Engineering and Physical Sciences Research Council

Resilience in research

Driving and developing real-world technologies

Foreword

The modern world relies on engineering, mathematics, ICT and the physical sciences to secure resilience to global challenges. Together they provide the backbone for all technological progress and are central to delivering the aspirations of the Government's Innovation Strategy and the Integrated Review.

EPSRC plays a central role in supporting the scientists and engineers who create the technologies that will enable the UK to continue to be at the forefront of preventing and mitigating natural and non-natural threats. To ensure compelling ideas become scalable solutions we fund adventurous research, develop skills, invest in scientific equipment, collaborate with industry, government agencies and the third sector, and create centres of excellence in which ideas and innovation can flourish.

With more than 75% of EPSRC's portfolio being relevant to the theme of resilience , we are helping the UK create the transformative technologies and systems of tomorrow, while ensuring that those same technologies can be used to tackle current natural and man-made challenges ranging from engineering a net zero economy and securing supply chains, through to scaling up vaccine manufacturing and realising robust and resilient decision-making through the use of AI and data science.

This means that when a crisis hits, the UK is ready to respond swiftly and effectively with knowledge and expertise, driving and developing the real-world technologies we need to tackle threats to the UK and globally. We need only look at the pivotal role played by EPSRC-supported scientists and innovators in tackling the coronavirus pandemic, such as in the astonishingly rapid design and manufacture of life-saving breathing aids, or the critical advice on air circulation that informed key government initiatives – for evidence of the effectiveness of our investments.

The scientists and engineers in this brochure are designing and developing exciting new systems and technologies that show it is possible to make our systems more resilient while supporting economic growth, preserving our natural resources, and improving our wellbeing.

It is essential that we continue to invest in a broad portfolio of high-risk engineering and physical sciences research and doctoral training – helping to turn innovative ideas into real-world future technologies, and ensuring that the UK remains a healthy, connected, productive and resilient nation.

Professor Dame Lynn Gladden
Executive Chair, EPSRC

76% **of EPSRC's portfolio being relevant to resilience investments**

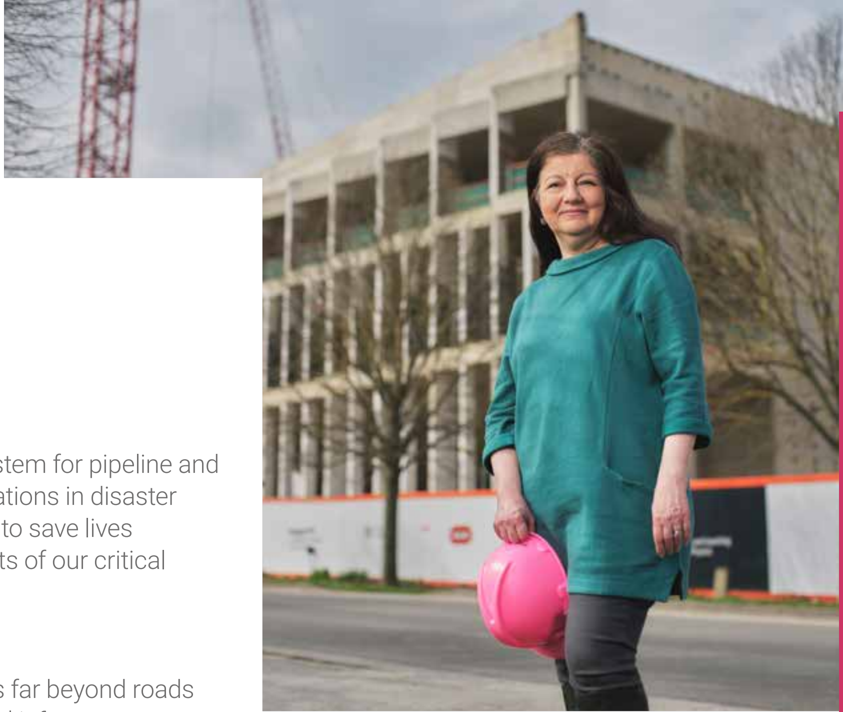
Ensuring Sustainable Resources For Future Generations

For the UK to meet its commitment to achieving net zero carbon emissions by 2050, it is essential that we move towards creating a circular economy in which we reuse, recycle, repair and refurbish our products and raw materials – from electronics and plastics to food and energy.

EPSRC is supporting the transition towards a circular economy through a host of research and training investments. These include greener, super-fast battery charging technologies (page 9); solar-powered buildings (page 10); energy policy advice (page 12) and a new research hub focusing on ways to prevent plastic pollution as it flows through the system (page 35).

We're also supporting remarkable research into the most unlikely of energy sources – urine. University of Bristol researchers have used fuel cells powered by microbes that convert our pee into sustainable energy to power electronic devices, appliances and lighting. The technology has already been deployed in one of the harshest environments known to man – the urinals at Glastonbury Festival (page 13).

Future-Proofing Our Infrastructure



In order for tomorrow's world to flourish, it is vital that we future-proof our infrastructure.

Physical infrastructure

Our physical infrastructure, such as roads and railways, requires constant monitoring and maintenance. But traditional solutions are falling short, particularly in terms of sustainability and longevity. Concrete, for example, accounts for eight per cent of global carbon emissions. To meet this challenge, EPSRC-supported researchers are creating low-carbon alternatives to cement using industrial waste (page 14). EPSRC-funded research at Loughborough University led to award-winning technology that 'listens' for earth movements.

Serving as an early warning system for pipeline and dam failure, with proven applications in disaster relief, the technology is helping to save lives and reducing maintenance costs of our critical underground utilities (page 16).

Data

The UK's infrastructure extends far beyond roads and railways and includes digital infrastructure such as 4G and 5G networks and the electricity grid. We're investing in the development of next-generation technology that can securely transmit vast amounts of data at a rate 100 times faster than current silicon chip-based systems (page 17).

Complex data can take a long time to process, let alone understand. Step forward Data2Text, a company created to commercialise EPSRC-funded research at the University of Aberdeen. The company's software can translate raw data into everyday text that anyone can read.

Devising Solutions to Universal Threats

We are our own worst enemies, responsible for some of the greatest threats ever faced – such as climate change. The relationship between nature and humans is inextricably linked to the emergence of zoonotic diseases.

Science and engineering have a pivotal role to play in tackling universal natural and unnatural threats such as these, and in responding to growing threats to our ever-more connected lifestyles. Cyberattack, for example, is estimated to cost the global economy an estimated $2.9 million per minute.

Cybersecurity

To help counter growing threats to our cybersecurity, EPSRC has invested in a wide range of research projects in areas such as data theft, computer viruses and malware, and secure communications networks (page 25).

We have also made long-term investments in dedicated cybersecurity centres such as the Centre for Secure Information Technologies (CSIT) at Queen's University Belfast.

With an enviable track record going back more than a decade, the award-winning centre's growing reputation has led to academic/industry partnerships with many of the world's leading high-tech companies, including Intel and IBM. For example, CSIT academics worked with BAE Systems to produce video-based 'semantic' analysis of crowd behaviour to improve the defence and security of the UK.

CSIT has also become a dynamic engine of local growth, launching 17 spin-out companies, attracting over 100 hi-tech companies to the area and creating more than 2,000 jobs.

Devising Solutions to Universal Threats (continued)

Healthcare for all

From the stethoscope to the MRI scanner, healthcare providers rely on technology to help them save lives. EPSRC's healthcare technologies portfolio covers the spectrum of human health and is firmly focused on next-generation solutions for today.

We recently invested £32 million in six exciting projects as part of our future healthcare programme. Projects include: developing robotic muscles to help stroke sufferers regain their strength; creating hearing aids that automatically adapt to the wearer's environment; and building airport-style scanners that can identify conditions such as cancers and osteoarthritis (page 28).

COVID-19

The COVID-19 pandemic has brought into sharp focus the importance of science and engineering in combating the deadly SARS-CoV-2 virus.

Projects to tackle the virus supported by rapid funding from EPSRC include the development of life-saving breathing devices (page 32); low-cost on-site tests; and, crucially, the development of a vaccine.

The EPSRC Future Vaccine Manufacturing Research Hub (Vax-Hub) was part of the combined effort that helped the UK to become one of the first countries in the world to develop a vaccine for COVID-19 (page 30).

Meanwhile, the fight against the virus continues, and EPSRC-supported researchers at the Imperial College London Vax-Hub are researching the role of booster jabs targeted at mutant strains of coronavirus.

EPSRC's role in delivering a Resilient Nation

Fundamental science ensures resilience in a crisis:

Long-term EPSRC-funded research in engineering, mathematical sciences, information & communications technologies and the physical sciences ensures that when a crisis hits, the UK is ready to respond swiftly, adapting fast and effectively with knowledge and expertise.

We address universal challenges that make the UK resilient:

EPSRC delivers the new ideas in engineering and physical sciences to drive the technologies to tackle global challenges, from ensuring a net zero economy and securing supply chains to scaling up the manufacturing of vaccines and developing the circular economy.

We protect and enhance everyday life:

EPSRC investments in research and training enable the new innovation and technologies needed to ensure a sustainable future from the circular economy of materials to manufacturing a green economy – meeting the needs of present and future generations.

In 2021:

55%

Percentage of research grants which are multidisciplinary

71%

Percentage of research grants which are multidisciplinary by value

Total portfolio by value

£5.4 billion

Leverage on portfolio from user organisations

£1.7 billion

5,203

Number of collaborating user organisations

Towards a net zero environment

Getting to net zero requires significant abatement of greenhouse gas emissions across all sectors of the economy. New systems and technologies are needed to sustainably power all aspects of everyday life, from heating our homes to powering cars.

Powering electric cars with faster charging batteries

Nyobolt, a company formed to commercialise research at the University of Cambridge, has secured over £7.5 million in funding to target the high-power and fast-charging battery market.

Co-founded by Professor Clare Grey who was supported through an EPSRC Programme Grant, Nyobolt has developed a proprietary process using niobium-based anode materials to create batteries that deliver record high power, have ultrafast charge times and are extremely durable. They can also be operated within a wide temperature range, which is not possible for many existing battery solutions. This presents a huge opportunity to supercharge the electric revolution.

Professor Grey says: *"Our EPSRC funding provided the support for the underpinning fundamental studies of Lithium-ion transport, structure and electrochemistry.*

"Ultimately, we have so much more to do in the field of batteries and if we can tackle fast charging that is addressing one small part of it – but it is a small part that has the potential for us to rethink how batteries are used in a variety of applications – both small and large."

Nyobolt will use the new funding to expand its operations globally and its materials development facility in Cambridge. The first product demonstrators are expected later this year.

Paving the way for self-sufficient buildings

in the UK almost
40%
of carbon emissions
come from the way our buildings are lit, heated and used

The SPECIFIC project has pioneered the development of 'Active Buildings' capable of capturing energy from the sun and using it to generate, store and release heat and electricity.

Buildings are energy-hungry, accounting for 39% of global CO_2 emissions. In the UK, almost 40% of energy consumption and carbon emissions come from the way our buildings are lit, heated and used.

Reducing the carbon footprint of buildings is therefore vital if we are to meet national and international net zero targets for reducing greenhouse emissions.

The solution is everywhere – sunlight. Every day the sun provides enough energy to power our planet for 27 years. So why not capture that energy with everyday buildings – using technologies that generate, store and release it?

This is the challenge being addressed by SPECIFIC (Sustainable Product Engineering Centre for Innovative Functional Industrial Coatings), an Innovation and Knowledge Centre based at Swansea University.

SPECIFIC was formed in 2011 through an initial £20 million investment from EPSRC, Innovate UK and the Welsh government. A key element of its mission is to create 'Active Buildings' that harness all the energy a building needs from sunlight, as well as provide occupants with low-carbon energy for transport and to supply the National Grid.

SPECIFIC's first Active Building, an off-grid demonstrator classroom, produced 1.5 times more energy than it consumed in its first year of operation. Electricity supply for the Active Classroom is generated by a steel roof with integrated solar cells, supplied by SPECIFIC spin out company BIPVco.

Paving the way for self-sufficient buildings (continued)

The success of the Active Classroom and other active buildings has led to a collaboration between SPECIFIC Neath, Port Talbot County Borough Council and a social housing developer to construct 16 Active Homes with solar roofs – the first development of social housing to use this design principle in the UK.

This work contributed to local authorities plans to introduce state-of-the-art design and energy efficiency technologies into thousands of homes across the Swansea Bay City Region area. It's hoped that this will kick start a construction programme with a projected investment of over £500 million when the concept is operational across the region.

Using £7 million in grants from EPSRC since 2011, and attracting over £40 million of funding from its original investors and partner organisations, the project has pioneered cutting-edge technologies including printed photovoltaics, thermo-electrics, electrical storage, thermal storage, industrial coatings and building energy systems.

SPECIFIC's Principal Investigator, Professor Dave Worsley, says: ***"Our active classroom, office, warehouse and homes have all proved successful and are an effective way of demonstrating the capabilities of the centre to industry and policymakers."***

The impact of the project also goes beyond the UK. For example, partner project and winner of *Times Higher Education's* International Collaboration of the year award, SUNRISE is bringing together industry and universities in the UK and India to develop low-cost solar technologies for rural Indian communities.

CREDS: Helping the NHS to be the first net zero national health service

Researchers from the UKRI-funded Centre for Research into Energy Demand Solutions (CREDS) are providing energy modelling, policy advice, and support on organisational change to build a solid evidence base and robust future plans to get the NHS to net zero greenhouse gas emissions by 2040.

Researchers at the centre, which is supported by EPSRC and ESRC, have been working with the Lancet Countdown team to peer-review the NHS's current method of calculating its greenhouse gas emissions.

The researchers, based at the UCL Energy Institute, worked with NHS operational and analytical teams, focusing on estates and facilities and transport.

Professor Paul Ruyssevelt, who provided support for estates and facilities team, explains: ***"We were able to federate data from the NHS Estate Return Information Collection, the UK government's Building Energy Efficiency Survey and our own 3DStock data platform to provide projections of future energy use and carbon emissions.***

"The cost-benefit analysis shows that overall the programme would have a net positive financial return, as well as many other benefits towards improved internal environments for staff and patients."

Looking forward, he suggests: ***"The development of a foundation digital twin based on 3DStock for the NHS estate has already enabled the automatic assessment of the potential for new technologies and in the future it could support the prioritisation of interventions and provide the means of monitoring and reporting on performance against the net zero target."***

Pee power – turning urine into off-grid electricity

Technology developed at the University of West England (UWE) which can directly convert urine into clean and sustainable electricity is being commercialised through a spin-out venture and is close to market readiness. The technology is based around microbial fuel cells (MFCs), which are fed with urine to produce electricity.

With around 38 billion litres of urine produced by humans and farm animals worldwide, urine-channelled fuel cells could eventually be used to produce large amounts of power, both in the developed and developing world.

The technology emerged from Ioannis Ieropoulos' EPSRC-funded PhD research project at UWE Bristol 17 years ago.

Known as PEE POWER®, the technology has already been successfully trialled in the urinals at Glastonbury Festival and introduced at schools in Africa with limited access to mains electricity.

Professor Ieropoulos, who has been Director of the Bristol BioEnergy Centre at UWE and now Head of the Water & Environmental Engineering Group at the University of Southampton, has received continued support from EPSRC, including a Career Acceleration Fellowship. The research has also been backed by the Bill & Melinda Gates Foundation and the EU.

Professor Ieropoulos says: ***"In less than 20 years, our development of this 100-year-old microbial fuel cell technology has advanced along the readiness scale to the point it's almost ready for the commercial world.***

"This means it can now begin to serve society and can be more widely deployed in more schools, more communities, more rural environments where it is needed the most."

Robial, a social enterprise, will advance the innovative PEE POWER® technology. Next steps include pursuing licensing agreements with multiple international commercial partners and bringing the technology closer to the public.

Safeguarding infrastructure

Alkali-activated cements can be manufactured at room temperature and could reduce the CO_2 emissions associated with the infrastructure sector by

40–80%

Traditional infrastructure solutions are falling short, particularly in terms of sustainability and longevity. EPSRC-supported researchers are creating low-carbon alternatives to help build the infrastructure of the future and to protect it from natural hazards.

Making concrete greener

EPSRC Early Career Fellow Professor Susan Bernal Lopez is developing low-carbon, sustainable alternatives to cement using industrial waste.

Concrete is the unsung hero of the modern world, forming the fabric of cities across the globe.

More than four billion tonnes of Portland cement – widely used to bind concrete – are produced each year. However, the concrete manufacturing process releases large amounts of CO_2, with almost one tonne of carbon dioxide released for every tonne of cement. Globally, concrete contributes to 8% of CO_2 emissions, and this is expected to rise over the next decade as the world's urban population grows.

Professor Bernal Lopez and her team at the University of Leeds are developing and studying low-carbon cements produced from industrial waste. Known as 'alkali-activated cements', the materials can be manufactured at room temperature and could reduce the CO_2 emissions associated with the infrastructure sector by 40-80%. The research is a transatlantic effort developed via an NSF-EPSRC grant.

Many waste products from industry, mining and agricultural processes have no current commercial value, but are widely available throughout the world. If successful, this would turn them into a valuable resource.

However, the performance of alkali-activated materials in the field is not yet fully proven. To make sure they are strong, durable and safe for use, Professor Bernal Lopez and her team subject their alkali-activated cements to rigorous tests in climate-controlled chambers capable of simulating marine environments and the extreme freeze-thaw action of very cold climates.

The team are also investigating the chemical reactions and physical processes that can cause cements to deteriorate.

2. Future-Proofing Our Infrastructure

They are looking in particular at the effect of adding natural cement replacements such as calcined clays and volcanic minerals to produce low-carbon concrete. The use of these natural materials as cement replacements is rising dramatically. However, there is concern that they could increase the vulnerability of concrete to carbonation, a process where CO_2 enters the material, leading to corrosion of the steel reinforcement in the concrete and changes in the structure of the cement itself.

This is critical, as CO_2 concentrations in air are now at their highest in human history, posing a threat to the durability of modern concretes.

"Concrete is like a sponge on the nanoscale: anything which enters the material will alter it," says Professor Bernal Lopez. *"A key challenge to engineers is that, as a result of climate change, it is not possible to predict how fast the climate will transform. This makes it difficult to replicate environmental conditions to predict how the material will behave."*

The ultimate goal of the research is to develop sustainable, low-carbon concretes able to withstand exposure to CO_2 without compromising on strength.

Professor Bernal Lopez is a member of the UKRI Interdisciplinary Circular Economy Centre for Mineral-Based Construction Materials, which aims to develop systems and technologies for more efficient use and recovery of mineral resources.

She is also Deputy Director of the EPSRC Transforming Foundation Industries Network+, which aims to improve sustainability in the UK's glass, ceramics, metals, paper, cement and bulk chemicals industries, which are worth £52 billion to the UK's economy but account for 10% of the UK's total CO_2 emissions.

2. Future-Proofing Our Infrastructure

Listening for landslides

Engineers from Loughborough University have developed an early warning system that listens for the acoustic emissions created by underground soil movements, and alerts those above ground that a landslide is imminent.

Landslides happen around the world and often have disastrous consequences, costing thousands of lives and damaging critical infrastructure.

Supported by two fellowships from EPSRC, Dr Alister Smith worked with Professor Neil Dixon to develop a landslide early warning system. The first version, Slope ALARMS, was developed with NERC's British Geological Survey and is used to monitor critical infrastructure.

The second, Community Slope SAFE, was developed in collaboration with Datalink Electronics, and is operated by local people in communities at risk of landslides.

The research has now been commercialised by Canadian firm RST Instruments, which has produced the Geo Acoustic Aware Slope Monitoring System.

"Traditional landslide early warning systems were prohibitively expensive or had technical limitations," says Dr Alister Smith.

"Our system 'hears' a landslide forming, and is useful for at-risk communities, as well as infrastructure owners and operators around the world."

The technology is remarkably simple but effective. A steel tube called a waveguide is driven into the slope in landslide risk zones. Inside its protective cover is a solar battery-powered sensor. If the slope moves, the soil in and around the tube generates high-frequency noises known as acoustic emissions. These are transmitted from within the slope, up through the tube and to the sensor, where the mechanical energy is converted into an electrical signal. If a threshold is exceeded, a warning is transmitted.

Community Slope SAFE has been trialled in several locations. For example, in a hilltop area of Kuala Lumpur with a history of slope failures first occurring in 2017.

In 2018, the system was installed in Chin state in Myanmar, where landslides had caused loss of life and damage to infrastructure. Twenty young volunteers were recruited through a local radio appeal, and were trained to install, operate and maintain the system.

"We initially focused on landslides, but now we're looking at the impact of ground movements on all sorts of critical infrastructure, from buried pipes to dams," says Smith.

"Using acoustic emissions to monitor the health of infrastructure is an entirely novel approach. This could transform how we monitor geotechnical assets."

Powering digital infrastructure

The UK is dependent on its digital infrastructure. EPSRC is investing in the development of next-generation technology for the transmission of vast amounts of data, and software that analyses it at ultra high speed to support a range of business applications and help solve real-world problems.

Humanising the way we interact with data

Arria NLG, a form of artificial intelligence that transforms structured data into natural language, has its roots in EPSRC-funded research at the University of Aberdeen.

The company's Natural Language Generation (NLG) technology, developed by Professor Ehud Reiter and Dr Yaji Sripada with sustained funding from EPSRC is transforming fields such as business intelligence, financial reporting, and automated journalism.

The technology analyses huge volumes of raw data, drawing out the most important trends and patterns, and within seconds presenting it in an easy-to-understand report tailored to a specific audience – work that would take many hours for a human to produce.

Developed in the early 2000s to show how NLG could create written weather reports based on student-generated meteorological data, the technology's potential inspired the Aberdeen researchers to form a spin-out company, Data2Text Limited, in 2009. This was then acquired by Arria NLG in 2013, with Reiter and Sripada remaining as chief scientists.

Arria NLG has since attracted a host of international clients across a wide spectrum of activity. For example, BBC News Labs used the Arria natural language generation tool to publish a local story for every licence fee payer on the night of the 2019 UK General Election.

In 2020, Arria NLG was integrated into Microsoft Excel, allowing Microsoft's 1.2 billion users to generate a narrative from data held in Excel spreadsheets. The software can turn tens of thousands of rows and columns in an Excel spreadsheet into a bullet-filled written report, pulling important insights to the surface.

2. Future-Proofing Our Infrastructure

Professor Reiter says: "NLG has gone from an obscure academic niche that no one in the commercial world was aware of to an established technology that people want and expect, and use in all kinds of context – from automatic journalism to business intelligence. It's been wonderful to see NLG accepted by the business world and used in so many ways."

With offices in Aberdeen, London, Auckland, Sydney and the USA, Arria NLG has raised over US$100 million in investments and employs over 100 people, including 47 in the UK.

The company has also been granted over 30 patents, most of which build on EPSRC-funded research conducted at the University of Aberdeen.

Arria NLG has raised over US$80 million in investments and employs over

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2. Future-Proofing Our Infrastructure

New approaches for data

A team of EPSRC-funded mathematicians, statisticians and computer scientists are driving the development and application of topological data analysis to improve existing data science techniques and solve real-world problems.

Data is everywhere; huge volumes of high-quality data are being generated every day, and the pace is accelerating. However, because data is often complex, high-dimensional and may include temporal and spatial information, extracting and interpreting it using standard machine learning or statistical techniques is not always easy or even possible.

A multidisciplinary team of mathematicians, statisticians and computer scientists is working on an EPSRC-funded research project that aims to improve the understanding, interpretation and application of data. The project is developing new mathematics and algorithms to explore the shape of data – the manner in which data falls into groups – and build on existing data science techniques.

Until recently, it has been difficult to do this, but advances in computation and algorithms have enabled topological data analysis – a field of mathematics that uses methods of topology and geometry to study shapes – to grow.

Heather Harrington, professor of mathematics at the University of Oxford and co-principal investigator of the research project, says: "People are generating such great data, but the data is ever-more complex and often noisy.

"We are working with scientists and practitioners in academia and industry to help them make sense of their data and unlock hidden patterns and insights. We are getting into the problems they are grappling with and helping them look at their systems in entirely new ways."

The research is being carried out at the Centre for Topological Data Analysis, an EPSRC-supported facility supporting a team of 50 experts working across sites in Oxford, Liverpool and Swansea.

Project partners include
GSK, GCHQ and Unilever

Although new, the centre is already investigating urgent, real-world problems, such as the COVID-19 pandemic.

Harrington said: ***"We have been involved in a large consortium of researchers and clinicians, looking at molecular data from COVID-19 patients. There are 17 different types of experiment measured for each patient, including gene expression, protein levels and immune cell populations. There is so much data and we are hoping to answer many questions; for example, can we identify molecular signatures that predict disease severity?"***

2. Future-Proofing Our Infrastructure

Biomedical science is one of the main areas of focus for the research team. They are currently using topological data analysis to study immune response, oesophageal cancer, and the growth of blood vessels near tumours, for example.

There is a small but rapidly growing community of people working in topological data analysis in the UK. Harrington hopes the project will enable that community to flourish and establish an international reputation.

Professor Harrington says: ***"We are extending the toolkit of data analysis and modelling techniques with topological data analysis. We believe these techniques will be enormously useful to the study of homogeneous data and complicated models, so the impact will reach scientific communities beyond the mathematical sciences."***

Boosting regional growth

CSconnnected delivered direct turnover of

£464 million in 2019

EPSRC plays a crucial role in supporting the scientists and engineers who make new technologies possible. Our investment in equipment, training and start-up support helps compelling ideas become scalable commercial solutions that drive future economic growth.

South Wales becomes world centre for compound semiconductors

A compound semiconductor (CS) is a material that partially conducts electricity made from two or more elements. Micro-chips manufactured from compound semiconductors can operate at much higher frequencies than silicon, operate at low voltage, can emit and sense light, generate microwaves, are magnetically sensitive and resistant to heat. They can store, transmit and detect data at a fraction of the energy used by current silicon-based products. All this means that compound semiconductors are set to revolutionise technology over the next decade, enabling a wide range of developments, from 5G to robotics and autonomous vehicles.

CSconnected is a cluster of advanced semiconductor-related activities in Wales. Through CSconnected, the UK will be at the heart of the CS revolution, which will establish South Wales as a vibrant, dynamic manufacturing economy. Bringing together leading-edge university researchers, high-tech companies and future-focused businesses, CSconnected spans and links the entire innovation chain – from blue skies research to market-ready products with real-world applications in fields as diverse as healthcare, digital communications, energy, clean transport and counter-terrorism. EPSRC and UKRI

2. Future-Proofing Our Infrastructure

are playing a pivotal role in this ground-breaking initiative. EPSRC support has:

- enabled the establishment of a CS Manufacturing Hub in Cardiff University, stimulating growth in the region and boosting jobs.
- set up a Centre for Doctoral Training in CS Manufacturing led by Cardiff University, helping to train the next generation of experts with the skills the UK needs to capitalise on this technological revolution.
- funded the acquisition of essential industrial equipment such as the new CS materials growth facility at Swansea University.

EPSRC is also supporting fundamental research in a range of application areas. By feeding the innovation pipeline, this work will enable CSconnected to maintain and sharpen its competitive edge in this rapidly growing field, and build on its status as the world's very first CS technology cluster.

Delivering direct turnover of £472 million and supporting 2,400 jobs in the region, CSconnected gained further momentum in June 2020 with the announcement that it would receive £25 million in support from UKRI's Strength in Places Fund as part of a major £43 million project.

Professor Wyn Meredith, chair of CSconnected: ***"EPSRC support is a critical component in maximising the cluster's credibility, performance and prospects, and in cementing the status of South Wales as a go-to location for CS and semiconductor innovation more broadly. The half-billion pound turnover already achieved by the cluster really is just the beginning.***

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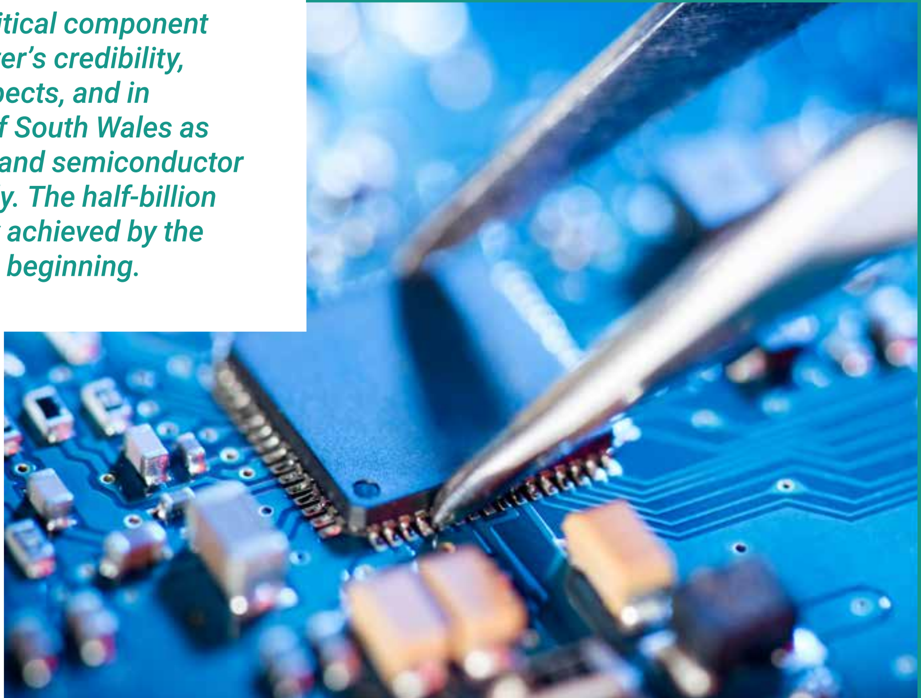

2. Future-Proofing Our Infrastructure

In the past two years, more than
£20 million
has been invested in companies that have emerged from the startup accelerator

Changing the world with ideas

Supported by an EPSRC Impact Acceleration Account, the Future Worlds startup accelerator is helping students and staff at the University of Southampton change the world with their ideas.

Universities are teeming with talent – students and staff doing groundbreaking research that could make a real difference in the world. Future Worlds, the on-campus startup accelerator at the University of Southampton, is helping individuals turn their research ideas into high-impact startups.

Ben Clark, who has previously held leadership roles in four startups and is now Director of Future Worlds, says: “There is an incredible wealth of talent coming through the doors of the university, talent that can make a real impact in the world.

“At Future Worlds, we believe that launching a startup can be an excellent vehicle for these talented individuals to maximise their impact, so we act as a catalyst, enabling them to achieve outcomes they might otherwise not have been able to achieve. It’s about unlocking people’s potential.”

Formed in 2015, Future Worlds has supported more than 500 aspiring entrepreneurs, with over 50 of them going on to launch successful startups and spin-outs. In the past two years, more than £20 million has been invested in companies that have emerged from the startup accelerator.

The Future Worlds project team works with EPSRC-funded researchers to help people studying and working at the university develop and launch their ideas. They do this through supporting them, mentoring them and connecting them with industry experts, partners and investors in the Future Worlds network. They also promote them on the world stage, such as at CES, an annual trade show organised by the Consumer Technology Association.

Although Future Worlds is based in the Faculty of Engineering and Physical Sciences, the initiative is open to members of the university community from all disciplines and at all levels – from undergraduates through to professors at later stages of their careers.

2. Future-Proofing Our Infrastructure

Throughout the academic year, Future Worlds hosts a series of events, workshops and talks to engage and inspire students and staff. Once a year, it runs a live Dragons' Den-style event, where the leading founders pitch their ideas to investors. More than half a million pounds of investment offers have been made live on stage over the last few years.

It was watching one of these events that inspired Dr Andrei Dragomir to approach Future Worlds about his research at the university. A physicist pioneering research into quantum physics, Dragomir has since founded the startup company Aquark Technologies.

Dragomir says: ***"Future Worlds has made the world of difference to me. I came out of the lab with no idea of how to think about a startup. The Future Worlds team showed me what it means, helping me make the transition from researcher to entrepreneur. They have kept me on track and given me the tools to work with.***

"I've been on the brink of quitting a lot of times, but they have been very good at shifting the focus back onto what I'm doing and why."

Building a resilient cyber secure future

CSIT works with global partners including **IBM, Thales and Direct Line**

We live in a world of escalating threats to our cybersecurity. EPSRC invests in research projects that create solutions to protect against these increasingly serious and sophisticated threats to the security of individuals and nations.

The Centre for Secure Information Technologies (CSIT) at the University of Belfast is helping to translate academic research into real-world solutions to cybercrime threats, boosting the safety and security of individuals and organisations worldwide.

Cybercrime is one of the world's fastest growing industries and costs the global economy an estimated $2.9 million per minute.

The resulting challenges are many, big and varied. They include:

- Safeguarding personal, business and government data from theft
- Protecting computer networks against intrusion
- Keeping mobile phones, tablets and other devices clean of malware
- Defending vital digital infrastructure against hostile attack

Based in the Titanic Quarter of Belfast, CSIT has forged its reputation by devising solutions to these increasingly serious and sophisticated threats. One of only seven UK Innovation and Knowledge Centres (IKCs) funded by EPSRC and the Technology Strategy Board (now Innovate UK), the centre helps commercialise its research findings into relevant, market-ready products and services.

"Over the last 20 years, effective cybersecurity has become one of society's critical needs," says Professor Máire O'Neill, CSIT's principal investigator.

"Here at QUB we recognised we had the skills and ambition to tackle this need head-on and, in doing so, boost economic renewal in Belfast and Northern Ireland."

3. Devising Solutions to Universal Threats

The centre has helped attract over 100 high-tech Foreign Direct Investment and startup companies that employ more than

2,000 people

A key part of the centre's success is its ability to foster collaboration between academics, industry and government. CSIT has formed long-standing advisory and industrial collaborations with global partners including BAE Systems, Cisco, Direct Line Group, IBM, Infosys, Intel, McAfee, Roke, Seagate and Thales.

So far, the flagship centre has helped attract over 100 high-tech Foreign Direct Investment and startup companies that together employ more than 2,000 people.

It has also led to the creation of a number of spin-out companies which are now developing technology in fields such as visual speech recognition, intrusion detection and automatic and intelligent image and video processing.

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world innovations in core sectors such as defence and security include a project with BAE Systems to produce video-based analysis of crowd behaviour.

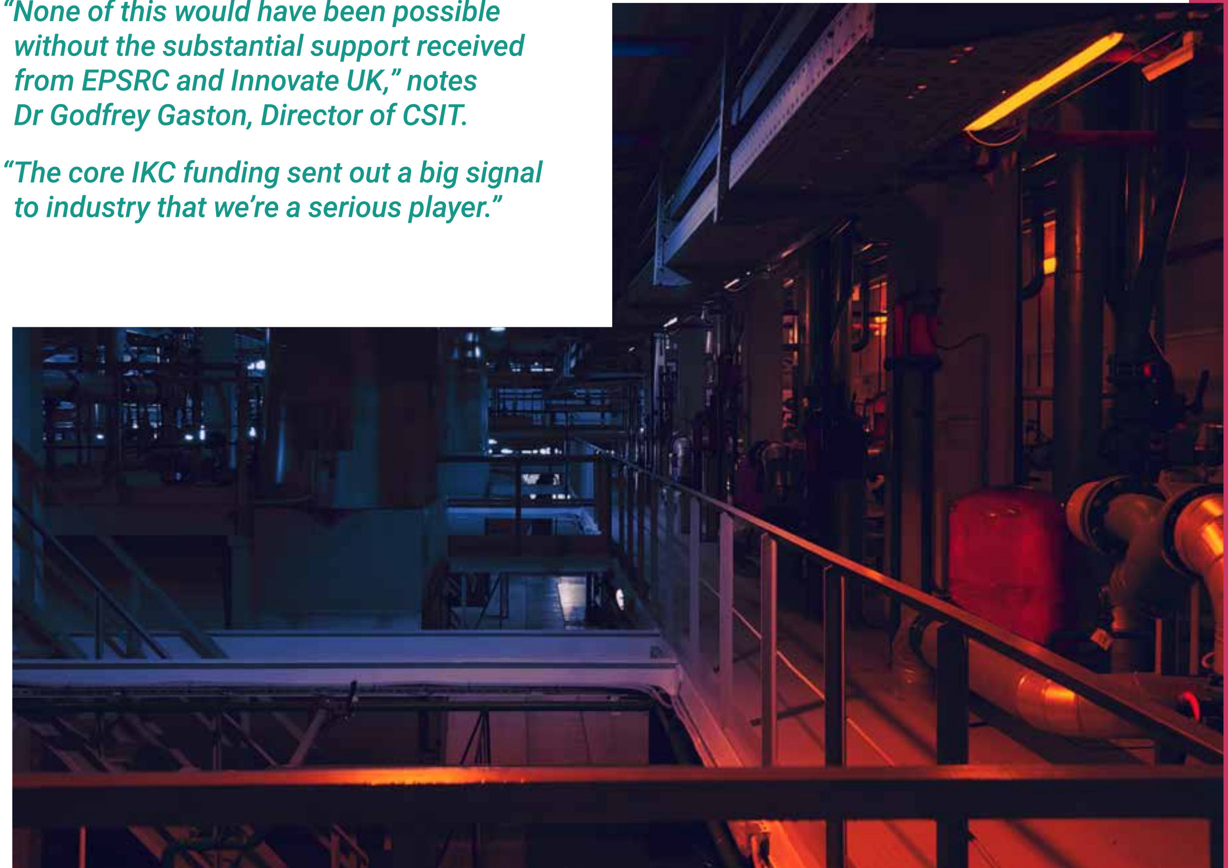
A collaboration with engineering experts TES Group, which provides specialist services to water and power industries worldwide, led to the discovery of a vulnerability affecting critical national infrastructure networks globally. As a result, the client developed a patch ensuring the vulnerability cannot be exploited by hackers.

Academics at the centre also developed new mechanisms for carrying out compliance regulations at one of the largest financial services companies in the world, and collaborated with American insurance company Allstate to help detect anomalous and fraudulent insurance claims.

CSIT is also a delivery partner for the London Office for Rapid Cybersecurity Advancement, providing mentoring to cybersecurity startups across the UK to help them break into domestic and world markets.

"None of this would have been possible without the substantial support received from EPSRC and Innovate UK," notes Dr Godfrey Gaston, Director of CSIT.

"The core IKC funding sent out a big signal to industry that we're a serious player."



Healthcare for the future

From the stethoscope to the MRI scanner, healthcare providers rely on technology to help them save lives. EPSRC's healthcare technologies portfolio covers the spectrum of human health, building the next generation of healthcare solutions that will benefit millions worldwide.

Imagine a world where cancer can be diagnosed simply by walking through a scanner, or where robotic muscles help stroke sufferers regain their strength. These are just some of the innovations being developed as part of a £32 million EPSRC investment which aims to transform care and treatments in the NHS by 2050.

The six projects will develop new technological approaches to healthcare that could become routine in the NHS, the community and care homes in the coming decades.

Professor Jonathan Rossiter at the University of Bristol is developing engineered robotic artificial muscles that can be used inside the body to restore strength and control in older people; it is also being developed for use by sufferers of trauma, stroke and degenerative diseases.

Professor Mark Bradley at The University of Edinburgh is using infrared lasers combined with computational optics and artificial intelligence to generate detailed 3D images of patients.

The technology could be used to develop handheld scanners for use on hospital wards and GP surgeries. By 2050, the aim is to scale-up to walk-through airport-style scanners capable of generating precise and detailed 3D images of structures usually hidden inside the human body, helping to identify and facilitate better treatment for conditions such as cancers and osteoarthritis.

At Imperial College London, Professor Dario Farina is pioneering the use of Non-Invasive Single Neuron Electrical Monitoring (NISNEM) to monitor the brain in ways never achieved before. The research could lead to new drug treatments for conditions like Parkinson's and Alzheimer's.

Meanwhile, at Edinburgh Napier University, Professor Amir Hussain is developing 'smart hearing aids. Most hearing aids make limited use of speech enhancement, so spoken words are still hard to distinguish. The COG-MHEAR project

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The COG-MHEAR project is developing hearing aids that can automatically adapt to the sounds and visual environment surrounding the wearer

is developing hearing aids that can automatically adapt to the sounds and visual environment surrounding the wearer, helping them distinguish and understand speech more clearly.

Professor Jon Cooper from the University of Glasgow is pioneering the use of remote technologies that can measure people's gait, movements, blood flow, heart rate and potentially even brain function. The sensors could provide feedback, advice and alerts to carers or health professionals, and could be used to help people recovering from illness or predict when someone may be about to have a heart attack or stroke.

The final project, U-care, led by Professor Robert Thomson at Heriot-Watt University, will exploit new laser, optical fibre and imaging technologies to deliver therapy without the use of antimicrobial treatments in targeted areas of the body. The platform will also deliver cellular precision resection in cancer surgery – aiming to offer a cure for currently un-operable tumours.

EPSRC plays major role in responding to COVID-19

COVID-19 has brought into sharp focus the importance of science and engineering in combating pandemics. EPSRC projects include the development of life-saving breathing devices, testing and vaccine development. These projects improve detection of the virus, the treatment of patients and ultimately the protection of populations.

EPSRC investment sped up the development of Britain's first COVID-19 vaccine, and gave doctors quick and timely access to life-saving treatments in the earliest days of the pandemic.

Vaccine development

EPSRC support enabled the UK to be one of the first countries in the world to develop a COVID vaccine, allowing its vaccination programme to be rolled out in record time. Now it is helping to develop a booster jab targeted to mutant strains of Coronavirus.

Usually vaccine development takes years, however Oxford University and AstraZeneca were able to begin human clinical trials for their successful vaccine just three months after the genetic sequence of the coronavirus was uncovered.

This was thanks to the work of the DHSC Future Vaccine Manufacturing Research Hub (Vax Hub), a collaboration between University College London and the Jenner Institute at the University of Oxford, which is administered by EPSRC.

When the pandemic arrived, researchers at Oxford had a head start, as Vax-Hub had already developed a delivery method – or 'platform' – for the vaccine and had been testing it for other diseases for almost ten years. Known as the ChAdOx1 viral vector technology, this platform was created by modifying a harmless adenovirus which causes the common cold in chimpanzees.

This meant that once the genetic sequence of the coronavirus was known, researchers were able to quickly produce a COVID-19 vaccine by combining

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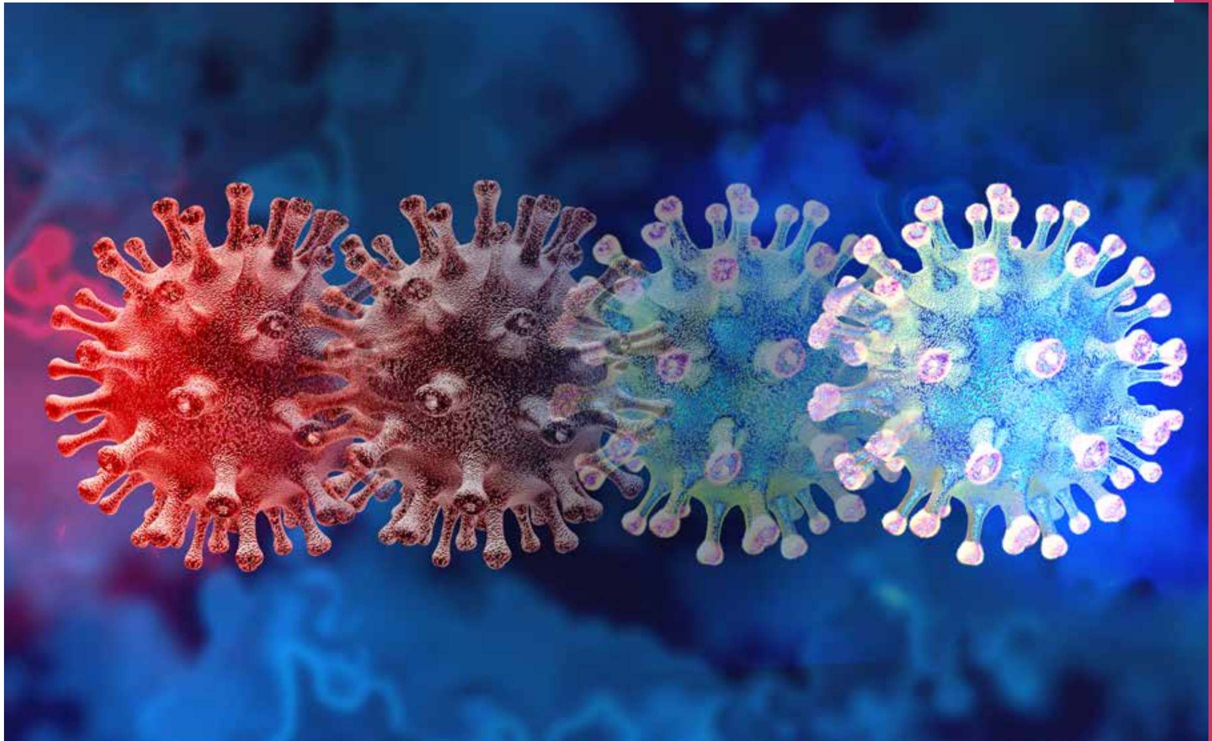
the vector with the genetic sequence for the Coronavirus spike protein. This head start allowed the scientists to move straight into animal testing in early 2020, and human clinical trials soon afterwards.

Vax-Hub is one of two hubs within the UK Vaccine Network, which was set up to facilitate the production of vaccines for infectious diseases with the potential to cause an epidemic.

The second – the Future Vaccine Manufacturing Research Hub – is based at Imperial College London and led by Professor Robin Shattock. The Hub was originally set up in 2018 to develop technologies to support vaccine manufacturing and delivery in low- and middle-income countries.



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The CPAP designs have been downloaded

2,000 times

across 105 countries

Oxygen Respiratory Support Therapy

In March 2020 the coronavirus pandemic began to spread around the globe. As hospitals and intensive wards filled up, doctors needed effective therapies and fast.

A breathing aid called a continuous positive airway pressure (CPAP) quickly emerged as a must have weapon in a clinician's arsenal. It works by pushing a mix of air and oxygen into the mouth and nose at a continuous pressure to keep airways open and increase the blood's oxygen levels. In other words, it helps patients breathe more easily, avoiding the need for a more invasive ventilator.

The problem was that CPAPs were in limited supply in the UK, and the huge global demand meant that it would take too long to procure enough. In addition, the unprecedented demand for oxygen supplies meant there was a risk that hospitals could run out.

To solve this problem, a team of mechanical engineers from University College London (UCL) joined forces with clinicians from UCL Hospital and Formula One engine manufacturer Mercedes-AMG High Performance Powertrains to reverse-engineer and redesign a CPAP that could deliver optimal benefits for patients, while reducing the oxygen required.

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The engineered CPAP gained regulatory approval in just 10 days – a process that can take years. Mercedes then began the process of manufacturing the devices, using 40 machines that normally produce F1 pistons and turbochargers. 10,000 CPAP devices were manufactured within four weeks, with 1,200 produced per day at one point.

The easy-to-use devices are being used in 130 NHS hospitals across the country, and are also saving the lives of patients in hospitals abroad in 29 other countries. For instance, over 500 devices have been manufactured for use in hospitals across Pakistan, while UCL-Ventura devices have also been supplied directly to Palestine and Uganda.

Findings have shown that approximately 50% of patients treated with CPAPs do not progress to needing invasive ventilation.

The UCL-Ventura team, co-led by Rebecca Shipley, an EPSRC-funded mathematician and professor of healthcare engineering at University College London (UCL) and Professor Tim Baker, an expert in mechanical engineering at UCL, also made the design and manufacturing instructions available for free to support the global response to COVID-19.

The designs have been downloaded 2,000 times across 105 countries, and the devices have been locally manufactured and in use in hospitals in Peru, Mexico, Pakistan, India, South Africa, Ecuador, Paraguay, Cuba, Iran, among other places.

Professor Rebecca Shipley (UCL Institute of Healthcare Engineering) said: ***"This huge global uptake of the UCL-Ventura CPAPs shows the clinical need for a simple, low-cost device that healthcare workers can be quickly trained to use. We are proud to have built collaborative partnerships with manufacturing and clinical teams across the globe, and will continue to support these efforts in every way we can."***

3. Devising Solutions to Universal Threats

Preventing the spread of COVID

Up until recently, scientists haven't known the extent to which Coronavirus spreads in enclosed trains and buses, and whether the virus is transmitted by particles in the air, from touching contaminated surfaces, or by being near an infected person.

A consortia of the universities of Leeds, Manchester and Cambridge, Newcastle University and Imperial College London, plus the UK Health Security Agency, the Defence Science and Technology Laboratory, and Department for Transport worked on a project to understand the risk of COVID-19 transmission on public transport and identify the best measures to control it. The findings are being used by policymakers to make transport systems as safe as possible, helping people get back to work and kick starting the UK economy. The project has been extended for another 18 months from April 2022 to take the results into longer term transport resilience planning, with a further £1.7 million funding across the consortia.

The £1.7 million EPSRC-funded Transport Risk Assessment for COVID Knowledge (TRACK) project is led by Professor Cath Noakes, a world-renowned expert in airborne viral transmission, and one of two engineers on the Scientific Advisory Group for Emergencies (SAGE).

The project involves conducting fieldwork on buses and trains in London, Leeds and Newcastle, and analysing the movement and behaviour of people as they pass through transport systems, including where they sit or stand, what surfaces they touch, how close they are to other travellers and for how long.

The researchers are using their results to develop detailed simulations of the way the virus can potentially spread, creating models to quantify the level of risk faced by passengers and transport staff. This will help government and transport operators decide if additional mitigation measures are needed, particularly when passenger numbers begin to return to the levels seen prior to the pandemic.

"This research is plugging a knowledge gap. It is allowing transport operators to identify the most important risks, and devise ways they can further reduce the risks of passengers getting COVID-19," says Professor Cath Noakes.

The researchers are also measuring the effectiveness of strategies such as increasing ventilation as well as new interventions such as anti-viral coatings on high-touch surfaces used on buses and trains, and cleaning compounds.

Securing a circular economy

EPSRC is supporting research and training that enable the transition towards a circular economy through interventions to reuse, recycle, repair and refurbish resources to minimise the creation of waste, pollution and carbon emissions.

The Exeter Multidisciplinary Plastics Research Hub (ExeMPLaR) is working with local businesses to find new solutions to plastic waste.

Plastic pollution, particularly from single-use plastics, is one of the world's most urgent environmental issues.

The Exeter Multidisciplinary Plastics Research Hub (ExeMPLaR), funded by EPSRC through UKRI's Plastics Research Innovation Fund (PRIF), is devising real-world solutions to plastic pollution.

Harnessing the expertise of academics from a wide range of disciplines, together with industry leaders, public bodies, businesses and the public sector, the hub is developing a 'regional circular plastics economy' in the South West of England aimed at ensuring that plastics never become waste or pollution.

ExeMPLaR co-lead, Professor Tamara Galloway, says: ***"Plastics are fantastic materials with myriad uses in modern society; what we need to do is find better, more sustainable ways of using them.***

"The idea behind ExeMPLaR is to use the South West as a kind of pilot study to see how plastic flows through the system, and see what works best at preventing waste. If we can see what works on a regional scale, that gives us an idea of how to scale up to a national scale.

"Our results show that the majority of plastic waste is domestic, and most of this goes to landfill. Preventing this from happening will make the biggest difference, and is what we have started doing."

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One way to achieve this is to stem the flow at source, and ExeMPLaR is working with local businesses to help them make their plastic products more sustainable. For example, Professor Galloway and her team worked with Materiom, a company that provides recipes for making biodegradable plastics out of waste materials.

She says: ***"We worked with Materiom to assess the nature of the biodegradable plastics they make, to see how they break down in the environment, and to see what impact they could have on human health. We have been encouraged to find that the plastics have extremely low toxicity compared to other materials."***

Elsewhere in the centre, Dr Xiaoyu Yan has developed a carbon life cycle assessment tool to assess the benefits of different interventions aimed at reducing plastic pollution.

The tool showed that, in Cornwall, glass bottles have double the carbon footprint of plastic ones. This demonstrates how important it is to consider the specific waste infrastructure and management practices in place to avoid just shifting the problem elsewhere.

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