MANCHESTER 1824

The University of Manchester

BREAK / THROUGH

Research beacons

GLOBAL CHALLENGES
MANCHESTER SOLUTIONS

CONTENTS

FOREWORD

Global challenges, Manchester solutions

To drive the technological changes that will improve the lives of us all, we need inspired, committed entrepreneurs – people who dare to think big and do things differently. But long before the licences and the launch, there is the breakthrough – that single moment of scientific discovery that opens up a universe of possibilities.

This publication demonstrates how Manchester's research beacons are tackling some of the biggest challenges facing the planet. From developing advanced 'wonder' materials, new renewable energy solutions and affordable fresh water sources, to delivering improved cancer survival rates, earlier diagnosis of Parkinson's and new ways of reducing global inequalities.

The story of how academic research leads to real-life innovations is about much more than scholarly breakthroughs. Within these pages we reveal insights from experts in the commercialisation of research – how world-class academic work is applied in the real world by scientists and engineers, medical professionals and life scientists, business and industrial leaders, and policymakers and political thinkers. The value of their contribution cannot be underestimated.

Almost every day we hear about another transformative achievement of our information age, delivering game-changing devices, such as the now ubiquitous smartphone, or the much-touted 'Internet of things', a phenomenon set to kick-start the next industrial revolution, all underpinned by global digital connectivity.

So it's easy to assume that humankind is constantly taking ever bigger strides in our progress towards a better society and a more resilient world economy. But this may not be the real picture. In his influential pamphlet, The Great Stagnation, the renowned American economist Tyler Cowen argues that economic growth has slowed in the US and other advanced economies as a direct result of falling rates of innovation. Cowen argues that the "low-hanging fruit" generated in the wake of the original Industrial Revolution have now been plucked and exploited.
So how do we reach those higher branches?

What we need are significant and consistent breakthroughs in science, engineering, medicine and political thinking; achievements that will provide us with the tools to shape all our futures.

One entrepreneur at the forefront of this future is Elon Musk, the mastermind behind Tesla electric cars and the private rocket-making company SpaceX. He was recently interviewed by Manchester's own Professor Brian Cox as part of a BBC documentary focusing on the new breed of space pioneers. Musk has firmly placed advanced materials at the heart of his own innovation revolution. Stronger, more conductive, lighter materials are helping to develop new battery technologies and reusable space rockets that are among the key advances in Musk's high-profile business empire.

He is just one example of how an enlightened investor is depending on game-changing breakthroughs associated with one of The University of Manchester's research beacons. Another is Sir Richard Branson, who has envisaged a new future for air travel following the isolation of graphene. And then there is Sir James Dyson – whose company spends £7 million a week on research and development. Sir James has announced plans to produce a new breed of electric vehicle. There will be many more commercial pioneers looking for similar quantum leaps across our other research beacon areas.

The key to making more rapid real-world progress lies in developing a more positive relationship between the interconnected worlds of academic discovery and commercial application.

From my own experience, I understand that it can be frustrating for industry to work with universities. The leadership shown by The University of Manchester's research beacon community – delivering Manchester solutions to global challenges – has changed the game entirely. It's no accident that national centres of excellence in applied research, such as the Henry Royce Institute, are increasingly being headquartered in Manchester.

Academic researchers are no longer hidden away in their ivory towers – they are now very much at the forefront of commercial innovation. These are very exciting times for academia, and Manchester is providing a model that I am confident will make our world a better place. I hope others will want to follow.

Dr Andrew Hosty

CEO, Henry Royce Institute

The Henry Royce Institute is the national organisation based in Manchester that is leading on advanced materials research and applications.

CASE STUDY:
ADVANCED MATERIALS

Affordable desalination

Manchester: bringing clean water to the world

Today nearly one fifth of the world's population – 1.2 billion people – live in areas plagued by water scarcity. However, a revolution in water filtration developed at The University of Manchester could provide a much-needed solution, with ready access to clean water finally a real possibility for the world.

Global problem: access to clean drinking water

Around 71% of the Earth's surface is covered by water, of which 96.5% is contained in saltwater oceans. Desalination technologies could bring fresh water to everyone, but are currently very costly.

Graphene-oxide membranes developed at Manchester's National Graphene Institute (NGI) were initially used to filter out small nanoparticles and organic molecules from water. Common salts used in desalination technologies, however, could not be sieved. The membranes would become slightly swollen when immersed in water, meaning smaller salts would flow through the membrane along with the water.

Manchester solution: affordable desalination

Manchester researchers in our NGI Membranes Lab developed a strategy to avoid the swelling of the graphene-oxide membrane in water. They enabled the pore size in the membrane to be precisely controlled – and commons salts to be sieved out of salty water – making it safe to drink.

Creating scalable membranes with uniform pore size down to atomic scale is a huge step forward, opening new possibilities for improving the efficiency – and lowering the costs – of desalination technology across the globe.

Professor Rahul Nair is one of the world's foremost graphene membrane scientists and a member of the team who made the research breakthrough. He says: "This is the first clear-cut experiment in this regime.

"We also demonstrated that there are realistic possibilities to scale up the described approach and mass-produce graphene-based membranes with required sieve sizes."

Fellow team member and PhD student Jijo Abraham adds: "The developed membranes are not only useful for desalination, but also have the potential to filter out ions according to their sizes, which could lead to developments in gas separation technologies."

Professor Nair says: "Manchester's pioneering spirit has made the UK a world leader in the field of advanced materials. Our centres of excellence – from our current NGI to the forthcoming Graphene Engineering Innovation Centre and Henry Royce Institute – are attracting the world's best physicists, chemists, biologists, material scientists and engineers, all working together to develop the life-changing materials of the future."

Life-changing impacts

With the potential to revolutionise water filtration across the globe, the University's new technology could:

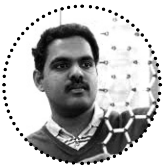
- bring affordable water filtration to countries that cannot afford large-scale desalination plants, giving clean water to millions of people who need it most;
- offset the effects of climate change, or natural disasters such as severe flooding, on modern cities' water supplies, providing affordable and sustainable alternative water solutions.

Find out more

'Tunable sieving of ions using graphene oxide membranes,' *Nature Nanotechnology*, 2017

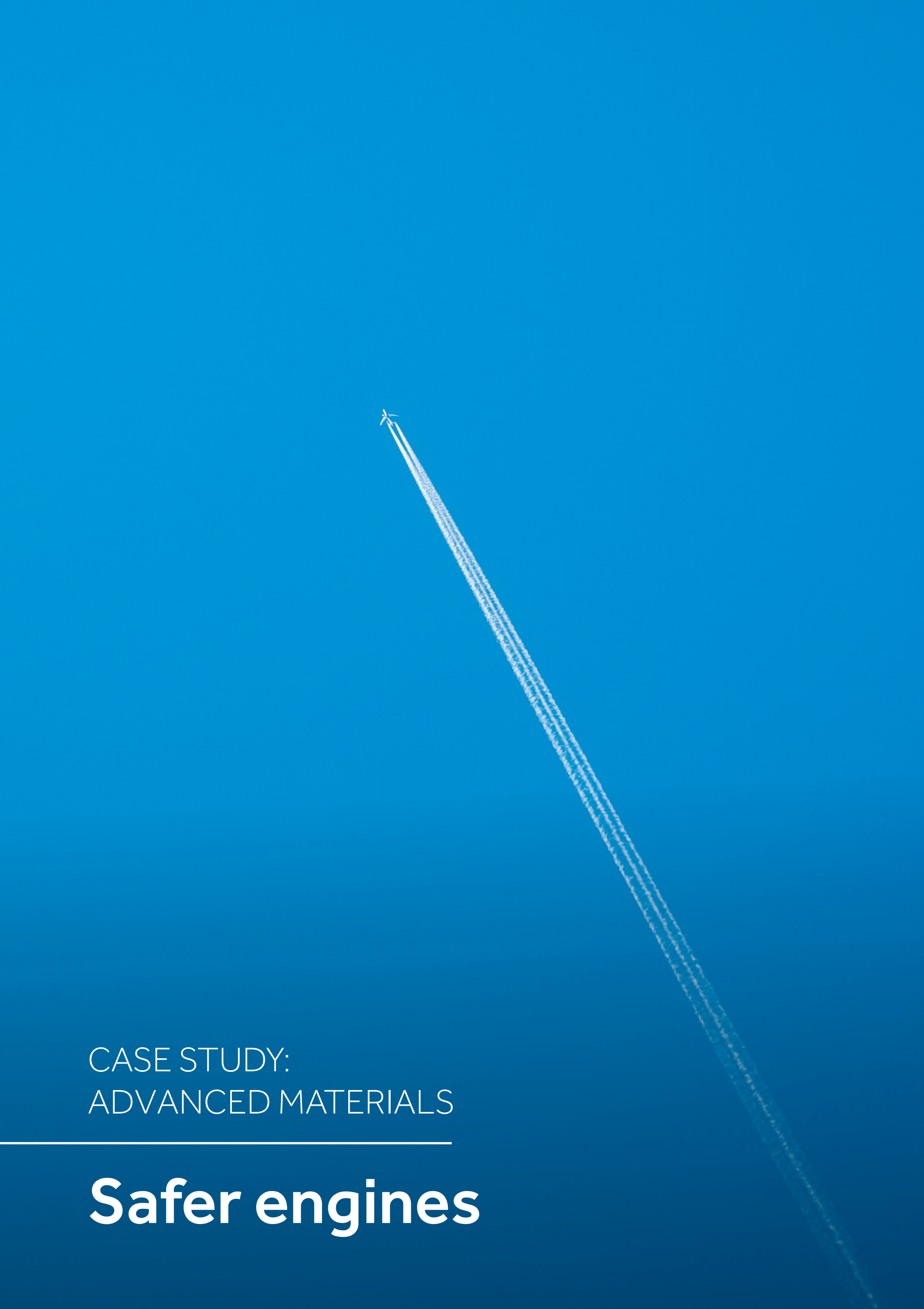
Visit www.manchester.ac.uk/affordable-desalination for links to related papers and video content.

Meet the researchers:



Professor Rahul Nair

Professor of Materials Physics,
National Graphene Institute



CASE STUDY:
ADVANCED MATERIALS

Safer engines

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 therefore investigated 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.

LSP has demonstrated it 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 2010 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 fatigue resistance blades 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.

Find out more

Visit www.manchester.ac.uk/safer-engines for a full list of related research papers.

Meet the researchers:

Professor Philip Withers
Regius Professor of Materials

Professor Michael Preuss
Professor of Metallurgy

Dr Philipp Frankel
Research Fellow

Professor Dave Rugg
Corporate Titanium Specialist, Rolls-Royce plc

EXPERT OPINION

Building the foundations of breakthroughs

Building the foundations of breakthroughs

Lynn Sheppard, Director of our Manchester Enterprise Centre, considers some of the necessary conditions for research and industry to encourage and enable innovation.

Albert Einstein famously said: “We cannot solve our problems with the same thinking we used when we created them.” Nowhere does this ring truer than in business.

Advances in technology and the breakdown of global barriers have created an increasingly competitive market that requires innovation to capitalise on opportunities. Organisations that see and act upon opportunities for innovation, particularly in today’s uncertain economic climate, are the businesses that will flourish in the face of adversity and fluctuating conditions.

Creativity is key; businesses that foster and use creativity to their advantage are much more likely to innovate successfully. It is also critical to connect with a range of diverse people and sectors, and collapse traditional silos to come up with new ideas and breakthroughs.

People power

Innovation goes beyond leadership: it starts with individuals. We need to empower people to develop the self-assurance, belief and ability they need not only to come up with creative ideas, but also to have the courage to try them out and persist to achieve breakthroughs. To do this there must be a culture of innovation, with accountable business management processes to support this style of working.

Courage is one of the key traits we see in entrepreneurs, and is fuelling a global movement of entrepreneurship. In places such as China, India and Africa, innovating can carry greater risk, but a growing number of people are showing the courage needed to take these risks – which is crucial to the growth of these emerging markets.

Governments across the globe are actively encouraging entrepreneurship and innovation, recognising its value as a vehicle for economic success and prosperity.

Academic spin-offs

Parallel to global entrepreneurship, the growth of spin-offs from academic institutions is tremendously important to society. These ideas have the potential to save lives, increase efficiencies in industry and the environment, and otherwise enhance society and make positive contributions to the economy.

We have seen a lot of this happening at The University of Manchester over many years – as you might expect from a university in the world's first modern city. This is where the IT revolution started in 1948, with the build of the world's first stored-program computer and it's where Rutherford carried out his experiments on atomic structure. More recently, we pioneered the isolation of graphene – one of the foremost innovations of our time.

Future breakthroughs

The city of Manchester has become synonymous with innovation. As we enter our next exciting stage of growth and change, following the election of our new Metro Mayor and greater control over devolved political powers, I can't wait to see what the future holds for us.

With the right conditions in place, I'm sure that Manchester will continue to lead the way in breaking down barriers, working through problems and developing the leaders and entrepreneurs of tomorrow.

Lynn Shepard
Director of the Manchester Enterprise Centre

The Manchester Enterprise Centre is a leader in enterprise education and aims to inspire, educate and develop enterprising individuals and enable them to positively impact the growth of dynamic organisations.

Find out more at mec.portals.mbs.ac.uk

CASE STUDY: CANCER

Breast Cancer

Helping more women to survive breast cancer

Currently, one in eight women will develop breast cancer in their lifetime. University of Manchester research has led to revolutionary changes in treatment that give these women a better chance of survival – and given hope that fewer women will develop the disease in the future.

Global problem: women's most common cancer

More than 1.7 million women develop breast cancer every year. The most common cancer in women worldwide (the second most common cancer overall), it represents around 25% of all cancers in women – and it is the most common cause of cancer mortality among middle-aged women.
Breast cancer survival is improved by early detection and the use of systemic therapy given after surgery. Endocrine therapy (treatment that blocks the body's natural hormones) can prevent relapse and improve survival, and can also extend the duration of survival after systemic relapse. Breakthroughs in this area are both life-changing and life-saving.

Manchester solution: the world's number one endocrine treatment

Manchester researchers have developed new approaches to endocrine therapy that have revolutionised breast cancer treatment worldwide.

In the 1970s we developed a breakthrough therapy using tamoxifen, an anti-oestrogen drug that blocked oestrogen receptors in tumours, which meant that the cancer grew more slowly or stropped growing altogether.

Manchester research from the 1990s led to clinical trials showing that fulvestrant, another anti-oestrogen drug, was effective in women with advanced breast cancer who had become immune to tamoxifen.

Working with AstraZeneca, our team went on to show that anastrozole, another hormone therapy, outperformed tamoxifen in preventing the relapse of breast cancer. Anastrozole proved to be a breakthrough drug that is now the major endocrine therapy for breast cancer.

Professor Tony Howell, Professor of Breast Oncology, has worked in cancer research at Manchester since the 1980s. He says: "Through extensive close collaborative clinical and laboratory work with colleagues at locally based AstraZeneca, Manchester researchers have successfully improved treatments over the years. Today, more women presenting with early breast cancer are cured, remission in advanced disease lasts longer and survival is prolonged.

"Furthermore, we have demonstrated that approximately half of breast cancer is preventable."

Life-changing impacts

The University's research into new approaches to endocrine therapy has resulted in:

- anastrozole being adopted as the world's major endocrine therapy;
- changes in clinical practice that are now national guidelines, and help to set international treatment standards;
- more women with breast cancer being cured, longer-lasting remissions and improved post-surgery survival, giving more women across the world their lives back.

Read the research papers

Visit www.manchester.ac.uk/breast-cancer for a full list of related research papers.

Meet the researchers:

Professor Anthony Howell
Professor of Breast Oncology

Professor Nigel Bundred
Professor of Surgical Oncology

CASE STUDY: CANCER

Childhood Leukaemia

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 particulary rapid and aggressive form of cancer requiring immediate treatment.

Manchester solution: breakthrough drug trials

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 clinical trials and translational research in ALL 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.

Read the research paper

Visit www.manchester.ac.uk/leukaemia for a full list of related research papers.

Meet the researchers:

Vaskar Saha
Professor of Paediatric Oncology

EXPERT OPINION

The science of breakthrough thinking

The science of breakthrough thinking

At Alliance Manchester Business School, creativity and innovation expert Dr Mark Batey tackles questions that have long vexed and perplexed researchers and industry: what is the best way to encourage great ideas? How can we achieve the next breakthrough? Where does the 'eureka moment' come from?

We often look to stories surrounding great scientific discoveries for inspiration. Imagine Archimedes streaking through the streets of Syracuse, proclaiming: "I have it"; Isaac Newton rubbing his head as a falling apple brought gravity home to him; the chemist August Kekulé's daydream of snakes biting one another's tails leading him to realise that benzene must have a ring-like structure.

Now science is identifying the processes that help deliver better creativity and innovation.

Key to optimising the creative problem-solving process is understanding the vital mechanism by which original and useful ideas are produced – connections. Creative ideas are born out of the fusion of existing ideas, thoughts and knowledge. The more complex and unorthodox the combinations, the greater chance of the idea leading to a significant innovation.

Mathematician Hermann von Helmholtz postulated a creative thinking process in 1896 not dissimilar to the models of today. It forms the basis of the following five simple steps that will help you to apply the science of breakthrough thinking:

1. **Problem-finding** – Start with the thoughtful identification of key questions, issues or challenges that need to be bested. Don't jump into brainstorming without thoroughly applying your curiosity, or seeking out key questions (and answers) from diverse sources. Get hands-on: deeply engaging with users, products, processes and services often sparks inspiration.

2. **Priming and preparation** – It is vital to absorb deep knowledge about your problem area. Immerse yourself. Read far and wide, talk to experts and novices, explore allied non-competing areas. Research shows that going beyond focused technical knowledge to include less relevant and tangential information can be the creative key to innovation.

3. **Incubation** – Make time to allow all that knowledge and insight to soak in, mash together and form those complex, unusual connections from which great ideas are born. This is an active process, too – talk to people, read more and see how everyday situations reflect back on your challenge.

4. **Generate and ideate** – Double Nobel laureate Linus Pauling allegedly said: "If you want to have good ideas, you must have many ideas. Most of them will be wrong, and what you have to learn is which ones to throw away." Creativity requires volume. Think of ideas, involve a diverse team to spur yet more ideas, go exhaustive and leave sensibility, reason and prejudice at the front door (for now).

5. **Evaluate** – Deliberately and slowly apply doubt, judgement, critique, testing and reality to the bank of ideas. Consider carefully the criteria that are being applied to make the final selection. Brilliant ideas are often rejected too early, when more development would have led to the big breakthrough. Don't throw the baby out with the bathwater.

Dr Mark Batey would love to hear your stories of applying these approaches. Email him at mark.batey@manchester.ac.uk

Dr Mark Batey
Senior Lecturer Organisational Psychology
Alliance Manchester Business School

Alliance Manchester Business School (AMBS) was established in Manchester in 1965 as one of the UK's first two business schools and is now the UK's largest campus-based business and management school. AMBS is research-led and delivers industry-focused business and management education at all levels.

CASE STUDY: ENERGY

Renewable biomass

Turning agricultural waste into clean energy

Biomass (plant, animal and organic material) has enormous potential for providing us with sustainable, low-carbon bioenergy – yet, across the world, most of it is used unsustainably for fuel-wood. Extending our focus from national to international is giving University of Manchester bioenergy research a far greater impact on the planet.

Global problem: greenhouse gas emissions from biomass burning

The UK has the potential to generate up to 44% of its energy from biomass sources, including household waste, agricultural residues and home-grown biofuels by 2050.

However, this country represents a tiny proportion of the global annual biomass use – and reducing greenhouse gas emissions on a global scale is the biggest sustainability challenge facing the world today.

A large variety of biomass sources exist worldwide – from farming by-products like crops and manure to household waste and sea algae – yet it often remains untapped. In Asia, for example, rice farming produces about 550 million tonnes of straw residue every year; but this potential fuel source is simply burnt in the fields, resulting in airborne emissions that are hazardous to human and ecosystem health.

Manchester solution: interdisciplinary research with real impact

Our researchers are already helping rural communities in the Vietnam, Colombia and sub-Saharan Africa to turn agricultural residues – like rice straw, coffee husks, and sugar cane residues – into sustainable energy sources.

Now we're working with industry partners NextGen Ltd and Qube Renewables to build a pilot processing plant in the Philippines that turns rice straw into clean energy.

Our multidisciplinary approach tackles logistical, technological and environmental issues, works sympathetically with the priorities and preferences of local social networks, and continually shares our results at both a local and global level. While laboratory results confirm when greenhouse gas reductions are made, our stakeholder interviews indicate that we can scale our solutions to deliver tangible benefits to local communities, thereby maximising uptake and success.

Professor Patricia Thornley is Director of the SUPERGEN Bioenergy Hub at our Tyndall Centre for Climate Change Research, and has more than 20 years' experience of working in bioenergy.

She says: "The interdisciplinary approach we have at Manchester is unique and essential. Looking not only at the technology, but also at local energy demands, we can maximise the probability of creating sustainable bioenergy in different communities across the world.

"If we are to deliver significant greenhouse gas reductions, the breakthrough comes from looking at the biggest global uses and improving them in a way that people will actually deploy, because it delivers what they need as well as meeting global sustainability objectives."

Life-changing impacts

Turning different biomass sources in diverse global communities into sustainable, clean energy means:

- rural communities and ecosystems worldwide benefit from cleaner energy and cheaper, sustainable disposal of excess waste, creating a more equitable distribution of green energy worldwide;
- local communities and entrepreneurs participate in community energy systems and decision making;
- we maximise the impact of Manchester research on global greenhouse gas emissions, helping to create a cleaner, greener planet.

Read the research paper

Visit www.manchester.ac.uk/renewable-biomass for a full list of related research papers.

Meet the researchers:

Professor Patricia Thornley
Professor of Sustainability Energy Systems

Dr Mirjam Röder
Research Fellow

Dr Andrew Welfle
Research Associate

Dr Paul Gilbert
Senior Lecturer in Climate Change Mitigation

CASE STUDY: ENERGY

Carbon dioxide turbines

Making cleaner energy cheaper

If we're to mitigate the impact of climate change, humanity 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 2009 Copenhagen Accord set a global warming target that aims to restrict increases in average global temperatures to less than 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 under way: at least 12 new reactors will be built by 2030, adding 16 gigawatt of new nuclear capacity at an estimated cost of £100 billion. Speeding up construction will bring cheaper, cleaner energy to the market more quickly.

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.”

Industry-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.

Read the research paper

Visit www.manchester.ac.uk/turbines for a full list of related research papers.

Meet the researchers:

Dr Andrea Cioncolini
Lecturer in Thermal Hydraulics, The University of Manchester's School of Mechanical, Aerospace and Civil Engineering

EXPERT OPINION

Creating a breakthrough culture

Creating a breakthrough culture: what the research tells us

Joseph Lampel, Eddie Davies Professor of Enterprise and Innovation Management at our Alliance Manchester Business School, looks at innovation research for clues on how to embed breakthrough thinking into business.

In a hyper-competitive world where strategic advantage is temporary if not ephemeral, creating breakthrough innovations has become the gold standard of organisational strategies. Today's business managers not only seek to launch breakthrough innovations, but also (and more importantly) are keen to develop an organisational culture that fosters breakthrough thinking.

Inevitably, managers look to 'celebrity firms' such as Apple, Google, or Tesla for lessons on how to create such a culture. But in truth, one can find breakthrough thinking in many lesser-known companies, in high-tech sectors not only from today, but also going all the way back to the Industrial Revolution.

Innovation research

Researchers have been actively looking at innovation and breakthrough thinking at least as far back as the 1960s, if not earlier. We now have a very large body of research, as well as multidisciplinary institutions such as our Manchester Institute of Innovation Research (MIOIR) that have been set up to understand the dynamics of innovation.

Many universities – including The University of Manchester – have used this accumulated research to introduce breakthrough innovation thinking into the undergraduate and post-graduate curriculum, and to engage in highly active executive education and outreach programmes.

Fostering innovation in the contemporary economy

Distilling the rich body of knowledge about how organisations develop breakthrough cultures into a set of principles is difficult. However, we can point to two areas that are proving increasingly crucial in the contemporary economy: connectivity and the ability to absorb knowledge.

While ideas for breakthrough innovations may start with individuals, or small groups, the ability to quickly take these ideas from conception to success depends on connectivity within and across organisations.

This should be remarkably easy in our digital age – but, paradoxically, while the Internet has made connectivity a prerequisite for breakthrough culture (since everybody now has the same connectivity tools), it has also made effective use of connectivity much harder.

Making and using high-quality connections

Knowing hundreds of people on a casual basis used to be a social feat, but with LinkedIn and other social media this has become commonplace. But quantity of contacts does not necessarily beget quality; in fact, it may even make it harder to put contacts to good use.

Connectivity that fosters breakthrough achievement is based on knowing which of your contacts will have the missing piece of knowledge you need to complete the puzzle. This in turn depends on what researchers on innovation call 'absorptive capacity': the knowledge base needed to understand the value of knowledge generated elsewhere, and to integrate this knowledge into your work.

Research suggests that organisations with a diverse knowledge base are more likely to have the high level of absorptive capacity needed for breakthrough innovations than less diverse organisations.

Outsourcing your knowledge base

Many organisations simply do not have the resources to maintain the diverse body of knowledge needed to develop strong absorptive capacity. Fortunately, they can often offset this problem by making use of the knowledge base that surrounds them.

Businesses based in the north-west of England are particularly fortunate in this respect. The region has a strong publicly funded knowledge ecology, which includes world-class research universities such as The University of Manchester.

But the role of a university is not only to create knowledge that others can use; it is also to develop the talent on which breakthrough culture depends. Organisations, both public and private, understand that knowledge and know-how are often indissolubly linked. This is why they look to universities such as The University of Manchester to supply cutting-edge knowledge, as well as knowledgeable and skilful researchers and graduates, to create the breakthrough culture they need to survive and prosper.

Joseph Lampel
Eddie Davies Professor of Enterprise and Innovation Management at our Alliance Manchester Business School

Alliance Manchester Business School (AMBS) was established in Manchester in 1965 as one of the UK's first two business schools and is now the UK's largest campus-based business and management school. AMBS is research-led and delivers industry-focused business and management education at all levels.

CASE STUDY:
GLOBAL INEQUALITIES

Cash transfers

Freeing families from 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;

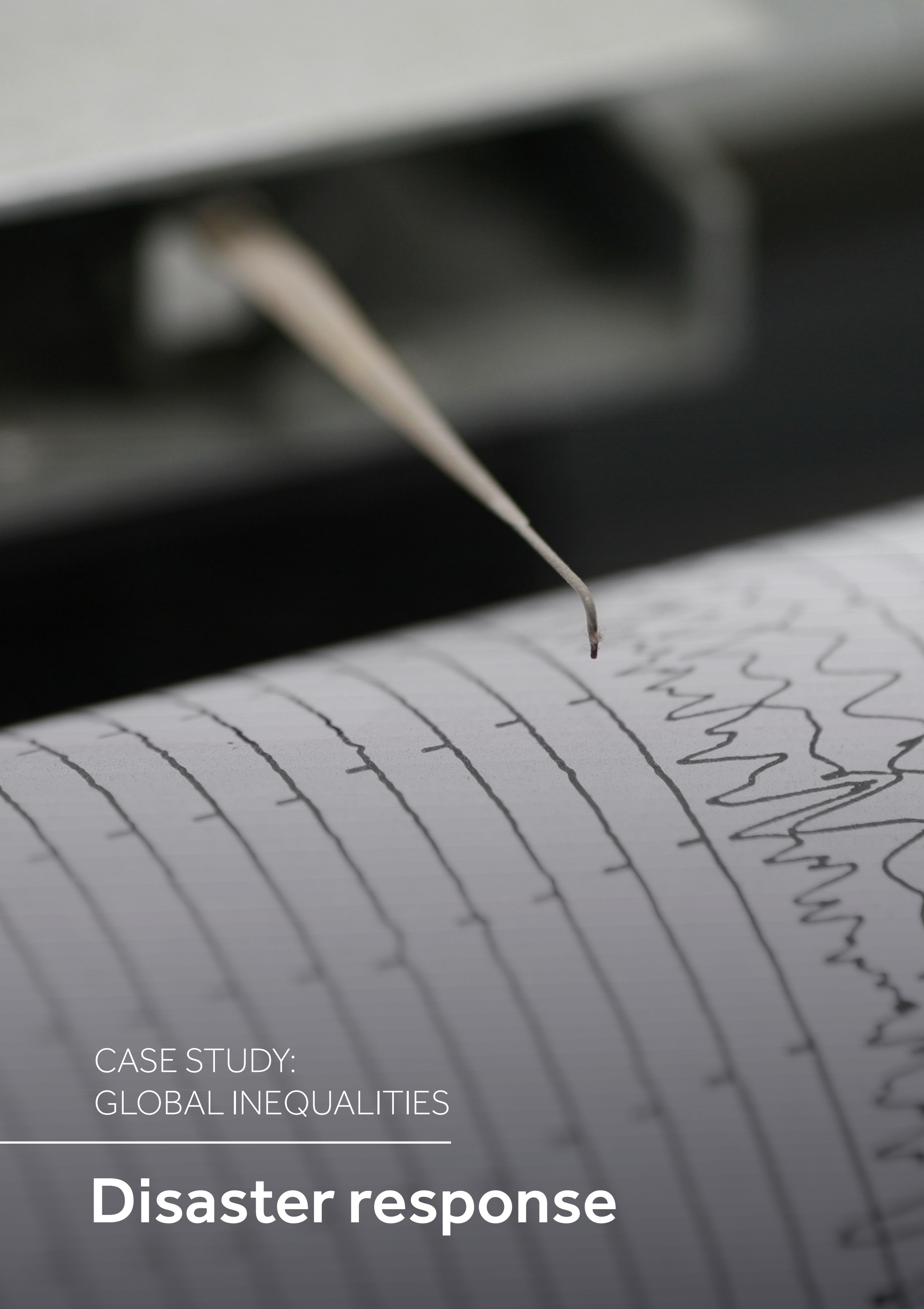
- implementation of a pilot anti-poverty transfer programme in Uganda;
- shaping of development policy at a global level, following Professor Barrientos advising the UN High Level Panel Report for the post-2015 development agenda.

Read the research paper

Visit www.manchester.ac.uk/cash-transfers for a full list of related research papers.

Meet the researchers:

Professor Armando Barrientos
Professor of Poverty and Social Justice



CASE STUDY:
GLOBAL INEQUALITIES

Disaster response

Revolutionising the UK's response to international disasters

A generation of Haitians may needlessly have lost limbs thanks to a lack of specialist medical training in those who responded to the 2010 Haiti earthquake. University of Manchester research has since ensured future overseas disasters can benefit from more effective medical response from the UK.

Global problem: international inequalities in medical standards

Humanitarian responses to international disasters are invariably well-intentioned but can have unforeseen negative consequences. One doctor attending to the 2010 Haiti earthquake victims estimated that the vast majority of those coming in with crushing injuries underwent amputations, partly as a result of infections – many of which it is now believed could have been avoided.

Professor Bertrand Taithe, a historian of humanitarian aid who is based at our Humanitarian and Conflict Response Institute, was directly involved with Handicap International and the UK evaluation of the Haiti relief effort in 2010, funded by the Department for International Development (DFID).

His qualitative assessment brought into sharp focus the Haitian perspectives on the standards of surgical interventions and poor levels of documentation, coordination and resource allocation in the international effort. These were issues that Professor Taithe had seen surface repeatedly in his prior research on the history of humanitarian responses to disasters and wars.

Manchester solution: supporting high quality medical interventions
Our Humanitarian and Conflict Response Institute is ideally placed to bring together the social sciences and medical sciences, in a space where researchers and NGOs can discuss relevant concerns and issues, to understand where research questions can impact on practice.

Professor Taithe says: “My research on Haiti gave crucial evidence of the urgent need to change humanitarian practices. It allowed me to feed through the work of Professor Tony Redmond, with whom I worked very closely, into relevant debates at the World Health Organisation (WHO) on foreign medical teams and the minimum data needed for health workforce registration.

“Together, our research brought about the breakthrough for the creation of the UK International Emergency Trauma Register (UKIETR): a body to help UK health professionals deliver a coordinated medical response during rapid onset of overseas disasters.

He added: “For me, this Manchester breakthrough for addressing global inequalities in medical standards was about Manchester researchers working together for the greatest good.”

The UKIETR has now expanded into a larger register that encompasses trauma, medical and public health professionals, and acts as an interface between volunteering, training and being effectively deployed. It lists specialists, trains them for work in resource-poor environments and austere working conditions, trains them in specific responses and then makes them available to NGOs or state responses.

The University of Manchester's Professor Tony Redmond established these registers, which are hosted within UK-Med – an NGO founded by Professor Redmond in 1995 which is located at the University.

Life-changing impacts

The creation of UK International Emergency Registers has provided:

- a highly effective way for the UK to share its NHS expertise with the world and deploy trained and fully prepared staff to complex emergencies;
- a pioneering instance of a new approach to better structured, evidence-based, thoughtful and respectful engagement in the problems and crises of others;
- a route for UK medical professionals to develop a lifelong engagement with volunteering that responds to real needs and is supported by training and education.

Read the research paper

Visit www.manchester.ac.uk/aid-register for a full list of related research papers.

Meet the researchers:

Professor Bertrand Taithe
Professor in Cultural History

Professor Tony Redmond
Professor of International Emergency Medicine

EXPERT OPINION

From lab to shop floor

From the lab to the shop floor: the commercialisation of graphene

Ivan Buckley, Project Manager at our National Graphene Institute (NGI), explores the journey towards the commercialisation of graphene and other 2D materials.

Today's graphene market can be characterised as one that is fast-growing with significant commercial possibilities. However, it is also extremely diffuse and fragmented, with little or no material standards. A very large number of potential applications across different material grades may – or may not – be realised.

Aligning expectations of research and commerce

It is important to understand that the "limitless potential" of graphene and its properties is something that has been founded primarily in the laboratory, not in the commercial world.

The lab allows for meticulous, time-consuming projects, using the best quality materials with limited reproducibility. Conversely, in the commercial environment viable industrial processes need to be developed or adapted, processes need to be scaled up, and results need to be reproduced with a high level of consistency and high yield.

The need for standards

Graphene's appeal to many varied industries stems from the material's versatility. However graphene should not be considered as one single material as it can be produced in a number of different forms; a single sheet of carbon atoms, a solution, or even in tiny flakes. What form of graphene to produce depends on the end application which will utilise the material. With such a wide range of materials available from many producers, each with their own manufacturing process, the development of agreed standards and characterisation techniques are integral to the accelerated adoption and commercialisation of graphene.

Without universal standards, the incredible commercial potential of graphene materials will go unfulfilled.

Universities do not make products

There is a perception that commonly arises with a scientific discovery that industry can simply replace the word 'science' with 'product'. But consider the key difference between research and innovation: the researcher wants to study the second law of thermodynamics; the innovator wants to develop a toaster.

While universities are a key part of the development of new products and processes, our role is primarily one of advancing science. Graphene is the science. However, close collaboration between science and industry can result in significant advantages, be it speed to market or product development – bearing in mind that on average only 1 in 20 new products succeed to commercial launch.

Innovation and imagination

The importance of market perceptions cannot be overstated in influencing the rate of technological change. If we don't ask the right questions, we limit the disruptive potential of a new material such as graphene.

Innovation is a means to an end, not an end in itself. End users often know what improvements need to be made to a product, but they do not know the means. The question to ask is therefore not how a customer's product may be improved, but what improvements the customer is seeking in terms of characteristics, performance and functionalities. However, there are problems to be solved that we don't yet know exist and so invention cannot always be guided by the end of the market. Once the latter is established, graphene can potentially bring about step-change improvement across various material markets.

Knowledge is key

Despite its known advantages, the lack of technical knowledge within an existing industry can often stifle innovation in the uptake of a new material such as graphene. Academics may consider the material as an end in itself; manufacturers need to consider wider parameters, such as the development of new processes, optimisation of those processes and the creation of new infrastructures to support the commercialisation of the material.

The value of public intervention

Public investments such as the NGI and the Graphene Engineering Innovation Centre (GEIC) at The University of

Manchester are designed to facilitate collaboration between industry and research.

Here, academics can work alongside end-users and their supply chains, providing leading scientific knowledge and state-of-the-art equipment in an environment which ultimately aims to give confidence to companies to commit to further investment to develop processes, hire staff or to take a new product or process to the market.

Commercial success

In order to become disruptive, new technology needs to offer significant rather than incremental improvements. Moreover, the more universal the technology, the better chance it has of broad-base success.

This can be summarised by the 'Lemma of New Technology' proposed by Herbert Kroemer, who received the Nobel Prize in Physics in 2000 for basic work in ICT: "The principal applications of any sufficiently new and innovative technology always have been – and will continue to be – applications created by that technology."

Graphene is no exception.

Ivan Buckley

Project Manager at our National Graphene Institute (NGI)

The £61m National Graphene Institute (NGI) is the national centre for graphene research in the UK, drawing in specialists from across the globe. It houses state-of-the-art cleanrooms, plus laser, optical, metrology and chemical labs and equipment - the ideal environment for world-class graphene research.

CASE STUDY:
INDUSTRIAL BIOTECHNOLOGY

Bio-propane

Helping to conserve our natural environment

The effects of fossil carbon depletion and climate change mean that it is vital, now more than ever, that we find cleaner and more sustainable forms of energy; our survival and well-being depend on it. Now, a significant breakthrough in biotechnology research at The University of Manchester could revolutionise the production of a form of cleaner energy that is affordable to industry.

Global problem: making cleaner energy commercially viable

With continually rising carbon dioxide levels, of which industry is a large contributor, industrial biotechnology is one of the most promising new approaches to pollution prevention, resource conservation and cost reduction.

Biofuels are a significant area of biotechnology research whereby fuels are produced through a biological process as opposed to a geological process as with fossil fuels. Although many sustainable biofuels on the market today are derived from plant materials, they have an adverse impact on food security, the natural environment and land use.

The University of Manchester is dedicated to the global energy challenge of developing new technologies where biofuel commercialisation is sustainable, economically viable, and environmentally friendly.

Manchester solution: creating synthetic, cost-effective renewables

At our Manchester Institute of Biotechnology (MIB), we have made a significant breakthrough in the development of synthetic pathways that will enable renewable biosynthesis of propane gas.

Natural metabolic pathways for the renewable biosynthesis of propane do not exist, but MIB researchers – in collaboration with The University of Turku in Finland and Imperial College London – have made a significant breakthrough in the development of an alternative microbial biosynthetic pathway to produce renewable propane.

Propane has very good physicochemical properties that allow it to be stored and transported in a compressed liquid form. It is a cleaner burning alternative fuel that has been used for decades in a wide range of applications from heating to vehicle fuel.

Our University spin-out C3 BioTechnologies Ltd is pursuing the commercial production of bio-propane through synthetic biology. The company is spearheaded by MIB Director Professor Nigel Scrutton and Michael Smith, Director of PressureTech Transport Services Ltd, a specialist regional supplier of liquid petroleum gas (LPG).

Professor Scrutton says: "The benefits of fossil fuel-based LPG are already proven within the world energy market, and a robust, reliable distribution infrastructure exists which will enable new volumes of bio-propane to be introduced to the market without significant change or investment from both local suppliers and consumers.

"This has the potential to revolutionise the production of biofuel – exactly the kind of cleaner, more sustainable form of energy that the world needs if we are to tackle the effects of fossil carbon depletion and climate change. We foresee a high industry demand for this exciting offer."

Industry-changing impacts

The development of an economically sustainable manufacturing process for full-scale bio-propane production would:

- transform the biofuel industry without adversely impacting food security, the natural environment and land use;
- enable new volumes of bio-propane to be introduced to the market without significant change or investment from both local suppliers and consumers.

Read the research paper

Visit www.manchester.ac.uk/bio-propane for a full list of related research papers.

Meet the researchers:

Professor Nigel Scrutton
Director of the Manchester Institute of Biotechnology

CASE STUDY:
INDUSTRIAL BIOTECHNOLOGY

Early diagnosis

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

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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.

Read the research paper

Visit www.manchester.ac.uk/parkinsons-diagnosis for a full list of related research papers.

Meet the researchers:

Professor Perdita Barran
Professor of Mass Spectrometry

Professor Roy Goodacre
Professor of Biological Chemistry

Dr Monty Silverdale
Consultant Neurologist at Greater Manchester Neuroscience Centre, Salford Royal NHS Foundation Trust and Honorary Senior Lecturer in Neuroscience at the Institute of Brain Behaviour and Mental Health at The University of Manchester

EXPERT OPINION

Breakthroughs that benefit the many

Entrepreneurial research: Breakthroughs that benefit the many

Entrepreneurial academic Paul O'Brien – Professor of Inorganic Materials at The University of Manchester and co-founder of the successful spin-out company, Nanoco Technologies Ltd – explains why he believes that scientists and engineers need to consider how their research breakthroughs could benefit wider society.

Getting the research and development balance right

In any knowledge-based society, scientists want to push against the furthermost boundary of imagined possibilities. This is their pioneering spirit, and subsequent research can lead to disruptive technologies or breakthroughs. We need a good balance between research and development; the development of process that enables invention should not be overlooked.

Any scientist who wants to be a successful innovator, however, also needs to ask themselves: could their great breakthrough be made to work on a scale that would benefit society at large? And would this be economically viable?

Science that meets social and commercial needs

Combining innovative science with the need to meet the realities of the commercial world are not incongruous ambitions. There is a long history of academic pioneers who have followed both paths, both in Manchester and across the world.

A good example is the discovery of penicillin in 1928 by Scottish scientist Sir Alexander Fleming. Due to the impetus generated by World War II, large-scale production of the drug was developed and a potentially life-saving substance, originally available only in limited amounts, became a widely administered medicine.

Case study: Nanoco Technologies Ltd

Nano particles became my first synthetic interest in the 1980s, inspired primarily by the work of Louis Brust at Bell Labs. These particles have the ability to absorb and emit different colours of light depending on their size, making them valuable in a variety of applications, such as in display screens on devices from smartphones to televisions, and in lighting and drug-delivery systems.

Our team discovered a simple method to make large quantities of quantum dots by a scalable process that simultaneously improved safety and environmental sustainability by eliminating the need for many of the more hazardous chemicals – a breakthrough method that we believed had clear commercial potential.

Along with postdoctoral researcher Dr Nigel Pickett, we set up The University of Manchester spin-out Nanoco Technologies Ltd in 2001, which developed and patented core technology that manufactures quantum dots in useful quantities.

Dr Pickett's pioneering work on a molecular seeding process underpinned Nanoco's unique technology, and this technology was protected and formed a keystone in obtaining funding from various investors and regional seed funds by leveraging the intellectual property.

By 2009, Nanoco had key partnerships in place with many businesses and floated on the Alternative Investment Market, which is owned and operated by the London Stock Exchange to provide a global stock market for small but growing companies. Interest in the technology grew rapidly and the company expanded production by commissioning a large-scale facility in Runcorn, Cheshire.

In 2015, Nanoco signed a licensing deal with Dow Chemical Company, one of the world's largest chemical companies - and Nanoco moved to the London Stock Exchange.

More recently, Nanoco has signed worldwide supply and licensing deals with Merck and Wah Hong, both of whom are looking to supply the growing demand for cadmium-free quantum dots needed for the next generation of LCD TV displays.

Nanoco are now one of the world's leading nanotechnology companies, taking Manchester innovation to global markets.

Advice for entrepreneurial academics

You've made your breakthrough – one that you believe has what it takes to make a significant difference in the world, and you want to make this happen.

First, make sure that this is what you want to do; it is likely to take up all of your time. Investors may require that you are

100% involved, which means that you may need to make a career choice between academia and industry. Which would you choose? Be efficient work out how much time you have.

Second, be prepared to change your model to suit the needs of the commercial world.

Paul O'Brien
Professor of Inorganic Materials at The University of Manchester and co-founder of Nanoco Technologies Ltd