UNIVERSITY OF BIRMINGHAM

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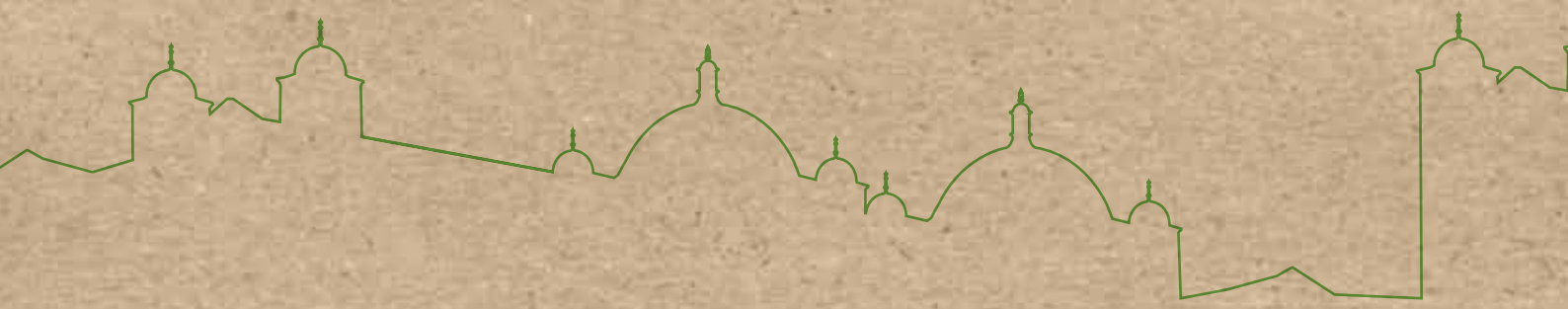


*Fore*word

Our current ways of supplying and using energy are not sustainable. Without the development and adoption of new technologies our increasing reliance on energy in our daily lives will have an ever escalating impact on our world environment. The challenge is global, and understanding the issues and finding solutions is at the heart of our research at Birmingham.

From our foundation over a century ago, the University of Birmingham has been synonymous with energy research. Our early departments of coal mining and oil refinery have evolved as the world has changed. Today, our academic researchers are working on resource recovery and manufacturing efficiency, whilst our chemical engineers have turned their attention to biofuels and hydrogen energy. Energy at Birmingham is a thriving community of over a hundred academics, who engage in collaborative research both at home and across the globe. We are educating the next generation of energy professionals and hundreds of students every year graduate from our specialised courses and doctoral programmes entering into employment in energy and energy related industries.

It is because of the scale and importance of the challenge ahead of us that we are proud to be known for our energy research and to be investing in furthering our vital work. The Centre for Nuclear Education and Research is a recent example of our commitment, with a multi-million pound investment in people, courses and infrastructure. We are host to the UK Doctoral Training Centre in Hydrogen Fuel Cell Research, which draws upon the strengths of the country's most comprehensive Hydrogen Research Group to train fifty PhD students in clean fuel technology. Our School of Metallurgy and Materials has been refurbished to better facilitate its leading research into the development of new materials that will allow greater efficiency in energy production, transmission and usage.

The methods and consequences of energy generation affect every person on this planet, which is why it matters so much to us.

We are proud to demonstrate our commitment to solving the problems that we face together, an academic environment which breeds outstanding excellence amongst our students and researchers, and a community that allows us to play a critical and leading role in developing global energy solutions.

Vice-Chancellor,
Professor David Eastwood

Introduction

The energy landscape

Energy lights and heats our buildings, feeds our transport systems, enables business and industry and fuels the global economy, and yet in the twenty-first century over a billion people worldwide still live without electricity in their homes. We are facing our biggest challenge; how do we develop an infrastructure which can give us the energy services we want, and make them accessible to all, without undermining the ecosystem which sustains our existence?

With the world's energy demand growing and many traditional sources arguably unsustainable, we need to address a vast range of issues. The need to reduce our greenhouse emissions and increase energy efficiency is critical, but we must also secure our future energy supply, replace our ageing power stations and infrastructure, and broaden our methods of generation. Our declining reserves of oil and gas must be replaced with new sources of energy. Whilst our infrastructure makes the transition to new energy technologies we should also consider carbon capture and storage and low carbon options for business.

These issues are at the very heart of the work we do here at the University of Birmingham. Through our expertise, knowledge partnerships and resources we are engaging with industry to help find real solutions and alternatives to the challenges we are facing. Through such collaborations our students gain a broad experience, helping us to educate and shape the energy professionals that will continue to play a critical role in the energy landscape for many years to come.

Bio-energy

Can biomass fuel our future?

Our bioscientists have successfully produced clean hydrogen fuel from chocolate waste.

Our anaerobic digestion specialists are collaborating with colleagues in India to optimise biogas production from waste water treatment and recover valuable phosphorous which is essential in agriculture and human health.

With the pressing need to find new ways of generating and recovering energy, the use of biofuels has the potential to provide a significant contribution to this challenge. In recent years we have had a glimpse of the potential impact of agriculture moving from food to fuel production. At Birmingham we have particular strength in the development of bio-processing techniques, technology for the production of biofuels, and bio-energy from organic waste and manufacturing by-products.

These technologies range from supercritical fluid based processing in the School of Chemical Engineering, the use of novel strains of bacteria for hydrogen production in the schools of Biosciences and Civil Engineering, through to wider gasification approaches. Our chemical engineers are looking at the use of industrial by-products such as glycerol, to produce synthetic gas and dimethylfuran (DMF) as potential future high energy biofuels. They are also working alongside our Future Power Systems Group in mechanical engineering to develop engine technology that can run on these fuels whilst minimising emissions.

Work is also being carried out to optimise the generation of energy from waste, both to be fed back into the grid and for use in transport. Our civil engineers are collaborating closely with the UK water industry to optimise the production of methane biogas through the anaerobic digestion process, in particular investigating the role of beneficial trace elements in optimising the production of methane.

We are also carrying out work in the area of bioremediation, analysing the role of bacteria in recycling precious metals from waste. These metals have the potential to be reprocessed by additional bacteria to be used in fuel cells for the automotive industry. The same bacteria can also make chemical catalysts which are more reactive than commercial catalysts, meaning that chemical synthesis of industrial chemicals can be carried out at lower temperatures and with fewer wasteful by-products.

Finally the smallest plants of all, algae, can be grown on waste carbon dioxide to make foodstuffs for both humans and animals, as well as bio-oils for processing into fuels. Algae require only light for growth and, with physicists, we are looking at ways to amplify the light delivery into carbon dioxide fixing algal cultures.

Materials

Equipping ourselves for the challenge

The School of Metallurgy and Materials here at Birmingham is ranked third in the UK* and currently has over 45 Postdoctoral Researchers looking at the application of materials across a range of areas.

** Source: The Guardian University Guide 2012*

Production of a secure energy supply whilst limiting the emission of green house gases is both a challenge and an opportunity. At Birmingham we are stepping up to this challenge with our in depth work to address the material issues affecting both nuclear and conventional power plants, along with the development of life prediction models for critical components used throughout the power generation industry.

The need for greater efficiency is a major driver in our work. We are looking into the use of new materials, fabrication and welding processes which will lead to end products with significantly higher performance and longer lifetimes, and that are able to withstand more extreme conditions. We are also working with the oil industry, looking at advanced material uses and techniques in deep oil extraction. Our strong partnerships with industry enhance our collaborations with world leading research intensive organisations.

Our leading facilities here at Birmingham enable extensive work in the fields of advanced processing and application of materials in order to reduce energy use in both manufacture and end use product operation. Our work includes the development of smart materials such as shape memory alloys, as well as net shape processing, which allows complicated components to be produced in a less energy intensive manner than traditional methods in our dedicated Net Shape Laboratory, the largest of its kind in Europe.

Magnetic materials are utilised in the creation and distribution of electricity and in many appliances that use that electricity. We are developing improved magnetic materials that will lead to the creation of more efficient, compact and lightweight machines. We are also investigating more energy efficient manufacturing routes and processes for recycling magnets at the end of use.

Using our expertise in the School of Chemistry in collaboration with the School of Metallurgy and Materials, we have an extensive programme dedicated to the discovery, synthesis and primary characterisation of new materials for applications in the hydrogen economy and in the chemical modification of existing materials to improve their performance.

We are extremely proud of our strong and established links with industry relating to our work on materials, in particular in the automotive, aerospace and nuclear industries. Such relationships not only allow us to directly impact upon the energy challenge by finding real solutions to real industrial issues, but also extend a huge benefit to our students by giving them access to resources and exposure beyond that of the university.

Our partnerships with leaders in the nuclear, aerospace and oil industries have opened up exciting new collaborations and investment, exposing students to industry driven needs and the opportunity to play a part in developing the solution.

Professor John Knott of the University of Birmingham received an OBE for Services to Nuclear Safety, conducting pioneering materials research that allowed the lives of Britain's existing nuclear power stations to be extended enabling them to still operate today.

Hydrogen

Developing alternative energy carriers

A fleet of hydrogen fuel cell cars can be seen operating around our campus. We opened the UK's first hydrogen vehicle refuelling station on our campus in 2008, under the Birmingham Science City programme.

The University of Birmingham is the only research institution in the UK to have integrated research work across all aspects of hydrogen energy, from sustainable production and hydrogen storage to commercial utilisations. With an internationally recognised programme of research into hydrogen as a future energy vector and the development of key technologies in all of these areas, we are working towards making a full hydrogen economy a reality.

Hydrogen as a clean energy carrier and its use in fuel cells holds great potential to help meet concerns over climate change, provided we can produce enough hydrogen through low emission technologies.

The School of Biosciences has a major strand of work developing the use of bacteria to directly produce clean hydrogen from organic wastes for use in fuel cells to generate electricity with no net emissions of carbon dioxide. Pure biological routes to producing hydrogen from biomass involving fermentation, anaerobic digestion and metabolic processing techniques are also being investigated. Hot processing of waste wood and agricultural residues is also being investigated as a source of hydrogen and synthesised gas for use in fuel cell generators.

Our Hydrogen Materials Group in the School of Metallurgy and Materials has over 35 years experience in the investigation and exploitation of hydrogen interactions with materials. The group has a laboratory with one of the most comprehensive ranges of techniques in the world for the characterisation of hydrogen storage materials. Research spans the use of lightweight metal powders that are able to efficiently store large amounts of hydrogen to membranes that can separate gases to give ultra-pure hydrogen. Our Hydrogen Storage Chemistry group in the School of Chemistry also has an extensive programme dedicated to the discovery and synthesis of new potential chemical hydrogen storage materials. For both groups, an important aim is the development of a new reversible hydrogen storage material that could greatly extend the driving range of a hydrogen fuel cell vehicle.

We are using our capabilities to look at hydrogen utilisation through our work in Fuel Cells. The Centre for Hydrogen and Fuel Cell Research in the School of Chemical Engineering is nationally and internationally recognised for its dynamism and expertise in fuel cell technologies. Our activities cover a wide range of areas from looking into Proton Exchange Membrane (PEM) Fuel Cells, Solid Oxide Fuel Cells and low-cost Electrolysers through to full scale hydrogen fuel cell demonstrators, such as hydrogen fuel cell hybrid cars, scooters and Combined Heat and Power. Academics in the School of Chemistry are collaborating in the development of new materials for fuel cell electrodes and Solid Oxide Fuel Cell membranes. In addition, our engineers at the Hydrogen Materials Group have also developed a zero emission canal boat powered by the application of a rare earth magnet motor, PEM fuel cell and metal hydride store technologies. This project in collaboration with British Waterways is regularly used to demonstrate and raise awareness of the practical applications of hydrogen.

Biowaste2energy Ltd was set up by the University in 2008 and development work is underway to bring the utilisation of waste biomass technology for the production of clean hydrogen to market.

The University of Birmingham with the Midlands Energy Consortium partners delivers the UK Doctoral Training Centre in Hydrogen, Fuel Cells and their Applications which will train 50 PhD students over five years.

Policy and society

The blueprint for success

The School of Computer Science is part of a nationwide EPSRC funded 'Taking on the Teenagers' project, aimed at engaging teenagers in energy issues. The project assesses their attitudes and behaviour towards saving energy and energy choices, and engages them in novel ways to shape energy use and behaviour as we move towards a more sustainable and efficient future.

Scientific and engineering solutions to the energy challenge can only be successful if they are socially desirable, economically affordable and environmentally acceptable. For these conditions to be met, we need effective government policies which support innovation and the deployment of new and advanced energy technologies and energy markets, to maintain the reliability of supplies, promote a competitive energy market and ensure that homes are adequately and affordably heated.

Academics at the Birmingham Business School specialise in the economics of energy, focussing on the cost of electricity, how the demand for a reliable and environmentally acceptable supply will be met and how this will impact on the way the electricity market needs to be organised and regulated. Our economists are also working with the Economic and Social Research Council and the Leverhulme Trust, looking at the impact of our environmental policy and regulations on the ability and willingness of businesses to operate in the UK, particularly in relation to pollution intensive industries.

We are also looking at the social and public aspects of policy decisions relating to the energy challenge. Our researchers in the School of Geography, Earth and Environmental Sciences (GEES) and in the Department of Political Science and International Studies (POLSIS) undertake work across the EU to examine the issues of fuel poverty and energy vulnerability, the politics of climate change and energy security, and the public acceptance of energy technologies, from biomass energy and wind farms to nuclear waste facilities. Funded by the EU and the UK Research Councils, we are running several projects to identify best practice in planning for a low carbon future, at spatial scales ranging from tower blocks and city districts to integrated marine spatial planning across national boundaries.

Academics in the Law School are analysing the linkages between energy, trade and climate change and their impact on present and future international and national regulation. Current projects with other international academics and policy makers focus in particular on the reform of World Trade Organisation subsidy laws to recognise more autonomy for countries' policies fighting climate change, and on the governance of the financing of climate change mitigation and adaptation.

Environment

Balancing our energy and environmental needs

The University of Birmingham proudly hosts the Facility for Environmental Nanoparticle Analysis and Characterisation (FENAC) funded by the Natural Environment Research Council (NERC). The facility produces reliable data analysing nanoparticles under realistic conditions providing a better understanding of the biological and environmental impacts of nanoparticles.

Our choices in energy use and supply have a global impact. It is critical that we understand the implications of energy decisions on both our natural and human environment. In addition, we face the need for society to adapt to living within the earth's carrying capacity and must develop business models to drive this adaptation.

Here at the University of Birmingham we are applying our expertise and capabilities across a number of disciplines to address the current and future impact of energy use on the environment, as well as the associated links to health and quality of life.

Our Air Pollution Group in the School of Geography, Earth and Environmental Sciences, is carrying out extensive work in this area. We are looking at how chemicals and particulates found in emissions from industrial processes and transport react in the atmosphere and the implications this can have on health and well-being. This work helps to inform our research on the use of different fuels and the wider implications. In conjunction with the School of Mechanical Engineering the group is looking at various technologies to help clean up the emissions from our exhausts.

We are also carrying out research in the areas of hydrogeology and biogeochemistry in relation to nuclear energy looking at the potential fate of radionuclides in ground water environments. Understanding the processes affecting radionuclides in the environment allows us to better determine the possible transportation risks and the wider impact of this on our environment, and develop novel strategies for remediation.

Extensive work is taking place looking at the impact of energy policy and how our choices affect the human environment both at the landscape and the domestic level. Our work on energy vulnerability and fuel poverty, especially relating to older generations and those on low incomes, aims to contribute to policy agendas that promote both winter wellbeing for older people and more sustainable levels of domestic consumption in the future. Research into the impact of different fuel usage in less developed countries is also being explored, looking specifically at the impact of the use of wood burning cooking stoves and the associated health and environmental implications.

The University is working with energy companies to investigate the impact of urban heat and climate change on electricity transformers. A variety of statistical downscaling and neural network techniques are being developed to identify transformers prone to heat overload across the Birmingham conurbation. The results of this will be used to drive future asset replacement programmes.

Transport

Remodelling our need to get around

The transport sector is one of the world's largest consumers of energy, and we face the challenge of reducing its environmental and health impacts whilst making it more fuel efficient. The challenge goes beyond technology. On a social level we need to understand the balance between localism and globalism, leisure and business transport, face to face and virtual communication. We need to minimise not just energy consumption, but environmental impacts including pollution and land take.

We are working extensively with industry to find solutions. The Birmingham Centre for Railway Research and Education is our leading interdisciplinary centre, with world recognised expertise and facilities in most aspects of railway technology and performance. Within this we address the energy concerns of the rail network, investigating alternative power and traction systems in addition to optimising efficiency in all parts of railways through the use of advanced simulation technology, for both existing systems and proposed new generation systems.

Our researchers in the schools of Civil Engineering and Geography, Earth and Environmental Sciences are leading a consortium looking at possible transport scenarios up to the year 2050 and the effects that climate change may have on the resilience of our infrastructure.

The Vehicle Technology Research Centre in our School of Mechanical Engineering is researching ever more novel ways to optimise the combustion engine and reduce emissions, as well as investigating the design and impact of next generation combustion engines and future fuels on the environment. With exceptional engine research and development laboratories, we collaborate with some of the biggest names in vehicle manufacture and fuel suppliers, allowing our researchers and students to have a real impact on shaping the future of our transport in years to come. We are one of the country's leading research institutions in the development of advanced power train technologies, including using hydrogen as an energy carrier.

Our School of Metallurgy and Materials is pioneering research into new materials and production processes for aircraft components, minimising energy use in manufacture while reducing overall weight. With new materials comes the potential for engines to operate at higher temperatures which leads to enhanced fuel efficiency and reduced emissions. Our Netshape Centre was established in 1989 and is host to one of the most well equipped laboratories of its kind in the country. Through our facilities and expertise we have formed strategic partnerships with many multi-national companies involved in design and build of next-generation engines and airframes.

The Birmingham Centre for Railway Research and Education has been involved in railway design projects around the world for many decades, including the Hong Kong Metro and the Docklands Light Railway in London.

Manufacturing

Refining manufacturing success

The University of Birmingham is a founding partner of the Manufacturing Technology Centre, a globally competitive manufacturing research hub working alongside high value manufacturing partners in the pursuit of world class manufacturing performance.

www.the-mtc.org

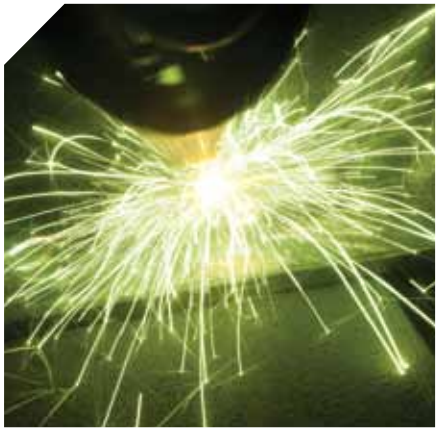
Roads to Riches is a developmental company based at the University of Birmingham that works to recover the precious metals deposited from the exhausts of cars, which end up in dust on the roadside, therefore reducing the need for mining virgin materials for use in manufacturing.

Reducing the resource and energy intensity of industrial processes is a necessity being faced by the manufacturing sector today. We are continuing a proud century's tradition in working with industry to help improve energy efficiency through improved processes and technology, as well as applying our expertise and knowledge to look at how manufacturing processes can contribute to materials recovery and security.

The UK is at the forefront of light metal casting and investment casting technologies, which are vital to the global aerospace and automotive industries. Our integrated approach to working with industry in manufacturing and sustainability process modelling, has led to the creation of a new casting process known as CRIMSON, resulting in the reduction of energy costs and waste production for light metal foundries.

Scientists in metallurgy and materials have world leading facilities for powder processing and through their work they have pioneered new techniques to create high performance aircraft components whilst reducing waste production by up to 90%.

Mineral security and their sustainable extraction and use is also a significant global challenge. We are playing an important role in material policy discussions in this area, through work funded by the UK Technology Strategy Board. On a technical level, we are working with industry internationally to analyse the waste products from the China Clay mining

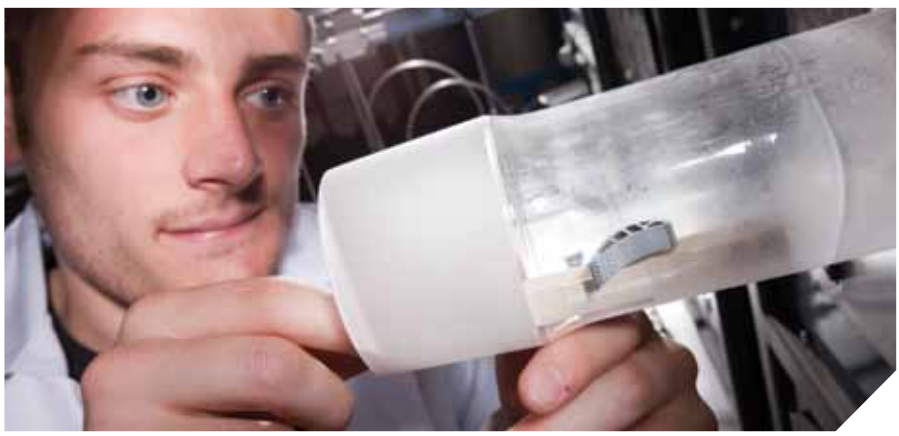


process and investigating the use of technology to extract lithium. Technology is also being developed by our chemical engineers to utilise the waste from coal fired power stations by extracting materials that can be used elsewhere, while our civil engineers collaborate in India working to recover phosphate from waste water treatment for re-use in agriculture.

The capture of low grade heat from manufacturing processes is an important part of reducing waste and conserving energy in industrial processes. As products cool and energy in the form of steam or general radiation leaves plants through chimneys and the general recirculation of air, heat energy is lost into the surrounding environment. Birmingham's mechanical engineers are working to find ways to reduce these losses and recover those that escape and recycle them.

Oil and gas

Living with oil and gas in the 21st century



Our researchers are collaborating with several UK institutions investigating carbon capture and storage challenges, including the conversion of captured gases into novel products such as transportation fuels and plastics.

We also have academics in the School of Law specialising in international oil and gas law.

Our infrastructure will continue to be heavily reliant on oil and gas well into the 21st Century. With stocks increasingly difficult to find and extract, we are facing the challenge of making the most of what we have left whilst minimising our impact on the world around us.

We are utilising our expertise to increase the safety of extraction through new high performance materials, as well as improving how efficiently we use fossil fuels in engines through our automotive research. Through our environmental research in emissions and nanoparticles we are assessing the impact that the consumption of these resources can have on our environment, health and ecosystems.

Our School of Metallurgy and Materials is working with industrial partners to optimise the performance of materials for deep oil extraction pipelines, which operate in extremely corrosive environments. Collaborations are investigating flexible pipes using novel materials that are less prone to deterioration and can transport oil more safely than conventional methods

Physicists at Birmingham in our Cold Atoms Laboratories are developing new quantum sensor technology, that it is hoped will one day aid in mineral exploration. Another example of new technology is the recovery and upgrading of heavy oil from Canadian oil sands. This oil is highly viscous and difficult to extract as well as being potentially environmentally damaging, requiring enhanced recovery methods.

The School of Chemical Engineering is working on 'Toe to Heel Air Injection' (THAI) technologies, to aid in the extraction and upgrading of this oil in an enhanced energy and environmentally efficient manner.

Our School of Geography, Earth and Environmental Sciences provides post-graduate-level training in micropalaeontology and seismic imaging technology, both used by the oil and gas industry to map underground trap structures. Our research into micropalaeontology and seismic imaging is partly targeted at hydrocarbon exploration applications, and we are also developing new ways to use oil industry data to research modern ocean circulation patterns and past climate.

Nuclear

Meeting our energy demands without emissions

Professor Andrew Worrall from the National Nuclear Laboratory has a Royal Academy of Engineering Visiting Chair at the University of Birmingham and is the Chairman of our Nuclear Industrial Advisory Board.

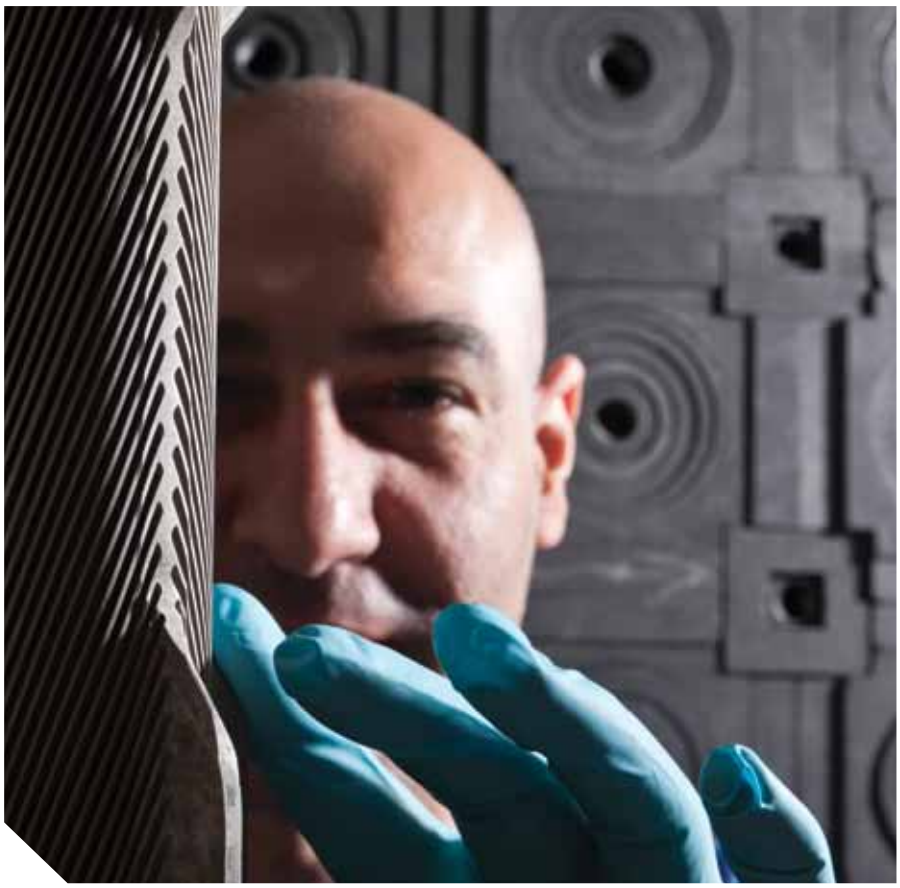
The UK has utilised nuclear power for over five decades, it is highly likely this source of energy will form an important part of the energy mix for the foreseeable future. The University of Birmingham has a long and established track record in working in the areas of materials de-commissioning, health monitoring and residual life prediction of existing nuclear power stations; research which dates back to the first phase of nuclear construction. Our Centre for Nuclear Education and Research brings together a multidisciplinary team from across the University focussed on the needs of the nuclear sector now and into the future, including the role of social and economic policy in shaping the landscape.

We are proud of our strong heritage in educating nuclear engineers and scientists over the last 50 years. Through our expertise and reputation we have strong active international links with industry, which directly steer the development of our teaching programmes. This collaborative environment enables us to align our research and teaching with real issues, with students often spending time in industry as part of their project work. The student experience is significantly enhanced from this exposure, resulting in high levels of recruitment opportunities for our graduates.

Our research in material degradation enables an understanding of the corrosion, oxidation, fatigue and fracture characteristics of key components used in power generation. This insight into material durability is critical for the safe operation and life extension of existing plants and development of the next generation of nuclear reactors, where increased efficiency will require reactors to operate and withstand increasingly high temperatures and volatile environments. Our expertise and facilities underpin our ability to collaborate with partners globally in developing these future materials.

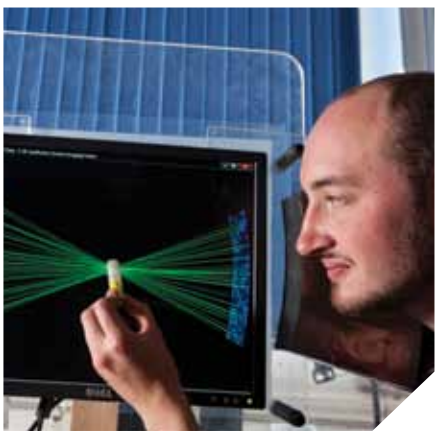
We have significant capability related to decommissioning and waste management. Our academics and students are investigating contamination scenarios in soil and groundwater, possible transportation risks and the wider impact of this on the environment. We have particular strengths in mineralisation and ion exchange and the potential for biological enhancement of radionuclide removal. One international environmental problem lies in waste run-offs from uranium mines. At the same time the price of uranium continues to rise and, due to the lack of native uranium in the UK, energy security becomes an issue. We have more than 20 years' experience in 'bio mining' uranium from wastes, and the technology also extends to wider radioactive waste cleanup.

Our School of Electronic, Electrical and Computer Engineering is also contributing to our nuclear work in the area of human factors, specifically supporting developments in simulation and telerobotics. Using 'serious gaming' technology, our experts have developed simulators for future specialist training applications, including threat assessment and advanced robot control for explosive ordnance disposal and safety awareness onboard submarines. The application of this technology is being further developed in partnership with Computer Science where they are developing robotics techniques for nuclear decommissioning.



Our Bio-medical and Micro Engineering Group is investigating the development of novel passive sensors for applications in high radiation environments that could monitor safety critical infrastructure and environmental conditions without degradation in performance.

Our Physics and Technology of Nuclear Reactors MSc has been running for more than 50 years and boasts an impressive 90% employment rate into industry or nuclear research.



Distribution

Energy delivery that is ready for the future

Since 2008 the University of Birmingham has been a leading collaborator with several Universities on a multi-million pound Engineering and Physical Sciences Research Council (EPSRC) project developing new capabilities for 'Mapping the Underworld'. The aim is to locate and map all buried utility assets without excavation. This technology will not only result in significant cost saving in terms of repairs but will also enable greater use of trenchless technology.

With the world moving towards distributed energy, the landscape is set to become ever more complex. There are a number of energy distribution challenges, from securing energy supplies through to improving energy efficiency and ensuring the longevity of infrastructure.

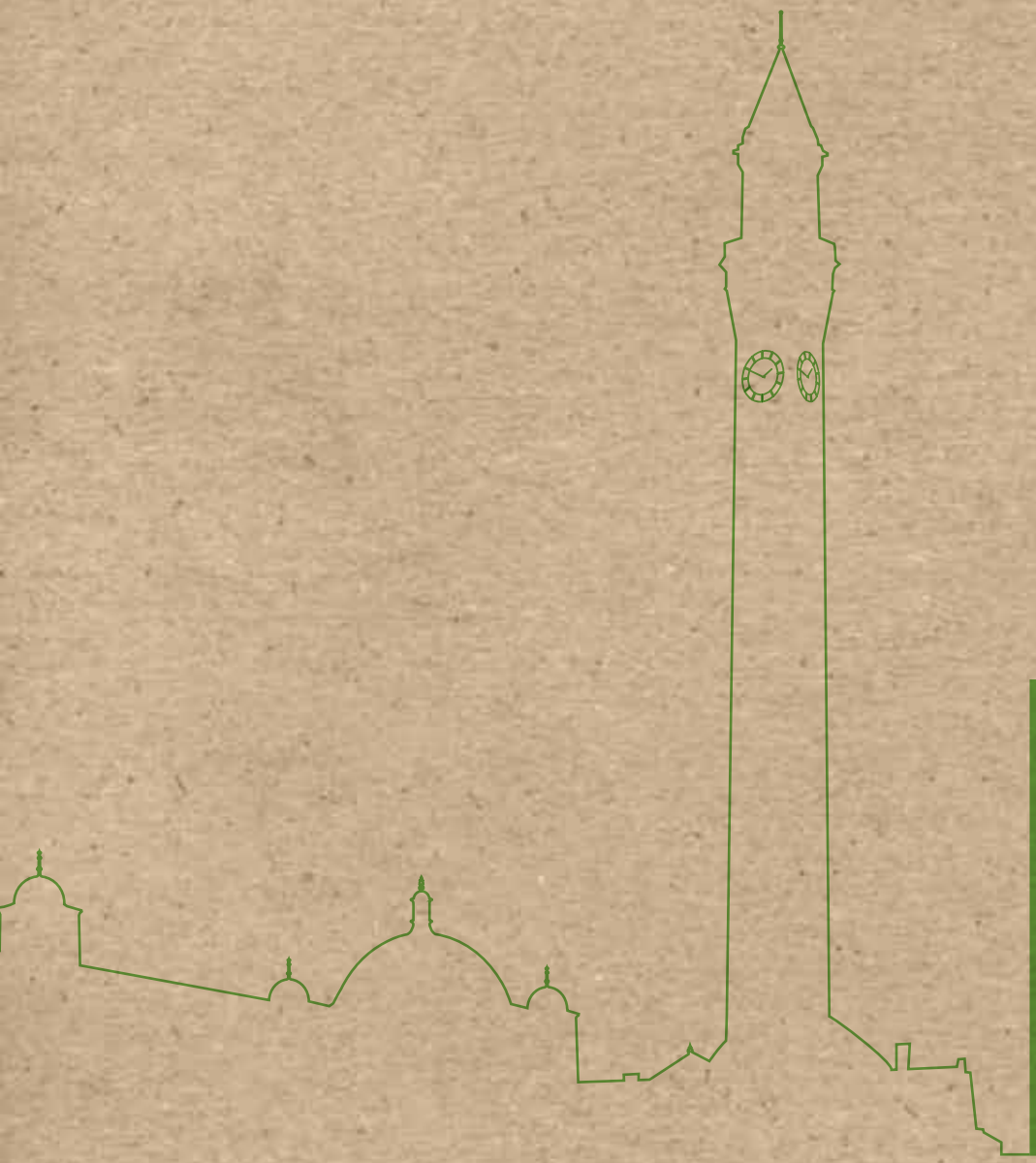
Here at Birmingham we are using our interdisciplinary expertise and facilities to help address these global issues. With our advanced simulation capability we partner in international projects, involving industry and other universities, to develop smart grids. We work with industry leaders investigating the modelling, control and protection of the existing electricity grid, helping to optimise it and make it smarter in preparation for more distributed renewable generation.

When the forecasted increase in distributed energy occurs, there will be need for a new generation of underground services and here at Birmingham we are working hard to plan ahead. Our ongoing work on trenchless technology looks at how we can be more energy and resource efficient by using the process of tunnelling underground to lay services, rather than putting them above ground on pylons. This offers a safer and more aesthetically pleasing solution. Our researchers are working to address how we can apply this technology to new challenges, for example bringing off shore wind energy to the land and connecting it to the existing grid, without impacting some of our most precious landscapes.

Our civil engineers and micro-engineering academics are working closely with utility companies to further develop sensor technology, so that they can be put into buried utilities in order to monitor a range of service life conditions. This smart monitoring and communication will allow greater efficiency, allowing companies to proactively manage their assets and plan their renewal programmes more effectively.

Global Challenges

Birmingham Solutions



The University of Birmingham has more than 100 academics working collaboratively with students, academics and industry around the world to address the energy challenges we face today.

Learn more

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