ENZ

Engineering Net Zero

#EPSRC_ENZ

Building a net zero future

UKRI Engineering and Physical Sciences Research Council

Building a net zero future

Foreword

Visionary ideas and transformative technologies are at the heart of what we do at the Engineering and Physical Sciences Research Council (EPSRC). These foundations of innovations improve our economy and society. In partnership with our key stakeholders and supported through co-investment by industry, EPSRC-supported research and innovation delivers against both national and global priorities to create a more sustainable, resilient and prosperous world. EPSRC works in collaboration across UKRI to connect and catalyse research, skills and innovation across the landscape.

Following COP26, there has never been a more critical time to support the research and innovation endeavour which will catalyse our progress towards the UK and global net zero ambitions. During the last 50 years, EPSRC-supported researchers have been pioneers in developing transformative technologies and informed policies which have shaped and facilitated our adaptation to and mitigation of the most extreme effects of global climate change to date. From supporting the development of lithium-ion batteries which are essential to the global electrical vehicle revolution, to creating the world's most efficient and powerful perovskite solar cell technology that puts the power in consumers hands, EPSRC-funded work is helping to drive a transformation in the energy system. But EPSRC reaches beyond, undertaking multidisciplinary and collaborative activities to consider how a combination of behavioural change, efficiency improvements, and the circular economy will be essential in supporting the transition to a secure and affordable, net zero society.

EPSRC has ensured that the UK is home to world-leading green businesses and attracts investment from major global players. EPSRC investments have led to the creation of over 1,000 companies still active in the UK that are exploiting our technology breakthroughs, with almost 100 spin-outs directly linked to net zero initiatives including world-leading businesses such as CERES power and Bramble energy.

As greenhouse gas emissions continue to increase, and the global economy recovers from the COVID-19 pandemic, it has never been more essential to support a green economic revolution. This will only be enabled through supporting world-leading research capabilities across the whole of the engineering and physical sciences remit, delivering the skills and training to create a green work force and continuing to support multidisciplinary research across UKRI. Collectively we can engineer our net zero future.

Dr Kedar Pandya
EPSRC Director, Cross-Council Programmes

Introduction

Leading the way in understanding and adapting to climate change

For decades UK research supported by EPSRC has helped the world understand the risk and challenges we face from the climate emergency. Now, researchers funded by EPSRC are providing the solutions to these myriad challenges – from advising governments on how best to respond, through to creating the technologies we will require to reach net zero carbon emissions and limit the damage climate change will cause to global society.

The net zero technologies of tomorrow are being built on fundamental research spanning decades, in diverse areas such as data and AI, manufacturing, advanced materials, energy efficiency and more. This brochure highlights just a few of the many climate solutions researchers are developing, which have benefitted from EPSRC investments.

We still have a long way to go to avoid the worst impacts of climate change, but world-leading research and innovation are taking us one step closer to a healthier, more sustainable, and resilient world.

Towards net zero energy

Can your home help tackle climate change?

Could your home, office or school classroom help reduce carbon emissions? According to researchers from the Universities of Swansea and Cardiff, it could.

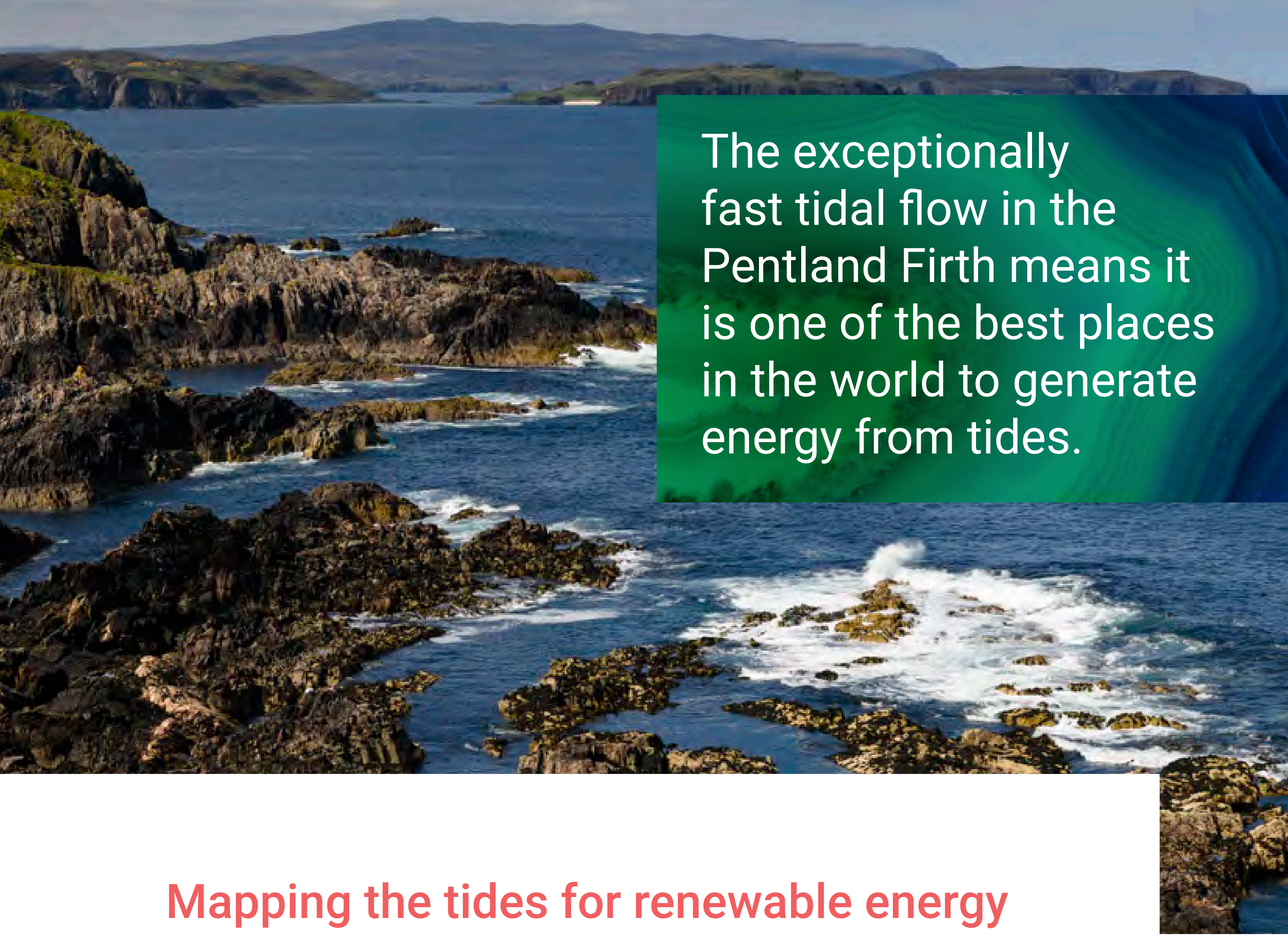
A long-term study of their first demonstrator building, a house built in 2015, showed it could save occupants around £1,000 on their energy bills. It inspired a roll-out programme called Homes as Powerstations across South Wales, which starts this year. Similarly, the UK's first energy-positive office was designed to generate more solar energy than it consumes. It opened at Swansea University in June 2018 and incorporates green energy technology such as integrated solar panels, a photovoltaic thermal system, and lithium-ion batteries. These enable the office to store and use energy as required. The award-winning Active Classroom is the UK's first energy-positive classroom.

In its first year of operation the classroom generated more than one and half times the energy it consumed, with the spare power used for electric cars.

The office and classroom were built at Swansea University by researchers from the SPECIFIC Innovation and Knowledge Centre, which is led by Professor David Worsley and has been funded by EPSRC since 2012. The house was built as part of an earlier project with Cardiff University. SPECIFIC is building a network of university researchers and companies to ensure the technologies can be scaled up, demonstrated and that there is a route to market for their ideas.

The design principle is known as active buildings. Active buildings incorporate renewable energy technology and are integrated intelligently with the wider energy grid. Buildings use around 40% of the UK's energy, so active buildings could play a vital role in reducing the UK's carbon emissions from energy generation.

Buildings use around 40% of the energy produced in the UK.



The exceptionally fast tidal flow in the Pentland Firth means it is one of the best places in the world to generate energy from tides.

Mapping the tides for renewable energy

The power of the seas often makes us think of towering waves, ferocious storms and ships wrecked on an unforgiving coast. Look at it slightly differently, however, and all of that raw ferocity is renewable energy just waiting to be tamed.

Unfortunately, taming it is easier said than done. That tremendous store of energy in tides can make it very difficult to build and position turbines to harvest that energy. To address this problem, researchers at the University of Edinburgh led by Professor Vengatesan Venugopal, are working with marine energy companies Nova Innovations and Orbital Marine Power (previously Scotrenewables Tidal Power) to understand the turbulent waters of Scotland's Pentland Firth and Orkney Waters region.

The data and mathematical models produced by the research team are enabling the companies to better understand and predict the environment in which they are deploying their tidal energy turbines, and to design more effective turbines. In return, the companies' experience of working in the region has helped refine and validate the researchers' models.

As an island nation, the UK is well-placed geographically to harness marine and tidal energy. In fact, we possess around half of Europe's tidal energy capacity. The immensely powerful currents of the Pentland Firth and Orkney Waters area, off the north coast of Scotland, make them an ideal site for generating tidal energy.

Those same currents generate a lot of underwater turbulence, however, meaning marine energy companies need to over-engineer their tidal turbines to withstand the buffeting they suffer. Turbulence also reduces the efficiency of turbines and increases maintenance costs. A better understanding of the turbulence in the local area will help companies minimise these additional costs, bringing tidal energy one step closer to becoming a commercial reality.

Shining a light on solar power use

On a grey morning in May 2022 the UK was generating around 5%, or 1.8GW, of its electricity from solar power. We know this because live electricity generation numbers are available online and, thanks to EPSRC-funded research, those figures include a number for solar electricity generation.

Understanding the amount of solar power in our energy mix is not an easy task. Yet Professor Alastair Buckley, leader of the Sheffield Solar project at the University of Sheffield, has devised a method to do just that. As a result, there is a potential National Grid saving of around £13 million a year.

Buckley and colleagues at Sheffield Solar have created the Microgen database, which collects solar power information from almost one million locations around the UK – a huge number of suppliers. Power suppliers range from tiny domestic solar panels to field-sized industrial solar farms, which makes it so difficult to track solar energy generation.

And that is costly. To make sure the lights stay on, National Grid can activate back-up gas generators when demand outstrips supply. It costs around £1 million to keep 10MW of reserve energy generation on standby, so accurate forecasts of energy supply are vital for making sure the right amount of standby energy generation is available. The Microgen database, together with clever statistical modelling, helps provide that accurate forecast, incorporating both solar energy producers across the nation and accurate weather forecasts.

Delivering zero emissions transport and mobility solutions

Transport accounts for over 25% of the UK's carbon emissions, with 91% of that coming from road transport.

Clean, green public transport on zero-emission buses

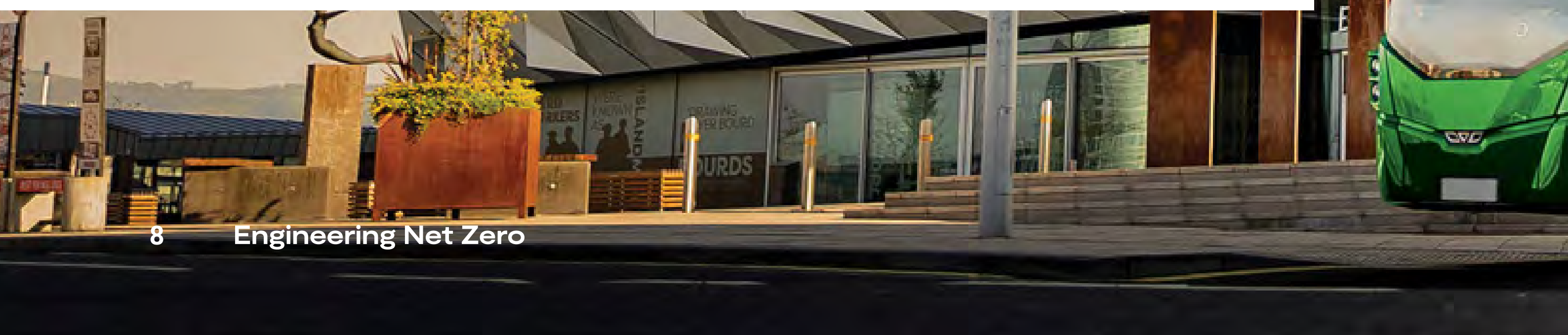
Zero-emission buses are on the UK's roads thanks to a partnership between Queen's University Belfast (QUB) researchers and bus company Wrightbus Ltd.

Achieving progress towards low-emission mobility in public transport is essential for a future low-carbon economy. University research collaborations are vital in providing businesses with new processes and technologies and access to world-leading experts. Such cooperation is critical to achieving UK net zero goals.

For over 25 years, Wrightbus, the UK's leading supplier of independent public buses, has collaborated with Queen's University Belfast (QUB) to develop next-generation bus technology. Initially, the teams efficiently integrated diesel engines into the vehicle driveline before turning to the challenge of electrification in the early 2000s. Wrightbus have successfully exploited outputs of this partnership to launch the Streetdeck Electroliner, the world's most efficient double-deck battery-electric bus. Eighty Electroliners are being gradually introduced into Belfast, operated by Translink and another 30 are destinated for London.

In 2019, QUB and Wrightbus secured EPSRC funding through a Prosperity Partnership programme led by Professor Juliana Early, to advance the roadmap to zero net emissions in the urban public transport sector, leveraging their joint experience in low- and zero-emission bus development. Using the modelling methods and techniques developed during this project, the team were able to apply this knowledge to support the rapid development of a new single-deck bus powered entirely by hydrogen, funded through The Advanced Propulsion Centre's (APC) Advanced Route to Market Demonstrator (ARMD) programme. The hydrogen-powered bus produces only water, both reducing carbon emissions and helping improve urban air quality. It runs on hydrogen produced using renewable electricity and has a range of 640 miles. In November 2021, Go-Ahead Group, which provides public transport across the UK, ordered 20 of the single deck hydrogen buses for Brighton & Hove and Metrobus. The company is committed to decarbonising its bus fleet by 2035.

Transport accounts for over 25% of the UK's carbon emissions. Although buses produce far less CO_2 per passenger than private cars, they do still have a significant carbon footprint and are responsible for other air pollutants from burning diesel, that contribute to poor urban air quality, particularly in major cities such as London. Switching to electric or hydrogen vehicles would help dramatically reduce carbon emissions from transport.



Boosting the green credentials of lithium-ion batteries

Researchers at the Faraday Institution, funded by EPSRC through the Faraday Battery Challenge, have found a way to recycle some of the key materials from lithium-ion batteries used in electric vehicles more effectively, reducing demand for mined raw materials and further boosting the environmental credentials of electric vehicles.

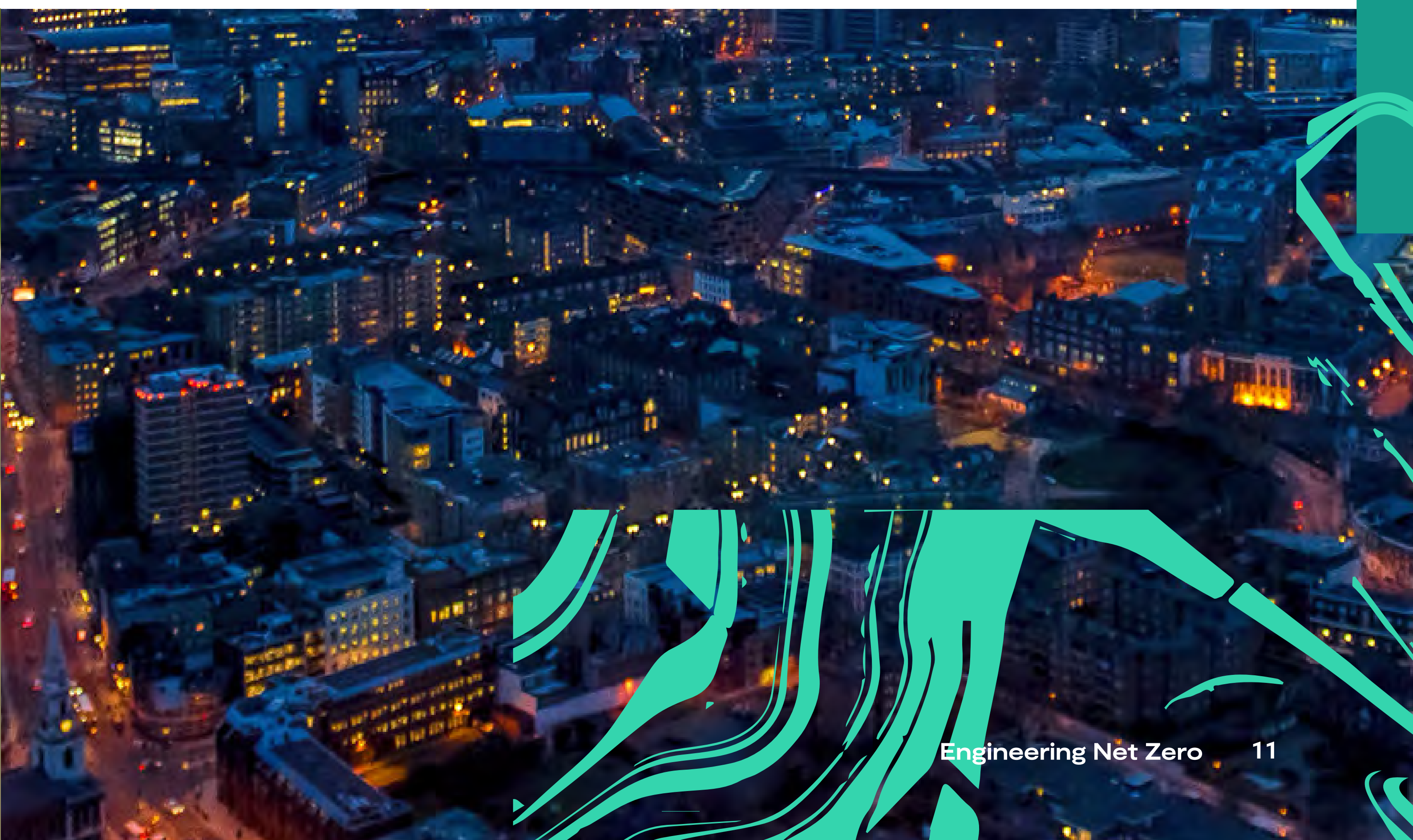
By 2030 the UK Government will end the sale of new petrol and diesel vehicles. They are likely to be replaced by electric vehicles, greatly reducing carbon emissions from transport. However, more electric vehicles mean greater demand for the rare metals needed to manufacture their batteries.

Led by Professor Paul Anderson at the University of Birmingham, the team of researchers are using high-power ultrasound to separate the incredibly thin layers of material in the batteries' electrodes. The material recovered is so pure that it can be re-used in new electrodes. The ultrasound technique only takes a few seconds to work, meaning the process is more than 100 times faster than alternatives.

The team are patenting their discovery and have entered discussions with several battery manufacturers and recycling companies to develop a technology demonstrator.

The environmental impact of mining for metals such as cobalt and lithium used in rechargeable lithium-ion batteries can be significant. Recycling certain components in the batteries, particularly the metal in the battery electrodes, will reduce demand for mined raw materials and alleviate the pressure on natural environments and on local water supplies affected by lithium extraction. The recycling technology also takes battery manufacturers and recyclers one step closer to implementing a circular economy approach to EV batteries.

Solutions for a greener industry and urbanisation



Globally, the chemical industry produces around 6% of CO_2 emissions each year

Putting the CO_2 back into manufacturing

What if CO_2, the prime cause of climate change, could be harnessed to drive our manufacturing industry? That's the aim of University of Southampton spin-out ViridiCO_2. By using CO_2 to produce valuable chemicals, ViridiCO_2 aims to both reduce CO_2 emissions and to provide a sustainable source of materials to replace those we currently extract from fossil fuels.

ViridiCO_2 was founded by Dr Daniel Stewart and Professor Robert Raja, an EPSRC Impact Acceleration Account Fellow, based on research conducted by Stewart during his EPSRC-funded PhD. The unique catalyst created by Stewart – and supported by the EPSRC-funded on-campus startup accelerator Future Worlds – can convert CO_2 into the raw materials required to manufacture recyclable plastics. The technology can be fitted to existing industrial plants to capture CO_2 emissions at their source, and could reduce manufacturing costs.

The process also reduces reliance on raw materials extracted from petrochemicals, helping the chemical industry transition to a circular economy.

To become a truly sustainable society, we must shift to a circular economy. Traditionally, economies rely on (often non-renewable) inputs to generate the products we need, and waste, which then mostly end up in landfill. In contrast, a circular economy utilises renewable resources and ensures waste material and products at the end of their useful lives are fed back into the manufacturing system.

Nyobolt; ultra-fast charging batteries to revolutionise electric vehicle use

We are heading for an electric future; electric vehicles will dominate our roads, our phones and other devices run off battery power. Even our homes can now run off solar panels and battery-based energy storage – both generating their own power, storing it and supplying it back to the grid.

For this vision of the future to be realised, however, we will need new ultra-fast charging, high-capacity batteries such as those being developed by University of Cambridge spin-out company Nyobolt.

Nyobolt, co-founded by Professor Clare Grey, who was supported through an EPSRC Programme Grant, commercialises the outputs of her research into new battery materials. The company's niobium-tungsten oxide-based batteries are high power, reducing the weight of the batteries needed to power electric vehicles. As the batteries can be fully charged in just a few minutes they would also be more convenient and flexible for consumers, eliminating long waits for recharging and helping tackle electric vehicle range anxiety. Finally, the batteries produced by Nyobolt are durable and can be operated within a wide temperature range, which is not possible for many existing batteries.

So far, Nyobolt has raised substantial investment to expand its operations globally and expand its materials development facility in Cambridge.

Nyobolt's batteries can be fully charged in just a few minutes

Making concrete greener

Concrete is the 'unsung hero' of our lives, forming the fabric of modern cities around the world. More than 4 billion tonnes of Portland cement, which is widely used to bind concrete, are produced each year.

However, the manufacturing process releases large amounts of CO_2 with up to one tonne of CO_2 released for every tonne of cement. Many waste and by-products from industry, mining and agricultural processes have no current commercial value, but are widely available throughout the world. If successful, production of low-carbon cements, such as alkali-activated materials, would turn them into a valuable resource.

However, despite this potential, the performance of alkali-activated materials in the field is unproven. Concrete needs to maintain its strength and integrity under challenging climate conditions over periods of decades or more.

EPSRC Early Career Fellow Professor Bernal Lopez and her team at the University of Leeds are developing and studying low-carbon cements produced from simple industrial waste or by-products. 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%.

Chemistry research leads to cleaner, greener business

HydRegen Ltd uses a new sustainable and environmentally friendly chemistry technology to produce products for the pharmaceutical, cosmetics and food industries. The spin-out company, HydRegen Ltd, has been founded by Professor Kylie Vincent and Dr Holly Reeve, at the University of Oxford.

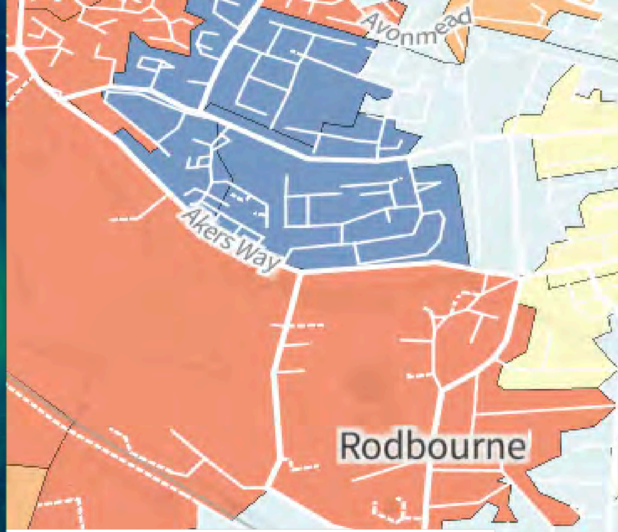
Long-term support from UK Research and Innovation led to the development of the novel technology that offers cleaner, safer, faster chemical production. Funding included early career development for Professor Vincent through EPSRC's Physical Sciences Inspire Programme and a five-year translation grant funded by EPSRC, Biotechnology and Biological Sciences Research Council and Innovate UK through the Industrial Biotechnology Catalyst fund.

The new technology allows producers of chemicals to get rid of toxic heavy metals, currently used as catalysts in the production of a range of products, which can be extremely environmentally damaging. Instead of heavy metal catalysts, the technology uses enzymes as catalysts. Although the use of enzymes is already established in areas of chemical manufacturing, the new technology is unique in using hydrogen as an energy source to regenerate 'co-factors'. These are the biological molecules needed to drive the action of enzymes.

Replacing metal catalysts with enzymes, powered by hydrogen, will lower the amount of energy used in traditional methods of manufacture and minimise waste production. An added benefit is that the whole system is reusable as well. HydRegen was incorporated in 2020 before being formally spun-out in May 2021, with support from Oxford University Innovation.

Our green future

The area around EPSRC's offices in the centre of Swindon is rated B for car driving, which is better than the average nationally, but F+ for electricity use, suggesting there is some room for improvement!



What is the carbon footprint of your local area?

Everything we do has a carbon footprint – the carbon dioxide emissions produced by an activity or generated in a product's manufacture. To help us understand what that footprint is, and how to reduce it, researchers from the EPSRC and ESRC-funded Centre for Research into Energy Demand Solutions (CREDS) have launched a free tool designed to map the carbon footprint for every neighbourhood in England.

But why might you want to understand the carbon footprint of where you live? Because everyone has a role to play in tackling climate change, from multinational companies and national governments, to local authorities and businesses, to individuals. The data presented on the map will enable local planners and other community groups to identify areas where they could reduce emissions, for instance by improving local public transport to reduce vehicle emissions, or insulating homes. Ultimately, community-level actions will help meet national goals for net zero emissions.

The map tool draws in data from a huge range of sources: population data, energy use statistics, data on the condition of buildings, travel surveys and public transport information, Ordnance Survey maps, and many others all play a role. It produces an average of the carbon footprint for people living in small geographic areas known as LSOA, encompassing between 1,500 and 3,000 people.

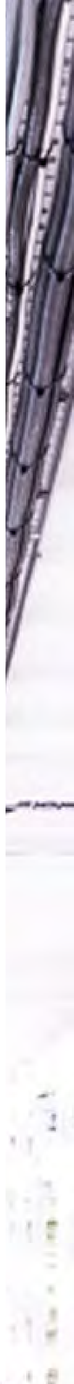
Areas are given a rating from A+ to F- for individual elements such as heating, electricity and gas use, driving, flights taken, and consumption of products and services, as well as an overall rating. The simple ratings can then be used to identify what that area could do to reduce its carbon footprint. For example, an area with lots of emissions from driving might benefit from better public transport links or more bike paths. The difference between a neighbourhood with an A+ rating and a neighbourhood with a F- rating is a factor of 8x the carbon footprint per person. Focusing efforts on high-carbon neighbourhoods will help deliver the rapid carbon reductions we need. The CREDS researchers, based at the Institute for Transport Studies, University of Leeds and School of Environment, Education and Development, The University of Manchester, worked with local authority partners whilst developing the Place-Based Carbon Calculator (PBCC) to ensure it would be as useful and as accessible as possible for users.

AI and data science leads to big climate change solutions

What do Arctic sea ice, the world's first underground farm and national security all have in common? All three, and more, are benefitting from data science, machine learning and AI research at the Alan Turing Institute. The area of the Arctic Ocean covered by sea ice each year is declining. The loss of ice cover will have serious implications for our climate, as darker-coloured sea water absorbs more energy from sunlight, leading to even greater warming and less sea ice in future. Understanding how this works will help us build better climate models and make more accurate predictions of how climate change will affect us all. Using machine learning, the researchers are improving our ability to more reliably and efficiently forecast seasonal sea ice cover, which will improve weather and climate models.

The world's first underground farm of its kind, built in an old air raid shelter beneath the streets of Clapham in London, is producing crops year round while minimising the carbon footprint of the farm. By building a digital twin – an incredibly detailed virtual model - of the farm based on a suite of sensors in the farm tunnels, researchers have helped the farm managers optimise conditions and manage their inputs such as light, heat, nutrients and water most effectively, reducing the time it takes to grow some crops by 50%.

Data science and statistical modelling is also helping us answer some of the biggest questions posed by climate change such as how it will affect societies around the world and where it poses risks to national security. By linking social data with environmental information, researchers are identifying how particular stresses caused by climate change are affecting human populations. They are also developing the ability to predict climate change impacts and warn affected populations, enabling them to prepare. These models help policymakers understand future climate change-driven security risks and help countries to adapt to or mitigate the worst impacts of climate change.



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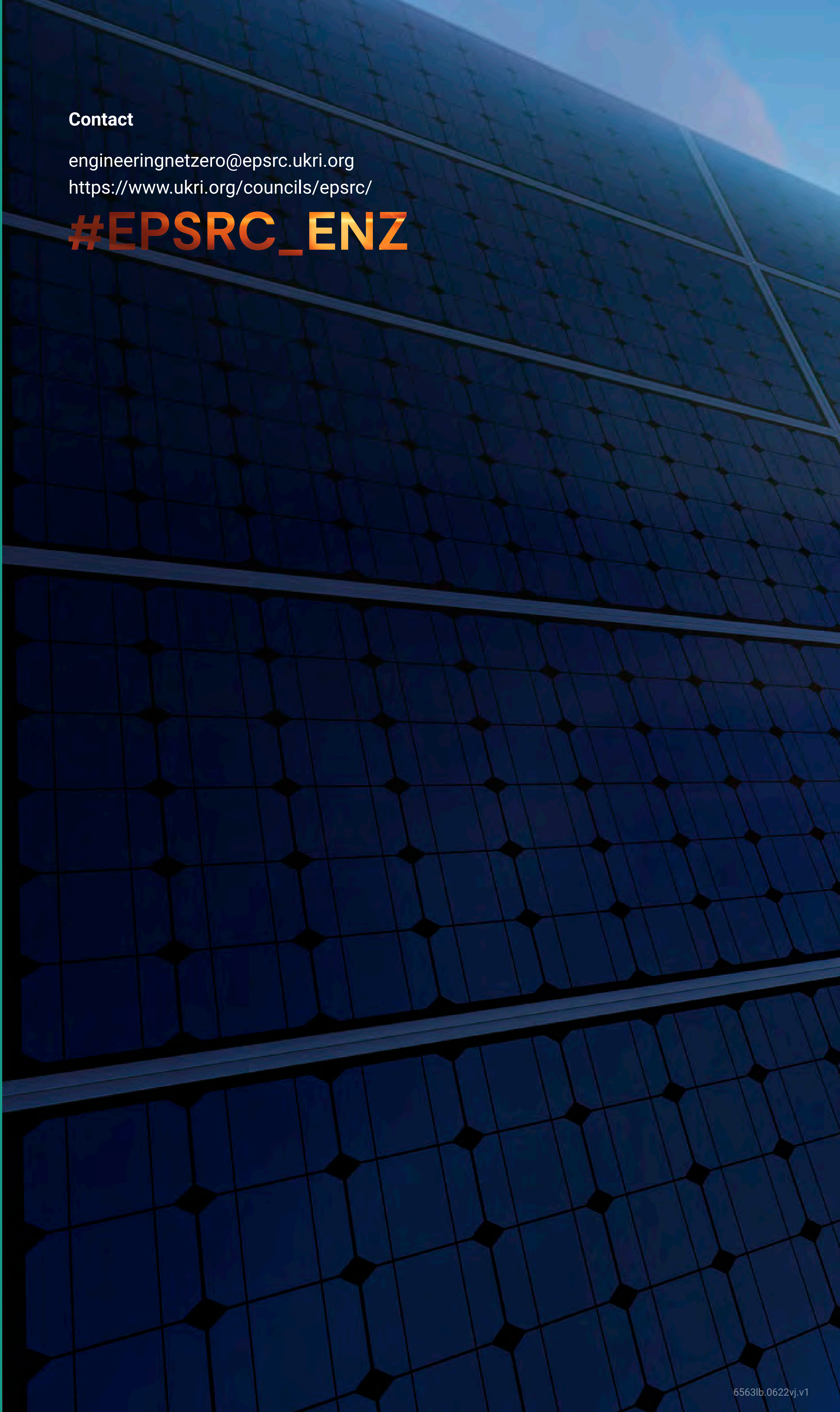

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