MANCHESTER 1824
The University of Manchester

GLOBAL CHALLENGES **MANCHESTER** SOLUTIONS

Research beacons

GLOBAL CHALLENGES
MANCHESTER SOLUTIONS

Advanced materials
Cancer
Energy
Global inequalities
Industrial biotechnology

At The University of Manchester our pioneering discoveries, interdisciplinary collaboration and cross-sector partnerships are tackling some of the biggest questions facing the planet.

Contents

Research is fundamental to The University of Manchester. We're committed to both the discovery of new knowledge and its application for social and economic value.

We have a range of high-quality research at this university that is rivalled by few other universities and much of our best research combines expertise from across disciplines, making the most of the opportunities that our size and breadth affords.

As a result, our researchers are able to work together to find innovative solutions to some of the world's most persistent and pressing questions.

The five research beacons covered in this brochure showcase concentrations and combinations of high-quality research activity that are distinctive to this university and demonstrate how our interdisciplinary approach is improving the lives of people around the world.

Through this work we're improving knowledge of inequalities to help bring about a fairer society. We're developing advanced materials that can withstand the harshest environments.

Our experts are investigating all aspects of cancer so that we can reduce its profound and devastating impact on so many families. they're pioneering the energy systems of the future and developing sustainable alternatives to the finite resources used in everyday manufacturing.

The scale of research activity at Manchester allows us to bring the best minds together to find new ways forward. By working together, we're advancing knowledge for a better world.

Professor Dame Nancy Rothwell
President and Vice-Chancellor
The University of Manchester

Each age is defined by the materials it has to hand, influencing, improving and defining life as we know it. As the world evolves, new, transformational, advanced materials are urgently required to tackle major challenges and drive innovation in sectors such as health, energy, security and the environment.

Transforming our world through advanced materials

Advanced materials allow us to work in the most demanding environments, at the frontiers of the energy sector or inside the human body. The University of Manchester is leading the way by developing the innovative solutions required to solve some of the world's most critical problems.

Research and innovation in advanced materials underpins all manufacturing sectors and pervades all spheres of economic and social activity - it's essential to economic growth. Advanced materials have the power to transform almost every industrial sector and every aspect of our lives, from aircraft to packaging, computers to clothing, and nuclear plants to vehicles of the future.

We need new and improved materials that can operate in increasingly demanding environments, to generate low-carbon energy or transport the fuels of tomorrow. As the world becomes more connected we need to travel more often and at greater speeds, and to be able to communicate with more immediacy. To meet the expectations of industry and society, we'll need stronger, lighter materials.

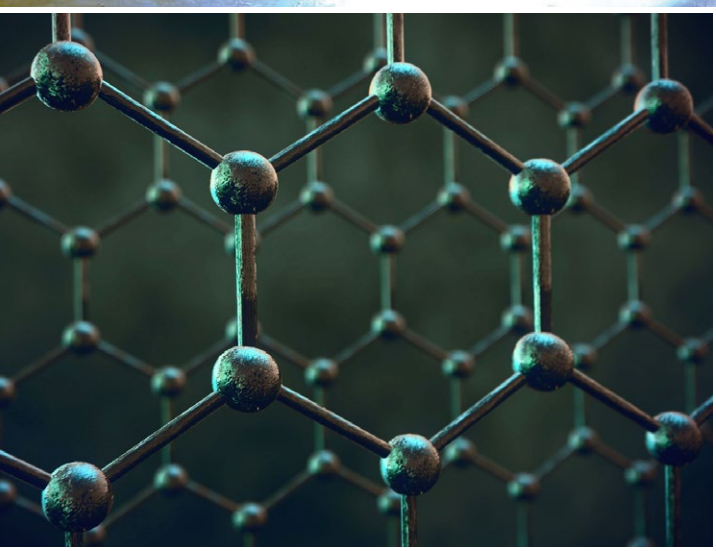
The University of Manchester is world-leading at developing new and existing materials for extreme environments. We also lead the world in the characterisation of materials from the atom to the component – measuring and exploring materials to help us fully understand their properties and potential.

Advanced materials

GLOBAL CHALLENGES
MANCHESTER SOLUTIONS

"The combination of academic leadership, relevant research expertise and our ability to work closely with industrial partners makes Manchester stand out in our field."

Professor Phil Withers, Regius Professor of Materials at Manchester and Chief Scientist for the Henry Royce Institute



Graphene Engineering and Innovation Centre (GEIC)

Graphene and other 2D materials

A shining example of the University's excellence in advanced materials is graphene; the world's thinnest, strongest, most conductive material, isolated at the University in 2004. Its potential is vast and diverse – giving us the possibility of: portable, energy-efficient water filtration and desalination plants; lighter, stronger and more fuel-efficient aircraft and cars; corrosion-proof coatings; anti-cancer drugs and ultrasensitive biosensors.

Demonstrating the remarkable properties of graphene won Sir Andre Geim and Sir Kostya Novoselov the Nobel Prize in Physics in 2010. The physicists led a team that managed to isolate graphene from graphite using simple sticky tape; peeling layer after layer of graphite until they were left with a layer one atom thick – graphene. When they observed its properties, the true realisation of what they had achieved became clear. Now more than 300 people across more than a dozen academic disciplines at the University work on graphene and related 2D materials. One of the most exciting areas of graphene and related 2D materials research is in membranes – thin barriers that allow water to pass through them while blocking off all impurities. Professor Rahul Nair leads the way in this field and is working alongside leading companies to create water filtration and desalination devices, as well as researching liquid and gas separation.

"Our breakthrough work at Manchester has demonstrated that there are realistic possibilities to scale up and eventually mass-produce graphene-based membranes with the required sieve sizes to enable the affordable desalinate of water," said Professor Nair.

The heart of advanced materials innovation

Our track record for research power is reinforced by vast capital and research investment, with around £420 million invested in Manchester's campus-based advanced materials research community; £121 million of this capital investment is for Graphene@Manchester, including £61 million for the research-focused National Graphene Institute and a further £60 million for the business-facing Graphene Engineering Innovation Centre. Together, these facilities support the University's vision to create a Graphene City in the heart of Manchester – made up of scientists, engineers, innovators, investors, manufacturers and industrialists, this community will build a thriving knowledge-based economy.

With our world-leading community of experts and supporting facilities, combined with Manchester's ability to build and lead partnerships between academia and industry, it will be possible to take research breakthroughs to finished product.

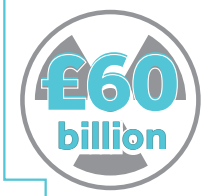
The Henry Royce Institute is the UK's national centre for advanced materials and represents more than £330 million of investment in materials science research and capability. Led by The University of Manchester and with support from eight founding partner institutions, the Royce is focused on the key materials challenges that define our times, and on creating real solutions that make a fundamental difference to the UK economy.

From future cities and their energy supplies, to computing, manufacturing and medicine, the Royce's research has the potential to have a significant impact that will be felt in people's everyday lives. The Institute's Chief Scientist, Regius Professor Philip Withers, says: "The vision behind the Royce is to create an integrated research supply chain in order to design, make and test advanced materials systems, cost-effectively and at speed".

ADVANCED MATERIALS

THE CHALLENGE

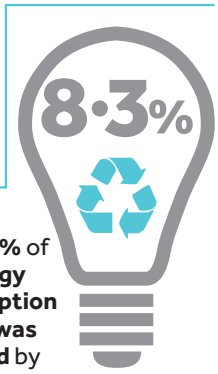
Every two minutes a **child under five dies** due to **inadequate water supply**, **sanitation** and **hygiene**



New nuclear build is **valued at £60 billion** in the **UK**

Businesses that **produce** and **process materials make up 15% of the UK's GDP**

Globally, **corrosion costs** more than **$2tn** per year



Just 8.3% of **UK energy consumption** in **2015 was provided** by **renewable sources**

21%

Transport accounts for a **fifth** of the **UK's carbon emissions**

10km

Deep sea platforms **drill for oil 10km below the seabed**, at temperatures of **more than 200°F** and under **pressures of 20,000psi**

3000°C

The planes of the future will need to withstand **temperatures as high 3,000°C**

HOW WE ARE TACKLING IT

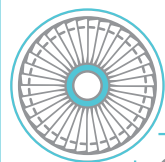
Single-layer graphene is a **million times thinner than a human hair** and **will revolutionise energy, health care, water** and **consumer electronics**

3D

Our **3D characterisation capability** is **enabling us to study the properties** of **new protective coatings** for **materials** such as **aluminium used in planes**

The BP International Centre for Advanced Materials works on research projects at the University to improve the safety, **reliability and performance** of materials across the oil and gas industry

£60bn



Manchester **pioneered a new process** to strengthen aero-engine fan blades used on 1,200 Trent XWB engines **worth over £60billion**

2D

We're home to the **global knowledge base** in **2D materials**, with **2 Nobel laureates** and more than **£170m of current investment**

230

Dalton Nuclear Institute's paper on **welding for nuclear new build** received **more than 230 citations** over a decade

WHY MANCHESTER?

We have more than £248m of **research projects**

£235m

MANCHESTER

Manchester has been chosen as the home to the **£235 million Henry Royce Institute**, a **hub to accelerate knowledge** and **applications of advanced materials** for the good of **industry** and the **economy**

300

More than 300 people working on **graphene** and **2D materials**

The University is home to the **$100m (£64m) BP International Centre for Advanced Materials**, the **£61m National Graphene Institute** and the **£60m Graphene Engineering Innovation Centre**

Vital to industry and everyday lives

Crucial to the success of Graphene@Manchester, the Henry Royce Institute, and our wider network of research centres is industrial partnership. In all of our advanced materials research we're working with dozens of industrial partners to bring discoveries from the lab to the lives of real people.

For example, Rolls-Royce, which is setting global standards in the aerospace sector, has worked with world-leading materials scientists at Manchester to help produce engines that deliver optimum performance and safety standards. At the $100 million BP International Centre for Advanced Materials (BP-ICAM), we work with BP and partner universities to develop a fundamental understanding of materials science which is applied to solve challenges for BP and the energy industry. And in graphene alone we're working with more than 35 commercial organisations, including UK brand inov-8 to develop and launch the world's first-ever sports shoes to utilise graphene. This pioneering academic-business partnership has developed breakthrough rubber outsoles for inov-8's high performance running and fitness shoes that in testing have outlasted 1,000 miles and are scientifically proven to be 50% harder wearing.

Dr Aravind Vijayaraghavan, Reader in Nanomaterials at Manchester, said: "Using graphene we have developed the G-SERIES outsole rubbers that are scientifically tested to be 50% stronger, 50% more elastic and 50% harder wearing. We are delighted to put graphene on the shelves of 250 retail stores all over the world and make it accessible to everyone."

Not only is our expertise recognised by industry – it also has royal approval. We've received the Queen's Anniversary Prize twice, once for our pioneering work on nuclear materials and again for our x-ray imaging of materials behaviour respectively. Our imaging capability has benefited sectors including nuclear, aerospace, oil and gas, airport security, automotive, healthcare, manufacturing and defence. It also produces wider benefits for medical and life sciences, cultural heritage, palaeontology and food technology, as well as training future engineers and scientists.

Another area where advanced materials can make a critical difference is nuclear energy. Professor Tim Abram, who leads the Rolls-Royce Nuclear University Technology Centre at Manchester, is working on advanced nuclear fuel materials that will benefit both the current and the next generation of nuclear reactors. Current fuel materials have performed well under normal operational conditions, but are not able to withstand some severe accident conditions – such as those at Fukushima.

Leading research into the future of fuels, developing new, transformational materials, and partnering with some of the world's leading companies – these are just a few of the reasons why The University of Manchester is the world's leading centre for advanced materials research and commercialisation.

Find out more

www.manchester.ac.uk/advanced-materials-research

" The Royce provides a national centre where we can bring the materials community together, to ensure we can translate new developments in advanced materials into companies, jobs and economic growth."

Baroness Brown of Cambridge,
Chair, Henry Royce Institute

Researcher profile

Professor Sarah Cartmell

Professor Sarah Cartmell leads the Materials in Medicine activity for the Faculty of Science and Engineering at The University of Manchester and is a research champion for the biomedical materials theme which is supported by the Manchester-based Henry Royce Institute as part of a national advanced materials research portfolio.

Sarah, who is also a member of the School of Materials senior management team, is leading several large research projects totalling more than £2 million. These transitional grants, funded by the Medical Research Council and the Biotechnology and Biological Sciences Research Council, focus on tendon repair techniques and electrical bioreactor development.

My research interests are focused on orthopaedics which includes bone structures, cartilage or tendons – basically, anything to do with skeletal structure that helps you walk and move around.

More specifically I work in tissue engineering, which means I grow pieces of tissue in the lab with a view to implanting them into the patient's body.

For example, if a patient has a worn or damaged hip joint my aim would be to grow a new section of replacement tissue rather than using a piece of metal that would need to be replaced every 10 years or so.

Biomaterials is a very exciting research area in the wider development of advanced materials – its potential to transform the way we treat patients will deliver major breakthroughs in global health care.

I believe the approach taken by Manchester is truly pioneering, partly because of the collegiate way we work with other research teams across the University's diverse materials science community – but also by the way we lead engagement with other experts and commercial partners.

Professor Sarah Cartmell

Meet more of our advanced materials experts at **www.manchester.ac.uk/advanced-materials-experts**

Setting global standards – making aero engines perform even better

Air travel is taking us further, more quickly, more often. Meeting this growing demand requires evermore rigorous standards of safety. Setting global standards in this area, Rolls-Royce worked with world-leading materials scientists at The University of Manchester to help produce engines that deliver optimum performance and safety standards.

Global problem: tiny cracks that could be a big issue

Fan blades in aircraft engines endure large loads and high-frequency vibrations. Over time, these stresses can create microscopic cracks in the blades which can lead to issues in service.

The traditional method for stopping cracks is 'shot-peening', ie firing shot (round metallic, glass or ceramic particles) at the blades in order to rework the metal's surface. The shallow indentations create compressive residual stresses that stop cracks growing.

Rolls-Royce wanted to explore alternative cutting-edge methods with leading experts at Manchester. The academic task force embarked on an investigation into laser shock peening (LSP), which introduces compressive stresses to a much greater depth via plasma created by a powerful pulsed laser.

Manchester solution: stress management for stronger materials

Manchester researchers worked with Rolls-Royce to study the fundamental nature of LSP-induced compressive residual stress. It became clear that LSP is an improvement on more established shallow peening: it effectively compresses the atomic structure of the fan blades to make them much more resilient to cracking and fatigue.

Professor Philip Withers, Regius Professor of Materials, received the Armourers and Brasiers' Company Prize from The Royal Society in recognition of his use of neutron and hard X-ray beams to map stresses and image defects.

He says: "Our team analysed the potential of LSP to improve fan blades' fatigue resistance by using penetrating synchrotron X-ray beams.

"We discovered that this method generates deep compressive stresses which remain stable during air travel.

This testing confirmed LSP could be safely applied to the fan blades to make them stronger and last longer.

"We've got excellent facilities and expertise at the Materials Performance Centre, Engineering and Process Metallurgy Group, and Materials Testing and Analysis Unit.

"The combination of academic leadership, relevant research expertise and our ability to work closely with industrial partners makes Manchester stand out in this field.

"Rolls-Royce trusted our evidence and immediately adopted LSP to treat its Trent 800 engines."

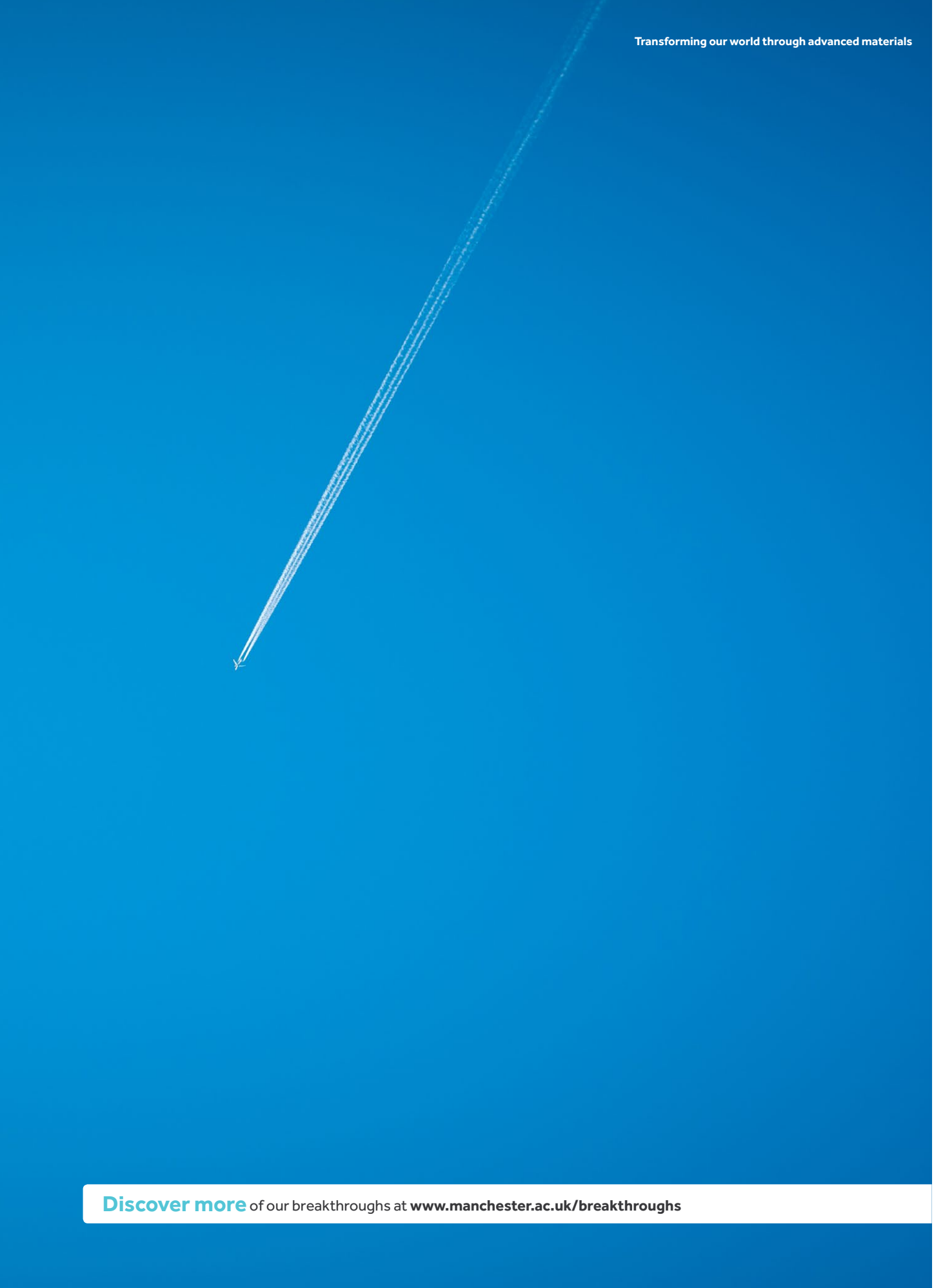
Industry-changing impacts

The University's research into LSP for Rolls-Royce has led to:

- LSP being used to treat all Trent 500, Trent 800, Trent 100 and XWB blades, making millions of air travellers safer every year;
- a longer lifetime for a high-investment product – sales of 1,200 treated Trent XWB engines alone are worth more than £60 billion.

" The combination of academic leadership, relevant research expertise and our ability to work closely with industrial partners makes Manchester stand out in this field. Rolls-Royce trusted our evidence and immediately adopted LSP to treat its Trent 800 engines."

Philip Withers, Regius Professor of Materials



Discover more of our breakthroughs at **www.manchester.ac.uk/breakthroughs**

More than one in three of us will be diagnosed with some form of cancer in our lifetimes. The disease can have a devastating impact on the lives of patients and on their friends and family who feel its economic and emotional fallout. As our population ages, health services and taxpayers face an increasing bill.

Loosening cancer's grip

Research is a key weapon in our fight against cancer. Survival rates from the disease have doubled in the last 40 years in the UK. Developing new treatments to cure cancer and tackle side-effects is crucial, but this work must be carried out alongside new methods to change lifestyles, build resilient health services and help people reduce cancer's impact.

The University of Manchester has a rich history of cancer research, stretching back to the early 20th-century research of Sir Arthur Schuster into x-radiography and radium. Today, we're working on the full range of ways to tackle what is the cause of more than one in four deaths in the UK.

"We've made some great progress in cancer research," according to Professor Rob Bristow, lead of our Cancer domain. "Unfortunately as we learn more, the immense scale of the challenge becomes apparent, but we're ready to face that head on."

"We're putting patients at the heart of our work. By starting with a clinical question, we can ensure that our laboratory research has the greatest impact."

Fundamental science and drug discovery

Discoveries made by our cancer scientists have led to a greatly improved understanding of the mechanisms behind the onset of the disease.

At the Cancer Research UK Manchester Institute, our work spans the whole spectrum of cancer research, from investigating the molecular and cellular basis of cancer to the development of therapeutics.

Professor Richard Marais is the Director of the Institute, and his work is focused on melanoma. Numbers diagnosed with this particular form of skin cancer are continuing to rise, with almost 13,000 people diagnosed in the UK each year. Professor Marais is leading a team whose research includes the development of a new generation of drugs to overcome the resistance that melanoma sometimes develops to existing treatment.

Manchester Cancer Research Centre

In another success, the Institute's Drug Discovery Unit took a target that had been identified by the Leukaemia Biology Group and created a series of new drugs in their medicinal chemistry lab. Following promising results in initial investigations, a commercial pharmaceutical company provided access to their own, similar, experimental treatment and doctors in Manchester are now successfully progressing with clinical trials in patients with leukaemia.

An all-round approach

We're one of the best placed universities in the world to access patients and transform research findings into practical benefits. We have hundreds of researchers working across areas such as immunology, psychology and nanomedicine, and we can also harness our wider scientific community, including the chemical, physical and mathematical sciences.

This collaborative approach is evident in our close links with The Christie NHS Foundation Trust. The University has a long history of working with The Christie's scientists and health care professionals, right back to the early part of the 20th century when researchers collaborated on early uses of radiotherapy.

Western Europe's largest cancer centre, The Christie jointly employs staff with the University to work at the Division of Cancer Sciences, working on tools to improve radiotherapy's accuracy and reduce its side-effects, trialing new drugs and bringing one of only two NHS proton beam therapy centres in the UK to Manchester.

This team approach is facilitated through the Manchester Cancer Research Centre (MCRC), which was established in 2006 by the University, The Christie and Cancer Research UK – the world's largest charitable funder of cancer research.

Since its creation, this partnership has expanded to include other local NHS organisations – providing unrivalled access to patients and samples, and broadening the scope and reach of research.

A new £28.5 million building opened in 2015 to house an additional 150 scientists and a further 100 clinical trials support staff. This is a joint venture between the MCRC partners, and will deliver even more world-class research into cancer biology, drug discovery and clinical trials.

The consequences of cancer

New drugs and understanding of the mechanics of cells are improving individual outcomes, but the World Health Organization still expects 22 million new cancer cases a year around the world by 2020 – an increase from 14 million today. Each new case represents someone unable to work, suffering the side-effects of the powerful treatments they are given, and a carer or carers looking after them and perhaps dealing with their death.

Our research has shown that carers for people with cancer are between five and seven times more likely to have mental health problems than the general population. Gunn Grande, Professor of Palliative Care, found that their ability to concentrate, make decisions and deal with problems may be affected. If we can ensure that carers feel better supported, we are likely to reduce some of the more extreme stresses of caregiving, so that carers are more able to carry on their valuable work without being 'broken' by the experience.

In a joint appointment with The Christie, Professor Janelle Yorke heads the patient centred research team. Her work investigates patient-reported quality of life measures and the management of symptoms and side effects.

"We're testing this family of drugs in clinical trials to establish that they are both safe and effective in cancer patients, potentially providing urgently needed new treatments for patients who have run out of options."

Professor Richard Marais, Director of the Cancer Research UK Manchester Institute

CANCER

THE CHALLENGE

More than one in three people **will develop** some form of **cancer** during their lifetime

In 2012, according to the World Health Organization:

14m
14 million new cases of cancer

8.2m
8.2 million people worldwide died from cancer

200+
The number of different **types of cancer**

OUR RESEARCH

6x NHS
organisations **collaborate** with the **University** as part of the **Manchester Academic Health Science Centre** (MAHSC)

60,000
60,000 women will be invited to join a study into whether **personalised breast cancer risk prediction** can be introduced into the NHS Breast Screening Programme – the **largest study of its kind** in the UK

25%
of people with **lung cancer live for two or more years** after diagnosis **thanks to Manchester** research

1.5m
women with **breast cancer** across the world are now **benefitting from endocrine therapy** approaches developed at the University

8% of all England's **complex single gene diagnostics** are handled at the Centre for Genomic Diagnostics and Innovation **based at the University** / Central Manchester Trust

8%

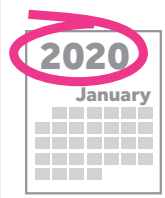
£30m
£30 million is invested in attracting **internationally leading** investigators to the **Manchester Cancer Research Centre**

100,000
patients a year benefit from **better nutrition** before and after treatment

OUR PARTNERSHIPS

We work with organisations including:

OUR GOALS



More than two-thirds of newly diagnosed patients in the Greater Manchester region will **live for more than five years** as part of **MAHSC's vision for 2020**

One of the top five: we aim for Manchester to be among the five **best integrated cancer systems in the world by 2020**

She has led the development of a website that helps cancer patients make crucial decisions about their treatment, and allows them to explore the implications of certain options and hear how patients in similar situations to themselves reacted.

A unique setting

In Greater Manchester, there is a devolved and integrated health and social care system. This gives local control of a £6 billion annual budget and presents an unrivalled opportunity to lead the implementation of clinically validated research into standard practice for a population of 3 million.

The Manchester Lung Screening Pilot was the UK's first NHS community-based, CT lung cancer screening service. Its pilot study invited people at risk of lung disease, from deprived areas of Manchester, to attend a Lung Health Check inside a pop-up facility at a local supermarket car park.

Results showed that CT scanning of high-risk people helps identify lung cancers earlier, giving doctors the chance to cure them. The Greater Manchester Cancer Plan allows this screening programme to now be rapidly rolled out across the region, offering potentially life-saving early diagnosis to millions.

Cancer is a disease that affects so many, in different, often devastating ways. We want to loosen cancer's grip and improve the lives of those it affects.

Find out more

www.manchester.ac.uk/cancer-research

"We will have a unique test-bed within the Greater Manchester healthcare system that will allow us to quickly trial and then implement new approaches for prevention, screening, diagnosis and treatment that could dramatically change the lives of the local population."

Professor Rob Bristow,
Director of the Manchester Cancer Research Centre (MCRC)

Researcher profile

Professor Rob Bristow

Rob is the Director of the Manchester Cancer Research Centre, as well as being head of our Cancer domain.

Rob came to Manchester because he saw an exciting opportunity to build research teams that could really make a change in the way that cancer patients are treated in the NHS.

To answer the big questions and improve outcomes for more patients, we need to bring together scientists, clinicians and other healthcare professionals.

I'm a real zealot for 'team science' and I think Manchester is the perfect city in which to push this approach forward.

The University's close working partnership with The Christie and other NHS trusts in Greater Manchester really helps to foster innovative multidisciplinary research. We've also got some fantastic collaborations with international academic institutions and industry that enable us to access newly developed technology and treatments and allow our patients to benefit.

We're creating exciting and bespoke Mancunian research ideas that could transform cancer care around the world.

Professor Rob Bristow

Meet more of our cancer experts at **www.manchester.ac.uk/cancer-experts**

Saving children's lives across the globe

Leukaemia is the most common cancer in children and teenagers, and acute lymphoblastic leukaemia (ALL) is the most common type of childhood leukaemia. Research at The University of Manchester has made a significant contribution to the UK having one of the highest cure rates in childhood ALL internationally.

Global problem: a deadly form of cancer

Acute lymphoblastic leukaemia (ALL) is a particularly rapid and aggressive form of cancer requiring immediate treatment.

Manchester solution: direct cash transfers

For the last 20 years, University of Manchester researchers have pioneered standards for improving the outcomes for children with ALL.

The work of Professor Tim Eden from 1993 to 2003 at Manchester led to the routine use of specific drugs that are now standard in the therapy of childhood ALL in the UK and Ireland. A further clinical trial (ALLR3) designed more recently by Vaskar Saha, Professor of Paediatric Oncology at Manchester, now forms the basis of relapse strategies worldwide for children with ALL.

Professor Saha says: "Manchester is recognised internationally as a centre for expertise in teenage and young adult cancers, and nationally as a centre for clinical studies in childhood leukaemia – which made it easy for us to find willing collaborators.

"Thanks to the scale and extent of our international partnership, The University of Manchester was able to design and run a unique trial – the largest study of its kind in the world – and the first-ever randomised international trial for relapsed ALL."

Collaborators from countries including the Netherlands, Australia and New Zealand needed to adapt the study quickly for their patients. To facilitate this, we created an innovative bespoke remote-entry clinical trial management system, which permitted remote registration and data entry, provided decision support and standardised reporting across all recruiting centres.

Professor Saha added: "We also built translational research into the clinical trials, which allowed the identification of previously unidentified mechanisms of therapeutic failure, paving the way for novel therapeutic strategies."

Life-changing impacts

Direct results of our research proving the long-term positive impacts of direct cash transfers in tackling persistent poverty include:

- children in the UK newly diagnosed with ALL now have a cure rate of over 85% – among the best in the world;
- outcomes for relapsed cases have improved by 10% in the UK, the Netherlands, Australia and New Zealand;
- a role has been identified for the drug mitoxantrone, which improves the outcome of all categories of relapse compared to previously used drugs;
- changes in clinical practice based on our research are now national standards of care for children with ALL in the UK and Ireland;
- various international groups have adopted key findings from the front-line trials, and the relapse protocol for childhood ALL now underpins European practice, helping save more children's lives in more countries.

" Thanks to the scale and extent of our international partnership, The University of Manchester was able to design and run a unique trial – the largest study of its kind in the world – and the first-ever randomised international trial for relapsed ALL."

Vaskar Saha, Professor of Paediatric Oncology

Discover more of our breakthroughs at **www.manchester.ac.uk/breakthroughs**

The University of Manchester is finding solutions to some of the biggest energy challenges facing the world, from the sustainability of resources to the social factors that stand in the way of equal access to energy.

Securing our energy future

As the world develops, we're using more and more energy in our everyday lives. The more our cities grow, the more energy we use to fuel our vehicles, keep our appliances running, light our streets and heat our buildings. That raises important questions about where energy comes from, how smartly we use it, how accessible it is and what impact our generation and consumption of energy has on the environment.

At Manchester we're finding the answers. We're looking at the whole energy system – generation, transmission, distribution, storage and eventual usage – to produce technologies and approaches to secure the planet's energy future.

Generation

The breadth of expertise at Manchester means we can push research boundaries and shape energy innovation. We are exploring alternative energy strategies, pioneering work in emerging renewable technologies and bridging fuels, and we're at the forefront of nuclear research.

Nuclear energy

Across the world, there is a pressing need for low-carbon, secure and affordable energy – this has led to a renaissance in civil nuclear power. New nuclear build and existing reactor life extension programmes are underway in the UK and further afield, contributing to the nuclear market's significant contribution to the economy.

The University of Manchester's nuclear expertise is built on a strong research heritage, with a focus on meeting the challenges of today and the future.

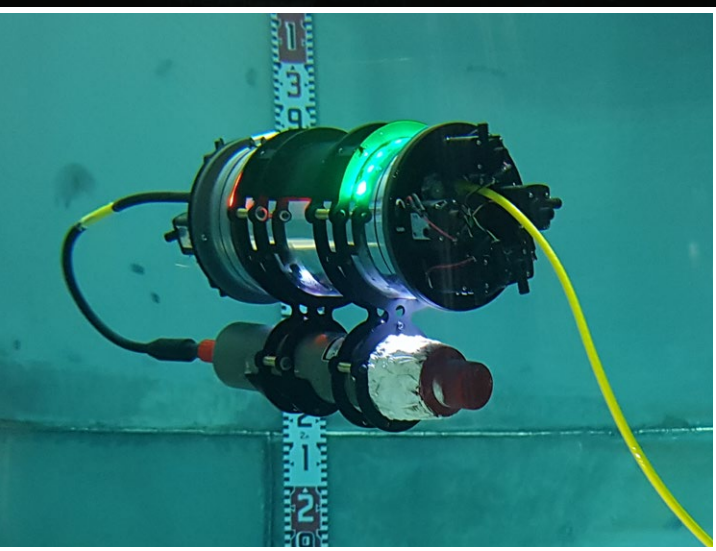
Our Dalton Nuclear Institute is the UK's largest academic centre for nuclear R&D and high-level skills development and has built a comprehensive network of national and international partnerships. With state-of-the-art facilities and substantial collaborative links, the Institute drives innovation and is an influential contributor to fundamental and applied research across the full nuclear fuel cycle. Research underpins the safe and extended operation of existing reactors, the future development of more efficient new-build nuclear power plants with

Energy

GLOBAL CHALLENGES
MANCHESTER SOLUTIONS

" The size of the University and the sheer range of knowledge here allows us to bring people together from a huge range of research areas. This helps us to find innovative ways to tackle some of the world's biggest energy challenges."

Ian Cotton, Professor of High Voltage Technology and Director of Manchester Energy



a longer lifespan, and innovation in decommissioning, spent fuel and radioactive waste management.

The Institute brings together world-leading experts from across disciplines and gives them access to some of the most extensive and advanced nuclear research facilities in Europe, including the £20m Dalton Cumbrian Facility for radiation science and nuclear engineering decommissioning research near Sellafield.

The Institute also leads The Beam – a novel research network fostering engagement between the nuclear sciences and social research to open up new thinking and approaches for civil nuclear decision-makers.

Research activities at the Institute support the competitive growth of the UK nuclear industry through research and innovation. One such example is the £12m Robotics and Artificial Intelligence for Nuclear (RAIN) programme which is led by Prof Barry Lennox at The University of Manchester.

Bioenergy

Bioenergy can deliver a continuous supply of low-carbon, renewable energy in the form of heat, electricity, transport fuels or other energy vectors (including hydrogen and substitute natural gas). At Manchester, we seek to enable the large-scale production and use of bioenergy in a sustainable manner.

Researchers from the humanities, life sciences, and engineering and physical sciences, are involved in bioenergy research at The University of Manchester. Our work has international impact, for example in the Philippines we're looking at how rice straw that's currently burnt as waste can instead be harnessed as an energy source. And we're finding ways to produce fuel from sources such as algae – engineering bacterial enzymes and hacking metabolic pathways to turn carbon into commercially valuable gases such as propane.

With an energy resource that's so inter-linked to land use and food production, it's important to ensure that real greenhouse gas reductions are being delivered along the supply chain and that systems are implemented in a way that promotes positive socioeconomic benefits. At Manchester our academics assess greenhouse gas balances and the wider impacts of bioenergy from feedstocks in many countries, from forest residues in North America to soy plantations in Argentina.

Tidal, wave, wind and solar

Our work is optimising offshore structure design to withstand the challenging environments and the extreme loadings that they must take. We're developing models and measurement techniques that can quickly identify faults in renewable energy systems. One such programme deploys advanced computer models to increase confidence in turbine design methods and support increased investment in tidal stream power. We also lead the EPSRC-funded HOME Offshore project, working with four other UK universities to investigate the use of advanced sensing, robotics, virtual reality models and artificial intelligence to reduce maintenance cost and effort for offshore windfarms.

For the solar sector, the challenge is to manufacture photovoltaic devices that are more efficient, less expensive and better integrated into the energy grid. We're developing a solution that uses quantum dots to increase the efficiency of solar cells and, working with colleagues from the National University of Singapore, we've found that combining graphene with similar materials can create extremely sensitive photovoltaic devices.

" In solving Sellafield's complex nuclear clean-up challenges we have worked extensively with members of the Dalton Nuclear Institute, where world-class academic research aligned to our real-world issues is carried out. Such scientific underpinning will continue to be needed throughout the decommissioning of the site, a task that will take us more than 100 years."

Neil G Smart, Chief Scientist, Sellafield Ltd.

ENERGY

THE CHALLENGE

x2 **Global electricity use** is likely to **double in the next 20 years**

33% **of our energy** used is for transport

Every year a typical large coal-fired power station produces about **10m tonnes** of CO_2 and **200k tonnes of gases** associated with **ACID RAIN** and **4,000 tonnes** of **FLY ASH**

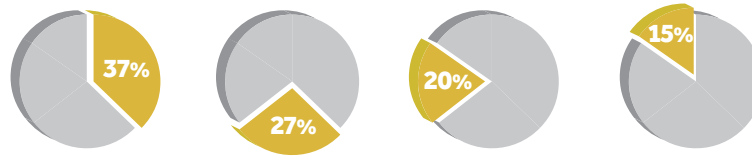
More than half of the world's population now lives in urban areas

UK CO_2 ↓ 100%

The UK is legally required to bring **all greenhouse gas emissions to net zero by 2050**, which means eliminating our use of unabated fossil fuels

The UK could generate **50%** **of its energy needs from biomass** by 2050

The current UK electricity mix is made up of approximately:



37% coal | 27% gas | 20% nuclear | 15% renewables

8% Energy bills are typically **8% of household income**

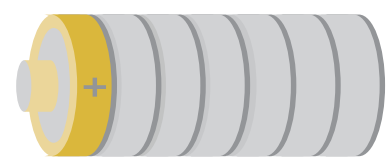
Globally, renewable power capacity is **expected to grow by 50% by 2020**, according to the International Energy Agency

HOW WE'RE TACKLING IT

Our projects are worth **over £80 million**, encompassing **energy generation, energy systems** and **energy use**

over £80 million

We have **on-campus** energy storage test facilities



We're home to leading energy research facilities including **nuclear irradiation facilities** at our **state-of-the-art Dalton Cumbrian Facility**, a **1MW** energy storage test bed, **a unique combined wave and tidal flume** and the **only 400kV-capable HV lab** of **any UK university**

150 **500**

We have 150 academic **staff** and 500 PhD **students** and postdoctoral **researchers working on energy research**

Strategic partnerships include:
National Nuclear Laboratory, EDF Energy, Rolls-Royce, National Grid, Siemens, Arup, Electricity North West and BP

We're also undertaking research on commercially-attractive perovskite solar cells to improve their stability and make them even more cost effective and efficient.

Oil and gas

We're helping the hydrocarbon sector to extract bridging fuels more efficiently from reserves. We're also improving understanding of the technical, environmental and social implications of extracting from unconventional reserves using techniques such as fracking.

Our reach in this area is global and our work is helping oil companies to recover oil more efficiently, making better use of precious resources. For example, our studies into rock outcrops in South Africa are resulting in a better understanding of how to mine deep ocean basins.

Transmission and distribution

To meet the UK's carbon targets, our electricity grid will need to be decarbonised by 2050, sourcing its energy from low-carbon sources and interacting with neighbouring countries' grids.

The multi-energy systems (MES) of the future will allow networks such as electricity, heat, cooling, fuels, transport and water to optimally interact with each other, unlocking technical, economic and environmental value. This could transform energy networks in urban areas – leading to the birth of truly 'smart' communities and cities. Our work in MES is underpinned by our leading research in electrical power systems and modelling.

At our National Grid Power Systems Research Centre, we have the largest high voltage laboratory of any UK university, capable of testing equipment designed for use on Great Britain's 400kV power system. Research here, in collaboration with EPL Composites Solutions, led to new technology that can significantly increase the capacity of existing overhead line infrastructure.

Storage

Energy storage will play a key role in decarbonising our energy system. Our research is finding ways to manage the intermittency of renewable generation and to improve the capability of electric vehicles to provide a reliable and viable form of green transport in the UK.

We're developing new storage devices for utility and grid applications such as low-temperature fuel cells, batteries and supercapacitors. An investment of more than £3 million by EPSRC has seen us create facilities that can better characterise, test, model and evaluate energy storage solutions.

One of our most exciting recent discoveries has been the role that graphene could play in a sustainable and secure energy future. By incorporating nitrogen to thermally-expanded graphene oxide, we increased its capacitance, creating a form of storage that could be suitable for large-scale industrial use. Complementing its National Graphene Institute, The University of Manchester's £60 million Graphene Engineering and Innovation Centre (GEIC) will enable industry-led development in graphene applications in partnership with academics.

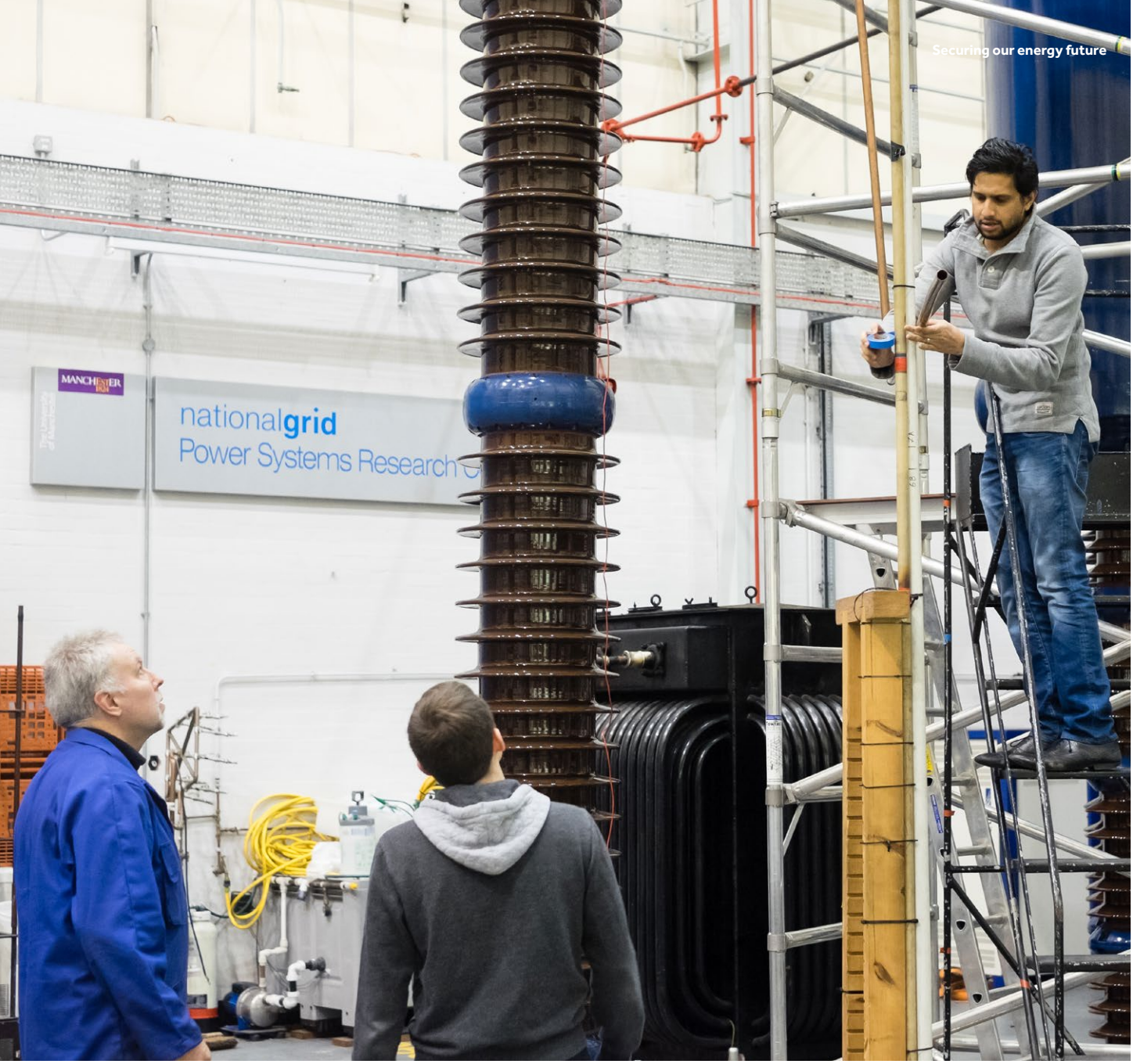
Energy consumption

The energy challenge is not just about generation, transport and storage – it's also about how we use energy in our homes, businesses and communities. Energy use can go unnoticed, despite being part of our everyday lives: from the electricity that we require to provide lighting and entertainment, to the fuel needed to transport goods on to shelves – not to mention the energy used by industries to process, manufacture and package goods.

We contribute to one of the EPSRC's End Use Energy Demand Centres, researching what drives energy demand within sectors including international shipping and the food and drink industry. We're examining how the public will respond to new technologies such as smart meters or cope with any unreliability in electricity supply.

"We are among the first in the world to try to capture the true diversity of energy demand in cities and project how this will change when smarter technologies will be available."

Prof Pierluigi Mancarella, Professor of Smart Energy Systems


nationalgrid
Power Systems Research

Energy in cities

Cities are both the key sites of energy production and consumption. They're also the main sites of social, economic and technological change.

As they evolve, we need technologies and policies that meet the needs of the individuals and organisations that inhabit them. Our work has already outlined how social housing landlords could cut fuel bills and raise living standards, and provided insights into fuel poverty in eastern and central Europe. The University's Manchester Urban Institute leads the European Commission-funded European Energy Poverty Observatory (EPOV) to bring about transformational change in knowledge about the extent of energy poverty in Europe and measures which can combat it.

We work closely with partners across the region to evaluate new technologies and techniques. The District Information Modelling and Management for Energy Reduction (DIMMER) project, for example, provided pioneering insights on our energy future. The outputs are now being used to create new models to explore the design of multi-energy microgrids that can represent energy use across entire areas and take account of potential future advances in technology and possible changes in consumer behaviour.

We work with the Greater Manchester Combined Authority (GMCA) to help reduce Greater Manchester's carbon footprint. The BEIS-funded SCATTER project (Setting City Area Targets and Trajectories for Emission Reduction Low), a partnership between GMCA, Anthesis Group and University academics from Tyndall Manchester, is being piloted in Manchester and will provide a tool to support cities across the UK to set emission reduction targets and define appropriate pathways to achieve them.

The Triangulum project, funded by the European Commission, on which we're working with partners including Siemens, involves a €9 million investment in Manchester to develop the smart energy systems of future cities. Findings from Triangulum will not only help ensure that Manchester's future growth is environmentally sustainable, but will also be used in other cities across Europe. In addition, our University Living Lab initiative transforms our campus, effectively a small town, into a test bed for tomorrow's energy systems.

Climate change policy

We're driving policy in the search for alternative energy solutions that will help mitigate dangerous levels of climate change.

This impact on policy is a vital goal of research at Tyndall Manchester, a founding partner in the Tyndall Centre for Climate Change Research. Here, natural scientists, engineers, social scientists and economists work together to provide considerable and diverse capability in all aspects of energy and climate change.

Tyndall Manchester researchers are regularly invited to contribute to high-level policy debates, locally and globally. For example, our insights led to the UK becoming the first country in the world to introduce cumulative carbon budgets into legislation.

Through the Resilient Electricity Networks for Great Britain consortium, we're looking at how population and industrial growth, climate change legislation, changes in energy demand and the incorporation of renewable generation impact on the UK National Grid. And through the STEPPING UP consortium, we engage with industry and policy makers to understand how innovation on a smaller, local level can drive a bigger step change in the sustainability of water, energy and food.

Efficiency from source to user

To get to tomorrow's consumers, energy will have to come from a mix of sources and travel new routes, going further and faster with a minimal carbon footprint. At Manchester our innovations are ensuring systems can be put in place for this to happen.

Find out more

www.manchester.ac.uk/energy-research

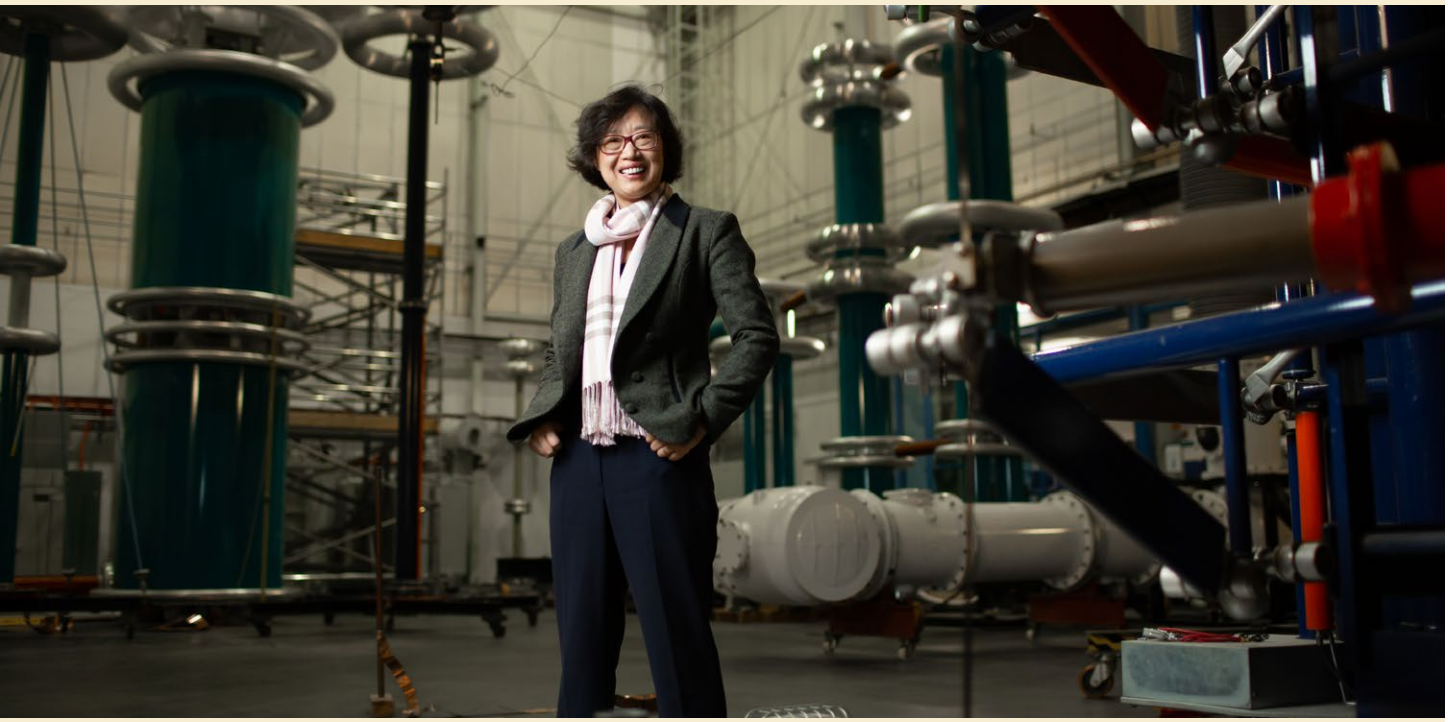
" Fuel poverty is about so much more than income and energy efficiency. It's the interplay between the environment, government policy and family circumstances. Our broad findings will be relevant to any government or corporate body that wishes to address fuel poverty."

Stefan Bouzarovski, Professor of Geography and Director of the Collaboratory for Urban Resilience and Energy at the Manchester Urban Institute

Researcher profile

Professor Zhongdong Wang

Zhongdong is Professor of High Voltage Engineering and Associate Dean for Internationalisation for the Faculty of Science and Engineering.



I studied for my PhD here at Manchester and am now leading research into power transformers. I collaborate with a wide range of industry partners, at home and abroad, providing independent research and technical consultancy. I have also maintained close links with China, where I studied for my undergraduate and Masters degrees, and have been involved in initiatives such as leading the EU-China Research and Innovation Partnership on Energy.

I enjoy seeing our research lead to significant advancements and developments in engineering applications, in particular I am pleased to see that our work over the last ten years has directly led to the creation of two international standards for the global power industry.

One project I've recently delivered is the application of environmentally-friendly and fire-safe transformer liquids. My team's research on ester liquids has proved they can be used in high-voltage transformers – bringing economic and safety advantages to the power industry and environmental benefits to society.

Our research has led to the design and operation of the first 132kV, 90MVA 'green' transformer in UK Power Networks' distribution network (valued between £1m and £2m) and revisions to National Grid's oil policy that have seen them recommend ester-filled HV transformers for use in London. These developments have contributed directly to a Manchester SME, M&I Materials Limited, increasing its sales from £15m in 2008 to £29m.

One of the differences with Manchester's approach is the push to benefit industry and society. We're solving real problems and advising people who are making multi-million pound decisions.

Professor Zhongdong Wang

Meet more of our energy experts at **www.manchester.ac.uk/energy-experts**

Making cleaner energy cheaper

If we're to mitigate the impact of climate change, humankind needs to find secure and affordable low-carbon energy that will help us meet international targets set to tackle global warming. Ongoing nuclear research at The University of Manchester may provide a vital next step towards a greener tomorrow.

Global problem: the cost of low-carbon energy

To avoid the worst impacts of anticipated climate change, the 2015 UNFCCC Paris Agreement set a global warming target that aims to restrict increases in average global temperatures to lwell below 2°C, relative to pre-industrial levels. To ensure we do not exceed this target, we must reduce greenhouse gas emissions – principally by transitioning to a largely carbon-free energy economy using alternative sources to fossil fuels.

Nuclear energy is currently the only mature, proven, demonstrably cost-effective energy technology which does not directly emit carbon. However, while reactors are very cost-effective to run, nuclear power plants are very expensive to build.

Development of the UK nuclear new build programme is underway with the construction of the Hinkley Point C twin station. It had been proposed to build in total 12 new reactors by 2030, adding 16 GW of nuclear electricity generating capacity at an estimated cost of £100 billion. However, two of the developers have failed to find funding so there will be a delay in achieving the required capacity. Finding ways of speeding up construction and reducing costs could enable this delay to be minimised.

Manchester solution: cheaper nuclear reactor construction

Manchester researchers are working on design innovations and new technologies to reduce the construction cost of nuclear reactors. Breakthrough research has looked at adopting carbon dioxide thermodynamic cycles for nuclear power conversion.

In nuclear power stations with pressurised water reactors, heat generated in the reactor core is used to produce high-pressure steam to run the turbines and produce electricity. Our researchers teamed up with Enel Produzione SpA in Rome (part of the Enel Group – a multinational energy company working in 31 countries across four continents) to examine the feasibility of replacing steam turbines with carbon dioxide turbines in existing nuclear power stations.

Dr Andrea Cioncolini, Lecturer in Thermal Hydraulics, says: "Steam turbines and associated machinery are bulky due to the very low density of the steam discharged at the last stage of the turbines. Carbon dioxide can be used instead and operated at much higher density than steam.

"We found that replacing steam with carbon dioxide would yield ten times more compact turbines and associated machinery, meaning huge savings – smaller components are generally far cheaper to build, install and maintain.

"Working with Enel gives our research immediate industry impact. We investigated closed carbon dioxide cycles for use in the Mochovce power station that is currently under construction in the Slovak Republic. Future work will consider rolling out this research to other nuclear reactor designs."

Life-changing impacts

Using smaller carbon dioxide turbines in place of bulky steam turbines would mean:

- huge potential savings on construction times, installation costs and plant footprint, making nuclear energy cheaper to produce;
- no negative impact on the plant efficiency, therefore no added costs detracting from the benefits;
- immediate industry (and environmental) impact, getting more nuclear power onto the grid in the quickest possible time.

Discover more of our breakthroughs at **www.manchester.ac.uk/breakthroughs**

There are pronounced inequalities wherever we look, both in our city of Manchester and across the world. While progress has been made in some areas, it's still the case that food, health care, infrastructure, resources and opportunities are plentiful for some yet scarce for others.

Addressing global inequalities to improve lives

For almost two centuries, The University of Manchester has been leading the way in tackling global inequalities. From poverty to social justice, from living conditions to equality in the workplace, we seek to understand our world and change it for the better.

Global Development

The entire field of international development is undergoing a transformation – in its ideas, institutions, financing and political relations. We're no longer looking at binary opposites of rich and poor, or developed and developing.

The UN Sustainable Development Goals are applicable to all countries. From eliminating extreme poverty and ensuring no one is left behind to tackling inequality and climate change, they provide a holistic global agenda our work is aligned to.

The University of Manchester has been at the forefront of development studies for over 60 years. Our Global Development Institute is the largest dedicated development research and teaching institute in Europe and our staff are committed using their research to tackle inequalities and promote social justice.

Manchester research is also giving vital insights into the relationship between consumption and global inequality. Our Sustainable Consumption Institute looks at the social structuring of consumption, how goods and services are ordered and organised, and how consumption can have an impact on global challenges. We're introducing innovative approaches to social and technological change that are central to the sustainable development debate.

Global inequalities

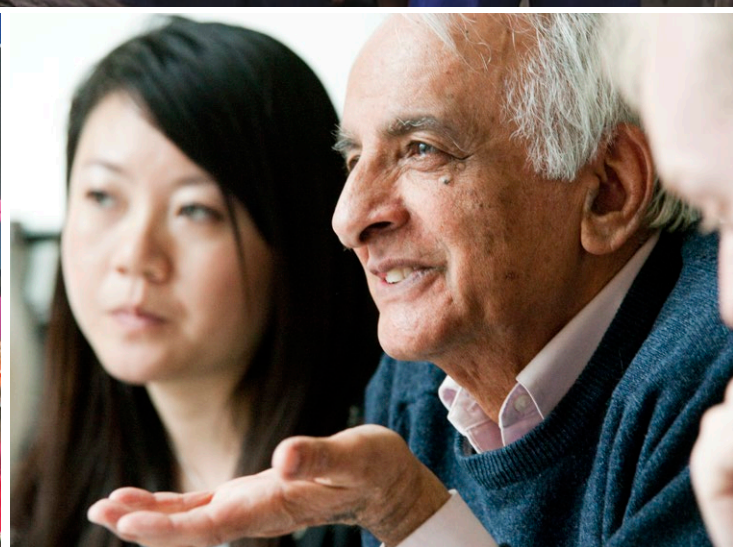
GLOBAL CHALLENGES
MANCHESTER SOLUTIONS

"We seek to not only offer an important contribution to intellectual debates around humanitarian aid, but also to transform the approach in equality in disasters and humanitarian crises."

Professor Bertrand Taithe, HCRI Executive Director, Humanitarian and Conflict Response Institute


বেইলী স্কুল


RTAINMENT
CHANGE
cex



Humanitarianism and conflict resolution

Social responsibility is as important a goal for the University as our commitment to outstanding research and teaching.

Our Humanitarian and Conflict Response Institute (HCRI) is key to both these aims, bringing together the disciplines of medicine and the humanities to facilitate improvements in global crisis response, while providing an internationally leading centre of training for humanitarian practitioners.

Through HCRI, we've pioneered a range of unique and exclusive partnerships with world-leading non-governmental organisations to shape the way that research, teaching and humanitarian aid and interventions are delivered. Nowhere has this been more prominent than through the Institute's partnership with UK-Med, which develops and deploys volunteer clinicians and allied health professionals to support international emergency medical response – an initiative funded by the Department for International Development (DFID).

UK-Med has more than 2,000 registered volunteers from across the UK and coordinates the national medical response to overseas disasters. We've worked with the UK Emergency Medical Team (UKEMT) and UK-Med to deploy medical teams to four of the most significant global humanitarian crisis responses of recent times: in the Philippines, in response to Typhoon Haiyan; in Gaza, following the 2014 Israeli-Gaza conflict; in Sierra Leone, in response to the Ebola virus epidemic; and in Bangladesh, in response to the 2017 diphtheria outbreak in the Rohingya refugee camps in Cox's Bazaar.

Our expertise is helping to bring about positive changes in global health policy. Professor Redmond has chaired numerous networks to improve and professionalise humanitarian response, while Dr Amy Hughes (MBE) from the HCRI has published recommendations on the World Health Organization's minimum standards for foreign medical teams.

Our practical humanitarian fieldwork collaborations with UK-Med, the British and International Federation of Red Cross and Red Crescent Societies, Save the Children, and Médecins Sans Frontières (MSF) informs research and knowledge exchange across our international network of partners. For example, HCRI are jointly delivering flexible Master's level professional courses with MSF and the Liverpool School of Tropical Medicine (LSTM), designed to complement the strategic aims of MSF UK, including short courses and a full Master's programme. The LEAP programme is designed to enhance management operations and learning and reflective practices, for those working in the field.

Ethnicity

Many of the barriers to equality – discrimination, exclusion and constraints on social mobility – heavily impact on ethnic minorities and migrant communities. Those who identify as African, Arab, Bangladeshi, Caribbean and Pakistani are more than twice as likely as the white British ethnic group to be living in England's most deprived neighbourhoods.

" To help those still trapped in poverty, we need path-breaking research to identify improved policies and approaches to supporting the efforts of the chronic poor to overcome the obstacles that block their prosperity."

David Hulme, Professor of Development Studies

GLOBAL INEQUALITIES

THE CHALLENGE

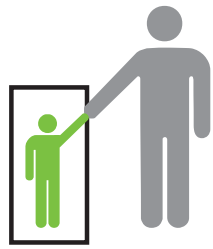
Around **800 million people go hungry** in the world **every day**[1]

767m

767 million people – one in ten people in the world – are estimated to be living below the international poverty line of $1.90 a day[5]

1,400

1,400 **women will die today**, as they do **every day**, from **illnesses** related to **pregnancy** and **childbirth** which are **easy to diagnose** and **treat**[3]



19,000

19,000 children under five will die today, most from easily preventable health problems[2]

Eight men own the same wealth as **half the world's population**[4]

Unequal opportunities, social injustice and discrimination and prejudice produce widespread inequalities by gender, ethnicity, educational background and other characteristics. These inequalities are revealed, for example, in different job and earnings prospects across people's lives.

Manchester

In 2017 we launched a **Human Development Report for Greater Manchester** to mirror the United Nation's annual global Human Development Report, providing new indices for comparing Greater Manchester to national benchmarks.

HOW WE ARE TACKLING IT

More than **300 academic staff** and **PhD students** are **working at The University** of **Manchester** to address **global inequalities**

Our employment **expertise has informed** the **European Commission**, the **European Parliament** and the **United Nations' International Labour Office**

We work with **Age Concern UK** and **local governments**, including **Manchester City Council**, **to inform policy** and **service delivery** for **ageing societies**.

Our insight into humanitarian efforts and technologies has influenced **Médecins Sans Frontières**, **Save the Children, Handicap International** and the **International Federation of Red Cross and Red Crescent Societies** – and has been recognised by the **British Academy**.

1. International Federation for the Red Cross and Red Crescent 2. UNICEF 3. World Health Organization
4. Oxfam, 2017 5. World Bank, 2013

We're making a major contribution to the understanding of issues of ethnic diversity, integration, immigration and identity. At the University's Centre on Dynamics of Ethnicity (CoDE), we set out to map and track the contemporary patterns of ethnic inequalities and how these relate to the changing ways in which ethnic identities are perceived, acted upon and experienced.

Funded by the Economic and Social Research Council (ESRC), CoDE assembles specialists from sociology, economics, demography, geography, politics and history. Through collaborations with the Joseph Rowntree Foundation and the Runnymede Trust, we've produced briefings and area profilers that make data on ethnic inequalities publicly accessible.

And at The Cathie Marsh Institute (CMI) we work to provide a better understanding of social and political inequalities, addressing key issues around ethnicity as well as gender, class, social mobility, political participation, ageing, health and wellbeing.

Employment inequalities

From differences in pay to lack of opportunities to build a career free from discrimination, inequalities in the workplace have a profound effect on individuals, societies and economies, locally and globally.

Our research on inequalities focuses on people's experiences of work, divisions and experiences in the labour market, and emerging patterns of vulnerability, exploitation, marginalisation and exclusion. This activity includes the research undertaken by the Work and Equalities Institute, building on the previous research of the European Work and Employment Research Centre and Fairness at Work Research Centre.

We have an international reputation for our contributions to labour debates – and our research impacts on the real world. Our work on global value chains and inequalities has had particular impact, for example with Cadbury on cocoa production in Ghana, and for garment workers in Bangladesh following the Rana Plaza disaster.

The ESRC funded a high-profile project on lesbian, gay and bisexual employees' experience of discrimination, bullying and harassment at work. We've completed investigations into social inclusion, trade unions and the experience of migrant workers across Europe, supported by the ESRC and the Leverhulme Trust. With funding from the ESRC, the International Labour Organisation and the European Commission we've conducted more than two decades of research into gender inequalities, including the impact of economic austerity policies, minimum wage regulation and low-wage work.

A fairer, healthier world

We're experts in unravelling the social inequalities that stand in the way of better health care for all – for example, our research has led to a better understanding of urban health issues in cities across Europe, and we're investigating the relationship between ageing, well-being and work, and the barriers to people exercising in later life. Health care researchers based at the University develop evidence to influence policies that help improve the health and well-being of the most disadvantaged in society. Our strengths in the field of global health range from the improvement of care for women in low and middle-income countries to engagement with donors and policymakers.

Our research is helping to bring about a fairer and more just world.

Find out more

www.manchester.ac.uk/advanced-materials-research

"We work with inspirational midwives who are working with limited resources and few developmental opportunities. The Centre for Global Women's Health is helping to support them in their work."

Tina Lavender, Professor of Midwifery
and Director of the Centre for Global Women's Health

Researcher profile

Professor Diana Mitlin

Diana is managing director of the Global Development Institute and is the academic lead for the Global Inequalities Research Beacon.

The focus of Diana's research is on the priorities of low income households in urban areas, looking at what's happening and how things can be improved. For the last 20 years, Diana has worked closely with Slum Dwellers International, a network of homeless and landless people's federations and support NGOs. This collaboration enables her to learn from the experiences of grassroots organisations in addressing social injustice, poverty and inequality.

Diana's research on the upgrading of informal settlements and the approaches that social movements have used to advance grassroots development caught the attention of the Bill and Melinda Gates Foundation, who committed almost US$30 million to support the approaches and initiatives Diana was writing about and involved with.

The barriers and differences between the Global North and Global South are breaking down. We need to understand how a bunch of academics sitting in Manchester can add value to development processes. This will involve more collaboration with existing communities, researchers and knowledge generators that we work around the world and will require additional collaborations to be established. It will be a hugely intellectually stimulating, but challenging task.

Diana Mitlin,
Professor of Global Urbanism

Meet more of our global inequalities expert at **www.manchester.ac.uk/global-inequalities-experts**

Helping lift families out of poverty

In 2013, 767 million people – or one in ten people in the world – were estimated to be living below the international poverty line. Dedicated to high-quality poverty research with real societal impact, The University of Manchester is now shaping policy and practice in several countries, helping to alleviate poverty on a massive scale.

Global problem: persistent poverty

Addressing persistent poverty across the world is an urgent issue, but many proposed solutions attempted in the past have failed. Promising ideas can prove unsuccessful in practice, and progress can often be temporary.

Families affected by such chronic poverty find it hard to send their children to school and have limited access to markets for goods and services.

Manchester solution: direct cash transfers

Armando Barrientos, Professor of Poverty and Social Justice at our Global Development Institute, led international research into the scope and effectiveness of direct cash transfers as a means to reduce persistent poverty. These are regular sums of money given by government to families living in extreme poverty to use as they see fit.

The research by Professor Barrientos and his colleagues in Manchester's Chronic Poverty Research Centre initially examined the impact of tax-financed pension programmes on poverty among older people, before extending its focus to all forms of direct transfer to poor households.

The research demonstrated that direct anti-poverty transfers are a practical, politically sustainable and financially feasible means to address extreme and chronic poverty in low-and middle-income countries.

Professor Barrientos says: "The key findings were that properly designed and implemented anti-poverty transfers strengthen the productive capacity of households, address long-term structural and persistent poverty and allow households to allocate their resources.

"These breakthrough Manchester findings have shaped development policy, influenced national governments and informed practice in several countries, helping to alleviate poverty across the globe.

"Poverty research has a long tradition at Manchester," he added. "I wanted to conduct my research here because of the critical mass of researchers from a range of disciplines working on poverty and development at an international level."

Life-changing impacts

Direct results of our research proving the long-term positive impacts of direct cash transfers in tackling persistent poverty include:

- US$2 per month pledged to all children born in South Sudan after the 2006 Peace Accord;
- 40% increase in UK government funding for the Department for International Development's Chars Livelihood Programme, which aims to improve the livelihoods of more than one million people in chronically poor households in the island chars of north-western Bangladesh;
- implementation of a pilot anti-poverty transfer programme in Uganda;
- shaping of development policy at a global level, following Professor Barrientos advising the UN High Level Panel Report for the post-2015 development agenda.

Discover more of our breakthroughs at **www.manchester.ac.uk/breakthroughs**

Fossil fuels have been the primary energy source for society since the Industrial Revolution. They provide the raw materials for the manufacture of most chemicals, materials and consumer products including medicines, personal care products, transport fuels and plastics.

Leading the revolution in industrial biotechnology

At The University of Manchester we've set out a bold vision to rethink the design of sustainable chemical manufacturing for industrial and healthcare needs. Key to this vision is our Manchester Institute of Biotechnology (MIB) – this leading industry-interfaced biotechnology research institute is driving bio-based chemicals manufacture in the UK.

As we transition from oil and gas to bio-based economies in the 21st century, the major needs for chemicals manufacture are smart, predictable and sustainable processes. Industrial biotechnology offers an attractive alternative to traditional petrochemical-based manufacturing, instead using biological resources such as plants, algae, fungi, marine life and micro-organisms to sustainably produce pharmaceuticals, chemicals, energy and materials. Biological processes have been honed through billions of years of evolution, and are capable of performing incredibly selective chemistry at lower temperatures and pressures than in traditional chemical manufacturing, using water to reduce the need for expensive and hazardous industrial solvents. Natural systems can now be tailored through biological sciences such as Synthetic Biology and Industrial Biotechnology to perform the processes required by industry to support future clean growth.

A bio-industrial revolution

Just as Manchester was at the heart of the first Industrial Revolution, The University of Manchester is leading the way towards a bio-industrial revolution. Industrial biotechnology and bio-based chemicals manufacture underpin one of the largest industrial sectors with the UK Bioeconomy estimated to be worth over £150bn gross, generating over 4 million jobs.

Industrial biotechnology

GLOBAL CHALLENGES
MANCHESTER SOLUTIONS

" A multidisciplinary approach is essential if we're to transform the traditional chemical and chemical-related sector to a sustainable and competitive one that draws on disciplines such as organic and synthetic chemistry, biochemistry, molecular biology, enzyme kinetics, genomics, proteomics, bio-informatics and bioprocessing."

Professor Nigel Scrutton, Director of the MIB

Combined with the emerging science of synthetic biology, Iindustrial biotechnology has the capacity to transform the UK industrial landscape offering safer, cleaner and greener bio-based manufacturing routes to all industrial sectors. These innovative manufacturing routes are also helping to reduce greenhouse gas emissions and enabling more effective use of agriculture, food and municipal wastes.

Centres of excellence

The MIB is internationally recognised as one of the leading industry-interfaced biotechnology research institutes in the world with exceptionally strong foundational sciences served by pioneering centres of excellence and state-of-the-art facilities. We have unrivalled expertise in industrial biotechnology research areas in the UK interfaced with major national Institutes including Henry Royce, Harwell and Rosalind Franklin.

The Centre for Synthetic Biology of Fine and Speciality Chemicals (SYNBIOCHEM) is a UK/European centre of excellence for the synthetic biology of fine and speciality chemicals production (including new products and intermediates for drug development, agrochemical and new materials for sustainable bio-manufacturing). Through active collaborations with a large variety of industry partners SYNBIOCHEM is harnessing the power of SynBio to propel the production of chemicals and natural products towards green and more sustainable manufacturing processes. More broadly, the Centre provides the general tools, technology platforms and know-how to drive academic discovery to benefit industry.

The UK is a leader in the use of Industrial Biotechnology for the production of flavours and fragrances (addressing a potential global market worth $27.5 billion) and the manufacture of high value chemicals. The proportion of chemicals produced by biotechnology is expected to increase significantly within a generation with biotechnology products expected to dominate the speciality chemicals sector by 2030.

A beacon of investment and collaboration

The MIB is a widely acknowledged beacon of interdisciplinary bioscience evidenced by a sustained commitment to the successful translation of basic science into commercial success. Since inception in 2006 our pipeline of discovery through Innovation has supported over 51 patents, 8 spin-out companies and more than 230 new invention disclosures and 12 licenses. Our research outputs demonstrate that industrial biotechnology research at Manchester has attained a scale and a level of quality which puts it in the top three or four universities in the world in this field.

Distinguished by a strong international profile our track record in academic-industrial collaborations, with partners including GlaxoSmithKline, Shell and Pfizer, is supported by strong networking with national and regional entities and leading UK universities. Through these partnerships we're well placed to translate scientific discovery into commercial reality. For example, Professor Nick Turner, in collaboration with Professor Romano Orru at the Free University of Amsterdam, devised an

" Improving the sustainability of our drug manufacturing processes through collaborations will not only reduce our industry's carbon footprint but will also provide savings that can be reinvested in the development of new medicines, increase access to medicines through cost reduction and drive innovations that will simplify and transform our manufacturing paradigm."

John Baldoni, Senior Vice-President of Platform and Technology Science, GlaxoSmithKline

INDUSTRIAL BIOTECHNOLOGY

THE CHALLENGE

The UK is the **seventh largest chemicals producer in the world** – chemicals is the **UK's most successful sector**, inputting into supply chains from new bio-based ingredients in **personal care** products to **bioplastics** and bio-based **synthetic rubber** for tyres

70.7%

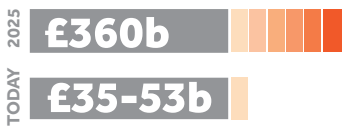
Industry accounts for almost **three-quarters** of **chemicals consumption** in the **EU**

The number of **tonnes of CO_2** emissions **spared by industrial biotechnology**

9.5bn

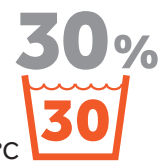
Municipal Solid Waste produced worldwide is **estimated to be 2 billion tons per year** with a projected **increase to 9.5 billion tons per year by 2050**

THE POTENTIAL



£360 billion: the **predicted global sales** for industrial biotechnology by 2025 – the current level is £35-53 billion

The **amount of electricity saved** by households on laundry by being able to wash at 30°C



The number of jobs estimated **to be created in Europe** by the **bio-based chemicals** market **by 2020**

90,000 JOBS

Industrial biotechnology companies employ **14,000** people in the UK, contributing **£1.2bn** in Gross Value Added to the economy.

Renewable energy generation is **expected to triple** between 2008 and 2035

75bn litres

BIOETHANOL

The number of **litres of bioethanol** that could be **sustainably produced** at a competitive cost by 2020, which would **represent about €15 billion** in **additional revenue** for the agricultural sector

WHY MANCHESTER?

The MIB is **one of Europe's leading** industry-facing **research facilities**

Almost a third of **MIB's research portfolio** involves **overseas partners**

Live research portfolio of **£107 million**

The **University leads four** of the **Biotechnology and Biological Sciences Research Council's Networks** in **Industrial Biotechnology** and **Bioenergy**

efficient synthesis of telaprevir, currently the leading medicine in the treatment of hepatitis C, helping to ensure that this drug becomes more widely available and affordable. The researchers have patented this route and have licensed the technology to Codexis for commercial manufacture.

Led by the MIB and GlaxoSmithKline Europe's largest public-private partnership CHEM21 was established bringing together academic groups to work alongside pharmaceutical companies and specialist SMEs to develop innovative catalytic processes for pharmaceutical synthesis. The project established a European research hub to act as a source of up-to-date information on green chemistry, developing training packages to ensure that the principles of sustainable manufacturing are embedded in the education of future scientists.

At the forefront of technology and research

Manchester has a major role to play in the delivery of the UK Government's Bioeconomy and Clean Growth Strategies that will propel the UK to future growth.

Industrial biotechnology research is revolutionising our understanding of chemical and biological processes with new discoveries in biotechnology holding the key to developing solutions to some of the world's greatest challenges such as feeding a growing population and offering new alternatives to our scarce natural resources.

Industrial biotechnology research can provide insight into the development of treatments for some of society's most debilitating conditions. For example, published in *Nature* and *Nature Comms*, Professor David Leys and Dr Ivan Ahel from the Cancer Research UK Manchester Institute demonstrated their success in deciphering the structure of a protein found in bacteria that could reveal new drug targets for inherited breast and ovarian cancers, as well as other cancers linked to DNA repair faults.

Professor Scrutton and his team made a significant breakthrough towards developing an effective treatment for neurodegenerative diseases. Published in *Nature*, researchers detailed how an enzyme in the brain interacts with an exciting drug-like lead compound for Huntington's disease to inhibit its activity, demonstrating that it can be developed as an effective treatment for such diseases.

Professor Andrew Munro, together with industrial partner DSM, redesigned an enzyme catalyst to enable it to convert the natural product compactin into the cholesterol-lowering drug pravastatin. This resulted in a patented process for production of the drug. The team have since built on this research to develop a single-step fermentative method that will allow efficient, industrial-scale production.

We're also transforming the industrial production of flavours and fragrances. In partnership with GlaxoSmithKline, our researchers used synthetic biology to engineer bacterial strains to produce flavours and fragrances that belong to the monoterpenoid family of compounds. This will provide 'natural' routes to the synthesis of these compounds and significantly enhance their market value. It will also reduce the environmental impact associated with classical chemical synthesis and release industry from the constraints of limited availability from natural resources.

Manufacturing the future

As Professor Scrutton says "There is no industry better positioned than industrial biotechnology to respond to society's grand challenges as we tackle an ageing and ever-increasing population, affordability of health care, resource efficiency, food security, climate change and energy shortages."

Find out more

www.manchester.ac.uk/industrial-biotechnology-research

Researcher profile

Dr Mark Corbett

Mark is Scientific Project Manager for the centre of excellence in Biocatalysis, Biotransformations, and Biocatalytic Manufacture (CoeBio3), based in the Manchester Institute of Biotechnology. Mark is also the co-author of the Industrial Biotechnology Leadership Forum's *National Industrial Biotechnology Strategy to 2030*.

Mark has worked in the academic sector for nearly 20 years, starting with a PhD in molecular cell biology from the University of Sheffield. For the past ten years, he has worked for the University of Manchester, managing UK and European collaborative research and innovation projects at the academic-industrial interface. In his current role, he is tasked with supporting the accelerated translation of biocatalytic manufacturing research into industrial biotechnology processes and products.

Alongside management of research projects based in the MIB, Mark is working with national networks and the Industrial Biotechnology Leadership Forum (IBLF) to develop UK strategy and policies that support responsible research and innovation in Industrial Biotechnology.

Mark is the author of 'Growing the UK Industrial Biotechnology Base: A National Industrial Strategy to 2030', developed with co-author Dr. Jen Vandehoven of Fujifilm Diosynth Biotechnologies on behalf of the IBLF. The Strategy is an example of how the MIB is not only developing the technologies required for a sustainable future, but is also shaping national industrial strategy to ensure that those innovations are realised and will contribute to the clean growth of the UK economy.

Biotechnology delivers the prospect of low-carbon, energy efficient manufacturing, using sustainable feedstocks to replace overexploited, polluting fossil resources. Not only that, but industrial biotechnology addresses markets worth billions of dollars. The greatest promise of biotechnology is that, for the first time since the Industrial Revolution, the economic prosperity of society can be intimately linked with responsible stewardship of natural resources.

The MIB is a globally recognised hub for industrial biotechnology. The work of our researchers in partnership with leading academics and industry drawn from across the world places us at the international forefront of the bio-industrial revolution.

Dr Mark Corbett, Scientific Project Manager, CoEBio3

Meet more of our industrial biotechnology experts at **www.manchester.ac.uk/industrial-biotechnology-experts**

Enabling early diagnosis of life-changing diseases

Every hour, someone in the UK is told they have Parkinson's disease – a progressive neurological condition with no definitive diagnostic test and no cure. At The University of Manchester we are tackling the development of a non-invasive diagnostic test that may have the ability to diagnose early Parkinson's – possibly even before physical symptoms are displayed.

Global problem: lack of diagnosis negates treatment impact

Parkinson's disease affects 127,000 people in the UK and 7.5 million worldwide, leaving many patients struggling to walk, speak and sleep.

The lack of a definitive test for Parkinson's means that, typically, too many neurons in the brain are lost irretrievably by the time of diagnosis, making treatment difficult and a cure impossible.

Manchester solution: biomarker breakthrough may deliver early diagnosis

In a collaborative programme funded by the Michael J Fox Foundation and Parkinson's UK, researchers from our Manchester Institute of Biotechnology (MIB) are undertaking investigations to identify novel small molecules from sebum – an oily substance found in the skin – which are believed to emit a subtle but unique scent in patients in the early stages of Parkinson's.

Our research is inspired by the case of Les Milne, a Parkinson's patient, whose wife Joy began to notice a change in her husband's scent more than six years prior to his diagnosis and then recognised the same "woody, musky odour" on patients at a Parkinson's UK awareness lecture many years later.

This breakthrough was confirmed in a pilot study involving parallel investigations that showed there are different chemicals present on the skin surface of people with and without Parkinson's.

We use state-of-the-art mass spectrometry technology to analyse skin swabs taken from people with and without Parkinson's. The research team then analyse the data to identify the small-molecule components present on the skin to identify specific biomarkers found in Parkinson's disease.

Professor Perdita Barran, who is leading the research team at MIB, says: "The sampling of the skin's surface provides a rich source of metabolites that we can mine to distinguish healthy patients from those in the early stages of Parkinson's. In parallel, we're using 'human detectors' drawn from individuals who have exceptional smelling abilities.

"The combined analytical and human approach is helping us to grade identical samples that will hopefully pinpoint which molecular changes in the skin might be producing the unique odour found in Parkinson's sufferers. This could enable early, non-invasive diagnosis – perhaps even before physical symptoms occur."

Life-changing impacts

Proving that there is a unique odour associated with Parkinson's could mean:

- early, non-invasive diagnosis of millions of patients worldwide, boosting their chances of effective treatment and a greater quality of life;
- easier identification of people to test drugs that may have the potential to slow, or even stop, Parkinson's – something no current drug can achieve.

" The combined analytical and human approach is helping us to grade identical samples that will hopefully pinpoint which molecular changes in the skin might be producing the unique odour found in Parkinson's sufferers. This could enable early, non-invasive diagnosis – perhaps even before physical symptoms occur."

Perdita Barran, Professor of Mass Spectrometry

Discover more of our breakthroughs at **www.manchester.ac.uk/breakthroughs**

Find out more

For further information about these five research beacons, including contact details and short films, visit:
www.manchester.ac.uk/beacons

To learn more about research activity at The University of Manchester, including our impact, research environment and key people, visit:
www.manchester.ac.uk/research

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