CLOCKS project

CIRCULAR ECONOMY SUMMER SCHOOL

Circularity and sustainability by design

2-5 September, 2024
Giessen

clocksproject.eu

Università degli Studi di Padova

Justus-Liebig-Universität Giessen

eit RawMaterials
Connecting matters

Co-funded by the European Union

TIMETABLE

	Monday 2		Tuesday 3	Wednesday 4	Thursday 5
08:00 - 08:30	Registration				
08:30 - 08:50	Welcome	8:30-9:15	**Klaus Kümmerer** (Institute of Sustainable Chemistry, Lüneburg, Germany) Benign by design	**Sven Jantzen** (Umicore AG & Co. KG, Germany) The digital battery passport as the role model for future DPPs and key enabler of circular economies and sustainable value chains	**Bernd Smarsly** (Justus Liebig University, Giessen, Germany) Concepts for making car wheels sustainable
08:50 - 09:35	**Silvia Gross** (University of Padova, Italy) Circular Chemistry as a methodological and powerful tool for circular economy – Part 1	9:15-9:20	5 mins. break	5 mins. break	5 mins. break
		9:20-10:05	**Benjamin Balke-Grünewald** (Fraunhofer IWKS, Hanau, Germany) Design for sustainability: guidelines for batteries, electromotors and fuel cells	**Frank Heringhaus** (Umicore AG & Co. KG, Hanau, Germany) Closing the loop on PGM-based products for chemical and special glass industries: circular product design to save resources	**Klaus Müller-Buschbaum** (Justus Liebig University, Giessen, Germany) Circularity of photovoltaic modules by improved design for the recovery of critical resources
09:35 - 09:40	5 mins. break	10:05-10:35	Coffee break	Coffee break	Coffee break

09:40 - 10:25	**Silvia Gross** (University of Padova, Italy) Circular Chemistry as a methodological and powerful tool for circular economy – Part 2	10:35- 11:20	**David Fahz** (Fraunhofer IWKS, Hanau, Germany) AI-supported optimization of the circular management of plastic packaging	**Oliver Hutin** (Umicore AG & Co. KG, Hanau, Germany) Sustainability and circularity of key NMC battery materials as strong competitive advantage: closing the material loop from battery-to-battery	**Urška Lavrenčič Štangar** (University of Ljubljana, Slovenia) Sustainable synthesis of catalysts for environmental applications
10:25 - 10:55	Coffee break	11:20- 11:25	5 mins. break	5 mins. break	5 mins. break
10:55 - 11:40	**Enrico Bernardo** (University of Padova, Italy) Sustainability by eco-informed material selection	11:25- 12:10	Networking session	Networking session	Networking session
11:40 - 11:45	5 mins. break	12:10- 13:35	Lunch	Lunch	Lunch
11:45 - 12:30	**Thea Kleinmagd** (Fairphone, Amsterdam, Netherlands) The ins and outs of making (and maintaining) a circular smartphone	13:35- 14:20	**Thilo Brämer** (Fraunhofer IWKS, Hanau, Germany) Transferring circular economy solutions into industrial scale and sustainable cities: understanding and overcoming the barriers for technological transfer – Part 1	**Nicholas Rau** (Umicore AG & Co. KG, Hanau, Germany) Why are metal chemistry & catalysis important in a sustainable world, and how do we build a circular business model?	**Marko Novinec** (University of Ljubljana, Slovenia) Industrial use of enzymes as green(er) alternatives to conventional catalysts
12:30 - 14:00	Lunch	14:20- 14:25	5 mins. break	5 mins. break	5 mins. break

14:00 - 14:45	**Olga Janikowska** (Mineral and Energy Economy Research Institute of the Polish Academy of Sciences) Eco-innovation for a circular economy	**14:25-15:10**	**Steffi Weyand** **(Fraunhofer Institute IWKS, Hanau, Germany)** Transferring circular economy solutions into industrial scale and sustainable cities: understanding and overcoming the barriers for technological transfer – Part 2	**Francesco Castellano** **(Tondo LAB, Milano Italy)** Circularity Measurement Tools as a fundamental design tool for products, companies and cities	**Julija Bonai** **(University of Ljubljana, Slovenia)** The role of design for circular economy from the perspective of entropy and dissipative structures
14:45 - 14:50	**5 mins. break**	**15:10-15:30**	**Coffee break**	**Coffee break**	**Coffee break**
14:50 - 15:35	**Jakob Nolte** **(Justus Liebig University, Giessen, Germany)** Design with plant-based solutions: tackling the global ecological crisis – Part 1	**15:30-17:00**	**Hackathon**	**Hackathon**	**Hackathon**
15:35 - 15:40	**5 mins. Break**				
15:40 - 16:25	**Jakob Nolte** **(Justus Liebig University, Giessen, Germany)** Design with plant-based solutions: tackling the global ecological crisis – Part 2				
16:25 - 16:30	**5 mins. break**				
16:30 - 17:00	**EIT RawMaterials** Presentation (online)				

ABSTRACTS

Balke-Grünewald Benjamin

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Design for sustainability: guidelines for batteries, electromotors and fuel cells

The concept of 'Design for Sustainability' (D4S) requires that the design process and resulting product take into account not only environmental concerns but social and economic concerns as well. D4S goes beyond how to make a 'green' product and embraces how to meet consumer needs in a more sustainable way. Companies incorporating D4S in their long-term product innovation strategies strive to alleviate the negative environmental, social, and economic impacts in the product's supply chain and throughout its life-cycle. This module will focus on design ideas for batteries, electro motors and fuel cell to achieve higher recycling efficiencies via an easier and less costing recycling processes.

Bernardo Enrico

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Sustainability by eco-informed material selection

A key aspect in the design of components for structural use is the control of masses, with fundamental constraints regarding stiffness (=ability to limit deformation under a system of applied forces) and strength (=ability to withstand a system of applied forces without failure). Such control does not depend simply on elastic modulus or tensile/bending strength, but on their combinations with density, which provide the basis for materials selection. Light components may be also sustainable when high modulus/density or strength/density ratio are coupled with low embodied energy and low carbon footprint. Since the latter properties are expressed as a function of mass, some solutions may be quite surprising. On the one hand, high nominal values of embodied energy and carbon footprint may be accepted if a material expresses very high modulus/density or strength/density ratios. On the other hand, despite the fact that, for any material, enhancing the recycled fraction in the starting feedstock reduces the values of embodied energy and carbon footprint, the overall sustainability is not always enhanced. A quite underestimated challenge, in fact, concerns the possible decay of functionality (e.g. reduction of mechanical properties with decreasing molecular weight passing from 'virgin' to recycled polymer). The conundrum may be solved only by enhancing the quality of recycling, e.g. by designing components in which different materials are easily separated, with minimized mutual contaminations.

Bonai Julija

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The role of design for circular economy from the perspective of entropy and dissipative structures

In their book Order Out of Chaos: Man's New Dialogue with Nature (fr. *La Nouvelle Alliance*), physical chemist Ilya Prigogine and philosopher Isabelle Stengers define dissipative structures as constructive features of processes that can appear in far-from-equilibrium systems at their bifurcation points. In other words, dissipative structures represent a higher level of order and consistency into which an open and irreversible system can evolve when it reaches the point of transformation. This new, highly evolved structures reflect the interaction of the system with its environment – with the multiplicity of other systems. As the entropy of a dissipative structure increases, the energy (that is usually understood as degraded or lost energy) cannot be considered as wasted. The increase in entropy can thus become the precursor of a new order – an irreversible change towards a new equilibrium.

Taking this into consideration, the lecture will address the following question: Can the circular economy be understood as a dissipative structure emerging from the far-form-equilibrium conditions of natural environment in the face of global warming and pollution? In this context, the process of design can be explained as a process of (co-)creating initial conditions (of possibility) through which humanity is able to, at least partially, control the energy transformations (the entropy) – in such a way that the energy is not wasted or lost. Consequently, the term waste takes on a new meaning, as waste can become a useful resource in the circular economy.

Finally, the role of design, which can be explained as an attempt to control the conditions for the possibility of circularity of matter and energy, reflects a tendency towards reversibility and closure of this system. However, it is shown how the role of design (from the point of view of dissipative structures and entropy) adds another, complementary aspect to the circularity of matter and energy, which can be explained by the concept of a spiral movement – a circular but irreversible movement that makes a progressive and profound difference with each of its circular turns.

Brämer Thilo and Weyand Steffi

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Transferring circular economy solutions into industrial scale and sustainable cities: understanding and overcoming the barriers for technological transfer

Using the example of mineral residues and construction waste, legal and factual obstacles are shown that are currently preventing the rapid industrial implementation of a resource-efficient circular economy. Based on this, possible solutions are discussed. Furthermore, the integration of district-related material flow management into municipal planning processes is presented as a key element for the resource efficient use of mineral material flows in urban areas.

Castellano Francesco

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Circularity Measurement Tools as a fundamental design tool for products, companies and cities

In this module Francesco will present Tondo's Circularity Measurement Tools. The Tools are made using nationally and internationally recognized methodologies to analyse and measure the circularity of companies, products and cities. The lesson will show how the Tools work, why they were conceived and what purpose they will have for a company, giving also a brief introduction of the main methodologies used to develop the Tools.

Fahz David

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AI-supported optimization of the circular management of plastic packaging

How can artificial intelligence (AI) help reduce mountains of waste? How can it help to keep important resources in the cycle? These are the questions addressed in this module. The goal of making the value chain of plastic packaging more sustainable will be addressed: from design and production to closing the loop, AI methods are tested in concrete use cases and put to use.

Heringhaus Frank

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Closing the loop on PGM-based products for chemical and special glass industries: circular product design to save resources

Recycling of precious metals holds many benefits, based on their value, on environmental consideration, and on political aspects. This presentation focusses on closing the loop on engineered products made from Platinum Group Metals (PGM). Such engineered products consist of PGM, rather than containing them in minor fractions, making them particularly well suited for a short closed-loop recycling process. After an introduction to such products, detailing the manufacturing and use thereof, this presentation explains how product design and product manufacturing help to improve recyclability, how close cooperation and joint-development with customers increases return rates on recycling, and which options there are for recycling of PGM.

Gross Silvia

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Circular Chemistry as a methodological and powerful tool for circular economy

The module will introduce the basic concepts and the paradigms of the recently (2019) introduced area of Circular Chemistry. The ratio and the main guidelines of circular chemistry in pursuing a more sustainable approach to the design of chemicals, materials and product in a circular framework, i.e. by facilitating their end-of-life recovery or recycling. Basics of substitution will also be introduced.

Hutin Oliver

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Sustainability and circularity of key NMC battery materials as strong competitive advantage: closing the material loop from battery-to-battery

Recycling of the growing volume of waste batteries (EoL and production scrap) is key to close the loop from battery-to-battery. By combining the expertise of its business units battery recycling solutions and battery materials manufacturing, Umicore offers an advanced internal closed loop solution in which the high-end recycled battery materials are used as input material for the production of cathode active materials (CAM). This closed-loop business model offers a scrap-to-CAM solution in which a customer (OEM or battery manufacturer) sends its waste batteries to BRS to be recycled and gets CAM material composed out of the recycled metals in return. The many competitive advantages inherent in this model include the facilitation of traceability of recycled and sustainably sourced metals, the transfer of recycled content certificates as required by the EU battery regulation, and the streamlining of administrative processes for Umicore’s customers.

Janikowska Olga

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Eco-innovation for a circular economy

The module focuses on imparting knowledge about concepts of environmental and resource economics as well as the circular economy. Its main aim is to improve understanding of these topics, cultivate critical thinking skills and teach students how to apply theoretical economic knowledge effectively to solve practical problems. Moreover, it aims to improve critical thinking skills, teach students how to properly apply the acquired theoretical economic knowledge to address practical challenges, identify eco-innovative solutions, explore methods of innovation and eco-innovation assessment, investigate possibilities of financial support for eco-innovative solutions, and deal with the management of eco-innovation projects.

Jantzen Sven

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The digital battery passport as the role model for future DPPs and key enabler of circular economies and sustainable value chains

The transformation of a quantity-based into a value-based economy requires a fundamental change in mindset and behaviour of all players in today's value chains. Digitalisation will play a massive role in this change process. The lecture will illustrate how a digital battery passport will support multistakeholder responsibility within the battery value chain, provide awareness and information for more professional decision-making, educate consumers in their buying behaviour and potentially help convert them to users, and finally support regulators in market surveillance and creation of smarter rules in line with ESG criteria. The module will also elaborate on the value that can be created by a digital product passport highlighting selected use cases for industry and society.

Kleinmagd Thea

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The ins and outs of making (and maintaining) a circular smartphone

Fairphone is a manufacturer of consumer electronics that puts people and the planet first. In an which short product lifetimes and frequent product replacements are promoted, the company has set itself the goal to offer an alternative to the inherently linear electronic products on the market. All of Fairphone's products are made to enable a circular product system to decrease the significant environmental lifecycle impact of using technology. In this presentation we will explore what circular design means for a smartphone which is meant to be used for a long time and to be maintained and repaired by its user. Furthermore, we will dive into how this design enables maintenance and recirculation in many different ways and what trade-offs and barriers are to be expected when challenging the status quo.

Kümmerer Klaus

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Benign by design - from green chemistry to sustainable chemistry

Chemistry is indispensable for a high standard of living and health. For long time chemistry came along with heavy environmental pollution by toxic waste, exhausts, and effluents from production. In the 1980ies and early 1990ies several approaches were developed by many individuals and organisations and manifested as legislation [1] and the 12 principles of Green Chemistry (GC) [2]. In between it has been learned that the products themselves may cause serious pollution [3, 4]. Molecules have been and are often still optimized for longevity in general resulting in environmental persistence. Many products and their constituents cannot be recycled. They end up in the environment and may persist there for long time (e.g. Per- and polyfluoroalkyl substances, PFAS, also called for ever chemicals [4]). Such molecules must be designed for complete and fast mineralization at the end of their life (Principle #10 of GC, design for degradation, "benign by design" [5]. We could demonstrate that design of molecules, pharmaceuticals even, is feasible, that fulfill service and function best, and at the same time mineralize readily and fully after they end up in the aquatic environment [e.g. 6,7] In the meantime, several shortcomings of GC become obvious when it comes to circular economy (CE) and sustainability [8-11]. Accordingly, chemical products must be designed for CE even before they are synthesized [8]. At the same time, it became obvious that substance, material, and products flows have to be reduced in size (time and space), dynamics and complexity [3,5,8-10]. This resulted in the development of sustainable Chemistry (SC) [9,11]:

Asking first for service and function needed and whether non chemical alternatives (e.g. different design) could provide it or if a chemical only can provide it. SC Includes systems thinking and all stakeholders, ethics, and social aspects along the whole life cycle of products and services. In other words, benign by design is needed on all levels from SC to CE to GC, in research, education and industrial practice [11-14].

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31996L0061 [2] https://www.epa.gov/greenchemistry/basics-green-chemistry#definition [3] L. Persson et al., Environ. Sci. Technol. 2022, 56, 3, 1510-1521 [4] E. L. Schymanski et al. Environ. Sci. Technol. 2023, 57, 44, 16918–16928 [5] K. Kümmererer, Green Chem., 9, 899 (2007) [6] C. Leder, et al., ACS Sustainable Chem. Eng. 9, 28, 9358–9368 (2021) [7] M. Suk et al., Green Chem., 22, 4498 (2020) [8] K. Kümmerer et al. Science 367, 369 (2020) [9] K. Kümmerer, Angew. Chem. Int. Ed., 56, 16420 (2017) [10] K. Kümmerer et al., Science, 361, 6399 (2018) [11] K. Kümmerer et al. (2021) https://www.isc3.org/cms/wp-content/uploads/2022/06/ISC3_Sustainable_Chemistry_key_characteristics_20210113.pdf [12] V.G. Zuin, K. Kümmerer, Nature Rev. Chem., 5, 76–77 (2021) [13] V.G. Zuin et al., Green Chem., 23, 1594-1608 (2021) [14] e.g. https://www.leuphana.de/en/professional-school/masters-studies/sustainable-chemistry.html, https://www.leuphana.de/en/professional-school/masters-studies/sustainable-chemistry-management.html

Lavrenčič Štangar Urška

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Sustainable synthesis of catalysts for environmental applications

Advanced and sustainable synthetic techniques, such as syntheses in the controlled/mild atmosphere, solvothermal synthesis, sol-gel synthesis, sonochemical synthesis, thermal decomposition of precursors of inorganic compounds, alternative reaction conditions. Case study from the area of sustainable nanomaterials synthesis with application in heterogeneous catalysis. Focus on immobilized systems to prevent release of nanoparticles in environment; coating methods: spin-coating, dip-coating, chemical bath deposition, inkjet printing.

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Circularity of photovoltaic modules by improved design for the recovery of critical resources

…Abstract expected shortly…

Nolte Jakob

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Design with plant-based solutions: tackling the global ecological crisis

Plants are the basis of our lives in many ways, but we are undervaluing their functional potential to achieve sustainability goals. The resulting possibilities of plant-based designs will be discussed in various areas, including urban space and sustainable land use.

Novinec Marko

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Industrial use of enzymes as green(er) alternatives to conventional catalysts

The module will provide a short introduction into the use of enzymes as green(er) alternative to conventional catalysts. Based on case studies from the pharmaceutical and other industries we will discuss the advantages of enzymes over other catalysts, such as sustainable production, enhanced stereospecificity, environmental impact etc. We will also provide an outlook of future developments in this field.

Rau Nicholas

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Why are metal chemistry & catalysis important in a sustainable world, and how do we build a circular business model?

Over the last decades, homogeneous catalysis, and more specifically platinum-group-metal based catalysis, has been a major contributor to more efficient and environment friendly syntheses of a large variety of chemicals, materials or pharmaceutical intermediates that have revolutionized our lives. Nobel prized technologies such as olefin metathesis, cross-coupling catalysis or stereoselective hydrogenation, among others, enable shorter syntheses, less side streams and material waste, lower solvent consumptions, or valuable energy savings through milder reaction conditions. Recycling the metals these catalysts contain additionally enables to reduce their CO2 footprint while taking good care of scarce resources and reducing exposure to price volatility or geopolitics. How do we keep improving? By using more efficient PGM-based catalysts, or new catalysts based on first-row transition metals such as nickel or cobalt? Let’s review what makes homogeneous catalysis sustainable, and what could help make it even more, and further support the broad chemical industry in its quest for more sustainability.

Smarsly Bernd

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Concepts for making car wheels sustainable

Car tires are a mass product and are manufactured in the order of millions. In spite of a certain recycling rate, their eco-footprint so far is unsatisfactory. Thus, the talk will introduce the composition of tires and show current design strategies to allow larger re-use and recycling rates, by changing the underlying resources.