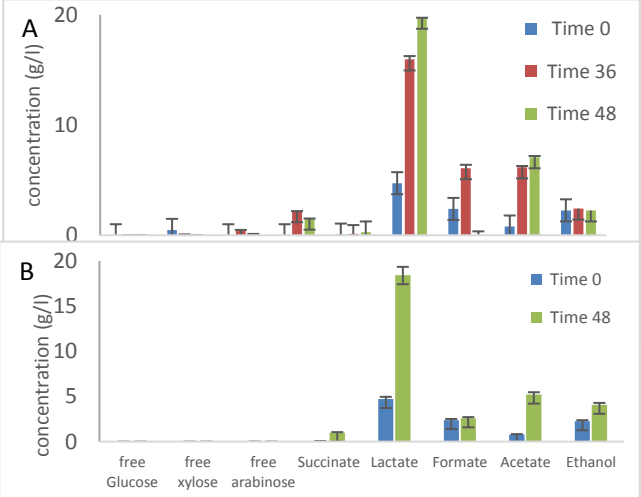


Fig.1: (A) Effect of enzymatic hydrolysis on lactic acid production, (B) Control (without applying EH)

At the end, this study showed that municipal bio-waste could be considered as a suitable feedstock for lactic acid production in mesophilic conditions.

REFERENCES

[1] Abdel-Rahman, M.A., Tashiro, Y., Sonomoto, K. 2013. Recent advances in lactic acid production by microbial fermentation processes. *Biotechnology advances*, **31**(6), 877-902.

[2] Bosma, E.F., Forster, J., Nielsen, A.T. 2017. Lactobacilli and pediococci as versatile cell factories–Evaluation of strain properties and genetic tools. *Biotechnology advances*, **35**(4), 419-442.

Session

U

Oral Presentations

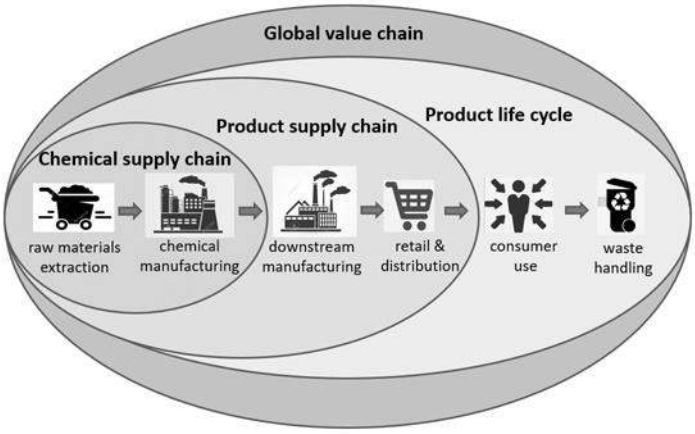
See session details and schedule on
www.sustain.dtu.dk

The Role of Chemicals in the 2030 Sustainable Development Agenda

Peter Fantke*[1]

1: DTU Management Engineering, Quantitative Sustainability Assessment Division, Kgs. Lyngby, Denmark
*Corresponding author email: pefan@dtu.dk

We live in a rapidly changing global society, driven by system-transforming megatrends, such as population growth, urbanization, automation, digitalization, land use intensity and climate change. Global income is rising, creating increased demand for chemicals as building blocks of goods and products. The worldwide expansion of chemical markets is creating complex value chains, posing management challenges for the chemical industry, downstream industries, retailers, and regulators. Increased production and consumption also results in accumulation in the technosphere and the environment, resulting in increasing exposures to chemicals that are traceable in biota and humans in all corners of the world. Through that, chemical pollution continues to have adverse effects on human health and the environment. This creates potential future legacies, as well as opportunities for sustainable production and consumption and circularity. Our knowledge about potential hazards and risks of chemicals has increased significantly. Yet, comprehensive and validated knowledge concerning the human health and environmental impacts of many chemicals is lacking. While methodologies to estimate the benefit of action and costs of inaction related to the sound management of chemicals and waste (or lack of it) are being further developed, current estimates of benefits and costs are significant.



The adoption of the 2030 Agenda for Sustainable Development creates opportunities to achieve a sustainable future with and through chemicals, where all three sustainability dimensions – environmental, economic, and social – are met without creating trade-offs. New approaches are urgently needed and emerging to complement existing risk management, such as sustainable chemistry research and policies, impact and information assessment over entire supply chains and product life cycles, and informed and function-based substitution and phase-out of hazardous chemicals across industrial sectors. New sustainability metrics emerge, helping to make informed choices. Integrating sound chemicals and waste policies and advancing sustainable design, life cycle approaches and chemistry innovation in key sectors include, but are not limited to agriculture, safe and affordable housing, health, energy, textiles, and electronics. My presentation will discuss these global trends and needs in relation to the role of chemicals for achieving the global goals of the 2030 Sustainable Development agenda.

Regulatory Exposure Modelling – Current Status and Work Needed

Antti J. Koivisto*[1]

1: National Research Centre for the Working Environment, Copenhagen, Denmark.

*Corresponding author email: jok@nrcwe.dk

The Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) regulation No 1907/2006 implemented by European Chemical Association (ECHA), demands that manufacturers or importers must report or estimate human exposure by all relevant routes to determine the appropriate risk management measures and prevent excessive exposure (EC, 2006). Since June 2018, this is applied to all chemicals that are manufactured or imported in quantities over 1 metric ton per year within the European Union. This means that exposure has to be assessed for hundreds of thousands of chemicals by all potential routes including environmental, occupational and consumer exposure scenarios. Such task is not possible to overcome only with measurements, and exposure assessment therefore relies on mathematical exposure modeling.

STOFFENMANAGER® (StM; stoffenmanager.nl) and the Advanced REACH Tool (ART; advancedreachtool.com) are higher tier occupational exposure models recommended in REACH guidance, even though the models are not physical models (e.g. mass is not preserved). Koivisto et al. (2018) found that there was an error in the general ventilation multipliers (GVMs) in the StM and the ART models. The uncertainties in mechanistic or conceptual models can be seen in their poor predictive capability. Comparison of these non-physical models modelling results with measurements has shown that the predicted exposure levels are under- or overestimated with 90% confidence interval limits typically two-order of magnitude or more (e.g. Landberg et al. 2017; Spinazzè et al. 2017). Because of the models high uncertainty, the rationale of using these models for regulatory decision-making is needed to be reviewed. Preferably, this should be made before the ECHA recommended exposure models are subjected to judicial review. At least, the models designed to support the regulatory decision-making should fulfill Daubert principles, which provides a framework for reviewing the quality of science for regulatory decision making (Raul and Dwyer, 2003).

Acknowledgements
This work was supported by the European Union's H2020 under EC-GA No. 760840 'GRACIOUS'.

References
EC (2006). *Off. J. Eur. Commun*. L136: 3–280.
Koivisto et al. (2018). *J. Occup. Environ. Hyg.* 15:D38-D43.
Landberg et al. (2017). *Ann. Work. Expo. Health.* 61:575-588.
Spinazzéet al. (2017). *Ann Work Expo Health*. 61:284-298.
Raul AC and Dwyer JZ (2003) *Law and Contemporary Problems 66: 4, Science in the Regulatory Process*, pp. 7-44.

Development of new climate change indicators for improved sustainability assessment of bioplastics

Serena Fabbri*, Mikołaj Owsianiak

Division for Quantitative Sustainability Assessment (QSA), DTU Management Engineering
*Corresponding author email: serf@dtu.dk

As a response to growing concerns about climate change and depletion of resources, production of biopolymers is expected to increase and there is a need to understand if the transition from fossil-based to bio-based material is a sound decision from the climate perspective. Climate performance of bioplastics is traditionally assessed using Global Warming Potential (GWP) as indicator. Although credits can be given for temporary carbon storage in the biomaterial, GWP does not consider the contribution of greenhouse gas (GHG) emissions to crossing of climatic tipping points, that is, levels of pressure on the climate system beyond which adverse and potentially irreversible changes may occur. Accounting for timing of GHG emissions is particularly relevant for some biodegradable materials made from biopolymers, which can degrade relatively quickly in the environment.

Here, building on recently developed Climate Tipping Potential (CTP) indicator, which quantifies impacts in relation to tipping the Arctic summer sea ice, a new indicator is proposed, which: (i) includes melting of Greenland ice-sheet as tipping element, and (ii) includes the contribution of tipping the Arctic summer sea ice to melting of the Greenland ice-sheet due to albedo changes. To understand the potential contribution to these impacts when biodegradable bioplastics are released in the environment, the new indicator was applied in practice to temporarily disaggregated CO2 emission inventories representing a wide range of bioplastics mineralization rate constants.

For biodegradable bioplastics, it was found that total climate tipping impact caused by temporal evolution of CO2 from mineralization of bioplastic is dominated by contribution of CO2 emissions to tipping the Arctic summer sea ice rather than tipping the Greenland ice-sheet. The latter may become important, however, for those bioplastics that degrade relatively slowly in the environment. These findings highlight the need for considering timing of emissions as determined by biodegradability of the biopolymer in the environment, when characterizing climate-tipping performance of bioplastics.

Lenton, T.M., Held, H., Kriegler, E., Hall, J.W., Lucht, W., Rahmstorf, S., Schellnhuber, H.J., 2008. Tipping elements in the Earth's climate system. Proc. Natl. Acad. Sci. 105, 1786–1793.

Jørgensen, S. V., Hauschild, M.Z., Nielsen, P.H., 2014. Assessment of urgent impacts of greenhouse gas emissions - The climate tipping potential (CTP). Int. J. Life Cycle Assess. 19, 919–930.

Persistence assessment for a circular economy

Stefan Trapp*[1], Fabio Polesel[1], Andreas Libonati Brock[1]

1: Department of Environmental Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
*Corresponding author email: sttr@env.dtu.dk

Persistence is a key parameter in the safety assessment of all chemical products and central to the registration of chemicals, plant protection products, biocides and veterinary drugs. This parameter is of high relevance in the context of the circular economy, which is confronted with the problem of the accumulation of persistent and toxic chemicals. To date, persistence of chemicals could hardly be predicted and is therefore assessed in lengthy and expensive degradation tests (e.g., OECD 301A-F, 307, 308, 309) [1]. In this study, we present the novel Microbial Turnover to Biomass (MTB) method, a theoretical approach that allows estimating the nutritional value of chemicals for the microbial community as an indication of their persistence. Briefly, the better "food", the better growth, the more turnover, the less persistence. The MTB method relies on the prediction of the true microbial yield from thermodynamics and structural information of the chemical, and can be applied for a range of environmental conditions (e.g., different electron acceptors) and when recalcitrant metabolites form. Recently, the use of MTB has been suggested to the European Chemical Agency (ECHA) in the EU registration process for chemicals, REACh [2].

In all degradation tests with labeled chemicals, non-extractable residues (NER) are formed. Despite recent improvements, their composition is poorly understood, with implications for chemical persistence determination. In recent guidance documents, ECHA differentiated between remobilisable NER (as non-degraded substance) and biogenic NER (incorporated in microbial biomass as a result of biodegradation) [1]. Our new *in silico* method was shown to be applicable for xenobiotics, such as plant protection products and environmental chemicals [3], allowing to differentiate between harmless biogenic NER and risky xenoNER only from the true microbial yield and the CO_2-development [3,4]. The relatively easy and inexpensive MTB approach can be used to assess whether advanced (and expensive) experimental methods should be applied to determine biogenic NER [2]. In future, the application of this method in bioenergy, chemical design and carbon cycle is envisaged.

The calculation sheet for the MTB method can be found at: http://homepage.env.dtu.dk/stt/ALIB/

[1] European Chemicals Agency – ECHA (2017). Guidance on Information Requirements and Chemical Safety Assessment, Chapter R.11: Endpoint specific guidance (PBT/vPvB assessment). Draft version 3.0, March 2017

[2] Kästner, M., Trapp, A., Schäffer, A. (2018). Consultancy services to support ECHA in improving the interpretation of Non-Extractable Residues (NER) in degradation assessment. Discussion paper - final report. Edited by the European Chemical Agency (ECHA), July 2018, available at www.echa.europa.eu/publications/technical-scientific-reports

[3] Brock, A.L., Kästner, M., Trapp, S. (2017). Microbial growth yield estimates from thermodynamics and its importance for degradation of pesticides and formation of biogenic non-extractable residues. SAR/QSAR Environ. Res. 28(8), 629–650.

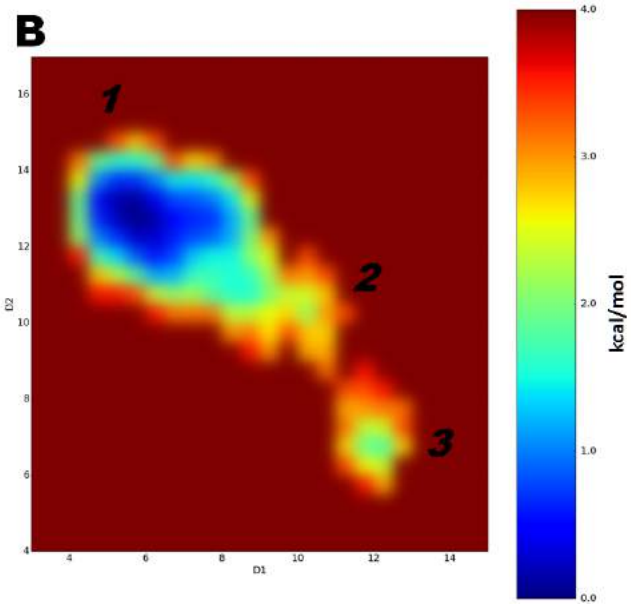
[4] Trapp S, Brock AL, Nowak K, Kästner M. 2018. Prediction of the formation of biogenic nonextractable residues during degradation of environmental chemicals from biomass yields. Environ. Sci. Technol. 52, 663-672.

In silico study of the interactions of perfluorinated compounds with PPARγ

Svava Ósk Jónsdóttir*[1], Filip Fratev[2], Thomas Steinbrecher[3]

1: insilTox ApS, Sverigesvej 20B, DK-2800 Kongens Lyngby, Denmark
2: Micar21 Ltd., Persenk 34B, 1407, Sofia, Bulgaria and The University of Texas at El Paso, USA
3: Schrödinger GmbH, Dynamostrasse 13, 68165 Mannheim, Baden-Württember, Germany
*Corresponding author email: soj@insiltox.com

Perfluorinated alkylic acids (PFAAs) are known to be highly persistent within the human organism, and for being implicated with a number of adverse effects. PFAAs are also documented to bind to and/or interact with many proteins, potentially interfering with their normal physiological function.



This study illustrates how *in silico* studies can be used to elucidate how PFAAs interact with proteins, such the peroxime proliferated-activated receptor gamma (PPARγ), that regulates glucose metabolism and storage of fatty acids. We propose a computational modelling workflow using the combination of docking, classical and accelerated molecular dynamics and free energy perturbation for the identification of possible ligands binding modes of PFAAs in the PPARγ nuclear receptor.

Multiple binding modes were identified for the PFAAs studied, and the shorter-chain PFAAs continuously moved between a few energetically favourable binding conformations. The picture shows the binding modes of perfluoroundecanoic acid (PFuDA) in PPARγ detected by classical molecular dynamics simulations [1]. A free energy perturbation (FEP+) protocol designed based on molecular dynamics predictions of binding conformations, accurately reproduced experimental differences in the binding energies. Our *in silico* workflow revealed the specific ligand-residue interactions within the ligand binding domain, the main characteristics of the PFAAs, and it was concluded that these compounds are weak PPARγ partial agonists.

This work also suggests a general pipeline for identification of ligand binding modes, ligand-protein dynamics description and relative free energy calculations, and illustrates how *in silico* techniques can be used to elucidate molecular mechanism related to adverse effects.

1. Fratev F, Steinbrecher T, Jónsdóttir SÓ. Prediction of Accurate Binding Modes Using Combination of Classical and Accelerated Molecular Dynamics and Free-Energy Perturbation Calculations: An Application to Toxicity Studies. ACS Omega. 2018; 3 (4): 4357-71.

Session

U

Poster Presentations

See session details and schedule on
www.sustain.dtu.dk

Safe and sustainable by design – the clever way of designing new products

Niels Hadrup[1*], Keld Alstrup Jensen[1], Ulla Vogel[1]

Underline presenting author if possible[2], Corresponding-author marked with*[3]

1: The National Research Centre for the Working Environment
*Corresponding author email: make-link-to-mail@mailme.dk

When designing new products it is important to take existing knowledge into account. This is especially relevant for human and environmental safety considerations, where it may be an advantage already in the design phase to take into account existing knowledge about the toxicity of different chemicals, and about how physico-chemical properties of particles, such as size, shape, solubility and surface modifications influence toxicity. An example is the fibre paradigm, the mechanism of asbestos-induced lung cancer. This paradigm describes how long and how thick an insoluble fibre has to be, in order to not reach the deeper parts of the lungs and exert toxicity such as development of lung cancer and mesothelioma. Understanding the mechanism of action of asbestos-induced lung cancer allowed the development of glass and mineral wool insulation materials with low biodurability as the safe alternative to asbestos. Furthermore, in order to deal with the many chemicals for which information on toxicity is non-existent, tools are required that, based on knowledge of already investigated chemicals, can predict the toxicity of novel compounds. For this reason, risk assessment tools in safe-by design, such as those being developed in the EU project caLIBRAte, are applicable. In this presentation the safe by design approach is presented in terms of its application to the large number of novel materials being proposed for future consumer products. The use of these tools will be demonstrated.

The Danish (Q)SAR Database with *in silico* predictions for 650,000 chemical substances

Nikolai G. Nikolov[1], Eva B. Wedebye*[1]

1: Department of Diet, Disease Prevention and Toxicology, DTU Food

*Corresponding author email: ebawe@food.dtu.dk

(Quantitative) Structure-Activity Relationships ((Q)SARs) are models to predict properties of substances based on their chemical structure. The Danish (Q)SAR database is a free searchable online repository of structural information and (Q)SAR predictions for more than 650,000 substances, including >80,000 REACH substances. The predicted properties cover many physical-chemical, environmental fate, bioaccumulation, eco-toxicity, absorption, metabolism and toxicity endpoints. The applied (Q)SAR models are developed in-house or obtained from external sources. To further increase prediction accuracy and/or model coverages of the chemical universe, three software systems, namely Leadscope, CASE Ultra and SciQSAR, were applied when possible to develop models for the same endpoint and an overall battery prediction was made as a majority vote between the three systems. To ensure transparency up against the OECD (Q)SAR Validation Principles, documentation for all models developed in-house as well as DTU-licensed commercial models is available from the database in the internationally agreed QSAR Model Reporting Format (QMRF).

The database is freely available via a web portal (http://qsar.food.dtu.dk) with an extensive search system including search by predictions, structure, similarity and experimental data from training sets. A full chemical profile is downloadable for any of the database substances. The database is developed by the QSAR team at the DTU Food Institute, with financial support from the Danish EPA and Nordic Council of Ministers, and is furthermore supported by the European Chemicals Agency. Scientific and user inputs from an international board including representatives from regulators, Industry, NGO and Academia during the development phase is likewise appreciated. Since the publication of the database in November 2015, it has been used by more than 5,400 unique IP addresses running more than 77,000 searches and requesting download of over 50,000 (Q)SAR profiles by users in >25 countries. The database was recently linked to the OECD QSAR Application Toolbox via a hotlink for dynamic data retrieval. The database was updated in mid-2018 with more than 10,000 new structures and predictions from new models, and work is under way to include predictions from more new models before the end of 2018.

Improving risk assessment of agricultural reuse of wastewater through predictive plant uptake modeling of ionizable contaminants

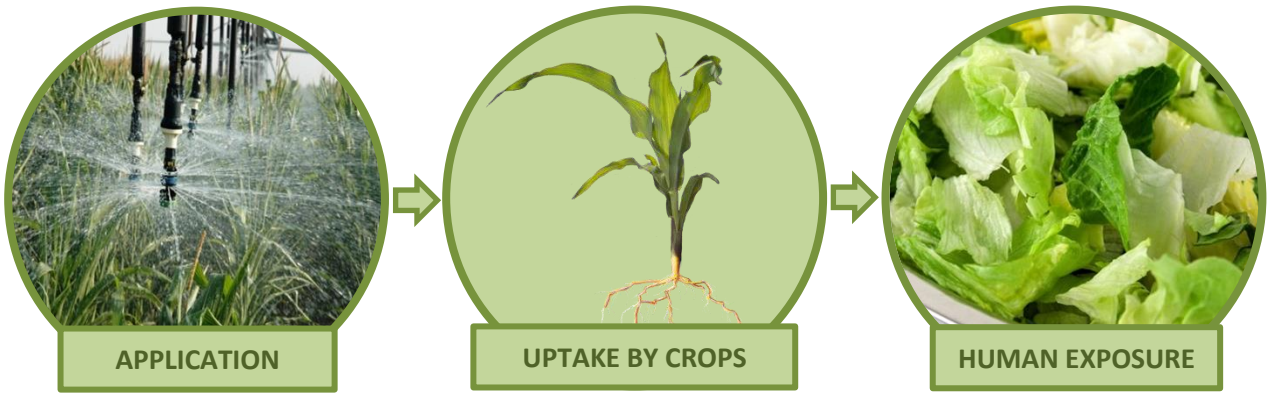
Christian Kjær Jensen*[1], Fabio Polesel[1] and Stefan Trapp[1]

1: Technical University of Denmark (DTU), Department of Environmental Engineering
*Corresponding author email: chrje@env.dtu.dk

In pursuit of circular economy, it is enticing to reuse treated wastewater for irrigation to tackle water scarcity and recycle nutrients. Direct reuse of wastewater for irrigation (fertigation) and/or application of stabilized sludge for fertilization and soil improvement are well established practices in many areas of Europe. In addition to nutrients, wastewater streams are known to contain heavy metals and organic contaminants such as pharmaceuticals and personal care products (PPCPs). Once released to agroecosystems, these chemicals may be uptaken by crops and translocated to edible crop tissues, with subsequent potential human exposure via dietary intake.

Due to the large number of chemicals present in wastewater streams and the challenges inherent to sampling and analytics, monitoring of agroecosystems at field-scale is a major undertaking. Therefore, modeling tools predicting plant uptake of chemicals in wastewater-receiving systems are a valuable option for pre-screening of potentially hazardous compounds and estimating associated risks. Plant uptake models have traditionally been partition-based and suited for neutral organic compounds. As most PPCPs are ionizable they are accumulated in crops through other processes than partitioning (e.g. electrical interactions and ion trapping), rendering traditional models inapplicable.

In this study, we present the first developments of a physically-based plant uptake model describing the uptake of ionizable chemicals down to a cellular level. Such a model holds the potential to describe the uptake and distribution of both neutral and ionic species in a site- and chemical specific way. To reduce the parameter space, work is currently being done to assess the parameter sensitivity and model uncertainty. Furthermore, the model is being continuously improved and tested against various datasets. The main research question in play is whether the large variability observed in field studies can be explained by the natural variability of the most sensitive parameters.



Session

W

Oral Presentations

See session details and schedule on
www.sustain.dtu.dk

Sustainable implementation of the EU Water Framework: Challenges in assessment of stream water quality under conditions of multiple stress

Poul L. Bjerg*, Giovanni Bigi, Anne Th. Sonne, Vinni Rønde, Ursula S. McKnight

Department of Environmental Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
*plbj@env.dtu.dk

The EU Water Framework Directive (WFD) is a visionary plan for achieving good ecological and chemical quality of water bodies in Europe. The WFD aims to obtain this ambitious goal through sustainable management and protection of freshwater resources. The need to consider the relationship between surface water and groundwater is central for the implementation as well as a combined management of quality and quantity of water bodies. Holistic approaches and strong stakeholder participation are also expected as this is an inherent part of sustainable management.

We are in the middle of the second planning period (2015-2021) and the big question is how the process has developed. Have we fulfilled the expectations and achieved our goals? The aim of the presentation is to discuss this using management of contaminated sites posing a risk to streams as an example.

Contaminated sites are among one of the major environmental problems in Denmark, potentially polluting soil, groundwater and surface water bodies. January 1st, 2014 the Danish Soil Act was changed in order to include impacts on surface water in the legislation. Previously the discharge of contaminated groundwater to surface water was neglected in Denmark, which was in contradiction to the vision in the WFD. Recently, screening tools and risk assessment methods have been developed in order to evaluate the potential impact on surface water. However, the presence of other sources of chemical stressors in the same watercourse can complicate the identification and separation of the distinct effects of contaminated sites.

In the presentation the methodology, results and challenges will be illustrated by examples from three Danish stream (Å) systems investigated by the authors. These studies revealed that it is difficult to predict and evaluate the major pollutant drivers in a multi stressors system, where spatial and temporal variations in pollutant loads and stream flow are substantial. In addition, the data collection and assessment highlighted several difficulties in the Danish WFD implementation:

- We are far from good ecological status in Danish streams
- The monitoring of chemical quality in Danish streams is very limited
- The link between chemical impact and good ecological status is poorly understood

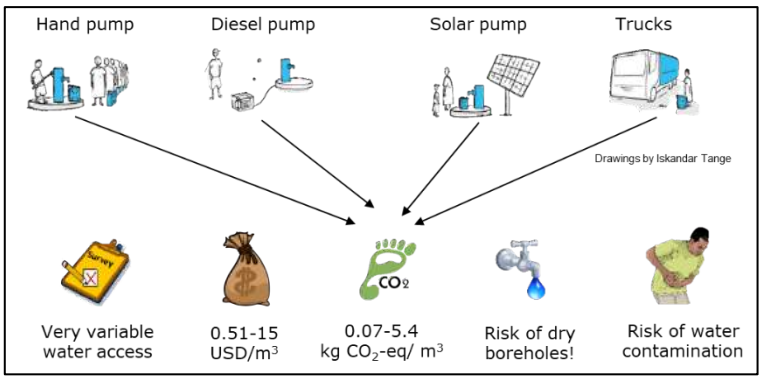
This lack of knowledge may lead to a poor understanding of the impacts on the stream system, delays in achieving good ecological and chemical quality and possibly even to the failure of river restoration projects. Finally, it seems that the original idea of holistic impact assessment and sustainable management including stakeholder involvement has vanished in a complicated and bureaucratic implementation process.

An Environmental and Economic Analysis of Water Supply Systems in Ugandan Refugee Settlements

Susanna Andreasi Bassi*[1], Iskandar Tange[2], Benjamin Holm[1], Alessio Boldrin[1] and Martin Rygaard[1]

[1]: Department of Environmental Engineering, Technical University of Denmark, Bygningstorvet, Building 115, 2800 Kongens Lyngby, Denmark
[2]: Department of Management Engineering, Technical University of Denmark, Bygningstorvet, Building 372, 2800 Kongens Lyngby, Denmark
*Corresponding author email: suan@env.dtu.dk

The recent record number of refugees and forcibly displaced people shows the need for a framework to evaluate water supply systems in emergency situations. We investigated several water supply system perspectives and time scales for South Sudanese refugee settlements in the north-western region of Uganda. Our study included an analysis of the end-user water demand, capital and operational costs, carbon footprint, freshwater availability and possible water contamination. The economic and environmental analyses compared 26 alternatives based on hand pumps, solar, diesel and hybrid motorized pumps and water trucking. The end-users' survey illustrated the significant variability of water access and the lack of data on water consumption/use. The economic evaluation showed that water supply costs are greatly affected by the length of the distribution systems and the chosen timeframes: for instance, unit costs decrease by 27% to 38% when shifting from a three- to a five-year operation. Excluding capital investment, the solar option is the cheapest in terms of operation, followed by hybrid and diesel and refugees could afford almost all the studied systems once the situation normalizes. However, the rank is less clear when including both operational and capital costs. The direct emissions from diesel generators are responsible for the highest impacts in the carbon footprint. Even if our analysis indicates that the cheapest and cleanest technology is represented by hand pumps, we need to highlight the risk of finding dry boreholes due to the need of drilling several times in the same area in order to avoid too long distances between the water provision points and the households. In fact, where there is a risk of overexploiting groundwater resources (as in the Ugandan settlements), it is more likely that NGOs will spend resources to monitor groundwater level only in case of larger motorized systems. Finally, water trucking is a meaningful solution only at the very beginning of the emergency: in fact, trucking water from a 25 m^3/h diesel-powered borehole is 1.7 to 9 times more expensive than a traditional distribution system after 2 to 10 years of operation, respectively. In conclusion, we emphasized the importance of economic results, while also including other aspects often neglected.



Andreasi Bassi, S.; Tange, I.; Holm, B.; Boldrin, A.; Rygaard, M. A Multi-Criteria Assessment of Water Supply in Ugandan Refugee Settlements. Water *2018,* 10*, 1493*

Planning infrastructure within the Zambezi water-energy-food nexus under uncertainties and climate change

Raphaël Payet-Burin[1,2*], Mikkel Kromman[2], Silvio Pereira-Cardenal[2], Kenneth Strzepek[3], Peter Bauer-Gottwein[1]

1: Department of Environmental Engineering, Technical University of Denmark, Kgs. Lyngby, 2800, Denmark
2: COWI A/S, Kgs. Lyngby, 2800, Denmark
3: MIT, Joint Program Sci & Policy Global Change, 77 Massachusetts Ave, Cambridge, MA 02139, USA
*Corresponding author email: rapp@env.dtu.dk

Water infrastructure development plans will help countries and regions realize the potential of their water resources. Ecosystem preservation, hydropower and irrigation development will contribute to multiple Sustainable Development Goals (United Nations, 2015), such as : End Poverty (1), Zero Hunger (2), Clean and available water for all (6), Clean and affordable energy for all (7) and Sustainable economic growth (8). However, some of these objectives might result in competing water uses, involving multiple stakeholders, upstream-downstream trade-offs and interactions between investments (Bauer-Gottwein et al., 2017). Furthermore, uncertainties related to socio-economic development and future climate add a layer of complexity. This study evaluates the infrastructure investment plans in the Zambezi river basin (World Bank, 2010), based on a hydroeconomic optimization model in a nexus framework (Figure 1). The value of the hydropower development plan is found very sensitive to future fuel prices or carbon pricing policies, the capital costs of solar technologies and climate change. Similarly, the irrigation development plan is found sensitive to the evolution of crop yields, world crop market prices and climate change.

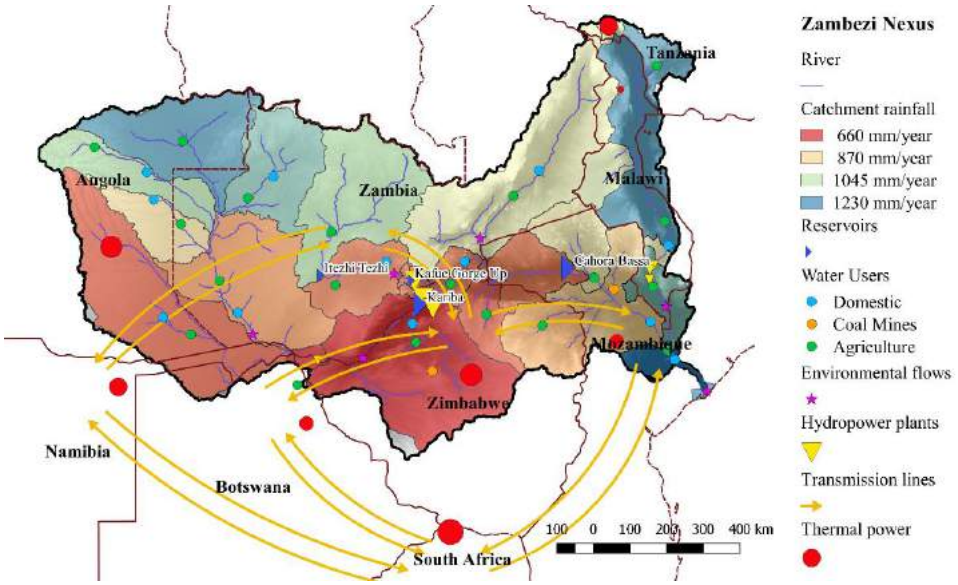


Figure 1: Conceptual representation of the water-energy-food nexus of the Zambezi river basin.

Bauer-Gottwein, P., Riegels, N., Pulido-Velazquez, M., Harou, J. J., Cai, X., Davidsen, C. and Pereira-Cardenal, S. J.: Hydroeconomic Analysis, in Handbook of Applied Hydrology, edited by V. Singh, p. 36/1-36/7, McGraw-Hill., 2017.

United Nations: Transforming our world: the 2030 Agenda for Sustainable Development, Gen. Assem. 70 Sess., 16301(October), 1–35, doi:10.1007/s13398-014-0173-7.2, 2015.

World Bank: The Zambezi River Basin, World Bank, 4, 1–202, doi:10.4324/9781315282053, 2010.

Mathematical models to improve wastewater treatment system within industrial context

Xavier Flores-Alsina[1], Hannah Feldman[1,2], Vicente Monge-Lopez[1], Pedram Ramin[1], Helena Junicke[1], Kasper Kjellberg[2], Ulf Jeppsson[3] Damien Batstone[4], , Krist V Gernaey[1]

1 Process and Systems Engineering Center (PROSYS), Department of Chemical and Biochemical Engineering, Technical University of Denmark, Building 229, DK-2800 Kgs. Lyngby, Denmark.
2 Novozymes A/S, Hallas Alle 1, DK-4400 Kalundborg, Denmark.
3 Division of Industrial Electrical Engineering and Automation, Department of Biomedical Engineering, Lund University, Box 118, SE-221 00 Lund, Sweden.
4 Advanced Water Management Centre (AWMC), The University of Queensland, St Lucia, Brisbane, Queensland 4072, Australia.

ABSTRACT

The objective of this presentation is to show a series of industrial projects dealing with model based assessment of full-scale granular anaerobic digestion reactors. A multi-scale mathematical approach is developed to describe reactor hydrodynamics, granule growth/distribution and microbial competition/inhibition for substrate/space within the biofilm. The main findings after running series of computer simulations can be summarized in the following points:

- Results reveal that the proposed approach can satisfactorily predict organics/nutrients/minerals transformations as well as methane, sulphide and the potential formation of precipitates. Using two independent data sets.
- The generation of Response surfaces (RSs) show that the reactor performance index (RPI) (a metric combining energy recovery in the form of heat and electricity, as well as chemicals needed for pH control) could be improved by 45 % when reactor pH is reduced down to 6.8. Model-based results reveal that influent S does not impose sufficient negative impacts on energy recovery (+ 5.7 %, in MWh/day, + 0.20 M€/year when influent S is removed) to warrant the cost of its removal (3.58 M€/year).
- Model predictions also suggest that a higher contribution of reject water promotes the potential risk of in-granule CaCO3 formation as a result of the increased quantity of Ca arriving with that stream (lime is used for sludge stabilization) + strong pH gradients within the biofilm. The study exposes the potential undesirable effects of the long term use of reject water (a decrease in energy recovery of 20 %), which are mainly caused by the competition (for space) between precipitates and biomass and the reduced buffer capacity
- The evaluation of post digestion treatment options (to deal with high nitrogen, methane and sulfide streams) show that traditional nitrification/denitrification processes based on activated sludge requires a decrease in digestion energy recovery in the digester in order to have enough organic substrate for subsequent post treatment NO_3 reduction (95 kW.h.Kg N-1). In contrast, partial nitration/anammox in an aerobic granular sludge reactor allows a higher conversion since N removal is carried out autotrophically.

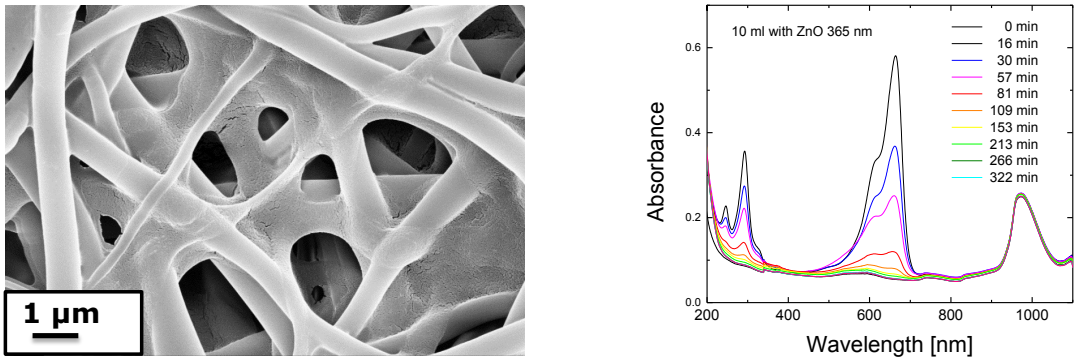
The presentation will show the benefits of virtual plant simulation and demonstrates the potential of model-based evaluation when process engineers in industry have to decide between competing options to avoid the implementation of undesirable options at early stage.

New water treatment research activities at DTU Energy

Jean-Claude Grivel*[1], Wenjing Zhang[1], Bhaskar Reddy Sudireddy[1], Roar R. Søndergaard[1], Ivano Eligio Castelli[1], Andreas Kaiser[1], Séverine Ramousse[1],

1: Department of Energy Conversion and Storage, Technical University of Denmark, Frederiksborgvej 399, DK-4000 Roskilde, Denmark
*Corresponding author email: jean@dtu.dk

The department of Energy Conversion and Storage at DTU recently started applying its competencies within materials processing to liquid treatment research activities. This contribution will provide an overview of on-going developments including polymeric filtration membranes made by electrospinning, ceramic thin ultrafiltration membranes on porous supports, ZnO thin films for photocatalytic pollutant degradation and preliminary studies on adsorption on sand. New ideas for potential future activities such as computational predictions of new low-dimensional materials for improved liquid filtration or membranes for sea mining will also be presented.



Left: Polyphenylsulfone (PPSU) electrospun membrane. Right: UV-Vis absorption spectra of a Methylene blue solution subjected to UV irradiation in presence of a ZnO film.

Session

W

Laptop Presentations

See session details and schedule on
www.sustain.dtu.dk

Solar powered drinking water

*Tom Juul Andersen[1],

1: AquaDania a/s, 2970 Hørsholm, Denmark
*Corresponding author email: tja@aquadania.com

Drinkable water is perhaps our worlds biggest challenge. Bottled water or high tech filter systems are the go-to solutions in many markets - a rapidly growing market. We do not yet have solutions for the NGO markets, but just about anyone else - even in Denmark.

We have developed and patented 3 systems that will clean just about any water source into the purest drinking water possible. We distill water and we do it where you are thirsty - in your home or workplace. Compared to bottled water and filters - they are simple, not-polluting and rigid.

We have developed and (field)tested for years and are about to bring our solutions to market.

This is a crucial time for (any) business and we have not found the right business model yet.

Besides showing our technology, we would like to discuss our next international steps with the audience.

HEPWAT – Higher Environmental Performance in Wastewater systems

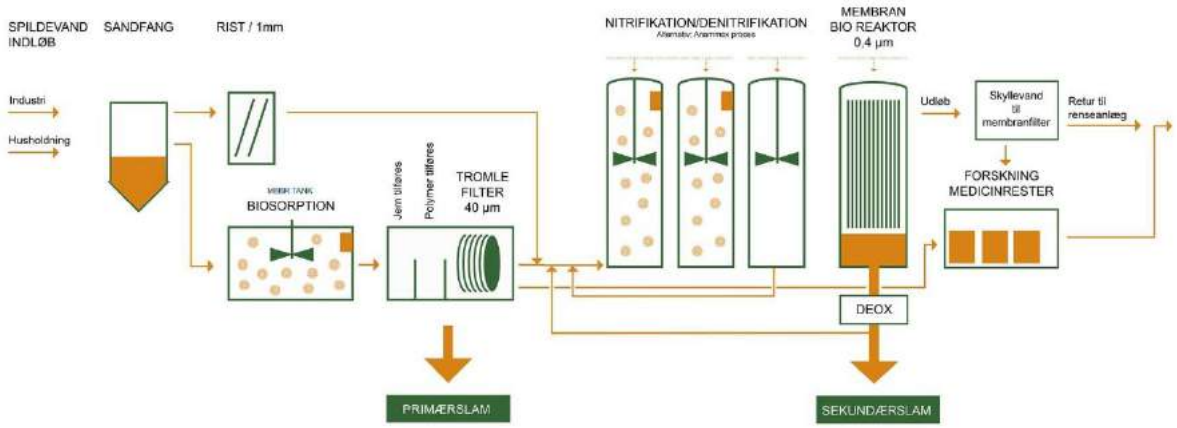
Carlos Domingo-Félez[1], Marlene M. Jensen[1], Henrik R. Andersen[1], Barth F. Smets[1]*

1: Department of Environmental Engineering, Technical University of Denmark, Denmark
*Corresponding author email: bfsm@env.dtu.dk

The Danish wastewater industry is getting a new "lighthouse" - a project to demonstrate the latest Danish wastewater treatment technology. It is about developing new solutions for operating the waste water system and for purification. Operation and cleaning will be optimized, more sustainable and cost-effective. The utility company Assens Forsyning [Utility Company] will realize the project in a partnership with pump technology company Grundfos, the engineering company Krüger, The Danish technical University (DTU) and the IT-firm ARTOGIS.

DTU will test strategies to:

a) Maximize carbon recovery (via further anaerobic digestion) from the influent wastewater.
b) Enhance autotrophic nitrogen removal at low temperature and high fluctuating C/N wastewater streams (municipal + industrial).
c) Mitigate low nitrous oxide (N_2O) emissions, a greenhouse gas emitted during biological nitrogen removal.
d) Test the best biofilm technologies for micropollutant and pathogen removal.



Session

W

Poster Presentations

See session details and schedule on
www.sustain.dtu.dk

Visible light driven nanoparticle for degradation of organic dye in aqueous solution

Hamed Baniamerian[1,2], Merlin Alvarado-Morales[1], Panagiotis Tsapekos[1], Malihe Safavi[3], Soheila Shokrollahzadeh*[2], Irini Angelidaki*[1]

1: Department of Environmental Engineering, Technical University of Denmark, Kgs. Lyngby, DK-2800
2: Department of Chemical Technologies, Iranian Research Organization for Science and Technology, Tehran, Iran
3: Department of Biotechnology, Iranian Research Organization for Science and Technology, Tehran, Iran
*Corresponding authors email: iria@env.dtu.dk; shokrollahzadeh@irost.ir

Photocatalytic removal of organic pollutants from water and waste water has been one of the most attractive research areas due to the environmental issues that polluted water can bring for the world [1]. TiO_2 is one of the most common nanoparticles (NPs) used because of cheapness, stability, availability and non-toxicity. However, practical application of TiO_2 is limited because it is activated in exposure of ultra-violet irradiation. Regarding this fact, there is a great affinity to modify TiO_2 in order to enhance its photocatalytic activity in exposure of visible light irradiation. Doping TiO_2 NPs with Fe_2O_3 (cheap, non-toxic metal element) adds new states in the bandgap of TiO_2, and subsequently, increases the visible light absorption [2]. During this process highly reactive oxygen species (ROS) are produced and destroy organic matters, i.e. dye, in the water. Following this strategy, Fe_2O_3-TiO_2 NPs with 2.5 weight percentage of Fe_2O_3 was synthesized via an ultrasonic-assisted co-precipitation method and their visible-light de-colorization of methylene blue dye was investigated. The NPs were characterized by powder X-ray diffraction, BET surface area, transmission electron microscopy plus selected area electron diffraction patterns, scanning electron microscopy, energy-dispersive X-ray spectroscopy and diffuse-reflectance spectroscopy. The ROS generated by Fe_2O_3-TiO_2 NPs in photocatalytic dye removal process were analyzed using radical scavenging techniques. As shown in Fig. 1 the addition of different scavengers caused some reduction in photocatalytic efficiency. Based on the results, the contribution of the different ROS is $h^+ > {}^{\bullet}OH > {}^{\bullet}O_2^-$ which is indicating h^+ radical is the most important species that synthesized NPs produced in the aqueous media.

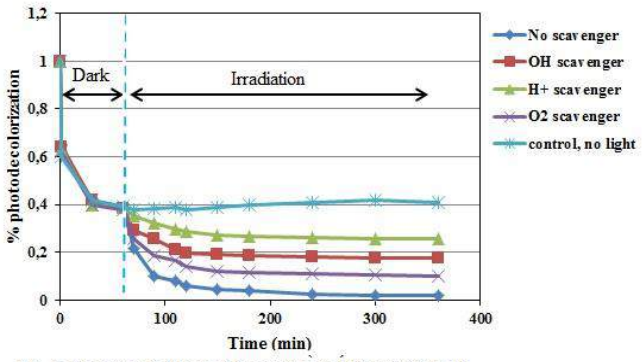


Fig. 1: Adsorption behavior of the samples in dark conditions and Photodecolorization results of the samples after UV light irradiations

Refrences

[1] Y. Xu, H. Xu, H. Li, J. Xia, C. Liu, L. Liu, Enhanced photocatalytic activity of new photocatalyst Ag/AgCl/ZnO, J. Alloys Compd. 509 (2011) 3286–3292.
[2] S.-Y. Lee, S.-J. Park, TiO2 photocatalyst for water treatment applications, J. Ind. Eng. Chem. 19 (2013) 1761–1769.

Removal of marine microorganisms from seawater in order to prevent biofouling in water desalination membranes

Hamed Baniamerian[1,2], Merlin Alvarado-Morales[1], Panagiotis Tsapekos[1], Malihe Safavi[3], Soheila Shokrollahzadeh*[2], Irini Angelidaki*[1]

1: Department of Environmental Engineering, Technical University of Denmark, Kgs. Lyngby, DK-2800
2: Department of Chemical Technologies, Iranian Research Organization for Science and Technology, Tehran, Iran
3: Department of Biotechnology, Iranian Research Organization for Science and Technology, Tehran, Iran
*Corresponding authors email: iria@env.dtu.dk; shokrollahzadeh@irost.ir

Clean water shortage is one of the main challenges in the many parts of the world. Among the various techniques, reverse osmosis (RO) membranes are extensively used for desalination of seawater, due to their high energy and space efficiency. Formation of biofilm on surface of RO membrane is the main challenge in desalination systems as decreases the economic and operation efficiency and increases hydraulic pressure drop [1]. Five active Fe_2O_3-TiO_2 nanoparticles (NPs) with different weight percentage of Fe_2O_3 (0-5 wt.%) were synthesized and fully characterized to remove *Vibrio fischeri* (as a well-known marine bacterium forming biofilm) from seawater under visible light irradiation via an aqueous photocatalytic system. The effect of three different parameters, i.e. type of NPs, concentration of NPs in the reaction system, and temperature, were investigated based on a central composite design of experiments. The photocatalytic microbial removal experiments were performed in artificial seawater appropriate for growth of the marine bacterium with simulated nutrient, pH, etc. The results showed that 1 g/L of 2.5 wt.% Fe2O3 doped TiO2 had the highest efficiency of *V. fischeri* inactivation (99.4%) at 35°C after 4 h of process (Fig. 1). Based on the active species capturing experiments, the high activity of NPs was attributed to the formation of highly reactive oxygen species (mainly H+) during photocatalytic process. Photocatalytic inactivation of microorganisms using visible light-driven Fe2O3-TiO2 photocatalysts could be a green method in pretreatment units of reverse osmosis plants to prevent membrane biofouling.

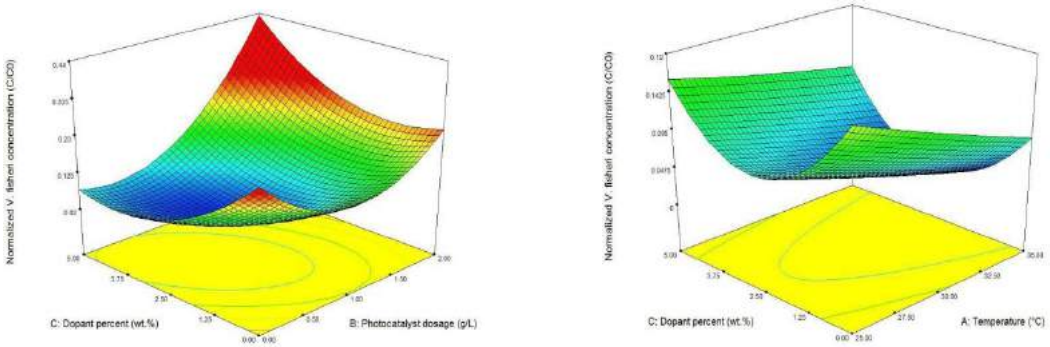


Fig. 1: The response surface of *Vibrio fischeri* concentration as a function of (a) NPs dosage and Fe_2O_3 percentage (dopant) and (b), process temperature and and Fe_2O_3 percentage

References:

[1] L.F. Greenlee, D.F. Lawler, B.D. Freeman, B. Marrot, P. Moulin, Reverse osmosis desalination: Water sources, technology, and today's challenges, Water Res. 43 (2009) 2317–2348.

Biogas production from brewery wastewater in forward-osmosis anaerobic-membrane bioreactors

Carina Schneider[1], Alberto Evangelio Oñoro[1], Claus Hélix-Nielsen[1,2], Ioannis Fotidis*[1]

1: Department of Environmental Engineering, Technical University of Denmark, Bygningstorvet Bygning 115, DK-2800 Kgs. Lyngby, DK
2: University of Maribor, Faculty of Chemistry and Chemical Engineering, Smetanova ulica 17, 2000 Maribor, Slovenia
* ioanf@env.dtu.dk

Global water scarcity and growing energy demand are caused by population growth, urbanization and climate change. These issuesare some of the major challenges for sustainable development (WWAP 2015). With growing awareness for environmental issues and rising costs for wastewater disposal, water-intensive industries, like the brewery industry, are now striving to establish more sustainable processes (Simate et al. 2011). Their focus is on finding novel processes to treat wastewater for re-use. Anaerobic membrane bioreactors (AnMBRs) combined with forward osmosis (FO) provide a unique method to extract water from high-strength industrial wastewater sources while simultaneously producing biogas (Wang et al. 2017).
The goal of this study was to examine the start-up phase of two lab-scale FO-AnMBRs solely digesting brewery wastewaters (Fig. 1). The hydraulic retention time (HRT) of the reactors was reduced stepwise from 20 to 2.5 days while the organic loading rate (OLR) was increased from 0.28 to 2.26 g COD/L reactor in order to evaluate the reactors efficiency and stability during start-up.
Results showed that methane production rate and water flux increased up to 220mL/ day/L reactor and 1,5 LMH, respectively with decreasing HRT. However, the process instability also increased over time. These findings demonstrated that in order to use FO-AnMBR for water recovery from brewery wastewater, further process optimisation is warranted.

Figure 1. The two FO-AnMBRs reactors' setup

- Simate, G.S., Cluett, J., Iyuke, S.E., Musapatika, E.T., Ndlovu, S., Walubita, L.F. and Alvarez, A.E. (2011) The treatment of brewery wastewater for reuse: State of the art. Desalination 273(2–3), 235-247.
- Wang, X., Wang, C., Tang, C.Y., Hu, T., Li, X. and Ren, Y. (2017) Development of a novel anaerobic membrane bioreactor simultaneously integrating microfiltration and forward osmosis membranes for low-strength wastewater treatment. Journal of Membrane Science 527, 1-7.
- WWAP (2015) The United Nations World Water Development Report 2015: Water for a Sustainable World, Paris.

Session

X

Oral Presentations

See session details and schedule on
www.sustain.dtu.dk

Where do green industries develop? And how?

Anne N. Tanner*[1]

1: Department of Management Engineering, DTU, Denmark and CIRCLE, Lund University, Sweden
*Corresponding author email: anny@dtu.dk

Sustainability is high on the political agenda and many regions wish to support a transition to a greener economy by developing new green industries. Green industries are as other new industries associated with innovation and entrepreneurial activity that may provide a platform for future economic growth. The presentation aims to answer the following questions: what are the fundamental drivers for new economic activity in regions and how can we design policy that encourage regional industrial development to be green? In doing so, I will give a state-of-the-art summary of the latest academic achievements in understanding the development of new industries.

The Explanation

In recent years, questions about how regions can develop new green industrial paths, which can deliver on both the environmental, economic and social sustainability of regions have received increasing attention among researchers in the field of economic geography. Based on a decade of research in this field (see e.g., Frenken & Boschma, 2007; Neffke et al., 2011; Tanner, 2014), evolutionary economic geographers have demonstrated that new industries develop in regions where the pre-existing economic activities are related to the emerging industry. This means that regional industrial diversification is a path- and place-dependent process whereby industries grow out of pre-existing local resources and capabilities. Local resources and capabilities are diverse by nature and are shaped by strong upstream technological knowledge resources, downstream application-oriented companies, natural resource endowments or strong institutional settings.

Policies for green industry development

For many years, regions have built their regional innovation policy on broad generic ideas stemming from the literature on 'clusters', where the most commonly used policy tool has been to support network activities (e.g., PPP or R&D projects). However, the articulation of regional clusters appears often as wishful thinking poorly reflecting a region's actual strengths. As a replacement for the visionary cluster-based policy, regional innovation policy ought to take pre-existing regional competences much more into consideration. Moreover, in promoting sustainable system transitions, regional innovation policy also need to address challenges in relation to directionality, experimentation, demand articulation, and learning and coordination of the system (Grillitsch et al., 2018).

- Frenken, K. & Boschma, R. (2007). A Theoretical Framework for Evolutionary Economic Geography: Industrial Dynamics and Urban Growth as a Branching Process. Journal of Economic Geography, 7(5), 1–15.
- Grillitsch, M., Hansen, T., Coenen, L., Miörner, J., & Moodysson, J. (2018). Innovation policy for system-wide transformation: The case of strategic innovation programmes (SIPs) in Sweden. Research Policy.
- Neffke, F., Henning, M., & Boschma, R. (2011). How do regions diversify over time? Industry relatedness and the development of new growth paths in regions. Economic Geography, 87(3), 237–265.
- Tanner, A. N. (2014). Regional Branching Reconsidered: Emergence of the Fuel Cell Industry in European Regions. Economic Geography, 90(4), 403–427.

Gate 21 – a regional driver for green growth

Lone Pie Kelstrup, Head of Program - Sustainable Digital Societies Gate 21

Lone.kelstrup@gate21.dk

Abstract
This presentation will address the key learnings points from one of Gate 21's important contributions to green transition in Greater Copenhagen.

Gate 21 is a catalyzing organization with the main purpose to accelerate green transition through partnerships, i.e. between municipalities, organizations, private partners, etc. The organization address challenges related to energy, mobility, circular economy, buildings and digital solutions. We use several methods in our work.

- Facilitate cooperation and common visions between key actors
- Increase competencies in municipalities to empower green decision-making
- Public-private Innovation
- Living Labs
- Testing new green solution with public market

A main example is the cooperation process between more than 40 partners (utilities and municipalities) to address sustainable energy transition in the Capital Region. The results include:

- A common vision
- A Road-map with 34 action points
- Investment overview – how far are we and where do we need more action
- Risk reduction
- Increased trust and cooperation
- Knowledge sharing and innovation

Another example is the challenge-based innovation process with the aim to translate municipal and other data to relevant green solutions for cities. Here, private companies are involved as innovators in a structured process to address challenges with mobility, congestion and climate adaptation.

With this work Gate 21 constitutes an organization as is entailed in the SDG number 17 Partnerships for the goal. Moreover, issues are addressed included in the SDG's; Sustainable Energy (7), Decent work and Economic Growth (8), Industry, Innovation and Infrastructure (9), Sustainable Cities and Communities (11), Responsible consumption and Production (12) and Climate Action (13).

The Sustainability Caravan, initiated by IDA

Sara Christina Martinez*[1]

1: Voices from the Future, Representing the Sustainability Caravan (Bæredygtighedskaravanen), *saracm@dtu.dk

This talk will present the IDA Sustainability Caravan, a new initiative which encourages knowledge sharing and cooperation in the industry, and calls for action towards sustainable development.

"The Sustainability Caravan" is an initiative started by volunteer members in IDA's Professional Networks. The Sustainability Caravan wishes to spread knowledge of the Sustainable Development Goals (SDGs) by mobilizing members of IDA around the country and identifying concrete methods for working with the SDGs in workplaces in Denmark, Greenland and the Faroe Islands. The purpose is to emphasize the efforts already taking place and at the same time stimulate innovation, interdisciplinary cooperation, learning and upscaling in the areas, where the work towards the SDGs has just started or has not yet begun.

The Caravan has developed a tool for Learning and Self-assessment, where you can assess your company's actions in relation to the SDGs, try it out here . The Caravan will include more than 60 workplace visits around Denmark, at companies that have used the self-assessment tool. These companies will have an opportunity to share their strategies and best practices for sustainable actions.

General assembly meetings will be held in the local IDA regions to share knowledge gained from the workplace visits. At the general assembly meetings, nominees will be chosen for the National Sustainability Award, and a winner will be found at the concluding event at the UN City in May 2019.

To represent an international youth perspective, the group "Voices from the Future "has been formed as part of the caravan. This group will contribute with the insights and perspectives of young professionals through blog posts and by engaging in discussions during the workplace visits. The objective is to shed light on the importance of international collaboration and the creation of sustainable, value-driven jobs in connection to the work around the SDGs.

The workplace visits and general assemblies are free of charge for everyone, and events will be published on the IDA Universe page for the Sustainability Caravan (Link).

A coherent transport system for Greater Copenhagen 2050

Andrés Valderrama[1*], Joe Jensen[2],

1: Aalborg University 2: Region Hovedstaden
*Corresponding author email: afvp@plan.aau.dk

Whether is autonomous vehicles or MAAS, all technological visions for the future of regional transportation have one element in common: the future systems are coherent and seamless for the user. Coherence is not something that technology can deliver on its own: it is a as much a technical challenge as it is organizational and social. In this presentation outlines some of the initiatives, considerations and ideas that can support the development of a coherent transportation system for Greater Copenhagen, a geographical unit that includes Region Zealand and the Capital Region in Denmark and Region Skåne in Sweden. Although much of the focus in term of transportation in Greater Copenhagen has been on the links across the Sound and congestion in the urban areas over the Sound, the reality is that the most pressing problem in Greater Copenhagen as a regional entity is the mobility poverty of many areas. How to harmonize then the demands of increasing urbanization with access to those all who live in the region? This is the question that addresses the Interreg project “A coherent transport for Copenhagen 2050”, through the discussion and collective development of four key areas: regional Supercycle highways; transportation nodes; transportation and health; and new collective transport solutions.

SDGs: 3; 4; 9; 11; 12

Targets

3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents; 4.3 By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university; 9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all; 9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities; 11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons; 12.2 By 2030, achieve the sustainable management and efficient use of natural resources

'Total Recycling Decommissioning (TRD)' linking to 'Circular Economy Network of Ports (LOOP-Ports)'

Kristian Johannesen, Innovation Consultant at NTU International (kj@ntu.eu)

Through several years of strong cooperation of Port of Frederikshavn and NTU International, the opportunity to pursue environmentally sound decommissioning in Frederikshavn became a possibility with the arrival of Modern American Recycling Services. Offshore equipment and maritime vessel decommissioning provide a widely untapped value for Northern Europe, with environmental impacts at the core of the business. Together with local stakeholders in Frederikshavn and DTU Environment, NTU investigated the feasibility of setting up a Total Recycling Decommissioning (TRD) network, where promotion of Circular Economy principles and stronger links between the value chain were central in obtaining environmental, social, and financial impacts. Each partner contributes with their strongest assets, creating a lighthouse project that can aid E- flagged ship and offshore operators in choosing environmentally sound decommissioning options, pressuring the current beaching operations in Southeast Asia to change procedures and improve conditions. The project directly targets SDG 13 Climate Action by providing a sizeable climate impact and paving the way for circular economy principles to be included directly in businesses. By connecting the businesses from diverse backgrounds, the TRD facilitates a network that promotes best practices in sustainability and recycling while focusing on innovation, co-creation and knowledge sharing to the benefit of all partners involved. Thereby, contributing to the SDG 9 Industry, Innovation and Infrastructure. The project was supported by EIT through Climate KIC in two stages (Pathfinder and Accelerator) and is currently pending the full implementation of MARS' operations before full scale testing of the TRD can, and will, be carried out.

The LOOP-Ports project which started in October 2018 follows up on the TRD, providing a pan-European approach to solving climate issues and promoting circular economy in ports with the following objectives:

- To understand the port sector particularities and its innovation needs, through the analysis of the main flows of materials generated and/or used in the port sector, the identification of the different initiatives developed across the world in terms of circular economy and the technologies used to recover waste;
- To contribute to the development of new products, processes, and services fostering circular economy in the port activity, by development of specific business models;
- To identify specific synergies and complementarities among different port-sector actors, value chains and markets, in order to highlight and evaluate potential strategic business cases and cooperations;
- To interact with the different agencies, initiatives and programmes launched at EU level aiming at transforming Europe's economy into a more sustainable one, as well as with EU port associations, in order to share knowledge, best practices and policy recommendations. Special attention will be given to the interaction with the Circular Economy Stakeholder Platform and ESPO.

As the LOOP Ports project is still materializing, this part of the presentation will focus on how the regional problems and opportunities identified in Frederikshavn are relevant on a European scale, and how different European stakeholders and ports of different sizes, including key maritime transports hubs such as Rotterdam, Hamburg, Valencia and Piraeus, can benefit from cross-cutting initiatives. The LOOP-Ports project is committed to provide impacts on SDG's 9 Industry, Innovation and Infrastructure and 13 Climate Action in particular.

COHERENT research project - status and perspective

Kirsten Halsnæs[1], Lea Skræp Svenningsen[1*]

1: Climate Change and Sustainable Development, Systems Analysis, DTU Management Engineering
*Corresponding author email: leasks@dtu.dk

In this presentation we will present the status of the COHERENT research project, which was initiated in the autumn of 2017. The presentation will focus on the estimation of dynamic cost functions from climate events in costal areas, including a discussion of the perspectives and limitations of approach taken.

The existing practice of estimating the economic costs of a storm surge involves a static approach, including simplified damage cost concepts that are focused on reconstruction of buildings and roads. To nuance this approach, the COHERENT project plans to include a broader range of cost concepts such as the cost of traffic delays, damage to environmental amenities, disruption of local business activity, decreases in real-estate prices and negative health effects. The dynamic aspect will be introduced by modelling a community's adaptive response over time, and this theoretical modelling will be informed by a focus-group process that aims at investigating how individuals, who participate in learning process on the risks of climate change, make decisions about adaptation over time.

Background for the COHERENT project

Coastal flooding hazard events have increased in magnitude and severity in recent decades in Denmark, Europe and globally. Rising sea levels and more extreme storms due to climate change are expected to increase these risks. Interactions between land use, hydrological systems, economic activities and human settlements in coastal areas can also increase vulnerabilities. Risk-prone coastal areas have for centuries been protected by dikes, water-pumping systems, etc., though it is now evident that established systems are not sufficient to protect against expected future risk levels. COHERENT will facilitate integrated system views and expert, government and business interactions in these areas. In particular, physics, engineering, economics and social sciences are integrated in the COHERENT project, and a key project output is to produce a user-friendly digital platform in support of planning and for testing different coping measures and strategies. Value creation to society includes reduced flooding damage costs and business development with exports, employment creation and innovation in the clean tech sector. The project outcomes will provide benefits to a wide range of interest groups from citizens and municipalities to small consultancy companies and other SMEs to larger companies such as Danish engineering consultancies.

Greater Copenhagen Green Connect - a regional climate adaptation project with double value for two major fjords in Denmark

Jens Rønnow Lønholdt [1]

1: LYCEUM Innovation and Process Consultancy.
*Corresponding author email: lonholdt@lyceumconsult.dk

Denmark is a coastal country, with over 8,000 kilometer of coastline. The maksimum distance you can get from the coast in Denmark is 60 kilometer. Consequently Denmark is vulnerable to rising sea level, flooding and erosion caused by climate change, the effect of which was very visible this summer, with very hot weather in a Danish context. As a large part of the coastline is low lying areas, it is a substantial challenge for Denmark to prepare for the consequences of rising sea level and flooding.

To meet this challenge the Danish Government has chosen a decentralized approach which was instigated 1st of September 2018. In short the Danish Municipalities are tasked with the responsibility of planning and management of all water within their respective borders. Rain from the sky, water from the sea, fjords and rivers, ground water from below, wastewater etc. But the individual house owner will have to pay for necessary measures to counter the effect of "too much water" on his or her plot. Naturally this support individual solutions, which can create problems up-stream or down-stream if not properly coordinated and integrated. It do not cal for a holistic approach which would be natural as water do not respective either property borders, municipal borders, regional or national borders.

Based on this, and as Denmark is an innovative country, a number of local, semi-local and semi-regional projects are springing up these year all over Denmark. Most om them very well technical justified and supported in solving a local problem, but with limited geografical coordination and exchange of knowledge and lessons learn between the different projects. To ensure this the think tank INUNDO, which was presented at last years SUSTAIN (see the Book of Abstract from 2017 Session L), were established two years ago. It covers organisations and individuals with deep and broad competences in relation to all aspects of integrated and sustainable coastal zone management.

However in one part of Denmark a regional climate adaptation project has been on the drawing board for around 4 years now. It is the Greater Copenhagen Green Connect Project (abbreviated GC2) ensuring regional protection of the catchment area of Roskilde Fjord and Isefjorden (see: www.gc2.dk). It is a double value project as it is also a infrastructure improving project connecting the two parts of Northern Zealand. Based on the above presented decentralized approach it has been difficult for the project to get local, regional and national political support, and consequently also difficult to ensure financing. Despite the fact that the cost of this project, around 2 billion DKK, is only twice the total cost in the area of the latest big storm in 2013. Not counting in the social and mental costs of the people living in the affected areas.

However, there is a growing recognition in Denmark amongst politicians, the affected house owners and climate change professionals that the fragmented approach based on the decentralized approach may not be the way forward. This is also supported by the fact that the local, semi-local and semi-regional projects have run into a lot of administrative and bureaucratic problems. In continuation of this the GC2 project is now in positive contact with private investors concerning a possible PPP (Public-Private-Partnership) model for the project, where the project is financed by pension funds and/or private investors.

GC2 and INUNDO adresses the following SDGs: 7 CLIMATE ACTION; 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE; 11 SUSTAINABLE CITIES AND COMMUNITIES; 17 PARTNERSHIPS FOR THE GOALS.

Climate adjustment, CO2-savings and cocreation goes hand-in-hand

Lene Jæger Klausen[1]

1: BlueKolding - Formerly Kolding Spildevand (Kolding Wastewater) – an environment, energy, and climate company

*Corresponding author email: lejk@bluekolding.dk

In the project Smart Spildevand Kolding Municipality and the wastewater company BlueKolding has developed a method which engage the citizens in developing climate adjustment solutions, which on one hand addresses the growing challenges with flooding due to increasing rainwater volumes, while simultaneously reducing CO_2-emissions.

The challenge is, that it is too expensive to perform a traditional separation in the inner city of Kolding, and there is no space for establishing new detention ponds.

This situation creates a socioeconomic need for alternative and cheaper terrain-based solutions for climate protection. This can be done e.g. by using the rainwater and facilities for recreational purposes on the terrain instead.

The project is still ongoing, but preliminary results show that it *is* possible to get climate adjustment projects to go hand-in-hand with cocreation and CO_2-savings – but it is not given. Experiences from Kolding reveals, that in order to succeed with the project, it is necessary to work persistent and strategic with the citizens involvement.

Our focus thereby lies on:

- How do we engage the citizens to participate in the development of solutions for climate adjustments?
- How can we create recreational environments, where rainwater actively contributes to the experience of an area?
- How do we ensure, that the citizens concerns and wishes becomes an essential factor in the technical development and urban planning?

These questions are essential in to make climate adjustment, CO_2-savings and cocreation go hand-in-hand, and these questions will we provide our answers and experiences to on the conference.

Smart Spildevand adresses the following SDGs: 7 CLIMATE ACTION; 11 SUSTAINABLE CITIES AND COMMUNITIES.

The Climate Laboratory in Middelfart / The Climate City

Engineer Mr. Bjarne Rasmussen
The Municipality of Middelfart, Nytorv 9, 5500 Middelfart, Denmark
E-mail: bjarne.rasmussen@middelfart.dk. Tel. +45 8888 4833

Climate Laboratory: The municipality of Middelfart are taking global responsibility through local action
The Municipality of Middelfart wants to be on the forefront in the field of climate and climate change. Both in regards to preventing climate change but also climate adaptation. The Climate Laboratory is the overall name of a whole host of projects dedicated to addressing the climate challenges.

The task is linked to education and learning, business growth and urban development.

With Middelfart as a climate laboratory, the municipality wishes to continue its efforts to develop and implement new innovative, concrete energy and climate projects.

The implemented solutions will also serve as a exhibitions for inspiration for others. The core idea is to develop and display energy and climate solutions for smaller cities/local communities in a scale of 1 to 1.

As part of the Climate Laboratory Strategy, a number of large-scale innovative climate adaptation projects are presently being developed and implemented in full scale EXPO-projects in the Danish town of Middelfart. Amongst these projects are “The Climate City” - the most beautiful climate adaptation project in Denmark.

A paradigm shift in both urban development and of the use of wastewater
One of the greatest social and financial challenges of the future is to ensure that towns and cities are climate resilient. “The Climate City” project thus rests on a pronounced paradigm shift in both urban development and wastewater management.

Using an innovative dialogue-based approach, ”The Climate City” project focuses on the development of innovative solutions that integrate both climate adaptation and urban design through focus on multifunctional design of urban spaces and structures. The project solutions aim to manage rainwater on the ground as a supplement to underground pipes, making rainwater a visible urban element.

The objective of “The Climate City” project is that innovative solutions and the principles behind these will become a source of inspiration for the work that lies ahead in the integration of urban development and climate adaptation, both nationally and internationally.

“The Climate City” project is being implemented as a partnership between Middelfart Wastewater Utility, the Municipality of Middelfart, and Realdania.

SDGs:
Goal 4: Quality education.
Goal 6: Clean water and sanitation.
Goal 11: Make cities inclusive, safe, resilient and sustainable.
Goal 13: Take urgent action to combat climate change and its impacts.
Goal 14: Conserve and sustainably use the oceans, seas and marine resources.
Goal 17: Revitalize the global partnership for sustainable development.

Targets
Reduce overflow from the common sewer to the sea, by making rainwater run on the surface.
Making solid climate solution that can handle extreme rainfall.