



Mineral and Energy  
Economy Research  
Institute  
Polish Academy of Sciences

# VII International Conference



**Young Researchers'  
Innovative Ideas:**  
Science | Start-Ups | Industry

27<sup>th</sup>-28<sup>th</sup> May 2021



VII International Conference

***Young Researchers' Innovative Ideas:  
Science | Start-Ups | Industry***

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***ORAL SESSION I:***  
***Circular Economy***

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**Yuliia MAKSYMIV\***

## ***Circular economy concept for the sustainability of the bioeconomy***

The introduction of the bioeconomy in a practical dimension emerges through the interaction between different stakeholders, resulting in a high probability of conflict of interest; objectively, private commercial interest prevails, which often does not take into account the need to be within planetary boundaries.

The purpose of the study is to substantiate the idea that the potential risks of practical implementation of the concept of bioeconomy can be overcome by implementing it with the circular economy concept.

The works of scientists on the description of potential risks of introduction of bioeconomy and ways of their overcoming are analyzed. The scientific works analyze the approaches to understanding the concept of bioeconomy and the risks of its implementation, as well as the strategy of bioeconomy development in OECD countries, EU countries and countries with potentially large bioeconomies. It has been established that even the strategic documents of countries with potentially large bioeconomies (in terms of available resources and biotechnologies) do not take into account possible risks to ecosystems. The existing problem of the need to ensure sustainable development of the bioeconomy must be solved by combining with the circular economy concept, because only in such a tandem can most of the goals of sustainable development be achieved and conflict between them be avoided.

The cycle of linear and circular bioeconomy is given on the example of bioenergy as a potentially important sector of bioeconomy.

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**Karolina DRAGUŁA\***

## ***Fungi as a part of circular economy***

Investing in fungal biotechnology will enable a sustainable change to our world. Future innovation potential of fungal technology can shift away from linear economy into a circular economy and mitigate climate change. Fungal biotechnology creates innovative solutions which may provide us new bio-based, renewable and resource-efficient solutions. In this presentation some examples of current developments are summarized.

This future technology is a driver of innovation. It creates opportunity for growth in a range of industries: textiles, construction materials, agriculture, water, food, transportation, energy, pharmaceutical etc. Mushroom materials have the potential for uses as textiles, building materials, furniture materials, packaging, leather and plastics. So far, leather alternatives have achieved significant market share. Mycelium has useful properties as a manufacturing material because it acts as an insulator for heat and sound. Materials based on fungi biotechnology generates smaller carbon footprint than traditional materials. Filamentous fungi are heterotrophic organisms which can efficiently degrade lignocellulosic plant biomass have a high potential in the upgrading of wood in biorefinery towards chemicals and biofuels.

Despite our best efforts at reducing waste we continue to produce more plastic. Plastic pollution has become one of the most important global problem. Microplastic are accumulating in the environment. Plastic-eating mushrooms can remove waste pollutants from the soil and convert them into biofuels. What is more, mycelium-based materials can greatly reduce the amount of plastic. Replacing synthetic textiles, traditional building materials, furniture, packaging materials with fungal materials can reduce plastic pollution.

In 2015, the General Assembly adopted the 2030 Agenda for Sustainable Development. These goals include: zero hunger, clean water, affordable and clean energy, responsible consumption and production and climate action. We should be aware that innovative fungal biotechnology can contribute to achieve 10 of the United Nations' 17 Sustainable Development Goals.

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*Anna GOBETTI\**, *Giorgio RAMORINO\*\**, *Giovanna CORNACCHIA\*\*\**, *Marco LA MONICA\*\*\*\**

## ***Innovative reuse of electric arc furnace slag as filler for polymer matrixes***

The increasing sensitivity towards the preservation of natural resources and the big problem of waste disposal led the EU Commission to issue Directive 2008/98 and the ambitious goal of “zero waste”. This led in turn the attention of manufacturing industries to focus on the valorization of waste as an environmentally and economically advantageous alternative to the ever-increasing disposal costs.

In this context, the European steel industry produces about 70million tons/year of steel by the electric arc furnace (EAF). Slag is the by-product produced in greater quantity and it is functional to the production of the metal itself. Since it consists of about 15% by weight of the produced steel, it has a high potential as a co-product.

The enhancement of by-products does not aim only at their use in the production of conventional products but also at the study and development of new products. Through a new destination of waste, on one hand, large quantities will be saved from landfills and, on the other, savings will be made in the extraction of new raw materials.

Currently, steel slags can be recycled for internal metallurgical purposes or used in road construction cement and concrete and others, but unfortunately, a large amount is not used today. The main critical aspect of the use of EAF steel slag is its leaching behavior. For safe reuse of EAF slag, the leaching of environmentally harmful into the environment must be kept under control. The leaching behavior is checked according to the standard CEN EN 12457.

This research aims to assess the influence of EAF slag in different polymer matrixes: thermoplastic (polypropylene (PP)), thermosetting (epoxy resin), elastomeric (nitrile butadiene rubber (NBR)), and recycled end of life rubber tire (ELT).

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**Gulshan SAFAROVA\***

## ***Cyclor economics in case of the fashion industry and beauty products***

Today, Fashion and Beauty Products (makeup industry) is considered the second most damaging industry to the ecosystem after petrol. The European Apparel Action Plan, an EU initiative to counter these wastes, was adopted to significantly improve the sustainability of textiles throughout their lifecycle from design to end-of-use by 2019. According to this law, if every brand in the clothing supply chain starts implementing environmentally friendly practices, the textile and fashion industries will become significantly more sustainable. Thanks to the recyclable economy, 95% of wastes can be reused.

As consumers become increasingly concerned about the social and environmental impacts of their buyers, businesses are beginning to recognize the benefits and undeveloped economic potential of waste efficiency.

As of the most recent European Commission reports, resource extraction and processing account for half of total greenhouse gas emissions and more than 90% of a total of coral bleaching and waterlogging. According to a recent study, Americans only keep recycling 35% of solid waste, while Germany, the most accurate state, reuses 68%.

The purpose of this study is to investigate the role that open design can play in bringing the circular economy to life and, as a result, a more sustainable material future in the Fashion and Beauty products industry.

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**Adam SULICH\***, **Letycja SOŁODUCHO-PELC\*\***

## ***The Circular Economy and the rise of Green Jobs***

The Circular Economy (CE) is one of many proposals for new, more sustainable and durable economic models. As consequence, these pro-environmental economic models induce visible changes on the labor market, especially in the emerging new 'Green Jobs' based on the shift from linear to Circular Economy. This paper aims to investigate Environmental Goods and Services Sector (EGSS) sector among 28 European Union countries from 2009 to 2019, focusing on new opportunities in the labor market changes caused by the shift towards the CE. A desk research complemented by the statistical analysis of secondary data was applied. Main findings revealed that CE model is striving to implement the idea of Sustainable Development (SD). One identified core feature of the CE is the green sector associated with workplaces and jobs. Then, some Sustainable Development Goals (SDGs) arose as main factors to be considered in this changing labor market. The adopted direction of economic development depends on the assumptions of strategic management which allows conditions for creating the Green Jobs in long planning horizon. Results are presented as an econometric model, indicating which fields, in strategic management, can support CE and enhance employment in the 'Green Jobs' paradigm.

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**Michał NOWOSIELSKI\***

## ***Circular economy – case study from Poland***

Clean energy transition which is related to European Green Deal requires supply of raw materials to renewable energy sources production. Most of these resources are critical for Europe, which means that the supply of those materials is risky and mostly concentrated in some countries outside Europe. Upgraded in 2020 list of critical raw materials in the EU contains 30 materials that are important for Europe's economy. Activities of European Commission are related to strengthening the supply chain of those materials and changing EU economy from linear to circular. Recycling is the most important process in a circular economy.

Energy transitions offer opportunities and challenges for Polish companies that produce minerals. One of a good examples of Polish company which chooses the path of the circular economy model is ZGH Bolesław.

History of ZGH Bolesław starts in Bukowno in 1955. Since that company grew to a huge mining and metallurgical complex, where the main activity was the extraction of zinc and lead ores (on December 31, 2020, the extraction of zinc ore in the Polish mine ended after nearly 70 years of ore extraction) and the production of electrolytic zinc, zinc-lead concentrates, galvanizing and casting alloys, and sulfuric acid. ZGH Bolesław manufacturing 154 thousand tonnes of the highest quality Zn (99.9975%), annually and as the main manufacturer of Zn in Central Europe, provides products to Austria, Hungary, Czech, or Slovakia.

Till the end of 2020 raw material for production at ZGH Bolesław mainly had come from their own mine extraction in Poland. Due to resource depletion and the COVID-19 pandemic which had an impact on the economic factor the company is changing structures to adapt to current market. At the moment huge share of the substrates comes from recycling and their own mine in Montenegro.

During 65 years of exploitation, around 60 mln tonnes of waste was deposited on the settlement pond. The post-flotation waste pond covers an area of approx. 110 ha and is 30 meters high. In 2016 this tremendous disposal waste became a source of metals for production (content of Zn 1.5% and Pb 0.5%) thanks to the technology that has been developed and patented by the company. ZGH Bolesław started the recovery of zinc and lead by the installation with efficiency 2 million tons of waste per year. This new source of materials over the next 15 years will account for approx. 15% of input in the zinc production. It has an impact not only on ZGH Bolesław lifetime extension but also on maintaining workplace in the region. Currently, the company is also implementing a technology in which more than half of the materials for the production of zinc will be from recycling.

To conclude, ZGH Bolesław is a pioneer of circular economy and waste management systems. Company uses technology which supplies one another and creates a closed-loop. This synergy provides a lot of benefits like decrease consumption of primary raw materials, savings in energy, reduction of gas emissions and landfills, and also reduction of contamination.

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**ORAL SESSION II:**  
***Circular Economy under patronage***  
***of PackAlliance Project***

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*Mateusz KOZICKI\*, Justyna TOMASZEWSKA\*, Katarzyna GUZIK\**

## ***Ceplafib as an example of research project providing novel material solutions compliant with Circular Economy concept***

Implementation of a new Circular Economy (CE) through the valorisation of postconsumer plastic waste and reclaimed pulp fiber is a title of a research project with the acronym Ceplafib, financed by the EC under Life programme, in the period of 2017–2021. The project aims to develop technologies allowing to process plastic bottles and newspapers in order to obtain polymeric-based composite materials reinforced with cellulose fibers, exhibiting competitive properties comparing to conventional materials. The speech will discuss the chemical properties of recyclates in terms of emissions of volatile organic compounds (VOCs) and the release of selected ions and heavy metals. The obtained results will be analyzed in the context of the Regulation of the Minister of Health on permissible concentrations and intensities of factors harmful to health emitted by building materials and other legal acts containing environmental requirements for construction products. In addition, the implementation of CE assumptions in the construction sector will be presented, on the example of the use of innovative composites with polyethylene (PE) and polypropylene (PP) matrixes reinforced with randomly orientated short cellulose fiber as materials for acoustic barriers and facade panels.

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## ***Development of biodegradable films for frozen food***

Currently, the increased use of plastics has created ecological problems to the environment because they become a major source of waste after use due to their poor biodegradability. In order to face this issue, the research is directed towards the development of eco-friendly materials that can substitute the conventional plastic ones. The packaging sector is the one that uses the highest amount of plastic, thus, the use of the so-called “bioplastics” in the food packaging field could be a strategy to reduce the environmental impact generated by the traditional plastics materials. Moreover, since a considerable amount of foods requires sub-ambient storage temperatures, the development of packaging solutions made by bioplastics suitable for low storage temperatures can be effective way to increase the spread of biopolymers and improve the food packaging sustainability.

However, few information is available on the mechanical behaviour of bioplastics at low temperatures and the application of bioplastics in this sector are still limited.

Among biodegradable polymers, PBAT stands out for its very high ductility and flexibility and low glass transition temperature ( $-35^{\circ}\text{C}$ ). However, its poor stiffness limits its use as packaging material. In this context, the melt blending of PBAT with is another biodegradable polymer can be an effective and economic way to improve its stiffness without compromising its biodegradability. Polylactic acid (PLA) is one of the most widespread one, it can be easily processed with conventional techniques and it has complementary mechanical properties to PBAT. The melt blending between these polymers allows to obtain good performance for possible application as packaging materials, particularly with respect to the mechanical properties.

Therefore, in this study blown films of PLA and PBAT in a wide range of compositions (100/0, 80/20, 60/40, 40/60 20/80 0/100 by weight) were produced using a lab-scale film blowing plant and were characterized in terms of rheology, morphology and functional properties in order to determine their suitability as food packaging materials for low storage temperatures.

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## ***Mechanical recycling of Pulper Waste***

In Europe, paper and paperboard are the most recycled materials, with a rate of about 85% but, at the end of the process, there is a rest, called Pulper Waste (PW), composed by mixed polyolefins, in particular Polyethylene (in form of LDPE and LLDPE) and Polypropylene, with a small percentage of cellulose (about 5%) and traces of polar contaminants. At now, mechanical recycling of PW has important limitations due to several major issues, mainly related to the immiscibility of the different plastic types that composed them and to the presence of cellulose and different type of contaminants such as inks and adhesives. This results in poor mechanical performances of the final recycled products. In addition, contaminants, like polyamides, and cellulose have a highly hygroscopic character, therefore high capacity to absorb humidity, and, given the high process temperatures during the extrusion phase, this would lead to macroscopic defects and embrittlement, together with the release of low molecular weight substances that causes bad odours. All these issues make difficult to re-enter PW into the market.

One possible strategy for the effective mechanical recycling of PW can be the upgrading of the polymeric blends through the inclusion of proper additives, able to improve the interfacial adhesion and the dispersion of the mixture components. To contrast the immiscibility of the polar and non-polar constituents a compatibilizer can be used. At this scope some polyolefin compatibilizer, mainly made up of PE and PP and functionalized with maleic anhydride (0.4 wt% and 0.25 wt%), added at 5 wt%, were tested. To reinforce the recycled matrix, polymeric (mixed polyolefins recovered from urban collection, R-PP, added at 25, 50 and 75 wt%), mineral (basalt fibers, FB, added at 5, 10, 15 and 20 wt%) or vegetable fillers (wood plastic compound, WPC, added at 50 and 75%) can be used. Finally, bad odours can be reduced using proper absorbers (commercial humidity and odours absorbers) or zeolite.

The work has the aim to select the best combination of additives in terms of type and percentage, in order to optimize the system and obtain an equilibrium between best performances and minimum quantity of additives. To goal this scope, pilot scale equipment, co-rotating twin-screw extruder for the melt compounding procedure and single-screw extruder for rectangular specimens' production, are used. Finally, all the compounds were characterized by several techniques (FT-IR, TGA, DSC, rheometry, SEM, mechanical tests) in order to determine their chemical composition, thermal stability, rheological behavior, morphological characteristics and tensile and flexural properties.

The blend composed by PW+R-PP+FB 40:40:20 turned out to be the one with the best combination of performance and number of additives used. To evaluate its suitability as a substitute for virgin polymers in the construction of car dashboards, its mechanical properties were compared with those of virgin PP and glass fiber reinforced PP, resulting superior in terms of elastic modulus (1014 MPa) to the former (592 MPa) and comparable to the latter (1162 MPa).

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## ***Decontamination efficiencies of post-consumer high-density. Polyethylene milk bottles and prioritization of high concern volatile migrants***

Among all polyolefins food packaging, HDPE milk bottles could be the first candidate for closed-loop recycling since they could be easier to collect and sort from a kerbside collection system and might have less contaminants compared to others. Knowledge about the compounds present and their concentration in post-consumer plastics, and the capabilities of various recycling processes to remove them, are crucial for the design of efficient HDPE recycling process. However, research studies on this topic are limited. The first objective of this work was to evaluate the batch effect in the recycling industry (samples collected at different time) on the chemicals present in flakes and pellets from rHDPE milk bottles by hierarchical clustering (HCA). The second objective was to evaluate the efficiency of two cleaning processes (washing twice and extra decontamination) on the removal of chemicals present in the rHDPE samples and to deeply understand the factors largely affecting the cleaning efficiency. Thirdly, with the aim to find out the most concerning chemicals in rHDPE from milk bottles samples, a highly sensitive DI-SPME-GC-MS method was employed for the untargeted screening of migrants coming from these rHDPE samples in both 95% ethanol (v/v) and 3% (w/v) acetic acid food simulants. The large number of migrants identified was then prioritized and quantified when available. Finally, several substances with prioritized concern were listed and addressed with particular attention for rHDPE samples with the aim to provide useful information for developing effective decontamination techniques and establishing legislation to assure high quality rHDPE.

1. rHDPE samples with significant amount of non-milk bottles plastics contamination showed considerable variation between batches, while those with negligible contamination were somehow consistent.

2. Chromatographic peak area of 63.3% of chemicals was halved after washing the flakes twice with water and the total chromatographic peak area dropped more than half. However, the efficiency gained could be the result of its ability to remove high proportion of non-milk bottle rHDPE contamination.

3. 48.5% and 81.4% compounds in flakes (A) and pellets (D), respectively, got less than half chromatographic response after being treated with the extra decontamination technique. After extra decontamination, many high concern substances such as DEP and BHT, DBP, DiBP and 1-tetradecane were significantly reduced, but octocrylene and 2-ethylhexyl-4-methoxycinnamate, which could be contaminants from cosmetic packaging, were not.

4. 58 migrants were prioritized based on their toxicity. They were then quantified.

From a practical point of view, we have pointed out that special attention should be paid for octocrylene and 2-ethylhexyl-4-methoxycinnamate, as they were detected in all studied sampled, when recycling HDPE from milk bottles for new food contact uses in terms of decontamination as well as legislation.

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## ***Modeling of bioenergy impact on food security***

Ensuring the energy and food independence of each state is an urgent issue and its importance will continue to grow given the constant need for the state to properly guarantee the basic needs of the population. However, the rapid development of bioenergy is a potential precondition for the fuel and food conflict over agricultural raw materials. We examine the relationship between food safety indices and the overall share of energy from renewable sources and bioenergy production in some European countries. The main factors characterizing the food security of these countries for the period from 2012 to 2018 are identified. Statistical methods of correlation analysis are used to determine the links between the outlined factors.

The initial data for the study were official statistics, energy balances, scientific literature on determining the foundations of food security and the development of the national economy. Indicators of bioenergy production and the share of energy from renewable sources were taken from the energy reports of the countries posted on the Eurostat website. The food security indices consider the key challenges of affordability, availability, and quality across a number of countries. The methodology for food security indices was developed by The Economist Intelligence Unit with consultation from a peer panel of experts.

The main statistical methods used in the study were the Kolmogorov-Smirnov consistency criterion (to determine whether empirical distributions are subject to the same law or model) and the Spearman rank correlation coefficient (to find correlations between food safety indices and the share of bioenergy and overall share of energy from renewable sources).

According to the indicators of the countries we study, the agricultural sector does not suffer losses with the development of renewable energy, in particular bioenergy. Biofuel production contributes to the development of the local economy, rural areas and the improvement of infrastructure. In some countries, GDP growth is directly correlated with bioenergy production, which is noticeable, in particular, in the example of Poland. Also, it was found that biofuel production does not affect the overall food safety index, and these indicators have a direct correlation, i.e. show common growth trends.

The statistically significant inverse correlation between the risk of political stability and the share of bioenergy production indicates the dependence of the sector on the political will of the country's leadership and a stable political course, as such development is based on a favorable legal framework and public investment in the industry. Thus, a necessary precondition for the development of the bioenergy sector is a prudent public policy that takes into account all aspects, including food security. At the same time, in Germany, bioenergy production affects the average cost of food with increasing costs. Therefore, the development of bioenergy in the state can also be determined by the environmental consciousness of its citizens.

Further research should focus on the study of correlations between indicators on the example of more countries in the world and over a much longer period of time using different statistical methods.

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***POSTER SESSION I:***  
***Circular Economy***

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**Bourhane LARIANE\***

## ***Obstacles of Implementation of circular economy in EU***

The global warming and environment destruction caused by the linear economy model (take-make-dispose) can no longer continue since it became a threat to life on earth. The solution to this issue is circular economy model. It is a general concept, contains many other theories, ideas, projects and principles that all aim to reduce carbon emissions and protect the environment. Therefore, we will focus on one part related directly to our studies, which is industrial symbiosis.

The objective of this study is to have more detailed understanding as future managers and leaders we should be aware of the circular economy challenges. Also, make sure that we be able to choose and prioritise the necessary strategies as decision-making participants in the companies that we will be part of, since this is becoming crucial to business success and it present both opportunities and threat to the industrial companies.

In this thesis, we will follow qualitative research approach where we try to answer the following research questions: The challenges of implementing Industrial symbiosis. The management strategies to apply inside the company to play an effective part in Industrial symbiosis network, what is the relation of industry 4.0 with Industrial symbiosis. How information technology and digitalisation can solve some of the IS obstacles.

To narrow the scope of the study clearly will focus on the use IT platforms or software in the in Industrial symbiosis in Poland compare it with different countries in the EU or/and in other cases around the world.

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## ***iTARG3T project as an example of development of Sn-W-Ta-(Li) recovery from secondary sources and sustainable mining from primary sources***

One of the wealthiest tungsten-tin-(tantalum-lithium) mineral belts worldwide is located in western and central-eastern Europe, where different types of mineralization are related to highly evolved peraluminous granitic rocks. These ore deposits were intensely mined till the 1980's when the global crash of metal prices triggered the closure of most of the tin mines. More recently, market and political changes initiated the gradual reactivation of this mining sector and currently, there are several producing mines and tens of advanced exploration projects. However, most of these projects are brownfields and occur in or near already existing mine sites. This is partially caused by several issues that are specific for this type of mineralization. The deposits are usually low tonnage and mostly worked by SME's, they form irregular masses or narrow veins with difficult grade control, resource evaluation, and ore processing. Furthermore, the restricted geographic location, away from the major ore belts, and the price crisis have kept these deposits away from the recent advances of conceptual exploration. All of these problems have hampered greenfields exploration and advances in ore concentration and resource estimation.

The iTARG3T project aims to contribute significantly to the discovery and development of new sources of tin, tungsten, tantalum and lithium in Europe by improving exploration in technically challenging environments and developing mineral processing solutions.

The Mineral and Energy Economy Research Institute of Polish Academy of Sciences (MEERI PAS) as one of the project partners was responsible for collecting information and preparing reports on recycling and substitution of these elements and also report about environmental aspects of Sn-W-Ta-(Li). Analysis of metal availability showed that each of these elements can be recovered from various secondary sources. For example, tantalum can be recovered from more than 16 different sources such as end-of-life waste (e.g. capacitors) or municipal solid waste landfills containing electrical waste and electronic equipment – tantalum concentrations in such landfills are estimated to be around 1 mg/kg. Lithium is recovered mainly from lithium-ion batteries, where the lithium content in such batteries is about 6% relative to other metals. At present, the most commonly used methods for lithium recovery are hydro- and pyrometallurgical methods. Another report about environmental aspects of Sn-W-Ta-(Li) show that metal mining processes may cause changes in environment, freshwater availability, soil degradation and water pollution with severe consequences for human health and biodiversity. Due to the growing ecological awareness and care for the environment, entities involved in the extraction of Sn-W-Ta-(Li) are taking more and more actions to reduce the negative impact on the environment during their operations. To ensure the increasing demand for minerals in the following years, mining companies are using new digital tools such as multiscale modeling and simulation to develop environmentally sustainable processes. The challenge for mining companies, is to produce more minerals at lower cost, with lower impacts and the highest safety. There are many startups and companies such us, Eramet,

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EnergyX, Solvay, Lilac Solutions, Bacanora, POSCO and K-UTEC that strive to move the science forward and develop a novel extraction and process technologies for Sn-W-Ta-(Li).

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## ***PHEIDIAS project as an innovative step in increasing the recovery of PGMs from automotive catalytic converter***

Increasing public awareness about low emission and stricter standards has a significant impact on the industry. The use of catalytic converters provides one of the solutions to the problem of lowering the amount of exhaust fumes. As most catalytic converters contain a combination of the three metals; Platinum (Pt), Palladium (Pd), and Rhodium (Rh) the manufacture of catalysts for automobiles is the largest sector of demand for and consumption of PGMs (Platinum Group Metals). Spent automotive Catalytic Converters (SCCs) are a significant, in terms of both volume and value, secondary source of Platinum Group Metals (PGMs). A single SCC weight ~800g and contains approximately 2g of precious metals, while extracting Platinum Group Metals from 1 kg of ore gives only 0.002 g and by 2022 there will be about 900.000 End of Life Vehicles (ELV) that will contain significant quantities of PGMs that can be reused. Heavy duty vehicle spent catalysts and diesel particulate filters could also be a valuable pool for devices to extract Pt and Pd, since they contain 3–5 times more PGMs than the light duty vehicles.

PHEIDIAS aims to bring into the market an innovative hydrometallurgical process for the recovery of Platinum Group Metals (PGMs) from Spent Catalytic Converters (SCCs). The competitive advantage of this technology is the increased material recovery rate (100% for Pt, 95% for Pd and 61% for Rh) in a single step, low acidity process where high amount of processed catalyst can be elaborated with low volume of low acidity generated water wastes as well as significantly lower operational costs. What is more, the technology uses solvents in low concentrations, which improves waste management performance.

PHEIDIAS foresees revenues from both selling the PGMs recovered, for which demand and prices are still increasing (Pt +165,68%, Pd +467,26% and Rh 1.490,30%), as well as from selling access to the technology and know-how through licensing. To that end, the partnership will also develop a Go-To-Market strategy and establish commercial networks and collaborations in the aforementioned markets, primarily with the car maintenance and recycling industry.

Mineral and Energy Economy Research Institute of Polish Academy of Sciences (MEERI PAS) as a project partner is currently in the process of preparing a report about the characterization of SVCCs that will include a chemical and mineralogical analysis, a granular analysis and specific surface determination of catalysts. Moreover, MEERI PAS is preparing a database of catalysts available in Poland and supervises the collection of catalysts by other partners of the project. These catalysts will be used for further analysis in the development of catalyst PGM recovery technology.

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## ***The influence of co-fermentation of agri-food waste with primary sludge on biogas production and composition of the liquid fraction of digestate***

An important element of the circular economy (CE) can be wastewater treatment through the use of industrial waste products, recovery of natural resources and energy. In recent years, there has been an upward trend in the production of “green” energy (including biogas) in Poland. The CE concept includes biogas plants located at wastewater treatment plants (WWTP) (i.e. municipal biogas plants), especially in facilities processing sewage sludge in anaerobic digesters (with final post-fermentation management). The advantage of locating a biogas plant in this place is, first of all, the year-round availability of the raw material (in the form of primary sludge or excess activated sludge). In addition, agricultural and municipal waste going to WWTP can be a complementary source for biogas production, increasing its total production. It can be a form of energy reserve that contributes to the improvement of the WWTPs energy balance. A potential problem with the use of co-fermentation is the increase in nutrient concentration in the leachate of the dewatered digestate. This is especially important in the case of nitrogen which, returning to the main sewage treatment line, increases the energy consumption for aeration. Moreover, the leachate may be characterized by an increased concentration of organic nitrogen, which can increase its concentration in the treated wastewater.

The aim of the study was to determine the effect of co-fermentation of waste from the agri-food industry on the amount of biogas production in connection with the change in nitrogen concentration in the leachate from digestate dewatering. Particular attention was paid to the organic nitrogen fraction (dissolved – DON, colloidal – CON and particulate – PON). Four tests were performed during the laboratory scale tests. Various reactor batch materials were used in the tests, which made it possible to analyze the influence of each components used in the co-fermentation process. The research used inoculum and primary sludge from WWTP Swarzewo, fish production flotata and a mixture of vegetable waste (cabbage, beans, onion).

It was shown that the substrate in the form of a vegetable mix contributed to a further increase in biogas production in relation to the test with the addition of flotata (7% increase of biogas production). At the same time, the addition of fish flotata and a mixture of vegetables significantly influenced the content of the organic nitrogen fraction in the effluents from digestate dewatering. Among the organic nitrogen fractions, the colloidal fraction (CON) and the dissolved fraction (DON), followed by the particulate fraction (PON), take the highest final values. The obtained concentrations were 3 times higher for the CON fraction and 5 times higher for the DON fraction compared to the values presented for the liquid fraction of the digestate from large municipal biogas plants located in WWTPs, in which only the sludge generated during wastewater treatment is fermented.

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## ***Preparation of an innovative bifunctional Cu,Zn/Al<sub>2</sub>O<sub>3</sub> catalyst for the hydrogenolysis processes***

In recent years, hundreds of tons of glycerol appeared on the chemical market, which is a by-product of the biodiesel production process. That is why it is important to find a way to re-use it. One of the possibilities is to use glycerol as a raw material for the production of propane-1,2-diol (propylene glycol), which is extremely desirable in the food, cosmetic and pharmaceutical industries especially in European Pharmacopeia quality. The use of glycerol for the production of propylene glycol fits in with the trends of the “green chemistry”, competing with the typical propylene glycol production technology that uses petrochemical products.

The main aspect of the research was the preparation of the stationary doped catalyst used for obtaining propylene glycol from glycerol. Catalyst Cu,Zn/Al<sub>2</sub>O<sub>3</sub> was prepared by extruder machine. Obtained catalyst was tested using thermoprogrammable methods (i.a. TPR-H<sub>2</sub>), surface analysis method (BET). The glycerol hydrogenolysis process was carried out in a trickle bed reactor and the obtained products were analyzed by gas chromatography (GC-FID).

The obtained catalyst is characterized by a high degree of dispersion of the active phase on the surface. In the hydrogenolysis reaction, glycerol has a high selectivity (95%) towards the production of propylene glycol as well as high activity and stability. Due to the use of an innovative preparation method, it exhibits high mechanical resistance and a low degree of leaching of the active phase from the surface.

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## ***Proposed indicators for monitoring the circular economy in the chemical industry in Poland***

The chemical industry, which consists of the chemical and fuel segment, is a key sector of the Polish economy, accounting for a significant part of domestic exports. It is closely related to other industries, and the manufactured products are used in virtually all areas of the economy. In order to appear on this market, companies must, however, demonstrate innovative solutions. Automation, robotization and computerization of production play an important role. Modern organizational solutions and innovative processes using e.g. biotechnology have already been implemented in many enterprises. However, it is important to reduce post-consumer waste through its reuse, recovery and recycling. This approach requires a broad view and monitoring of the material flow from the design process to final disposal and reuse. The aim of the work is to identify and propose circular economy monitoring indicators in the chemical sector in Poland.

In order to analyze and select the circular economy monitoring indicators for the chemical industry, the literature and reports on the activities of enterprises were reviewed. Key indicators for enterprises from the chemical sector were selected on the basis of a review of indicators proposed under the GOS-POSTRATEG – Oto-GOZ project by the The Division of Strategic Research at the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences. In order to verify the proposed set of circular economy monitoring indicators, a survey questionnaire was developed with a set of 25 pre-selected circular economy monitoring indicators in terms of three basic aspects: environmental, economic and social.

Circular economy can significantly affect the shape and development prospects of the industry and stimulate the activity of enterprises, improving the competitive position on global markets. Selected indicators may be classified as potential indicators for CE in the chemical industry. The proposed indicators in the longer term may constitute the basis for application in other industries of key importance for the development and transformation of circular economy in Poland.

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## ***Safety analysis of the installation for biofuel production from municipal solid waste as an important aspect of the BioRen project***

The average European generates over 500 tons of municipal waste. Municipal solid waste contains a significant amount of biomass that can be used as feedstock for second generation biofuels. In contrast, the production of biofuels from agricultural crops such as sugar cane and corn is putting increasing pressure on available land for food crops. Therefore, work is currently underway to investigate the feasibility of biofuel production from the organic fraction of municipal solid waste within the Bioren project. The BioRen team will develop a process that will extract the biomass fraction from municipal solid waste and use it as a feedstock to produce bio-ethanol and bio-isobutanol, which when further processed will result in bio-GTBE, a diesel additive that improves engine performance by improving combustion characteristics and thus reducing harmful emissions. The BioRen Team will develop a process that separates the biomass fraction from Municipal Solid Waste and uses it as feedstock to produce bio-ethanol and bio-isobutanol that after further treatment will result in bio-GTBE, which is fuel additive for diesel to improve engine performance by improving its combustion characteristics thereby reducing harmful emissions.

The objective of BioRen is to develop techno-economical competitive drop-in biofuels for road transport from the organic fraction of municipal solid waste (OFMSW). A higher value fuel is targeted: glycerol tertiary butyl ether (GTBE) is a promising fuel additive to both diesel and gasoline that improves engine performance and cuts harmful exhaust emissions (i.e. fine dust). It can be blended in higher amounts than e.g. ethanol, without having to change the engine. Bio-ethanol and bio-isobutanol from OFMSW are required intermediaries in this innovation path towards GTBE. Their specific business case as second generation drop-in fuel will be compared to the bio-GTBE business case, to select the most sustainable option for building a demo plant. Second generation biofuels would be a major next step towards a more circular future for the transportation sector as a whole. The current state of the industry is mostly at first generation biofuels, whereas the ambition of Bioren goes beyond this state. Project is continuously monitored by LCA, techno-economic, market and regulatory analysis in order to come up with a realistic business plan. The developed processes will be integrated in a revolutionary MSW treatment plant that combines the most efficient technologies of material reuse, and is currently looking into optimising the profitability of its organic waste fraction.

MEERI PAS, as project partner, is currently responsible for preparing a safety analysis report on the functionality of the entire plant. The issue of security and safety in the whole value chain issues is complex and it will be considered regarding human health and safety. For human health and safety, an analysis will be conducted according to the following steps:

- identification of hazards for each stages of the proposed technology,
- risk assessment, by estimating the parameters of probability and consequences,
- proposals to eliminate, prevent or reduce risks by changing working environment, reducing the time of exposure to threats (changing technology or the organization of work), the use of personal protective equipment, development of procedures for the safe performance of duties despite the risks.

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Therefore, safety analysis will cover all above aspects and will be prepared according to the following steps:

- formulate a safety and security strategy,
- conducting a risk assessment,
- developed a plan to manage and reduce identified risks.

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## ***International cooperation for Rational Use of Raw Materials and Circular Economy under the International Academic Partnership Programme announced by the National Agency for Academic Exchange***

The project “International cooperation for Rational Use of Raw Materials and Circular Economy under the International Academic Partnership Programme” is implemented in 2019–2021 by the The Division of Strategic Research at the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences. The aim of the project is to analyze and develop a methodology in an international partnership economy demand for mineral resources in Europe, while increasing mobility of young scientists, establishing and maintaining international cooperation and making the obtained research results public. The project partners are leading research centers from Germany, Norway, Sweden and Latvia.

The result of the project is to develop a method of economy demand for mineral resources, taking into account: changes in the national economy (e.g. assessment of the demand by selected industry sectors, development of innovation and new technologies, planned changes in the development of the country), European (e.g. megatrends and assessment of raw material flows based on material system analysis and material flow account), security of supplies ensuring the development of advanced high-tech technologies. The analysis of trends and dynamics of the development of demand is carried out in the short and long term. The developed methodology will allow to predict the size of the demand for selected raw materials minerals and development of development scenarios depending on trends in the European economy and conditions on international raw material markets.

For the European Union (EU), the shortage minerals is a particularly worrying problem – countries are dependent on imported minerals metallic and metals needed in high-tech productions. The rapid development of the world economy requires answers on the availability of primary and secondary minerals necessary for functioning of individual sectors of the economy. Lack of appropriate standardization and methods, that would enable material flow management is a barrier to efficient use raw materials on the European market. The project results will be important for the implementation of the strategy development and EU raw material policy.

The effects of the project will contribute to the promotion of innovative technological solutions, which requires the involvement of interdisciplinary promotional teams solutions and products in the country and abroad.

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## ***Development of a system of measurement indicators to assess the progress in transformation towards a circular economy and its impact on socio-economic development at the meso (regions) and macroeconomic (national economy) project – oto-GOZ***

The objective of the oto-GOZ project is to develop a set of measurement indicators enabling assessment of the progress in transformation towards a circular economy (CE) and its assessment the impact of the economy on socio-economic development at the meso (regions) and macroeconomic (national economy) level.

The project is implemented by the Consortium, whose project leader is the Ministry of Development and partners: Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, the Central Statistical Office and the University of Economics in Krakow.

The project is implemented in two phases: research (phase A) and preparation (phase B).

As a result of the research phase, a definition of circular economy adapted to Polish conditions was developed, areas of circular economy of priority for socio-economic development were identified, and measures and indicators relating to CE were developed.

In the phase of preparing the results of scientific research for practical application, the developed CE indexes will be tested and implemented in selected Polish planning documents at the local level (in the strategy of the city of Krakow and Krakowski Holding Komunalny SA), regional (in the strategy of the Małopolska Voivodeship) and national (integration with the Road Map). Transformation towards circular economy).

Currently, there is no comprehensive and adapted to Polish conditions proposal of aggregated indices measuring the transformation towards circular economy, as well as its impact on socio-economic development.

The presented project is to fill this gap and meet the expectations of the Commission European Union on the development of national instruments in this area. The project used a combination of qualitative and quantitative research methods in order to best adjust the indicators of circular economy to the social and economic conditions of Poland.

The result of the project is the development of circular economy indexes, which will be implemented in planning/strategic documents at the regional and national level, which will result in faster socio-economic development of the country and enable monitoring of the transition from a linear economy to a circular economy.

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## ***Enhancement of methane production from maize silage via hydrodynamic disintegration***

In agricultural biogas plants treating biodegradable fractions of waste in the process of anaerobic digestion, increasingly more attention is paid to the pre-treatment of the substrate introduced to anaerobic digesters. Appropriate preparation of the feedstock permits an increase in the efficiency of anaerobic digestion, resulting in actual profit in the form of a greater amount of produced biogas or/and its better composition (higher content of methane in biogas). One of the methods of waste pre-treatment is mechanical disintegration, aimed at an increase in the bioavailability of substrates for bacteria performing acetogenesis and methanogenesis. Materials and Method.

The maize silage used in the study was obtained from an agricultural biogas plant (Poland). The disintegration process employed a newly designed hydrodynamic disintegrator [patent application: WP-84/JW 13766118, 27.12.2018]. The process was conducted at variable electricity consumption defined as energy density ( $\epsilon_L$ ): 10, 20, and 35 kJ/l. Before conducting these processes, the substrate was diluted with stood tap water to total solids concentration at the level of 5%. Biochemical methane potential tests (BMP) were performed in an AMPTS (Automatic Methane Potential Test System) device in accordance with the methodology by Holliger et al., 2016 with the assumption that the inoculum load equals 5 gVS/l.

The results presented in Figure 1 indicate that hydrodynamic disintegration increased the specific methane potential (SMP) of maize silage. Moreover, the energy density at which the disintegration process was conducted was found to be an important parameter affecting the specific methane potential. A maximum SMP of 492 Nm<sub>l</sub>CH<sub>4</sub>/gVS was recorded for  $\epsilon_L=10$  kJ/l and this was 34.4% higher than the value obtained for the untreated sample (366 Nm<sub>l</sub>CH<sub>4</sub>/gVS). The application of increasingly higher energy density in the hydrodynamic disintegration process caused a lower increase in the SMP of maize silage by 27.0% and 21.6%, respectively, for samples disintegrated at  $\epsilon_L$  of 20 kJ/l and 35 kJ/l.

Considering the above, hydrodynamic disintegration is a promising method of pre-treatment of maize silage before its use as substrate in the anaerobic digestion process. Based on the results, it is recommended to conduct the disintegration process of maize silage at the energy density equal to 10 kJ/l.

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## ***Effect of the addition of eggshell power on the nutritional and physicochemical properties of teff bread or injera***

Ethiopia is a country where 44% of the child population suffers from malnutrition and stunted growth due to a low calcium deficit in the diet based mainly on cereals and legumes. In response to the malnutrition problem, this work addresses a solution by improving the diet through the enrichment of the injera with eggshells powder (EP).

The methodology carried out in the physicochemical analysis in this work was according to official standard methods, for pH the official method AOAC 943.02 for the pH of flour, for titratable acidity was used potentiometric method described in the UNE 34-211-81, in the case of color measurement was used a digital Digieye. In other hand, the nutritional analyses were carried out using the official AOAC 985.35 method for total calcium and the INGOGEST in vitro digestion method.

In relation to the results, the addition of different treatments in the injera did present significant differences  $p\text{-value} < 0.05$  in the physicochemical parameters of pH, color and titratable acidity where significant differences were observed in pH between each individual treatment and their interaction. The 4.5% and 9% EP samples obtained the highest pH levels in each of the treatments, observing that the higher the degree of fermentation, the lower the pH value in the samples.

For the same treatment, acidity values increased as fermentation time increased, showing higher values in the control at 48 hours of fermentation. On the other side, the highest  $L^*$  values were found in the control samples in relation to the different fermentation times. High  $L^*$  values refer to a brighter grape and low  $L^*$  values are related to a darker grape.

Regarding the nutritional level, the control sample had a 6.8% bioavailability and the addition of (EP) presented an increase of 39% for (S45) and 40% for (S9). Considering the daily consumption of injera in Ethiopia, it was obtained that the addition of (EP) of (S45) would be insufficient to reach the recommended calcium daily intake with a bioavailability percentage of 31% and the addition of (S9) gave an intake of 644mg of calcium above the recommended daily intake value with a bioavailability percentage of 32%.

In conclusion, it is a solution to mal nutrition and child development deficits since the addition of EP does not detract from the quality and enhances the bioavailability of the mineral. However, requires the evaluation of other different treatment level to reach the recommended daily calcium values and also requires a safety study and a sensory evaluation to assess whether EP fortification has an impact on the acceptability of the teff bread.

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## ***Batteries recycling and environmental passport***

Batteries play an important role in realization of the energy transition and broadening energy access around the world. What is more, they are used to decarbonize road transportation and support the transition to a renewable power system, keeping global emissions on track to stay below the 2°C Paris Agreement target. Besides decarbonization, batteries also contribute to the UN SDGs by bringing energy to the people without access to electricity. Demand for lithium-ion batteries is constantly growing, which is proven by large adoption of batteries and other energy storage solutions. Experts predict that this growth trend will continue. Since batteries have a limited lifetime, the number of end of life Li-on cells will also increase. This raises concerns about managing such a large amount of waste in a sustainable way. Left unchecked, this could create serious economic and environmental consequences.

Currently, battery recycling rate is insufficient to process such an amount of end of life batteries. Therefore, efforts should be heightened across industry in order to reduce discrepancy between battery usage and recycling rates and reusing. To make it possible in 2020 the EU Commission has proposed new regulations on batteries in line with the circular economy strategy, which contributes to the protection, preservation and improvement of the quality of the environment by minimising the negative impact of batteries and waste batteries. This regulation aims to ensure that batteries placed in the EU market are sustainable and safe throughout their entire life cycle, which is crucial to achieve the objectives of the European Green Deal. The Commission set new requirements and targets for the content of recycled materials and for the collection, treatment, recycling and reusing of batteries after reaching their end of life. This would ensure that the batteries remain useful even after their service life has expired and that the valuable materials will remain within the economy.

To streamline the process, the concept of battery's passport has been introduced. It will work as a type of quality seal on a global digital platform for sharing value chain data of batteries. This innovative tool aims to enable the user to verify the battery's material provenance and measure the sustainability and environmental impact of the battery. The use of battery passports and new information technologies such as blockchain will be key to secure data exchange, increasing the transparency of the battery market and traceability of batteries throughout their life cycle. This will enable manufacturers to develop innovative products and services implementing eco design as part of a dual transformation- ecological and digital. In addition, such a solution would enable recyclers to better plan and improve recycling technologies, as well as facilitate the reusing of batteries from electric vehicles, e.g. as stationary energy storage systems.

This work includes comparison between Italian and Polish battery market, regulations and perspective for development. Moreover, sustainable practices within the battery sector have been investigated as well as the access to the information about batteries, based on CSR reports and data presented by manufacturers, that may be the basis for implementation of environmental passports.

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## ***Possibility of application of membranes in geothermal systems for lithium production***

Lithium is becoming one of the most critical raw materials in a modern economy. It is a crucial component for Li-ion batteries which power devices like smartphones, laptops, electric vehicles and help in energy storage. The European Commission forecast that up to 2030 utilization of lithium increase 18 times and up to 2050 60 times (in comparison to 2020). Simultaneously, Europe does not have any significant resources of that raw material. Therefore, addiction to the import of lithium (lithium carbonate or lithium oxide) and geographic concentration (Chile has ca. 78% share in the market the second are the USA and third Russia) could be a big danger for the development of emission-free technology. Because of that, lithium compounds are on the Critical Raw Material List published by the European Commission.

The necessity of reducing carbon dioxide emission force mankind to look for more sustainable energy resources. One of them is geothermal energy which is more stable than the wind or solar energy. Moreover, that energy resource could be also a reservoir of valuable minerals and elements like zinc, silica, boron, and lithium. We have estimated that in Poland, one well could produce about 10% of the country's demand for lithium compounds (ca. 35 tons of lithium carbonate). Because of that and the fast-developing geothermal sector, hot water could be a significant source of raw material for industry.

Unfortunately, it is uneasy to extract lithium from brine. Numerous impurities disturb in production of feedstock. Also, relatively low concentration is inconvenient. We would like to use membranes for selective brine separation during the nanofiltration and membrane distillation process. Because of the size and charge of cations, lithium is one of the fastest elements transported by the pores of the membrane. Moreover, a typical geothermal plant is working under 30 bars of pressure what is also an ideal condition for that membrane process. A small amount of permeate would be directed to a concentrator (membrane distillation plant) where lithium with other compounds and water would be separated. In the next stage, highly concentrated brine is filtrated again as long as lithium concentration reaches demanding purity (over 99%). Another goal for such a way of production is a mitigation amount of chemical compounds using because driving forces are strictly physical. The process will be utilizing a lot of heat from geothermal installation, therefore the impact on the environment will be significantly reduced compared to conventional processes. Up to now, our theoretical considerations and literature review show that it could be an efficient method for lithium mining but only as an accompanying process for geothermal plants.

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## ***Research on the technology of manufacturing traction accessories based on copper scrap***

The traction equipment is made on the basis of pure copper in the form of alloys for example CuNi<sub>2</sub>Si and CuZn<sub>37</sub>Ni<sub>1</sub>Si<sub>0.5</sub>. The conducted research work was focused on the development of a technology enabling the use of exhausted traction scrap for the production of new railway and tram equipment. The basic materials used for metallurgical synthesis in the research work are contact wire scrap and carrier ropes, which are usually made of pure copper. In the first stage of the research, the degree of contamination of scrap materials was estimated, which may adversely affect the properties of the new materials. As part of the research work undertaken, a full analysis of the chemical composition of residual surface contaminants was carried out under a scanning microscope, the thickness of the layer of contaminants on scrap materials was assessed under an optical microscope, and an analysis of the chemical composition after melting individual scrap materials was carried out. On the basis of the obtained results, it was possible to select an appropriate method of scrap cleaning, allowing for their direct use during metallurgical synthesis of alloys intended for traction accessories. The presentation presented the first results of own research, which were necessary at the first stage of the research. On their basis, a scrap cleaning method has been developed that allows for the removal of most of the contaminants on their surface.

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**ORAL SESSION III:**  
***Environmental Protection***

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## ***Natural zeolite as a precursor of the catalyst for the reduction of nitrogen oxides from tail gases in a nitric acid plant***

Nitric acid (HNO<sub>3</sub>) is one of the most important chemicals used for the production of fertilizers, caprolactam, or dinitrotoluene. However, during its production, a large amount of NO<sub>x</sub> is produced. The most widespread method to abate their emission is selective catalytic reduction with ammonia (NH<sub>3</sub>-SCR). Nevertheless, the commercial catalyst of this technology – V<sub>2</sub>O<sub>5</sub>-TiO<sub>2</sub> causes many problems, such as generation of N<sub>2</sub>O or the necessity of re-heating of the exhausts to provide sufficient activity. Therefore, the presented work covers the analysis of the catalytic performance of the substitutive catalyst, based on natural zeolite (clinoptilolite) modified with iron. The choice of this kind of material was motivated by the excellent thermal stability of the zeolite, its considerable surface acidity, and high abundance in the environment.

The iron-modified clinoptilolite (Fe-Clin) was prepared according to two routes. The first sample was protonated with HCl, while the second with HNO<sub>3</sub>. Additionally, HNO<sub>3</sub>-protonated material was formed, while the first remained in a powder form. The catalytic tests over both materials in their powder form were performed using model gas containing NO, NH<sub>3</sub> and O<sub>2</sub> in He. In addition, one of the samples was tested in the real tail gases stream from the pilot nitric acid plant containing NO, NO<sub>2</sub>, N<sub>2</sub>O, and O<sub>2</sub>. In order to reflect appropriately the industrial conditions, various compositions of the gases, temperatures of the reaction, and GHSV values were considered. Additionally, physicochemical properties of the materials were analyzed.

On the basis of the obtained data, it can be assumed that the tested material can be possibly a competitive catalyst for V<sub>2</sub>O<sub>5</sub>-TiO<sub>2</sub>. The catalysts' performance was highly satisfactory, regardless the synthesis procedure. The reduced amount of synthesis steps and low-cost modifications are undeniably attractive from the economical point of view. Moreover, the proposed catalyst can be utilized not only in nitric acid plants, but also in power plants and coke plants.

It was observed that both non-modified clinoptilolite and clinoptilolite doped with iron exhibited highly satisfactory catalytic activity in DeNO<sub>x</sub> process in range of 250–450°C, that stands for the temperature scope of the work of nitric acid plant installation. The support exhibited 58% of NO reduction at 450°C. It suggests that the selected zeolite naturally contains catalytically active species. When the model gas was applied, both of the samples were highly active, especially above 250°C. Regardless of the selected protonation route, both materials promoted with Fe did not emit N<sub>2</sub>O that is by-product of the process.

The obtained results of characteristics of the catalysts and the catalytic experiments indicated that clinoptilolite is an appropriate precursor of the novel catalyst of NH<sub>3</sub>-SCR. Independently on the applied modifications and the reaction conditions, the catalytic performance remained on a satisfactory level. Therefore, the proposed material can be used as an eco-friendly substitute of the commercial, problematic system.

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## ***Chemical reactions in high-temperature water using mathematics and physics concepts***

A mathematical model for the primary chemical process occurring in 1 J/pulse electrical discharge in water has been developed. The discharge channel is divided into two zones: The core and recombination region. The core is a very narrow (ca 10  $\mu\text{m}$ ) part of the channel where high temperature initiation reactions take place and where the majority of molecular hydrogen and 47% of the molecular oxygen are formed. The recombination region is a 200  $\mu\text{m}$  radius zone where additional reactions such as hydrogen peroxide formation take place. The temperature in the core ranged from 5000 K at the centre to 2000 K at the boundary and the pressure. The only adjustable parameter in the system was found to be 14 atm. The model describes for the first time how molecular oxygen is formed in an underwater discharge and it is also able to describe the experimental observed stoichiometry of  $\text{H}_2$ ,  $\text{O}_2$  and  $\text{H}_2\text{O}_2$  formation. The concentration and temperature profiles inside the discharge channel as well as a general scheme for the water dissociation and molecular species formation are also reported. There have been few studies in the literature that closely examined the different potential influences of High temperature – water (HTW) on chemical reactions. Although the existing reviews and overviews of reactions in aqueous media include some discussion of solvent effects, in none of these reviews is the focal point the role of the reaction medium. This previous treatment of this topic is neither complete nor critical.

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## **Zero-valent iron, hematite and magnetite as co-catalysts in advanced oxidation processes application for cosmetic wastewater treatment**

The aim of the research was to develop effective method for the treatment of cosmetic wastewater, which contains compounds that are difficult to remove, resistant to biochemical decomposition, no susceptible to biodegradation and toxic to the environment, using catalytic advanced oxidation processes (AOP). The heterogeneous Fenton process used in the study is an efficient method that can be applied for industrial wastewater pretreatment before the biological process, to decrease harmful compounds. The wastewater is formed during the stage of cleaning of the cosmetics production plant. The research innovation is based on the obtained efficiency of joint action of Fe<sup>0</sup>, Fe<sub>2</sub>O<sub>3</sub> and Fe<sub>3</sub>O<sub>4</sub> as mutually supporting catalysts. For the first time, it used synergy effects in the treatment of industrial wastewater by the AOP method.

Catalyst compounds applied in the process came from Hepure and Kramer companies and can be widely used in industry. An effective technology was developed on basis of process parameters optimization: change of pH (2.0, 3.0, 4.0, 5.0 and 6.0), reagents mass ratios (H<sub>2</sub>O<sub>2</sub>/COD 1:1 and 2:1), catalyst doses (total mass: 4000, 2000 and 1000 mg L<sup>-1</sup>), process duration (15, 30, 60 and 120 min), catalyst ratio (Fe<sup>0</sup>/Fe<sub>2</sub>O<sub>3</sub>/Fe<sub>3</sub>O<sub>4</sub>) and application of additional energy sources (UV radiation). To effectively treatment and compare the effectiveness of the catalysts used in the process it was necessary to determine the optimal dose of reagents and conditions of the process.

The experimental part of work included determination of physicochemical wastewater parameters such as chemical oxygen demand (COD), suspended solids (TSS), nitrogen compounds, five-day biochemical oxygen demand (BOD<sub>5</sub>) and Total organic carbon (TOC) before and after the treatment process as well as the performance of wastewater treatment process from an industrial plant located in Poland. The head space-solid phase micro extraction-gas chromatography-mass spectrometry analysis was also analyzed.

The highest efficiency of the lightless process was obtained with the use of significant advantage of metallic iron and a comparatively lower dose of hematite and magnetite (the quantitative ratio of the compounds was 1500/250/250 mg L<sup>-1</sup>). The amount of TOC decreased from 306.3 to 134.1 mg L<sup>-1</sup> (56.2% TOC removal), after 120 minutes of treatment for a 1:1 mass ratio of H<sub>2</sub>O<sub>2</sub>/COD and 1000/500/500 mg L<sup>-1</sup> Fe<sup>0</sup>/Fe<sub>2</sub>O<sub>3</sub>/Fe<sub>3</sub>O<sub>4</sub>. The UV-assisted process was more effective than the lightless one. In a series of studies with UV/Fe<sup>0</sup>/ Fe<sub>2</sub>O<sub>3</sub>/Fe<sub>3</sub>O<sub>4</sub> for a 1:1 mass ratio of H<sub>2</sub>O<sub>2</sub>/COD the largest decrease in TOC concentration was achieved by using a mixture of individual catalysts in equal proportions of 1000 mg L<sup>-1</sup> Fe<sup>0</sup>, 500 mg L<sup>-1</sup>, Fe<sub>2</sub>O<sub>3</sub> and 500 mg L<sup>-1</sup> Fe<sub>3</sub>O<sub>4</sub>. The TOC concentration was decreased from 306,3 mg L<sup>-1</sup> to 178.97 mg L<sup>-1</sup> (58.4% removal). The chromatographic results obtained confirmed the efficiency of decomposition of various chemical compounds. The decamethyltetrasiloxane or decamethylcyclopentasiloxane

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and fragrances like galaxolide characteristic of cosmetics wastewater were not detected after treatment. The kinetics of the process were described by the modified second-order model. Based on ANOVA results, we have confirmed the hypothesis regarding the accuracy and reproducibility of the research.

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## ***SamplAir – stratospheric sensing of air pollution***

Due to the rapidly increasing pollution of the air, monitoring its quality has become a serious issue. Despite this, there exists very little research which gathers in-situ samples of air from various altitudes and analyses them in laboratory setting. Facing this problem, our team has designed a prototype of a device dedicated to direct sensing of different environmental parameters and collecting air samples from different altitudes above the ground, up to 35 km. In this work, the device was prototyped using FDM 3D printing technology. The device allows for collection of eight environmental samples (including particulates suspended in air) for further laboratory analysis. The prototype utilises a centrifugal turbine to draw surrounding air into an 8-position selector mechanism which contains 8 cartridges with appropriate filters to capture atmospheric pollutants. The device has been designed to open each cartridge at one of 8 predetermined altitudes above the ground and collect solid particulates onto the alumina oxide sterile filter with 200 nm pore size. During the flight of the mission, various environmental parameters were logged by the on-board sensors. The prototype was equipped with multiple cameras, capturing imagery of the environment and of itself for engineering and analysis purposes. During the test flight, the device has achieved altitude of ~19km above the Sea Level, and safely returned back to Earth.

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## ***A proprietary application engaging Polish businesses and individuals to take action towards green transformation***

The Carbon Footprint Calculators created by the Carbon Footprint Foundation are one of the most specific tools designed for the use of Polish businesses and individuals. The primary purpose of the calculators is to determine the magnitude of the impact of individuals (Calculator 1.0) and office spaces (Calculator 2.0) on the environment. The impact is calculated in the amount of carbon dioxide equivalent emitted to the atmosphere due to specific actions taken by the organizations or individuals.

The Calculator 2.0 for office purposes considers all the processes in an office that generate carbon emissions. It is divided into two sections, one for the manager and one for the employees. The manager section calculates the emissions from energy consumption and processes that are not dependent on individuals. The employee's section considers the individual behaviours such as the specific use of work time (amount of electric devices, emails sent, etc.), dietary habits, transport to, from work and during working hours, paper use, and others. All of this information is used to estimate the amount of carbon dioxide equivalent that the company emits in tonnes. Additionally, the company receives personalized recommendations on how to effectively reduce their carbon footprint and what to change to make the changes noticeable.

The Calculator 1.0 was created for the use of individuals. It calculates carbon dioxide equivalent emissions from 6 main categories. These include household energy use, transport, waste generation and management, food consumption, entertainment and everyday life activities. In its over 50 question review, the calculator gives an overview of the complete carbon footprint of an individual. Even though the primary goal is to educate Polish citizens on their impact on the surrounding environment, the tool can be used in companies to spread awareness and increase the spirit of employees towards implementing sustainable practices at work. The result received by the user is a set of recommendations of measures that can be implemented to decrease one's carbon footprint.

The innovation of the Carbon Footprint Calculators is primarily based on precision. The calculations are supported by a thorough literature review, and the final results are the starting point for implementing the recommended changes.

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## ***MOOC education as a key tool in gaining sustainable development. The Erasmus+ Project experience***

Nowadays, in view of climate change, increasing environmental pollution and scarcity of natural resources, it is necessary to educate, raise the awareness and qualification in these topics. Education is a powerful and key tool for achieving a sustainable world, promotes the development of the knowledge and skills that ensure environmental protection. It is also in line with demands of UNESCO Agenda for Sustainable Development. Education for All has been and is a core issue of European and international sustainable development.

Online education has become an easily accessible learning tool to all, offering everyone equal opportunities to access the knowledge and instructors. To reach adults in all life stages, the UNESCO give high priority to Open Distance Learning tools. One of the platforms offering e-learning is Massive Open Online Courses which provide mass learners open education services. MOOCs are changing the way learning and teaching as well with the help of electronic resources. The proper use of MOOCs can ensure that student can gain knowledge more efficient and practically, which in long-term view can make more benefits for students and teachers, as well as leads to more sustainable development. The joint German–Hungarian–Polish–Romanian Project “MOOC4all” in the Erasmus+ Founding Scheme develops European educational concept as a MOOC. Elaborated under the Project courses will familiarize the recipients with the fundamental knowledge of geothermal energy, solar energy, and themes related to waste management and the environmental protection.

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## ***Probiotic-based non-dairy innovative food as future foods***

Purpose of the research: the review of the literature and gathering data to (i) developing an innovative non-dairy potentially probiotic product dish and (ii) the assessment during in vitro digestion in the artificial gastrointestinal tract i.e. survival of selected beneficial bacteria and nutritional value of the product.

Methods: the literature review, selection and analysing the data.

Results: The health benefits of probiotics have been proven by recent studies, and functional foods containing probiotics are consumed in terms of both preventing diseases and protecting health. Most of the functional foods containing probiotics are from dairy sources. However, people who do not consume dairy products for various reasons cannot get benefit from these products. Non-Dairy probiotic products are preferred because they meet consumer's expectations, have good quality nutritional value. On the other hand environmental concerns of dairy products such as greenhouse gas emissions, the contamination of surface and groundwater due to poor waste management and the salinization of soils and unsustainability because of environmental externalities may lead the consumers to non-dairy and vegan products.

Besides, to have beneficial effects of probiotics, they must be resistant to digestive system conditions, colonized in the lower gastrointestinal tract and be in an adequate number. For the effects of probiotics to be understood, they must be monitored throughout the gastrointestinal tract. It is possible thanks to in vivo and in vitro studies. However, in vivo studies are quite expensive and complex. Developed in vitro artificial digestive systems are more reliable, have less ethical conditions and show promising results. The main difference between digestion systems is configuration. The most widely used models today the SHIME® and TNO artificial gastrointestinal models. Simulator of Human Intestinal Microbial Ecosystem (SHIME®) artificial gastrointestinal system that allows the examine complex intestinal microbiota for a long periods and under conditions representative for different intestinal regions.

As a result, it was found that cereal, legumes, fruits and vegetables have been extensively examined to design non-dairy probiotic foods; their nutritional value, sustainability, sensory properties and symbiotic relationship with probiotic microorganisms have beneficial effects while producing non-dairy probiotic products.

The application of probiotics in functional foods is common because of recent researches that explain the health benefits of probiotics. However, consumer expectations, environmental concerns and the food industry are looking for different kinds of probiotic-containing products other than dairy products. Non-dairy probiotic foods are more sustainable, nutritious and successful to meet consumer expectations.

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## **Low-temperature geothermal systems – a case study for Rabka-Zdrój**

Rabka-Zdrój is a very popular Polish health resort located in the Southern Part of the country. In the analyzed area, the problem of exceeding the limit value of harmful substance was defined for benzo(a) pyrene and particulate matter PM<sub>10</sub>. Therefore, the implementation of corrective action to improve air quality is necessary to provide the healing properties of the climate conditions. One of the proposed corrective actions is a diversity of the structure of the energy carriers in the municipality and consider low-temperature geothermal systems. The purpose of the work is to define and evaluate the major factors of the utilization of low-temperature geothermal systems in local conditions.

To assess the possibility of utilization of low-temperature geothermal systems the environmental, legal and technical aspects were considered. For the analysis data from the Polish Geological Institute (PGI) were used, including: Central Geological Database and Central Hydrogeological Database. Moreover, based on lithological profiles for selected boreholes determine the basic geothermal properties of rock and soils – the weight average thermal conductivity  $\lambda$  [W/m·K] and unit heat efficiency [W/m<sup>2</sup>]. Heat conduction coefficients and unit heat efficiency for individual lithological precipitates were adopted on the basis of literature data, also taking into account the moisture content of the deposits. Low-temperature energy potential was designed for different depth of vertical heat exchangers.

The low-temperature geothermal systems are an alternative source of energy for commonly used solid fuels. Application of proposed activities is possible to implement in Rabka-Zdrój and other Polish health resorts which struggling with air quality problem. The work presents a solution and a methodological approach that can be successfully used in other areas. To ensure the possibility of implementing the proposed solutions, it is necessary to conduct an educational campaign of the local community in the context of alternative energy sources and to present the possibilities of co-financing the replacement of the heat source.

In the range of set depth, the weighted average thermal conductivity coefficient varies from 1.55 to 2.36 – for 25 m depth; 1.93 to 2.41 – for 50 m depth and 2.06 to 2.43 – for 75 m depth. The high thermal conductivity ( $\geq 2$  W/m·K) of the rock substrate occurs in two boreholes from the depth 25 and 50 m and all boreholes from 75 m depth. The unit heat output vary between 41.1 W/m – in the central part of the research and 51.9 W/m – in the northern part up to a depth of 50 m.

In the area of the Rabka-Zdrój health resort, the air quality problem was defined, which occurs mainly during the heating season. Therefore, an important issue is to indicate the solutions which improve air quality and will be adapted to the needs of local governments and society. The assessment of the possibility to utilization low-temperature geothermal systems showed that in the area of the health resort occurs the potential for this technology. The weighted average thermal conductivity coefficient varies from 1.55 to 2.36; 1.93 to 2.41 and 2.06 to 2.43, respectively for the depth of 25 m, 50 m and 75 m. The presented results can be used by local government and the community. Implementation the low-temperature geothermal systems is way to increase the environmental values of the health resort and reduce air pollution.

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***POSTER SESSION II***  
***Environmental Protection***

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Uliana SEMAK\*

## ***Bioindication by the degree of leaves damage of woody plants***

The morphological reaction of woody plants leaves under the influence of man-caused factors of technological sites has different feature. There are such modifications of the assimilation apparatus in the technogenic environment like the reduction of morphometric sizes of leaves, changes in their shape, fall of leaves and others. The main morphological reaction is chlorosis and necrosis, which is the reason of the highest accumulative capacity against phytotoxicants. Occurrence of necrosis and chlorosis, which is a consequence of excessive contamination with phytotoxic compounds and indicates a crisis state of plant organisms, can be used as indicative features of plant organisms in a technogenic-transformed environment.

In our research we studied necrosis lesions of leaves of woody plants under the condition of man-caused factors of Burshtyn thermal power plant (TPP) ash and slag dumps.

Necrosis develops on the periphery of the leaf blades at the site of chlorosis. Plants growing on the territory of Burshtyn TPP ash slag dumps most often develop necrosis of the “fish skeleton” type, which indicates the highest level of accumulation of toxic elements by plants. Also observed asymmetric necrosis extending to half of the leaf blade.

CoralDRAW X6 software was used to measure the area of necrotic lesions of leaves. Selection data were greater than 1,500 leaflets.

In our research was detected different levels of necrotization under the conditions of growth on the ash and slag dumps of Burshtyn TPP and on the territory of references ecosystem (Galician national park). The highest degree of leaves damage was detect in *P. tremula*. Necrotic lesions occupies 2.98 cm<sup>2</sup> of leaves surfes. It take 18.65% of assimilation surface. At the same time, leaves necrosis of plant which grown without man-made factors is 0.1 cm<sup>2</sup>. Necrosis of *B. pendula* occupies approximately 2.05 cm<sup>2</sup> (14.1% of the leaves surface). While on the territory of references ecosystem it take 0,2 cm<sup>2</sup> of the assimilation surface. Degree of necrotization of *S. caprea* leaves occupies 2.44 cm<sup>2</sup>. Its aproximety 11.17% of leaves surfes. To compare with the references territory, where it takes 0,88 cm<sup>2</sup>, its more by 1.56 cm<sup>2</sup>.

We detected an increase on the level of necrotic lesions in the range from 18.65% to 11.17% under the conditions of growth on the ash and slag dumps of Burshtyn TPP. So, such parameters as degree of leaves damage can be use as bioindication marker of high levels of man-made load.

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Magdalena ZABOROWSKA\*, Katarzyna BERNAT\*\*, Magdalena ZIELIŃSKA\*\*

## **Co-existence of activated sludge and biofilm in sequencing batch reactors (SBRs) improved biological treatment of leachate from aerobic stabilization of organic municipal solid waste**

The increasing production of municipal solid waste (MSW) and limits in landfilling biodegradable waste have led to the application of a new strategy for waste management, i.e. mechanical-biological treatment. One of the most common solutions for the biological treatment of organic fraction of municipal solid waste, mechanically separated from MSW, is aerobic stabilization during which leachate, a waste by-product, is generated. The leachate is characterized by a high concentration of organics (17,298 mg COD/L), ammonium (823 mg N-NH<sub>4</sub>/L) and total Kjeldahl nitrogen (1,543 mg TKN/L). Thus, prior to discharge to the environment, the leachate should be treated. The leachate is commonly directed to the main stream of wastewater treatment system (mainly with activated sludge method), and constituted a few percent of this stream. However, it significantly increases the nitrogen and organic loads in the influent. In the present study, a mixture of real leachate from aerobic stabilization and synthetic wastewater (1:9 (v/v)) with a composition similar to that of municipal wastewater was used. The aim of the study was to determine the effect of the presence of carriers on the treatment efficiency of the leachate in SBRs. The use of carriers favors the conditions for microorganisms with lower growth yield, simultaneous nitrification and denitrification, and resistance to nitrogen shock loading and other environmental changes. R0 was operated only with activated sludge. In R1 and R2, the carriers were submerged, which resulted in the presence of suspended biomass and biofilm. In R1 carriers did not contain iron, and in R2 they contained 5% (w/w) iron in their structure. The iron ions would enable to generate the alternative group of microorganisms, such as Anammox, to improve nitrogen removal. Volumetric exchange ratio was 50% per cycle that consisted of filling (0.5 h), mixing (3 h), aeration (19 h), settlement (1 h), and withdrawal (0.5 h).

In all SBRs the high removal efficiencies of ammonium (ca. 98%) and COD (ca. 86%) were achieved. The average concentrations in the effluent did not exceed 1.5 mg N-NH<sub>4</sub>/L and 268.0 mg COD/L. The highest orthophosphate removal effectiveness was noted in R2 (ca. 93.5%), while the lowest in R0 (86.2%). The effluent concentrations of COD, N-NH<sub>4</sub> and P-PO<sub>4</sub> did not significantly differ in all the SBRs. In the R0, nitrate concentration was significantly higher (ca. 40 mg N-NO<sub>3</sub>/L) than in the R1 and R2 (15 and 21 mg N-NO<sub>3</sub>/L, respectively). Nitrite concentrations were very low (below 1.5 mg N-NO<sub>2</sub>/L) meaning that the nitrification intermediate product was not present in the effluents. There were no significant differences in the nitrite and nitrate concentrations in the effluents from R1 and R2. The presence of carriers with biofilm affected the efficiency of TN removal, whereas the presence of iron in carriers did not affect it. Lower DO concentration in reactors with carriers (despite aeration) favored TN removal. The effectiveness of TN removal in R0 was 39.2%, whereas in R1 and R2 it was higher, 67.8 and 61.6%, respectively.

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*Weronika URBAŃSKA\*, Magdalena OSIAŁ\*\**

## ***Challenges in waste management in the context of the COVID-19 pandemic***

The purpose of the presentation is to discuss the impact of the ongoing global COVID-19 pandemic on waste management systems. Statistical and scientific reports on changes in the quantitative and qualitative composition of municipal and medical waste, as well as the methods of its management in the context of the prevailing epidemiological situation, are presented and commented.

The COVID-19 pandemic has impacted significantly all aspects of people's lives. Its influence on the environment is also important. On the one hand, it might seem that a restriction of mobility and economic activity may have a positive effect on the natural environment (e.g. reducing air pollution), on the other hand, the fear for health and life has significantly contributed to the increased demand for personal protection products or disposable packaging.

Therefore, from the beginning of the pandemic, constant changes in the quantitative and qualitative composition of the generated waste have been observed, especially high increases in the amount of medical waste, but also paper and plastic packaging, which require appropriate processing using modern and innovative technologies. A particularly great challenge is faced by medical waste incineration plants, where it is required to ensure a sufficiently high capacity. Another challenge for waste management systems is to ensure the continuity of operations of waste management, processing and recycling, especially in the field of municipal waste collection. Moreover, previously rarely observed categories of waste appeared in the composition of municipal waste, i.e. used gloves or masks. There is also an increase in the amount of mixed waste stream. Another problem, especially at the beginning of the COVID-19 pandemic, was the method of collecting and collecting waste from people in quarantine or isolation. As a result, rules were developed for dealing with waste in such a situation, including packing waste in double bags, 72 h insulation before throwing the bags into containers or even stopping selective collection.

In conclusion, on the basis of the literature and various reports review, it can be concluded that the limitation of the current mode of functioning had a significant impact on waste management because many of the attitudes promoted so far have been disturbed by improving sanitary conditions and changing the behaviour of society (e.g. cessation of selective waste collection, limiting the use of reusable packaging etc.). Therefore, the most important challenge facing the current waste management systems is to adapt them to the prevailing situation while maintaining previously established directions of action and development.

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## ***Green composite based on organic core and magnetic shell for wastewater treatment***

Currently, the aqueous contamination by chemicals rapidly grows. As a result, many existing water sources have become polluted. Despite the fast development of water purification systems, a high level of water pollution requires efficient and cost-effective techniques for maximizing pollutant efficiency removal. In this paper, green material for pharmaceutical pollutants removal from the water was proposed. The composite based on organic core covered with magnetic nanoparticles was synthesized and characterized within several techniques. The morphology was investigated with Scanning Electron Microscopy. The chemical composition was confirmed with X-ray Photoelectron Spectroscopy and Fourier-Transform Infrared Spectroscopy. After characterization, the composite was used to remove organic compounds from water, including pharmaceutical compounds. This work proposes a low-cost composite based on non-toxic organic materials that couples nanotechnology and environmental studies.

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Weronika BOROWSKA\*, Olga ZAJĄC\*\*

## ***Biofilm vs activated sludge as a better environment for growth of nitrifying bacteria in the IFAS-MBSBBR***

Biogenic compounds are quantified as the most important component of wastewater. Bringing such substances into the environment, especially nitrogen compounds, adversely affects surface waters and organisms living in them. The reduction of nitrogen that enters the environment with treated sewage is one of the key objective of sewage treatment plants.

Nitrification is the central link of the conventional biological nitrogen removal process. Nitrification is usually a two-step process in which ammonia is oxidized to nitrate by two distinct groups of chemolithotrophic bacteria. In the first phase (nitrification), which is considered to be the limiting factor for the entire process, AOB bacteria (Ammonia Oxidizing Bacteria) oxidize ammonium to nitrite. In the second phase (nitration), NOB bacteria (Nitrite Oxidizing Bacteria) oxidize nitrite to nitrate.

One of the new and highly effective methods of wastewater treatment is the hybrid IFAS (Integrated Fixed-Film Activated Sludge) technology, based on the combination of activated sludge and biomass immobilized on carriers. Although hybrid technology combines both forms of biomass in one reactor, each of them can provide a better environment for the development of another group of nitrifying microorganisms.

The aim of this work was to compare the activity of AOB and NOB bacteria for two forms of biomass – activated sludge and biofilm developed in the IFAS – MBSBBR.

The research was conducted for biomass collected from the integrated fixed film activated sludge – moving-bed sequencing batch biofilm reactor (IFAS – MBSBBR) with a working volume of 28L. Cylindrical EVU-Perl carriers with dimensions  $\Phi 5$  mm and  $h = 8$  mm, characterised by an active surface of  $600 \text{ m}^2/\text{m}^3$ , were used as a carriers of biofilm.

For the control of individual groups of nitrifying microorganisms activity, batch tests were applied to determine the rate of the I (AUR – Ammonia Utilization Rate Test) and the II (NitUR – Nitrite Utilization Rate Test) nitrification phase. Tests were carried out for each form of biomass separately in constantly aerated test reactors with a working volume of 2l.

The scope of the analysis included the determination of concentration of  $\text{N-NH}_4$ ,  $\text{N-NO}_2$ ,  $\text{N-NO}_3$  by means of cuvette tray tests by Hach Lange in accordance with the methodology described by the producer, and concentrations of mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) were determined using methods in accordance with the Polish standard PN-EN 872:2007.

The obtained results showed that activated sludge flocs provide a better environment for the growth of ammonia oxidizing bacteria whereas biofilm provides a better environment for the growth of nitrite oxidizing bacteria.

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Analysing AUR tests results, it was also noticed that in the case of the activated sludge, nitrite accumulation occurred (4.77 mg N-NO<sub>2</sub>/l), which was not recorded for the biofilm. This observation indicates that activated sludge was more susceptible environment to NOB suppression.

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Karolina FURTAK\*, Anna GALĄZKA\*\*, Agnieszka WOLIŃSKA\*\*\*

## ***Can soil microorganisms support plants under hydrological events?***

Soil moisture is defined as the water content of the soil. Natural moisture fluctuations associated with the seasons are an environmental factor that regulates microbial activity. The amount and distribution of precipitation over time and air temperature are regulated by climatic conditions, which are also influenced by human activities, especially industrial activities. Studies on soil moisture confirm the complexity of interactions between environmental elements. In recent years, the frequency of floods across Europe has been increasing and drought periods have become longer. The hydrological stress caused by these phenomena affects the soil environment and plants. Drought causes soil drying and the reduction or complete destruction of crops. On the other hand, excess water results in difficulties in field work, rotting of plants and the development of many fungal diseases.

Some soil bacteria (e.g., *Bacillus* sp., *Alcaligenes* sp.) displayed resistance to low water content in soil and related osmotic stress and excessive oxygenation. Their ability to produce siderophores, indole-3-acetic acid and exopolysaccharides (EPS) has been demonstrated. These mechanisms allow the bacteria to survive changes in osmotic pressure caused by lack of water in the soil. Little is known, however, about bacteria in a moisture stress condition.

We conducted research based on a microcosm model experiment in which selected fluvisols were taken from floodplain meadows and subjected to simulated flood conditions. Fresh soils and soils collected after 7 and 14 days of flooding were analyzed. The structural diversity of the soil microbiome at each stage of the experiment was determined using next-generation sequencing (NGS, Illumina).

Results showed an increase in the structural diversity of the bacterial community under flooded conditions. Considering only the identified bacterial sequences, it was observed that although the individual soils were characterised by a different core microbiome, 5 types of bacteria were common to all the river muds: Actinobacteria, Bacteroidetes, Firmicutes, Nitrospirae and Proteobacteria. Bacteria of the Actinobacteria type were the most abundant. Moreover, bacteria of the family Flavobacteriaceae, Desulfovibrionaceae, Streptomycetaceae, whose representatives are known for their ability to produce EPS, were present in flooded soils. The results obtained from this experiment were so intriguing that it was decided to extend the research in search of bacteria capable of surviving in these conditions and with potential positive effects on plants/environment. Thus, the project entitled: The search for bacteria adapting to extreme soil moisture conditions and the assessment of the effects of hydric stress on the quality of the soil environment (National Science Centre Poland), was created. The aim of the project is to assess the rate of change in the soil environment following changes in moisture content and to isolate bacteria that survive water stress, and to investigate whether the bacterial isolates obtained have the characteristics to survive osmotic stress. Once the bacteria have been characterized, it will be possible to assess their potential impact on plants under conditions of excessive moisture.

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Nikodem KUŹNIK\*\*\*

## ***The use of natural polymers in coated fertilizers***

The purpose of this work is to compare the commercially available CoteN™ Haifa coated fertilizer, with the prepared multilayer coated granular NPK-type fertilizer. The obtained fertilizer was coated with modified natural polymers, derivatives of cellulose and linseed oil. Double and triple coated fertilizer was used in the research. The main goal was to obtain a fully biodegradable granular fertilizer that would compete with those available on the market.

Following the standard PN-EN 13266:2003, it was studied how nutrients were released from the fertilizer. The biodegradability of coated fertilizer was assessed according to the standard ISO 21263.

The fertilizers were coated by spraying from a solvent solution using self made coating machine.

Results showed that the fertilizer complies with the standard set for coated fertilizers, in terms of the amount of nutrients released over time.

Both prepared fertilizers meet the release criteria for slow-release fertilizers. After 28 days the triple coated fertilizer shows the same level of released nitrogen as a commercial fertilizer.

In relation to the studies on potential biodegradability, the results about 10% per month, which was promising and suggested that the entire fertilizer will biodegrade after approximately one year.

*The content presented in the poster is protected under patent applications number P434355 and P434356, and the work was done as a part of research in the “Doktorat wdrożeniowy” financed by Ministry of Science and Education.*

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**Sofiia ROTAR\***

## ***The un sustainable development goals: sweden's results in achieving SDG 9: "Innovation and infrastructure"***

The SDG 9: "Innovation and Infrastructure" aims to build sustainable infrastructure, promote comprehensive and sustainable industrialization and accelerate innovation.

In 2016, the Swedish government introduced draft legislation for 2018–2029, "Infrastructure for the future – innovative solutions to increase competitiveness and sustainable development," aimed at facilitating the transition to a useless welfare state, expanding housing, and improving conditions for the private sector. The government also unveiled a strategy for new industrialization, "Smart industry," which will help strengthen companies' capacity to move and increase competitiveness at both the national and regional levels in digital development and sustainable production. The government also presented its CSR policy. The government also adopted a new broadband strategy to cover high-speed Internet by 2025 fully.

Swedish society has long stimulated innovation and entrepreneurship. Today, about a third of the population has higher education. Sweden's R&D spending in 2018 amounted to 18.33 billion US dollars, which corresponds to 3.3% of GDP. This percentage is higher than in many other EU countries, and the country ranks 3rd in the world. The private sector accounts for almost 70%, the higher education sector, which is mainly state-funded, for 27%, the public sector for 3%, and the private nonprofit sector for less than 1% of total costs.

Sweden is a country with an export-oriented economy. The share of high-tech exports in 2019 amounted to 14.6% of total exports or 17.55 billion US dollars.

Sweden is a country with a feminist parliament, a law against gender discrimination, and women's rights. Therefore, the share of women among scientists and engineers is almost 50%, which puts Sweden in 6th place among EU countries.

The country is among those that actively implement the Sustainable Development Goals in business practice: 90% include the SDGs in their sustainable development activities, and 10% do not. For example, Goal 9: "Innovation and Infrastructure" included 12 companies in its sustainable development activities, while the most significant number of companies – 15, included Goal 8: "Decent Work and Economic Growth." That is, SDG 9 has a considerable impact on business strategy.

Sweden is successful in achieving 60% of the declared indicators of SDG 9, 30% are on track to achieve, and 10% – supports the current level. Transport and infrastructure policy aims to provide cost-effective and sustainable transport services for people and businesses across the country. Sweden is characterized by high-quality access to transport infrastructure for people and goods, although the economic costs of such infrastructure increase due to reduced emissions and due to the broader use of biofuels and increased energy efficiency in traffic.

In a global comparison, Sweden usually shows promising results for all SDGs. It should be noted that both the government and the citizens of Sweden are responsible and aware of implementing these goals. The results of the achievement of SDG 9: "Innovation and Infrastructure," tend to increase indicators or maintain their current state indicate a high level of innovation and infrastructure development using renewable energy.

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**ORAL SESSION IV:**  
***Energy Industry and Management of Mineral  
Resources***

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Olga TEĆCZA\*

## ***Analysis of the possibility of using the heat generated in an installation concentrating solar radiation***

The topic of the paper is the analysis of the possibility of using the heat generated in an installation concentrating solar radiation. The motivation for the considerations is the constantly growing demand for electricity and heat, which leads to an increase in CO<sub>2</sub> emissions. Turning to renewable resources can provide a solution to climate change that is worsening year by year. The study is focused on the energy of solar radiation, which is a widely available, economic and, above all, ecological source of energy. The analysis was based on the results of tests carried out on the existing solar installation which consists of two solar collectors serial connected with a parabolic-dish solar concentrator and is located in Krakow (Poland). Based on the measurements, the generated thermal power was calculated and analyzed in terms of its management. The solar radiation delivered on the day of measurements was 1200 W/m<sup>2</sup>. Three variants of conversion of the obtained thermal energy were considered: into electricity through the use of photovoltaic modules, mechanical energy through the use of a Stirling engine and cooling power through the use of an absorption chiller. For each of the variants, the value of the power that can be generated under the tested insolation conditions and design assumptions was calculated. The conducted analysis showed that by maximizing the incident radiation through its concentration, 1,200 W/m<sup>2</sup> of solar energy supplied can be processed into 2,000 W of heat, 826 W of electricity, 185 W of mechanical power and 322 W of cold.

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*Izabela ZIĘCIK\**

## ***Concentrated solar radiation as a solution for improving the performance of flexible photovoltaic cells***

The research work analyze the impact of the concentration of solar rays on the efficiency of flexible photovoltaic cells. Solar energy is currently one of the fastest-growing sectors among renewable energy sources. It is estimated that further power increase in installations concentrating solar radiation will be exponential. The use of concentrating radiation systems is economically justified in countries with both high insolation levels and relatively low ambient temperatures. With the development of materials technology, the number of potential locations for such installations is increasing. The aim of the research is to broaden the knowledge about the operation of photovoltaic cells with a flexible structure in a beam of concentrated solar radiation. Despite their relatively low-efficiency such cells are significantly more resistant to high temperatures than standard silicon cells. Developing research into this technology can be a great step towards sustainable energy development and environmental protection.

The research work used a stand consisting of two mirror systems, a lamp and a flexible photovoltaic cell. It made it possible to measure the irradiation, heat, and power generated by the cell. The obtained results were then subjected to a numerical analysis which allowed for a technical and economic analysis in a wider aspect – European and Global. The analysis was made in Krakow (Poland), Madrid (Spain) and Codpa (Chile). It showed that solar radiation concentration technology for a flexible cell can increase its power output by up to 1.4 times. It was also concluded that this increase does not depend only on the radiation value but also on the temperature growth of the cell and the efficiency decrease related to this.

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**Anna JAROSZ\***

## ***Microgrid DC***

Motivated by environmental, economic and technological aspects, the penetration of renewable energy sources into the electrical networks is increasing worldwide. This fact requires a paradigmatic change in power system operation. The solution of the problem a deficit of electrical energy. is usage of renewable energy source in meet the demand of electrical energy. Among a variety of configurations of application of RES in electricity generation system there is microgrid system. Implementation of such systems provide many pros both from from the electric utility provider and the user, including environmentally friendly, better power quality.

The presentation shows the components of the microgrid, the division depending on the type of electricity and the way of operation, arguments for investing in such systems, comparison with a conventional network, as well as advantages and disadvantages.

Analyzing technique for managing and coordinating load demand is implemented by time characteristics in PowerFactory. Then, according to the resulting scheduled load curve, the quasi-dynamic simulation is utilized in order to optimally calculate parameters for different renewable sources to cover the demand and allowable energy to exchange between the main grid and microgrids. The problem with optimization of analyzed microgrid is solved in PowerFactory.

There was also talk about the investigated microgrid which is now being built in Lesser Poland and the tasks performed as part of the analysis in the PowerFactory 2020 program to improve the installation in the future.

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## ***Use of simulation tools for the parametric calculation of a biogas plant***

The publication presents the concept of developing a simulation model of a hybrid system based on the cooperation of renewable energy sources operating in energy self-sufficient farms. The simulation analysis can be used to study an energy hybrid consisting of an agricultural biogas plant (agrogas plant) and a photovoltaic farm. In the simulation process, modern software will be used to optimize the analyzed integrated energy processes and to visualize these processes in 3D/2D technology.

Agricultural biogas plants perfectly fit into each of the four contemporary economic concepts, which are: sustainable development, bioeconomy, green economy and the circular economy. The operating biogas plant implements the key assumptions of all four concepts, allowing for the useful management of organic waste, which significantly reduces the comfort of people's life. Biogas plants produce electricity and heat necessary to function in the modern world without significantly harming the natural environment, using renewable resources. They also reduce environmental pollution caused by the use of non-sanitized natural fertilizers. Biogas plants are also one of the elements of self-sufficiency at the local level.

By building an agro-gas plant on the farm, you can reduce the costs of building the installation by using the existing tanks and electrical connections. The revenues related to the use of own electricity, heat and digestate are also increasing.

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**Agnieszka BAŁK\*, Kinga PŁAWECKA\*\***

## ***The use of phase change materials in geopolymers – literature review***

Phase change materials built into the building structure increase its heat capacity. The heat capacity of the building structure improves its energy efficiency, which reduces the energy consumption necessary to maintain thermal comfort conditions. It also allows the use of energy from renewable sources at no additional cost. Phase change materials are mainly used in construction, therefore their use in geopolymeric materials will be discussed. Phase change materials have several basic properties. The most important of these are: heat capacity, phase transition temperature and thermal conductivity. The ability of phase change materials to accumulate heat depends on the heat of phase change. In building materials, this parameter ranges from about 100 kJ/kg to about 250 kJ/kg. The greatest amount of energy is released and absorbed by phase change materials during a phase change. In view of this aspect, the material should be selected such that its melting point is within the range of the temperatures present in the system. In the case of using these materials in construction, this range is determined by the ambient temperature and the temperature of thermal comfort. Phase change materials should absorb and release heat very well, especially when there are small temperature differences between the system and its surroundings. For this condition to be met, the substance needs high thermal conductivity. Due to different properties, phase change materials can be divided into organic and inorganic. The detailed classification includes homogeneous substances, mixtures and eutectic mixtures. Organic materials are saturated hydrocarbons with a carbon number in the chain from 16 to 20 (for construction applications), fatty acids, esters, alcohols and other hydrocarbon derivatives. Inorganic substances are salts, their hydrates and eutectic mixtures.

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*Magdalena ABRAMOWICZ\*, Weronika URBAŃSKA\*\*, Magdalena OSIAL\*\*\**

## ***Metal oxide-based magnetorheological fluid – synthesis and characterization***

Magnetorheological (MR) fluids are classified as intelligent materials whose viscoplastic characteristics change under the magnetic field. Due to their rapid thickening under the external magnetic field can be applied for dynamic energy dissipation. In this work, the core-shell suspension of metal oxide-based nanoparticles was synthesized, characterized, and dispersed in a viscous liquid. The magnetic core was modified with organic compounds to obtain a stable colloidal suspension. Characterization was performed within the Scanning Electron Microscopy and Transmission Electron Microscopy. Characterization was performed with Fourier-Transform Infrared Spectroscopy and viscometer. Much effort has been made to prepare MR fluid suspension meeting requirements – forming chain-like structures under the external magnetic field. This study presents a cost-effective and straightforward synthesis way suitable for MR fluid formation for its application in dynamic energy dissipation.

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**ORAL SESSION V:**  
**Mechanics, mechatronics and nanotechnologies**

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Katarzyna SKIBIŃSKA\*, Karolina KOLCZYK-SIEDLECKA\*\*, Dawid KUTYLA\*\*, Anna JEŃDRACZKA\*\*,  
Beata LESZCZYŃSKA-MADEJ\*\*, Mateusz M. MARZEC\*\*, Piotr ŻABIŃSKI\*\*

## ***Electrocatalytic properties of Co conical structured electrode produced by one-step and two-step method***

One-dimensional (1D) nanostructures, such as nanotubes, nanopores, nanodots and nanocones, are characterized by better catalytic properties than bulk material due to their large active surface area and small geometrical size. These structures can be produced by several methods of synthesis including the one- and two-step methods. In the one-step method, a crystal modifier is added to the solution in order to promote the vertical direction of structures growing during electrodeposition. In this work, NH<sub>4</sub>Cl was added as a crystal modifier. Another way of fabrication of conically-shaped materials is the electrodeposition of metal in porous anodic alumina oxide (AAO) templates, called the two-step method. Using this method allows to synthesis of nanomaterials. In this case, the AAO template was obtained using two-step anodization process. Nanocones obtained by two-step method show smaller geometrical size. In this work, cobalt nanoconical structures were obtained from an electrolyte containing COCl<sub>2</sub> and H<sub>3</sub>BO. The electrocatalytic properties of materials fabricated in one-step and two-step method were measured in 1M NaOH and compared with bulk material electrodeposited from the same electrolyte.

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Mateusz KOPEĆ\*

## ***A highly efficient 'FAST' hot stamping process for complex shaped panel components from titanium alloys***

Demand for low density and high strength materials in the aviation sector has expanded greatly due to ambitious carbon emission and fuel consumption targets. In order to meet these targets, manufacturers have focused on weight reduction via the use of lightweight materials. In the aerospace sector, high strength structural components are made from titanium alloys. However, the forming of complex-shaped components from titanium alloys is time, energy and cost intensive. One promising solution to overcome these difficulties proposed in the literature is using the hot stamping process to form complex-shaped components from sheet metal with cold dies, and rapidly quenching the workpiece in the dies simultaneously. The hot stamping process promises to reduce the tool wear commonly found in conventional hot forming processes and be an overall more efficient and economical process when compared to conventionally used isothermal hot forming techniques. A novel hot stamping process for titanium alloys using cold forming tools and a hot blank was studied systematically in this thesis. This work aims to investigate the microstructural evolution and flow behavior of a titanium alloy (Ti6Al4V) under hot stamping conditions experimentally, and to model these parameters using the constitutive equations proposed. The material behavior was modelled using mechanism-based viscoplastic constitutive equations to replicate the material response of a two-phase titanium alloy Ti6Al4V under hot stamping conditions. Finally, the developed model's accuracy was validated by comparing to experimental uniaxial tensile tests and microstructural maps of the deformed alloy. Microstructural analysis revealed that the heating and soaking conditions are vital to the microstructure and post-form strength, whereas the plastic deformation during the hot stamping only has a negligible effect on both recrystallization and phase transformation due to the very short deformation time. The developed material model was implemented into the Finite Element (FE) simulation to study the deformation characteristics during the hot stamping process. The verified simulation data were analysed through a novel hot stamping technique with good agreements achieved between the predicted and experimental results. A complex shaped wing stiffener panel component was successfully formed from TC4 titanium alloy, demonstrating the great potential of investigated technology in forming complex shaped titanium alloys components. Finally, Fast light Alloys Stamping Technology (FAST) was proposed for titanium alloys, where fast heating to a two-phase titanium alloy sheet with equiaxed microstructure is employed. A novel 'FAST' hot stamping process allows to form complex shaped panel components from titanium alloys with an improved forming efficiency by more than 80% in comparison to traditional forming technologies for titanium alloys.

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**Vitaly ZHIRONKIN\***

### ***Determination of loads on deflecting pedals of a push-the-bit rotary steerable system***

In this research, a study was conducted on the deflecting pedals of the bias unit of the Push-The-Bit Rotary Steerable System as a specific factor for the reliability of the system, gaining particular importance as the number of deposits with non-traditional deposits, entered into the development, increases. To achieve our goal, we presented a module of a rotary managed system as an absolutely elastic rod, to which a complex of forces arising from the wiring of obliquely directed and horizontal, as well as wave-like wells. In the course of construction of directional wells with certain drilling modes, load changes resulting in the load on a deflecting pedal, which increases the risk of failure of the entire Bottomhole Assembly of a rotary steerable system, as there is a risk of approximation of the load values for deflecting pedals to the maximum. This work identifies the existence of a multiple load on the deflecting pedal in the process of changing the drilling segment of directional wells from ascending to descending segments during the construction of a horizontal section in the presence of a wave-like plot. In order to reduce the load level, as well as the risk of deflecting module push-the-bit Rotary Steerable System, based on the analysis of the effect of the axial load on the deflecting pedal, is recommended to adjust the drilling mode.

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## ***The influence of the manufacturing method on the properties of materials obtained from mixtures of zirconium and copper powders***

Zirconium is one of the most biocompatible elements available, it is considered a substitute for titanium in implantological applications. Magnetic resonance imaging is used as a medical imaging technique in radiology. Two-component ZrCu alloys have the lowest magnetic susceptibility of all known metals, even lower than pure zircon itself. Copper is present in the human body in small amounts, but in all tissues, and supports metabolism, but at a higher concentration it can lead to poisoning. Direct application of ZrCu alloys to implants seems impossible, but one potential place for them to be used is in diagnostic devices using magnetic resonance imaging.

The study investigates the consolidation of zirconium powder mixtures containing 2.5 wt. and 10 wt.% copper by two methods. The first method was SPS plasma spark sintering and the second method was hot coextrusion. In the study, material tests were carried out in the field of phase composition, microstructure, hardness, density and tensile strength of Zr-Cu materials obtained by powder metallurgy. Fractographic analysis of the materials stretched at room temperature and 400°C was performed. The tested properties were compared for materials of the same chemical composition obtained by both the SPS method and the hot coextrusion method.

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## **Corrosion resistance of Inconel 625 additively manufactured by L-PBF and L-DED technologies**

Additive manufacturing technologies, known as 3D printing, are increasingly used in industry, also to produce metal products. They make it possible to overcome the limitations associated with the production of parts with complex shapes, also from materials difficult to machine, such as nickel-based superalloy Inconel 625. Due to its high strength, corrosion resistance, and weldability, Inconel 625 is widely used in the aeronautic, automotive, and chemical industries. Additive manufacturing processes, like powder bed fusion (PBF) and direct energy deposition (DED) allow to overcome the problems with poor machinability and low thermal conductivity and thus provide a solution for fabrication components with complex geometry. However, there are significant differences in microstructure and properties between Inconel 625 obtained by conventional and additive manufacturing.

The aim of this work was a characterization of the resistance to electrochemical corrosion of Inconel 625 fabricated by using laser-assisted powder bed fusion (L-PBF) and direct energy deposition (L-DED). Corrosion tests were performed for 1, 3, and 7 days in sulfuric acid (H<sub>2</sub>-SO<sub>4</sub>) and sodium chloride (NaCl) solutions utilizing impedance spectroscopy and polarization curves techniques. Additionally, the microstructure before and after corrosion was examined by using scanning electron microscopy (SEM).

Electrochemical corrosion measurements showed an increase of the corrosion current with prolongation of the exposure time in NaCl, and on the contrary, a decrease of current in H<sub>2</sub>SO<sub>4</sub>. The observed decrease of the corrosion current indicates the formation of the passivation layer in H<sub>2</sub>SO<sub>4</sub> solution, which slows down the corrosion process of Inconel 625. SEM microstructural analysis revealed the occurrence of pitting in both types of samples after 7 days of corrosion tests in H<sub>2</sub>SO<sub>4</sub>, while after the same time in a NaCl solution only L-PBF Inconel 625. In both solutions, L-PBF samples exhibited weaker corrosion resistance than L-DED ones.

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## **Creep behavior of 3D printed Inconel 625 nickel-based superalloy**

Due to good corrosion resistance and high mechanical properties at elevated temperature, Inconel 625 is widely used in the aerospace and power plant industries. Nevertheless, the poor machinability makes it advantageous to produce Inconel 625 parts using additive manufacturing technologies. The high cooling rate ( $103\text{--}106^\circ\text{C}\cdot\text{s}^{-1}$ ) of the melt pools in the L-PBF process leads to the formation of very fine columnar and equiaxed grains with the cellular-dendritic substructure. These microstructural features are related to the specific properties of AM metallic components, different than their counterparts produced conventionally. Therefore, the characterization of microstructure and properties at elevated temperature is critical for additively manufactured Inconel 625 as a possibility of high-temperature applications.

The aim of this work was to characterize the high temperature creep properties and microstructure of 3D printed nickel-based superalloy Inconel 625 produced by laser-assisted Powder Bed Fusion (L-PBF) method. The samples were stress relieve annealed at a temperature of  $980^\circ\text{C}$  for 1 h. Creep tests were performed at a temperature of  $600^\circ\text{C}$ ,  $700^\circ\text{C}$  and  $800^\circ\text{C}$  under constant uniaxial tensile stress of 100 MPa according to ISO 204:2018 standard. The tests at  $600^\circ\text{C}$  and  $700^\circ\text{C}$  were terminated after 2000 h, while at  $800^\circ\text{C}$  the test was conducted until rupture after 240 h. The microstructure of creep-tested samples was investigated by means of scanning and transmission electron microscopy.

The creep test at a temperature of  $600^\circ\text{C}$  revealed the unexpected behavior of L-PBF Inconel 625. Although high uniaxial tensile stress was applied, negative deformation was recorded by a sensor. As the Inconel 625 is often used in service applications at  $600^\circ\text{C}$  and the external load, this observation is an essential finding. A similar phenomenon is described in the literature as the negative creep, but further investigations are necessary to confirm this hypothesis. Microstructural investigation shown that after creep test the cellular-dendritic substructure remained. Moreover, disc-shaped morphology precipitates of the g' phase precipitates were observed by TEM.

In turn, after 2000 h of the creep test at  $700^\circ\text{C}$ , the steady-state of creep deformation was achieved, what was associated with the microstructural changes consisting of disappearance of the cellular substructure, precipitation of densely arranged plate-like precipitates of the d phase and formation of the small cavities localized mainly at the grain boundaries.

The rupture after 240 h of creep testing at  $800^\circ\text{C}$  and 100 MPa revealed a very low creep resistance of L-PBF Inconel 625 at such conditions, which was caused by the intensification of the d phase precipitates coarsening and coalescence of the cavities, forming chains along grain boundaries.

The results have shown that 3D printed Inconel 625 can be applied for service involving creep conditions at high temperature up to  $700^\circ\text{C}$ , while at higher temperature its creep resistance significantly reduces.

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## **Quantitative analysis of precipitates and oxide inclusions in 3D printed Inconel 625**

Inconel 625 superalloy is used in various industrial applications requiring high strength and corrosion resistance in harmful environments. Recently, 3D printing of Inconel 625, e.g., by Laser-assisted Powder Bed Fusion (L-PBF) method, allowed the use of this alloy for fabrication components of complicated shapes. Ensuring the properties of the 3D printed parts requires precise characterization and control of their microstructure. For this purpose, it is necessary to develop methods allowing quantitative analysis and modelling of the microstructure. Particularly difficult is the analysis of precipitates and inclusions due to their submicrometric and nanometric sizes. Therefore, the aim of the study was the quantitative microstructural analysis of precipitates and oxide inclusions in the L-PBF Inconel 625 as well as the generation of 2D mesh geometric models of the microstructure.

Microstructural analyses were performed by means of light microscopy (LM), scanning, transmission, and scanning-transmission electron microscopy (SEM, TEM, STEM) using specimens prepared from planes parallel (xz) and perpendicular (xy) to the build direction. The model of the microstructure was generated with the use of the MicroStructPy library written in Python.

LM images revealed the differences in the melt pools shape in both planes. SEM observations with the use of secondary electrons (SE) detector have shown that the microstructure within the grains was finely cellular with different cell sizes and shapes. The area fraction of the intercellular areas was 30.56% for the xz plane and 42.45% for the xy plane. The precipitates were visible as bright particles located in the intercellular areas. Microanalysis of the chemical composition by energy dispersive X-ray spectroscopy (EDS) in SEM showed that the precipitates were rich in niobium. The diameters of the precipitates ranged from 0.01  $\mu\text{m}$  to 0.44  $\mu\text{m}$ , with an average diameter of 0.2  $\mu\text{m}$  for both planes. In turn, SEM investigation using the backscattered electrons (BSE) detector revealed particles with dark contrast, spherical and hemispherical shape, size range from 0.03  $\mu\text{m}$  to 0.29  $\mu\text{m}$  and a mean diameter of 0.10  $\mu\text{m}$ . EDS microanalysis in STEM showed that these particles were aluminum oxides.

TEM microstructural studies revealed also the presence fine precipitates located at the cell boundaries, which were not possible to observe in SEM. Their diameters ranged from 10 nm to 231 nm. Based on the microstructural analysis performed by TEM, 2D mesh geometric models were created. The model allowed showing the microstructural features observed at the microscale and nanoscale with the distinction of cell structures, precipitates and non-metallic inclusions.

The results show a successful example of developing a geometric model of a microstructure based on the results of quantitative microstructural analysis. It may be useful to control the microstructure evolution in L-PBF Inconel 625 using computational modeling

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## ***Comparison of failure forms of anti-wear coatings after indentation and micro-impact tests***

Hard anti-wear coatings are often used in many industrial applications primarily to increase the wear resistance of machine components and improve the overall durability of the system. In this area, coatings are widely used as a protection of the surfaces of cutting tools, forging molds, casting molds, and the surfaces of kinematic pairs. A wide variety of tribological tests and mechanical properties investigation methods are used to define coating wear. One of them is the micro-impact test, which allows to determine the surface fatigue resistance of the coating as well as to study the wear mechanism of the coating exposed to cyclic impacts. The surface fatigue strength of the coating depends on the ratio of hardness and elastic modulus, and thus the load-bearing capacity. Crucial is also the ability of the coating-substrate system to take the load in successive impacts.

The typical coatings such as CrN, TiN, and DLC (Diamond-Like Carbon) deposited on a steel substrate were tested in this work. The effect of the low-cycle micro-impacts at a specific frequency on failure forms of the coatings was studied. The results of static and dynamic tests were discussed. In the micro-impacts tests, a spherical ceramic indenter was used. Each crater formed after the cycle of impacts was analyzed using a Profilm 3D contactless profilometer to determine the depth penetration and geometric shape of the crater. Coating failure forms were investigated under an optical microscope. The main cause of coatings destruction were cracks formed within the crater as well as their further propagation. The results of the tests were widely discussed to confirm similarities or differences in coatings wear.

This study helped to understand better where the first crack appears and how the destruction evolves. The improved recognition of the process can reduce the wear of coatings and prevent serious breakdowns of machines or devices.

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## ***Para-aramid fabric functionalized with AgNWs@SnO<sub>2</sub>***

In recent years, the functionalization of high-performance textile materials has attracted a lot of attention due to the rapid development of industry and technology. Aramid materials are well known for their excellent properties such as mechanical strength, excellent chemical resistance, lightweight, thermal resistance. These properties lead to the wide use of aramid fibrous structures in many industries, incl. military, protective equipment and advanced industrial materials. However, it is important to provide them with additional functional features that will extend the scope of their use in many areas. The development of nanotechnology has enabled the functionalization of textile materials and the development of composite materials for industrial applications. One of the nanomodifiers is silver nanowires (AgNWs), which, thanks to their properties, allow to give aramid textile materials new functions such as electrically conductive, antibacterial properties, greater thermal stability and, the barrier to IR irradiation. However, AgNWs have no long term stability in air and show a tendency to degradation. In order to protect them, AgNWs passivation with SnO<sub>2</sub> layer was used, ensuring high environmental stability. The AgNWs passivation process was carried out in the presence of sodium stannate in an aqueous solution at a temperature of 100°C, which resulted in the formation of AgNWs@SnO<sub>2</sub> core/shell nanowires. In the study, the para-aramid fabric was modified with AgNWs and AgNWs@SnO<sub>2</sub> nanowires using the ultrasonic spray-coating method. This functionalization was aimed at creating the material for thermal management and as protection for extreme condition. Thermal properties were studied by TG/DTG analysis, IR thermography and heat transfer analysis. The studies showed that the 4-month exposure of AgNWs@SnO<sub>2</sub> in the air did not cause their degradation, and the passivation of AgNWs with SnO<sub>2</sub> protects them. The fabric with AgNWs@SnO<sub>2</sub> showed lower thermal conductivity ( $8.90 \cdot 10^{-8} \text{ m}^2\text{s}^{-1}$ ) compared to the unmodified and AgNWs modified fabric, for which the thermal conductivity was  $1.05 \cdot 10^{-7} \text{ m}^2\text{s}^{-1}$  and  $1.77 \cdot 10^{-7} \text{ m}^2\text{s}^{-1}$ , respectively. The initial decomposition's temperature of the unmodified fabric was 553.4°C, didn't change after AgNWs modification and increased by 7.9°C after AgNWs@SnO<sub>2</sub> functionalization. The weight loss decreased from 59.7% for the unmodified fabric to 52.6% and 44.5%, respectively for AgNWs and AgNWs@SnO<sub>2</sub> modified fabrics. The AgNWs and AgNWs@SnO<sub>2</sub> modified para-aramid fabrics showed a significant increase in the IR reflection efficiency in comparison with reference fabric.

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**Paweł STRZEPEK\***

## ***New generation of high strength CuMg alloys dedicated for metal working with applications in electronic systems***

Constant tendency toward the improvement of the materials properties nowadays creates the opportunities for the scientists all over the world to design and manufacture new alloys almost every day. This research is focused on developing of manufacturing technology of a new generation of high strength CuMg alloys based on the process of metallurgical synthesis, their continuous casting and subjecting the manufactured products to heat treatment in order to activate the precipitation hardening process. The alloys obtained in this way will be used as the batch material for metal working processes, i.e. drawing process of round profiles and die forging and subsequent mechanical processing, which will allow to obtain finished products for the automotive or transport industry, but primarily electrotechnical industry due to the high set of mechanical and electric properties. A noticeable advantage of these alloys will be the reduction of production costs through the alloying additive in the form of magnesium with a simultaneous significant increase in the listed properties. The final result of the research will be the design of production technology for products from a new generation of high-strength CuMg alloys, which are currently not produced on an industrial scale in Poland or in the world, which proves their innovation. Products obtained based on the designed technology will be fully competitive, and in many respects will outweigh the products currently used on the market made of other, commonly used alloys in terms of both utility and technological properties, and the lower cost of production will allow for quick implementation and effective sale of products manufactured based on designed technology.

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***POSTER SESSION III:  
Energy Industry, Management of Mineral Resources,  
Mechanics, mechatronics and nanotechnologies***

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**Natalia GENEROWICZ\***

## ***Use of waste heat from PVT panels for ground regeneration to maximize ground source heat pump performance***

Recently, in accordance with the European Directive 2020, every EU member state is paying increasing attention to the energy sector. The targets set are to reduce greenhouse gas emissions by 20% compared to 1990 levels, to cover 20% of energy demand from renewable sources and to increase energy efficiency by 20%. With regard to buildings in particular, the buildings sector, accounting for 27% of global energy consumption and CO<sub>2</sub> emissions, has attracted considerable attention. In recent years, much research has focused on ground source heat pumps as heating systems that reduce low emissions. These installations are one of the few renewable energy solutions capable of covering the energy demand of multi-family buildings. However, over time, the ground as the lower source of the heat pump no longer regenerates as quickly as it should. This results in a reduction of the coefficient of performance (COP) of heat pump and thus a higher electricity consumption of the heat pump compressor. Therefore, the proposed solution here is to use PVT panels. These are liquid-cooled photovoltaic modules, as a result of which the device produces both thermal and electrical energy. They provide the energy needed to run the compressor in the heat pump, while the waste heat from cooling the panels is used to regenerate the ground after the heating period. Excess energy produced by the installation will be stored in underground tanks. They will be used when the COP of the heat pump decreases during the heating season. An example of such installation and its parameters will be analyzed on two installations in Poland. One of them is located in Cracow the other in Limanowa. The composition of the whole system includes:

- Sun-Track solar collectors, which produce heat for production of domestic hot water,
- PVT panels with sun tracking system, which will be used for ground regeneration in summer and electricity production,
- Underground energy storage; the storage tanks will be used when the COP of the heat pump decreases during the heating season,
- An energy data acquisition system that will be used to evaluate energy efficiency, and a building temperature control system.

The use of ground source heat pumps and PVT photovoltaic panels is the most promising solution when it comes to efficient operation of the whole system in the long run. This paper aims to show how the use of waste heat from PVT panels allows the heat pump to operate over a longer period of time without compromising the efficiency of the heat pump.

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## ***Verification of the two-dimensional model of 1.0037 steel oxidation in relation to microscopic measurements***

Millions of tonnes of iron-bearing waste are generated annually from high-temperature steel treatment. The scale formation contributes to the magnification of the surface defects appearing in the metallic base material. The kinetics of high-temperature oxidation is faster than that of low-temperature processes, which results in higher material consumption. During forging, hot rolling or continuous casting of steel, the scale is at the interface between the substrate and the tool. The resulting oxidation layer increases the thermal contact resistance and thus affects the heat transfer.

The presented work concerns cylindrical samples made of 1.0037 steel. The samples were heated in an electric furnace in an air atmosphere at temperatures above 1000°C. Different heating times were used: 2, 4 and 6 minutes. After the samples had cooled down, measurements were made in the cross-section of the formed scale using a light microscope and a scanning electron microscope. The obtained photographs made it possible to measure the thickness and determine the structure and morphology of the formed scale. The achieved results constituted a reference point for the numerical simulation of the oxidation layer growth two-dimensional model. Due to the fact that the experiment concerned a high-temperature process, it was assumed in the calculations that the oxidation followed the parabolic law.

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## ***Electrochemical synthesis of Pd-Se coatings from chloride solutions***

Metal chalcogenides are a very large group of compounds that are primarily known for their semiconductor properties. Therefore, they are widely used in the electronics industry and as a potential catalysts. Intensive research is carried out related to the synthesis of transition metal chalcogenides. Recently, chalcogenides associated with noble metals have started to attract more and more attention. The interest in the above compounds is not only due to the very good catalytic properties of the noble metals themselves. The inspiration to start research on the possibility of their synthesis was the spectacular properties of other chalcogenides, namely molybdenum and tungsten sulfides. The latter show very good catalytic properties in terms of hydrogen evolution. The presented researches describe the electrochemical synthesis of Pd-Se coatings which can be used as a catalyst in the process of hydrogen evolution. The coating deposition process was accomplished in an aqueous chloride solution at a rotating disc electrode in the different potential range. The deposited coatings varied in both the elemental and phase composition, as well as the surface morphology. The above differences depend on the applied potential. In the coatings obtained at low potentials, a significant increase in selenium content was detected. The above alteration is the result of a change in the electrode reaction mechanism. The post-deposition heat treatment revealed the presence of Pd<sub>4</sub>Se in the coating deposited and Pd<sub>17</sub>Se<sub>15</sub> and Pd<sub>8</sub>Se in the other layers, respectively. It is possible to precisely control the palladium and selenium co-deposition by controlling the electrode potential, and as a result of thermal treatment after the deposition process, a specific intermetallic compound can be obtained.

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### ***Study of the impact of decentralized generation on the electrical quantities of the HTA-AMALOU-Bejaia network***

The liberalization of the electricity market has allowed the appearance, in conventional distribution networks, of distributed production units based on renewable energies, which are considered as a solution for the current increase in energy demand, the improvement of the voltage profile and the reduction of energy losses and emissions. However, because these networks were not designed to accommodate this type of production, a high rate of their penetrations causes significant impacts on power transit. In this article, a contribution to the calculation of the power flow of a distribution network, with the presence of decentralized productions, will be made in order to visualize the impact of this insertion on the voltage plan, voltage drops, losses power as well as the circulation of the energy flow, and this will be accomplished by considering several scenarios. The Algerian Company of Distribution of Electricity and Gas, subsidiary of the SONELGAZ group, proposes the studied network it is a 30kV departure, from the municipality of Amalou, located in the valley of the Soummam to the city of Bejaia, it has a radial structure and consists of 88 nodes. The method adopted for the calculation is based on the formulation of two matrices; the matrix [BIBC] (bus-injection to branch-current) represents the ratio between the currents injected at the load nodes and the currents of the segments and the matrix [BCBV] (branch-current to bus-voltage) which represents the ratio between the currents of the segments and the voltages at the nodes

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## ***Analysis of training needs in the field of technology transfer management in the aspect of non-energy raw materials***

The transition towards a sustainable green economy can generate new opportunities for the workforce while also posing a risk. Upskilling and reskilling is one of the ambitious goals of the European Commission in support the green economy. Nevertheless, a skills gap can also be a barrier to further developing local, regional and national sustainability. One of the main aspects that can impact the implementation of the environmental-friendly solution is the relation between science and business.

The bridge connecting science and needs of business is one of the area of technology transfer management. The crucial part of effective technology transfer is to have the proper skills and competence to understand the business's expectation and education level, especially in the context of the non-energy raw materials that are the basis for developing a sustainable solution. Therefore, the research aims were to examine training needs in non-energy resource management and determine the demand for a training tool in technology transfer. The survey was carried out on first, second and third-degree students. Based on the provided research, the tools and methods that are commonly used in universities can be selected. Furthermore, the survey results may have an impact on the disengaged essential skills, knowledge, and competency needed to establish an entrepreneurial mindset in light of local conditions.

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## ***The benefits of recovering metals from mining waste. Case of Romania***

The non-renewable nature and depletion of mineral resources as well as the growing need for materials force their economic and rational management, which is also consistent with the principles of sustainable development. Today's management of mineral resources is characterized, inter alia, by a shift to the extraction of useful minerals and the utilization of waste collected in landfills. The introduction of new technologies enables the recovery of basic, strategic or precious metals from the huge amount of waste generated in the mining and exploitation of ores, usually stored in various impoundments or piles, being also an important source of pollution for the surrounding areas.

The above approach is not the only reason for the development of research projects aimed at developing a technology for waste recovery from landfills. In addition to the growing demand for secondary raw materials and the need to limit the negative environmental impact of deposited waste, other ecological, economic and social factors are also analyzed. The management and use of mining and processing waste can bring substantial environmental and economic benefits not only at the corporate level, but also for the region. It is mostly connected with reduction of waste and environmental burdens, as well as reclamation and remediation of contaminated sites that benefit society from new land-use opportunities such as recreation, and thus more attractive housing conditions and an increase in property value. One should also not forget about the reduction of the health risk and better quality of life.

The paper will focus on the benefits of recovery of precious metals from tailings (8,5 Mt of tailings and 50 ha of land) resulted from the flotation of nonferrous polymetallic ores from the Baia-Mare area in Romania having a significant content of Au and Ag (0.6 g/t Au and 11 g/t Ag respectively). The existing tailings are deposited on flat land without geomembrane to prevent the waters infiltrations. After the tailing deposition was stopped (1975), several attempts were made to re-vegetate the surface of the deposit, but all of them were unsuccessful. Presently, about 25% of the deposit surface is vegetated by shrubs, grass and some tree species (acacia, poplar, birch). As the city grows around the landfill the intervention is needed. If the technology would be applied for the recovery of metals, the resulting tailings will be deposited on a newer tailing impoundment situated in another part of the city meeting all requirements from an ecological point of view (having geomembrane). The main effect of implementing the new technology will be the reduction of gold and silver production using primary sources (limiting the consumption of natural resources). The global average production of one kilogram of gold and silver is associated with a significant environmental burden and amounts to 41,78 Pt and 1,70 Pt, respectively. The preliminary studies of the gold and silver recovery process have shown that the environmental burden of this process will be about a third smaller. Moreover, the area of the primary landfill would be transformed into green areas (grasslands). This will have positive impact for the environment – transformation from landfill (dump site) to green areas (grassland), reduction of waste and environmental burdens. Additionally, lower environmental fees

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can be assumed resulted from reduced waste and emissions, as well as lower costs of health of Baia Mare inhabitants, increase in property value because of the rehabilitation of land and higher attractiveness of the surroundings.

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**Adil NAWAZ\***

## ***Economic importance of the pink salt, a precious gem from the Himalayan belt of Pakistan***

Little is known in Poland about the Pink salt origin which is world second largest Salt mine in Pakistan after Poland. The aim of this study is to evaluate for the pink salt available for purchase Situated at the foothills of the Salt Range, Khewra Salt Mines are the oldest in the salt mining history of the sub-continent. Salt occurs in the form of an irregular dome like structure. There are seven thick salt seams with cumulative thickness of about 150 m. At places rock salt is 99% pure. Salt is transparent, white, pink, reddish to beef-color red. In certain horizons it is crystalline. Inside the mine there are beautiful alternate bands of red and white color salt. There are 18 working levels. Cumulative length of all drivages is more than 40 km.

Himalayan salt is one of nature's most purest and effective gifts. It's obvious from the name that the point of origin of this salt is around Himalayan mountain ranges which lies in Asian continent but there are also some deposits in the European region. When we talk about Asian salt deposits, Khewra Salt mines located in the country of Pakistan is the most famous in this region. Himalayan salt is providing Pakistan with a truly ancient ocean of energy and regenerates our body on all levels. Himalayan Pink Salt was originally formed from marine fossil deposits over 250 million years ago during the Jurassic era. Himalayan Crystal Salt originated from the evaporation of the primeval sea by the sun's energy, at a time when pollution did not exist and planet Earth was an immaculate ecosystem.

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*Małgorzata WÓJCIK\*, Justyna NOWIŃSKA\*\*, Natalia WALCZAK-TORBA\*\*\**

## ***Proprietary software for design and simulation of operations in gas storage cavern in bedded rock salt deposit***

This paper presents the application of selected software for numerical modeling of underground cavern-type gas storage facilities. Modeling the operation of a warehouse in a salt cavern requires an appropriate approach to the analyzed issue, including taking into account thermodynamic phenomena occurring in the stored gas and thermomechanical phenomena in the cavern itself and in the surrounding rock mass.

In order to implement this issue, specialized proprietary computer software was used, among others KAGA and GEOSOLK. KAGA is a computer program that allows simulating the temperature distribution during the operation of a gas storage cavern. During the simulation, the user receives information on the amount of gas in the cavern, its density, temperature and pressure both in the cavern and on the cavern head, and the temperature distribution in the salt rock mass surrounding the cavern. With the help of the KAGA program, you can analyze the storage operations performed so far and get to know the current state of gas in the cavern, as well as the current thermal state of the surrounding rock mass. The GEOSOLK program allows a user to analyze the displacement, strain and stress distributions around the chamber in the rock mass.

The study and analysis of the data obtained during the simulation work allow for the optimal selection of the geometry of the designed cavern to the deposit conditions, which directly affects the efficiency of warehouse operations. The presented software is a professional tool for designing and simulating the operation of underground gas storage caverns.

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Robert GROLIK\*, Michał GÓRA\*\*

## ***Estimation of energy demand for the purposes of a predictive extrusion temperature control algorithm – stabilization of fast-varying extrusion processes with the use of a multilayer perceptron***

The 3D printing technology in FDM technology consists in the application of successive layers of molten thermoplastic material. Regardless of the type of material, the temperature at which it is extruded is one of most important parameters of the printed elements. The current standard is the use of various types of PID or bang-bang regulators. The aim of the research is to collect assumptions for the development of a more extensive, self-learning algorithm regulating the temperature of melting zone in the printing head. The main task is to select the key measurable and non-directly measurable parameters of the 3D printer and to determine their impact on the energy demand of the head heater.

For research purposes ATMAT Signal (standard printer) and ATMAT Saturn (large format printer) putted together with the PLA, PET and PA materials were used to carry out the tests and data collection. The measurements were made by registering the operating parameters of printers by their control devices such as industrial PLC or microcontroller based printed circuit. The following parameters were measured with the frequency of 10 Hz: printer head temperature, output value of the previously calibrated PID controller, temperature in the printer chamber, material flow. The collected data was used to build and teach an algorithm for estimating the energy demand of a 3D printer heater, the algorithm was based on the structure of a multi-layer perceptron.

The conducted research allowed to focus on the printer parameters that are important in the regulation process and add measurement devices to collect them precisely. New data included in the self-learning algorithm regulating the temperature in the printer head during material extrusion resulted in improved quality of temperature control in the printing process.

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**Bartosz PSZCZÓLKOWSKI\***

## ***Influence of the exposure parameter in SLA 3D printing on the change of the structure and functional properties of the print surface***

3D printing is increasingly used in many factories and workplaces. Its popularity and implementation in the manufacturing branches creates a new reality of production. Technological progress and the current use of so-called additive technologies have made it possible to reduce time and resources in the case of small series production. It is also a revolutionary solution in the production of a single detail, it makes it possible to obtain the product at a given moment without having to store it before use. Therefore, the subject of the study is to analyze the influence of the parameter of the process known as "single-layer exposure time" on the structure and performance of the printing surface of SLA technology (Stereolithography). The study analyzed the change in Geometrical Product Specification (GPS) and its properties. The samples tested were prepared from the light-curable resin commercially available. In the experiment, samples were prepared in three single-layer exposure times 5s, 10s, and 15s. Single-layer exposure times were selected based on the instructions of the manufacturer, who recommends that the resin irradiation time interval in the 5s to 15s range. Roughness measurements were made using the profile method in accordance with ISO 3274: 2011. The registered profiles of the examined surfaces were subjected to numerical analysis in fractal terms using the structure-function  $S(\Delta x)$  fig (1). The functional properties of the surface were assessed based on the Abbott-Firestone curves, in accordance with the ISO 13565-2: 1999 standard. The research shows that the exposure time of a single layer changes the roughness parameters. The average profile of surface roughness (Ra), root mean square roughness profile (Rq), and the height of the core roughness (Rk) decrease with exposure time. On the other hand, in the case of functional properties, the effect of irradiation on the decrease in parameters responsible for the material's ability to hold liquids is noted. The obtained results show that by means of the exposure time of a single layer it is possible to control the geometrical structure of the surface, which has a significant impact in the case of elements resistant to abrasion. In addition, a very promising way to use this effect is the production of decorative elements, which is a part of the developing trend of personalized jewelry production.

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Michał GÓRA\*, Robert GROLIK\*\*

## ***Elaboration of flexible, high-flow printing unit for thermoplastic polymers***

The necessity to develop a new type of printing head system arose with fabrication of a very large format printer designed as a new solution for the thermoplastics 3D printing market. Many years of work with standard design heads have resulted in a whole series of hypotheses for the technology advancement and requirements for a high performance head. The goal was to develop a solution that allows printing with parameters at least ten times higher than typical unit.

The basic limitation was necessity for direct application in the industrial printer immediately after research conclusion. It meant that for real application could be selected only the forms of materials which ensure consistent quality and were commercially available on the market. For this reason, the chosen material is in the form of typical 3D printer filament of the maximum accessible diameter and feeding units are standard industrial filament drives as to not to cause further complications when implementing.

The research work focused on developing the shape of the material melting zone and the methods of synchronization of many simultaneously fed material lines. The structure of two to six independent filament drives was analyzed. Changing the angle of material introduction and the size of the head chamber resulted in abrupt and non-linear changes in efficiency. Thanks to a series of experiments, was developed specification of the dependence of the flow on the shape of the chamber, with additional parameterization by the unit temperature.

Various methods of supplying thermal energy to the melting zone were tested, including a system of many cartridge and band heaters. Thermal computer aided analysis of the head showed directions for the construction of a series of prototypes. On their basis, in the final stage of works, the shape of the nozzle was refined and a series of verification tests were carried out.

The result of the research is an extensive and advanced printing unit for thermoplastics that allows for stable execution of large-format 3D prints at an accelerated pace. Its construction allows for the exchange of material container without interrupting printing process and adapting to the variable printing speed, which has a much greater impact on the quality of details with large dimensions.

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Anna MIŚ\*, Małgorzata KAĆ\*\*

## ***Magnetic nanowires – innovation in nanotechnology***

Nanotechnology is currently one of the most dynamically developing branches of physics. Among many nanostructures, nanowires (NWs) play a crucial role. They are one-dimensional objects with a length of a few micrometers and diameters of the order of nanometers, so they take the shape of highly elongated cylinders. Especially magnetic nanowires, which have been gaining popularity in recent years, are an extremely interesting case. They have a lot of potential applications in biomedicine, in such fields as a cancer therapy in the process of hyperthermia, or drug delivery systems, as well as MRI contrast agents. Nanowires may also be used in electronic elements, high-density magnetic recording media, magnetic sensors, and permanent magnets.

There are a lot of methods to produce nanowires. One of the most popular is the template-assisted electrodeposition which was used in our experiment. During this process, in reduction reaction, the material is accumulated into the channels of the porous template placed on the cathode surface. The electrodeposition was performed at potentiostatic mode at the cathodic potential of  $-1.1$  V vs. Ag/AgCl in a three-electrode system immersed in iron sulfate electrolyte.

The purpose of the work was to prepare and study iron nanowires deposited at the electrolyte temperatures in the range of  $15^{\circ}\text{C}$ – $40^{\circ}\text{C}$ . The porous polycarbonate membranes with a pore size of 100 nm and thickness of 6  $\mu\text{m}$  determined the nanowire diameter and maximal nanowire length. The current vs. time transients allowed us to control the electrodeposition process, which was stopped when the sudden increase of the current informed about the complete membrane filling confirmed by scanning electron microscope images. Moreover, an increase in electrolyte temperature caused an enhancement of the cathodic current which led to the reduced electrodeposition time.

The scanning electron microscopy measurements performed after membrane dissolution revealed an array of smooth and continuous nanowires with homogenous diameter without any trace of porosity independently of electrodeposition temperature. The X-ray diffraction (XRD) analysis of the nanowire kept in the template indicated polycrystalline bcc structure with texture observed in the samples deposited at lower electrolyte temperatures that favored the growth of (211) planes. The slight peak broadening, which increased at the higher temperatures, indicated a decrease of the crystallite size confirmed by calculation carried out based on the Scherrer equation. The estimated crystallite size changed from 25 nm to 19 nm for nanowires obtained at lower and higher temperatures. Mössbauer spectroscopy measurements and XRD proved the metallic state of iron nanowires without any traces of Fe oxide. The magnetic measurements performed by SQUID revealed the magnetic anisotropy of nanowires with an easy axis along nanowires. The determined small coercivity values are connected with a high aspect ratio of nanowires, which enhances the dipolar interaction that causes reduction of coercive field. The magnetization values related to the mass were found to be approximately twice larger than the value of the bulk iron. It may be explained by an enlarged magnetic moment of Fe atoms located on the nanowire surface.

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Mateusz WIRWICKI\*, Rafał RUGAŁA

## ***Manufacturing prostheses with a bar using modern biocompatible zirconium dioxide***

As awareness and public opinion grows, it becomes more and more demanding. They expect dentures to be more durable (resistant to difficult use: food, taking off and putting on) and less visible (color matched to the teeth, no discoloration). These trends later on prosthetists looking for new materials and technologies. The use of ZrO<sub>2</sub> will be groundbreaking – there will be a significant improvement in the aesthetics of the denture (the color matches the dentition). The prosthesis will be more biocompatible than the material used so far (metal), which will improve its usefulness and reduce its impact on the palate. The structure of the material will be favorable for permanent files next to the prosthesis (zircon has a lower roughness, which will damage the dentition when removing and putting on the prosthesis). The new product is in demand by patients from home and abroad. Currently manufactured skeletal dentures and bar-based dentures are separated from the chromo-cobalt alloy and acrylic framework along with the imitation of acrylic teeth. The use of the above-mentioned alloy may cause sensitization in the oral cavity of the patient. Alloy dentures are not biocompatible, which can cause inflammation of the palate and periodontium. The prostheses made of chromo-cobalt alloy are made in two layer technologies by cutting and casting, but these technologies are burdened with high surface roughness (irritation of the contact points of the oral mucosa). Such dentures can be used with adherence to the mucosa and natural natural ones in the mouth. Currently manufactured dentures are kept in the oral cavity thanks to clamps and beams that surround the patient's tooth. The metallic color reveals the possession of such a prosthesis, which results in a loss of self-confidence and a lack of aesthetics. Project entitled: zirconium dioxide emission in dentures, which is currently used only in fixed prosthetics (implants).

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## ***Magnetorheological fluid-based floor mechanics***

Magnetorheological fluids (MRF) are classified as intelligent materials that change viscosity under the external magnetic field. In zero-field, they behave like a viscous liquid, while in non-zero fields, magnetic colloidal suspension forms a chain-like structure and thickens. For that reason, they are widely used for dynamic energy dissipation. Recently, the MRF has been applied even in rehabilitation equipment for stabilization of the injured joints like ankles, elbows, knees, or other joints. The MRF dampers play the role of a variable resistance element and are used, for example, in portable training devices for strength training. Therefore, modern rehabilitation equipment is limited in operation only to a specific part of the body – usually, solutions focus, for example, on the rehabilitation of a particular joint, muscle, or limb. In this work, we created MRF based on metal oxides and applied it to novel devices dedicated to rehabilitation. The system will consist of individual flexible modules filled with intelligent fluid and designed overlays for the user's feet or shoes. The principle of operation of such a device is based on the control of the viscosity of an intelligent fluid placed inside, which directly affects the resistance put on the user by the actuator/damper. Adjusting the overlays with different sizes of the magnetic field allows obtaining the expected hardness of the base of the rehabilitated person. Hence it will be easy to use and thus comfortable for the rehabilitated person and the rehabilitator. The adjustable “softness” of these modules enables the adjustment of coordination exercises, e.g. in patients with Parkinson's disease. It will significantly increase the comfort and safety of people who need physical rehabilitation for the elderly, disabled, and children. However, the proposed device can be successfully used to perform motor coordination exercises.

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***ORAL SESSION VI:***  
**Economics and Management**

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Sviatoslav MALIBRODA\*, Liana CHERNOBAY\*\*, Altyn YESSIRKEPOVA\*\*\*

## **Migration policy and migrants' patterns: shaping the economic benefits**

In our previous research (Chernobay, Adamyk, Malibroda, 2020) we made an attempt to directly link the migration policy of host countries and the economic outcomes of migration which were finally represented by the share of GDP caused by migration. That research resulted in a model of the impact of international migration on the economy of receiving country and its test on Germany's economy in 2017, which revealed that migrants contributed € 51.36 bln. or 0.62% of Germany's GDP in 2017.

However, the developed model is based on quite general functional linkages, which as Boswell (2007) concludes "need to be broken down into observable (and if possible measurable) variables which conform generalized laws."

Therefore, current research is aimed at a profound analysis of migration policies for improving the developed model.

Meyers (2000), in his comparative analysis of theories of international migration, provided two important for our research ideas. First, he points out that "immigration policy shapes immigration pattern, which in turn has a tremendous impact on ... economy." This idea is fundamental for our model as we made several assumptions about migrants' patterns depending on the migration policy. The second, Meyers admits that "immigration policy consists of two parts: 1) ... the rules and proceeding governing the rules and proceeding of selection and admission of foreign citizens; and 2) ... the conditions provided to resident migrants (e.g., work and housing, welfare provision, and education opportunities). While creating the model, we developed a similar list but divided rights into six categories: rights to enter and live, to be employed, to obtain social protection, to own and dispose property, to get an education, and to obtain citizenship.

These two ideas shape the scope and tasks of the current study. First, we analyse the migration policy to break down each rights category into specific rights migrants may obtain. Secondly, we link specific rights with suggested patterns. Finally, we describe how extending or limiting specific rights may affect the patterns and their economic outcomes.

Supranational legislation and international public law are taken as a basis for analysis as they are adopted by most host countries and determine the "maximum" rights migrants may obtain. The rights-pattern linkage and description of the final effect on economic outcome are presented in the form of "extending/limiting specific right → stimulating/blocking specific pattern → increasing/decreasing specific outcome."

The general conclusion is that extending migrants' rights increases the positive economic outcome for the host country. However, extending some rights, mainly which regulate the number of migrants, is possible under favourable domestic conditions. Meanwhile, extending rights to obtain social protection, owning and disposing of property, and getting an education is recommended under any domestic conditions. These findings are the basis for further applying statistical approaches to test the model.

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### ***The econometric analysis of water productivity and its drivers***

We examine the relevance of resource productivity for the assessment of resource efficiency strategies and decoupling analysis. For this purpose, we carried out an econometric analysis to one of the widely-used indicators: water productivity. The econometric analysis shows that changes in water productivity is mostly originated from the sources of economic growth, rather than efficient management of water resources. Therefore, we recommend policy-makers and scholars to avoid using water productivity or exercise caution when interpreting it.

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**Konrad PIĘTKA\***

## ***Integration of Lean Manufacturing and Industry 4.0 concepts***

The aim of this study was to analyze the relationships and dependencies between the concept of Lean Manufacturing/Lean Management and the idea of the fourth industrial revolution – Industry 4.0 within a manufacturing company. At the beginning the definition and basic assumptions of the Lean Manufacturing philosophy were presented. Based on the available literature, the most important aspects of Lean Manufacturing in relation to suppliers, customers, process, control and human factors were reviewed. Next, the basic assumptions and possible impact of Industry 4.0 on a manufacturing environment that functions according to Lean were discussed. The central stage of the study was to analyze examples of mutual integration of Lean Manufacturing and Industry 4.0. On the basis of the literature, an assessment was made of how Industry 4.0 technologies allow achieving such goals as e.g. Just in Time deliveries, pull production, continuous flow and others (resulting from Lean Manufacturing). The conducted analyses allowed to conclude that technologies and solutions applied within the Industry 4.0 concept allow to: increase production capacity and flexibility, contribute to increasing its effectiveness, improve the quality of manufactured products, eliminate major wastage. The application of Lean Manufacturing principles in a company facilitates the introduction of solutions characteristic of Industry 4.0. Therefore, a strong connection between these two concepts is indicated and the need for further research on the directions of development and the relationship between Lean Manufacturing and Industry 4.0 is emphasized.

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## ***HappyVet will make veterinarians happy about their work and proud of their profession***

Veterinary industry struggles with the growing number of veterinarians who leave the profession within a few years after graduation. Young doctors experience long working hours, low payments, unfriendly work environment, dealing with animal cruelty, euthanasia and lack of mental health support. Because of that, veterinarians have 3 times higher risk of committing suicide than general population. These problems start already during the studies. To become a specialist, veterinary students must do a certain number of externships at the hospitals. Sadly, there is a lack of control over the clinics, which do not always offer good conditions for students and their staff, nor learning opportunities for young doctors who are just starting their careers. Opinions about these clinics are not publicly available, which leads to an uncontrolled market and a big problem of unpaid, highly exhausting externship culture without opportunities for professional development and specialisation. This leads to disappointment and burnout, which contribute to the decision of leaving the profession. Our solution has the potential to improve this situation.

HAPPYVET is a website and an app where veterinary students and veterinarians seek externship, internship or job placements considering all the aspects that are important to them. They choose animal species they want to work with, accommodation options, dates that suit them, fields of veterinary medicine they are interested in, etc. HAPPYVET provides them with all the suitable options. After their placement or period of work, they can leave open and visible comments about the clinic and evaluate their experience including all the above mentioned features and more. This will help others to decide whether the clinic meets their expectations and guarantees a comfortable work environment. Moreover, constant feedback will allow clinics to improve the conditions and maintain a good atmosphere for their staff. HAPPYVET will be a platform that promotes open dialogue between clinic owners and staff & students, with the intention to always improve the work conditions. This favours health and satisfaction with your profession.

HAPPYVET will improve veterinary education by giving students the access to high practical education standards in clinics worldwide. It will allow students and veterinarians to seek experience abroad more easily and know the placement in advance thanks to the feedback published on the platform. HAPPYVET will also benefit veterinary clinics by reducing the amount of time needed to manage student placements and will be a great platform to showcase themselves as a good place to work at. This will save them time and money when searching for new staff. Less popular clinics will be able to easily connect with and hire foreign students and veterinarians. HAPPYVET will benefit the veterinary market by providing access to practical, high quality veterinary education and a respectful work environment. HAPPYVET will make veterinarians happy about their work and proud of their profession!

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***POSTER SESSION IV:  
Economics and Management, New Information  
Communication Technologies and University Social  
Responsibility***

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*Iryna PIATNYCHUK\**

## ***BSC as an analytical tool for implementing utcs' social responsibility***

Under decentralization, local governments gain more rights and opportunities to use various types of resources, thus, increasing their level of responsibility (including social responsibility) for the use of resources. The Abstract indicates that the system of balanced indicators is an analytical tool for ensuring the realization UTCs social responsibility.

The Abstract aims to reveal the consequences of decentralization reform for the indicators of UTCs' budgeting that reflect their general socio-economic condition; and to outline the nature of the system of balanced indicators as an analytical instrument of securing the implementation of UTCs' social responsibility concept as well as the nature of the latter one.

Decentralization problems, forming of UTCs and search for the ways to improve their functioning based on social responsibility concept is the subject of scientific research and contemplations of experts in the countries of Eastern Europe, China and Ukraine. Statistical data and documents on strategic development of various countries and scientific literature were the initial data for the research of the impact of social responsibility concept as an instrument capable to link the interests of residents, business environment and state. Foreign practical experience, fundamental provisions and principles of decentralization and concepts of social responsibility are the basis of the research. System-structural analysis, grouping method and comparison were used in our research.

The research resulted in the development of the balanced scorecard of indicators for UTCs. It includes the following blocks: internal business processes, funding, service providers, service consumers, and environment. The research contributed to the development of UTCs strategic map based on BSC adapted to the peculiarities of UTCs. The strategic map provides an opportunity to link strategic goals of UTCs with the developed BSC blocks and allows for a successful implementation of the concept of UTCs' social responsibility.

The research shows that social responsibility is the tool that links the interests of services consumers as UTC's residents with service providers for their realization, promoting the improvement of the services. The system of balanced indicators adapted to the specifics of UTCs and forming of information necessary for managers with a higher level of analyticity, accuracy, and relevance serves as an analytical tool for securing the implementation of UTC's social responsibility concept. The Abstract shows that four blocks can be outlined in the system of companies' BSC: internal economic processes, finances, training and growth, clients. However, the research shows that the structure of the BSC system at the UTCs level will differ from the abovementioned one, which is related to the specifics of UTC's functioning as an economic entity.

The strategic map developed for Broshniv-Osadska UTC that contributes to connecting of the UTC's strategic goals with the BSC blocks and determined target indicators is an important element for the efficient implementation of the concept of the UTC's social responsibility. Therefore, the UTC's strategic map developed and suggested for practical use will contribute to the implementation of the concept of the UTC's social responsibility by connecting it with the strategic goals of the community.

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### ***The main components of investment potential as a condition for the development of the region***

One of the key tasks of decentralization is the development of territorial communities and the growth of their economic potential. One of the most important factors of economic growth is an investment. Investment in UA offers a wide range of legal and tax matters, including corporate, M&A, commercial, migration, international trade, banking and finance, real estate, public sector, EU, competition, energy, intellectual property, employment, and dispute resolution.

At the same time, the largest degradation in Ukraine today is investment activity. One of the first questions asked by foreign clients is the return of investment or of dividends received from the investments. It is worth mentioning the lack of unified rules of the game for business, bureaucracy and corruption, cause delays in business processes. As a result, the investor is less competitive than the local entrepreneur, who is more flexible on the market. As well, the situation is not hopeless. Numerous governmental and non-governmental organizations and government officials really promote investment and protect investors from any negative influences.

At the national level there exists the Investment Attraction Office (UkraineInvest), which was created under the Cabinet of Ministers to help the investors; The European Business Association (EBA), which is really concerned with the business of its members, promotes their legal and political lobby, etc. The article analyzes a set of factors that form the investment potential, as well as the factors determining the investment attractiveness of the region.

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**Natalia KRAWCZYK\***

## ***The crisis management during the COVID-19 pandemic***

Since 2019, the SARS-CoV-2 virus has spread rapidly in China, reaching many other countries. This virus has become a great global threat for which the world was not prepared. Despite the fact that the conditions for the spread of pandemic viruses are known in the world, no one is able to fully determine their effects. Therefore, the preparation of crisis plans by health care institutions should become the basic undertaking enabling the proper functioning of medical facilities and the continuity of health services.

This study is based on an analysis of the six best European healthcare systems according to the presented in 2018, Euro Health Consumer Index (EHCI) ranking. The study was based on literature research and secondary research in the field of healthcare systems in the context of the COVID-19 pandemic in Belgium, Denmark, Finland, the Netherlands, Luxembourg, Sweden and Poland.

The main purpose of the article is to analyze the crisis management during the COVID-19 pandemic in selected European Union countries in the period from January 2020 to April 2021. The obtained results were compared with the Polish system. The conducted analysis of management methods during the crisis caused by the coronavirus pandemic allowed for drawing conclusions.

The presented research shows that there is no correlation between the result in the EHCI and the effectiveness of crisis management, the results of which can be linked to the number of cases and deaths caused by COVID-19.

Healthcare facilities should cooperate with other organizations and use benchmarking in activities that may reduce the size of the pandemic and minimize its impact. In all analyzed healthcare systems, such cooperation takes place, emergency plans are developed and these systems achieve different results during the COVID-19 pandemic. In conclusion, it should be noted that even countries with the most developed and well-financed health sectors are not coping with the crisis.

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**Tomasz DZIUBIŃSKI\***

## ***The use of crisis management models by Polish enterprises based on the life cycle in relation to the use of relational models***

The aim of the study was to conduct a pilot study to determine whether and to what extent Polish enterprises apply the elements of crisis management in practice. The study covered the use of crisis management by Polish enterprises located in Malopolska, its scope and scale. The subject of the research were small and medium-sized enterprises, with the deliberate exclusion of large and micro entities. Information on the crisis management models used by these entities was obtained and analyzed. The author's focus was on gaining information and practical experience and testing target interview forms for collecting results. In the future, it is planned to conduct research on Polish enterprises on the same issues, but on a wider research sample, while maintaining the principles of representativeness in terms of its structure. The next part of the study was to obtain information about the type of crisis management model used and an attempt to answer to the question which of the models is most often used by Polish enterprises?

Methodology consisted in conducting 12 structured interviews regarding the use of crisis management in terms of the choice of crisis management method and time horizon. Based on the results, it turned out that in the strategic dimension only a very small number of Polish enterprises apply crisis management. On the other hand, the remaining very large part of enterprises treat crisis management as a typical operational tool. The last part of the respondents treat the crisis situation as fully defined for which the company has already developed a procedure. These enterprises do not take into account the risk factor that a completely new situation may arise, for which the enterprise does not have a developed procedure. This is characteristic for a linear lifecycle model. Only one subject from the study used the relational model, more resistant to completely new situations.

Based on the obtained results, we can conclude that Polish enterprises participating in the survey in the minority had crisis management procedures in place and at the same time applied them. A minority of them had developed procedures for crisis situations. However, not all of them, despite having crisis procedures, apply them. Enterprises that have used their procedures, at least in part, have practically limited themselves to using the method based on the life cycle of a linear crisis for this purpose. It stays in compliance with thesis that in Polish conditions only some enterprises apply crisis management in practice. And if companies do, then they use sequential crisis management methods based on the crisis life cycle. Only one of the surveyed companies had a crisis management system using the relational (non-linear) model.

The final conclusions of the study include the need to modify the proper research in terms of methods used by Polish enterprises in crisis management. The results of the study illustrated the orientation of Polish enterprises towards short-term goals and on postponing problems in time rather than applying a comprehensive approach to solving the problem. Moreover, it may constitute the basis for conducting studies with the use of a wide scale.

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## ***Gamification as a modern tool of HR-management: advantages of usage***

The article considers the actual HR management tool that has been evolving as new form of personnel development with elements of games and social networking inside the company. The importance of this topic was proved by conducted international survey, which displayed that gamification makes employee feel more productive, happier and motivated.

Taking into account the contemporary importance of this topic, the aim of this work is to explore the gamification tool of HR management by considering the types of gamification, determining the principles of gamification, investigating the methods and mechanics of gamification as a tool in HR-management, finding the benefits of this management tool.

To achieve this goal, the following research methods have been used: analysis – for investigation the sense and value of gamification in HR management, synthesis – for gathering got information to put it into conclusions and recommendations, systematization of scientific literature and generalization of theoretical materials – for summarizing the modern vision on gamification by tailing this management instrument with the scientific research on basic concepts of learning.

It is highlined that gamification is used wherever a game or competitive element are introduced in non-game contexts with using of game elements, namely: game dynamics through the possible scenarios of game development and results that the player can achieve, game mechanics by using rules of the game, game aesthetics on the base of emotional experiences and social interaction.

There were considered two types of gamification as HR management tool: an internal gamification – aimed at the personnel of the enterprise to increase their productivity by developing soft skills ; an external gamification – aimed at consumers in order to increase their loyalty and enterprise revenue by activating the mobile devices and the availability of the Internet for the population, as well as an involvement of a significant number of people in various gaming events.

To provide the practical recommendation for gamification, methods and mechanics of gamification were pointed out: the competition method – to motivate employees and encourage them to improve the quality of work; Win-Win strategy – method allowing employees reward, depending on the quality of work performed; aesthetics and emotional coloring – method, using the aesthetically visualized participance of employees at the enterprise life; quests – method that helps not only to find a leader of the team, but also to unite the team by resolving common situations and participating in making decision.

In order to investigate the implementation of gamification in practice of Ukrainian enterprises there were conducted the survey, the findings of which has shown up the main obstacles in this area, namely: poor recognition of such management tool, bad understanding the value of games for the personnel's learning, lack of experience.

The main principles of effective gamification implementation in HR-management at the enterprises are highlighted. The main advantages of gamification in HR management at the enterprises are described.

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*Anna STRUTYNSKA\*, Iryna BORYSHKEVYCH\*\**

## ***Formation of an effective mechanism of motivation of employees in modern conditions***

Relevance of research. In modern economic conditions, the issue of employee motivation becomes important. The lack of effective motivation mechanisms in companies, proper working conditions, fair and decent wages cause employees to be dissatisfied with their work and, as a consequence, reduce productivity. An important task for personnel management is the formation of an effective motivational mechanism that meets modern conditions and is flexible to rapid economic change.

The purpose of the study is building employee motivation mechanism for modern enterprises.

Research methods. The theoretical and methodological basis for scientific research were the provisions of domestic and foreign economic research on employee motivation. To implement the tasks, general and special methods of scientific research were used, namely: the method of theoretical generalization, systematic approach, sociological survey and graphical method.

Results of the research. The decisive factor in the effectiveness of people's activities is their motivation. The problem of motivation has been and remains the subject of research by many economists.

Motivation is a set of factors affecting the staff and management of the company for the purpose of their active activities aimed at achieving their own goals and the goals of the company.

To study the impact of motivation on human productivity, a survey was conducted. In the course of the research 165 questionnaires were processed. One of the questions was: "How does the developed effective motivation mechanism affect the improvement of employee productivity?"

Results of research showed a high impact of the developed effective mechanism of motivation to improve employee productivity.

Respondents who rated the interdependence at a low level (0-1 points) to the question "In your opinion, in the company (institution, organization) where you work developed an effective motivation mechanism?" gave a negative answer. This may be the reason for the low assessment of the impact of an effective motivation mechanism on human performance. Based on the study and the results of the survey, we have formed a mechanism for motivating employees in modern conditions.

Conclusions. The developed mechanism of employee motivation is based on the existence of two main types of motivation, as well as the idea that people prefer both material and moral motivation. This should be considered when paying salaries and other rewards, because it depends on how motivated employees will be the effectiveness of achieving the main goals of the company, the implementation of development strategies and market success in relation to competing companies. Among all the tools to solve this problem, we have chosen a modern KPI system, which is a fair mechanism for rewarding employees and it considers their main results. World practice proves that the use of the KPI system increases the profit of enterprises by 10–30% depending on the achievement of employees' goals, as well as increases the motivation and loyalty of staff.

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*Kristina DVORIANIN\*, Lesya VERBOVSKA\*\**

### ***The prospect of organizing trainings in the company's training center***

Optimization of the number of personnel in the training department is one of the most promising anti-crisis measures. In contrast, it is necessary to organize a new business direction for training third-party personnel at training sessions. To do this, it is necessary to assess the prospects for the development of this business area. The Personnel Training Department is part of the personnel management service and has its own qualified personnel. Various seminars and trainings were conducted independently for the company's own staff. It is planned to conduct seminars and trainings on sales and personnel management for the personnel of third-party organizations. Currently, the company has a training center equipped with classrooms with excellent material and technical base for training and has qualified teachers. On the issue of developing a new business direction, it is necessary to determine the market prospects for development and conduct a comprehensive analysis of the business direction in the region, as well as assess the commercial success of conducting its own qualified employees on the existing training base. To do this, you must:

- conducting educational courses by highly qualified business coaches with extensive practical experience,
- modern material base of the training center,
- development of effective practice-oriented trainings,
- commitment to an excellent result of business coaches,
- cozy and business environment in the training center,
- availability of proprietary technologies and well-developed infrastructure, for effective development of skills in the learning process,
- feedback from clients who have been trained on the effectiveness of the knowledge and skills gained based on the information received from the course programs.

There are certain risks and weaknesses: the placement of the training center in a remote area of the city and the provision of a transport network, incomplete information of potential customers about the capabilities of the training center, short-term cooperation in order to find new professional tasks. To be able to occupy a market niche, external factors are also necessary:

- increasing the number of people who need professional retraining due to the financial crisis and who want to independently improve their skills in order to look confidently into the future
- improving the skills of their own staff in the development of sales systems and new technologies,
- the growth of the market of educational services in the field of new technologies and sales and the availability of offers in the labor market for qualified personnel,
- federal programs for financing educational projects for retraining of unemployed citizens,
- the general policy of the government aimed at the innovative development of the economy through the development of intellectual potential.

Unfortunately, the following factors have a negative impact: the financial crisis, the tightening of

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the legal framework, the constant development of training technologies in demand in the market, the lack of understanding by business owners of the need to learn new technologies, the growth of unemployment, lower incomes, strong competition, the need to improve the system of retaining key employees of the training department. The prospects for the development of the proposed business direction include a plan for conducting an advertising campaign and timely necessary funding. Conducting introductory free seminars with the heads of large companies, aimed at increasing their understanding of the importance of this training. The ability to competently organize the educational process of professional development and retraining of personnel. In conclusion, in order to assess the prospects of the business direction for training personnel at trainings on new technologies and sales, it is necessary to conduct a comprehensive analysis of internal and external factors and determine the market prospects for the development of the proposed business direction in the region. This will allow us to organize cooperation with large companies in the conditions of a shortage of personnel, and a high practical result of training will allow us to attract citizens to training under the professional retraining program. Great financial, administrative, and other capabilities will be able to withstand increasing competition and the tightening of the legal framework.

**Maria BAJAK\***

## ***Sustainable development: the example of The Crystal building***

Today, the concept of sustainable development increasingly often indicates the direction of economic, political, social and environmental activities. The specificity of the construction industry, in particular the high development potential of buildings, as well as their susceptibility to innovation make this sector have a significant role in activities aimed at achieving the above-mentioned objectives. Sustainable construction thought is a signpost of the development of architecture, which is characterized not only by a modern shape, but also by high functionality, low maintenance costs, and minimizing the negative impact on the environment. The main purpose of the speech is to present the idea of sustainable development on the example of The Crystal building in London. The building was analyzed from the economic, environmental, and social side to determine its compliance with the assumptions of the concept. As part of the research, secondary data was used, including reports, articles, and interviews. The analysis was additionally supported by a review of world scientific literature. Based on the research, it has been established that The Crystal building, apart from its avant-garde shape, is distinguished by attention to ecological details. It is a self-sufficient, independent building, which is at the same time an integral and coexisting part of the city. It can serve as an example for the further practical implementation of the concept of sustainable development.

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**Magdalena CHOWANIEC\***

## ***Determinants of innovativeness of Polish enterprises***

Innovative activity is based on the definition of entrepreneurship created by J. Schumpeter. According to him, innovations are new ideas, discoveries or inventions that are the result of creative thinking in the field of new technical, economic and organizational solutions in the field of interpersonal relations. On the other hand, entrepreneurship is the domain of people persistent in overcoming barriers and striving to achieve the set goals, which include the implementation of a new technology, product, opening a new market or acquiring new sources of raw materials. Entrepreneurial activities are aimed at improving the company's efficiency. On the other hand, the innovative activity of enterprises, according to the definition of the Central Statistical Office, is all scientific, technical, organizational, financial and commercial activities leading or intended to lead to the introduction of innovations. The scope of innovative activities also includes research and development (R&D) activities that are not directly related to the creation of a specific type of innovation.

One of the main problems of Polish enterprises is their low level of innovation, measured with almost all types of innovation indicators used in the literature on the subject and in innovation policy. Obviously, the low innovativeness of Polish enterprises translates into slower economic growth. The level of innovativeness of Polish enterprises definitely differs from the level typical of the old EU countries. Therefore, a question arises about the determinants (factors) of innovativeness of Polish enterprises and about the differences in this respect compared to enterprises in highly developed countries. This paper is devoted to answering this question. The paper analyzes how groups of external conditions affect internal conditions, and thus the level of innovativeness of Polish enterprises.

The main research method adopted in this study is a descriptive analysis and an analysis of the literature on the subject. The main source of empirical data is data from the Central Statistical Office. The research methods presented above were used to identify the conditions in Polish enterprises.

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## ***Information technologies in public administration: the practice of Ukraine***

Relevance of research. In the last decade, one of the priorities of public policy has been the use of information technology in public administration systems of all countries. According to the level of development of information and communication technologies in 2015, the leaders are South Korea (index 8.93), Denmark (index 8.88), Iceland (index 8.86). Whereas Ukraine lags significantly behind other countries, ranking 79th (index 5.23). In this regard, the priority tasks of the state include the formation and development of information infrastructure at the state level.

The purpose of the study is to study the use of information technology in public administration in Ukraine and the problems of their implementation. General and special methods of scientific research were used, namely method of theoretical generalization, system approach, synthesis, SWOT-analysis.

The main regulatory framework for the use of information technology in public administration are The concept of e-government development in Ukraine dated September 20, 2017 № 649; Law of Ukraine "On Citizens' Appeals" of 1996 № 47; Law of Ukraine "On Access to Public Information" of 2011 № 32. But these regulations are not enough to implement an effective ICT information system in public administration.

Currently, a number of government electronic services operate in Ukraine that simplify relations with citizens. The E-Data web portal is an official state information portal on the Internet, which publishes information on the use of public funds. The iGov portal was launched by a team of Ukrainian and foreign IT volunteers to fight corruption in Ukraine, etc.

With the help of SWOT-analysis we have identified such problems in the development of ICT in Ukraine: 1. Insufficiently thought-out policy in the field of ICT and information security. 2. Slow modernization of existing equipment. 3. Infrastructure is too expensive and of poor quality.

It is possible to create conditions for overcoming obstacles to the introduction of e-government services in Ukraine: a thorough analysis of the experience of European countries; the presence of a large number of high-class specialists-civil servants in public institutions; improving information security systems to protect personal data.

According to the results of the study, we have identified several systemic problems that can be traced in Ukraine in the implementation of ICT, including in the field of information security. To solve these problems, it is first and foremost necessary to carefully analyze the experience of European countries. Promising from the point of view of the theory and practice of modern science are studies on information security for citizens and authorities, in the process of using information and communication technologies in public administration in Ukraine.

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**Sylwia SIERACKA\***

## ***New technologies in industry-university cooperation in VUCA world according business***

New technologies used at an increasing scale, and networking of the economy have an influence on the development of impact of various forms of communication and competitiveness on a global scale. The aim of the article is to show the chance to improve cooperation between the enterprise and research universities from the perspective of business needs, based on the example of the bio-pharmaceutical sector and new technologies. In the article was used analysis of the literature on the subject and personal research.

The biopharmaceutical sector is currently a world leader in investment in research and development, where for a decade there has been a growing productivity gap, in which the number of authorized drugs is decreasing while the expenditure related to drug research continues to increase. This type of situation forces research leading to an increase in productivity through the use of solutions using new technologies.

At universities, especially those with a technical profile is enormous research potential which creates opportunities for cooperation with companies from the biopharmaceutical sector in this area. However, insufficient quality of communication at the level of business-research universities deprives universities of opportunities for direct cooperation with the industry. In the current peloton of suppliers of new technologies to the biopharmaceutical industry, universities rank as subcontractors, not business partners.

A network platform, enabling faster contact between business and research and scientific centers, could compete with current suppliers to business solutions. The author sees opportunities in the marketing orientation of the cooperation topic and proposes the establishment of a confederation of research universities on the basis of the platform. The cooperation network has a chance to contribute both to the improvement of innovative and market results.

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This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation



### **PHEIDIAS: An Innovative hydrometallurgical recycling system for PGMs recovery**

**PHEIDIAS** aims to bring into the market an innovative hydrometallurgical process for the recovery of Platinum Group Metals (PGMs) from Spent Vehicle Catalytic Converters (SVCCs). The competitive advantage of this technology is the increased material recovery rate, as well as significantly lower operational costs. What is more, the technology uses solvents in low concentrations, which improves waste management performance.

The project will focus on the markets of Greece, Poland, Hungary, Bulgaria, Slovakia, Slovenia, Romania, Cyprus, and Serbia, where project partners have already developed a network of SVCCs suppliers through their previous collaboration in the INNOCAT project. To that end, partners will upscale and pilot-test the proposed technology at large-scale operation conditions, bringing it from TR5 to TRL8 during the project, and commercialise it within one year after project completion (TRL9).

The consortium consists of following Partners:

- Enalos Research and Development, Greece
- Hellenic Society for the Promotion of Research and Development Methodologies (PROMEA), Greece
- International Center for Advanced Materials and Raw Materials of Castilla y León – ICAMCyL, Spain
- Mineral and Energy Economy Research Institute of the Polish Academy of Sciences (MEERI), Poland
- Technical University of Kosice, Slovakia
- University of Miskolc, Hungary
- RIS TASK PARTNER 2 – ROMANIA, Romania
- RIS TASK PARTNER 1 – SLOVENIA, Slovenia
- Monolithos Ltd (Lead Partner), Greece



**RES-SKILL:** Reskilling coal industry workers for the renewable energy sector.

The aim of the project is to analyze and expand the offer of vocational education and training in the energy sector, addressed to employees of the coal industry, in response to market demand in the era of Energy transition. The project will result in increasing the possibilities of professional restructuring, which will be adjusted to the skills required in the RES sector identified by the forum of experts. The project's specific objectives are to:



1. Develop a novel curriculum & tailored training content to facilitate coal workers' reorientation to the RES industry.
2. Support VET providers to integrate the RES-SKILL materials into their VET & WBL offerings.
3. Improve cooperation between VET providers & businesses to provide opportunities that will enable coal workers to transition to the RES sector.

**Target groups of the RES-SKILL project::**

- VET providers
- Coal industry workers (primarily low-skilled) that need to up-skill themselves to strengthen employability or job security
- Sector representatives and key players/employers, social partners, and associations of employees and employers
- VET authorities & career guidance bodies (incl. regional development agencies responsible for training initiatives)



The consortium consists of following Partners:



**PROME A**  
• Hellenic Society for the Promotion of Research and Development Methodologies, Greece



**BFI**  
• Vocational Training Institute, Austria



**RENAC**  
• Renewables Academy AG, Germany



**LTT**  
• Ticleni Technological High School, Romania



**SZREDA**  
• Stara Zagora Regional Economic Development Agency, Bulgaria



**MEERI**  
• Institute for Research on Minerals and Energy Economy, Poland



### **BioRen: Development of competitive, next generation biofuels from municipal solid waste**

The objective of BioRen is to develop competitive drop-in biofuels from the organic fraction of municipal solid waste (OFMSW). The project focuses on glycerol tertiary butyl ether (GTBE), a promising fuel additive to both diesel and gasoline that improves engine performance and cuts harmful exhaust emissions (i.e. fine dust).

The process consists of enzymatic processing of municipal organic residual waste separated from the RDF fraction, mainly paper and cardboard and kitchen waste. The residues from the fermentation process are subjected to hydrothermal carbonization to biochar.

The developed processes is integrated in a revolutionary MSW treatment plant located in Oostende, Belgium, which combines the most efficient technologies of material reuse, and which is currently looking into optimising the profitability of its organic waste fraction.

The consortium brings together nine Partners:

- D.C. CORPORATE FINANCE (D.C.F.), Belgium,
- Mineral and Energy Economy Research Institute PAS (MEERI PAS), Poland
- DRYSEP BV (DrySep B.V.), Netherlands
- VIB, Belgium
- VOSSEN Laboratories int. bv (Vossen Labs), Netherlands
- Bio Base Europe Pilot Plant VZW (BBEPP), Belgia
- PROCEDE Group BV, Netherlands
- Ingelia SL, Spain
- Lunds Universitet (ULUND), Sweden



**RM's Manager- Raw Materials Manager Course:** Creating a new educational program for future managers in the fields of management, sustainable development, efficient use of resources and the circular economy.



This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation



**RM's Manager** is a project co-financed by EIT RawMaterials. The aim of the course is to introduce and promote circular economy and sustainable development solutions in raw materials sector. It is a response to the students' aspirations and the needs of the mining and processing industry for a qualified team of strategic, technological, operational and social managers.

The aim of the project is to create a platform for the exchange of good practices in education in the field of resource management. The classes and scope were selected on the basis of surveys conducted among representatives of industry and science. As a result, more than 200 students of technical faculties from 30 countries were trained in the area of sustainable development, corporate social responsibility, human resource management and circular economy. As part of the RM's Manager program, participants can expand their knowledge and skills during various activities such as: lectures, workshops, idea camps (Idea Camp) and short, seasonal, intensive courses organized in summer and winter (Summer and Winter School).

The project leader is AGH, and the partners are both academic and research centers from Italy, Spain, Finland, Greece, Ukraine, Poland and Slovakia.

#### Project Partners:



More details can be found on the project website: <https://rmsmanagercourse.pl/>

### **SPIN: Transfer Centers of Knowledge in Małopolska Region**



The Mineral and Energy Economy Research Institute of the Polish Academy of Sciences implements the SPIN-Transfer Centers of Knowledge in Małopolska Region project, providing pro-innovative services for micro, small and medium-sized enterprises located in Małopolska Region (a branch or a subsidiary) which want to increase their innovation and develop within the scope of the key specializations of Małopolska Region.

The Institute provides services in the field of intelligent specialization: **PRODUCTION OF METALS AND METAL PRODUCTS, VERY FAVORABLE CONDITIONS, UNDER DE MINIMIS ASSISTANCE.**

Do you run a company, have a branch in Małopolska? Do you want to develop your company, are you looking for innovative solutions to improve the company's situation on the market and gain a competitive advantage? Do you have a clearly defined goal for the company's development, but you do not know how to achieve it, or maybe you lack specific ideas, but do not lack the courage to surprise the market with new products? Use the services of Transfer Centers of Knowledge operating under the SPIN project as support for entrepreneurs.

There are teams of experts who will analyze the situation of your company, propose solutions that can be applied in a specific case, and if necessary, they will also try to indicate the possibilities of financing the implementation of the proposed solutions from external funds. The solutions can be diverse, but their common feature is "tailoring" the needs of a specific company.

Scientists associated with the largest academic centers, experts from various industries, with unique research opportunities are finally within your reach! Take advantage of their knowledge. Don't wait for your competition to overtake you.

Detailed information and explanations are provided by Agnieszka Nowaczek (tel. No.: 12 617 16 11, mobile phone: 504 824 603, e-mail: [anowaczek@min-pan.krakow.pl](mailto:anowaczek@min-pan.krakow.pl)).

Find out more at: [www.spin.malopolska.pl](http://www.spin.malopolska.pl) or contact the Contact Point for Entrepreneurs at the Marshal's Office of the Małopolska Region, Kraków, ul. Wielicka 72B, e-mail: [spin@umwm.malopolska.pl](mailto:spin@umwm.malopolska.pl); tel. 12-29 90 662.

**MINE.THE.GAP:** Creation and integration of new value chains for SMEs in the mining sector and raw materials supported by innovations taking into account ICT, circular economy, resource efficiency, advanced manufacturing processes.

MINE.THE.GAP is a **support platform** for companies from these “provider” and “target” sectors. Through funding, business support services, communication and dissemination activities, and links to other projects, networks, and public authorities, MINE.THE.GAP aims to:

- Promote cross-sectoral innovation
- Serve as a starting point to boost strategic interregional collaboration
- Provide direct financial support to SMEs
- Integrate in one single platform a variety of support innovation tools
- Establish close-links and suitable complementarities with regional policies and related schemes through its consortium partners
- Foster the participation of cluster organisations as facilitators



#### **Project objectives:**

- Raw materials are the basis of most industrial value chains. This is especially true for the industrial and metallic mining, construction, and related sectors.
- A viable and responsible minerals and metals mining provides essential assets to our society’s sustainable development, and help us to promote innovation, growth, and a low-carbon, more circular economy.
- MINE.THE.GAP supports sustainable development among European actors in the raw material value chain. It offers SME support in the implementation of cutting-edge technologies compliant with:
  - principles of the circular economy,
  - increasing resource efficiency,
  - implementing advanced technological solutions.
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- The idea is to bring together technology providers and businesses in the mining industry to create new and improved value chains. Through MINE.THE.GAP, European SMEs can enter new collaborations to develop products, technologies, solutions, and services for the raw materials and mining sectors.

#### **Project Partners:**

MINE.THE.GAP is brought to life by a consortium of nine cluster, one RTO and one association from seven European countries. MINE.THE.GAP is coordinated by ICAMCyL (Spain), a key European player and competence centre in raw materials and advanced materials sectors.. The consortium partners bring different competences to the project and represent more than 500 SMEs and companies.

### InSysHub: Industrial Symbiosis Hub

The Industrial Symbiosis Hub, a project funded by EIT RawMaterials, was set up to introduce industrial symbiosis in a wide range of studies at universities.



This hub stimulates industries to provide real-life challenges to students as course assignments, graduation projects, etc. On the other hand, companies obtain solutions to their challenges based on the most recent academic insights.

The hub organises events to introduce industrial symbiosis and gather industry representatives, universities, and students to work on challenges in industrial symbiosis. The challenges include a wide range of disciplines, such as mechanical engineering, energy technology, chemistry, sustainability, business and management.

The project's industrial partners are CoolRec (Belgium), Circularise (the Netherlands), and Resourceful BVBA (Belgium), which will provide valuable practical input to the project.

The focus of the hub is to bring industry, universities, and students together to work on challenges in industrial symbiosis. This hub stimulates industries to bring their questions and challenges on closing the material loops to universities as course or graduate assignments for a broad range of studies (business, engineering, management). The hub directs the assignments for students at industries with mentors from industries on the theme of industrial symbiosis.

Benefits of the hub:

- Assignments that lead to PhD's
- Assignments that lead to post doc
- Assignments that lead to industries funded research
- Input to research
- Arranging assignments for teachers
- Students attracted

Project Partners:





**PackAlliance: European alliance for innovation training & collaboration towards future packaging**

PackAlliance intends to contribute to modernize the Higher Education curricula by enhancing its alignment with the Plastics Packaging labor market needs. PackAlliance is a Knowledge Alliance that brings together academic and industry partners from 4 EU countries (Spain, Poland, Finland and Italy) in order to foster Academia-Industry collaboration for innovation and competence building in innovative and sustainable packaging, as a nuclear element for the transition to the Circular Economy within the plastic industry.

**Project informations**

Grant Agreement	612212-EPP-1-2019-1-ES-EPPKA2-KA
Programme	Erasmus+
Key Action	Cooperation for Innovation and the exchange of good practices
Action Type	Knowledge Alliances for higher education
Project Title	PackAlliance: European alliance for innovation training & collaboration
Project starting date	01/01/2020
Project end date	31/12/2022
Project duration	3 years

**This project has received funding from the European Union**

**Project Partners:**



**The information and views set out in this report are those of the authors and do not necessarily reflect the official opinion of the European Union. Neither the European Union institutions and bodies nor any person action on their behalf may be held responsible for the use which may be made of the information contained therein.**





Pack Alliance | European alliance for innovation training & collaboration towards future packaging

## **SPECIALIST IN THE CIRCULAR ECONOMY OF PLASTIC PACKAGING**

The programme “Specialist in the circular economy of plastic packaging” is an exclusive learning experience especially designed for freshly graduated students and professionals who aim to increase their skills and prepare for becoming circular economy specialists in the framework of the plastics sector.

The programme is funded by the EU, through the ERASMUS+ KA2 PackAlliance project, participated by leading educational and industrial partners in the field.

The programme has an overall load of 30 ECTS and will take place from October 1st 2021 to May 20th 2022. The course will be divided in five thematic modules:

Module 1. New materials and biomaterials.

Module 2. Eco-design and novel manufacturing processing.

Module 3. Residue management and valorisation.

Module 4. Citizen and consumer engagement.

Module 5. Challenge-based collaborative practice.

By completing the course, you will expand your knowledge of the circular economy applied to plastics through an ambitious training syllabus created by academic and industry experts. The first 4 modules, with duration of 5 weeks each will include expert-led sessions and both synchronous and asynchronous activities designed for equipping you with the skills and knowledge required for playing an active role in the swift towards circular economy.

First admission period:

- Deadline for applications: June 20th 2021 at 13:00 CET
- Communication to applicants: before July 1st 2021

Second admission period and waiting list:

- Start: July 1st 2021
- Deadline for applications: 7th September 2021 at 13:00 CET
- Communication to applicants: before September 15th 2021

More information: <https://www.packall.eu/training-programme/>

# MINTECO



Instytut Gospodarki  
Surowcami Mineralnymi  
i Energią  
Polskiej Akademii Nauk



The National Centre  
for Research and Development



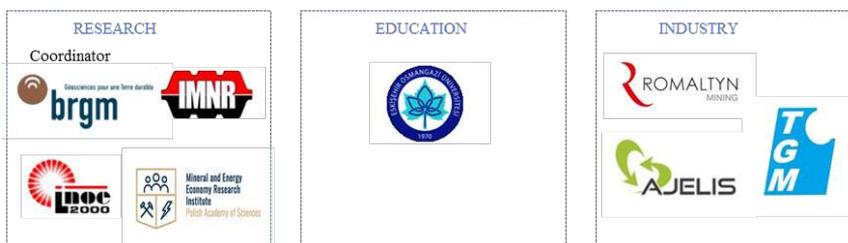
**Minteco: Integrated eco-technology for a selective recovery of base and precious metals in Cu and Pb mining by-products**- project, reference no ERA-MIN-2017\_119, is co-financed by The National Center for Research and Development within ERA-MIN 2 program.

The MINTECO project aims to develop an integrated innovative, efficient and ecological global technology for the recovery of base (Cu, Pb, Zn) and precious (Au, Ag) metals from copper and lead bearing mining waste (CLMB) and to promote more consistent methods for managing these wastes generated from dumps sites and tailings.

The project will allow establishing a global management methodology to treat historical mining sites and reduce disposed volumes of metal-bearing waste. Lab scale experiments (TRL<4), on well-known representative samples, will first allow establishing optimized protocols to concentrate the metals in smaller fractions by innovative mineral processing and recover the metals by hydrometallurgy techniques. The main steps (pre-concentration/ leaching/ high grade metal recovery) will be studied in details by research institutes to optimize first relevant process sequences. Then, a global coherent flowsheet will be proposed and the developed technologies will be further validated by the industrial partners (SMEs) at TR>4. Final economic and environmental assessment will be performed.

The consortium gathers eight partners from four countries (France, Romania, Poland and Turkey) with complementary expertise. It is composed of a University (Turkey), three research institutes (Romania, Poland), a public institution (France) as well as three small and medium companies (France, Romania, Poland).

## Project Partners:



## Contact:

Dr hab. Joanna Kulczycka, kulczycka@meeri.pl



### **iTARG3T: Innovative targeting and processing of W-Sn-Ta-(Li) ores: towards a sustainable self-supply in Europe**

Europe has a large potential for the production and self supply of W, Sn, Ta, and Li- raw materials „critical” for the economy. Despite their deposits being abundant, specific problems related to their exploration, resource evaluation, mining and concentrate production hamper their development. This project aims to overcome these limitations, leading to the opening of new mines by providing innovative tools for deposit targeting & development.

This proposal is oriented to solve most of the problems that arise during the early and advanced stages of W-Sn-(Ta-Li) exploration, effective targeting, and ore processing. We estimate that using the methods proposed here, around the new mines can be developed and opened, reaching the European self-production on a mid-term time scale.

- **13 partners (11 RIS)**
- **8 countries, 5 CLCs**
- **4 key test sites**
- **1 common goal**

Additional information on the iTARG3T project and project updates are posted on this website:  
[www.itarg3t.eu](http://www.itarg3t.eu)

**Selected consortium partners and external collaborators:**



**Contact in Poland: [The Division of Strategic Research, MEERI PAS](#)**

mgr inż. Natalia Generowicz, [ngenerowicz@meeri.pl](mailto:ngenerowicz@meeri.pl)

**International cooperation for Rational Use of Raw Materials and Circular Economy (COOPMIN) Academic Partnership Programme announced by the National Agency for Academic Exchange**



The project "International cooperation for Rational Use of Raw Materials and Circular Economy under the International Academic Partnership Programme" is implemented in 2019-2021 by the The Division of Strategic Research at the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences. The aim of the project is to analyze and develop a methodology in an international partnership economy demand for mineral resources in Europe, while increasing mobility of young scientists, establishing and maintaining international cooperation and making the obtained research results public. The project partners are leading research centers from Germany, Norway, Sweden and Latvia.

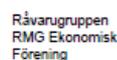
The result of the project is to develop a method of economy demand for mineral resources, taking into account: changes in the national economy (e.g. assessment of the demand by selected industry sectors, development of innovation and new technologies, planned changes in the development of the country), European (e.g. megatrends and assessment of raw material flows based on material system analysis and material flow account), security of supplies ensuring the development of advanced high-tech technologies. The analysis of trends and dynamics of the development of demand is carried out in the short and long term. The developed methodology will allow to predict the size of the demand for selected raw materials minerals and development of development scenarios depending on trends in the European economy and conditions on international raw material markets.

For the European Union (EU), the shortage minerals is a particularly worrying problem - countries are dependent on imported minerals metallic and metals needed in high-tech productions.

The rapid development of the world economy requires answers on the availability of primary and secondary minerals necessary for functioning of individual sectors of the economy. Lack of appropriate standardization and methods, that would enable material flow management is a barrier to efficient use raw materials on the European market. The project results will be important for the implementation of the strategy development and EU raw material policy.

The effects of the project will contribute to the promotion of innovative technological solutions, which requires the involvement of interdisciplinary promotional teams solutions and products in the country and abroad.

**Project Partners:**







# ORGANIZERS



Mineral and Energy  
Economy Research  
Institute  
Polish Academy of Sciences

# PARTNERS



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