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#94
JULY 2020

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New tools improve cabin air quality
and protect against organic pollutants and ozone levels

Radical glasses blend eye
tracking with augmented and mixed reality display features

A step closer
to synthesis of a moving near-living crystal

SPECIAL FEATURE
HYDROGEN'S GROWING ROLE IN SUSTAINABLE ENERGY SYSTEMS

Editorial

How hydrogen is lighting the way for more sustainable energy systems, biodegradable food packaging that increases shelf life and new techniques in ceramic manufacturing

welcome to this month's Research*eu magazine

After nearly 6 months of pandemic, many policymakers and commentators, in Europe and across the world, are now starting to actively focus on how 2020 could be the bridge between the 'old' pre-COVID world and a fresh, new start for humanity with new priorities. Everything is on the table, from a fairer economy that enables opportunity for everyone to, of course, a renewed focus on the need to combat climate change and transform our societies and economies to make them greener, more sustainable and overall less carbon-belching. Nascent technologies that have shown promise but have yet to really jump into the mainstream are being eagerly re-examined and could be prioritised for mass scaling-up as part of a new post-COVID order.

Hydrogen is one such promising technology and is the focus of this month's special feature. Even before the current situation, hydrogen was slowly but surely becoming a more popular solution for powering our energy systems. Admittedly, most hydrogen production currently stems from fossil fuels but with the advent of cheaper forms of renewable energies, many researchers are convinced that hydrogen and renewables are destined to be perfect future bedfellows. The European Commission has its own dedicated Fuel Cells and Hydrogen Joint Undertaking, an initiative highlighting how hydrogen technologies can be upscaled and contribute positively to a low-carbon, sustainable energy system and economy. Our seven projects showcased in this month's special feature shine a light on how this can happen.

Meanwhile, **Life After** reconnects with the coordinator of the **CerAMfacturing** project that has been developing innovative industrial processes in the field of ceramic multi-material additive manufacturing (AM), allowing for the creation of intricate products, ranging from jewellery to surgical instruments. In **Project of the Month,** we meet **YPACK**, a project that has created biodegradable food packaging that they also discovered can improve the shelf life of various foods, from pasta to meat and fruit and vegetables. Then of course, our nine regular sections give you a succinct summary of some of the most intriguing developments that our many projects have recently filled us in on.

Finally, even as COVID-19 seems to be losing some steam in Europe, it is still raging in several regions of the world, particularly the Americas and South Asia at the time of writing. Many EU-funded researchers are steadfast in continuing their quests to develop treatments, coping strategies and the all-important potential vaccine. So do please go to the News section of the CORDIS website at cordis.europa.eu/news, available in six languages and our various social media channels to keep up to speed with the latest EU-funded research news on the pandemic.

As always, wishing all of our readers good health and until next month – but if you have any queries, questions or suggestions (but hopefully never a complaint), please feel free to drop us a line at editorial@cordis.europa.eu

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HEALTH

Unlocking metabolic regulation in leukaemic cancers for future treatment

Better understanding how metabolism influences cell function could herald more personalised therapies. Studying metabolic regulation in leukaemic cancers has allowed HaemMetabolome to identify drug targets.

Metabolic changes in cells are a major hallmark of cancer. Cellular metabolism is regulated by the expression or suppression of enzymes that control the production of energy and other essential building blocks for cells. These pathways are often rewired in cancer cells, although much remains unknown about the mechanisms involved.

The EU-supported HaemMetabolome (Deciphering the Metabolism of Haematological Cancers) project focused mainly on acute myeloid leukaemia (AML), a blood cancer driven by a combination of mutations leading to a malignant transformation of cells. As these cancers are still very difficult to treat, with 5-year survival rates only around 15 % in Europe, better treatment options are urgently needed.

The Marie Skłodowska-Curie Training Network provided specialist training for 10 Early Stage Researchers in disciplines linking cancer cell biology with key technologies involving bioinformatics, mathematical modelling and drug discovery.

METHODOLOGICAL BREAKTHROUGH

As energy metabolism is linked to cellular control, being able to influence it would offer an opportunity to treat cancer. So HaemMetabolome investigated how energy metabolism is related to genetics and signal transduction in AML cells.

To do so, the project used mass spectrometry (MS) and nuclear magnetic resonance (NMR) techniques to screen haematological cancer cell lines and primary patient samples for their metabolic phenotypes. They also performed gene-function analyses on key metabolic regulators.

"We were the first to use NMR for in-depth metabolic analyses in cancer cell lines and primary cancer cells – an important methodological breakthrough," says Ulrich Günther, project coordinator.

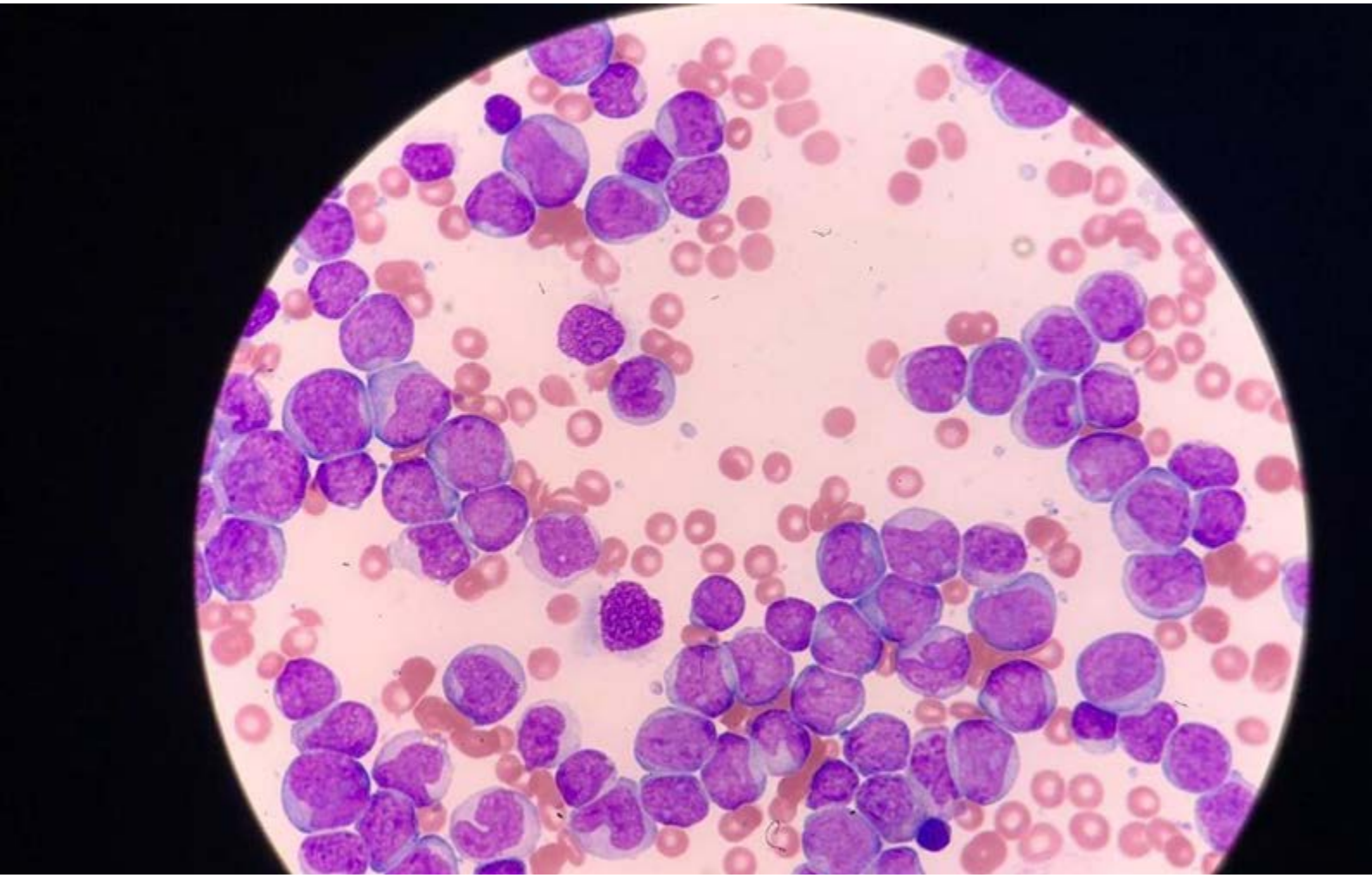
HaemMetabolome investigated the small molecule chemicals of immature blast cells from AML patients. They compared these to the patient's genes and all the proteins that can be expressed by a cell.

"Prior to our study, little was known about the differences between healthy stem cells and AML cells. AML genetic mutations result in clear signalling differences, and so we suspected we would also identify metabolic differences," explains Jan Schuringa, deputy coordinator and research lead.

Energy metabolism produces adenosine triphosphate (ATP), a compound driving many cell processes. The project's studies indicated that some subtypes of AML produce ATP from glucose, a process known as glycolysis, while others rely on enzymes oxidising nutrients.

The team identified a key element which regulates this switch – important because inhibition of this switch impaired leukaemia development in a subset of cases. This was validated in laboratory tests, including in patient-derived xenograft immunodeficient mice.

Another study examined the role of individual metabolites by screening cells in metabolite-depleted media, identifying the importance of specific amino acids. One student studied metabolic reprogramming in those connective tissue cells in contact with AML cells. They identified



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"We were the first to use NMR for in-depth metabolic analyses in cancer cell lines and primary cancer cells – an important methodological breakthrough."

metabolites which provide AML cells with the nutrients necessary for their survival.

THERAPEUTIC POTENTIAL

The MS methods used kits such as Biocrates kits to measure metabolism and metabolic fluxes. They also developed data analysis software based on gas chromatography-mass spectrometry flux methods. Both are currently available to researchers.

Information about the project's new NMR methods for studying real-time metabolism has already been published, with other NMR labs already adopting the methods.

"Revealing the range of AML metabolic reprogramming should help therapeutic targeting. Our metabolite depletion results, which identified a strong role for individual metabolites associated with enzymes, represent promising drug targets," concludes Günther.

As primary human cells were only used for a subset of the metabolic mechanisms revealed by the project, further corroborative work is needed.

HAEMMETABOLOME

- Coordinated by the University of Birmingham in the United Kingdom
- Funded under H2020-MSCA-ITN
- cordis.europa.eu/project/id/675790
- Project website: haemmetabolome-itn.eu

Improved understanding of retinal bipolar cell function

Retinal bipolar cells are an almost perfect model for learning how sensory input is translated into meaningful output by a single class of neurons. By studying them, switchBoard offers new insights into visual signal processing which could benefit sight impairments.

In the visual system, a group of neurons called bipolar cells collects light-evoked photoreceptor signals in the outer retina and relays these signals to the inner retinal ganglion cells. From there, the images are projected as information to the brain.

There are at least 14 bipolar cell types, and the unique way they transform the photoreceptor signals allows the inner retina's neural circuits to form a visual description of the world.

As bipolar cells are structurally and functionally well understood by researchers, they offered the EU's Marie Skłodowska-Curie ITN-ETN project switchBoard (In the eye of the observer: Visual processing at the heart of the retina) an opportunity to learn more about how the input signals, from light-sensitive photoreceptors, are relayed to the ganglion cells that form the optic nerve.

"The switchBoard metaphor came to us while writing a review article about the bipolar cells as the 'building blocks of vision'. But bipolar cells not only connect the photoreceptor input signals with the retinal ganglion cells, they also seem to process these signals," explains Thomas Euler, project coordinator.

THE RETINA AS AN IDEAL MODEL

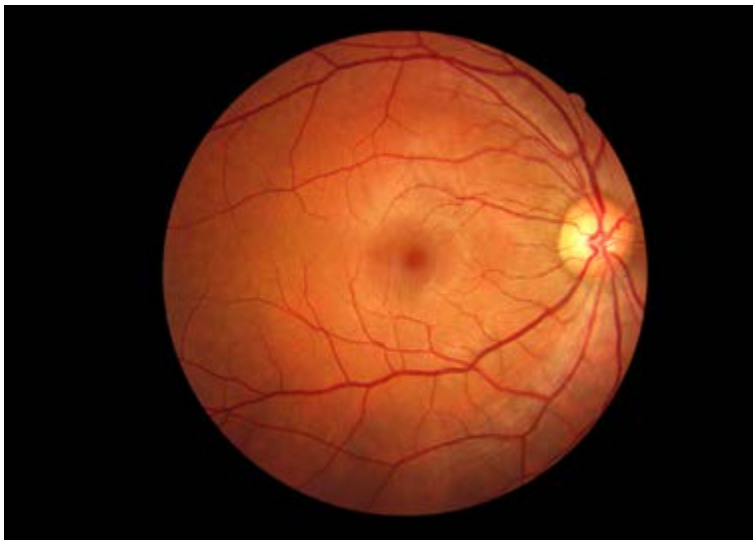
Unlike most brain systems, retinal sensory input and outputs can be relatively easily measured. switchBoard's Marie Skłodowska-Curie Early Stage Researchers used retinas of different animal models to investigate the processing of sensory signals.

Neuronal activity in the retina was measured at both network and synaptic levels using multi-electrode recordings and two-photon imaging. These practical investigative methods were complemented with theoretical approaches to extract and predict 'general features' of bipolar cell function.

Furthermore, the researchers were also exposed to a variety of additional cutting-edge technologies ranging from immunolabelling to electron microscopy to identify cellular and synaptic structures.

One crucial finding was that zebrafish process colour across visual space to match natural underwater scenes, suggesting that their retinal circuits have evolved to process behaviourally important visual information.

Another key finding in a mouse model was that the involuntary oscillating small eye movements, known as nystagmus, seen in patients with congenital stationary night blindness, are likely caused by activity in the inner retinal circuits. Locating the condition's origin could pave the way for therapies.



> *The project has contributed to the next generation(s) of young retinal scientists and so the EU's ability to tackle health concerns.*

A BETTER UNDERSTANDING OF RETINAL DISEASES

While the photoreceptors degenerate, and in the worst cases are lost, in people with visual impairment, most bipolar cell function is still preserved.

This makes bipolar cells an important target for various therapies which seek to replace or rescue photoreceptor function. switchBoard has contributed to the knowledge about how bipolar cells change morphologically and functionally, and connect with other neurons underpinning these therapies.

"By ensuring that these 15 international young researchers received in-depth training in experimental and computational neuroscience, neurotechnology and biomedicine, the project has contributed to the next generation(s) of young retinal scientists and so the EU's ability to tackle health concerns," says Euler.

SWITCHBOARD

- Coordinated by the University of Tübingen in Germany
- Funded under H2020-MSCA-ITN
- cordis.europa.eu/project/id/674901
- Project website: etn-switchboard.eu

HEALTH

Electric discovery could revolutionise bone surgery

EU researchers have developed polymer materials that can stimulate bone-forming cells and potentially help to regenerate surrounding tissue. The breakthrough is based on the discovery that bone mineral is flexoelectric, which means that it can produce electricity in response to mechanical pressures.

This discovery could lead to the development of a new generation of grafts and prostheses that react to body pressure and help bone regeneration after surgery. The technique could also potentially reduce the need for bone donors, resulting in a reduction in both medical costs and risks.

A FLEXIBLE MATERIAL

"Our bones have outstanding remodelling properties," explain FLEXOBONEGRAFT's Marie Skłodowska-Curie fellow Nathalie Barroca, and project coordinator Gustau Catalan, from the Catalan Institute of Nanoscience and Nanotechnology (ICN2).

"Fractures heal, while impacts can make them stronger. But a lack of exercise – or a lack of gravity, as experienced in space – can make bones more porous and weaker."

Furthermore, the impressive adaptive abilities of bone decline with age. In fact, bone has become the most transplanted tissue after blood, with over 1 million procedures a year carried out in Europe alone.

With an ageing population, Europe is likely to see an increase in bone-related conditions such as osteoporosis. "There is a clear need for novel treatments for musculoskeletal diseases, and research in bone repair is a flourishing field," adds Catalan.

We saw that flexoelectricity thus opens up new perspectives for regenerative treatments of bone.

BIOMEDICAL BREAKTHROUGHS

Catalan's group at ICN2 in Barcelona had previously discovered that bone mineral is flexoelectric. Flexoelectricity (which literally means 'bending electricity') describes the ability of a material to produce electricity in response to deformations, which is important as our bones are constantly subjected to mechanical pressures.

Following the success of this initial ERC-funded study, a team including biologist Raquel Nuñez, two physicists (Gustau Catalan and Fabian Vasquez) and materials scientist Nathalie Barroca investigated some of the physiological effects of flexoelectricity on bone remodelling in the FLEXOBONEGRAFT (Flexoelectric Scaffolds for Bone Tissue Engineering) project.

They discovered that flexoelectricity first causes osteocyte cells adjacent to bone fractures to die, thereby starting the bone's repair protocol. It then stimulates bone-forming cells (called osteoblasts) to secrete bone mineral and generate higher levels of osteocalcin (a calcium-binding protein).

"We saw that flexoelectricity thus opens up new perspectives for regenerative treatments of bone," says Barroca, who was the beneficiary of the Marie Skłodowska-Curie fellowship.

"The next step was to select medically approved biocompatible and biodegradable polymers that could be used as bone-mimicking materials, and to then characterise their flexoelectric properties."

To further mimic the chemistry of bone, Barroca mixed polymers with nanoparticles of hydroxyapatite, the main mineral of bone. A few compositions were identified as having the same flexoelectric coefficient as bone, sufficient to stimulate cells.

This discovery, soon to be published, will be useful for biomedical engineers aiming to incorporate flexoelectricity as a design parameter.

"The identified materials have also been used to create structural designs that undergo local micro-bending (and thus generate flexoelectricity) in response to body-like mechanical pressures," notes Barroca.

"This has been achieved by 3D printing scaffolds with overlapping micro-beams and hollows of variable sizes. We also aim to study the effect of such micro-textured composites on actual bone cells."

The project findings tap into growing interest in the use of biomaterials for medical purposes. Polymers can already be found in bone prosthetics, and as scaffolds to 'guide' the regenerative activity of bone cells. These scaffolds then degrade in biocompatible sub-products that can be processed by the body.

FLEXOBONEGRAFT

- Coordinated by the Catalan Institute of Nanoscience and Nanotechnology in Spain
- Funded under H2020-MSCA-IF
- cordis.europa.eu/project/id/753186
- Project website: icn2.cat/en/oxide-nanophysics-group

SOCIETY

‘Housing First’ approach to homelessness has proven benefits for recovery and integration

Despite being amongst the wealthiest regions of the world, homelessness remains a problem within the EU. HOME_EU’s ‘Housing First’ model represents a paradigm shift for integrated social intervention and an opportunity to rethink community life.

There are approximately at least 700 000 homeless people sleeping rough or in emergency/temporary accommodation per night across the EU. It is argued that for long-term homelessness to be tackled effectively, it should be considered a social emergency. Only when viewed as a life-threatening condition will genuine efforts be made for a more inclusive society.

The EU-supported HOME_EU (Homelessness as unfairness) project set out to empirically highlight a ‘theory of justice’ approach to homelessness. This is based on an individualised and permanent Housing First (HF) angle, combined with recovery and social integration support.

The project offered comprehensive supporting evidence from different countries for the solution’s viability.

HOUSING FIRST UNDER THE MICROSCOPE

HOME_EU conducted research in France, Ireland, Italy, the Netherlands, Poland, Portugal, Spain and Sweden. In Spain, the HF policy has been explicitly adopted, in Portugal it has been embraced at government level and in Poland an HP pilot has been started in three cities.

To better understand EU citizens’ knowledge, attitudes and practices, the project conducted a telephone survey with a representative sample. This involved 5 600 participants, 700 per country, with country-weighted samples. It revealed that 76 % of respondents thought that governments should invest more to end homelessness and 49 % were willing to pay more taxes to support the HF model.

The researchers wanted to analyse the opinions and perceptions of people who are currently homeless and those who have been integrated into HF programmes. They considered benefits, service efficacy and the impact on social integration.

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Using surveys and interviews, HOME_EU analysed the experiences of 245 participants of 49 HF programmes across the eight countries. They compared these findings with the experience of 292 users of 31 traditional 'stair case' programmes.

In these programmes, treatment is prioritised for underlying conditions that could be contributing the person's homelessness. Secondly, participants must show evidence of being 'house ready' or 'house deserving' to qualify for housing.

Of those involved in the HF programmes, 71.8% spent more time in their allocated accommodation, compared with 20.8% in stair case programmes. The first cohort also reported a reduced need for psychiatric services, higher integration and more satisfaction with the support services made available.

Through 29 focus groups involving 121 participants from seven EU countries, the study also found that HF providers considered housing a basic human right, more supportive to recovery.

A survey of 197 respondents involved in policymaking said they considered homelessness in their region to be a moderate or major problem. However, only 16.2% reported integration of an HF model in their region.

"Our varied levels of analysis show that to obtain an in-depth understanding of the complex social dynamics around homelessness and to achieve community transformation, you need the perspectives of a range of stakeholders," says José Ornelas, project coordinator.

> *"We showed that homelessness is reversible, using a two-pronged solution: immediate housing provision, alongside the support of a community integration team."*

TRANSFORMATIVE CHANGE

HOME_EU's findings contribute to existing research which highlights the vulnerability of homeless people to violence, especially of a sexual nature for women.

"But we showed that homelessness is reversible, using a two-pronged solution: immediate housing provision, alongside the support of a community integration team. Longer-term empowerment is only possible when basic human rights are met," explains Ornelas.

The project has been instrumental in the creation of the new Applied Psychology Research Centre Capabilities and Inclusion in Portugal. Project partner organisations have committed to assist other initiatives such as the Portugal National Housing First Network, which already has the interest of more cities.

The HF model could also be relevant for other social interventions. It could help migrants and domestic violence survivors. It can also be used in the deinstitutionalisation of youth in sheltered or foster care, or for those released from psychiatric care or prison.

There are approximately at least
700 000 homeless people
sleeping rough or in emergency/
temporary accommodation
per night **across the EU**

HOME_EU

- Coordinated by ISPA CRL in Portugal
- Funded under H2020-SOCIETY
- cordis.europa.eu/project/id/726997
- Project website: home-eu.org

Politics and dynamics of the Roman trade system: What do we really know?

There are many hypotheses surrounding the organisation of the Roman Empire trade system. They, however, remain speculative due to the absence of formal approaches in historical and archaeological contexts. An EU-funded project offers a solution.

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Ancient history is based on abductive reasoning and its evolution is dependent on the capacity to argue, test and falsify previous hypotheses. Over the years, several scholars have developed a variety of hypotheses to explain the organisation of the Roman Empire trade system.

The study of food management represents one of the main debates among specialists in this field. These hypotheses, however, are speculative and difficult to falsify due to the lack of formal models that would enable the analysis of available data.

OVERCOMING THIS BOUNDARY

"The main goal of the EPNET project was to use formal tools to falsify existing hypotheses concerning the Roman economy to understand which products, in which periods, were distributed through the different geographical regions," explains José Remesal, coordinator of the project EPNET (Production and distribution of food during the Roman Empire: Economics and political dynamics). The coordinator adds: "We also wanted to ascertain the role different political and economic agents played in controlling the products and the trade networks."

To find answers to these scientific questions, a strong interdisciplinary research team worked towards setting up an innovative framework to investigate the political and economic mechanisms that characterised the dynamics of the commercial trade system during the Roman Empire.

A SPOTLIGHT ON EPNET'S WORK

EPNET focused on the exploration of epigraphies and amphoras from the CEIPAC dataset, one of the most precise archaeological and historical semantic markers available from the Roman Empire trading system. This provided EPNET with the opportunity to participate in the Eagle Network. "In particular, research activity was dedicated to the development of the domain ontology, the release of the semantic database of CEIPAC and its successive integration with a series of existing datasets using an ontology-based data access and integration approach," reports Remesal.

Using this approach, a semantic portal was also created. "This part was particularly innovative because it coupled the semantic approach with data visualisation technologies, for supporting data-driven explorations and pattern detections," adds Remesal.

> *The main goal of the EPNET project was to use formal tools to falsify existing hypotheses concerning the Roman economy to understand which products, in which periods, were distributed through the different geographical regions.*

Additionally, the project, in their study of the Roman Empire, chose some of the poles/paradigmatic points to achieve an overview. Remesal confirms this to be: "Colonia Ulpia Traiana: Xanten (Germany), Mutina, Pompeii and in Rome, the capital of the Roman Empire, in Monte Testaccio." Remesal further notes: "We have also published some books and articles as well as developed interdisciplinary environments."

LOOKING TO THE FUTURE

"We have identified new challenges to our research. One immediate result of this has been our incorporation into the ARIADNEplus project, which aims, through the application of an ontological system, to interconnect numerous databases related to the history and archaeology of the classical world," notes Remesal.

Furthermore, the analysis of amphora epigraphy, the starting point of EPNET's studies, has created a need for the project to approach these documents from new perspectives. EPNET, using the innovative methods of analysis developed within the project, also aims to develop a study which analyses professional corporations linked to food trade and the new perspectives.

EPNET

- Hosted by the University of Barcelona in Spain
- Funded under FP7-IDEAS-ERC
- cordis.europa.eu/project/id/340828
- Project website: roman-ep.net/wb

SOCIETY

Anna of Denmark was more than queen consort: Mapping childhood and cultural influence

An EU-funded initiative delved into the childhood and transnational experiences of Anna of Denmark, widening the discussion on the queen consort's later cultural endeavours and conception of status.

"Anna of Denmark's time at the Stuart court in England has historically been the primary focus of research," notes Jemma Field, lead researcher on the Mapping Anna (The Politics of Cultural Exchange: Anna of Denmark and the Uses of European Identity) project, funded under the Marie Skłodowska-Curie programme. "This Anglo-centric approach has clouded our understanding of how Anna's Oldenburg birthright and European connections shaped her role and value at court and impacted Stuart foreign policy, and how her transnational experiences underpinned her aims, activities, networks and behaviour." This knowledge gap had to be addressed.

With the support of James Knowles, project coordinator and currently Dean of Arts and Social Sciences at Royal Holloway, University of London, Field conducted in-depth archival research to learn more about Anna's cultural activities in England and Scotland, as well as those of her parents and siblings. She also considered the interaction between European and British/English/Scottish culture at the time. Project work "consistently sought to uncover the influential role that her childhood experiences in Denmark-Norway (and the ongoing activities of her siblings at their marital courts) had on her later cultural endeavours and conception of status," Field explains.

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Key to the research was Anna of Denmark's connection to an extended dynastic network – mother and aunts, in particular. Against this background, Knowles notes: "The key is how early modern elite women used culture to empower themselves – especially in diplomacy and foreign policy where they had a more involved and direct role than hitherto recognised." This is significant in terms of the political impact of the research. "In part, this requires us to recognise different ways of doing politics – itself a significant shift in understandings of the period, of gender-based distribution of roles and attributes, and of power," he underlines.

REACHING A WIDE AUDIENCE

Other research included the analysis of extant artefacts associated with Anna of Denmark in holdings across Denmark, England, Scotland and Sweden. The findings informed several conference papers and peer-reviewed articles, including one publication in The Court Historian. Field is also preparing a monograph to be published by Manchester University Press.

Project work and outcomes have been communicated beyond academic circles too, including an interview with BBC Radio Scotland for their programme 'Time Travels'. Field has been writing an essay on clothing and jewellery at the Stuart courts, which was originally marked for a catalogue publication to accompany an exhibition on King James VI and I.

THE IMPORTANCE OF RECOGNISING HERITAGE

When asked about the gender dimension, Field notes: "Raising academic and public awareness about women's role in history is an ongoing conversation." She further reports that Mapping Anna confirms the political value of early modern cultural forms, adding: "It demonstrates how these were successfully used by women to legitimise positions, visualise political ambitions, or show their allegiance, favour or dynastic membership."

Research findings have helped uncover the centrality that Anna's dynastic heritage had to her consortship. "For Anna of Denmark," Field concludes, "the project has made a significant contribution to our understanding of her role and value at the Stuart courts and further discredits the negative historiography that has followed her well into the 20th century."

MAPPING ANNA

- Coordinated by Brunel University London in the United Kingdom
- Funded under H2020-MSCA-IF
- cordis.europa.eu/project/id/706198
- Project website: earlymoderncourts.com

TRANSPORT AND MOBILITY

New tools improve cabin air quality and protect against organic pollutants and ozone levels

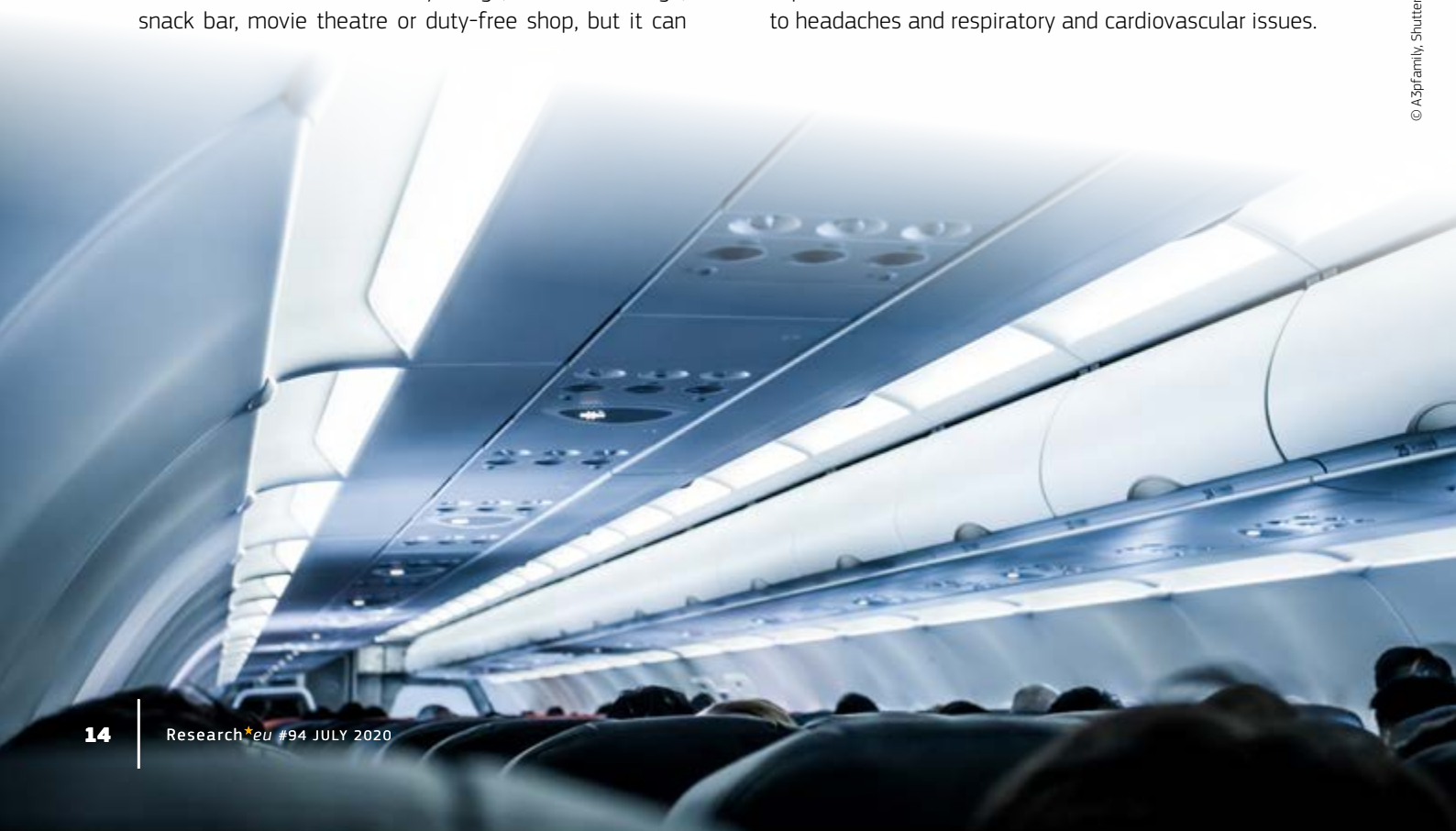
Air quality is not just an outdoor concern, it is equally important in indoor environments – when staying at home, driving in cars or flying in aeroplanes. EU-funded researchers developed new tools to address the burgeoning air pollution problem in aircraft cabins.

The EU-funded MACAO (Development of VOCs and ozone Micro-analysers based on microfluidic devices for Aircraft Cabin Air mOnitoring) project introduced efficient and accurate microanalysers for detecting and analysing the circulation of various gaseous pollutants generated in aircraft cabins or stemming from air conditioning systems. The new tools can monitor the harmful volatile organic compound (VOCs) and ozone concentrations at unprecedented speed, including species that have never been detected before.

AIRCRAFT CABIN: A CHEMISTRY LABORATORY OF SORTS

An aircraft cabin can be many things, such as a lounge, snack bar, movie theatre or duty-free shop, but it can also be a space of a cumulative cocktail of pollutant gases. The air wafting inside an aeroplane is a combination of recycled air within the cabin along with outside air that is compressed by the aircraft's engines.

VOCs and ozone can also find their way into the cabin, but especially ozone, when the aircraft is flying high near the ozone layer. Unwanted by-products of engine combustion, such as nitrogen oxides, can also pollute the cabin, while other pollutants emanate from within the cabin – ethanol in alcoholic beverages can evaporate and interior furnishings can release formaldehyde. All these pollutant gases present concerns for the health and comfort of passengers and crew. Prolonged exposure to elevated ozone and VOC levels are linked to headaches and respiratory and cardiovascular issues.



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> *Requiring a small air sample collection, the devices shorten the sampling time to around 4 minutes before analysis, which lasts for 10 minutes.*

FAST, HIGH-SENSITIVITY ANALYSIS

MACAO aimed to provide a route around these issues. The project developed two analytical instruments based on microfluidic devices for measuring the concentrations of major air pollutants in aeroplanes. One microanalyser measures concentrations of various VOCs whereas the other measures ozone concentrations.

Technical progress on the VOC microanalyser was excellent. A benzene analyser equipped with a new pre-concentration unit was successfully developed and validated under laboratory conditions, demonstrating the capability of the prototype to adsorb and to desorb the targeted organic species. "The patented instrument successfully detected VOC concentrations of 60 parts per million with a sample of only 20 ml of air," notes Stéphane Le Calvé, project coordinator of MACAO and research director at the French National Centre for Scientific Research (CNRS). With a detection limit of 3.6 picogrammes, the new device is about 40 to 260 times more sensitive compared to state-of-the-art portable miniaturised instruments (with detection limits of 140 to 940 picogrammes).

One of the advantages of the newly developed technologies is that sampling and analysis times are very fast. "Requiring a small air sample collection, the devices shorten the sampling time to around 4 minutes before analysis, which lasts for 10 minutes. In fact, it is possible to conduct air quality analysis every 15 minutes," explains Le Calvé.

What is particularly innovative in MACAO is that up to now there haven't been any suitable instruments specifically designed to measure the VOCs and ozone concentrations that circulate in the cabin environment. Being able to analyse very small quantities of these gases using microfluidic devices is relatively new.

The MACAO team now seeks to further advance the microanalysers and integrate more powerful software to make them fully automatic and more robust. All these factors are essential for a demonstration in real flight conditions.

MACAO

- Coordinated by the National Centre for Scientific Research in France
- Funded under H2020-TRANSPORT
- cordis.europa.eu/project/id/687014
- Project website: icpees.unistra.fr/en/macao-project-h2020

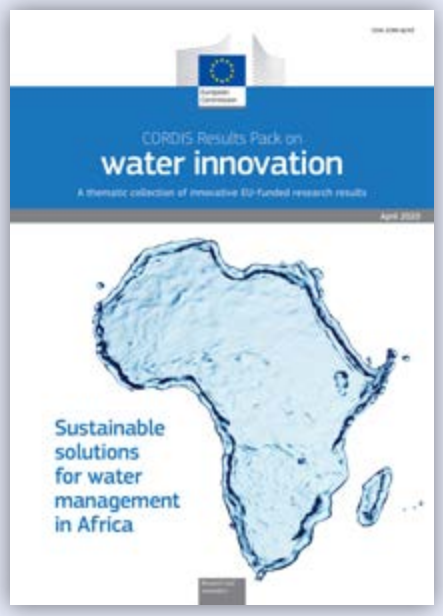
WATER INNOVATION FOR AFRICA: SUSTAINABLE SOLUTIONS FOR WATER MANAGEMENT

In general, in low-income countries, and in some countries in Africa in particular, sustainable water supply and sanitation are not a given. Without water, there is no life. However, according to the World Health Organization (WHO), water scarcity affects one in three people in Africa. This situation is further aggravated by population growth, challenges to economic development, urbanisation, demographic shifts and climate change.

On top of this, contaminated water and poor sanitary conditions result in vulnerability to waterborne diseases such as diarrhoea, cholera and typhoid. This can carry grave human and economic costs and may potentially affect peace and security in the Africa region.

The European Union launched two dedicated Horizon 2020 calls on this issue and this CORDIS Results Pack showcases some of the cutting-edge projects in research and innovation that address water-related challenges in Africa.

To find out more, browse, download or order a physical copy of the Results Pack here:
cordis.europa.eu/article/id/415801



Algorithms diagnose train doors' faults from vibration patterns

Keeping train doors properly maintained helps to avoid train delays, and now the doors say when they need fixing.

European travellers state that punctuality is one of their primary concerns. Yet, 30 % express dissatisfaction with the punctuality and reliability of current rail services. Even minor train delays can cause significant disruption.

Although only 5-25 % of train faults affect doors, doors are linked to important safety systems, so such faults often stop trains completely. Thus, door faults cause 30 % of train delays in Europe.

Adequate door maintenance would fix the problem. However, it is difficult for engineers to know when maintenance is needed. Engineers usually service trains too frequently, increasing costs unnecessarily, or after a breakdown has occurred, costing even more. The problem is finding the optimal maintenance schedule.

OPTIMAL MAINTENANCE

The EU-funded project VA-RCM (Innovative Product for train door condition monitoring based on vibration analysis algorithms), an acronym for vibration analysis for remote condition monitoring, developed a solution. The system monitors the condition of train door actuators, using algorithms that analyse the patterns of vibration.

© VA-RCM

"Continuous monitoring means that the VA-RCM system can reduce failures by detecting malfunctions before they become an issue," says Richard Howes, senior project manager. Timely alerts allow train operators to plan maintenance schedules more efficiently, keeping on top of maintenance as needed while also avoiding delay-causing faults.

The system includes a subsystem for acquiring train door vibration data, algorithms for analysing the data and a web-based graphical user interface. Each door in a train carriage has a VA-RCM node that hosts sensors responsible for collecting vibration data. All nodes connect to a local Wi-Fi network, which connects to a broader cellular network. User teams control the system through the graphical interface.

ANALYSING VIBRATIONS

"The system acquires vibration data, using an accelerometer to measure vibrations while the door is in motion," explains Howes. "An embedded processor analyses the vibration patterns and extracts representative features." The algorithms compare the door vibration features, expressed mathematically, against the same features obtained from doors known to be in good condition. So, the algorithms can detect whether the vibration patterns deviate from normal. If so, the system recommends a maintenance inspection. The system also collects patterns for a machine learning model, so the pattern analysis improves with time.

Researchers tested the system in laboratories, at rail facilities in Spain and the United Kingdom. This included testing in the real environment of Barcelona's metropolitan trains. Results confirmed that the system is able to detect more than 97 % of common faults that could lead to door malfunction. These include obstacles in door rails, loose

> *Continuous monitoring means that the VA-RCM system can reduce failures by detecting malfunctions before they become an issue.*

bolts and vertical door-leaf misadjustments. The processing algorithms were also shown to run on simple embedded processors, which will keep costs to a minimum.

As a result of the successful trials, the VA-RCM system has been certified for European trade. The project team is now looking for customers.

Thanks to the innovative VA-RCM system, operators will always know the condition of train doors, and be able to efficiently schedule maintenance as needed. This will improve reliability and lower costs, two things train operators and commuters agree on.

VA-RCM

- Coordinated by Hitex GmbH in Germany
- Funded under H2020-Societal Challenges and H2020-Industrial Leadership
- cordis.europa.eu/project/id/730766
- Project website: va-rcm.co.uk

TRANSPORT AND MOBILITY

Europe shares expertise in support of improved African road safety

African economic growth brings more traffic and so more road deaths. SaferAfrica sought to enable cooperation among African-European governments, research institutions and NGOs, to strengthen national and local road safety efforts in Africa.

African road safety figures are concerning, with 26.6 fatalities per 100 000 population in 2016 – three times that of Europe. While European road deaths are stabilising, the organisations in Africa responsible for improving the situation lack the necessary knowledge and skills.

The EU-funded SaferAfrica (Innovating dialogue and problems appraisal for a safer Africa) project, set up to share expertise between the two continents, was founded on four pillars: Road Safety Knowledge and Data, a Road Safety Traffic Management Capacity Review, Capacity Building and Training, and Sharing Good Practices.

Last year, the project's range of approaches and tools won the Prince Michael International Road Safety Award for their contribution to road safety improvement through scientific innovation.

SHARING KNOWLEDGE

The SaferAfrica team established the African-European Dialogue Platform on road safety as a means to enable intercontinental cooperation. It linked road safety policymakers, donors and professionals – those who can implement the necessary regulatory, financing and planning measures – for supportive exchanges leading to policy recommendations and concrete actions.

When it comes to **African road safety**, there were 26.6 **fatalities** per 100 000 population in 2016 – **three times that of Europe**

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"One of the aspects of the project I am most proud of was the African Road Safety Observatory, a web portal with specialised road safety information, such as country factsheets, good practices and webinars. Using crowdsourcing, we also developed a means for ordinary citizens to report road safety problems and potential solutions," says Luca Persia, project coordinator.

A free road safety e-learning course was developed, targeted at professionals and covering topics such as road safety management, accidents data collection, safe roads, safe vehicles, safe users and post-crash care.

A Train the Trainer manual was also introduced to lecturers to incorporate into their curriculum. Additionally, to help improve research capability, a twinning project was set up between the Research Centre for Transport and Logistics (CTL) at Sapienza University, Italy and the National Advanced School of Public Works (ENSTP), Cameroon.

A Transferability Audit was completed to identify potential cultural, institutional and economic barriers to the implementation of road safety good practices and a tool developed for assessing the likely impact of interventions.

The Africa-EU Task Force on Transport and Connectivity (part of the new Africa-Europe Alliance for Sustainable Investment and Jobs) highlighted road safety as one of its focus areas. The signs are that there is still much scope for building on the project's achievements. "Both

"One of the aspects of the project I am most proud of was the African Road Safety Observatory, a web portal with specialised road safety information, such as country factsheets, good practices and webinars."

SaferAfrica's platform and observatory are frontrunner examples of capacity building that can be replicated around the world," notes Persia.

DRAWING ON A BROAD RANGE OF STAKEHOLDER EXPERTISE

Stakeholders ranged from government ministries and road authorities to international NGOs and community-based organisations, as well as business providers of products and services.

The Management Board comprised 11 prominent international institutions of political unions (AU and EU), multilateral development banks (WB and AfDB) and other key organisations (UNECA, WHO, IRF, IRU, ITF, FIA and PIARC).

To date, the Dialogue Platform has held four workshops, eight webinars, dedicated web consultations and country meetings, generating an online community of almost 200 stakeholders from 41 African countries.

Taking into account the heterogeneity of Africa, a Road Safety Management Capacity Review was conducted in five countries (Burkina Faso, Cameroon, Kenya, South Africa and Tunisia) representing a range of socio-economic situations and availability of data.

These reviews resulted in proposals for remedial and sustainable activities, with initial steps already underway in all countries. However, a well-defined road safety investment strategy still needs to be developed.

SAFERAFRICA

- Coordinated by Sapienza University of Rome in Italy
- Funded under H2020-TRANSPORT
- cordis.europa.eu/project/id/724029
- Project website: saferafrica.eu
- bit.ly/2MvCk5b

Researching the risk posed by antifungal azoles to aquatic ecosystems

An EU-funded initiative has conducted a detailed study of the exposure of aquatic ecosystems to antifungal azoles. This emerging family of pollutants are of particular concern due to their endocrine-disrupting effects that pose a potential environmental risk.

Azoles are widely used as agricultural fungicides or pharmaceuticals for the treatment of mycoses, parasitic infections and cancer in humans. Initially designed to inhibit CYP51 enzymes, responsible for the biosynthesis of ergosterol in fungi, they also disrupt a broad range of other cytochromes (the CYPs) involved in steroidogenesis, for example CYP19, and xenobiotic detoxification like CYP1A in mammals and fish.

These antifungal agents therefore have the capacity to act as endocrine disruptors and to affect the survival, development, growth, reproduction and behaviour of non-target organisms. Although a few of these compounds are routinely investigated and detected, an accurate exposure assessment for evaluating the associated environmental risk of most azoles is still lacking.

The EXPOZOL (Exposure of aquatic ecosystems to antifungal azoles: assessment of occurrence and fate in sediment, water and aquatic organisms) project sought to widen scientists' understanding of the exposure of aquatic ecosystems to antifungal azoles, and their occurrence and biotransformation in aquatic organisms and associated effects, to improve environmental risk assessment. This research was undertaken with the support of the Marie Skłodowska-Curie programme.

CONFIRMATION OF THE EXPOSURE OF AQUATIC ORGANISMS TO AZOLES

Investigators employed cutting-edge high-resolution mass spectrometry technology (Q-Exactive by Thermo Fisher) to perform retrospective screening of azoles in

archived digital samples and investigate their biotransformation. "Such technology is increasingly used in the field of environmental chemistry to get a full picture of the chemical complexity of the contamination, by investigating both known and unknown contaminants, for example biotransformation products," says research fellow Nicolas Creusot.

Results indicated that antifungal azoles are widely distributed in terrestrial and aquatic ecosystems in accordance with their wide range of physico-chemical properties. "We showed that biota from different trophic levels are exposed to these chemicals," explains Creusot. "One of the key points is EXPOZOL confirms that linking exposure and effects is very important for improving chemical risk assessment."

In fact, risk quotient calculations also revealed the threat associated with exposure to antifungal azoles, especially if some of the investigated rivers and streams are used for drinking water production. In addition, scientists confirmed through toxicokinetic and toxicodynamic experiments that aquatic organisms can accumulate and transform azoles, which may trigger adverse effects such as a reduction in growth – and even death.

IMPORTANCE OF FURTHER INVESTIGATION

Beyond the specific case of antifungal azoles, investigations clearly demonstrated that the retrospective analysis of data acquired by high-resolution mass spectrometry can improve current knowledge of exposure and the related risks attached to chemicals of emerging concern and can be effectively employed for such purposes in future. "We are now able to increase our knowledge of the spatial and temporal dynamic of thousands of chemicals that were not initially investigated," Creusot emphasises.

"One of the key points is EXPOZOL confirms that linking exposure and effects is very important for improving chemical risk assessment."

EXPOZOL showed that aquatic ecosystems and humans (through drinking-water consumption) can be at risk from contamination by antifungal azoles. "This should act as a warning sign by providing proof that these chemicals should be studied more closely with regard to occurrence and effects, in order to limit their impact on aquatic ecosystems and beyond," Creusot concludes.

EXPOZOL

- Coordinated by EAWAG in Switzerland
- Funded under H2020-MSCA-IF
- cordis.europa.eu/project/id/744052
- Project website: bit.ly/3hBHcnP

CLIMATE CHANGE AND ENVIRONMENT

Sea urchins reveal how organisms respond to a changing marine environment

Coastal marine invertebrates are important around the world with regard to the ecosystem services and functions that they provide. Can these species adapt and evolve to cope with multiple stressors at the rate at which they are occurring due to climate change?

The world's oceans are changing faster than at any other time over the last 300 million years. As a result, marine animals are being exposed to multiple rapid environmental changes. At the same time, seasonal and daily

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variability in environmental conditions such as temperature and ocean acidification is increasing.

The EU-funded TERMS-Ocean (Transgenerational Ecophysiological Responses to Multiple Stressors in a changing Ocean) project addressed these challenges by studying transgenerational plasticity (TGP), a possible mechanism that marine organisms can use to cope with changing environmental conditions. This research was undertaken with the support of the Marie Skłodowska-Curie programme.

TGP is where observable characteristics (such as size) in offspring change in response to the environment that their parents were exposed to during reproduction. "Offspring displaying TGP are better able to cope with the conditions their parents were exposed to than they would have been if their parents had not experienced those conditions," says research fellow Kathryn Smith.

PRESENT AND FUTURE COMPARED

The initiative investigated the role of TGP in the response of a keystone marine invertebrate, the sea urchin *Paracentrotus lividus*, to the combined impacts of climate change and ocean acidification. The aim was to determine whether TGP plays a role in alleviating the effects of these stressors when experienced in combination.

Although scientists often examine a variable, like temperature, in isolation, it does not reflect reality, where many different variables are changing at the same time. "TERMS-Ocean therefore looked at how *P. lividus* responded to current temperature and ocean acidification levels using variable readings to mimic changes that are observed across a tidal cycle. Both were then restudied using the temperature and ocean acidification levels predicted to occur in oceans in 2110," Smith explains.

EFFECT OF MULTIPLE STRESSORS

Researchers observed that egg sizes in females were influenced by temperature and ocean acidification and also by environmental variability (i.e. the variability observed across a tidal cycle, which was incorporated into experimental regimes). In contrast, the way that sperm swam was only influenced by environmental variability.

Fertilisation success did not vary across different experimental regimes, but within each experimental set-up there was a huge amount of individual variability between the proportion of eggs from different females that were fertilised. Larval survival and larval development were influenced by temperature and ocean acidification, and also by environmental variability.

The most exciting finding from TERMS-Ocean is the importance of individual variability in the responses of organisms to environmental change. "Results suggested that when looking at the responses at an individual level rather than a population, it becomes clear that not all individuals are impacted by environmental change in the same way. While some individuals are negatively affected by environmental change, others thrive under predicted future ocean conditions," notes Smith.

TERMS-Ocean will lead to advances in our understanding of the impacts of climate change (temperature and acidification) on marine species. "These findings will benefit fisheries, which can explore the potential for targeting specific individual genetic lines that may provide higher yields in the future. They will also inform policymakers as well as being of interest to the scientific community and the general public," Smith points out.

TERMS-OCEAN

- Coordinated by the University of Exeter in the United Kingdom
- Funded under H2020-MSCA-IF
- cordis.europa.eu/project/id/704895
- Project website: biosciences.exeter.ac.uk

PROJECT OF THE MONTH

A biodegradable food packaging solution that also promises to increase food shelf life

Whilst developing biodegradable food packaging from upcycled cheese whey and almond shells, the EU-funded project YPACK has discovered that integrating zinc oxide and oregano essential oil helps biopapers protect against bacterial contamination in food packaging. This promises to increase the shelf life of fresh products such as meat, fruit, vegetables and fresh pasta.

> *"The ideal packaging involves lower carbon and water footprints, is biodegradable and/or compostable, makes use of wastes or by-products, is properly eco-designed and safe, and has the right preservation properties to minimise food waste. YPACK is delivering on this vision."*
>
> **José María Lagarón**, YPACK project coordinator

Zinc oxide and oregano essential oil are compounds that have good antimicrobial activity against two prominent bacteria renowned for causing food poisoning – *Staphylococcus* and *Escherichia coli*.

The YPACK team discovered an optimal ratio of the active ingredients that showed successful short-term (15 days) and medium-term (up to 48 days) antibacterial effects in 'open' and 'closed' systems for food products where the packaging is opened and closed several times, for example ham slices or bread. The active components could be used in both trays and flow films as an active layer.

Plastic pollution, including single-use plastic food packaging, is a major environmental concern with millions of tonnes of plastic waste ending up in our oceans. The ongoing work of YPACK to develop its innovative biodegradable food packaging, that also has the added bonus of helping to preserve food for longer, offers a tantalising – and practical – solution to the challenge.

To find out more, please see the official YPACK website.

YPACK

- Coordinated by the Spanish National Research Council in Spain
- Funded under H2020-FOOD
- cordis.europa.eu/project/id/773872
- Project website: ypack.eu
- bit.ly/3ffR44K

If you are interested in having your project featured in 'Project of the Month' in an upcoming issue, please send us an email to editorial@cordis.europa.eu and tell us why!

SPECIAL FEATURE

HYDROGEN'S GROWING ROLE IN SUSTAINABLE ENERGY SYSTEMS

Editorial

Unlocking the potential of the most common element in the universe

The notion of using hydrogen as a means to power everything from factories to your car may sound a bit futuristic but actually it has been around since the dawn of the Industrial Revolution – hydrogen powered the first internal combustion engine and has since become an integral component in the modern refining industry, as reported by the International Energy Association (IEA). Many countries around the world, including here in Europe, are increasingly supporting initiatives and policies to scale up hydrogen technologies and embed them deeper into our energy and transport systems.

But will hydrogen just naturally burn out in time, its brief rise being nothing more than just the latest fad in the search for clean and climate-friendly energy alternatives? For example, there has been a buzz about hydrogen-powered fuel cells as a clean alternative to fossil fuels for more than a decade but yet it seems that their great rival in the form of the electric car has been the one capturing public and political imaginations. When seeking to answer this question, it actually appears that this truly might just be hydrogen's time to shine as the recent interest and enthusiasm for hydrogen-based solutions doesn't seem to be dissipating anytime soon. Its popularity is only likely to increase further as the worldwide trauma of COVID-19 is now starting to focus minds on how we can build a new and truly sustainable economy in the post-pandemic world.

As noted by the IEA in its 'Future of Hydrogen' report, published in 2019, supplying hydrogen to industrial users is now a booming business and demand for hydrogen is threefold what it was in 1975 and still growing. The agency also noted that today, the majority of hydrogen production stems from fossil fuels, especially natural gas. Admittedly at first glance, this doesn't sound very eco-friendly, but many recent projects and demonstrations are highlighting how hydrogen production can (and should) be shifted from fossil fuels to renewable energy sources.

With the lower costs of solar, hydro and wind power, constructing electrolysers in locations with good renewable resource conditions to produce hydrogen could become a low-cost and green solution, even if there are added costs of actually transporting the hydrogen to end users. In the long term, there are already good ideas being promoted about integrating hydrogen into sectors that are currently completely untouched by it thus far, such as construction and power generation – though it's likely that transport will be the first sector really able to utilise hydrogen to its fullest potential.

The European Commission has its own dedicated Fuel Cells and Hydrogen Joint Undertaking, an initiative that aims to demonstrate fuel cell and hydrogen technologies as one of the key pillars of future European energy and transport systems. All of the seven projects showcased in this month's special feature are funded and supported through the Joint Undertaking, each one dedicated to demonstrating how hydrogen really could be a viable low-cost, energy-efficient fuel of the future, thus with the real potential of making an important contribution to the EU's ambitious target of being fully carbon-neutral by 2050.

We look forward to receiving your feedback. You can send questions or suggestions to editorial@cordis.europa.eu

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SPECIAL FEATURE

HYDROGEN'S GROWING ROLE IN SUSTAINABLE ENERGY SYSTEMS

Power-to-hydrogen plant in Denmark overcomes the renewable energy intermittency problem

In just 3 years of work, the HyBalance consortium has successfully built one of Europe's largest hydrogen plants based on water electrolysis. The team have demonstrated the value of power-to-hydrogen to efficiently store and transport excess wind energy production. And it did so with a new, more flexible process.

The intermittent nature of solar and wind energy means there will always be times when these sources can produce more power than what consumers need. To prevent this surplus capacity from being wasted, power-to-gas looks like an ideal solution. Renewable power is converted into hydrogen before being used as such or being converted into syngas, methanol or ammonia.

The former solution is called Power2Hydrogen or PtH2. It uses hydrogen directly and is considered as the most sustainable hydrogen production solution currently available. "If the power derives from renewable sources like wind turbines, the hydrogen can be regarded as green – as opposed to hydrogen produced from fossil fuels. Conversion into hydrogen makes it possible to store renewable energy and deliver it into sectors like industry and mobility," says Diederick Luijten, vice president hydrogen energy for northern Europe at Air Liquide and HyBalance project manager.

The technology had been known about for a while, but it had yet to be demonstrated across the entire value chain, at industrial scale and with multi-sectoral end use – which is considered as a prerequisite for investment to pay off. This demonstration was one of the main purposes of HyBalance.

The six-strong consortium set out to build a PtH2 demonstration plant in Denmark. The plant was inaugurated in September 2018 in Hobro, a location selected for its vicinity to wind power, the high voltage electricity grid, gas networks and gas storage facilities. This 1.2 MW

© HyBalance

plant is one of Europe's largest hydrogen plants based on electrolysis.

DEMONSTRATING PEM ELECTROLYSIS

Unlike most hydrogen plants using alkaline electrolysis – in which water splits into hydrogen and oxygen when electricity is introduced via two electrodes – the Hobro plant uses proton exchange membrane (PEM) electrolysis. It works like a PEM fuel cell with an inverted process, so that the end product is hydrogen rather than electricity.

"The project aims at validating the PEM electrolysis technology and its ability to balance the grid in a flexible and dynamic manner. This includes high availability and short ramp-up/shut-down time for the grid. HyBalance is one of the first PtH2 facilities in Europe to provide grid-balancing services," Luijten notes. In short, a PEM electrolysis plant can be quickly adapted to the varying amount of electricity available on the market, which is essential for converting and storing excess wind turbine electricity.

Since it became operational, the facility has been delivering hydrogen to industrial customers and refuelling stations through pipelines and trailers. "The PEM electrolyser plant has gone through a series of performance tests and is able to produce 180 tonnes of hydrogen annually at high quality (≥ 99.998 %). The system is currently in line with the European Commission's Fuel Cells and Hydrogen Joint Undertaking (FCH JU) targets and produces hydrogen with an energy consumption in the range of 55 to 58 kWh/kg at nominal load," Luijten explains.

"The PEM electrolyser plant has gone through a series of performance tests and is able to produce 180 tonnes of hydrogen annually at high quality (≥ 99.998 %).

All in all, the project has successfully demonstrated the capacity of PtH2 to help decarbonise our economy. By the end of 2019, HyBalance had delivered over 76 tonnes of green hydrogen, filled more than 150 trailers and accumulated 13 300 hours of operational time.

Luijten is confident that the plant will contribute to accelerating the deployment of PtH2 installations across Europe. The team will keep evaluating the performance of its fuel cells on a regular basis, while additional balancing tests will be conducted to assess potential gain by the end of the project in September 2020.

HYBALANCE

- Coordinated by Air Liquide in France
- Funded under H2020-ENERGY
- cordis.europa.eu/project/id/671384
- Project website: hybalance.eu
- bit.ly/3hhqCJG

Cheap hydrogen from natural gas streams

Europe's natural gas network could one day be used to deliver renewable energy to citizens and businesses in the form of hydrogen. One of the last remaining obstacles to this grand design – the absence of a cost-effective separation technology – may soon be removed.

Experts may disagree on how and in how much time society will get there, but we can pretty much take one thing for granted: the future of energy lies in renewable electricity. We 'just' need to produce enough and, perhaps most urgently, find out how to efficiently store and transport it.

There is one option that increasingly stands out. It's the use of existing natural gas pipelines to bring electricity to end users in the form of hydrogen. "Several studies have shown that up to 10-15 % of hydrogen can be injected into high-pressure natural gas grids without major safety concerns," says Fausto Gallucci, professor of inorganic membranes and membrane reactors at the University of Eindhoven. "The next problem would be to separate this hydrogen from natural gas at the point of interest."

This is precisely what the HyGrid (Flexible Hybrid separation system for H2 recovery from NG Grids) project is about. While some separation options like pressure swing adsorption (PSA) already exist, they have proved too costly to use for gases with low hydrogen concentrations in which 90 % of the gas to be compressed and recompressed is the carrier. The project consortium led by Gallucci decided to overcome this problem by using a combination of different technologies. These include temperature swing adsorption (TSA), membranes and electrochemical separators.

"The idea is to achieve high recovery at low cost. We take the stream from the natural gas grid, make it pass through different steps including inorganic membranes with sweep gas, and finally recover the remaining hydrogen with electrochemical separators. From thereon, we can reinject the clean natural gas into the grid," Gallucci explains.

The project still has a few months to go before it can be wrapped up, but the list of outcomes is already substantial. The electrochemical separator, membrane production and membrane separators have been scaled up, and the membranes have been tested in industrial conditions up to 50 bar. Project partners, the Technical University of Eindhoven (TUE) and Tecnalia, have submitted two patent applications: one for the development of different separator schemes that can be used in different scenarios of hydrogen recovery, and one focused on the use of carbon-based membranes for gas separation.

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"We have also generated new knowledge distilled in various scientific papers," adds Gallucci. "These include open access publications on electrochemical separators in the Chemical Engineering Journal. In these publications we tested for the first time the purity of the separated hydrogen, developed detailed models for the separator and elucidated the mechanism of poisoning of the system."

Other published papers cover the likes of the evaluation of membrane permeation mechanisms, membrane production and the utilisation of both palladium-based membranes and carbon membranes.

PATH TO COMMERCIALISATION

Complete system modelling has demonstrated costs 25 to 40 % lower than with state-of-the-art technology. Final tests have yet to demonstrate the purity and recovery rates achieved by the technology, but TUE and Tecnalia are not wasting any time. A joint company has already been created to exploit part of the technology developed under HyGrid. Called H2SITE, it will develop small-scale hydrogen production and separation systems for high-purity hydrogen production.

"We now have a system that works and is cost-effective. If the injection of hydrogen in the natural gas grid is to be implemented – which looks likely from the different actions taken at EU level – we are ready to recover this hydrogen at the point of use. HyGrid will definitely facilitate the penetration of hydrogen injection technology into the market," Gallucci concludes.

HYGRID

- Coordinated by the Technical University of Eindhoven in the Netherlands
- Funded under H2020-ENERGY
- cordis.europa.eu/project/id/700355
- Project website: hygrid-h2.e

Safe and reliable: HySTOC's promise for the future of hydrogen supply

Liquid organic hydrogen carriers are one of the most suitable options for transporting hydrogen over long distances. The HySTOC project has been using novel materials to increase their storage capacity, reduce their cost and make them even safer.

Hydrogenious LOHC Technologies was founded in 2013 around a groundbreaking discovery: a new hydrogen carrier material potentially beating all existing alternatives. The new material was safe, almost non-flammable, increased storage capacity fivefold and reduced the cost of hydrogen transport by up to 80 %. Five years later, the company received funding under the European Commission's Fuel Cells and Hydrogen Joint Undertaking.

Martin Johannes Schneider, lead product manager and coordinator of the HySTOC (Hydrogen Supply and Transportation using liquid Organic Hydrogen Carriers) project, tells us about the project. He discusses its objectives and expands on plans for its future commercialisation.

What is LOHC technology and how does it work exactly?

Martin Johannes Schneider: Our company is a pioneer and global industry leader in the field of hydrogen storage. We made it this far thanks to patented liquid organic hydrogen carriers (LOHCs) materials, which enable the safe and efficient storage of hydrogen in the form of an easily transportable oil. Our technology completely eliminates the need for pressurised hydrogen tanks.

LOHCs can chemically store hydrogen at high storage densities under ambient conditions. Hydrogen storage is done through exothermic catalytic hydrogenation reaction, while the release process is based on an endothermic catalytic dehydrogenation reaction.

Hydrogenious LOHC Technologies develops and operates the StorageBOX and ReleaseBOX systems for LOHC-based hydrogen infrastructures.

How does this technology compare to existing storage solutions, both non-LOHCs and LOHCs using other materials?

Our LOHC oil (dibenzyltoluene) is hardly flammable and non-explosive. It makes large-scale hydrogen storage and transport completely safe, whereas other LOHC materials have different characteristics. Toluene for instance has a lower gravimetric hydrogen storage density and a higher flammability.

© Hydrogenious LOHC Technologies GmbH

When it comes to non-LOHC options, these mostly revolve around high-pressure and cryogenic hydrogen storage. They require either extreme pressures (500 to 1 000 bar) or extreme temperatures (-253 °C) to store and transport hydrogen. Our LOHC oil is much easier to move around. You can use existing infrastructure for fossil fuels such as trucks, trains and ships.

How far are you in the development process?

The StorageBOX system was successfully built and sent from Germany to Finland. We were also able to develop successful CE-classified systems that have a high potential for standardisation. This allows for rapid market introduction with an increase in the number of systems delivered.

Did you face any difficulties in developing and demonstrating the technology? If so, how did you overcome them?

The environmental conditions in Finland, with temperatures as low as -30 °C, presented us with unknown challenges. Likewise, the integration of new process stages, such as the compression step, has made the design of the plant more complex than we initially thought. We had to factor in explosion protection for instance.

The specific requirements of this project have strengthened our technical expertise, especially when it comes to complex and extreme site requirements.

What do you still need to achieve before the end of the project in December?

The coronavirus outbreak has made it impossible to operate the StorageBOX as planned for months. At the very least we hope to successfully commission both plants on-site in Finland and to be able to operate them on a permanent basis by the end of 2020.

What has been the feedback from potential customers so far?

Interest in this type of LOHC system is high. In the first quarter of this year alone, we sent out several offers for identical plants to customers.

However, sometimes we have to work with completely different framework conditions for the requested application scenarios at their respective locations. This has an influence on the extent to which follow-up orders can be contracted.

Martin Johannes Schneider,
lead product manager and coordinator of HySTOC
© Martin Johannes Schneider

> *Our LOHC oil (dibenzyltoluene) is hardly flammable and non-explosive. It makes large-scale hydrogen storage and transport completely safe.*

Large-scale hydrogen infrastructure projects have shown strong interest and even started to scale up our LOHC systems for the market introduction of StoragePLANTs and ReleasePLANTs, towards multi-ton hydrogen storage and release with LOHC.

Lack of confidence, high cost and limited infrastructure are the most important problems faced by the sector. How do you hope HySTOC will contribute to overcoming these barriers?

HySTOC has taken important steps in the adaptation of LOHC technology to specific market needs, such as high hydrogen quality, high-pressure hydrogen and extreme weather conditions. The StorageBOX and ReleaseBOX systems have become the reference for state-of-the-art systems using LOHC technology. A successful field test will ensure a strong market placement of the technology as well as lay the basis for its further scale-up.

Lack of confidence and high cost can only be tackled if large-scale projects become a reality. Hydrogen technologies including LOHC are market-ready from a technological point of view, just like renewable energies were 20 years ago. Public authorities and funding mechanisms like the ETS Innovation Fund and IPCEI, with a specific focus on OPEX funding, will now be required to prevent market failure and rapidly bring hydrogen infrastructure into the market. This will reduce cost through economies of scale.

HYSTOC

- Coordinated by Hydrogenious LOHC Technologies in Germany
- Funded under H2020-ENERGY
- cordis.europa.eu/project/id/779694
- Project website: hystoc.eu

Water electrolysis – a promising remedy for the off-grid solar energy storage problem

Renewables are not a complete solution without energy storage. EU-funded researchers demonstrated cutting-edge water electrolysis technology that offers a viable way to store renewable solar energy in the form of hydrogen fuel.

Renewable energy sources such as solar suffer from supply and demand imbalances: they produce a surplus of unused energy during the summer months when electricity demand is low, and provide limited energy during the winter months when electricity demand peaks. To overcome this challenge, renewables must be supplemented with energy sources that can instantly fill the gaps in energy supply and demand.

Hydrogen production provides this much-needed solution for storing renewable energy. If solar power is used, hydrogen production is in itself a clean process. The energy surplus is used to power electrolysis, a process that separates water into its constituents: hydrogen and oxygen.

HYDROGEN ENERGY STORAGE: THE BEST OFF-GRID ALTERNATIVE

Diesel generators are currently one of the most common off-grid solutions for backing up solar power. However, these generators release large amounts of carbon dioxide, nitrogen oxide and other harmful emissions into the atmosphere. What's more, operating costs are largely affected by the volatile diesel market.

© Aragon Hydrogen Foundation

"Batteries could be another option for storing solar energy for later use, but they would need to be giant to manage seasonal variations. Besides being run by zero-carbon renewable electricity, electrolysis can manage both short- and long-term transient variations in renewable supply," notes Pedro Casero, coordinator of the EU-funded ELY4OFF (PEM ElectroLYsers FOR operation with OFFgrid renewable installations) project.

ELY4OFF successfully demonstrated an autonomous off-grid electrolysis system exclusively sourced by solar power technology. "We designed a 50-kW proton exchange membrane (PEM) electrolysis system coupled to a solar cell. The hybrid system produces over 1.5 tonnes of hydrogen per year. PEM electrolysis technology has fast response time and start-up/shut-down characteristics. Hydrogen production starts immediately at ambient conditions," explains Casero.

Overall, the hybrid system works at high efficiency at any load, producing high-purity hydrogen for any use. All of these are possible thanks to a reliable control and communication system that allows safe, robust and energy-efficient operation.

The project boasts the development of a novel connection system between the power source and the PEM electrolyser. Depending on the load, current solutions that rely on the combined use of a rectifier and an inverter demonstrate a maximum efficiency of around 92 %. ELY4OFF's solution achieved impressive efficiency rates, as high as 97.4 %.

ON-GRID VERSUS OFF-GRID HYDROGEN PRODUCTION

Most electrolyser producers typically provide products optimised for on-grid scenarios, where the solar system is tied to a utility's grid that guarantees stable and permanent power supply. These solutions cannot apply to

> *What ELY4OFF shows is that hydrogen from renewable energy can be produced almost anywhere and for multiple uses: telecom backup power, fuel cell vehicles, or even fertiliser production.*

off-grid configurations: the power source is variable – it can even drop to zero in a matter of seconds or less – the electrolyser has to shut down and start every day, and needs a backup system to protect its core elements.

ELY4OFF successfully dealt with all of these aspects. Its goal was to improve the efficiency of the overall process – hydrogen production and round-the-clock reliable operation of the hybrid system.

There are many locations worldwide suitable for installing solar cell systems that ultimately fail to materialise due to lack of grid infrastructure. "What ELY4OFF shows is that hydrogen from renewable energy can be produced almost anywhere and for multiple uses: telecom backup power, fuel cell vehicles, or even fertiliser production," concludes Casero.

ELY4OFF

- Coordinated by the Aragon Hydrogen Foundation in Spain
- Funded under H2020-ENERGY
- cordis.europa.eu/project/id/700359
- Project website: ely4off.eu
- bit.ly/3cPE3wY

Best electrolyser/photovoltaics combinations demonstrated in test fields

One of the most promising ways to increase the availability of solar energy is to convert excess production into hydrogen. The PECSYS project has investigated the best possible material and technology combinations to facilitate such an operation.

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It all comes down to electrolysis. By combining photovoltaic (PV) modules with electrolyser systems, you can convert excess electricity into hydrogen and use it later, as demand starts exceeding supply. No more need for backup batteries or DC-DC converters. The hydrogen can be used in multiple industry processes, and users are provided with a zero-net carbon energy cycle, from generation to storage and use.

The PECSYS (Technology demonstration of large-scale photo-electrochemical system for solar hydrogen production) project aimed to advance this technology by exploring various combinations of electrolysers and PV cells.

"Initially the plan was to test different materials and then select the best for final implementation in a demonstrator. However, we soon learned that different approaches provide different benefits. Instead of deselecting several options and keeping only one, we therefore decided to investigate a number of technologies," says Sonya Calnan, group lead, photovoltaics to fuels technology, at the Helmholtz Zentrum Berlin (HZB) and project coordinator.

COUPLED OR INTEGRATED?

On the electrolyser front, the consortium focused on both direct coupling and PV-integrated electrolysers.

The direct coupling of PV and electrolysers is not new, but the team found there was still scope to optimise their engineering. As Calnan explains: "Our colleagues at Forschungszentrum Jülich developed unique polymer electrolyte membrane PEM stacks with reduced platinum

group catalyst loading and systems. These receive water input only on the cathode side. In so doing, we reduce the complexity and lower the cost of our solution compared to conventional electrolysers."

PV-integrated electrolysers, on the other hand, were chosen to fill an existing research gap. No study had ever demonstrated their long-term outdoor operation in sizes exceeding laboratory scale. Both HZB and Uppsala University filled this gap, while avoiding the use of platinum group metals for catalysts and using proven PV technologies for capturing solar energy.

On the PV front, the consortium opted respectively for silicon heterojunction PV cells and CuInGaSe PV cells. They chose the former because of their high solar to electricity conversion efficiency, low temperature coefficient, high open circuit voltage and their intrinsic bifacial ability. Finally, the move was justified by existing plans to build one or more big manufacturing facilities in Europe.

"CuInGaSe PV cells, on the other hand, were chosen because the bandgap is easily tuned. We can optimise the matching of the voltage of the PV and electrolysis cells based on local climatic conditions at the operation site," Calnan adds.

TEST FIELDS

The project's two most notable outcomes are undoubtedly its test field demonstrations. In Jülich, Germany, project partners set up a solar collection area of 8.2 m². It consists of full-sized silicon heterojunction modules and

> *Initially the plan was to test different materials and then select the best for final implementation in a demonstrator. However, we soon learned that different approaches provide different benefits.*

CuInGaSe modules connected to detached PEM electrolysers. The installation generated an average of 42.9 g/h of hydrogen with an average solar to hydrogen efficiency of 10 % over 1 month of continuous outdoor operation.

A second demonstration by the Italian Research Council in Catania, Italy involved a 730 cm² collection area using silicon heterojunction PV modules in bifacial operation. "Bifaciality represents an innovative solution to increase the hydrogen production yield without increasing cost. We could demonstrate a solar to hydrogen efficiency of 13.5 % and a hydrogen production rate of 307 mg/h at a solar irradiation level of 1 000 W/m² and an ambient temperature of 25 °C. This is an increase of 14 % compared to a monofacial operation," Calnan and her colleagues explain.

The project is set for completion in December 2020. In the meantime, the team will be completing the final assembly of the integrated demonstrators as well as quantifying the benefits of their solutions. In the long run, they hope the project will contribute to new ideas for the deployment of low-cost, autonomous renewable energy systems.

PECSYS

- Coordinated by the Helmholtz Zentrum Berlin in Germany
- Funded under H2020-ENERGY
- cordis.europa.eu/project/id/735218

Innovative compressors make hydrogen a viable fuel of the future

The innovative combination of two compression technologies could make hydrogen fuel more reliable and less expensive at the pump. This could encourage an uptake in hydrogen-fuelled cars and help Europe transition to clean mobility.

A quarter of all greenhouse gas emissions are caused by transport, which can lead to dangerous levels of air pollution. This is why transport needs to explore new pathways towards achieving cleaner mobility.

One possible solution is hydrogen, a carbon-free fuel that can be stored as gas in vehicles and converted into electricity in an on-board fuel cell. The only other by-products are water and heat; only water vapour is released into atmosphere.

"This technology combines the advantages of electric mobility, such as silence and zero emissions, with the advantages of a chemical fuel," explains COSMHYC (COmbined hybrid Solution of Multiple HYdrogen Compressors for decentralised energy storage and

refuelling stations) project coordinator David Colomar, engineer at the European Institute for Energy Research (EIFER).

"These include short refuelling times and the ability to store a large amount of energy. This makes the technology suitable for vehicles in constant use such as taxis and buses, as well as long-distance vehicles like coaches and trucks."

A lack of widespread, affordable and reliable refuelling infrastructure however has presented an obstacle on the path towards commercialisation. "It is clear that more work needs to be done in terms of strengthening the hydrogen value chain, from hydrogen production to getting the fuel into vehicles," says Colomar. "This is why the COSMHYC project was launched."

RELIABILITY AT THE PUMP

The COSMHYC project focuses on a specific element of the hydrogen value chain – the hydrogen refuelling station (HRS). "Here, hydrogen has to be compressed to very high pressures (450 to 950 bar)," explains Colomar. "The compressor is the main component of an HRS, the most expensive and the most difficult to operate."

The project therefore set about developing innovative new HRS compressors capable of delivering fuel in a cheaper, more reliable and more efficient way. The COSMHYC concept works like this. Hydrogen is transported from source to a metal hydride compressor, where it is stored. The fuel is then compressed in the mechanical compressor, to the pressure required for fuelling systems.

"This smart coupling of two technologies enabled us to arrive at a very efficient solution that we believe can deliver fuel at a reduced cost," adds Colomar. The project team is confident that the cost of fuel at the pump can be reduced by 20 %.

A quarter of all greenhouse gas emissions are caused by transport

The project team has finalised and validated the design of its prototype compressor and entered the construction phase. Analysis of the pre-industrial size prototype will enable the project team to accurately assess the technological and economic added value of the concept.

BOOSTING EUROPEAN INDUSTRY

Scheduled for completion in September 2020, the COSMHYC project has already made some important advances. "We managed to identify new materials that will enable us to completely eliminate rare earth minerals from our technology," says Colomar. "This is hugely significant, as it means that European industry will no longer be reliant on rare earth mineral imports and unreliable supply chains. This will give us an important economic and geostrategic advantage."

The COSMHYC concept is also scalable. A sister EU-funded project, called COSMHYC XL and launched last year, will build hydrogen compressors for large-scale applications like buses and trains. The project is due for completion at the end of 2021.

Finally, Colomar believes that the project can play a critical role in increasing societal acceptance of hydrogen, through providing solutions to some key issues like reliability and noise disturbance. "All of this will contribute towards accelerating the energy transition in the transport sector," he notes. "And by developing innovative technological solutions that are made in Europe, I think we can also contribute to developing new industrial ecosystems and new green jobs for future generations."

COSMHYC

- Coordinated by the European Institute for Energy Research in Germany
- Funded under H2020-TRANSPORT
- cordis.europa.eu/project/id/736122
- Project website: cosmhyc.eu
- bit.ly/37m5rBz

Novel fuel cell technology eases industry transition towards hydrogen-powered fleets

The CH2P project brings about a new technology for hydrogen refuelling stations, capable of cogenerating hydrogen, heat and electricity from natural gas and biomethane. The device combines high efficiencies with low environmental impact and high hydrogen purity.

We won't see all fossil fuel stations being replaced by electric vehicle (EV) charging stations tomorrow, let alone by hydrogen ones. The transition will be progressive, and in the case of fuel cell electric vehicles (FCEVs), so will the technologies being implemented.

The CH2P (Cogeneration of Hydrogen and Power using solid oxide based system fed by methane rich gas) project was born out of the realisation that green hydrogen from renewables is variable by nature and will sometimes require a backup from other sources. The project therefore aimed to come up with a transition technology: a system generating hydrogen from carbon-lean natural gas or biomethane.

CH2P's solid oxide fuel cell (SOFC) is akin to a combined heat and power system. It uses high-quality heat from the fuel cell to generate hydrogen. A prototype is being prepared for testing at the Shell Technology Centre in Amsterdam, the Netherlands. We find out more from Luigi Crema, CH2P's coordinator.

EVs seem to be the priority of car manufacturers and refuelling networks right now. How do you explain the lack of interest in FCEVs?

Luigi Crema: This is a valid observation from an external perspective, and is probably due to the current state of development of hydrogen refuelling networks and infrastructure. But the situation is rapidly changing in several EU countries. In Germany, for example, 80 hydrogen refuelling stations (HRSs) have been built in a plan to create a network of 1 000 HRSs by 2030.

It must also be said that interest in FCEVs is growing with the consolidation of programmes introducing recharging stations for battery electric vehicles (BEVs). Although the BEV has been in development for a longer time, I see two important factors that will contribute to increasing the interest in FCEVs over the coming years. First, there is a growing interest from the heavy-duty transport sector in FCE trucks, rail convoys and ships. Here, hydrogen

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is perceived as the optimal solution for long-distance vehicles. Second, there is growing evidence that we can't count only on the electric grid to support all future energy consumption. We rather need sectorial integration to reach a net-zero emitting society by 2050. There are several relevant applications where molecules (hydrogen) have advantages over electrons (batteries or cables). My opinion is that we need both to reach the European Commission's targets for 2050.

How does a project like CH2P ease the transition towards FCEVs' wider adoption?

CH2P is an innovative HRS system. It can support early transport infrastructure deployment for the uptake of FCEVs.

The CH2P system cogenerates hydrogen, heat and power using solid oxide cell technology fuelled by methane-rich gases. It reduces carbon footprint by achieving an extremely high overall system efficiency – close to 80 %. The system generates both hydrogen and electricity

with lower environmental impact than conventional technologies. It could very well be applied to all alternative fuels listed by the European Directive DAFI for a single, multi-fuel station.

What exactly makes this system so innovative? Can you elaborate?

There are several innovations introduced by CH2P. The first is the reforming of methane combined with the flexible use of a solid oxide fuel cell. This flexibility perfectly meets end users' refuelling needs. Meanwhile, the cogeneration of a variable portion of hydrogen, heat and power optimises economic value and carbon footprint and makes for a very efficient solution.

There is also the core of the fuel cell: we are working on an innovative balance of plant (BoP) wrapped around both the hot and cold parts. We put a lot of efforts into the optimisation of the overall layout. This covers an efficient purification system in the form of a pressure swing adsorber (PSA) together with a pressurisation step by a hydrogen compressor.

How close are you to meeting your objectives?

We have validated all building blocks of the final system and minimised the risks of failures through in-depth simulation process. We have analysed the overall technology layout, as well as the design of the control and safety system for the first prototype. This has been done by means of laboratory and factory testing, checking behaviour and validating individual component performance. The activity has been supported by all partners, including Shell.

What were the main difficulties you faced and how did you overcome them?

We accumulated some delay during the activities, compensated by the good results obtained. The CH2P technology is a breakthrough rather than an incremental innovation for solid oxide cells. The design and validation of the different parts of the technology were complex, and it was challenging to accommodate our targets with the constraints of single components.

In the end, we exceeded our initial expectations by building a solution able to match flexibility in use and energy generation with high performances and low cost. This was not foreseen at the beginning of the project for the basic technology blocks, but it progressively became the value proposition of the CH2P system.

Luigi Crema,
CH2P project coordinator
© Luigi Crema

> *"We exceeded our initial expectations by building a solution able to match flexibility in use and energy generation with high performances and low cost."*

What do you still need to achieve before the end of the project?

We are now preparing for the testing of the full 20 kgH2/day prototype at HyGear in Arnhem (the Netherlands). It will be followed by the integration of a second module to conduct pilot testing at the Shell Technology Centre in Amsterdam. The CH2P system will then be connected to a local hydrogen refuelling infrastructure.

At the end of the CH2P project, we will have the complete life cycle analysis (LCA) performed by Vertech to assess the environmental footprint, carbon emission and cost impacts. But the story doesn't end there. We received a second grant which covers the reversible use of the same technology, enabling the inverse electrolysis mode coupled with the use of renewables.

The new SWITCH project will extend the scope of the CH2P system by developing a new solution that can generate mostly green hydrogen (from renewables in electrolysis mode) that is always secured (in CH2P operation, from methane-rich mixtures). This is a prerequisite to grant a service of use while maximising the use of renewable energy.

CH2P

- Coordinated by the Bruno Kessler Foundation in Italy
- Funded under H2020-ENERGY
- cordis.europa.eu/project/id/735692
- Project website: ch2p.eu

FOOD AND NATURAL RESOURCES

Europe's walnut woods get the productive forest therapy

Walnut trees are part of our landscape and history, and a source of richness for many rural areas, but, being slow growing, they are unattractive investments. The EU-funded WOODnat project has worked to counter the threat posed by faster developing, often foreign species to Europe's forests.

Europe has vast forests and most are part of associated industries that need to be competitive to survive in a globalised world. WOODnat (Second generation of planted hardwood forests in the EU) researchers have modified procedures all along the walnut value chain, from young plants to already dried timber, to nurture European forests for productive landscape.

FROM STUMPS TO MUSHROOMS

"Thanks to the project, it has been possible to test better walnut plants, more profitable forestry models, innovative tools for managing both the logs and the timber, and new final products," outlines Elias Cueto, head of the coordinating company, Seistag Innovación.

Improved performance of the walnut plant for timber production started with selection of walnut clones with superior qualities. Lifelong research by Ricardo Licea, head of the Biotechnology Department at consortium member Bosques Naturales, Spain, has bred a fast-growing walnut plant with high survival rates and straight logs with high-quality timber.

Thanks to the collaboration with Industrial Plants from Bulgaria, production of this new super walnut tree has moved outside the lab. "After all, growing the actual tree takes production closer to the market," Cueto emphasises.

Collaboration with CREA, an Italian public research body and also part of the consortium, proved the feasibility of combining fast- and slow-growing species. "This improves profit from the plantation due to intermediate returns," Cueto explains.

Thanks to the project, it has been possible to test better walnut plants, more profitable forestry models, innovative tools for managing both the logs and the timber, and new final products.

Stump removal after harvesting of trees is expensive and unsustainable. Spanish partner company ECM Ingeniería Ambiental developed a biological process that produces edible mushrooms on the degrading stump.

CHANGING THE COLOUR OF NATURALLY PALE WALNUT

Regarding technical tools, two Spanish companies have achieved results. An app provides information and brings transparency to the forest business, and solutions were developed by Asimov Efficiency for handling timber and veneer.

The project has also enabled innovative manufacturing procedures to overcome the specific challenges of the European walnut. One restriction is the small diameter of logs; to overcome this limitation, WOODnat developed boards of mixed species.

Naturally rather pale in colour, walnut wood normally commands less in the market, darker being associated with hardwoods like mahogany. In addition to the traditional technique of vaporising, WOODnat partners have developed two methods for darkening timber: using chemical dye and digital printing. A recent publication in Annals of Silvicultural Research (ASR) describes the process involving digital printing. The darkening procedure can also be seen on video.

THE FUTURE WALNUT FOREST

"Research at the cutting edge of available knowledge was possible thanks to the support provided by CREA, and also thanks to the fact that walnut is a species with much added value." Cueto envisages the next step should be to extend these methodologies to other species, with lower prices but much bigger impact on the European economy and landscape.

A special issue of ASR anticipated soon will be dedicated to the main topics of the WOODnat project: plant production, forest models, mushroom cultivation and timber transformation. "This is also a tribute to Gaetano Castro and his family, a CREA researcher who contributed to the project despite illness which finally caused his death at the end of 2019," concludes Cueto.

WOODNAT

- Coordinated by Seistag Innovación SL in Spain
- Funded under H2020-FOOD
- cordis.europa.eu/project/id/728086
- Project website: bit.ly/2zIGUdK
- bit.ly/3dywcVQ

FOOD AND NATURAL RESOURCES

Quinoa, a key to unlock saline soil production

Soils are becoming more saline due to an increase in unsustainable irrigation practices in response to climate change. This situation is further exacerbated by the need to feed a growing population and a shortage of suitable agricultural lands because of competing land and water uses for human consumption and non-food crops production.

Most plants, and particularly agricultural cash crops, cannot survive on saline soil. Fortunately, halophytes are a group of plants that not only thrive in salt concentrations that are damaging for most other flowering plants, but often also have a combined tolerance to other stresses as their habitats are frequently prone to flooding, drought and high temperature.

The EU-funded HALO (Understanding Halophytes for an Agriculture Worth its Salt) project studied quinoa

(*Chenopodium quinoa*), a halophytic crop species from Peru, to try to understand how plants adapt to saline environments. "We were interested in the specialised, unique hair-like (trichome) external structures called epidermal bladder cells where excess salt is sequestered away from the sensitive sites in the leaves," says Marie Skłodowska-Curie research fellow Nadia Bazihizina.

AN UNEXPECTED DISCOVERY

One important question facing researchers was how salt sequestration occurs in bladders. "As stalk cells are the key intracellular ion controllers between the epidermal and bladder cells, we characterised key ion fluxes (chloride (Cl-), potassium (K+) and sodium (Na+)) and used comparative transcriptomics to shed light on the transporter genes involved in ion transport in these cells. We also investigated if epidermal salt bladders alone define salt tolerance in quinoa or if other key traits in the plant should be considered," Bazihizina explains.

When researchers characterised the transporters involved in salt movement in the bladders, they unexpectedly found that quinoa transports a lot of Cl- (an important ion in saline soil that has been previously overlooked in saline studies), even more than Na+. Understanding how the transporters control the sequestration outside metabolically active plant tissues can be used by plant breeders to select lines expressing these transporters in species closely related to halophytes (crops like spinach, sugar beet, chard). They can also express them in homologous epidermal trichomes of traditional cereal crops.

© Nadia Bazihizina

SIGNIFICANT BENEFITS

HALO will therefore provide fundamental knowledge of how plants work in saline environments, helping to explain how salt is transported into the bladders, and potentially deliver new traits to target in breeding programmes. Furthermore, understanding how epidermal bladder cells influence the overall salt tolerance of quinoa will help scientists gain insights into greater crop yield gains under saline conditions.

With an increasingly unpredictable climate, these plants could ensure more stable yields and help to conserve our precious fresh water. However, currently, the importance of these issues, from the problem of salinity to the potential benefits of halophytes for society, is often underappreciated in the wider community – hence the importance of the HALO project and dissemination of its work and outcomes.

Working with salt-loving halophytes has the potential to be exceptionally rewarding. "They promise new insights into old problems and a whole set of new questions to help in our quest to use sustainably more marginal and saline resources, both soil and water, which would then reduce the pressure on the more limited 'good' resources used for human consumption," Bazihizina points out.

HALO

- Coordinated by the University of Florence in Italy
- Funded under H2020-MSCA-IF
- cordis.europa.eu/project/id/700001
- Project website: bazihizinanadia.wixsite.com/halo

> *"[Salt-loving halophytes] promise new insights into old problems and a whole set of new questions to help in our quest to use sustainably more marginal and saline resources."*

INDUSTRIAL TECHNOLOGIES

High-throughput laser for precise, cost-effective material processing

If manufacturing is to keep up with product innovation, it needs to take advantage of micromachining advances. HIPERDIAS has developed a 1 kW femtosecond laser offering cost-effectiveness, quality and precision.

Micromachining – precision engineering of micro components – holds out the promise for many industries of higher productivity at lower cost. Its adoption has been made easier by progress with ultrashort pulse (USP) laser and photonic technology. But challenges remain in cost-effectively combining high precision with yield/productivity, with high quality.

The HIPERDIAS (HIgh throughPut LasER processing of DIamond and Silicon) project was set up to demonstrate USP laser-based material processing at unprecedented (high-throughput) levels of productivity, precision and quality.

EU support enabled the project to integrate all the necessary components into a stable, flexible and versatile machine base for a high-power femtosecond laser and to develop a 1 kW demonstrator system, tested and validated by end users.

Using the technology, the project surpassed the desired ablation rate for silicon processing and achieved the majority of key performance indicators for the fine cutting of metals and diamond polishing.

A HIGHLY ADVANCED PROCESSING SYSTEM

The goal is to have a high productivity rate without losing precision, along with high quality without compromising speed. This requires a femtosecond laser with very high average power and well-adapted beam parameters. The laser needs to cater for pulse duration, pulse energy, intensity profile and polarisation, and provide a flexible beam delivery.

The beam has to be applied to the workpiece in a well-defined, application-specific manner which permits it to be split by a diffractive element, or moved rapidly by

a scanner or ultrafast modulators. The latter is necessary to avoid heat accumulation which degrades processing quality.

To achieve this, the HIPERDIAS project combined a high-power, ultrafast, laser system Master Oscillator Power Amplifier (MOPA) with a well-adapted processing machine for diamond processing, 3D silicon structuring and fine cutting of metals.

The system was tested for three target applications and found it was faster than the current state of the art: it both processed 3D silicon and polished synthetic diamonds 50-60 times more quickly and finely cut metal 20-25 times faster.

FOR MULTIPLE APPLICATIONS

The results of HIPERDIAS can be adopted by all the sectors where laser technology can enhance product quality, while affording cost benefits and new production solutions.

"The HIPERDIAS system will have a two-fold impact: creating leadership in this exciting field and so strengthening Europe's companies, while also reducing the cost of many everyday items, such as mobile phone screens, for consumers," says Marwan Abdou-Ahmed, project coordinator.

The technology can be applied to a range of applications including microelectromechanical system devices, pico-projectors and medical devices.

It will also be useful to various industries for micro-machining of transparent materials, drilling of nuzzles, and large-area surface structuring for super water-repellent applications. From watchmaking to aeronautics and automotive manufacturing, the HIPERDIAS project has developed a system that could make manufacturing more efficient.

There are also many scientific applications, such as spectroscopy and proton therapy, that could benefit from scaling the technology to higher energy and peak power.

The team envisage having a 1 kW class femtosecond industrial laser system available within 3 to 5 years.

"HIPERDIAS has paved the way to make this technology possible, but to be faster and able to withstand the higher powers required, the system needs further development. For example, we need to fine-tune various components such as fibre beam delivery and scanners," concludes Abdou-Ahmed.

HIPERDIAS

- Coordinated by the University of Stuttgart in Germany
- Funded under H2020-LEIT-ICT
- cordis.europa.eu/project/id/687880
- bit.ly/2Xwutuz

INDUSTRIAL TECHNOLOGIES

Turning beer waste into eco-friendly knives and forks

The FriendlyKnife project is developing a process that could turn brewers' spent grain into fully eco-friendly cutlery – perhaps proving that drinking may be good for the environment.

Many of us have already used eco-friendly cutlery: whether it's single-use bamboo or wooden knives and forks or recyclable plastic spoons and the like, these objects have become the preferred choice for various food outlets all over Europe.

Some of the single-use solutions available on the market still contain polylactic acid (PLA) and crystallised polylactic acid (CPLA) – compounds that require the use of industrial composting facilities to ensure they are biodegradable.

Enter the EU-supported FriendlyKnife (How to get rid of plastic cutlery? Biodegradable products made out of beer waste) project, whose aim is to use beer waste to produce cutlery that is fully biodegradable and compostable.

As project coordinator (and FriendlyKnife board member) Joanna Krajewska puts it: "We want to develop a product that can literally decompose in your garden."

STRANGE BREW

When beer is brewed, one of the key residues produced is brewers' spent grain (BSG), which constitutes approximately 85% of the total by-products of the brewing industry.

FriendlyKnife's goal is to use BSG as the basis for creating a mixture that could then be used to produce single-use cutlery items.

At first glance, the production process behind the mixture looks straightforward: spent grains are wet, so they are pressed under very high pressure before being mixed with other (natural) ingredients to produce a unique mixture that is then moulded.

"Naturally, the devil is in the detail," Krajewska explains. "We have to find the correct shape for the mixture and make sure the production process is adapted to it in order to create the items we have in mind."

BEER COASTERS AND BEYOND

So far, the project has achieved the goals it had set under the Phase 1 stage, namely creating several mixtures and selecting (after proper testing) the one best adapted for future cutlery production.

FriendlyKnife has prepared samples that have been tested to check how they behave in terms of fragility, flexibility and strength, and is now close to being able to produce beer coasters. This is an essential first step towards producing fully fledged cutlery items as well as plates and cups further on down the line.

When beer is brewed, one of the key residues produced is **brewers' spent grain**, which constitutes approximately **85% of the total by-products of the brewing industry**

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Producing cutlery is tricky however and often requires the addition of PLA and/or CPLA to be completed successfully. But Krajewska is confident her team will be able to manufacture cutlery items without any addition of PLA or with the smallest amount possible to create a genuinely eco-friendly product.

Though the goal of producing these more elaborate items is ambitious, FriendlyKnife has already attracted the attention and support of major beer producers.

"They confirmed that our idea fits perfectly with their market needs," Krajewska says. "Our next aim is to further perfect the production process while fine-tuning the design of our products."

WHAT IS BREWING FOR THE FUTURE?

The products now need to be tested in real conditions. The next phase in the project aims to further refine the production process, making it even more attractive to stakeholders.

Krajewska and her team are also keen not to forget what she calls the 'final link' in the chain of users – meaning you and me. "We also plan to conduct some tests 'on humans' further down the line," she concludes.

FRIENDLYKNIFE

- Coordinated by FriendlyKnife Sp. z o.o. in Poland
- Funded under H2020-Societal Challenges, H2020-SME and H2020-LEIT
- cordis.europa.eu/project/id/868340
- Project website: friendlyknife.com/en/our-technology

LIFE AFTER...

Catching up with CerAMfacturing: New and truly innovative ceramic additive manufacturing technologies edge closer to the market

In our May 2019 edition, we introduced you to the CerAMfacturing project that had developed a completely new approach for ceramic multi-material additive manufacturing. More than a year later, we have a fresh conversation with the project's former coordinator, Tassilo Moritz, to find out how they've fared in pushing their technology onto the market.

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The big promise of ceramic additive manufacturing (AM) is previously impossible but absolutely precise geometry for a range of components, allowing for the easy and efficient manufacturing of a range of components, from personalised jewellery to surgical instruments. The CerAMfacturing (Development of ceramic and multi material components by additive manufacturing methods for personalized medical products) project lay the groundwork for showing the numerous opportunities of AM techniques, but the ambition was always to move to wider commercialisation.

Continued collaboration, with new and old partners

"When we first spoke, we had filed two patent applications," Moritz comments. "So far the IP rights have not yet been awarded, but we have our fingers crossed that they will be soon. However, for all three methods that we focused on in CerAMfacturing, we've attained milestones that have definitely led to marketable devices," Moritz adds.

The further continued efforts on refining the CerAMfacturing devices have taken place in nationally funded development projects and alongside direct industrial collaboration with other European partners who were not previously a part of the EU-funded consortium.

Highlighting further positive developments

Looking at individual success stories, CerAMfacturing's Dutch consortium partner, Admatec, which developed the project's Digital Light Processing (DLP) device, has since developed a software update that allows their device to handle multiple parts, with unique parameter sets, in one print job, allowing for multiple different settings within the same layer, saving time and thus being more efficient.

Meanwhile, the Austrian consortium partner, HAGE, has finalised a print head for the CerAM fused filament fabrication (FFF) process in their device with an innovative belt-driven filament supply, thus allowing for the use of brittle particle-filled filament for the AM of ceramics or metallic components.

The third CerAMfacturing machine, focused on thermoplastic 3D printing (T3DP), and developed by Moritz's own organisation, Fraunhofer IKTS, has also been further improved for a much higher precision in droplet positioning and repeatability. "Up to three different materials can be applied in one building process," Moritz says. "And indeed, we plan to commercialise this machine and publicly present it – coronavirus allowing – in Autumn 2020."

All nine CerAMfacturing participants were able to expand their experience in their own specialised AM fields. "Thus, the machine developers within the consortium were able to improve their devices by applying specific knowledge gathered within the project and, most importantly, carry it forward," concludes Moritz. "CerAMfacturing was truly a great springboard for advancing this innovative technology further."

CERAMFACTURING

- Coordinated by the Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Germany
- Funded under H2020-LEIT-ADVMANU
- cordis.europa.eu/project/id/678503
- Project website: ceramfacturing.eu/index.php?id=3

Tassilo Moritz,
former CerAMfacturing project coordinator
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"Indeed, we plan to commercialise this machine and publicly present it – coronavirus allowing – in Autumn 2020."

DIGITAL ECONOMY

Radical glasses blend eye tracking with augmented and mixed reality display features

Eye tracking technology measures eye activity to better understand sight, perception, reaction and emotions. An EU initiative introduced a system combining eye tracking with mixed and augmented reality for a more immersive user experience. The glasses work under uncontrolled, real-life settings.

The impact of augmented and mixed reality technologies is still fairly limited because of one common flaw: they don't react to natural human gaze behaviour. Eye tracking (ET) technology can bridge the gap between humans and technology, providing complete bidirectional communication with the environment and leading to much smarter user interactions.

IMMERSING USERS INTO A COMPLETE DIGITAL LOOP

"Seamlessly connecting humans into the digital loop via smart wearables is a global challenge that will transform the market," says Frank Linsenmaier, coordinator of the EU-funded Digital Iris (Bringing the human being into the

© Viewpointsystem

> *Digital Iris is the first wearable technology combining ET with an extended reality display element.*

digital loop) project. Market interest in making biometric data accessible for wearable technologies is extremely high. "This disruptive leap forward would occur once a robust, reliable and certified head-wearable system became available."

The Digital Iris project team at Vienna-based Viewpointsystem developed the mobile Eye Hyper Tracking (EHT) system consisting of sophisticated smart glasses with eye camera sensors for eye movement recognition and a front camera for visual field observation and recognition. The glasses are connected to a portable minicomputer that records, compresses and stores data, allowing video live streaming to laptops and tablets where a software solution exploits the data's full potential. They are extremely lightweight, can be worn for hours and work in nearly all lighting conditions. While other systems require the wearer to constantly shift their eyes by jumping back and forth between digital information and real life, the glasses display information in the line of sight where it can easily be processed.

INTUITIVE HUMAN-MACHINE INTERFACE

The technology combines ET and mixed reality to recognise the need for information via the interface of the eyes and to constantly provide the right information in front of the eyes. The system is modular; the very precise ET glasses can be extended with a mixed reality click-on placed in front of the glasses. "Based on eye movements and pupil reactions, human needs and sensations, orientation in space, and also stress and fatigue, become digitally recognisable," explains Linsenmaier. In addition, users can interact with the elements displayed by simply using their eyes instead of hands or voice.

Eye gestures and hands-free operation make the system highly practical for all professional applications, especially those in manufacturing, security, mobility and transport, retail and logistics. Customers can improve the quality of work, share newly acquired knowledge and reduce costs. "The solution will be a game changer for the workplace," continues Linsenmaier.

The system's robustness is a key factor in ensuring that the wearer gets the best possible user experience under realistic situations like changing light conditions. "According to customers, lack of robustness is the main weakness of competing products," adds Linsenmaier. "Our glasses have the same user-friendliness as normal glasses, the wearer feels completely comfortable with the system."

At the 2019 CES Innovation Awards, the VPS 19, the first smart glasses prototype incorporating the technology, was an Honoree under the wearable technologies category. The product will soon go into volume production and be market-ready during 2020. Project partners are targeting the European and North American markets. "Digital Iris is the first wearable technology combining ET with an extended reality display element," concludes Linsenmaier.

DIGITAL IRIS

- Coordinated by Viewpointsystem GMBH in Austria
- Funded under H2020-LEIT-ICT and H2020-SME
- cordis.europa.eu/project/id/804549
- Project website: viewpointsystem.com/en/eu-program

Mobile app revolutionises in-store shopping and checkout experience

Can you imagine checking out a full shopping cart in under a minute using only a smartphone? An EU initiative has introduced a new concept in self-checkout systems that reduces checkout time while enhancing the overall customer shopping experience.

For consumers, one of the most common complaints in retail shops is queueing times at checkout lines. Shorter perceived waiting times improve service experience, customer loyalty and market share. Shoppers who need to wait more than 5 minutes at checkout will try shopping elsewhere. This results in high costs and lost profit for retailers around the world.

LOVE SHOPPING, HATE QUEUES

The EU-funded YouBeep (InStore mobile shopping and analytics) project developed a mobile shopping and checkout solution that reduces checkout times and improves the shopping experience of customers. "We help retailers worldwide to digitise their customers' shopping experience by providing an ultramodern and attractive shopping journey while getting to know their shopping habits and interests," says João Rodrigues, CEO of project coordinator Xhockware, a Portuguese start-up that develops innovative retail solutions. "We successfully tackle one of the biggest complaints and friction points in physical retail: queueing and waiting time at checkout."

The YouBeep team designed a mobile app enabling shoppers to scan products directly from shelves with their smartphones. They scan the check-in QR code at the entrance, and scan product barcodes before placing them in the cart. When finished, they can go to any available counter and scan the checkout QR code. The whole process can be completed in less than 60 seconds. Furthermore, reducing the checkout time to 30 seconds leads to operational savings.

Among the many benefits, app users can create, manage and share shopping or wish lists. They can add loyalty cards, have access to points, rewards and savings, and get personalised coupons from retailers and brands. E-receipts organised by shop and time means never losing track of purchase history. "YouBeep allows customers to take full control of their shopping journey by scanning, price checking, list creating, voucher/coupon redeeming, loyalty card validating and finally, paying for their purchase," notes Rodrigues.

DIRECT COMMUNICATION CHANNEL BETWEEN RETAILER AND SHOPPER

The patented plug-in device is compatible with every existing manned or self-checkout system in the world, with zero point of sale (POS) software integration. Checked-out items are processed at or by the external unit. After validation, these items are forwarded to the retailer's POS system that completes the payment process, as well as all loyalty aspects of the sale. This means that billing and accounting are handled by the retailer, ensuring total transparency and full compatibility with all work processes and procedures in place.

By closely observing some similar underlying needs, the project team decided to add a new product/service to

> *YouBeep allows customers to take full control of their shopping journey by scanning, price checking, list creating, voucher/coupon redeeming, loyalty card validating and finally, paying for their purchase.*

its umbrella that wasn't initially foreseen. "We manufactured and designed custom smart self-checkout units that allow retailers to gradually move into a full scan&go mobile reality without creating a user technology gap between a traditional and advanced shopping reality," explains Rodrigues.

Xhockware is planning a full roll-out of the solution with two major European retailers over the next 18 months. "We will deploy the same implementation roadmap across this one particular target group around the world and position ourselves as a global provider of such a solution," concludes Rodrigues.

YOUBEEP

- Coordinated by Xhockware SA in Portugal
- Funded under H2020-LEIT-ICT and H2020-SME
- cordis.europa.eu/project/id/739408
- Project website: youbeep.com
- bit.ly/308V2rA

DIGITAL ECONOMY

New personalised apps and games help make learning to read fun

A team of game designers, researchers and educators are working together to develop a range of personalised learning applications and teaching tools to help primary school children learn to read.

With nearly 800 million illiterate people in the world, illiteracy is a global problem – and one that's not limited to developing countries. In England, for example, 25 % of young adults have poor literacy (compared to an average of 9 % in the top-performing European countries).

Because literacy is a critical skill that impacts one's educational attainment, social integration and employment opportunities, finding new ways to teach reading and writing is of paramount importance. With increasing evidence suggesting that technology can be used to foster literacy, the EU-funded iRead (Infrastructure and integrated tools for personalized learning of reading skill) project has developed a portfolio of personalised learning applications and teaching tools to help primary school children learn to read.

"We are a team of interaction and game designers, educational researchers and industry partners from different

sectors working together to develop tailored technology that supports primary school children in becoming confident and skilled readers," says Mina Vasalou, an associate professor at UCL and iRead project coordinator. "Through partnerships with schools, we are supporting teachers in six European countries to implement new ways of teaching with personalised technology."

AN AWARD-WINNING GAME

At the heart of the project is the design and evaluation of personalised classroom applications that support the development of reading skills in primary school students. One of these applications is Navigo, a collection of over 4 000 games that help a student practise a specific language skill through different activities. Each game is designed to mirror the types of games children play at home, and each offers elaborative feedback and motivation.

"The Navigo game is the flagship app of the iRead project," notes Antonios Symvonis, a researcher at the National Technical University of Athens and the project's technical coordinator. "The game received a Serious Games Society award in 2018 and 2019, and the UK Department of Education awarded Navigo a quality mark for its pedagogical design."

Available in English, German, Greek and Spanish, the game covers the first 3 to 4 years of the primary curriculum. Designed to cater to younger students and older, struggling readers, it also includes materials to teach children learning English as a foreign language.

800 million:
number of **illiterates**
in the world

> *It has been encouraging to see the strong commitment and enthusiasm on the part of the teachers and students using and learning with our apps.*

In addition to Navigo, the project produced an e-Reader Amigo, an innovative text recommendation system, and a personalised e-book. The team is currently engaging with EdTech SMEs to encourage the future use of the linguistic resources underpinning the project's apps.

A BIG IMPACT AT SCHOOLS

The iRead apps are already being used by over 4 000 primary school students. "Through this project, we are learning how our apps and resources can help teachers engage students in learning to read," adds Vasalou. "It has been encouraging to see the strong commitment and enthusiasm on the part of the teachers and students using and learning with our apps."

According to Vasalou, the project team is looking for opportunities to commercialise the more mature technologies. "The project allowed us to learn important lessons about the cross-cutting opportunities and barriers regarding digital learning, all of which is fundamental to the future development of our tools," she explains. "With our school pilots now underway, we will soon have a better understanding of the micro-, meso- and macro-level factors that foster or inhibit technology adoption in schools across a diversity of education contexts."

IREAD

- Coordinated by University College London in the United Kingdom
- Funded under H2020-LEIT-ICT
- cordis.europa.eu/project/id/731724
- Project website: iread-project.eu
- bit.ly/33alaRh
- bit.ly/2Q9puMq

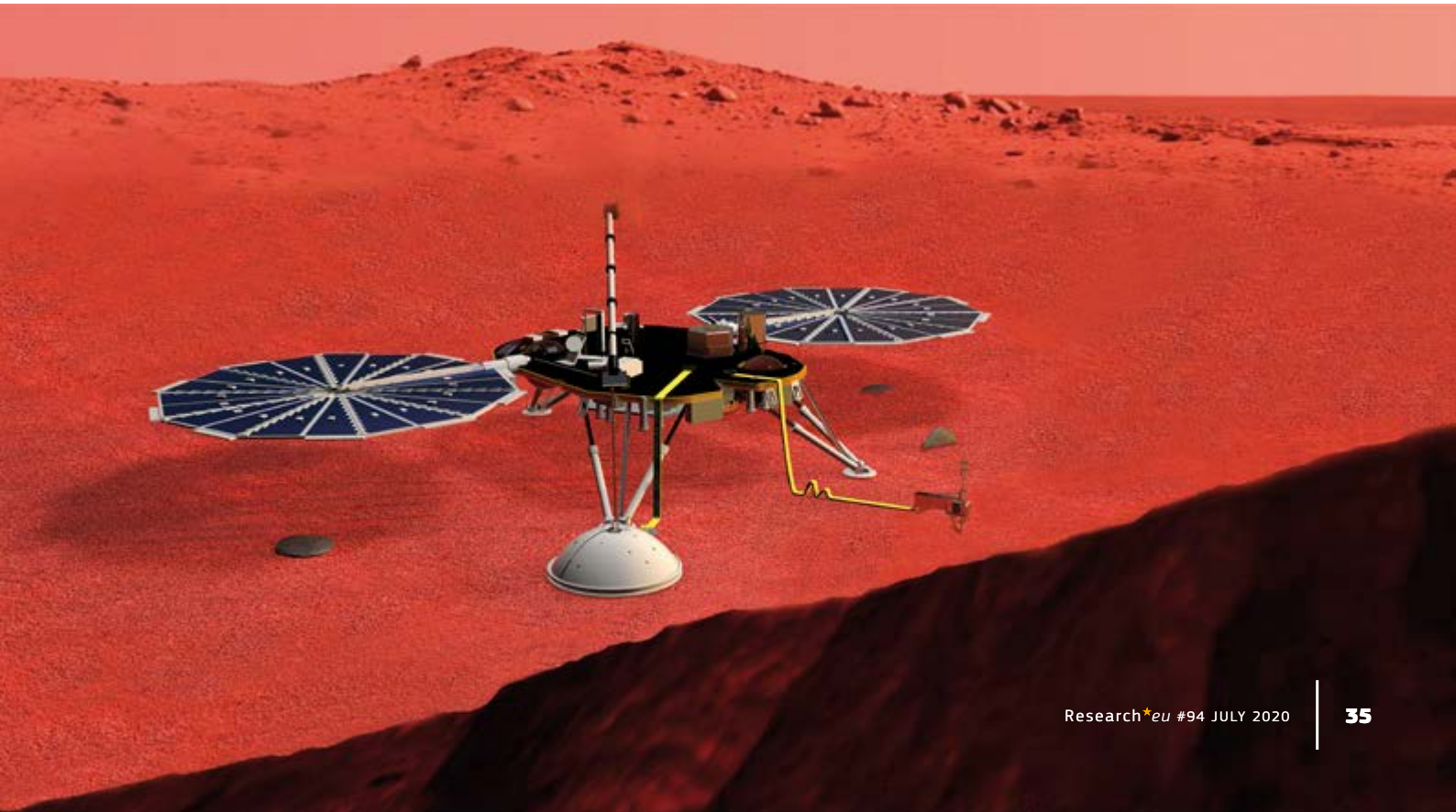
SPACE

Geological and geophysical investigations on Mars's subsurface ready to reveal tantalising clues about rocky planet formation

InSight, the first robotic lander designed to study the deep interior of Mars has finished its first full year, making history in a slew of scientific firsts. Detailed geological information collected by EU-funded scientists has been crucial to interpreting the seismic activity recorded by the lander's supersensitive instrument.

In November 2018, the InSight lander screamed through the Martian atmosphere and set down safely on a flat smooth expanse of lava called Elysium Planitia. The mission seeks to uncover how a rocky body forms and evolves to become a planet by investigating the interior structure and composition of the Red Planet. Previous missions to Mars have investigated the surface history by examining features such as canyons, volcanoes, rocks and soil. So far, little has been known about what's going on a couple of kilometres below the surface.

"Mars's interior structure bears the record of how the planet evolved differently from Earth over time. This information can also be used to predict the composition



of rocky exoplanets that are believed to have Mars-like internal properties," points out Lu Pan, coordinator of the GeoInSight (Geological constraints on the crustal structure at InSight landing site, Elysium Planitia, Mars) research project undertaken with the support of the Marie Skłodowska-Curie programme.

INSIGHT INTO THE RED PLANET'S INNER WORKINGS

Mars's new robotic resident is the first robotic explorer using cutting-edge instruments that delve deep beneath its surface for detailed studies of the planet's interior. So far, the supersensitive seismometer suite has detected many vibration events, more than 300 of which are confirmed 'marsquakes' of up to magnitude 3-4 based on a scale developed by Mars seismologists.

Seismic waves produced by a quake move like rays of light – they get trapped, reflected and refracted in different directions. Different materials interact with the waves in different ways, resulting in complicated waveforms. "Using spectroscopy data on the Martian surface helps determine the type and composition of rocks and estimate how deep the rocks lie beneath the lander. This information could potentially explain some characteristics of the seismic waveforms recorded by InSight's seismometer," explains Pan.

The GeoInSight researchers believe that the first few kilometres of the crust are likely to host structurally complex regions. They found crust structures made up of interbedded sedimentary deposits beneath the lava flows close to the landing site. "These heterogeneities in the Martian crust may create a low-velocity zone or increase the scattering of the seismic waves, alter the seismic waveforms and complicate the interpretation of the seismic data collected by the lander's instrument," adds Pan.

While scientists are thrilled about the detected motions underground, they wish the marsquakes were stronger. Over the course of the mission, they expect to record many more, some as powerful as 5 or 6 in magnitude that would provide plenty of energy for revealing details of Mars's mysterious core.

> *"Mars's interior structure bears the record of how the planet evolved differently from Earth over time. This information can also be used to predict the composition of rocky exoplanets that are believed to have Mars-like internal properties."*

SPECTRAL SIGNATURES OF THE LANDING SITE

Spectroscopy has played a crucial role in Mars exploration missions, including confirmation of the presence of various hydrated minerals on the Martian surface. As in this expedition, the GeoInSight researchers used the Compact Reconnaissance Imaging Spectrometer for Mars – a visible-infrared spectrometer aboard a satellite that has been orbiting the planet since 2006. Analysis of the orbital spectral data on more than 90 shortwave-infrared spectral images, and further processes to reduce noise and artefacts, helped researchers reveal more about the type of minerals and rocks on Mars's surface.

Insight's mission cannot be regarded as only a Mars mission, but rather an entire solar system mission. GeoInSight's reported findings and future geophysical data will help reveal clues about rocky planet formation, especially why Venus, Earth and Mars had different fates in the course of planetary evolution.

GEOINSIGHT

- Coordinated by Claude Bernard University Lyon 1 in France
- Funded under H2020-MSCA-IF
- cordis.europa.eu/project/id/751164
- Project website: bit.ly/2USjry4

Modelling and simulations shed new light on the high-density matter of neutron star cores

Resulting from the explosion of massive stars called supernovae, neutron stars provide the opportunity to study the behaviour of matter under extreme conditions – at much higher pressures and densities than those available in any lab. An EU initiative offered insight into the physics governing these little-understood states of matter.

These states of matter have extremely strong magnetic fields, and host both superfluids and superconductors. In particular, the density in their cores is so high that exotic states of matter are likely to appear. "The possible states are still not understood theoretically, so neutron stars provide stable sources that we can observe to learn more about the physics at extreme densities," says Yuri Cavecchi, a Marie Skłodowska-Curie fellow who led the EU-funded Burst3D (Type I bursts in 3D) project.

Neutron stars in binary systems display extremely bright X-ray flashes known as type I bursts. When matter from the companion star lands on the neutron star because of the strong gravity, it is compressed to extremely high pressure and effectively explodes, emitting bright X-ray flashes. "The time evolution of the intensity of these flashes contains information about the core of the neutron star due to the effects of general relativity," Cavecchi explains. "However, we need to be able to model the evolution of the burning and the temperature of the surface in order to fully unravel the information we seek."

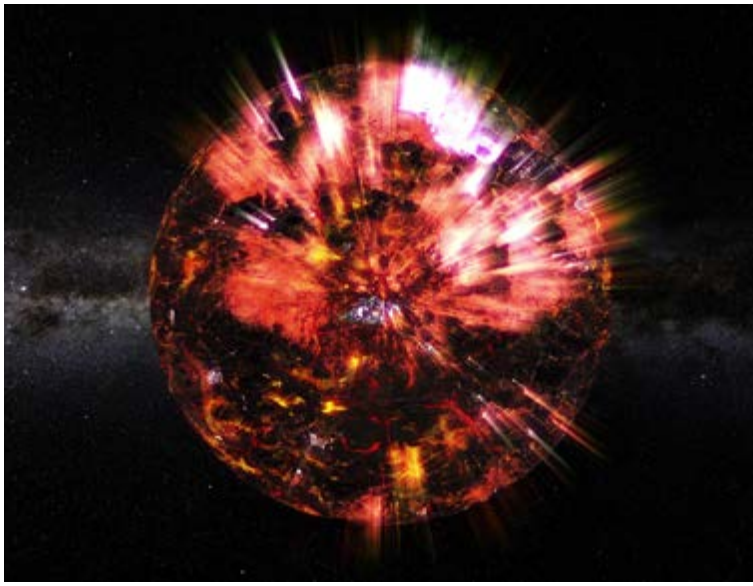
UNPRECEDENTED SIMULATIONS DURING BURSTS

The researchers ran computer simulations of the type I bursts that take place on neutron stars. The most important achievement of the simulations relates to the role of instabilities at the front of the burning flame. "As the flame propagates across the surface, strong winds develop at the front where hot and cold fluids are in contact," observes Cavecchi. "This configuration is highly unstable and breaks the front into separate, smaller vortices, similar to hurricanes of fire."

There are two net effects, according to Cavecchi: "First, these vortices move ahead of the flame front, leading to a much faster propagation that can explain the fast rise of the burst flashes. Second, these same vortices provide an emission pattern that's asymmetric and could potentially explain features observed in the time evolution of the flash intensity that are key to understanding the nature of matter in the neutron stars' core." The vortices may be the direct source of those features, or may instigate waves in the burning ocean that lead to these signatures.

RECONCILING THEORY AND OBSERVATIONS

Analyses showed how to reconcile the theory of nuclear burning with the observed frequency of ignition of the



> *Burst3D provided answers to open questions on burst phenomenology, opening the way to the exploitation of X-ray observations in studying the behaviour of ultra-dense matter in neutron star cores.*

type I bursts, and how to connect observations to burning parameters. "From an observational point of view, different sources challenged our theoretical understanding of nuclear burning and ignition," notes Cavecchi. "Counter-intuitively, while more and more matter accumulates on the surface, some of these sources display less and less frequent burst explosions." The analytical calculations included the effects of different conditions on the star surface and the role of mixing new material with the ashes of previous bursts.

"Burst3D provided answers to open questions on burst phenomenology, opening the way to the exploitation of X-ray observations in studying the behaviour of ultra-dense matter in neutron star cores," concludes Nils Andersson, project coordinator and professor of Applied Mathematics at the University of Southampton.

BURST3D

- Coordinated by the University of Southampton in the United Kingdom
- Funded under H2020-MSCA-IF
- cordis.europa.eu/project/id/703916

SPACE

The search for life on Mars begins on Earth

Was there ever life on Mars? To find out, a UK-based geoscientist is studying ancient rocks from Earth's subsurface that resemble those found on Mars.

When it comes to uncovering the Earth's history, there's really nothing better than a good rock. Not only do rocks provide us with important information about our planet's changing geology, they sometimes even contain evidence of ancient life. They are also our best hope for answering one of the most compelling questions in science: was there ever life on Mars?

"Although we know that the Earth's subsurface contains a huge number of organisms, we don't know how this deep biosphere has changed over geological time or what kind of fossils it might have left in the rocks," points out Sean McMahon, a geoscientist at the University of Edinburgh's UK Centre for Astrobiology.

"This means we don't know how to look for evidence of deep subsurface life on Mars or other planets."

Through support from the Marie Skłodowska-Curie programme and EU funding for the D BIOME (Deep Biosignatures on Mars and Earth) project, McMahon has expanded his search for traces of ancient life in rocks from Earth that resemble those from Mars.

"This project aims to advance our understanding of microorganisms like bacteria living in pores and fractures deep beneath the surface of the Earth and, hypothetically, other planets," adds McMahon.

RECOGNISING FOSSILS IN EARTH ROCKS

Around the world, space programmes like the European Space Agency (ESA) are preparing robotic missions to search for fossils on Mars. However, for the vast majority of history, Mars has been extremely cold, dry, caustic and irradiated.

"The surface of early Mars was habitable, but conditions deteriorated more than 3 billion years ago, meaning if

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there was life after that it may have been sheltered deep underground where geothermal heat could keep water flowing," explains McMahon.

"It is far too expensive to dig kilometres into Mars, but we can look for fossils in minerals formed deep underground that later became exposed at the surface."

Hence the importance of being able to recognise and understand fossil microorganisms in rocks here on Earth. To advance this understanding, McMahon studied fossil material using microscopes and high-resolution analytical techniques.

He also conducted experiments to learn how bacteria become fossilised and calculations to estimate the biomass in subsurface environments over time.

"This work suggests that for most of Earth's history, the planet's biomass has been hidden away underground," notes McMahon. "We also opened the door to seeking fossil and chemical evidence for ancient subsurface life in certain mineral veins that have already been discovered on Mars."

ADVANCING SCIENCE'S SEARCH FOR SUBSURFACE LIFE

A somewhat unexpected outcome of the project was a showing of just how difficult it is to recognise deep subsurface fossils. This is because certain chemical reactions can produce tiny structures that look just like microfossils but in fact have nothing to do with life.

"Although this is certainly frustrating, in the end the cryptic nature of these materials is important information for astrobiology," explains McMahon. "For example, if we found them on Mars, we would not want to use them as evidence of life."

Despite these challenges, McMahon says he is proud to have worked with some of Europe's leading scientists to study the overlooked fossil record of underground habitats.

"The D BIOME project has advanced science's progress in its search for evidence of ancient subsurface life on Earth and Mars," he concludes.

"The D BIOME project has advanced science's progress in its search for evidence of ancient subsurface life on Earth and Mars."

D BIOME

- Coordinated by the University of Edinburgh in the United Kingdom
- Funded under H2020-MSCA-IF
- cordis.europa.eu/project/id/747877
- Project website: seanmcmahon.co.uk/d-biome

FUNDAMENTAL RESEARCH

A step closer to synthesis of a moving near-living crystal

An EU research team created artificial crystals doped with active particles. This design paves the way for a new generation of 'dynamic' materials that draw energy from their environment to sustain their own motion.

Biological systems display collective behaviours that are responsible for amazing feats and breathtaking patterns in nature. Schools of fish, colony formations of bacteria, or flocks of birds demonstrate an instant adaptive behaviour – a 'consensus' – between the individuals and self-organise into collective patterns despite their apparent individual randomness.

Examples of self-organisation are ubiquitous in nature, and the best way to understand something – such as life – is to build it yourself. The collective behaviour of swarms is easier to study in 'active' particles than in living matter. Recent experimental work has demonstrated how light prompts life-like, swimming micro-machines – synthetic particles – to move and then assemble in groups much like birds flock and move together in flight.

Despite progress in the field, studies have so far focused on colloids, suspensions of particles, within a fluid medium. "Little is known about how active particles behave in denser colloidal phases such as crystal and glassy structures. Active particles embedded in solid-like structures could serve as promising building blocks for the design of new dynamic, mobile materials," explains Ivo Buttinoni, coordinator of the EU-funded MicACol (Microrheology of two-dimensional active colloidal crystals and glasses) project.

WATCHING HOW JANUS BEADS SWIM IN CRYSTALS

The project demonstrated examples of 2D active lattices, exploring the critical forces that active particles must overcome to make the crystal structure mobile.

Converting energy into self-propulsion is particularly challenging on the micro- and the nanoscale. "While macroscopic objects use inertia to swim in a fluid, micro- and nanoparticles in water behave as if they were immersed in a tremendously viscous fluid such as honey or cornstarch, where inertia plays no role. To swim, colloidal particles need to break the so-called time-reversal symmetry, i.e. they must possess asymmetric properties," outlines Buttinoni.

Spherical particles whose surface has two distinct physical properties such as half-coated beads offer an ideal testbed for studying this symmetry violation. The two hemispheres of these Janus particles interact differently with the surrounding medium and establish local thermal or chemical gradients. MicACol researchers used a popular self-propulsion scheme that involves particles partially coated with platinum, and immersed them in a solution of water and hydrogen peroxide. The colloids were forced to self-propel due to the hydrogen peroxide being decomposed (catalysed) by the platinum-coated hemisphere.

In a first, the project demonstrated that the spherical particles exhibit long-range repulsive forces at the interface between the two liquids. "Self-propelled particles acted as if they were driven by an effective force proportional to their free-swimming velocity. We envisage that the same principle can be applied to more complex structures such as colloidal glasses," adds Buttinoni.

MOVING OUT OF EQUILIBRIUM

To date, most experiments add active particles like intruders in the lattice, occupying random positions away from the lattice points. MicACol's experiment took a different approach to studying the particle mechanics in the out-of-equilibrium regime. "Our aim was to pinpoint the critical forces required to move active particles out of their equilibrium lattice positions," explains Buttinoni. "Measuring the local (repulsive) forces offers an additional 'knob' for controlling microswimmer motion in the crystal. As a

> *Self-propelled particles acted as if they were driven by an effective force proportional to their free-swimming velocity. We envisage that the same principle can be applied to more complex structures such as colloidal glasses.*

result, we know which type of active particles we need to add to make the crystal structure actuate."

Researchers may still be far from synthesising solid artificial active matter, for example 3D dynamic/mobile materials. However, MicACol researchers have come off the usual beaten track, pushing the boundaries in the field.

MICACOL

- Coordinated by the University of Oxford in the United Kingdom
- Funded under H2020-MSCA-IF
- cordis.europa.eu/project/id/747029
- Project website: buttinoni.co.uk

FUNDAMENTAL RESEARCH

Looking into how complex eyes of lizards and snakes evolved

Snakes and lizards have amazingly flexible visual systems linked to the range of habitats they live in – from pitch-dark to dazzling desert sunshine. EU researchers have investigated their evolution.

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With greater variation in eye morphology and photoreceptors than all other vertebrates combined, lizards and snakes (squamates) show exceptional diversity. "My Marie Skłodowska-Curie (MSC) funding enabled me to investigate links between genome and eye structure variation in the visual systems of squamates," outlines Bruno Simoes, a fellow in the Evol-Eyes (Elaboration and degeneration of complex traits: The visual systems of lizards and snakes) project.

Taking a broader look at the evolution of complex traits in vertebrates, Simoes applied recently developed omics technologies as well as integrated molecular data to eye anatomy and physiology. Specifically, he addressed three lines of investigation: extent of flexibility in the genomic machinery underlying these highly diverse visual systems, their adaptation to ecological transitions, and whether a complex visual system can be regained following evolutionary loss.

GENETIC PATTERNS EMERGE THAT MIRROR ECOLOGICAL NICHES

"Some results are still being worked on and awaiting publication, and we are currently analysing huge amounts of genomic data," Simoes comments. However, he reports an emerging pattern during this project – the visual system of squamates is highly diverse, reflecting the high number of ecological niches occupied by this lineage.

Snakes and geckos that have undergone ecological transitions between nocturnality (active at night) and diurnality (day) have reshaped their visual systems losing vision genes. "However, following occupation of new ecological niches there were changes in the light sensitivity of visual pigments responsible for colour vision as well as changes in the cell composition of some snake retinae," Simoes adds. Interestingly, sea snakes also developed novel sensory abilities such as being able to detect light on their tails to avoid predation.

GENETICS AND EVOLUTION PERSIST DESPITE BORDERS AND FUNDING REQUIREMENTS

"Each Australian state has its own permits and some parks are co-managed with Aboriginal communities, making the process bureaucratic," the fellow relates. However, with the undying support of the host in Adelaide, local herpetologists, Aboriginal rangers, and Wildlife and Natural Parks departments, Simoes managed to secure all permits required for fieldwork.

"The project also became more expansive, and expensive, than initially expected!" However, small grants from the Environment Institute University of Adelaide and the awarding of a Discovery Grant from the Australian Research Council made sure the project was completed as well as significantly extended.

Evol-Eyes research was able to include lineages with huge ecological diversity, such as Australian skinks, some South American gymnophthalmid lizards and sea snakes. Moving forward, "we are currently integrating other methods such as *in situ* hybridisation, microscopy and computed tomography scanning to understand other aspects of visual evolution in squamates," he adds.

"Following occupation of new ecological niches there were changes in the light sensitivity of visual pigments responsible for colour vision as well as changes in the cell composition of some snake retinae."

Simoes emphasises that the MSC fellowship has a huge focus on making their fellows independent. "I acquired independence by writing successful grants, and supervising honours and PhD students as well as research assistants." Sorting fieldwork permits, experimental design and lab work as well as managing budgets and collaboration with an extensive network of scientists increased organisational skills.

Dissemination included valuable participation in some public engagement activities in schools as well as radio interviews and nature TV shows. He concludes on a very positive note: "Having reached some maturity in my research career as a result of this fellowship, I have since been appointed as a Lecturer at the University of Plymouth."

EVOL-EYES

- Coordinated by the University of Bristol in the United Kingdom
- Funded under H2020-MSCA-IF
- cordis.europa.eu/project/id/703438

RESULTS PACK ON ARTIFICIAL INTELLIGENCE & INDUSTRY

AI and advanced robotics are opening new horizons in all sectors of industry, by developing novel manufacturing techniques, as well as overhauling the interaction between human workers and automated tools. This CORDIS Results Pack presents 13 Horizon 2020 projects that are leading the way in embedding AI applications into industry.

Check out the pack here:
cordis.europa.eu/article/id/417992

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