MANCHESTER

Graphene and 2D Materials
Opportunities in the City of Innovation

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"Best UK City to Live"
Economist Intelligence Unit, 2015

"Fastest Growing Economy Outside of London "
Grant Thornton, High Growth Index, 2014

"Best regional city in the UK for global investment"
IBM, Global Locations Trend, 2015

WELCOME TO MANCHESTER: THE HOME OF GRAPHENE

Graphene and 2D materials opportunities in the city of innovation – a definitive guide to Manchester's pioneering 2D materials sector.

Manchester is a city looking to the future. Home to many of the world's firsts; from the birthplace of the industrial revolution to the splitting of the atom, the first stored-program computer and the first test tube baby – it is a city of pioneers. This spirit of innovation attracts the brightest business and academic minds, exemplified by the city's newest innovation: graphene and 2D materials.

Graphene is the world's first 2D material, originally isolated at the University of Manchester. Consisting of a single layer of carbon atoms, it is incredibly light, strong, flexible and transparent with high conductivity for electricity and heat. The potential for this 'wonder material' is huge, with prospective applications ranging from electronics to composites to flexible touch screens.

The isolation of graphene has spurred a boom in discovery of other 2D materials. Here layered materials are split into single layers of atoms and in some cases combined into new layers with graphene. Examples include boron nitride (or 'white graphene') and molybdenum disulphide which are already well characterised and could have the potential to revolutionise industrial applications.

Manchester is now in the process of developing a comprehensive graphene infrastructure. Home to the National Graphene Institute and the Graphene Engineering Innovation Centre, the city will facilitate the utilisation and commercialisation process of graphene applications from start to finish.

Manchester's engineering and manufacturing expertise is well known, and is a huge bonus for businesses looking to invest or relocate to the city. Manchester's central location means that it is at the heart of the advanced manufacturing supply chain with the North West of England's 60,000 aerospace workers and 450 automotive companies within easy access, offering many options for supply chain collaboration.

As a leading centre for advanced materials, Manchester has the right ingredients to energise your business. It provides unparalleled access to significant market opportunities, a strong and established skills base and an impressive range of cutting-edge research and world-class educational facilities.

You don't need a Nobel Prize to choose Manchester, but if you're looking for somewhere that can unlock a world of possibilities and where the future is being made today – Manchester is the place for you.

WHY MANCHESTER

Graphene City

Manchester is an ambitious city, and the vision is for Manchester to become the Silicon Valley of graphene. Substantial funding and a wealth of development will reinforce the city's position as the graphene capital of the world.

Graphene was discovered at the University of Manchester in 2004 by Professor Andre Geim and Professor Konstantin Novoselov who were awarded the 2010 Nobel Prize for physics for their pioneering work with the world's thinnest material. The award of the Nobel Prize means there are four Nobel Laureates currently working at The University of Manchester.

The National Graphene Institute (NGI)
£61 million has since been invested into The National Graphene Institute, a new facility at The University of Manchester to support the material's continued development. The Institute is the world's leading centre for graphene research, housing state-of-the-art facilities for universities and businesses from around the world to collaborate on a variety of projects, across various sectors.

The Graphene Engineering Innovation Centre (GEIC)
Due to open in 2017, The GEIC will be critical in the development of commercial applications for graphene and 2D materials. Located at The University of Manchester, it will enable graphene products to be fast-tracked from initial concept to the market.

Sir Henry Royce Institute for Advanced Materials
Opening in 2018, the Institute will act as a catalyst for research and development of advanced materials and their use. Its research centre will be at The University of Manchester, supported by satellite centres at universities across the country.

Talent

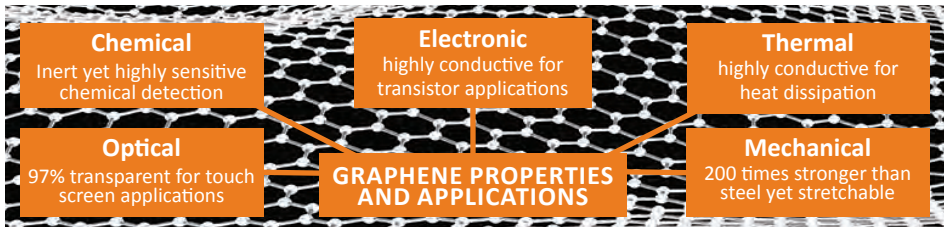
The city's four universities have over 14,000 students studying disciplines relevant to advanced materials. Manchester is home to Europe's largest school of materials at the University of Manchester. Businesses located here will benefit from the region's strong heritage in this sector and its enviable skills base which includes a talent pipeline of 27% of the UK's materials science students. Graphene is a major focus of multi-disciplinary research at The University of Manchester with more than 200 researchers. Areas of research include membranes, composites, energy, electronics/ sensors and biomedical. Manchester Metropolitan University also has researchers with experitise in nano-materials and the application of graphene.

Thriving cluster of companies

A host of international organisations have recognised Manchester's strengths in the field. **BGT Materials** has set up its European production plant for thin film graphene in Manchester in partnership with the National Graphene Institute. **2-DTech** is a start-up company from The University of Manchester focusing on the application and product development of graphene. The company works alongside industry to identify and develop potential graphene applications.

Access the global market opportunity

While initial demand is to produce graphene for academic research, applied research and prototype development, the market is projected to be worth almost £122 million by 2018, reaching £800 million by 2023, with a five-year compound annual growth rate (CAGR) of 47.1% from 2018 to 2023. The opportunities for collaboration with the NGI and the GEIC mean that businesses located here are perfectly positioned to exploit the commercial opportunities presented by this demand.



CENTRES OF EXCELLENCE

Home to world-class universities with leading graphene research capabilities, Manchester offers unparalleled access to knowledge transfer, cutting-edge research facilities, collaborative working and a skilled and talented graduate base

Graphene is a major focus of multi-disciplinary research at The University of Manchester. Over 200 researchers are dedicated to the applied research of graphene in areas such as membranes, composites, electronics and sensors, energy, and biomedical.

Key Assets

The National Graphene Institute

The National Graphene Institute is a new £61 million facility at The University of Manchester operating as a 'hub and spoke' model, working with other UK and global institutions involved in graphene research.

The 7,600m^2 development provides a home for researchers and industry to work together on potential applications of graphene.

Cutting-edge facilities include 'cleanrooms' for experiments and research without contamination, and a 1,500m^2 open innovation research lab for university's scientists to collaborate with industry.

The University already has more than 30 partners, including some industrial household global names, working on graphene applications.

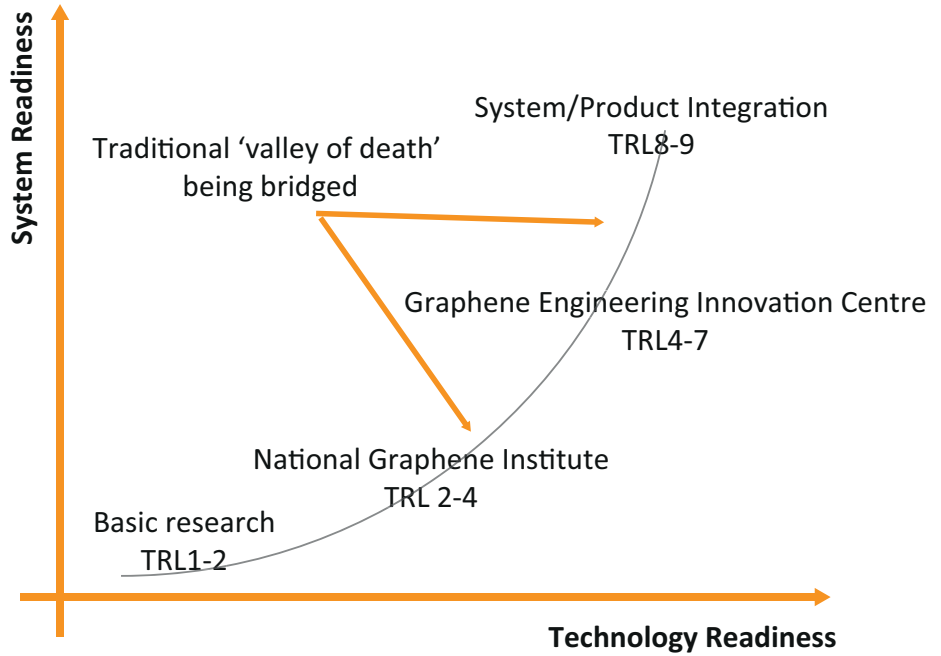
Manchester is not alone in recognising graphene's exciting potential, with research groups established in Bristol, Oxford, Lancaster, Exeter and Cambridge. Manchester, as the home to the largest research centre and the country's only comprehensive graphene ecosystem, is well placed to be a central research hub for collaboration with these regions.

"The National Graphene Institute will be the world's leading centre of graphene research, combining the expertise of University of Manchester academics with their counterparts at other UK universities and with leading global commercial organisations"

Professor Colin Bailey, Vice-President and Dean of the Faculty of Engineering and Physical Sciences

Graphene Engineering Innovation Centre (GEIC)

Opening in 2017, the £60 million Graphene Engineering Innovation Centre will be critical in the development of commercial applications with graphene and related 2D materials. The Centre will bridge the 'traditional valley of death', where research fails to lead to commerialisation. It will enable graphene products to be fast tracked from applied research to the market. Located at the University of Manchester, GEIC will complement Manchester's existing National Graphene Institute (NGI), where over 200 scientists and engineers are dedicated to graphene and 2D materials research. Together, the two facilities will reinforce Manchester's position as a globally leading knowledge bank in graphene research and commercialisation, and provide ample opportunities for collaboration with industry.



"The new Sir Henry Royce Institute for Advanced Materials in Manchester, with satellite centres across the region, has become such an important part of our plans for putting science at the heart of the Northern Powerhouse"

George Osborne, Chancellor of the Exchequer

The University of Manchester

Aerospace Research Institute

The University of Manchester's Aerospace Research Institute is funding a PhD to assess the potential of graphene to enhance composite strength and provide smart monitoring. Graphene would be applied via polymer spray in the manufacturing process to improve toughness and give the potential for smart monitoring as graphene could act as an embedded sensor.

Manchester Metropolitan University

Researchers at Manchester Metropolitan University are working on a technique for screen printing graphene on sheets which, if successful, would provide a reliable method of scaling up production. Another method being researched is catalytic particles which can be used to produce graphene in a batch through process. In addition, MMU is using 3D printing to make graphene super-capacitors for electrical energy storage.

MARKET OPPORTUNITIES

Over the next few years the market demand for graphene will be focused around academic research, applied research and prototype development. Globally, significant sales of graphene products are expected to develop over the next five years.

The graphene market is projected to be worth almost £122 million by 2018, reaching £800 million by 2023, with a five-year compound annual growth rate (CAGR) of 47.1% from 2018 to 2023.

Some of these markets offer huge potential. For example, Indium tin oxide (ITO) is a scarce, brittle material currently used in touch screen devices, with researchers currently searching for a replacement.

Graphene shares many of the same properties as ITO, but with the significant advantages of being flexible, thinner, and made of a much more abundant element.

Global smartphone sales were estimated at 1 billion units in 2013 and analysts forecast that the Touch Screen Display market will grow at a CAGR of 30% over the period 2013-2018. The replacement market for ITO is valued at £1 billion.

This is just one example of the market potential for graphene. It is anticipated that graphene will have uses in applications including radio frequency identification (RFID), smart packaging, supercapacitors, composites, sensors, logic, and memory to name a few.

THE MANCHESTER OPPORTUNITY

Being located in Manchester will enable companies to get their product to market quickly as they can take advantage of the city's collaborative graphene ecosystem and well-trained workforce.

Now at an early stage of commercialisation, graphene has many hundreds of potential applications that could emerge. The National Graphene Institute, Graphene Engineering Innovation Centre and Sir Henry Royce Institute will provide the foundations for such research, development and fruition.

The National Graphene Institute is seeking both strategic partners and project partners to develop graphene applications, with short-term projections indicating ink printed circuits and ITO replacement as potential key applications of graphene.

Access to these organisations will enable businesses to:

- Produce high quality graphene consistently and in sufficient quantities to support commercial manufacturers
- Develop initial applications offering a strong cost/benefit over existing materials

The University has particular expertise in characterising graphene that will allow a set of industry standards to emerge. Firms such as **2-DTech, BGT Materials** and **Graphene Industries** have capabilities in characterising and producing graphene for research and commercial applications and have benefited from working closely with the university.

"The link with The University of Manchester and The National Graphene Institute is integral to our strategy of working with our customers to bring products and processes from the lab to the workplace.

With our long term commitment and cooperation with The University of Manchester, BGT will have access to a critical mass of world-class research talent, facilities and resources and we are very excited to be located at the home of graphene."

Dr. Chung Ping Lai, Chief Executive Officer for BGT Materials

CASE STUDY

BGT Materials

BGT Materials is one of the key players in the emerging graphene market, with laboratories in New York and Taiwan. The company already mass produces high-quality 2D materials for graphene-enhanced applications, such as advanced displays, flexible electronics, energy storage materials and cosmetics.

BGT Materials is initially focusing on thin film production of graphene for electronics applications such as touch screens for phones based on chemical vapour deposition. The company's European production plant for thin film graphene has been set up in Manchester in partnership with the National Graphene Institute.

In addition to providing material for research projects, BGT Materials is opening a pre-production facility at the University of Manchester to partner with leading consumer companies, as well as a larger European headquarters and a pilot production plant within Manchester.

They will work closely with the University of Manchester to develop the next generation of graphene applications such as advanced displays, flexible electronics, energy storage materials, and cosmetics. Research projects BGT will be involved in include:

- Plasmonics (rapid transmission of information using wires).
- Supercapacitors using graphene and other 2D materials.
- Graphene oxide membranes.

BGT Materials is also developing bulk graphene production techniques based on breaking down graphene and filtering it. This is likely to be scaled up in the near future. There are opportunities to develop bulk production of graphene in Manchester alongside BGT, where the University could quality assure the production.

CASE STUDY

2-DTech

2-DTech is a start-up company from The University of Manchester focusing on the application and product development of graphene. The company works alongside industry to identify and develop potential graphene applications.

Now 85% owned by Versarien plc, with the University retaining 15%, 2-DTech has developed an environmentally-friendly method of producing high quality graphene sheets in collaboration with The University of Manchester and Ulster University. This work is currently being scaled up.

Versarien will also set up an intellectual property and research collaboration with the University, initially investing some £300,000 in two projects, which will add to its own and to 2-DTech's product range, in areas such as graphene reinforced composites.

ABOUT MIDAS

MIDAS, Manchester's inward investment agency, can help you and your business with relocation and expansion plans. MIDAS has a reputation for understanding diverse business needs and helping to remove any barriers for companies looking to locate or expand into Manchester.

Their specialist business development team can assist you with a range of free, bespoke packages of confidential support that will make your journey as smooth and simple as possible.

The services provided by the team, which are also available to intermediaries such as location consultants, will save you time, money and effort and will enhance your project with the expert knowledge and local intelligence that results in a faster and more successful move.

MIDAS Services
Free support includes:

- Research support and business case development
- Introductions to local networks
- Recruitment and training support and advice
- Property solutions
- Relocation advice and assistance
- Post-investment PR support

See how MIDAS can help you make Manchester part of your success story.

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MANCHESTER - BUILT FOR SUCCESSFUL BUSINESS

With a skilled commuter population of over seven million people, outstanding IT connections, a world-class property portfolio – not to mention significantly lower costs than London – it's no wonder Manchester is has been recognised as the most competitive business location in Europe.*

Whether you are looking for a large development site, new office space or local business networks, MIDAS – Manchester's inward investment agency – offers a range of services that makes investing in Greater Manchester easy.

MIDAS provides an extensive package of expert, free and confidential advice for companies looking to expand, grow and locate in Greater Manchester. Our services are also available to location consultants.

To become part of Manchester's success story, contact us on:
T: +44 (0) 161 237 4470 E: info@midas.org.uk

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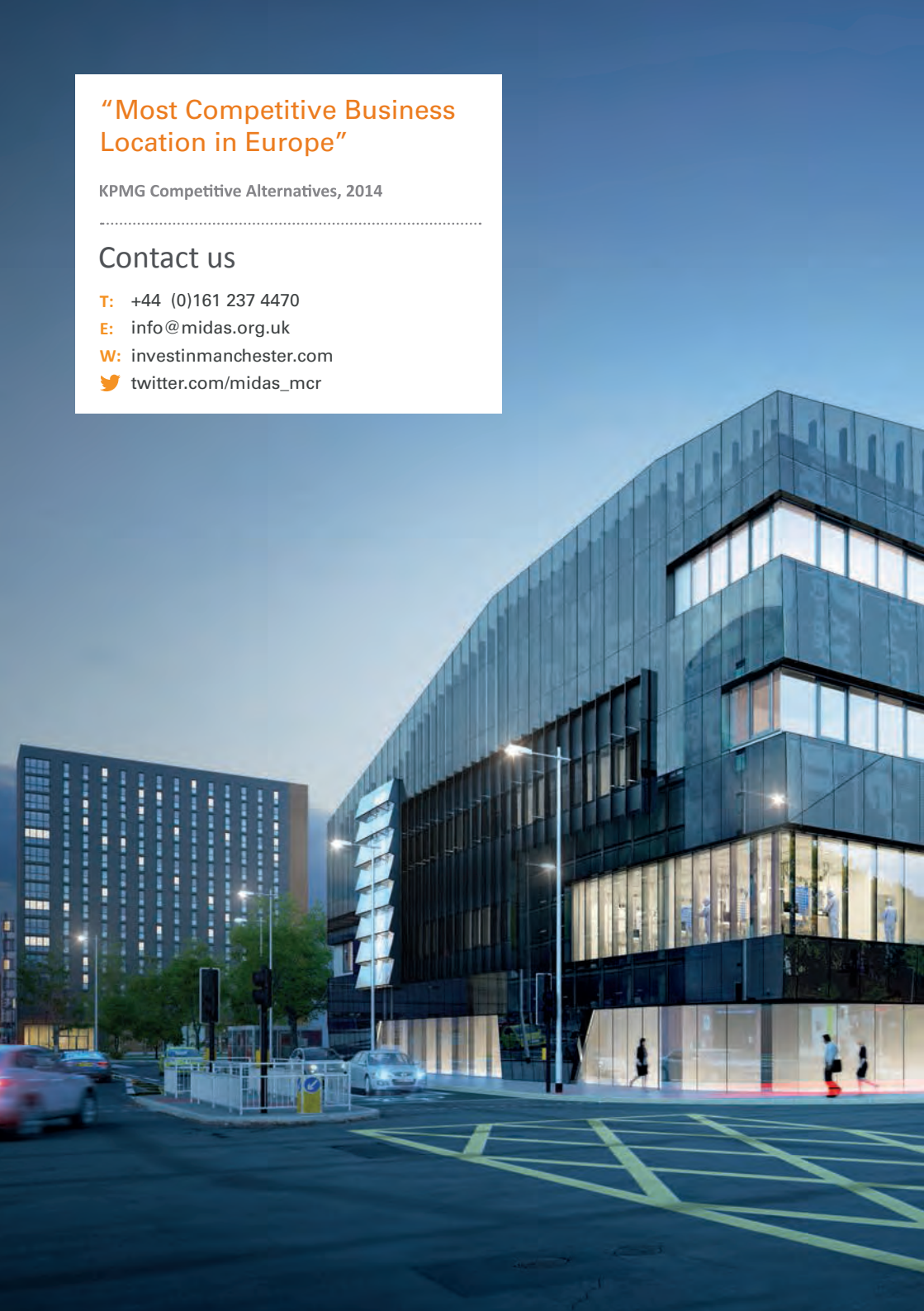
*KPMG Competitive Alternatives, 2015



“Most Competitive Business Location in Europe”

KPMG Competitive Alternatives, 2014

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