ABSTRACTS

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RENUVA™ Polyurethane recycling program

In Europe each year around 40 million mattresses are discarded. Currently the majority of these mattresses end up being incinerated or landfilled. Through the RENUVA™ Mattress Recycling Program, Dow aims to reduce this mountain of waste by enabling a circular economy for polyurethanes (PU). In France the polyurethane foam from dismantled old mattresses is processed by chemical recycling to make a recycle polyol All types of foams from mattresses can be used in the process. No pre-sorting is required.

Polyols are a key intermediate for the production of polyurethanes. The resulting RENUVA™ polyols are the first products on the market to close the loop from post-consumer polyurethane foam from mattresses to new foams Dow's RENUVA™ polyols are available in the market since October 2021. The product portfolio consists of two commercial grades: one for flexible foam (e.g. for mattresses) and one for rigid foam (e.g. for insulation panels).

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Glass recycling: contradictions & opportunities for new sustainable construction materials

The recycling of glass into original articles, by cullet remelting, is controversial. For some compositions, remelting is excluded a priori, due to the need for absolute control over the chemical composition, optical quality, or emission of pollutants. A fundamental example is represented by glass for pharmaceutical containers, which had a dramatic increase, in terms of production rates, during the Covid-19 emergency. The seminar aims to present new sustainable products from the recovery of vitreous, waste, i.e. deriving from simple and economic processes and with wide possibilities of use in construction and further recycling. The intention is to exploit viscous sintering, at low temperatures (<1000 °C), for dense products, similar to natural stones, or fro highly porous foams, useful for thermal and acoustic insulation. Attention is also paid to cold consolidation, through the study of the reactions between glass and alkaline activators.

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On-site metal recovery and reuse from complex wastewaters: closing the circle inside the factory

Wastewaters containing valuable metals with complex chemistries represent a paradoxical challenge, as they compound a very high economical value with high treatment and disposal costs. Here we present an example of metal recovery from such solutions, coupled with the synthesis of the chemical precursors used by the very same process, all performed on-site. This approach effectively zeros the metal waste from a 10-30% typical disposal rate, reducing the raw materials needs accordingly, thereby closing the metal loop with the narrowest radius of curvature.

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Introduction to recovery, refurbishment, recycling

A general introduction on end-of-life of products/materials will be provided, focusing and introducing the four R of the Summer School and on their role in a circular economy model.

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ESG and Circular Economy: what can they do for the green revolution

ESG, acronym for Environmental, Social and Governance, highlights the holistic view sustainability should point at, extending beyond the environmental sphere. ESG is best recognised as a framework that support stakeholders and their entities in managing risks and opportunities related to the above three dimensions. However, investments in this direction are still limited, due to lack of data and proper rating metrics. The module will discuss the meaning of ESG and how it fits in the financial scenario of today, and how it complements with the CE principles for a radical transition, from investments to supply chains.

Sustainability reporting: an introduction

Sustainability reporting is becoming commonplace among medium and large companies. This module discusses the reasons behind sustainability reporting, what makes a report credible to stakeholders, and mentions some of the most recognised reporting standards. The standards that will be discussed are GRI (Global Reporting Initiative), which is an overall template, CDP (formerly the Carbon Disclosure Project) that specifically address carbon and water reporting, and SASB (Sustainability Accounting Standards Board), which identifies the key performance indicators (KPIs) for different industries. The three standards are not mutually exclusive, but fit together. An overview of how reports are generally structured will be outlined. In addition, the last directive on sustainable reporting will be briefly discussed, as well, the correlation between sustainable reporting and measuring circularity.

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Waste as a resource: reuse and recycle opportunities in the circular economy of cement and concrete

Cement and concrete production can offer a crucial contribution to CO2 footprint reducing and boosting circular economy in the construction sector as well. Sustainable raw meal design, clinker and cement grinding process optimization, use of alternative fuels, recycled mineral additions for innovative binders allow for a more sustainable way of cement production. Use of artificial aggregates and recycled aggregates from construction of demolition wastes, high durable mix design and applications, responsible management of water enable concrete production to became a more and more virtuous example of synergy between technical performance and the essential human wellbeing.

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Remanufacture to decouple

The new Eco Design for Sustainable Products Regulations (ESPR) aim to improve the design of many more products to enable a decoupling of resource use from economic activity.

45% of CO2 emissions are estimated to be related to product life cycles and so product life extension processes such as remanufacturing and refurbishment could be important to decoupling economic activity from CO2 emissions.

To what extent can we expect remanufacturing and refurbishment processes to have a material impact on decoupling objectives? We will investigate specific remanufactured products and components taken from three main business models.

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A metal-intensive transition full of opportunities - ongoing initiative to boost the European critical raw materials sourcing

Many recent reports are showing how the transition to a CO2-free economy, where renewable energies play a fundamental role, implies an unprecedented increase of metals demand. Against this scenario, Europe has experienced a 27% decrease of primary extraction from the beginning of the year 2000 to date. Europe's mineral and metals dependency can be addressed using different approaches. We will show some examples of projects pushing urban mining through innovative approaches can mitigate the dependency and also contribute to reduce the overall CO2 footprint of metals production. We will illustrate also a number of initiatives that Europe is launching to increase domestic metals and minerals sourcing and what challenges and opportunities are ahead of us.

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Recycling of (precious) metals from catalysts and EV-batteries: technical procedures and business models

Building upon the previous module we will look into the specific technologies and business procedures to recycle precious, base and special metals from complex products such as catalysts, electronic scrap and batteries. Due to their high value and mature recycling technologies, precious metals can be seen as a forerunner in establishing closed metal cycles. We will discuss closed loops in industrial PGM applications such as chemical catalysts and compare this with less successful open loop cycles in consumer applications such as automotive catalysts or electronics. The experiences gained here are valuable for developing closed cycles for non-precious metals e.g. from EV-batteries. In addition, we will learn how state-of-the-art precious metals recycling technologies are capable of recovering even traces of PM from complex material compositions, and what specific business procedures have been developed in this context.

Sustainable metals management for clean technologies: on metal markets, criticality, recycling & circularity strategies

A secure access to metals is the backbone of the EU economy as they play a key role for climate protection technologies, the energy and mobility transition as well as for digitalization. The module provides insights on how metal use has evolved over time and why it will become even more important in future; on the fundamentals of metal markets (supply-demand-price interdependencies); on metals scarcity and critical raw materials; on the related EU policy initiatives; and on the basic drivers for metals circularity and recycling to complement mine supply. This will be shown on concrete examples of past and current emerging technologies. As it is necessary to make the utilization of metals much more resource-efficient than before and to use them as purposefully as possible instead of consuming them, advanced circular economy systems and sophisticated recycling technologies are crucial for a sustainable society. Closed metal cycles contribute to this by securing relevant parts of the material supply for high-tech products and by reducing CO2 emissions and environmental burden in their production at the same time.

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Circular and sustainable rubber

In the module, the following aspects will be presented and discussed. Worldwide scenario of rubbers: what are the relevant rubbers, production, CAGR, geographic distribution, economic impact, main applications. Structure-property correlations, to justify the applications of the rubbery materials. In particular, the role of rubbers for the mobility of people and freight. How it is faced the challenge of sustainability in the rubber field, with reference to all the pillars of sustainability. Sustainability of rubbers with reference to their main application: tyre compounds. Circularity of thermoset rubber materials: main technologies for the recycling, hints of lyle cycle assessment. New frontiers of rubbers: thermoset materials degradable by triggering.

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Eco-innovation for a circular economy

The module will focus on providing students with knowledge in concepts of environmental economics, resource economics and circular economy. The main goal of the module is improvement of understanding of environmental economics, resource economics and circular economy topics, improvements in critical thinking skills and learning how to properly apply acquired knowledge of theoretical economics to solutions of practical problems. Additionally, improvement of critical thinking skills and learning how to properly apply acquired knowledge of theoretical economics to solutions of practical problems. As well as, identification of eco-innovative solutions, method of innovation and eco-innovation assessment, possibilities of financial support for eco-innovative solutions – eco-innovation project management.

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Catalytic conversion of carbon dioxide to value-added products

Carbon dioxide (CO_2) emissions are increasing tremendously due to the use of fossil fuels. It is a significant greenhouse gas that must be reduced and/or mitigated. Carbon capture and sequestration are efficient ways to solve the CO_2 problem. Considering CO_2 is an abundant C1 source, CO_2 conversion reactions are most in demand. CO_2 utilization reactions such as CO_2 reforming of methane to syngas, CO_2 hydrogenation to methanol, and CO_2 carbonylation to carbonates are potential solutions for the sustainable route to high value-added products. The thermal catalytic conversion of CO_2 into value-added products is the main focus. The catalysts used for various CO_2 reactions and their structure-activity correlation are presented.

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From agricultural waste to energy and high value products, different approaches for a prosumer farmer

The challenge on the future agriculture technologies is to support farmers in obtaining the energy they require when it is needed. Several technologies can be deployed, but our goal is to employ waste biomass to obtain energy for the farmer to increase both ecosystem services and the value generation from agriculture. Precision farming, using drones, satellite data and other IoT solutions, can provide data to predict yields and biomass production. A set of different technologies, deployed according to the specific requests from the single client, can convert the waste biomass in heat (compost heat recovery system and pyrolysis), electricity (organic rankine cycle) and cold (heat pumps). At the end, the entire process not only provides energy from waste but also new products such as compost and biochar, to be used to increase soil quality. The final aim of the lecture is to show a possible roadmap to support farmers in achieving up to 100% energy self-sufficiency and reducing greenhouse gas emissions in the agricultural sector by producing energy from agricultural waste while adopting precision farming technologies and obtaining locally produced organic fertilizers.

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The Chemical recycling concept

Chemical recycling is a process used to recover plastics by breaking down the polymer chains into smaller molecules, which can then be used to produce new products. Unlike mechanical recycling, chemical recycling can handle a wider range of plastic types, including mixed or contaminated plastics, and can potentially produce higher-quality recycled materials. Chemical recycling typically involves several steps, such as depolymerization, purification, and/or repolymerization. In depolymerization, the plastic waste is broken down into its constituent monomers or oligomers through various methods such as pyrolysis, gasification, or hydrolysis. Purification involves separating and purifying the recovered monomers or oligomers, while repolymerization involves using these building blocks to create new plastics.

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Polymer circularity and mechanical recycling

Polymer circularity and mechanical recycling are closely related concepts in the effort to reduce plastic waste and promote a more sustainable approach to plastic production and consumption. Mechanical recycling is one of the main processes used to achieve polymer circularity, by mechanically breaking down plastic waste into reusable material. However, achieving full polymer circularity requires a multifaceted approach that goes beyond mechanical recycling. It involves designing plastics with circularity in mind, implementing effective waste management practices, and developing innovative recycling technologies. By combining mechanical recycling with other circular economy strategies, we can create a more sustainable future for both people and the planet.

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Food waste: closing the loop

Food production and consumption generate enormous amounts of waste that contains many different and precious organic materials and substances whose fate is – at best – composting, or – in the worst case – landfilling. An alternative approach for food waste valorization, involves developing technologies to make it the feedstock for new products, following the value-chain dictated by its components. The first part of this module will contextualize food waste, its nature, origin, amounts, current fate, and composition. The second part of the module will describe new technologies aimed at processing waste to obtain families of useful products with focus on the value-chain of its components.

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Upcycle leftover fabrics: design for circularity

The fashion and textile industry is one of the most polluting industries in the world. As part of the research on the various stages of product creation, it is estimated that the fabric and textile waste generated in the production of garments varies from 25 to 40% of the total fabrics used.
Upcycling helps save resources and keep tons of textile waste out of the stream of their destruction and can be defined as a creative approach to recycling where you design unique and high value products.

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Recycling concepts for permanent magnets - closing the loop in e-mobility

In this module we will focus on the recycling concepts for permanent magnets – a key pillar for closing the loop in e-mobility. Since its discovery in 1983, Nd-Fe-B has become the permanent magnet (PM) material with the highest energy product at ambient temperature. Today Nd-Fe-B is used in many key technologies and the demand for high quality PMs will increase significantly in the near future. The required rare earths (RE) elements are considered as highly critical and the metallurgical processes to gain the RE oxides from ores have a large environmental footprint. The usage of recycled material would lower the criticality and increases the sustainability of RE PMs. For a viable and efficient industrial recycling process a circular economy will be necessary in which a material can be recycled multiple times. To enhance such a recycling process with reproducible outcomes the knowledge of the material behavior through every processing step or recycling cycle is mandatory. As a case study the multiple functional recycling of Nd-Fe-B permanent magnets and the effect on different material properties will be discussed with the students.

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Sustainable materials – without the hot air

Materials are particularly relevant in establishing closed-loop strategies, as they account for different problems, namely energy consumption, CO2 release, and environmental impact. The major relevant materials are steel, aluminum, concrete, paper, and plastics. The module will summarize the general, major issues with these classes of abundant materials, based on the excellent book “Sustainable Materials – with the hot air” by a group of students and experienced researchers of Cambridge University. Particular emphasis is put on future options for generating circularity for each of the material classes.

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Implementation of the EU Circular Economy Action Plan - Ecodesign for sustainable products

On 30 March 2022 the European Commission adopted a proposal for a new Ecodesign for Sustainable Products Regulation, the cornerstone of the Commission’s approach to more environmentally sustainable and circular products. The proposal builds on the remarkable success of the existing Ecodesign legislation, which currently only covers energy-related products.

The proposal establishes a framework to set Ecodesign requirements for specific product groups to significantly improve their circularity, energy performance and other environmental

sustainability aspects. It will enable the setting of performance and information requirements for almost all categories of physical goods placed on the EU market (with some notable exceptions, such as food and feed, medicines and medical devices). For groups of products that share sufficient common characteristics, the framework will also allow to set horizontal rules.
The framework will allow for the setting of a wide range of requirements, including on

- product durability, reusability, upgradability and reparability
- presence of substances that inhibit circularity
- energy and resource efficiency
- recycled content
- remanufacturing and recycling
- carbon and environmental footprints
- information requirements, including a Digital Product Passport

The new “Digital Product Passport” will provide information about products’ environmental sustainability. It should help consumers and businesses make informed choices when purchasing products, facilitate repairs and recycling and improve transparency about products’ life cycle impacts on the environment. The product passport should also help public authorities to better perform checks and controls.
By 2030, the new sustainable products framework can lead to 132 mtoe of primary energy savings, which corresponds roughly to 150 billion cubic meters of natural gas, equivalent to EU’s import of Russian gas before the aggression on Ukraine.

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Advanced oxidation processes for water treatment and reuse

“Advanced Oxidation Processes (AOPs)” emerged as the innovative water treatment technologies for mineralization and disinfection. In this module various AOPs will be presented, which are all based on the in-situ generation of highly reactive species (i.e. H_2O_2, OH•, $O_2•^-$, O_3) for mineralization of refractory organic compounds, water pathogens and disinfection by-products. Before learning AOPs details, wastewater types will be introduced: municipal, industrial, agricultural, landfill leachate and surface run-off. AOPs imitate natural oxidation processes, being the main goal to degrade and mineralize organic pollutants to CO_2, water and mineral acids. The main AOPs for water treatment will be thoroughly presented and discussed: Fenton/photoassisted Fenton process (homogeneous catalysis/photocatalysis), heterogenous photocatalysis, ozonation, anodic oxidation, sonolysis, and wet air oxidation. Individual AOPs may be combined to integrated AOPs that are categorized as UV irradiation based AOPs, ozonation/Fenton process-based AOPs, and electrochemical AOPs. Advantages and limitations will be discussed along with various factors affecting the efficiency.

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WEEE collection and recycling: Italian case studies about the use of smart bin for WEEE's collection and photovoltaic panels treatment

The management of Waste Electrical and Electronic Equipment (WEEE) is more challenging than other waste streams due to the complexity of WEEE, in terms of the wide variety of commercial products, from mechanical devices to highly integrated systems, and rapid technological innovation. The recycling of WEEE offers significant opportunities in terms of making secondary raw materials available on the market. And in fact we are talking about urban mines. Then, cases of research projects dealing with the collection and recycling of WEEE are illustrated.