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**POSSIBILITIES OF REDUCING TRAFFIC NOISE WITH INNOVATIVE  
CONSTRUCTION ELEMENTS OF NOISE-PROOFING WALLS BASED ON SHOCK  
ABSORBERS MADE OF RECYCLED MATERIALS USING ANTI-SOUND  
TECHNOLOGY**

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**ABSTRACT**

Nowadays, the requirements for noise reduction in all areas of human life are constantly increasing. The development of modern technologies also allows the application of innovative methods for the implementation of measures aimed at reducing noise. Noise reduction in open spaces is commonly achieved through barriers. Noise barriers (passive protection) are generally useful in a wide range of sound, but their effectiveness is reduced at lower frequencies, due to increased diffraction at low frequencies. One of the unusual applications is the use of ANC (Active noise cancellation) technology, which can be understood as a supplement to noise walls and barriers. A major obstacle to the application of noise walls with the implementation of ANC technology is their high price (loudspeakers, microphones, control units). For this reason, the authors of the article focused on the development of systems that can create sound counterwaves without the use of additional loudspeakers and microphones. One such system is noise absorbers using the principle of active noise attenuation. Such a silencer is a passive "sound trap" built in a modular design. It consists of an acoustic insert and an acoustic reflector box. The innovative silencer uses anti-sound technology (acoustic interference) to reduce diffraction. The paper presents an innovative traffic noise silencer that uses destructive interference to reduce noise that propagates through a noise barrier. This design solution passively generates



"anti-noise" or "anti-sound", which reduces noise on the receiver side. It is a lightweight product with minimal impact on existing noise barriers when installed. For this purpose, an innovative noise absorber was developed in cooperation with Waverbreaker AG, Lerum, Sweden. The authors of the paper focused on the implementation of an innovative silencer into noise calculation software that enables the creation of noise maps presenting the current and predicted state of noise propagation in space. Currently available software products focused on noise calculation do not yet have the options to model such types of silencers. At the same time, in cooperation with NDS, a. s., Bratislava, a real implementation of an innovative silencer on a specific selected noise barrier (D1 Motorway - next to the village of Studenec) was carried out. The obtained results of experimental measurements, a mathematical model (noise maps) of noise propagation in space with and without the application of innovative noise absorbers on a noise barrier wall are presented. The authors also present the possible achieved environmental and economic effects of the proposed solution.

**Keywords:** environment, noise, transport, emissions, measurement, anti-sound

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## CATALYTIC AND ELECTROSTATIC METHODS FOR EMISSION MITIGATION IN SMALL HEAT SOURCES

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### ABSTRACT

Combustion of solid fuels in small-scale heat sources generates a wide spectrum of emissions, including particulate matter (PM), oxides of various elements, and persistent organic pollutants (POPs). This study focuses on the monitoring and mitigation of carbon monoxide (CO) and selected polycyclic aromatic hydrocarbons (PAHs), specifically benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-cd)pyrene. In contrast to conventional combustion configurations, the flue gas path is equipped with an electrostatic precipitator, a catalyst system based on catalytically active wires, and a heated secondary air supply. The catalytically active wires are prepared by electroplating Kanthal resistance wire (an iron-based alloy resistant to high temperature and corrosion) with noble metals, using Pt–Ag or Pd–Ag combinations as the catalytic elements. Coal is employed as the fuel in a continuous solid-fuel boiler.

The proposed system—comprising an electrostatic precipitator for particulate removal, catalytic screens, and preheated air supply—is designed to achieve reductions of at least 90% in PM, 75% in CO, and 70% in the target PAHs, while maintaining relatively low investment and operational costs. All emission parameters will be continuously monitored using facilities at the Department of Energy Technology and the UNIZA Research Center.

This method provides a practical and long-term option for enhancing air quality in Slovakia.

**Keywords:** reducing, emission, PAH, catalyst, small heat source



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## APPLICATION OF RUBBER WASTE TO THE WOOD-CEMENT BOARDS

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### ABSTRACT

Wood-cement boards (WCB) are made of cement and wood fibers of various sizes and shapes. They are most often in the form of wood wool, but they can also be shavings or other wood particles. WCB is made of both inorganic and organic materials, their properties are a combination of both types of materials.

The paper focuses on production of wood-cement boards containing 10 % or 20 % of rubber waste (tires, mixture of carpets and isolator) from the automotive industry. Wood-cement boards were manufactured using conventional technology using a production line designed by ELTOMATION, Barneveld, Netherland to produce wood-cement boards. The boards were manufactured in cooperation with VERÓNY OaS, s.r.o. Krupina, Slovakia. A mixture of wood wool, cement (type AS 42.5 R) and calcium chloride (to accelerate cement set during hydration) was used to produce wood-cement boards with dimensions of 0.5 m × 2.0 m × 0.025 m (length × width × thickness) and a weight of approximately 14.42 kg. The wood wool was made from air-dried spruce (*Picea abies L.*) wood.

Wood-cement boards with rubber/tire content were produced using the same technology, however, to produce 10 boards with dimensions of 0.5 m × 2.0 m × 0.025 m (length × width × thickness) either 10 kg or 20 kg of rubber/tire granulate was used. The production line is set up so that due to the addition of granulate, the weight of the other raw materials (wood wool, cement, water, calcium chloride) is proportionally reduced so that the resulting weight of the board remains the same.

**Keywords:** rubber granulate, wood-cement panel, rubber recycling, tire waste, rubber waste



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## EXPERIMENTAL RESEARCH ON THE WEAR OF SCRAPING TOOLS IN THE PROCESSING OF HIGHLY ABRASIVE MATERIALS

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### ABSTRACT

The processing of highly abrasive materials represents a major challenge in recycling and material recovery. This contribution focuses on glass as a specific representative of such materials in various industrial applications. Particular attention is given to the recycling of automotive glass, especially laminated windshields combining glass and polymer films, which are technologically demanding due to their hardness, abrasiveness, complex structure, and the need for layer separation. Another group includes construction glass used in facades, window glazing, and interior elements, characterized by large dimensions, high hardness, and resistance to mechanical stress, which significantly affect the recycling process. A distinct category is glass from photovoltaic panels, specific in its composition and surface treatment, requiring solutions for both abrasive properties and the presence of metallic and polymer layers. The common feature of all these glass types is their high abrasiveness, imposing increased demands on processing technologies, equipment wear, and efficient separation of components. The aim is to outline the specific aspects of processing these materials and highlight the technical and technological factors decisive for their recycling.

**Keywords:** abrasive material, wear, surface treatment

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**EFFECT OF FEEDSTOCK PREPARATION AND MOISTURE CONTENT ON THE  
QUALITY OF CONSTRUCTION BOARDS MADE FROM RECYCLED PP, LDPE,  
AND PAP****Iveta Čáčková<sup>1\*</sup>– Viliam Čáčko<sup>2</sup>**

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**ABSTRACT**

The production of construction boards from recycled polymers such as polypropylene (PP) and low-density polyethylene (LDPE), combined with paper waste (PAP), offers a pathway toward circular economy solutions in the building sector. However, the performance of the final boards is strongly influenced by the quality and preparation of the feedstock. This study evaluates the effect of feedstock preparation and moisture content on the stability and mechanical properties of composite boards manufactured using the technology line. Key findings demonstrate that insufficient preparation—particularly lack of homogenization or improper particle-size distribution—leads to non-uniform bonding and reduced strength. Moisture control emerged as a critical factor: target values of 4–6% were identified as optimal, preventing bubble formation and delamination during pressing. Excess moisture caused blistering and weak adhesion, while overly dry feedstock reduced processability. Technical measures such as drying, sensor-based monitoring, dust removal, and impurity separation were essential for reproducible quality. Proper blending of PP, LDPE, and PAP fractions before adhesive dosing further minimized defects. The results underline that feedstock preparation and moisture regulation are core determinants of product quality and can substantially improve strength, density, and durability of recycled composite boards, enabling their broader industrial application as sustainable building materials.

**Keywords:** recycled composites, polypropylene, LDPE, paper waste, moisture content, feedstock preparation, construction boards



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## POSSIBILITIES OF BATTERY CAPACITY RECOVERY FOR SECOND LIFE USAGE

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### ABSTRACT

In the last decade, the electromobility become more and more popular, thus number of the electric vehicles and the plug-in hybrid vehicles significantly increased. The batteries which are source of the energy for the electric vehicle limited lifetime. The most often, the battery must be replaced after loses 20% of the capacity. After the battery replacement, old battery can be recycled. The recycling in whatever way is complex and the time-consuming process. The second option, what can be done with the old battery is using battery in the application which require the lower performance. This usage of used battery is called the second life. Before the second life, the loss of the capacity can be restored to some extent. Capacity can be restored with the pulsed charging with the right parameters. The most important parameter is the frequency of the pulses. In this paper, 25Ah lithium battery cells from the VW eGolf were tested, how much the frequency can affect the result of the recovery. There are several ways to achieve pulse charging. Main three ways are described with the advantages and the disadvantages are presented. As mentioned before, for the maximum restored capacity, the right parameters of pulsed charging are needed. To verify the dependence of the frequency, four frequencies was chosen based of the previous test of battery cells. The previous test was the impedance spectroscopy which show the response of battery in spectrum of frequency from DC up to 20kHz. The frequency which where the battery has the lowest impedance, will have the highest effect during the pulse charging. One lower and two lower frequencies to test how much the frequency affect the result.

**Keywords:** second life, battery, battery regeneration, capacity recovery, pulse charging



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**PROPOSAL FOR A NEW INTERNAL PROCESSING APPROACH FOR  
SECONDARY PRODUCT FROM CAR BODY SURFACE TREATMENT AT THE  
WASTEWATER NEUTRALIZATION STATION OF THE AUTOMOTIVE PAINT  
SHOP**

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**ABSTRACT**

The study focuses on evaluating a change in the management of secondary product generated in an automotive paint shop during the application of coatings on vehicle bodies, through its treatment in a newly designed technology integrated into the existing operation of the wastewater neutralization station (NS). The proposed technology allows for the separation of secondary product into filtrate (1,080 t·y<sup>-1</sup>) and sludge (120 t·y<sup>-1</sup>), enabling more efficient and environmentally responsible processing directly at the point of origin. Laboratory tests confirmed the effectiveness of FeCl<sub>3</sub> as a coagulant in the separation process, reducing the chemical oxygen demand (COD) concentration from 177,000 mg·L<sup>-1</sup> in the original secondary product to 92,360 mg·L<sup>-1</sup> in the filtrate and further to 616 mg·L<sup>-1</sup> in the treated wastewater. Compliance with legislative COD and pollutant limits was confirmed, with the plant outlet value (1,200 mg·L<sup>-1</sup>) remaining within limits despite a 100% increase after filtrate addition. The implementation of internal waste treatment has eliminated dependence on external end-of-life facilities, resulting in annual cost savings of €227,943 and a reduction in carbon footprint by 26.6 t CO<sub>2</sub>·y<sup>-1</sup>, primarily due to decreased reliance on tank truck transport. The integrated technological process comprises pipeline transport, coagulation, neutralization, flocculation, and sludge dewatering. The estimated volume of filtrate, 5.4 m<sup>3</sup>·d<sup>-1</sup>, is marginal in comparison to the plant's average daily wastewater volume of 1,453 m<sup>3</sup>·d<sup>-1</sup>. The findings confirm the technology's environmental safety, operational viability, and support for sustainable automotive waste management.

**Keywords:** automotive paint shop, COD, secondary product, neutralization station, wastewater treatment



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## APPLICATION OF HYDROGEN TECHNOLOGIES IN THE TRASPOT SECTOR

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### ABSTRACT

The presented article deals with the potential use of low-pressure hydrogen storage technology based on metal hydride materials in urban public transport vehicles. This concept represents an alternative to traditional high-pressure storage tanks, offering increased safety, compactness, and the potential for long-term system durability. The paper provides a detailed analysis of the principles of hydrogen absorption and release in metal hydride storage systems, as well as their integration into the vehicle's energy chain. Special attention is given to the development of the energy balance between the fuel cell, storage batteries, and the traction electric engine, focusing on the energy flow dynamics under various operational modes of the vehicle. The analysis enables the identification of key factors influencing the efficiency and stability of the propulsion system, particularly in terms of optimizing the cooperation of individual energy components. The results suggest that a well-designed integration of metal hydride storage systems can contribute to increased energy efficiency, reduced operational risks, and broader adoption of hydrogen technologies in the field of sustainable urban mobility.

**Keywords:** hydrogen, metal hydrides, hydrogen battery, fuel cell

**ACKNOWLEDGEMENT:** The contribution was realized with the financial support of the SKEBA association, based on the agreement on the pooling of financial resources No. 0180/2023 dated 05. 04. 2023 between the Ministry of Education, Science and Technology of the Slovak Republic and the leader of the SKEBA association, STU BA.



## TECHNOLOGY OF CONTINUOUS BIOGAS PRODUCTION FROM LIQUID BIOSUBSTRATES

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### ABSTRACT

The presented article deals with an innovative design solution of a bioreactor intended for the continuous production of biogas from liquid biosubstrate, representing a modern tool for the efficient valorization of biodegradable waste and its conversion into a renewable energy source. The proposed device consists of a hermetically sealed vessel with a volume of 50 to 100 m<sup>3</sup>, made of thermal insulation material and equipped with spiral heating-cooling pipes. The bioreactor is covered from above with a conical dome with a mounting flange, contains hermetically installed inlet and outlet funnels, and in its lower part is supplemented with a scraper driven by an electric motor to ensure sludge removal.

The fermentation process is supported by electric agitators and an ultrasonic extraction rod that breaks down complex organic compounds into simpler molecules, thereby accelerating methanogenesis. Process control is ensured by a computer system with dedicated software, which, based on data from multifunctional sensors (temperature, pH, chemical composition, microbiological parameters), doses enzymes, nutrients, and bacteria through hermetically sealed funnels with dosing flaps. A stable temperature regime in the range of 30 to 75 °C contributes to optimizing fermentation progress and achieving high biogas yield.

The produced biogas accumulates in the gas holder under the dome and is subsequently directed for energy use via a gas detector and a safety valve. Secondary products include flotation material and sludge, which, after dewatering, serve as high-quality organic fertilizer, while the water fraction can be reused as an inoculation component. The proposed solution enables the efficient processing of diverse liquid waste from municipal and industrial sources, including catering operations, food industry plants, and waste oils.

The main advantages of the device are a hermetically sealed continuous operation without digestate formation, high production stability, the possibility of integration with cogeneration units or municipal heating systems, and full environmental acceptability of all outputs.



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The bioreactor thus represents a technology with significant application potential, particularly in regions lacking wastewater treatment infrastructure, while simultaneously offering a promising tool for sustainable biodegradable waste management and renewable energy production.

**Keywords:** bioreactor, biogas, fermentation process, methanogenesis, device

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## USE OF GRID-LEVEL ENERGY STORAGE IN CITY DISTRICT

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### ABSTRACT

Energy storage represents one of the key elements for the further development of modern energy systems based on renewable energy sources (RES). Due to the fluctuating nature of these sources, the ability to efficiently store and utilize energy plays a crucial role in ensuring the stability and reliability of the power system. Storage technologies not only allow for better alignment of generation with consumption but also help balance differences between peak and minimum electricity demand. Energy storage at the district level represents an important step towards building smart and resilient energy communities. It enables the local storage of surplus energy from photovoltaic or wind installations and its subsequent use during periods when generation does not meet current consumption. In this way, the need for grid supply during peak periods is reduced, relieving the distribution infrastructure while optimizing the use of electricity directly at the point of consumption.

This article focuses on the potential use of Battery Energy Storage Systems (BESS) at the distribution network level in a district of Žilina. The implementation of such solutions in an urban environment brings several advantages – from increasing energy self-sufficiency and independence from the central grid, through more effective integration of renewable sources into local infrastructure, to improving the quality of electricity supply for residents.

**Keywords:** renewable energy, energy storage, battery system, city district

**ACKNOWLEDGEMENT:** This article was supported by the projects: KEGA 026ŽU-4/2024 Innovative approaches to teaching thermomechanics and fluid mechanics, and project: SKEBA - Slovak university and industrial education platform of the European Battery Academy.

**A HYBRID LI-ION AND REDOX FLOW BATTERY SYSTEM: A SYNERGISTIC SOLUTION FOR GRID-SCALE ENERGY STORAGE****Andrea Straková Fedorková<sup>1\*</sup>– Natália Podrojková<sup>2</sup>, Veronika Niščáková<sup>3</sup>,  
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**ABSTRACT**

This paper deals with hybrid energy storage system (HESS) that combines a lithium-ion battery (LIB) and a redox flow battery (RFB) to address the limitations of each technology for grid-scale applications. While LIBs excel at high-power, short-duration tasks, their high cost and degradation limit their use for long-term storage. RFBs are ideal for long-duration, high-energy needs but have lower power density. Our research proposes a synergistic solution that leverages the strengths of both systems. A model predictive control algorithm dynamically manages power flow, using the Li-ion battery for rapid response and the RFB for bulk energy storage. This approach significantly extends the cycle life of the Li-ion component by offloading deep discharge cycles. The integration of advanced chemistries, such as lithium-sulfur (Li-S), becomes more practical within this hybrid framework. This model offers a robust and economically viable solution for modern grid demands.

**Keywords:** Hybrid Energy Storage System, Lithium-ion Battery, Redox Flow Battery, Grid-Scale Energy Storage, Energy Management System, Lithium-Sulfur Batteries

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## INTRODUCTION

The increasing integration of intermittent renewable energy sources, such as solar and wind power, into the electrical grid necessitates the development of advanced and reliable energy storage solutions. Traditional energy storage systems often struggle to meet the dual demands of high power output for short-duration events and high energy capacity for long-term storage. Lithium-ion batteries (LIBs), with their high power density and energy efficiency, are well-suited for short-duration, high-power applications, such as frequency regulation and grid stabilization. However, their scalability for large-scale, long-duration storage is limited by high capital costs and the degradation of electrode materials over time (Nasajpour-Esfahani et al. 2024). Conversely, redox flow batteries (RFBs) offer a promising alternative for long-duration storage due to their decoupled power and energy capacities, enabling them to be scaled independently by simply increasing the volume of the electrolyte tanks. Despite this, they typically exhibit lower power density and energy efficiency compared to LIBs (Shoaib et al., 2024). This paper investigates the feasibility and benefits of a hybrid energy storage system (HESS) that integrates a lithium-ion battery with a redox flow battery to leverage the strengths of both technologies (Reveles-Miranda et al. 2024). The goal of this research is to design and analyze a system that can provide both high power for fast-response applications and high energy for long-duration grid support, thereby enhancing overall system performance, efficiency, and economic viability.

## RESULTS AND DISCUSSION

Our research demonstrates that a hybrid Li-ion/RFB system can effectively manage diverse grid demands by dynamically allocating power and energy between the two battery types. The control strategy, based on a model predictive control algorithm, prioritizes the use of the Li-ion battery for rapid charge/discharge cycles to handle power fluctuations, while the RFB handles the bulk energy transfer and longer-duration storage needs. A key finding is that this hybrid approach significantly extends the cycle life of the Li-ion component by reducing its deep discharge cycles, which are instead managed by the more robust RFB. This is particularly relevant for technologies like advanced **lithium-sulfur (Li-S) batteries**, which, despite their high theoretical energy density, suffer from rapid degradation of the sulfur cathode. By offloading long-duration demands to the RFB, the Li-S battery can be reserved for its high power capabilities, thus mitigating its degradation issues.

Experimental results show a 25% improvement in overall system efficiency compared to a standalone RFB system and a 40% reduction in degradation-related maintenance costs compared to a large-scale Li-ion system. The optimal sizing of the system components was determined using a techno-economic model, which revealed that a 1:5 ratio of Li-ion to RFB energy capacity provides the most cost-effective solution for typical grid applications. This finding is consistent with the work of several researchers who have explored similar hybrid configurations (Al-Saadi et al., 2021). Our previous work on Li-S batteries (Capková, et al., 2022) characterization and testing showed that degradation of commercial Li-S cells is not as fast as it was predicted and thus these batteries are very good candidates for using in hybrid energy storage systems.



Fig. 1 Redox flow battery testing rig and single cell for testing of battery components.

## CONCLUSION

In conclusion, the development of a hybrid energy storage system combining the high power density of a lithium-ion battery and the high energy capacity of a redox flow battery presents an innovative solution for the evolving needs of modern electrical grids. The synergistic operation of these two technologies allows for a system that is not only more efficient and durable but also more economically viable than either technology operating in isolation. This research has demonstrated that a strategic control system can significantly extend the operational life of the Li-ion component, making a broader range of advanced chemistries, such as Li-S, a more practical option for grid-level applications. Future work will focus on the development of novel materials for Li-S and redox flow batteries coupled with sophisticated models and simulations techniques. This hybrid model provides a robust framework for the next generation of grid-scale energy storage solutions.

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## POSSIBILITY OF DIAGNOSTIC OF IGNITION SYSTEM

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## ABSTRACT

This article focuses on pointing out the importance of regular inspection of ignition systems in cars with internal combustion engines due to the fact that it not only checks the engine's operation but also its emissions. In the Slovak Republic, emissions testing is mandatory for road vehicles every two years, but many industrial devices with combustion engines are not subject to regular emission checks.

During these two years, especially during visits to car service stations for routine operations such as changing engine oil, it is also possible to measure the condition of the ignition system using an oscilloscope, which is part of most licensed and authorized service stations. These measurements show us the condition of the spark plugs, which primarily affect the ignition process in the engine - formation of emissions.

The article presents the design of a measurement system based on an oscilloscope using voltage and current probes. The measured data presented in this article are directly measured on test vehicles together with the measured waveforms of electrical quantities with visible differences. The current system is designed to provide us with fast and accurate results of the condition of spark plugs under various working conditions.

Experimental results demonstrate that chosen diagnostic method is able to identify characteristic differences in component behavior and thus increase the possible accuracy of



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fault detection. The article therefore presents an innovative non-dismantling procedure applicable in the development of modern automotive tools and contributes to improving the reliability and efficiency of internal combustion engines.

**Keywords:** internal combustion engine, ignition, diagnostics, analysis, LabVIEW

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**ECO-FRIENDLY MATERIALS IN A CIRCULAR ECONOMY: DEGRADATION  
AND REDUCING CRITICAL RAW MATERIALS DEPENDENCY IN BATTERY  
AND HYDROGEN SECTOR**

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**ABSTRACT**

The lecture explores the challenges and innovations in battery and hydrogen sector with focus on compatibility of novel eco-friendly materials, corrosion mechanism, degradation, hand in hand with strategy to minimize the use of critical raw materials. Emphasizing sustainability, it highlights the balance between advancing eco-friendly approach and performance vs. life-time paradigm. It gives partially insights into material lifecycle management, eco-design principles, and the role of sustainable alternatives in reducing environmental impact while safeguarding resource availability. Results from corrosion testing show how important is to predict life-time of materials used in whole battery and hydrogen economy cycle and how important is to know about changed electrochemical and physicochemical properties during operation before secondary life or battery, electrolyzers etc. recycling will take place.

**Keywords:** batteries, corrosion, degradation, recycling, sustainable economy

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**OCCURENCE AND POSSIBILITIES OF RECYCLING OF WASTE CONTAINING  
ELECTRIC AND ELECTRONIC COMPONENTS FROM ELECTRIC VEHICLES**

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**ABSTRACT**

After the end of the service life of electric vehicles, there is a need to dispose of them and process them in accordance with applicable legislation. Electric vehicles contain a large proportion of electrical and electronic components. These discarded components are not considered e-waste according to Slovak legislation. On the other hand, discarded electric vehicles are considered an old vehicle according to the law and must be handled as such. The practical steps of recyclers must then consist of removing substances hazardous to the environment, removing batteries and accumulators, removing operating fluids and subsequent processing. The recycler is obliged to hand over these removed parts to persons authorized to handle them and subsequently ensure compliance with the requirements for recycling, reuse of parts and components of old vehicles and recovery of waste from the processing of old vehicles set out in the implementing regulation.

Although the electrical parts of an end-of-life electric vehicle are not considered e-waste, these parts have the characteristics of e-waste and must therefore be handled and processed accordingly.

The aim of this paper is to map and analyze the material composition of electric vehicles in the context of their electrical and electronic components and to point out the possibilities of material recycling of electric vehicles as a whole, as well as the possibilities of material recycling of their individual electrical components.

**Keywords:** electric vehicle, e-waste, recycling

**ACKNOWLEDGEMENT:** This article was created within the framework of the UNIVNET project and with financial support from Automotive Industry Association of the Slovak republic.



## WASTE RECOVERY IN PARTICLEBOARD COMPOSITES AND THEIR ENVIRONMENTAL IMPACTS ON THE AQUATIC ENVIRONMENT

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### ABSTRACT

The study presents the assessment of environmental impacts of wood-based composites containing waste from the automotive industry (incorporated in the middle layer) on aquatic environments. Standard particleboard with the addition of waste from the automotive industry and three-layer (with waste in the middle layer) were tested. Aqueous extracts were prepared from the samples. The leaching lasted 24 hours. The extracts were evaluated using ecotoxicological tests with the test organisms *Lemna minor* (producer), *Sinapis alba* (also a producer) and *Daphnia magna* (consumer). The bioassays performed were preliminary tests. The pH and chemical oxygen demand (COD) values were determined in the samples, which represent the total amount of organic substances leached into the water. Chipboard without any waste from the automotive industry was used as a control sample. Based on the results, we can conclude that the use of automotive industry waste into wood-based composite materials represents one of the appropriate methods and ways of recycling such waste. The use of bioassays has been confirmed as an effective tool for assessing environmental impacts, in our case on the aquatic environment. The results of the environmental impact assessment using ecotoxicological tests and selected physicochemical indicators showed that, in order to protect the aquatic environment, it is necessary to reassess the maximum amount of individual types of waste that are incorporated in the production of wood-based composites in order to reduce inhibitory effects on test organisms in the aquatic environment while preserving the physical and mechanical properties of these composites.

**Keywords:** particleboard, waste, automotive industry, aqueous extracts, ecotoxicological tests, environmental impacts



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**FULL SCALE EXPERIMENTAL MEASUREMENT OF PRODUCTION HALL  
GREEN ROOF' WITH DRIP IRRIGATION**

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**ABSTRACT**

In the time of the climate change the focus slightly changes from heating demand to the cooling demand. Use of green roof is one of the simplest answer to mitigate this climate change. Extensive green is usually not very demanding and requires minimal maintenance and is also quite inexpensive. Green roof structure serves as protection layer on the waterproofing membrane, because it helps to reduce the temperature courses and blocks the UV radiation. The production hall located in Dubnica and Vahom now serves for full scale measurement of four different roof structures, which have common basis – flat roof. Reference roof is bright TPO membrane without cover, two green roof segments differ with different indoor climate and the last segment has PV panels. Use of drip irrigation is not standard, but in this case is used with water amount of 5 l/m<sup>2</sup> daily. With the usage of drip irrigation, this roof can be used for evaporative cooling. In this paper, the influence of drip irrigation and actual water content on the heat flow is analyzed. Another aim is the vegetation, leaf area index is crucial, because the vegetation creates possibility of increased evapotranspiration. The vegetation was planted with cuttings, which need two or three years to cover the area. This could be problematic, because it is cheaper solution, than use of pre-vegetated rolls, but the positive results are several years postponed.

**Keywords:** experimental measurement, cooling, hall green roof

**ACKNOWLEDGEMENT:** This research was supported by VEGA 1/0404/24 and KEGA 023ŽU-4/2023.



**ASSESSMENT OF METHODOLOGY FOR INCREASING ENERGY EFFICIENCY  
OF AN AUTOMATED PRODUCTION LINE**

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**ABSTRACT**

This study presents an assessment of a methodology aimed at increasing the energy efficiency of an automated production line. The proposed approach integrates energy monitoring, process optimization, and intelligent control strategies to minimize energy consumption without compromising productivity or product quality.

The methodology was applied to a real-world production line in the manufacturing sector, where key performance indicators (KPIs) such as energy consumption per unit, idle energy losses, and equipment utilization were systematically analyzed. Based on the analysis, targeted improvements were implemented, including process synchronization, reduction of machine idle time, and dynamic control of energy-intensive components. The impact of these interventions was evaluated using a before-and-after comparison, demonstrating a significant reduction in total energy consumption-up to 18% - while maintaining production throughput.

The results confirm the effectiveness of the proposed methodology and highlight the importance of data-driven decision-making in energy management. The study concludes with recommendations for further integration of AI-based predictive maintenance and energy forecasting tools to ensure sustainable long-term improvements in energy efficiency within automated industrial environments.

**Keywords:** energy efficiency, methodology, energy-intensive components, energy consumption, energy management

**ACKNOWLEDGEMENT:** This article was prepared with the support of the project VEGA No. 1/0470/23.



**METHODS AND SYSTEMS FOR ASSESSING THE ENERGY EFFICIENCY  
OF AUTOMATED SAFETY SYSTEMS AND EQUIPMENT**

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**ABSTRACT**

The increasing emphasis on sustainable development and energy conservation has led to a growing need for reliable methods and systems to assess the energy efficiency of automated systems and equipment. This study reviews and categorizes existing methodologies used in evaluating energy performance, with a focus on industrial automation, smart manufacturing, and intelligent control systems. Key approaches include energy audits, performance benchmarking, life cycle assessment (LCA), and real-time energy monitoring through integrated sensor networks and IoT-based platforms. Advanced data analytics, including machine-learning algorithms are increasingly being applied to predict energy consumption patterns and optimize operational efficiency.

This study also explores standards and frameworks such as ISO 50001, which support structured energy management practices. Several case studies are presented to illustrate practical implementation of energy assessment techniques in automated environments, highlighting measurable improvements in energy use and cost savings. Furthermore, the paper discusses challenges in standardizing metrics and the need for harmonized evaluation protocols across different industries and equipment types. The integration of digital twins and simulation models for predictive analysis is identified as a promising direction for future development. Ultimately, this work aims to contribute to the creation of smarter, more energy-efficient automated systems through robust and scalable assessment methodologies.

**Keywords:** energy efficiency, automated systems, energy consumption, assessment methodologies, energy assessment techniques

**ACKNOWLEDGEMENT:** This work was supported by KEGA project No. 012ŽU-4/2025.



## USAGE OF HYPERSPECTRAL IMAGING FOR WASTE SORTING

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### ABSTRACT

In our modern days and age, the amount of electronic waste produced in the world represents a significant burden on landfills and the environment. This paper presents the usage of a hyperspectral imaging accompanied with virtual instrumentation as a tool for detecting materials present on electronic boards waste, which can help in deciding whether it is economically viable to recycle the waste due to the valuable elements/metals present, or not. The crucial part of entire system is a hyperspectral image, in which varied materials provide different reflected light spectra in digital image. These material spectra are used for classification of material content on electronic boards. Using kNN (k-Nearest Neighbor) algorithm, the system analyzes the images of the electronic waste, and depending on the material that the kNN algorithm assigns it to, will segment the final image. The result of analysis is percentage of selected materials on electronic board. System is primarily focused on frequent materials such as copper, aluminum, plastic, PCB and tin, and can be easily trained for other materials. The best results of proposed system designed for 2 material analysis reached over 80%, (accuracy of segmentation) and an experimental attempt designed for 5 material analysis showed worse results, with some possibilities for improvement.

**Keywords:** hyperspectral imaging, virtual instrumentation, recycling, economy, material identification, classification



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**GREEN TRANSFORMATION IN PRACTICE: LI-ION BATTERY RECYCLING  
PROCESS AT THE OSLA PLANT**

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**ABSTRACT**

BTS&SAKER, sp. Z o.o., founded in 2021, specializes in recycling batteries from electric vehicles (EVs), responding to the need for sustainable energy solutions. Advanced and environmentally friendly technologies enable the safe and efficient extraction of critical raw materials such as lithium, nickel, cobalt, and copper, promoting the circular economy and reducing environmental impact.

In 2021, the company acquired a 5-hectare strategic site in Oslo, Poland, close to major European electric vehicle and battery manufacturers. A year later, it obtained environmental impact assessment (EIA) approval, the company has an R4 permit, and in 2023 it completed the construction of a modern recycling plant for discharging, dismantling and producing so-called black mass, with the result of the process being BM product and by-products such as Cu, Al, Fe and others.

The Oslo plant has a capacity of 27,000 tons per year, processes up to 3 tons per hour of input, and has processed 2,547 tons since it began full operation in February 2025 until July 2025.

This is a unique facility within the EU. The technology enables the simultaneous operation of dry and wet processing routes and the processing of NMC, NCA and LFP batteries, which represents a significant competitive advantage.

BTS&SAKER plans to build a new plant in Košice, Slovakia, where it already has an approved EIA and is in the process of obtaining a building permit. Operations are expected to start by the end of 2026, confirming the company's ambition to be a leader in the sustainable recycling of electric vehicle batteries.

**Keywords:** black mass, recycling, product



**ECONOMIC IMPLICATIONS OF THE TRANSITION TO ELECTRIC VEHICLE  
PRODUCTION IN SLOVAKIA: IDENTIFYING THE WORST-CASE SCENARIO  
AND STRATEGIES FOR ITS MITIGATION**

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**ABSTRACT**

The paper examines the socio-economic impacts of various scenarios for the transition to electric vehicle production in Slovakia. A multi-regional input-output model with an extension for employment is used to model the impacts. The scenarios and exogenous changes in development are formulated on the basis of expert estimates by stakeholders and international studies in this area. The difference between the positive and pessimistic scenarios represents a significant loss of value added and employment in the case of an unsuccessful transition to electric vehicle production, regardless of the rate of electric vehicle purchases in Slovakia.

**Keywords:** input-output model, automotive industry, electric cars, transition

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**COMPARISON OF GAMMA RADIATION DETECTORS FOR CITIZEN  
MEASUREMENTS AND STATE MONITORING SYSTEM**

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**ABSTRACT**

The paper compares the properties and technical parameters of detectors used for monitoring gamma radiation in the environment. Two portable devices commonly employed in citizen measurements are evaluated alongside a professional detector used in the state monitoring system in Slovakia. The devices for citizen measurements include the RadiaCode portable gamma spectrometer, recommended to members of the civic association “Hot Spots”, and the CzechRad portable detector, distributed to citizens within the framework of the European CITISTRA project. As a representative of professional instrumentation, the RPSG-05 stationary probe developed by MicroStep-MIS and operated by the Slovak Hydrometeorological Institute at multiple monitoring sites across Slovakia is analyzed. The comparative analysis highlights differences in the design of detectors, technical solutions, and different metrological properties of devices for citizen and professional measurements.

**Keywords:** environment, citizen measurement, gamma radiation, detector, dosimetry

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**QUANTIFICATION OF THE RELATIVE HEAT AND COOLING REQUIREMENTS  
IN AN OFFICE BUILDING, PRODUCTION HALL, AND WAREHOUSE BUILDING  
DEPENDING ON THE LOCATION IN SLOVAKIA AND THE INTERIOR  
TEMPERATURE**

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**ABSTRACT**

When quantifying an indicative estimate of the relative heating and cooling demand in the office building, production hall and warehouse building depending on the location in SR and the interior temperature, the heating and cooling demand at the selected temperature is indicated as 100%. For cooling, the interior temperature is also indicated, from which no machine cooling is required and the selected interior temperature is achieved by natural ventilation. The heating demand is calculated for October-April and the cooling demand for May-August. The proportional estimation was quantified by calculating the heating and cooling demand of the building according to "STN EN ISO 52016-1 Part 1: Calculation Procedures" with specific parameters of the building envelope and roof, taking into account both internal and external heat loads. Representative buildings differ in internal heat load, occupancy, façade glazing and building type. For the location of the building, the climate of about 2885 municipalities in Slovakia is considered, with the corresponding parameters of the lowest design outdoor temperature and solar heat load by month according to "STN EN ISO 13790/NA National Annex". For comparison of heating and cooling needs for buildings, graphical outputs for individual building types are also provided. The calculated data are indicative and are intended to be used for assessing potential savings when changing interior temperatures. For a more accurate and detailed analysis of the heating and cooling demand of a specific building, a detailed energy audit should be carried out in accordance with the applicable STN for energy performance of buildings.

**Keywords:** cooling, building, relative heat



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**ANGLES OF REPOSE EVALUATION OF RUBBER AND PLASTIC GRANULATES  
FROM AUTOMOTIVE WASTE**

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**ABSTRACT**

The paper focuses on measuring the angle of repose of rubber and plastic granulates using the cone method and the cylinder method. The measurement methods were performed based on the valid technical standard on rubber and plastic materials from automotive waste (fuel tanks, bumpers, tires, seals with carpets) in the form of granulates of the 1-3 mm fraction. The cone calculation method, the cone measurement method and the cylinder measurement method were used as methods for measuring the angles of repose. The results of the individual deviations were subsequently processed into tables and graphs. The results showed several deviations of the values between the individual measurements, which could be caused by the human factor. The average values of the angles of repose ranged from 33.41° to 40.45° for the cone calculation method, from 37.2° to 46° for the cone measurement method and from 30.4° to 39.4° for the cylinder measurement method. Based on the results, it can be assumed that the most accurate results were achieved with the cone calculation method. The results of this paper will provide important information in the handling and storage of the above types of waste rubber and plastic granulates, which can be used and applied in the production process of composite materials within the framework of waste recovery.

**Keywords:** rubber, plastic, granulate, angle of repose, cone method, cylinder method

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**SHAPED INSULATION PRODUCTS MADE OF RECYCLED POLYURETHANE  
FOAM – TECHNOLOGY CONTROL, PRODUCT PROPERTIES, APPLICATION****Miloš Matúš<sup>1\*</sup> – Richard Šupík<sup>1</sup>, Lubomír Šooš<sup>1</sup>, Lucia Ploskuňáková<sup>1</sup>**

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**ABSTRACT**

Soft polyurethane foams find application as seats in automobiles, mattresses, furniture, laminating textiles, for packaging purposes, for the production of insulation and sealing strips. They are also widely used in the construction industry. The world production of polyurethane foams is constantly increasing due to their availability and useful properties. The production is directly related to the increase in polyurethane waste. However, this waste represents a significant problem in waste management, especially due to its large volume, low weight and strict legal regulations. The paper deals with the development of an effective technology for recycling waste polyurethane foam by dry pressing under pressure without a binder. The aim of the experimental research is to optimize the pressing force, temperature and heating time in the production of shaped insulation elements with guaranteed mechanical and thermal insulation properties. This research provides a prerequisite for the design of production machines for processing a large amount of polyurethane waste into shaped insulating parts. The achieved results confirmed the successful production of shaped insulating elements from 100% recycled polyurethane foam. Shaped thermal insulation parts will find wide application in the automotive, energy and construction industries. Part of the developed production technology is also the application of a specific coatings, which further increases the utility properties and expands the possibilities of applying such shaped parts.

**Keywords:** polyurethane foam, recycling technology, insulation, shaped parts

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**SMART COMBUSTION CONTROL OF WASTE-DERIVED BIOMASS PELLETS IN  
SMALL-SCALE HEATING SYSTEMS**

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**ABSTRACT**

The utilization of biomass energy is a key element in the transition towards sustainable energy systems and the reduction of carbon footprint. Small-scale heating appliances, however, often exhibit low efficiency and elevated emissions of particulate matter and gaseous pollutants during daily operation. This paper introduces a concept of intelligent combustion control employing a IoT-based sensor network that accomplishes real-time monitoring of flue gas composition and combustion parameters. The collected data are processed in MATLAB in real time, from which supervised learning algorithms and neural networks are trained and deployed to optimize the combustion regulation process. This is done by finely controlling the primary combustion air supply and the pellet feeder speed. Experimental tests with pellets produced from waste-derived biomass materials confirmed the potential to reduce particulate emissions and enhance thermal efficiency, thereby contributing to the circular economy and sustainable energy production. The proposed approach highlights the feasibility of integrating machine learning techniques into conventional heating systems without significant hardware modifications. Moreover, it paves the way for scalable applications in decentralized energy production, where intelligent control can ensure both ecological and economic benefits.

**Keywords:** biomass, waste-derived pellets, intelligent combustion control, emission reduction

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**COMPARISON OF THE REDOX PROPERTIES OF ANTHRAQUINONE DPiVOHQ  
AND He<sub>2</sub>VBr<sub>2</sub> VILOGEN FOR APPLICATION IN REDOX FLOW BATTERIES****Veronika Niščáková<sup>1\*</sup>– Andrea Straková Fedorková<sup>2</sup>, Nikolas Király<sup>3</sup>, Miroslav Almási<sup>4</sup>,  
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**ABSTRACT**

Organic redox-active molecules are a promising alternative to conventional vanadium electrolytes in redox flow batteries (RFBs), particularly due to the need for sustainable and affordable solutions for large-scale energy storage. This paper compares two important classes of organic molecules: anthraquinones (AQ) and viologens. Anthraquinones are characterized by a two-electron redox mechanism and exhibit good cyclic stability in acidic and alkaline environments. However, their main limitations are their susceptibility to nucleophilic additions and disproportionation reactions at neutral pH. Viologens undergo a two-step reduction with high reversibility and fast electrokinetics, making them suitable for use in neutral and slightly acidic conditions.

Electrochemical measurements in this work showed that He<sub>2</sub>VBr<sub>2</sub> in 1 M NH<sub>4</sub>Cl has good transport properties (a diffusion coefficient of approximately  $1 \times 10^{-6} \text{ cm}^2 \cdot \text{s}^{-1}$ ), which is fully comparable to other viologens reported in the literature. Compared to anthraquinones, He<sub>2</sub>VBr<sub>2</sub> is more suitable for neutral electrolytes, while anthraquinones remain the preferred choice for acidic and alkaline systems. The results highlight the complementary nature of these molecules and suggest their potential for targeted use depending on the chosen operating environment.

**Keywords:** anthraquinone, viologen, redox-flow battery, organic electrolyte



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**IS THERE A DEEP CONFLICT BETWEEN THE MARKET-LED SALE OF ECVS  
AND EU MARKET REGULATION?**

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**ABSTRACT**

Current developments in the car market and trends in sales of electric chargeable vehicles (ECVs) in EU countries indicate a potential conflict between the interests of consumers, car manufacturers in the EU and the regulatory objectives in the area of sales of zero-emission vehicles by the representatives of the EC and EP. As the results of the panel regression show, both the development and the differences between countries in the market share of ECVs are significantly influenced by four factors: fiscal incentives (fiscal support index in EU countries), the density of the charging network, the economic efficiency of countries (Real Expenditures per Capita in PPS), the share of renewable energy in its total consumption in the EU country. The current weakening of consumer interest and changing preferences in purchasing vehicle types as a result of the slowdown in economic growth, changes in fiscal expenditures and priorities, as well as the energy mix, raise serious concerns about the fulfilment of the EU emission targets in the area of sales of zero-emission passenger cars.

**Keywords:** Electric chargeable vehicles Market Shares, Fiscal Stimulus, Emission Targets

**ACKNOWLEDGEMENT:** The paper is part of research project under national research platform UNIVNET.



## ESTIMATING COST-SAVING POTENTIAL FOR WOOD-INDUSTRY PRODUCTS USING SECONDARY INPUTS

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### ABSTRACT

Amid the market's shift toward sustainable goods with recycled content, manufacturers must rely on cost analyses that are both precise and adaptable to identify potential savings. We present a methodology for quantifying cost reductions in the production of innovative wood-based products that incorporate plastic, rubber, or cement-derived secondary materials. The framework combines indexed cost indicators with machine-hour rates, enabling dynamic adjustment to changes in input prices, energy consumption, and other influential factors, while supporting effective control of production costs. By linking costs to these indices and rates, the procedure delivers precise, adaptable assessments that remain responsive to shifts in raw-material prices, energy use, and related drivers. Applying methods for quantifying cost savings to the production of three-layer particleboard with a plastic additive revealed a 2.22% reduction in total production costs and a 4.55% reduction in material costs, calculated per costing unit of 1 m<sup>3</sup> of particleboard. The methodology is intended for use in manufacturing settings where secondary materials are integrated with wood. This framework helps wood-focused manufacturers compete more effectively and establishes a platform for ongoing research on cost-management strategies for sustainable and recycled materials.

**Keywords:** sustainable, cost, index, secondary materials, machine-hour rates, wood, plastic, cement

**ACKNOWLEDGEMENT:** We wish to thank project UNIVNET “University Research Association for Waste Recovery, especially from the Automotive Industry” No. 0201/0082/19, and VEGA no. 1/0093/23 “Research of the potential of the circular economy in the Slovak business environment in the production of innovative products based on recycled materials wood-rubber-plastic”.

**EFFICIENT PROCESSING OF DISCARDED LITHIUM-ION BATTERY ANODES  
AT THE SAKER-KOŠICE PLANT FOR SUSTAINABLE FUTURE****Ondrej Paprčiak<sup>1\*</sup>**<sup>1</sup>*Address: (SAKER, s.r.o., Horný Hričov), saker@saker.sk**\*corresponding author: saker@saker.sk***ABSTRACT**

The production of lithium-ion batteries for electromobility generates a relatively large amount of waste battery anodes. This is composed of a carrier made of pure conductive copper in an amount of about 30% and an anode material made of carbon material in an amount of about 70%. These semi-finished products do not contain electrolyte or any other substances. From this point of view, they are a very interesting material for the recycling of copper and carbon material.

Since 2024, the SAKER Košice company has been operating a facility for processing waste anodes of lithium batteries, which is unique and unique in the entire European Union with a current capacity of 4900 tons of input waste per year with a possible increase as needed. The facility has two separate independent processing lines based on dry and wet waste processing. The dry line involves controlled comminution and subsequent sorting of copper and carbon on a screening device. In the wet line, copper and carbon are obtained in an aqueous environment and then both products are gravitationally sorted.

The benefits of processing are low-waste technology within the framework of fulfilling the goals of the Green Deal, contribution to the circular economy, reduction of environmental impacts, offering waste processing for the needs of Slovak car manufacturers, obtaining critical raw materials for the EU and also creating jobs.

For the wet method of processing waste anodes, SAKER was granted two author's certificates and one patent.

**Keywords:** electromobility, lithium-ion battery, electromobility, recycling, copper, carbon



## MATERIAL RECYCLING OF PHOTOVOLTAIC PANELS USING SILVER SILICON TECHNOLOGY

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### ABSTRACT

SILVER SILICON, a.s. is a Czech startup that is engaged in the development of technology for recycling silicon photovoltaic panels. In the course of our activities, we have designed and manufactured a unique technology for processing discarded silicon panels.

A silicon photovoltaic panel is made up of a sandwich structure. When recycling a solar panel using SILVER SILICON technology, we take advantage of the different physical properties of the individual layers of this sandwich structure. This allows us to mechanically separate the individual layers without consuming large amounts of energy. The whole process is fast, efficient and does not generate any additional waste.

SILVER SILICON uses mechanical procedures to gradually remove the layers of the sandwich structure of the photovoltaic panel in the following order:

- cover glass,
- encapsulant EVA (foil 1) and silver-plated copper buses,
- silicon containing silver,
- Tedlar foil with encapsulant EVA (foil 2).

Other commonly used technologies crush the sandwich structure of the solar panel into a small fraction, which they then try to sort into materials. Alternatively, by milling or cutting, they remove the covering layer of glass and then obtain silver and copper from the rest of the sandwich. The result is low-quality glass and not very pure metals and silicon.

SILVER SILICON can create homogeneous shards from the top layer of the cover glass, which it then mechanically peels off. With this procedure, we can separate more than 99 % of the glass layer and obtain a high-quality clean glass shards. Subsequently by using our unique procedure, we delaminate the top layer of the encapsulant (EVA 1 foil) and obtain the buses and the released silicon shards.

The last output of the technology is the plastic back sheet with the bottom layer of encapsulant (EVA 2 foil).



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Thanks to the high quality removal of glass in the first step, the SILVER SILICON technology opens up the possibilities of subsequent mechanical processing of the inner sandwich structure of the solar panel. At the same time, we are able to reuse more than 95% of the weight of solar panels, separate silver, and produce raw materials that are suitable for direct use in production without further processing. For Eva 1, EVA 2 and Tedlar plastic foils, we are solving their energy use.

**Keywords:** recycling, photovoltaic panel, SILVER SILICON technology



## ENERGY RECOVERY OF TEXTILE SEAT COVERS FROM END-OF-LIFE VEHICLES THROUGH PYROLYSIS

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### ABSTRACT

The increasing volume of end-of-life vehicles represents a growing challenge in terms of waste management and resource utilization. A significant portion of these vehicles consists of non-metallic materials, among which textile seat coverings form a considerable fraction. Due to their heterogeneous composition, including natural and synthetic fibers, fillers, and polymer coatings, direct material recycling is often technologically complex and economically inefficient. Pyrolysis, as a thermochemical conversion method, offers an effective pathway for the energy recovery of such waste streams, enabling the production of valuable gaseous, liquid, and solid products.

This study focuses on the energetic valorization of textile seat coverings from used automobiles using pyrolysis. Laboratory-scale experiments were performed at selected temperatures under an inert atmosphere to analyze the influence of operating parameters on product yields.

The results confirm that pyrolysis of automotive textile waste leads to the formation of a combustible gas mixture with a heating value suitable for energy applications, along with a liquid fraction exhibiting promising fuel properties. These findings demonstrate that pyrolysis can provide a sustainable solution for the energy recovery of textile seat coverings, contributing to the circular economy and reducing the environmental burden of end-of-life vehicles.

**Keywords:** pyrolysis, end-of-life vehicles, textile seat coverings, energy recovery, gaseous and liquid fuels, circular economy

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**COMPARISON OF OPTICAL AND ROBOTIC WASTE SORTING SYSTEMS.  
PRACTICAL EXAMPLES FROM REALIZED PROJECTS IN THE CZECH  
REPUBLIC AND SLOVAKIA**

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**ABSTRACT**

Optical and robotic waste sorting is currently one of the most advanced stages of waste sorting known and used by the current market. However, each technology, in addition to its advantages, also has its limitations and technological and process limits that have emerged from their testing in direct operation. However, this does not mean that the limitations are permanent due to their nature, but rather from the incomplete possibilities of their application, type of use or technological improvement of their application possibilities. The obtained process data allows us to work on their improvement, which is also assisted by the level of artificial intelligence, which, especially in robotic systems, helps to debug errors in detection or object gripping in the waste stream, which results in improved parameters. Comparing the advantages of optical and robotic waste sorting depends on several factors, such as the type of waste, requirements for sorting accuracy, costs and efficiency. The work discusses the technical capabilities of both advanced detection technologies and object classification systems, as well as real comparisons of data obtained during operation, with the aim of assessing the current and future trend of application of each technology in practice, and the possibilities of technical adjustments with a real application model in operation from an economic and process perspective.

**Keywords:** waste recovery, technological processing, municipal waste, sorting, optical and robotic sorting systems, AI, recycling, nature protection

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## CHARACTERIZATION AND RECYCLING OF LFP BATTERIES

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## ABSTRACT

LiFePO<sub>4</sub> (LFP) batteries are among the most widely used lithium-ion batteries in the field of electromobility and stationary energy storage, mainly due to their safety and long life. However, their recycling is challenging due to their specific chemical composition and lower content of critical metals compared to conventional lithium cells. The article is devoted to the characterization of selected LFP batteries through chemical composition, physical properties, electrochemical properties and analysis of recycling processes, mainly pyrometallurgical and hydrometallurgical.

**Keywords:** LFP batteries, recycling, lithium, characterization

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**ASSESSMENT OF BIODEGRADATION PROPERTIES OF CHIPBOARDS WITH  
THE ADDITION OF WASTE PLASTICS**

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**ABSTRACT**

The aim of this paper was to evaluate the environmental properties of particleboards containing waste plastics compared to boards without such additions. Composite materials, both during and after their service life, can contaminate various environmental components, with the extent of contamination depending largely on the amount and type of added chemicals. These substances also strongly influence the recyclability of the boards.

To determine the aerobic biodegradability of particleboard in an aqueous medium, we conducted manometric respiration tests using activated sludge as the inoculum. A standard leachate was prepared by mixing crushed particleboard samples with deionized water at a ratio of 100 g of dry sample per 1,000 ml of water. The leaching procedure followed the STN EN 12457-4 (2006) standard.

Our results showed that samples containing plastics were slightly less degradable than those without; however, biodegradability varied widely across both types. Overall, we concluded that the addition of waste plastics does not significantly influence the biodegradability of the tested particleboards.

**Keywords:** biodegradability, particleboard, manometric respiration tests

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## NEGATIVE IMPACT OF TRANSPORT ON THE ENVIRONMENT

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### ABSTRACT

The relationship between the environment, transport and transport systems has become increasingly important in recent years. The constant growth of urbanisation and vehicle use creates challenges that require a thorough assessment of current transport conditions and the implementation of modern traffic management systems. Proper management of transport networks not only improves mobility and efficiency but also contributes to reducing negative impacts on the environment. An important factor affecting safety and sustainability is the technical condition of vehicles, in particular the wear of tyres, brake pads and road surfaces. Worn tyres have a direct impact on braking distances, stability and fuel consumption, while also contributing to emissions of dust particles that worsen air quality. Particles generated when tyres come into contact with road surfaces are among the significant sources of microplastics in the air and soil, thereby reducing the quality of the environment. A systematic assessment of the condition of tyres, brake pads and their interaction with road surfaces is therefore essential in transport planning and improving transport infrastructure.

In conclusion, the interlinkages between the environment, transport, vehicle condition and transport efficiency highlight the need for comprehensive strategies. Continuous monitoring of tyre wear, together with innovations in traffic management, are key to achieving sustainable and safe mobility in the future.

**Keywords:** transport, emissions, measuring, environment

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**INNOVATIONS IN BUSINESS MODELS FOR SUSTAINABLE INDUSTRIAL  
PRODUCTION**

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**ABSTRACT**

Industrial production today faces a dual challenge – to ensure economic growth while reducing its negative impact on the environment. The key lies in linking digitalization, sustainability, and economic efficiency, which creates space for new forms of business. This article focuses on innovative business models that enable the transition from a linear production system to the principles of the circular economy. The analysis explores approaches based on digitalization of production and logistics processes, the use of data for resource optimization, and the introduction of product-as-a-service models. These approaches not only support more efficient use of materials and energy but also generate new economic opportunities and forms of cooperation between companies, consumers, and the public sector. Special attention is paid to the factors of successful implementation, such as the innovation capacity of firms, the regulatory environment, and collaboration within value chains. Barriers and risks are also discussed – from financial investments to the need for changes in corporate culture – and possible solutions are proposed. The article provides a framework for understanding how business model innovations can contribute to reducing environmental burdens, increasing competitiveness, and creating value for society. At the same time, it sets the ground for further discussion on the opportunities to connect digitalization, the economy, and sustainable development in industrial practice.

**Keywords:** business model innovation, circular economy, sustainable industrial production

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## FIRE SAFETY OF BATTERIES AS ENERGY SOURCES

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### ABSTRACT

The paper deals with the issue of fire safety of accumulators used as energy storage and the test of a high-voltage traction battery. It implements current knowledge in the field of extinguishing and the behaviour of storage (batteries) in fire conditions. It describes experiments conducted as part of research at the Department of Fire Engineering, mainly in the field of extinguishing efficiency with fire blankets. The experiment itself conducted on a high-voltage traction battery of an electric vehicle. In addition to external behaviour, the ambient temperature measured with thermocouples.

The paper concludes with recommendations for good practice for fighting fires in devices using accumulators as energy sources, whether in storage, as part of a photovoltaic system, or in means of transport - e-bikes, e-scooters, e-motorcycles and electric vehicles.

**Keywords:** batteries, fire suppression, fire blanket, experiment, vehicle fire

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## POSSIBILITIES OF MATERIAL AND ENERGY RECOVERY OF PAPER SLUDGE

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### ABSTRACT

Paper sludge is large and still effectively unsolved. There are several studies that present the possibilities of both material and energy recovery. An example of material recovery is adding sludge to the production of building materials such as bricks or building blocks. One of the possibilities is also adding materials to the soil. There are also examples of energy recovery. The problem with all methods of recovery is the need to treat the waste, such as moisture, and in energy recovery, it is also the relatively low calorific value of the sludge itself. Additional modification, or rather the addition of additional materials, significantly reduces the ratio of costs for the production of new products versus income from their sale, and without financial subsidies this task is practically unsolvable.

The aim of the paper is to present the possibilities of the presented paper is to present the results of research on the material and energy recovery of paper sludge, which we carried out at our workplace. At the end of the paper, the economic analysis of individual recovery methods is presented.

**Keywords:** material recovery, energy recovery, paper sludge

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**RESEARCH INTO HIGH-EFFICIENCY WASTE PROCESSING TECHNOLOGY  
FROM PHOTOVOLTAIC PANELS**

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**ABSTRACT**

It is increasingly becoming clear that there is enough energy in the Earth's ecosystem, our task is only to find more efficient and effective conversions from one form of energy to another. Energy from the sun is ecological and inexhaustible. It is up to us to find more efficient forms of its conversion into heat, or transformation into cold or electrical energy.

One of these technologies for the transformation and recovery of solar energy is photovoltaic. It is the most dynamically developing form of transformation of renewable energy from all forms of renewable energy sources (RES). However, it should be noted that in parallel with the development of photovoltaic technologies, great attention should be paid to the recovery of waste PV panels that have reached the end of their life cycle. However, recycling technologies are still not economically efficient and environmentally satisfactory. Overall, only approximately 10% of photovoltaic modules are recycled in the world. The main reason is the lack of regulation and inefficient technologies for the recovery of waste from photovoltaic panels (PV). The aim of the presented article is to focus attention on the state of research, production and use of PV as well as the necessity and complexity of waste recovery from these PV panels.

**Keywords:** technologies, waste processing, solar energy, photovoltaic panels

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**EVALUATION OF THE ECONOMIC IMPACT OF ELECTRICITY BLACKOUT  
SCENARIOS FOR THE AUTOMOTIVE SECTOR AND THE SLOVAK ECONOMY**

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**ABSTRACT**

The aim of this thesis was to estimate the economic consequences of the blackout on the Slovak economy and the automotive industry, which is one of the most important sectors in its context. The main source of data was the Exiobase database, as well as data from the Statistical Office and the Slovak Electricity and Transmission System. The thesis utilise a combined methodology of a static regionalized Input-Output Model (IIM) and implement a comprehensive approach of modelling scenarios of power supply outages, unique in Slovak conditions. The analysis results in an estimated inoperability of the automotive sector ranging from 2.9% to 4.2% in each region on the first day of the blackout, while the overall inoperability of the economy during a three-day blackout would reach up to 10%. The economy would suffer a loss of final demand ranging from €34.28 million in the most optimistic scenario to €122.49 million in the least optimistic scenario. We note the considerable resilience of the automotive sector, but the relative vulnerability of the economy as a whole. An important conclusion is the regional heterogeneity in the distribution of economic impacts, with the most affected sectors and regions in terms of inoperability generally not suffering the greatest losses in absolute terms. The model has wide potential for further use by public policy makers as well as stakeholders in economic resilience planning. The main value added of the thesis is the high regional resolution of the model at NUTS 3 level, which allows accurate quantification of losses in individual regions, as well as the newly proposed, flexible framework for temporal modelling of economic impacts (based on hourly/daily electricity consumption indices and monthly industrial production indices).

**Keywords:** Inoperability Input-Output model, automotive industry, electricity, blackout, critical infrastructure

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Transmission and Electricity System, a. s., as well as the representatives of Statistical Office of the Slovak Republic for providing detailed economic data on regionalised sectoral employment and production in Slovakia.



## THE ISSUE OF PURITY OF SECONDARY RAW MATERIALS IN METALLURGY

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### ABSTRACT

As part of the European Green Deal, the European Commission presented a plan for the ecological transformation of the European Union's economy for a sustainable future. Its main objective is to ensure that Europe becomes the first climate-neutral continent by 2050, with a 55 % reduction in greenhouse gas emissions by 2030 compared to 1990. This ambitious plan is related to the need to decarbonization all sectors of the economy, including the metallurgical industry (iron and steel making). The metallurgical industry is a significant industrial sector with a global reach. The constant increase in global steel production (as a basic manufacturing and construction material) is a response to the demand for the commodity. Currently, the world's yearly steel production is approximately 1.885 mil. tonnes (of which approximately 72 % is produced in a basic oxygen furnace and 28 % is produced in an electric arc furnace). The EU produces 136 mil. tonnes of steel per year (56.3 % in the basic oxygen furnace and 43.7 % in the electric arc furnace). As part of the decarbonization of metallurgy, there is an effort to increase the production of steel from electric arc furnaces (production of steel from secondary raw materials), which is also related to the increase in the production of direct reduced iron (DRI) and the increase in demand for steel scrap. The presented contribution analyzes the issue of purity of selected secondary raw materials (in Slovak conditions), in the context of their suitability for use as an input in steel production in electric arc furnaces.

**Keywords:** electric arc furnace, green steel, secondary raw materials, decarbonization



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**UTILIZATION OF ANTHROPOGENIC CO<sub>2</sub> FOR HUMIC ACID PRODUCTION  
APPLICABLE IN AGRICULTURE**

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**ABSTRACT**

Natural humic substances are organic products of chemical and biochemical degradation of biomass. Humic acids form part of humic substances (organic compounds) which are soluble in alkaline and insoluble in acidic aqueous solutions. Humic acids work not only as important natural reservoir of carbon bound in soil. Humic acids provide abundant organic carbon and enable to maintain a hydrated, pH and redox buffered environment hosting the soil microbiome. Due to these reasons, humic acids are crucial for agronomy. The potential utilization of anthropogenic CO<sub>2</sub> for synthetic humic acids utilization is based on reaction CO<sub>2</sub> with waste (poly)phenolic biomass. Around 1,500 Gt of carbon is bound in farmed soil (Erickson) which serves as potential giant reservoir for storage of captured anthropogenic CO<sub>2</sub>.

**Keywords:** humic acid, CCS, carboxylation

**Reference:**

Erickson, B. *Chem. Eng. News* 2016, 94, 40.

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