ROYAL ACADEMY OF ENGINEERING

EPSRC
Engineering and Physical Sciences Research Council

Engineering for a successful nation

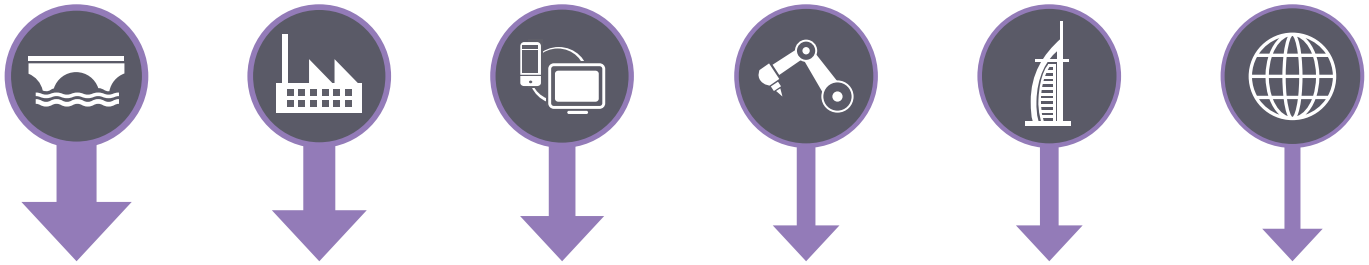
Key findings from *Assessing the economic returns of engineering research and postgraduate training in the UK*

March 2015

Engineering is pervasive in our modern society, enabling every sector from communication and entertainment to finance and healthcare, as well as its more visible applications in construction, manufacturing and transport.

Engineering is opening doors for next generation healthcare: engineering research offers improved quality of life for young and old alike. In addition to the well-established areas such as medical devices and medical imaging, the development of new and novel engineering approaches to biological systems will lead to major advances in diagnostic, therapeutic and regenerative medicine. Dr Nicola Irwin, Royal Academy of Engineering Enterprise Fellow, Queen's University Belfast

Engineering contribution to UK gross value added



Construction
£87 billion

Medium and low tech manufacturing
£75 billion

Computing and Telecoms
£60 billion

High tech manufacturing
£22 billion

Architectural and engineering activities
£22 billion

Other sectors (weighted by concentration of engineers with Level 4+ qualifications)
£12 billion

Total: **£278 billion** = **20%** of UK GVA

Summary

Engineering is central to the well-being and economic development of every nation. Creative and dynamic, it evolves continuously to meet the needs of human civilisation. Engineering is pervasive in our modern society, enabling every sector from communication and entertainment to finance and healthcare, as well as its more visible applications in construction, manufacturing and transport. Progress is driven, as it has always been, by human curiosity and experimentation, but resources are finite and the art of engineering is to devise affordable solutions to problems.

As the UK recovers from its deepest recession for a generation, the Engineering and Physical Sciences Research Council and the Royal Academy of Engineering have commissioned the consultancy Technopolis to conduct a review of the economic return on the resources made available for engineering research and related postgraduate training in the UK. This summary document highlights the key findings of this review.

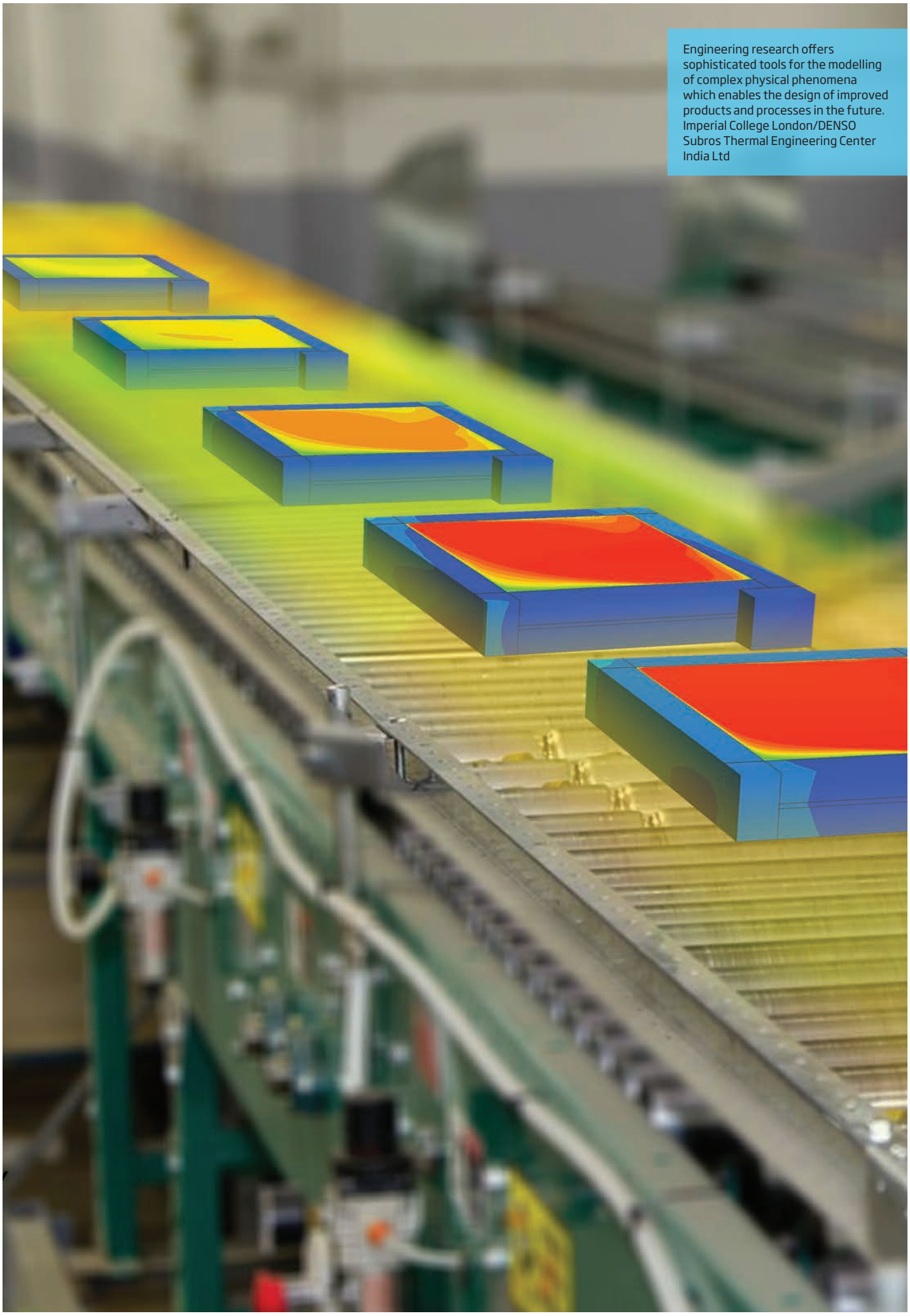
The results are encouraging: engineering-related sectors contributed an estimated c. £280 billion in gross value added (GVA) in 2011 – 20% of the UK's total GVA. This represents a rise of 3% from the 2007 figure and suggests that UK engineering has recovered to pre-financial crisis levels of economic output.[1]

As a nation, our engineering research operation is extraordinarily efficient and focused. The UK is first in the world in terms of productivity, second in the world in terms of research excellence and yet well behind many of its competitors in terms of research and development spending. In a world economy where technological expertise drives economic growth, we need to increase investment in engineering research if we want to continue as a world-leading nation.

[1] In simple terms, GVA is a measure of profits and salaries in a sector and excludes the value of the goods and services necessarily bought-in, to avoid double counting. GVA is HM Treasury's accepted measure of the additional value that a sector brings into the economy. Previous studies have estimated figures of 28% GVA[2] and 27.1% GDP[3] – variations are due to methodological differences in selecting engineering-based sectors and the qualification level of the engineers included in the analysis. Whatever methodology is used, engineering is clearly demonstrated to make a major contribution to the UK economy.

[2] *Jobs and growth: the importance of engineering skills to the UK economy*, Royal Academy of Engineering, 2012.

[3] *The contribution of engineering to the UK economy*, a report for Engineering UK (Cebr), October 2014.

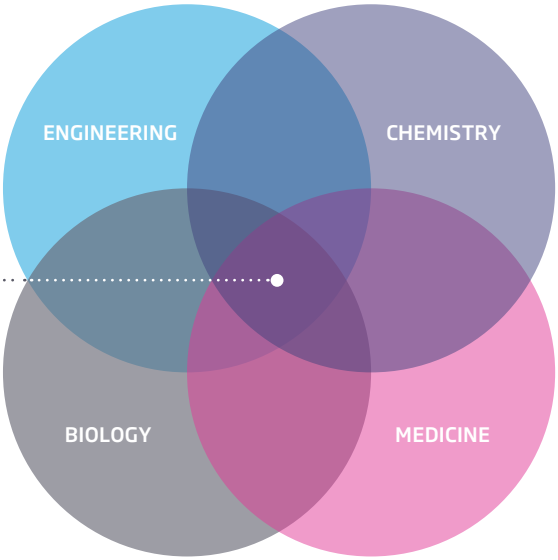


Engineering research offers sophisticated tools for the modelling of complex physical phenomena which enables the design of improved products and processes in the future. Imperial College London/DENSO Subros Thermal Engineering Center India Ltd

Potential for the global industrial biotechnology market

£150 – 360 billion Total global market by 2025

£4 – 12 billion Predicted UK share



Engineering for the 21st century

Engineering provides the means to convert excellent research into new and improved products and services that can and do make a substantial contribution to the economy. Innovative engineering is the key to future growth in the UK and we will have to make increasing use of our intellectual abilities and our creative talent if we are to take advantage of this opportunity.

Engineering is vital to all the sectors prioritised in the government's industrial strategy, which builds on our existing strengths in aerospace, pharmaceuticals, software and computing. Case studies included in the Technopolis assessment demonstrate genuine advances being made possible through engineering research across the priority sectors including automotive, aerospace, renewable energy and healthcare.

Engineering has changed dramatically during the last 20 years. Emerging technologies now provide important opportunities for future growth and the boundaries between traditional disciplines are becoming increasingly blurred as many of the most exciting discoveries and developments are made at these boundaries. For example, the global industrial biotechnology market in the chemical and pharmaceutical sectors is expected to be worth £150 – 360 billion a year by 2025, with the UK positioned to capture a £4 – 12 billion share. This is an entirely new area of exploration that has arisen through the interaction of chemistry, biology, medicine and engineering.

UK Engineering Research: high impact despite a lower activity level

Figure 1 – Research Activity Index

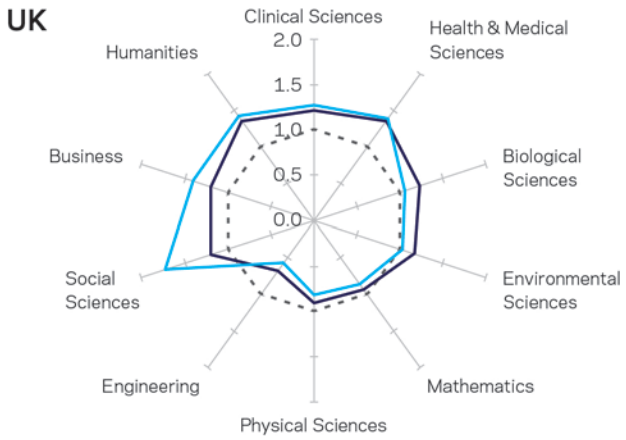


Figure 2 – Citation impact

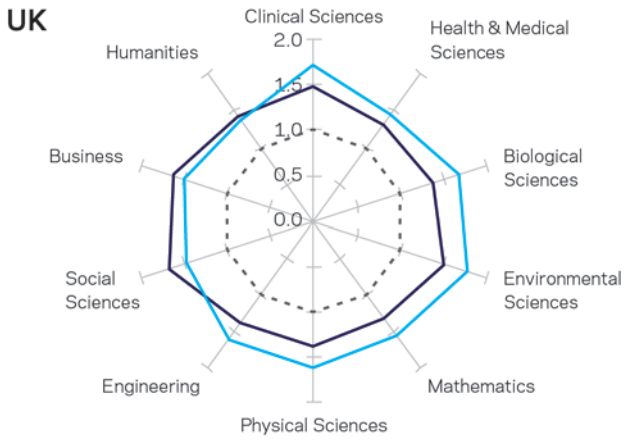


Figure 1 shows the Research Activity Index for the UK across ten research fields in 2002 and 2012. The Activity Index is defined as a country's share of its total article output across subject field(s) relative to the global share of articles in the same subject field(s): an Activity Index of 1.0 equals world average share in that particular research field. Figure 2 shows the corresponding field-weighted citation impact for the UK and the same comparators in the same two years: a field-weighted citation impact of 1.0 represents world average in that particular research field. Reproduced with permission from Elsevier's international review of UK research 2013.[4]

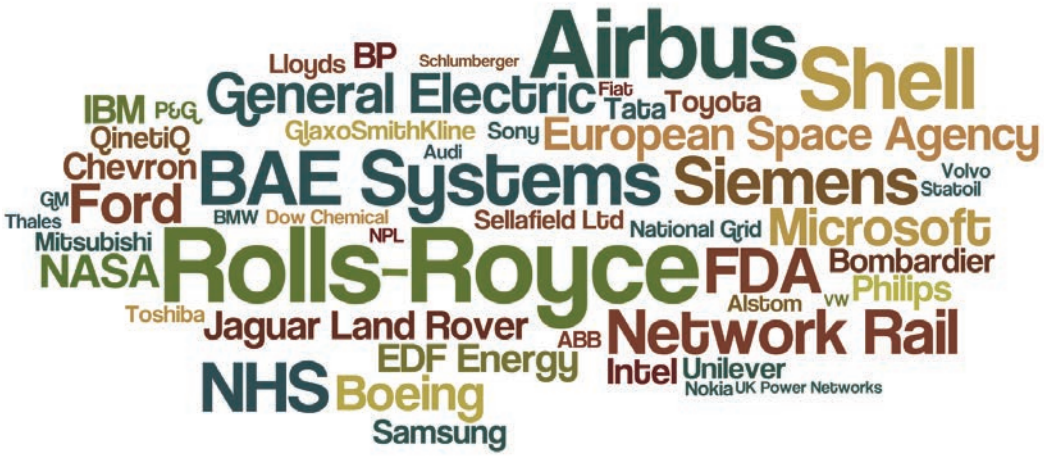
Excellent and highly efficient

The UK's engineering research is world class, a fact reflected in the REF2014 results: 70% of research outputs submitted to the five engineering-related Units of Assessment were classified as 'world-leading' or 'internationally excellent'. At over one and a half times the world average, the citation impact of UK engineering research has been particularly strong over the last decade relative to comparator countries such as the US, Germany, Japan and Canada. This is despite the activity level of engineering research in this country being only half the world average, and well behind emerging economies like China and India.[4] A higher level of activity would undoubtedly enable even greater achievements for the UK, but this depends crucially on the level of funding available to support it.

The UK runs one of the most efficient and effective research operations in the world, partly out of necessity, given the strictures imposed by the recent economic crisis. However, the impact achieved is remarkable and further demonstrated by our success in participating in international research and development programmes such as the EU Seventh Framework Programme for Research and Technological Development, FP7. By October 2013, UK-based universities and businesses had secured FP7 grants amounting to around €7 billion out of the total €40 billion funding available over seven years for the FP7 Cooperation Programme.

[4] *International comparative performance of the UK research base 2013*. A report prepared for the UK's Department of Business, Industry and Skills (BIS), Elsevier, 2013.

Top 50 organisations in REF case studies reviewed by Technopolis, by number of citations



UK engineering researchers are engaging with large numbers of major international companies, delivering impacts in a multiplicity of sectors and providing important technology and innovation in the public sector as well as the private sector.

Attracting inward investment

Encouraging inward investment by international companies is a crucial component of the UK's industrial strategy. The undisputed quality of engineering research conducted in the UK, combined with access to world-class engineering facilities and businesses, has helped to attract substantial high-value and high-tech inward investment from Europe, the US and the Far East.

Overseas investors are drawn to the UK's globally recognised engineering expertise and their support is helping to benefit regional economic development initiatives. For example, Samsung Heavy Industries announced in 2012 that it would base its first European offshore wind project in Fife. The Samsung Energy Park Fife Offshore Demonstration project carries investment of up to £100 million and is expected to create more than 500 new jobs in Scotland.

The European Centre for Space Applications and Telecommunications (ECSAT), currently being established in Harwell, will create over 100 new high-tech jobs from this year, thanks to investment from the European Space Agency. In Wales, the Japanese electronics giant Panasonic is creating a new fuel cell research and development centre in Cardiff as part of a £2 million investment.

Around 260 jobs are being created by a US global engineering firm in County Tyrone. Terex manufactures equipment used in the construction, quarrying and mining industries and has factories in Dungannon and Omagh in Northern Ireland. It is part of a £21.7million investment and the jobs will be created over the next four years. Terex plans to build new factory space, purchase new equipment and invest in research and development. These are but a few examples of the many inward investments being made by companies attracted by factors such as the strength of the UK's engineering research and talent base.

£9.5 billion/year

invested in engineering R&D by UK businesses

£1.5–3.1 billion/year

invested in engineering R&D by UK government

Engineering resilience: we rely increasingly on complex networks consisting of many components which interact with each other. Engineering research will enhance our understanding of these systems, and provide solutions for managing our environment. Institute of Sound and Vibration Research, University of Southampton

Academic excellence translates into tangible economic benefits: new technology developed with funding from EPSRC in partnership with Nissan is paving the way for future driverless cars. Professor Paul Newman FREng, EPSRC Leadership Fellow, Mobile Robotics Laboratory, University of Oxford

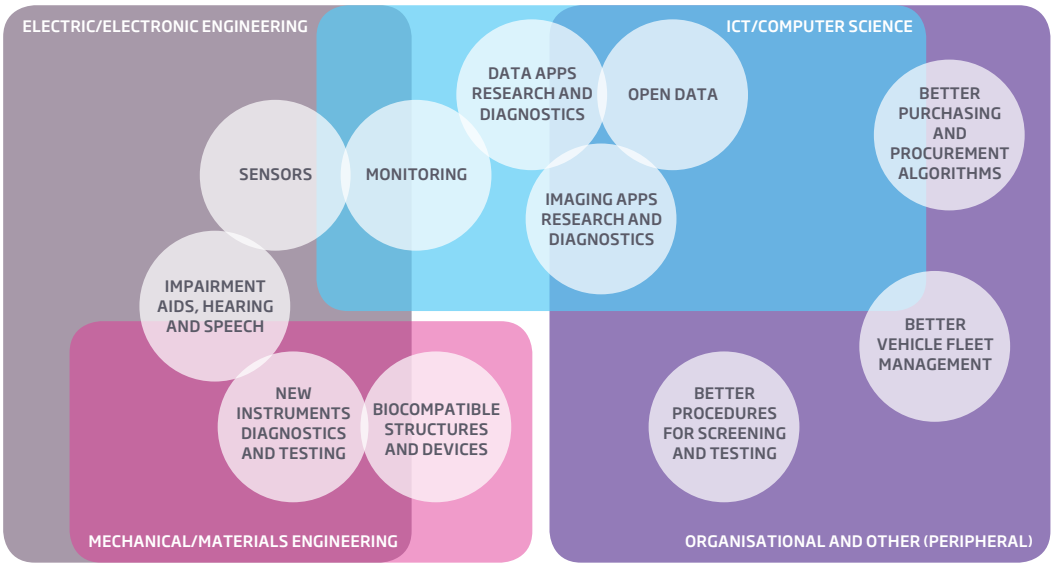
Successful and competitive

The Technopolis review estimates that UK businesses invest at least £9.5 billion per year in engineering research and development, around 4% of which is contributed by SMEs. The UK government is estimated to spend £1.5 – 3.1 billion a year on engineering research through a wide variety of programmes including those run by EPSRC and Innovate UK. These data would seem to indicate that the UK achieves significant leverage on its public investment in engineering research, which in turns generates substantial wealth for the nation.

Outshining our competitors in the 21st century and beyond will involve focusing even harder on our own, long-standing advantage – engineering innovation: the key to enabling the development of world-leading engineered services and products. This is reflected in the central role than engineering companies play in fuelling UK exports. Engineering-related sectors exported goods and services valued at around £240 billion in 2011, which amounted to 48% of the total value of exports, more than double the share of GVA accounted for by these sectors.

Engineers also have the skills and ability to tackle the grandest of challenges and find solutions that work. Whether in research, technology, business or policy, they are equipped to analyse problems, synthesise solutions, manage projects that create the right outcomes and turn those experiences into new opportunities. As a result, engineering research plays a key role in policy and public services, as evidenced by many of the REF case studies inspected during this study. For example, researchers at University College London created the user-centric perspective that underpins current security thinking for both the corporate and public sectors. Their protocol shaped the UK government's Identity Assurance Programme IDAP, which will provide access to all UK e-government services. It has also facilitated new security products, including First Cyber Security's SOLID and Safe Shop Window tools, which protect over 70% of the UK's online shopping revenue.

Engineering in healthcare: case studies from the Research Excellence Framework demonstrate the breadth of innovation

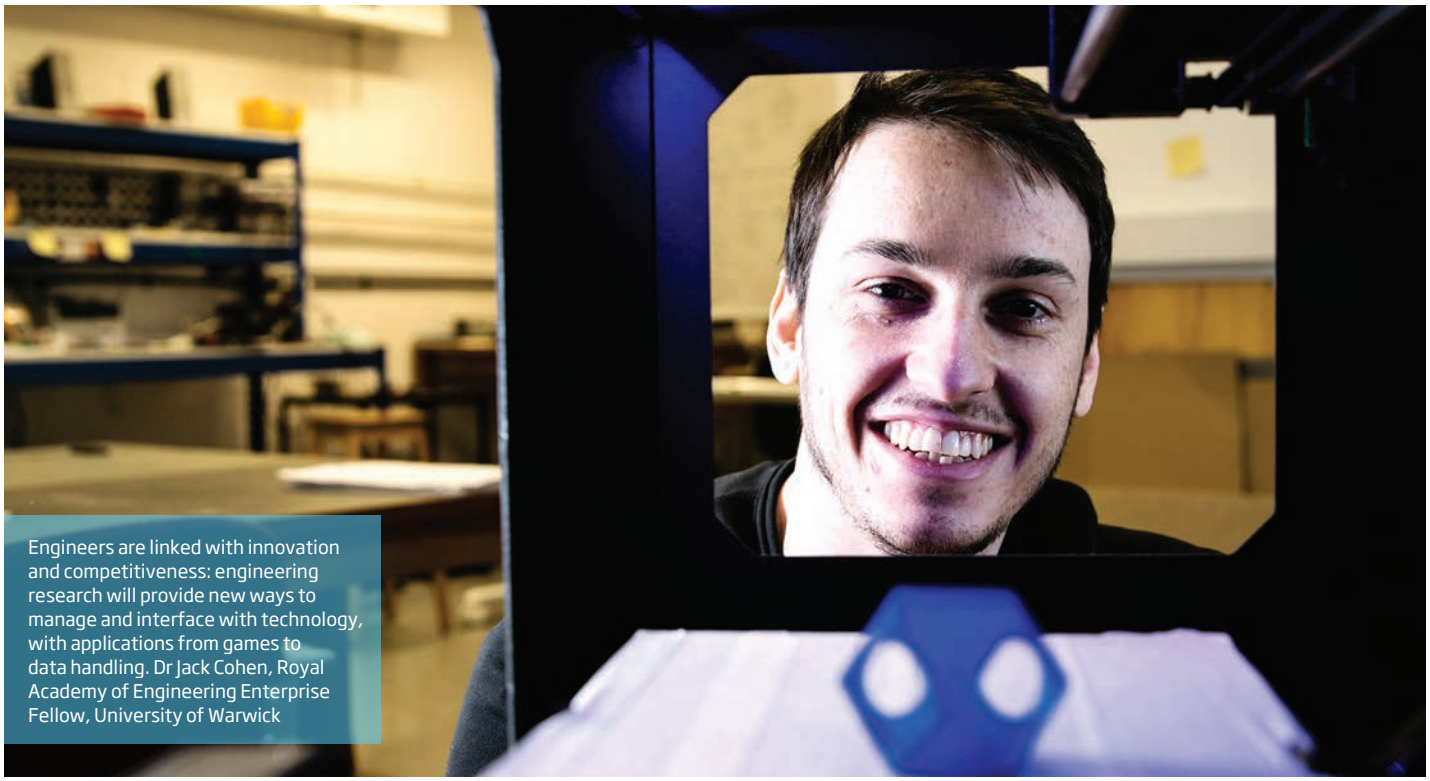


Driving innovation

This review benefited from privileged access to over 500 individual Research Excellence Framework (REF) case studies from around 50 different higher education institutions, which showcase the impact of engineering research in all its forms. Together, they provide comprehensive evidence of the economic and social impact of UK engineering research over the last 20 years. One third of the case studies refer to increases in productivity and competitiveness, citing research that has led to new processes offering efficiency gains and cost savings.

The UK's National Health Service provides a good example of how engineering research has made a difference over the last two decades, with 27% of the REF case studies citing applications in medicine and healthcare. The field of sensors is just one area that has seen major advances in applications to healthcare, which also have the potential to enable advances in other areas. For example, Lab-on-a-chip technologies developed at the University of Glasgow to enable screening for chronic diseases and acute infections, and to improve drug discovery, are now being taken forward to commercialisation by three spin-out companies in collaboration with the NHS: Mode-Dx, Saw-Dx and Clyde Biosciences.

Engineering graduates and postgraduates help to drive product development and innovation across many parts of the economy, and sectors with high concentrations of graduate engineers all report higher than average levels of innovation activity, innovation-related income and labour productivity.



Engineers are linked with innovation and competitiveness: engineering research will provide new ways to manage and interface with technology, with applications from games to data handling. Dr Jack Cohen, Royal Academy of Engineering Enterprise Fellow, University of Warwick

Skills for a knowledge economy

Great talent is essential for great innovation and great business. It is now well documented that the UK has a skills shortage, particularly in engineering.[5] Employers struggle to meet the demand for engineers in general – and for more senior staff in particular, and continued investment in high-skill engineering training is vital.[6] Engineering qualifications attract a wage premium of around 15% of the median salary for newly qualified graduates, clearly indicating that engineers' skills are highly valued in the economy.

Research by the Institute of Economic Research at Warwick University also suggests a marked trend in industry over the last 20 years towards fewer administrators, fewer skilled trades and operatives and a long-run expansion in the number of managers and other professionals such as skilled engineers. Globalisation has seen the outsourcing of millions of lower-skilled jobs, leaving us with a 'knowledge economy'.

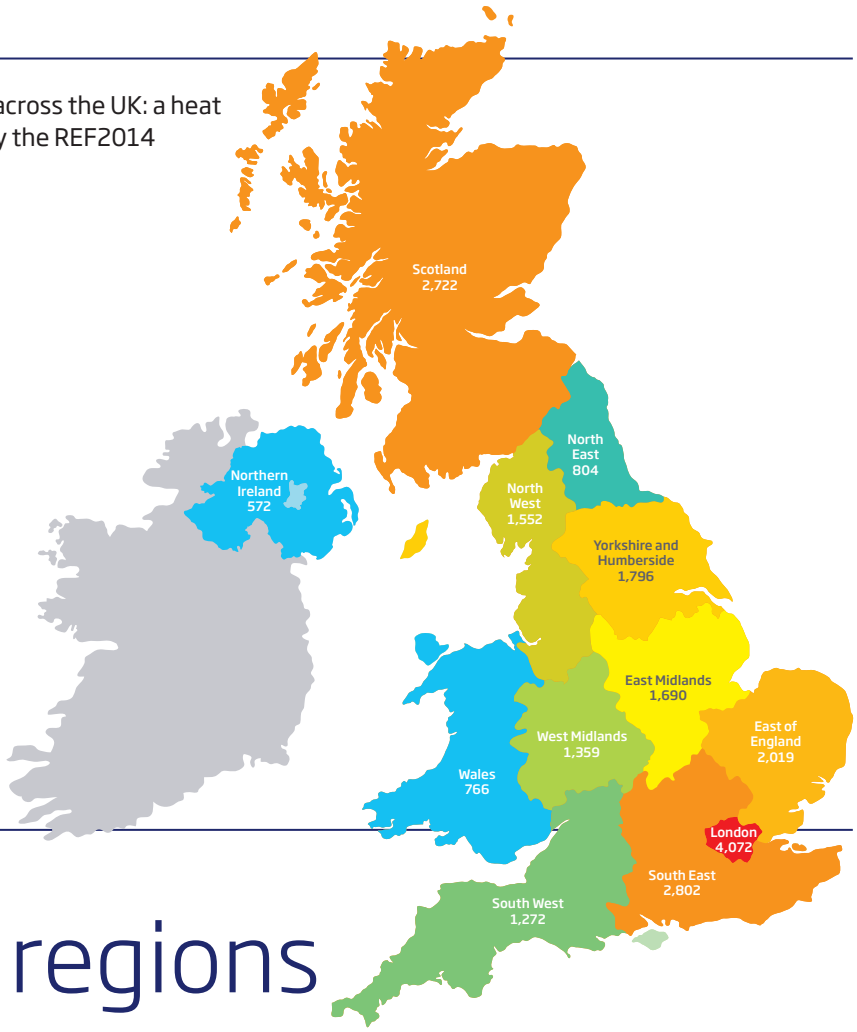
However, in engineering higher education, the number of UK-based students achieving engineering degrees has been almost static over the past eight years with 12,700 students in 2004 and 13,700 in 2012.[7] We need to more than double this number to redress the skills shortage. Postgraduate skills in the right areas can influence an industry's international competitiveness or even the performance of a country's knowledge economy. EPSRC is the dominant funder of this important level of training, particularly for UK-resident students, with an active portfolio of grants for engineering postgraduate training of £322 million in 2014.

[5] *Engineering UK 2015: the state of engineering*, Engineering UK, 2015

[6] *Professor John Perkins' Review of Engineering Skills*, BIS, 2013

[7] *The Universe of Engineering: a call to action*, Royal Academy of Engineering, 2014

Engineering research excellence is well distributed across the UK: a heat map of regional engineering strength as reflected by the REF2014



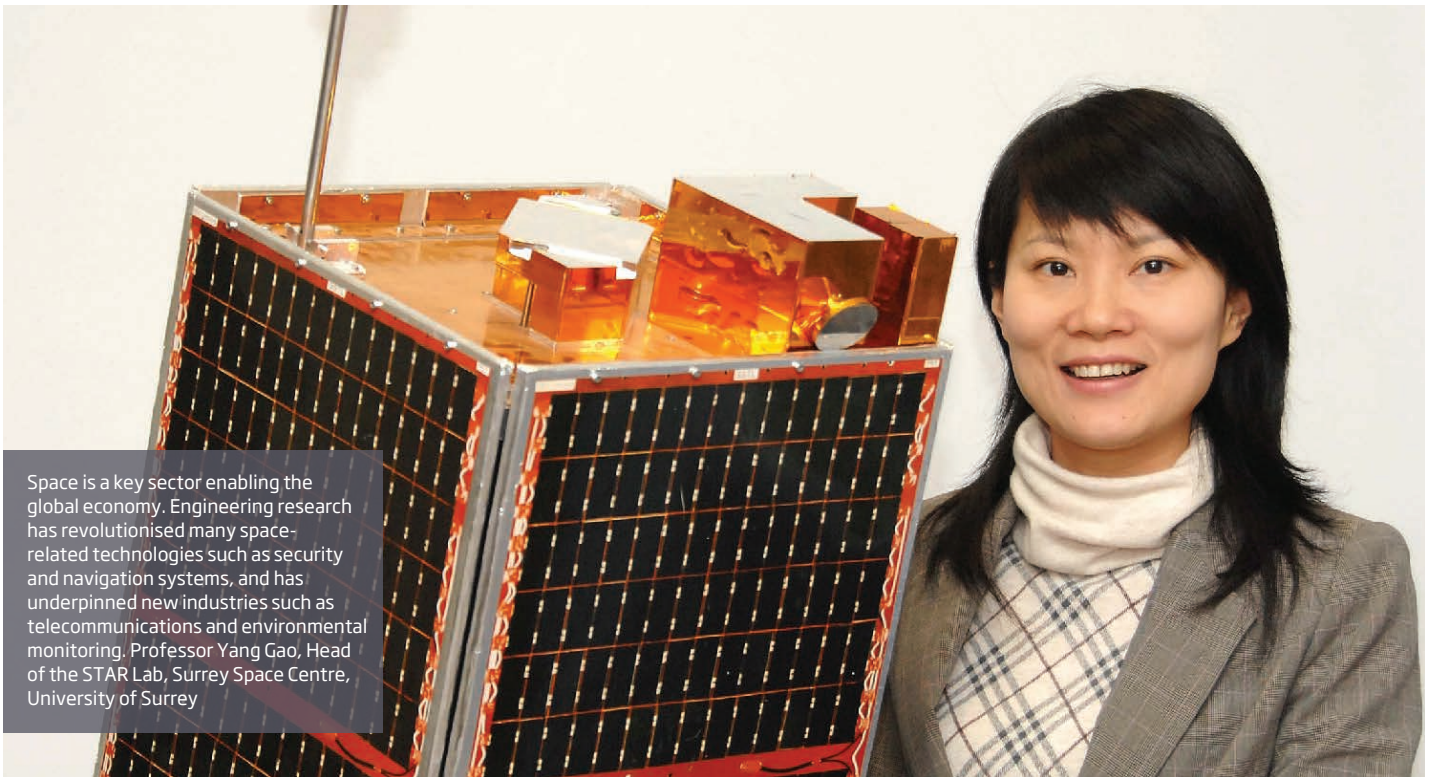
The map shows the value of REF Research Power for universities by region (based on engineering units of assessment only). Research Power is based on the Grade Point Average multiplied by the full-time equivalent staff submitted, and reflects both the quality and size of research activity

Powering the regions

High-quality UK engineering research can have a very positive impact on regional development, helping to generate new economic activity and employment in the regions. Stimulating enterprise is essential to revitalise economically deprived areas and the contribution of SMEs and micro companies, many formed as university spin-outs, is vital.

The presence of engineering skills in regions such as the Midlands and the North has led to major inward investments, which in turn have generated clusters of innovative local companies around them. The reinvigoration of Jaguar Land Rover (JLR) is a case in point, benefiting from major investment by Tata, which notably brought in the 'Tata way' to encourage innovation – JLR recorded a 9% increase in global sales in 2014. Now BorgWarner, a $7.5 billion a year US-based automotive components manufacturer, is building a new engineering centre and production line in Bradford for JLR. The £7.5 million Turbocharger Research Institute will provide turbocharging technologies for JLR's new family of four-cylinder engines. BorgWarner is also launching a master's degree in turbocharger engineering at the University of Huddersfield.

Engineering research is well distributed across the UK – this is a national strength that can be utilised to help the regions to prosper.



Space is a key sector enabling the global economy. Engineering research has revolutionised many space-related technologies such as security and navigation systems, and has underpinned new industries such as telecommunications and environmental monitoring. Professor Yang Gao, Head of the STAR Lab, Surrey Space Centre, University of Surrey

Leading the world

Engineering research and postgraduate training have an enormous influence on engineering internationally. Many UK consulting engineering companies, including Arup, Atkins, Mott MacDonald and many others, are hugely successful in large numbers of countries throughout the world, because they are applying the high quality engineering research and postgraduate training provided to their engineers by the UK. Our nation is at the forefront of contributing to global infrastructure and urbanisation especially in emerging economies.

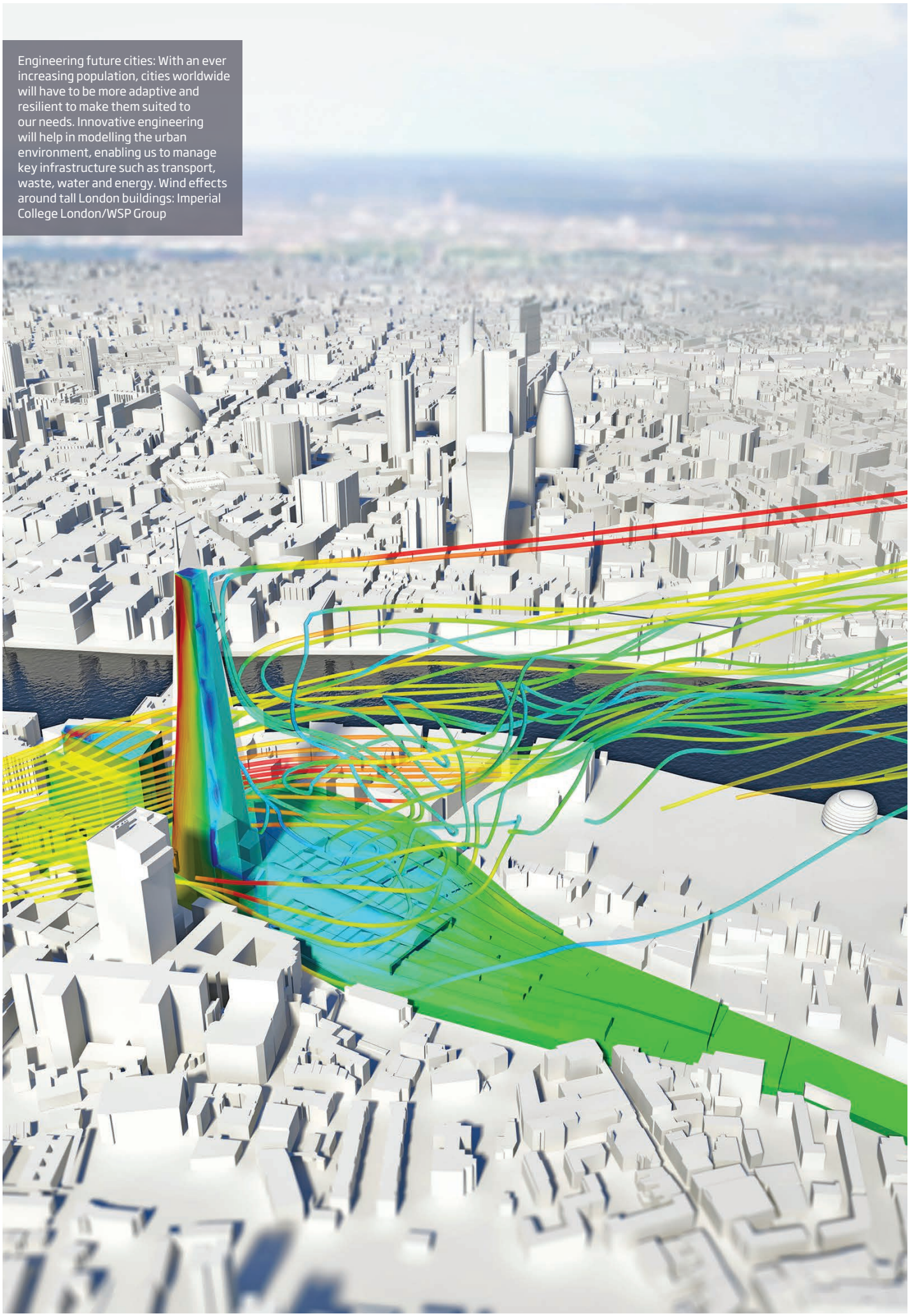
International engineering activity is increasingly driven by engineering research and training undertaken in the UK. The number of non-EU international engineering students completing engineering degrees in the UK has increased by 70% over the last eight years, from 3,200 to 5,500. Non-EU international students make up 75% of postgraduate engineering degrees achieved and many engineering MSc courses depend entirely on overseas students for their continued existence.[7] While this poses challenges for the UK, it also serves to illustrate the world-class standing of UK engineering education and training.

Research Councils UK and the Royal Academy of Engineering are among the delivery partners for the government's Newton Fund, which is part of the UK's official development assistance and aims to develop science, engineering and innovation partnerships that promote the economic development and welfare of developing countries. The fund will grant £75 million each year for five years of partnerships with 15 emerging nations, to be matched by contributions from these partner countries. This will both extend the UK's international network of engineering research collaborations and ensure that our engineering research community continues to contribute to poverty alleviation across the world.

Engineering research is essential to enable the nation to forge ahead with its industrial strategy

Engineering for growth

Economic growth is a means to improving quality of life, addressing society's challenges, strengthening social cohesion and creating the education and training that can give young people real opportunity. As one of the world's leading economies, the UK now faces a massive challenge to remain competitive on a global stage. This review has demonstrated that the UK achieves substantial and wide-ranging returns from its public investment in engineering research and associated training. However, real and sustained support from across the political spectrum will be essential in the years ahead if we are to reap the full rewards offered by engineering ingenuity and innovation.



Engineering future cities: With an ever increasing population, cities worldwide will have to be more adaptive and resilient to make them suited to our needs. Innovative engineering will help in modelling the urban environment, enabling us to manage key infrastructure such as transport, waste, water and energy. Wind effects around tall London buildings: Imperial College London/WSP Group

Royal Academy of Engineering

As the UK's national academy for engineering, we bring together the most successful and talented engineers for a shared purpose: to advance and promote excellence in engineering.

We provide analysis and policy support to promote the UK's role as a great place to do business. We take a lead on engineering education and we invest in the UK's world-class research base to underpin innovation. We work to improve public awareness and understanding of engineering. We are a national academy with a global outlook.

We have four strategic challenges:

Drive faster and more balanced economic growth

Foster better education and skills

Lead the profession

Promote engineering at the heart of society

Engineering and Physical Sciences Research Council (EPSRC)

EPSRC is the UK's main agency for funding research in engineering and physical sciences. EPSRC invests around £800 million a year in research and postgraduate training, to help the nation handle the next generation of technological change. The areas covered range from information technology to structural engineering, and mathematics to materials science. This research forms the basis for future economic development in the UK and improvements for everyone's health, lifestyle and culture.

Our vision is for the UK to be the best place in the world to research, discover and innovate.

ROYAL ACADEMY OF **ENGINEERING**

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