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TECHNOLOGIES

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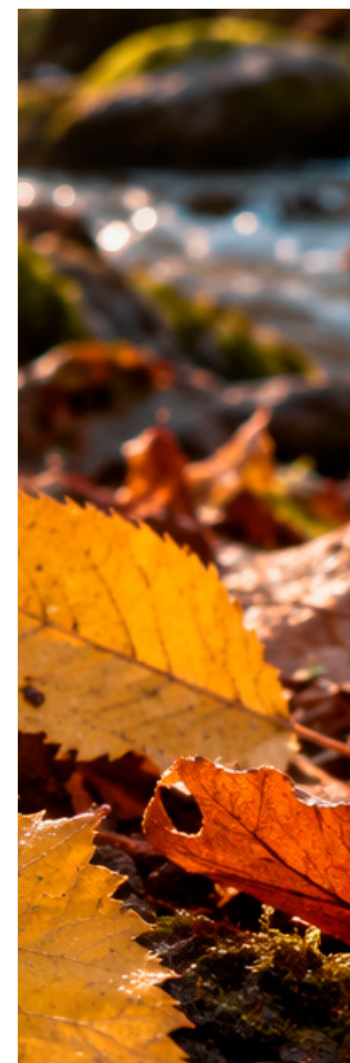
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FOREWORD BY THE DIRECTOR OF CEET

Dear readers,

Since the beginning of my scientific career, I have held the belief that science must, first and foremost, be conducted for the benefit of people.

Fundamental research and new knowledge are essential for the advancement of science. However, I believe that the journey of a scientific result should not end with its publication. Wherever possible, we should continue to develop new findings and gradually guide them towards practical application.

I consider societal impact to be one of the most important measures of successful research. This could mean lower energy consumption and reduced emissions, cleaner water, safer technologies, the more efficient use of raw materials, or an improved quality of life.

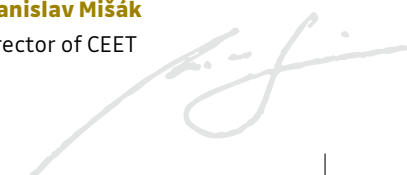
I am therefore pleased to see that societal relevance and impact are being given greater prominence in the evaluation of science under Methodology 2025+. Alongside the question of what we have created, we should also be asking ourselves who we can help and what changes can be achieved as a result.

The stories in this issue of CEETletter demonstrate that this is precisely the path we wish to take at CEET – from new discoveries to solutions for real-world problems.

And that is exactly the kind of science I would like us to do at CEET. Science that advances our knowledge, whilst simultaneously seeking ways to utilise this knowledge for the benefit of society. Science for people.

I hope you enjoy an inspiring read.

Stanislav Mišák
Director of CEET





HYDROGEN UNDER CONTROL

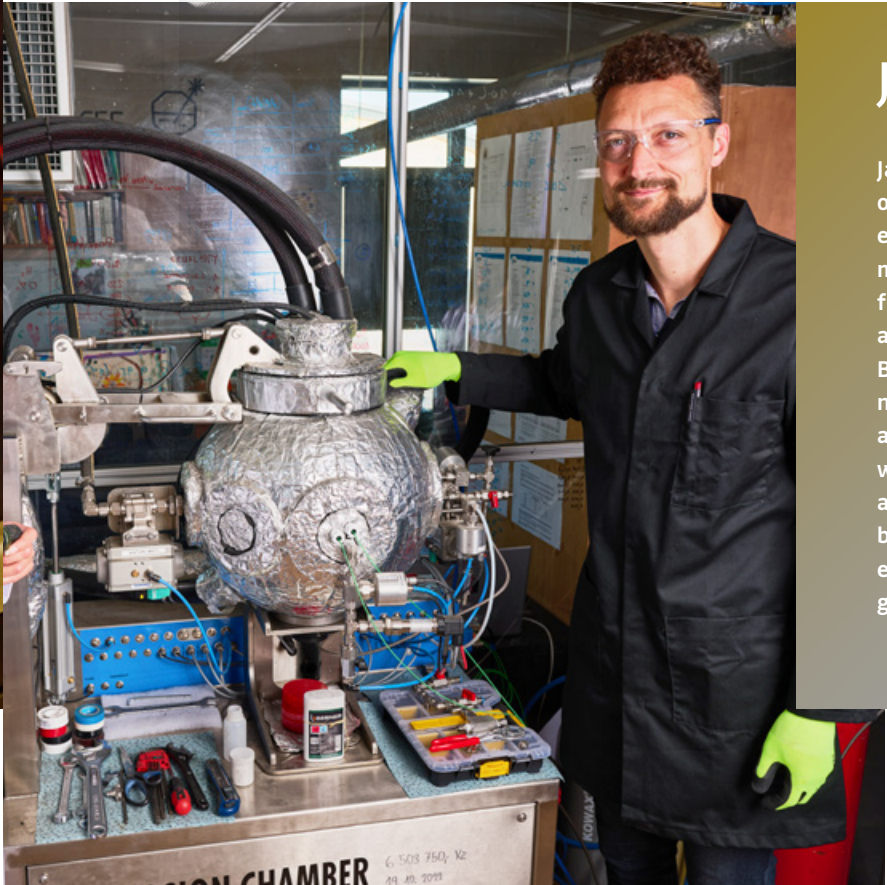
TEAMS AND PROJECTS

THE TRANSHYLAB PROJECT CONTRIBUTES TO SAFER HYDROGEN TECHNOLOGIES

Hydrogen may play an important role in the future of both the energy sector and industry. However, its wider use is not only a question of production or cost. Equally important is how it can be stored safely and how it can be handled. One possible solution is the use of metal hyd-

rides. Materials capable of binding hydrogen directly within their structure. Compared with high-pressure storage tanks, they allow hydrogen to be stored and handled at lower pressures. However, this technology is not entirely without risks. During repeated use, metal hydrides

may gradually degrade into fine powder, which can spontaneously ignite when exposed to air and, under certain conditions, may also explode. The international TransHyLab project focuses precisely on the safe utilisation of these materials.



Jan Skřínský

Jan specialises in fire and explosion safety, with a particular focus on hydrogen technologies, alternative fuels and new materials for energy applications. He contributes to the development of experimental methods, technical standards and safety instrumentation for laboratory and industrial use. He has gained experience at research institutions and companies in the Czech Republic and abroad. Building on his background in engineering and the humanities, he is now studying software engineering, applying his knowledge to data analysis and the automation of experiments. He has collaborated with more than 70 companies and has many years of experience teaching and supervising Czech and international students. His work brings together knowledge from different disciplines and industrial experience to help make technologies safer and educate the next generation of professionals.



The project brings together the Energy Research Centre (ERC) of the Centre for Energy and Environmental Technologies (CEET) at VSB – Technical University of Ostrava with partners from the Czech Republic and South Korea. Researchers aim to better understand the behaviour of metal hydrides, develop reliable methods for evaluating their safety, and transfer the acquired knowledge into practical applications.

What Does the Name TransHyLab Mean?

The name TransHyLab was created by combining the English words Transfer, Hydrogen and Laboratory. It captures the essence of the project: transferring knowledge about the safety of hydrogen technologies from laboratories into industrial applications. The three-year project, supported by the SIGMA DC4 programme of the

Technology Agency of the Czech Republic, connects research institutions and companies across continents. The Korean company Wonil T&I Co., Ltd. develops materials for hydrogen storage. The Korea Institute of Science and Technology (KIST) investigates how much hydrogen these materials can store, how their properties change during repeated use, and under what conditions they can be safely utilised. Within CEET, rese-

archers from the Research Energy Centre focus on determining how metal hydrides behave during fire or explosion scenarios and which factors influence their hazardous behaviour.

The experimental approach developed within the project combines two aspects that are usually studied separately: the ability of a material to store hydrogen and its behaviour during a potential accident. Researchers can therefore examine the same material not only in terms of its ability to bind and release hydrogen, but also from the perspective of fire and explosion safety. The experimental research is complemented by IHAS s.r.o., which develops predictive models and creates a publicly accessible database of safety characteristics of metal hydrides based on measured data. The results will also be available to other research and industrial organisations and may contribute to further development of this promising and dynamic field.

When a Metal Turns into Flammable Powder

Metal hydrides are alloys capable of binding hydrogen within their crystal structure. They are not merely a laboratory concept. Wonil T&I Co., Ltd. uses these materials, for example, in autonomous underwater systems and stationary hydrogen storage applications.

However, the key challenge is the gradual degradation of the material. During each cycle in which a hydride absorbs and subsequently releases hydrogen, its structure changes slightly. The originally compact material gradually breaks down into increasingly smaller particles. The finer the particles become, the larger their specific surface area and the faster they can react with oxygen in the air. The resulting fine powder may then spontaneously ignite after contact with oxygen or create an explosive mixture. Researchers from ERC, together with KIST, are studying how chemical composition, particle size and the amount of bound hydrogen influence the

self-ignition and explosion behaviour of metal hydrides. The collected data should help in designing safer materials and defining safer operating conditions. The evaluation also includes an environmental assessment using the Life Cycle Assessment (LCA) method throughout the entire material lifecycle, including possibilities for processing and reusing spent hydride powder.

An experimental explosion-testing autoclave

For experimental research into highly reactive powdered materials, the ERC team uses a twelve-litre explosion autoclave made of Hastelloy alloy, which can withstand high temperatures, aggressive chemicals and high pressures.

The apparatus enables researchers to experimentally observe explosion processes and measure the safety characteristics of powdered materials according to internationally recognised methodologies. However, standard measurement



procedures are not sufficient for metal hydrides because the material may react already upon contact with air. The equipment has therefore been modified so that researchers can work with smaller

samples, simulate repeated hydrogen charging cycles, and subsequently observe what happens when air is introduced — without using a conventional external ignition source.

Goal: A Safer Material Without Losing Its Function

The development process begins in KIST laboratories. There, metal hydrides undergo repeated hydro-

gen absorption and release cycles that simulate long-term operation. The samples are then transported to Ostrava. At the Research Energy Centre, they are exposed to air under controlled conditions, and researchers observe whether spontaneous ignition occurs and how intense the reaction is. Measurements include, for example, the rate of explosion pressure increase, the concentration at which an explosive mixture can form, or the amount of energy required for ignition.

The project has a clear objective: to develop a metal hydride whose explosion characteristics are approximately 20% more favourable than those of a reference material. At the same time, its hydrogen storage capacity must not deteriorate. Researchers therefore modify the alloy composition and analyse the effect of individual elements. Some elements may influence sorption and desorption properties, others may affect mechanical stability or the material's tendency to self-ignite.

The objective is therefore not only to maximise hydrogen storage capacity. Equally important is how reliably the material binds, retains and repeatedly releases hydrogen, and how it behaves after dozens or hundreds of operating cycles.

International Internships

Three international students from Berliner Hochschule für Technik in Germany, Università di Bologna in Italy, and Dalhousie University in Canada have also joined the experiments. Each of them focuses on their master's or doctoral thesis on a different element used in metal hydrides. Their results should help identify which alloy components contribute to spontaneous ignition and how their influence changes within the final material.

The project also includes exchange stays between VSB – Technical University of Ostrava and KIST. Korean students and researchers will gain experience in Ostrava by testing the fire and explosion

properties of materials, while students from VSB-TUO will have the opportunity to follow the development and testing of hydride alloys directly in Korea.

TransHyLab therefore connects material development, hydrogen storage capacity, long-term operational safety and environmental assessment. In addition to KIST, Wonil T&I and VSB – Technical University of Ostrava, the project also involves IHAS s.r.o. and OZM Research s.r.o. The expected outcomes include not only new knowledge about the behaviour of metal hydrides, but also data and methodologies that can be used in the design of safer hydrogen storage systems and in establishing appropriate operational guidelines.

What does this type of research look like directly in the laboratory, and how do researchers work with a material that can ignite spontaneously after contact with air? We asked Jan Skřinský, the principal investigator of the project.

Jan, let us start with the first question. The TransHyLab project has connected CEET with partners from South Korea. Do you remember your reaction when you learned that the Korean side had selected your laboratory for this safety research?

I was very pleased. When an institution such as the Korea Institute of Science and Technology selects a partner for hydrogen technology safety research, it is primarily a sign of trust. Hydrogen technologies are being introduced on a large scale in East Asia, and therefore great attention is being paid to safety issues. Having advanced equipment alone is not enough. It is also necessary to be able to address problems for which standardised procedures do not yet exist.

Our laboratory has long focused on the experimental evaluation of explosion properties of pyrophoric metal hydrides and their

relationship to hydrogen storage capabilities. I therefore see this cooperation as recognition of the work of our entire team and at the same time as an opportunity to compare our approaches with international partners.

In your research, you use a special twelve-litre explosion autoclave. What can this device capture, and how does it differ from conventional laboratory equipment?

A twenty-litre explosion chamber is commonly used for measuring the explosion characteristics of dusts. However, for working with highly reactive metal hydrides, we developed a special twelve-litre explosion autoclave in cooperation with OZM Research. The smaller test volume allows us to work with smaller amounts of material, while the equipment simultaneously provides higher pressure resistance.

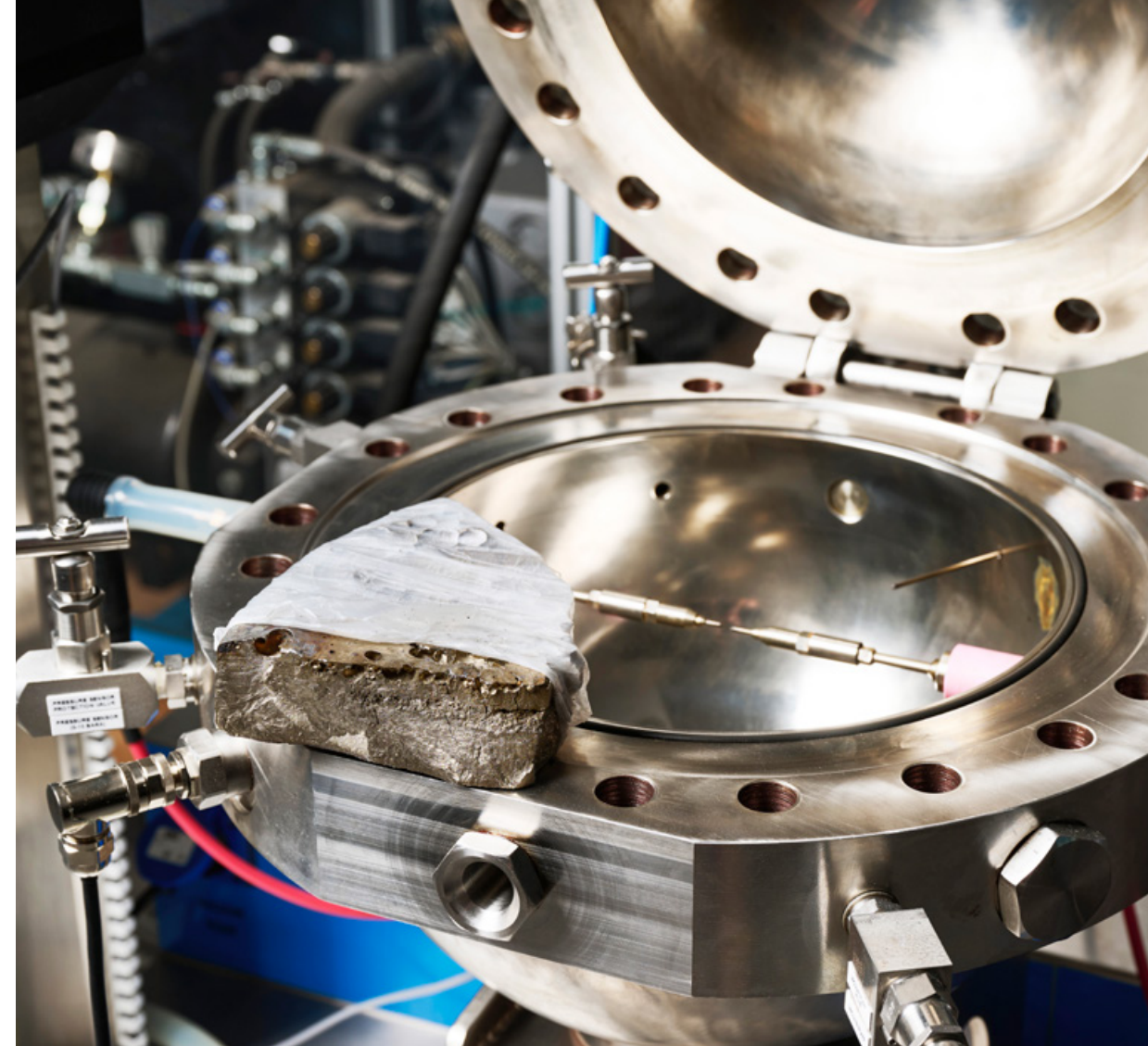
The chamber also enables us to simulate hydrogen absorption

and desorption cycles at elevated temperatures. Afterwards, we can introduce air into the system and observe whether the material ignites spontaneously, without any additional ignition source. This allows us to understand how the behaviour of the hydride changes depending on the amount of bound hydrogen, while also measuring the course of a potential explosion.

Few people realise that an explosion chamber must be “tuned” before experiments in a similar way to a musical instrument. What does this mean in practice?

The comparison is quite accurate. A musical instrument must produce a precisely defined tone when properly tuned. Similarly, an explosion chamber must repeatedly produce a precisely defined explosion behaviour when a reference dust is used.

Our “tuning instrument” is therefore an internationally used



reference dust. However, it is not enough simply to place the sample inside and press a button. We must adjust the way the dust is dispersed, the direction of the nozzles, the timing of ignition and many other parameters. The goal

is to obtain values corresponding to a reference device on which measurements were performed more than thirty years ago.

When you think about it, there is a certain paradox. Today we

have much more advanced technology, but we still need to achieve the same reference result. I sometimes say that in the past a fly was killed with a flyswatter, while today we have a sniper rifle. The technology itself, however, is

not enough. The decisive factor is who operates it and how well they understand the methodology.

Hydrogen is often associated by the public primarily with high-pressure storage tanks. Why are metal hydrides being investigated as an alternative, and what advantages can they offer?

Most people imagine hydrogen as a gas compressed to hundreds of bar. The principle of metal hydrides is different. Hydrogen is incorporated into the structure of a metal alloy, meaning that it is not stored only as free compressed gas. The advantage is therefore not only the lower operating pressure. Hydrogen is also chemically bound within the material, and its storage and release can be controlled, for example, by changing the temperature.

This is particularly advantageous for stationary storage systems, backup power sources, or

applications where hydrogen is repeatedly stored and released. The material can undergo repeated cycles and, depending on operating conditions, switch between hydrogen storage and hydrogen release. However, this does not eliminate the safety challenge, it simply changes its nature. With a pressure vessel, the main concern is high pressure. With a hydride system, it is necessary to understand what happens to the material after hundreds of hydrogen storage and release cycles. And that is precisely what we are investigating.

Following up on the previous question. Metal hydrides consist of several different metals. How can changing a single element in an alloy affect both hydrogen storage capability and the risk of spontaneous ignition?

It is similar to cooking a recipe. You change one ingredient or its amount, and the final result can be completely different. In

ANY TECHNOLOGY
IS ONLY AS SAFE AS
OUR UNDERSTANDING
OF ITS LIMITS.

metal hydrides, one element may increase hydrogen storage capacity, another may influence the rate of hydrogen release, and another may affect the mechanical stability of the material. Some elements may also increase, while others may reduce, the material's tendency to undergo spontaneous ignition.

That is why we first try to understand the influence of individual components and only then look for the most suitable combination. It is not enough to create a material that can store a large amount of hydrogen. It must also remain safe during long-term operation.

Current results indicate an important role of titanium in spontaneous ignition. Was this an expected result, or did the behaviour of this metal surprise you?

For fine metal powders, the behaviour is determined not only by which element is present. Other factors also play a major role, including the specific surface area of particles, the condition of the protective oxide layer, crystal defects and the oxidation rate. Titanium is highly reactive with oxygen. If its protective layer is disrupted, it can oxidise very intensively and release a significant amount of heat.

In our experiments, pure titanium powder proved to be more reactive than powders of zirconium, vanadium, iron or aluminium. We are now verifying whether the same effect will also occur in real metal hydride alloys.

The project also includes reciprocal internships for

Czech and Korean students and researchers. What significance do these exchange stays have for the research itself, and what can they bring to participants professionally and personally?

I consider student internships to be one of the most valuable parts of the project. You can buy an instrument, but experience is transferred primarily through joint work. Korean students will learn how to experimentally evaluate the fire and explosion properties of metal hydrides in our laboratories. Our students, on the other hand, will see how new materials are prepared and tested directly in KIST laboratories.

Each research institution uses slightly different procedures and has different experience. A stay in a foreign laboratory therefore shows researchers that the same problem can be approached in several different ways. Students will gain new professional knowledge, valuable contacts and experience working



in an international research team. These are things that cannot be learned from textbooks.

If you had to sum up the main contribution you would like TransHyLab to make in a single sentence, what would you say?

If the results of TransHyLab are still being used by researchers and industry professionals ten or twenty years from now, that will be the best proof that our work had a meaningful impact.

YOUNG SCIENTISTS AT CEET

OUR SCIENTISTS

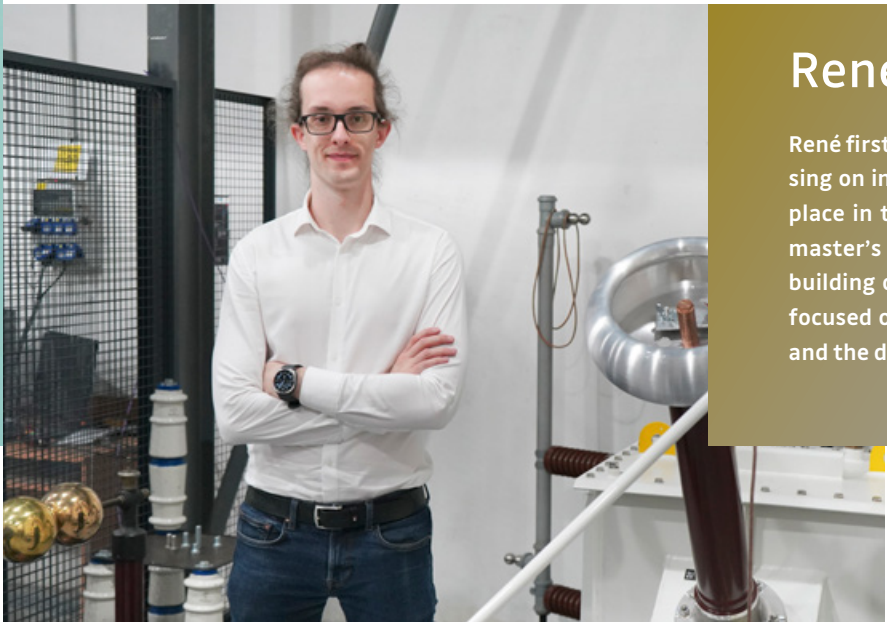
RESEARCH AND MODELLING OF INSULATION FAILURES IN GAS-INSULATED SWITCHGEAR



The transition towards sustainable energy, the growing share of renewable sources and increasing demands on the reliability of power grids are creating new challenges that cannot be addressed without high-quality research. Behind the technologies that ensure the safe and stable

transmission of electricity is often the work of scientists whose names remain largely unknown to the public. One of them is René Záruba, a researcher at the ENET Centre, part of the Centre for Energy and Environmental Technologies (CEET).

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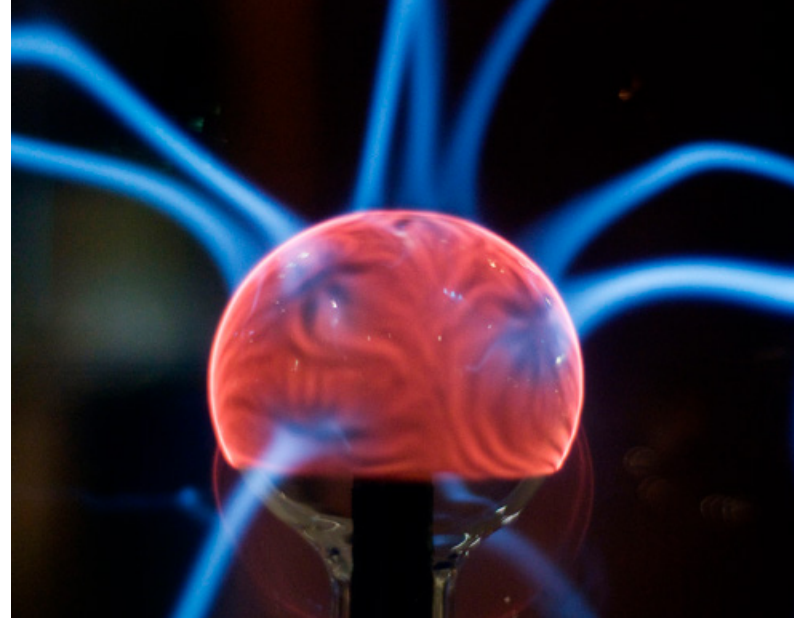
René Záruba

René first attracted attention during his master's studies with a thesis focusing on insulation faults in gas-insulated switchgear. The work won second place in the 2025 Werner von Siemens Award in the category for the best master's theses dealing with smart infrastructure and energy. He is now building on this research in his doctoral studies and is involved in projects focused on modern power engineering, diagnostics of electrical equipment and the development of solutions for the energy systems of the future.

How did his interest in high-voltage engineering begin? What does research into electrical discharges and insulation systems actually involve? And what challenges lie ahead for the power sector as the energy landscape continues to change rapidly? We discussed these topics with René Záruba in the following interview.

Let us start with your motivation. What led you to power engineering and high-voltage technology? Was this something that interested you from the beginning, or did you gradually find your way into the field?

It was not really an area I had planned to pursue from the start. After primary school, I decided to study electrical engineering with a focus on low-voltage electronics. It was only after finishing secondary school that I became more interested in



power engineering, and once I started studying at VSB – TUO, I gradually found my way into high-voltage engineering. Each stage of my studies took me a little further. In my bachelor's thesis, I worked on Paschen's law, which describes electrical breakdown in gases, while my master's thesis focused on partial discharges in gas-insulated switchgear. That was what ultimately led me to the topic I am now pursuing in my doctoral studies and research work.

I noticed that your master's thesis received an award in the Werner von Siemens Award competition. What do you think

caught the jury's attention, and what did the award mean to you?

My master's thesis focused on the research and modelling of insulation faults in gas-insulated switchgear, which is an important component of modern power infrastructure. The reliability of this equipment has a direct impact on the safe and stable transmission of electricity, so the topic has considerable practical relevance.

I think the jury may have appreciated the combination of a highly topical subject, its practical significance and the

experimental part of the work. For me, the award was primarily confirmation that the thesis had reached a strong professional standard and that the effort I had put into it was worthwhile. It also reinforced my belief that the field I am working in is relevant not only from a scientific perspective, but also in practical terms.

The topic sounds rather complex. How would you explain to a non-specialist why insulation systems are such an important part of electrical equipment?

An insulation system has one basic purpose: to ensure that electric current flows only where it is supposed to. This allows electrical equipment to operate safely, reliably and over a long service life. Without high-quality insulation, short circuits or unwanted electrical discharges could occur. Many high-voltage devices would also have to be several times larger, because the only way to prevent an electrical discharge from jumping between

individual components would be to increase the distances between them. That is why special insulating materials or gases with high dielectric strength are used. They make it possible to build equipment that is both compact and highly reliable, such as gas-insulated switchgear.

Even modern insulation systems, however, are not completely free of defects. Small manufacturing imperfections or contaminants can cause partial discharges that gradually damage the insulation. If such a fault is not detected in time, it can eventually lead to a serious equipment failure after years of operation. This is why research into insulation systems and diagnostic methods is so important.

Your work also deals with the physics of electrical discharges, gas ionisation and insulation breakdown. What fascinates you most about these phenomena from a scientific point of view?

What fascinates me most is that a medium which normally does not conduct electricity can, under certain conditions, suddenly become a conductive path for an electrical discharge. Partial discharges are particularly interesting because they do



not destroy the insulation immediately. They are small discharges that cause gradual damage. Each individual discharge produces only a tiny amount of degradation, but when they occur repeatedly over a long period,

the properties of the insulation system deteriorate and may eventually result in complete breakdown. Understanding these mechanisms is essential for detecting faults at an early stage and preventing costly failures.

What does research in this field actually look like? Is it mainly laboratory work and experiments with high voltage, or do you spend more time modelling and analysing data?

Speaking from my own experience, a large part of the work consists of laboratory experiments. It is often a process of trial and error. You design an experiment, prepare a sample and expect a certain result. But instead of partial discharges, the chosen voltage may cause an immediate insulation breakdown, or something completely different from what you expected may occur. You then have to modify the experiment and repeat the whole process.

CURIOSITY IS OFTEN THE
BEST DRIVING FORCE
BEHIND RESEARCH.

Only once you have created a model or sample that behaves as expected and allows you to observe partial discharges reliably can you begin systematic data collection and evaluation. Experimental work therefore forms the basis, followed by analysis and interpretation of the results.

Many people also do not realise that working in a high-voltage laboratory is not just about computers and measuring instruments. Transformers, enclosed equipment and other devices can be large and heavy, so preparing experiments can also be physically demanding.

Electrical equipment is facing ever greater demands in terms of reliability, efficiency and

environmental impact. What changes do you expect to see in this field in the coming years?

The energy sector is changing rapidly, and with it the requirements placed on electrical equipment. This means that some established technologies will need to be adapted to new conditions. One example is the gradual phase-down of SF₆ insulating gas. It has excellent insulating properties, but it is also a greenhouse gas with a very high global warming

potential. Gas-insulated switchgear will not disappear, but alternative insulating media, such as synthetic air or other modern gas mixtures, will increasingly be used.

These alternatives have different properties, which means their behaviour, reliability and diagnostic possibilities must be tested again. This is just one example of the many changes the energy sector is facing. Research will therefore continue to play

a central role in developing safer, more reliable and more efficient solutions.

Tell us about the research you are currently working on. Does it build on your master's thesis, and where would you like to take your research during your doctoral studies?

My master's thesis actually led me directly to the topic I am now pursuing in my doctoral studies. While my thesis focused on partial

discharges in gas-insulated switchgear, I am now studying how they originate and behave under specific environmental conditions, particularly at reduced pressure.

At present, I am focusing on partial discharges on printed circuit boards intended for operation at high altitudes, for example, in aerospace applications. The aim of my research is to gain a better understanding of these phenomena and, based on experimental results, develop recommendations for PCB design that would improve reliability and safety under these conditions. My research will naturally continue to evolve throughout my doctoral studies. That is one of the interesting things about scientific work: you may start with a particular goal, but new findings and experimental results often open up entirely new questions and research directions.



Research in power engineering often has direct practical applications. Are you already working with industrial partners or energy companies? How successful are you in connecting academic research with real operational needs?

Connecting research with practice is very important in our field. My current work partly builds on results and experience gained through an earlier collaboration between our research group and Honeywell. Together with colleagues, we also carry out diagnostic measurements on electrical equipment directly in operation. We visit industrial facilities, hospitals, power plants and other sites, where we assess the condition of electrical equipment and insulation systems. This keeps us in regular contact with real-world operational problems and provides valuable feedback that helps guide our future research.

Scientific research is often associated mainly with success, but the path towards results is usually far more complicated. Can you remember an experiment or situation that caused you real difficulty but ultimately taught you something valuable?

There are many such situations in research. They are simply part of the process. It is actually quite rare for everything to work exactly as planned on the first attempt, and when it does, it almost feels suspicious. You

often learn the most from failed experiments because they force you to understand why something behaved differently from what you expected.

And this does not apply only to the experiments themselves. Sometimes the problem becomes apparent only when processing the data or analysing the results, when you realise that you chose the wrong approach at the very beginning or overlooked an important detail. At that point, there is nothing else to do but go back several steps and repeat the

process. It can be frustrating, but experiences like these teach you how to design future experiments much more effectively.

To finish, let us look to the future. Where would you like to be as a scientist in ten years, and what advice would you give students considering a career in power engineering research?

In ten years, I would mainly like to have gained substantial experience, be involved in high-quality research and have published several papers in respected scientific journals that make a genuine contribution to the field. I hope to work on interesting projects and continue exploring topics with practical relevance to power engineering. My advice to students would be not to be afraid to show their interest and approach their lecturers. From my own experience, the environment at VSB – Technical University of Ostrava is very supportive, and if someone is genuinely

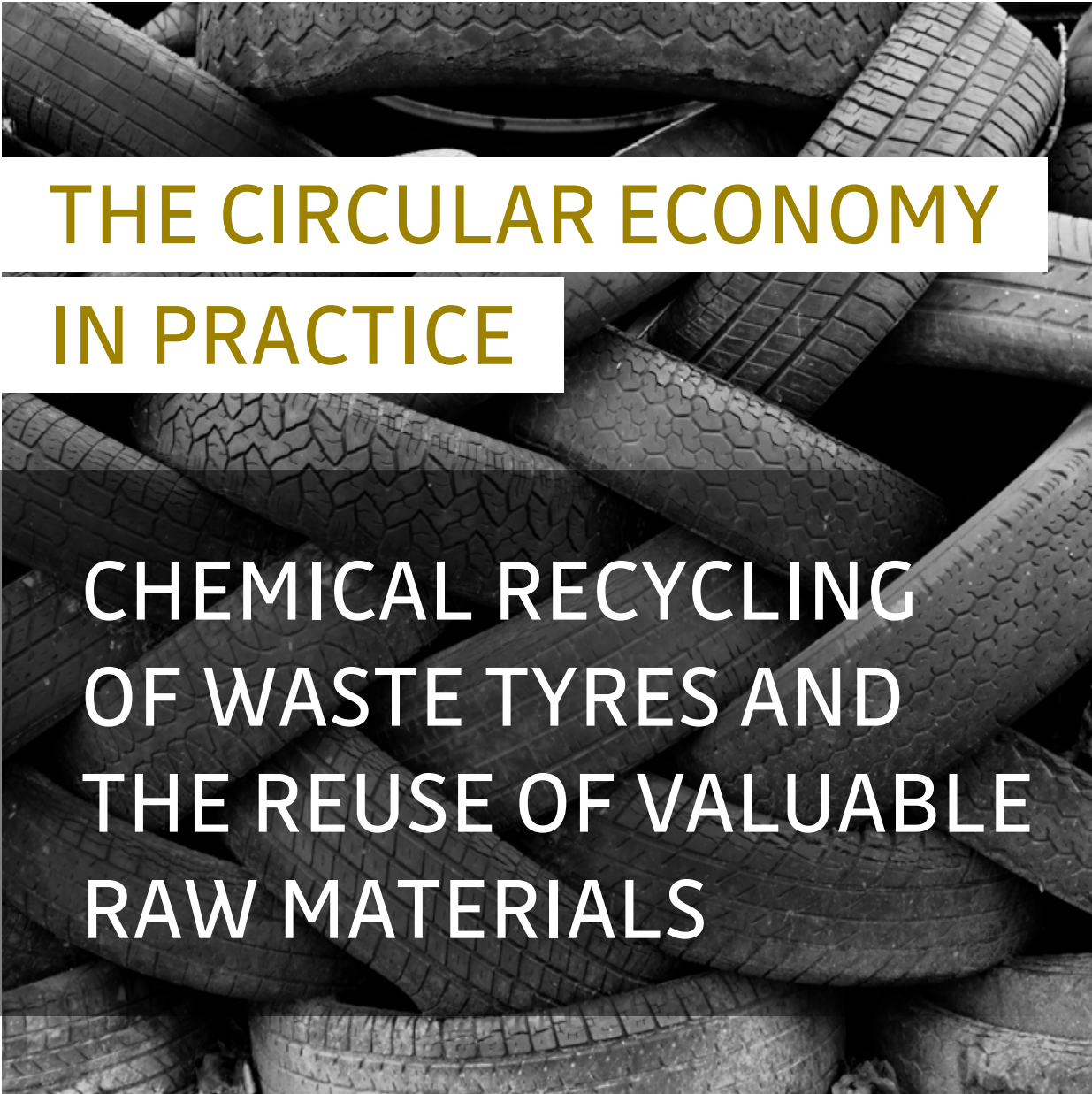


interested in a particular topic, it is quite possible to become involved in research while still studying. Students can experience laboratory work, participate in real research projects and often choose a thesis topic that reflects their own interests.

There is one more thing I would recommend: do not lose sight of what makes you curious. Curiosity is often the best driving

force behind research. When a problem genuinely interests you and you want to understand how it works, it becomes much easier to overcome periods when experiments fail, data analysis takes longer than expected, or you simply have to start again. Without genuine curiosity and interest, it is very difficult to sustain a long-term career in research.





THE CIRCULAR ECONOMY IN PRACTICE

RESEARCH & INNOVATION

CHEMICAL RECYCLING OF WASTE TYRES AND THE REUSE OF VALUABLE RAW MATERIALS

Every year, around 3 to 4 million tonnes of tyres reach the end of their service life in Europe. Today, waste tyres are managed primarily in two ways: material recycling and energy recovery. European data from 2019 indicate that approximately 52%

were mechanically recycled and 40% were used for energy recovery. The exact proportions, however, vary depending on the year and the methodology used. In material recycling, tyres are shredded into rubber granulate, which is then used, for exam-

ple, in playground and sports surfacing, noise barriers and insulation, or as an additive in asphalt. Owing to their high calorific value, waste tyres are also used as fuel for energy recovery, mainly in cement and lime kilns, and sometimes in incinerators.



Pavel Leštinský

Pavel is an expert in the field of chemical and process engineering, specialising in the design of sustainable technologies and the optimisation of environmental processes in the chemical and energy industries. He is currently collaborating with ORLEN Unipetrol within the framework of the National Competence Centre for Polymer Materials and Technologies for the 21st Century on the chemical recycling of waste tyres. The topics of chemical recycling, waste material processing, and the concept of the circular economy are further addressed and developed through projects at both national and international levels. Since 2024, his research group has been involved in the international call of the Clean Energy Transition Partnership, working on a project entitled “Gasification and Electrolysis Novel Integration Used for Sustainable Fuels”.

Retreading is a separate approach that extends the service life of tyres before they become waste. Where the tyre's condition permits, a new tread is applied to an undamaged casing. This process is used mainly for truck tyres. Although landfilling both whole and shredded waste tyres is banned in the EU, some still end up outside the waste management system. It might seem, then, that there is no real problem with waste tyres. From a circular economy perspective, however, several questions remain: whether it is appropriate to burn such a large proportion of this material, whether some uses of rubber granulate contribute to the release of microplastics into the environment, and whether demand for playground surfacing, noise barriers and insulation is unlimited. Another question is whether tyres can yield the raw materials needed to make new ones, such as carbon black for rubber production. This is precisely the question that chemical recycling of waste tyres seeks to answer.

Breaking Tyres Down Rather Than Burning Them

One of the most promising methods of chemical recycling is pyrolysis. This is a thermochemical process in which waste tyres are heated to high temperatures in the absence of oxygen. Unlike combustion, it does not involve oxidation or burning, but rather the controlled decomposition of the tyres into several products.

Pyrolysis produces three main products: pyrolysis gas, pyrolysis oil and a solid carbonaceous residue known as recovered carbon black (rCB). Depending on the technology used, steel cords are separated either before or after pyrolysis. Textile fibres are best removed before pyrolysis. Each of these products is a valuable raw material for further processing. Pyrolysis gas consists of a mixture of hydrogen, methane, carbon monoxide and other light hydrocarbons. It usually supplies part of the energy needed for the pyrolysis process itself, although more extensive



treatment, particularly desulphurisation, can make it suitable for other uses. Pyrolysis oil contains a wide range of hydrocarbons that can be used in the chemical and petrochemical industries, while rCB offers a promising “alternative” to commercially produced carbon black. The aim of modern chemical recycling is therefore not simply to break down waste tyres, but to maximise the value of the resulting products and return them to the material cycle.

Tyre pyrolysis has been studied for several decades. In recent years, however, the number of commercial-scale waste tyre processing plants has grown across Europe,

including in Germany, Sweden, Poland, Hungary and Slovakia. This has increased the pressure to ensure consistent product quality.

The Real Challenge Begins After Pyrolysis

It might seem that breaking tyres down through pyrolysis solves the problem. In reality, this is only the first step. Pyrolysis products must meet industrial requirements, and there must be reliable markets for them. Simply producing them is not enough: they need a consistent composition, sufficient purity and properties that allow them to be used in further applications at an acceptable cost.

This is particularly true of pyrolysis oil, which contains a number of compounds of interest to the chemical industry, such as limonene, used in the manufacture of chemicals and solvents. For limonene to be used as an industrial feedstock, however, it must be efficiently separated from the other components and purified to the required level. The situation is similar for the solid carbonaceous residue, rCB. This material could partially replace industrially produced carbon black used in tyres, plastics and rubber products. However, different types of tyres—summer versus winter tyres, or truck versus passenger car tyres—have different compositions, so the properties of the resulting carbonaceous material also vary. Researchers are therefore looking for ways to purify it, remove mineral constituents, standardise its quality and modify its properties to meet the requirements of industrial customers. This is now the main focus of research, including work carried out in the laboratories of the Industrial Chemistry research group

at the Institute of Environmental Technology, part of the Centre for Energy and Environmental Technologies.

The project “Advanced Valorisation of Waste Tyres to Produce High-Value Limonene and Purified Carbon Black” is part of the National Competence Centre for Polymer Materials and Technologies for the 21st Century (PolyEnvi21). The research team is looking beyond pyrolysis itself and the effects of process conditions on product quality. Its primary focus is on increasing the value of the resulting products through refining and purification processes.

The aim is to turn pyrolysis oil and rCB from process intermediates into raw materials that can be used by the chemical, petrochemical and rubber industries over the long term. Close collaboration with ORLEN Unipetrol RPA is therefore an important part of the project. Regular working meetings allow the team to compare laboratory research findings with

the practical requirements of industrial companies and explore ways of putting new technologies into practice.

Towards a Circular Economy

Chemical recycling of tyres is not just about waste management. Above all, it is about using raw materials more efficiently. If consistent quality can be achieved for both rCB and the substances recovered from pyrolysis oil, old tyres could become an important source of secondary raw materials for further manufacturing. Depending on the technology and how the products are used, replacing a proportion of virgin raw materials could reduce both the energy demand and the carbon footprint of production. Research is therefore shifting from the question of how to process a waste tyre to how to recover raw materials with consistent properties and genuine industrial applications.

We spoke to Pavel Leštinský, head of the Industrial Chemistry research group and the project's principal investigator, about the potential of chemical tyre recycling, the challenges it faces and the future of the technology.

Pavel, the article above explains that the future of chemical recycling depends above all on the quality of the recovered raw materials. In your view, what is the biggest obstacle that needs to be overcome today?

First, I would like to emphasise that chemical recycling complements existing methods. We also need to recognise the value of the treatment methods already in use. Cement kilns need fuel, and waste tyres can be an attractive alternative if we want to reduce fossil fuel use. The sulphur in tyres can also have a positive effect on clinker quality. When fed at the right rate, tyres therefore offer demonstrable benefits for operating costs, environmental

performance and the properties of the final product. We need to view chemical recycling in the same way. Its products must offer clear benefits in existing industrial processes; otherwise, there is little point.

In my view, one obstacle is the lack of communication between industry and the waste management sector. Each side has its own established way of doing business, and bringing them together is not easy, because both will have to make compromises. Without wishing to generalise, some of the blame also lies with the “cowboys” in the pyrolysis sector. As recently as five or ten years ago, I regularly saw technology presentations claiming that the recovered carbonaceous material could readily be used as a pigment and in black printing inks. Yet this is one of the most demanding applications for carbon black, with specifications that even standard grades from conventional carbon black plants often fail to meet. I therefore fully understand why

industrial partners have simply lost interest after twenty years of this kind of nonsense being promoted in the pyrolysis sector.

Your project focuses on the valorisation of pyrolysis oil and the solid carbonaceous residue. What does valorisation mean in practice?

Pyrolysis oil is a mixture of hundreds or even thousands of organic compounds, mainly hydrocarbons. However, its typically high sulphur content means that it does not meet EU regulatory limits for direct use, even as a light fuel oil. It therefore needs to be processed, for example by vacuum fractional distillation, to separate it into fractions according to boiling point. These fractions contain compounds worth isolating through further refining processes, such as extractive distillation or liquid-liquid extraction. Limonene is one such compound.



**THE AIM OF CHEMICAL
RECYCLING IS NOT
SIMPLY TO DECOMPOSE
WASTE TYRES, BUT
TO RECOVER THEIR
VALUABLE COMPONENTS
AND RETURN THEM TO
THE MATERIAL CYCLE.**

The solid carbonaceous residue, referred to as rCB (recovered carbon black), is also a mixture of different substances. Its main component is the carbon black originally present in the tyres, which accounts for approximately 25–30% of their mass and remains in the solid residue during pyrolysis. The residue also contains inorganic additives, such as vulcanising agents (particularly zinc and sulphur) and mineral fillers (for example, SiO_2), as well as pyrolytic carbon, polycyclic aromatic hydrocarbons (PAHs) and other non-volatile impurities. Recovering rCB for reuse is one of the most promising opportunities. Major rubber manufacturers are already testing the replacement of a small proportion of commercially produced carbon black with rCB in new tyres. However, it is not yet in widespread use. Each manufacturer has its own formulations, and a high ash content is not acceptable in every application. Pyrolysis also changes the properties of the

carbon black in rCB compared with virgin carbon black produced in conventional plants. Valorising rCB therefore involves purification processes, particularly the selective removal of specific inorganic constituents and the restoration or modification of the carbon black surface.

You also work with industrial partners on the development of these processes. How much do their requirements influence the direction of your research?

Industrial partners are essential to this type of research. Their feedback keeps our work grounded in practical realities. ORLEN Unipetrol is directly involved in the project, assessing the potential of pyrolysis oil fractions and their suitability

for use in the refining and petrochemical industries. This helps us define the individual stages of pyrolysis oil refining. We also receive valuable support from the Plastics Cluster and the consortium of companies within the National Competence Centre for Polymer Materials and Technologies for the 21st Century. Their rCB quality requirements and their insights into the barriers to its use in specific applications are particularly important. We use this information to optimise rCB purification processes.

How do you see the future of chemical tyre recycling in Europe, and what role could Czechia play?

Based on our market research, the EU's total capacity for the chemical recycling of waste tyres could reach as much as 500,000 tonnes per year in the coming years. This includes plants already in operation, those under construction, and those beginning construction following approval



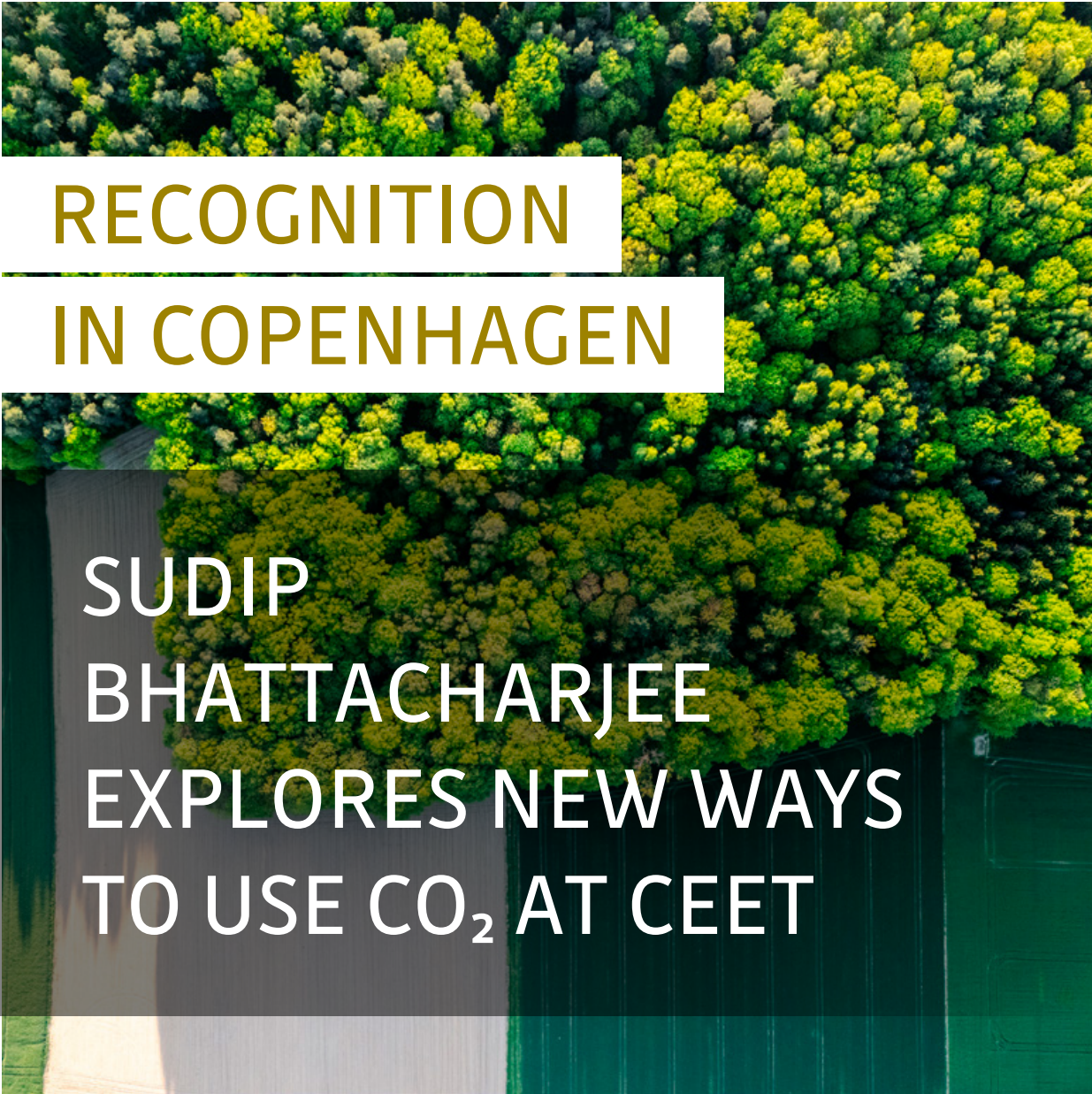
through the environmental impact assessment (EIA) process. That represents roughly 12–17% of the total volume of waste tyres. Chemical recycling will therefore complement today's treatment methods. Czechia could also play an important role in this field. A waste tyre chemical recycling plant with a planned capacity of more than 22,000 tonnes per year is being developed in Vřesová. The project is being carried out by SUAS reTire, a joint venture

established by SUAS Ecology and the German technology company Pyrum Innovations AG.

If you could choose one thing for readers to take away from this interview, what would it be?

If I had to choose one thing, it would be that pyrolysis is not a solution in itself, but just one step in the overall process. It is rather like baking a cake. Simply putting the ingredients in the oven is not enough. Choosing and

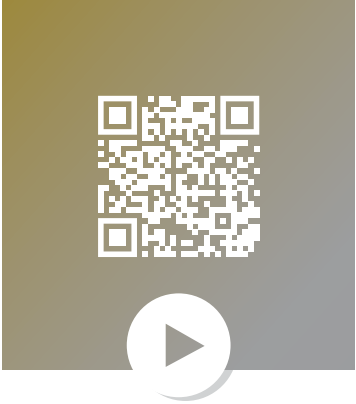
mixing them matters, and after baking there is still the filling to spread between the layers and the decorating to do before the cake is sliced and served. The same is true of tyres: what matters is not just pyrolysis itself, but also proper feedstock preparation and subsequent processing of the resulting products so that they can find real applications in industry. Pyrolysis is just the oven, not the whole recipe.



RECOGNITION IN COPENHAGEN

SUDIP BHATTACHARJEE EXPLORES NEW WAYS TO USE CO₂ AT CEET

INTERVIEWS & PERSONALITIES



Sudip Bhattacharjee from the Centre for Energy and Environmental Technologies (CEET) at VSB – Technical University of Ostrava has received the Early Career Scientist Award at the international Cata-

Want to learn more about the research?
Watch the video interview with the author.

lytic CO₂ Conversions Conference (CCC2026), held in Copenhagen on 25–28 August 2026. He presented his research on single-atom catalysts for carbon dioxide conversion. Behind the technical terminology lies a straightforward goal: finding ways to turn CO₂ into useful chemicals.

Carbon dioxide as a raw material

Capturing carbon dioxide and turning it into something useful are two different challenges. Sudip Bhattacharjee focuses primarily on the second. He develops catalysts — substances that speed up chemical reactions — and investigates how they can help turn the carbon contained in CO₂ into other compounds. His research includes reactions that produce substances



Sudip Bhattacharjee

Sudip is a scientist at CEET, VSB – Technical University of Ostrava, exploring ways to give CO₂ a second life. He studies how a gas best known for its role in climate change can be turned into useful chemicals and fuels. After completing his PhD in India in 2025, he joined colleagues in Ostrava to take this research further. In 2026, he received the Early Career Scientist Award at an international conference on CO₂ conversion in Copenhagen. His work has a practical goal: to help make the products we need with less impact on the environment.



suitable for use in polymer manufacturing. The question is therefore not simply where to store carbon dioxide, but also what we can make from it.

One example is his work combining the use of CO₂ with glycerol, a by-product of biodiesel production. The research team showed that, with a suitable catalyst, the two raw materials can be converted together into salts of formic and lactic acids. These salts can then be processed into the acids themselves, which have applications in the chemical industry. The study also highlights that economic via-

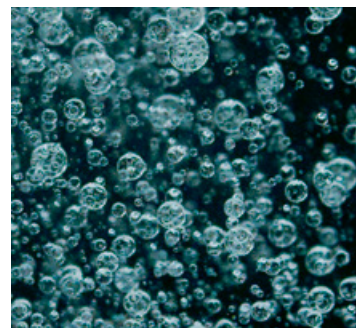
bility depends not only on the reaction itself, but also on the cost of raw materials and the subsequent processing of the products.

Using CO₂ does not, however, automatically mean reducing emissions. The amount and source of energy required, the other substances needed and what ultimately happens to the final product all matter. The aim is therefore not merely to achieve an interesting chemical transformation, but to identify approaches whose benefits hold up when the entire production process is assessed.

A focus on individual atoms at CEET

Sudip Bhattacharjee was already exploring these challenges during his doctoral studies at the Indian Association for the Cultivation of Science, where he completed his PhD in 2025. He is now building on that work as a postdoctoral researcher at CEET under the supervision of Professor Radek Zbořil. As part of the REFRESH project, he focuses on developing advanced single-atom catalysts for CO₂ conversion.

What does a single-atom catalyst look like? Rather than forming larger metal particles, individual metal atoms are anchored to a solid support. Together with their immediate surroundings, they create sites where chemi-



cal reactions can take place. This approach can make highly efficient use of the metal while allowing researchers to investigate how the arrangement of an active site influences the catalyst's behaviour.

But how do researchers go about finding such materials? What must a catalyst be able to do before it can be used beyond the laboratory? And what roles do colleagues, mentors and personal motivation play along the way?

You returned from Copenhagen with the Early Career Scientist Award. What does this recognition mean to you, and what was the main idea from your research that you wanted the audience to take away?

The award was a very encouraging recognition of my research and gave me confidence that the direction I am pursuing is relevant to the wider catalysis community. More importantly, it was an opportunity to share my ideas with researchers working

on CO₂ conversion from different perspectives. The main message I wanted the audience to take away was that CO₂ utilization should go beyond simply fixing CO₂—we need to develop atom-efficient catalysts and innovative reaction strategies that can convert CO₂ into genuinely valuable chemicals while addressing energy and sustainability challenges.

If you had to use just one example to show someone outside your field why it is worth producing chemicals from CO₂, which would you choose, and why?

I would show them the wide range of products that can potentially be produced using CO₂ as a carbon source. For example, polyurethanes and polycarbonates are used in everyday products such as chairs, cushions, trolley bags and other consumer materials. CO₂ can also be used to produce various solvents and chemical building blocks that are routinely used in



laboratories and industry. Seeing these familiar products helps explain the bigger idea: CO₂ is not only a waste gas it can also be considered a valuable carbon feedstock for producing chemicals and materials that we use every day.

A successful reaction in the laboratory is not yet a technology ready for practical use. What do you see as the biggest obstacle to putting the processes you work on into practice, and how are you trying to overcome it?



The biggest challenge is scalability and overall economic and environmental viability.

A catalyst may work well in the laboratory, but it must remain active and selective under realistic conditions, be stable for long-term operation, and allow efficient product separation.

I therefore try to design catalysts with practical conditions in mind from the beginning, while considering energy consumption, raw-material sources, catalyst stability and product recovery. The goal is to develop not just an interesting reaction, but a process with genuine potential for practical application.

How has working at CEET helped your research develop? Could you share a specific example of how your experience complements the expertise of your colleagues here or your international partners?

Working at CEET has helped me broaden my research through its interdisciplinary environment.

TURNING CO₂ INTO USEFUL PRODUCTS IS ONLY PART OF THE CHALLENGE. THE REAL GOAL IS TO MAKE THE WHOLE PROCESS MORE SUSTAINABLE.

My background is mainly in porous materials and heterogeneous catalysis, while my colleagues and international collaborators bring complementary expertise in single-atom catalysis, advanced characterization, computational studies and energy applications. By combining these strengths, I have been able to develop new

research ideas connecting CO₂ utilization, biomass valorization and sustainable catalysis, while gaining a broader understanding of their mechanisms and applications.

Radek Zbořil is your mentor at CEET. How has working with him shaped the way you approach research — for example, when deciding which questions to pursue and which direction to take?

Working with Prof. Radek Zbořil has strongly influenced the way I think about catalyst design. One question I increasingly focus on is how we can maximise the utilisation of every atom in a catalyst. A major challenge in conventional heterogeneous

catalysis is that a large fraction of the metal atoms may remain inactive or poorly utilised, while the reaction mechanism is not always clearly understood. His guidance has encouraged me to think beyond simply making a highly active catalyst—to design materials where the active sites are precisely controlled, highly accessible and efficiently utilised, while understanding the mechanistic pathway behind the reaction. This approach has helped me move towards more atom-efficient and rational catalyst design.

When you are not in the laboratory, what helps you switch off from research? Have you found a favourite place or activity in Ostrava that has become part of your life here?

When I am not in the laboratory, I really enjoy going on road trips and exploring the surroundings of Ostrava. Hlučín Lake and the Ostrava River are among the places I particularly like. It is

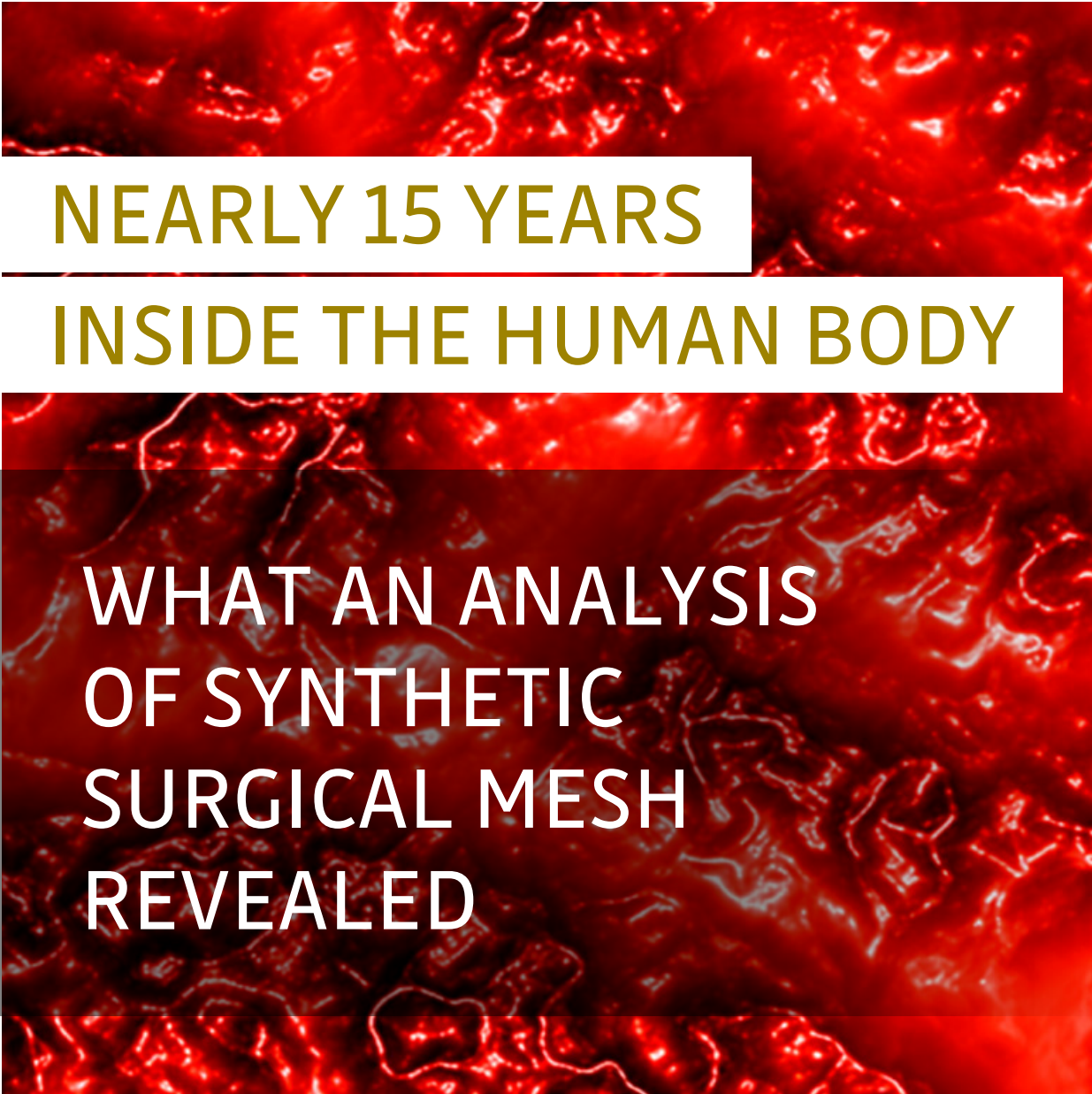
not only the scenic beauty but also the greenery and peaceful atmosphere that I find very refreshing. Ostrava also has some beautiful hiking places, and I enjoy spending time there whenever I get the opportunity. These small escapes from the laboratory help me switch off from research and appreciate the natural side of life here.

What message would you like to share with other researchers working in catalysis and CO₂ utilisation, especially those who are just beginning to find their own path in science?

My message would be to stay curious, be patient, and always ask why your research matters beyond the laboratory. In CO₂ utilisation, we should look beyond conversion and selectivity and consider energy, sustainability, and real-world applicability. For young researchers, I would encourage them to explore unconventional ideas, learn from failures, and develop their own



scientific questions. Ultimately, the goal is not simply to consume CO₂, but to use its carbon intelligently to create something genuinely valuable.



TEAMS AND PROJECTS

NEARLY 15 YEARS INSIDE THE HUMAN BODY

WHAT AN ANALYSIS OF SYNTHETIC SURGICAL MESH REVEALED

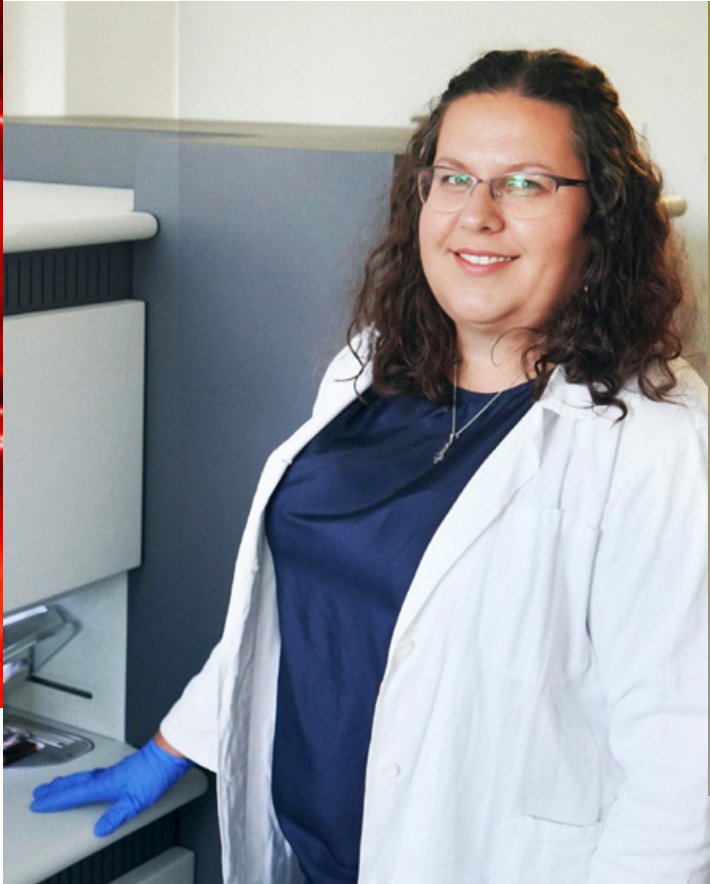


Researchers from the Nanotechnology Centre at CEET, VSB – Technical University of Ostrava (VSB-TUO), helped analyse

Want to learn more about the research?
Watch the video interview with the author.

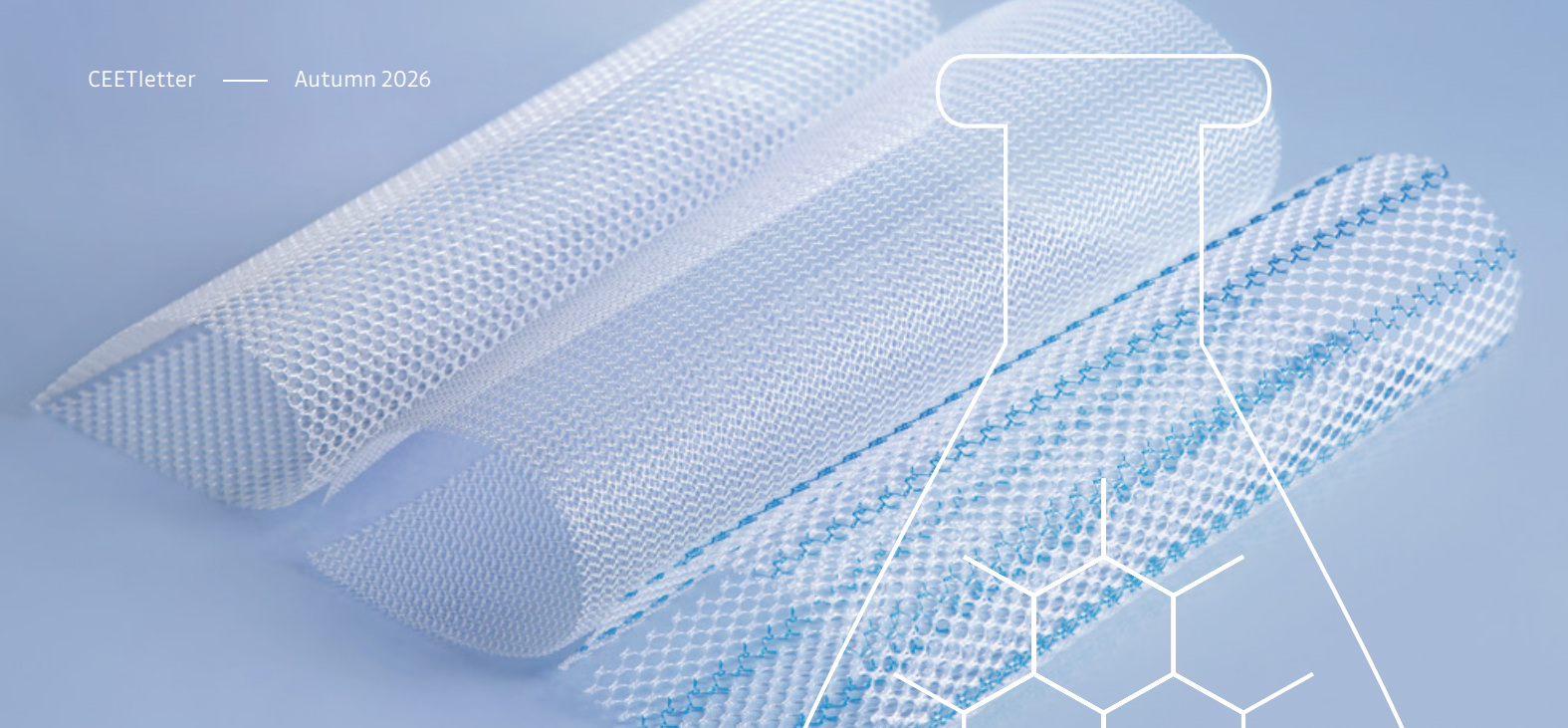
an exceptionally rare sample: a material that had been implanted during surgery and remained in the human body for 14.7 years. Using electron microscopy and spectroscopic techniques, they examined its structural integrity, morphology and changes in its surface chemistry.

Most of us associate plastics and polymers with packaging, bottles and everyday products. But some of these materials have a much more demanding job to do: they need to function reliably for years inside the human body. In certain types of surgery, for example, they are used as a fine mesh to reinforce and support weakened tissue.



Pavlína Peikertová

Pavlína originally trained as a physicist and has gradually aligned her professional career with materials research, nanotechnology, and environmental topics. She studied General Physics and Biophysics at the Faculty of Mathematics and Physics at Charles University and completed her doctoral studies in Chemical Metallurgy at VSB-TUO. She has been working at the Nanotechnology Centre since 2011, with her scientific work focusing primarily on materials characterisation using spectroscopic methods, particularly FTIR, Raman spectroscopy, and XPS. Her research activities encompass a wide range of materials, from nanomaterials and nanocomposites to polymers, carbonaceous materials, and materials for environmental applications. Throughout her scientific career, she has been involved in numerous national and international research projects and has completed several research placements abroad, including in the USA and Slovakia. Alongside her research, she is also dedicated to teaching, working with students, and activities related to research data management.



These materials are exposed to the body's internal environment and mechanical stress over long periods.

An international team from the University of Sheffield, Sheffield Teaching Hospitals and the Nanotechnology Centre at CEET, VSB-TUO, was able to obtain just such a sample. The surgical mesh, made from polyethylene terephthalate, commonly known as PET, was implanted in a patient in 2010 and removed in January 2025. It had spent 176 months, or 14.7 years, in her body. Samples that have been implanted for this long are very

rare in materials research.

This gave the researchers a unique opportunity to examine the condition of the material after nearly 15 years inside the human body. Electron microscopy showed that its overall structure remained largely intact. Localised damage was found mainly in areas subject to the greatest mechanical stress, such as the mesh knots and around the titanium fixation components.

Spectroscopic analyses also revealed changes in the chemical composition of the material's surface that may be linked to hydrolytic or oxi-

dative processes. In simpler terms, while the overall structure remained largely intact, the surface showed chemical changes associated with long-term exposure to the environment inside the human body.

According to the authors, the study, published in Materials Today Communications, provides the first materials characterisation of PET surgical mesh explanted after this type of surgery. Since the researchers had only one sample to work with, the findings serve primarily as a starting point for further research.

Our colleagues Pavlína Peikertová and Jan Schäfer from the Nanotechnology Centre at CEET contributed to the study. We spoke to Pavlína about what a material can look like after nearly 15 years inside the human body, as well as her research, laboratory equipment and the possibilities offered by modern surface analysis techniques.

Pavlína, how does someone from Ostrava end up studying a surgical mesh that spent almost 15 years inside a patient in the UK? And how did the collaboration with Sheffield come about?

It came about through Jan Schäfer, who leads my group within the REFRESH project and has been collaborating with the University of Sheffield for more than ten years. I became involved through the XPS analysis, as I'm one of the people who operate the instrument.

Following on from that, what made this particular sample so interesting to you as a materials scientist? From a materials analysis perspective, is nearly 15 years inside the human body an exceptionally long time?

To be honest, this research has a personal dimension for me, too. I've had surgery myself in which a similar mesh was implanted. Mine hasn't been in place for as long, of course, but that personal experience made me particularly interested in how stable these materials are and what happens to them after years inside the body, both as a patient and as a materials researcher.

The material itself also made the sample unusual. In this case, it was a PET mesh, a type that isn't widely used any more. These days, we tend to see polypropylene meshes instead. That was another reason the sample was so interesting. As for the implantation time, almost 15 years really is a long time.

THE MATERIAL MAY APPEAR COMPLETELY INTACT AT FIRST GLANCE, BUT CHEMICAL CHANGES MAY ALREADY BE OCCURRING IN ITS SURFACE LAYER.

To make a slightly tongue-in-cheek comparison with the length of our research projects, we'd have virtually no chance of following a material for that long in a conventional experiment. As part of this collaboration, we've also analysed other explanted meshes, this time made of polypropylene, and we're now preparing the results for publication. But that's a story for another time.

Let's turn to the material itself. When you started analysing the mesh, what surprised you most about the results? Had you expected more damage, or greater stability?

I don't think I had any particular expectations before the analysis. As a patient, of course, I'd hope for no damage at all. But from my experience with materials, it's clear that almost 15 years inside the human body will leave some kind of mark. The mesh itself, though, seemed to be in very good condition. Its overall structure was preserved, and there was no sign of extensive mechanical damage. After almost 15 years, that actually surprised me quite a bit.

Electron microscopy showed that a large proportion of the fibres remained intact, while damage was concentrated mainly at the knots and around the fixation components. What does that tell us about how we should assess the long-term durability of materials like these?

Well, we certainly can't draw general conclusions about the long-term durability of these materials from a single sample,

and I don't have a great deal of experience with their mechanical testing myself. In general, though, damage in the areas under the greatest stress is to be expected. What I find particularly interesting is that our analyses showed that it isn't enough to assess only the material's appearance or the condition of its overall structure. Changes taking place right at the surface also matter, even though they may not be apparent at first glance.

With XPS, you examined only the top few nanometres of the material. To a non-specialist, it's fascinating that a material can look almost undamaged, yet you can still detect chemical changes at its surface. What can such a thin layer tell you about how a material ages?

XPS gives us information about only the top few nanometres of the material. But when it comes to interactions with the surrounding environment, that's precisely the most interesting part. The surface

is the first part of the material to come into contact with the body's internal environment, and a whole range of interactions takes place at the interface between the material and its surroundings. So a material can look very well preserved overall while its surface layer already shows changes in chemical composition. In our case, we observed changes in the relative proportions of different types of chemical bonds at the surface that are consistent with hydrolytic or oxidative processes. Since our data come from just one PET mesh, we're very cautious about our conclusions.

What would you need to analyse next to learn more about how these materials behave in the human body over the long term?

Analysing a larger set of samples would certainly give us much more information, especially if we could also link the findings to the medical histories of the patients whose meshes were removed. It would be interesting to see



whether there is a relationship between the condition of the material, how long it was implanted and any complications. A comparison with the original, unimplanted material would also be very important. Unfortunately, we weren't able to obtain that in this case.

Let's move away from this particular paper and talk a little more about you. How did you come to VSB-TUO and get into materials analysis, and what

keeps you interested in this field of research?

I joined VSB-TUO as a PhD student. Before that, I'd studied biophysics at Charles University, but I wanted to move back from Prague to Ostrava. That's how I came to work with Professor Čapková, who was then the director of the Nanotechnology Centre. At first, I just wanted a job in a lab, but she steered me straight towards a PhD. For my doctoral research, I studied brake wear and

its environmental implications, particularly the nanoparticles released during braking. That was also when I started working with Raman and FTIR spectroscopy. Those techniques have led to collaborations with a wide range of colleagues, both here and abroad.

And what do I enjoy about the work? Above all, the variety. One day I might be studying surgical meshes, and the next I'm helping colleagues determine the structure of biochars used as sorbent materials. It's certainly never boring.

What materials or research questions make up the bulk of your own work these days? Is there a topic you'd like to focus on much more in the coming years?

My main role is operating the instruments for FTIR, Raman and XPS spectroscopy. I took on XPS as part of the REFRESH project. I carry out measurements for

colleagues and analyse the wide variety of materials they bring to me. Alongside that, I'm also responsible for a Technology Agency of the Czech Republic (TA CR) project that is now nearing completion and focuses on the self-healing properties of brake materials. So, in a way, I'm still returning to the subject I started with during my PhD. Brakes, the particles released during braking, and their potential effects on human health and the environment are still topics I find very interesting.

The centre has only had its XPS spectrometer Nexsa G2 (Thermo Fisher Scientific) for a relatively short time. What can the technique do, and what possibilities does it open up?

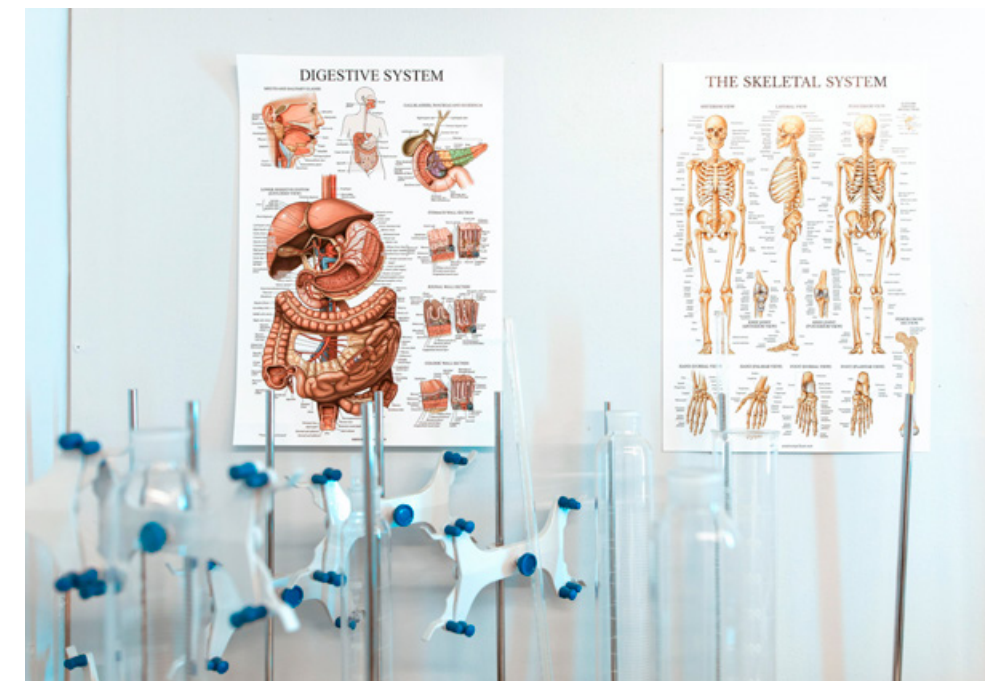
XPS is highly surface-sensitive. As I mentioned, it probes only a few nanometres below the material's surface. This allows us to study the regions where the first interactions and changes in the material take place, making



it ideal for studying catalysts, for example, or material degradation. It can also distinguish between different chemical states and forms, so it has a wide range of applications. Another interesting possibility is correlating XPS analysis with electron microscopy: looking at a specific area of a sample and linking information about its appearance with information about its chemical composition. We're still testing this approach, but it's something I'd like to develop further in the future.

Looking back on your career in science so far, what has research given you? And what would you say to students or young people who are drawn to this kind of work but aren't yet sure whether science is for them?

Well, to start with what science has given me: an enormous amount. Above all, the chance to work with wonderful people, both here and abroad. Research projects have also taken me to



many interesting places, including the United States. Experiencing science in other countries, whether through conferences or research placements, has been hugely valuable. You see how people work elsewhere, meet new people and often gain an entirely different perspective on your own work.

But let's be honest: science can be a struggle at times, too. You

can spend hours or days poring over analyses, with results that make no sense and no idea what to do with them. Then, suddenly, something works, the pieces start to fall into place, and those are the moments that make it worthwhile. And for anyone who isn't sure whether science is for them, I'd bring up Schrödinger's cat. Until you open the box and try science for yourself, you simply won't know.



His work focuses primarily on so-called metaheuristic algorithms – computational methods inspired by natural processes and the behaviour of living organisms. Just as flocks of birds or colonies of ants can adapt to changing conditions and collectively search for the most efficient way to reach a goal, computer algorithms can use similar principles to solve complex optimization problems.

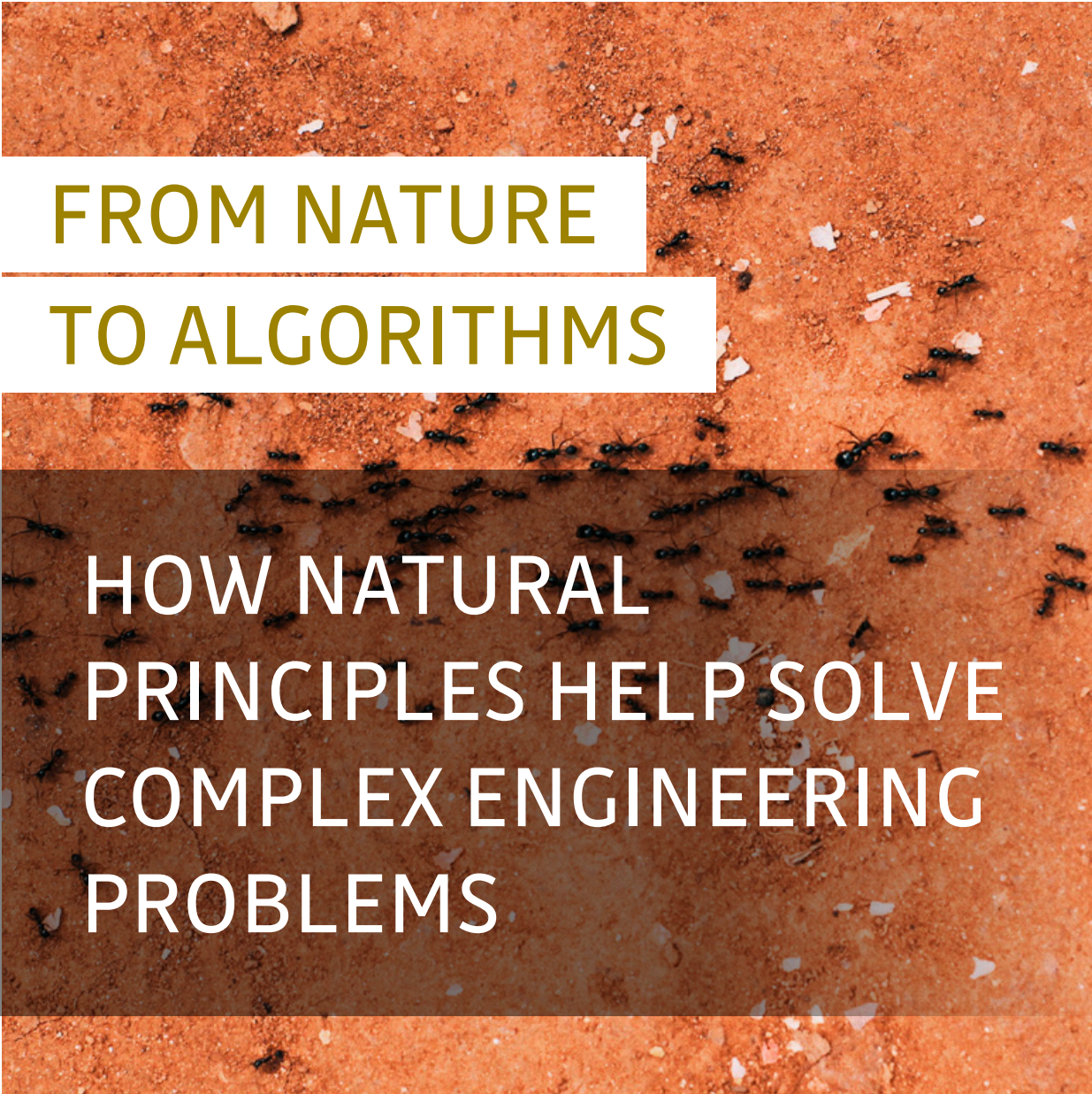
Finding the best possible solution to complex engineering problems is not only a matter of computational power, but also of designing the right algorithms. This is the focus of Mohamed Metwally Mahmoud's research. He combines mathematical principles with artificial intelligence

methods to develop new optimization algorithms with applications across a wide range of scientific and industrial fields. He is also actively involved in international research collaboration, including cooperation with the Centre for Energy and Environmental Technologies (CEET).



Mohamed Metwally Mahmoud

Mohamed is a researcher in electrical and energy engineering with more than nine years of academic experience and five years of industrial experience. His work combines artificial intelligence, nature-inspired optimization methods and advanced control, with a particular focus on renewable energy, smart grids, energy storage, electric vehicles and intelligent energy management. He is also actively involved in international scientific collaboration, including cooperation with the Centre for Energy and Environmental Technologies (CEET).



FROM NATURE TO ALGORITHMS

HOW NATURAL PRINCIPLES HELP SOLVE COMPLEX ENGINEERING PROBLEMS

INTERVIEWS & PERSONALITIES

In the following interview, we discuss his professional journey, the inspiration behind the development of new algorithms, and the role artificial intelligence and advanced optimization could play in addressing future technological challenges.

Let's start with your research. You work on optimization algorithms inspired by natural processes. Why did you choose this particular approach, and what attracted you to the field?

My interest began with a simple question: "How can nature's ability to adapt, learn and cooperate be translated into computational methods for solving complex engineering problems?"

Many real-world problems are nonlinear, involve several competing objectives and operate under constantly changing conditions. Conventional mathematical methods can struggle with this level of

complexity. Nature-inspired optimization offers a flexible way to search large solution spaces without requiring the problem to have a simple mathematical structure.

What interests me most is the connection between natural intelligence, mathematical modelling and practical engineering. An idea observed in nature can be transformed into an algorithm, tested mathematically and ultimately applied to renewable energy systems, smart grids, energy storage or advanced control.

That is an interesting idea. How can behaviour observed in nature actually be transformed into a computer algorithm?

Nature offers many strategies for dealing with uncertainty, limited resources, cooperation and the need to adapt to changing conditions. The aim is not simply to copy nature, but to understand the mechanism behind

a particular behaviour and translate it into mathematical rules. Imagine, for example, a flock of birds searching for food. Each bird explores its surroundings while also making use of information obtained from other members of the group. In an optimization algorithm, individual birds can represent candidate solutions moving through a mathematical search space and sharing information about promising regions.

One of the main challenges is finding the right balance between exploration, searching for new possibilities and exploitation, where the algorithm focuses on promising solutions it has already identified. Too much exploration makes the search inefficient, while too much exploitation can cause the algorithm to become trapped in a local optimum. The scientific value therefore lies not

in the biological analogy itself, but in whether the underlying principle can be formulated rigorously and whether it provides a genuine computational advantage.

Since we have already touched on algorithms, how is a new optimization algorithm actually created?

There is no single starting point. A new algorithm can emerge from observing a natural phenomenon, from a mathematical idea, or directly from the need to solve a specific engineering problem. If nature provides the inspiration, the key step is to identify a useful mechanism – such as adaptation, cooperation or a particular search strategy – and express it mathematically. A resemblance to a natural phenomenon alone is

NATURE MAY PROVIDE THE INSPIRATION, BUT MATHEMATICS, RIGOROUS TESTING AND VALIDATION IN REAL-WORLD ENGINEERING APPLICATIONS ULTIMATELY DETERMINE WHETHER AN ALGORITHM IS GENUINELY USEFUL.

not enough. Practical engineering problems can also drive innovation. Renewable energy systems and modern power grids, for example, involve nonlinear behaviour, numerous constraints and rapidly changing operating conditions. If existing methods are not sufficiently effective, this can motivate the development of new computational strategies. For me, developing an algorithm is therefore a combination of inspiration, mathematics, experimentation and real-world engineering needs.

How do you determine whether a new algorithm is actually better than existing methods?

Creating an algorithm is only the beginning. The more important task is to verify whether it can reliably produce competitive results. The first step is usually to test it on standard benchmark problems with varying levels of complexity. The new algorithm is then compared with established optimization methods under the same conditions and with comparable computational budgets.

Because metaheuristic algorithms are generally stochastic, a single successful run proves very little. Repeated experiments and statistical analyses are needed to determine whether an observed improvement is consistent and not simply the result of chance. Finally, the algorithm should also be validated on real engineering problems. Good results on mathematical benchmarks are important, but the true value of





a method becomes clear when it can improve the efficiency, stability, reliability or control of an actual system.

If we look at real-world applications, where do you see the greatest practical potential for intelligent optimization today?

One of the most promising areas is the energy sector. Modern energy systems increasingly combine photovoltaic and wind generation, battery storage, electric vehicles, flexible loads and other distributed energy resources. Their operation changes continuously depending on weather conditions, electricity demand and the state of the grid. Optimization can help determine, for example, when batteries or

electric vehicles should charge or discharge, how power should be distributed efficiently among different resources, or how frequency and voltage stability can be maintained while reducing costs and making better use of renewable energy.

More broadly, I see optimization as a bridge between data and decision-making. Artificial intelligence can analyse large amounts of data and predict future system conditions, while optimization methods can determine which specific action is most appropriate under given constraints. The same principles can also be applied in manufacturing, robotics, transportation, logistics and industrial process control.

Cooperation and professional connections are very important in science. How does your cooperation with CEET fit into your research?

CEET provides an interdisciplinary environment that connects my work in intelligent optimization, advanced control and renewable energy with broader expertise in energy and environmental technologies. Today's energy challenges cannot be addressed from the perspective of a single discipline. They require expertise in power systems, renewable energy, energy storage, smart grids, digital technologies and advanced computational methods.

For me, this collaboration provides an opportunity to connect computational approaches with real engineering challenges. I see significant potential for joint work in areas such as renewable energy integration, intelligent energy management, energy storage, electric vehicles, smart grids and AI-based optimization. International cooperation is also valuable because it brings together different areas of expertise and different



perspectives on research problems. This can generate new ideas that would be much more difficult to develop independently.

We have already mentioned artificial intelligence several times. How is the rapid development of AI changing the field of optimization?

Artificial intelligence and optimization are becoming increasingly interconnected. Machine-learning models can, for example, predict system behaviour or identify promising regions within a search space, while optimization algorithms can use this information to support decision-making. Future optimization methods may also become much more adaptive, learning which search strategies work best at different stages of the optimization process.

This development creates significant opportunities, but also new challenges. Complex AI-based

systems can require substantial computational resources, and in critical applications such as energy systems, reliability and interpretability are essential. We need to understand why an intelligent system has made a particular decision and at the same time ensure that the resulting solution is physically meaningful and safe. I therefore do not see artificial intelligence as a replacement for optimization. The greatest potential lies in combining AI's ability to learn and adapt with the mathematical decision-making and constraint-handling capabilities of optimization methods.

To finish, let me ask a classic question: What would you like readers to take away from your research?

I would like readers to see that complex engineering problems can sometimes be approached from unexpected directions. Nature, mathematics and artificial intelligence may at first seem like

very different worlds, but bringing them together can create very powerful tools.

Nature provides principles of adaptation and cooperation, mathematics translates them into rigorous models, and artificial intelligence can further develop these methods, making them more adaptive and better able to work with data. For me, the most fascinating part is the journey from observation to mathematics, from mathematics to computation, and finally from computation to a real engineering application.

Ultimately, the goal is not simply to create new algorithms. The aim is to develop methods that can help improve the efficiency, stability, reliability and sustainability of modern engineering systems. Some of the most interesting innovations emerge precisely at the intersection of different disciplines.

MASS SPECTROMETRY AT CEET

FROM MATERIAL CHARACTERIZATION TO CATALYTIC PERFORMANCE

INFRASTRUCTURE

How effectively can a catalyst remove harmful substances, and why do some materials perform better than others? Catalytic activity tests show how a catalyst behaves under specific reaction conditions, but they do not explain which of its properties are responsible for that behaviour. This is why the characterization of catalytic materials is also an essential part of the research. A range of methods can be used to investigate, for example, catalyst reducibility, interactions

with different gases, adsorption and desorption properties, or the accessible surface area of active metal components. Combining this information with catalytic testing results allows us to better understand the relationship between a material's composition and properties and its resulting catalytic activity.

The Heterogeneous Catalysis research group at the Air Protection Laboratory of the Institute of Environmental Technology CEET, combines catalytic testing with detailed material characterization. The group is led by Kateřina Míčková Pacultová, with Kateřina Karásková and Dagmar Fridrichová also involved in catalyst characterization. Its research includes the development of catalysts for the treatment of waste gases from stationary sources, the study of adsorption and desorption processes, and the investigation of relationships between material structure and catalytic activity.

Kateřina Míčková Pacultová

Kateřina leads the Heterogeneous Catalysis research group. Her work focuses primarily on gas-phase catalytic reactions, catalyst characterization, and adsorption-desorption processes. She also studies the kinetics of catalytic reactions and models their reaction mechanisms. In addition to her research and publication activities, she contributes to research projects and supervises bachelor's, master's, and doctoral theses.

When the Signal Alone Is Not Enough

In our laboratory, we use two interconnected instruments that complement each other in catalyst characterization. The Micromeritics AutoChem II 2920 chemisorption analyzer provides precise control over sample temperature and gas composition, while a thermal conductivity detector (TCD) records changes in the composition of the gas phase during an experiment. However, the TCD provides an overall response and does not always allow us to identify unambiguously which gaseous component is responsible for an observed change.

For this reason, the analyzer is coupled to a Hiden Analytical HPR-20 EGA mass spectrometer, which makes it possible to monitor individual gaseous species simultaneously. Combining the two techniques provides more detailed information about the processes occurring during catalyst characterization and helps distinguish

between phenomena taking place within the same temperature range.

A specific example is described by Kateřina Karásková in an article published on the Hiden Analytical website. During temperature-programmed reduction (TPR), simultaneous mass spectrometric analysis revealed that part of the observed signal was associated not only with catalyst reduction but also with the decomposition of nitrate species present in the sample. While the TCD signal alone would not have been able to distinguish these overlapping processes unambiguously, mass spectrometry made it possible to monitor the gaseous products formed and interpret the measured profile more accurately.

Different Experiments, Different Questions

Temperature-programmed methods are based on monitoring the behaviour of a sample as its temperature is changed in a controlled manner. Reduction and oxidation experiments help determine the conditions under which catalyst components are reduced or oxidized and the extent to which these processes occur. Desorption measurements, in contrast, monitor the release of substances previously adsorbed on the surface. The amount of gas released and the way in which it is released provide information about the surface sites to which it had been bound.

The choice of gas depends on the specific research question. Ammonia desorption is used to study acidic sites, while carbon dioxide desorption provides information about basic sites. Experiments with water vapour help characterize the material's interaction with moisture. In this way, the laboratory can investigate a range of surface properties that are important for understanding catalyst behaviour.

Appropriately designed chemisorption experiments can also be used to determine the accessible surface area of the metallic component and its dispersion, i.e. the proportion of metal atoms located at the surface relative to the total number of metal atoms. The calculation is based on the amount of gas adsorbed and assumptions about how it binds to the surface. It is therefore not only the total amount of metal contained in the catalyst that matters, but also how much of it is accessible to reacting molecules.

The value of these measurements lies in combining them with catalytic activity tests, kinetic studies, and other material characterization techniques. Mass spectrometry alone does not provide a complete picture of the reaction mechanism, but it supplies important information needed for its interpretation. The aim is to move beyond simply establishing that a catalyst works and towards understanding which properties govern its behaviour and should therefore be targeted in further development.

A more detailed overview of the methods used, specific applications, and links to scientific publications from 2025 and 2026 is available in Kateřina Karásková's article Mass Spectrometry in Heterogeneous Catalysis on the website

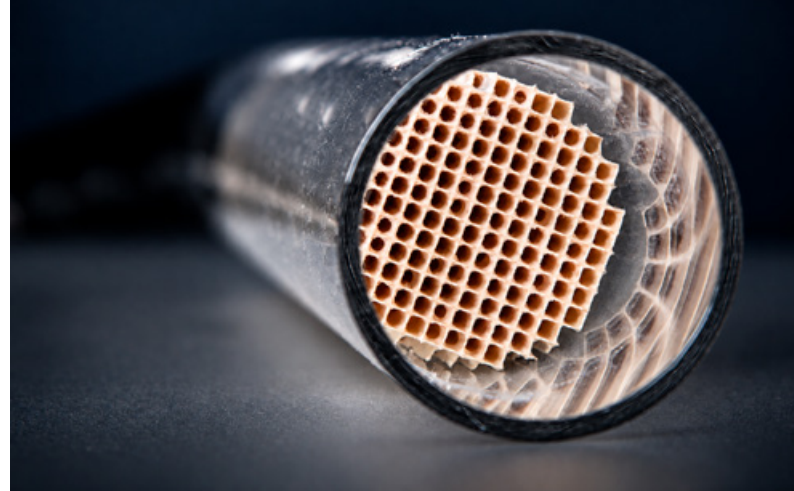
Hiden Analytical.



Catalyst research, however, is not only about instruments and measurements. In the following short interview with Kateřina Míčková Pacultová, we also discuss unanswered research questions, the path from laboratory results to practical applications, and cooperation within the research team.

Kateřina, let us start with what you are currently working on. Which question in your research are you still trying to answer, and what would finding that answer enable you to do?

One of the topics we are currently working on is the direct catalytic decomposition of nitric oxide. This reaction has been studied for decades, yet it is still not entirely clear exactly how it proceeds or which catalyst properties are decisive. We have certain ideas about the mechanism and know which material properties should play an important role. But then we prepare two apparently



very similar catalysts and find that their behaviour differs substantially. Or we encounter a sample that behaves completely differently from what we would expect based on our current understanding. To us, this indicates that there are still aspects of what actually happens on the catalyst surface that we do not fully understand.

It is therefore not enough simply to determine which material is more active. We want to understand why it is more active and what exactly determines its activity. In addition to the methods we routinely use, we therefore want to introduce further experimental techniques that we have not worked with before and that will allow us to examine the catalyst and the processes occurring on its surface from a different perspective. The aim is to gradually link information about the material's composition, structure, and physicochemical properties with its catalytic behaviour and thereby develop a more

comprehensive understanding of the reaction mechanism. In the future, this could allow us to design more effective catalysts in a more targeted way rather than searching for them by trial and error.

If we move from the laboratory to practical applications, what, apart from good experimental results, determines whether a catalyst can also be used in an industrial process?

Good results at the laboratory scale are really only the beginning. If we want to transfer a catalyst into industrial practice, it is not enough simply to prepare several kilograms of the same material instead of a few grams. When the preparation process is scaled up, the process conditions change, including heat and mass transfer, mixing, precipitation, drying, and thermal treatment. As a result, the final material may not exhibit the same properties as a material prepared on a laboratory scale. It is therefore often necessary

to design and optimize what is essentially an entirely new technological process.

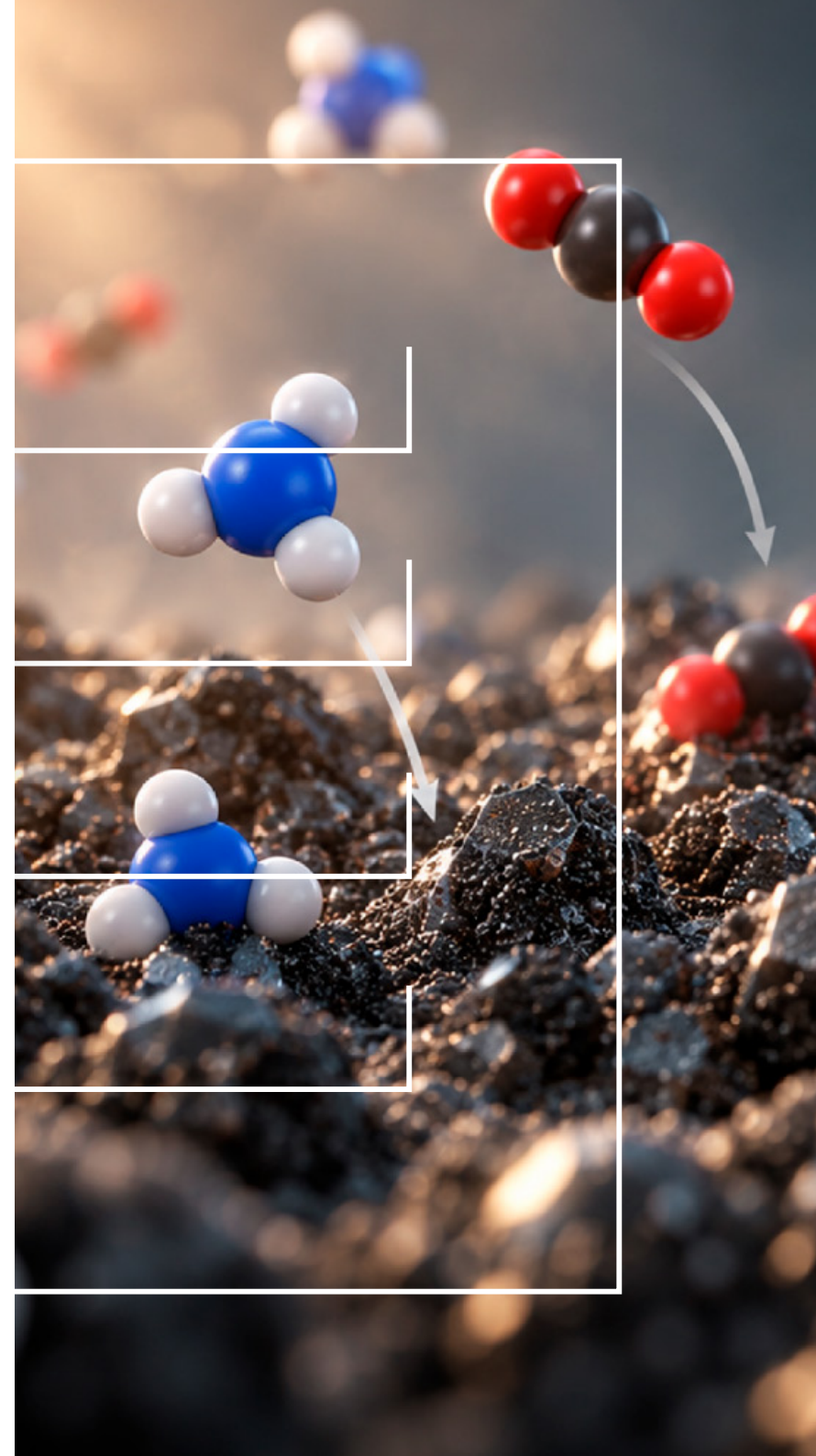
Another issue is the physical form of the catalyst itself. In the laboratory, we commonly test powdered materials, whereas an industrial reactor may require pellets, extrudates, or catalytic coatings. Their preparation can alter the material's mechanical properties, porosity, and accessibility of active sites, thereby also affecting its catalytic activity. In addition, the catalyst must exhibit long-term stability and resistance to the actual gas composition encountered in operation, while the cost of raw materials and production must also be taken into account.

Even a catalyst that performs well from a technical perspective will not necessarily find an industrial application. It is also important whether there is a genuine need for it and whether market conditions allow a new technology to compete with established solutions. Ultimately,

success therefore depends not only on catalytic activity, but on the entire chain—from the ability to manufacture the material reproducibly on a larger scale, through its operational performance, to its economic competitiveness and market potential.

Let us return to the measurements themselves for a moment. Which part of evaluating mass spectrometry data requires the most experience?

In my view, the greatest experience is required not only to interpret the signals themselves, but above all to explain why we observe them in the first place. A mass spectrometer does not directly measure a specific molecule; it detects ions characterized by their mass-to-charge ratio. A single compound can therefore produce several signals, while a single signal may correspond to several different compounds. Even the initial



assignment of a signal is therefore not always straightforward.

What is even more difficult is determining what a particular result actually means. The first explanation that comes to mind can sometimes turn out to be very different from the process that is actually taking place. Measurements can be affected by

impurities or residual precursors in the sample, overlapping processes, measurement artefacts, an inappropriate experimental procedure, or, for example, insufficient stabilization of the system before the measurement begins. The same or a very similar signal can therefore have different meanings in different experiments.

When evaluating the data, it is therefore important not to consider an individual signal in isolation, but always to interpret it in the context of the entire experiment. This means monitoring several signals simultaneously, knowing the sample's composition and history, taking the measurement conditions into account, and

comparing the results with those obtained using other characterization methods. In my view, distinguishing whether we are observing a genuine process occurring on the catalyst, a side reaction, or merely a measurement artefact is where experience plays the greatest role.

I would also like to ask how different perspectives within the team complement one another when you are looking for answers. Can you recall a situation in which a colleague or student led you to see a problem differently?

That happens quite often, and I think it is one of the important aspects of research. Everyone looks at the same problem slightly differently depending on their experience and area of expertise. One person may notice a change in the material structure, another an interesting feature of a catalytic test, and someone else an unusual characterization result. Discussing

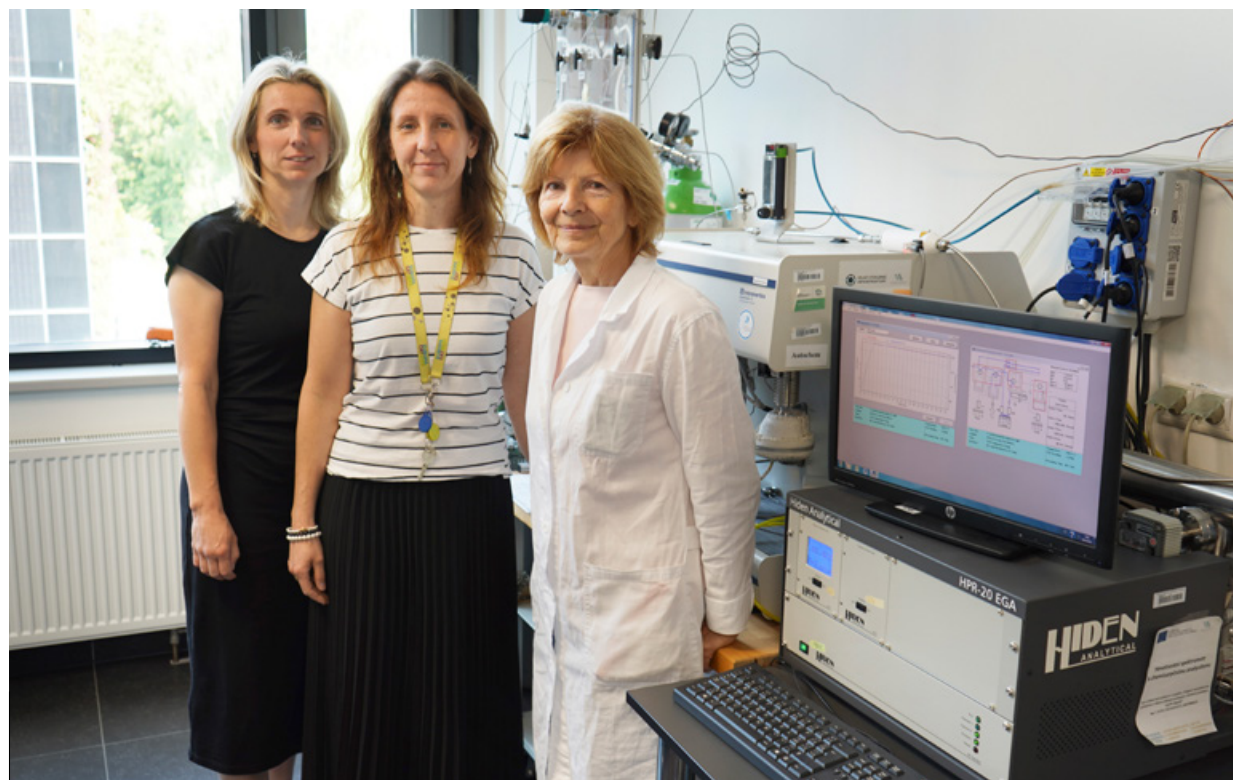
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these observations together and combining results obtained using different methods often helps us identify relationships that are not obvious at first sight. Sometimes a different perspective leads to a new interpretation of the results; at other times, it points us towards an additional experiment that we had not originally planned at all.

Finally, on a slightly more personal note: what gives you the greatest satisfaction in research? Is it different today from what it was at the beginning of your career?

I still enjoy the moment when individual results begin to fit together and make sense. You have results from several different measurements, and at first there may be no obvious connection between them. Gradually, however, a story begins to emerge that explains why the material behaves the way it does. That has probably not changed much since the beginning of my career.

What has changed is how much satisfaction I get from working with students and younger colleagues. Today, it is no longer only my own results that I find most rewarding, but also seeing students gradually learn to think independently about experiments, discuss their results, and come up with their own ideas. And of course, it is always satisfying when an experiment works out exactly as we expected—although in research it may be even more interesting when it does not, and we have to figure out why.





KEY TO THE WORLD

CEET HELPS YOUNG PEOPLE GAIN THEIR FIRST WORK EXPERIENCE

SOCIAL RESPONSIBILITY



At school, Klárka Nevolná is preparing for a career in hospitality. Over the summer, she had the chance to put her learning into practice. She spent part of her holidays at the university's Hotel Garni through the Key to the

Want to learn more about the project?
Watch the video.

World project, with support from the Centre for Energy and Environmental Technologies (CEET) at VSB – Technical University of Ostrava. Her experience could inspire other young people from children's homes. CEET hopes to offer more of them similar opportunities and support them as they take their first steps into working life.

Klára brought her enthusiasm for the industry and the knowledge she had gained at hospitality school. Working with the children's home in Opava, CEET helped find a place where she could put both to use: Hotel Garni, right on the university campus. The placement gave her an insight into the day-to-day running of a hotel and a chance to connect classroom learning with hands-on work. Experiences like this can help young people recognise their abilities and feel more confident about the path they want to take.



About the project

The „Key to the World“ project, a joint initiative by the Confederation of Industry and the Eva Pavlová Endowment Fund, connects young people from children's homes and refuges with companies that will help them enter the working world and transition to independent living. The aim of the initiative is to provide these young people with opportunities to develop practical skills, gain work experience, and receive professional mentoring to help them stand on their own two feet.

*YOUR FIRST WORK
PLACEMENT MAY NOT
DEFINE YOUR FUTURE.
BUT IT CAN HELP YOU
DISCOVER WHAT YOU
ENJOY, WHAT YOU CAN
ALREADY DO AND WHAT
YOU WOULD LIKE TO
LEARN NEXT.*

Klárka discussed her placement alongside CEET Director Stanislav Mišák at an event in the university auditorium. With First Lady Eva Pavlová in attendance, project partners reviewed the pilot year in the Moravian-Silesian Region. The discussion gave a voice not only to the participating organisations, but also to the student herself.

A chance to get started and someone to turn to

Key to the World is a joint initiative of the Eva Pavlová Endowment Fund and the Confederation of Industry of the Czech Republic.

The project is led on the Confederation's behalf by its Vice-President, Kateřina Kupková. It connects young people from children's homes and shelters with businesses and institutions that can offer work experience and support as they move towards independent living.

For some, the first step may be a workplace visit or a workshop; for others, a placement in their chosen field or a temporary job that gives them their first earnings. Just as important can be an experienced colleague who explains how things are done, offers advice on a new task and makes time for questions. Support can also extend to help with finding independent accommodation or having someone to turn to even after leaving the children's home.

The pilot year showed that each partnership calls for a slightly different approach. It depends on the young person's interests and needs, as well as what the children's home and the employer

can offer. The aim is not to create the same path for everyone, but to work together to find one that helps each individual move forward.

The project was officially launched at Prague Castle on 22 April 2025, with a pilot phase designed for the Moravian-Silesian and Zlín regions. VSB – Technical University of Ostrava is also taking part in the initiative.

"I see the Key to the World initiative as a wonderful opportunity to support one of the most vulnerable groups of young people: children and students from children's homes. These children often grow up without the role models that parents provide for most of us. That makes it all the more important to give them a chance to experience a different environment, meet new people and discover opportunities that can help them develop both professionally and personally.



What I find particularly valuable is how far the initiative has come in just six months. We have moved from tentative first steps and exploring ways to work together to real stories of young people gaining their first work experience and opportunities to develop further. Klárka, our newly discovered gem, is a wonderful example. We were impressed by her motivation, social maturity and conscientiousness, as well as her willingness to share her story and inspire others.

And that is another important part of what this initiative is about. We want to say to other young people: don't be afraid to go the extra mile and make the most of the opportunities available to you. And don't let our university's technical focus

put you off. There are plenty of opportunities here—and, above all, people who are ready to help.

My sincere thanks therefore go to First Lady Eva Pavlová for supporting this initiative, to the Confederation of Industry of the Czech Republic for putting it into practice, and of course to Klárka and Zuzana from the children's home in Opava. Thanks to them, we now have a positive story to share—one that we hope will inspire others," said Stanislav Mišák, Director of CEET.

Opportunities for more young people

CEET hopes to build on its work with Klára and help more young people from children's homes be-

come involved in the project. Some already know which field they would like to work in; for others, experiencing the workplace may help them discover what interests them. Both have a place in the project.

Klára's placement was made possible through cooperation between CEET, the children's home in Opava, Hotel Garni, the Eva Pavlová Endowment Fund and the Confederation of Industry of the Czech Republic. Thanks go to everyone who makes time for these young people, shares their experience and helps them tackle their first tasks in the workplace.



Cooperation drives new energy solutions

Developing new energy solutions for industry relies on sharing experience across disciplines and institutions. The international seminar **New Energy Solutions for Industry**, organised at CEET by the Nanotechnology Centre, provided a forum for this exchange. The event brought together researchers working on the strategic projects REFRESH, MATUR, DMS MEET and CirkArena, including experts from European universities and research institutions. Discussions focused on new energy solutions and their potential applications in industry.

Science for curious minds of all ages

Curiosity knows no age limits. This was clear once again at **Art & Science 2026**, where our stand attracted visitors of all ages, from young children to adults with an interest in science. Colleagues from CEET's Institute of Environmental Technology and Nanotechnology Centre had the opportunity to engage with the public and offer a glimpse into the world of research.





A closer look at waste and odours

How should we deal with waste, and where do unpleasant odours come from? These questions are closely connected to everyday life and are also the focus of research by colleagues at CEET. They presented their work on these topics at the **21st SDEWES Conference**, sharing it with the international research community.

Sustainable energy: from theory to practice

Research takes on a new dimension when it finds real-world applications. Putting new knowledge into practice and advancing sustainable energy were the aims of the **29th International Energy and Environment Conference (IEEC)**. The conference was organised jointly by CEET's Energy Research Centre and the Department of Power Engineering at the Faculty of Mechanical Engineering, VSB – Technical University of Ostrava.





Catalysis: a small change with big potential for industry

Catalysts help chemical reactions proceed faster and often under milder conditions, making catalysis one route towards a more sustainable industry. This field was the focus of the **17th Pannonian International Symposium on Catalysis**, organised by the Catalysis Group of the Czech Chemical Society. Colleagues from CEET's Institute of Environmental Technology helped with the on-site organisation. Alongside experts from across the Pannonian region, the event welcomed plenary speakers from Italy, Germany and Spain.

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