Book of Abstracts
Time: December 17th. 2015, all day
Venue: Technical University of Denmark
Regstration in Oticon Hall 8.00-9.00

www.sustain.dtu.dk
See website for time and location of sessions!

Published 13/12 2015

Table of Contents

Sustainability

A sustainable society is considered to involve a balanced interplay of three main elements to meet the needs of present generations without compromising the possibilities of future generations to meet their own needs [1]:

- The environmental boundary conditions that set the limits on resource supply, waste disposal and environmental pollution;
- How the economy balances production and consumption processes within – or currently beyond - the environmental constraints;
- How society politically and culturally decides to manage the social effects of the above constraints given by the short and long term consequences of our activities.

Our developing knowledge of our own environmental impact imposes limits on our activities, while our expectations to the quality of life we wish to have requires expansion of activities.

Radically improved efficiency of our technologies are urgently needed in order to reduce both reliance on scarce resources and the long term effects on the environment and the climate, but also to handle the longer term demographic changes and the increase in material wealth in developing economies.

Society's growing awareness of the many challenges is causing a gradual but unavoidable change in our perspective on technology, from the traditional optimization of economic cost with the specific technological performance to a much broader view including environmental impact and performance in terms of resource efficiency etc.These considerations are becoming increasingly important in how we direct R&D and assess emerging technologies.

Both citizens and policies are evolving with this changing perspective. The EU Commission states that “Sustainable development will be an overarching objective of Horizon 2020” and allocates 60% of the budget to this [2]. The Danish Forsk2020 has also made the societal challenges in creating a sustainable society an important factor in their scope.

Sustain DTU is a conference where everyone involved in research at DTU from PhD students to Professors can meet to share their knowledge and inspire each other to create the best possible teams and solutions for solving the challenges.

The conference is divided into 5 tracks, and these broadly speaking cover the main societal challenges on sustainability and also involve the majority of DTUs many technology domains.

[1] United Nations General Assembly (1987) Report of the World Commission on Environment and Development: Our Common Future. http://www.un-documents.net/our-common-future.pdf
[2] “Horizon 2020 - The Framework Programme for Research and Innovation” Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 30.11.2011.

Sponsors

The Sustain DTU conference is grateful for the following support:

- Novozymes for sponsoring poster prizes
- DTU Jubilæums fonden
- DTU environment and DTU nanotech for administrative aid

Plenum Talks

See schedule on
www.sustain.dtu.dk

Living within the biophysical boundaries of the Earth: Defining a safe operating space

Katherine Richardson

Professor, Biological Oceanography, Center for Macroecology, Evolution and Climate

(www.macroecology.ku.dk), The Danish Natural History Museum

Leader of the Sustainability Science Centre (www.sustainability.ku.dk)

University of Copenhagen

Until relatively recently, humanity had no reason to believe that management of natural resources and waste deposition at the global level was necessary for the continued wellbeing of human societies. Now, however, there is growing understanding that the Earth "functions as a single, self-regulating system comprised of physical, chemical, biological and human components" (Amsterdam Declaration on Global change) and that human activities are altering the functioning of that system. Therefore, society is in the midst of the development of mechanisms to manage natural resources at the global level, e.g. climate COP process. This talk focuses on the role of natural and technical sciences in developing these mechanisms.

SOER 2015 — The European environment — state and outlook 2015

Jock Martin, European Environment Agency, Copenhagen, Denmark. Jock.martin@eea.europa.eu

The European Environment Agency (EEA) is an agency of the European Union whose task is to provide sound, independent information on the environment for those involved in developing, adopting, implementing and evaluating environmental policy. The main clients are the European Union institutions — the European Commission, the European Parliament, the Council — and its 33 member countries.

The European environment — state and outlook report 2015 (SOER 2015)[1] is a comprehensive, integrated assessment of the European environment's state, trends and prospects in a global context. It explicitly links to the current EU policy agenda, in particular the 7th Environmental Action Programme. SOER 2015 draws upon the evidence base available to the EEA and is presented online to enable full traceability.

Among many findings, the SOER 2015 offers four overarching messages. Firstly, well designed, ambitious and well implemented environmental and climate policies deliver clear results. Secondly, Europe faces persistent and emerging environmental challenges linked to our systems of production and consumption, and the rapidly changing global context. Thirdly, fundamental socio-economic transitions are needed in energy, transport, food and material use as well as education, finance, taxation and health to achieve the 2050 vision. Lastly, effecting transitions can put Europe at the frontier of science and technology, create jobs and contribute to Europe's future economic performance.

The overall trends are quite clear. We are making progress in improving resource efficiency but this has not translated into improved ecosystem resilience and human well-being. Moreover, the long-term outlooks raise several concerns driven by a wide range of global megatrends largely outside Europe's control. Policy approaches that explicitly recognise the relationships between resource efficiency, ecosystem resilience and human well-being can accelerate the reconfiguration of systems of production and consumption.

The concept of a green economy has emerged as a framework for an integrated response to these long-term systemic challenges – one that addresses jobs, competitiveness and equity/fairness alongside environmental sustainability. SOER 2015 analyses current opportunities to recalibrate policies, governance, and investments in innovation and knowledge in line with this framework.

There is an urgent need to act now. Decisions being made today on long-term investments in systems such as energy and mobility will go a long way to determine our 2050 future. Innovations in engineering will play a central role in driving these systemic transitions: infrastructure developments, new technologies, and products as services. Living within ecological limits, in an innovative circular economy, will require us to avoid investments that lock into existing resource-intensive patterns of production and consumption, limit innovation options and hinder investment in substitutes.

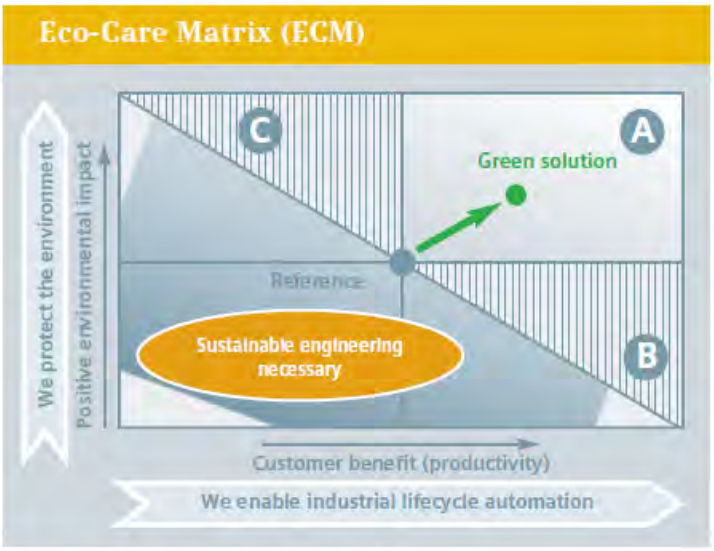
Niche innovations which merge the role of consumers and producers in developing and providing energy, food and mobility goods and services look promising. Publicly funded investment fostered many of the most successful innovations of the 20th century from the internet to nanotechnology. The EU's 7th Environment Action Programme, Multiannual Financial Framework 2014–2020, Europe 2020 Strategy and the Framework Programme for Research and Innovation (Horizon 2020) offer unique opportunities to harness synergies across policy, investment and research in support of the transition to a green economy.

EEA, 2015a. The European environment – state and outlook 2015: synthesis report. European Environment Agency, Copenhagen.

EEA, 2015b. European environment – state and outlook 2015: assessments of global megatrends. European Environment Agency, Copenhagen.

Sustainability and Innovation Management

Prof. Dr. Dieter Wegener, Siemens



The environment and profit go together: an analysis using the Eco-Care Matrix helps in the development of green solutions.

The Eco-Care Matrix, developed in cooperation with universities, enables an environmental and economic assessment of individual products, systems and solutions all the way up to complete industrial facilities. Put simply, the customer benefit including the economic factors of capital and operational expenses is weighed against the impact on the environment. The Eco-Care Matrix considers the entire value-added chain and not only individual process steps. This allows new developments to be compared against one another in regard to sustainability, costs and environmental protection. This holistic approach sets the framework to reduce or avoid the emission of greenhouse gases, avert the production of waste destined for landfills, and more efficiently use heat and energy in industrial production processes.

Session

A

Oral Presentations

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

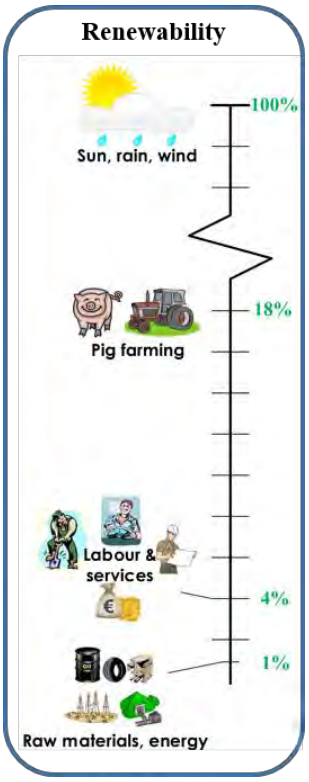
Renewability of products assessed using emergy

Hanne Østergård*[1], Andreas Kamp[1]

1: DTU Chemical Engineering

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

Often products are claimed to be 'green' and sustainable without being backed up by a scientifically rigorous understanding of sustainability. Sustainable development implies making use of largely renewable resources. Thus, a sustainability assessment must identify hotspots for reducing the use of non-renewable resources and the potentials for substitution of these with the three natural renewable energy flows. These flows are solar radiation (including wind and rain), deep earth heat and tidal energy. Emergy assessment (EmA) provides tools for such hotspot analyses distinguishing on-site, local and global renewable resources[1]. Emergy is defined as the total available energy (exergy) directly or indirectly required to make a product or service[2]. It is accounted in solar equivalent joules (seJ). EmA is a kind of life cycle assessment which is are largely based on the same type of inventory of energy and material flows as standard LCA, but which applies different theories of values and system boundaries. LCA draws system boundaries around the studied system as supported by purely human dominated processes (resource extraction, refining, transportation etc.), whereas EmA in addition considers processes occurring in natural systems and, thereby, includes all direct and indirect flows of freely available resources such as the sun, rain and wind. Another difference is that EmA includes labour in order to take into account the indirect resources from society, e.g. infrastructure, needed to support the system[3].



EmA will be demonstrated with focus on estimating the renewability of bioenergy from a combined heat and power (CHP) plant co-fired with willow chips[4]. The inventory includes material, energy and labour inputs classified as renewable or non-renewable (see figure) for the life cycle stages production, transport and combustion of willow. The study is based on inputs for growing willow under commercial conditions in Denmark with pig manure as fertilizer. The resources used for producing the pig manure are included as the idea of regarding an input as 'waste' is against the principles of EmA[4].

Despite the popular understanding of bioenergy as 'renewable energy', the analysis shows that in fact, only 16% of the resource use may be traced back to the natural renewable energy flows. Hotspots for non-renewable emergy flows are the pig farming providing the fertilizer and the costs of externalities.

[1] Wright, C., Østergård, H. 2015. Scales of renewability exemplified by a case study of three Danish pig production systems. Ecological Modelling 315:28-36.
[2] Odum H.T. 1996. Environmental Accounting: Emergy and Environmental Decision Making. Wiley and Sons.
[3] Kamp A, Morandi F., Østergård H. 2013. Development of concepts for human labour accounting in Emergy Assessment and other Environmental Sustainability Assessment methods. Ecological Indicators 60: 884-92.
[4] Kamp A, Østergård H. 2013. How to manage co-product inputs in emergy accounting exemplified by willow production for bioenergy. Ecological Modelling 253: 70-8.

Opportunities and challenges for including Planetary Boundaries in Life-Cycle Assessment

Morten Walbech Ryberg[1*], Anders Bjørn[1], Mikolaj Owsianiak[1], Michael Hauschild[1]

1: DTU Management

*Corresponding author email: moryb@dtu.dk

Life-Cycle Assessment (LCA) is a tool to quantify and assess the potential impacts of products to identify the environmentally better performing product as an aid for decision-makers. Environmental carrying capacities represent the environmental intervention a system can handle without shifting to a state which is impossible or difficult to revert back from. Carrying capacities, such as those quantified within the planetary boundary (PB) framework (Steffen *et al.* 2015), opens up the possibility for assessing products and services in absolute terms, relative to their occupation of carrying capacities. The planetary boundaries concept has already been taken up by international organizations and there is a growing interest from companies who wants to assess their products and relate these to the PBs.

This study present and discuss the opportunities and challenges related to including the PB-framework as part of the life-cycle impact assessment (LCIA) phase in LCA. The challenges lie in developing, using and interpreting the results of a new PB-based impact assessment methodology, where the impact scores are compatible with the indicators used in the PB-framework. This includes modifying current and developing new characterization models to comply with the indicators used in the PB-framework. The challenges on use and interpretation of the LCIA-methodology are primarily related to (I) the PB-framework and the selected indicators which are only concerned with keeping the Earth in the Holocene state, and for instance not taking into account human health and resource use; and (II) allocating the carrying capacity that the studied systems are entitled to in order to ensure that the accumulated impact of all studied systems are not exceeding planetary carrying capacities.

Although a number of difficult challenges can be identified, the new approach relating the environmental performance of products to environmental carrying capacities can provide greater insight on the sustainability of the assessed products and can further aid decision-makers by elaborating the question on whether choices are environmentally better by indicating whether the choices are environmentally good enough.

References

Steffen, W., Richardson, K., Rockstrom, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., de Vries, W., de Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B., and Sorlin, S., 2015. Planetary boundaries: Guiding human development on a changing planet. *Science*, 347 (6223).

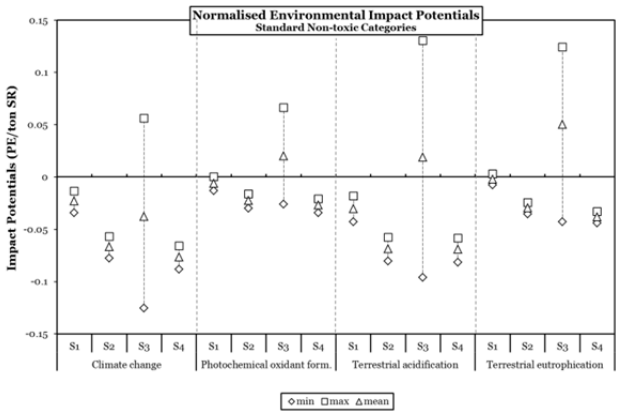
Life cycle assessment modelling of new technologies considering uncertainty

Anders Damgaard[1*], Line Brogaard[1], Thomas Astrup[1], Alessio Boldrin[1]

1: DTU Environment; *Corresponding author email: adam@env.dtu.dk

Life cycle assessment (LCA) is commonly used for assessing the sustainability of new environmental technologies. Even though material handled in many environmental technologies is heterogeneous, many LCA studies only consider the uncertainty to a limited degree focusing on sensitivity of process choices or not even assessing the uncertainty of the system at all. The study investigated what new knowledge would be gained if the modelling considered the uncertainty of all parameters used in the modelling of the technologies assessed, and how this could support the decision of technology to apply. To carry out the modelling we used the LCA model EASETECH (Clavreul et al., 2014) developed by DTU Environment and DTU Compute. EASETECH allows both single values, as well as distributions of values. This allows us to consider the aleatoric variability and epistemic uncertainty of data.

As a case study we investigated the handling of shredder residue (SR) in Denmark. The assessment compared the potential environmental impacts and depletion of abiotic resources in relation to four alternative scenarios: S1) landfilling; S2) co-combustion at a waste incineration (WI) plant; S3) pyrolysis; S4) co-combustion at a cement kiln. Distributions (normal, lognormal and triangular) were assigned to process parameters and emissions for all of the treatment technologies. Besides the distributions mean values were also assigned so conventional life cycle impact assessment values could be calculated for comparison.



Normalized environmental impact potentials for non-toxic categories are presented in the figure. The results show that for all impact categories were the emerging technology, Pyrolysis, considerably more uncertain than the mature technologies (landfill, WI, Cement Kiln). The reason for these results is that where pyrolysis is still under development and very uncertain, most of the other technologies are more mature, and good inventory data could be employed in the study. Including the uncertainty in the LCA modelling allowed us recognizing that a lot more data about pyrolysis of SR is needed before a robust decision can be made whether or not to use pyrolysis as a viable treatment technology. This stresses the fact that, when modelling emerging technologies, it is important to consider the full uncertainty for the technology when compared to more mature technologies which are associated with a smaller degree of uncertainty.

References:

Clavreul, J., Baumeister, H., Christensen, T.H., Damgaard, A. 2014. An environmental assessment system for environmental technologies. Environmental Modelling & Software 60: 18–30

GHG emission factors of biofuels: A case study for Denmark

Davide Tonini*, Merlin Alvarado-Morales, Thomas Fruergaard Astrup

DTU Environment

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

Biofuels are promising means to reduce fossil fuel depletion and mitigate greenhouse gas (GHG) emissions. However, recent studies questioned the environmental benefits earlier attributed to biofuels, when these involve land-use changes (direct/indirect, i.e., dLUC/iLUC). Yet, biofuels produced from residual biomass promise important environmental savings. However, since these residues are today used for specific purposes (e.g., feeding), a detailed modelling of the consequences (e.g., on the feed-market) induced by their diversion to energy should be performed to capture the actual environmental impacts.

This study quantified the GHG emission factors for production of: i) electricity, ii) biomethane and iii) bioethanol from a number of substrates including industrial/agricultural/urban residues and terrestrial/aquatic energy crops. Four conversion pathways were considered: combustion, fermentation-to-ethanol, fermentation-to-biogas, and thermal gasification. Consequential life-cycle assessment was used to quantify the GHG emission factors. The modelling was facilitated with the LCA-model *EASETECH*. The functional unit was 1 unit-energy produced (i.e., 1 kWh electricity or 1 MJ transport-biofuel). Benefits from the use of (eventual) co-products (e.g. heat) were included.

Overall, bioenergy production from residues always showed significant GHG savings compared with conventional fossil fuels. This holds true as long as these residues are not (currently) used as animal feed. This is the case of industrial residues (e.g. beet molasses/pulp, whey, brewer's grain) for which diversion (from the feed sector) to energy production did not induce GHG savings compared with conventional fossil means of production. Because of their high yields, low fertilizer input and favorable soil carbon balance, perennial energy crops such as willow and *Miscanthus* also showed significant GHG savings compared with fossil fuels. This was also the case for algae, while annual crops, such as wheat and maize, showed GHG emission factors comparable with coal/gasoline (or higher) because of the potential indirect land-use change (iLUC) impacts associated with their establishment.

Green manufacturing – Environmental Sustainability in Production

Jan-Markus Rödger[1*], Jan Beier[2], Malte Schönemann[2], Niki Bey[1]

[1] Division of Quantitative Sustainability Assessment (QSA), DTU Management

[2] Product- and Life-Cycle-Management Research Group, Institute of Machine Tools and Production Technology, Technische Universität Braunschweig, Germany

*Corresponding author email: januw@dtu.dk

Sustainability awareness in industry is rising, and manufacturers are reporting their sustainability performance to several non-governmental organizations like Carbon Disclosure Project and Dow Jones Sustainability Index. External stakeholders are using those to evaluate the worthiness of investments. Meanwhile manufacturers and the European Commission see environmental sustainability as a competitive edge and developed a roadmap for the factories of the future [1]. In reality manufacturers are focusing on eco-efficiency of their products due to political and legal frameworks (e.g. eco-labels for white goods and specific emission targets for cars). But it can be questioned if this leads to environmental sustainability. Recently evolved terms like eco-effectiveness and absolute sustainability are expanding the system by considering the whole life cycle of products, companies or services [2],[3]. These approaches are recognizing e.g. burden-shifting between life cycle stages and rebound-effects due to more sales. Also the International Organization for Standardization includes the life cycle approach as a prerequisite for certification in the updated ISO 14001 [4].

To minimize environmental impacts in production, companies are planning to use more renewable energy in first instance. The integration of renewable energy needs new components, and this means that manufacturing system planning gets more complex. To avoid sub-optimization, a framework to integrate sustainability into manufacturing has been derived from industry projects. Since companies are deterred by possible high implementation cost and time constraints [5], our approach employ already existing planning parameters so the existing decision-making process is not compromised.

A Life Cycle Assessment model for production lines was developed and applied which analyze the performance based on widely used parameters. A linkage to those parameters and life cycle databases has been established to predict environmental impact of the process, infrastructure and overhead consumption holistically. By this approach sub-optimization can be avoided and the decision making process in production planning is supported.

[1] EFFRA, “Factories of the Future,” European Union, Brussels, 2013.
[2] M. Z. Hauschild, “Better – But is it Good Enough? On the Need to Consider Both Eco-efficiency and Eco-effectiveness to Gauge Industrial Sustainability,” Procedia CIRP, vol. 29, pp. 1–7, 2015.
[3] A. Bjørn and M. Z. Hauschild, “Introducing carrying capacity-based normalisation in LCA: framework and development of references at midpoint level,” Int. J. Life Cycle Assess., vol. 20, no. 7, pp. 1005–1018, 2015.
[4] ISO 14001, “ISO 14001 Environmental Management Systems Revision,” 2015.
[5] A. Veshagh, S. Marval, and T. Woolman, “Making the Business Case for Eco-Design and Sustainable Manufacturing,” 2012.

Session

A

Laptop Presentations

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

How do we assess "sustainability" with proper indicators?

Yan Dong[*12], Michael Z. Hauschild[12]

1: DTU Management 2: DTU GDSI

*Corresponding author email: yado@dtu.dk

Assessment of sustainability of technologies is a challenge. Social and economic sustainability are both largely influenced by culture perspective and local conditions. Therefore, the approaches for their assessment are diverse and there is no clear understanding of what the critical elements are [1]. In comparison, environmental sustainability is more scientifically robust, but there is also very little consensus on the assessment. The aim of the study is to identify and compare relevant environmental sustainability assessment indicators across different domains of application, within the context of supporting decision making around choice and development of technologies. We reviewed some mainstream realms that have been under development in the past few decades, aiming at achieving sustainability. The realms that will be presented in this study include Life Cycle Assessment (LCA), planetary boundaries (PB) and broader regulatory contexts (e.g. Sustainable Development Goals (SDGs), Environmental Performance Index (EPI, Hsu et al., 2013) and OECD indicators [3]).

Essential aspects to consider for sustainability indicator sets, include what is the protected system, time scale and system quality that needs to be maintained. Generally speaking, LCA and PB have similar purposes. They aim at protecting ecosystems, and the considered time scales depend on the impact category. However, for LCA there is no clear indication of the system quality that will be maintained, while PB tries to retain the ecosystem in the zone that is safely operatable for humanity. In comparison, the regulatory context environmental sustainability indicators are more human centered. The time scale is always within certain years for political reasons (e.g. until 2030 for SDGs). Similar to LCA, the system quality that will be maintained is not clearly stated.

A widely used flexible framework for relating human activities to environmental status is Driver-Pressure-State-Impact-Response (DPSIR) scheme. In general, LCA and planetary boundaries mainly include states indicators. SDGs put more focus on pressure indicators. OECD and EPI provide both pressure and states indicators. Comparably, SDGs and OECD cover the most impact categories, while EPI covers the least. There are some common impact categories that are covered by at least 3 out of 5 mentioned indicator sets, including climate change, acidification, ozone depletion, eutrophication, air pollution, chemical pollution, freshwater use and forest resources. We noticed that indicators under some impact categories are still under development, including noise, accident, land system change, marine system change, fish resources, fossil resources and mineral resources depletion.

When assessing sustainability of a technology, it is essential to choose indicators properly towards the goal, considering the criteria mentioned above, e.g. protected system, time scale, system quality to be maintained, and the proper position in the DPSIR scheme.

1. Moldan, B., Janoušková, S. & Hák, T. How to understand and measure environmental sustainability: Indicators and targets. *Ecol. Indic.* **17,** 4–13 (2012).
2.Hsu, A., Johnson, L. & Lloyd, A. *Measuring progress: A practical guide from the developers of the Environmental Performance Index (EPI)*. (2013).
3.OECD. *Indicators to measure decoupling of environmental pressure from economic growth*. 1–3 (2002).

Assessing the importance of machinery, buildings and infrastructure in LCA of waste management systems

Line Kai-Sørensen Brogaard[1*] and Thomas Højlund Christensen[2]

1: DTU Environment *Corresponding author email: lksb@env.dtu.dk

Life cycle assessment (LCA) has been used many times to evaluate the environmental impacts from waste management systems. However, in most studies the environmental costs of the capital goods have not been included. Capital goods are in this context what is used in the management system as invested materials and energy to make the system work: machinery, buildings and infrastructure. Brogaard et al. (2013a+b, 2015) developed detailed inventories of materials and energy used in providing the capital goods for incineration, biological treatment facilities (composting and anaerobic digestion) and for landfilling. By conducting a full LCA for the four waste management systems and including the capital goods, it was found that the capital goods should be included in waste LCAs, although capital goods in terms of Global Warming may not always be important (See Figure 1). Key aspects are the use of steel in the infrastructure and how well it is possible to recycle the materials when the goods are scrapped and the facilities are demolished.

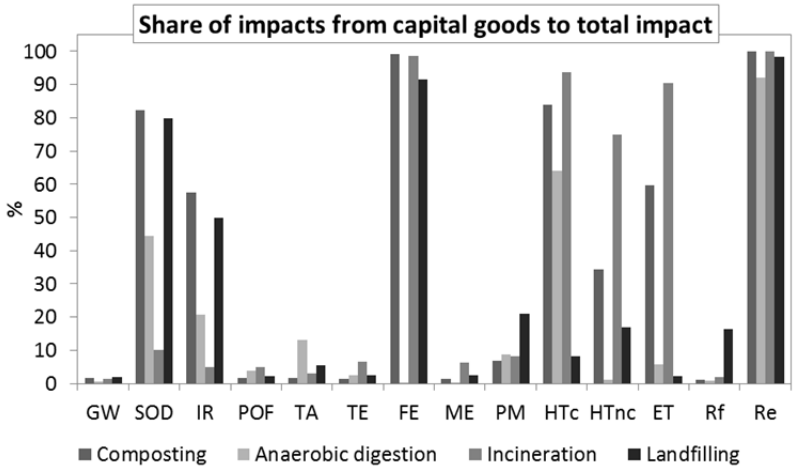


Figure 1: Share of impacts from capital goods to the total impacts to each of the four waste management systems. The categories on the x-axis refer to the impact categories specified in the ILCD handbook.

References:

Brogaard, L. K-S., Petersen, P. H., Nielsen, P. D., & Christensen, T. H. (2015). Quantifying capital goods for biological treatment of organic waste. Waste Management and Research, 33(2), 96-106. 10.1177/0734242X14565212

Brogaard, L. K-S., Riber, C., & Christensen, T. H. (2013a). Quantifying capital goods for waste incineration. Waste Management, 33(6), 1390-1396. 10.1016/j.wasman.2013.03.007

Brogaard, L. K-S., Stentsøe, S., Willumsen, H. C., & Christensen, T. H. (2013b). Quantifying capital goods for waste landfilling. Waste Management and Research, 31(6), 585-598. 10.1177/0734242X13482032

Session

A

Poster Presentations

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

Life Cycle Costing for Solid Waste Management Systems in EASETECH

Veronica Martinez Sanchez[1]* and Thomas Fruergaard Astrup [1]

[1]DTU Environment

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

Municipalities and private companies are responsible for managing household and commercial waste. To decide among various waste management options, data on both environmental and economic performances are needed. The purpose of this project is to implement the capability of performing cost assessment in addition to the LCA capabilities already included in the EASETECH model.

SETAC-Europe Working Group on Life Cycle Costing suggested life cycle costing (LCC) as a consistent framework with LCA. This investigation used the basis established by SETAC to develop further the LCC methodology to satisfy the specific needs of the waste management sector.

The proposed modelling framework distinguishes between: Conventional LCC; Environmental LCC and Societal LCC. Conventional and Environmental LCCs are both financial assessments that only include budget costs and transfers (market goods/services). But while Conventional LCCs exclude environmental impacts since they are not of interested for the decision-maker, the Environmental LCCs include them in a parallel LCA. Contrary, the Societal LCC is a welfare economic assessment that includes budget costs (market goods/services) as well as effects outside the economic system (externality costs). To perform each LCC, the model defines unit costs of each technology (per ton of input waste), which is afterwards combined with a mass balance to calculate the technology cost. Later, the costs of individual technologies can be combined to calculate the system or scenario costs (Figure 1).

The paper provides an overview of: 1) which cost items should be included in each LCC, 2) calculation principles and 3) cost data for Denmark in 2015. In addition, it demonstrates the applicability of the cost assessment model for solid waste management technologies and systems through a case study.

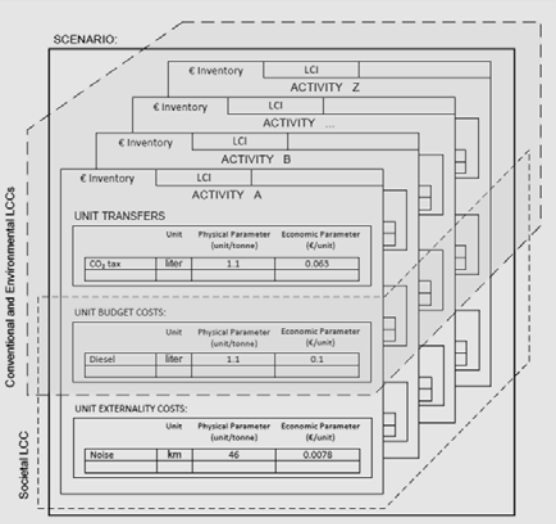


Figure 1: Overview of the cost model structure, illustrating a range of activities (A through Z) and the cost coverage of Conventional, Environmental and Societal LCCs from Martinez-Sanchez et al. (2015).[i]

[i] Martinez-Sanchez, V., Kromann, M. A. & Astrup T.F. (2015) Life Cycle Costing of waste management systems: Overview, calculation principles and case studies. Waste Management 36 343-355

The Hamlet dilemma for aluminium cans in the circular economy: to be or not to be in a closed loop?

Monia Niero*[1], Simon B. Hoffmeyer[2], Håkon Langen[2], Stig I. Olsen[1]

1: DTU Management; 2: Carlsberg Breweries A/S

*Corresponding author email: monni@dtu.dk

The aim of this work is to show how the Cradle to Cradle® (C2C) design framework [1] can inspire Life Cycle Assessment (LCA) in considering the multiple future uses of resources in continuous loops for beverage packaging, e.g. aluminium cans. The C2C design framework inspired the creation of the Carlsberg Circular Community, a cooperation platform launched in January 2014 featuring Carlsberg Group, the fourth largest global brewer in the world, and a selection of global partners with the ultimate aim to eliminate the concept of waste by rethinking the design of packaging, including the aluminium can [2].

In its current status the Life Cycle Inventory (LCI) modelling of aluminium processes is based on a pure aluminium flow, neglecting the presence of alloying elements [3]. However, within the circular economy context, the C2C vision calls for improving the quality and value of materials, through a characterization of chemicals included in the products and the development of an optimization strategy [1].

In this study, we focused on aluminium cans, which are made of two parts: the can body (typically A3004 alloy) and the lid (typically 5182 alloy). We quantified the influence of alloying elements on the overall environmental performances of aluminium can recycling and performed a LCA comparing different sources of aluminium: primary aluminium and mixed scraps, Used Beverage Can (UBC) scrap, mixed aluminium packaging scrap and building scrap [4]. The LCA results showed that the lowest environmental impacts come from the use of UBC scrap [5]. This suggests that in a circular economy context for aluminium cans it is better to be in a closed product loop.

References:

[1] McDonough W., Braungart M. (2002) Cradle to cradle—Remaking the way we make things. New York, NY, USA: North Point Press.
[2] Carlsberg Group (2015) Carlsberg Group CSR Report 2014; 2015; 1–57.
[3] EAA (2013) Environmental Profile Report for the European Aluminium Industry. Life Cycle Inventory data for aluminium production and transformation processes in Europe. European Aluminium Association; 1-78.
[4] Niero M., Boas S.H., Langen H., Olsen S.I. The Hamlet dilemma for aluminium cans in the circular economy: to be or not to be in a closed loop? – In: Scalbi, S., Dominici Loprieno A., Sposato, P. (Eds.), International conference on Life Cycle Assessment as reference methodology for assessing supply chains and supporting global sustainability challenges LCA FOR "FEEDING THE PLANET AND ENERGY FOR LIFE", Stresa, 6-07th October 2015 - Milano, Expo 2015, 8th October 2015, pp. 351-354, ISBN 978-88-8286-321-0
[5] Niero M., Olsen S.I. (2015) Circular economy: to be or not to be in a closed product loop? A Life Cycle Assessment of aluminium cans with inclusion of alloying elements. Submitted to Resources, Conservation and Recycling.

Role of data quality in assessment of the sustainability of technologies

Trine Henriksen*[1], Thomas F. Astrup[1], Anders Damgaard[1]
1: DTU Environment. *Corresponding author email: trinhen@env.dtu.dk

Data quality is crucial for the reliability of sustainability assessments of technologies. In environmental life cycle assessment (LCA) of technologies, data representing the emissions and resource consumption associated with the production, use and disposal are collected and assessed in terms of potential environmental impacts. The life cycle inventory (LCI) is the compilation of the data used in an LCA, see Figure 1.

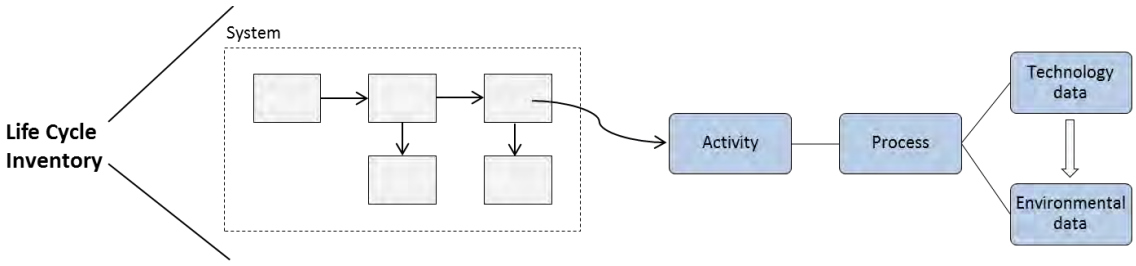


Figure 1 Structure of LCI data. Boxes within the studied system represent processes in the life cycle of a technology. Blue boxes show the data layers: Activity) Societal need to be fulfilled; Process) Industrial step in the system; Technology data) Exchanges of economic goods between processes, Environmental data) Environmental exchanges caused by the economic exchanges.

Each of the grey boxes (processes) in Figure 1 expresses data choices made by the modeller. One important indicator of the quality of the chosen data is its technological, geographical and temporal accuracy, i.e. the data must represent the technologies being studied. However, in cases of lack of knowledge or lack of appropriate data the modeller may choose to use non-accurate data instead (Laurent et al., 2014).

In LCAs, different single technologies are compared or one specific technology is benchmarked against a group's average (JRC, 2010). Comparisons can include emerging, state-of-art, current and old technologies leading to data quality issues due to different availability of data for new or emerging versus current or old technologies. The use of non-accurate data may give wrong conclusions and unreliable results, why the choice of data is crucial for the relevance and reliability of sustainability assessments.

A case study of landfill technologies is being used as an example of an analysis of the influence of data choices on an LCA. Data for state-of-the-art, current and old technologies are combined in one model to show the maximum range of results that can be obtained based on the choice of data. The preliminary results of the case study will be presented at the Sustain DTU Conference.

References

JRC. (2010). *International Reference Life Cycle Data System (ILCD) Handbook: General guide for LCA - Detailed guidance*. Ispra, Italy.

Laurent, A., Clavreul, J., Bernstad, A., Bakas, I., Niero, M., Gentil, E., … Hauschild, M. Z. (2014). Review of LCA studies of solid waste management systems - Part II: Methodological guidance for a better practice. *Waste Management*, *34*(3), 589–606. http://doi.org/10.1016/j.wasman.2013.12.004

Advances in assessing terrestrial toxicity of metal emissions for improved sustainability characterization of technologies

Mikolaj Owsianiak*[1], Michael Z. Hauschild[1]

1: DTU Management

*Corresponding author email: miow@dtu.dk

Today's technologies strongly rely on the use of metals, and metal emissions also occur from the energy system's thermal power plants. Many metals are toxic in the environment and better methods are needed to quantify the potential environmental impacts that may arise from these metal emissions when assessing environmental sustainability of technologies. Here, recent advances in life cycle impact assessment of metal emissions in terrestrial ecosystems are presented, which include: (i) the development of a new method for calculating comparative toxicity potential (CTP) of cationic metals in soils that addresses speciation in environmental fate, exposure and effects and deals with geographic variability of environmental chemistry parameters at a global scale; (ii) the inclusion of long-term (>100 years) aging mechanisms in the soil as influenced by the type of metal emission source and soil properties in calculation of the CTP values; and (iii) the development of quantitative ion character – activity relationships for prediction of metal exposure in soils. The influence of these advances on quantitative assessments of environmental sustainability of technologies will be illustrated on a case study of power generation from coal-fired power plants, and perspectives for assessing environmental impacts from a total of 60 elements of metallic character which are all used in today's technologies, will be presented.

Quantifying uncertainty in sustainability assessments: from feedstock to end-of-life

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

[1]DTU Environment, [2]DTU Compute

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

Life Cycle Assessments (LCAs) are increasingly being used to quantify the sustainability of technological solutions in decision-making contexts, for product and waste management systems. However, uncertainty in LCAs is widespread, from modelling decisions (methodological uncertainty) and data quality and appropriateness (technical uncertainty) to model representativeness of the system being studied (epistemic uncertainty) (*i.a.*, Spielmann et al., 2005). However, even if practitioners are primarily aware of uncertain inputs in their models and critical modelling choices, results are rarely accompanied with uncertainty quantifications (Laurent et al., 2014; Lloyd and Ries, 2007).

Uncertainty quantification has been addressed in the literature by many authors, mainly suggesting tiered approaches characterized by increasing levels of complexity, where the basic steps are usually contribution, sensitivity, uncertainty analyses (Clavreul et al., 2012; Heijungs et al., 2005). Yet, due to differences and the often high complexity of formulations for uncertainty propagation in the literature, as well as difficulties in representing the input uncertainty, practitioners most often relegate uncertainty quantification to an early sensitivity analysis stage, and to a technology or scenario level (Laurent et al., 2014; Lloyd and Ries, 2007).

Sensitivity represents the evaluation of the robustness of the model only, while uncertainty of parameters and processes represents the connection from the modelled system with real-life variety. Confining uncertainty quantification to sensitivity analysis or worse, propagating uncertainty just for highly sensitive parameters, may result in a severe misinterpretation of results. Moreover, the link with reality is further lost when the environmental sustainability assessments aim at quantifying emissions excluding the connection with the chemical characteristics of the material fractions constituting the feedstock. Only rarely LCA models allow input-specificity (Clavreul et al., 2014), and the importance of substances and chemicals related to the input material is most often not represented.

The presentation wants to provide a clear understanding of how uncertainty propagates in sustainability assessments, especially on the connection between sensitivity and uncertainty, with examples based on model inputs and technologies. The aim is to highlight how uncertainty quantification can help practitioners mastering the knowledge of their models and improving transparency and reliability, which are essential in the context of decision making.

References

Clavreul, J., Baumeister, H., Christensen, T.H., Damgaard, A., 2014. An environmental assessment system for environmental technologies. Environ. Model. Softw. 60, 18–30.

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

Heijungs, R., Suh, S., Kleijn, R., 2005. Numerical Approaches to Life Cycle Interpretation - The case of the Ecoinvent'96 database. Int. J. Life Cycle Assess. 10, 103–112.

Laurent, A., Clavreul, J., Bernstad, A., Bakas, I., Niero, M., Gentil, E., Christensen, T.H., Hauschild, M.Z., 2014. Review of LCA studies of solid waste management systems--part II: methodological guidance for a better practice. Waste Manag. 34, 589–606.

Lloyd, S.M., Ries, R., 2007. Characterizing, Propagating and Analyzing Uncertainty in Life-Cycle Assessment. A Survey of Quantitative Approaches. J. Ind. Ecol. 11, 161–179.

Spielmann, M., Scholz, R.W., Tietje, O., Haan, P. De, 2005. Scenario Modelling in Prospective LCA of Transport Systems Application of Formative Scenario Analysis 10, 325–335.

A Multi-Scale, Multi-Disciplinary Approach for Assessing the Technological, Economic, and Environmental Performance of Bio-Based Chemicals

Miguel Campodonico*[1], Markus Herrgard[1], Sumesh Sukumara[1], Kai Zhuang[1]

1: DTU Biosustain

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

In recent years, bio-based chemicals have gained interest as a renewable alternative to petrochemicals. However, there is a significant need to asses the technological, biological, economic, and environmental feasibility of bio-based chemicals, particularly during the early research phase. Recently, the Multi-scale framework for Suatinable Industrial Chemicals (MuSIC) was introdiced to adress this issue by integrating modeling approaches at different scales ranging from the celular to the ecological scales. This framework can be further extended by incorporating modeling of the petrochemical value chain and the de novo prediction of metabolic pathways by using generic biochemical reaction operators in conjuction with genome-scale models.

Sustainable and Safe Process and Product Development supported by Risk assessment, and Life Cycle assessments

Frank Markert*[1]

DTU Management

*Corresponding author email: framl@dtu.dk

A new process and technology should not provide a higher risk to workers and the society compared to established processes and products. New products need to be safe for consumers and harmless to the environment. An example for the dilemma is for instance the development and application of biomaterials. They may be regarded as sustainable alternatives within a wide range of applications, but in order to be in compliance with regulations as e.g. building fire safety codes, larger amounts of additives have to be added that may compromise the environmental friendliness of the biomaterials.

Based on the experience of former conducted European projects the application of risk assessment and life cycle assessments to support development of innovative new products and technologies is described. The combination of these methods provide the means to both assess the industrial and consumer safety aspects together with the environmental, economic and social aspects.

The Nature of Thorium in Bauxite and Bauxite Residue from Greece

Platon Gamaletsos*[1,2,4], Athanasios Godelitsas[2], Takeshi Kasama[1], Alexei Kuzmin[3], Jörg Göttlicher[4], Ralph Steininger[4], Yiannis Pontikes[5]

1: DTU Cen; 2: University of Athens, School of Science (Greece); 3: University of Latvia, Institute of Solid State Physics (Latvia); 4: KIT, ANKA Synchrotron Radiation Facility (Germany); 5: KU Leuven, MTM (Belgium)

*Corresponding author email: plagka@dtu.dk

Rare earth elements (REEs) are considered strategic metals as they are incorporated in a wide range of materials (e.g., permanent magnets, metal alloys and catalysts) that constitute the often unnoticed matrix of daily-life applications today (e.g., high-efficiency turbines, electric motors in cars and mobile phones).[e.g.1,2] This has led to a growing demand from high-tech industries and REEs supply risk,[3] in view of China's REE export restrictions[4] regardless its recent plans to eliminate export quota for REEs,[5] has propelled research towards the use of alternative resources. Bauxite residue (BR), originating from the refining of alumina ore (bauxite) to alumina through the Bayer process, has been identified as a promising source. In this case, REEs and Sc, are of particular interest, and efforts to develop an extraction process also have to provide a clear and safe management strategy for the accompanying actinides, as well. In particular, the environmental significance is critically arising due to the co-existence of Th together with REEs in bauxite and BR.[e.g.6-8] However, the exact nature of Th in them has been unknown until the recent studies,[6-8] constituting the basis of this abstract. Thus, it is crucial to determine Th hosting phases in order to try to separate them, creating a "clean" stream for subsequent REE extraction. To meet this need, we applied electron microscopy (TEM) and synchrotron-based spectroscopy (EXAFS) to understand the nature of Th in the Greek bauxite and BR.[6-8] Th in bauxite has been found to be hosted in LREE-minerals (mostly bastnäsite/parisite-group), zircon ($ZrSiO_4$) and, especially, in anatase (TiO_2) in microscale. The Th L_{III}-edge EXAFS spectra gave evidences that Th^{4+} may not replace Ti^{4+} in distorted [TiO_6] octahedral units of anatase lattice (CN=6). The occupation of either extraframework sites of higher coordination (CN=6.9 or even CN=7.4) or defected/vacant (□) sites is more probable.[6,7] On the other hand, TEM study of BR revealed that Th^{4+} is hosted into a novel perovskite-type phase with major composition $Ca_{0.8}Na_{0.2}TiO_3$. The Th L_{III}-edge EXAFS spectra demonstrated that Th^{4+} ions, which are hosted in the nano-perovskite, occupy Ca^{2+} sites, rather than Ti^{4+} sites.[7,8] We consider that the study of Th, in bauxite and BR, can redound to a sustainable supply of strategic metals and oxides, contributing to a more sustainable "modus operandi".

[1] Hatch G. P., Elements 8 (2012), 341; [2] http://www.cnet.com/news/digging-for-rare-earths-the-mines-where-iphones-are-born; [3] http://www.bgs.ac.uk/downloads/start.cfm?id=2643; [4] http://investorintel.com/rare-earth-intel/chinas-rare-earth-exports-tumble-january; [5] http://investingnews.com/daily/resource-investing/critical-metals-investing/rare-earth-investing/china-eliminate-rare-earth-export-tariffs-medallion-resources; [6] Gamaletsos P. et al., Nucl. Instrum. Meth. B 269 (2011), 3067; [7] Gamaletsos P., PhD Thesis, University of Athens, Greece (2014), 386 pp.; [8] Gamaletsos P. et al., Sci. Rep. (2015 – Under Review)

Session

B

Oral Presentations

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

High-level ethanol production by metabolically engineered *Lactococcus lactis* using economically renewable feedstocks

Jianming Liu[1], Christian Solem[1], Peter Ruhdal Jensen[1*]

1: National Food Institute, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark.

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

Lactococcus lactis, one of the best characterized lactic acid bacteria (LAB), is well-established within the dairy industry and has been demonstrated to have potential as a cell factory for a broad range of useful compounds. Arguments for choosing *L. lactis* as production platform include its high glycolytic flux, well-characterized metabolic network, well-developed toolbox and general robustness. Here we provide another good example of how *L. lactis* can serve as a cell factory, by engineering a derivative that can convert waste stream material from the dairy industry into ethanol. The engineering efforts include substantial rewiring of metabolism, where we 1) inactivate competitive pathways by knocking out lactate dehydrogenase (LDH), phosphotransacetylase (PTA) and native alcohol dehydrogenase (ADHE), 2) introduce the heterologous enzymes-pyruvate decarboxylase (PDC) and alcohol dehydrogenase (ADHB) sourced from *Zymomonas mobilis*, and finally 3) incorporate lactose metabolism (substrate engineering). High yield and titer ethanol production is achieved using a low-cost medium containing a cheap nitrogen source derived from corn steep liquor. The results obtained demonstrate great potential for commercial production of ethanol.

Bioproduction of chemical Compounds by CO_2 fixing cell factories.

Fariza Ammam[*], Pier-Luc Tremblay[1], Dawid Mariusz Lizak[1], Karsten Zengler[1] and Tian Zhang[1].

1: DTU Biosustain, Kogle Alle 6, 2970 Hørsholm, Denmark

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

Acetogens are strict anaerobes able to fix carbon dioxide and to synthesize metabolic end-products suitable directly for use or as precursors for the production of biofuels. Technologies using acetogenic bacteria as biocatalysts to reduce carbon dioxide to chemical commodities like syngas fermentation and microbial electrosynthesis have attracted increasing attention during the last decades. Microbial electrosynthesis (MES) is the process in which bacteria receive electrons from a cathode and reduce carbon dioxide into multi-carbon compounds. This technology is in its nascent stage of development and requires optimization to achieve success and reach commercialization. Understanding the biology of the process and improving the performance of the biocatalysts (electroautotrophic acetogens) is important and required for further development. To date only acetate and traces of 2-oxobutyrate are produced by MES. Our objectives are to diversify MES products and to increase the production yield. In order to reach our objectives, we deploy different strategies: (i) rapid enhancement of the production by optimization of MES parameters, (ii) carbon chain elongation using a mixed culture, (iii) conversion of fatty acids to fuels using enzymes proprieties of acetogens in MES system. These approaches resulted in the improvement acetate production of and the generation of ethanol, butyrate and caproate as end-products in MES. Our results demonstrate the potential of CO_2 fixing factories as a clean and sustainable strategy for biocommodities production.

Integrated approaches for assessing cell factories for sustainable bioprocesses

Mhairi Workman*

Section for Eukaryotic Biotechnology, DTU Systems Biology

*Corresponding author email: mwo@dtu.dk

The pursuit of identifying efficient cell factory candidates for production of pharmaceutically relevant products and commodity chemicals, relies heavily on the successful selection of process suitable microorganisms. Hence the selection of efficient cell factories is paramount for successful scale-up to economically viable industrial processes. Accurate quantitative assessment of cellular performance is required for the evaluation of the overall suitability of a micro-organism as an industrial cell factory, ensuring that not only product but also process parameters are optimised.

Significant recent advances in genetic engineering coupled with the demand for novel cell factories, producing a wide range of bioproducts from renewable resources, has led to a dramatic increase in the number of fungal stains generated with potential applications in industrial biology. The revolution in genome sequencing has made rational design and metabolic engineering strategies available, and this has been coupled with a simultaneous advancement of increasingly efficient genetic engineering tools. These developments have been amplified by the advent of new high throughput molecular biology techniques such as USER cloning/fusion and EasyClone and recently, the genome editing system CRISPR/Cas9 has been demonstrated for filamentous fungi. In addition there is a growing demand for cell factories capable of utilizing non-conventional substrates such as glycerol and plant hydrolysates, where both molecular biology techniques and evolutionary engineering is employed in the design process. Consequentially, the bottleneck has shifted from strain construction to characterization, that with the increasing strain numbers makes it imperative to develop and employ high throughput systems for quantitative physiological characterisation.

This presentation will explore how we can integrate the approaches of quantitative physiology, metabolic engineering and systems biology to understand and exploit the full potential of fungal cell factories. Using examples from current research, we will discuss how a progression towards higher throughput, together with improved level of detail in physiological characterisation can pave the way for more rapid implementation of novel cell factories and new bioprocesses.

Conditional protein depletion using small degradation tags and CRISPR/Cas9 systems

Virginia Martínez[1], Ida Lauritsen[1], Tonja Wolff[1] and Morten H. H. Nørholm*[1]
1: DTU Biosustain

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

In the last decade, metabolically engineered microorganisms have been developed for the bio-based production of chemicals, fuels, bioactive compounds, proteins or materials. For these purposes, metabolic engineers need a toolset to accurately control the native and heterologous reactions inside the cell, by manipulating the involved enzymes[1]. However, selective post-translational inhibition of enzymatic activity is still challenging since proteins prevail in cells for much longer than their transcription or translation has been inhibited.

Here, we provide a conditional protein knockdown technology that allows the *in vivo* regulation of protein abundance inside the cells. This strategy, termed "Protein interference" (PROTi), is based on the use of small degradation tags (N-degrons)[2] that can be integrated by CRISPR/Cas9-based genome editing, targeting proteins for degradation. Further, combination of the PROTi technology with gene repression by CRISPRi system[3], accelerated cellular depletion of the targeted proteins. This technology provides a valuable tool for balancing cellular pathways at the post-translational level for metabolic engineering purposes, for studying essential proteins or for discovering novel antibiotic targets.

1. Holtz, W.J. and Keasling, J.D. 2010. Engineering static and dynamic control of synthetic pathways. *Cell* 140: 19–23.

2. Erbse, A. *et al*., 2006. ClpS is an essential component of the N-end rule pathway in *Escherichia coli*. *Nature* 439: 753–756.

3. Qi, L.S. *et al*., 2013. Repurposing CRISPR as an RNA-guided platform for sequence-specific control of gene expression. *Cell* 152: 1173–1183.

Session

B

Laptop Presentations

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

Session

B

Poster Presentations

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

Exploiting fungal cell factories for pigment production

Gerit Nymschefsky[1*], Thomas Isbrandt Petersen[1], Kasper Bøwig Rasmussen, Ulf Thrane[1], Mhairi Workman[1]

1: DTU Systems Biology

*genym@dtu.dk

The growing concern over eventual harmful effects of synthetic colorants has led to an increased nterest in natural coloring alternatives. Currently, these natural colorants are extracted from fruit skins or seeds and their production is thus dependent on the supply with raw materials. To overcome this limitation, the potential production of colorants by fungal cell factories is at the focal point of interest. Fungi are known to naturally synthesize and excrete diverse classes of pigments within an extraordinary range of colors, but are often difficult to grow under laboratory conditions and therefore so far not suitable for industrial production. However, several pigments used in the Asian food industry are produced by *Monascus purpureus*, but the production is associated with the mycotoxin citrinin. Hence, these pigments are not approved for human consumption in Europe and the USA [1].

To propose new microbial cell factories for safe and reliable color production and thereby providing an alternative for the European food market, the potential of the red pigment producer *Talaromyces atroroseus* was investigated. It was shown that *T. atroroseus* is able to produce red and orange pigments and a standard minimal cultivation medium as well as a standard cultivation protocol was proposed. Furthermore, *T. atroroseus* was physiological characterized in batch cultivation and different *Monascus* pigments were identified in the fermentation broth.

This study shows stable and controllable color production using a minimal medium as well as identification of the pigments produced by *T. atroroseus* and sets therewith the cornerstone in implementing pigment production in fungal cell factories.

Batch cultivation of *T. atroroseus* at pH 5

Production of orange pigments in a chemostat cultivation

References: [1] Mapari SA, Thrane U, Meyer AS. 2010. Fungal polyketide azaphilone pigments as future natural food colorants? Trends in Biotechnology 28 (6): 300-307

Differential expression of small RNAs under chemical stress and fed-batch fermentation in *Escherichia coli*

Martin Holm Rau [1], Klara Bojanovič [1], Alex Toftgaard Nielsen[1], Katherine S. Long*[1]

1: DTU Biosustain

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

Abstract

Background: Bacterial small RNAs (sRNAs) are recognized as posttranscriptional regulators involved in the control of bacterial lifestyle and adaptation to stressful conditions. Although chemical stress due to the toxicity of precursor and product compounds is frequently encountered in microbial bioprocessing applications, the involvement of sRNAs in this process is not well understood. We have used RNA sequencing to map sRNA expression in *E. coli* under chemical stress and high cell density fermentation conditions with the aim of identifying sRNAs involved in the transcriptional response and those with potential roles in stress tolerance.

Results: RNA sequencing libraries were prepared from RNA isolated from *E. coli* K-12 MG1655 cells grown under high cell density fermentation conditions or subjected to chemical stress with twelve compounds including four organic solvent-like compounds, four organic acids, two amino acids, geraniol and decanoic acid. We have discovered 253 novel intergenic transcripts with this approach, adding to the roughly 200 intergenic sRNAs previously reported in *E. coli*. There are eighty-four differentially expressed sRNAs during fermentation, of which the majority are novel, supporting possible regulatory roles for these transcripts in adaptation during different fermentation stages. There are a total of 139 differentially expressed sRNAs under chemical stress conditions, where twenty-nine exhibit significant expression changes in multiple tested conditions, suggesting that they may be involved in a more general chemical stress response. Among those with known functions are sRNAs involved in regulation of outer membrane proteins, iron availability, maintaining envelope homeostasis, as well as sRNAs incorporated into complex networks controlling motility and biofilm formation.

Conclusions: This study has used deep sequencing to reveal a wealth of hitherto undescribed sRNAs in *E. coli* and provides an atlas of sRNA expression during seventeen different growth and stress conditions. Although the number of novel sRNAs with regulatory functions is unknown, several exhibit specific expression patterns during high cell density fermentation and are differentially expressed in the presence of multiple chemicals, suggesting they may play regulatory roles during these stress conditions. These novel sRNAs, together with specific known sRNAs, are candidates for improving stress tolerance and our understanding of the *E. coli* regulatory network during fed-batch fermentation.

Identification and validation of small proteins in *Pseudomonas putida* KT-2440

Xiaochen Yang, Sheila Ingemann Jensen, Tune Wulff, Scott James Harrison, Katherine S. Long*

DTU Biosustain

kalon@bio.dtu.dk

Small proteins (s-proteins) that contain 50 or fewer amino acids have been overlooked due to difficulties in their annotation and identification. Recent research indicates that s-proteins widely exist in bacteria and are involved in various biological processes. Our research focuses on identification and validation of s-proteins in the production organism *Pseudomonas putida*. By using proteomics, bioinformatics tools and the Pseudomonas genome database (PGD), we have identified 283 putative small open reading frames (sORFs) in the *P. putida* KT2440 genome. The transcription, conservation and genome contexts of sORFs were analyzed and 32 conserved sORFs with evidence of transcription selected for validation. The sORFs are validated by expressing them with a C-terminal SPA-tag (Sequential peptide affinity tag) followed by Western blotting[(2)]. The expression of 3 sORFs has been confirmed and testing of 20 additional sORF candidates is currently in progress. This will be followed by functional characterization of selected sORFs.

Screening of novel microbial catalyst in Bioelectrochemical systems (BES)

Nabin Aryal[1], Pier-Luc Tremblay[1], Tian Zhang[1]*
1: Novo Nordisk Foundation Center for Biosustainability, Technical University of Denmark, Kogle Allè 6 DK-2970 Hørsholm
*Corresponding author: zhang@biosustain.dtu.dk

Microbial Electrosynthesis (MES) is an artificial type of photosynthesis for microbial conversion of carbon dioxide ($CO_{2)}$ to organic chemical commodities when it utilizes the electricity from the solar cell. Some of acetogens, obligate anaerobic bacteria able to accept electrons from the cathode and produce chemicals. Until now, limited numbers of microorganisms have been defined for the cathodic reduction of CO_2 in MES system. The electron transfer rate from the cathode to the best electro autotroph *S. ovata 2662*, are still significantly lower than what is observed in bio-anodic processes with other electrotrophic bacteria. Hence, we are screening other pure cultures for better MES activities. With the objective of finding new cathodic biocatalysts, pre-selections of acetogens were done based on their performance in syngas fermentation technology. In our study, novel electrotrophic bacteria have been identified with the production rate of 368.8 mM per day per m^2 for 14 days, which is almost three-fold higher than the best reported result in the literature obtained with a pure culture of a different strain of *Sporomusa ovata.*

Keywords: - Microbial electrosythesis, CO_2 reduction, *Sporomusa ovata*

.

Sustainable production of biochemicals by CO_2 -fixing cell factories

Justyna Maria Lesiak[1]*, Michael Baureder[1], Fariza Amman[1], Tian Zhang[1] and Karsten Zengler[1]

1: DTU Biosustain

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

Industrialization has led to a drastic increase in the carbon dioxide emissions, causing a global climate change, and actions to counteract this problem need to be taken. It is possible to reduce the atmospheric CO_2 levels by using it as a cheap, accessible and ubiquitous carbon source for gas fermenting bacteria, and manipulate them to synthesize valuable multicarbon organic compounds. Existing pilot plants for the production of ethanol from i.e. steel mill exhaust gas have shown the feasibility of the concept.

We employ molecular biology tools for metabolic engineering of the gas fermenting bacterium *Clostridium ljungdahlii* to manipulate cell's natural carbon flow and create amino acids producing cell factories. The major challenge in amino acid production is the direct feedback inhibition of key enzymes by the end products at multiple steps of the biosynthesis pathways. To overcome this limitation we constructed feedback inhibition resistant (fbr) variants of the crucial enzymes by directed mutagenesis and used strong promoters to overexpress the modified enzymes. Additionally, the developed markerless deletion/insertion system for *C. ljungdahlii* should create new possibilities to genetically modify the organism, eliminating the necessity to use antibiotic selection for modified strains.

Physiological characterization of three different *Yarrowia lipolytica* strains growing on glycerol, glucose, xylose and arabinose

Patrice Lubuta, Mhairi Workman*

Section for Eukaryotic Biotechnology, DTU Systems Biology

*Corresponding author email: mwo@bio.dtu.dk

The nonconventional yeast *Yarrowia lipolytica* is, due to favorable physiological features, a promising candidate for future biotechnological applications. As an oleaginous yeast *Y. lipolytica* is able to synthesize and accumulate lipids to levels exceeding 50% of cell dry weight (Beopoulos et al., 2009). Besides that, this species can secrete large amounts of organic acids (e.g citric and isocitric acids, α-ketoglutaric acid), produce sugar alcohols (e.g. mannitol, erythritol) and single-cell protein. It can also be used as a platform for the production of various heterologous proteins (e.g. lipases, proteases) (Darvishi Harzevili, 2014). Furthermore *Y. lipolytica* is generally recognized as safe (GRAS). Besides the industrial applications, *Y. lipolytica* is also used as a model organism in several studies of academic interest (Barth, 2013).

The overall goal of this research project is to evaluate *Y. lipolytica*´s potential to be used as a biocatalyst in a biorefinery process where the conversion of agro-industrial wastes and renewable low-cost substrates (such as glycerol) to value added products is desired. A challenge in this context is the seasonal variation in availability and composition of biomass. This study addresses, therefore, the applicability of *Y. lipolytica* as a cell factory for conversion of glycerol and hydrolysates of lignocellulosic materials which mainly consists of fermentable sugars like xylose, glucose and arabinose (Tsigie et al., 2012). A quantitative physiological investigation was carried out in order to assess the cellular performance on different carbon sources and on combinations of these. In this context we were also interested in strain diversity regarding carbon utilization. The DTU in-house strain IBT 446, and the publically available strains W29 and H222 were used in this study.

Barth, G. (Ed.). (2013). *Yarrowia lipolytica* (Vol. 25). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-38583-4

Beopoulos, A., Cescut, J., Haddouche, R., Uribelarrea, J.-L., Molina-Jouve, C., & Nicaud, J.-M. (2009). *Yarrowia lipolytica* as a model for bio-oil production. *Progress in Lipid Research*, *48*(6), 375–87. doi:10.1016/j.plipres.2009.08.005

Darvishi Harzevili, F. (2014). *Biotechnological Applications of the Yeast Yarrowia lipolytica*. Cham: Springer International Publishing. doi:10.1007/978-3-319-06437-6

Tsigie, Y. A., Wang, C.-Y., Kasim, N. S., Diem, Q.-D., Huynh, L.-H., Ho, Q.-P., … Ju, Y.-H. (2012). Oil production from *Yarrowia lipolytica* Po1g using rice bran hydrolysate. *Journal of Biomedicine & Biotechnology*, *2012*, 378384. doi:10.1155/2012/378384

Conversion of fatty acids to their corresponding alcohols by *Sporomusa ovata* using Microbial Electrosynthesis (MES) technology

Fariza Ammam[1*], Nabin Aryal[1], **Dawid-Mariusz Lizak**[1], Pier-Luc Tremblay[1], Karsten Zengler[1]and Tian Zhang[1].

1: DTU Biosustain, Kogle Alle 6, 2970 Hørsholm, Denmark

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

Diminishing crude fossil fuel resources has received increasing attention during the last decade and mobilized lots of efforts to develop new technologies for the production of sustainable biofuels. Despite intensive efforts, only ethanol so far has served the purpose of alternative fuel due to its easy and cost effective manufacturing process. Higher carbon chain fuels like propanol and butanol are more attractive due to their energy density, making them suitable for engine usage. From the process point, alcohol production can be divided into two distinct biological processes: (i) fatty acids production and (ii) their conversion to biofuel molecules. Microbial electrosynthesis (MES) is one of these new green technologies, aiming for sustainable production of bio-commodities. MES employs microorganisms as biocatalysts and electricity as energy to reduce carbon dioxide into multicarbon compounds (e.g. acetate). The objective of this work is to reduce long chain fatty acids (e.g. propionic, butyric, valeric and hexanoic acids) beforehand produced by different fermentation processes to their corresponding alcohols with a concomitant reduction of carbon dioxide using electricity as the electron source. For the first time we were able to demonstrate the conversion of propionate acid to 1-propanol in MES system using *S. ovata* as biocatalyst. The conversion efficiency was around 15% using a potential of -900 mV vs Ag/AgCl. In addition to the 1-propanol, acetate and ethanol were also produced from carbon dioxide fixation. Despite the low bioconversion efficiency, these results open the door for new applications for Microbial electrosynthesis. Further optimization is undoubtedly required to improve the conversion efficiency of propionic acid to 1-protopanol and other fatty acids could be tested in MES system for biofuels production.

Biosensor-based genome screening platform for the production of Biosynthetic Precursors and coFactors in *E. coli*.

Cardinale S.*, Ye L., Sommer M.

Novo Nordisk Fonden Center for Biosustainability – DTU Biosustain

* stefca@biosustain.dtu.dk

We combine barcoded mutagenesis and molecular biosensors to study the genetic and metabolic adaptation to the overexpression of enzymes for regenerating fundamental cellular biosynthetic precursors and co-factors such as NADPH and Malonyl-CoA. Our goal is to map bacterial response to metabolic engineering aimed at producing chemical compounds sustainably.

Directed evolution of living systems allows selection for improved biomolecules, but robust, stable and reliable systems are important, and particularly targeted and multiplexed insertion into the genome [1].

Forward genetic screens are 'phenotype to genotype' approaches that involve modulating the expression of many genes, selecting the cells or organisms with a phenotype of interest, and then characterizing the mutations that result in those phenotypic changes [2]. We are using this approach to map cellular responses and the adaptation to strain engineering that will enable predictive strain optimization and refactoring.

1 Warner, J. R., Reeder, P. J., Karimpour-Fard, A., Woodruff, L. B. A. & Gill, R. T. Rapid profiling of a microbial genome using mixtures of barcoded oligonucleotides. *Nat. Biotechnol.* **28,** 856–862 (2010).

2 Cardinale, S., Joachimiak, M. P. & Arkin, A. P. Effects of genetic variation on the E. coli host-circuit interface. *Cell Rep.* **4,** 231–7 (2013).

Unlocking the potential of fungi: QuantFung project

Milica Randelovic, Sietske Grijseels, Mhairi Workman

DTU Systems Biology

milira@bio.dtu.dk, sigri@bio.dtu.dk

The crisis of antibiotic resistance has been much discussed in recent decades within research communities and in public. However, options to slow down the spread of resistance and the opportunities to discover new antimicrobial agents seem to be limited at present. Can we, by unlocking the hidden potential of fungi, attain new means to gain advantage in this battle?

Filamentous fungi produce a large number of structurally and chemically diverse compounds known as secondary metabolites. These compounds include the industrially relevant antibiotic penicillin, the immunosuppressant cyclosporine and the cholesterol lowering agent lovastatin.

The fungal kingdom exhibits a huge reservoir of bioactive secondary metabolites. However, the wealth of diversity of the fungal species is still not represented in large scale bioprocesses and the development from discovery to application remains a challenge.

The Marie Curie Initial training Network on Quantitative Biology for Fungal Secondary Metabolite Production (QuantFung) has the objective to find novel bioactive molecules by exploiting the wealth of fungal biodiversity and to translate these into useful products. It involves seven universities and a research institute, one industrial company as a full partner and three associated industry partners, and is located in five different countries. 11 early-stage researchers and 4 experienced researchers are trained to work on discovery of secondary metabolite gene clusters, targeted activation of gene clusters, quantification of secondary metabolites in industrial hosts, and bioactivity testing. In the coming years, we envision to make a significant contribution to new methods for finding and producing novel bioactive molecules from fungi.

A CRISPR/Cas9 system for genetic engineering of filamentous fungi

Christina Spuur Nødvig[1], Jakob Blæsbjerg Hoof[1], Martin Engelhard Kogle[1], Uffe Hasbro Mortensen*[1]

1: DTU Systems Biology

*UM@bio.dtu.dk

Many fungi are both excellent degraders of biomass and natural producers of industrially interesting compounds, making them good candidates for cell factories. Several members of the genus Aspergillus are successfully used as industrial cell factories for production of organic acids, enzymes and other primary or secondary metabolites, and many other Aspergilli are currently being sequenced and might possess traits making them similar suitable as potential cell factories. Yields from such cell factories can be greatly enhanced by employing genetic engineering strategies, however there are several obstacles such as low gene targeting frequencies, slowing down the process.

The harnessing of the prokaryotic and archaeal immune mechanism CRISPR (clustered regularly interspaced short palindromic repeats) as a tool for genetic engineering in eukaryotes, has proved to be a powerful technology. CRISPR/Cas9 introduces specific DNA double strand breaks (DSB) with high precision, which in turn can be employed to efficiently stimulate gene targeting. Consisting of two components, an RNA guided nuclease Cas9 and a chimeric guide RNA (gRNA), a specific DSB can be produced in the host organism. The cleavage target site is determined by 20 base pairs (bp) in the gRNA, and by exchanging those 20 bp, Cas9 can be programmed to target a specific chromosomal location with few constraints. The technology has had a huge impact on genetic engineering of organisms, such as plants or mammalian cells where gene targeting is notoriously inefficient, but has only recently been adapted to filamentous fungi.

Low gene targeting frequencies is a common problem when attempting to do gene editing in filamentous fungi. A common strategy to circumvent this problem is to delete or disable one of the key genes in the non-homologous end-joining (NHEJ) pathway to greatly enhance gene-targeting frequencies. However, for fungi where a genetic toolbox is not in place, the initial establishment of genetic markers and NHEJ-deficiency can be laborious. Here we present a CRISPR/Cas9 system adapted for filamentous fungi and show that it can be efficiently used to introduce specific genomic modifications. Considering that the number of fully sequenced fungi is dramatically increasing, and that the vast majority of these fungi does not possess a genetic toolbox, our system will be a highly useful in developing the initial marker- and NHEJ gene mutations to establish such a toolbox. To this end, we have also developed a gRNA design software that facilitates identification of gRNA sequences that can target a desired gene in several different species, hence, reducing the plasmid construction workload. Together, we envision that our tools can be used to rapidly expand the repertoire of fungi where genetic engineering is possible and therefore greatly accelerate the exploration of fungal biology and design of fungal cell factories.

Expanding the N-terminal tag toolbox for functional expression of Cytochrome P450s in cell factories

Dario Vazquez-Albacete[1], Mafalda Cavaleiro[1], Ulla Christensen[1], Susana Seppälä[1] and Morten H. H. Nørholm*[1]

[1] Novo Nordisk Foundation Center for Biosustainability, Technical University of Denmark, Denmark

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

Membrane-associated Cytochrome P450s represent one of the most important enzyme families for biosynthesis of plant-derived medicinal compounds such as terpenoids. Unfortunately terpenoids are often produced in tiny amounts *in planta* and despite they may represent an effective treatment for many diseases such as cancer or malaria, direct extraction from feedstocks is far from sustainable. High and stable expression of these enzymes in microbial hosts is a must for fast development of new cell factories. However, the hydrophobic nature of P450s related to their biological environment makes their expression the main bottleneck. Despite several strategies have been applied to overcome this problem such as N-terminal tags or truncations, the modification toolbox is still limited to a very few examples. Here we have created a small library of N-terminal tag chimeras of the model P450 *Sb*CYP79A1 to facilitate expression in *Escherichia coli* (Fig.1). Using a high-throughput screening technology consisting of C-terminal GFP fusions we were able to identify highly expressed and properly folded chimeras. Three N-terminal tags were subsequentially selected for assembling a heterologous pathway consisting of two plant P450s to test their activity in a meaningful cell factory scenario. Based on these, we chose a leader sequence tag to extend the expression analysis to a larger library of 49 different P450s, some of them uncharacterized, belonging to insect and medicinal plants. With this approach we expanded the toolbox of N-terminal tags thereby improving expression of chimeras to different degree with respect to the native *Sb*CYP79A1. The combination of differently tagged P450s resulted in high turn-over of the metabolic pathway compared to the native enzymatic forms (Fig.2). Additionally, the leader sequence tag was responsible for improving the expression of ~50% of the plant P450 library by more than 2 fold. Our data suggest that N-terminal tag-based cell factory design provides a new powerful toolbox for biotechnological production of plant medicinal compounds.

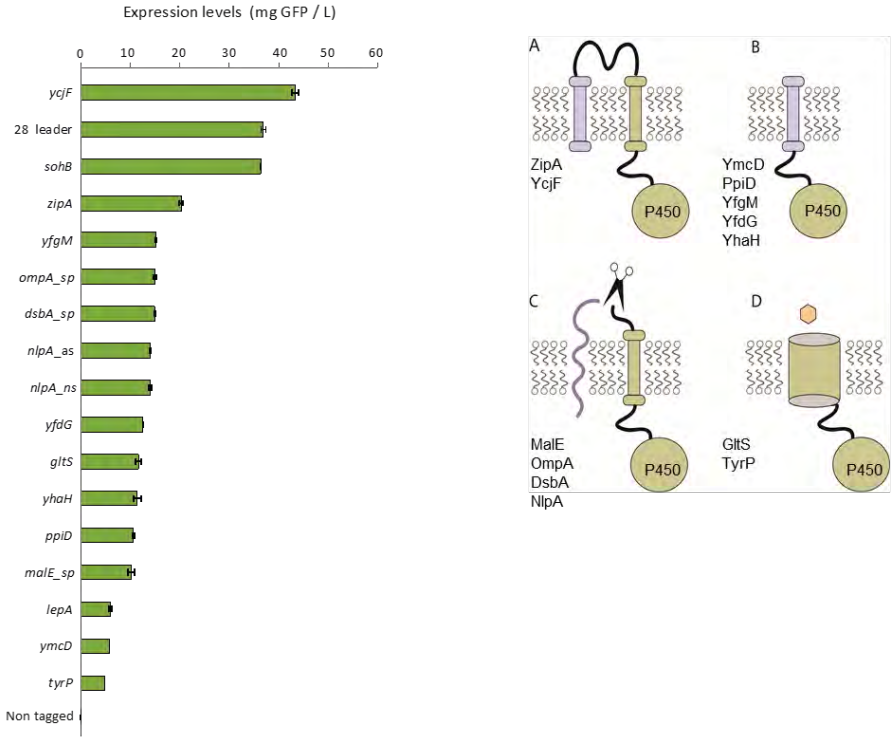


Fig. 1. Summary of the N-terminal tag library of the cytochrome P450 *Sb*CYP79A1. Right; the plot shows expression levels of the different tag fusions of the *Sb*CYP79A1 in *E.coli* after 24h induction time. Left; Illustration of the different tag topologies based on transmembrane and signal peptide prediction tools.

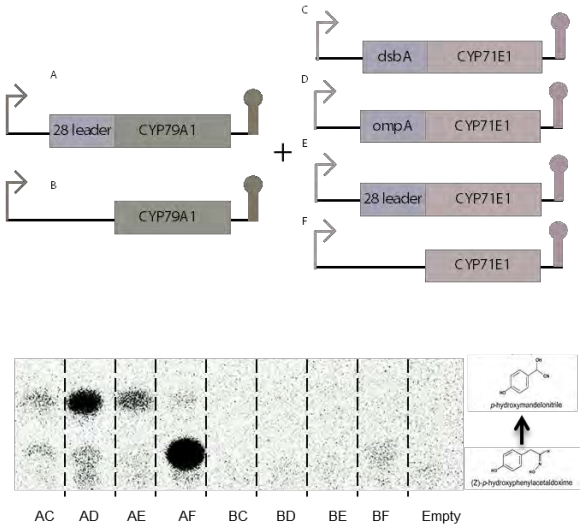


Fig. 2. DNA Assembly and activity of a plant metabolic pathway consisting of two cytochrome P450s (CYP7A1 and CYP71E1) in *E.coli*. Above; depiction of different combinations of the two N-terminally tagged and native P450s assembled together by uracil-excision cloning. Below; metabolic pathway activity assay analyzed by Thin-Layer Chromatography (TLC). Intact *E.coli* cells expressing the different cytochrome combinations were fed with radioactive labelled substrate, the two products of the pathway extracted from the supernatant and eluted in a TLC silica plate.

Ethanol production in microbial electrosynthesis using *Sporomusa ovata* as biocatalyst

Fariza Ammam[1*], Pier-Luc Tremblay[1], Karsten Zengler[1]and Tian Zhang[1].

1: DTU Biosustain, Kogle Alle 6, 2970 Hørsholm, Denmark

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

Microbial electrosynthesis (MES), a new promising process based on the use of bacteria as catalysts and electrical current as energy to reduce CO_2 to multi-carbon organic compounds, has emerged during the last decade as a route of excellence for exploitation of CO_2 as a chemical feedstock. To date, a few microorganisms mainly homoacetogens have been reported to be able to accept electrons from the cathode and to reduce CO_2 to mainly acetate and traces of 2-oxobutyrate. Acetogens use the Wood_Ljungdahl pathway to convert CO_2 to acetyl-CoA, which plays a central intermediate for the production of a diversity of useful organic products, including fuels. It´s well established that under appropriate conditions, the metabolic flux in acetogens can be redirected to others products than acetate. The objective of this study is to investigate the impact of the growth conditions, including medium composition on the end-products generation in MES process. By variating trace metals concentrations in the growth medium, we were able to identify a positive effect of tungstate on the growth, acetate and ethanol production in H_2:CO_2 condition. A maximum production of 52 mM and 14 mM of acetate and ethanol were respectively produced when the concentration of tungstate was increased 10 fold. The optimized medium has also showed a better acetate production in MES, with 5 times increase comparing to the standard medium. Tungstate-optimized medium promoted also the production of ethanol in MES. These results demonstrate that trace elements could have a positive effect on the end-products generation from acetogens both in H_2:CO_2 and MES conditions.

Session

C

Oral Presentations

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

Providing sustainability competences to all engineering students at DTU?

Stig Irving Olsen[1*]

1: DTU Management

*Corresponding author email: siol@dtu.dk

Societies increasingly face the need to address global sustainability challenges and an awareness of these challenges and needs is a key point in the education of future engineers. Due to their influence as builders of tomorrow's societies they should acquire an understanding of their influence on sustainability through their decisions as engineers. The DTU strategy states that sustainability must be an integrated part of every study programme. In the division for Quantitative Sustainability Assessment we have interpreted this and suggested that engineers should have competences at different levels. They must (1) know what sustainability is and how their decisions as engineers can affect sustainability, (2) be aware that there are methods and tools to assess the sustainability of their decisions, and (3) for those specialized in innovation and technology development, understand the principles of sustainability assessment and be able to apply tools for quantitative sustainability assessment.
Our vision is that all engineers graduating from DTU are taught a basic knowledge about sustainability and about methods and tools to assess the sustainability of their decisions. Three levels of learning have thus been defined:

1. Teaching in methods and tools for sustainability assessment targeted at the different technological domains at DTU, providing a background knowledge to students pursuing a career in other technical fields
2. More in depth education for student aiming to work with the development of technical solutions and therefore wishing a more in depth knowledge of the tools available to assess sustainability of technologies
3. Specialized teaching and education in principles and methods for sustainability assessment targeted at the student pursuing a professional career within the field

The proposed strategy embeds sustainability throughout the engineering curriculum, but is challenging. How to make room for the sustainability competences in an already packed curriculum?

Continuing education in Wind Energy through E-learning

Merete Badger[1]*, Niels-Erik Clausen[1], Martin O.L. Hansen[1], Jacob Berg Jørgensen[1], Niels Gylling Mortensen[1], Jens Nørkær Sørensen[1], Anders Yde[1]

1: DTU Wind Energy

*Corresponding author email: mebc@dtu.dk

In 2013, DTU Wind Energy stepped into the era of virtual teaching and launched a 100% online version of an existing course in WAsP – the Wind Atlas Analysis and Application Program [1, 2]. The course received excellent feedback from the learners and lead to the development of other E-learning courses about wind energy tailored to the industry needs for continuing education.

The WAsP E-learning course builds upon a five-stage pedagogical model [3] where learners are trained to exchange information in discussion forums; thereby supporting each other's learning. The teacher's role is to moderate the group discussions along the way and to motivate learners to complete the course, which is rewarded by a diploma. Nearly 100% of the learners complete the WAsP E-learning courses.

One challenge, when working with busy individuals from the industry, is that only a fraction of the learners tend to be active in group discussions. An unsupervised version of the WAsP course is being considered in order to make the participation fully flexible (i.e. study anytime and anywhere). This is inspired by the current movement of Massive Open Online Courses (MOOCs), which are typically offered on-demand and with much lower completion rates (typically <5% of learners).

The strategy for E-learning at DTU Wind Energy is to expand the portfolio of E-learning courses with 1-2 new courses per year and to build up a one-year master program for continuing education. The master courses can be followed over several years and will lead to a specialization in wind energy. The master program is targeted at employees in the wind energy industry and other engineers who wish to specialize in wind energy. The working style will be flexible and easy to adapt into a busy working schedule.

In order to attract students to existing and future courses at DTU Wind Energy, the Department has developed a MOOC to be released on the open platform Coursera.org in early 2016. This flagship course gives an introduction to different research topics in wind energy from planning and siting to wind turbine design. Since most Coursera courses are followed by more than 10,000 learners at a time, the direct teacher-learner contact is limited. Instead, the teachers attempt to create an engaging learning environment through visual appearances in 10-minute video lectures and in the discussion forums.

[1] Badger, M, Monty, A, Badger, J, Berg, J, Bingöl, F, Cronin, T, Gryning, S-E, Hansen, BO, Ejsing Jørgensen, H, Karagali, I, Kelly, MC, Larsen, SE, Mortensen, NG, Nielsen, RA, Peña, A, Rathmann, O & Stenbæk, L 2013, Community building and cross-border collaboration through online courses in wind energy. In *Proceedings of EDULEARN13 Conference.* IATED, pp. 5096-5104.

[2] Badger, M, Prag, S-MW & Jowitt, WR 2014, *WAsP E-learning - Developing and running an interactive online course*. DTU Wind Energy. DTU Wind Energy I, no. 0094.

[3] Salmon, G. (2011). E-moderating. The key to teaching and learning online. 3rd Ed. Routledge: London and New York.

Sustainability through hands-on experience: Solar Decathlon

Ongun Berk Kazanci*, Lotte Bjerregaard Jensen, Christian Rønne, Bjarne W. Olesen

DTU Civil Engineering

*Corresponding author email: onka@byg.dtu.dk

It is crucial to reflect the idea and concept of sustainability into something tangible. An international student competition, Solar Decathlon, achieves exactly this through giving the students an opportunity to design, build and operate a plus-energy house that uses solar energy as its only direct energy source. The competition consists of many different sub-competitions such as energy-efficiency, sustainability, architecture, market viability and others.

DTU has competed in Solar Decathlon twice, in 2012 in Madrid, Spain and in 2014 in Versailles, France. The student-designed, built and operated houses were constructed and tested in Denmark and then transported to the respective competition locations. Figure 1 shows these two houses.


Figure 1. The exterior views of the two houses: FOLD (left) and EMBRACE (right) (Source: Solar Decathlon Europe)

Student involvement takes place in different ways including special courses, theses, integration into existing DTU courses, and sometimes even on a voluntary basis. The students learn to think the design process from a holistic point of view and learn to think of buildings as a part of a bigger energy structure.

The competition in its nature is multi-disciplinary and involves a broad range of professions from computer science, architectural engineering to building services engineering. The students involved in the competition obtain a unique hands-on experience in designing a sustainable and plus-energy dwelling that is a once in a lifetime experience.

A MOOC in a DTU course: Global Environmental Management

Henrik Bregnhhøj[1*]

1: DTU Environment

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

A new 10 ECTS MSc level course on Global Environmental Management was established at DTU and run for 37 students for the first time in the autumn semester 2015. The MSc students in DTU Environment are already quite an international group, though mostly from EU countries. In order to expose the students to an even more global group of peers, 5 week of teaching was set up on the Coursera MOOC platform (with the same heading), open to the whole world, starting 2 weeks into the DTU course. The MOOC course consisted of a total of 35 online lectures of 7-15 minutes with inbuilt quizzes, which were mostly video shots outside or in teachers' offices, mixed with illustrations. The learning was guided by five weekly quizzes testing the knowledge obtained and three peer assessed essays, where the students should demonstrate some more analytical skills. All essays were small 200-400 words cases descriptions, where students analysed environmental trends, management and technologies in a particular area (often their own), and then they should assess three fellow students' essays, randomly and anonymously, following a detailed rubric given by the teacher. Apart from the five weeks of MOOC-activities the DTU students also had lectures and a couple of group work reports to make up for the full 10 ECTS.

More than 3,000 people signed up for the MOOC part, but (as in other MOOCs) only 400 did at least one of the exercises and 137 passed the course by obtaining more than 60% of the max score of all eight deliveries. Hereof 75 were on "signature track" (got certificate, paid 25 USD), 37 were the DTU students, so 25 did the full program "just" for the learning experience. 25,000 times one of the lectures were seen, which is not that high in Coursera standards, and the reason is that the course was only flashed on the Coursera page about 3 weeks before the course. The students' evaluation of the online lectures on a 5-level Likert-type scale were between 3.6-4.5 out of 5. The course as a whole were evaluated by 88 students with an average of 4.4 out of 5.

Based on the first experience and the comments received, the rubric-based peer assessment functioned well as an examination tool, but a qualitative open statement from student to student was requested. There was also good satisfaction with the lectures and content and in future it will be offered as an on-demand course with similar content and assessment, which can be taken any time by students. It was also appreciated by the DTU students as part of the DTU course. This modality seems to have potential as a way integrate the use of MOOC study platforms (that is free for the students, but quite expensive to produce) as part of the regular studies at the university.

Session

C

Laptop Presentations

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

CHANGING THE GAME: Tangible Energy Planning and Knowledge Sharing

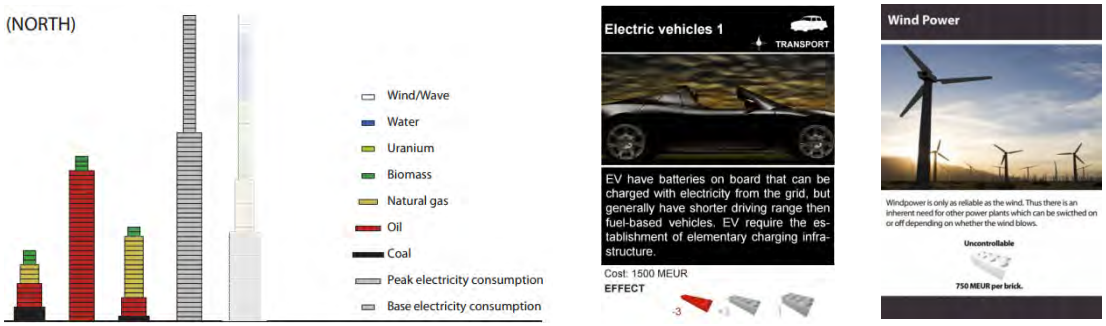
Gabriel Zeitouni[3], Kai Heussen*[2,3], Sascha Schröder[3], Piret Liivak Stern Dahl[3,4]

1: DTU Management; 2: DTU Electrical Engineering; 3: EnergyCrossroads Denmark[3]; 4: Climate KIC Nordic

*Corresponding author email: kh@elektro.dtu.dk

Energy systems planning decisions are characterised by a complex set of limitations and trade-offs that affect the resulting system's costs, security and carbon footprint. Changing the Game[1] (CtG) was designed to de-mystify this energy planning and policy development process. It is a cooperative game and facilitates an informed discussion about the future the European energy system among stakeholders from multiple backgrounds such as economists, engineers and environmentalists as well as schools and universities.

CtG is based on a quantitative model of the European energy system divided in four characteristic regions, and its mechanics captures the underlying principles and limitations when planning energy systems. Fed with data derived from open scientific planning tools[2] it provides, albeit crude, approximations of realistic energy scenarios divided into electricity, transportation, heating and industry sectors. CtG thus translates concepts and numbers into a visual representation expressed in LEGO® bricks and game cards, using brick colour and size to convey essential planning elements such as primary sources of energy and related CO2 emissions, and cards to offer pre-computed planning options and costs. In the six years since its first launch, the concept has proven internationally successful and has been developed into versions for schools, universities, conferences, and ad-hoc workshops, as well as an online version[4].



Energy use is divided into energy towers comprising LEGO bricks representing the primary energy use in the region (left); decision options are reflected in game cards for consumption change (middle) and electricity generation (right).

Facilitated group discussions ranging from two hours up to two days, including negotiations and conceptual explanations, result in a deep-dive, yet accessible, understanding of the energy challenges and opportunities. It is a proven, valuable didactic tool for different participants groups because it provides a frame to gain tangible insights into a clean, secure and prosperous energy future.

References

[1] http://www.changing-the-game.org/
[2] http://www.streammodel.org/
[3] http://www.energycrossroads.org/
[4] http://playpowerplay.dk/

Note: Changing the Game embraces open access: all game materials are openly accessible via [1].

Session

C

Poster Presentations

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

Joint PhD Research, at DTU and NTNU, on the Implementation of Sustainability Approaches in Companies

Raphaëlle Stewart*[1], Faheem Ali[2], Niki Bey[1], Casper Boks[2].

1: Division for Quantitative Sustainability Assessment, Department of Management Engineering, DTU; 2: Department of Product Design, NTNU.

*Corresponding author email: rste@dtu.dk

Integrating sustainability considerations, in business is gaining increased attention due to concerns of policy-makers, other external stakeholders, and companies' own agendas related to strategic and market positioning interests. Thus, a growing number of companies currently work on the integration and implementation of sustainability criteria in design-related departments, product development processes, manufacturing and supply chain management, and many other decision-making contexts throughout the entire company. Although a plethora of support approaches and tools are available for companies, practice shows that the implementation process of sustainability approaches is not straightforward. In fact, many companies struggle to turn sustainability goals, commitments and single initiatives towards long-lasting approaches, integrated into daily-standard business practice. The current research lacks comprehensive reasoning and supportive evidence explaining why sustainability approaches may fail during the implementation phase. Similarly, no systemized and detailed recommendations on how to overcome whatever impedes the implementation are provided. The project explores the following assumption: when implementing a sustainability approach in a company, beyond the very issue of formalizing, quantifying and monitoring sustainability indicators, there is a need for consideration, context-wise prioritization and management of a certain set of dimensions, which are key to a successful long-term implementation. These dimensions may be related to both soft and hard systems and located both within and beyond the company boundaries. With two parallel PhD projects, this joint research is articulated around two main purposes: increasing the visibility of why it is so complex to make sustainability approaches in companies "fly" on the long term and providing recommendations to improving the implementation of sustainability approaches in companies. Both PhD students combine their efforts based on the complementary expertise of the Department of Product Design, NTNU, and the Division for Quantitative Sustainability Assessment division, DTU Management Engineering.

Selected references

Bey, N., Hauschild, M. Z. & McAloone, T. C., 2013. Drivers and barriers for implementation of environmental strategies in manufacturing companies. CIRP Annals - Manufacturing Technology, Volume 62, pp. 43-46.

Boks, C., 2006. The soft side of ecodesign. *Journal of Cleaner Production,* Volume 14, pp. 1346-1356.

Epstein, M. J. & Buhovac, A. R., 2010. Solving the sustainability implementation challenge. *Organizational Dynamics,* Volume 39, pp. 306-315.

Hallstedt, S., Ny, H., Robèrt, K.-H. & Broman, G., 2010. An approach to assessing sustainability integration in strategic decision systems for product development. *Journal of Cleaner Production,* Volume 18, pp. 703-712.

Henriksen, K. et al., 2012. *Green Business Model Innovation: Business Case Study Compendium,* s.l.: s.n.

Linnenluecke, M. K., Russell, S. V. & Griffiths, A., 2009. Subcultures and Sustainability Practices: the Impact on Understanding Corporate Sustainability. *Business Strategy and the Environment,* Volume 18, pp. 132-452.

Pigosso, D. C. A. & McAloone, T. C., 2015. Supporting the development of environmentally sustainable PSS by means of the Ecodesign Maturity Model. *Procedia CIRP,* Volume 30, pp. 173-178.

Verhulst, E. & Boks, C., 2012. The role of human factors in the adoption of sustainable design criteria in business: evidence from Belgian and Dutch case studies. *Int. J. Innovation and Sustainable Development,* 6(2), pp. 146-163.

Joint PhD Between NTNU and DTU on the Industrial Implementation of Design for Sustainability

Faheem Ali*[1]Rapahelle Stewart[2], Niki Bey[2], Casper Boks[1].

1: Department of Product Design, Norwegian University of Science and Technology (NTNU), Trondheim; 2: Division for Quantitative Sustainability Assessment, Department of Management Engineering, DTU

*Corresponding author email: Faheem.ali@ntnu.no

Increasing pressure on global resources and growing interest in environment friendly initiatives have made sustainability integration in business models a prime area of concern for all businesses alike. Academic research and industrial experience have shown that sustainable practices in economic, social and environmental contexts are rewarding both in economic and environmental performance terms. In light of these observations, more and more industries are adopting sustainability in their business activities. These activities extend across product development, raw material acquisition, supply chain management and further. The research also shows that there are a number of tools and frameworks to aid and facilitate these initiatives. However, most tools and models developed for this purpose are devoid of parameters capable of identifying and evaluating organization specific characters such as employee perception of the idea, geographic issues, cultural dissimilarities existing in global organization located in around the globe and so on. The project stems from the view that these soft side parameters play a decisive role in determining the success or failure of design for sustainability tools. Focus group of the research would be small and medium sized companies that are large enough in terms of operations and economic scale to have sustainability issues, but restricted in terms of internal resources required to identify and mitigate these issues. The research as part of the PhD project aims to contribute to the successful implementation of design for sustainability in by creating knowledge about soft and hard side requirements in the organizations that are necessary for the development of such initiatives. Further, use this knowledge for integrating these requirements into tools and methods used for sustainable product portfolio development. The joint PhD program designed between NTNU and DTU aims to make use of the diverse yet mutually complementary expertise of both the Department of Product Design, NTNU, and the Division for Quantitative Sustainability Assessment division, DTU to achieve the aforementioned goals.

Selected references

Ambec, S., Cohen, M.A., Elgie, S., Lanoie, P., 2013. The Porter hypothesis at 20: can environmental regulation enhance innovation and competitiveness? Rev. Environ. Econ. Policy res016.
Bocken, N.M.P., Short, S.W., Rana, P., Evans, S., 2014. A literature and practice review to develop sustainable business model archetypes. J. Clean. Prod. 65, 42–56. doi:10.1016/j.jclepro.2013.11.039
Byggeth, S., Hochschorner, E., 2006. Handling trade-offs in Ecodesign tools for sustainable product development and procurement. J. Clean. Prod., EcoDesign: What's happening? 14, 1420–1430.doi:10.1016/j.jclepro.2005.03.024
Dangelico, R.M., Pujari, D., 2010. Mainstreaming Green Product Innovation: Why and How Companies Integrate Environmental Sustainability. J. Bus. Ethics 95, 471–486. doi:10.1007/s10551-010-0434-0
Boks, C., 2006. The soft side of ecodesign. *Journal of Cleaner Production,* Volume 14, pp. 1346-1356.
Epstein, M. J. & Buhovac, A. R., 2010. Solving the sustainability implementation challenge. *Organizational Dynamics,* Volume 39, pp. 306-315.
Verhulst, E. & Boks, C., 2012. The role of human factors in the adoption of sustainable design criteria in business: evidence from Belgian and Dutch case studies. *Int. J. Innovation and Sustainable Development,* 6(2), pp. 146-163.

Session

E

Oral Presentations

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

Photocatalytic Water Splitting: Using a 2-Photon Tandem Approach

Brian Seger*[1], Bastian Timo Mei[1], Dowon Bae[1], Erno Kemppainen, Thomas Pedersen[2], Peter Vesborg[1], Ole Hansen[1], Ib Chorkendorff*[1]

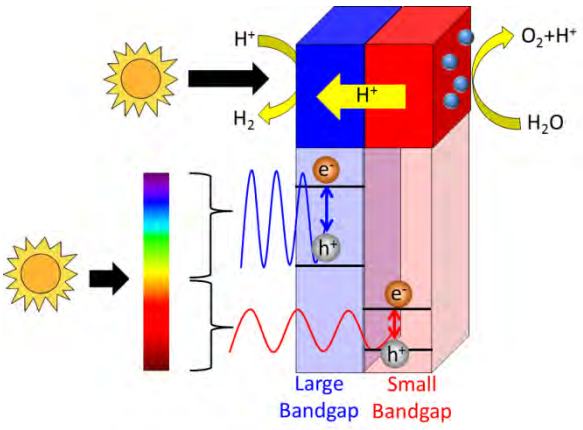
1: DTU Physics; 2: DTU Nanotech 3: Aalto University

*Corresponding author email: bseger@dtu.dk

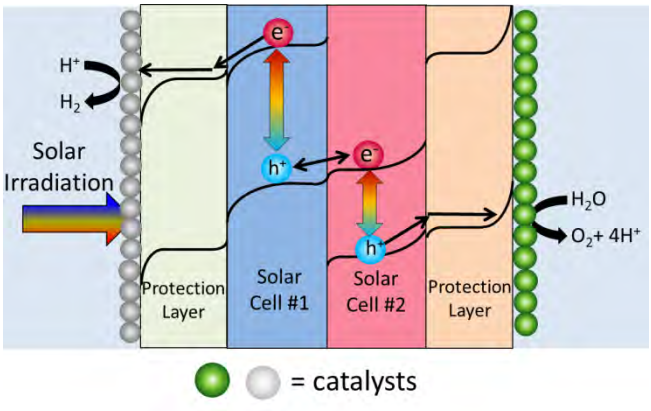
Currently the world uses 17 TW of energy, with ~85% of that coming from fossil fuels. The solar irradiation that strikes earth is 120,000 TW, thus we only need to capture a fraction of this. However the greatest issue with solar energy from a practical and economic standpoint is its intermittency. (The sun doesn't shine at night.) This means storing solar based energy is just as important as harvesting it. As biological processes have proven, a very efficient way of storing energy is in the form of chemical bonds. The electrolysis of water into hydrogen and oxygen is an excellent way to store energy since water is a plentiful resource, hydrogen is an extremely energy dense molecule (by weight), and the oxygen by-produce can be discarded to the atmosphere.

Rather than use a solar cell and an electrolyzer separately, we can combine these devices thus minimizing capital costs. This talk will focus on how we construct a photoelectolyzer that is both highly efficient and highly durable in the corrosive environments needed for water splitting. Our focus is to use 2-photon tandem solar cells with transparent, conductive protective coatings to allow for highly efficient photoelectrolyzers. Figure 1A and 1B shows the general design of our approach to photoelectrolysis. While there are many parts to the device we are focusing on all of these in our quest to make a 20% efficient solar to hydrogen device. This talk will discuss what materials we use for both the large band gap and small band gap photoabsorber as well as our recent improvements in catalytic efficiency for both the H_2 evolution and O_2 evolution reaction.

1 A)



1 B)



Electrolysis for Power to Fuel

Mogens B. Mogensen
Department of Energy Conversion and Storage, Technical University of Denmark
DTU Risø Campus, 4000 Roskilde

Synthetic fuels (synfuels) in the form CO_2 neutral "green" hydrocarbon fuels seem particularly benign to replace the fossil fuels, and electrolysis seems to be a feasible step in production of green fuels. In particular, synthetic hydrocarbon based fuel will be necessary for the heavy transportation vehicles such as airplanes, ships, and trucks.
In order to produce green fuel it is necessary to use green (sustainably produced) energy, e.g. wind solar or hydropower, which we may get in the form of electricity. If the electricity is used to produce H_2 and/or CO from H_2O and CO_2 by electrolysis then the synthesis gas (or syngas, H_2 + CO) can easily be converted into CO_2 neutral hydrocarbon fuel. This kind process is called "power to fuel" (P2F). The salient process in this technology is electrolysis.
The presentation will briefly summarize the status and perspectives of electrolytic production of H_2 and CO and the further possibilities for production of synfuels on basis of these two gases.

A new DTU-lead European Research Infrastructure for 3D Wind Field Measurements using Space and Time Synchronized WindScanners

Torben Mikkelsen[1*], Mikael Sjöholm[1]; Nikolas Angelou[1,] Anders Tegtmeier Pedersen[1]and Nikola Vasiljevic[1]

[1]DTU Wind Energy; *Corresponding author email: tomi@dtu.dk

Modern wind turbines steadily increase in size and today wind turbines soar hundreds of meters into the sky. Their blades sweep through areas bigger than football fields.

Obviously, the wind can no longer be characterized from a single-point measurement but characterization require detailed knowledge of the dynamics of the entire 3D wind fields over the entire rotor plane upwind and in the turbine wakes.

Inflow and wakes around turbines exposed to wind and turbulence in complex terrain are scanned in 3D space and time from WindScanners.

WindScanner.eu provides a new open access and joint European research infrastructure for promoting research and innovation in atmospheric wind and turbulence via full-scale open air experimental investigations. Real-time measurements of the 3D wind velocity and turbulence vectors in the atmospheric boundary-layer are obtained using advanced remote sensing-based wind measurement techniques known as wind lidars.

Distributed European WindScanner nodes are now established as national/regional competence centers engaged with a central hub located at DTU Wind Energy regarding the continued development, coordination of applications and training of experts to operate the WindScanner wind measurement technology. The new joint European research infrastructure WindScanner.eu will lead and disseminate coordinated experimental research for large European-level wind energy measurement campaigns throughout Europe.

DTU Wind Energy leads and hosts the European central hub for coordinating access, planning operation, training and maintenance and disseminates instrument manufacturing plans to build the mobile WindScanners locally. The DTU hub will also maintain the scanners control software and data processing and secure data flow and management of host servers, and train experts and users from research community and industry. The open access experimental facility also serves atmospheric boundary-layer research, air safety, wind load measurements on buildings and bridges, 3D wind circulation field measurements in streets and the urban environment, etc. The talk addresses recent WindScanner based research activities and present several WindScanners experimental setups including 3D wind field measurements from recent WindScanner measurement campaigns. Cf. www.WindScanner.dk

What is the impact of different energy futures on the optimal waste treatment?

Marie Münster*[1], Amalia Pizarro[1], Raffaele Salvucci[1], Hans Ravn[2]

1: DTU Management Engineering; 2: RAMløse-edb

*Corresponding author email: maem@dtu.dk

The framework around management of waste and use of waste for energy is changing. The waste sector faces increased privatization, a growing international market, increasing waste amounts and ambitious goals for increased material recycling. Meanwhile, the energy sector faces increased demand for renewable energy including organic waste as well as increased demand for flexibility in the energy system. In order to take the changed framework into account, it is necessary to develop new decision support tools for waste companies and national authorities to identify expedient investments and avoid suboptimal environmental solutions. There will be increased competition between using waste as an energy resource and as a source of recycled raw-materials, and in order to understand which types of waste will be available for each of these purposes it is necessary to consider the whole waste management sector as well as the energy sector.

Decisions related to investments in the energy and waste sectors are normally separated with different institutions handling the different sectors. This article argues that linked optimisation is necessary in order to avoid sub-optimization. This is particularly true in countries, such as Denmark, with a high share of heat from waste (20%) in the extensive district heating system covering 60% of all buildings.

Waste treatment alternatives are normally analyzed by comparing static alternatives in LCA's or cost benefit analyses. Analyses of combinations of possibilities, which take into account the dynamic nature of the energy systems and the flexibility requirements, are not currently undertaken as shown in the comparison of models for waste management done by Finnveden et.al (Finnveden et al. 2006). On the other hand energy system models only have rudimentary representation of waste technologies and no possibility of prioritizing between energy and material recycling options, as shown in the PhD thesis "Energy System Analysis of Waste-to-Energy technologies" (Münster 2009). A decision support tool has therefore been developed, which target both the demands of waste companies as well as, in an up-scaled version, the demands of national waste and energy authorities, thereby facilitating better planning for the energy and waste sectors.

Linked optimisation of energy and waste systems is here undertaken in the new linear programming tool called OptiWaste. The model optimises both investments and operation taking spatial distribution and fluctuating demands and productions into account. The work was originally presented at the Sardinia 2015 Symposium, but has since then been updated with new analyses.

EXPERIMENTAL ANALYSIS OF A SOLID OXIDE FUEL CELL STACK COUPLED WITH BIOMASS GASIFICATION

Rasmus Østergaard Gadsbøll[1,*], Jesper Thomsen[1], Christian Bang-Møller[2], Camilla Nygaard[1], Amrei Tomaszewski[1], Jesper Ahrenfeldt[1], Ulrik Birk Henriksen[1]
[1]Technical university of Denmark, department of chemical and biochemical engineering, Frederiksborgvej 399, 4000 Roskilde, Denmark
[2]Haldor Topsoe A/S, Haldor Topsøes allé 1, 2800 Kgs. Lyngby, Denmark
*Corresponding author, Tel: +4560668815, E-mail: rgad@kt.dtu.dk

Thermal gasification and solid oxide fuel cell (SOFC) technologies represent an interesting combination for power generation, as high fuel flexibility and high electric efficiencies are expected. The TwoStage gasifier is a high-efficient downdraft gasifier fueled by wood chips that produces a very clean product gas with virtually no tar – see Figure 1. This study operated an 800 W_e SOFC stack (Figure 2) with product gas from the TwoStage gasifier for a total of 145 hours. Only minimal gas conditioning was used, including a bag filter, carbon filter, humidifier and desulphuriser. The obtained results show excellent part-load performance at 55% flow for the SOFC, with no loss in efficiency. High SOFC electric efficiencies up to 46.4% were measured at a fuel utilisation up to 90%, the highest reported values of such a system. The gasifier-SOFC system efficiency was estimated to 38-43%. No significant losses in SOFC performance were observed during the hours of operation.

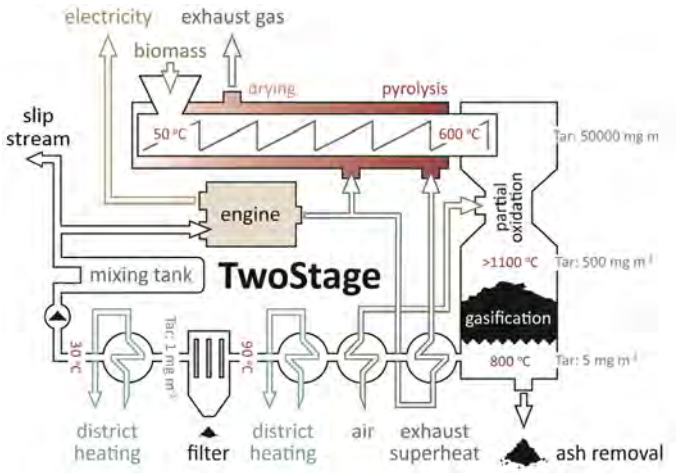


Figure 1: Flow diagram of TwoStage gasification with an engine.

Figure 2: Solid oxide fuel cell stack

Session

E

Laptop Presentations

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

Comparing superconducting and permanent magnets for magnetic refrigeration

R. Bjørk, K. K. Nielsen, C. R. H. Bahl, A. Smith, and A. C. Wulff*

DTU Energy

*Corresponding author email: anwu@dtu.dk

We consider the initial cost of a high temperature superconducting (SC) tape-based solenoid versus a permanent magnet (PM) Halbach cylinder for magnetic refrigeration. Assuming a five liter active magnetic regenerator volume the price of each type of magnet is determined as a function of aspect ratio of the regenerator and desired internal magnetic field. It is shown that in order to produce a 1 T internal field in the regenerator a permanent magnet of several tons is needed or an area of superconducting tape of tens of square meters (see Figure 1). Assuming a cost of the SC tape of 6000 $/m^2 and a price of the PM of 100 $/kg, the superconducting solenoid is shown to be a factor of 1-3 times more expensive than the permanent magnet. However, this factor decreases for increasing field strength (see Figure 2), indicating that the superconducting solenoid could be suitable for high field, large cooling power applications.

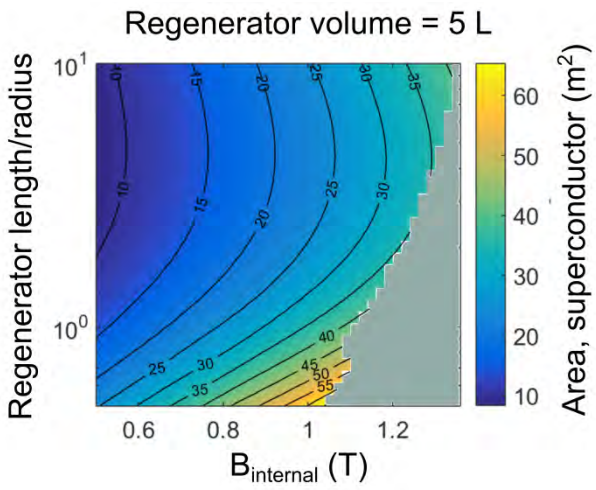


Figure 1: The area of the superconducting tape needed to produce a desired internal magnetic field for a given aspect ratio of the regenerator cylinder.

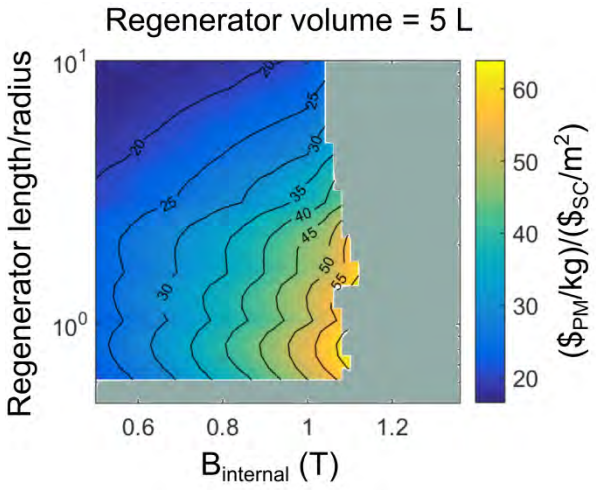


Figure 2: The factor between the price of the superconductor tape per m^2 and the price of the permanent magnet per kg.

Coupling of phase change material with nighttime radiative cooling

Thibault Péan*[1], Eleftherios Bourdakis[1], Bjarne W. Olesen[1]

1: DTU Byg

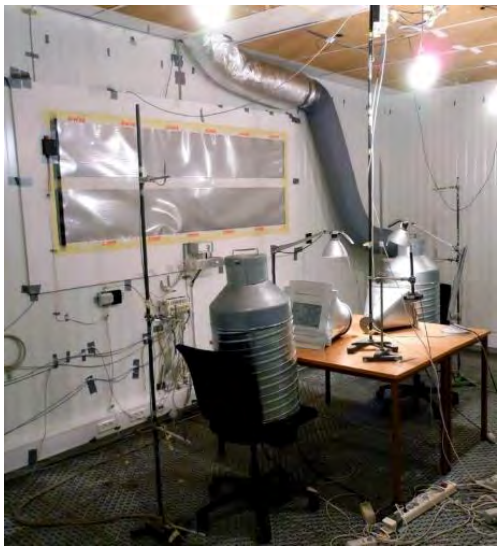
*Corresponding author email: thipe@byg.dtu.dk

Phase change materials (PCM) can be used to reduce the peak cooling demand of a building by storing thermal energy through the phase change [1, 2]. Nighttime radiative cooling can be used to release heat by radiation towards the cold nocturnal sky, for example via solar panels [3]. Those two technologies can be combined, using the cold water produced by radiative cooling to discharge the thermal energy stored in the PCM.

The present experimental study investigates this coupling in the case of the cooling of an office room. For simulating an office room a climatic chamber in the facilities of DTU was used. In this chamber a radiant ceiling cooling system with PCM was installed. For cooling water through nighttime radiative cooling, three photovoltaic/thermal (PV/T) panels were utilized. Apart from cold water for space cooling, the installation was capable of providing domestic hot water and electricity from the PV/T panels. This system was tested for the period from 31st of August 2015 until 18th of September 2015. During this period three different combinations of water flow rate in the solar and the PCM panels were tested, each one of them for five working days. The first combination was 240 kg/h for the solar loop and 150 kg/h for the PCM loop, the second combination was 184 kg/h for the solar loop and 180 kg/h for the PCM loop and the third combination was 104 kg/h and 210 kg/h for the solar and the PCM loop, respectively.

During the first experimental case the operative temperature was within the range of Category III of EN 15251 (22 – 27^{o}C)[4] for 100% of the occupancy period, while in the second and the third case it was 95% and 87%, respectively. The average cooling power of the PCM for the three cases was 16, 15.8 and 16.7 W/m^2 of PCM surface area, respectively. Furthermore, the average cooling power per unit area provided by the PV/T panels was 18 W/m^2 of solar panel area for case I, while for case II and case III it was 31.8 W/m^2 and 8.5 W/m^2, respectively. Finally, the total electricity produced in the first case was 9.4 kWh, while for cases II and III it was 5.6 and 7.8 kWh, respectively.

It was concluded that nighttime radiative cooling can be a satisfying solution for providing space cooling to office buildings. Moreover, from the three combinations of water flow rates that were examined, the one that performed best in terms of providing the best thermal environment in the office room was the first combination. On the other hand, the one that had the highest cooling power from nighttime radiative cooling was the second one.




Figures. Experimental chamber with PCM radiant ceiling (left) and PV/T panels (right).

References

[1] Sharma A. et al. 2007. *Review on thermal energy storage with phase change materials and applications.* Renewable and Sustainable Energy Reviews, vol. 13 (2009), pp. 318–345.

[2] Cabeza F.L. et al. 2006. *Use of microencapsulated PCM in concrete walls for energy savings.* Energy and Buildings, vol. 39 (2007), pp. 113–119.

[3] Eicker U. and Dalibard A. 2011. *Photovoltaic-thermal collectors for night radiative cooling of buildings*. Solar Energy, vol. 85, pp. 1322-1335.

[4] DS/EN 15251 (2007). *Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*. European Committee of Standardization.

Session

E

Poster Presentations

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

Recovery Potential and Emissions of Excess Heat in Denmark

Fabian Bühler*[1], Tuong-Van Nguyen[1], Brian Elmegaard[1]

1: DTU Mechanical Engineering

*fabuhl@mek.dtu.dk

Large amounts of excess heat are continuously emitted into the environment as waste, in particular from industrial processes and power plants. The recuperation of this excess heat could considerably reduce the amount of primary energy used by society and thus decrease greenhouse gas emissions associated with a fossil energy supply. Several challenges occur for the utilization of these heat sources, as they may have a low temperature or be difficult to access.

The identification and quantification of the available heat sources is a first step to allow the development of methods and technologies for their utilization. Using exergy, as a thermodynamic measure for the maximum useful work obtainable from a stream, the potential of excess heat in Denmark is shown for the industry and utility sector. Considering the thermal processes of the most energy intense industrial sectors, the exergy loss was 3,800 TJ in 2012. An additional 1,100 TJ of exergy losses occur indirectly for the supply of electricity and district heat for industrial thermal processes, as shown in Figure 1. From the utility sector, the total found exergy loss was approximately 50,000 TJ of which 35,000 TJ originated from large-scale combined heat and power plants.

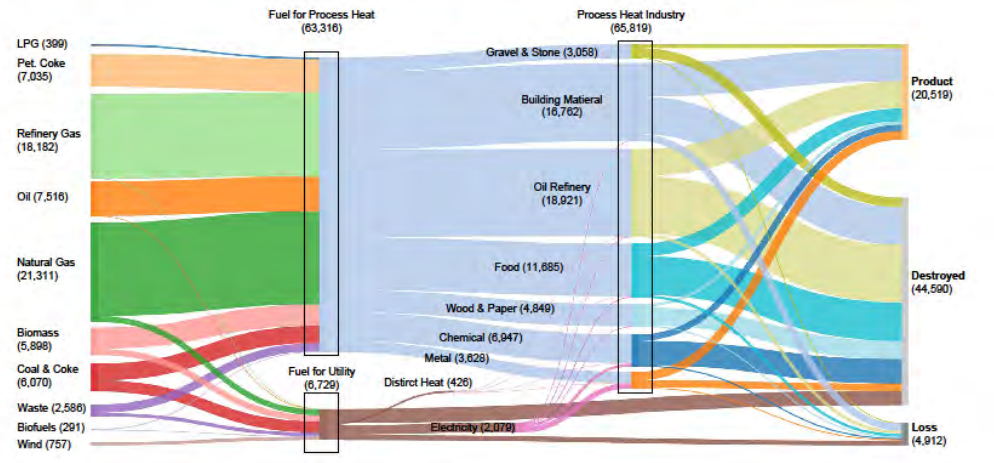


Figure 1: Exergy analysis of industrial process heating in the most energy intense industries in Denmark [TJ].

The focus of the current research is to find applicable methods for the assessment of efficiency improvements focusing on industrial energy systems and, depending on the type of the waste heat source, the recovery of losses with technologies such as organic Rankine cycles or heat pumps. In addition, the emission of greenhouse gases, dependent on fuel type and industrial process, are investigated and thus an indication of the avoidable emissions is given.

Role of computers in stimulating sustainable development: an example in efficient utilization of wind energy

Hamid Sarlak[1]

DTU Wind Energy, Denmark. hsar@dtu.dk

Abstract

As we all know today, sustainable development is closely related to renewable energy. Renewable energy technologies are being developed in order to leave human beings with cleaner environmental and long lasting energy resources owing to the use of computers for numerical simulations and optimization studies. Among various sources, wind energy is achieving cost parity with fossil fuels, in recent years, owing to the fast technological developments. The pleasing increase in wind energy harnessing has, nevertheless, introduced new challenges to the wind energy community. Every day, hundreds of wind turbines are erected at different locations and it is foreseen that in the near future, there will not be enough space to erect new turbines. The remedy for this situation is to increase the wind turbine size and design new families of airfoils. Larger turbines are, however, prone to higher wind shear and turbulence loads from the atmospheric boundary layer (ABL), causing severe external loads. As a consequence, advanced and detailed numerical simulations have become important tools for design and optimization of wind turbines and wind farms.

The use of computers can facilitate developing advanced numerical tools for prediction and analysis of flow behaviour in different applications within wind energy. Computers can be used in a broad range of applications from wind turbine simulations in the atmospheric boundary layer to simulation and modeling of wind turbine wakes and wake interactions as well as design and aerodynamic assessment of wind turbine airfoils with the aim of improving the performance of not only individual wind turbines, but the entire wind farm.

While making complex flow physics more understandable, the more advanced numerical flow-prediction models obtained by recent powerful computers will reduce the uncertainty associated with the wind energy production, which is achieved by simulating details of the fluid flow. A direct financial concequence will be for instance reduction of interest rates for the bank loans associated with wind energy investments and eases the financing of wind farm productions, therby promoting wind power as an alternative to the conventional fuels. As an example, harnessing only 1% more power by employing more advanced numerical models results in achieving a sizeable reduction in the cost of energy (CoE), through increased annual production with fixed CAPEX and OPEX. Particularly in Denmark, this means moving towards the goal of 50% CoE reduction by 2050, as seen in the Megavind's vision [1]. It should be noted that here we address only economic and environmental, and not the social, aspects of sustainability.

Reference

[1] *Denmark - supplier of competitive offshore wind solutions, Megavind's Strategy for Offshore Wind Research, Development and Demonstration,* megavind report, December 2010.

Innovative bioelectrochemical-anaerobic-digestion integrated system for ammonia recovery and bioenergy production from ammonia-rich residues.

Yifeng Zhang[1]*, Irini Angelidaki [1]

1 DTU Environment

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

Ammonia (NH_4^+/NH_3) inhibition during anaerobic digestion process is one of the most frequent problems existing in biogas plants, resulting in unstable process and reduced biogas production. In this study, we developed a novel hybrid system, consisted of a submersed microbial resource recovery cell (SMRC) and a continuous stirred tank reactor (CSTR), to prevent ammonia toxicity during anaerobic digestion by in-situ ammonia recovery and electricity production (Figure 1). In batch experiment, the ammonia concentration in the CSTR decreased from 6 to 0.7 g-N/L with an average recovery rate of 0.18 g-N/L(CSTR)/d. Meanwhile, a maximum power density of 0.71±0.5 W/m^2 was produced (10 Ω). Both current driven NH_4^+ migration and free NH_3 diffusion were identified as the mechanisms responsible for the ammonia transportation. With an increase in initial ammonia concentration and a decrease in external resistance, the SMRC performance was enhanced. In addition, the coexistence of other cations in CSTR or cathode had no negative effect on the ammonia transportation. In continuous reactor operation, 112% extra biogas production was achieved due to ammonia recovery. High-throughput molecular sequencing analysis showed an impact of ammonia recovery on the microbial community composition in the integrated system. Results clearly indicate the great potential of the SMRC-CSTR-coupled system for efficient and cost-effective ammonia recovery, energy production and treatment of ammonia-rich residues.

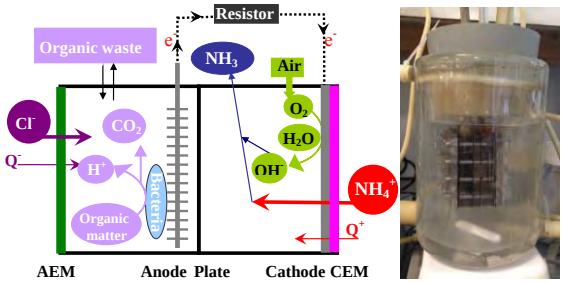


Figure 1 Schematic of the SMRC (A) and the image of the integrated SMRC-CSTR (B). Q+ and Q- are unspecified cations and anions, respectively.

Acetaldehyde as an intermediate in the electroreduction of carbon monoxide to ethanol on oxide-derived copper

E. Bertheussen[1], A. Verdaguer-Casadevall[1], D. Ravasio[2], C. Roy[1], D.B. Trimarco[1], S. Meier[3], J. Wendland[2], I.E.L. Stephens[1], I. Chorkendorff*[1]

1: DTU Fysik; 2: Carlsberg Laboratory; 3: DTU Kemi; *Corresponding author email: ibchork@fysik.dtu.dk

With implementation of more intermittent renewable energy sources, such as wind and solar power, efficient energy storage technologies need to be developed. In addition, alternative energy carriers to fossil fuels need to be found in order to decrease emission of CO_2 from the transport sector. A highly promising means of doing so would be to hydrogenate CO_2 via electrolysis into fuels, such as methanol or ethanol; as such, it would constitute a carbon-neutral energy carrier.[1] Carbon dioxide could be captured from point sources, such as fossil fuel power plants or by burning biomass.[1] In order to make CO_2 electroreduction feasible for implementation in real devices, an efficient and stable catalyst exhibiting selectivity towards few, preferably liquid, compounds is required. Such a material is yet to be discovered; even so, the field is relatively unexplored. In particular, recent studies have shown that the performance of CO_2 reduction catalysts, in particular copper, can be greatly enhanced by nanostructuring.[2–4]

Our group recently carried out a study on CO reduction on oxide-derived copper (OD-Cu), showing that acetaldehyde is an intermediate product, yielding mechanistic information about the reaction.[5] This compound has not been previously reported for this reaction on OD-Cu, even though it is present in moderate amounts (produced with a Faradaic efficiency of ~5 % at -0.3 V vs. RHE). The reason for this lies within the product detection. It is undetectable in routine NMR spectroscopy measurements, the method-of-choice for many groups in the field, but can be easily detected using headspace-gas chromatography. We hypothesise that the reason for this is that it agglomerates and polymerizes, leading to line broadening in NMR spectra, and precipitation out of solution.

The knowledge that ethanol is produced through acetaldehyde provides us with valuable mechanistic information. Moreover, acetaldehyde is a valuable chemical in its own right. Future work will aim to determine how the catalyst can be engineered to exclusively produce acetaldehyde or ethanol at high kinetic rates with minimal potential losses.

References

[1] A. Goeppert, M. Czaun, J. P. Jones, G. K. Surya Prakash, G. A. Olah, *Chem. Soc. Rev.* **2014**, *43*, 7995–8048.

[2] W. Tang, A. A. Peterson, A. S. Varela, Z. P. Jovanov, L. Bech, W. J. Durand, S. Dahl, J. K. Nørskov, I. Chorkendorff, *Phys. Chem. Chem. Phys.* **2012**, *14*, 76–81.

[3] C. W. Li, M. W. Kanan, *J. Am. Chem. Soc.* **2012**, *134*, 7231–7234.

[4] C. W. Li, J. Ciston, M. W. Kanan, *Nature* **2014**, *508*, 504–507.

[5] E. Bertheussen, A. Verdaguer-Casadevall, D. Ravasio, J. H. Montoya, D. B. Trimarco, C. Roy, S. Meier, J. Wendland, J. K. Nørskov, I. E. L. Stephens, et al., *Angew. Chem. Int. Ed.* **2015**, *Accepted*.

Development of Catalysts for ORR HT-PEMFCs

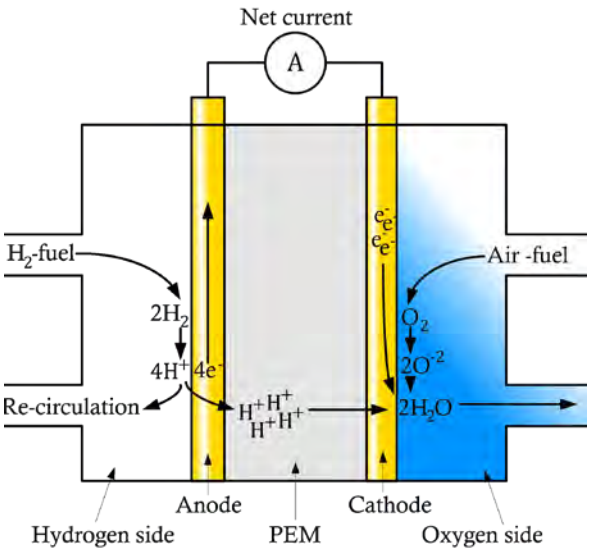
Kim Degn Jensen*[1], Eleonora Zamburlini[2], Amado Andres Velazquez-Palenzuela[2], María Escudero-Escribano[2], Ifan Stephens[2], and Ib Chorkendorff [2]

1: DTU Physics, CINF; 2: DTU Physics, CINF;

*email: kimdj@fysik.dtu.dk

Abstract

The emergence of technologies for efficient zero-emission energy conversion using hydrogen Fuel Cells (*FCs*) holds great potential for future sustainable energy schemes.



This work aims at investigation and improvement of existing FC research platforms by tuning catalysts for the Oxygen Reduction Reaction (*ORR*) for Proton Exchange Membrane (*PEM*) FCs applications. The overall project aims at identifying catalysts for High Temperature (*HT*) PEMFCs, which are resilient towards the phosphate anion poisoning associated with PolyBenzImadazole (*PBI*) based PEMs.

A special focus concerns the understanding and improvement of Pt-based FC cathode catalyst material for the ORR, both in terms of stability (thermally, non-oxidizable), efficiency (activity, selectivity) and costs (non-toxic, cheap and abundant non-noble, scalability), *i.e.* the material should be capable of operating in highly acidic (pH~1), phosphate rich, and heated environments (>160 °C) for improved kinetics.

Different approaches to minimizing phosphate poisoning on Pt-based catalyst have been attempted. In this work electrochemical investigations of a Pt(111) single crystal model catalyst and subsurface alloys are used to elucidate the importance of tuning surface binding energies of oxygen species for optimum activity and phosphate resilience.

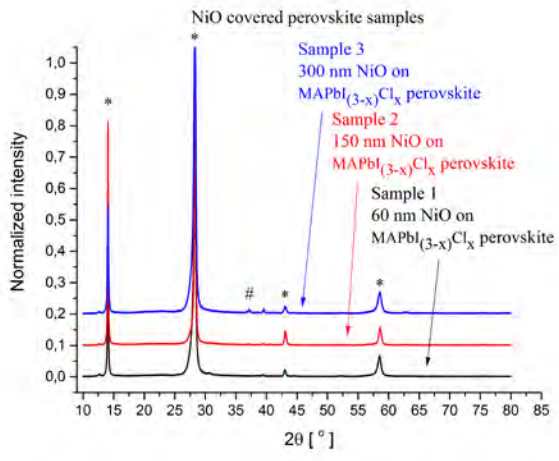
Protected methylammonium lead halide perovskite photoelectrodes for efficient two-photon water splitting

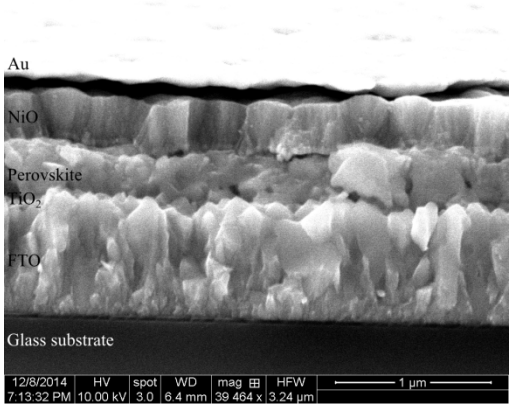
M.J. Bækbo (1), B. Mei (1), D. Bae (1), B. Seger (1), P. C. K. Vesborg (1), I. Chorkendorff (1)*

(1) DTU Physics, Technical University of Denmark, Copenhagen, Denmark

*Corresponding author email: majeba@fysik.dtu.dk

The production of sustainable energy has in recent years received an increasing amount of attention due to the environmental consequences of using fossil fuels to power society. Windmills and photovoltaics are among the most common technologies for producing 'green' energy which, however, both have the drawback that the electricity that they produce is hard to store efficiently. Storing excess energy in chemical bonds offers a way to negate this problem and using hydrogen as energy carrier offers many advantages. To produce the hydrogen the approach proposed here is to utilize a monolithic two-photon tandem photoelectrochemical (PEC) cell which can theoretically yield a solar to hydrogen (STH) efficiency of 22.8% by splitting water [1]. In the device a large band gap (LBG) material is placed on top of a smaller band gap (SBG) material where the overall band gap of the optimal device should be 2.7 eV [2]. The LBG material suggested is methylammonium lead halide perovskite ($CH_3NH_3PbX_3$, X = I, Br, Cl) which offers a high absorption in the visible range, low price, and a tuneable band gap depending on the halogens included in the structure [3]. The major drawback of using perovskite is that it decomposes very rapidly in water meaning that a pin hole free protection layer is paramount for ensuring device functionality. NiO is envisioned as the protective layer, in case the LBG electrode is used as anode, as is features a good stability while being a decent catalyst for the oxygen evolution reaction [4].





References

[1] B. A. Pinaud, J. D. Benck, L. C. Seitz, A. J. Forman, Z. Chen, T. G. Deutsch, B. D. James, K. N. Baum, G. N. Baum, S. Ardo, H. Wang, E. Miller, T. F. Jaramillo, *Energy & Environmental Science* **6** (2013) 1983.

[2] B. Seger, I. E. Castelli, P. C. K. Vesborg, K. W. Jacobsen, O. Hansen, I. Chorkendorff, *Energy & Environmental Science* **7** (2014) 2397.

[3] N. Pellet, J. Teuscher, J. Maier, M. Grätzel,*" Chemistry Materials"* **27** (2015) 2181.

[4] B. Mei, A. A. Permyakova, R. Frydendal, D. Bae, T. Pedersen, P. Malacrida, O. Hansen, I. E. L. Stephens, P. C. K. Vesborg, B. Seger, I. Chorkendorff, *" Journal of Physical Chemistry Letters"* **5** (2014) 3451.

H_2CAP - Hydrogen Assisted Catalytic Biomass Pyrolysis for Green Fuels

Trine Marie Hartmann Arndal[1], Magnus Zingler Stummann[1], Martin Høj[1], Peter Arendt Jensen[1], Anker Degn Jensen*[1], Lasse Røngaard Clausen[2], Jan-Dierk Grunwaldt[3], Jostein Gabrielsen[4], Delfina Pintos[5] and Felix Studt[5].

1: DTU Chemical Engineering, 2: DTU Mechanical Engineering, 3: Karlsruhe Institute of Technology (KIT), 4: Haldor Topsøe A/S, 5: Stanford University.

* aj@kt.dtu.dk

The H_2CAP process (Figure 1) aims at converting solid biomass into fuel grade oil through continuous catalytic hydropyrolysis and downstream deep hydrodeoxygenation (HDO). Conventional pyrolysis of biomass produces a high yield of condensable bio-oil at moderate temperature and low pressure[i]. Removal of oxygen from this bio-oil is necessary in order to achieve a stable product with an appreciable heating value. Catalytic HDO is a promising method for bio-oil upgrade, but severe coking of bio-oil upon heating challenges the upgrading of condensed bio-oil[ii]. In the H_2CAP process HDO takes place both during pyrolysis of biomass and downstream on the pyrolysis vapors before condensation. A bench scale experimental setup is being constructed for the continuous conversion of solid biomass (100 g /h) to low oxygen, fuel-grade bio-oil.

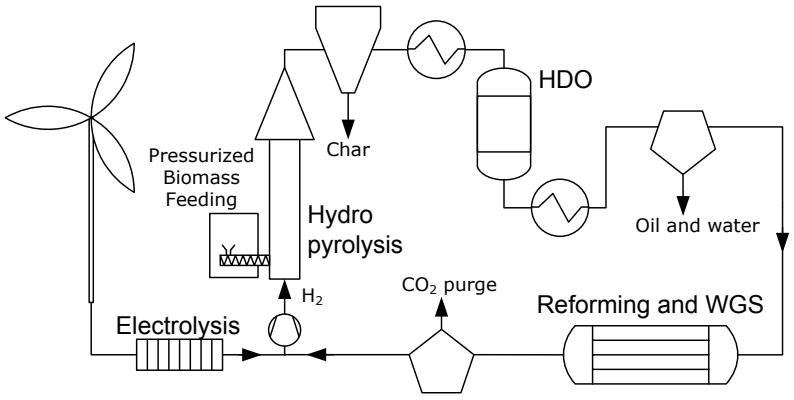


Figure 1 *Proposed process diagram including catalytic hydropyrolysis, char separation, temperature adjustment, deep HDO, liquid separation, pyrolysis gas reforming and water gas shift (WGS). Additional hydrogen may be obtained from water electrolysis.*

Supported CoMoS and NiMoS catalysts show promise in catalytic HDO[ii]. The conversion of different bio-oil model compounds is being tested in order to understand the reaction mechanisms of HDO, to develop active and durable catalysts for hydropyrolysis and HDO and to optimize the operating conditions; all in order to develop a sustainable production of green transportation fuels from biomass.

i) A.V. Bridgwater, Biomass and Bioenergy, 38 (2012), pp. 68-94. ii) P. M. Mortensen, J.-D. Grunwaldt, P.A. Jensen, K.G. Knudsen, A.D. Jensen, Appl. Catal. A: General, 407 (2011), pp. 1-19.

TEM characterization of NiGa model catalysts for methanol synthesis

C. Spiga[1, 2] , M.R. Almind[1,2], N. Secher[1,2], H.J.L. Silva[2], J.B. Wagner[1], I. Chorkendorff[2], C.D. Damsgaard*[1,2]

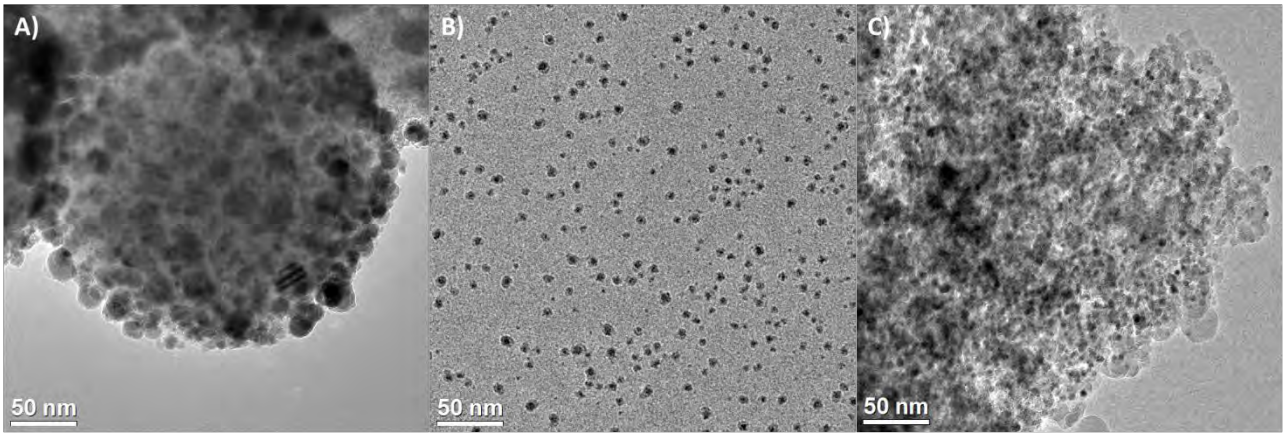
1: DTU Cen; 2: DTU Physics, *Corresponding author email: cdda@dtu.dk

Catalysis will play a crucial role in all technologies, which potentially could be used for producing sustainable chemical fuels from solar energy. One specific challenge concerns energy conversion based upon decentralized hydrogen production. One solution could be to store hydrogen on location by methanol synthesis under lower pressure conditions.

δ-Ni_5Ga_3 catalysts prepared by incipient wetness impregnation on a high surface area SiO_2 support, have shown comparable turn-over frequencies to the preferred commercial $Cu/Zn/Al_2O_3$ catalyst system[1-2]. The catalysts have been studied and characterized extensively by activity measurements, in situ XRD, and Environmental Transmission Electron Microscope (ETEM)[3] during nanoparticle formation, methanol synthesis[2], and accelerated aging experiments.

In order to optimize the catalyst even further the active state and de-activation mechanism should be determined. However, the morphology of the support may complicate interpretation of EM images of the catalyst on the atomic level due to limited depth of field. One way to circumvent this is to synthesize the NPs on a low surface area support representing the “real” high surface area SiO_2 supported catalyst.

This study presents synthesis and characterization of NiGa NPs supported on 200 nm SiO_2 spheres and SiO_2 membranes[4], respectively. By studying the structure-activity relationship of these model catalysts, we aim to identify catalytic active state and pre-dominant deactivation mechanisms that represent the behavior of the high surface area SiO_2 supported catalyst.



TEM micrographs of NiGa NPs supported on A) 200 nm SiO_2 spheres, B) SiO_2 membranes and C) High surface area SiO_2 support.

References:
[1] F. Studt et al., Nature Chemistry 6(2014), p. 320.
[2] I. Sharafutdinov et al., Journal of Catalysis, 320(2014), p. 77.
[3] T.W. Hansen et al., Materials Science and Technology 11(2010), p. 1338.
[4] C.D. Damsgaard et al., Microscopy 63(2014), p. 397.

Synthesis and Characterization of FeNi/γ-Al2O3 Egg-Shell Catalyst for H2 Generation by Ammonia Decomposition

Hugo Silva, Morten G. Nielsena, Elisabetta M. Fiordalisob, Christian D. Damsgaardb, Carsten Gundlacha,

Takeshi Kasamab, Ib Chorkendorffa, Debasish Chakraborty*

1: DTU Physics; 2: DTU Cen

*Corresponding author email: debc@fysik.dtu.dk

The FeNi alloyed nanoparticles are a promising alternative to expensive ruthenium-based catalysts for a real-scale application of hydrogen generation by ammonia decomposition. In practical applications, millimeter-sized extrudates supports are used as catalysts, where the spatial distribution of the active phase should match with the type of reaction. In this work, a novel synthesis route was developed for the preparation of a FeNi/Al_2O_3 egg-shell catalyst. Egg-shell is a preferred profile considering the highly endothermic nature of ammonia decomposition reaction. The high viscosity of glycerol, used as a solvent, prevents the fast migration of the FeNi active phase solution towards the inner-core of Al_2O_3, giving control over the large capillary pressures during impregnation. The distribution profiles were analyzed at macroscopic scale through scanning electron microscopy mapping (SEM-EDX) and optical microscopy. A three-dimensional (3D) reconstruction of the spherical-shaped Al_2O_3 was achieved using x-ray micro tomography and the FeNi egg-shell spatial distribution was inspected throughout the entire volume of the support body. Transmission electron microscopy (TEM) and scanning TEM (STEM) analysis of ultrathin lamellas (< 20 nm) carved from the outer-shell region established the presence of FeNi alloy nanoparticles with a size of approximately 5 nm. The egg shale catalyst showed significant higher activity in ammonia decomposition by converting 3 times more ammonia to equilibrium conversion than either egg-white or catalyst with uniform distribution.

Stellarators and small, modular fusion power plants: New ideas for sustainable fusion power.

Volker Naulin[1], Jens Juul Rasmussen[1], Mikhail Gryaznevich[2]
1: DTU Fysik, Fysikvej 1, 2800 Kgs. Lyngby, DK
2: Tokamak Energy, 120A Olympic Avenue, Milton Park, Oxon, OX14 4SA, UK
*Corresponding author email: vona@fysik.dtu.dk

Nuclear fusion provides humankind with an unlimited and clean source of energy for millions of years to come. The way forward to achieve the stellar conditions needed to sustain energy producing fusion reactions on a technical scale on earth has focused on the development of ever bigger devices. The flagship of these is the ITER machine, presently under construction in Cadarache, France. The scale of this experiment is so huge that it is constructed by an international agreement including two thirds of the world's population. The complexity of a machine like this, the scale of the project, and its uniqueness implies that it is prone to even longer delays and cost overruns than the average construction project.

Recent development in the performance of high temperature superconductors and in modelling may however open alternative paths to achieve fusion on a shorter timescale and at potentially lower cost. For once there is the prospect of fusion machines relying on external magnetic fields to achieve the confinement of the hot energy producing plasma. These stellarators are demanding to design, but here newly developed technologies and available computer power make construction possible. A new machine is just coming to life in Greifswald, Germany: The Wendelstein 7 X project.

Additionally the development of high temperature superconductors has made it possible to construct compact machines with much stronger magnetic cages to hold the plasma. These machines pose a number of advantages, as scalability and initial cost per unit. This, and a prospective shorter time to market, makes these machines interesting for private and institutional investors.

In this presentation we provide an overview of these new, alternative approaches and their impact on the existing energy systems.

Can diverging regulatory approaches hinder the deployment of renewable energy? The case of offshore wind in Europe.

Lena Kitzing*[1], Klaus Skytte[1]

1: Energy Economics and Regulation Group, DTU Management Engineering

*Corresponding author email: lkit@dtu.dk

Abstract

The interest in developing offshore wind is very high within the related industry sectors in Europe. As of today, 61 commercial offshore wind projects have been developed in eight European countries. In these eight countries various regulatory approaches exist addressing similar issues in different ways. These differences can have significant impact on the development of offshore wind, not only in terms of unnecessarily high development cost, but also in terms of hindering the exploitation of additional sites.

In the future, offshore wind sites have to move further from shore and into zones where cross-country cooperation becomes a crucial factor for making project development possible at reasonable cost. This is especially the case for projects connected to the planned offshore grids.

We explore differences in regulatory approaches across countries for offshore wind, and give examples of major differences in the areas of planning, design, operation and decommissioning requirements. This includes, amongst other things, grid access conditions, market participation rules and support scheme design. We describe the implications these differences may have for the cost-efficient achievement of renewable energy targets in Europe.

Planning of Future Energy Systems focusing on exergy destruction minimization

Dominik Franjo Dominkovic[1 *], Allan Schrøder Pedersen[1], Dadi Þorsteinn Sveinbjörnsson[1]

1: DTU Energy

*Corresponding author email: dodo@dtu.dk

Mitigating harmful greenhouse gas emissions, increasing security of energy supply and developing a sustainable society in general are common topics on agenda when talking about future development of mankind. In order to achieve these goals, implementation of renewable energy sources is essential. In order to integrate intermittent power generation such as wind and solar energy, it is important to analyze, understand and plan a transition to low-carbon society. There are many energy planning tools developed for this purpose which focus on different specifics in a certain energy sector or on energy system as a whole. Usual targets in these modelling tools is to minimize socio-economic costs or to reduce the fuel consumption (and consequently to reduce CO2 emissions), using the energy conservation principle (the first law of thermodynamics) during the transformation from primary to end-use energy forms.

However, the second law of thermodynamics, which tells us about irreversibilities of conversion processes, can give us the answer about quality of specific energy form, information which cannot be obtained from the first law of thermodynamics. The concept connected to the second law of thermodynamics is Exergy. Exergy is the maximum useful work which can be obtained from the system by reaching the equilibrium with its environment. Due to the better developed methodology and clearer definition of methods used, a large share of researchers have been focusing on energy analysis, neglecting the beneficial outcome which can be obtained by exergy analysis. Thus, in this paper the authors are presenting the development of novel energy planning tool which focuses on minimizing the exergy destruction within the system. The developed model is a linear optimization tool, having in its initial phase only a few renewable technologies in heating and power sector. The comparison of energy and exergy analysis in energy planning has been shown on imaginary energy system comprising of 15 000 people, living in 7 000 households in Denmark and working in the island mode. Results have shown that a more sustainable energy system can be planned for using the exergy destruction minimization as the goal of planning process, especially the sustainable biomass utilization.

Title: Integration of energy, GHG and economic accounting to optimize biogas production based on co-digestion

Authors: Temesgen Fitamo[1], Alessio Boldrin[1], Khagendra Raj Baral, Ali Heidarzadeh Vazifehkhoran, Ida Græsted Jensen, Ida Kjærgaard, Kari-Anne Lyng, Quan Van Nguyen, Lise Skovsgaard Nielsen, and Jin Mi Triolo

[1] Department of Environmental Engineering, Technical University of Denmark, Miljoevej, 2800 Kgs. Lyngby, Denmark;

Several countries have set a number of targets to boost energy production from renewable sources. Biogas production is expected to increase significantly over the next few decades and to play an important role in future energy systems. To achieve these ambitious targets, the biogas production has to be improved. The economic and environmental performances of the biogas chain must be optimised to ensure viable and sustainable solutions. Different types of feedstock materials will have to be considered, including agricultural residues, agro-industrial residues and, to some extent, dedicated energy crops.

In this study, we integrated three types of analysis - energetic, GHG and economic – in order to optimise biogas production from the co-digestion of pig slurry (PS) and sugar beet pulp silage (SB). We found that the energy and GHG balances are improved when utilising SB as a co-substrate, mainly because of increased energy production. However, the profitability of biogas production is negatively affected when utilising SB, because of the increased costs involved in feedstock supply. The scale of the processing plant is neutral in terms of profitability when SB is added. The results indicate that medium- to large-sized biogas plants, using low shares of SB co-substrate, may be the preferred solution.

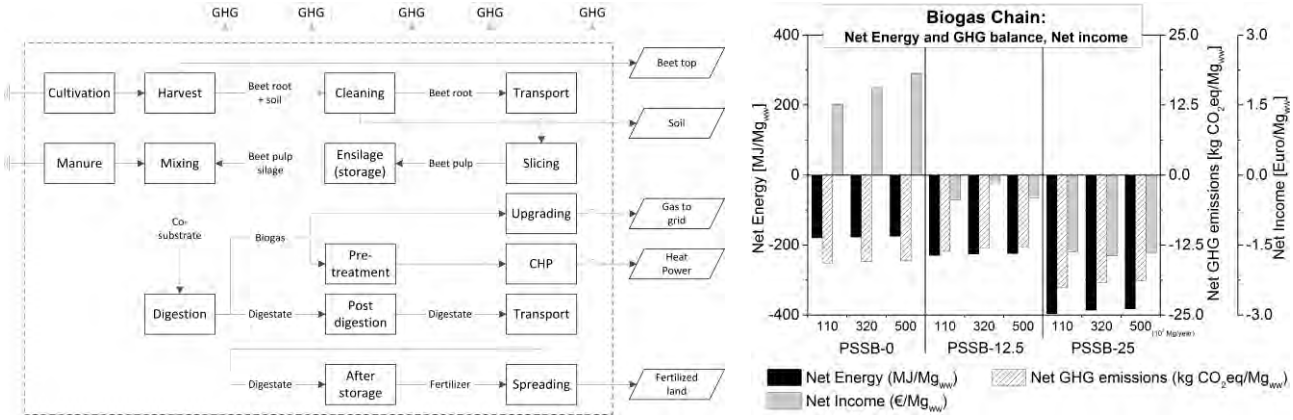


Figure 1 – Biogas production chain (left) and results for integrated energy, GHG, and economic analysis (right), taken from Boldrin et al. (2015).

The abstract is based on the following publication:

Boldrin, A., Baral, K.R., Fitamo, T., Vazifehkhoran, A.H., Jensen, I.G., Kjærgaard, I., Lyng, K-A., Nguyen, Q.V., Nielsen, L.S., Triolo, J.M. (2015) Optimised biogas production from the co-digestion of sugar beet with pig slurry: integrating energy, GHG and economic accounting. Submitted to *Energy*.

FEM Validation of a Single Degree of Freedom Model for Piezoelectric Energy Harvesters

Lucia R. Alcala[1], Anders Lei[1], Mikkel V. Larsen[1], Døgg Durhuus[1], Erik V. Thomsen[1]

1: DTU Nanotech

Analytical calculations and finite element modeling (FEM) are important tools for efficient design and optimization of piezoelectric vibrational energy harvesters [1-3]. We have previously shown [4] that cantilever based vibrational energy harvesters with large attached proof masses, Fig. 1, can be described by an analytical impedance based single degree-of-freedom (SDOF) model using appropriate lumped parameters. In this paper we validate the analytical model using FEM by performing a design study where the thickness of the piezoelectric layer is optimized.

The FEM studies were performed in COMSOL 5.1. For power calculations, the load resistance was optimized for each geometry to achieve maximum power. The device is made in silicon and uses a thin layer of AlN as piezoelectric material with dimensions listed in Tab. 1.

Using AlN for vibrational energy harvesting has several advantages compared to other commonly used materials like PZT. However, it is difficult to deposit thick layers due to the very slow deposition rate. It is therefore essential to determine the AlN layer thickness necessary to achieve a maximum output power. The peak harvested RMS power versus the AlN layer thickness has been studied. Two regions have been found. In the first region the power harvested from the device increases as the AlN layer thickness is increased. From [4] it can be inferred that the device is behaving as in the low coupled case. In the second region a maximum power is reached when the AlN thickness is above ~350 nm. In this second region the maximum output power corresponds to the total available power in the device. The explanation to this output power is that the device enters a region characterized by a behavior that corresponds to the high coupled case described in [4]. Depositing thicker AlN layers than ~350 nm in order to harvest the maximum available power is therefore not necessary.

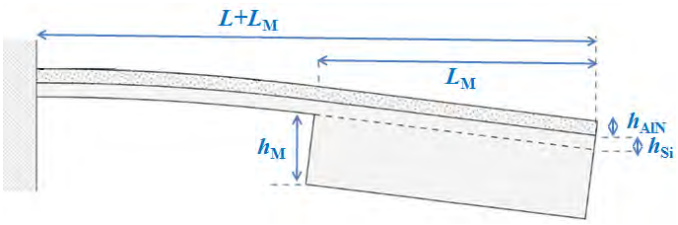


Figure 1. Schematic design of the device.

Device parameter	Value
Total beam length, $L+L_M$	6.5 mm
Mass length, L_M	3.2 mm
Beam width, W	6.0 mm
Cantilever thickness, h_{Si}	30 µm
AlN thickness, h_{AlN}	400 nm
Mass thickness, $h_M + h_{Si}$	500 µm

Table 1. Device dimensions.

[1] A. Erturk and D. J. Inman, *Journal of Vibration and Acoustics*, 130(4):041002–15, 2008.
[2] F. Goldschmidtboeing et al., *J. Micromech. Microeng.*, vol. 21, no. 4, pp. 045006–045016.
[3] M. Renaud, et al., *J. Micromech. Microeng.,* vol. 22, no. 10, pp. 105030–105042, Oct. 2012.
[4] Anders Lei et al., J. Microelectromechanical Systems, vol. 23, no. 4, pp. 842-845, Jan. 2014.

Electrochemical Impedance Spectroscopy as a Tool for PEMECs Development

Katrine Elsøe*[1], Johan Hjelm[1], Mogens B. Mogensen[1].

1: DTU Energy

* katel@dtu.dk

Impedance spectroscopy is a widely applied electrochemical characterization method often used for characterization of energy conversion and storage devices. This PhD project is concerned with impedance spectroscopic investigations of proton conducting electrolyte membrane electrolysis cells (PEMECs) used as a tool for further development of PEMECs. The idea is to determine internal resistance of the cell from the two electrodes, the electrolyte and of mass transport limitations by analysis of differences in impedance spectra (ADIS). This method has previously been successfully demonstrated on solid oxide fuel cells (SOFCs), and the intention is to be able to transfer the method to the PEMECs, which primarily differ from the SOFCs in the electrode reaction mechanisms and the electrodes and electrolyte materials (Nielsen and Mogensen, 2011) (Jensen et al., 2007). Furthermore, physically reasonable equivalent circuit models will be used to parameterize the observed impedance, guided by information obtained from ADIS/DRT, to provide insight into performance limiting processes in the cells.

This poster gives a brief general introduction to impedance spectroscopy followed by a discussion of the ADIS procedure and the analysis method of distribution of relaxation times (DRT). Furthermore recently recorded impedance results obtained during operation of a commercial PEMEC is presented and discussed.

Acknowledgement
The work is part of the research project e-STORE funded by the Innovation Fund Denmark.

Bibliography

J. Nielsen, M. Mogensen. (2011). SOFC LSM:YSZ cathode degradation induced by moisture: An impedance spectroscopy study. *Solid State Ionics*, 189, 74-81.

S. H. Jensen, A. Hauch, P. V. Hendriksen, M. Mogensen, N. Bonanos, T. Jacobsen. (2007). A Method to Separate Process Contributions in Impedance Spectra by Variation of Test Conditions. *Journal of The Electrochemical Society*, 154 (12), B1325-B1330.

Durable thin ceramic films for improvement of Proton Exchange Membrane (PEM) electrolysis

Filippo Fenini*, Peter Vang Hendriksen, Mogens B. Mogensen
Department of Energy Conversion and Storage, DTU Risø Campus

* filfe@dtu.dk

The growth of renewable energy production in the latest years has made it essential to find a way to store the excess energy in an efficient and potentially large-scale, easily accessible way. Electrolysis of water can play a key role in this field, since the high purity H_2 produced can be both a powerful energy vector and a multi-purpose synthesis precursor.

One way of producing hydrogen by renewable energy is by using a PEM electrolyser (PEMEC), which is a very compact low temperature electrolyser that allows a fast response to variations in electrical power supply. Moreover, the possibility of operating at high pressure enables a direct production of compressed, storage-ready output gas, thus potentially reducing the overall costs of H_2 production and storage, if the present high cost of the PEMEC can be reduced. The state-of-the-art PEMEC uses an anode based on IrO_2/RuO_2, which deliver high catalytic activity and a good corrosion resistance to the high overvoltage conditions necessary for the oxygen evolution reaction (OER) and to the low pH environment due to the membrane. Together with the Ti separator plates, generally coated with precious metals to enhance conductivity, it results in extremely high costs.

Basic material research, to identify and develop low-cost corrosion resistant stack element materials and coatings, is therefore essential. The aim of this project is primarily to identify electronic conducting materials with high chemical stability together with low cost and high availability.

This goal will be reached with extensive testing of electronic conducting ceramics in strongly oxidizing and acid environment, simulating the OER conditions in a real cell. Moreover, the evaluation of the real potential and pH experienced *in operando* by the anode material will be targeted, for properly tuning of the testing conditions. After this first screening stage, the most promising candidates will be further tested by measurement of their conductivity and other physical properties.

In a second stage of the project, the conductive and corrosion resistant materials will be deposited in thin films onto the cell electrodes; the interconnection and the adhesion between films will be object of great attention. The materials can be deposited by mean of several techniques such as PVD, RF-sputtering and PLD. The thin films will be investigated using electric conductivity, electron microscopy and x-ray photoelectron spectroscopy (XPS) and possibly other physical and chemical methods.

Micro-scale organic Rankine cycle units for industrial waste heat recovery

Enrico Baldasso*[1], Stephan Olesen[2], Fredrik Haglind[1]

1: DTU Mechanical Engineering; 2: Innogie ApS

*Corresponding author email: enbald@mek.dtu.dk

A combination of different strategies should be pursued in order to develop a more sustainable energy system. Great attention is now devoted to the study of renewable sources, but it is also necessary to focus on the already existing technologies in order to increase the overall effectiveness of thermodynamic cycles and to investigate novel solutions to economically exploit freely available heat sources. In this context, a recent study carried out at DTU Mechanical Engineering has shown that around 266 PJ of heat is wasted every year in the Danish business sectors [1]. The low temperature and dispersed nature of this waste heat makes it challenging to convert it into power in an economical way. Nevertheless, this heat represents a freely available hot source whose exploitation could enable to decrease the fossil fuel consumptions.

This project, carried out in collaboration with Innogie ApS, aims at modeling, developing and testing a micro-scale organic Rankine cycle (ORC) unit (1-5 kW_{el}) able to perform an efficient and economical conversion of industry low temperature (80 – 120 °C) waste heat into power. The ORC is thermodynamic cycle suitable for the conversion into power of low temperature heat sources. Its main advantage compared to the traditional steam Rankine cycle lies in the possibility to choose a proper working fluid in order to obtain a good thermal match between the cycle and the heat source. The final objective of the project is to ensure the economical profitability of these micro-scale systems and to make them suitable for commercial purposes. The main tasks to be carried out include the development and validation of detailed numerical models of the cycle and its component, experimental tests and the economical assessment of the integration of the unit in real industrial processes.

An already available ORC prototype comprising a scroll expander will be tested soon. The scroll expander is a rotative volumetric expander usually employed in low temperature – low capacity ORC power plants [2]. The scroll is a reliable technology that has been widely used as a compressor in the field of air conditioning and refrigeration. Its main advantages include the high reliability, the good isentropic efficiency and the tolerance toward the presence of a liquid phase during the expansion process. The first scroll expander prototypes are now being commercialized but, in most of the cases, they are derived from existing scroll compressors and are thus not optimized for expander operation.

References:

[1] F. Bühler, F. M. Holm, B. Huang, J. G. Andreasen and B. Elmegaard, ”Mapping of low temperature heat sources in Denmark”, Proceedings of ECOS 2015, Pau, France, 2015.

[2] P. Song, M. Wei, L. Shi, S. N. Danish, C. Ma, “A review of Scroll expanders for organic Rankine cycle systems”, Applied Thermal Engineering, Vol 75, pp. 54-64, 2015.

Recent advances in Catalysis Research using Electron Microscopy

Jakob B. Wagner[1*], Davide Deiana[1], Ib Chorkendorff[2], Ifan Stephens[2], Thomas W. Hansen[1]

1: DTU Cen; 2: DTU Fysik

*Corresponding author email: jakob.wagner@cen.dtu.dk

Electron microscopy provides a highly versatile platform for the characterization of supported metal nanoparticles for heterogeneous catalysis. With both high spatial resolution as well as spectroscopic capabilities, the EM platform can characterize materials in detail. Recent developments include high solid angle EDX detectors, which can rapidly acquire high-resolution elemental maps, and micro electro-mechanical systems (MEMS) based heating holders that can heat samples at very high rates with only little spatial drift. With the addition of environmental capabilities, the microscope can even probe samples under reactive environments.

A recent trend in catalysis is the use of materials that have been engineered at an atomic level. In particular, Density Functional Theory (DFT) is used to computationally screen for new materials. These are often multi-metal alloys, which add new functionality and can reduce the amount of precious metals. Such samples can be size selectively produced either by physical routes, e.g. time of flight mass selection or chemical synthesis e.g. micelle encapsulation. Whereas these approaches may not be technically applicable for large-scale synthesis, they provide a valuable route for gaining fundamental knowledge.

Here, we show findings from three different systems used in three different reactions. Namely, Pt-Y for oxygen electroreduction to H_2O, Pd-Hg for electrochemical synthesis of hydrogen peroxide and ruthenium based catalyst used for methanation [1-3]. With these examples, we illustrate two principle points of nanoparticle functionality: composition and shape.

In the case of the bimetallic catalysts, the elemental distribution in the nanoparticles is of fundamental interest: Do they form a core-shell system or do form an evenly distributed mixture/alloy? Using a high solid angle EDX detector, elemental maps can be efficiently collected and the elemental distribution monitored. Such verification is essential to understand the working principle of the catalyst.

Ruthenium nanoclusters can be used for methanation of carbon monoxide, a reaction used to clean up feed gas for e.g. proton exchange fuel cells (PEM). As-synthesized, the Ru particles assumed high surface-area raspberry-like shapes. However, after treatment under conditions relevant for the methanation reaction, the particles adopted more spherical shapes.

[1] F. Masini *et al.* J. Catal. 308 (2013) 282

[2] S. Siahrostami *et al.* Nature Materials 12 (2013) 1137

[3] A. Verdaguer-Casadevall *et al.* Nano Letters 14 (2014) 1603

Spray-coated CZTS Nanoparticles in Water for Environmentally-friendly, Inexpensive Solar Cell Absorber Material

Sara Engberg*[1], Naghmeh Mirbagheri[1], Andrea Crovetto[2], Edoardo Bosco[2], Ole Hansen[2], Jørgen Schou[1]

1: DTU Fotonik; 2: DTU Nanotech

*Corresponding author email: sleen@fotonik.dtu.dk

The kesterite material, Cu_2ZnSnS_4 (CZTS), is very promising as absorber material in future thin film solar cells. The elements are abundant, the material has a high absorption coefficient, and it is non-toxic. These properties make CZTS a potential candidate also for large-scale applications. Here, solution processing allows for comparatively fast and inexpensive fabrication and the power conversion efficiency is also relatively high. The current challenges are, (1) that the nanoparticles do not sinter during annealing, and (2) that grain boundaries and defects are believed to be a site for recombination that limits the efficiency. Annealing in vacuum, nitrogen and/or a diluted hydrogen atmosphere facilitates grain growth and improves the electronic properties.

In this work, nanocrystals of CZTS with a targeted Cu-poor/Zn-rich composition are synthesized through a hot-injection method with diethylene glycol as the solvent, which makes them dispersible in water. The nanocrystal inks are deposited through spray coating, and annealed in a vacuum furnace using a graphite box with sulfur. The surface morphology and thus grain growth are studied for various annealing conditions.

The films are characterized with scanning electron microscopy (SEM), and an example before and after annealing is displayed in Fig. 1 (a) and (b), respectively. Compositional changes are monitored by energy dispersive X-ray spectroscopy (EDX) and the crystallinity by X-ray diffraction (XRD).

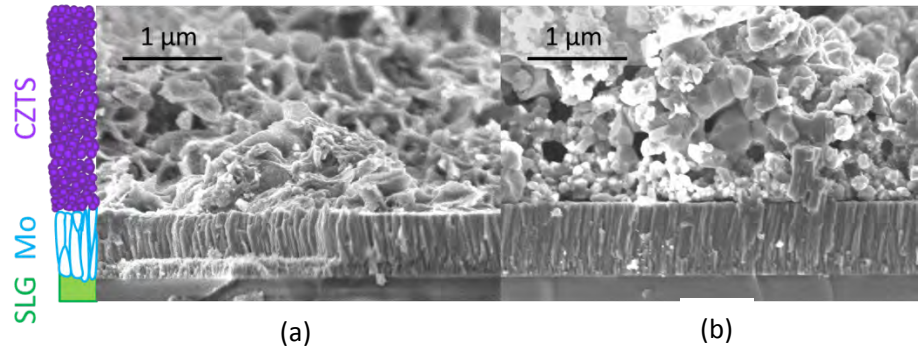


Fig. 1 SEM image of cross-section of spray-coated CZTS film after (a) pre-annealing at 200˚C, and (b) annealing in nitrogen atmosphere at 550˚C, where grain growth is visible.

Nano scaled electro catalysts, a versatile concept for novel solid state fuel cells and electro-catalytic reactors.

Kent Kammer Hansen, Peter Holtappels, Tania Ramos, Bhaskar Reddy Sudireddy, Marie Lund Traulsen

DTU Energy

*Corresponding author email: peho@dtu.dk

Solid state electrochemical cells based on oxygen ion conducting electrolytes are mostly known for their application as lambda sensors and currently under development as solid oxide fuel and electrolysis cells. The transport of oxygen through the electrolyte to and from the fuel electrode can be used to convert a large variety of high energy density fuels such as hydro carbons with superior efficiency than in conventional combustion processes. The cells can also be used to reduce other oxygen containing species such as NOx. During the recent years, a novel electrode concept has been developed, that is based on decoupling the electro chemical activity and current collection in the electrode. By using a ceramic porous scaffold, and incorporating additional electro catalysts, the electrochemical activity can be tailored to the desired application of the cell. The concept will be explained and examples provided for novel electrodes and their application.

For solid oxide fuel cells, strontium titanates have been developed as the support material and various metals (Fe, Pd, Pt, Ru) have been incorporated and investigated towards their performance in natural gas based fuels for micro CHP. Stable structures can be achieved even at operating temperatures as high as 850 C (1). Cell performance was shown compatible with state-of the art Ni based cells reaching 0.5 W cm^{-2}.

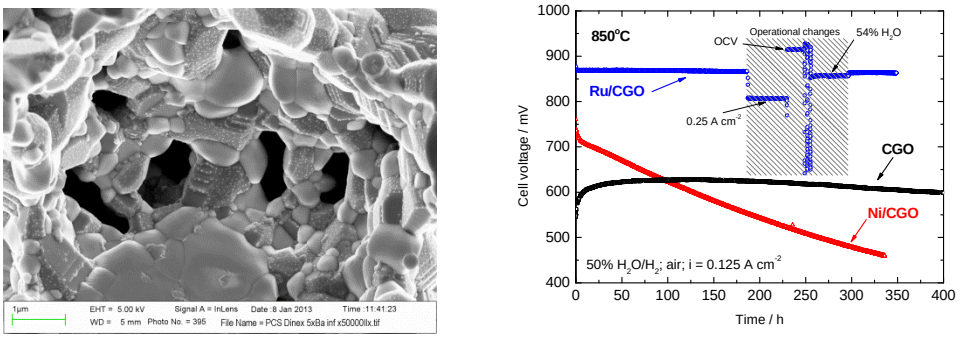


Figure (left): Porous ceramic electrode with impregnated Ba-oxide, (right): durability test of a full ceramic SOFC anode.

Another application is the development of NOx selective electrodes for cleaning of engine exhaust gases. Here the oxygen electrode, typically La-Mn perovskites, which are stable and electrically conductive in oxidizing atmospheres are used as the catalyst support (2,3). Addition of BaO onto the perovskite surface has increased the reduction of NO_x to N_2. The mechanism is still under investigation, but a strong interaction between the electro catalyst and the support is indicated by advanced in-operando spectroscopic studies.

The research leading to these results has received funding from the Fuel Cells and Hydrogen Joint Undertaking under grant agreement n° 256730 and the Danish Strategic Research Council, contract no. 09-065186.

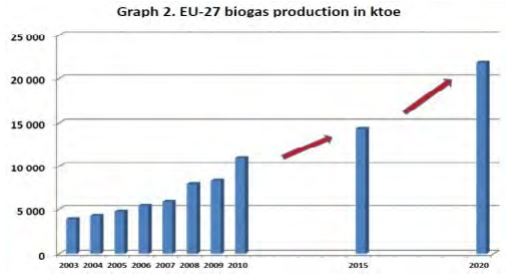
1. T. Ramos, S. Veltzé, B.R. Sudireddy, P.S. Jørgensen, L.T. Kuhn, P. Holtappels, Fuel Cells 14(6) (2014) 1062-1065
2. M.L. Traulsen, K.B. Andersen, K. Kammer Hansen, J. Mat. Chem., 22 11792-11800 (2012)
3. J. Shao, K. Kammer Hansen, J. Mater. Chem. A, 1 7137-7146 (2013)

CO_2 adsorbers for upgrading of bio-gas to methan.

Leonhard Schill[1], Anders Riisager[1], Rasmus Fehrmann*[1]

[1]Centre for Catalysis and Sustainable Chemistry, Department of Chemistry, Building 207, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark

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



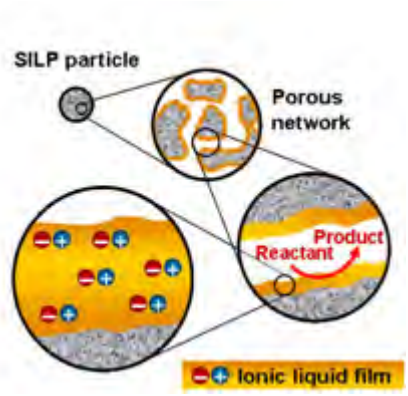


Figure 1: Growht of the EU biogas market.[1] Figure 2: Concept of Supported Ionic liquids (SILP)

The bio-gas market in the EU has experienced strong growth over the last 10 years and is expected to expand even further in the near future, see Figure 1. While the anaerobic digestion is a relatively mature technology, the upgrading of bio-gas (i.e. removal of CO_2 to yield pure methane) still needs to be optimized. Currently, the most widespread technology for CO_2 removal is treatment with aqueous amine solutions. However, implementing this technology at small biogas plants can be problematic, because it is not modular.

Using Ionic liquids which can reversibly bind CO_2 is an alternative way to upgrade bio-gas. However, these liquids are very viscous which makes the gas-uptake extremely slow. By forming a thin film of ionic liquids onto inorganic support materials like alumina and silica can remove the problem of slow gas-uptake. The resulting materials are also called “Supported Ionic Liquds” (SILP).

In order to integrate the SILP materials into gas filters, it is necessary to shape them into monolithic form. Our group has made some progress in this field.

References:

[1]: *The GreenGasGrids Project: Boosting the European biomethane market*

Life Cycle Management in wind energy technologies and planning – a case from Siemens Wind Power

Alexandra Bonou*[1] , Stig Irving Olsen[1]

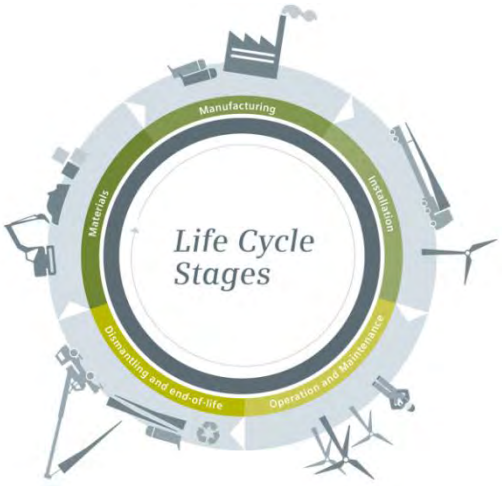
1: DTU Management

*abon@dtu.dk

We performed the LCA of 4 average wind power plants and assessed the environmental impacts related to the provision of kWh to the grid (FU). We assumed state of the art technology of 2015 and turbines of capacity 2.3, 3.2, 4.0 and 6.0 MW provided by Siemens Wind Power. We addressed two differ markets: onshore with 20 turbines and offshore with 80 turbines and two generator technologies (direct drive and geared). We accounted for the system from cradle to grave and we included all process required to provide the service. The energy payback time is less than 6 months for onshore and less than 11 for offshore plants. The CO2-eq emissions are correspondingly less than 6kgCO2-eq/MWh and 10kgCO2-eq/MWh. Climate change is a good proxy for environmental hotspot identification while human toxicity is identified as the most relevant impact category.

The results indicate that onshore wind energy environmentally performs better per functional unit compared to the offshore. This is mainly because offshore requires 3 times more material weight for the capital equipment and more resources for installation and maintenance and these needs do not counterbalance the benefits of higher energy output compared to the onshore market. In both markets the newer turbines with more advanced generator technology perform better. Also, in both markets more than 80% of the impacts are due to material stage and mainly due to the foundations (reinforced concrete for the onshore and steel monopiles for the offshore) the steel towers nacelles and blades.

The impacts need to be seen as a combination of impact intensity per material type and the amounts consumed. The materials of highest improvement potential per kg material are found in the blades. The negative impact of materials is to a great extend counterbalanced by the high recycling potentials at the end of life due to avoided production of primary materials and mainly steel. The system's performance is highly sensitive to wind speed, life time and recycling related assumptions related to technology and future management practices. These EOL assumptions are also the most uncertain part of the system.



A conceptual model of life cycle thinking used to determine how it applies to the daily work of internal cross-functions (Siemens AG, 2014)

Siemens AG, 2014. Environmental Performance- Assessing the environmental impact of Siemens wind turbines. Available at: http://www.energy.siemens.com/hq/en/renewable-energy/wind-power/epd.htm [Accessed June 1, 2015].

Pt-based catalysts for diesel exhaust oxidation: support effect and bimetallic elements

Hugo Silva[1], Nicola Mazantti[1], Cristiano Spiga[2], Ib Chorkendorff[1], Debasish Chakraborty*[1]

1: DTU Physics; 2: DTU Cen

*Corresponding author email: debc@fysik.dtu.dk

The emission control of harmful gases from diesel-fuelled automobiles is currently a global challenge with environmental and public health implications. Tighter emission regulations is driving the automotive industry to develop highly efficiency catalytic converter devices, where the diesel oxidation catalyst (DOC) has the crucial role of decreasing the pollution levels through the oxidation reaction of nitrogen oxides (NO_x), carbon monoxide (CO), unburned hydrocarbons (HC, e.g. propene) and sulfur oxides (SO_x) [1].

Scarce and precious metals, especially platinum (Pt), or platinum combined with palladium (PtPd) as bimetallic elements represent the state of the art DOCs. Cost reduction, in eg. platinum, and improving the catalyst lifetime are two main goals of the current technology. In the oxygen-rich environment of a diesel engine exhaust at high temperatures, the active nanoparticles that are deposited typically in a high surface area support (e.g. ɣ-Al_2O_3, SiO_2) are prone to sintering by particle migration or Ostwald ripening mechanism [2], leading to a loss of metallic surface area and subsequent efficiency.

In this work, the activity for HC oxidation and stability of platinum catalysts prepared by incipient wetness impregnation method was studied regarding the support effect ($MgAl_2O_4$, SiO_2 and ɣ-Al_2O_3) and addition of a second metal element (Ni, Fe, W, Pd). The Pt/$MgAl_2O_4$ catalyst presented a remarkable stability at extreme conditions (750 °C, 10% O_2), allied to better activity after a high temperature reduction pre-treatment (800 °C, 5% H_2). On the other hand the PtFe, especially for lower metal loadings of Fe (ca. 0.1 wt.%) exhibits a promising behavior as a replacement of the commercial PtPd.

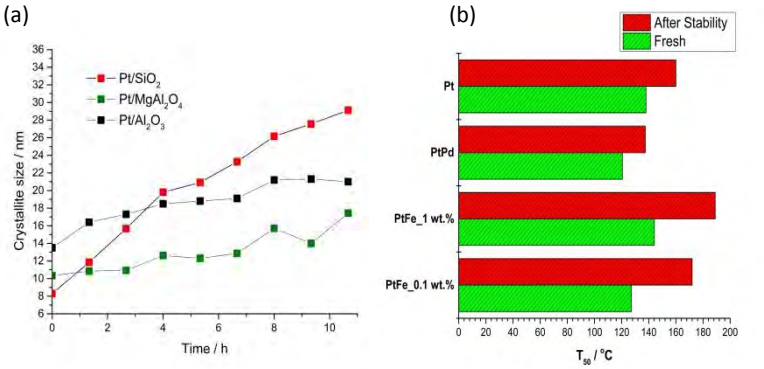


Figure 1 – (a) Crystallite size of Pt on different supports from *in situ* XRD measurements; (b) Temperature of half conversion (T_{50}) for Pt/SiO_2 and PtX/SiO_2 (X=Fe and Pd).

References:
1. Russell A, Epling WS (2011) Diesel Oxidation Catalysts. Catal Rev 53:337–423.
2. Simonsen SB, Chorkendorff I, Dahl S, et al. (2012) Effect of Particle Morphology on the Ripening of Supported Pt Nanoparticles. J Phys Chem C 116:5646–5653.

Thin film CZTS solar cells made by Pulsed Electron Deposition

Rebecca Bolt Ettlinger[1*], Andrea Crovetto[2], Edoardo Bosco[2], Jørgen Schou[1], Francesco Pattini[3] and Stefano Rampino[3]

1: DTU Fotonik; 2: DTU Nanotech; 3: IMEM-CNR, Parma, Italy
*reet@fotonik.dtu.dk

Copper Zinc Tin Sulfide (Cu_2ZnSnS_4 or CZTS) is a promising new material for thin film solar cells because it is made from cheap, abundant, non-toxic elements. It is similar to the solar cell material Copper Indium Gallium Diselenide (CIGS) which is already in commercial production. Unlike CIGS, CZTS does not have constituents that are rare in the Earth's crust and it is therefore suited for truly large-scale implementation. Adding to the allure, CIGS and CZTS are both well suited for building-integrated photovoltaics because they can be made on semi-flexible or curvy substrates and even directly on ceramic building elements.

Pulsed electron deposition (PED) is a relatively new low-cost, low-temperature vacuum-based method that has been used successfully to make CIGS > 18 % efficient (the CIGS world record is 21,7 %) [1, 2]. For CZTS, the world record efficiency is currently 9.4 % [3]. Usually both CIGS and CZTS need to be annealed at relatively high temperature (570 °C for CZTS) but with pulsed electron deposition enough energy is provided by the electron pulses to avoid high temperature annealing for CIGS. The question is whether this is also the case for CZTS. Therefore in cooperation with IMEM-CNR in Parma, Italy, we have carried out the first attempt to make CZTS by PED. We found that thin films deposited at 250-325 C (Fig. 1) have the correct CZTS crystallographic structure as measured by X-ray diffraction and have few secondary phases. However they are not fully dense and are low in S. The first trial solar cells with as-deposited films yielded a maximum efficiency of 0.2 %. This may be improved by controlling the film thickness and providing a heat treatment (preferably in situ, avoiding the use of an extra 570 °C annealing step in an oven), using a more uniform target of the correct composition and possibly doping with alkali metals.

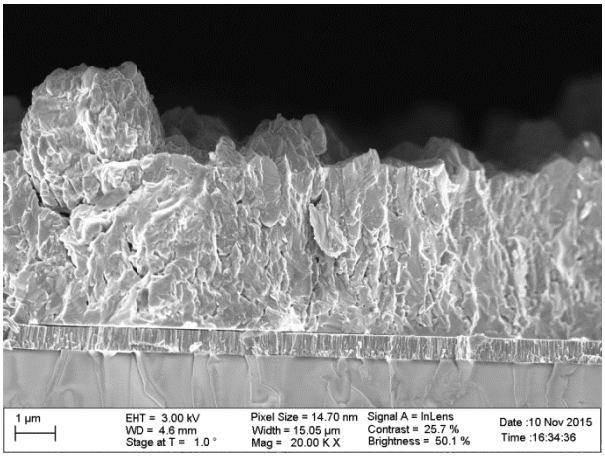


Fig. 1: SEM cross-sectional image of a CZTS layer identical to the one used in a 0.2 % efficient solar cell. The CZTS layer (4-5 µm thick) is deposited on a 500 nm layer of Mo that has been sputtered on soda lime glass.

[1] Rampino et al., J. Renew. Sustain. Energy **7**, 013112 (2015).
[2] Jackson et al., Phys. Status Solidii RRL **9**, No. 1, pp 28-31 (2015).
[3] Tajima et al., poster CP3-14 at the EMRS Spring Meeting in Lille, May 14, 2015.

Pulsed laser deposition (PLD) of the solar cell materials CZTS and CTS

Andrea Cazzaniga[1], Sara Engberg[1], Rebecca Ettlinger[1], Andrea Crovetto[2], Jørgen Schou[1] 1: DTU Fotonik; 2: DTU Nanotech;

Corresponding author: andcan@fotonik.dtu.dk

Background: The world demand of electricity supply at a Tera-Watt scale means that there is a need for earth abundant and non-toxic materials. Therefore, many efforts are currently devoted to exploit the full potential of the absorber layer Cu2ZnSn(S,Se)4 (CZTS), which has a similar structure and similar band-gap as Cu(In,Ga)Se2 and is fully made by earth-abundant materials. The record efficiency of CZTS solar cells has been greatly improved during the last few years, reaching 12.6% with a sulfo-selenide blend and with a 50 nm thick buffer layer of CdS. While these results are very encouraging, Se- and Cd- free solutions are still at an early stage of development. Regarding the pure sulfide Cu2ZnSnS4, the annealing step is very critical for the physical quality of the absorber layer. Many difficulties are related to the high volatility of sulfur and of its binary compounds.

Idea: The idea is to make the annealing process more controllable and reproducible by using a cap layer on top of the CZTS before the annealing. The cap layer should prevent decomposition reactions and assist in self-balancing the stoichiometry. For this purpose we have selected a thin layer of ZnS.

- ZnS can serve as buffer layer.
- ZnS is made of earth abundant material, unlike CdS.
- ZnS withstands high temperatures, so it can be annealed together with the CZTS layer.

We compare the results of annealing the bilayer CZTS/ZnS to the annealing of a single CZTS layer. In the first case, the enhancement in the crystalline quality of both layers is clearly visible from the x-ray diffraction patterns and SEM images.

Experimental technique: We deposit a bilayer of CZTS/ZnS onto Mo-coated Soda Lime Glass by using Pulsed Laser Deposition (PLD). The laser is operating at 248 nm, 10 Hz and 3 J/cm^2. The targets were made of stoichiometric, sintered powder; Depositions were carried out under high vacuum (p ~ 1*10^{-6} mbar) and the substrate temperature was fixed at 300^o C. Annealing was done in a tube furnace in a N_2 + S_2 atmosphere at 550^o C for 30 minutes.

TiO_2-Si solar cells with carrier selective contacts and low temperature processing

Maksym Plakhotnyuk[1*], Ole Hansen[1]

[1]Department of Micro- and Nanotechnology, Technical University of Denmark

Introduction. Most crystalline silicon based photovoltaic technology based on high temperature diffusion processes in the range of 800-900 °C. We present recent progress on development of low process temperature TiO_2-Si heterojunction solar cell with carrier selective layers with efficiency 2.39%, V_{OC}= 0.41V and J_{SC} = 9.79 mA/cm^2.

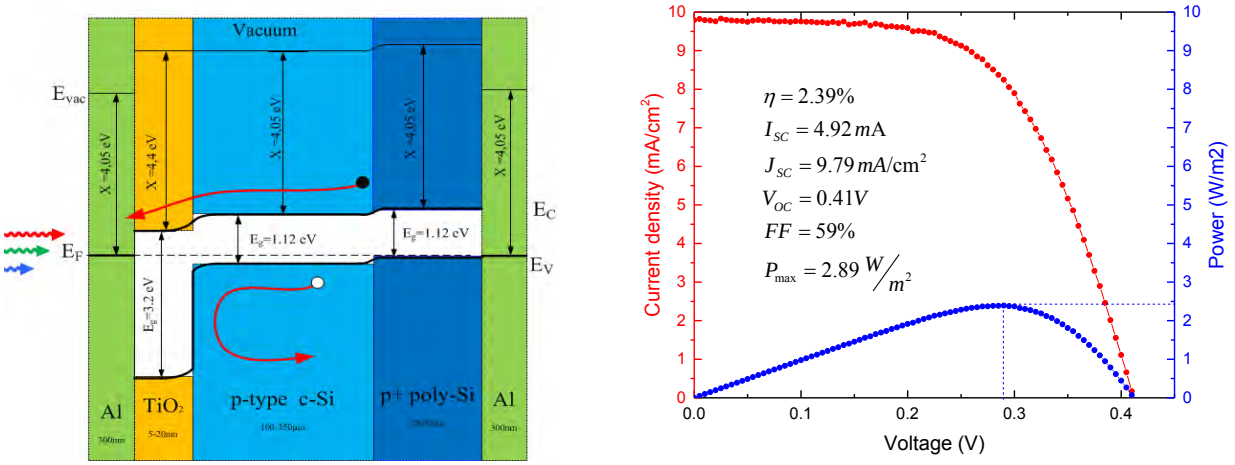


Figure 1: Energy band diagram of TiO2-Si-poly Si structure (left), current-voltage and power –voltage characteristics (right)

Experimental results. Titania-silicon heterojunction solar cell was fabricated using ALD deposition of TiO2 at 120°C. with the thickness of 20 nm on front side of silicon p-type wafer, polycrystalline silicon film was deposited on a back side of the silicon wafer. Titania is an electron selective layer as it was shown on the figure 1 (left). Polycrystalline boron doped silicon layer with the thickness of 25 nm play a role of a hole selective layer. 300 nm of aluminium was deposited on the backside of the cell and 15 nm on the front side of the cell. After fabrication the cell was characterized with a Newport solar simulator that allowed to measure current-voltage and power-voltage characteristics. The best solar cell device has shown 2.39% efficiency, open circuit voltage equal to 0.41 V, current density – 9.79 mA/cm^2, fill factor – 59% and maximum power 2.89 W/m^2. Our analysis has shown that current efficiency record was limited by 50% reflectivity from top aluminum layer, chemical surface damage of titania that caused inhomogeneity of the layer and due to other test process faults.

Further work focuses on optimization of ALD TiO_2 deposition parameters, titania protection during further processing, application low reflective top layers and contact that can improve solar cell efficiency and parameters.

*Corresponding author: email: makpl@nanotech.dtu.dk, phone: +45 45255848, Department of Micro- and Nanotechnology, Technical University of Denmark (DTU), Ørsteds Plads, building 345East, DK-2800 Lyngby, Denmark

Improving the oxygen reduction reaction by strain effects: bulk and nanoparticles studies

Amado Velázquez-Palenzuela[1*], María Escudero-Escribano[1], Federico Masini[1], Anders F. Pedersen[1], Davide Deiana[2], Paolo Malacrida[1], Thomas Willum Hansen[2], Daniel Friebel[3], Anders Nilsson[3], Ifan E.L. Stephens[1], Ib Chorkendorff[1]

1: DTU Fysik; 2: DTU CEN; 3: SLAC (USA)

*Corresponding author email: aavp@fysik.dtu.dk

The sluggish kinetics of the oxygen reduction reaction (ORR) hinders the commercialization of proton exchange membrane fuel cells (PEMFC). The ORR activity could be enhanced by combining Pt with late transition 3d metals (i.e. Fe, Co, Ni, and Cu). However, such alloys are often not stable enough in the corrosive PEMFC environment and suffer from dealloying [1]. In contrast, Pt alloys containing lanthanide metals, such as Pt_5Gd, exhibits high ORR activity and stability [2]. In this work we present the structural and electrochemical characterization of mass-selected platinum-gadolinium alloy nanoparticles (Pt_xGd NPs) as potential oxygen reduction reaction (ORR) electrocatalysts. The alloy nanoparticles are synthesized for the first time using gas aggregation after sputtering of an alloy target under ultra-high vacuum (UHV) conditions [3]. The morphology of the Pt_xGd catalysts is characterized and their catalytic performance towards the ORR is assessed in acidic media using half-cell configuration. As result, the Pt_xGd 8 nm catalyst shows an outstanding performance (3,6 A (mg Pt)$^{-1}$), surpassing our preceding maximum activity reached with Pt_xY NPs catalysts and resulting in the highest activity reported for nanocatalysts based on an acid-leached "Pt-skeleton" structure. In addition, the optimum Pt_xGd catalyst also presents superior stability compared to Pt_xY, as suggested by the long-term stability tests under ORR potential cycling. Extended X-ray Absorption Fine Structure (EXAFS) spectroscopy measurements confirm that as-prepared Pt_xGd NPs are compressively strained relative to pure Pt and that a Pt_xGd core/Pt-rich shell structure is adopted after partial Gd leaching. We proposed that the ORR enhancement accounts for the compressive strain within the Pt shell induced by the alloyed core. Indeed, the estimated strain is used as valid descriptor of the measured ORR activity. The results herein presented confirm the suitability of Pt_xGd NPs as cathode nanocatalysts for proton exchange membrane fuel cells (PEMFCs). In addition, our investigation of sputter-clean polycrystalline Pt-lanthanide and Pt-alkaline earth alloys shows that the compressive strain also controls the activity and stability of bulk catalysts.

References

[1] F. Maillard, L. Dubau, J. Durst, M. Chatenet, J. Andre, E. Rossinot. *Electrochem. Commun.* 12 (2010) 1161.

[2] M. Escudero-Escribano, A. Verdaguer-Casadevall, P. Malacrida, U. Grønbjerg, B. P. Knudsen, A. K. Jepsen, J. Rossmeisl, I. E. L. Stephens, I. Chorkendorff. *J. Am. Chem. Soc.* 134 (2012) 16476.

[3] F. J. Perez-Alonso, D. N. McCarthy, A. Nierhoff, P. Hernandez-Fernandez, C. Strebel, I. E. L. Stephens, J. H. Nielsen, I. Chorkendorff. *Angew. Chem. Int. Ed.* 51 (2012) 4641.

Thin Films of Pt and Pt-Gd as Model Catalysts for Oxygen Electroreduction

Eleonora Zamburlini, Christoffer Mølleskov Pedersen, Paolo Malacrida, Maria Escudero Escribano, Ifan Stephens, Ib Chorkendorff

CINF, Department of Physics, Technical University of Denmark, 2800 Kgs. Lyngby,

Eleza@fysik.dtu.dk

In order to enable the widespread production of fuel cells, the load of platinum in the cathode catalysts must be reduced and the activity must be improved. One way to do so is to fabricate thin films of platinum alloyed with other materials, such as non-precious metals and rare earths. [1] [2] [3]
We know from previous studies that sputter-cleaned, polycrystalline Pt_5Gd shows a five-fold increase in ORR activity [4], relative to Pt at 0.9 V in 0.1 M $HClO_4$, and it is highly stable. [4]
In comparison to those earlier studies on bulk samples, working with thin films will allow a high degree of control over the catalyst composition and thickness, so that we can determine the optimal alloy for high stability and activity.
Herein we present first a preliminary study of the strain in as prepared pure Pt thin film, induced by the deposition process. The structure have been analysed by X-ray diffraction (XRD), in the attempt to link the microstrain and the differences in crystallites to the electrochemical activity towards the ORR.
Furthermore, we will show the fabrication and characterisation of Pt_5Gd alloy thin films, produced via physical sputtering in ultra-high vacuum.
Rotating disk measurements were performed, and the resulting electrochemical activities have been compared with the ones from bulk extended surfaces of polycrystalline platinum alloys.
X-ray photoelectron spectroscopy and XRD were used to investigate the structure and composition before and after electrochemical measurements.
Results show a 3-fold improvement in activity of the thin film Pt_5Gd catalysts compared to the bulk sample, and the physical characterization highlights the formation of an oxygen free alloy, with structure and lattice parameters similar to the polycrystalline Pt_5Gd.

1. H. A. Gasteiger, Shyam S. Kocha, Bhaskar Sompalli, Frederick T. Wagner. *Appl. Catal. B* **2005**, *56*, 9.
2. J. Greeley, I. E. L. Stephens, A. S. Bondarenko, T. P. Johansson, H. A. Hansen, T. F. Jaramillo, J. Rossmeisl, I. Chorkendorff & J. K. Nørskov *Nature Chem*. **2009**, *1*, 552.
3. I. E.S. Stephens, Alexander S. Bondarenko, Ulrik Grønbjerg, Jan Rossmeisl and Ib Chorkendorff *Energy Environ. Sci*. **2012**, *5*, 6744
4. M.Escudero Escribano, A. Verdaguer-Casadevall, P. Malacrida, U. Grønbjerg, B.P. Knudsen, A.K. Jepsen, J. Rossmeisl, I.E.Stephens, I. Chorkendorff *J Am Chem Soc.* **2012**;134(40):16476-9

Impact of thermal annealing onto CO electroreduction at mesoporous Cu electrodeposits

C. Roy[1,2]*, S. Garbarino[1], I. E. L. Stephens [2], I. Chorkendorff [2], and D. Guay[1]

1: INRS-EMT, Canada; 2: DTU Fysik

*Corresponding author email: claroy@dtu.dk

Kanan's research group [1] recently discovered a catalyst that can produce significant amount of EtOH and AcO^- (among other products) by electroreduction of carbon monoxide. Indeed, using copper derived from copper oxide, up to 57% Faradic efficiency was reached for EtOH and AcO^- at potential as low as -0.3 V *vs RHE*. The major reactions occurring during CO reduction are given by the following equations:

$$2CO + 3H_2O + 4e^- \rightarrow CH_3CO_2^- + 3OH^-,\ E^0 = 0.50V$$

$$2CO + 7H_2O + 8e^- \rightarrow CH_3CH_2OH + 8OH^-,\ E^0 = 0.18V$$

Cu is the only catalyst making appreciable amounts of hydrocarbons [2,3] . So, based on Kanan's work, mesoporous Cu structures were synthetized through electrodeposition followed by different annealing processes. The catalysts were then tested for CO reduction.

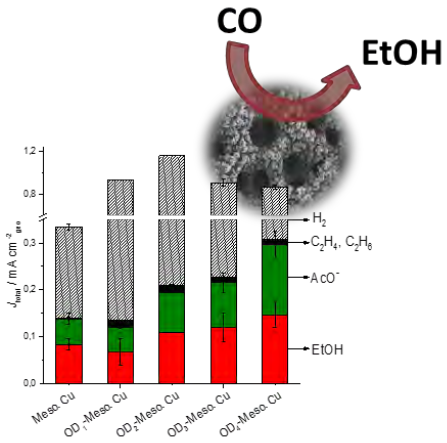


Figure. Comparison of partial current density performed in 0.1 M KOH saturated with CO at -0.25V vs RHE

[1] C. W. Li, J. Ciston, and M. W. Kanan. Electroreduction of carbon monoxide to liquid fuel on oxide-derived nanocrystalline copper. *Nature*, 2014, 508: 504-507.

[2] J. Qiao, Y. Liu, F. Hong, and J. Zhang. A review of catalysts for the electroreduction of carbon dioxide to produce low-carbon fuels. *Chem. Soc. Rev*, 2014, 43: 631-675.

[3] K. P. Kuhl, E. R. Cave, D. N. Abram, and T. F. Jaramillo. New insights into the electrochemical reduction of carbon dioxide on metallic copper surface. *Energy Environ. Sci.*, 2012, 5: 7050-7059.

Session

F

Oral Presentations

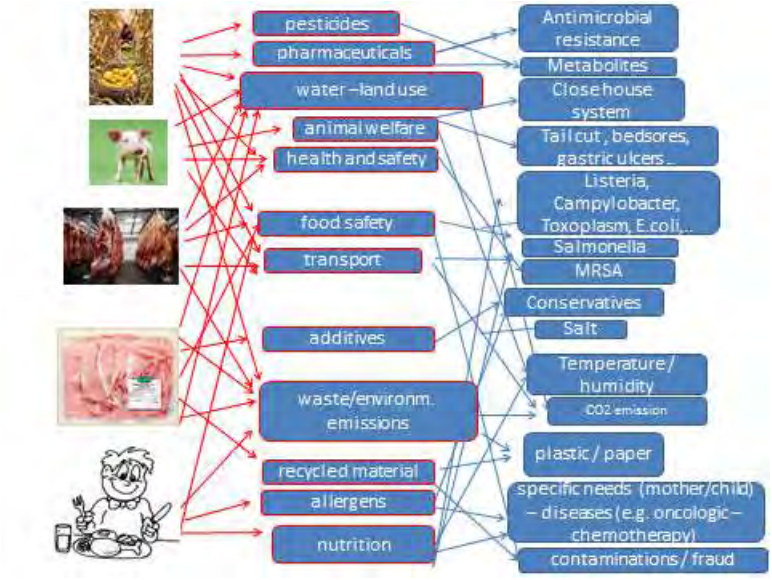
See session details and schedule on
www.sustain.dtu.dk

INTEGRATED FOOD SECURITY: mapping and selecting different indicators and metrics from sustainability till safety, pig product case study

Elena Boriani, Tine Hald DTU GDSI, DTU FOOD *corresponding author: ebor@food.dtu.dk

In food security, integration of data and knowledge across disciplines is needed to prevent food-related diseases, improve sustainability, traceability, quality, animal welfare, diminish food waste, have a clear picture of the environmental impact, improve communication to different stakeholders and introduce nutritional factors considering the enlarging need to "feed the planet". In this study, we propose a map of indicators and metrics along the production and consumption chain from "farm to fork ", in specific for an Italian pork product (Prosciutto cotto-ham), useful for decision making processes. Databases and predictive models are combined in a broad manner to find interconnections, important variables, and potential nodes to assess the overall sustainable nutrition security and improve elements such as traceability, detection of foodborne hazards, nutritious value and communication in every step of the value chain. Sustainability indicators and metrics from Life Cycle Assessment and Risk Assessment are integrated to provide a more holistic assessment of the food chain. Certified products can gain increased credibility from the consumer, if adequate information is provided through all steps in the production chain from primary production to retail. The map considers human health risks (e.g. infectious agents, contaminants), benefits (e.g. nutritional values), environmental impacts (e.g. energy consumption), and social impacts (e.g. in vulnerable population). The map helps to compare products or product chains, to identify critical steps, and to observe the problems, risks or benefit from several different perspectives.

Fig 1: Extract of indicators and metrics along the food chain and their interdependencies



De Roest K., Pignedoli S., Belletti G., Menozzi D., Arfini F. (2014). Glamur project Italian case study: local and global cured ham chains. CRPA.

Lake I.R., Hooper L., Abdelhamid A., Bentham G., Boxall A.B.A., Draper A., Fairweather-Tait S., Hulme M., Hunter P.R., Nichols G., Waldron K.W. (2012), Climate Change and Food Security: Health Impacts in Developed Countries . Environmental Health Perspectives. Vol.120, num.11.

Waste management in food production

Zaza Nadja Lee Hansen*[1], Peter Jacobsen[1]

1: DTU Management

*Corresponding author email: znlh@dtu.dk

Raw materials in industrial food production have traditionally been cheap. As a consequence the focus has been on efficiency. Waste management, recycling material and other sustainable concerns has first recently entered into the production concerns for this sector.

Figure: 1: Waste material due to height differences on the belt (fixed with the fellow fork truck)

In this industry the need for quick action, due to the perishable nature of the raw materials and partly finished goods, as well as the need for hygiene and other food safety requirements, means that it is normal to have waste margins up to 20% per batch as it is considered better to save 80% by throwing out 20%.

The challenge is to present a new production paradigm which focus on sustainable yet competitive industrial food production initiatives. Some of the ideas we will present for this include:

1. Automated quality control
2. Documented workflow descriptions
3. Embedded lean philosophy
4. Improved sales and operations planning process
5. Improved supply chain management
6. Improved sustainability awareness in the industry

The goal is to develop a sustainable production framework which considers the unique characteristics of industrial food production. This framework should consider the embedded nature of production as detailed above, including sales and operations planning, supply chain management and organizational structures. We wish to test this framework in several SME and large industrial food companies in Denmark and after implementing their feedback we wish to publish the framework as a guide to the industry as a whole.

Emulsifying and antioxidant properties of fish protein hydrolysates obtained from discarded species: evaluation on fish oil-in-water emulsions

Pedro J. García-Moreno*[1], Antonio Guadix[2], Emilia M. Guadix[2], Charlotte Jacobsen[1]

1: DTU Food; 2: Department of Chemical Engineering, University of Granada, Spain

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

Fish discards are that portion of the catch (e.g. non-target species, small specimens, etc.) not retained on board and returned to the sea. Due to the fact that most of discards are dead or dying when returned to the sea, they not only represent an irresponsible underutilization of marine stocks, but also they have a negative impact on marine ecosystem [1]. Thus, the European Commission is currently undertaking a depth reform in common fisheries policy, adopting a set of measures towards the complete elimination of discards in EU fisheries, the so-called zero-discard policy [2]. Nevertheless, discards bans must be accompanied with the production of added-value products from this non-commercial material which must be totally landed. In this context, enzymatic hydrolysis of the protein fraction of discards is a convenient up-grading process, since fish protein hydrolysates (FPH) can be used as emulsifier in food applications due to their recognized emulsifying and antioxidant properties [3].

This study aimed to investigate the emulsifying and antioxidant properties of FPH for the physical and oxidative stabilization of 5 wt% fish oil-in-water emulsions. Fish oil-in-water emulsions were used since they are normally employed as delivery systems for the enrichment of food in omega-3 polyunsaturated fatty acids. FPH with different degree of hydrolysis (DH: 3, 4, 5, and 6%) were produced from muscle proteins of discarded species such as sardine (*Sardina pilchardus*) and small-spotted catshark (*Scyliorhinus canicula*). Sardine hydrolysates with low DH, 3 and 4%, presented the most effective peptides to physically stabilize emulsions with smaller droplet size. This implied more protein adsorbed at the interface with capacity to scavenge free radicals. This fact might be also responsible for the higher oxidative stability of these emulsions, as shown by their lowest peroxide value and concentration of volatiles such as 1-penten-3-one and 1-penten-3-ol. Among the hydrolysates prepared from small-spotted catshark only the hydrolysate with DH 3% yielded a physically stable emulsion with low concentration of unsaturated aldehydes. These results show the potential of FPH as alternative protein emulsifiers for the production of oxidatively stable fish oil-in-water emulsions.

[1] Kelleher, K. (2005). Discards in the world's marine fisheries: An update. FAO. Fisheries Technical Paper.

[2] Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the common fisheries policy.

[3] Klompong, V., Benjakul, S., Kantachote, D., & Shahidi, F. (2007). Antioxidative activity and functional properties of protein hydrolysate of yellow stripe trevally (Selaroides leptolepis) as influenced by the degree of hydrolysis and enzyme type. Food Chemistry, 102, 1317-1327.

Microalgal bioremediation of nutrients in wastewater and production of food/feed ingredients

Hamed Safafar[1]*, Per Møller[2], Susan Løvstad Holdt[1], Charlotte Jacobsen[1]

1: DTU food; 2: Eco Lipids, Jyderup, Denmark
*hasaf@food.dtu.dk

Microalgal bioremediation (Phycoremediation) is a green process for removing nutrients from wastewater; diminish the pollution load and producing biomass which can be used as an ingredient in food/feed. Compared to conventional treatment processes it is a sustainable and economical technology for treating wastewater. Microalgae have great potential for the removal of carbon dioxide from flue gas and nutrients such as nitrogen and phosphorus from wastewater, providing a sustainable solution to the challenge of environmental pollution. Many industrial processes produce contaminated waste water capable of causing serious ecological harm if released into the environment without suitable pre-treatment. Algal bioremediation of agro-industrial waste water streams from intensive production activities, such as aquaculture, piggeries and food production, is capable of producing commercial volumes of algae biomass suitable for human and animal nutrition. Micro-algae are already used as sources of nutrition for humans and animals.

In this study, the phycoremediation of some microalgae species including *Nannochloropsis salina, Nannochloropsis limnetica, Desmodesmus sp., Chlorella vulgaris, Chlorella pyrenoidosa* and *Chlorella minutissima* was investigated in a batch culture medium containing different levels of industrial waste water. Nutrient uptake, optical density, biomass yield and chemical composition including protein (amino acid), lipids (fatty acids), tocopherols and carotenoids were analyzed during the course of cultivation.

Green algae were found as the most efficient in phycoremediation. *Chlorella minutissima, Chlorella vulgaris, Chlorella pyrenoidosa and Desmodesmus sp.* grew well on 100% industrial waste water and can therefore be used for phycoremediation purposes. The removal efficiency in all of them was high. Results also show that Chlorella spp. biomass contained higher amounts of protein (52%), Chlorella spp. biomass contained the highest amount of protein (52%), suggesting a future potential as protein source in the feed industry. Moreover, *Nannochloropsis salina* produce highest amounts of fat (40%) and EPA content (38%) when it is being cultivated on a mix of industrial waste water and normal growth media. This study also presents data on a wild type of *Desmodesmus sp.,* isolated from Kalundborg water treatment system, which showed the highest biomass production and growth rate when grown on 100% industrial waste water.

Evaluation of the Danish cultivated sugarkelp as possible future source of ingredients such as minerals and pigments

Susan L. Holdt*[1], Goncalo S. Marinho[2], Jens J. Sloth[1], Hamed Safafar[1], Jette Jakobsen[1], Irini Angelidaki[2]

1: DTU Food; 2: DTU Environment
*suho@food.dtu.dk

The seaweed *Saccharina latissima* (sugarkelp) is cultivated near a fish and mussel farm, Hjarnø Havbrug A/S near Horsens Fjord in Denmark (Figure 1). The sugarkelp is cultivated commercially for the bioremediation (waste water management) of especially nitrogen, and the valuable biomass then sold and used for various purposes such as food or potentially as a feed supplement. Generally, seaweed is known for their nutraceutical application, but also for being able to accumulate e.g. very high iodine concentrations and unwanted heavy metals (Holdt and Kraan, 2011). In this study, the year-round minerals (incl. trace and heavy metals), pigments and vitamins (vit A and E), were analysed to evaluate the nutritional value, possible risks and harvest time of the *S. latissima* biomass for optimized value and application.

Rope cultivated sugarkelp was sampled both in close proximity to a blue mussel and fish farm (IMTA; see Figure 1) and in a reference/control site, both outside Horsens fjord in Denmark. Sugarkelp biomass was measured from 1m rope droppers (n=3) at 2 m depth in 2013-2014 (deployed in February 2013). Biomass was weighed, followed by freeze drying, homogenizing, frozen before further chemical characterization by various methods for the specific analyses of biomass composition.

Surprisingly high concentrations of potassium (K) and calcium (Ca) were found in the sugarkelp, and also the other trace metals Cr, Fe, Mn, Co, P, Na, Zn, and Se were found. The unwanted elements such as Cu, Hg, As, and inorganic arsenic were below legislative threshold values, whereas a few samples of Cd and Pb were problematic in some seasons, but not considering the recommended daily intake. The iodine was found in so high levels (up to 5 g/kg) that this will be the limiting element for the daily recommended intake of sugarkelp. The pigment profile did not change during the year, however the concentration did, and with fucoxanthin as the most interesting. Generally the year-round variations were due season, and not between the two locations (reference and IMTA), so harvest time are important for optimized use, and may be conflicting with highest yields of sugarkelp.

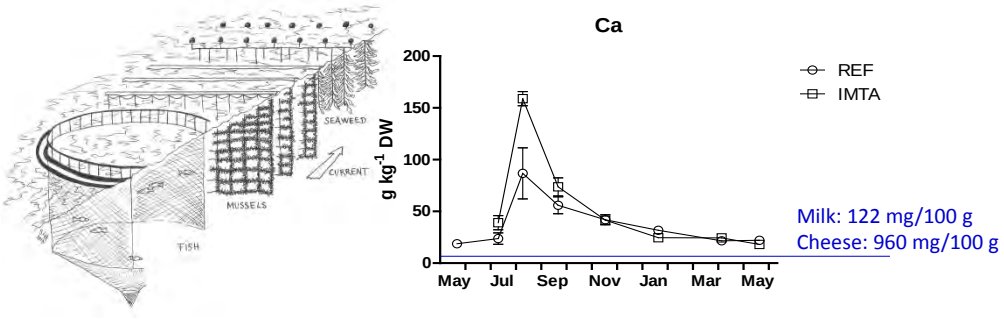


Fig. 1 Left: Integrated Multi-trophic Aquaculture with the fed organisms (fish), filtrating (mussels) and assimilating (seaweed) organisms combined. Right: Year-round calcium contentration (g/kg dry weight) of the sugarkelp. Levels of calcium from milk and cheese are inserted for comparison (source: www.foodcomp.dk).

Reference: Holdt, S.L., Kraan, S. (2011). Bioactive compounds in seaweed: functional food applications and legislation. *Journal of Applied Phycology*, 23, 543-597

Fisheries Management: Is Europe turning the corner?

Pr. Clara Ulrich*

DTU Aqua

*Corresponding author email: clu@aqua.dtu.dk

This speech title, borrowed from Australian T. Smith (2013), illustrates what nobody thought would be possible just few years ago: Europe is on the path towards successful fisheries management and recovery of fish stocks, after decades of bad news. This positive development hasn't come on its own though, and to a very large extent it can be attributed to political changes, rather than natural changes. A better application of standard management tools in the last ten years has first halted the decline. But importantly, Europe is also increasingly aiming to modern and ambitious management tools, which revolutionize the principles and the means that govern fisheries. The 2013 Reform of the Common Fishery Policy aims to implement, among others, MSY-based (Maximum Sustainable Yield) management objectives, mixed-fisheries management plans, a ban on discarding of commercial fish, catch quota management, regionalisation, and results-based management instead of technical rules; all of them contributing to making fisheries management more effective, more holistic and better complied with.

Should these goals be successful, amazing progresses will have been achieved. But the path to each of these new paradigms is individually long and difficult; and when changing them all together at the same time, the risks of failure are real. In this talk, I will provide a global overview on what is going on around us, which successes have been achieved where and why, and what are the main threats and hurdles that deserve specific attention over the next few years.

Ref:

Smith, Anthony D M, 2013. Fishery Management: Is Europe Turning the Corner? Current Biology — 2013, Volume 23, Issue 15, pp. R661-R662

Resilience and reactivity of global food security

Samir Suweis[1], Joel A. Carr[2], Amos Maritan[1], Andrea Rinaldo[3,*], and Paolo D'Odorico[2]

1: Add short affiliations as DTU Management; 2: DTU Environment; 3: DTU Fysik

*Corresponding author email: andrea.rinaldo@epfl.ch.

The escalating food demand by a growing and increasingly affluent global population is placing unprecedented pressure on the limited land and water resources of the planet, underpinning concerns over global food security and its sensitivity to shocks arising from environmental fluctuations, trade policies, and market volatility. Here, we use country-specific demographic records along with food production and trade data for the past 25 y to evaluate the stability and reactivity of the relationship between population dynamics and food availability. We develop a framework for the assessment of the resilience and the reactivity of the coupled population–food system and suggest that over the past two decades both its sensitivity to external perturbations and susceptibility to instability have increased.

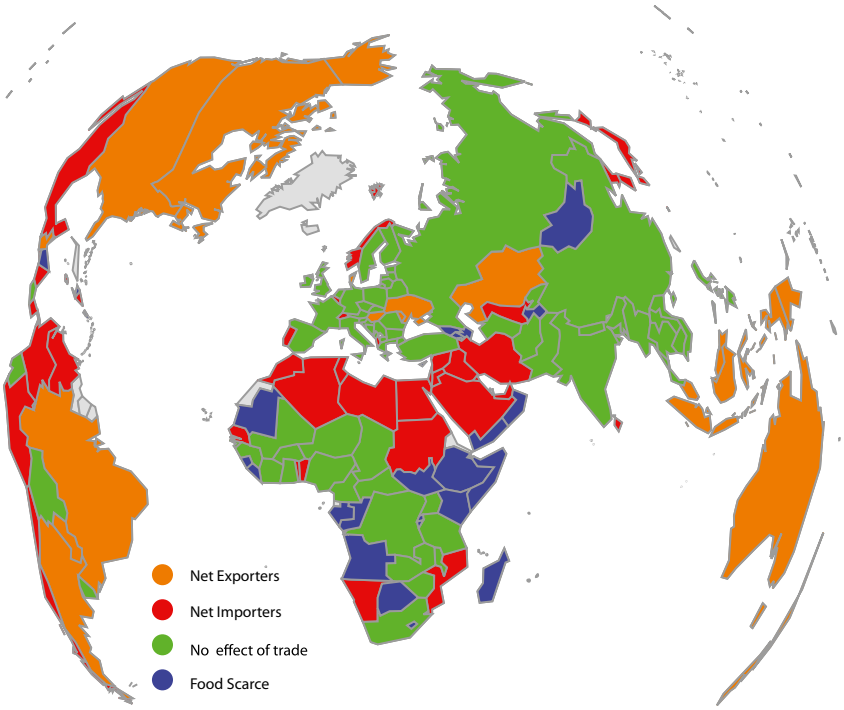


Figure: Map displaying the geographic distribution of countries belonging to the four groups: (A) Exporting countries whose food trade has an impact on the carrying capacity. (B) Trade-dependent countries where population relies on food available through both domestic production and trade (import). (C) Countries where the impact of trade on food availability is negligible. (D) Countries exhibiting clear signs of food limitation as evidenced by the poorer diets.

Reference: Suweis, Samir, et al. "Resilience and reactivity of global food security." Proceedings of the National Academy of Sciences (2015): 201507366.

Session

F

Laptop Presentations

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

Network analysis of food risks and crises in the global seafood market

Patrizio Mariani[*1], Christian Mullon[2], Matt Burgess[3] Samir Sweiss[4]

1: DTU Aqua; 2: Institute for Research and Development, Sete, France; 3: Uni. California, Santa Barbara, USA 4: Uni. Padova, Italy

*Corresponding author email: pat@aqua.dtu.dk

Over the last decades we have been assisting to the sharp increase in global interchanges of goods, services, ideas and cultures, in a process known as globalization. This is on-going process acting at the global scale and one of it's the major aspects is the development of international trades for primary goods such as energy, raw materials and food. Demand and consumption of those commodities are then dependent from a large set of interactions, which involves multiple actors in different part of the world. Hence, changes in some local market or area can have cascading effects on other distant markets with global effects and dynamics that will depend on the complexity of the global network.

This can often give rise to price volatility for some of these commodities in specific markets thus generating effects on the societies exposed to such fluctuations. In particular, over the last 10 years there has been a sharp increase in price volatility of several food products that are traded at international level and among those seafood products appear to be the most volatile. Moreover, it is also expected that the global food system will come under strong pressure from the combined effects of several fundamental factors, including population growth, energy, land demand and climate change To match the supply and demand of food products and then to guarantee food security is therefore important to assess how trades and prices can respond to those pressures and identify resilience and stability of the global food trade network.

To describe some of those dynamics we consider a minimal model for the global seafood market, which is described by a set of producers (e.g., fishery), distributed consumers and set of global suppliers that are able to trade and distribute the commodity over the global market network. Different markets are linked in the network and we consider cost related to production, distribution and consumption of the seafood. Each actor in the network will have different goal functions that they will try to maximize, but their best strategy will depend from the strategies of the other players. We use then a game theoretical approach to establish the equilibrium on the network, which is the set of strategies that maximize the gain for all players.

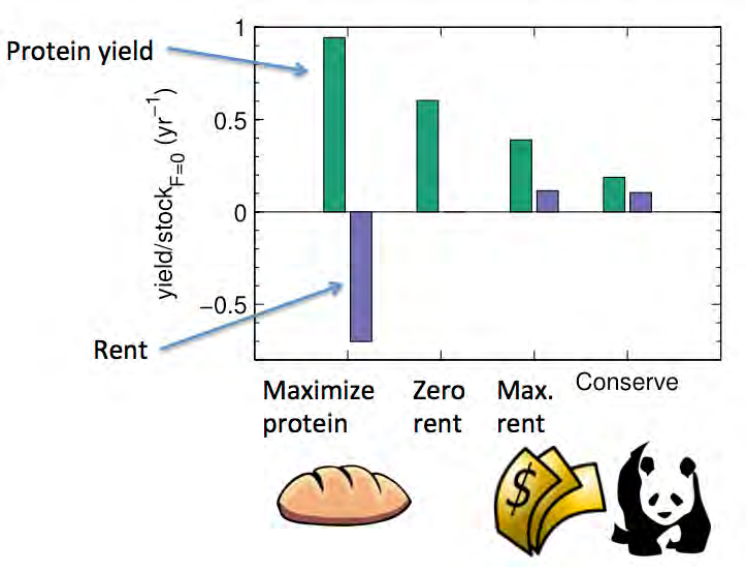
Maximum sustainable yield from fisheries: food production, resource rent and conservation

Ken H. Andersen[1*], Keith Brander[1], Lars Ravn-Jonsen[3]

1: DTU Aqua; 2: Department of Environmental and Business Economics, SDU

*Corresponding author email: kha@aqua.dtu.dk

Marine fisheries contribute about 17% of human protein consumption with a year global turnover on the order of 100 billion euro. The strategic objectives for managing fisheries, enshrined in international conventions, is to maintain or restore stocks to produce Maximum Sustainable Yield (MSY) and implement the ecosystem approach requiring that conservation constraints be respected. While the yield and conservation aims are to some extent compatible when a fishery for a single species is considered, species interactions entail that MSY for a species depends on the species with which it interacts and the yield and conservation objectives therefore conflict when an ecosystem approach to fisheries management is required. We apply a conceptual size- and trait-based model to clarify and resolve these issues, by determining the fishing pattern that maximizes the total yield of an entire fish community in terms of catch weight or economic rent under acceptable conservation constraints. Our results indicate that the eradication of large, predatory fish species results in a potential maximum catch at least four times as high as when conservation constraints are imposed. However, such a large catch could only be achieved at a cost of forgone rent; maximum rent extracts less than half of the potential maximum catch weight. When a conservation constraint is applied, catch can be maximized at negligible cost in forgone rent, compared with maximizing rent. Maximization of rent is the objective that comes closest to respecting conservation concerns.



Session

F

Poster Presentations

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

DTU's Sustain Conference

Food waste generation in office areas at DTU

Maklawe Essonanawe Edjabou, Alessio Boldring, Charlotte Scheutz, Thomas Fruergaard Astrup

Department of Environmental Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark

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

As a response to the growing pressure on the supply chains, developing a resource-efficient circular economy will be fundamental to satisfy the future demands for material resources. In this context, the Danish Government, in 2013, launched its Resource Strategy Plan, mandating that, by 2018 at least 60% of food waste – that cannot be prevented or reduced –generated by service sector, including in office areas, should be source-sorted and collected separately. In order to establish the baseline of the current situation, and to allow for any evaluation of performance against target indicators, data on solid waste generation and composition are required.

The overall aim of this study was to quantify the potential for source-sorted food waste in office areas, by quantifying food waste generation rates, source sorting efficiencies and the purity of sorted fractions. Additionally, temporal variations of food waste was investigated and biochemical methane potential of the collected source-sorted food waste were determined.

This study was carried out in the office areas of the Department of Environmental Engineering at Technical University of Denmark. In the course of this study, two plastic waste bins of 60 L each were placed in the kitchens: food waste bins and residual waste bins. Food waste and residual waste from these kitchens were collected and weighed separately, on a daily basis, during 133 working days (29 weeks). Furthermore, waste composition analyses were conducted every week to investigate the efficiency of the source-sorting campaign and the purity of the source-sorted food waste.

The result showed that food waste generation amounted to 23 ± 5 kg/employee/year, of which 20 ± 5 kg/employee/year was source-sorted, with a considerably high purity of 99%. Residual waste amounted to 10 ± 5 kg/employee/year and consisted mainly of paper (29 ± 13%), plastic (23 ± 9%) and missorted food waste (24 ± 16%). The waste generation rates were not significantly influenced by the seasonal variation, however, we found a significant difference in generation rates on weekdays. The methane potential of source-sorted food waste was 463 ± 42mL CH4/g VS. These results show that food waste in office areas offers promising potential for relatively easily collectable and pure source-sorted food waste, suggesting that recycling targets for food waste could be achieved with reasonable logistical ease in office areas.

Organic micropollutants in sugar beets cultivated in sludge amended soil

Eriksson E.*[1], Hörsing M.[2], Ledin A.[2]

1: DTU Environment, 2: Lund University, Sweden, *Corresponding author email: evek@env.dtu.dk

The world's phosphate resources are debated, and phosphorus conservation and recycling such as municipal sewage sludge is suggested as a plentiful source for nutrients, in particular primary macronutrients phosphorus (P) and nitrogen (N), as well as three secondary macronutrients: calcium (Ca), sulfur (S), magnesium (Mg). At the same time the sludge may contain organic micropollutants derived from industries and households that are unwanted in sludge intended for bio-fertilization of crops. Here the aim was to evaluate the risk exerted by organic micropollutants when sewage sludge was used as fertilizer. The chosen crop, sugar beet (Beta vulgaris) is cultivated for its high concentration of sucrose. It's grown commercially, and accounts for 20% of the world's sugar production (The Food and Agriculture Organization, 2009). The case site has been subjected to sludge amendments since 1981, and chemical analyses of 29 organic micropollutants were conducted in soil, sugar beet root and sugar beet leaves (Hörsing et al. 2014). In the sludge amended soil, none of the micropollutants was observed in quantifiable levels. In the sugar beet roots were the branched phenols (nonyl and octyl phenols) present where the soil had been fertilized with sewage sludge and with mineral fertilizer. Polycyclic aromatic hydrocarbons (PAHs) in sugar beet leaves uniformly distributed in sludge amended and unamended fields, thus, the source for them were most likely atmospheric deposition, Figure 1. Chemical fingerprinting of the PAHs confirmed that they originated from traffic. A person of 60 kg needs to consume 34 kg of sugar beet root per day in order to be at risk with respect to Tolerable daily intake (TDI). The distances between highways and agricultural fields are not to be disregarded as PAHs were present here although the distances were more than 600 meters. Vegetable screens such as acoustical barriers may be needed to safe guard leaf vegetables.

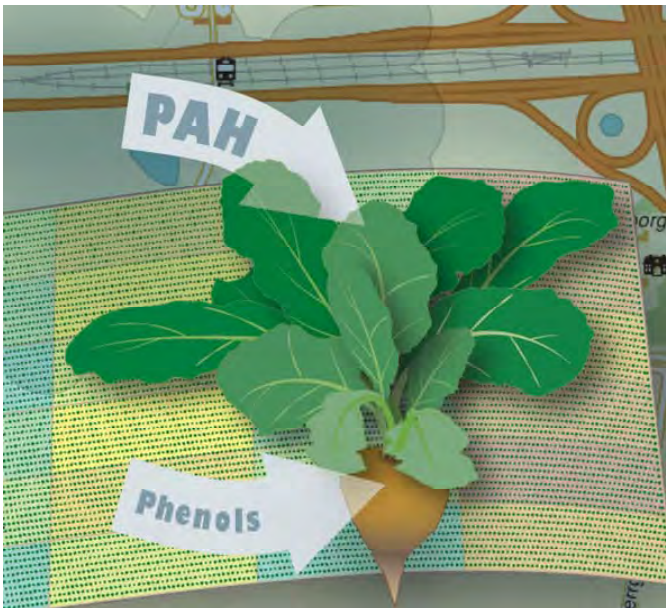


Figure 1. Micropollutant flux into sugar beets

References:

Hörsing M., Eriksson E., Gissén, C., la Cour Jansen J., Ledin A. (2014) Organiska miljögifter i sockerbetor och blast odlade på mark gödslad med kommunalt avloppsslam. Rapport nr 2014-12. Svenskt Vatten Utveckling; http://vav.griffel.net/filer/SVU-rapport_2014-12.pdf

The Food and Agriculture Organization (2009) The Agribusiness Handbook: Sugar beet white sugar; http://www.eastagri.org/publications/pub_docs/4_Sugar_web.pdf

Production of omega-3 rich fish oil from by-products of Danish trout farms

P.J. Honold, M.L. Nouard, C. Jacobsen*

DTU FOOD, Division for Food Technology, Research Group for Bioactives – Analysis and Application

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

Rainbow trout is the main species produced in Danish fresh water farming. Filleting by-products as head, bones, tail and intestine is at present turned into ensilage and sold to the mink industry with low revenue. To create more value from the trout filleting, by-products could be used for the production of fish oil suitable for human consumption. Production of fish oil from by-products involves: mincing of the raw material, heating, separation in a three phased decanter centrifuge, reheating of the oil fraction before a final separation of oil and residual water. The aim of this study is to investigate the effect of the processing temperature during extraction on the oxidative stability of fish oil produced from fish by-products. We investigated the effect of varying processing temperatures (70/90°C) in different steps during extraction. The raw material and crude oil were characterized by lipid content, fatty acid profile, free fatty acids and tocopherol. The oxidative status was assessed by measurement of primary oxidation products (peroxide value) and secondary volatile secondary oxidation products (anisidine value and determination of volatiles by dynamic headspace GC-MS) and an accelerated oxidation test. Secondly, we investigated the effect of temperature on the two fractions processed together. The effect of high and low omega-3 content in the raw material on the oxidative stability was also evaluated. Findings showed that the natural variation between production days influenced the quality of the produced oil to a high extent. The temperature was found to play a minor role regarding oxidative quality of the produced oil. However, the omega-3 fatty acid content of the raw material influenced the oil quality. Oil with a high content of omega-3 fatty acid showed higher degree of oxidation.

References

Honold, P.J., Nouard, M.L. and Jacobsen, C., Fish oil extracted from fish-fillet by-products is weakly linked to the extraction temperatures but strongly linked to the omega-3 content of the raw material. Eur. J. Lipid Sci. Technol. 2015, 117

Marine eutrophication impacts from present and future production of spring barley

Nuno Cosme * and Monia Niero *

DTU Management Engineering

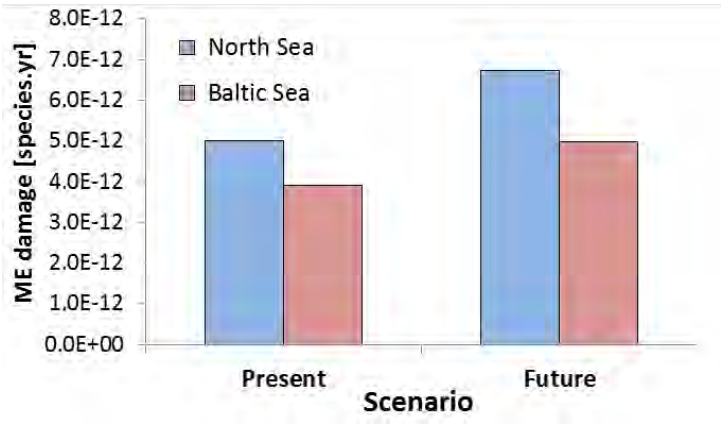
*Corresponding authors emails: nmdc@dtu.dk (N. Cosme), monni@dtu.dk (M. Niero)

Agricultural activity is the main driver for environmental emissions of nutrients. The need to increase its productivity to feed a growing population, the predicted increasing use of fertilizers, and future climatic pressures anticipate larger nutrient emissions to the environment. These originate from the surplus of fertilizers applied over plants assimilation and may cause freshwater (mainly phosphorus, P) and marine eutrophication (mainly nitrogen, N).

We applied the LC-IMPACT methodology [1] modified with recent developments [2] [3] to estimate the marine eutrophication impacts of N enrichment in a case-study that is representative of spring barley production in Denmark [4]. The modelled emission routes from the agricultural field compartment include airborne transport and deposition of volatile N-forms (NH_3 and NO_x) and waterborne transport of N through freshwater systems, to the North Sea and Baltic Sea.

Emissions inventory data was also obtained for a scenario under future climatic conditions, with crop yields estimated from experiments mimicking a worst case climate scenario, i.e. double carbon dioxide concentration and 5°C temperature increase. Impact assessment of the future scenario was modified to represent the parameterization of expected changes in fate, exposure and effects modelling [5].

Preliminary results of endpoint impacts (species.yr) [5] show 29% larger impacts to the Baltic Sea in the present scenario and an increase of 34% (North Sea) and 28% (Baltic Sea) in the future scenario. The results are justified by reduced agriculture yield [4] [6], and increased emissions and species sensitivity [5]. Using LCA indicators we can estimate (the magnitude of) the effects of future climatic changes and anticipate (some of) the impacts, so that responses may be implement sooner. In this line, LCIA indicators give valuable information to decision support.



References

(1) Azevedo LB, Cosme N, Hauschild MZ, et al. (2013), FP7 (243827 FP7- ENV-2009-1) LC-IMPACT report. 154 pp.
(2) Cosme N, Koski M, Hauschild MZ (2015), Ecol. Modell. 317, 50–63.
(3) Cosme N, Hauschild MZ (submitted), Ecol. Indic.
(4) Niero M, Ingvordsen, CH, Hauschild MZ et al. (2015), Agric. Syst. 136, 46–60.
(5) Cosme N, Niero M (submitted), J. Clean. Prod.
(6) Niero M, Ingvordsen CH, Jørgensen RB, Hauschild MZ (2015), J. Clean. Prod. 107, 693–706.

Rapid determination of ^{90}Sr from ^{90}Y in Marine Fish

Kai Xu*[1], Per Roos[1]

1 Center for Nuclear Technologies, DTU

*Corresponding author email: kaixu@dtu.dk

Abstract: A rapid method for indirect determination of ^{90}Sr from its progeny ^{90}Y in Marine fish is developed. The method employs a fast and effective two-step co-precipitation followed by leaching ash of fish through 8M HNO_3 .Comparing conventional approach using vast fuming nitric acid, the novel co-precipitation technique removing excessive calcium of the flesh of marine fish is an environmentally friendly and sustaining procedure. And the rapid determination enables sequential measurement of ^{90}Y by both Cerenkov counting liquid scintillation assay (LSA) and gas-flow anti-coincidence shielded GM-counting. Mean chemical recovery is 60 ± 7 %. Sample preparation time is estimated to be<4 h for a set of four samples(not including ashing time). The minimum detectable concentration of ^{90}Y measured LSA techniques is 0.23 Bq kg^{-1}, for 5,17 kg mackerel and 2,5 h counting time on a liquid scintillation counter. Method performance evaluation demonstrated excellent results.

Keywords: Marine Fish, ^{90}Sr , ^{90}Y, Co-precipitation, Purification, Liquid Scintillation Assay

Economic and environmental benefits from integrating Aquaculture and Agriculture (IAA) in Ghana - presentation of system setup

Nelson Agbo*[1], Benjamin B. Campion[1], Daniel Adjei-Boateng[1], Regina Edziyie[1], Raymond Djangma[1], Peter Skov[2,] Morten Birkved[3], Arne Wangel[3]

[1]Department of Fisheries and Watershed Management, Kwame Nkrumah University of Science and Technology (KNUST); [2] DTU Aqua, Technical University of Denmark; [3]DTU Management Engineering, Technical University of Denmark

*Corresponding author email: nelagbo@yahoo.co.uk

A team of researchers of the Department of Fisheries and Watershed Management, Kwame Nkrumah University of Science and Technology (KNUST)[1], Ghana, has developed methods for integrating vegetable production with fish farmers' pond production cycle as test farming systems on the KNUST campus, Kumasi. Based on experiences from Asia and Africa, this article explains how the integrated aquaculture and agriculture system (IAA) maximizes the use of land, water, nutrients and labour with the aim of increasing farmer income and lower environmental impacts. Three different production scenarios have been defined for evaluation: (1) rainy season production, (2) dry season production, and (3) end of the fish cycle production. Fish and vegetable farmers participated in a field survey and a stakeholder workshop in order to provide feedback on the feasibility of the three scenarios. The system setup presented in this paper has been designed to optimize the economic and environmental performance of the IAA scenarios during a full one year fish and vegetable production cycle at the test site on KNUST campus. The subsequent data analysis will reveal to what extent this potential can be realized in each scenario.

This article concludes that IAA offers a better potential to improve the productivity of fish farmers in peri-urban areas with easy access to local markets, as compared to a simple expansion of anon-integrated pond area. However, the stakeholder discussions also revealed that collaborative arrangements between fish and vegetable farmers may be difficult due to mistrust. Rather, pond owners may offer their farmhands more work for a share in the harvested vegetables. In Ghana, aquaculture is run as a business, and less as a source of subsistence therefore, the entry barrier remains significant for smallholders.

Selected references

Campion, B. B. & Owusu-Boateng, G. 2013. The Political Ecology of Wetlands in Kumasi, Ghana. International Journal of Environment and Bioenergy, 7(2): 108-128.

Kassam, L. 2014. Aquaculture and food security, poverty alleviation and nutrition in Ghana: Case study prepared for Food Security, Poverty Alleviation and Nutrition project. WorldFish, Penang, Malaysia. Project Report: 2014-48.

Ofori, J .K. (2000). Status and trends in integrated agriculture-aquaculture in Ghana, p. 36-37. In: E.K Abban, C.M.V: Casal, T.M. Falk and R.S.V: Pullin (eds.) Biodiversity and sustainable use of fish in the coastal zone. ICLARM Conference Proceedings 63, 71 p.

[1] Kwame Nkrumah University of Science and Technology and Technical University of Denmark are partners in the project *Knowledge Sharing, Research Dissemination and Communication* which is part of *the Building Stronger Universities in developing countries* (BSU) programme funded by the Danish Development Agency (DANIDA).

Brewing with 100% unmalted grains

Shiwen Zhuang*, Radhakrishna Shetty, Mikkel Hansen, Preben Bøje Hansen, Tim John Hobley

DTU Food (DTU Brewery)

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

Beer is traditionally produced from malted barley, however, with commerical enzymes great beers could be made from 100% unmalted barley. Avoiding malting can save ca. 8g CO_2 emission per 33cl beer and reduce 7% land use, leading to reduced industrial cost, optimised raw material utilisation and improved productivity. Whilst brewing with 100% unmalted barley has been well-established, brewing performance using other raw materials remains mostly unknown. The purpose of this study was to investigate the potential of brewing with 100% unmalted oat, wheat and rye, and to compare their brewing performances to 100% barley and malt. To address this, five different ingredients (oat, wheat, rye, barley and malt) were processed to mimic industrial brewing process, including milling, mashing (a 13L DTU-patented mashing system), boiling, fermentation and maturation. Full comparisons were made between raw ingredients, wort attributes and beer qualities; in particular, flavour profiles of the five beers were analysed using headspace GC-MS. It is anticipated that this study will provide a greater understanding of brewing performance using 100% unmalted grains, potentially leading to process optimisation and new products in future.

100% unmalted grains

DTU-patented mashing system

Reference

Steiner E., et al J Sci Food Agric 2012; 92: 803-813
Aastrup, S. (2010). Scandinavian Brewers' Review 67 (4): 28-33
Bamforth, CW. 2009. Journal of Cereal Science, 50 (3), 305-414
Bamforth, CW. 2001. Brewer International, 1 (2): 26-29
Aastrup, S & Hannemann, W. 1999. MBAA Congress. Keystone

Session

G

Oral Presentations

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

Maturing the sustainability performance of manufacturing companies

Daniela C. A. Pigosso[1*], Tim C. McAloone[2]

1: DTU MEK; 2: DTU MEK
*Corresponding author email: danpi@dtu.dk

Product development (PD) is a key business process for sustainability integration into manufacturing companies: around 90% of the environmental, economic and social impacts across a product life cycle are determined in the initial phases of PD. Despite recognizing the needs and benefits, companies still face various challenges for an effective, consistent and successful implementation of sustainability into PD.

In order to support companies in the managerial integration of sustainability into PD and related processes (such as marketing, purchasing and manufacturing), the Ecodesign Maturity Model (EcoM2) has been developed and tested in a varied set of large manufacturing companies, such as Grundfos and Coloplast.

The EcoM2 is composed by a comprehensive body of knowledge of more than 700 sustainability best practices, organized in five maturity levels. The maturity levels represent successive stages for incorporating sustainability into business processes.

The EcoM2 application starts with a diagnosis of the current maturity profile ("as-is") and definition of strategic goals for implementation ("to-be") (Figure 1). Based on the gap between the "to-be" and "as-is" maturity profiles, strategic roadmaps and actions plans are deployed based on the EcoM2 body of knowledge of best practices and on the defined maturity levels. Subsequently, the projects are planned and implemented with special consideration of Change Management. The results of each project are continually evaluated throughout the improvement cycle, which is finalized by a new diagnosis that will evidence the achievements and allow the identification of other projects to be implemented towards higher maturity profiles.

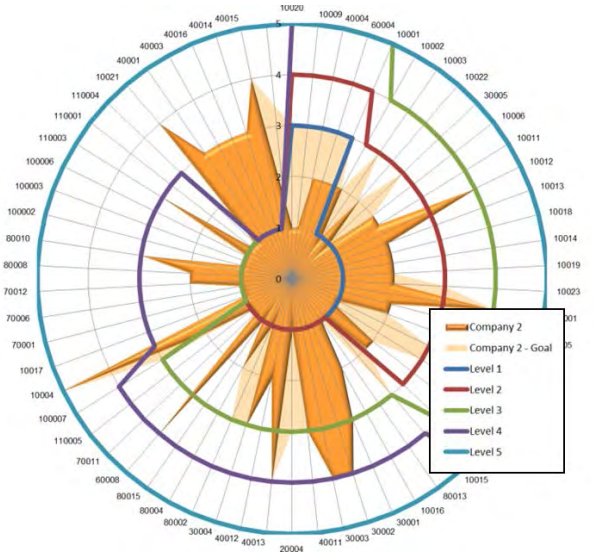


Figure1: Example of a maturity profile of a company – the maturity profile measures the integration of sustainability into product development and related processes

Further developments of the EcoM2 includes the development of a recognition scheme for companies involved in the EcoM2 implementation, which will allow a direct communication to the main stakeholders and increased competitive advantages. Furthermore, best practices for shared value, social innovation and product/service systems are being explored to broaden the focus of the EcoM2 to new areas.

Value Propositions for Sustainable Businesses

By

CEO Bjarne Henning Jensen

SDTI A/S, Cortex Park 26.2, DK-5230 Odense M. Denmark

Summary

Business cases based on novel and sustainable technologies present a dilemma, as the sustainability premium, although widely recognized, is hard to capitalize. Hence such business cases have simultaneously to be attractive both with and without the sustainability premium taken into account in order to be realized.

The business cases based on novel and sustainable technologies are often also characterized by high initial capex and low opex. Although being very competitive in a life cycle economy perspective, such business cases suffer from lack of investor interest.

Products and services which are based on sustainable technologies hence needs to have two dimensional value propositions, covering both the traditional commercial profile and the sustainable profile in order to gain market acceptance.

Examples on business cases and proposals to value propositions for sustainable technologies are given.

Bridging the Valley-of-Death – Demonstration projects' role in advancing sustainable energy and transport technologies.

Per Dannemand Andersen*[1], Dorothy Sutherland Olsen[2],

1: DTU Management Engineering; 2: NIFU, Norway, *Corresponding author: pean@dtu.dk

There is a growing interest within industry, policy making and academia in the role of demonstration project in developing and implementing to sustainable energy and transport technologies. The reason for this interest is that demonstration projects "*shorten the time within which a specific technology makes its way from development and prototype to widespread availability and adoption by industrial and commercial users*" (Lefevre, 1984). However there are only few empirical studies of the learning from demonstration and trail projects in sustainable energy and transport (e.g. Hendry, Harborne, & Brown, 2010).

A recently concluded research project, InnoDemo, funded by the Research Council of Norway has targeted this research gab with a solid empirical foundation. The project was based on three sources of empirical data: 1) a database of 433 demonstration projects within sustainable energy and transport in Denmark, Norway and Sweden started in the period 2002-2012, 2) an online survey with 80 responds, and 3) in-depth interviews with 26 project managers and project participants covering 17 of the 433 projects.

There are four preliminary conclusions across the three countries. First, to promote succesfull projects public institutions need an absorptive capacity as full-scale demonstration projects test & provoke the whole (innovation) system around a new technology – in particular existing standards and regulation as well as financial institutions (e.g. venture capital, business angles). Second, policies towards adaption/innovation of standards and regulation must be supported and future needs must be foreseen. Third, financial institutions' learning needs to be included in early stages of demonstration projects – not added afterwards. Forth, individual actors are crucial as entrepreneurial persons and 'ordinary' staff (e.g. bus drivers in demonstration of hydrogen driven busses) are key to success and dissemination.

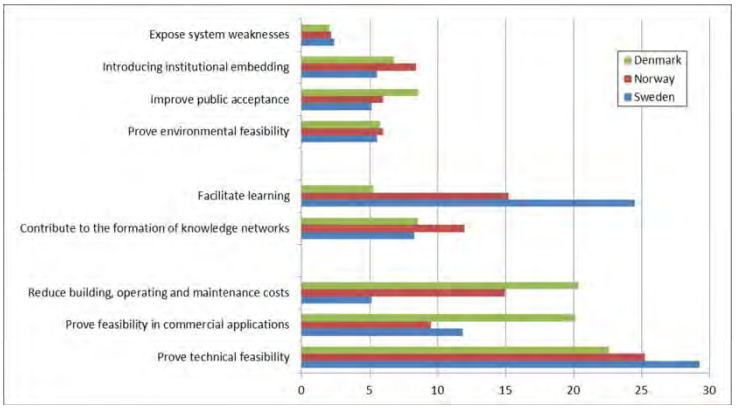


Figure 1. Aims of the projects in the database. Multiple aims possible, percentage (normalised) within each country.

Session

G

Laptop Presentations

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

Reduction of thermal budget in the solar industry

Rasmus Schmidt Davidsen[a]*, Michael Stenbæk Schmidt[a], Anja Boisen[a], Ole Hansen[a]
[a]Department of Micro- and Nanotechnology, Technical University of Denmark

Introduction Industrial production of silicon solar cells relies on the formation of a pn-junction typically realized by thermal diffusion of phosphorus or boron. Such thermal diffusion processes are performed at $\sim$ 800-900 °C for 15-30 minutes, depending on the target sheet resistance. We present initial results on enhanced thermal diffusion on black Si made by maskless RIE. Sheet resistance and carrier density have been measured with a micro-four-point probe.

Experimental Results Micro-four-point probe and electro-chemical capacitance-voltage (ECV) measurements were performed on the nanostructured front and planar rear side of 200 μm thick CZ Si wafers with a resistivity of 1.6 Ω-cm. P- and n-type wafers with phosphorus- and boron doped emitters, respectively, were used. Macro-four-point probe measurements of sheet resistance show 51.5 Ω on the nanostructured front and 82.3 Ω on the planar rear.

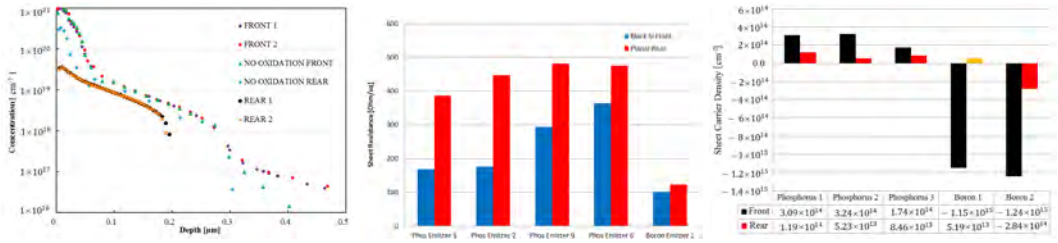


Figure 1: ECV (left), sheet resistance (middle) and carrier density (right) on nanostructured and planar Si

The doping profile (from ECV), sheet carrier density and sheet resistance seen in Figure 1 show that the nanostructured front is more highly doped than the planar rear. The sheet resistance in all cases is significantly lower on the nanostructured front compared to the planar rear. For sheet resistances suitable for solar cell fabrication (100-200 Ω/sq. selective emitters) the difference between the nanostructured front and planar rear is more than 100%.

From an industrial perspective the result indicates a potential decrease of the thermal budget of large-scale, industrial thermal diffusion processes, used for all emitter formations in the solar industry: If RIE-texturing is applied to industrial Si solar cells, emitters (with sheet resistances of 60-120 Ω/sq.) may be formed at lower thermal budget due to the lower sheet resistance on nanostructured Si for a given diffusion process. The thermal budget may be decreased by reduced time, temperature or a combination of the two.

Our hypothesis is that the RIE-textured nanostructures increase the surface area and induce surface defects. These two effects in combination enhance the diffusive flux of dopants into Si and thus enable emitter formation at a lower thermal budget in general.

*e-mail: rasda@nanotech.dtu.dk, phone: +45 45255848, Department of Micro- and Nanotechnology, Technical University of Denmark (DTU), Ørsteds Plads building 345East, DK-2800 Lyngby, Denmark

Session

G

Poster Presentations

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

The decisive factors for profitability in direct reuse of polystyrene packaging materials

Samuel Brüning Larsen*[1], Peter Jacobsen[2]

1: DTU Management; 2: DTU Management

*Corresponding author email: sbla@dtu.dk

This study represents a first exploration of the factors that are decisive for profitability in operating a reverse supply chain (RSC) that reuses polystyrene packaging materials used for transporting temperature sensitive items. The paper uses data from a manufacturer of measurement instruments, who distributes temperature sensitive liquids to its customers. Customers use these liquids during the measurement equipment's operation. Every year the firm sends more than 12.000 shipments to the German market and for each of these shipments the firm purchases a polystyrene box, which the customer disposes of through their waste management process. The study calculates the financial performance of a RSC that takes back all polystyrene boxes for direct reuse. Boxes that are unfit for reuse are discarded at the firm's factory at the firm's cost.

Using the RSC-concept and the business perspective on the RSC formulated by Guide and Van Wassenhove (2002, 2006), and the extension of this perspective by Larsen and Jacobsen (2014, 2015) as theoretical basis, the study first identifies the set of relevant variables for calculating the RSC's financial performance. This is conducted by combining a literature review to identify known variables with the case study described in the previous paragraph to identify any unknown variables. Second, and once the total set of variables is identified, the study calculates the RSC's financial performance. Third, the study assesses the relative impact among the identified variables to identify the most decisive factors. This method, which is novel in the RSC field, is constituted by a sensitivity analysis that determines the decisive factors by changing each variable by +20% while observing the impact on the calculated profitability. Results show that the decisive factors for profitability in polystyrene packaging materials reuse are 1) the avoided costs of purchasing virgin packaging materials, 2) the costs of reverse logistics.

Given that the study's data is limited to only one firm's operation, generalizability may appear limited. However, polystyrene packaging materials are used in many industries for the same purpose and using the same basic processes as this study's case, which strengthens finding's generalizability. In addition, the study provides the basis for future investigations of the bilateral relationships between the identified decisive factors and profitability, and also aid in the search for the decisive factors' sub-level antecedents and mechanisms (e.g. how reduced purchasing volumes of packaging materials impact prices, which impact the amount of avoided costs).

References:

Guide, V. D. R., and Van Wassenhove, L. (2002), "The reverse supply chain", *Harvard Business Review*, Vol. 80, No. 2, pp. 25-26.

Guide, V. D. R., & Wassenhove, L. N. (2006), "Closed-Loop Supply Chains: An Introduction to the Feature Issue (Part 1)", *Production and Operations Management*, Vol. 15, No.3, pp. 345-350

Larsen, S. B., & Jacobsen, P. (2014), "Determining the total cost of reverse supply chain operations for original equipment manufacturers". In *21st EurOMA Conference: Operations Management in an Innovation Economy*

Larsen, S., & Jacobsen, P. (2015), "How the reverse supply chain enables original equipment manufacturers to compete on low price", In *2nd International EurOMA Sustainable Operations and Supply Chains Forum*

Strategizing for sustainability in a changing world: a dynamic capability approach

Marcelo F. Mazzero*[1], Francesco Rosati[1], Maj Munch Andersen[1], Jason Li-Ying[1]
1: DTU Management Engineering, Technology and Innovation Management Division
*Corresponding author email: marmaz@dtu.dk

On an evolutionary perspective, firms have been learning how to cope with sustainability issues and developing capabilities for sustainability purposes. The reasons can vary a bit – environmental and social responsibility, legitimacy, access to resources –, but integrating sustainability into the core business is the one key factor for a long-term strategy (Bocken et al. 2014; Richardson 2008; Boons & Lüdeke-Freund 2013). In this way, the combination of a strategy for sustainable innovations with dynamic capabilities enables firms to be prepared for addressing (new) customer needs, targeting the right markets (new and old ones), and managing suppliers and partners accordingly (Teece 2012). Dynamic capabilities as "the capacity of an organization to *purposefully* create, extend, or modify its resource base" (Helfat et al. 2007) provide competitive advantage to establish and sustain superior performance in the marketplace (Teece 2014). We understand 'purposefully' as making a deliberate strategy, choosing from a set of business models (Casadesus-Masanell & Ricart 2010) when firms are sensing, seizing and transforming opportunities in a rapidly changing environment (Teece 2014). The set of business models is meant to be alternatives of a specific strategy that seeks appropriating the eco-innovation's value embedded in a product or service. This working paper develops a smooth and consistent framework for firms eco-strategizing in a competitive and heterogeneous business environment. Furthermore, we question why, when and how firms strategize to comply with sustainability issues and stakeholders' expectations. The novelty here is to explicitly incorporate sustainability into a well-designed business framework for eco-strategizing (Figure 1). Although the framework is currently conceptual, it will be further developed and validated to be applied in any business environment.

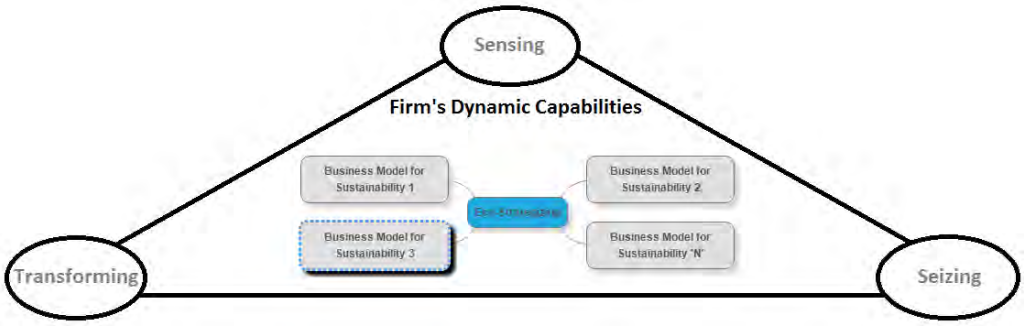


Figure 1 - Conceptual framework for eco-strategizing using dynamic capabilities for business model innovation

References

Bocken, N.M.P. et al., 2014. A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production*, 65, pp.42–56.

Boons, F. & Lüdeke-Freund, F., 2013. Business models for sustainable innovation: state-of-the-art and steps towards a research agenda. *Journal of Cleaner Production*, 45, pp.9–19.

Casadesus-Masanell, R. & Ricart, J.E., 2010. From Strategy to Business Models and onto Tactics. *Long Range Planning*, 43(2-3), pp.195–215.

Helfat, C.E. et al., 2007. *Dynamic Capabilities: Understanding Strategic Change in Organizations*, Wiley-Blackwell.

Richardson, J., 2008. The business model: an integrative framework for strategy execution. *Strategic Change*, 17(5-6), pp.133–144..

Teece, D.J., 2012. Dynamic Capabilities: Routines versus Entrepreneurial Action. *Journal of Management Studies*, 49(8), pp.1395–1401.

Teece, D. J. (2014). The foundations of enterprise performance: Dynamic and ordinary capabilities in an (economic) theory of firms. T*he Academy of Management Perspectives*, 28(4), 328-352.

A Dynamic Capabilities Perspective on Grocery Retailers' Eco-Strategizing

Marcelo F. Mazzero*[1], Maj Munch Andersen[1]

1: DTU Management Engineering, Technology and Innovation Management Division

*Corresponding author email: marmaz@dtu.dk

A core question from an evolutionary economic viewpoint is to inquire into the creation of variety and selection related to green economic evolution. It is essential to understand the market for green products (demand side) that is co-evolving with the eco-innovation developments. We believe that is relevant to have a broader understanding about the evolution of the market for green products on the retailers' perspective. Large grocery retail chains can help fostering the market for green products, especially because of their market power and because they count on economies of scale and scope in their operations (Dawson 2013; Lehner 2015; Styles et al. 2012). Thus, we explore the heterogeneous strategies that grocery retail firms are applying in situations of change, especially in the case of pervasive change on the greening of the economy. Due to the high costs of green food products relative to their conventional counterparts (Smits et al. 2014), we believe that these production high costs are associated with high friction to eco-innovation developments. Hence, it represents a very interesting case of the friction to green market evolution. As sustainability issues remain unexplored in the retail literature (Wiese et al. 2015), this literature neglect an understanding of grocery retailers' business model developments and strategizing for environmental sustainability. Thereby, using the dynamic capabilities framework we developed a theoretical model in seeking to understand over time how grocery retail firms are eco-strategizing to promote and strengthen the green food market. The model is mostly based on Dawson's (2013) and Lehner's (2015) macro and micro strategy perspectives of the retail firms. The result of our model shows that large firms in the grocery retail industry have deliberate strategies to function as green market makers in order to develop the green food market, which is entailing changes to their business models.

References

Dawson, J., 2013. Retailer activity in shaping food choice. *Food Quality and Preference*, 28(1), pp.339–347.

Lehner, M., 2015. Translating sustainability: the role of the retail store D. Anne Wiese, Associate Professor Ste, ed. *International Journal of Retail & Distribution Management*, 43(4/5), pp.386–402.

Smits, M. et al., 2014. *When Social Responsibility Leads to Growth: an imperative for consumer companies to go green*.

Styles, D., Schoenberger, H. & Galvez-Martos, J.-L., 2012. Environmental improvement of product supply chains: A review of European retailers' performance. *Resources, Conservation and Recycling*, 65, pp.57–78.

Wiese, A., Zielke, S. & Toporowski, W., 2015. Sustainability in retailing – research streams and emerging trends. *International Journal of Retail & Distribution Management*, 43(4/5).

Session

I

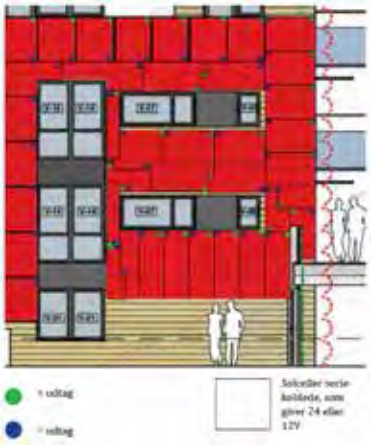
Oral Presentations

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

Bio-inspired aesthetic solar cells

Torben Lenau[*1], Anders Kristensen[2], Thea Brekke[1], Laura Stokbro[1]
1: DTU Mekanik, 2: DTU Nanotech, * Corresponding author email: lenau@mek.dtu.dk

In nature by far the largest amount of energy comes from the sun, and through synthesis in plants, it is the basis for the existence of all other organisms. However, we human beings are not very good at directly utilizing the solar energy. Denmark only produced 0.9 PJ solar heat which equals 0.6 % of the entire production of distance heating. The potential is 30Pj solar heat if placed on buildings [1]. In 2013 Denmark produced 518 GWh (1,9PJ) of electricity from solar power, which equals 1.5% of the electricity consumption [1]. The question is why these numbers are not larger? One reason could be that the appearance of solar collectors and photo voltaic cells do not match the requirements from users, which request aesthetic acceptable solutions. Existing solar cells and panels are all black or other dark colours and the surface texture is very different from existing roof and façade materials. This is most often very difficult to incorporate into existing buildings with an aesthetic acceptable result.



In a preliminary study the requirements for more aesthetic appearances has been analysed and needs been identified [2]. These include better options for incorporating the geometry of solar cell panels in buildings and for a broader range of appearance properties (colours, patterns). A modular system of smaller solar cells is proposed, which allow for individual adaption to the specific geometry of house facades. 15 x 15 cm modules are individually assembled at the factory into either 12 or 24 volt panels which are mounted at the façade using traditional façade mounting rails. Colours and patterns are proposed made using structural colours similar to the way nature solves the combined challenge of both requesting reflection and transmission. Structural colours reflect a fraction of the incoming light while allowing the reminder of the light through as transmission. In this way a large portion of the solar energy can pass through the colour reflector and supply the solar cells. In nature many insects and other organisms use structural colours to achieve spectacular appearances or the reverse highly efficient camouflage. The structural colours often vary depending of the viewing angle, which normally would not be desired for outer surfaces on buildings. One way of solving this is to apply plasmonic metasurface coatings [3] either directly to the solar cell or to the coating glass. Another option is to use twisted birefringent nematic structures, as done by the golden beetle Plusiotis resplendens [4].

References

1. Energistyrelsen, 2015, http://www.ens.dk/undergrund-forsyning/vedvarende-energi/solenergi
2. Brekke, T.S. & Stokbro, L. (2015) Æstetiske Solceller, B.Sc. thesis, DTU Mekanik & DTU Nanotech.
3. Clausen, J. S., Højlund-Nielsen, E., Christiansen, A. B., Yazdi, S., Grajower, M., Taha, H., Levy, U., Kristensen, A. & Mortensen, N. A. (2014). Plasmonic Metasurfaces for Coloration of Plastic Consumer Products. Nano Letters, 14(8), 4499–4504.
4. Lenau, T. and Barfoed, M. (2008) Colours and metallic sheen in beetle shells- a biomimetic search for material structuring principles causing light interference, J. of Adv. Eng. Mat. 10-4, 299-314.

Ink-free color decoration

Anders Kristensen*[1], Emil Højlund-Nielsen[1], Cristian Lavieta[1], Xiaolong Zhu[1], N. Asger Mortensen[2]

1: DTU Nanotech; 2: DTU Fotonik

*Corresponding author email: anders.kristensen@nanotech.dtu.dk

This paper describes plasmonic colors based on the concept of localized surface plasmon resonances (LSPR) for decoration of high volume manufactured plastic products [1]. A palette of bright and angle-insensitive colors, spanning the entire visible spectrum, is realized by utilizing the hybridization between LSPR modes in aluminium nano-disks, and nano-holes. Research grade, clean-room fabricated plasmonic metasurfaces are transferred to industrial production of plastic consumer products. Plastic components are embossed or injection moulded with a nano-textured surface, comprising an array of nano-scale pillars. The master-original for the square-centimeter nano-texture is realized by means fast e-beam writing or colloidal lithography. The nano-disk/nano-hole plasmonic metasurface is formed when a thin film of aluminium is deposited on top of the nanopillar array. The nanotextured plasmonic metasurface is covered with a transparent protective coating, which can withstand the daily life handling. This approach also supports a cradle-to-cradle production philosophy: Plastic products can be injection moulded using a single plastic base material, where the color decoration is realized by the as-injection-moulded nano-textured surface, covered by a thin (10-20 nm) metal film plus a 1-20 µm protective coating. After use, the product can be grinded, where the thin film coatings, which are the same for all products, represents a contamination level in the sub ppm level of the base material granulate – which is thereby directly re-usable.

Flexible plastic foil with embedded plasmonic color meta-surface decoration. The color appears from a thin film of aluminium deposited on top of a nanotextured surface.

1. Jeppe S. Clausen et al., Nano Letters, **14**, 4499-4504 (2014)

Surface Functionalization with Polymers: Towards Biocompatible and Ecofriendly Lubrication of Engineering Systems

Seunghwan Lee*[1]

[1]DTU Mechanical Engineering

*Corresponding author email: seele@mek.dtu.dk

Life-long maintenance of biotribosystems, such as synovial joints, ocular tracts, and oral cavity, is remarkable and even puzzling considering that the base stock for the lubrication is water. For most man-made engineering systems, water is generally excluded as lubricant due to its poor capabilities to withstand external loads on its own. Nature solves this problem by incorporating pressure-responsive, "smart coatings", such as mucus gel layers on the surface, and thus facilitate the entrainment and retainment of water (lubricant) at the rubbing interfaces [1]. Mucins, a family of high-molecular-weight glycoproteins and a main macromolecular constituent of mucus gels, are interesting also because they show unique slipperiness at the interface with synthetic materials too [2]. This, in turn, has inspired the development of mucin-like, brush-forming synthetic polymers, which can be applied in the lubrication of engineering materials with water [3]. Biophysical properties of both mucinous glycoproteins and their mimics, brush-forming polymers, are very sensitive to environmental changes, and this feature can be exploited to optimize their properties for particular applications. Presently, surface functionalization of soft matter at the rubbing interfaces appears as the most promising and practical means to achieve biomimetic and ecofriendly lubrication of engineering systems. This talk will provide an overview on recent researches on surface adsorption, functionalization, and triobological properties of various synthetic or biopolymers, including poly(ethylene oxide)(PEO)-based copolymers, polyeletrolyte-based copolymers, and mucins.

References

[1] S. Lee and N.D. Spencer, "Sweet, Hairy, Soft, and Slippery" Science 2008, 319 (5863), 575-576.
T. Røn, I. Javakhishvilli, K. Jankov, S. Hvilsted, and S. Lee, "Ultralow friction with hydrophilic Polymer brushes in water as segregated from silicone matrix" accepted for publication in Advanced Materials Interfaces 2015
[2] "Sticky and Slippery: Interfacial Forces of Mucins and Mucus Gels" In: "Aqueous Lubrication: Natural and Biomimetic Approaches" ed. Nicholas D. Spencer, 2014, pages: 33-71, World Scientific Publisher, ISBN-13: 978-9814313769.
[3] "Achieving Ultra-low Friction by Aqueous, Brush-assisted Lubrication" S. Lee and N.D. Spencer, Chapter 21 (pp. 365-396) In: SUPERLUBRICITY, edited by Ali Erdemir and Jean-Michel Martin: 1st ed. 2007 Elsevier.

Diatoms for a green future

Christian Maibohm[1*], Karsten Rottwitt[1], Josefine Holm Nielsen[1], Søren M. M. Friis[1], Torben Anker Lenau[2] Marianne Ellegaard[3]

1: DTU Fotonik; 2: DTU Mekanisk Teknologi; 3: PLEN KU

*Corresponding author email: chmai@fotonik.dtu.dk

The world's limited resources impact every level and aspect of decision making today. Recognition of this has catapulted research into optimizing the use of known materials but also finding and exploring new materials, where especially organic or biological materials have created a growing interest. Microalgae represent such a novel material and considering the enormous biodiversity and production upscaling this group of organisms represents one of the most promising sources for new products and applications. Diatoms are a class of unicellular photosynthetic microalgae and among the most common phytoplankton, contributing with approx. 25% to the total primary production of the world equal to that of the rainforests. Diatoms are unique from a biological and photonic point, because of the complex 3D nano-structured silica shell, called the frustule that surrounds the cell, as seen fig. 1A and 1B.

To unlock the photonic application potential of the frustule we have studied the wavelength dependent structural influence of light in the growing phase [1]. We have mapped the wavelength dependent light-frustule interaction, for several species [2, 3]. We have shown how the interference pattern of transmitted light through the frustule can be utilized as an optical switch with a 20 dB extinction ratio, as seen in fig. 1C [2]. Furthermore we have looked at the UV-filtering properties of the frustules.

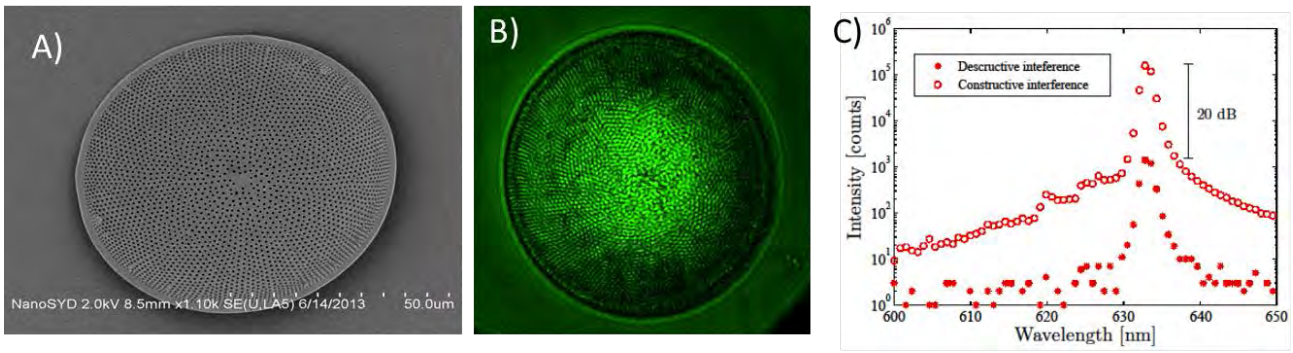


Figure 1: A) SEM image of the nano-structured frustule. B) Optical transmission image through the frustule @532 nm laser. C) Prove of principle of optical switch with 20 dB extinction ratio. Adapted from [1]

[1] Yanyan Su, Nina Lundholm, Søren M. M. Friis, and Marianne Ellegaard, Nano Research, 2015, 8(7): 2363-2372, DOI 10.1007/s12274-015-0746-6

[2] C. Maibohm, S. M. M. Friis, M. Ellegaard and K. Rottwitt, 2015, Vol. 23, No. 7, DOI:10.1364/OE.23.00954, OPTICS EXPRESS 9543

[3] C. Maibohm, S. M. M. Friis, Y. Su, K. Rottwitt, Organic Photonic Materials and Devices XVII, Proc. of SPIE Vol. 9360, 93600B · © 2015 SPIE, doi: 10.1117/12.2078822

Acknowledgment: This work was part of the project ALPHA, project number 12-127569 of the Danish Council for Independent Research

Session

I

Laptop Presentations

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

Session

I

Poster Presentations

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

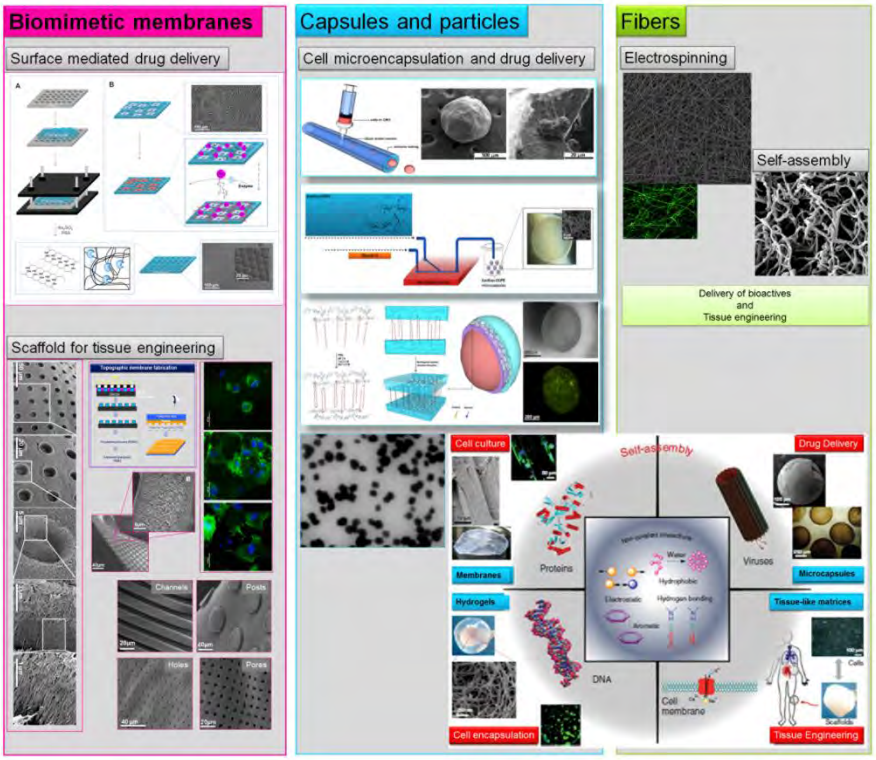
Highly functionalized nano-microstructures for Bioengineering

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

1: *Nano-BioScience Research Group, DTU-Food,Technical University of Denmark, Søltofts plads, B227, 2800 Kgs. Lyngby, Denmark.*

*[1]Corresponding author email: anac@food.dtu.dk

Biopolymers are of great interest for Bioengineering applications, and materials research, due to their environmentally friendly production, biocompatibility and biodegradability. However, the knowledge and manipulation about its structure/function relationships is fundamental to create effective solutions to fabricate nano-microstructures (NMS) with increased level of control over their structure, shape, bioactivity and overall performance. Therefore, this work intends to show different approaches to fabricate NMS by exploring the properties of the biopolymers in combination with fabrication techniques such as molecular self-assembly, micro-fluidics, soft lithography, electrospinning. Specific applications of these NMS include: MNS as scaffolds tissue engineering; NMS as hydrogels and fibers for drug delivery (and delivery of bioactives in general) and NMS as capsules for cell microencapsulation.



Interactions between electrospun fibers and the surrounding biological environment; cells and small molecules

Karen Stephansen[1,2*], María García-Díaz[2], Flemming Jessen[1], Hanne M. Nielsen[2], Ioannis S. Chronakis[1]

1: DTU Food; 2: KU Pharma

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

Electrospun fibers have a morphology that can be controlled to resemble structures found in nature such as spider silk, a ragwort leaf and the extra cellular matrix. This unique morphology makes the fibers suitable among others for biomedical applications such as tissue engineering, wound healing, and drug delivery. The choice of material also affects the performance of the fibers. Biopolymers are highly appealing due to their excellent biocompatibility and biodegradability, and interactions between biopolymeric fibers such as electrospun fish proteins (FSP) (Figure 1. A) and a biological system may provide further beneficial effects. However, the electrospun fibers may also interact with the surrounding environment, such as small molecules, which can affect the fiber properties.

The potential of using FSP fibers as a carrier matrix for therapeutic proteins has been investigated, especially focusing on the challenges related to oral delivery. The inherent structural and chemical properties of the FSP fibers displayed excellent biocompatibility, yet interacted with enzymes found in the gastrointestinal tract and intestinal epithelium, which lead to an increased insulin transport across a Caco-2 cell monolayer to around 12 % of the of the applied dose (Figure 1. B). Moreover, the insulin loaded FSP fibers (FSP-Ins) interacted with biorelevant molecules in solution. In specific, the presence of surfactants in the solution to which the FSP-Ins fibers where added affected: i) the release properties of insulin from FSP-Ins fibers (Figure 1. C), ii) the inner porosity of the fibers, and iii) the properties of the accessible fiber surface. The effects caused by the biorelevant molecules were dependent on their physico-chemical properties such as charge. Altogether these results indicate that electrospun fibers interact with the surrounding environment; e.g. cells or small molecules.

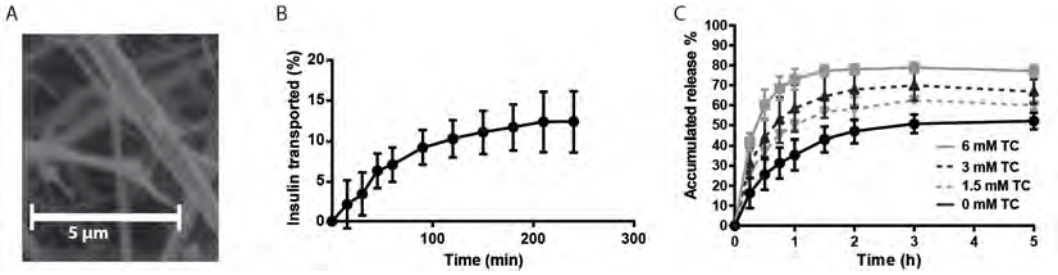


Figure 1. A) SEM image of FSP-Ins fibers, B) transport of insulin released from FSP-Ins fibers across a Caco-2 cell monolayer, C) release of insulin from FSP-Ins fibers in MES-HBSS buffer with different amounts of taurocholate (TC). Data represent mean ± SD, n > 3.

References

1. Stephansen, K.; Chronakis, I. S.; Jessen, F. *Colloids Surfaces B Biointerfaces* **2014**, *122*, 158–165.
2. Stephansen, K.; García-Díaz, M.; Jessen, F.; Chronakis, I. S.; Nielsen, H. M.. *Int. J. Pharm.* **2015**, *495* (1), 58–66.
3. Stephansen, K.; García-Díaz, M.; Jessen, F.; Chronakis, I. S.; Nielsen, H. M. *Mol. Pharmaceutics*, Accepted, DOI: 10.1021/acs.molpharmaceut.5b00614.

Session

J

Oral Presentations

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

Sustainability in transport planning – a cross-university subject par excellence?

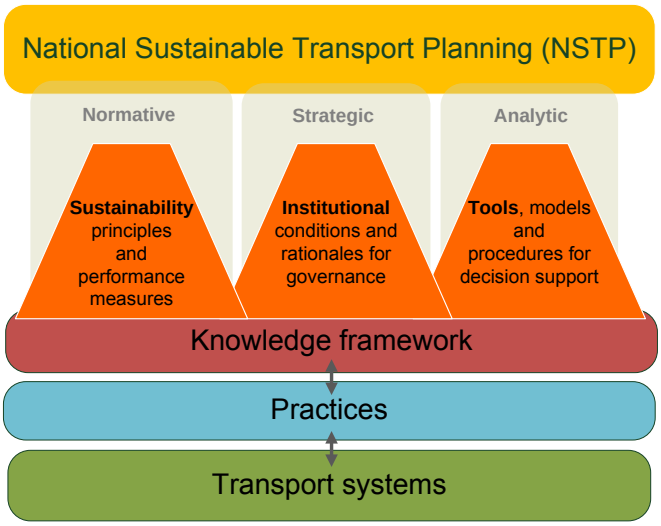
Henrik Gudmundsson [1], Carsten Greve [2],

1: DTU Transport; 2: Carsten Greve, Department of Business and Politics, CBS

*hgu@transport.dtu.dk

Transport systems and mobility are needed to support economic and social development, while also significantly contributing to global environmental impacts such as climate change, air pollution and oil depletion. Meanwhile transport systems are undergoing substantial changes in terms of technology, organization and governance. This raises profound challenges for transport policy and planning at all levels.

In the ongoing research project 'SUSTAIN: National transport planning – sustainability, institutions and tools' DTU and CBS have joined forces to explore what sustainability means for national transport planning, in terms of new normative performance objectives, analytic planning tools, and strategic institutional arrangements. We are developing towards a new governance framework for integrating sustainability.



At this point we have developed some experience with cross-disciplinary and cross-university collaboration on sustainability. The presentation will discuss some of the benefits and challenges we have encountered.

An example of a *benefit* is bringing different types of expertise to bear on the same subject. DTU Transport has a long experience in planning tools for multi-criteria transport decision support while CBS has the analytic means to uncover institutional mechanisms and political constraints for the ideal technical planning process. An example of a *challenge* is that we value sustainability in different ways, e.g. as a concept to be operationalized with scientific criteria, numbers and thresholds, versus as more of a rhetorical construct that may or may not become influential in a political-institutional context.

Centre for Energy, Environment and Health (CEEH)

Kenneth Karlsson[*1], Eigil Kaas[2], Jørgen Brandt[3]

1: DTU Management Eng.; 2: KU NBI; 3: AU Environmental Science

*Corresponding author email: keka@dtu.dk

The CEEH project started in 2007 and lasted for 5 years. It was a highly interdisciplinary project with project partners from four Danish universities (KU, DTU, AU, SDU) and 8 different departments.

The focus of the project was to build and model the full chain from emission of air pollutants from energy conversion to what the impact is on public health. To accomplish this several advanced models within different disciplines was expanded, updated with state-of-the-art knowledge, and linked together.

Researchers within atmospheric physics, meteorology, air pollution, energy systems, health economics and public health was working together and especially in the beginning it was a big challenge to find a common language as many terms are defined and used differently between the disciplines. It turned out to be extremely powerfull to collect all this knowledge in one room in the coordination meetings and none of the partners in the project could have achieved the same quality and insight if working on their own.

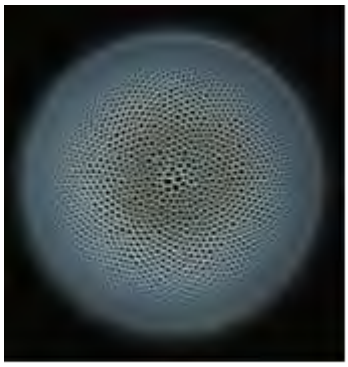
The project also created networks across the universities improving the chances for future collaboration. Some of the partners are now a part of a large EU project utilizing some of the methodologies developed in CEEH.

The pictures below to the left illustrate the linking of the involved models and methodologies. The picture to the right is from an international conference on air pollution organized by CEEH.

http://ceeh.dk/CEEH_Reports/Report_1/index.html http://ceeh.dk/conference/memento.html

The ALPHA project – collaboration between DTU-Photonics and UCPH

Marianne Ellegaard, me@plen.ku.dk, Department of Plant and Environmental Sciences University of Copenhagen



The ALPHA project focuses on developing photonic materials from diatoms. Diatoms are a globally dominant group of micro-algae representing a staggering 20-25% of the world's net primary production, which are yet a still virtually unexploited resource. Diatoms are of special interest due to their intricate silica walls with repetitive nanostructures in the size range for special optical properties with broad industrial application potential. By using our combined photonics expertise of DTU-Photonics and algae production-expertise of UCPH we aim to develop new sustainable materials with direct industrial applicability. We have in this project analysed the optical and photonic properties of diatom walls using the living diatoms themselves to test the effects of different colour and intensities of light on the formation of nanopatterns in the silica walls. Utilization of diatom walls may drastically reduce production costs and improve environmental performance for e.g. UV protection in applications such as paint and solar cells.

Session

J

Laptop Presentations

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

The Copenhagen Sustainability Initiative (COSI): A DTU-CBS-KU cooperation effort

Stefano Ponte*

Professor of International Political Economy; co-director, CBS Sustainability Platform

Copenhagen Business School

*Corresponding author email: sp.dbp@cbs.dk

Abstract

It is becoming increasingly clear that continued societal development requires an entirely new approach to resource use both in terms of natural and human capital. Thus, 'sustainability' has become an important theme in both business and in public policy. This places new and growing demands on universities to provide relevant, cross-disciplinary knowledge platforms that can contribute to sustainable societal innovation. Through their complementary profiles, DTU, CBS, and KU can, together, provide a complete suite of the sustainability competences required for informed decision-making. To foster cross-disciplinary activities on sustainability, these three universities have created the **COpenhagen Sustainability Initiative (COSI)**, involving the Global Decision Support Initiative (DTU), the Sustainability Platform (CBS), and the Sustainability Science Centre (KU). The purpose of this cooperative effort is to link existing and upcoming sustainability initiatives to provide external decision-makers with access to their combined competences through a single contact point. COSI stimulates joint initiatives within research, education and outreach within sustainability and sustainability science between the three universities.

Session

J

Poster Presentations

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

DTU's Sustain Conference

Teaching sustainability in *Aquatic Science and Technology* - collaborations between DTU-Aqua, UCPH-BIO and UCPH-PLEN

Marianne Ellegaard, me@plen.ku.dk, Department of Plant and Environmental Sciences, University of Copenhagen
Marja Korksi, DTU-Aqua, Head of studies
Mathias Middelboe, Marine Biological Section, University of Copenhagen

Sustainable use of marine resources and unlocking the biotechnological potential of the sea are two topics of current intense interest and relevance. In the courses Applied Marine Biology and Applied phycology we collaborate in teaching and supervising students from DTU, UCPH and other Universities in marine ecology, sustainable management of marine systems and Blue Biotechnology. We will present specific topics of this teaching program and our experiences with inter-university collaboration on teaching and education.

Session

L

Oral Presentations

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

Smart Cities and Integrated Utilities – how to get things realized?

Henrik Kærgaard, Director Cross-Cutting Development, NIRAS

1: NIRAS (Danish consulting company)

hka@niras.dk

The presentation will outline some of the key challenges posed by smart city projects like the complexity, the many often very different stakeholders involved, the importance of smart organisations and smart physical and infrastructure systems (and not only ICT-systems), the many different perspectives, the challenges in public-private sector cooperation etc., etc.

First and foremost, however, the lack of operative business models will be discussed; if we do not have operative and efficient business models, nothing will happen, no matter whether the technology is available or not. So who is going to pay? – and for what?

The complexity of the whole issue poses completely new and alien organisational challenges and demand completely new approaches: We cannot plan and implement as we normally like to and are comfortable with – we have to "build the road as we travel", i. e. step by step, and we have to do this with a lot of very different stakeholders on board.

The presentation discusses how to approach all these challenges in practice.

Control of Electricity Load in Future Smart Cities

Henrik Madsen[1], Jacopo Parvizi[1], Rasmus Halvgaard[1], John Bagterp Jørgensen[1]

[1]: DTU Compute

*Corresponding author email: hmad@dtu.dk

Traditionally, electricity power production has been adjusted to balance the time-varying electricity load. However, a transition to a system based on an increasing, fluctuating and non-dispatchable renewable power implies that new methodologies for controlling the electricity load in future smart energy systems become crucial.

This talk describes methods for control of electricity loads in future smart cities. Smart cities offer possibilities for intelligent energy systems integration based on ICT. This includes methods for integrating large shares of, e.g., wind and solar power production. Hierarchies of aggregators and predictive controllers, for electricity loads in flexible demand side response in smart cities, are implemented to achieve a balance with the non-dispatchable energy production. Two distinct approaches are described: direct control of the load consumption of individual DERs, and indirect control by broadcasting an electricity price. The advantages and challenges of these two approaches are discussed, and examples of the suggested techniques are provided.

Testing the assertion that urban agriculture is sustainable

Benjamin Goldstein*[1], Morten Birkved[1], John Fernández[2] and Michael Hauschild[1]

1: DTU Management; 2: MIT Architecture

*Corresponding author email: bgol@dtu.dk

As of 2008 the majority of humanity lives in cities. By virtue of their wealth and population, cities now dominate global energy and material flows, and consequently, are the majority driver of environmental degradation at the local, regional and global scales. One of the least sustainable aspects of the archetypical modern city is the way it satisfies its food demands; typified by an agricultural system reliant on non-renewable resources for nutrient provision, significant energy inputs for transport and processing, out-of-season consumptive habits, high edible food wastage and poor recycling rates of bio waste produced in the cities where food is consumed. Because of these factors, food consumption is often as significant a driver of gross urban environmental pressure as transport, building energy or construction.

Urban agriculture has recently been championed by concerned citizens, numerous academics and policy makers alike as a means to address the environmental burdens of urban food consumption. It is postulated that urban agriculture can have multiple benefits relative to the food supply chains cities currently rely on; reduced distance from farm to fork, lower packaging needs, mitigated edible food losses and a symbiotic relationship with the urban environment (energy exchanges with the built environment, organic waste assimilation, storm water capture). Despite these purported benefits, there has hitherto been only passing quantitative assessment to determine whether urban agriculture is an appreciable improvement over dominant channels of urban food supply.

This study used primary data from four urban agriculture sites in Boston and New York City (see figure below) to develop environmental footprints of the food they produced in 2014 and 2015 and compare it against that of conventional agriculture for the same products. We found that in most cases urban agriculture offered little or no benefit over conventional supply food supply chains, and that in some cases it actually performed worse when significant grow-space conditioning was required. In cases where urban agriculture displayed superior performance, this was mainly a result of reduced energy consumption of the building in which it interacted, begging the question; could equal or better environmental benefits be produced using enhanced building technologies (insulation, load reduction or solar panels)? We conclude that at its current level of development urban agriculture does not represent a ‘silver bullet’ to the urban food sustainability problem and that substantial efficiency gains are required before most of these systems can offer an environmental improvement over conventional agriculture.

The organizational context for sustainability in Municipal Facilities management

A contribution to Smart Livable Cities

Susanne Balslev Nielsen, DTU Management Engineering, sbni@dtu.dk

Sustainable Facilities Management (SFM) is an essential discipline to realize a societal vision of smart sustainable liveable cities; as facilities managers own, operate and manage buildings. In theory this profession has the possibilities to make all the right decisions but still the transformation seems to go rather slow (technologies are available but not put into use). There are barriers in decision making processes which hamper lifetime thinking when renovating buildings, building new buildings or when providing building services such as ICT-solutions, catering, cleaning etc.

This is a presentation of a current investigation of the organisational context for integrating sustainability in facilities management in Danish municipalities. The 98 Danish municipalities own, operate and manage in total more than 61.000 buildings equal to 27,6 km^2(1). From this perspective the municipalities are relevant stakeholders as they are major owners of buildings/facilities essential in our welfare society. Facilities Management (FM) organisations in private organisations are also relevant stakeholders in a societal transformation process, but are excluded in this investigation. 74 municipalities have responded to a survey of the organisation of the municipal FM organisation today and the result is that 3 models are dominating. There is a tendency of centralising ownership and building operation in facilities management centres with increased authority to coordinate building activities with the following operation, maintenance, space management and adaptation to changing user needs.

Model 1:	**Independent FM centre with the full authority (and political leadership) to manage the municipal facilities.** *31% of the respondents stated that this model had the best match with their organisation.*
Model 2:	**A FM centre which manages the municipal facilities on behalf of the owners, which are various administrative departments and institutions.** *43% of the respondents stated that this model had the best match with their organisation.*
Model 3:	**Decentral organisation where the ownership and the operation is assigned to the various administrative departments and institutions.** *26% of the respondents stated that this model had the best match with their organisation.*

The mapping of the municipalities FM organisations show that even though the municipalities own and operate their buildings, the organisational structure within the municipal organisation separate the ownership and the operation, which is a problem from an economy and knowledge management perspective and hamper e.g. building lifetime thinking and sustainable operational friendly buildings.

With the full authority to sustainable facilities management the municipal organisations could set their strategy and management measures with key performance indicators for economic, environmental and social sustainability (2).

(1): Hansen og Nielsen (2015): Kommunal Ejendomsforvaltning- 6 fortællinger om etablering af et centralt ejendomscenter
(2): Nielsen, Junghans & Jones (2016): Sustainability chapter. In "Facilities Management and Corporate Real Estate Management as Value Drivers: How to Manage and Measure Added Value" edited by Per Anker Jensen and Theo van der Voordt, Oxfordshire: Routledge.

Importance of detailed meteorological information for smart city development

Neil Davis[1], Jake Badger[1], Gregor Giebel[1], Andrea Hahmann[1], Anna Maria Sempreviva[1]

1: DTU Wind Energy

*Corresponding author email: neda@dtu.dk

Smart cities rely on the development and implementation of Key Performance Indicators to help drive decision making. Many of these indicators rely on atmospheric data as an input. For example, buildings depend on air temperature and solar radiation to determine heating or cooling needs, and flood control systems need accurate precipitation information.

Additionally, renewable energy production is dependent on weather. Therefore, high resolution modeling can be used to investigate the strategic planning of urban energy networks, and provide advanced forecasting of distributed power plant production. Climatological studies can aid in identifying extreme conditions that fall outside of the range of normal variance, but have significant impact on the cities operation.

The meteorological section of DTU wind energy is the only meteorological section at DTU and has a wide range of competencies in mapping and forecasting atmospheric conditions.

Urban meteorology focuses broadly on two areas.

1. The description of atmospheric variation inside of urban areas through the study of the urban boundary layer and the urban heat island effect. The figure shows how temperature can vary across a city.

2. The influence of urbanization on larger circulations and the climate system, such as changes in precipitation patterns.

Standard meteorological forecasts do not resolve these impacts at high detail. Therefore, localized microscale studies can provide decision makers with additional information to better run a smart city.

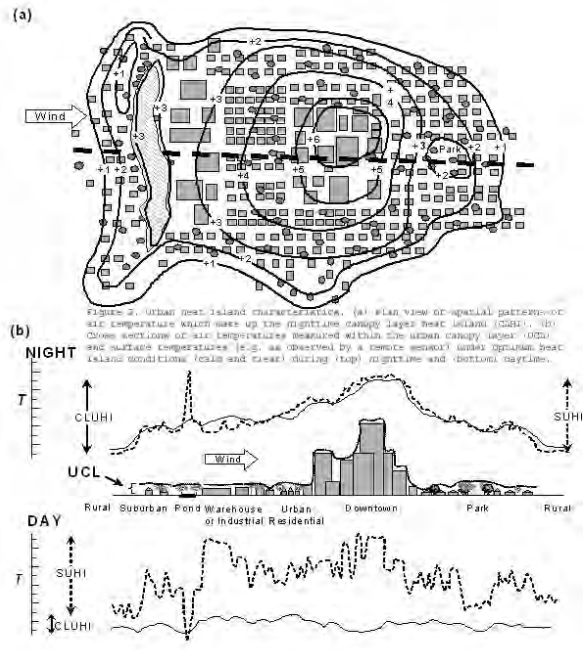


Illustration 1: From http://actionbioscience.org/environment/voogt.html

EnergyLab Nordhavn, Integrated Energy Infrastructures and smart components

Christoffer Greisen*[1]

1: DTU Elektro

*Corresponding author email: cgre@elektro.dtu.dk

EnergyLab Nordhavn is a large-scale integrated research and demonstration project that contributes to the grand challenge of transforming the energy system to efficiently integrate a large share of renewable energy.

The project focuses on a cost-effective future smart energy system that integrates multiple energy infrastructures (electricity, thermal, transportation) and provides an intelligent control of subsystems and components –

providing necessary flexibility for efficient utilisation of renewable energy. The demonstration takes place in Copenhagen's Nordhavn, one of the largest development districts in Europe.

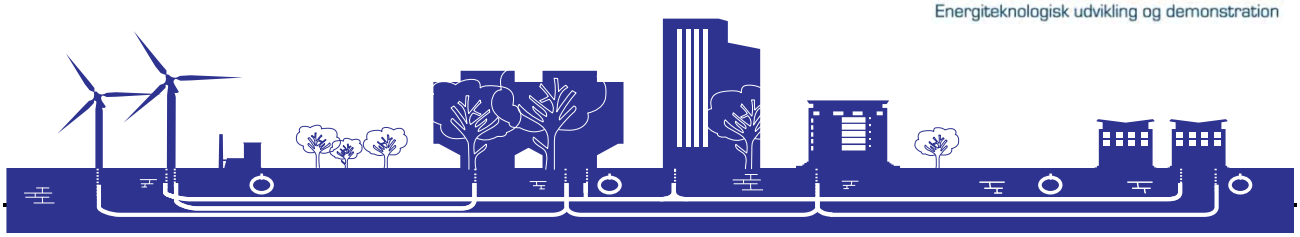
The EnergyLab Nordhavn project will establish itself in Copenhagen's Nordhavn as a living laboratory for future smart-energy technologies, innovative business models and new operational solutions on all scales - component, building, grid infrastructure and system level - and provide basis for design and dimensioning of future energy infrastructure in sustainable low-energy city districts.

EnergyLab Nordhavn brings together for the first time at this scale stakeholders from different energy infrastructures with authorities, industries and knowledge institutions. The project interlinks development and research activities creating an environment for strong research-based innovations. The partners are DTU BYG, DTU MEK, DTU CEE, Københavns Kommune, DONG Energy Electricity Distributions, HOFOR, By&Havn, ABB, Danfoss, Balslev, MetroTherm, Glen Dimplex, CleanCharge and the PowerLab facilities.

The EnergyLab Nordhavn project has a total budget of DKK 143 mio. (€ 19 mio.), hereof DKK 84 mio. (€ 11 mio.) funded in two rounds by the Danish Energy Technology Development and Demonstration Programme (EUDP).

ENERGYLAB NORDHAVN

EUDP
Energiteknologisk udvikling og demonstration



Multifunctionality, new technology and involvement as backbone of a smart, resource efficient and liveable Copenhagen

Lykke Leonardsen

City of Copenhagen

lykleo@tmf.kk.dk

Copenhagen is going through an incredible development. Every month another 1000 citizens are added to the population, and at the same time the Copenhageners are using the city much more intensively than ever before. We have more people bicycling, swimming in the harbor, dining out or playing at the city's playgrounds.

All this puts a pressure on the city. There is a fight for space and it challenges the planners who are working on the city of the future. How do you make room for all of that? And do we need to have room for everything? And if not, what do we select not to prioritize?

And apart from the urban space issues there is the question of resources. We want to become carbon neutral, want more circular economy and take good care of global resources. But at the same time there is a demand to have focus on growth and job creation.

Finally there is the question on social equity. We need housing for all economic classes because Copenhagen must not become a city just for the wealthy. There has to be room for the teacher, the shop assistant and the student.

So we have many agendas at stake – and when you add yet another challenge – that we have to prepare the city for a warmer, wilder and wetter climate, it doesn't get any easier. The future Copenhagen has to be able to handle cloudburst, storm surges and hot periods of drought – and at the same time always securing the quality of life for people in the city. This calls for smart thinking – and smart solutions where we work with multifunctionality and new technology to secure the best solutions for the city.

Session

L

Laptop Presentations

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

Intelligent Transport Systems in the Smart City

Francisco Camara Pereira, DTU Transport

*Corresponding author email: camara@transport.dtu.dk

Transportation is a key component in any urban sustainability ambition, and it is known to be one of the urban systems that is most difficult to change, because it involves deep daily habits in a system that is usually too complex to understand for people and to manage optimally by operators and managers. The Intelligent Transport Systems (ITS) group in DTU Transport is a new initiative, dedicated to study how new data types and methodologies from Computer Science and Transport can be put together to develop solutions that are more intelligent in treating transport system problems and support a paradigm shift towards a more sustainable mobility.

In this presentation, I will show earlier projects in Boston, Singapore and Copenhagen, and discuss how the new ITS initiative will develop in the next few years.

LAR-potentiale:
a new planning tool to support sustainable stormwater management

Sara Maria Lerer*[1], Hjalte Jomo Danielsen Sørup[12], Karsten Arnbjerg-Nielsen[12] and Peter Steen Mikkelsen[13]

1: DTU Environment; 2: DTU GDSI, 3: Water DTU

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

Stormwater management systems are essential for creating and maintaining safe and healthy cities. Current challenges to these systems include climate change, growth and densification of cities, and an increase in demands for sustainability and livability. Among the suggested solutions is a suite of decentralized stormwater control measures known as e.g. Water Sensitive Urban Design (WSUD), which aim at improving the sustainability of stormwater management by applying a more holistic and multifunctional approach. Unlike traditional stormwater planning, WSUD must bring together drainage engineers with city planners, architects and other professionals. We have developed a new tool to support this interdisciplinary collaboration.

The tool facilitates a fast and simple quantification of the core hydrologic effects of a suggested WSUD retrofitting plan. We use the following two key indicators to represent the hydrologic effects of WSUD: 1) the runoff volume/return period at the single event scale, and 2) the water balance impact at the annual scale. The significance of the first indicator is illustrated using the “Three Points Approach”, which has a proven ability to improve conversations about how well different drainage solutions meet expectations. The significance of the second indicator is illustrated against typical annual water budgets, emphasizing the potential for restoring a more natural hydrological cycle and managing pollution on site.

The tool includes simple methods for assessing these effects for a number of different WSUD techniques including permeable paving, rain gardens and detention basins. Local constraints, such as the available area for collection of rainwater and the soils infiltration capacity, are taken into account. We will present the tool using an example application on a case study in Copenhagen. Danish cities are investing large amounts of resources in urban infrastructure renewal, and actors are eagerly waiting for tools like this to more effectively prioritize their spending.

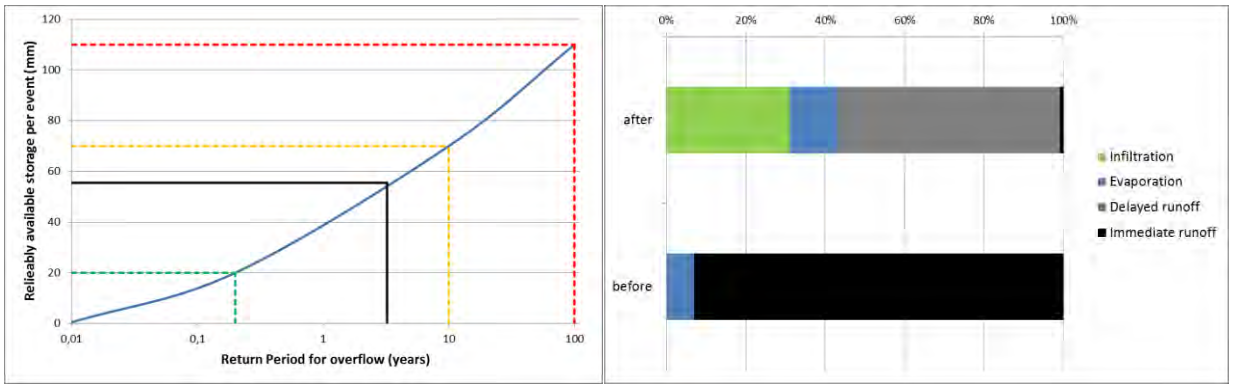


Figure 1: Example outputs. To the left: Key indicator 1 – volume of runoff/return period at the single event scale. To the right: Key indicator 2 - annual water budget before and after.

Challenges and Opportunities in Urban Water Governance Case Study: Malmö

Author[1] :Hilda María Gutiérrez Elizondo

1: Affiliation to DTU: N/A

HildaG24@gmail.com

As the world faces great sustainability challenges, climate adaptation and mitigation strategies are being linked to sustainability transitions as a desired approach for many cities, especially in Nordic countries. Water management is being considered crucial for the transition towards climate adaptation and environmental sustainability. In many parts of the world, the innovation of water management practices has focused on advancing technical solutions and not on new forms of governance. My research looked at how the City of Malmö in Sweden, as a case study, is currently governing the transition towards climate adaptation and environmental sustainability, with a focus on urban water governance.

The aim of my research was to identify water governance innovations within the context of climate change and sustainability transitions in cities. Malmö has a vision of becoming a world leader in sustainable city development by 2020 and of becoming Sweden´s most climate friendly city. Identifying, describing and analysing Malmö's governance qualities and institutional capacity attributes can be informative for other cities. To this end, the city of Malmö located in Southern Sweden, can offer insights into how strategic planning can innovate water governance practices and enable transitions towards environmental sustainability.

This research was based on a qualitative research methodology. A case study research method as defined by Yin (2009) was used. A total of 9 interviews within Malmö City administration were conducted. The interviewees work in the following departments: Consumer and Lifestyle; Real Estate Office-FK; Environmental Department-MF; City Planning Office-SBK; Water and Waste municipal Authority-VA SYD. To describe the institutional attributes within the administration of Malmö a version of the framework as advanced by Van de Meen and Brown (2009) was used.

There are two processes going on within the administration of Malmö that shed light on some of the attributes that provide guidance and structure to urban water governance in Malmö. The first process is Malmö's Environmental Programme 2009-2020 which provides the City with political environmental goals. The other process is the Master Plan for Water in Malmö which provides insight into how strategic planning and design is done. Malmö's Environmental Programme 2009-2020 and the Master Plan for Water both provide opportunities for strategic planning and design as well as political and institutional support for water related issues. These two processes place

water management within the broader City Administration. Consequently, the urban water regime is directly linked to urban planning and development. Integrating water management into the wider city planning process puts water issues beyond water utility companies and allows for more innovative water governance practices that includes collaboration across administrative boundaries in relation to water management.

Session

L

Poster Presentations

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

Sustainable district of Nordhavnen – energy system modelling

Ben Amer, Sara*[1], Ravn, Hans[1]

1: DTU Management Engineering

*Corresponding author email: sbea@dtu.dk

Abstract

Close to 70% of greenhouse gas worldwide is emitted from urban areas (UN, 2011). Due to increasing urbanization, the situation will not improve unless cities take action to reduce the use of fossil fuels and increase energy efficiency.

By 2025 Copenhagen, the capital of Denmark, is planning to become CO_2-neutral (The City of Copenhagen, 2012). While the municipality will implement several activities within the existing city infrastructure, a development of a new seafront district called Nordhavnen will allow more radical energy transition. However, larger scale energy investments are costly, thus should be preceded by techno-economic system analysis. In the present study, a model called Balmorel is used.

This ongoing research examines how implementation of energy infrastructure in an urban area such as Nordhavnen can contribute with low CO_2 emissions, while remaining cost-efficient. This study focuses on integrated heat and electricity systems modelling of the area as part of Copenhagen and Denmark.

We construct and analyze scenarios for future energy supply of Nordhavnen, with focus on heating. The selected alternatives are: extension of Copenhagen's district heating scheme to supply Nordhavnen, individual ground source heat pumps and a large seawater heat pump. The assessment focuses on capital cost, total operation and maintenance cost, fuel cost and CO_2 emissions.

The preliminary results of this study show that individual heat pumps scenario is optimal from a socio-economic viewpoint. However, due to relatively small differences among scenarios the results will be examined further and extended by sensitivity analysis focusing on assumptions such as e.g. future heat demand, COP of heat pumps and varying technology prices.

References

The City of Copenhagen, 2012. CPH 2025 Climate Plan.

UN, 2011. Cities and Climate Change: Global Report on Human Settlements 2011.

Models for flexible operation of buildings in district energy system Nordhavn

Foteinaki K.*, Heller A., Rode C.
DTU Civil Engineering

*Corresponding author email: kyfote@byg.dtu.dk

An overview of a recently started project is given following. The project is a part of the "EnergyLab Nordhavn" project, whose general objective is to demonstrate for a city district such as the new Nordhavn, how electricity, heating, energy-efficient buildings and electric transport can be integrated into an intelligent, flexible and optimized energy system based on renewable energy. It is included in Work Package 3 on "Smart Energy Buildings", which aims to provide new understanding of low-energy buildings with their occupants and users as active energy-flexible elements in a smart energy system, and to develop and demonstrate novel control solutions for smarter operation and monitoring of energy in modern buildings transforming challenging fluctuations of the various energy forms into an interconnected system.

The objective of the project is to contribute to the development of methods for modelling the dynamic thermal response of buildings that will facilitate energy flexibility, using energy storage and load shifting potentials. In this context, conceptual flexibility indicators are to be developed. Considering all parameters that could contribute to that, namely technical parameters of buildings, user behaviour and micro-climate around buildings, the purpose is to create models that can contribute to optimal control strategies. This derives from the base hypothesis that energy flexibility would enable the system to integrate a larger share of renewable energy and that energy flexibility in buildings, in particular, would have a key role in facilitating energy systems based entirely on renewable energy sources. It is the goal of the present project to examine whether and to which extent this could be verified and to provide methodologies to make such investigations.

A bottom-up modelling approach will be followed, working on the building level and having the energy system as the boundary condition. Categories of buildings will be studied with regards to their varying possibility for flexible operation, enabling shifting peak energy loads to off-peak hours. The different parameters that energy flexibility in buildings can be derived from will be studied and examined. This involves investigating the possibilities and the effects of storage both in the thermal mass of the building structures and by using different components and HVAC systems, for example Thermally Activated Building Structures (TABS) and heat pumps. Moreover, the study will focus on users' comfort and behaviour. In this context users' acceptability will be taken into consideration, investigating how the limits for comfort can be exploited and influenced. At the same time, the interaction between the users and the system will be also taken into account, on a design phase, examining how users affect the operation of the building. What is more, the micro-climate and other external influences will be considered, along with their effects on the operation of the buildings, identifying the contribution of different parameters such as solar gains and wind exposure. Experimental data from case buildings will be used to validate the models. Finally, a generic model engine will be created.

The main expected outcome of the project will be a methodology for simulating the dynamic thermal flexibility of buildings. Conceptual flexibility indicators will be delivered, in combination with the outcomes of the order of magnitude analysis of how the individual parameters affect the overall flexibility of the building. A simplified model will be provided, which will be used as input for model predictive control and aggregation modelling on city level.

Quantifying sustainability in architecture

Mathilde Landgren, Lotte Bjerregaard Jensen, Alfred Heller, Jørn Kiesslinger, Ole Hornbek and Peter Andreas Sattrup.

DTU Byg

Email: maland@byg.dtu.dk

Abstract: Sustainability has since the Brundtland report in 1987 been defined as *"a development, which fulfills the existing needs, without compromising the needs of the future generations"* [1]. In relation to this report the concept of sustainability were divided into three main columns: Environmental, Social and Economical, of where they all are weighed equally [1]. The past years the focus upon sustainability has increased worldwide, as sustainability is a broad topic, research in sustainability had to be focused within the different realms of knowledge. In Civil engineering the main focus has been the reduction of fossil based energy consumption for operating indoor climate of buildings. The design processes designated to achieve this was developed and labeled: "Integrated Energy Design" method (IED) [2]. After the development of the IED method the certification systems for sustainable buildings have been developed and are currently occupying major part of the discourse on sustainability in buildings. In 2012 the Danish version of a German sustainability certification system was launched; DGNB (Deutche Gesellschaft für Nachhaltiges Bauen) [3]. This indicates a shift from the focus of IED to a much broader notion of sustainability in the building industry. The central research question here is how to broaden the span of sustainability issues in the building industry, without losing the quantification manifest in IED. IED had a main focus on the early design phases, as many crucial decisions are made here and thereby will have a large influence upon the final building [2]. Another research question is how the focus on the early design phases can be expanded to integrate quantification at all levels of the design process. This last mentioned research question is closely related to the ideas behind BIM (Building Information Modeling).

The purpose of this study is to quantify sustainability in architecture by using the known sustainability parameters from the DGNB DK and thereby improving the design process towards more measurable sustainability in architecture and still maintain excellence in architectural quality. The method of this study will be based on a mapping of the IED method and the DGNB criteria's. Hereby it will be possible to compare and see how the two methods are connected and get an initial idea of how the design process will change when using DGNB´s criteria as framing for the design process.

References:

[1] Brundtland report (1987) *Report of the World Commission on Environment and Development "Our Common Future"*, Available online: http://www.bne-portal.de/fileadmin/unesco/de/Downloads/Hintergrundmaterial_international/Brundtlandbericht.File.pdf?linklisted=2812 [03.11.15]
[2] Kongebro, Signe (2012) *Design with knowledge*, Henning Larsen Architects
[3] GBC DK (2014) DGNB, Available online: http://www.dk-gbc.dk/ [03.11.15]

Optimization of municipal energy strategies: Are community energy profiles the key to a higher implementation rate of renewable energies?

Jens-Phillip Petersen[1]

1: DTU Civil Engineering, ICIEE

*Corresponding author email: jepete@byg.dtu.dk

It is at the local level where policies to increase the share of renewable energies and higher energy efficiency measures get implemented. Municipalities, as responsible entity for physical planning, can hold a key role in transforming our energy systems towards carbon-neutrality. The implementation has to be approached at community scale, rather than at building or city scale, which has many advantages.[1] Despite the promising efforts to approach this at community scale, the implementation of renewable energies is still too slow to meet global or just national GHG reduction goals.[2,3]

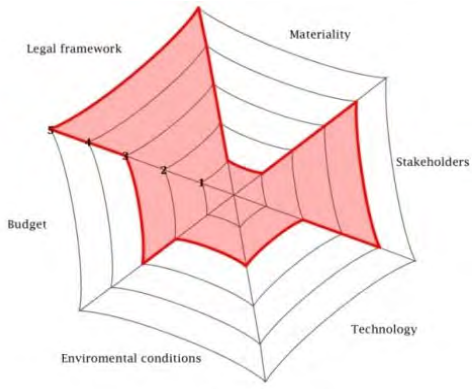


Fig. 1: Example of a CEP visualization

The study evaluates the current state of community energy planning in northern Europe via a review of literature and practice. Two major mismatches have been identified: First, community energy concepts and the available literature are too technical and rarely consider qualitative factors that are crucial for implementation of energy strategies. Thus, there is a general gap between literature, community energy concepts and the actual implementation process. Second, municipalities lack knowledge on energy planning; ensuing, a guideline on choosing adequate planning methodologies to implement technical concepts. As a reaction on the found barriers a decision-support methodology was developed: It should help municipalities in the pre-project phase to (A), identify possible energy technology strategies and assess their impact on the energy performance of the community and (B), connect the technical strategies with qualitative information on the community, allowing choosing adequate planning methodologies to implement the suggested energy strategies – community energy profiles (CEP). The CEPs enrich quantitative energy modelling, which too often produces techno-economic standard solutions, with qualitative information on the specific community via the identification of local socio-economic challenges. Besides enhancing community energy system modelling, communities in various local settings become comparable.

The basic function of the methodology can be described as a rough energy strategy feasibility analysis, with an addition of soft factors from the CEP to find the technology bundle that is most likely to be implemented and an advice about possible planning strategies to achieve this. The first application of the methodology enabled the municipality Elmshorn (Germany) to build-up a cost-efficient and low-carbon district heating.[4] The case showed the capacity as well as the potential for optimization of the methodology, which makes further development of the methodology into a decision-support tool necessary.

[1] Erhorn-Kluttig, H. (2011): Energetische Quartiersplanung. Methoden - Technologien - Praxisbeispiele. Stuttgart: Fraunhofer-IRB-Verl.
[2] Sperling, K.; Hvelplund, F.; Mathiesen, B. V. (2011): Centralisation and decentralisation in strategic municipal energy planning in Denmark. In Energy Policy 39 (3), pp. 1338–1351.
[3] Thellufsen, J. (2014): How to establish local renewable energy scenarios in the context of national energy systems. Conference: Proceedings of SEEP2014, 23-25 November 2014, Dubai.
[4] Petersen, J-P (2015): Energy concepts for self-supplying communities based on local and renewable energy sources: A case study from northern Germany. Manuscript sumbitted for publication.

COPING WITH COLD – in situ observation

Jennifer Fiebig, MA Architect, PhD candidate*[1]

1: DTU Civil Engineering

*Corresponding author email: jenfi@byg.dtu.dk

Figure 1: Residential housing, picture by Jennifer Fiebig, Sisimiut, Greenland 2014

For centuries extreme climatic conditions are prevailing in arctic regions where snow and ice are known as a significant problem for the built environment. Simultaneously, the weather affects the outdoor activities for a long period of time and restricts the mobility and social interaction. Snow and wind have a high impact on the structural design of buildings and urban planning. The observed higher temperatures in the arctic cause higher densities of snow and rain events lead to wet and heavy snow. In order to understand the interaction of snowdrift between the architectural designs an in situ observation is necessary. In the field observation the snow phenomenon will be studied in two main cities on Greenland. A photometric study of snowdrift and accumulation around and between buildings in Sisimiut and Nuuk will be conducted. The photometric full-scale observation provides information for investigations of snow depositions for wind tunnel testing at reduced scale. The experimental study will be performed in the small boundary-layer wind tunnel at DTU Civil Engineering.

Using Numerical Weather Prediction Ensembles to Anticipate Flows in Urban Area

Vianney Courdent [1,2], Morten Grum[2], Peter S. Mikkelsen[1]
1: DTU Environment; 2: Kruger A/S
*Corresponding author email: vatc@env.dtu.dk

Weather forecasts can provide valuable information to improve the operational performance of urban drainage systems (UDS) and wastewater treatment plants (WWTPs). For example, radar-based rainfall forecast are increasingly being used within real-time control (RTC) concepts (Vezzaro et al. 2014). Numerical weather prediction (NWP) models can also contribute to forecasting rainfall with the advantage of an increased lead-time. For example Meneses et al. (2015) use NWPs to generate operational flood warnings, and Bjerg et al. (2015) described the potential of flow domain forecasting using NWP to optimise energy consumption: The UDS can be used as buffer when no rain is expected to control the timing of energy consumption which, enables coupling with the electrical smart grid system optimizing expenses and CO_2 footprint.

Using uncertain information, such as NWP, to optimize storm- and wastewater systems in real time is generally challenging. Indeed, NWP is embedded with a significant uncertainty. Therefore Ensemble Prediction Systems (EPS) are generated and prediction strategies using multiple ensemble members are implemented e.g. (Courdent et al. 2015), Figure 1 illustrates the principal.

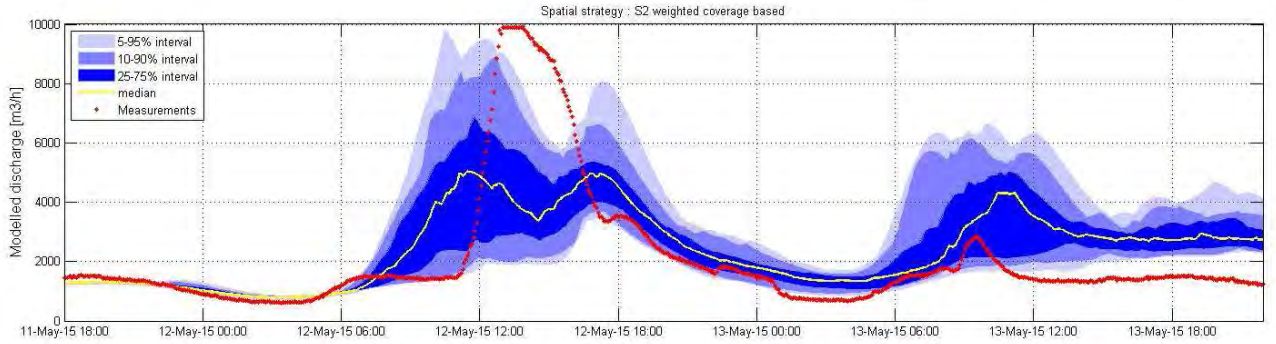


Figure 1: Flow prediction at Damhuså catchment generated the 11th of May 2015 at 18:00 using the DMI-HIRLAM-S05 NWP model

Bjerg, J.E. et al., 2015. Coupling of Weather Forecasts and Smart Grid-Control of Wastewater inlet to Kolding WWTP (Denmark). In *10th International Urban Drainge Modelling Conference*. Mont Sainte-Anne, Québec, Canada, pp. 47–59.

Courdent, V., Grum, M. & Mikkelsen, P.S., 2015. Using numerical weather prediction ensembles to dstinguish urban drainage flow domains 2 days ahead. In *10th International Urban Drainge Modelling Conference*. Mont Sainte-Anne, Québec, Canada, pp. 123–126.

Meneses, E.J. et al., 2015. SURFF - Operational flood warnings for cities based on hydraulic 1D-2D simulations and NWP. In *10th International Urban Drainge Modelling Conference*. Mont Sainte-Anne, Québec, Canada, pp. 97–104.

Vezzaro, L. et al., 2014. Water Quality-based Real Time Control of Integrated Urban Drainage Systems: A Preliminary Study from Copenhagen, Denmark. *Procedia Engineering*, 70, pp.1707–1716. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1877705814001908.

Life Cycle Assessment of Cloudburst Management Plans in Adaptation to Climate Change in Copenhagen, Denmark

Sarah Brudler*[1,2], Karsten Arnbjerg-Nielsen[1], Martin Rygaard[1]

1: DTU Environment; 2: VandCenter Syd

*sabr@env.dtu.dk

The environmental impacts of cloudburst management systems are assessed using Life Cycle Assessment (LCA). A terrestrial LCA approach as introduced by Loiseau et al. (2013) is first used in connection to storm water management (SWM) and tested using two different climate change adaptation strategies for a catchment in Nørrebro, Copenhagen. The catchment area is defined as the reference flow, from which different functions are derived based on the Three Points Approach, which divides rain events in different domains according to frequency (Sørup et al., 2012). This allows defining different safety targets for everyday and rare rain events, which are met by a combination of different elements that differ in the two scenarios. The "green" scenario mainly utilizes green infrastructure, local retention and infiltration, while the second "grey" solution employs underground pipes and retention basins. The environmental impacts resulting from implementing, operating and decommissioning are significantly smaller for the "green" scenario in all eight considered categories (41% down to 13% of the "grey" impacts). The main contributor in both scenarios is the generation of materials, e.g. concrete and steel, which highlights the possibility for system design optimization in order to reduce negative effects. The allocation of impacts shows that different functions of urban SWM systems affect the environment to a different extent, e.g. the management of extremely rare events has negligible impacts compared to handling events with a return period of up to ten years.

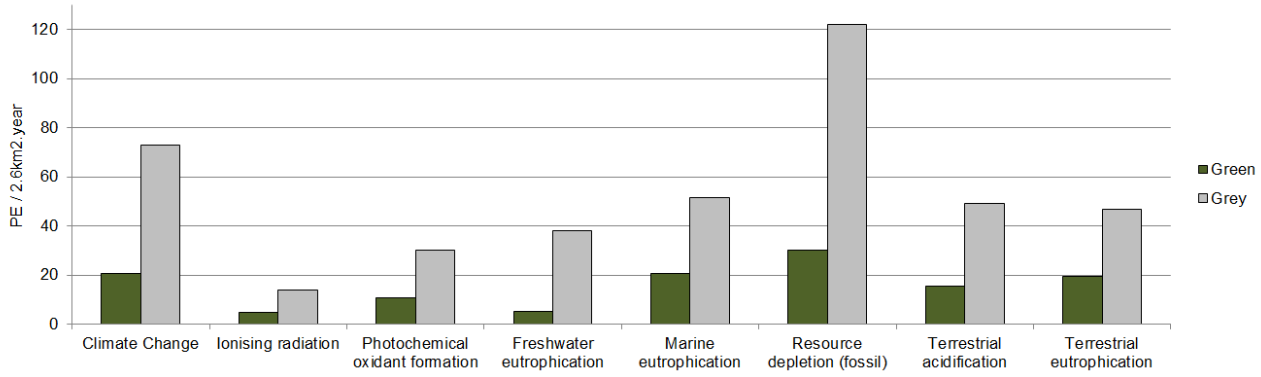


Figure 1: Normalized environmental impacts per year of the two scenarios, for eight selected midpoint categories

Loiseau, E., Roux, P., Junqua, G., Maurel, P., Bellon-Maurel, V., 2013. Adapting the LCA framework to environmental assessment in land planning. Int. J. Life Cycle Assess. 18, 1533–1548.

Sørup, H.J.D., Arnbjerg-Nielsen, K., Mikkelsen, P.S., Rygaard, M., 2012. Quantitative potential for rainwater use. Technical University of Denmark, Department of Environmental Engineering, Lyngby, Denmark.

Session

M

Oral Presentations

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

Natural Fibre Composites: Properties and Challenges

Bo Madsen*, Hans Lilholt, Christen Malte Markussen, Tom Løgstrup Andersen

Composite Materials and Mechanics, DTU Wind Energy

* Corresponding author email: boma@dtu.dk

Natural fibres from plants have attracted wide interest as reinforcement in composite materials due to the good technical performance of the fibres, and their potential sustainable nature and low cost. Natural fibre composites have been extensively studied at the Department of Wind Energy, Risø Campus, DTU in the past many years to demonstrate that the composites show high stiffness and low weight, directly comparable to benchmark glass fibre composites, but with moderate strength. A number of demonstrators have been fabricated to reveal the promising potential of natural fibre composites. Examples of existing industrial applications can also be found. A number of still unsolved issues exist for natural fibre composites, which call for further research and development. Recently, the existence of defects in natural fibres has been studied to explain their moderate strength. Methods for the quantification of defects have been developed, and the effect on the mechanical properties of the fibres has been studied.

Demonstrators of natural fibre composites

Sculpture developed by a joint venture of 20 companies coordinated by 3XN architects, Denmark.

Wheel rim developed within the EU 7th Framework Programme project NATEX

High Temperature Materials for Efficient, Flexible Thermal Energy Plants

John Hald

DTU Mechanical Engineering

jhald@mek.dtu.dk

Abstract

Traditional fossil-fired thermal power plants are challenged in regions like Denmark and Germany, where renewable energy technologies such as wind and PV are introduced in large scale. Due to priority for wind and PV in the grid, their production time is limited, which is an economic challenge. Due to fluctuating output from wind and PV they have to operate with highly flexible output, which increases fatigue loads on sensitive components designed for more steady operation modes.

In Denmark, the strategy for existing thermal power plants involves replacement of fossil fuels with biomass like straw and wood, which are considered CO_2-neutral. However, the biomass contains highly aggressive species, which introduce accelerated corrosion in heat exchangers and limit efficiency and lifetime.

On the global scale, Thermal power from coal and gas provide 65% of electricity production, and many scenarios predict that this share could remain almost constant in the next 25 years[1]. This means that we have never had as many coal and gas fired power plants in the world as we have now, and that they will most likely be more numerous in coming decades. Efficiency increases of thermal power by a few percentage points can lead to savings in the order of Gigatonnes of CO_2 emissions on the global scale[2].

The lecture describes research to develop and introduce stronger and more corrosion resistant high temperature materials and surface coatings for critical components of thermal power plants. Such materials can lead to improved efficiency and flexibility, longer lifetimes and reduced emissions.

[1] Eia, US Energy Information Administration, “International Energy Outlook 2013” DOE/EIA -0484(2013)

[2]IEA, International Energy Agency, Technology Roadmap “High-Efficieny Low-Emissions Coal Fired Power Generation” OEDC/IEA 2012

Materials characterisation tools towards lead-free piezoceramics

Jette Oddershede*[1], Marta Majkut[1], Emily Yap[2], John Daniels[2], Søren Schmidt[1]

1: DTU Physics; 2: UNSW Australia

*Corresponding author email: jeto@fysik.dtu.dk

Electro-mechanical materials directly couple applied mechanical stress and generated electrical charge, or conversely, an applied electric field and a resultant mechanical strain. Airbag triggers, ultrasound emitters and receivers for acoustic imaging, nano-positioning systems, and vibrational energy harvesting devices – these are just a small selection of applications built on the use of electro-mechanical coupling materials such as the piezoceramic PZT ($Pb(Zr_{1-x}Ti_x)O_3$ – 60wt% lead). Within the EU, the allowed maximum concentration of lead is 0.1 wt% in new electronic equipment as of 2006, though PZT based devices are exempt from this rule until practicable substitutions are available. Hence, major research focus is currently on the development of lead-free alternatives to PZT, but it has proven difficult to achieve comparable properties. A prime reason for the difficulties in replacing PZT is that the electro-mechanical coupling cannot be predicted from material composition and microstructure; the behaviour is complex and multi-length-scale in nature and its exact origins are still a matter of debate.

We have developed 3D grain mapping techniques that enables us to measure changes in microstructure for hundreds of individual grains within the polycrystalline electro-mechanical materials as a function of applied electrical field. The methods are based high energy X-ray diffraction and give access to information on grain positions, sizes, shapes, neighbour relations, phases, crystallographic orientations, strains and volume fractions of the so-called ferroelectric domains. This implies that – for the first time – interactions between neighbouring grains or domains in the polycrystalline electro-mechanical materials can be probed, and the data can be used to directly validate and improve current models describing the electro-mechanical response of ceramic materials. For a more complete picture of the microstructure, X-ray CT can be used to obtain complimentary information on material inhomogeneity and porosity. Examples of using the above 3D characterisation techniques to aid the design and development of new lead-free piezoceramic materials will be presented.

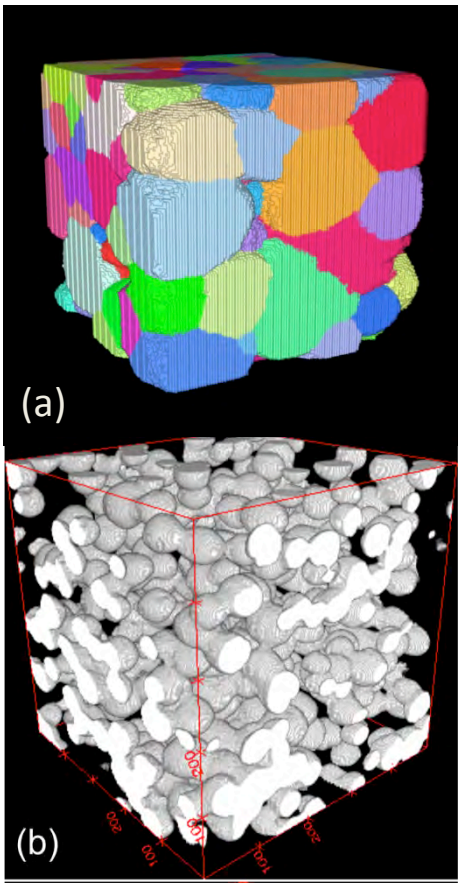


Figure 1 Piezoceramic microstructure**:** (a) 3D grain map of $BaTiO_3$, colours reflect individual grain orientations, and (b) pore structure in $(Ba_{0.85}Ca_{0.15})(Zr_{0.1}Ti_{0.9})O_3$ of potential use as bone implant.

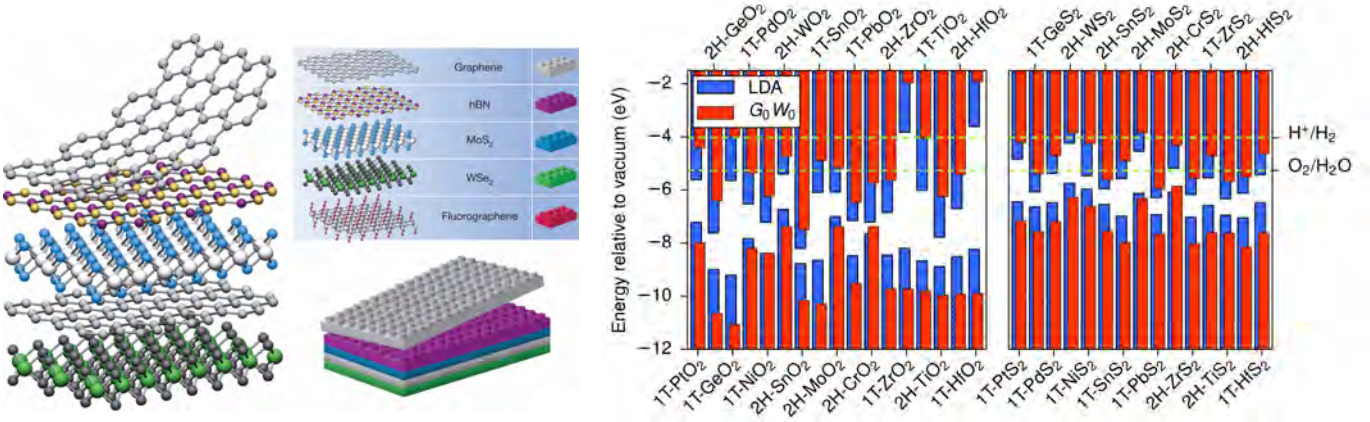
Computational Discovery of Sustainable Energy Materials

Kristian Sommer Thygesen[1]*

1: DTU Fysik

*thygesen@fysik.dtu.dk

Identifying new high-performance materials is a significant challenge. At present on the order of 200.000 inorganic materials are known. Their chemical composition and crystal structure are stored in crystallographic databases, however, the basic properties (mechanical, electronic, etc.) of these materials remain largely unknown. A systematic, experimental characterization of the properties of this huge set of materials is impossible, but it can be done efficiently and at low cost using modern electronic structure calculations. According to the US Materials Genome Initiative (MGI) and the Materials Science and Engineering Expert Committee, computational materials science will be totally indispensable for materials discovery and design during the next decade. I will review our efforts of employing large-scale quantum mechanical computations to explore and discover new materials for solar energy conversion. Examples will include design of functionalized porphyrins for dye sensitized solar cells(1), novel two-dimensional materials for high performance opto-electronics(2), and perovskites for photo-catalytic water splitting(3). In the spirit of the MGI we contribute to the development of computational property databases that will serve industry and academia in the search for new materials(4).



References:

(1)Optimizing porphyrins for dye sensitized solar cells using large-scale ab initio calculations, K. B. Ornso, C. S. Pedersen,J. M. Garcia-Lastra, K. S. Thygesen, Phys. Chem. Chem. Phys. **30**, 16246 (2014)

(2) The Dielectric Genome of van der Waals Heterostructures, K. Andersen, S. Latini, and K. S. Thygesen, Nano Lett. **15**, 4616 (2015)

(3) New cubic perovskites for one- and two-photon water splitting using the computational materials repository,I. E. Castelli, D. D. Landis, K. S. Thygesen, S. Dahl, I. Chorkendorff, T. F. Jaramillo, K. W. Jacobsen, Energy and Env. Science **5**, 9034 (2012)

(4) *Computational Materials Repository*, https://wiki.fysik.dtu.dk/cmr/(software), and https://cmr.fysik.dtu.dk/ (database).

The sustainable future of packaging: A biodegradable paper beer bottle

Ellen Brilhuis-Meijer[1] and Prateek Saxena*[1]

1: DTU Mechanical Engineering

*Corresponding author email: prasax@mek.dtu.dk

The vision of the Green Fiber Bottle (GFB) project is to develop the world's first paper beer bottle, which will be both recyclable and biodegradable. It is intended to be an environmentally sustainable alternative to the existing glass and plastic beer bottles. To achieve this, both the bottle and the production process that is required to shape the cellulose fibers into the bottle need to be developed. This is done in a collaboration between Carlsberg, EcoXpac, Innovation Fund Denmark and DTU.

To ensure that the GFB will offer an environmentally friendly solution, sustainability will be integrated in the development process. Ecodesign approaches will be selected and applied each step of the way for both the bottle itself and the required technologies. One of these approaches will be the use of Life Cycle Assessment (LCA). Early on, the LCA will be based on predictions and assumptions, which will be replaced with more precise data whenever it becomes available. The resulting calculation of the potential environmental impact provides insight into the areas that may require specific attention, such as energy consumption during the production process, transportation and recycling. With the availability of more precise data will come more detailed insight, allowing more precise assessment of materials and emissions that may be of concern. Other sustainability considerations include the sourcing of bio-based materials, biodegradability and prevention of waste.

Besides the sustainability considerations, there are many other challenges for developing the GFB. These include production challenges, such as the required throughput for Fast Moving Consumer Goods (FMCG) and functional challenges, such as maintaining a pressure of up to 6 bar inside the bottle, limiting oxygen ingress and achieving a shelf-life of at least 6 months.

To enable the production of the GFB, a new mass production process based on integrating fiber molding and in-mold impulse drying technology will be developed, able to cope with the required production rate and volume. Impulse drying is a technique to enhance the removal of water from paper pulp using a tool heated to a temperature in the order of 250 °C. It exploits the partial vaporization of the liquid phase and the consequently generated overpressure to quickly push the water out of the pulp which thus dries and hardens.

The impulse drying will reduce both the need for energy and the production time for each bottle, thereby reducing the production cost significantly. In this way the price of a GFB is intended to be competitive with existing market solutions, thus making it attractive for companies to use.

Material challenge for future fuel factories

Malene Kaab*[1], Per Møller[1],

1: DTU Mechanical Engineering, Department of Materials and Surface Engineering

*makaa@mek.dtu.dk

The modern society consumes a lot of energy every day and need efficient energy supplies. At the same time, the world pursues an energy matrix where the major part of the energy production originates from green but often fluctuating energy sources. In some periods renewable energy will produce much more energy than consumed and other times not enough. To handle these variations and achieve efficient energy utilization, a need for eco-friendly storage and enhancement of these green energies will be central for the future. Fuel factories will be a fact for the world of tomorrow; a place where oversupplied energy will be taken; converted, upgraded and stored.

A considerable focus since the eighties has been on converting energy from etc. wind turbines to hydrogen and from hydrogen to liquid fuels. The conversion from electricity to hydrogen occurs in harsh environment like alkaline electrolyzes, solid oxide electrolyzer cells and polymer electrolysis cells, all having different and challenging material issues. Further post-processing e.g. methane and methanol production from biogas requires yet a process which also put out need for durable and corrosion resistant catalysts. The advantage of using the hydrogen in a methane production in Denmark, is the gas grid and gas storage facilities which already exist.

This presentation will focus on durability of materials for hydrogen production and upgrading, with focus alkaline electrolyzes components and catalytic electrodes, catalysts and corrosion issues in the methane production line.

Lightweight aluminium alloys for sustainable future

Rajan Ambat and V.C Gudla

DTU Mechanical engineering

email: ram@mek.dtu.dk

Increased efficiency has become a key issue for technology development in the 21st century, especially in the transportation sector in order to reduce fuel consumption, fulfil further legislation demands, reduce greenhouse gases and maximize overall environmental protection. Light weight alternative materials are key aspects of strategic research in this area and sustainability. Aluminium and its alloys have great potential to achieve these objectives due their light weight and the ability to recycle. This talk will provide an overview of technological importance of aluminium alloys today, various applications, recycling issues, surface modification issues, future challenges, and an overview of focus of our research in this direction.

Session

M

Laptop Presentations

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

In situ ETEM Study on the Growth Termination of Single-Wall Carbon Nanotubes

Lili Zhang[1], Thomas W. Hansen[1], Maoshuai He[2], Jens Kling[1], Hua Jiang[3], Esko I. Kauppinen[3], Jakob B. Wagner*[1]

1: Technical University of Denmark, Center for Electron Nanoscopy, Fysikvej 307, 2800 Kgs. Lyngby, Denmark
2: Laboratoire d'Étude des Microstructures, ONERA-CNRS, BP 72, 92322 Châtillon CEDEX, France
3: Department of Applied Physics, Aalto University School of Science, P.O. Box 15100, FI-00076 Aalto, Finland

*Corresponding author email: jakob.wagner@cen.dtu.dk

Single-wall carbon nanotubes (SWCNTs) with specific structures are ideal materials in nano-electronics. Taking thin film field effect transistors as an example, semiconducting SWCNTs show more promising performances than traditional indium-containing semiconductors as channel materials. Besides, the latter is a kind of critical materials derived from limited natural resources. Therefore, in a long run, the study on indium replacement by SWCNT thin film with improved performance and reliability is important for both fundamental research and industrial applications. The first step for that is to synthesize SWCNTs with high yield and specific structure. Understanding the growth termination mechanism of SWCNTs is of great importance for maximizing the quality and yield, and for controlling their structure. Generally, it involves the deactivation of catalysts by carbon encapsulation or morphology evolution (Ostwald ripening), and the diffusion-limited supply of carbon feedstock to the catalyst. However, the detailed microscopic causes of tube growth cessation are still lacking. Here we show the direct experimental evidence on the growth and termination of SWCNTs from Co/MgO catalysts using CO as carbon source inside the environmental transmission electron microscope (ETEM) (see [1, 2]). The dissociation of SWCNTs from the catalysts was widely observed. Interestingly, new tubes are able to nucleate and grow from the same particle that is abruptly deactivated for the initial SWCNT, suggesting a high activity of catalysts and a different nucleation and termination process of SWCNTs.

Reference

[1] He, M., et al.; Chiral-Selective Growth of Single-Walled Carbon Nanotubes on Lattice-Mismatched Epitaxial Cobalt Nanoparticles. Sci. Rep., 3, 2013
[2] Hansen, T.W.; J.B. Wagner; Catalysts under Controlled Atmospheres in the Transmission Electron Microscope. ACS Catal., 4, 1673, 2014

Polarization enhancement of ferroelectric nanoparticles

B.S. Baekke[1], M. Beleggia*[1]

1: DTU Danchip/Cen

*mailto:marco.beleggia@cen.dtu.dk

Ferroelectric (fe-) nanostructures are the core elements of several modern technologies, from fe-capacitors, to random access memories (fe-RAM, a viable alternative to the popular flash memory). They bring the promise of *lower power consumption*, *increased durability and speed* over existing technologies for information storage and manipulation. A physical limitation is, however, preventing their large-scale implementation: *the polarization is suppressed at small sizes* [1]. We demonstrate here why this is the case, and illustrate a possible avenue for *enhancing the polarization of ferroelectric nanoparticles* with suitable energy-relief mechanisms to *create the smallest ferroelectric capacitor yet*. Our strategy is to embed the structures in a matrix to screen the depolarizing field while preventing the formation of domains, and to exploit elongation and shape effects by controlled lithographic patterning. Aiming at achieving spatially-resolved measurements of the polarization with electron holography, we estimate the signal to be expected in the electron microscope and support the feasibility of such experiments. Electron holography, a specialty of DTU Cen, is a phase-sensitive technique in transmission electron microscopy capable of detecting the fields generated by elementary charges [2] and spins inside materials while maintaining near-atomic spatial resolution. Combining theoretical and experimental analysis will provide us with the opportunity to *develop functional ferroelectric nanodevices with a degree of miniaturization, performance and sustainability far greater than what currently possible.*

[1] Phatak C et al., Phys Rev B 89 (2014) 214112
[2] Beleggia M et al., Appl Phys Lett 98 (2011) 243101

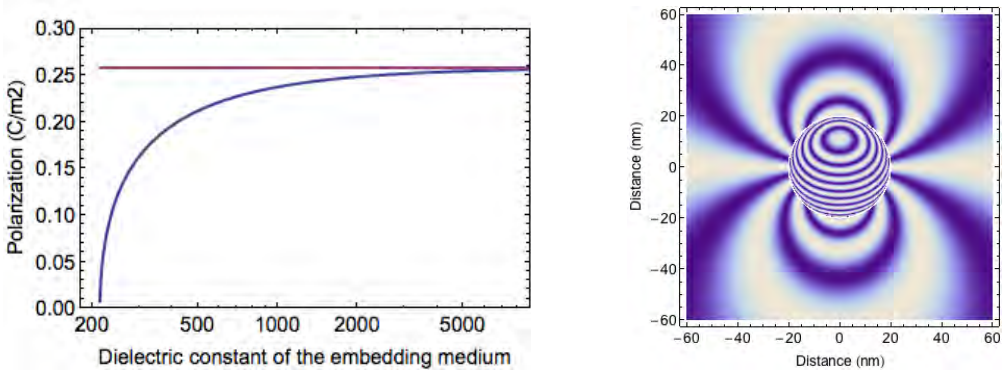


Figure 1. Left: polarization of a hypothetical single-domain BaTiO nanoparticle as a function of the dielectric constant of the embedding medium; the polarization vanishes below a critical value of e_r=214. Right: cosine-map (256x amplified) representation of the electron-holographic phase shift for a BaTiO nanoparticle when e_r=300 with the effect of the mean-inner-potential (MIP) added to that of the polarization; the particle radius is 20 nm, the accelerating voltage 300 kV, and the MIP 1 V.

Session

M

Poster Presentations

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

Waste management of ENM-containing solid waste

Laura Heggelund[1]; Alessio Boldrin[1,*]; Steffen F Hansen[1]; Thomas F Astrup[1]

1: DTU Environment; *Corresponding author email: aleb@env.dtu.dk

Little research has been done to determine emissions of engineered nanomaterials (ENM) from currently available nano-enabled consumer products. While ENM release is expected to occur throughout the lifecycle of the products, this study focuses on the product end-of-life (EOL) phase. We used the Danish nanoproduct inventory (www.nanodb.dk) to get a general understanding of the fate of ENM during waste management in the European context. This was done by: 1. assigning individual products to an appropriate waste material fraction, 2. identifying the ENM in each fraction, 3. comparing identified waste fractions with waste treatment statistics for Europe, and 4. illustrating the general distribution of ENM into incineration, recycling and landfilling. Our results (Figure 1) indicate that "dirty plastic" is the most abundant and diverse waste fraction, comprising a variety of both nanoproducts and materials. While local differences are seen between individual EU countries/regions according to the local waste management system, results show that all waste treatment options are significantly involved in nanowaste handling, suggesting that research activities should cover different areas. The results of this study may be used for the environmental and human health risk assessment of nanowaste, and to assist future regulatory and management decisions. Current research activities at DTU Environment focus on assessing the release on ENM during waste treatment.

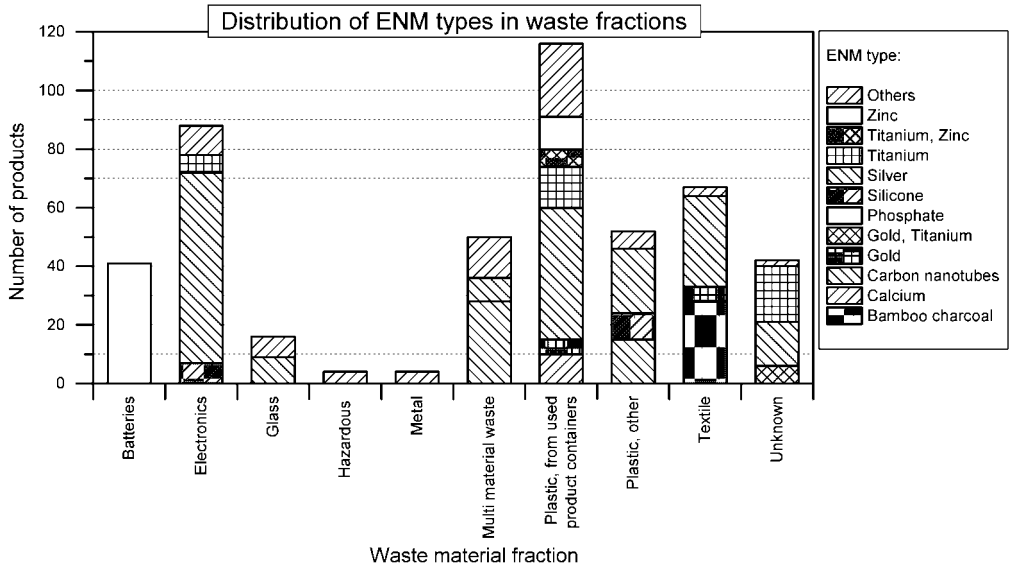


Figure 1 – Distribution of engineered nanomaterial (ENM) types into waste material fractions. Taken from Heggelund et al. (2015)

Reference:
Heggelund, L., Hansen, S.F., Astrup, T.F., Boldrin, A. (2015) Semi-Quantitative Waste flow analysis of nano-enabled products in Europe, Denmark and the United Kingdom – abundance, distribution and treatment. Submitted to *Waste Management*.

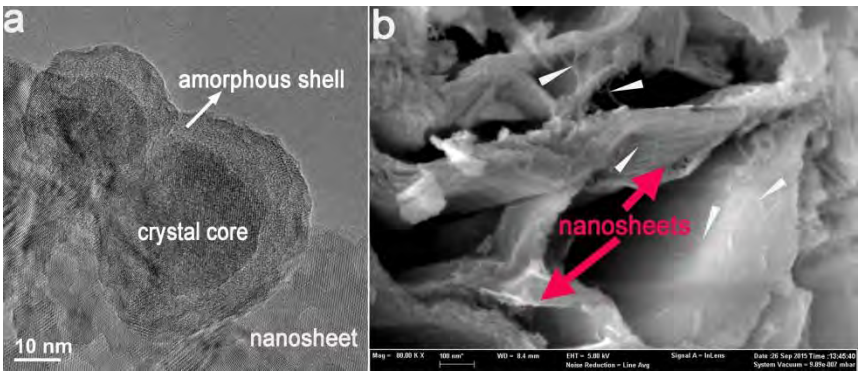
Chemically Modified Hierarchical Metal Oxide Nanostructures for Excellent Lithium Storage

Hongyu Sun[1, 2, *], Jawayria Mujtaba [2], Jing Zhu [2], Kristian Mølhave [1, *]

1: DTU Nanotech; 2: Beijing National Center for Electron Microscopy, School of Materials Science and Engineering, Tsinghua University, Beijing 100084, P. R. China

*Corresponding author email: hsun@nanotech.dtu.dk, Kristian.molhave@nanotech.dtu.dk

The overall performance of lithium-ion batteries (LIBs) is highly dependent on the inherent electrochemical properties of the electrode materials.[1, 2] Specifically, three-dimensional complex hierarchical architectures assembled by low-dimensional nano-sized building blocks usually possess enhanced LIB performance.[3, 4] Herein, by employing post chemical modification, we obtain novel hierarchical metal oxide nanostructures: crystalline@amorphous core/shell Co_3O_4 nanoparticles decorated ultrathin Co_3O_4 nanosheets; NiO nanowires decorated NiO nanosheets. The concentration of oxygen vacancies can be well controlled in the nanostructures, which is of importance because the conductivity can be tuned accordingly. The lithium storage properties of the chemically-modified hierarchical electrodes are found to be strongly correlated with oxygen vacancy concentration. It is believed that the excellent electrochemical performance can be attributed to the unique designed hierarchical nanostructures. The presented facile synthesis route can be applied to other metal oxides with desirable nanostructures, which provides a novel way to optimize their functions.



(a) Crystalline@amorphous core/shell Co_3O_4 nanoparticles decorated ultrathin Co_3O_4 nanosheets, (b) NiO nanowires (the white arrows) decorated NiO nanosheets

1. Goodenough, J. B. *et al*. A perspective on electrical energy storage. *MRS Commun*. **4**, 135 (2014).
2. Goriparti, S. *et al*. Review on recent progress of nanostructured anode materials for Li-ion batteries. *J. Power Sources* **257**, 421 (2014).
3. Sun, Y.-K. *et al*. Nanostructured high-energy cathode materials for advanced lithium batteries. *Nat. Mater*. **11**, 942 (2012).
4. Magasinki, A. *et al*. High-performance lithium-ion anodes using a hierarchical bottom-up approach. *Nat. Mater*. **9**, 353 (2010).

Preliminary analysis of recycled fishing nets in construction materials

Bertelsen, I.M.G.[1], Ottosen, L.M.[1]

1: Centre of Arctic Technology, DTU Civil Engineering

*Corresponding author email: imgber@byg.dtu.dk

Marine plastic waste is a growing concern and is nowadays widely documented. One particular troublesome marine waste fraction is discarded fishing gear, which is about 18 % of the marine plastic debris [Andrady, 2011]. In the vulnerable Arctic environment, the impact of non-biodegradable waste materials can have severe consequences on the environment. A new international project, Circular Ocean, investigates possible ways of reusing discarded fishing gear in remote areas within the Northern periphery and Arctic (NPA) region in order to reduce discarded fishing gear as marine debris.

This PhD study is part of Circular Ocean and focus on finding new applications for the discarded fishing nets within the construction sector. The main idea is to use the nets as fiber reinforcement in different types of construction materials. Since the project focuses on remote areas within the NPA region, the developed products and solutions must be simple and possible to manufacture on-site.
During the recent years, plastic waste utilization in construction materials has become an attractive alternative to disposal and several studies have already shown that waste materials, such as plastic waste, can be used for reinforcement techniques of structural and non-structural materials in the construction sector [Siddique et al., 2008].

In this study, several types of both new and discarded fishing nets will be investigated, and mechanical and physical properties such as tensile strength, Young's modulus, deterioration rate at different pH's, thermal behavior and microstructure will be determined and compared. Next, experimental testing of building materials such as concrete and unfired bricks with different types, lengths and weight fractions of fibers of recycled fishing nets will be carried out.
Initial testing of concrete beams with fishing nets used as fiber reinforcement has been done, and the results showed that the fishing nets had a positive influence on the ductility of the concrete failure.

References

Andrady, A. L. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin*, *62*(8), 1596-1605.
Siddique, R., Khatib, J., & Kaur, I. (2008). Use of recycled plastic in concrete: a review. *Waste management*, *28*(10), 1835-1852.

Use 200x less material! Solar cells based on the Cu_2ZnSnS_4 compound

Andrea Crovetto[*1], Sara Engberg[2], Rebecca Ettlinger[2], Andrea Cazzaniga[2], Jørgen Schou[2], Ole Hansen[1,3]

1: DTU Nanotech; 2: DTU Fotonik; 3: CINF, Center for Individual Nanoparticle Functionality

*Corresponding author email: ancro@nantotech.dtu.dk

For solar energy to really compete with fossil fuels for production of bulk grid power, its cost needs to be further decreased. Conventional silicon-based solar cells have almost reached their theoretical efficiency limit and their cost is dominated by the cost of the high-quality silicon crystal needed for high-efficiency solar cells. The new photovoltaic material Cu_2ZnSnS_4 (nicknamed 'CZTS') is a promising alternative since it absorbs light about 200 times more strongly than silicon and therefore can be made 200 times thinner, greatly reducing material costs (Figure 1). Further, CZTS only contains earth-abundant, environmentally-friendly elements and requires a lower processing temperature than conventional solar cells, so it is a viable candidate for Terawatt-sized solar energy production. Its potential theoretical efficiency is as high as conventional solar cells (more than 30%), but current record efficiencies are still below 10% [1].

Our strategy is to produce CZTS films by 1) a research-oriented vacuum method (pulsed laser deposition) for studying the material's properties, and 2) an industry-friendly wet chemical method (spin/spray coating of nanocrystals in a liquid solution) for large-scale production. Preliminary conversion efficiencies of 2.1% have been measured on solar cell devices fabricated by our group using a glass/Mo/CZTS/CdS/ZnO/ZnO:Al stack (Figure 1,2) and further optimization is underway.

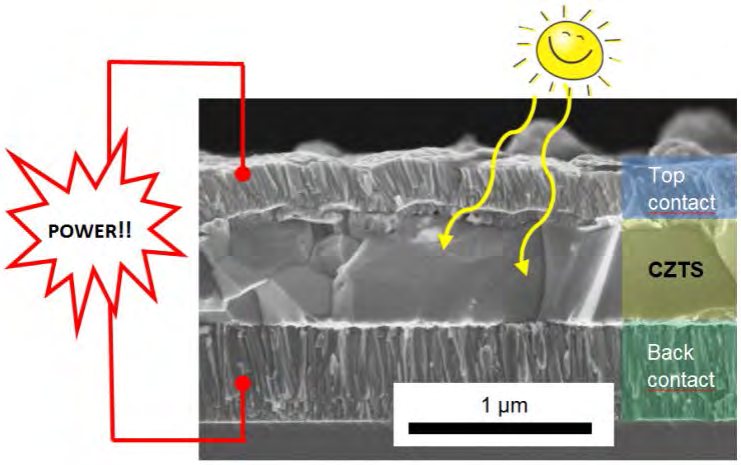


Figure 1. Cross-sectional view of a CZTS solar cell produced by our group.

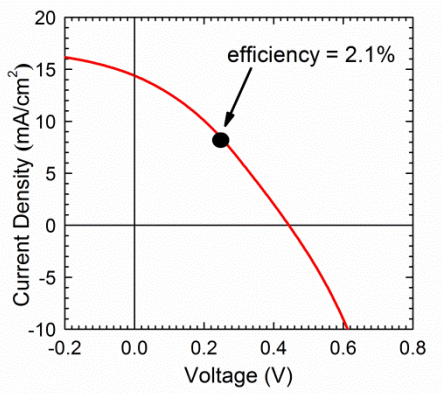


Figure 2. Current-voltage curve of our best solar cell under standard illumination

[1] S. Tajima, T. Itoh, H. Hazama, K. Ohishi, R. Asahi, *Appl. Phys. Express* **2015**, *8*, 082302.

Developing methods for In-situ TEM and potential studies in energy storage, electrochemistry, material science, and bioscience etc.

Murat Nulati Yesibolati[1], Silvia Canepa[1], Rolf Møller-Nilsen[1], Simone Laganà[1], Hongyu Sun[1], Kristian Mølhave*[1]

1: DTU Nanotech

*Corresponding author email: kristian.molhave@nanotech.dtu.dk

Transmission electron microscope (TEM) is capable of imaging with a significantly high resolution, i.e., scale less than sub nanometer [1]. Conventional TEM can provide information including, morphology, composition, topographical and crystalline etc. . Thanks to the construction of micro/nanolab in TEM holder, recent years witness the rapid development of dynamic process studies with high spatial and temporal resolution. Remarkable research results have been demonstrated, for instance, nucleation process[2], crystal growth[3], intrinsic electrochemistry reactions for micro/nano battery[4].

Currently, we focus on designing and fabricating TEM holders with different capabilities for various applications. For instance, a TEM holder (Fig. 1a) with liquid flow and 5 electrical contacts is developed. It has a closed cell configuration (Fig. 1b) which could be used for battery, electrochemistry and bioscience researches. An open cell structured TEM holder with 16 electrical contacts is in the final stage of production. A TEM holder with heating/magnetic/optical elements is also under consideration. More information about different TEM holders and corresponding chips will be demonstrated in the conference. You are sincerely invited to make collaborations with us.

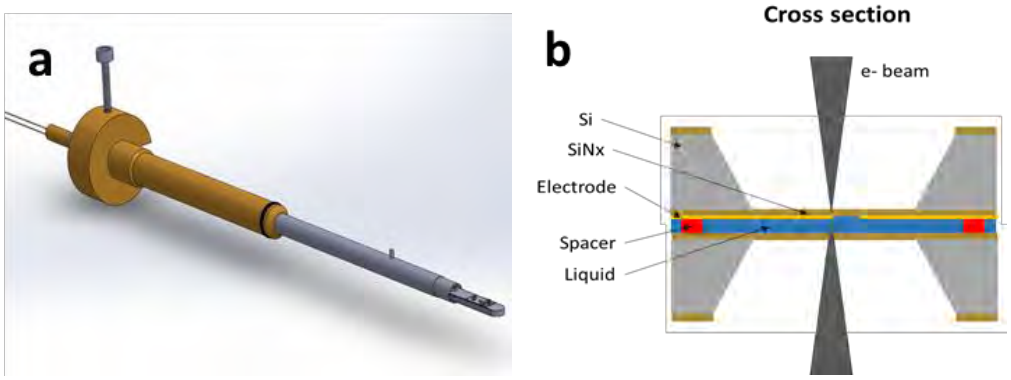


Figure 1. a). Schematic view of the manufactured TEM holder with liquid flow and 5 electrical contacts; b). Schematic cross section view of a double-chip setup with electron transparent window (SiNx) which is used for observing.

References
[1] R. Erni; M.D. Rossell; C. Kisielowski; U. Dahmen, Physical Review Letters 102 (2009) 096101
[2] M.H. Nielsen; S. Aloni; J.J. De Yoreo. Science, 345 (2014) 1158-1162
[3] F. M. Ross, 2012, ISBN: 978352765216
[4] J.Y. Huang, L. Zhong, C.M. Wang, J. P. Sullivan, W. Xu, L.Q. Zhang, S.X. Mao, N.S. Hudak, X.H. Liu, A. Subramanian, H.Y. Fan, L. Qi, A. Kushima, J. Li, Science, 330 (2010) 1515-1520

Session

P

Oral Presentations

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

High-resolution multi-material 3D printing by stereolithography

Niels B. Larsen*, Esben Kjær Unmack Larsen, Rujing Zhang, Mikkel Hofstedt Juul, Kristoffer Almdal

DTU Nanotech

*Corresponding author email: niels.b.larsen@nanotech.dtu.dk

3D printing has become widespread in recent years with the majority of printers being based on serial deposition of a narrow molten polymer filament (so-called fused deposition modeling). Recently, 3D printing by local light-induced polymerization of a polymer solution, commonly termed stereolithography, has gained momentum due to inherent possibilities for higher spatial resolution and higher fabrication speeds by parallel light exposure using commercially available light projectors. Stereolithography is currently limited to a single material in a printed object, since shaping of multiple materials will require separate polymerization of each material with different light sources. Such materials and printing systems have so far been unavailable.

We have addressed this challenge in a joint effort by polymer chemists and fabrication technologists to develop a multi-color printing system matched to a newly developed starting material. Based on the exposure color and time, the local mechanical properties of the resulting 3D object can be varied by more than 100 times with high spatial resolution. In addition, the new printer system can achieve a printing resolution of <15 µm which is superior to any commercially available system (Figure 1). In this presentation we will discuss current limitations and possible solutions to enhance printing resolution as well as printing throughput to make the technology commercially attractive.

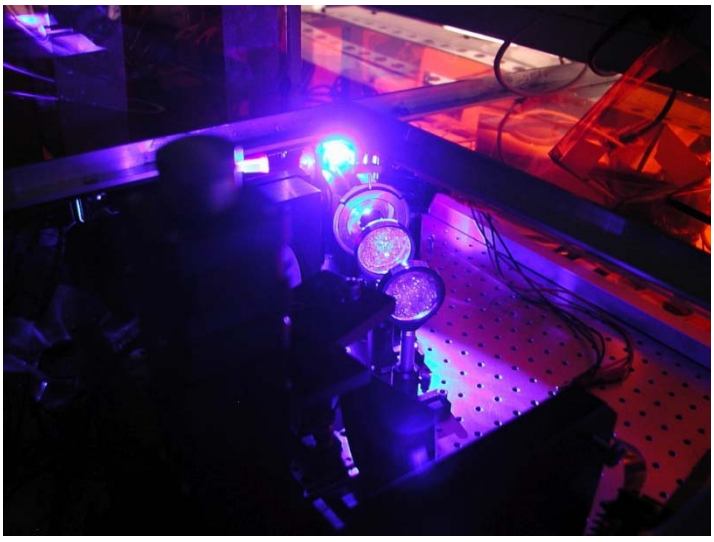


Figure 1. The recently developed 3D polychromic stereolithography printer at DTU Nanotech can expose with multiple wavelengths, here 365 nm and 450 nm, at <15 µm pixel size to freely combine multiple materials within a printed object.

3D Graphene-based bio-cathode for Carbon dioxide reduction in Microbial Electrosynthesis

Nabin Aryal[1], Arnab Halder[2], Pier-Luc Tremblay[1], Qijin Chi [2], Tian Zhang[1]*
1: Novo Nordisk Foundation Center for Biosustainability, Technical University of Denmark, Kogle Allè 6 DK-2970 Hørsholm
2: Department of Chemistry, Technical University of Denmark, Kemitorvet, 2800, Kgs. Lyngby, Denmark
*Corresponding author email: zhang@biosustain.dtu.dk

Microbial electrosynthesis (MES) is an attractive strategy to utilize carbon dioxide as a carbon source and electron from externally polarized cathode for the synthesis of multi-carbon chemical commodities. This technology is one of the efficient technologies for sequestration and conversion of carbon dioxide into the organic chemical. The electro-autotrophic bacteria fix CO_2 via Wood-Ljungdahl pathway and accept electrons from the cathode. This technology mainly depends on the performance of the electro-autotrophic bacteria; cathode material and reactor set up for the enhancement of microbe-electrode electron transfer. For the first time, we reported the catalytic activity of three-dimensional graphene-based electrodes in microbial electrosynthesis (MES) for Carbon dioxide gas reduction in pure culture platform. The carbon felt was modified with three-dimensional graphene for the enhancement of electron transfer in microbial electrosynthesis. The three-dimensional graphene-enhanced the adherence of bacterial cell on the electrode interface and formed the thick biofilm and hence production rate was increased by fivefold compared to the unmodified electrode

Keywords: - Microbial electrosythesis, CO_2 reduction, Three-dimensional graphene, *Sporomusa ovata*

Chemical production by microbial electrosynthesis

Tian Zhang*

DTU Biosustain

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

Powering microbes with electrical energy to produce valuable commodities is a new concept and a potential alternative to a petroleum-based economy. Microbial electrosynthesis (MES) is a novel bioproduction process in which microbes reduce CO_2 to multicarbon organics using electrical current. MES has tremendous potential for the storage of energy into covalent chemical bonds of commercially viable products without the need for arable land and has the flexibility to be coupled with electricity from renewable resources. In the long term, this technology will enable the European Union to cut greenhouse gas emissions, develop new energy sources and make it less dependent on imported energy. Key to the success of the MES process is effective electrical connection between bacterial cells and electrode surface. However, low electron transfer rate from electrochemical hardware to microbial platforms, unknown electron transfer mechanism, and poor adherence of microorganisms on the electrode has been the main obstacles to commercialization to date. Developing superior bioelectrochemical hardware with state-of-the-art technique like 3D printing, establishing alternative MES processes relying on multi-cultures and investigating extracellular electron transfer from the cathode to the microbes are some of the strategies that we are implementing to transform MES into a commercially viable technology.

Stereolithography-based 3D printing of hydrogels for long-term cell culture and synthetic vasculature

Rujing Zhang[1], Rodrigo Guzmán[1], Niels B. Larsen*[1]

1: DTU Nanotech

*Corresponding author email: nibl@nanotech.dtu.dk

Three-dimensional (3D) soft biomaterial scaffolds for long-term cell culture are critical components in tissue engineering and regenerative medicine. However, it is still challenging to construct such scaffolds with desired structural stability and resolution using soft hydrogel. We have developed a method to fabricate 3D biocompatible hydrogel scaffolds at sub-200 µm resolution using projection-based stereolithography to address the biomedical challenges of stem cell culture and synthetic vasculature. Poly(ethylene glycol) (PEG) hydrogels were 3D printed by spatially controlled, light-induced solidification of an aqueous pre-polymer solution (PEG-diacrylate 700 Da and 5000 Da, lithium acylphosphinate photoinitiator, Quinoline Yellow as absorber) using a modified commercial stereolithography printing system (envisionTec Micro, 405 nm illumination). Optimization of the printing configurations allowed for printing of pyramid-shaped micro-containers for long-term 3D stem cell culture and perfusable micro-channels approaching arteriole dimensions (100 µm cross-section). Human mesenchymal stem cell (hMSC) culture on the pyramidal micro-containers showed that hMSC spheroids formed spontaneously after 24 h incubation, and high cell viability (> 80%) was sustained in the stable cultured spheroids for 7 days of incubation. Compared to the technically delicate state-of-the-art hanging drop methodology used for spheroid formation, our time- and work-efficient approach in 3D printed low cell adhesion hydrogels provides improved control of hMSC spheroid size and shape. As synthetic arteriole and venule analogs, our channel structures could be freely designed and constructed at sub-200 µm resolution in a single automated process (100 µm X 100 µm square channels), a resolution few methods can achieve in soft hydrogels with full design freedom in all three dimensions, compared to conventional methods such as hydrogel bonding and sacrificial molding. The aim of printing micro-channels within bulk hydrogels is to further fabricate 3D microvascular scaffolds for tissue engineering, since vascularization is generally considered as the most important obstacle in the field. On-going cell culture experiments show high compatibility of the printed micro-channel structures to an endothelial cell line (CRL2922) to be employed for endothelialization of the printed vascular network analogs.

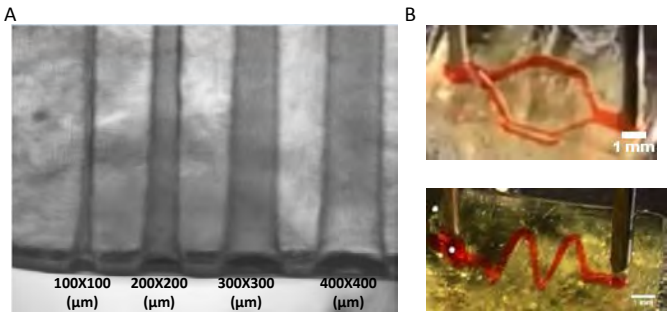


Figure: A) Top view of printed micro-channels by phase contrast microscopy. B) Snapshots for perfusion of a bifurcation channel system (top) and a spiral channel (down).

Fabrication of nano and micro structured polymer foils by roll-to-roll-extrusion coating.

S.Murthy[1,3], M.Matschuck[1], H. Pranov[1], G. Kofod[1], H. Pedersen[3],R.Taboryski[2]
1. InMold A/S, Gregersensvej 6H, DK - 2630 Taastrup, Denmark
2. Department of Micro- and Nanotechnology, Technical University of Denmark
3. Department of Photonics Engineering, Technical University of Denmark
E-mail: smurthy@fotonik.dtu.dk

We suggest a novel roll-to-roll process for nano- and microstructuring, which will accelerate the integration of nanostructured materials in a broad range of applications, including optical, technical and functional surfaces and devices. Possible applications may even include cast molding of advanced materials for photo-voltaic, thermo-electric, electro-active and electro-storage applications, where nanostructuring often leads to improved properties. The process is known as roll-to-roll extrusion coating (R2R-EC : in the packaging industry commonly referred to as co-extrusion), and is widely used for production of smooth polymer films, but has not previously been employed for replication of nanostructures (shown in figure 1). Among benefits of the process are availability of a wide range of commercial extruders, off-the-shelf extrusion grade polymers, functional additives, polymeric materials with good diffusion barrier properties, and the overall maturity of the technology. In roll-to-roll extrusion coating a molten polymer film is extruded through a flat nozzle forming a melt curtain, then stretched in air, and finally laminated onto a carrier foil. The lamination process takes place as the melt curtain is squeezed between a cooling roller and a rubber counter roller. By attaching a nanostructured metal sheet to the surface of the cooling roller, the relief structure from the sheet can be replicated onto a plastic foil. We have demonstrated that nanostructures with typical linewidths in the range 100 - 400 nm are best replicated using semi-crystalline polymers such as polypropylene (PP), running at high roller line-speed of 60 meters per minute, and high cooling roller temperature of 70° C. Replication in other common polymers like polyethylene (PE) and polystyrene (PS) was not possible for nanostructures. However, structures with linewidths and depths above ca. 400 nm were more forgiving and allowed for a wider range of materials. For such microstructures, it was found that process parameters had to be individually optimized for each pattern, indicating that viscoelastic flow into the relief plays a more important role.

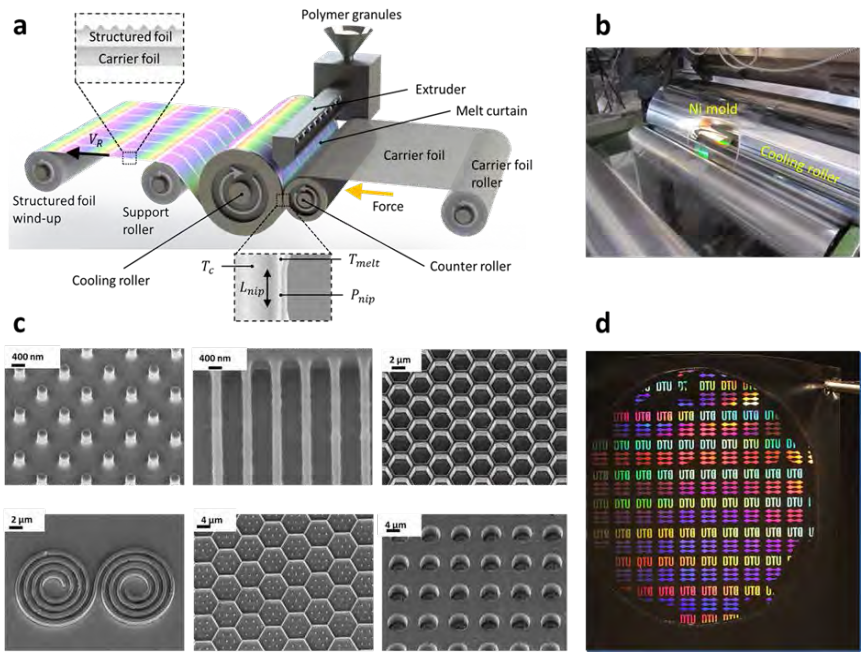


Figure 1. a: Schematic of R2R-EC process. b: Photograph of the cooling roller with the Ni mold mounted. c: Scanning electron micrographs of structures with various shapes, linewidths ranging from 400 nm to ≳1 µm, and aspect ratios ≳1 replicated in PP by R2R-EC. Images were taken at a 30° tilt angle. d: Example of an application of the technology; diffraction grading pattern with DTU logo produced by R2R-EC. The pattern was originated from a 100 mm Si wafer, electroformed into a Ni mold, and replicated by R2R-EC on PP foil.

Session

P

Laptop Presentations

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

Session

P

Poster Presentations

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

Pyrolysed carbon microelectrodes with improved performance for cyclic voltammetry and EIS

Yasmin M. Hassan*, Florence Gavin, Claudia Caviglia, Suhith Hemanth, David Mackenzie, Letizia Amato, Dirch H. Petersen, Stephan S. Keller
DTU Nanotech
*yamoh@nanotech.dtu.dk

Conductive carbon structures can be obtained from a polymer template through a pyrolysis process. These structures can be used for example as electrodes or scaffolds. One possible application of the microelectrodes could be integration in a measurement setup with microfluidic and electronic components to study the toxicity of heavy metals and hormones in water. This study focuses on the optimization of 2D pyrolysed carbon microelectrodes obtained from a lithographic process to improve performance for electrochemical characterization (Fig. 1.a). SU-8 was used as photoresist to create the polymer template on a Si-based carrier substrate, and then pyrolysed at 900°C. Different electrodes were fabricated, focusing on the optimization of the fabrication process to decrease impedance, parasitic effects and improve performance in cyclic voltammetry (CV). A gold pseudo-reference electrode and gold contact pads were deposited by e-beam evaporation through a shadow mask, and a 5µm thick film of SU-8 was used as passivation layer. Electrochemical analysis was performed using CV and impedance spectroscopy both in PBS and in ferri-ferrocyanide using a self-aligning magnetic clamping system (Fig. 1.b). By increasing the carbon thickness, the peak current increased, the ΔEp decreased (Fig. 1.c), and the measured impedance at high frequencies was reduced (Fig. 1.d). The optimal final thickness of the pyrolysed carbon was 2.2 µm with a sheet resistance of 81.1 Ω/sq.

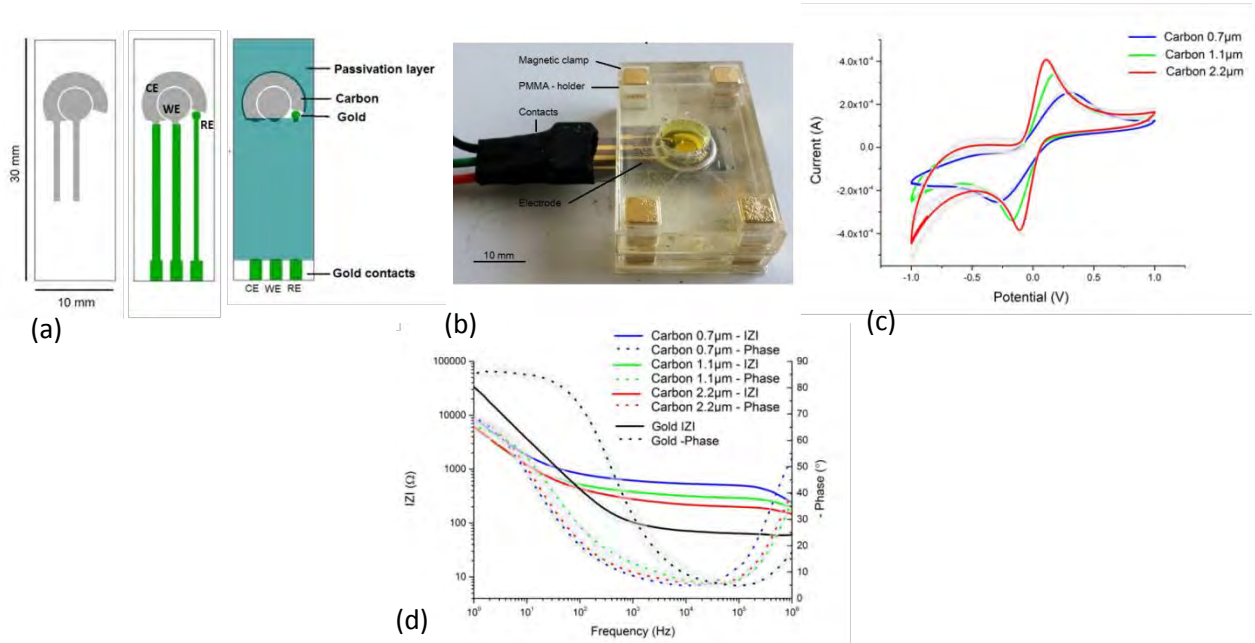


Figure 1: Top view of the microelectrodes composed of a circular carbon working electrode (WE), surrounded by a carbon counter electrode (CE), gold reference (RE), and passivation layer (SU8) (a), self-aligning magnetic clamping system for electrochemical analysis (b), CV spectra in ferri-ferrocyanide (c) and impedance spectra in PBS (d) of the optimized electrode with long gold leads and increased carbon thickness

Deep-UV -Lithography: Principles, Optimization, and Simulation

Matthias Keil* [1], Niels Peder Møller [1], Elena Khomtchenko[1], Leif Steen Johansen[1]

1: DTU Danchip, Ørsteds Plads, Building 347, 2800 Kgs. Lyngby

*Corresponding author email: makei@danchip.dtu.dk

One of the key issues for lithographic optimization is the definition of metrics needed to classify the process quality. This quality can be improved by the modification of relevant optical parameters, as e.g. the wavelength, the numerical aperture and the coherence of the aerial image. Additionally, the impact of the reaction kinetics of the resist during exposure, post exposure bake and development must be considered in order to exceed the requirements of the device to be fabricated.

An overview of improvement techniques of deep-UV lithography processes will be presented that will gain insight into its fundamental principles required to characterize and to optimize the optical and chemical process. A combination of two different approaches has been investigated, assisted by simulation calculations with the help of the Prolith™ software from KLA-Tencor. In the first approach the focus-exposure matrix is used to determine a process window that leads to a maximized depth of focus for the required specification, as i.e. the target CD, the exposure latitude, the resist loss and/or the side-wall angles. Figure 1 shows the focus-exposure matrix of a hole-array, including the relevant information obtained by a simulation, i.e. the isofocal point, the target CD, the resist bias and the isofocal bias). Secondly, with the help of the gradient-based approach, the gradients of the image that is projected and recorded into the photoresist can be used as a metric for both the achieved image and resist contrast (not shown here).

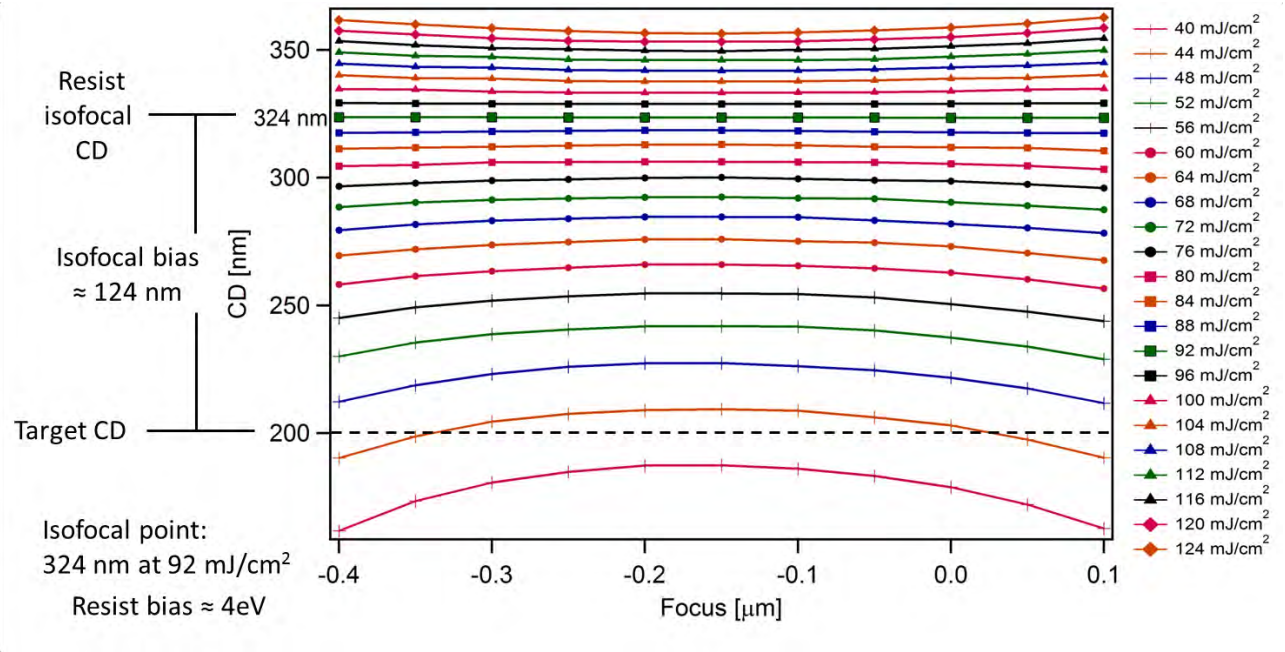


Fig. 1: Focus exposure matrix (Bossung curves) for a hole-array (200nm linewidth, 500nm pitch)

Towards development of a novel online tool wear compensation method for dry micro-electrical discharge milling

Govindan Puthumana*[1] and Guiliano Bissacco[1]

1: DTU Mechanical Engineering

*Corresponding author email: gput@mek.dtu.dk

Micro-manufacturing technologies play a vital role in the manufacturing industry with several applications involving generation of products offering advantages such as compactness, multi-functional capabilities and lower cost. Among micro manufacturing processes, micro electrical discharge machining has become an established process for the generation of complex 3D micro components. Micro-EDM milling is the micro-EDM configuration, which provides the highest flexibility and shortest setup time [1]. During processing, because the discharges remove material also from tool electrode, the tool electrode changes its geometry thereby affecting the achievable part accuracy. Tool wear is the single most important factor limiting the manufacturing accuracy in the geometry of the workpiece in micro-EDM [2]. Currently, kerosene-based mineral oil is one of the important dielectric fluids in micro-EDM, however the fumes generated during the process are hazardous to the environment and the oil disposal poses a potential threat to the environment. The gas dielectric-based EDM technology (dry EDM) is a potential eco-friendly alternative to the liquid dielectric-based EDM process. An earlier comprehensive experimentation on assessment of productivity and machined surface quality in dry EDM of SS304 workpiece using copper tool electrode showed few important results related to tool wear [3]. One of the most striking feature that is observed in the dry EDM is the tool wear rate close to zero. A predominant deposition of molten and eroded work material on the tool electrode surface instead of tool wear was evident. Statistical analysis of the tool wear rate (TWR) shows that pressure of the gaseous dielectric (*P*) is significant at 90% confidence level. An analysis of surface topography of electrode surfaces shows the formation of black patches of carbon on tool electrode surfaces (layer of carbon), which reduces the tool electrode wear in dry EDM. The metallurgical characterization of deposited material on the tool electrode using EDAX analysis shows that the elements Iron (Fe), Chromium (Cr) and Nickel (Ni) in workpiece act as catalysts for diffusion of carbon. Currently, the EDM research group in DTU Mechanical is actively involved in development of a robust, reliable and real-time method for compensation of tool electrode wear in liquid dielectric micro-EDM milling process. Therefore, it is envisaged that an adaptation of the novel online tool wear compensation method with enhanced capabilities for dry micro-EDM process, would provide few additional advantages such as: i) lower magnitude of tool electrode wear and, ii) environmental friendliness.

References

[1] G. Bissacco, H. N. Hansen, G. Tristo, J. Valentincic, 2011, Feasibility of wear compensation in micro EDM milling based on discharge counting and discharge population characterization, CIRP Annals, 60/1, 231-234.

[2] G. Bissacco, G. Tristo, H. N. Hansen, J. Valentincic, 2013, Reliability of electrode wear compensation based on material removal per discharge in micro EDM milling, CIRP Annals, 62/1, 179-182.

[3] P. Govindan and Suhas S. Joshi, 2010, Experimental characterization of material removal in dry electrical discharge drilling, International Journal of Machine Tools and Manufacture, 50/5, 431-443.

TiO_2 and Al_2O_3 ALD Grown Multilayers for Subwavelength Photonics.

Evgeniy Shkondin*[1], Flemming Jensen[2], Andrei Lavrinenko[3], Mikkel Dysseholm Mar[4], Pernille Voss Larsen[5], Radu Malureanu[6], Sergei V. Zhukovsky[7], Andrei A. Andryieuski[8], Osamu Takayama[9]

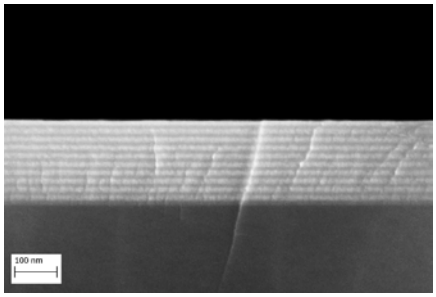
1: DTU Danchip, DTU Fotonik; 2: DTU Danchip; 3: DTU Fotonik; 4:-5: DTU Danchip, 6:-9: DTU Fotonik

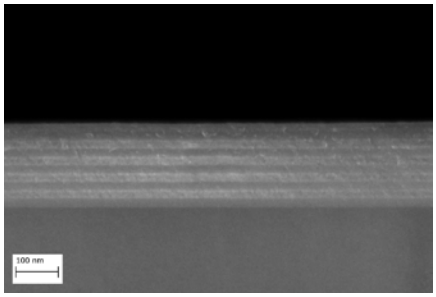
*eves@fotonik.dtu.dk

Atomic Layer Deposition (ALD) is playing a steadily increasing role in micro- and nanofabrication technologies. This is also the case for many applications within sustainability such as solar cells, energy harvesting in general and efficient micro-power solutions where ALD offers new tailor-made material compositions, highly conformal deposition and excellent control over layer thickness and uniformity [1].

ALD allows deposition of nanometer scale thin multilayer coatings, which can be used in fields of optics and nanophotonics [2]. Recent theoretical publications [3], [4] suggest that well-defined effective media approximation (EMA) [5] assumption may fail in transparent dielectric multilayers with deep subwavelength thicknesses. The transmission spectrum in this case becomes different than predicted by EMA. The spectrum becomes sensitive to layers thicknesses on nanometer scale and their order in multilayer. In this work we present the fabrication approach to the described structure.

TiO_2 and Al_2O_3 metal oxides were selected as the multilayer components. The fabrication of the multilayers was performed in a commercial hot-wall ALD system (Picosun R200, Finland). The precursors used for Al_2O_3 and TiO_2 deposition were trimethylaluminum $Al(CH_3)_3$ and titanium tetrachloride ($TiCl_4$), respectively. An oxidant source in both processes was deionized water. The deposition temperature was chosen at 120C in order to prevent the anatase phase transition of TiO_2 known to occur at temperatures above 150C [6]. The deposition of Al_2O_3/TiO_2 multilayers was carried on 100mm <100> silicon wafers. After the ALD process was completed, the sample was cleaved and its cross-section was characterized using scanning electron microscopy (SEM). The SEM images reveal high-quality homogeneous, conformal coatings, as seen in the examples in Figs 1 and 2.





We believe this fabrication flow opens possibility for experimental demonstration of EMA theory breakdown in deep subwavelength multilayers. This technology can be applied for developing of variety of new optical sensing and switching applications.

References:

[1] S. M. George, Chemical Reviews 110 (2010) 111-131
[2] J. D. Joannopoulos, S. G. Johnson, J. N. Winn, R.D.Meade, Photonic Crystals: Molding the Flow of Light, 2nd ed. (Princeton University Press, Princeton, NJ, 2008)
[3] H. H. Sheinfux, I. Kaminer, Y. Plotnik, G. Bartal, M. Segev, Physical Review Letters 113 (2014), 234901
[4] A. Andryieuski, A. Lavrinenko, S. Zhukovsky, Nanotechnology 26 (2015) 184001
[5] D. E. Aspenes, Thin Solid Films 89 (1982) 249-262
[6] D.R.G. Mitchell, D.J.Attard, K.S. Finnie, G. Triani, C.J. Barbe, C. Depagne, J.R. Barlett, Applied Surface Science 243 (2005) 265-27

Proximity Effects in a Chemically Amplified Electron Beam Resist Patterned at 100 keV

W.Tiddi[1,2]*, T. Greibe[1], M. Beleggia[2], A. Han[1]

1: DTU Danchip; 2: DTU CEN

*wiltid@dtu.dk

Electron beam lithography (EBL) is a patterning technique providing nanometric resolution. It is widely used in research, optical and nanoimprint lithography mask production, and parallel EBL is intended to be adopted in future next generation high through-put semiconductor device production [1]. Sub-20 nm patterning has been demonstrated on negative tone, epoxy-based chemically amplified EBL resists such as mr-EBL 6000 [2]. This material is characterized by significantly reduced dose sensitivity, which would provide faster, more cost-effective production.

When distances between structures are comparable to the intended critical (smallest) feature dimension, proximity effects (PE) caused by forward and back scattered electrons deteriorate the quality of the resulting pattern. PE on mr-EBL 6000 were observed when patterning with 10 and 20 keV electron beams, and compensated through dose modulation algorithms [3]. The present investigation focused instead on PE in mr-EBL at substantially higher electron energy and is to our knowledge new. To understand these conditions and their expected profound influence on PE, we patterned carefully arranged structures at 100 keV, and transferred them into a silicon substrate by reactive ion etching (RIE). We successfully patterned 50 to 500 nm wide lines, and we observed pattern deterioration when feature separation approached 5 times the line width (Fig. 1). We attribute this to PE. As a simple optimization, we showed how under-dosed patterns offer appreciable improvements in minimum obtainable pitch, and obtained analogous results in films thinner than 40 nm, an expected mandatory requirement to push manufacturing towards sub-10 nm half-pitch resolution [4].

[1] G. de Boer et al., Proc. Of SPIE 8680 (2013) 86800O-12.
[2] B. Bilenberg et al., J. Vac. Sci. Technol. B 24 (2006) 1776.
[3] G. Rius, E-beam litho. for Nanofabrication, Ph.D. Thesis, Dept. of Phys., Uni. Autò. Barcelona, 2008.
[4] A. Tavakkoli K. G. et al., J. Vac. Sci. Technol. B 29 (2011) 011035.

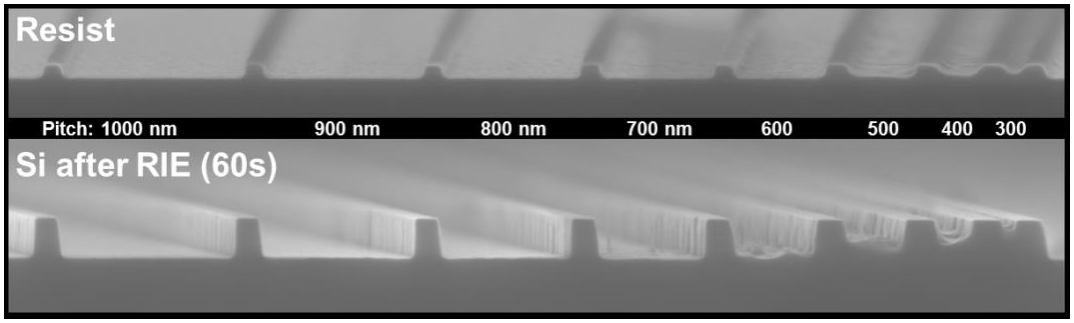


Figure 1 – Cross sectional SEM image of progressively closer spaced lines patterned in resist (a) and transferred into silicon through RIE (b). We observe overexposure in denser patterns because of PE; the resulting distorted pattern is this way reproduced into the underlying substrate.

Life Cycle Assessment Injection Mold Inserts: Additively Manufactured, in Brass, and in Steel

Michael Mischkot*[1], Thomas Hofstätter[1], Niki Bey[2], David Bue Pedersen[1], Hans Nørgaard Hansen[1], Michael Z. Hauschild[2]

1: DTU Mechanical Engineering;
2: DTU Management Engineering
*Corresponding author email: micmi@mek.dtu.dk

3D printing applied to Manufacturing Engineering is known as Additive Manufacturing (AM) Polymer AM can be used to produce soft tooling inserts for injection molding. As life time of such inserts is significantly shorter than the life time of traditional brass, aluminum, or steel inserts, soft inserts are mainly used for pilot production and prototyping. The short lived nature of these molds renders little allowance for run-in errors, and as such, a Life Cycle Assessment study has been carried out in order to provide for the maximum yield throughout the development and pilot phase. Spite a short life-span, and depending on the insert geometry, AM inserts can be made cheaper and quicker than traditional pre-production tooling, which is particularly advantageous for pilot production and small production sizes.

In this research, Life Cycle Assessment (LCA) is used to compare the environmental impact Soft Tooling by AM to two traditional methods for the manufacture of inserts for injection molds during the pre-production phase:

- 3D printing of a photopolymer using Digital Light Processing (DLP)
- Milling of a brass insert
- Milling of a steel insert

References:

[1] Curran M A, Life Cycle Assessment Handbook – A Guide for Environmentally Sustainable Products, Scrivener Publishing LLC 2012, ISBN 978-1-118-09972-8

[2] Gibson I, Rosen D, and Stucker B, Additive Manufacturing Technologies – 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Springer New York 2015, ISBN 978-1-4939-2112-6

[3] Wohlers Report 2015 – 3D Printing and Additive Manufacturing State of the Industry Annual Worldwide Progress Report, Wohlers Associates, Fort Collins Colorado

[4] Kreiger M, and Pearce J M, Environmental life cycle analysis of distributed three-dimensional printing and conventional manufacturing of polymer products, ACS Sustainable Chem. Eng. 2013, 1, 1511−1519, dx.doi.org/10.1021/sc400093k

Optimisation of polymer processes through induction heated tools

Peter Torben Tang*[1], Nikolas A. Paldan[1] & Christian Ravn[1]

1: IPU

*Corresponding author email: tt@ipu.dk

Polymer processes such as injection moulding, welding, thermoforming and hot-embossing all involves heating of a tool or tool insert. The material that is heated is also required to cool down before the polymer process can be completed, and thus will the resulting cycle time of the process depend heavily on the volume, heat capacity and maximum temperature of the tool.

Induction heating is one of the fastest direct heating methods known, and by building the tools in a combination of magnetic and un-magnetic materials, significant reduction of the cycle time, reduction in energy consumption or higher tool temperatures can be achieved. Higher tool temperatures are extremely useful for injection moulding of nanostructured tool inserts by improving the replication fidelity [1]. However, normally higher tool temperatures are achieved by various types of vario-therm processes – always leading to much longer cycle times.

This paper will give a short introduction to inductions heating in general and then focus on two examples; injection moulding of nanostructured surfaces and welding of polymer foils.

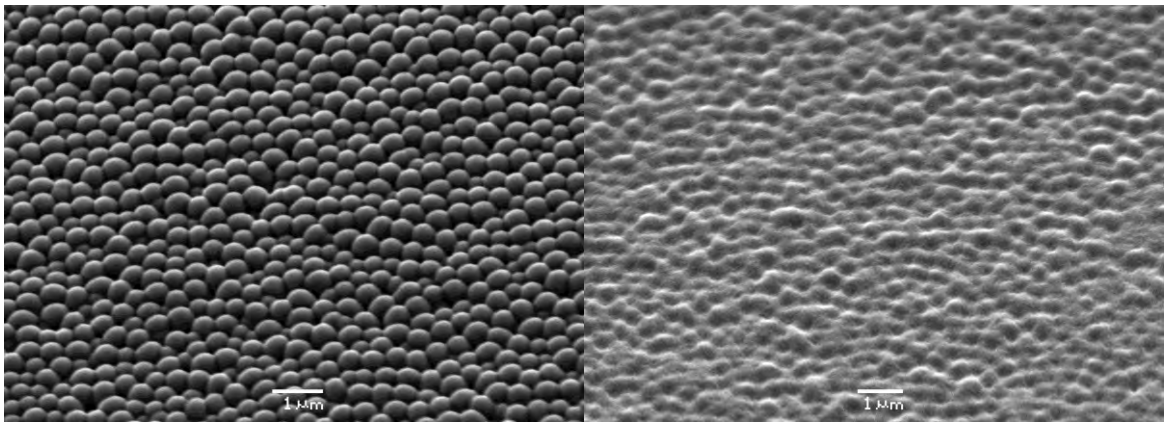


Figure 1: A nanostructured nickel tool insert (left) and a polypropylene replication (right) made by injection moulding without applying induction heating to the tool. It is obvious that replication is not as sharp as the tool, but this can be dramatically improved by introduction local heating of the tool insert.

[1] S. Menotti, H.N. Hansen, G. Bissacco, M. Calaon, P.T. Tang & C. Ravn, "Injection Molding of Nano Patterned Surfaces in the Sub-Micrometer Range with Induction Heating Aid", Int. J. Adv. Manuf. Technol., Vol. 74, pp. 907-916 (2014)

Session

Q

Oral Presentations

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

Working in the biomedical engineering domain: opportunities and challenges.

Lars Jelsbak
DTU Systems Biology
lj@bio.dtu.dk

Despite advances in medicine and public health, bacterial infectious diseases are major causes of death and disability worldwide. The eradication and control of such diseases requires focused research initiatives that can deliver novel and innovative solutions. Although there are endless opportunities for biomedical engineering based on systems biology principles in this area, there are also barriers for productive collaboration between engineers, medical doctors and scientists that need to be addressed. These challenges – which scale beyond the specific field of "controlling bacterial infections" - include 'cultural' differences in the different fields, and that collaborations are most often established at the individual level based on mutual interests rather than by systematic analysis. I will present a couple of examples that illustrate the need for biomedical engineering in relation to fighting bacterial infectious diseases, and discuss some of the challenges that prevent us from translating our research into medical solutions.

Healthcare Engineering @ DTU?

Thomas N. Kledal, PhD & eMBA
Head of section for Virology, DTU Vet

The healthcare system is under immense pressure to deliver more cost effective solutions with improved health outcomes. In developed societies healthcare is managed and operated by highly complex systems assembled by several more or less interconnected stakeholders. By exploring the healthcare system, outlining its stakeholders and investigating its most eminent challenges it is clear, that the biggest healthcare challenges are not select diseases or technologies, nor positioned within the individual stakeholders, but actually associated with the healthcare system itself.

While there has been tremendous progress within the art of medicine and technology during the last century, there has been relatively little progress in optimizing operations or measuring the quality and productivity of healthcare; and engineers has contributed only marginally to improvements in the operations of healthcare delivery. However, by embracing different engineering methods, healthcare engineers can work on healthcare challenges at several levels spanning product engineering to engineering systems. Thus, a focused approach to meet the needs of the whole healthcare system is mandated; one such approach could be a strategic investment Healthcare Engineering.

Healthcare Engineering could contribute to the development of a more cost effective healthcare sector with improved health outcome. This goal can be accomplished by embracing a cross disciplinary corporation between stakeholders in the healthcare system and engineers; the healthcare professionals can bring their needs and challenges to the engineering community, which then in turn can provide valuable solutions to the problems. Interestingly, the center can build on a wide range of different engineering strongholds, and the center can facilitate an active and valuable interaction between the technical sciences, the natural sciences and medicine; between basic and applied research; between researchers and students, and between the university and the society.

The concept of Healthcare Engineering ensures an efficient linking of research and innovation, taking both market aspects as well as technological perspectives into consideration. The key driver for the concept design is the value generating process - bringing solutions to challenges in the healthcare system. What are unique to the value chain described here, are the needs/challenge evaluation and selection steps; supported by the health/cost effect assessment capability, and the business development step; supported by the target product profiling capability. The evaluation process should be a three-step process, first dealing with the potential value creation opportunity, secondly with the technical mission and thirdly evaluating the solution business opportunity. The outlined process will at the same time serve as a ‘portal’ for healthcare professionals to the engineering community, thereby facilitating the interaction between the healthcare system and relevant scientists and infrastructure.

The proposed organizational center design takes advantage of different stakeholder resources, cultural differences, strategic priorities and incentives. Furthermore, the suggested organizational setup aims at strengthening management’s attention to the value creation process. In order to anchor responsibility close to operations and help emphasizing the unique purpose of each group; being needs finding, product development or research, the individual groups are designed to work as autonomously as possible.

Carbon nanopillars for stem cell differentiation and dopamine detection

Ada-Ioana Bunea*, Letizia Amato, Arto Heiskanen, Stephan Sylvest Keller, Niels Bent Larsen and Jenny Emnéus

DTU Nanotech

Parkinson's disease is characterized by insufficient dopamine in the brain, a neurotransmitter involved in the motor function. One of the future ideas for treatment is cell replacement therapy. We have shown that pyrolysed 3D carbon micropillars induce spontaneous differentiation of human neural stem cells (hNSCs) into dopaminergic neurons and that they can also be employed for detecting dopamine release from maturing neurons attached to them [1]. Here, we report 3D carbon nanopillars, fabricated through colloidal lithography, with even more pronounced effect on the differentiation process.

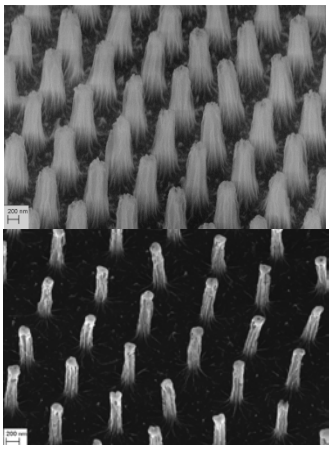


Figure 1: SEM image of nanopillars before (top) and after (bottom) pyrolysis

The 3D carbon nanopillars were obtained using 1 µm beads and etching time of 20 min, leading to structures with a height of 1.2 µm and a diameter of 450 nm (before pyrolysis) and a height of 600 nm and a width of 200 nm after pyrolysis (figure 1).

Carbon nanopillars were employed as substrate for cell-growth and differentiation after plasma treatment (surface wettability) and poly-L-lysine coating (cell adhesion). Even without adding differentiation factors, differentiation into dopaminergic neurons is observed. SEM imaging, immunocytochemistry of TH and amperometry confirm that most cells are TH-positive and dopaminergic. Dopamine exocytosis was induced using KCl and monitored using amperometry on electrodes with nanopillars 48 h after cell seeding, in the absence of differentiation factors and 10 days after cell seeding, in the presence of differentiation factors. For comparison, flat carbon surfaces were tested in parallel. Amperometry measurements were conducted on electrodes with nanopillars 48 h after cell seeding, in the absence of differentiation factors and 10 days after cell seeding, in the presence of differentiation factors. For comparison, flat carbon surfaces were fabricated and tested in parallel.

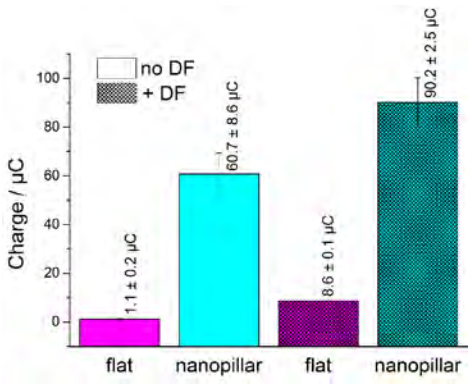


Figure 2: Charge comparison for dopamine exocytosis for flat and nanopillar carbon surfaces with or without of differentiation factors

Compared to flat carbon surfaces, nanopillar electrodes show a high increase in currents, although the surface area increase is negligible (figure 2).

We here show carbon surfaces with nanopillars that induce a remarkable spontaneous differentiation of human neural stem cells into dopaminergic neurons and that they can be employed as electrodes for dopamine detection from mature dopaminergic cells and that they show a much better electrochemical response compared to flat carbon surfaces and 3D carbon micro-pillars previously reported [1].

References: 1. L. Amato et. al., Pyrolysed 3D-Carbon Scaffolds Induce Spontaneous Differentiation of Human Neural Stem Cells and Facilitate Real Time Dopamine Detection, *Advanced Functional Materials*, **2014**, Vol. 24, Issue 44, 7042-7052.

Technologies for creating and screening biological libraries at ultra high speeds.

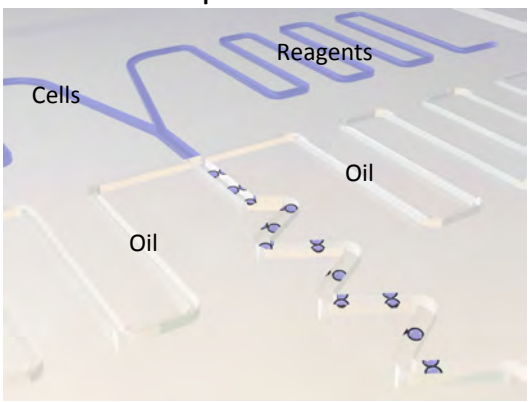
Thomas Glasdam Jensen[1], Jenifer Clausell-Tormos[2], Anders Christiansen[2], Nikolaj Dietrich[2], Thomas Bouquin[2], Martin Dufva*[1]

1: DTU Nanotech; 2: Symphogen A/S

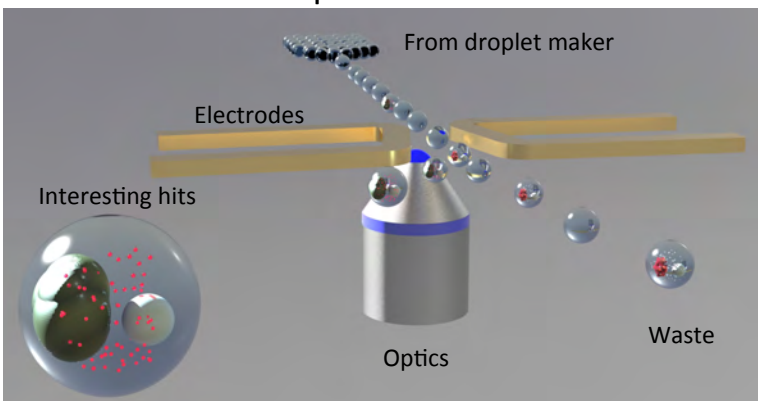
*Corresponding author email: martin.dufva@nanotech.dtu.dk

Healthcare is central for a sustainable community. However, healthcare costs are increasing and recently medicine costs have become an increasingly large expense. The reason is that developing new medicine is risky and costly. Here we describe technologies to address high costs (and slow) traditional high throughput screening. In particular we focus on creating and screening biological libraries, which is central for Denmark being one of the world leaders of biotech for medicine and protein engineering. The technology described is based on microfluidics droplets. These miniaturized reaction vessels (about 50pL and upwards) are generated at 1000 fold higher speed than pipetting robots operates microtiter plates (current high throughput screening system). Application areas that we currently are working with is isolation of therapeutic antibodies (together with Symphogen A/S), single cells transcriptomics (together with Vet), isolation of high protein producing cells for isolation of production cell lines (together with Symphogen A/S and DTU Food respectively) and isolation of bacteria mutants controlling the pH of yoghurt. Assays not possible in FACS machines are possible using the droplet technology.

Droplet maker



Droplet sorter



Droplet technology is based on a droplet maker that makes water droplets in oils at a speed of 2-20kHz (up to 20000 droplets per second). In this chips, cells and detection regents is mixed and encapsulated. After a brief incubation off chip, droplets are reintroduced into a sorting chip placed in a fluorescent microscope. If the cell has a desired function, a fluorescent signal can be detected from the droplet and then sorted by pushing the droplet into another channel than the waste. The sorting is done at about 1000 drops per second.

Microcontainers as an oral drug delivery system

Ritika Singh Petersen*[1]; risi@nanotech.dtu.dk, Line Hagner Nielsen[1], Paolo Marizza[1], Stephan Sylvest Keller[1], Thomas Rades[2], Anette Müllertz[2], Anja Boisen[1],
[1]Department of Micro and Nanotechnology, Technical University of Denmark, Kgs. Lyngby, Denmark
[2]Department of Pharmacy, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark

Oral delivery is the preferred administration route for drugs. Advanced drug delivery (ADD) systems help in achieving targeted and/or sustained delivery in the gastro-intestinal (GI) tract after oral administration. Micro fabricated drug delivery devices have been proposed as an ADD system being able to increase the oral bioavailability of drugs [1]. Of these micro devices, microcontainers are suggested as especially promising [2]. Primarily, this is due to the fact that the size and shape of the microcontainers can be controlled very precisely and therefore, polydispersity as seen for example for micro- and nanoparticles is avoided [3]. Microcontainers are polymeric, cylindrical devices in the micrometre size range (Figure 1) [4]. A major advantage is that these devices allow for unidirectional release, as only one side of the microcontainers is open compared to microparticles where release can occur over the whole area of the particle [5].

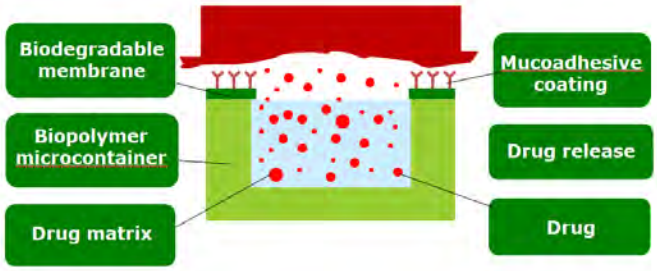


Figure 1. Conceptual design of microcontainers for oral drug delivery

SU-8 microcontainers were fabricated using lithography, whereas PLLA microcontainers were prepared by hot embossing. In terms of drug filling, the SU-8 microcontainers were filled with polyvinylpyrrolidone (PVP) by inkjet printing followed by supercritical CO_2 impregnation of ketoprofen into the PVP matrix. As an alternative filling method, the powder furosemide (p-Furo) were filled into the SU-8 microcontainers. The PLLA microcontainers were filled with drug formulation by embossing the microcontainers into a polycaprolactone (PCL) and furosemide layer. For the p-Furo filled microcontainers, an pH-sensitive lid of Eudragit L100 was spray coated onto the cavity of the microcontainers. Release of p-Furo from the coated microcontainers was investigated using a µ-Diss profiler in simulated intestinal medium. A fast release of ASSF was facilitated from the SU-8 microcontainers. *In-vivo* rat studies were performed showing high oral bioavailability.

REFERENCES

1. Chirra, H.D. and Desai, T.A. Multi-Reservoir Bioadhesive Microdevices for Independent Rate-Controlled Delivery of Multiple Drug., Small. 8, 3839–3846 (2012).
2. Chirra, H.D.; Shao L.; Ciaccio, N.; Fox, C.B.; Wade, J.M.; Ma, A. and Desai, T.A. Planar microdevices for enhanced in vivo retention and oral bioavailability of poorly permeable drugs. Adv. Healthc. Mater, 3, 1648–1654 (2014).
3. Randall, C.L.; Leong, T.G.; Bassik, N. and Gracias, D.H. 3D lithographically fabricated nanoliter containers for drug delivery, Adv. Drug Deliv. Rev., 59, 1547–1561 (2007).
4. Nielsen, LH; Keller, SS; Gordon, KC; Boisen, A; Rades, T, and Müllertz, A. Spatial confinement can lead to increased stability of amorphous indomethacin. Eur J Pharm and Biopharm., 81, 418-25 (2012)
5. Eaimtrakarn, S.; Itoh, Y.; Kishimoto, J.; Yoshikawa, Y.; Shibata, N. and Takada, K. Retention and transit of intestinal mucoadhesive films in rat small intestine, Int. J. Pharm., 224, 61–67 (2001).

Development of a Plastic Membrane Containing Micro-hole(s) for a Potential Bio-Sensing Application

Vida Krikstolaityte*[1], Tautgirdas Ruzgas[2], Arto Heiskanen[1], Chiara Canali[1], Jenny Emnéus[1]

1: DTU Nanotech; 2: Malmo University

*Corresponding author email: vkri@nanotech.dtu.dk

A poly(methylmethacrylate) (PMMA) membrane containing single or several micro-holes (MHs) as a prototype of a simple sensing platform of a lab-on-a-chip device for a potential analysis of clinical samples has been developed. MHs with a diameter in the range of 20 to a few hundred µm were fabricated using laser ablation and mechanical micro-milling. Laser ablation enabled to cut MHs down to 20 µm in diameter. However better reproducibility and MHs structural resolution was achieved with micro-milling. The MHs were characterised by optical and scanning electron microscopy as well as electrochemical impedance spectroscopy (EIS). Four probe EIS setup, with two electrodes placed on each side of a membrane, was adopted for monitoring of MH impedance. To investigate, if EIS could be used to sense the trapping of an analyte in the MHs, latex micro-beads of different sizes were tested for clogging MHs. For this purpose, the surface of MHs was rendered hydrophilic using air plasma, and the MH trapping exploited by capillary forces. The beads in the MH were cross-linked by using glutaraldehyde vapour to retain the stability of the MH-based sensor construction. The influence of the aspect ratio of MHs on MH impedance was evaluated when using PMMA membranes of different thicknesses. EIS measurements on a single 100 µm diameter MH showed that the presence of beads in the MH considerably increased the impedance of the MH. When comparing the ratio of the impedance of the modified and unmodified MHs, the higher impedance ratio, i.e. the higher normalized response, was observed for the MHs in 500 µm membrane than the ones in 250 µm membrane. Thus, the lower MH aspect ratio enables the higher normalized response of MH-based impedance measurement. Finite element model simulations were performed using Comsol Multiphysics software to theoretically evaluate the electric current distribution and the sensitivity field of the EIS measurement through the MH(s), thus to help to understand the limitations and improvement possibilities of the MH-based EIS measurement setup.

Genomic Epidemiology

Ole Lund*[1], Martin Thomsen[1], Jose L. Bellod Cisneros [1], Johanne Ahrenfeldt [1], Anna Maria Malberg Tetzschner[1], Shinny Leekitcharoenphon[2], Rolf Sommer Kaas[2], Oksana Lukjancenko[2], Frank Aarestrup[2]

1: DTU Systems Biology; 2: DTU Food;

*Corresponding author email: make-link-to-mail@dtu.dk

WGS holds the promise to revolutionize surveillance and diagnostics of infectious diseases due to its high resolution. It may be used across many areas such as monitoring food, environment, clinical, veterinary, wildlife, etc., for all known pathogens, i.e., viruses, bacteria, fungi, parasites, etc. A major obstacle is how to create a robust and simple to use system that will allow its adaptation within the relevant labs. A goal would be to establish a Web-based system, allowing users to upload sequence and meta data for several isolates in one batch up- load, and have several analysis made on each isolate: assembly, species typing, MLST typing (for bacteria), resistance gene finding, virulence prediction, and gene finding. Furthermore the system should allow single nucleotide poly- morphism (SNP) based comparison of the uploaded isolates with all previously uploaded isolates.

The Center for Genomic Epidemiology (CGE) has, over the last 4 years, worked on developing a system for surveillance and diagnostics of infectious diseases. This system has been running since 2012 (genomicepidemiology.org). So far, more than 150,000 isolates have been analyzed. This has demonstrated that online analysis of WGS information is possible. This means it should be possible to create a unified portal so that all area and pathogen data can be compared, enabling us to trace back all infections. The work will in the coming years be continued in the context of the COMPARE project.

Why Big Data is relevant in Health care

Ramneek Gupta, Helle Krogh Pedersen, Rachita Yadav

1: DTU Systems Biology

*Corresponding author email: ramneek@cbs.dtu.dk

Place your abstract here, add an image or two if possible and add references below.

Life Sciences today easily fulfils the major tenets of the need for Big Data thinking: Volume of Data, Velocity of data accrual, Variability and Veracity in data. Indeed, all of these offer opportunities in gathering unprecedented insights into living systems, yet also present challenges in handling, interpreting and converting into value. However, how far up the Hype Curve is current Big Data thinking in Life Sciences ? How do we translate insights to value in the life sciences domain and improved patient care ? In this talk, I will draw on examples of research from childhood leukemia and type-2 diabetes, where we integrate various streams of data with prior knowledge and context, and utilize machine learning approaches that are typical of Big Data thinking.

Session

Q

Laptop Presentations

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

Towards new research tools for cell derived microparticles

Solène Cherré[1*], Noemi Rozlosnik[1]

1:DTU Nanotech

*solch@nanotech.dtu.dk

Described for the first time as platelet dust by Wolf in 1967, cell-derived microparticles (MPs) are a type of extracellular vesicles released by membrane blebs on activated or apoptotic cells. In the recent years, MPs have been proposed as novel diagnostic markers for a wide range of diseases such as cancers, inflammatory or autoimmune diseases. One of the main challenges of using MPs as diagnostic markers is the lack of standardization of isolation and characterization protocols. The methods currently used are not well adapted for the isolation of such small and polydisperse vesicles (50 to 1000 nm in diameter).

In this work, we aim at developing novel isolation and characterization methods specially adapted to MPs. We have developed a biological system to obtain a reproducible population of MPs. This is based on the release of MPs from apoptotic HUVEC cells, an endothelial cell line. To determine the size of the MPs we developed an imaging protocol based on atomic force microscopy. Results were compared with nanoparticle tracking analysis (NTA) measurement.

In a second part, we will present the development of a microfluidic device for the isolation of MPs based on diffusion. Compared to the gold standard of high speed centrifugation, this isolation method will be gentler for the MPs that will not be exposed to high stress and preserve their morphology.

We expect that the developed methods will allow a more accurate analysis of MPs so that new diagnostic methods can be made available for the society.

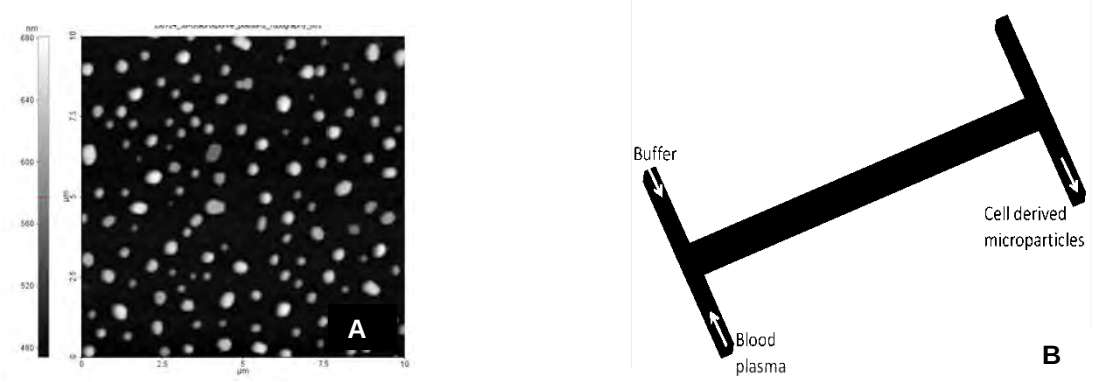


Figure 1:. A/ AFM topography image of microparticles derived from HUV-EC-C after undergoing apoptosis for 24 hours. B/ Scheme of the device for isolation of MPs

Session

Q

Poster Presentations

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

Innovative Solutions for Ostomy Care: Combining Consumer Insight and New Technologies

Bahar Bingöl*

*: Coloplast A/S, Global Research and Development Center for Adhesive, Holtedam 1 3050, Humlebæk, Denmark 3050

*Corresponding author email dkbbi@coloplast.dk

2.5 million people live with an ostomy, which is a condition resulting from treatment of digestive and urinary diseases. They have a surgically created opening in their body for discharging waste (Figure 1 a). A bag is attached to stoma to collect the waste (Figure 1 b). Coloplast is a medical device company, which aims at bringing new and innovative products to ostomy care market to improve quality of life of people living with an ostomy. To realize this goal at Coloplast, we are combining user insight with new technologies.

Coloplast is working towards new ostomy devices, which will reduce or eliminate leakage problem and protect the skin. Success in this area requires an interdisciplinary team with expertise in material science, engineering, biology and device design. Skin-friendly and processable polymeric materials are an important ingredient of ostomy devices. It is crucial to understand how these materials behave at rest as well as when they deform, and how they interact with skin. In addition, test methods are needed to evaluate the application related properties of ostomy devices. Moreover, understanding conditions leading to leakage is only possible by building simple systems that can follow and monitor the users while they use the products. In addition to these function related aspects, products are designed to be discrete and secure.

The global Research and Development Team at Coloplast is pursuing applied research in collaboration with various academic partners. Master projects carried out in collaboration with Technical University of Denmark and Coloplast represent the diversity of applied research, which is necessary to develop new products. We will share our motivation and results of selected recent master projects to inspire both students and researchers at DTU.

(a)

(b)

Figure 1: (a) An ostomy base plate on a consumer with stoma (b) A full ostomy device

Integrated micro/nanofibrous PLGA-Collagen scaffolds for bladder tissue regeneration

Fatemeh Ajalloueian[1], Jons Hilborn[2], Magdalena Fossum[3], Ioannis S Chronakis[1],

1: DTU Food, 2:Uppsala University, 3:Karolinska Institutet

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

Fabrication of an ideal scaffold mimicking the native extracellular matrix components, structure and function has remained a challenge in tissue engineering. The basic structural element in ECM is collagen type I with a fibrillar nano-scale structure. Collagen nanofibers can be fabricated using electrospinning or plastic compression (PC) of collagen hydrogel. PC is a simple and fast method, which has appeared better than electrospinning, since fluoroalchoholic solvents used in collagen electrospinning denature collagen to gelatin. The collagen layer obtained from PC contains small inter-fiber pores limiting cell infiltration and is mechanically weak. Performing collagen PC onto another polymeric substrate leads to a two-layered construct with improved mechanical properties. Here, we present the design of a hybrid, electrospun poly(lactic-co-glycolide) (PLGA) - plastically compressed (PC) collagen scaffold that could allow bladder mucosa expansion. Optimisation of electrospinning was performed in order to obtain increased pore sizes and porosity to consolidate the construct and to support neovascularisation and tissue ingrowth. The PLGA support scaffold was placed between two collagen gels, and the minced tissue was distributed either on top or both on top and inside the construct prior to PC; this was then cultured for up to four weeks. Morphology, histology and SEM demonstrated that the construct maintained its integrity throughout cell culture. Cells from minced tissue migrated, expanded and re-organised to a confluent cell layer on the top of the construct after two weeks and formed a multilayered urothelium after four weeks. Cell morphology and phenotypewas typical for urothelial mucosa during tissue culture.

Risk factors for *Campylobacter* infection of broiler flocks

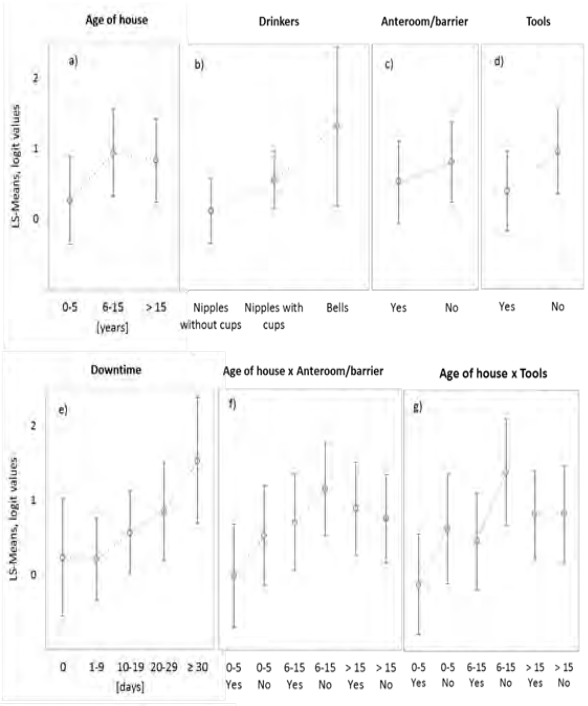
Helle M Sommer*[1], B.B. Høg[2], N.Williams[3], J.Y. Merga[4], M.Cerdà-Cuélla[4], S. Urdaneta[4] ,R.Dolza[4] ,K. Wieczorek[5], J. Osek[5], B. David[6], M. Jonsson[6], M. Hofshagen[6], J.A. Wagenaar[7], N. Bolder[7], H. Rosenquist[2]

1: DTU Compute; 2: DTU Food; 3: University of Liverpool; 4: University of Barcelona; 5: Veterinary Institute of Poland; 6: Veterinary Institute of Norway; 7: University of Utrect

*Corresponding author email: hems@dtu.dk

Campylobacteriosis has become the leading bacterial zoonosis in humans in the European Union and other developed countries. There are many sources of human *Campylobacter* infections, but broilers and broiler meat have been shown to be the most important sources. The objective of the study was to identify on-farm risk factors for *Campylobacter* colonization of broiler flocks based on comparable data from six European countries.

The data included explanatory variables from a large questionnaire concerning production, farm management procedures and conditions, climate data on mean temperature, sunshine hours, precipitation, as well as data on *Campylobacter* status of broiler flocks. Overall, the study comprised data from more than 6000 flocks. The data were analyzed using a generalized linear model using backwards elimination and forward selection. Due to the structure of the data, several model approaches were explored, by applying different strategies for categorizing explanatory variables and for selection and elimination of variables in the model.



The risk of broiler flocks becoming colonized with *Campylobacter* was clearly affected by country. In descending order; broiler flocks were more likely to be colonized in Poland, UK, Spain, the Netherlands, Denmark and Norway due to country specific factors that could not be explained by the management, physical conditions or climate variables in the explored models. The seasonality in the prevalence of *Campylobacter* was described nicely by temperature, i.e. the number of positive flock increased with increasing temperatures. The age of broiler houses, presence of anterooms and barriers in all houses, designated tools for each house as well as length of downtime and the type of drinker systems were found to affect the risk of the broiler flocks becoming colonized by *Campylobacter.* In the figure some of the risk factors are shown.

Session

R

Oral Presentations

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

Microbial electrochemical monitoring of volatile fatty acids during anaerobic digestion

Xiangdan Jin[1], Irini Angelidaki[2], Yifeng Zhang*[3]

2: DTU Environment

*Yifeng Zhang: yifz@env.dtu.dk

Due to increasing environmental concerns of using fossil fuels and decreasing in their reserves, the promotion of renewable energy technologies is crucial. Anaerobic digestion (AD), a well-developed technology converting organic waste into biogas, is gaining increased attention in recent years. Bioelectrochemical systems (e.g. MFC, MDC, MEC *et al*.) which transfer chemical energy to electricity by degrading organic waste have attracted great interest due to their environmental friendly and sustainability. In this study, to control and optimize AD process, a smart bioelectrochemical system (microbial desalination cell, MDC) was built to realize the on-line measuring the concentration of volatile fatty acid (VFA). The correlation between current densities of the biosensor and VFA concentrations was firstly evaluated with synthetic digestate. Two linear relationships were observed between current densities and VFA levels from 1 mM to 200 mM. The detection range was much broader than that of other existing VFA biosensors. The MDC biosensor had no response to protein and lipid which are frequently found along with VFAs in the organic waste streams from AD, suggesting the selective detection of VFAs. The current displayed different responses to VFA levels when different ionic strengths and external resistances were applied, though linear relationships were always observed. Finally, the biosensor was further explored with real AD effluents and the results did not show significance differences with those measured by GC. The simple MDC-based biosensor showed promising potential for online, inexpensive and reliable measurement of VFA levels. The outcomes offer a powerful tool for cost-effective monitoring and optimization of AD process and expand the application of bioelectrochemical system.

Hydrogen mediated biogas upgrading in a two-stage mesophilic reactor

Ilaria Bassani, Panagiotis G. Kougias, Laura Treu, Irini Angelidaki*

DTU Environment

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

In this study, biogas upgrading was tested in an innovative two-stage mesophilic reactor, where the CO_2 in the biogas was coupled with external H_2 and converted into CH_4 by hydrogenotrophic methanogenesis. The first stage was responsible for the most of the biogas produced, while in the second one, where the H_2 was injected, the CO_2 was converted to CH_4 (Fig 1). Prior to the H_2 addition, the biogas was composed by 70% CH_4 and 30% CO_2. On the contrary, upon H_2 addition, the CO_2 content decreased to 9% upgrading the biogas to 89% CH_4 (Fig 2). Archaeal population increased to approximately the half of the total community. The increase of hydrogenotrophic methanogens, with Methanoculleus as dominant genus, and syntrophic bacteria and the decrease of aceticlastic methanogens and fermentative bacteria assert the selective pressure of the H_2 toward the hydrogenotrophic pathway, enhancing the CO_2 consumption and thus the biogas upgrading. Moreover, in absence of aceticlastic methanogenesis, acetate was likely degraded via syntrophic acetate oxidation with hydrogenotrophic methanogens, by bacterial groups such as Thermoanaerobacteraceae (1).

Fig 1: Two-stage reactor configuration.

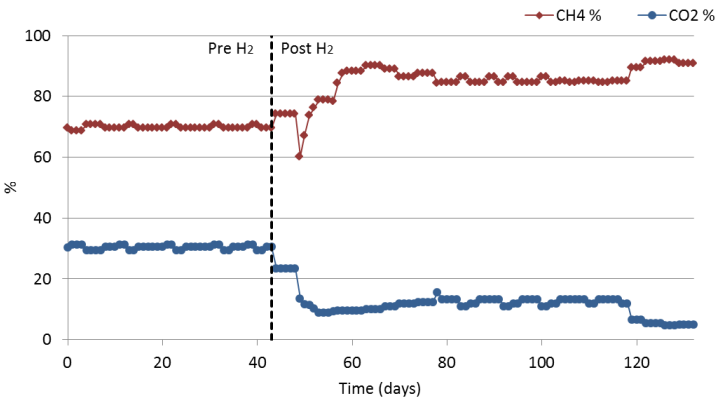


Fig 2: Biogas composition prior and after the H_2 addition.

REFERENCES:

1. Lü et al. Metaproteomics of cellulose methanisation under thermophilic conditions reveals a surprisingly high proteolytic activity. ISME J. **2014**, 8 (1), 88–102.

Investigation of Potential Benefits in Biorefinery Processes by the Use of Aquaporin Inside™ Membrane Separation

S. Kalafatakis[1], S. Braekevelt[2], A. Lymperatou[1], I. V. Skiadas[1], L. Lange[1], H. N. Gavala[1*]

1 DTU Chemical Engineering; 2: Aquaporin A/S

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

Great interest has been attracted towards 2nd generation biorefineries, since they can potentially provide a sustainable way for production of biofuels and bio-based chemical. However, in most of the cases, the production is not economically or environmentally sustainable. The latter is a result of extensive water use for substrate dilution in order to reduce potential inhibition effects during the bioconversion process [1].

The aim of this study is to investigate the water recovery potential by using forward osmosis and Aquaporin Inside™ membranes [2] and test the integration of this biomimetic system in different biorefinery processes. The greatest benefit of this technology is the low energy operational demands since the main driving force is the osmotic pressure difference between the two sides of the membrane. For the scope of this study, two fermentation cases were considered: i) wet-exploded, enzymatically hydrolyzed wheat straw (Biogasol, Denmark) with *C. tyrobutyricum*, strain DSM 2637 and ii) crude glycerol (Daka EcoMotion, Denmark) with *C. pasteurianum*, strain DSM 525. A preliminary techno-economic analysis was performed with Superpro Designer® (Intelligen, Inc) and consecutively a 2^3 Inscribed Central Composite (ICC) design was applied with the use of Unscrambler® x 10.3 (CAMO, Norway). The variables to be investigated were a) the pump cross flow velocity and b) the osmolality difference between the feed and draw solution (expressed as dilution factor). The relevant values are shown in Table 1.

Table 1. Range of design variables for optimization of forward osmosis separation

Parameter	Coded factor levels				
	-a	-1	0	1	a
Pump cross-flow velocity (ml s^{-1})	4.46	6.53	11.51	16.5	18.57
Dilution factor	70	59.9	35.5	11.1	1

Crude glycerol showed a higher potential compared to wheat straw as the water fluxes obtained in preliminary tests were substantially higher in the first case. Furthermore the preliminary techno-economic analysis revealed that a 50% water recovery could result up to 35% reduction of the downstream processing cost (represented by a distillation unit). Finally, the investigation of the most important parameters and their correlation with the water flux will bring this method one step closer to its in-line integration with the bioconversion process.

To sum up, Aquaporin Inside™ biomimetic separation technology have shown great potential for providing a sustainable solution for water recovery during bioconversion processes. The main benefit of this process is the relatively low energy demand that can be proved crucial for the viability of the biorefinery industry.

[1] S. Nicolaou, S. Gaida, and E. Papoutsakis, "A comparative view of metabolite and substrate stress and tolerance in microbial bioprocessing: from biofuels and chemicals, to biocatalysis and bioremediation," *Metab. Eng.*, vol. 12, no. 4, pp. 307–331, 2010.

[2] Y. Zhao, C. Qiu, X. Li, A. Vararattanavech, W. Shen, J. Torres, C. Hélix-Nielsen, R. Wang, X. Hu, A. G. Fane, and C. Y. Tang, "Synthesis of robust and high-performance aquaporin-based biomimetic membranes by interfacial polymerization-membrane preparation and RO performance characterization," *J. Memb. Sci.*, vol. 423–424, pp. 422–428, 2012.

The glycerol Biorefinery: Valorization of crude glycerol through its conversion into biofuels and green chemicals by mixed microbial consortia

C. Varrone[1*], G. Floriotis[1], T. M. B. Heggeset[2], S. B. Le, T. Haugen[2], S. Markussen[2], I. V. Skiadas[1] and H.N. Gavala[1.]

[1]DTU Chemical Engineering; [2] SINTEF Materials and Chemistry.

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

In recent years, the exponential growth of biodiesel production has led to concomitant increase in crude glycerol (CG). Even though pure glycerol represents a valuable product for the cosmetic and pharmaceutical industry, CG from biodiesel production is contaminated with compounds such as salts, methanol, soap, long chain fatty acids, etc. These contaminants cause high purification costs when converting glycerol by traditional chemico-physical methods. Thus, the use of anaerobic fermentation to convert abundant and low-priced glycerol streams generated in the production of biodiesel into higher value products has been proposed as a promising route to achieve economic viability in the biofuels industry [1]. However, most studies on glycerol fermentation so far have been focusing mainly on the use of purified glycerol and pure cultures, while typically observing reduced yields and/or productivities when testing CG[2].

The objective of this study was thus to select and adapt mixed microbial consortia (MMC) directly on CG, targeting MMC able to produce biofuels (hydrogen and ethanol) and/or green chemicals (i.e. VFAs and 1,3 propanediol). Various adaptation strategies were investigated for the enrichment of suitable and stable MMC, trying to overcome inhibition problems and enhance substrate degradation efficiency, as well as generation of soluble fermentation products. Moreover, different CG types were tested, including CG from animal fat derived (second-generation) biodiesel[2,3]. Repeated transfers in small batches and fed-batch conditions have been applied, comparing the use of different inocula (different origin and thermal pre-treatment), growth media and kinetic control, while continuous stirred tank reactor (CSTR) operations have been established to test the effect of pH and hydraulic retention time (HRT). Changes in microbial composition were monitored by means of Next Generation Sequencing technique, revealing a dominance of glycerol consuming species, such as *Clostridium*, *Klebsiella* and *Escherichia*[3]. Our previous experiments with biofuels production showed the possibility to reach a yield of > 0.9 mol $_{H2}$/mol $_{Gly}$ and 1 mol $_{EtOH}$/mol $_{Gly}$[4], in non-sterile conditions and without nutrient supplements[5]. We are now going to start a new investigation targeting the process intensification, by means of gas-stripping removal of ethanol, cell mass recirculation, as well as optimization of microaerophilic conditions to enhance ethanol production.

Regarding green chemicals, 1,3 propanediol turned out to be the dominant metabolite in most of the cases (maximum yield of 0.52 g/g), followed by butyrate. Maximum butyrate production yield reached around 0.4 g/g (with 10 g/L substrate), but stabilized at around 2 g/g during the steady state. Substrate (≈10 g/L) was completely consumed during CSTR experimentation (with only one exception), and no ethanol production was observed, while reaching a maximum of 0.46 g $_{EtOH}$/g in batch[3]. Interestingly, the same phenomenon was observed also with the MMC optimized for ethanol production. In general, different inoculum sources requested different approaches, but were able to be acclimatized to the diluted (also fat-derived) crude glycerol, without the need of any costly pretreatment of the feed. Ongoing work is now focusing on identification of the operating parameters for maintaining a stable MMC and statistical optimization of key parameters for enhanced green chemicals production.

References: 1) Yazdani, S. S. & Gonzalez, R. *Curr. Opin. Biotechnol.* **18,** 213–9 (2007). 2) Varrone, C. (Patent) PCT/IT2012/000281; International Publication Number: WO 2013/038435 A1. (2013). 3) Varrone, C. *et al. Biomed Res. Int.* 1–14 (2015). 4) Varrone, C. *et al. Int. J. Hydrogen Energy* **37,** 16479–16488 (2012). 5) Varrone, C. et al. *Appl. Energy* **105,** 349–357 (2013).

Multi-Scale Technoeconomic Framework for Assessing Viability of Emerging Bio-based Processes

Kai Zhuang[1], Sumesh Sukumara*[1], Miguel Campodonico Alt[1] and Markus Herrgard[1]

1: Novo Nordisk Foundation Center for Biosustainability (DTU Biosustain)

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

With recent advances in the development of bioprocesses, several new production schemes utilizing renewable feedstock have emerged for a wide range of chemicals based on several potential host organisms. Many of these have demonstrated promising outcomes in a small scale set up. Hence, lately many efforts were devoted to validate the feasibility of these processes using technoeconomic framework which intended to be used by researchers as one of the major tools to quantify the economic viability and test the potential market vulnerability.

While many exist, one of the major challenges in optimizing such a multifaceted framework is to obtain accurate parameters at various stages of the development of biochemicals[1]. This contribution will demonstrate the manner by which these parameters are generated and subsequently linked to a Multi-Sector technoeconomic framework. This framework can be further extended by incorporating modelling of the petrochemical value chain and the de novo prediction of metabolic pathways connecting existing host metabolism to desirable chemical products[2]. Wholly, these models have the capability to capture various attributes of fundamental research and link those with the higher level economic sector, guiding the monetary investment towards the selection of robust candidate biochemicals. The resulting decision support tool can be used to study the existing market and test the viability of bioprocesses while accounting for inter and intra sector interactions in the existing value chain. The traits of this tool, bolstered with detailed models, make it an apt venue to test various renewable process technologies, provide insights towards future production strategies and guide the research to produce bio-based products.

Refrences

1. Yue D, You F and Snyder S W. Biomass-to-bioenergy and biofuel supply chain optimization: Overview, key issues and challenges. *Comput. Chem. Eng.* 2014;66:36-56. doi:10.1016/j.compchemeng.2013.11.016.

2. Markus J H, Sumesh S, Miguel C and Zhuang K. A multi-scale, Multi-disciplinary approach for assessing the technological, economic and environmental performance of bio-based chemicals. *Biochem. Soc. Trans.* 2015 (In the press);43. doi:10.1042/BST20150144.

Session

R

Laptop Presentations

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

Microbial dynamics in anaerobic digestion (AD) reactors with sodium oleate in the substrate

X. Zhu[1], D. De Francisci[1], L. Treu[1], P.G. Kougias[1], S. Campanaro[2] and I. Angelidaki*[1]

1: DTU Environment 2: Department of Biology, University of Padua

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

In AD systems, the accumulation of long chain fatty acids (LCFA) leads to process instability and decrease of the methane production. The understanding of how the microbial communities change in response to LCFA pulses is essential to optimize the overall process. In this study two lab-scale continuously stirred reactors used to characterize, via 16s rRNA gene analysis, the microbial shifts due to LCFA increase in the feedstock composition. Genera that had relative abundance higher than 1% or increased more than 2 folds after sodium oleate addition are chosen for discussion. The result shows that the average methane yield was 150 ± 4 ml CH4/gVS for cattle manure and 380 ± 37 ml CH4/gVS for manure with sodium oleate addtion. 75% of the added sodium oleate was utilized to produce methane. The addition of sodium oleate caused a slight decrease on the methane yield with a concomitant increase of VFA. In average, 1.6 million sequencing reads were generated from each sample and 20% of the reads were identified using RDP classifier. Results showed that 4 genera had relative abundance higher than 1% after the LCFA addition, suggesting that these members involved in the LCFA degradation process. The relative abundance of *Pseudomonas*, *Clostridium XI* and *Clostridium* III was not significantly affected (changed less than 2 folds) by the addition of LCFA, suggesting that these genera are not directly involved in the ß- oxidation process but probably in later steps of the degradation process, i.e. the metabolism of VFA. This observation consists with the previous study where *Pseudomonas* has been reported to have versatility in catabolizing esoteric organic compounds (von Graevenitz 1976), and *Clostridium III* has been found playing important role in the efficient operation of anaerobic reactors (Shiratori, Ikeno et al. 2006). *Syntrophomonas* increased significantly after the addition of sodium oleate and became the most abundant genus. Several members of *Syntrophomonas* genus have been proven to be specialized in performing ß- oxidation on LCFA (Sousa, Smidt et al. 2009). The significant increase of *Syntrophomonas* found in this experiment confirmed that this genus is a key player in the LCFA degradation under thermophilic anaerobic conditions. As for methanogens, *Methanoculleus* was found to be the most abundant genus, with no significant change before and after sodium oleate addition.

Reference:

Shiratori, H., H. Ikeno, S. Ayame, N. Kataoka, A. Miya, K. Hosono, T. Beppu and K. Ueda (2006). "Isolation and characterization of a new Clostridium sp. that performs effective cellulosic waste digestion in a thermophilic methanogenic bioreactor." Applied and environmental microbiology 72(5): 3702-3709.

von Graevenitz, A. (1976). "Genetics and Biochemistry of Pseudomonas." The Yale journal of biology and medicine 49(3): 308

Sousa, D. Z., H. Smidt, M. M. Alves and A. J. Stams (2009). "Ecophysiology of syntrophic communities that degrade saturated and unsaturated long‐chain fatty acids." FEMS microbiology ecology 68(3): 257-272.

Hori, T., S. Haruta, Y. Ueno, M. Ishii and Y. Igarashi (2006). "Dynamic transition of a methanogenic population in response to the concentration of volatile fatty acids in a thermophilic anaerobic digester." Applied and environmental microbiology 72(2): 1623-1630

Assessing the utilization of Green Biorefinery by-products

Andrea Corona*[1], Morten Birkved[1]

1: DTU Management

*Corresponding author email: corona@dtu.dk

The current trend on biomass conversion points towards a more efficient utilization of the feedstock in multi-output biorefineries, and the identification of the best biomass resources, since the feedstock cultivation itself plays an important role in the overall sustainability and cost of the process [1].

Grassy biomass in this context provides an interesting choice. This feedstock can be grown with high yields and low inputs of fertilizer and pesticides, can be cultivated on marginal land and could have intriguing side effect like conservation and improvement of cultural landscape and of the so called “stay option” for the farmers [2]. Thus exploiting this feedstock in a sustainable way not only offers high economic potential, but support sustainable development in rural region [3].

In this study, the initial results of a life-cycle assessment (LCA) of an integrated green-biorefinery utilizing grassy biomass are presented. The biorefinery has three output streams (protein, solid residue, liquid residue) and is compared to the existing conventional single-output process, namely green-crop drying process. The green-biorefinery can be easily implemented in the existing infrastructure of the green-crop drying plant.

The assessment combines LCA and material flow analysis and is done using EASETECH [4], a specific LCA software developed for waste and biorefinery analysis. Specific attention is given to the utilization of the output streams for different purposes, especially the solid stream.

Results show the integrated biorefinery solution provides large environmental burden reduction compared to the conventional plant. The best utilization of the solid stream is for feed purposes, mainly due to lower Indirect land use changes (iLUC) induced by this solution [5]. Utilization of the solid residue for energy production could lead to higher savings but those are counterbalanced by inducing higher iLUC.

References:

[1] B. Kamm, “Introduction of Biomass and Biorefineries,” Role Green Chem. Biomass Process.” pp. 1–26, 2013.
[2] S. Kromus, B. Wachter, W. Koschuh, M. Mandl, C. Krotscheck, and M. Narodoslawsky, “The Green Biorefinery Austria – Development of an Integrated System for Green Biomass Utilization,” Chem. Biochem. Eng. Q., vol. 18, no. 1, pp. 7–12, 2004.
[3] M. G. Mandl, “Status of green biorefining in Europe,” Biofuels, Bioprod. Biorefining, vol. 4, pp. 268–274, 2010.
[4] J. Clavreul, H. Baumeister, T. H. Christensen, and A. Damgaard, “An environmental assessment system for environmental technologies,” Environ. Model. Softw., vol. 60, pp. 18–30, 2014.
[5] J. H. Schmidt, B. P. Weidema, and M. Brandão, “A framework for modelling indirect land use changes in Life Cycle Assessment,” J. Clean. Prod., vol. 99, pp. 230–238, 2015.

Session

R

Poster Presentations

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

Effect of pulse and continuous addition of oleate on microbial communities involved in anaerobic digestion process

Manel Garrido Baserba, Dimitar Karakashev, Irini Angelidaki*

DTU Environment

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

Abstract

Oleic acid is the most abundant long chain fatty acid (LCFA) present in industrial and domestic wastewaters. However there is still a lack of knowledge regarding the microbiological aspects of the complex consortia involved in LCFA degradation during anaerobic digestion of high strength wastewaters. The aim of the present work was to evaluate microbial diversity of bacteria and archae in anaerobic reactors treating cattle manure during continuous addition, CA (2g oleate.L^{-1}.day^{-1}) and pulse addition, PA of oleate (final concentration 5g.L^{-1}) under thermophilic methanogenic conditions. Non exposed to LCFA thermophilic digested manure from a full scale biogas plant (Vegger, Denmark) was used as inoculum. PCR-DGGE combined with sequence and phylogenetic analysis was used to study bacterial and archael community changes and identify the microrganisms involved in oleate degradation. Results obtained showed significant shift in bacterial community structure which was more pronounced during CA of oleate. Similar trend was also observed for archael communities but changes were less remarkable indicating that dominant archael composition remained relatively stable over operation. Bacterial and archael similarity indices between reactor effluents and original inoculum decreased up to 60.2 and 65.9 respectivelly in the reactor with CA compared to 84.7 and 88.4 in the reactor with PA. Bacterial community changes in response to LCFA addition resulted in a new and less diverse bacterial consortium related to functional specialization towards LCFA degradation. For the archael domain, the sequences were affiliated within *Euryarchaeota* phylum. Results obtained in this study delivered a detailed comprehensive picture on LCFA degrading microbial communities in high organic strength wastewater such as animal manure.

Application of comminution machines to enhance the anaerobic biodegradability of ensiled meadow grass

Panagiotis Tsapekos, Panagiotis Kougias, Irini Angelidaki*

DTU Environment

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

Anaerobic digestion (AD) is one of the most widespread renewable energy technologies in Denmark and subsequently is of primary interest. During AD, biogas is produced by the utilization of a variety of organic substrates. Recently, lignocellulosic substrates from grasslands, as meadow grass, are considered to be an alternative option to feed the biogas plants, as they pose numerous advantages (Tsapekos et al., 2015). However, for a feasible AD, an efficient pretreatment method is required prior to the addition of biomass into the biogas plant feeding tank. Thus, comminu
of the microbial community into the degradable ce

The present study aims to elucidate the efficienc
of various mechanical comminution machines t
increase the digestibility of ensiled meadow gras
Hence, batch experiments were conducted. Th
methane potential of the substrates was defined i
triplicates, under thermophilic conditions an
based on the biochemical methane potential (BMF
protocol (Angelidaki et al., 2009). More specifically
the impact of the comminution machines wa
examined through two experimental tests. Durin
were loaded with the same grass amount and subsequently, their effect on the biomethanation process was examined. Concerning the second test, the effect of different grass load was examined only in the most promising comminution machine, according to the results obtained from the first BMP test.

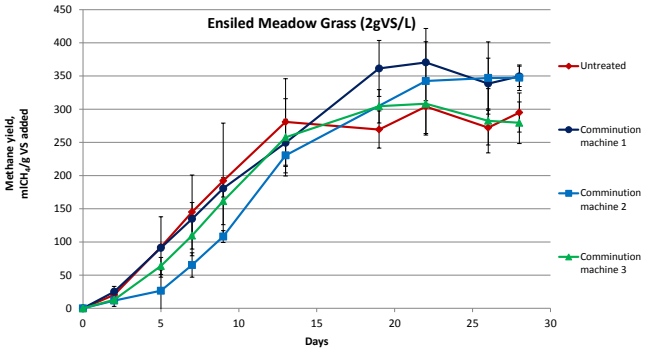


Figure 1. Accumulated methane production

The results showed that the different comminution machines enhanced the biodegradability in significantly different levels ($p < 0.05$) (Fig. 1). The highest methane production increase was appeared to be more than 30% compared to the untreated substrates. Moreover, the highest methane production was revealed when the lowest amount of biomass was processed by the most efficient machine.

REFERENCES

Angelidaki, I., Alves, M., Bolzonella, D., Borzacconi, L., Campos, J.L., Guwy, a. J., Kalyuzhnyi, S., Jenicek, P., van Lier, J.B., 2009. Defining the biomethane potential (BMP) of solid organic wastes and energy crops: a proposed protocol for batch assays. Water Science & Technology 59, 927.

Tsapekos, P., Kougias, P.G., Angelidaki, I., 2015. Anaerobic mono- and co-digestion of mechanically pretreated meadow grass for biogas production. Energy & Fuels. doi:10.1021/ef5027949.

Salinity-Gradient Energy Driven Microbial Electrosynthesis of Hydrogen Peroxide from Oxygen Reduction

Xiaohu Li, Yifeng Zhang*, Irini Angelidaki*

DTU Environment

*Corresponding author email: yifz@env.dtu.dk (Y. Zhang), iria@env.dtu.dk (I. Angelidaki)

Hydrogen peroxide (H_2O_2) is widely used in various chemical industries and environmental remediation. Recently, bioelectrochemical systems (BES) have gained increasing attention for synthesizing H_2O_2 with simultaneous wastewater treatment[1]. However, in order to get high-yield H_2O_2 requires additional electrical energy to power these BES or control the cathode potential. In this study, we develop an innovative BES called microbial reverse-electrodialysis electrolysis cell (MREC) to produce H_2O_2 in cathode. In the MREC(See Fig.1), the salinity-gradient energy between seawater and river water can be used to generated renewable eleltrical energy to replace the external power supply[2]. Operational parameters such as air flow rate, pH, cathodic potential, flow rate of high and low concentration NaCl solution in RED were investigated as to improve the H_2O_2 yield. The optimal parameters for H_2O_2 production are air gas flow rate of 8-20 ml/min, cathode potential of -0.485 ± 0.025 V vs Ag/AgCl, the corresponding dissolved oxygen is 6.80 ± 0.30 mg/l in catholyte. Under the optimal conditions, a maximum H_2O_2 yield of 770 ± 18 mg/L could be obtained with corresponding H_2O_2 production rates of 0.44 ± 0.04 g/m^2/h and current density of 1.40 ± 0.13 A/m^2. Results indicate the air gas flow rate and cathode potential are the key parameters for H_2O_2 production in MREC. This study indicate for the first time high yield synthesis of H_2O_2 from oxygen reduction in BES without external power supply, furthermore, we also discover the cathode potential can be controlled through adjusting the air flow rate without power supply and potentiostat.

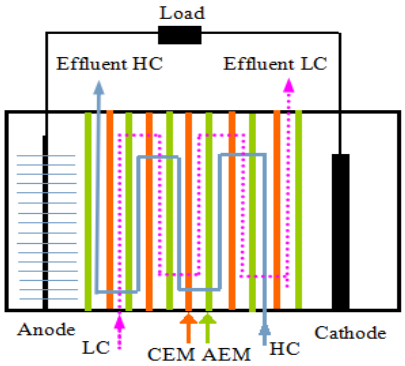


Fig. 1. Schematic of MREC (CEM, cation exchange membrane; AEM, anion exchange membrane; HC, high concentration solution; LC, low concentration solution;)

Reference

[1]. Sim, J., An, J., Elbeshbishy, E., Ryu, H., Lee, H.S., 2015. Characterization and optimization of cathodic conditions for H_2O_2 synthesis in microbial electrochemical cells. *Bioresour. Technol.* 195, 31-36.

[2]. Logan, BE., Elimelech, M., 2012. Membrane-based processes for sustainable power generation using water. *Nature.* 488, 313-319.

Life Cycle Assessment of producing potential biorefinery feedstocks

Ranjan Parajuli[1,*], Marie Trydeman Knudsen[1], Tommy Dalgaard[1]

1: Department of Agroecology, Aarhus University, Blichers Allé 20, 8830-DK, Tjele, Denmark

*Corresponding author email: Ranjan.parajuli@agro.au.dk

Biorefinery is gaining importance with prospects of producing not only high value bio-chemicals but also to cope with the increasing dependency of imported sources of food, feed and fuel. In the current study, Life Cycle Assessment (LCA) of producing potential biomass is carried out. Maize (MZ), grass-clover (GC), grass (G) and winter wheat (WW) based straw (WW-S) are selected with the environmental impact categories: Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP), Non-Renewable Energy (NRE) use, Land Use (LU), Potential Human Toxicity (PHTox), Potential Fresh Water Ecotoxicity (PFWTox) and Potential Biodiversity Damage (PBD). Tools used for the assessment are: SimaPRO 8.0.1 for simulating the first five impact categories; C-tool (Petersen et al., 2013) for simulating Soil Organic Carbon and Nitrogen cycling; PestLCI 2.0.6 (Dijkman et al., 2012) and "USEtox" (Rosenbaum et al., 2008) for PHTox and PFWTox. Characterization factors for PBD was calculated based on Knudsen et al. (un-published results).

The net GWP for WW, MZ, GC and G was 404, 302, 299 and 321 kg CO_2eq/t DM/y respectively, and economic allocation to WW-S (i.e. 5% of WW (Mogensen et al., 2014)) was 37 kg CO_2eq/t DM/y. AP related to WW, MZ, GC and G was 3.14, 1.9, 2.22, 2.54 kg SO_2eq/t DM/y, respectively. EP related to WW, MZ, GC and G was 1.73, 1.19, 1.58 and 1.23 kg PO_4eq/t DM/y respectively. NRE use in the case of WW, MZ; GC and G was 2621, 1607, 2076 and 2140 MJeq/t DM/y respectively. MZ has the highest PFWTox (59.6 CTU_e/ t DM/y) and WW has the highest PHTox ($3*10^{-9}$ CTU_h/t DM/y). PBD related to MZ and WW-S was 585 and 49 PDF/t DM/y respectively; whilst for GC and G it was -78 and -69 PDF/t DM/y respectively – indicating a better impact on biodiversity compared to MZ and WW. LU per t DM of WW was 1750 m^2a/t DM/y and was higher by 1.6-fold than MZ; and higher by about 1.5-fold than GC and G. This study can be summarized as: (i) the calculated environmental impacts are mainly related to the processes "field preparation" (e.g. undesired emissions from agrochemicals input, tillage activities and related SOC changes); and the "production of agro-chemicals". This makes relevant to optimize the crop productivity to ensure lower impacts per ton of biomass production; (ii) all the biomass assessed in this study can be treated as animal feed, hence their respective impacts can be compared with the alternative conversion routes, e.g. fuel vs food or feed delivered from biorefineries.

Reference List

Dijkman, T.J., Birkved, M., Hauschild, M.Z., 2012. PestLCI 2.0: a second generation model for estimating emissions of pesticides from arable land in LCA. Int J LCA 17, 973-986.

Knudsen, M.T., Dennis, P., Hermansen, J.E., Cederberg, C., Herzog, F., Vale, J., Jeanneret , P., Sarthou, J.-P., Friedel, J., Balazs, Katalin , Fjellstad, W., Kainz, Max., Wolfram, S., un-published results. Characterization factors from direct measures of plant species in European farmland for land use impacts on biodiversity in life cycle assessment.

Mogensen, L., Kristensen, T., Nguyen, T.L.T., Knudsen, M.T., Hermansen, J.E., 2014. Method for calculating carbon footprint of cattle feeds – including contribution from soil carbon changes and use of cattle manure. Journal of Cleaner Production 73, 40-51.

Petersen, B.M., Knudsen, M.T., Hermansen, J.E., Halberg, N., 2013. An approach to include soil carbon changes in life cycle assessments. Journal of Cleaner Production 52, 217-224.

Rosenbaum, R., Bachmann, T., Gold, L., Huijbregts, M.J., Jolliet, O., Juraske, R., Koehler, A., Larsen, H., MacLeod, M., Margni, M., McKone, T., Payet, J., Schuhmacher, M., van de Meent, D., Hauschild, M., 2008. USEtox—the UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. Int J LCA 13, 532-546.

An integrated approach for enhancing biogas yield of manure-based anaerobic digestion

Anna Lymperatou[1], Hariklia N. Gavala[1], Ioannis V. Skiadas*[1]

1: DTU Chemical Engineering

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

Anaerobic digestion (AD) is a biological process that occurs spontaneously in nature under anaerobic conditions and results to the formation of biogas (CH_4 and CO_2). When performed under controlled conditions, the biogas can be collected, stored and used as a renewable energy source for both heat and power production. Livestock manure is an abundant waste stream that poses the adequate characteristics for AD and thus it is widely used for biogas production in many countries. Nevertheless when digested solely it results to be an economically non-feasible process due to the low degradability of its solid fraction. Thus, pretreating the solid fraction could release the biogas potential of manure and decrease the dependence of the process on additional organic materials.

AMMONOX is an innovative concept that aims at improving the biogas yield of manure-based AD by integrating an ammonia-pretreatment of the solid fraction of manure without encumbering the economy of the whole process. Based on previous results [1,2] Aqueous Ammonia Soaking (AAS) is capable of increasing significantly the CH_4 yield of the solid fraction of manure (up to 180%). These results indicate that the AAS pretreatment coupled with an ammonia recovery/recycling step (securing thus the availability of ammonia) could be a promising technology for improving the performance of manure-based AD. Furthermore, an excess of ammonia is expected to be produced when the ammonia recovery process includes both the pretreatment mixture (aqueous ammonia and manure fibers) and the N-rich effluent of the digester. This excess can be used for the catalytic reduction of NO_x emissions of gas engines that convert biogas to electricity. An overview of the proposed process is illustrated in Figure 1.

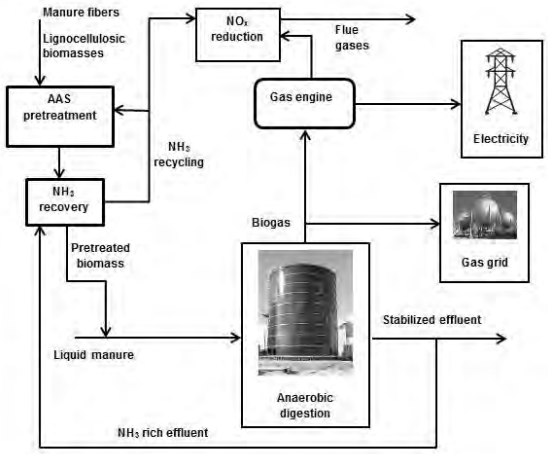


Figure 1 ***Overview of the AMMONOX concept for improving the biogas yield of swine manure in a sustainable way.***

The implementation of the AMMONOX concept follows a first step where statistical optimization of the most influencing parameters of AAS takes place for maximizing the CH_4 yield of treated manure fibers. Subsequently, the economic feasibility of different ammonia recovery technologies will be assessed in order to proceed with the proof of concept by performing the AMMONOX process in a continuous mode at laboratory scale.

References

[1] Jurado, E., Skiadas, I.V. and Gavala, H.N. Enhanced methane productivity from manure fibers by aqueous ammonia soaking pretreatment. Applied Energy, 109, 104-111 (2013)

[2] Lymperatou, A., Gavala, H.N., Esbensen, K.H., Skiadas, I.V. AMMONOX – Ammonia for enhancing biogas yield and reducing NO_x: Analysis of effects of aqueous ammonia soaking on manure fibers. Waste & Biomass Valorization 6, 449-457 (2015)

Effect of ammonia on hydrogenotrophic methanogens and syntrophic acetate oxidizing bacteria

H. Wang, I. A. Fotidis, I. Angelidaki*

DTU Environment

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

Substrates that contain high ammonia levels can cause inhibition on anaerobic digestion process and unstable biogas production. The aim of the current study was to assess the effects of different ammonia levels on pure strains of (syntrophic acetate oxidizing) SAO bacteria and hydrogenotrophic methanogens. Two pure strains of hydrogenotrophic methanogens (i.e: *Methanoculleus bourgensis* and *Methanoculleus thermophiles*) and two pure strains of SAO bacteria (i.e: *Tepidanaerobacter acetatoxydans* and *Thermacetogenium phaeum*) were inoculated under four different ammonia (0.26, 3, 5 and 7g NH_4^+-N/L) and free ammonia levels (Mesophilic: 3.31, 38.2, 63.68 and 89.15 g NH_3-N/L. Thermophilic: 8.48, 97.82, 163.03 and 228.24 g NH_3-N/L)(Westerholm, et al., 2011; Satoshi, et al., 2000; Jacob, et al., 1997). The results indicated that both *T. acetatoxydans* and *T. phaeum* were more sensitive to high ammonia levels compared to the hydrogenotrophic methanogens tested. Thus, it seems that hydrogenotrophic methanogens could be equally, if not more, tolerant to high ammonia levels compared to SAO bacteria.

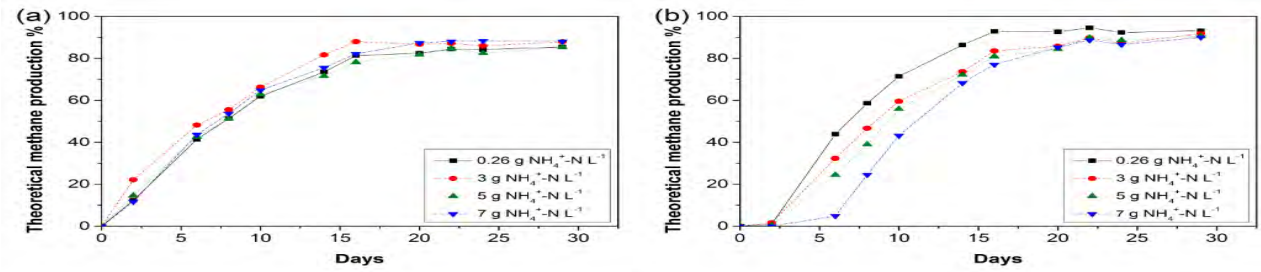


Figure 1. The accumulative production of a) *M. bourgensis* and b) *M. thermophiles*

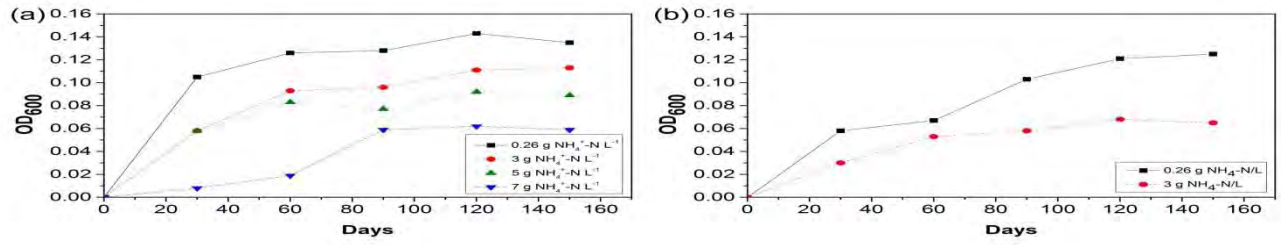


Figure 2. The OD_{600} of a) *T. acetatoxydans* and b) *T. phaeum*

REFERENCES

Jacob, S.H., Birgitte, K.A. (1997).FEMS. Microbiology Ecology. 23. 31-38.

Satoshi, H., Yoichi, K., Satoshi, H., Hirofumi, S (2000). Systematic and Evolutionary Microbiology. 50,1601-1609.

Westerholm, M., Roos, S., Schnürer, A. (2011). Systematic and Applied Microbiology.34, 260-266.

Macroalga *Laminaria digitata* as potential carbon source in heterotrophic *Chlorella protothekoides* cultivation: an innovative biorefinery concept

Martina D'Este, Merlin Alvarado-Morales, Irini Angelidaki*

DTU Environment

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

Algae are considered as one of the most promising and suitable feedstock to produce energy and high value products in a sustainable way (Wei et al. 2013). Algae can generate more biomass than terrestrial crops do and, growing in water, they can overcome the land competition problem.
Moreover, microalgae, unicellular organisms able to grow by autotrophic and heterotrophic conditions, are receiving increasing interest due to their composition. The variety of products that can be obtained by microalgae is extremely huge ranging from basic chemical substances such as vitamins to high value products as pigments (Borowitzka 2013).
The focus of this research was on two brown macroalgae species: *Laminaria digitata* and *Saccharina latissima*. Both macroalgae are the most common species in Danish waters with solid cultivation techniques (Andersen 2005). Thanks to their composition rich in sugars they represent an interesting nutrient source in heterotrophic microalgae cultivation.
Therefore an integrated biorefinery concept has been developed for conversion of *L. digitata* and *S. latissima* into energy carriers and a protein enriched fish feed. Sugars and nutrients from macroalgae can be recovered by enzymatic hydrolyses and used as substrate for the growth of heterotrophic *Chlorella protothekoides* units to be used directly as fish feed (Figure 1).

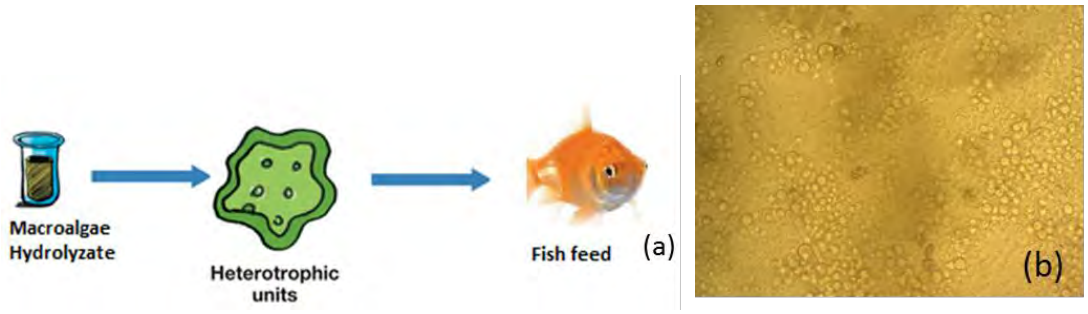


Figure 1: Scheme of the process (a) and *C.protothekoides* cells grown in macroalgae hydrolyzed (b)

References:

Andersen. Algal culturing techniques. Elsevier Academic Press. London. UK., editor. 2005.

Borowitzka MA. High-value products from microalgae—their development and commercialisation. J Appl Phycol. 2013;25(3):743–56.

Wei N, Quarterman J, Jin Y-S. Marine macroalgae: an untapped resource for producing fuels and chemicals. Trends Biotechnol. Elsevier Ltd; 2013 Feb;31(2):70–7.

Fractionation and enzymatic processing of biomass for biorefinery applications

Demi Tristan Djajadi[1], Anne Meyer[1], Manuel Pinelo[1], Henning Jørgensen*[1]

1: DTU Kemiteknik

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

Development of second generation (2G) biorefinery using biochemical-based processes has focused mostly on producing ethanol as liquid fuel. However the economic viability of this setup is questionable due to volatility in the crude oil price. Hence there is a need to find other potential value-added products from the existing lignocellulosic biomass feedstocks. Lignin, a major component of lignocellulosic biomass and the second most abundant organic polymer in Earth (1), has been rather overlooked in the conversion process. In current large scale 2G ethanol plants, biomass is hydrothermally pretreated and enzymatically hydrolyzed. The resulting lignin-rich residue is burnt to produce energy to power the operations in the plant, preventing its use as source of material. Moreover, lignin has also been known to impede enzymatic deconstruction of biomass through non-productive adsorption and the effect of hydrothermal pretreatment to lignin has not been well established (2). The research project aims to understand this effect and to modify lignin's properties in order to promote more efficient hydrolysis and better separation of lignin from carbohydrates.

The main focus in this study is the hydrophobic property of lignin. Hydrophobic interaction has been thought to be the main factor governing the non-productive adsorption of cellulases to lignin (3). Properties of hydrothermally pretreated lignin will be assessed by isolating the lignin through extensive enzymatic hydrolysis. Subsequently, the isolated lignin will be characterized and subjected to treatments. The effect of lignin variation is incorporated by using biomass of different botanical origin: corn stover, wheat straw and miscanthus. Treatment of lignin will be approached using enzymes, i.e. various esterases for the removal of lignin-carbohydrate complexes (LCCs) and laccase treatment for lignin modification. Isolated lignins, both before and after treatments, will be subjected to characterization of surface properties which include adsorption of cellulases, surface charge and hydrophobicity. The effect of treatments towards enzymatic hydrolysis yield will also be assessed.

References

1. Boerjan W, Ralph J, Baucher M. Lignin biosynthesis. Annu Rev Plant Biol. 2003;54:519–46.
2. Rahikainen JL, Martin-Sampedro R, Heikkinen H, Rovio S, Marjamaa K, Tamminen T, et al. Inhibitory effect of lignin during cellulose bioconversion: The effect of lignin chemistry on non-productive enzyme adsorption. Bioresour Technol. 2013;133:270–8.
3. Sammond DW, Yarbrough JM, Mansfield E, Bomble YJ, Hobdey SE, Decker SR, et al. Predicting enzyme adsorption to lignin films by calculating enzyme surface hydrophobicity. J Biol Chem. 2014;289(30):20960–9.

The biodegradabily of a feedstock is determining the optimal C/N ratios in anaerobic digestion.

Fokion Kaldis [1,2], Dimitar Karakashev [2], Irini Angelidaki [2*] (1) Biological Applications and Technologies, University of Ioannina, Ioannina, Greece, (2) Department of Environmental Engineering , Technical University of Denmark

*Email: iria@env.dtu.dk

Anaerobic digestion is a collection of processes by which different types of microorganisms break down biodegrade material in the absence of oxygen. Microorganisms need nitrogen for building up their cell mass. Approx. 15% of the cell mass is nitrogen. Therefore nitrogen is a necessary nutrient for growth of microorganisms. On the other hand excessive amounts of nitrogen in the form of ammonia are toxic for the microbial growth (Xiaojiao et al 2012 and Kayhanian, 1999). In the past main focus has been paid on the carbon to nitrogen (C/N) ratio as an important parameter for design and operation of AD process. However, this conception is a simplification of the reality and is not connected with any mechanistic explanation. Biomass is degraded to build new cells, with a cell to substrate yield depending on the microorganism and the energy content of the feedstock biomass used as substrate. For a successful balanced process in respect to C/N ratio, we would need exact balance of nitrogen to adequately cover the nutritional needs of the microorganisms, but not excessive to create inhibition problems. Therefore, we hypothesise that the biodegradability of the feedstock is a very important factor which has been ignored so far, in the optimisation of the C/N ratio of the feedstocks.

In order to test our hypothesis we have investigated feedsocks with different biodegradability in order to determine the effect of biodegradability on the C/N ratio, and to establish the connection of the C/N ratio with the cell biomass composition. As model-substrates (feedstock biomasses) with different biodegradability we tested: glucose (easy degradable) and grass (rich in lignocelulose and difficult to biodegrade). Based on literature data for optimal, sub-optimal and super-optimal ranges for C/N ratio following ratio were chosen: 5, 20, and 35 and 50. All experiments took place under thermophilic (55°C) conditions due to its superiority when compared to the mesophilic conditions for the bio-conversion of the substrates into bio-methane. Results obtained can be utilized for development of innovative co-digestion process configuration with substrates with different biodegradabilities

References:

Xiaojiao W., Gaihe Y., Feng Y., Guangxin R., Xinhui H., 2012. Optimizing feeding composition and carbon-nitrogen ratios for improved methane yield during anaerobic co-digestion of dairy, chicken manure and wheat straw. Bioresource Technology ; 120:78-83.

Kayhanian M., 1999. Ammonia inhibition in high-solids biogasification: an overview and practical solutions Environ. Technol., 20, pp. 355–365

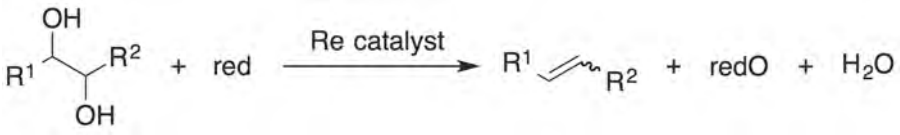
Development of the Molybdenum-Catalyzed Deoxydehydration of Polyols

Lasse B. Nielsen, Ayele T. Gorfo, Daniel B. Larsen. Allan R. Petersen, Johannes R. Dethlefsen, Peter Fristrup*

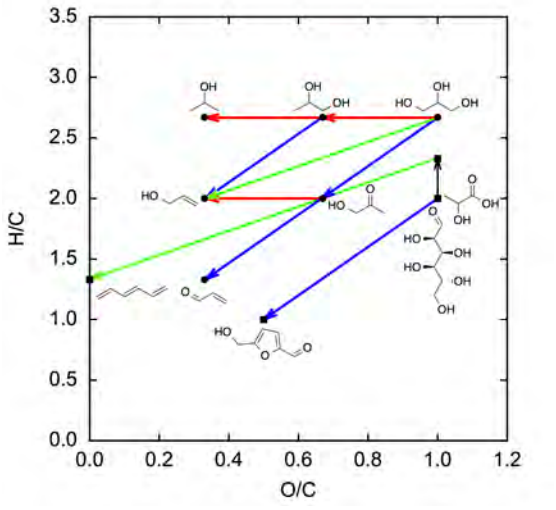
DTU Chemistry

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

The transformation of biomass-derived compounds into platform chemicals is one of the possible contributions from chemistry to the realisation of an economy completely independent of fossil reserves. In order for oxygenrich biomass-derived compounds such as glycerol and sugar alcohols to substitute petroleum, reactions capable of reducing their oxygen content are in demand, and in particular the deoxydehydration (DODH) of vicinal diols into alkenes in the presence of a reductant ("red") and a catalyst (typically a rhenium complex) has received ample recent attention from the scientific community (figure 1).[1]



The transformation represents a model system for the various hydroxyl groups present in biomass (e.g., in carbohydrates), but is also relevant in itself as a potentially useful transformation of glycerol. The reaction is interesting since it combined a formal reduction and dehydration in a single chemical transformation. This makes the change in the van Krevelen diagram quite dramatic as exemplified by the triple deoxydehydration converting sorbitol to the completely deoxygenated 1,3,5-hexatriene (figure 2).



Considering the huge amounts of glycerol and sugar alcohols that would have to be processed for the utilization of biomass to make a substantial impact, the development of alternative catalysts, based on elements with higher terrestrial abundance than rhenium, is clearly desirable. We therefore set out to investigate the possibility of using the transition metal molybdenum because of the similarities between oxorhenium(VII) and oxomolybdenum(VI) complexes. In this talk our results from both experiments[2] and theoretical modelling using density functional theory will be presented.[3] Application of the methodology for the conversion of glycerol will be presented.

(1) Dethlefsen and Fristrup *ChemSusChem* **2015**, *8*, 767 (minireview).
(2) a) J .R. Dethlefsen and P. Fristrup *ChemCatChem* **2015**, *7*, 1184-1196. b) Dethlefsen, Lupp, Teshome, Nielsen, Fristrup *ACS Catalysis* **2015**, *5,* 3638-3647
(3) Lupp, Christensen, Dethlefsen, Fristrup *Chem. Eur. J.* **2015**, *21*, 3435-3432

Catalytic oxidation of lignin and lignin model compounds

M. Melián-Rodríguez, S. Saravanamurugan, S. Kegnæs, and A. Riisager*

DTU chemistry, Center of catalysis and sustainable chemistry.

*ar@kemi.dtu.dk

Lignin represents the second most abundant component in lignocellulosic biomass, and it is well know that the emerging biomass refinery industry will inevitably generate an enormous amount of lignin. Development of selective bio refinery lignin conversion processes will play an important role increasing the economic feasibility and sustainability of biofuel production from renewable biomass. For this reason, research on upgrading lignin has become of recent interest, as many interesting products, mainly aromatics, can potentially be produced from lignin. [1-3]

In the present work we have prepared, characterized and examined the performance of heterogeneous catalysts with ruthenium and other transitions metals supported on different supports like γ-alumina or silica for the conversion of β-O-4 lignin model compounds (veratryl alcohol, guaiacyl glycerol-β-guaiacyl ether) and lignin by aerobic oxidation. [4]

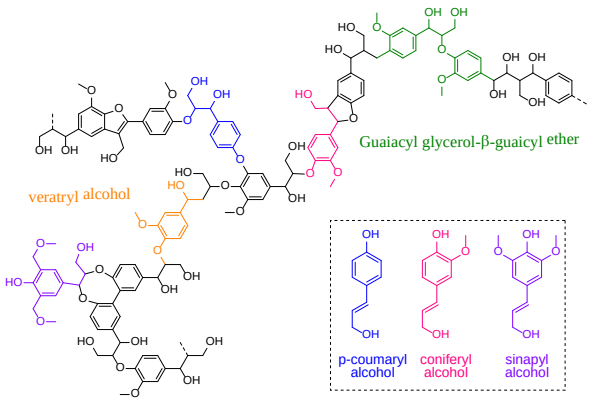


Fig. 1. Schematic representation of lignin structure and its three monolignol monomers.

Acknowledgments

The authors appreciate financial support to the work from The Danish Agency for Science, Technology and Innovation (International Network Programme, 12-132649), Haldor Topsøe A/S and the Technical University of Denmark.

References

[1] J. Zakzeski, PCA Bruijnincs, AL Jongerius, BM Weckhuysen, *Chem. Rev.* **110,** 3552 (2010)
[2] PT Patil, U Armbruster, M Richter, A Martin, *Energy & Fuels* **311**, 4713 (2006)
[3] C Zhao, JA Lercher, *ChemCatChem* **4**, 64 (2012)
[4] M Melián-Rodríguez, S Saravanamurugan, S Kegnæs, A Riisager, *Top. Catal*. **58**, 1036 (2015)

Session

S

Oral Presentations

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

Changes in the freshwater inventory of Young Sound-Tyroler fjord system (NE Greenland): Evidence from 10 years of Greenland Ecosystem Monitoring.

Colin A. Stedmon1*; Mikael Sejr2; Jørgen Bendtsen3; Tage Dalsgaard2; Thomas Juul Pedersen4; John Mortensen4; Søren Rysgaard2,3

1 DTU Aqua; 2 Arctic Research Centre, Aarhus University, Denmark; 3 ClimateLab; 4 Greenland Climate Research Centre; 5 Centre for Earth Observation Science, University of Manitoba.

*Corresponding author email: cost@aqua.dtu.dk

Freshwater supply to the fjord systems in NE Greenland can be expected to change as a result of climate change induced ice melt. The most obvious alteration is in that of increased freshwater supply from snow and ice melt on land. A more subtle change may also occur at the marine end as the contribution from Arctic Ocean sea ice melt and upstream freshwater discharge may alter the salinities of the inflowing marine water. Here we analyse 10 years data collected from a fjord system in NE Greenland to reveal that there although there are no systematic changes in local freshwater run off, the coastal shelf waters that flow into the fjord have doubled in freshwater content.

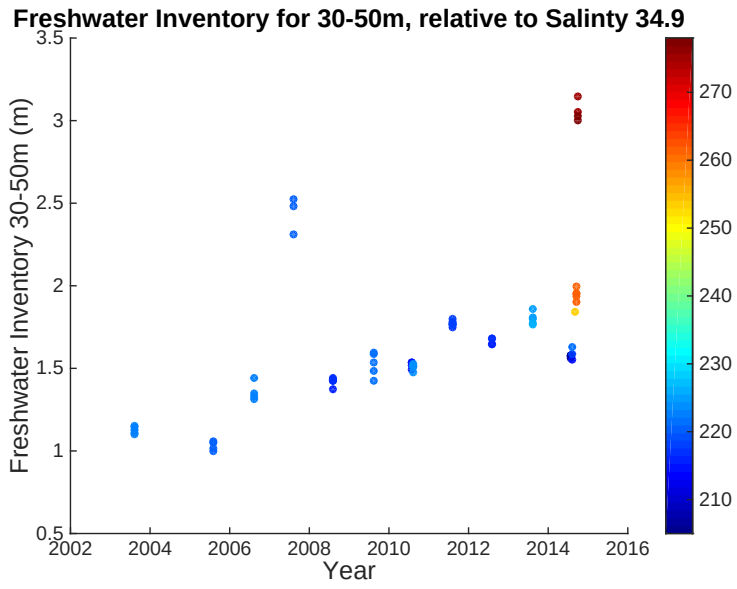


Figure: Freshwater content of coastal waters outside the fjord system at depths between 30-50 m which corresponds to the sill depth. The colour of the symbols represent the year sampled. Note in 2014 samples are from July, August September and October. All other years only August. The data points with much higher freshwater content originate from profiles with deep surface mixed layer, where local freshwater has likely been recently mixed downwards by high winds (e.g. October 2014).

Primary production in oligotrophic ocean regions likely greater than currently underestimated

Katherine Richardson[1]

Jørgen Bendtsen[2]

[1]Center for Macroecology, Evolution and Climate, Natural History Museum of Denmark, University of Copenhagen, Copenhagen, Denmark

[2]ClimateLab, Symbion Science Park, Copenhagen, Denmark

Applying a primary production (PP) protocol in which photosynthetic parameters were measured in the surface mixed layer (5 or 10 m) and at the deep chlorophyll maximum (DCM) on sampling in all major ocean basins except the North Pacific reveals a universal pattern in the vertical distribution of PP in relation to the depth of the nutricline (defined as depth where NO_3 $\geq$1µmol kg^{-1}). Using this relationship and satellite derived PP for the surface waters, the annual average of particulate PP is estimated as 10.0 Pg C yr^{-1} during 2002-2013 for deep nutricline (oligotrophic) regions. This result is 64% greater than the corresponding estimate (6.1 Pg C yr^{-1}) based on VGPM (Vertically Generalized Production Model : Behrenfeld and Falkowski, 1997 Limnology and Oceanography, 42, 1-20) for the same period. The identification of a consistent relationship between the vertical distribution of PP and water column characteristics opens for the potential of developing more accurate algorithms for estimating global PP.

Modelling the Antarctic Ice Sheet

Jens Olaf Pepke Pedersen* and Ask Holm

DTUSpace

*Corresponding author email: jopp@space.dtu.dk

The Antarctic ice sheet is a major player in the Earth's climate system and is by far the largest depository of fresh water on the planet. Ice stored in the Antarctic ice sheet (AIS) contains enough water to raise sea level by about 58 m, and ice loss from Antarctica contributed significantly to sea level high stands during past interglacial periods.

A number of AIS models have been developed and applied to try to understand the workings of the AIS and to form a robust basis for future projections of the AIS contribution to sea level change. The recent DCESS (Danish Center for Earth System Science) Antarctic Ice Sheet (DAIS) model (Shaffer 2014) is forced by reconstructed time series of Antarctic temperature, global sea level and ocean subsurface temperature over the last two glacial cycles.

In this talk a modelling work of the Antarctic ice sheet over most of the Cenozoic era using the DAIS model will be presented.

G. Shaffer (2014) Formulation, calibration and validation of the DAIS model (version 1), a simple Antarctic ice sheet model sensitive to variations of sea level and ocean subsurface temperature, *Geosci. Model Dev*., 7, 1803-1818

Regional modelling of the Earth System: a summary of recent work

Martin Drews* and Morten Andreas Dahl Larsen

Systems Analysis, DTU Management Engineering
*Corresponding author email: mard@dtu.dk

Climate and Earth System models are important tools for mapping and interpreting environmental monitoring data – both remotely sensed and in-situ observations – in a regional and global context. They are also crucial for projecting possible future states of the Earth in an increasingly variable and extreme climate system, which will pose one of the most significant challenges to global long-term sustainable development. In this contributed paper we will present examples of recent advances in regional earth system modelling carried out in the context of the Centre for Regional Change in the Earth System (CRES) and the project HYACINTS (Hydrological Modelling for Assessing Climate Change Impacts at different Scales); in each of the examples different kinds of observations played an important role for the model development.

The first example stems from a concerted effort within CRES to address the implications of extreme global warming in Northern Europe, which involved researchers from DTU Management Engineering and DTU Environment (Drews & Christensen 2015, Bøssing Christensen et al. 2015). In the combined study we assessed the impacts of climate change at the upper limits of the IPCC climate scenarios from a transdisciplinary point of view, while testing the applicability of existing tools for projecting the present and future states of the earth system (atmosphere, hydrology, groundwater, sea level) as well as socio-economic systems (economy, urban development). The second example concerns the development of a novel coupled climate and hydrology model based on DMI's regional climate model and DHI's hydrological modelling system MIKE-SHE; this integrated modelling tool represents a significant stride towards achieving detailed regional earth system models e.g. as required for solving the nexus of energy-water-land use-food security at local scales. In conclusion we will briefly offer perspectives on future work and offer ideas for collaborative research within the overlapping fields of modelling climate change and sustainable development.

The authors gratefully want to acknowledge the significant contributions by the research teams of the CRES and HYACINTS projects, some of which will be highlighted in this paper, and in particularly Jens Hesselbjerg Christensen, Danish Meteorological Institute; Jens Christian Refsgaard, GEUS; and Michael Butts, DHI.

Drews M., Christensen J. H. (2015). Implications of extreme global warming in Northern Europe. Clim Res 64: 3–6
Christensen O. B., Yang S., Boberg F., Fox Maule C., Thejll P., Olesen M., Drews M., Sørup H. J. D., Christensen J. H. (2015). Scalability of regional climate change in Europe for high-end scenarios. Clim Res CR 64:25-38
Butts M., Drews, M., Larsen, M.A.D., Lerer S., Rasmussen, S.H., Grooss, J., Refsgaard, J.C. and Christensen, J.H. (2014): Embedding complex hydrology in the climate system – dynamic coupling across scales. Adv. Water Resour. 74: 166–184

Key drivers and economic consequences of high-end climate scenarios: uncertainties and risks

Kirsten Halsnæs & Per Skougaard Kaspersen*

DTU Management

*Corresponding author email: pskk@dtu.dk

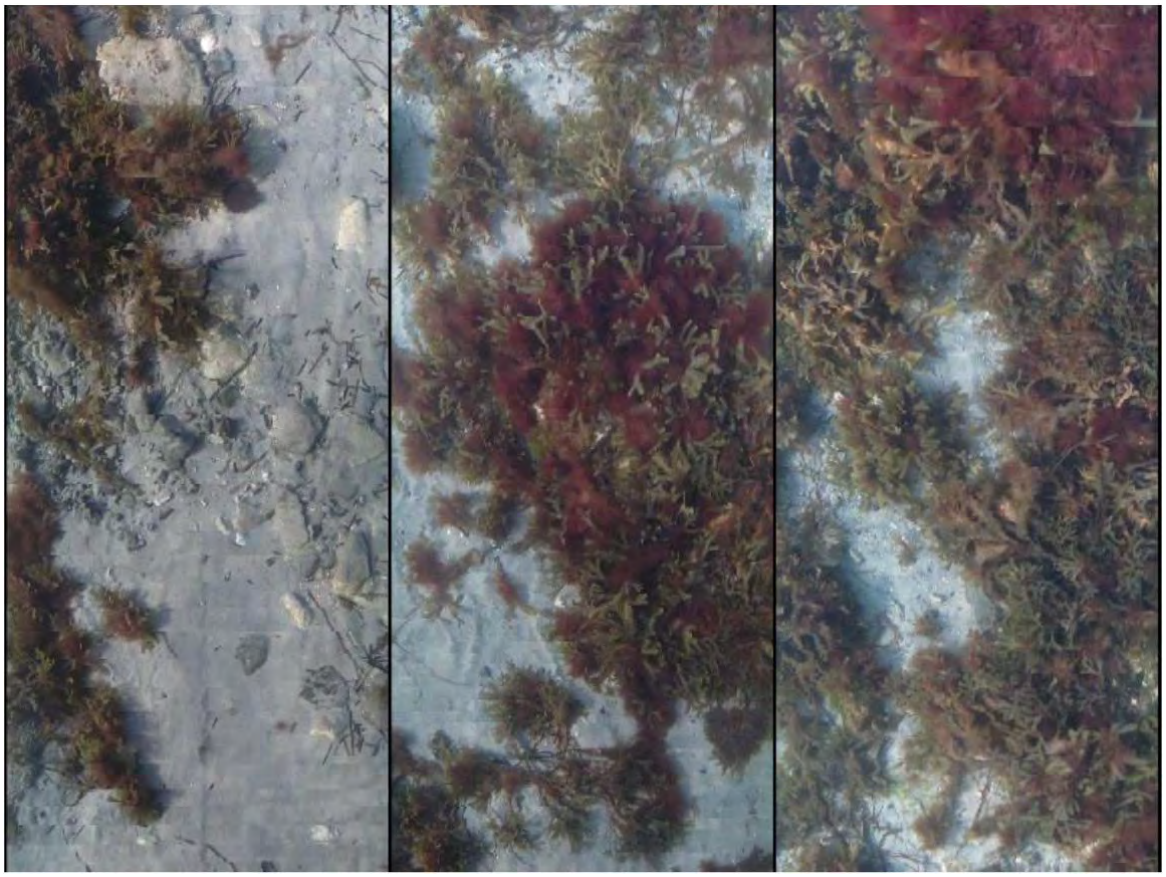
The consequences of high-end climate scenarios and the risks of extreme events involve a number of critical assumptions and methodological challenges related to key uncertainties in climate scenarios and modelling, impact analysis, and economics. A methodological framework for integrated analysis of extreme events and damage costs is developed and applied to a case study of urban flooding for the medium sized Danish city of Odense. Moving from our current climate to higher atmospheric greenhouse gas (GHG) concentrations including a 2°, 4°, and a high-end 6°C scenario implies that the frequency of extreme events increase beyond scaling, and in combination with economic assumptions we find a very wide range of risk estimates for urban precipitation events. A systematic sensitivity analysis including 32 scenario combinations demonstrates that alternative climate scenario assumptions as well as economic assumptions together result in risk estimates with a very large variation. We find that a major source of uncertainty relates to the climate scenario uncertainty, in particular related to the probability of tail events associated with high consequences to society. The economic assumptions, particularly on risk aversion factor and discount rate, are both very important and contribute to a very large variation of risk estimates. Furthermore, the actual level of damage costs associated with different levels of precipitation intensity is important in determining the risk levels. The latter is a challenge to impact modellers, and the accuracy of damage cost studies could benefit from the availability of more context-specific studies on impacts on physical assets, human welfare, and risk perception, and on how the full range of economic activities in the city could be affected. In the context of uncertainty and decision making, the results of the sensitivity analysis seen from a climate modelling perspective and from an economic perspective can be interpreted in different ways. Uncertainties related to the climate scenarios reflect both the state of current climate modelling and statistical downscaling approaches applied to the case study, as well as more general uncertainties related to global decision making on climate change mitigation and future temperature levels. In terms of adequately eliciting these uncertainties in an integrated framework, an ensemble of comprehensive model experiments, specifically designed to decompose the variance, which take into account key factors such as the scenario and model uncertainty is required.

Observing marine living resources

Bjarne Stage*[1], Eva Maria Pedersen[1]

1: DTU Aqua

*Corresponding author email: bst@aqua.dtu.dk



Fish, mollusks, crustaceans and seaweed are valuable marine living resources. Sustainable exploitation of these resources requires management based on precise information on the state of the marine ecosystem in general and the exploited species in particular. This presentation provides an overview of contemporary methods for observing marine living resources and possible future developments.

Stratospheric Air-Ships a Platform for Earth Observation

René Fléron*[1]

1: DTU Space, Building 327

*Author email: rwf@space.dtu.dk

Remote sensing technologies are essential for Earth monitoring. Satellites offers monitoring on a global scale, however satellite missions are costly, difficult to reconfigure and cannot monitor the same area continuously. Stratospheric airships may remain aloft at zero energy expenditure thus allowing continuously monitoring of areas of interest for extended periods of time. Furthermore they may be brought down for reconfiguration. With autonomous navigation and control the airships may conduct missions in remote areas. Thus stratospheric airship offers a desirable compromise between a space based solution and a land or sea based local observer. At DTU Space we are working towards the realization of an autonomous stratospheric airship. Here we present the airship as well as current and future activities in the development.

Session

S

Laptop Presentations

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

Sustain DTU Abstract: S-8

Session

S

Poster Presentations

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

Data Use and Complexity in Coastal Climate Adaptation and Planning

Carlo Sorensen*[1], Karina Nielsen[1], Ole B. Andersen[1], Per Knudsen[1]

1: DTU Space

*Corresponding author email: carlos@space.dtu.dk

Climate research advances our knowledge of current and future sea level changes at global and regional scales[1,2], extreme water levels[3], natural variability and anthropogenic footprint in sea level[4], and of methods to evaluate sea level change from satellite[5] and tide gauge data[6,7]. Future impact from erosion, floods and inundation to people and the environment in coastal regions is substantial[8, 9]. Still, for several reasons gaps exist between scientific knowledge and actual measures to mitigate climate change effects: the communication of uncertainty in projections is not a 'one size fits all'; the translation of climate change evidence to concrete impact measures is difficult; different agendas and opinions exist across levels of governance; and politics and economy matter. Climate research budget cuts in Denmark and elsewhere challenge the ways we perceive, address, and act on climate change issues in society.
Based on a Danish case study, starting out from future storm surge impact, we investigate how climate change interacts with other factors to reveal a broader platform and perspective for municipal climate change adaptation. This includes the use of existing and new in situ and satellite data, and different local stakeholder standpoints and knowledge. Adaptation to future coastal floods then becomes an integral part of urban and environmental planning and is not solely addressed as a climate change issue. Conceptually, this provides the municipality with a simple framework for decision-making in relation to water related challenges that is cost-effective, provides better solutions, and accommodates current municipal legislation, planning, and service levels. To advance sound management solutions the involved stakeholders must, however, acknowledge that a common gain is achieved only through collaboration and a shared appraisal of potential actions. Easy access to earth observation satellite data and services will greatly benefit municipal work and an enhanced national focus on the development of such services is advocated.

1: IPCC, 2013. WGIAR5 doi:10.1017/CBO9781107415324 **2**: Grinsted et al., 2015. *Clim. Res.*, doi:10.3354/cr01309 **3**: Arns et al., 2015. *Coast. Eng.*, doi:10.1016/j.coastaleng.2014.12.002 **4**: Dangendorf et al., 2015. *Nat. Commun.*, doi:10.1038/ncomms8849 **5**: Nerem et al., 2010. *Mar. Geol.*, doi:10.1080/01490419.2010.491031 **6**: Wahl et al., 2013. *Earth Sci. Rev.*, doi:10.1016/j.earscirev.2013.05.003 **7**: Visser et al., 2015: *J. Geophys. Res. Oceans*, doi:10.1002/2015JC010716 8: Cramer et al., 2014, WGIIAR5,Ch.18 **9**: IPCC, 2012. ipcc-wg2.gov/SREX.

Water levels of lakes and Rivers observed from space

Karina Nielsen[1*], Heidi Villadsen[1], Lars Stenseng[1], Ole B. Andersen[1] and Per Knudsen[1]

1: DTU Space

*Corresponding author email: karni@space.dtu.dk

Satellite radar altimetry has been used for more than 20 years to monitor the water level of the Earths continental water resources. The launch of CryoSat-2 in 2010 has marked a new era in satellite radar altimetry. CryoSat-2 is the first satellite that carries a synthetic aperture radar (SAR) altimeter on-board. The SAR technology provides an along-track resolution of approximately 300 m. The higher resolution makes it possible to accurately monitor much smaller water bodies than previously. Here we demonstrate the potential of SAR altimetry to derive water levels of continental water bodies. We consider lakes at various sizes and evaluate the CryoSat-2 derived lake levels in terms of along-track precision and agreement with in-situ data. As a reference we compare our CryoSat based results with conventional altimetry such as Envisat. We find that the precision of the along-track mean water level is a few cm, even for lakes with a surface area of just 9 km^2. The high precision makes it possible to detect water level variation below the decimeter level. Some of the results is now available in a new open service AltWater (altwater.dtu.space/), where along-track water levels and water level time series can be obtained for a subset of globally distributed lakes.

The Work was partly funded by the FP7 project Land and Ocean take up from Sentinel-3 (LOTUS).

Electron Microscopy for Morphological Analysis of Black Carbon Accumulated in Glaciers

Ramona Valentina Mateiu[1]*, Naoko Nagatsuka[2], Kumiko Goto-Azuma[2] and Jakob Birkedal Wagner[1]

1: Technical University of Denmark, Copenhagen, Denmark; 2: National Institute of Polar Research, Tokyo, Japan

*Corresponding author email: ramona.mateiu@cen.dtu.dk

Since the mid-20th century the decrease in anthropogenic emission of Black Carbon in Europe and North America has been recorded as a decreased Black Carbon accumulation in Greenland. However, the present-day concentrations of Black Carbon in Greenland are higher compared to the Black Carbon concentrations from the pre-industrial time, and the Black Carbon concertation in the Arctic.

Accumulation of Black Carbon in the glaciers correlates with a decrease in the surface albedo and therefore Black Carbon is thought to be one of the causes that lead to the melting of the glaciers. The morphology of Black Carbon depends on its origin, the various processes during transportation and the incorporation process into snow.

In the present study we evaluate the use of electron microscopy for morphological analysis of Black Carbon. We use both scanning electron microscopy (SEM) and transmission electron microscopy (TEM) for the analysis of Black Carbon in snow collected from Greenland and Alaska. We show that there is a morphological preference for the Black Carbon depending on the snow origin: Black Carbon found in snow from Greenland has fewer monomers arranged in a lacey, chain like, shape, while Black Carbon found in snow from Alaska has a large number of monomers arranged in a compact, onion like, shape.

These preliminary results show that electron microscopy can be used for morphological analysis of Black Carbon accumulated in show and glaciers, and that the Black Carbon particles present morphological differences depending on their origin.

Session

T

Oral Presentations

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

New free Danish online (Q)SAR predictions database with >600,000 substances

Eva B. Wedebye[1,*] / Nikolai G. Nikolov[1], Marianne Dybdahl[2], Trine K. Reffstrup[2], Sine A. Rosenberg[2]

DTU Food

1. Shared first and last authors
2. Co-authors

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

(Q)SARs are models that can predict properties, e.g. toxicity, for chemical substances solely based on their structure. Since 2005 the Danish (Q)SAR Database has been freely available on the Internet. It is a tool that allows single chemical substance profiling and screenings based on predicted hazard information. The database is also included in the OECD (Q)SAR Application Toolbox, which is a free software application to fill information gaps needed for assessing the hazards of chemicals. The free software is used worldwide by regulators and industry. A lot of progress in (Q)SAR model development, application and documentation has been made since the publication in 2005.

A new and completely rebuild online (Q)SAR predictions database was therefore published in November 2015 at http://qsar.food.dtu.dk. The number of chemicals in the database has been expanded from 185,000 to >600,000. As far as possible all organic single constituent substances that were pre-registered under REACH have been included in the new structure set. The new Danish (Q)SAR Database includes estimates from more than 200 (Q)SAR models covering a wide range of hazardous properties relevant for human health and the environment such as acute toxicity to rat, mouse, fish, daphnia and algae, as well as many physical-chemical and environmental fate properties, skin irritation, sensitization, genotoxicity, cancer, endocrine activity and reproductive toxicity. In agreement with software vendors, (Q)SAR predictions for 600,000 substances from commercial and free software (CASE Ultra, Leadscope PDM, SciQSAR, ACD/Tox Suite and EPI Suite) are included in the database.

The database is one of the most comprehensive freely available (Q)SAR tools for substance evaluations and large-scale screenings. The online interface to the database allows for advanced combination of searches as well as sorting functions on chemical similarity. Negotiations are underway with the OECD to integrate the new database with the OECD (Q)SAR Application Toolbox. The database was developed by the DTU National Food Institute in cooperation and with financial support from the Danish Environmental Protection Agency, the Nordic Council of Ministers and the European Chemicals Agency (ECHA).

Environmental risk assessment of chemicals and nanomaterials — The best foundation for regulatory decision-making?

Kristian Syberg*[1,3], Steffen Foss Hansen[2]

1: ENSPAC, Roskilde University, 2: DTU Environment, Building 113

*Corresponding author email: ksyberg@ruc.dk

Environmental risk assessment (ERA) is often considered as the most transparent, objective and reliable decision-making tool for informing the risk management of chemicals and nanomaterials. ERAs are based on the assumption that it is possible to provide accurate estimates of hazard and exposure and, subsequently, to quantify risk. In this paper we argue that since the quantification of risk is dominated by uncertainties, ERAs do not provide a transparent or an objective foundation for decision-making and they should therefore not be considered as a "holy grail" for informing risk management (see figure 1). We build this thesis on the analysis of two case studies (of nonylphenol and nanomaterials) as well as a historical analysis in which we address the scientific foundation for ERAs. The analyses show that ERAs do not properly address all aspects of actual risk, such as the mixture effect and the environmentally realistic risk from nanomaterials. Uncertainties have been recognised for decades, and assessment factors are used to compensate for the lack of realism in ERAs. The assessment factors' values were pragmatically determined, thus lowering the scientific accuracy of the ERAs. Furthermore, the default choice of standard assay for assessing a hazard might not always be the most biologically relevant, so we therefore argue that an ERA should be viewed as a pragmatic decision-making tool among several, and it should not have a special status for informing risk management. In relation to other relevant decision-making tools we discuss the use of chemical alternative assessments (CAAs) and the precautionary principle.

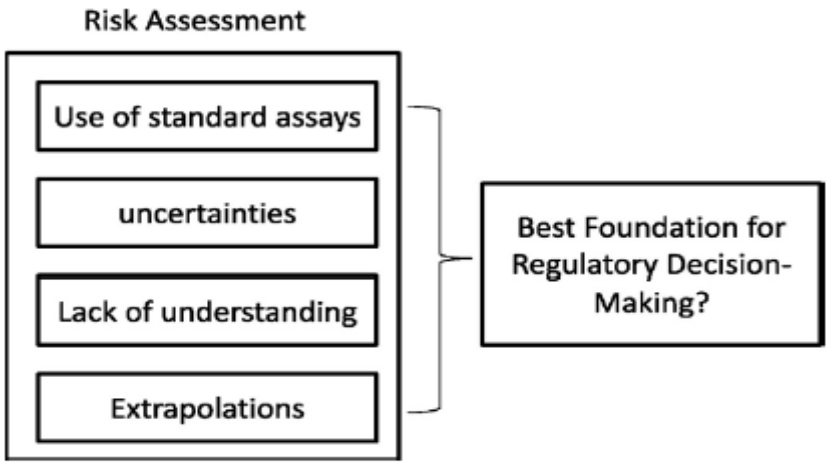


Figure 1

References:
Syberg, K., Hansen, SF. 2016. Environmental risk assessment of chemicals and nanomaterials — The best foundation for regulatory decision-making? Science of the Total Environment 541 (2016) 784–794

The Applicability of Chemical Alternatives Assessment for Engineered Nanomaterials

Rune Hjorth*[1], Steffen Foss Hansen[1], Molly Jacobs[2], Joel Tickner[2], Michael Ellenbecker[2], Anders Baun[1]

[1]DTU Environment; [2]University of Massachusetts Lowell
* ruhj@env.dtu.dk

The use of alternatives assessment to substitute hazardous chemicals with inherently safer options is gaining momentum worldwide as a legislative and corporate strategy to minimize consumer, occupational, and environmental risks. Engineered nanomaterials represent an interesting case for alternatives assessment approaches as they can be considered both emerging "chemicals" of concern, as well as potentially safer alternatives to hazardous chemicals. However, comparing the hazards of nanomaterials to traditional chemicals or to other nanomaterials is challenging and critical elements in chemical hazard and exposure assessment may have to be fundamentally altered to sufficiently address nanomaterials. The aim of this study is to assess the overall applicability of alternatives assessment methods for nanomaterials and outline recommendations to enhance their use in this context. This study focuses on the adaptability of existing hazard and exposure assessment approaches to engineered nanomaterials as well as strategies to design inherently safer nanomaterials. We argue that alternatives assessment for nanomaterials is complicated by the sheer number of nanomaterials possible. As a result, the inclusion of new data tools that can efficiently and effectively evaluate nanomaterials as substitutes are needed to strengthen the alternatives assessment process. However, we conclude that with additional tools to enhance traditional hazard and exposure assessment modules of alternatives assessment, such as the use of mechanistic toxicity screens and control banding tools, alternatives assessment can be adapted to evaluate engineered nanomaterials both as potential substitutes for chemicals of concern and to ensure safer nanomaterials are incorporated in the design of new products.

Environmentally sustainable nanoparticles - Towards a new paradigm for ecotoxicity testing and hazard assessment of engineered nanoparticles

Anders Baun, Sara Nørgaard Sørensen, Lars Michael Skjolding, Nanna Bloch Hartmann, Steffen Foss Hansen

DTU Environment

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

For a sustainable development and use of engineered nanoparticles it is crucial that the potential environmental risks related to these are evaluated. In risk assessments of engineered nanoparticles the current practice is that the existing test guidelines for chemical risk assessment are used, though it has been realized that some technical changes may be needed. Evidence in the scientific literature is emerging that these conventional methodologies for assessing chemical risks may not be appropriate for assessing risks associated with nanomaterials.

In the project EnvNano funded by the European Research Council, we challenge the assumptions behind the use of methods developed and optimized for dissolved chemicals. Our starting point is the fact that particles behave fundamentally different than dissolved chemicals in the test systems used for risk assessment. Through a range of experimental studies of engineered nanoparticles in ecotoxicity tests with algae and crustaceans we have found that understanding and quantification of the dynamic changes occurring to engineered nanoparticles in water before and during testing may hold the key to a proper interpretation of test results obtained. Based on these findings we propose that a combination of a shortened exposure period with an aging step of engineered nanoparticles in medium prior to testing should be implemented to achieve increased control of exposures in ecotoxicity tests [1]. Results obtained for uptake and excretion of nanoparticles in freshwater crustaceans (Daphnia magna) and zebrafish underline that the principles of assuming chemical equilibrium between test species and the surrounding environment, traditionally used for dissolved chemicals, are not valid for nanoparticles [2,3].

The experimental findings in EnvNano are directly connected to the development of new risk evaluation approaches. This has so far resulted in two frameworks for alternative risk evaluation of engineered nanoparticles. Both of these are designed to operate under severe lack of data and are adaptable to including new experimental findings. The first framework is aimed at an operationalization and application of “early warning signs” to screen nanomaterials for harmful properties. It shows how the warning signs of novelty, persistency, bioaccumulation, dispersivity, and irreversible action can used as a first screening for potentially hazardous nanomaterials [4]. The second framework is a conceptual tool for categorization and communication of exposure potentials and hazards of nanomaterials in consumer products [5].

This presentation will show how the findings described above, besides contributing the fundamental knowledge base on ecotoxicological properties of engineered nanoparticles, also assist in the development of methods appropriate for evaluating the environmental risks.

References:

[1] Sørensen, S.N. & Baun, A. (2015). Nanotoxicology, 9, 201-209.
[2] Skjolding, L. M., Kern, K., Hjorth, R., Hartmann, N., Overgaard, S., Ma, G., Veinot, J.G.C., Baun, A. (2014). Ecotoxicology. 23(7), 1172-1183.
[3] Skjolding L. M., Winter-Nielsen M., Baun A. (2014) Aquatic Toxicology, 157, 101-108.
[4] Hansen SF, Nielsen, K., Knudsen, N., Grieger, K. Baun, A. (2013) Environmental Science: Processes & Impacts, 15, 190-203.
[5] Hansen, S.F., Jensen, K.A., Baun, A. (2013). J. Nanoparticle Res., 16, 2195.

Safe use of nanomaterials

Ulla Vogel[1,2]*

1: National Research Centre for the Working Environment; 2: DTU Nanotech;

*Corresponding author email: ubv@nrcwe.dk

Nanotechnology has introduced new materials, many of which may be classified as nanomaterials, since they are 1-100 nm in at least one dimension. Being new materials, nanomaterials have undergone extensive investigations to reveal possible toxicity. It is now clear that inhalation of low toxicity, insoluble nanomaterials is more hazardous per mass unit compared to inhalation of larger particles with the same chemical composition. Inhalation of nanomaterials induces acute phase response and inflammatory response which a proportional to the total surface area of the deposited particles [1, 2]. Acute phase response is causally linked to risk of cardiovascular disease [2]. Carbon nanotubes are new nanomaterials that appear to be especially hazardous by inhalation. One specific carbon nanotube was recently classified as 'possibly carcinogenic to humans' by the International Agency for Research on Cancer (IARC) [3], and pulmonary deposition of carbon nanotubes induces a strong and persistent acute phase response [4]. Since the hazardous effects are seen for the free nanomaterials, safe use of nanomaterials is mainly a problem in occupational settings since the consumer is primarily exposed to nanomaterials in their intended use in products, whereas workers may be exposed to free nanomaterials in production. Nanomaterials are hazardous by inhalation, and we know that workers are exposed to nanomaterials in the Danish working environment. Therefore, in order to prevent nanomaterial-induced occupational disease, the Danish Working Environment Council (Arbejdsmiljørådet) has made 23 recommendations (www.amr.dk/nano.aspx) to promote safe use of nanomaterials in the work environment.

Reference List

1. Duffin R, Tran L, Brown D, Stone V, Donaldson K. Proinflammogenic effects of low-toxicity and metal nanoparticles in vivo and in vitro: highlighting the role of particle surface area and surface reactivity. Inhal Toxicol. 2007;19:849-856.

2. Saber AT, Jacobsen NR, Jackson P, Poulsen SS, Kyjovska ZO, Halappanavar Set al. Particle-induced pulmonary acute phase response may be the causal link between particle inhalation and cardiovascular disease. Wiley Interdiscip Rev Nanomed Nanobiotechnol. 2014;6:517-531.

3. Grosse Y, Loomis D, Guyton KZ, Lauby-Secretan B, El GF, Bouvard Vet al. Carcinogenicity of fluoro-edenite, silicon carbide fibres and whiskers, and carbon nanotubes. Lancet Oncol. 2014;15:1427-1428.

4. Poulsen SS, Saber AT, Mortensen A, Szarek J, Wu D, Williams Aet al. Changes in cholesterol homeostasis and acute phase response link pulmonary exposure to multi-walled carbon nanotubes to risk of cardiovascular disease. Toxicol Appl Pharmacol. 2015;283:210-222.

Food safety and sustainability of chemicals in food contact materials – is risk assessment the right tool?

Xenia Trier*

DTU Food

- xttr@food.dtu.dk

Food contact materials (FCM) are an example of consumer products with the potential to release chemicals into food during the food production, packaging or preparation, and in amounts that are harmful to human health. During the production and the disposal, FCM chemicals can also be released to workers and the environment. It has been estimated that more than 15,000 chemicals can be present in FCM. The question is therefore if it is possible to ensure that this mixture of chemicals is safe and sustainable for humans and the environment – and if the tools we currently apply are adequate to perform such assessments?

In the EU, risk assessment (RA) is used to assess the safety of chemicals in food, and requires quantification of both the hazard (evaluation and characterization) and the exposure (concentration in a food and the food consumption). In practice this requires knowledge of the chemical structures. However, only for five (mainly plastics and ceramics) of the 17 categories of FCM, there are lists of authorized *starting* substances with limits set by the EU Commission. These IAS are evaluated by EFSA, one by one in relation to human health. Cocktail effects, aggregate exposure, the toxicity of the intentional reaction products (IRP) or the non-intentionally added substances (NIAS) and environmental effects are not evaluated. For the rest of the 12 non-harmonised materials, such as coatings, printing inks, and paper and board packaging, the FCM manufacturers and business are expected to perform the RA, since it is their responsibility to ensure the safety of their FCMs. These data can be kept as proprietary and are not evaluated but independent parties.

Not having a limited list of suspect substances to look for, makes it extremely time consuming to assess materials: First each substances must be identified, then the concentrations be measured by confirmatory methods in various foods (Backhaus & Trier 2015), which requires access to standards which more often than not are not commercially available (Trier et al. 2011). Then the hazard needs to be evaluated and characterized. An option is to make bio-directed analysis, but even after fractionation of the sample and identifying which of the fraction(s) that are toxic, each fraction may contain 50-100 substances that need to be quantified and/or identified (Bengtström et al. 2014). This talk will mainly focus on how to accurately quantify the exposure of chemicals, which in turn also is used to prioritize the level of hazard evaluations, e.g. using the threshold of toxicological concern.

Given the economical, scientific and time constraints, several questions arise: Should we perform few, accurate measurements on few substances, or frequent less accurate measurements on more substances? Is the RA uncertainty too large to prioritize semi-quantified substances? Can classical RA in practice ensure food safety and an environmentally sustainable production of FCM? Or is it time to consider other pragmatic tools, fewer chemicals, or innovation of less toxic chemicals being more compatible with a human and environmental health in a circular economy (Scheringer et al. 2014; Fantke et al. 2015)?

Session

T

Laptop Presentations

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

Session

T

Poster Presentations

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

Chemical contamination of material cycles

Kostyantyn Pivnenko*[1], Thomas F. Astrup[1]

1: DTU Environment

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

Material recycling represents a backbone of sustainable society in the context of circular economy. Ideally, materials are converted into products, used by the consumers, and discarded, just to be recycled and converted into newly manufactured products. Furthermore, materials may also contain chemicals, which would be re-introduced into the loop once a product is recycled. Such chemicals may not be removed in the recycling process, persist, and contaminate the newly manufactured products. Chemical contamination could potentially put product consumers at unnecessary risk and jeopardize public acceptance of recycled-material-based products.

Paper and plastics are conventional materials used to manufacture a variety of products within main sectors of economy (i.e. packaging, transportation, construction, services, and other). A number of chemicals can be either intentionally or unintentionally added to these materials in the process of product manufacturing or final product conversion. Extend of chemical use, as well as their presence in paper and plastic products remains largely uninvestigated. The aim of this project is to obtain reliable quantitative data on presence of selected (potentially hazardous) chemicals in paper and plastic materials, and furthermore discuss the likely impacts of chemical contamination on material recycling. The work is part of the new Danish initiative focusing on Integrated Resource Management and Recovery (IRMAR, grant no. 11-116775). The outcomes of the work will provide crucial basis for future waste characterization activities, environmental and risk assessments of material recycling, as well as provide authorities, scientific community and society with a necessary basis for evaluating potential future limitations to recycling and address means of mitigating accumulation and spreading of chemicals in various materials.

Figure 1. Integrated Resource Management and Recovery (IRMAR, grant no. 11-116775)

Health risk assessment of chemical mixtures

Julie Boberg*, Sofie Christiansen, Marta Axelstad, Anne Marie Vinggaard, Karen Mandrup, Ulla Hass

DTU Food

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

When evaluating the health risk of chemical exposures, classical risk assessment methods only look at one chemical at a time. But humans are exposed to numerous chemicals from many sources, and methods to perform a cumulative risk assessment of mixed exposure to chemicals are needed.

At DTU Food we have established methods to integrate the knowledge on several chemicals that humans may be exposed to at the same time. Our research has focused on animal and cell-based studies on chemicals with endocrine disrupting properties, i.e. altering the levels or function of hormones and thereby resulting in adverse effects on the male and female reproductive system. We have found that chemicals acting via the same modes of action can have cumulative effects in vivo. Interestingly, also chemicals with different modes of action may have cumulative effects in vivo, if they cause the same type of effects in the organism. Overall, our data indicate that cumulative risk assessment of chemicals is needed as assessment of one chemical at a time may underestimate the risk.

This poster presents examples of our research and discusses the following topics:

- How do we predict the combined risk of exposure to several chemicals at the same time?
- Can we group the chemicals according to their type of effects? Or is it necessary to know their exact mechanisms of action?
- Should health risk assessment of food take chemical exposure from other sources into account?
- Should health risk assessment of chemicals in products or environmental take chemical exposure from food into account?

Session

W

Oral Presentations

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

Global integration model for Life Cycle Assessment in Small and Medium Sized Enterprises (SME)

Tracey Colley[1*], Morten Birkved[1]

1: DTU Management, *Corresponding author email: trco@dtu.dk

This PhD project aims to look at how the principles of LCA can be applied to SMEs, through integrating Environmental Management Systems (EMS) and risk assessment (RA) with current trends in environmental management in SMEs on a global level. The study site is a food (red meat) SME processing plant in Australia and the PhD will look at two current priority issues for the site, carbon and water footprinting, and the opportunities for supply chain integration upstream in the supply chain and catchment area respectively. The objectives are to assist with making food production and SMEs more sustainable by developing a LCA application model which is suited to the resources of an SME. It may also be possible to work with food supply chains in developing countries to test the model and assist with identifying differences for developing economies.

From a water and carbon perspective, the PhD will take a circular economy approach to supply chain integration within the same local area, as a way of strengthening regional economies and reducing the overall impacts of the supply chain by looking at synergies between complimentary local agribusiness supply chains. For the water footprint, one of the primary concerns will be the pathogen risk posed by recycling treated nutrient rich effluent back to farms as a means of reducing the overall nutrient load on the water catchment and looking at how this risk is reflected in current LCA methodologies.

Sessions: F: Food Resources (morning session) or W: Water & Sustainability (afternoon session)

Multi-function anti-fouling bio-active surfaces

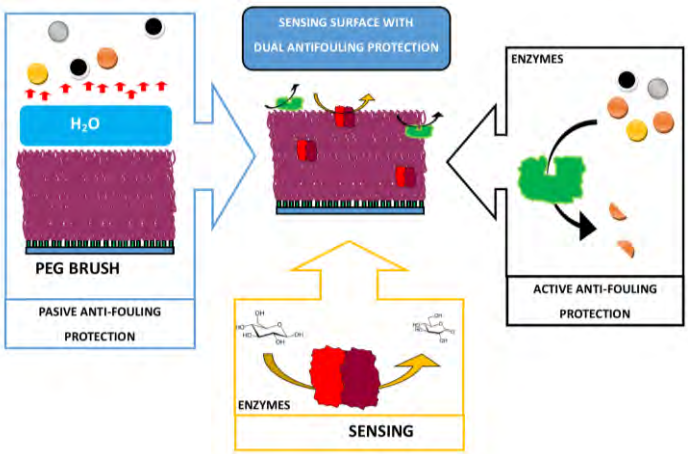
Roberto Ortiz*[1], Esben Thormann[1]

1: DTU Kemi

*Robor@kemi.dtu.dk

The development of long-term, non-contaminating, biocide free anti-fouling surfaces is of great importance and a challenge that requires cutting-edge scientific tools to gain successful outcomes. One solution, to overcome the coverage of biological material on wetted surfaces, called biofouling, is the use of non-adherent surfaces as polyethylene glycol (PEGs)[1] combined with environmentally friendly enzymes instead of environmentally harmful chemical biocides.[2] Using this combination of passive (PEGs) and active (enzyme) effects a more resistant surface against protein adhesion can be achieved. This surface attachment of proteins, microbes and marine organisms creates big problems in many applications, as for example medical implants, biosensors, water purification systems, textiles, food packaging and food storage, and marine and industrial equipment.[3]

Short PEGs are used (1000 -10000 nm) and covalently bounded to the surface producing a few nanometers barrier against protein adsorption. To achieve an even longer long-term stability the protease subtilisin is covalently bonded to the PEG surface. Proteases are known to remove the fouling substances or organisms that succeed to reach the surface in an effective way. Finally, traditionally used enzymes for sensing, e.g. glucose oxidase or horse-radish peroxidase are included in the coating to give sensing properties to the surfaces. In this proof of- concept design, we achieve a longer stability for long-term usage of the sensors in water environment.



[1] a J. A. Callow et al., Nat Commun 2011, 2, 244; b T. Ekblad, et al., Biomacromolecules 2008, 9, 2775-2783; c S. Schilp, et al. Langmuir 2009, 25, 10077-10082. [2] a J. E. Gittens, et al. b J. B. Kristensen, et al, Biotechnology Advances 2008, 26, 471-481; c S. M. Olsen, et al., Biofouling 2007, 23, 369- 383; d M. E. Pettitt, et al., Biofouling 2004, 20, 299-311; e M. Tasso, et al., Biofouling 2009, 25, 505-516. [3] I. Banerjee, et al., Advanced Materials 2011, 23, 690-718.

Water Supply Water Footprint: How the scale impacts the assessment

Ryle Nørskov Gejl[1,2], Poul Løgstrup Bjerg[1], Berit Godskesen[2], Anne-Marie Hybel[3], Jens Rasmussen[2] og Martin Rygaard[1]*

[1]*DTU Environment*, [2]*HOFOR and* [3]*Orbicon*

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

There exist several methods to quantify how water abstraction affects the freshwater resource that result in different impacts for the same area. In addition to method, the geographic scale and the demarcation of the catchment area will affect the impact assessment. The absence of a consistent and generally accepted assessment method can lead to mistrust in these assessments and make water footprints impractical. Therefore it is crucial to develop a method that obtains consistent demarcations of the area for the water footprint, in order to get a generally accepted assessment of the impact on the freshwater resource. This would give: 1) a simple tool to compare different water supplies freshwater impact and a better understanding of sustainable water abstraction and 2) start the process to find a tool that allows for implementing water in lifecycle assessments of the water supply. The purpose of this project is to investigate how the geographical scale influences the assessment of the freshwater impact, by calculating the water footprint with two different methods, on three different scales, for the utilities in Copenhagen, Aarhus, Odense and Esbjerg. The calculation are based on data of the available water resource from the River Basin Management Plans, RBMP (e.g. Miljøministeriet 2011). The applied methods are Withdrawal-To-Availability (WTA) and Water Stress Index (WSI). The assessed scales are 1) regional (e.g. Zealand), 2) River basins (540-7600 km^2) and 3) a weighted average of the groundwater bodies that constitute a river basin (0.01-2737km^2). The initial results show that the water footprint varies significantly depending on scale for the assessment, e.g. the WSI varies a factor 10 between the regional assessment 0.62 (Funen) and 5.99 for the weighted average of groundwater bodies in Odense Fjord River Basin. The water footprints for Odense are generally higher, op 900% compared to the other utilities. This may be due to the administrative demarcations in the RBMPs. Since the data does not demarcate after natural water boundaries, the assessment cannot be used to compare between utilities freshwater impact.

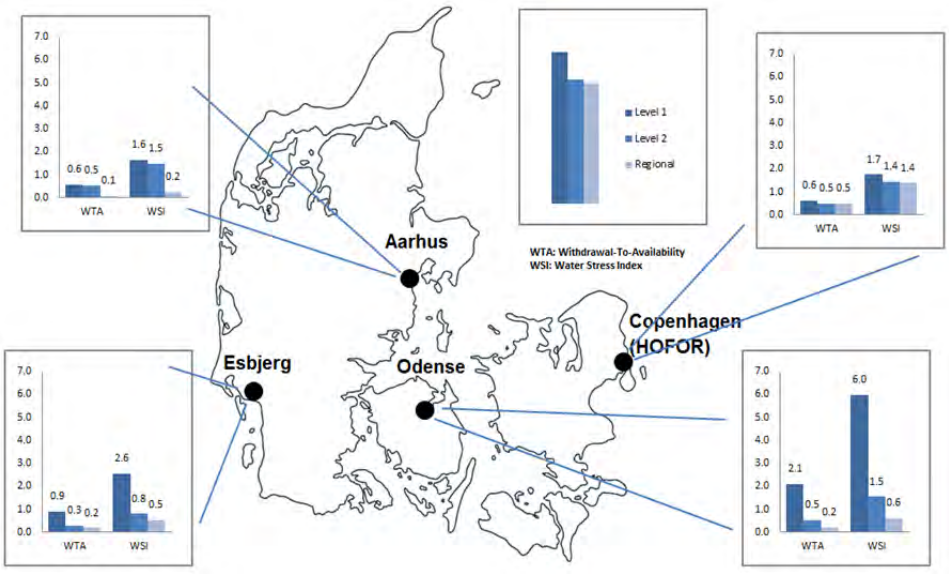


Figure 1: Water footprints for the utilities in Copenhagen, Aarhus, Odense and Esbjerg. The water footprints are found by two different methods WSI and WTA and for three scales: Regional, River basin and a weighted average of the groundwater bodies that constitute a river basin. Revised from (Hybel et al. 2015)**.**

Bibliography: Hybel, a.-M., Godskesen, B. & Rygaard, M., 2015. Selection of spatial scale for assessing impacts of groundwater-based water supply on freshwater resources. *Journal of Environmental Management*, 160, pp.90–97.
Miljøministeriet, 2011. *Vandplan 2009-2015. Vadehavet, Jylland*, Miljøministeriet, Naturstyrelsen.

Addressing the Chinese water challenges with hydroeconomic modelling

C. Davidsen*[1,2,3], S. Liu[2], X. Mo[2], P. E. Holm[3,4], S. Trapp[1], D. Rosbjerg[1], P. Bauer-Gottwein[1,3]

1: DTU Environment; 2: Key Laboratory of Water Cycle and Related Land Surface Processes, IGSNRR, Chinese Academy of Sciences; 3: Sino-Danish Center for Education and Research; 4: Department of Plant and Environmental Sciences, Faculty of Science, University of Copenhagen.

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

Population growth and rapid development of the Chinese economy have increased water scarcity and put the natural water resources and aquatic ecosystems in the North China Plain under pressure. Dry rivers, decreasing groundwater tables and strongly polluted surface water are some of the consequences of this development. As a response, the Chinese authorities have launched 2011 No. 1 Central Policy Document, with the Three Red Lines setting strict targets related to water scarcity and water quality. These policy documents mark an important step towards sustainable management of the Chinese water resources. The targets are, however, highly coupled and attempts to meet all targets with uncoordinated regulation will therefore likely fail. Water allocation, groundwater pumping, hydropower production, wastewater treatment, river water quality, water for ecosystems and water diversion are all elements of one large coupled management problem, which underlines the need for decision support tools that can deal with water management in an integrated manner. A traditional stochastic dynamic programming (SDP) approach was used to minimize the basin-wide total costs arising from water allocation, water curtailment and water treatment. One-step-ahead sub-problems were solved for all combinations of discrete reservoir storage, Markov Chain inflow classes and monthly time steps. A water quality module to handle conservative pollutants, first order depletion and non-linear reactions was introduced. This compromised linearity of the objective function which was handled by outsourcing complicating decision variables to a genetic algorithm, which calls a linear program to determine the remainder of the decision variables. This hybrid formulation keeps the optimization problem computationally feasible and represents a flexible and customizable method. The proposed hydroeconomic optimization modelling approach has been applied to the Ziya River Basin, a part of Hai River in North China. The model provided valuable decision support, such as long-term optimal reservoir operation and optimal allocations to the water users. Finally, the model can also be used to assess costs of meeting constraints such as minimum water quality or to economically prioritize investments in waste water treatment facilities based on economic criteria. While the SDP-based model provides important decision support for the Ziya River Basin, the method scales poorly to more complex management problems with multiple state variables, e.g., reservoirs and aquifers. Future research will target this computational limitation by switching to a Model Predictive Control-based approach. This will allow inclusion of a more realistic representation of the system, e.g. delayed yield in agriculture along with multiple reservoirs, aquifers and water quality aspects.

Session

W

Laptop Presentations

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

Fouling of forward osmosis membranes on municipal waste streams

Agata Zarebska*[1], Tobias Hey[2,3], Jes la Cour Jansen[2], Irena Petrinic[4], Jasmina Korenak[4], Hermina Buksek[4], Claus Hélix-Nielsen[1,4]

1: Technical University of Denmark, Department of Environmental Engineering, Miljøvej 113, 2800 Kgs. Lyngby, Denmark,

2: Faculty of Engineering, Lund University, Getingevägen 60, 221 00 Lund, Sweden

3: VA SYD, 201 21 Malmo, Sweden

4: University of Maribor, Faculty of Chemistry and Chemical Engineering Smetanova ulica 17, SLO-2000 Maribor, Slovenia,

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

ABSTRACT

Water recycling for agricultural and industrial applications offers resource and economic savings. In addition, water recovery can alleviate global water stress which currently exists. Therefore is it of general interest to restore/reclaim water from waste streams. Conventional ways to reclaim water from wastewater such as membrane bioreactors combined with reverse osmosis (RO), or micro/ultrafiltration coupled with RO and sand filtration, or advanced oxidation process are all energy intensive.

In comparison to pressure driven membrane processes, forward osmosis (FO) can operate in the absence of applied hydraulic pressure resulting in a lower fouling propensity and consequently lower need for cleaning. However, FO membranes are not completely resistant to fouling. Therefore it becomes important to identify methods to reduce or if possible eliminate fouling as this will lead to increased FO membrane performance and lifespan thus increasing the economic viability of the FO process. As fouling can occur by a variety of processes including inorganic, organic, and biological processes, fouling characterization becomes a non-trivial task.

The objective of this study is to characterize fouling of FO biomimetic aquaporin membranes used for water recovery from municipal wastewater. Membrane fouling was analyzed using Scanning Electron Microscopy, X-ray Dispersive Spectrometry, Fourier Transform Infrared Spectrometry, Inductively Coupled Plasma Optical Emission Spectrometry, Ion chromatography, contact angle and zeta potential measurements.

Our preliminary experimental results indicate that FO biomimetic aquaporin membranes can tolerate being exposed to municipal waste water and that fouling within the first 20 h operation is not severe. When fouling is observed it appears uneven in character, leading to local surface hydrophilization and overall to more negative surface charge. Taken together our results show that it is feasible to use biomimetic membranes in waste water treatment and the analyses can assist in future optimization of membrane performance.

Session

W

Poster Presentations

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

Quantitative potential for stormwater control measures

Hjalte Jomo Danielsen Sørup[*12], Sara Maria Lerer[1], Karsten Arnbjerg-Nielsen[12], Peter Steen Mikkelsen[13] and Martin Rygaard[1]

1: DTU Environment; 2: DTU GDSI, 3: Water DTU

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

Rainwater in the urban context is both a resource for e.g. recreational and amenity purposes and a potential problem due to e.g. pluvial flooding. In Denmark municipalities are increasingly trying to handle rainwater in both everyday and extreme situations using other techniques, here referred to as Stormwater Control Measures (SCMs), than traditional sewers as a means of climate adaptation (Copenhagen Municipality, 2012). This study provides a new framework to communicate the potentials for SCMs taking into account the properties of rainfall making it both a problem and a resource. The quantitative potentials of SCMs are calculated in relation to the municipal water balance (figure 1 left) and the Three Points Approach (Figure 1 right, Fratini et al., 2012). Different SCMs where rainwater is infiltrated or harvested are used to illustrate the tool. The potentials are calculated for the two largest municipalities of Denmark: Copenhagen and Aarhus. The Three Points Approach is used to distinguish between different rain domains, and to subdivide the quantitative potentials accordingly. This analysis shows that designing SCMs for larger return periods than 5 to 10 years, and thus making them attractive for flood protection, result in a very marginal increase in the rainwater these systems will actually handle compared to systems designed for less severe events and result in heavily increases in the size of the SCMs.

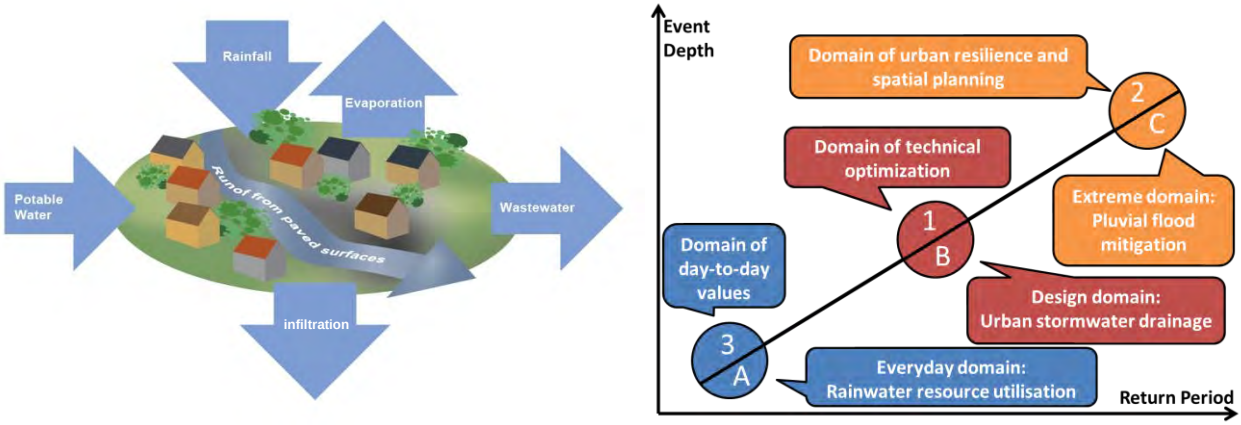


Figure 1 Left The most important flows in a municipal-wide water balance. Right: Delineation of the Three Points Approach.

Copenhagen Municipality (2012) The City of Copenhagen - Cloudburst Management Plan 2012.

Fratini, C.F., Geldof, G.D., Kluck, J and Mikkelsen, P.S. (2012) Three Points Approach (3PA) for urban flood risk management: A tool to support climate change adaptation through transdisciplinarity and multifunctionality. Urban Water Journal, 9(5) pp. 317. doi: 10.1080/1573062X.2012.668913.

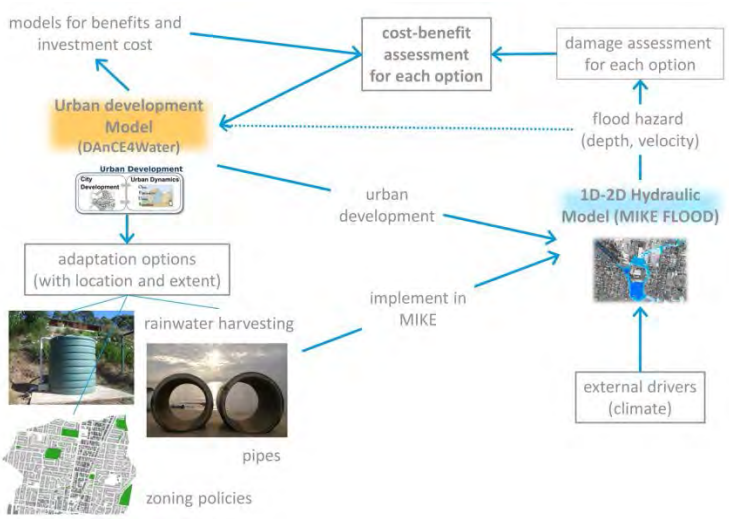
Flood risk assessment as an integral part of urban planning

R. Löwe*[1,4], C. Urich[2,4], N. Sto. Domingo[3], V. Wong[2], O. Mark[3], A. Deletic[2], K. Arnbjerg-Nielsen[1,4]

1: DTU Environment; 2: Monash University (Australia); 3: DHI, 4: CRC for Water Sensitive Cities (Australia)

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

Identifying robust, liveable and economically efficient options for the design of urban water infrastructure is a formidable problem that requires projections of future developments of climate, society and urban space, each of which is subject to deep uncertainties. For this reason, design decisions based on detailed assumptions about the future will often prove suboptimal and a better planning approach is required. One possible approach is to test potential designs of infrastructure against a variety of potential futures. Designs should ideally be both robust and adaptable in the case of unanticipated changes.



We have developed a software framework that integrates systematic assessment of flood adaptation options (Zhou et al., 2012) using the 1D-2D hydraulic model MIKE FLOOD and recent developments in urban development modelling using the DAnCE4Water platform (Urich and Rauch, 2014).

This framework allows for the systematic evaluation of flood adaptation strategies given a variety of future scenarios for urban development and climate change. In addition, flood adaptation options can also be evaluated with respect to non-hydrological aspects that may be relevant in the urban planning process. In an Australian case study, we demonstrate that systematic evaluation allows identifying robust strategies that reduce future flood risk while maintaining the overall speed of urban development.

References

Urich, C. and Rauch, W. (2014), Exploring critical pathways for urban water management to identify robust strategies under deep uncertainties. Water research, 66C, 374–389.

Zhou Q., Mikkelsen P.S., Halsnæs K., Arnbjerg-Nielsen K. (2012), Framework for economic pluvial flood risk assessment considering climate change effects and adaptation benefits. J Hydrol, 414-415, 539-549.

Hybrid nanofibers of TiO_2-silicone and TiO_2-Ag-silicone for high water flux photocatalytic degradation of dairy effluent

Muzafar A. Kanjwal[a],∗ Martin Almb, Peter Thomsen[b], Nasser A.M. Barakat[c] , Ioannis S. Chronakis[a], ∗∗

[a]Nano-BioScience Research Group, DTU-Food Technical University of Denmark, , Soltofts plads, B 227, 2800 Kgs. Lyngby, Denmark

[b]BioModics ApS, Gregersensvej 7, DK-2630 Taastrup, Denmark

[c]Department of Textile Engineering, Chonbuk National University, Jeonju 561-756, Republic of Korea

∗ Corresponding author. Tel.: (+45 45254941) E-mail addresses: muka@food.dtu.dk (M.A. Kanjwal),

∗∗ Corresponding author. Tel.: (+45 40206413) E-mail addresses: ioach@food.dtu.dk (I.S. Chronakis),

Abstract

TiO_2 and TiO_2-Ag nanofibers were produced by electrospinning technique and surface coated on silicone elastomer discs (diameter: 10.0 mm; thickness: 2.0 mm) by dipcoating method. The coated discs were characterized by various morphological and physicochemical techniques (like SEM, TEM, XRD, FTIR, EDS and UV). These characterizations reveal that the surface morphology of electrospun nanofibers remain intact by the dipcoating technique. The produced TiO_2- and TiO_2-Ag silicone discs were utilized as photocatalysts to degrade dairy waste water with an efficient water flux and water photosplitting properties.

Key Words: Silicone Elastomer; Electrospinning; Silver titanium nanomaterials; Dairy effluent; Water Flux; Photodegradation; Water Photosplitting

Revising an OECD Test Guideline on toxicity in aquatic environments

Bjarne Kjær Ersbøll*[1]

1: DTU Compute

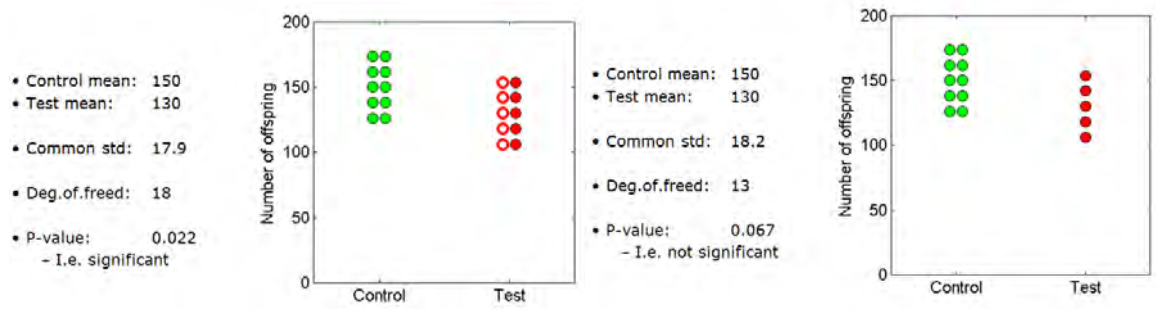
*Corresponding author email: bker@dtu.dk

Numerous Test Guidelines for different types of toxicity tests exist. The idea behind such a guideline is to provide a fairly rigorous procedure on how to design, perform, collect data, perform the statistical analysis, and finally to report on the results. Such guidelines are often a compromise in order to make the statistics easy to understand.

Guidelines are usually developed over time, other designs may be developed, new end-points may be defined, other types of statistics may be preferred, etc.

Here we present some of the experience gained in trying to adapt statistics to environmental policies by trying to provide argumentation for introducing alternative methods for the statistical analysis.

The "TG211 *Daphnia magna* Reproduction Test" refers to one of the internationally most commonly used test standards for assessing chemical toxicity in aquatic environments. We have assisted the OECD in updating and negotiating the standard by adjusting the statistical methodology and interpretation hereof to match current practice. Many different stakeholders (e.g. governmental bodies, environmental agencies, industry) have a say before such an update can be rectified. It has therefor been of utmost importance that we carefully and pedagogically were able to communicate why the proposed changes were sensible.



Figur 1 Adults die shortly before end of experiment - and are retained to the left but removed to the right. This seemingly simple decision has drastic consequences for the outcome of the toxicity test.

Reference:

OECD (2012), *Test No. 211: Daphnia magna Reproduction Test*, OECD Guidelines for the Testing of Chemicals, Section 2, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789264185203-en

Utilization of biomass combustion ash for liming purposes on top of forest soils

A. Maresca *[1], T.F. Astrup [1]

1: DTU Environment; *Corresponding author email: almar@env.dtu.dk

The use of energy from wood combustion is becoming an increasingly popular source of renewable energy. Ashes are generated and although alternative uses – e.g. for liming and fertilizing purposes - have been proposed (e.g. Steenari et al., 1999), biomass ashes are commonly landfilled (Knapp & Insam, 2011). Benefits and risks owing to ash utilization have to be evaluated based on the ash chemical composition but also on the actual leaching release. Although several studies have focused on the ash composition and potential leaching release (e.g. Mellbo et al., 2008; Steenari et al., 1998; Zhan et al., 1996), the results are still fragmented.

In this study, two biomass combustion ash samples were investigated. The samples were characterized for their chemical composition, thus acid digested and analyzed by ICP-MS/OES. The long term leaching of the ash samples was investigated according to CEN/TS 14405:2004. Overall, higher contents of some plant nutrients – i.e. Ca, K, Mg, Mn and P - as well as of a few heavy metals - i.e. Cd and Ni - were found in the ash samples compared to Danish forest soil (Ingerslev et al., 2014). A long term leaching of alkaline compounds was found and although a decrease in the pH value – initial pH of 12.5 - was detected along the experiment, a pH value above 10.5 was registered at the L/S ratio 1000 l/kg. High releases of soluble compounds, such as K, Na and S were found, and drops of about two orders of magnitudes were shown by the L/S ratio 20 l/kg. The concentrations of P, Cd and Ni were always below detection limit: 15 µg/l, 0.20 µg/l and 0.52 µg/l respectively. Although similar patterns in the release of Cr were found by comparing the two ashes, the higher Cr releases were found for the fly ash sample.

The suitability of wood ash for liming purposes was confirmed. Although high contents of nutrients were found in our ash samples in comparison with the investigated Danish forest soil, their different solubility (e.g. K and P) limits the assessment of the actual fertilizing value of the ash. Considerable amounts of some soluble nutrients are likely to leach out after the first rain event, while others showed relatively small releases according to our results. Although generally low releases of heavy metals were found, their toxicity in relation to the actual soil organisms should be investigated to assess potential risks owing to ash utilization.

REFERENCES

CEN/TS 14405:, 2004. Characterization of waste – Leaching behaviour tests – Up-flow percolation test.

Ingerslev, M., Hansen, M., Pedersen, L.B., Skov, S., 2014. Effects of wood chip ash fertilization on soil chemistry in a Norway spruce plantation on a nutrient-poor soil. For. Ecol. Manage. 334, 10–17.

Knapp, B.A., Insam, H., 2011. Recycling of Biomass Ashes: Current Technologies and Future Research Needs, in: Insam, H., Knapp, B.A. (Eds.), Recycling of Biomass Ashes. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 1–16.

Mellbo, P., Sarenbo, S., Stålnacke, O., Claesson, T., 2008. Leaching of wood ash products aimed for spreading in forest floors - Influence of method and L/S ratio. Waste Manag. 28, 2235–44.

Steenari, B.-M., Karlsson, L.G., Lindqvist, O., 1999. Evaluation of the leaching characteristics of wood ash and the influence of ash agglomeration. Biomass and Bioenergy 16, 119–136.

Steenari, B.-M., Marsic, N.., Karlsson, L.-G., Tomsic, A.., Lindqvist, O., 1998. Long term leaching of stabilized wood ash. Doktorsavhandlingar Vid Chalmers Tek. Hogsk.

Zhan, G., Erich, M.S., Ohno, T., 1996. Release of trace elements from wood ash by nitric acid. Water, Air, Soil Pollut. 88, 297–311.

Workshops

See schedule on
www.sustain.dtu.dk

Workshop X

What is the sustainability of your project?

This workshop will introduce you to the different aspects and methods of assessing the overall impact of a technology and documenting 'how green it is'. This will help guiding and optimizing your research towards documented sustainable solutions.

After a brief introduction to the fundamental principles of life cycle assessment (LCA) as a tool to assess environmental sustainability we will look more into the details of concrete projects and help identify the environmental hot spots and the main environmental improvement possibilities for your technology or project, looking across its whole life cycle from the cradle (raw material extraction) to the grave (end of life and potential new life in other products), and addressing all the relevant environmental impacts.

We have a limited number of LCA experts available so register quickly to have a discussion of your case during the workshop.

Workshop registration on www.sustain.dtu.dk

Organized by Michael Zwicky Hauschild, DTU Management

Workshop Y

Kick-start Your next Post Doc Funding Application

In this two-hour workshop, you will: Get an overview of where to apply for post doc funding

- Be introduced to the different sections of a typical post doc application, such as state-of-the-art, research plan and budget
- Benefit from talking to other early stage researchers
- Do a one-page-proposal of your best research idea
- Get some sound writing principals and some tips for the successful application
- Learn where to get more help when applying for external research funding
- It is our ambition that you leave the workshop with a better possibility of writing a successful application

Aimed at Post docs, but others are very welcome too. Later you can follow a one-day course in the spring 2015.

Workshop Program

- Welcome and introduction
- Where to apply for post doc funding
- The 1-page proposal
- Your research idea! - interview exercise
- Going through and application - section by section
- Writing principles and tips for the successful application
- Your research idea - writing exercise
- Q&A and wrap up

Workshop registration on www.sustain.dtu.dk

Organized by Fundraisers from DTU Nanotech

Workshop Z
Fundraisers Lounge
- Get help for you fundraising!

DTU fundraisers will be available for questions and discussions in the Fundraisers Lounge. Just come by to hear more about the possibilities you have and what help you can get.

Registration is *not* needed for this event

Open Access and ORCID poster presentation

Ole Michaelsen (http://orcid.org/0000-0002-7474-805X) & Jeannette Ekstrøm (http://orcid.org/0000-0003-2791-4219)

DTU Library
jeek@dtu.dk

Open Access

Open Access is high on the agenda in Denmark and internationally. Denmark has announced a national strategy for Open Access that aims to achieve Open Access to 80% in 2017 and 100% in 2022 to peer review research articles. All public Danish funders as well as H2020 requires that all peer review articles that is an outcome of their funding will be Open Access.
Uploading your full texts (your final author manuscript after review) to DTU Orbit is a fundamental part of providing Open Access to your research.
We are here to answer all your questions with regards to Open Access and related topics such as copyright, DTU Orbit, Open Access journals, APCs, Vouchers, FP7 Post-Grant Open Access publishing funds, etc.
Meet us near the Fundraiser Lounge.

ORCID

ORCID – Open Research & Contributor ID – is an internationally recognized and widely used researcher-ID. ORCID makes it easy to reuse your data across disciplines, publishers and databases – all you need to do is to refer to your ORCID instead of entering your data again. But most importantly is maybe that ORCID ensures, that you will get cited correctly – no matter if your name is spelled with special characters or if you change your name for one reason or another. Increasingly publishers and funders are asking you to submit your ORCID when you submit articles or apply for funding. DTU is a member of the international ORCID organization and you can register your ORCID through DTUBasen. We are here to help you answer all questions related to ORCID. Visit our poster and get your ORCID and learn about