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EUIndTech2025: INNOWACYJNE POMYSŁY MŁODYCH NAUKOWCÓW – NAUKA, START-UP, PRZEMYSŁ

W dniach 2–4 czerwca 2025 roku Kraków oraz region Małopolski stały się europejskim centrum dialogu. Omawiano zagadnienia związane z przyszłości przemysłu, technologii i zrównoważonego rozwoju. Konferencja EUIndTech2025 to jedno z flagowych wydarzeń Unii Europejskiej, mającym na celu promowanie międzynarodowego dialogu oraz wymiany wiedzy w zakresie polityki europejskiej. W ramach konferencji odbyło się 6 sesji plenarnych, 20 sesji tematycznych, 8 wydarzeń towarzyszących oraz 10 wizyt studyjnych. Łącznie w wydarzeniu uczestniczyło 824 uczestników oraz ponad 100 panelistów z całej Europy.

Jenym z wydarzeń towarzyszących EUIndTech2025 była konferencja „Innovative Ideas of Young Scientists: Science – Start-up – Industry 2025", dedykowana młodym naukowcom, doktorantom, studentom prowadzącym badania nad innowacyjnymi rozwiązaniami technologicznymi i informatycznymi, a także nowymi produktami i materiałami wspierającymi zrównoważony rozwój. Wydarzenie to było okazją do prezentacji wyników badań i platformą wymiany wiedzy i doświadczeń pomiędzy środowiskiem akademickim, start-upami i przemysłem. Niniejszy numer zawiera streszczenia wystąpień zaprezentowanych podczas tej konferencji.

Streszczenia podzielono cztery obszary tematyczne:

1. **Ochrona środowiska** – rozwiązania wspierające gospodarkę o obiegu zamkniętym, redukcję emisji, efektywne zarządzanie zasobami oraz technologie minimalizujące antropopresję.
2. **Innowacyjne rozwiązania dla przemysłu spożywczego i opakowaniowego** – nowe materiały, technologie przetwarzania, systemy pakowania oraz rozwiązania zwiększające bezpieczeństwo, trwałość produktów.
3. **Przemysł energetyczny** – zagadnienia związane z transformacją energetyczną, odnawialnymi źródłami energii, efektywnością energetyczną oraz inteligentnymi systemami zarządzania energią.
4. **Nanotechnologie** – ukazujące potencjał zaawansowanych materiałów i struktur w skali nano, znajdujących zastosowanie w przemyśle, medycynie, energetyce oraz ochronie środowiska.

Przedstawione streszczenia odzwierciedlają wysoki poziom badań naukowych prowadzonych przez młode pokolenie naukowców oraz ich zdolność do łączenia wiedzy teoretycznej z praktycznymi wyzwaniami współczesnej gospodarki. Ukazują także świadomość potrzeby projektowania rozwiązań odpowiadających na wyzwania transformacji energetycznej, cyfrowej i przemysłowej we współczesnej Europie.

EUIndTech2E025: INNOVATIVE IDEAS OF YOUNG SCIENTISTS – SCIENCE, START-UP, INDUSTRY

From 2–4 June 2025, Kraków and the Małopolska region became the European hub for dialogue on the future of industry, technology, and sustainable development. The **EUIndTech2025** conference was a flagship event of the European Union, aimed at promoting international dialogue and knowledge exchange in European policy. The conference featured 6 plenary sessions, 20 thematic sessions, 8 side events, and

10 study tours. A total of 824 participants and over 100 panelists from across Europe attended, creating a dynamic environment for substantive debate and collaboration.
A special highlight within the side events of EUIndTech2025 was the conference **"Innovative Ideas of Young Scientists: Science – Start-up – Industry 2025"**, dedicated to early-career researchers, doctoral candidates, students, and scientific clubs conducting research on innovative technological and IT solutions, as well as novel products and materials supporting sustainable and competitive development. This event provided not only an opportunity to present research results but also a platform to build bridges between academia, startups, and industry. The current issue gathers abstracts presented during this conference.
The abstracts are grouped into four key thematic areas:

1. **Environmental Protection** – solutions supporting the circular economy, emission reduction, efficient resource management, and technologies minimizing human impact on the natural environment.
2. **Innovative Solutions for the Food and Packaging Industry** – new materials, processing technologies, packaging systems, and solutions enhancing product safety, durability, and sustainability.
3. **Energy Industry** – focusing on energy transition, renewable energy sources, energy efficiency, and smart energy management systems.
4. **Nanotechnologies** – highlighting the potential of advanced nano-scale materials and structures applicable in industry, medicine, energy, and environmental protection.

The presented abstracts reflect the scientific quality of research conducted by the young generation of scientists and their ability to combine theoretical knowledge with practical challenges of the modern economy. They also demonstrate an awareness of the need to design solutions addressing the challenges of climate, digital, and industrial transformation in contemporary Europe.

RECENZOWANE ARTYKUŁY NAUKOWE

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EUIndTech2025: INNOVATIVE IDEAS OF YOUNG SCIENTISTS – SCIENCE, START-UP, INDUSTRY – ENVIROMENTAL PROTECTION

1. MATERIALS FROM −10 MM WASTE FRACTION AS AN OPPORTUNITY FOR THE CIRCULAR ECONOMY

Circular economy models can be divided into two main groups: those that support reuse and extend product lifespans through repair, refurbishment, remanufacturing, and upgrading; and those that transform old goods into new resources through material recycling.

In a world of steadily increasing demand for high-quality materials and depleting natural resources, attempts to produce new materials from waste are becoming increasingly common. The available literature contains numerous publications devoted to the production of new materials from waste. The waste components most frequently used in the manufacture of such materials include glass, sewage sludge, ceramic cullet (ceramic dust), fine organic waste such as wood-cutting chips, coffee grounds, fly ash, slag, and others. Clay or clay-based materials are often used as the base matrix for these products.
The aim of this paper is to present the possibilities of closing the loop for the −10 mm waste fraction.

2. STRUCTURE AND COMPOSITION OF COMPOSTS

In today's highly urbanized world, increasing amounts of waste are being generated. Composting is one of the methods of waste treatment. The aim of this study was to examine the morphological composition of four types of compost based on the Polish standard PN-93-Z-15006. The following materials were analyzed: composted grass, household compost, a soil improver produced from composted green waste, and stabilate — a waste material generated from the mechanical-biological treatment of municipal waste, collected from a Mechanical-Biological Municipal Waste Treatment Plant. From each compost type, 50 samples were collected, each weighing 2000 grams. All samples were divided into seven fractions: organic waste, plastics, ceramics, paper and cardboard, glass, metals, and others. The analyses indicate that it is very difficult to obtain homogeneous compost due to the heterogeneity of the input material. The results were thoroughly examined with differentiation by individual fractions. In terms of mass, cut grass contained the highest proportion of organic matter, while stabilate contained the lowest. Moreover, the lowest content of plastics was found in household compost, whereas the highest was observed in stabilate. There is a need to explore new treatment pathways for stabilate, including its potential use as a form of energy recovery.

3. DATABASE OF WASTE TREATMENT INSTALLATIONS AS A SOURCE OF KNOWLEDGE ON TECHNOLOGICAL WASTE

Vehicles are a source of numerous types of waste, including hazardous waste, which not only constitutes a potential source of emissions and may cause serious environmental damage, but also represents a valuable source of secondary raw materials. These include non-ferrous metals, batteries and accumulators, plastics, operating fluids, and engine oils. For this reason, proper management of these materials at the end of a vehicle's life cycle is essential. Vehicle dismantling stations are relatively simple in terms of technology and are designed to manage waste classified under codes 16 01 04* (end-of-life vehicles) and 16 01 06 (end-of-life vehicles not containing liquids or other hazardous components). They constitute the starting point in the waste treatment chain for vehicle-derived waste.
The aim of this article is to present the types of waste generated as a result of vehicle dismantling and to describe the functioning of dismantling stations, whose waste-related operations are defined within the waste database system. The operation of such a database constitutes a rich source of knowledge on waste streams and the potential possibilities for their treatment, recovery, and recycling. The data contained in this database enable analyses concerning the need to establish new installations, verify their processing capacity, and provide justification for the regionalization of specific facilities. Furthermore, the analysis of demand submitted by waste producers, collectors, intermediaries, or sellers makes it possible to assess the need for processing specific waste codes and to determine the annual volume of such demand.

4. POSSIBILITY OF USING GEOPOLYMERS AS MATERIALS FOR CO_2 SEQUESTRATION

Geopolymers are materials with significant potential for carbon dioxide sequestration, making them an attractive alternative in the fight against climate change. Their specific chemical structure enables the permanent binding of CO_2 through carbonation processes and reactions with alkaline components. In recent years, numerous studies have been conducted on the capacity of geopolymers to capture and retain carbon dioxide, confirming their effectiveness as materials for CO_2 storage. Research has shown that optimizing the composition of geopolymers and the conditions under which they are cured can significantly enhance their CO_2 absorption capacity. Depending on the raw materials used and environmental conditions, geopolymers can bind CO_2 both during the production process and throughout their service life. As a result, they can serve a dual function — as construction materials and simultaneously as active media for reducing greenhouse gas emissions. In terms of practical applications, geopolymers may be used in power plants to capture CO_2 from flue gases, as well as in urban construction, where they can contribute to improving the overall carbon balance. Their widespread application could represent an

important step toward reducing global emissions and advancing sustainable development.

5. THE ROLE OF INNOVATIVE BIOMATERIALS IN CLOSING FLOWS WITHIN VALUE CHAINS

The transition to a circular economy in the biomaterials sector can support the achievement of sustainable development goals by reducing the negative environmental impacts of production. This publication presents a circularity assessment study for three types of innovative biomaterials: multifunctional rubber panels, bioplastic bottle caps, and wood composite bearings. An integrated methodology was applied, combining Material Flow Analysis (MFA), circularity indicators, and Bill of Materials (BoM) assessments. This approach enabled a quantitative evaluation of resource-use efficiency and the identification of areas with potential to reduce waste generation and close material loops.

The results revealed significant differences in the level of circularity among the analyzed biomaterials. Multifunctional rubber panels are characterized by a high share of recycled materials; however, their circularity is limited by technological challenges, particularly regarding the quality of recovered rubber. Bioplastic bottle caps contain a high proportion of renewable materials but face barriers related to the scalability of recycling processes and regulatory requirements concerning the contact of recycled materials with food. In contrast, wood composite bearings effectively integrate wood waste streams, although further improvements in recycling technologies are required to fully close their material cycle.

The study also identified potential strategies for improving the circularity of the analyzed materials, including the development of advanced recycling technologies, optimization of eco-design for reuse, and strengthened collaboration among stakeholders. The developed analytical approach may serve as a decision-support tool aligned with the objectives of the European Green Deal and the global Sustainable Development Goals.

This research was funded under the GREEN-LOOP project, which received funding from the European Union's Horizon Europe programme (GA 101057765).

6. CAN WASTE BECOME A SOLUTION? CONVERSION OF FLY ASH INTO HIGH-PERFORMANCE CATALYSTS FOR NO_x REDUCTION

Selective catalytic reduction with ammonia (NH3-SCR) is an effective technology to reduce the emission of nitrogen oxides (NO_x), major contributors to air pollution. The utilization and recycling of industrial waste, such as fly ash, are gaining increasing attention, as sustainable waste management strategy. Converting fly ash into zeolites, which can serve as catalytic supports for NH_3-SCR, offers an innovative approach that combines both environmental and technological benefits. The presented studies aimed to synthesize zeolites using fly ash to develop catalysts for NH3-SCR. The research evaluated the impact of various active phase compositions, consisting of iron and/or copper, on activity and selectivity across a broad temperature range. The influence of the active phase deposition methods on catalytic performance was also assessed.

The crucial physicochemical properties of the samples were determined using advanced instrumental methods. Laboratory-scale catalytic tests were conducted using a model gas mixture (NO, NH_3, O_2, He). The results indicated that the physicochemical properties of fly ash-derived zeolites are highly advantageous for both low- and high-temperature NH_3-SCR. Furthermore, the composition of the active phase was a key factor influencing NO conversion, as well as the emission of N_2O. Moreover, the use of fly ash-derived zeolites aligns with circular economy principles.

7. FROM PIXELS TO PROGRESS: DIGITAL STRATEGIES FOR ESG AND SDGS IN POLISH COMPANIES

The digital transformation of industrial enterprises has emerged as a fundamental driver of operational efficiency, sustainability, and corporate governance enhancement. This study examines the correlation between digital initiatives and Environmental, Social, and Governance (ESG) performance within the Polish industrial sector, focusing on 15 publicly listed companies from the WIG50 index. The research seeks to assess the extent to which Industry 4.0 technologies—such as AI-driven energy optimization, IoT-integrated production systems, and digital twin applications—facilitate corporate sustainability and contribute to the realization of Sustainable Development Goals (SDGs). A mixed-method research design was implemented to address this objective, integrating textual analysis of corporate sustainability reports with statistical evaluation of ESG scores. The textual analysis employed a predefined set of

digitalization-related keywords to quantify the presence and intensity of digital initiatives within corporate disclosures. Statistical analyses, including Pearson correlation and regression modeling, were conducted to evaluate potential associations between digital adoption and ESG performance. Furthermore, the study considers external determinants, such as regulatory frameworks and competitive market dynamics, that shape digital transformation strategies in Polish industrial enterprises. The findings elucidate the role of digital transformation as a pivotal enabler of sustainable business practices, reinforcing its strategic importance in corporate governance and ESG advancement. Moreover, the research underscores the multifaceted nature of ESG performance, demonstrating that while digital initiatives exert a positive influence, additional organizational and environmental factors remain integral. This study contributes to the existing body of knowledge by providing empirical insights into the digitalization-sustainability nexus in the Polish industrial sector, advocating for a comprehensive and interdisciplinary approach to corporate sustainability. Future research should expand the dataset, incorporate longitudinal methodologies, and integrate qualitative perspectives to enhance the understanding of the evolving interplay between digital transformation and corporate sustainability objectives.

8. DIATOMITE AS A FILTRATION MATERIAL FOR THE REMOVAL OF NUTRIENTS FROM STORMWATER

Progressive urbanization leads to increasing environmental pressures, including the deterioration of stormwater quality entering receiving bodies. Nature-based solutions, such as rain gardens, are being increasingly employed to improve stormwater retention and purification. This study evaluated the effectiveness of diatomite—a naturally occurring mineral material—as an additive to rain garden substrate in the context of nutrient pollutant removal. Laboratory tests were carried out using three retention columns: one without diatomite and two with mixtures of diatomite and sand at weight ratios of 1:4 and 1:2. A simulated rainfall of 32 mm was applied, along with known concentrations of NO_3^-, NH_4^+, and PO_4^{3-} at 15 mg L^{-1}, 5 mg L^{-1}, and 2 mg L^{-1}, respectively. The presence of diatomite significantly enhanced the removal efficiency of nitrogen load (expressed as the sum of $N\text{-}NO_3^-$ and $N\text{-}NH_4^+$) from 9% to 44%, and phosphorus load in the form of orthophosphates from 38% to 96%. The results confirm that diatomite can be an accessible and environmentally friendly component in modern stormwater management systems, supporting local efforts to protect water resources.

9. INNOVATIVE AND SUSTAINABLE BIOCOMPOSITES FROM PAPER WASTE

The increasing volume of paper waste presents both environmental challenges and opportunities for sustainable material development. As industries shift toward circular economy models, the development of sustainable technologies for reusing paper and cardboard waste is becoming increasingly vital. Biocomposite materials derived from these waste streams offer a promising, eco-friendly alternative to traditional materials, the production of which often carries a substantial environmental footprint.

This study investigated the effects of selected additives on the properties of bio-based adhesives formulated with gelatin, and starch. It was found that incorporating rosin, carboxymethylcellulose, and bentonite enhanced the adhesives' hydrophobic properties. The addition of these substances increased the static contact angle to 118°. Materials with a static contact angle >90° exhibit hydrophobicity. The biocomposite panels incorporating paper waste fractions sized between 2 and 4 mm exhibited high mechanical strength, reaching 12.2 N/mm².

Biodegradation tests confirmed that the adhesives are highly biodegradable under composting conditions, achieving full decomposition in less than 28 days. In contrast, composting tests on the biocomposite panels showed that those bonded with gelatin-based adhesive degraded in under 28 days, while preliminary results indicated that panels bonded with additive-enhanced adhesives required more than 45 days for decomposition. Further studies are ongoing.

10. SATELLITE OBSERVATIONS ON THE GROUNDWATER RESERVES OF SAUDI ARABIA

Water is an important natural resource and its significance amplifies in countries like Saudi Arabia that have arid environments. In Saudi Arabia, groundwater is being heavily mined, and due to the scarcity of rainfall, the recharge is not enough to counter the groundwater withdrawal rates. So, it is important to maintain a constant look at groundwater reserves by using the latest tools. This study uses Gravity Recovery and Climate

Experiment (GRACE/GRACE-FO) satellite data to analyze groundwater depletion rates in Saudi Arabia, focusing on four key regions: Qurayt Al Ayn, Riyadh, Taif, and Tabuk. A comprehensive time-series analysis of the selected locations was conducted. The data were first decomposed into the seasonal and trend components using the Hodrick-Prescott (HP) filter. The seasonal component was modeled using the least square fit and has shown variability in amplitude at all locations. It has maximum values at Qurayt Al Ayn (−2 to 2 cm peak to peak) while has a minimum value at Riyadh (−1 to 1 cm peak-to-peak). The extracted trend component can be modeled using simple linear regression at Tabuk and Riyadh, which have decline rates of −0.14 and 0.06 cm/month, respectively. Due to the variability of the change rates at different epochs, the trend was modeled using a piecewise linear regression at Taif and Qurayt Al Ayn. Till 2019, both locations exhibited a continuous decline with slope values of −0.025 and −0.047 cm/month respectively. However, after 2019, the behavior of the trend seems to have reversed at these locations with slightly positive values in recent times. To ensure water conservation, Saudi Arabia implemented new policies that seem to have been working on Taif and Qurayt Al Ayn, while for Tabuk and Riyadh, due to continuous linear decline rates, more aggressive water resource conservation actions are required. This study emphasizes the need for effective water management in Saudi Arabia, especially in areas with rapid groundwater depletion. By incorporating the GRACE/GRACE-FO satellite results, targeted interventions can assist in groundwater management that can ensure groundwater sustainability and long-term availability.

11. SEA LEVEL VARIABILITY OF THE OMAN AND ADEN GULFS OBSERVED FROM SPACE

Monitoring sea level changes is essential for understanding climate variability and assessing potential risks to coastal regions. The Gulf of Oman and the Gulf of Aden, located at the intersection of major oceanographic systems, exhibit distinct sea level patterns influenced by regional and global processes. This study applies time-series decomposition using the Hodrick-Prescott (HP) filter, seasonal modeling using least-square fitting, and trend modeling using piecewise linear regression (PLR). Satellite altimetry data with a temporal baseline of one month, spatial resolution of 0.25°, and time coverage from 1993 to the present were used. Data were collected from four locations—two in the Gulf of Oman and two in the Gulf of Aden—to investigate spatial and temporal sea level variations. Piecewise linear regression (PLR) analysis of sea level anomalies at the study points revealed distinct regional behaviours. In the Aden Gulf and Eastern part of Oman Gulf, one can find three varying trend values, while in the Western part of the Oman Gulf, the trend component changes five times during the study period. Moreover, except for the Aden Gulf north, all the other points indicate a fall in sea level in recent times. The coefficient of determination (R^2) differed between sites and ranged from 0.98 to 0.99. The seasonal component was modeled using the least square fit, indicating that Aden Gulf has the highest amplitudes, ranging from −20 cm to +10 cm. The smallest seasonal amplitudes are detected in the eastern part of Oman Gulf, ranging from −5 cm to +5 cm. These findings highlight the dynamic nature of these systems and suggest that both short-term climatic variability and long-term trends play a role in shaping sea level changes in these regions. Continuous monitoring and integration with other satellite datasets will be essential for improving predictive models and supporting coastal sustainability efforts.

12. PLASTIC WASTE MANAGEMENT POLICY 2020: AN APPRAISAL

The escalating plastic waste crisis in Nigeria, driven by rapid urbanization and inadequate waste management infrastructure, poses significant environmental and public health challenges. The National Plastic Waste Management Policy 2020 was introduced as a strategic framework to mitigate these issues by promoting waste reduction, recycling, and the use of sustainable alternatives to single-use plastics. This research critically appraises the policy's implementation, examining its successes and identifying barriers hindering effective execution at both national and sub-national levels. Despite improvements in public awareness and private sector involvement, the policy's impact has been limited by weak enforcement, budgetary constraints, and insufficient infrastructure. The study highlights the need for stronger regulatory oversight, expanded recycling facilities, and increased public education to enhance policy effectiveness. By addressing these gaps, the research aims to contribute to a more sustainable approach to plastic waste management in Nigeria.

12. ANALYZING TRENDS AND SEASONAL VARIATIONS OF BLACK CARBON IN THE UAE AND ANTHROPOGENIC EMISSION: A SATELLITE-BASED STUDY

Black carbon (BC), a potent byproduct of incomplete fossil fuel combustion, exerts a warming impact up to 1,500 times stronger than CO_2 by mass. This property significantly contributes to climate change, especially in regions like the United Arab Emirates (UAE), which has seen rapid industrial growth since 1971. This study quantifies the historical and current trends in BC sedimentation in the UAE, correlating these trends with intensive industrialization and anthropogenic activities to identify seasonal variations that could inform policy development.

Utilizing satellite images from the Giovanni online data system, this study analyzes two specific datasets: Anthropogenic BC Emissions and BC Sedimentation, covering the period from 1980 to 2025. The Hodrick-Prescott (HP) filter was applied to decompose these datasets into trend and seasonal components. Trend analysis was conducted using piecewise linear regression to identify shifts during distinct phases of industrial development. Seasonal patterns were examined using first-order least squares to assess fluctuations related to seasonal anthropogenic emissions.

Results indicate a general increase in BC sedimentation over the years, with a slope value of 0.0801 kg/m²/s. From 1980 to 2007, the increase was more linear, with a slope of 0.077 kg/m²/s. However, from 2008 to 2025, the trend stabilized, showing a slope of only 0.0103 kg/m²/s. Seasonal variations ranged from 5.3 to −4.8 kg/m²/s, indicating significant fluctuation.

Anthropogenic trends initially showed instability, with an overall slope of 0.1529 kg/m²/s. From 1980 to 1992, the slope was relatively low at 0.0747 kg/m²/s, but it significantly increased to 0.2906 kg/m²/s from 1992 to 2005, indicating a period of intense BC emission. The trend again stabilized from 2006 to 2025, with a minimal slope of 0.0012 kg/m²/s.

The analysis reveals a general increase in BC sedimentation, paralleling rises in anthropogenic emissions. The subsequent stabilization in both datasets after these peaks aligns with implementing stricter environmental regulations and improved emission control technologies in the UAE. Understanding these links is crucial for crafting policies that effectively mitigate BC's role in climate change.

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EUIndTech2025: INNOVATIVE IDEAS OF YOUNG SCIENTISTS – SCIENCE, START-UP, INDUSTRY – INNOVATIVE SOLUTIONS FOR THE FOOD AND PACKAGING INDUSTRY

1. DEVELOPMENT OF A PROTOTYPE TECHNOLOGICAL LINE AUTOMATING THE PRODUCTION PROCESS OF PRETZEL STICKS

The project "Development of a Prototype Technological Line Automating the Production Process of Pretzel Sticks" was realized by Lajkonik Snacks Sp. z o.o. with funding under 1.1.1 of the Operational Programme Intelligent Development – Fast Track – AGROTECH NCBR. The main objective of the project was to develop automated and flexible solutions within pretzel stick production technology (process innovation). The project resulted in a prototype installation integrating solutions directly addressing Lajkonik's needs: automation of the production process, reduction of waste, and decreased use of plastic (PP film), including the implementation of biodegradable material – PLA film. A key aspect of the automation effect was replacing manual packing of pretzel sticks into cartons with a dedicated device, alongside the introduction of advanced quality control systems.

2. THERMOPLASTIC MATERIAL BASED ON CHITOSAN AND INNOVATIVE PLASTICIZERS

Using a bioadditive system, a recipe for producing plasticized chitosan material by thermomechanical method was developed with the use of screw devices designed for processing thermoplastics. Chitosan was mixed with the components of the auxiliary system and the resulting mixture was plasticized, then its physical-mechanical, thermal and structural properties were studied. For the product in the form of a line, selected performance properties were presented, including physical and mechanical parameters, SEM analysis and thermal analysis. In contrast to the most commonly used methods, the developed formula limits the use of acid solutions and excludes the use of the most aggressive ones, such as acetic acid, formic acid and hydrochloric acid. Moreover, the content of chitosan in the material itself is relatively high (over 50% w/w). The key component of the plasticizing system is an esterification product from the group including: esterification products of lactic acid and a polyol such as glycerin. The obtained material can be used especially in the production of dressing/medical and packaging products.

Work was carried out as part of the POIR.04.01.04-00-0041/20-00 project financed by the National Center for Research and Development.

3. 3RD REVOLUTION IN HOSPITALS TEXTILES FOR HEALTHCARE SYSTEM

BIONWOVEN – a new type of advanced material dedicated as a raw material for biodegradable and bioactive hospital textiles. This innovation will bring the bioprotection of hospital patients to a previously unknown level. BIONWOVEN is the third revolution in hospital textiles. The Biovalley research in cooperation with the Lodz University of Technology has invented biomaterial and technology for mass production. The production method allowed for an effective combination of a natural non-woven fabric with a biocidal polymer composite. On a constructed tech lab station, the first part of the new bio-material was produced. It was tested in laboratories in accordance with the well-known ISO standards for the evaluation of textile bio-activity. Results confirmed the effective and stable bio-activity of the bio-material against viruses, bacteria, fungi and molds, whose membranes were destroyed by electrostatic interactions. BIONWOVEN can be a fantastic raw material that will provide patients with soft, comfortable and absorbent, opaque textiles, whose

antimicrobial bio-activity will protect users from hospital SEPSIS, and its biodegradability will protect water resources in the natural environment by eliminating the water washing process. The durability of bio-activity allows cycle-use bio-textiles to be used in hospitals throughout the treatment period without reusable or disposable textiles substitutes.

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EUIndTech2025: INNOVATIVE IDEAS OF YOUNG SCIENTISTS – SCIENCE, START-UP, INDUSTRY – ENERGY INDUSTRY

1. THIRD-GENERATION PHOTOVOLTAICS

A lot of research has been carried out aiming to find a new, effective and widely available way to generate energy. Some of the solutions are already well known and popular such as solar panels, photovoltaic modules, wind turbines and hydroelectric power plants. According to the International Energy Agency (IEA), modern renewable energy sources—such as wind, solar, hydro, geothermal, and ocean energy—accounted for approximately 5.7% of global primary energy consumption in 2023. Additionally, modern bioenergy contributed 6.5%, bringing the total share of renewables in primary energy use to around 12.2%. Despite the significant share of renewable energy in the global energy balance, they still constitute only a small percentage. This is primarily due to the instability of these sources and their high dependence on weather and climatic conditions.

This work presents energy conversion systems utilizing the photovoltaic effect based on nanomaterials, including low-dimensional structures. Rapid technological developments over the past 20 years have enabled the use of advanced material fabrication techniques, such as Atomic Layer Deposition (ALD), on large substrate surfaces, which can be effectively transferred to commercial processes. Precise control of layer thickness at the nanoscale, combined with uniformity and complete surface coverage achieved through the ALD process, allows the creation of new active compounds and transport layers with optimized conductivity parameters and tailored energy levels.

2. FAST/SPS FABRICATION OF CRM-REDUCED MATERIALS FOR ENERGY STORAGE

In light of the contemporary challenges faced in the development of metal-ion batteries, there is an urgent need to identify new materials and manufacturing methods that reduce production time and cost without compromising functional performance. A major concern in this context is the high dependency on critical raw materials (CRMs), particularly lithium and cobalt, which poses a significant barrier to sustainable development in the energy sector.

This study explores the application of Field Assisted Sintering Technology/Spark Plasma Sintering (FAST/SPS) for the fabrication of ceramic-based components for metal-ion cells. The FAST/SPS technique enables synthesis and sintering of materials, offering enhanced control over microstructure and physical properties, while significantly reducing processing time compared to conventional techniques. Structural analysis was performed using X-ray diffraction (XRD) to monitor changes in phase composition during various stages of the manufacturing process.

The results demonstrate that FAST/SPS can be successfully used to produce ceramic-based metal-ion cell materials with a reduced content of critical raw materials. The technology supports the manufacturing of the materials in powder form, as well as partially or fully densified discs. This

suggests a promising pathway for the development of next-generation components of metal-ion batteries for environmentally responsible energy storage solutions.

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3. BATTERY METALS RECOVERY FROM PRIMARY AND SECONDARY RESOURCES THROUGH A SUSTAINABLE PROCESSING METHODOLOGY

The European Union has underexploited potential to produce critical raw materials (CRM) and special metals, as stated in the Study on the EU's list of Critical Raw Materials (2020). Concretely, the battery sector is considered as a key strategic sector for the EU due to the increased use of batteries in different important sectors such as electric mobility. Thus, the METALLICO proposal presents a new opportunity for the European Union. It is composed of a strategic consortium along the value chain, including mining and industrial sites with primary and secondary sources of critical and battery metals (Li, Co, Cu, Mn, Ni); experienced partners to pilot novel processes for producing battery-grade materials based on previous projects and activities; industrial and SME end-users in the battery, cement, paint, and ceramic sectors; and partners to demonstrate the social-license-to-operate (including the support of government bodies), sustainability and commercial chances that the solution represents. Worldwide, these battery metals are predominantly in Chile, Australia, South Africa, China, and The Democratic Republic of Congo, representing a high risk for the EU in terms of supply shortage. METALLICO includes 4 case studies in the EU to recover: battery-grade Li_2CO_3 from a primary spodumene/lepidolite/petalite deposit; Co concentrates and battery-grade $CoSO_4$ from a mine secondary resource (CLC); and Cu, Co, Mn, and Ni concentrates from metallurgical slag and secondary mine tailings.

4. NICKEFFECT: NI-BASED FERROMAGNETIC COATINGS WITH ENHANCED EFFICIENCY TO REPLACE PT IN ENERGY & DIGITAL STORAGE APPLICATIONS

The NICKEFFECT project, funded under Horizon Europe, aims to develop innovative nickel-based alternatives to platinum group metals (PGMs) for use in electrochemical processes such as water electrolysis, fuel cells, and magnetoelectronic devices. By replacing scarce and expensive PGMs with more abundant nickel, NICKEFFECT supports Europe's strategic goal of reducing dependence on critical raw materials and promoting sustainable industrial transformation.

The project integrates a Sustainable-by-Design (SbD) approach to develop at least three new porous nickel-based coatings with tailored properties. These materials are tested for their performance in harsh environments and evaluated for scalability, industrial applicability, and environmental safety. NICKEFFECT also contributes to future standardisation and policy development by working with regulatory bodies and technical committees. Through cross-disciplinary collaboration and strong exploitation planning, NICKEFFECT aims to accelerate the uptake of green, cost-efficient materials across the energy and manufacturing sectors.

5. THE NEW TECHNOLOGIES OF THE NEO-CYCLE PROJECT FOR WEEE RECYCLING

The NEO-CYCLE project (https://neo-cycle.eu/) aims to demonstrate at TRL6 the sustainable upcycling of spent NdFeB magnets coming from hard disk drives (HDDs), reaching high-quality end products for 4 case studies: pharmaceutical, ammonia, fertilisers, and polymers industries, and will include necessary paths to reach the market uptake. To reach this aim, NEO-CYCLE involves all the relevant actors in the value chain, from public authorities to WEEE recycling companies, technology developers, associations, NGOs, SMEs, and commercial companies in the targeted sectors. The NEO-CYCLE consortium brings together 22 entities from 12 countries around the world. Among the participants in this initiative are leading academic institutions, research centres, small and medium-sized enterprises, as well as large industrial centres.

One of the main objectives is to transform the European economy by boosting the recycling of rare earths and boron from residual materials within Europe and building up its own production capacities. This ensures a supply of strategic raw materials to European manufacturers and traders, thus promoting the development of a European raw materials industry in the long term.

Exploitation results planning: identification of barriers, requirements and actions needed to achieve the highest TRL; development of a strong and sustainable business model for NEO-CYCLE results.

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EUIndTech2025: INNOVATIVE IDEAS OF YOUNG SCIENTISTS – SCIENCE, START-UP, INDUSTRY – NANOTECHNOLOGIES

1. EXPOSURE ASSESSMENTS ALONG THE LIFE CYCLE OF SWCNT NANOCOMPOSITES: TWO CASE STUDIES OF EPOXY RESINS AND ACTIVE MATERIALS FOR LITHIUM-ION BATTERIES

Carbon nanotubes have exceptional properties that enable applications in high-performance concrete, supercapacitors, sensors, conductive electrodes, and polymer nanocomposites. However, rigid multi-wall carbon nanotubes may pose asbestos-like hazards if released and inhaled during a product's life cycle. To minimize health risks, the Safe and Sustainable by Design (SSbD) approach aims to use nanotubes with short length and low stiffness, allowing macrophages to transport them in the lungs. We propose that single wall carbon nanotube brand TUBALL™ meets this requirement. To confirm this, further release and toxicity studies are needed. In this context, we conducted two case studies on potential TUBALL™ release from polymer nanocomposites. Airborne exposure was examined in laboratory-scale tests of epoxy resins and lithium-ion batteries, where TUBALL™ was used in the polymer matrix and conductive electrode material, respectively. Data from these studies, conducted under the European Commission projects DIAGONAL and SUNSHINE, indicate that nanomaterial TUBALL™ is safe for use, supporting its role in SSbD.

2.BIOPOLYSACCHARIDE-BASED NANOPARTICLES – A NOVEL STRATEGY FOR THE TREATMENT OF DIABETIC FOOT INFECTIONS

Diabetic foot infections (DFIs) are a serious health and economic burden globally. Diabetes affects about 537 million of people worldwide, and about 19-34% people suffering from diabetes will develop problems with DIFs, which can lead to foot amputation. DIFs are characterized by the invasion and multiplication of microorganisms in diabetic non-healing wounds. They are commonly polymicrobial and involve antibiotic-resistant strains of microorganisms. Thus, DIFs can be difficult to treat, and despite the administration of multiple rounds of antibiotics, prospects of clinical resolution of infection can still be poor, and repeated courses of antibiotics risk selecting for antimicrobial resistance.

Our goal is to develop a series of novel biocompatible antimicrobial nanoparticles that efficiently include selected antimicrobial combinations specifically designed to combat antimicrobial resistance in DFIs.

Artificial intelligence in drug development, green chemistry principles for nanoparticle creation, and a diverse array of sophisticated biological models—including advanced human skin organoids infected with clinical DFI isolates, and an infection mouse model with induced diabetes. Development of innovative biocompatible

antimicrobial nanoparticles with high translational potential.

3. TAILORING THE STRUCTURAL AND OPTICAL PROPERTIES OF ZNO THIN FILMS THROUGH CARBON ION IMPLANTATION

Zinc oxide (ZnO) is a wide-bandgap semiconductor with applications in optoelectronics, gas sensing, and catalysis. Despite extensive research, improving its interfacial and electronic properties remains a significant challenge. Ion implantation with carbon ions is a promising method for modifying structural and electronic properties of ZnO. Here, we study the effects of 20 keV C+ ion implantation on ZnO morphology, defect states, and interfacial bonding using atomic force microscopy and spectroscopic techniques. Numerical simulations using dedicated ion transport software reveal that implanted ions follow a Gaussian distribution, penetrating the near surface oxide layer to a depth of around 125 nm, with an average range of 41.4 nm. Carbon implantation induces Zn and O vacancies, with oxygen vacancies forming more efficiently, leading to localized structural modifications. Microscopy analysis shows a reduction in grain size from 70–100 nm to 40–70 nm, with increased grain size heterogeneity, suggesting nanoscale material redistribution and possible amorphization as a result of ion implantation. Despite ion bombardment, the ZnO layer remains continuous, with no evidence of structural degradation. Optical measurements indicate an increase in both the optical bandgap (Eg) and the Urbach energy (Eu) with fluence. The increase in Eu suggests the introduction of defect states, which are significantly reduced after annealing at 500°C. These results demonstrate that carbon implantation enables controlled modification of ZnO thin films, potentially improving its optical and electronic properties.

4. SAFE AND SUSTAINABLE BY DESIGN (SSBD) FOR NEXT-GEN COATING MATERIALS

High Entropy Alloys (HEAs) are an emerging materials category very promising for coatings production (high entropy coatings-HECs), but also for their sustainability performance throughout their entire lifecycle. LCA integrated with the SSbD holistic approach and Machine Learning (ML), incorporates different sustainability aspects (safety, environmental and socio-economic), identifies hotspots at low technology readiness level (TRL) and also facilitates the decision making towards a green transition on materials sector.

5. ADVANCING SSBD IN THE PLASTIC INDUSTRIAL VALUE CHAIN THROUGH INTEGRATED ASSESSMENT AND DIGITAL INNOVATION

Plastics pose significant safety, sustainability, and circularity challenges due to their persistence in the environment, toxicity risks, and limited recyclability. Their widespread use in sectors such as automotive and construction highlights the urgent need for integrated solutions to reduce their impact on human health and the environment and support resource-efficient, circular design. The EU-funded ANALYST project aims to accelerate the transition towards a safer and more sustainable industrial value chain. It advances the Safe and Sustainable by Design (SSbD) framework by expanding scientific knowledge, informing policy development, and guiding investment through integrated assessments of safety and sustainability trade-offs.

ANALYST introduces three key innovations. ANALYST-BOX provides robust methodology and guidelines for holistic health, environmental, economic, and social impact assessment. ANALYST-DIGI is a digital platform incorporating a multi-criteria decision-making tool supported by a harmonised, multi-source database. ANALYST-T-PACK is a validation programme involving three polyvinyl chloride (PVC) use cases along the value chain: suspension-PVC (flexible), emulsion-PVC (flexible), and suspension-PVC (foamed rigid), targeting the automotive and construction sectors. By combining methodological, digital, and validation tools, ANALYST drives a paradigm shift toward inherently safe, circular, and sustainable plastic value chains.

6. ANTIMICROBIAL, ANTIVIRAL AND ANTIFUNGAL NANOCOATINGS FOR EVERYDAY SURFACES

Since the end of 2019, the spread of COVID has deeply changed our lifestyle, resulting in historical events and decisions, such as the EU block of non-essential travel among countries (COMM (2020) 499), affecting the whole EU society economically and psychologically. However, as reported in the HERA target priorities, the persistence of the emergency status requires daily actions that tackle the spread of COVID. In this economical, societal and clinical context, the project MIRIA aims to develop wide-range-antimicrobial nanocoatings to be used in

hospitals and other environments where cross-contamination and contagion risk are significant issues. In the wake of the covid outbreak, there has been large concern about infection spread of pathogens (i.e., bacteria, fungi, virus, and specifically SARSCoV-2) via high traffic surfaces (i.e., medical equipment). State of the art and commercial products coating solutions that both target a range of mixed pathogens and different surfaces (e.g., glass, metal, textile) are unfortunately scant. EU-Funded project MIRIA solutions aim to fill this void, impacting on EU health, both directly (by creating public safe environments) and indirectly (by reducing COVID spreading and decreasing ill-related work absences and psychological pathologies).

7.EUROPEAN RECYCLING AND CIRCULARITY IN LARGE COMPOSITE COMPONENTS: EURECOMP PROJECT

Reuse, repair, refurbish, remanufacture, recycling and repurpose; the R6 strategy is the main pathway to achieving circularity and reusability of large-scale end-of-life products. Composite materials are used in various applications such as aeronautics and renewable energy industries. However, they have not been adequately recycled, due to several difficulties in processing those materials. As the use of composite materials is ever-growing, it is important to come up with solutions to deal with the increasing waste. The EU-funded EuReComp project develops sustainable methods for reducing, recycling and reusing composite materials from components used in various industries, such as aeronautics and wind energy. As such, waste reduction and the creation of high-added-value products are accomplished.

8. ADVANCING RELIABLE AND TRACEABLE RECYCLING FOR HIGH-QUALITY RECYCLATES FROM AND FOR HOME APPLIANCES, TOYS AND TEXTILE

Polymers are extensively utilized across various industries, including packaging, home appliances, toys, and automotive sectors. A significant contributor to polymer waste is electric and electronic waste (WEEE), which reached a record 62 Mt globally in 2022, figure projected to escalate to 82 Mt by 2030, marking a 32% increase from 2022 . Despite the growing volume, only 22.3% of WEEE was formally collected and recycled in 2022, a rate expected to decline to 20% by 2030 , urging the need for improved recycling infrastructures and policies to manage the escalating plastics waste effectively. Moreover, reliable methods for calculating, verifying, and reporting recycled content are essential to meet EU circular economy goals, yet remain challenging due to the need for robust material tracing and contamination control. This work presents a comprehensive methodology for sorting, tracing, and processing plastic waste into high-quality recyclates, supported by smart digital tracking and standardization. Efforts included large-scale polymer waste characterization using LIBS and Raman technologies, optimization of advanced recycling routes such as DBR and scCO2, and polymer stabilization via tailored additivation and solid state polymerization. Analytical protocols and predictive models for material degradation and lifetime were validated, while digital traceability platforms enhanced transparency in recycling chains. Demonstrators in toys, textiles, and home appliances confirmed technical viability. This integrated approach shows clear potential for adoption across multiple sectors, enhancing trust in recycled materials and fostering a safe, functional circular economy.

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