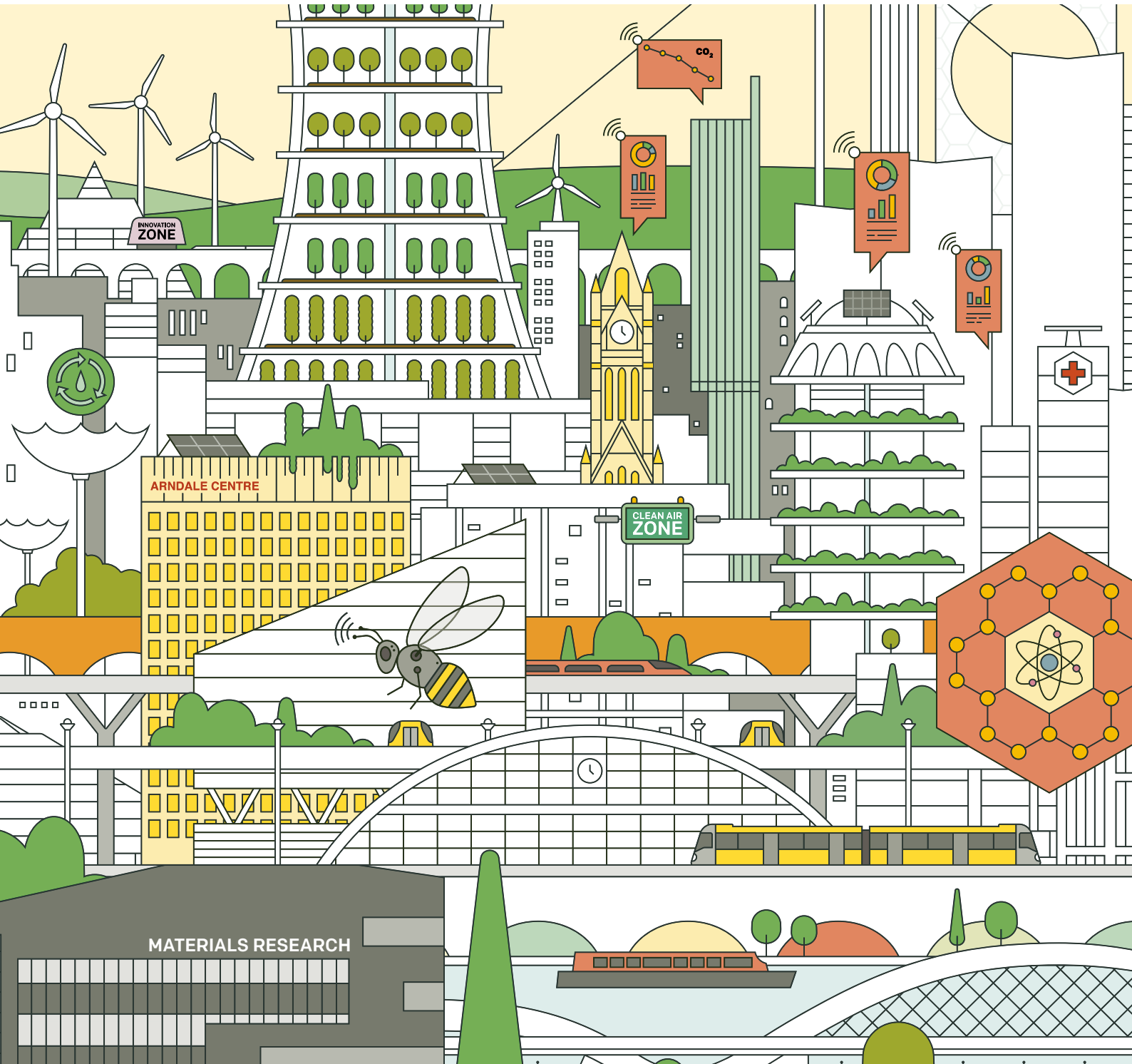
Greater Manchester
Local Enterprise Partnership

Material Gains:

Building Better Cities for People and the Planet



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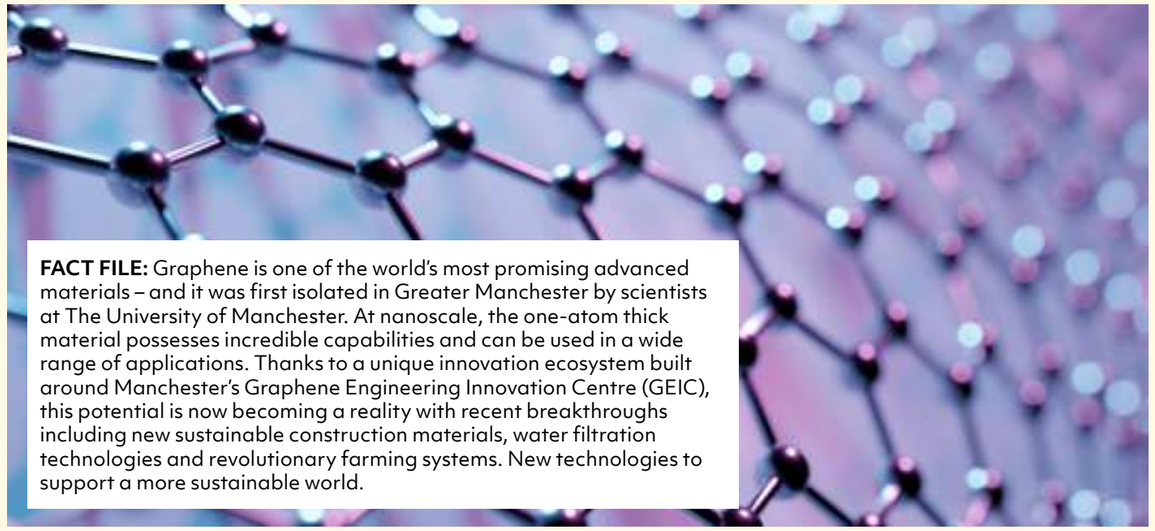


FACT FILE: Graphene is one of the world's most promising advanced materials – and it was first isolated in Greater Manchester by scientists at The University of Manchester. At nanoscale, the one-atom thick material possesses incredible capabilities and can be used in a wide range of applications. Thanks to a unique innovation ecosystem built around Manchester's Graphene Engineering Innovation Centre (GEIC), this potential is now becoming a reality with recent breakthroughs including new sustainable construction materials, water filtration technologies and revolutionary farming systems. New technologies to support a more sustainable world.

Foreword – Lou Cordwell, Chair of Greater Manchester Local Enterprise Partnership

What is the future for global cities and how is innovation in advanced materials shaping a world which is greener, better connected and more equal?

The illustration on the front of this white paper provides a futuristic view of one such city region.

Imagine Greater Manchester in 2038, enabled by low carbon economic growth, advanced materials and initiatives including Innovation Greater Manchester, which seeks to ensure that every community in the North can share in the socio-economic benefits of Research and Development (R&D) activity.

Brought to life by illustrator Barney Ibbotson, this futuristic vision represents the views of leading commentators from the fields of science, industry and academia, who recently participated in a GM LEP roundtable discussion in partnership with MIDAS and The University of Manchester and hosted by Alok Jha, science correspondent with The Economist.

Panellists were:

- Professor Dame Nancy Rothwell, GM LEP board member and President and Vice-Chancellor of The University of Manchester
- Tim Newns, CEO of MIDAS, Greater Manchester's inward investment agency
- James Baker, CEO of Graphene@Manchester
- Dr Beenish Siddique, Founder and CEO of AEH Innovative Hydrogel Ltd, a company which is researching new practical applications for advanced materials.

By 2038, they suggest a future of vertical urban farms; rainwater purification units utilising graphene membranes; road surfaces which defy potholes and charge the batteries in the driverless lightweight vehicles which pass along them.

The air is clean and people have a vast array of career opportunities in innovative industries that have not yet been imagined.

Transportation is net carbon neutral, integrated, affordable and efficient.

The cityscape remains familiar but incredible new architectural structures are possible due to enhanced building materials which are lighter, stronger and conduct heat and power.

Healthcare has been transformed by the ability to produce intricate replacement body structures.

As a result, Greater Manchester is a magnet for talent and investment and the city-region's effort to tackle global challenges has supported the fight against climate change.

Pre-pandemic, Greater Manchester set an ambitious target of achieving carbon neutrality by 2038 – 12 years ahead of UK national targets.

The Greater Manchester Economic Vision outlined a blueprint for a "fairer, greener, growing" economy achieved through tackling inequalities and innovation.

With specialist expertise in advanced materials and a commitment to green growth, Greater Manchester now has an opportunity to influence global innovation as we move towards that low carbon future.

This opportunity goes beyond shaping the future built environment. Identifying sustainable energy sources, solving transport challenges and answering fundamental questions about how we will provide a growing global population with food and water are vital.

Innovation to create new products and services built around advanced materials will also create opportunities for thousands of new skilled jobs in industries which are only now being imagined.

At the heart of the Greater Manchester Economic Vision, Innovation Greater Manchester is a blueprint for a partnership with Government to stimulate R&D investment and level up the North, generating a £7 billion economic benefit and creating up to 100,000 jobs across the city-region.

This document captures some of the insight and intelligence provided by key thinkers and is intended to stimulate further conversation about Greater Manchester's role in influencing the future for global cities.

Greater Manchester is already a fantastic place to live, work, invest and study. Join us in imagining an even better future.

What will Greater Manchester be like in 2038?

PROFESSOR DAME NANCY ROTHWELL

President and Vice-Chancellor of The University of Manchester, and a member of the Greater Manchester Local Enterprise Partnership board

In 2038, I expect to see a green city, transformed through advanced materials, but most importantly, a magnet that attracts the greatest talent and is driven by innovation. If we look back at our history, we're a city and a region that's been built on innovation, on revolution, on doing things differently.

That will depend on skilled people, and that means skilled people across the whole region, not just in the city centre, but in the towns around.

It means both skills for the people who are born and live here, but also attracting skilled people - to be an international magnet for the smartest people to come, where ideas can really flourish.

Driving a green agenda is important both in terms of making the place better to live but also from our surroundings and our leisure time, as well as our work.

Manchester has commited to 2038 as the date for achieving carbon neutrality whereas most others are aiming for 2050. Manchester just likes to be a bit more ambitious than others.

There is a sense of 'can we do it'? And my answer is, 'better we aim higher and miss slightly than be unambitious'.

I think having that commitment is so important to the people who live here and the people who come to study and work here.

We have 40,000 students at The University of Manchester. Why do they come to Manchester? Well, obviously there are lots of reasons, but I think the commitment to the environment is a really important one.

What we need to be better at, and I count 'we' as all universities, is joining up with other sectors to make sure our discoveries get translated into real life applications that are of benefit to people.

Discovering something is brilliant; it's the beginning and it's how you transform things. But then you need to turn it into something that's useful, that can be applied.

One example might be a plane that has a net zero carbon footprint. It is entirely possible to have one with very light components, with a battery that captures wind power or solar power, that's perhaps catapulted. These things are not dreams anymore - they are within the realms of possibility.

But it's going to take universities working with start-up companies, large companies, small companies, British companies, global companies. And I think Manchester has a shot at doing that.

If I can I'll cite Andre Geim, who, of course, is often called the 'father of graphene'.

Andre commented that humans are the most inventive and creative when under pressure.

He said that what we need is a meteor heading towards Earth that will cause all the creative minds to come together and come up with solutions. Now we haven't had a meteor, but we have had a pandemic.

There's some truth in that, when under pressure, we are incredibly creative.

And I think that as we come out of this pandemic, despite all the difficulties and challenges, that we will all start to think a little bit differently about the future.

TIM NEWNS

Chief Executive of MIDAS, the inward investment agency for Greater Manchester

What will the world be like in 2038? I think that Greater Manchester will be a global centre for innovation, and Advanced Materials is at the absolute heart of that.

The city-region is developing a programme called Innovation Greater Manchester, which will underpin much of our economic growth strategy, focussed on translating innovation from our current centres of excellence such as universities and institutions, in to new innovation districts in our town centres and outlying business and industrial parks such as Gateway North in Bury and Rochdale.

As we progress our journey to net zero in 2038, I would like to think there'll be a little bit of Greater Manchester in every city-region around the world, taking some of the technology and learnings from our own ambitious journey in order to achieve their own net zero status.

But this requires global collaboration. The science and forecasts behind our own plans for net zero transition tell us that we need significant innovation in order to reach our target. If we were to implement the technologies available to us now, then we wouldn't hit our 2038 net zero target, therefore we need to overcome the 'innovation gap'.

So the call is out to companies from around the world: if you want to innovate in new low carbon products or services, and you want to do it in a place where you can demonstrate capability at scale, and where there is the supportive ecosystem to help you succeed, then Greater Manchester is the place.

And to make the journey from idea, through innovation to demonstration and commercialisation smoother, we're establishing the Energy Innovation Agency – a single point of entry to Greater Manchester – a partnership between Local Government, Private Businesses, Universities and the Energy Suppliers – so it brings together all the parties companies need to work with to succeed.

Although the pandemic has brought huge challenges, it's also highlighted just how quickly transformation can take place. We've seen incredible digital transformation take place in industries across the board with commentators suggesting that we have experienced 10 years of progress in 12 months.

It's proven the speed at which companies can pivot and adapt to new environments and consumer behaviour through digital transformation but also how quickly changes of behaviour can affect and impact on the environment.

The change of behaviour around transport and decrease in use of private transport, for example, saw a huge increase in air quality in an incredibly short space of time, which was nothing short of phenomenal. It just shows that if we can change that behaviour or develop different ways of operating and living over the long-term, rather than a temporary change, through greater trial and adoption of innovation, we can have a very immediate and significant impact on the local environment within our places.

JAMES BAKER

Chief Executive Officer of Graphene@Manchester

Advanced materials can transform the cities we live in. Imagine roads that last longer, with fewer potholes, and that are also connected with integrated sensors, that can tell you how much traffic is going along the road, or superchargers built into them so you can charge your car whilst you're going along the road.

Could we also potentially take plastic to create graphene in the first place? Which we could then add to our roads to make this circular and integrated economy and city.

The whole science of two-dimensional materials has opened new possibilities for new batteries, for new forms of concrete, for lighter aircraft, for biomedical applications, for food production.

Imagine a world in the future where we can design functionality into a material; layer by layer of two-dimensional material to build multi-functionality into a product or application.

Achieving this in the next two decades will take an innovative approach.

Traditionally, new materials have taken many years, if not tens of years, to go from discovery through to products and applications.

And what we're trying to do here in Manchester is not just the science. What we're now trying to do is to really accelerate and create the supply chain of small businesses, of large businesses, across Greater Manchester.

Some of those are established businesses. We're also working with small to medium sized enterprises, including start-ups.

And we're not just trying to create start-ups, we're trying to create scale ups.

Advanced materials really will open possibilities and help us towards that target of carbon neutrality by 2038, If we can build a supply chain and accelerate those products and applications.

DR BEENISH SIDDIQUE

Founder of AEH Innovative Hydrogel Ltd

My vision for Manchester by 2038 is it will be not only a greener city, but also known for helping indoor and outdoor growers across the world to produce food in sustainable and cost-effective ways. The way we will achieve this is by Manchester providing a sustainable products to these indoor and outdoor growers.

See full AEH Innovative Hydrogel Ltd case study - page 10.

Greater Manchester in 2038, as enabled by advanced materials

ENERGY AND TRANSPORT

FAST FACTS: Greenhouse gas emissions from the transport sector have more than doubled since 1970, with around 80% of this increase coming from road vehicles.

Currently, the transport sector is almost completely dependent on fossil fuels. It contributes approximately one quarter of all energy-related carbon dioxide emissions. Source

Switching to an electric car can help improve air quality and boost green jobs — if the electricity is powered by renewables. By achieving a 60% share of battery-electric and plug-in hybrid vehicles on the road, more than 60 billion tons of CO_2 could be saved between now and 2050.

A radically different approach to local, national and international travel are key to Greater Manchester's ambitions to achieve net carbon neutrality by 2038 and many of the solutions are already being engineered within the city region.

New batteries, supercapacitors and lightweighted composites will increase the scale and range of electrified transport. Similarly, lightweighting of vehicle components is already supporting the move to more energy efficient means of transport.

Used as an additive, graphene and other 2D materials can improve multiple elements of vehicles. When combined with rubber, it could potentially give a tyre both durability and grip. This could mean no more trade-offs between longevity and traction. One company, SpaceBlue - a spin-out from The Univerity of Manchester - even looks to recycle tyres after they have reached the end of their life, by converting them into hardwearing floor mats, which have been enhanced with tiny amounts of graphene.

The 2D material can also be used to form compounds with other elements of a car to make it lighter. Briggs Automotive Company, a partner in Manchester's Graphene Engineering Innovation Centre (GEIC - the world-class advanced materials innovation accelerator), built the Mono, 'the first production car in the world to fully incorporate the use of graphene-enhanced carbon fibre in every body panel'.

The material improved the structural properties of the fibre to make the supercar's panels stronger and lighter, while also significantly improving the car's mechanical and thermal performance.

Even outside of the car, the material could help make a difference to road users. Responsible for the UK's motorways and major roads, Highways England is working with the GEIC to explore the addition of graphene to bitumen in road surfaces. The aim is to make roads not only hard wearing but flexible when it comes to extreme weather. If surfaces are able to expand and contract to adapt to hot and cold conditions, the likelihood of potholes would decrease, alongside the potential for damage to vehicles.

But how does graphene play into current automotive trends? As the industry experiences an electrified undercurrent, pulling vehicle development towards e-mobility, a material which decreases weight could be essential.

Light-weighting is a key challenge with electric cars as they get progressively heavier. This process can help shed weight from all over the car, including the interior, with plastics and fabrics being made thinner and lighter. The less an electric vehicle (EV) weighs, the less work the motors will have to do and the more efficient the car will become. Graphene can also be added to battery elements, such as the casing, to make it lighter and tougher, as well as more thermally conductive.

Ultracapacitor specialist Skeleton Technologies, also recently partnered with the Karlsruhe Institute of Technology, to complete the development of a graphene 'SuperBattery.' With a 15-second charge time, the unit would also be capable of charging cycles counted in hundreds of thousands. The company claims this makes it 'a perfect solution for the three main issues affecting electric vehicles: slow charging times, battery degradation, and range anxiety.'

It is possible that a car's door or floor panels could one day store energy, although a challenge would be dealing with a potential collision, and what would happen if a panel became damaged.

Going forward, graphene could be crucial to the development of a new type of supercapacitor. This could allow vehicles to be equipped with a relatively smaller battery for range, which is then supplemented with a supercapacitor used for acceleration. For taxis and buses, which do a lot of stop-start driving, this split would be ideal as they would receive better range and performance from a supercapacitor that can recharge through braking.

The University of Salford is playing a leading role in developing technologies with industry that will support the quest for net carbon neutrality, including plans for the Salford Innovation Triangle – an innovation cluster demonstrating the potential for Innovation Greater Manchester.

The Energy House Laboratories are helping businesses understand how effective their products and services are in lowering consumers' carbon footprint and reducing energy bills. The new North England Robotics Innovation Centre will be a beacon for the University of Salford's robotics and automation specialisms, supporting innovation that will be vital in achieving net carbon neutrality and improved health outcomes.

Other potential alternative energy sources which are being explored in Greater Manchester include hydrogen, while advanced materials which are electrically conductive offer the potential to charge and power vehicles as they pass along the city streets.

Based in the GEIC, collaborative research by Australia's First Graphene and the Manchester Fuel Cell Innovation Centre at Manchester Metropolitan University has proven that metal oxide coated graphene can be an effective catalyst for next-generation hydrogen fuel cells. The skies above Greater Manchester in 2038 could be filled with more efficient flying vehicles too. Graphene enhanced composites are stronger for the same mass of material.

This light-weighting means less material can be used and the aircraft range increased without compromising the structural integrity.

A graphene skinned aircraft named 'Juno', was unveiled in 2016 at the Farnborough International Airshow. The future for travel and transport is already being imagined.

HEALTHCARE REIMAGINED

Greater Manchester is leading research that will reimagine the delivery of healthcare, enabled by new technological advances utilising advanced materials including graphene.

By 2038 it is likely that biosensors, tissue regeneration and new treatments for cancer and neurological disorders will have helped to revolutionise medicine.

In 2021, a consortium led by The University of Manchester launched a new multi-million-pound research and innovation institute that will build on Manchester's academic strengths in digital health and advanced materials to discover innovative health and care solutions. The Christabel Pankhurst Institute for Health Technology and Innovation is part of an ambitious plan set out in the Greater Manchester (GM) Local Industrial Strategy to boost the city-region's provision in this area.

It is being launched following a £5 million Local Growth Fund award from Greater Manchester Local Enterprise Partnership (GM LEP) and Greater Manchester Combined Authority (GMCA). The consortium is made up of the University, Manchester Science Partnerships (MSP), The University of Manchester NHS Foundation Trust (MFT), and Health Innovation Manchester (HInM).

The initiative will build on investments from the University, Manchester Science Partnership, the Engineering and Physical Sciences Research Council (EPSRC), and The Alan Turing Institute, creating a total budget of more than £25 million.

The aim of the collaboration is to capitalise on the University's strengths in digital health and advanced materials and develop innovative products and services for the health care sector. In turn this will drive business growth and employment as well as boost the long-term health benefits of the city-region.

Live examples of research utilising advanced materials include developing frameworks for the growth of replacement body parts and structures.

A collaboration between two Barcelona institutions and the Nanomedicine Lab at The University of Manchester - aimed at treating brain disorders such as epilepsy and Parkinson's Disease - has secured £12 million in funding, one of the largest investments to date in the European medical nanotechnology industry.

INBRAIN Neuroelectronics is a spin-out company from the Catalan Institute of Nanoscience and Nanotechnology (ICN2) and the Catalan Institution for Research and Advanced Studies (ICREA), partners of - and supported by - the European Commission's Graphene Flagship programme.

INBRAIN's work involves the decoding of brain signals by implanting innovative, flexible nanoscale graphene electrodes, developed in conjunction with researchers at Manchester's Nanomedicine Lab and the National Graphene Institute (NGI).

These signals may then be used to produce a therapeutic, personalised response for patients with epilepsy, Parkinson's and other neurological disorders.

Manchester-based ProMake discovered that graphene is an effective medical solution for reconstructive surgery. In leading their business from Manchester, they have been able to turn graphene into a functional form for their pioneering work.

See full ProMake case study on page 13.

At the University of Salford, The Health Sciences Research Centre (HSRC) is a multidisciplinary group, focused on improving health outcomes through innovation, research and partnerships. The centre has a strong focus on technological advancement, often working closely with NHS and industry partners to develop and test new treatments and to create innovative healthcare products and services.

EMPLOYMENT AND SKILLS

Achieving net carbon neutrality by 2038 will require new jobs and skills in industries that are only now being imagined.

Some new roles will be created in retrofitting public and private sector buildings to increase energy efficiency and reduce carbon production.

The Greater Manchester Retrofitting Task Force, chaired by Mayor of Greater Manchester Andy Burnham, is setting out a detailed action plan to deliver low-carbon retrofitting across the city-region.

Its aim will be to outline how home and building improvements can take place on a mass scale, while identifying opportunities to boost new skills, create good jobs, and drive investment in low-carbon industries.

All of these goals are designed to support a sustainable economic recovery from the pandemic and meet Greater Manchester's target of achieving carbon neutrality by 2038.

The Task Force will include representatives from local and national government, social landlords, building authorities, colleges, energy suppliers, industry experts and investors.

The single biggest source of carbon emissions in Greater Manchester is heating, totalling 2.8 megatons of carbon dioxide and other greenhouse gases every year. While a variety of renewable heating systems exist, the low efficiency of many houses and commercial buildings has meant they are often unaffordable for residents.

An estimated 60,000 buildings would need to be upgraded in Greater Manchester every year if the city-region is to achieve its target of becoming net-zero carbon by 2038.

Retrofitting just 20 per cent of Greater Manchester's 1.2m homes would create a market size in the region of £3-£5.4bn, generating local and inward investment opportunities.

WATER

FAST FACTS: Water is a precious resource: Less than 3% of the world's water is fresh (drinkable), of which 2.5% is frozen in Antarctica, the Arctic and glaciers. And humans are misusing and polluting water faster than nature can recycle and purify water in rivers and lakes. Source

Severe water scarcity affects about four billion people, or nearly two thirds of the world population, at least one month each year.

Agriculture is by far the largest water consumer, accounting for 69% of annual water withdrawals globally. According to the United Nations, water use has been growing globally at more than twice the rate of population increase in the last century, and an increasing number of regions are reaching the limit at which water services can be sustainably delivered, especially in arid regions.

Climate change has brought additional concerns about the potential impact of severe flooding on modern cities' water supplies.

More than 2 billion people live in countries experiencing high water stress and 1.42 billion people – including 450 million children – live in areas of high or extremely high water vulnerability (UNICEF, 2021).

A revolution in water filtration developed at The University of Manchester could provide a much-needed solution, with ready access to affordable clean water finally a real possibility for the world.

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 they were immersed in water, which meant smaller salts could flow through the expanded membrane along with the water.

Manchester researchers in the 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 common salts to be sieved out of salty water – making it safe to drink.

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.

Greater Manchester is renowned as a city-region with plenty of fresh water, but could its work with advanced materials one day provide provide a cheap, clean and efficient addition to the global water cycle - making sea water drinkable?

BUILT ENVIRONMENT AND SMART CITIES

FAST FACTS: According to Chatham House, the global production of cement – the 'glue' that holds concrete together – accounts for a staggering 8% of the world's CO_2 production. Source

Innovation in advanced materials offers the disruptive potential to transform the way we build our future cities – and make them greener and smarter.

Construction is associated with the so-called Foundation Industries – which span the cement, glass, ceramics, metals, paper and bulk chemicals sectors – which in total produce 28 million tonnes of materials per year and account for up to 10 per cent of the UK's total CO_2 emissions.

If we consider the Climate Change Act (2008) and the UK Government's call to reduce carbon emissions to 80 per cent below the levels that were seen in 1990 by 2050 then clearly this sector is an obvious focus for a new approach. Innovation in new materials will greatly help city planners, developers and builders to construct a zero-carbon world from the foundations up.

By 2038, advanced materials could have helped to transform the skyline of Greater Manchester still further, while making construction practices more sustainable.

Studies have suggested that adding just 0.03% graphene powder increased the strength of concrete by a conservative average of 25%.

"What's exciting on the sustainability agenda is this circular economy," says James Baker. "So, for example, our construction in the future, we might add graphene into concrete.

"That would enable us to use equivalent performance of the concrete for less material.

"So by adding less than 0.1 percent graphene into concrete, you could potentially use 30 to 50% less concrete. That's not only a lower material footprint, it's also lower CO_2 footprint from the production of concrete and it's also a lower

footprint in terms of cement mixers and lorries in a city centre where those buildings are taking place."

Advanced materials could also support the smart cities of the future – allowing technologies that could better integrate and manage our utility and energy systems to be embedded within the fabric of the city.

As an example, the Graphene Engineering Innovation Centre is currently working on a number of projects with Highways England, the Government company responsible for much of the nation's road network, and Arcadis, a leading global design and consultancy firm for natural and built assets.

An example might be when electric circuitry needs to be applied to the network, usually underground, and the feasibility of developing technology that could be embedded within the road structure itself and laid at the same time as the highway, for example, as an integral part of the structure.

But what if we could have this multifunctional capability used across all the infrastructure and buildings that make up a town or city? It would transform connectivity and make the very fabric of our built environments responsive and intuitive to our daily needs.

So, we can start to imagine charging points that are embedded across our road network – and every time an electric vehicle comes to a stop at traffic lights or rests in a parking space it can be charged in situ. If the vehicles of the future were using hybrid energy storage – i.e. a battery powertrain with a supercapacitor unit – then they could be rapidly charged as their drivers happily go about town. And those batteries and supercapacitors would, of course, feature new materials that enable them to operate far more effectively compared to the energy storage devices we are forced to use today.

Similar advances could be made with sensor technology, which will be critical if cities are to achieve the required connectivity levels needed to become smarter, more efficient and ultimately greener. Graphene and sensors are a natural combination because graphene's large surface-to-volume ratio, unique optical properties, excellent electrical conductivity and mobility and high thermal conductivity can all greatly enhance the functionality of a range of sensors.

Graphene and Greater Manchester's strengths in composites and alloys gives rise to all manner of multi-functional materials – those graphene enhanced building materials or car parts could double up as batteries to store the energy – with a super-thin coating of solar cells generating renewable electricity.

The potential opportunities to work internationally are being realised too. A new business established in Manchester by Gerdau - the steelmaking giant based in Brazil - Gerdau Graphene will offer pioneering technology to the construction, industrial and automotive lubricants, rubber, thermoplastics, coatings and sensors industries in Brazil and in countries across North America.

In the UK, Concretene - a concrete mixture fortified with graphene - is already being trialled by National Engineering Group.

FEEDING THE PLANET VIA VERTICAL FARMS

FAST FACTS: The world will need to produce about 50% more food by 2050 to feed the growing world population, assuming no changes occur in food loss and waste. Source

With additional challenges from climate change, water stresses, energy insecurity and dietary shifts, global agricultural and food systems will have to change substantially to meet the challenge of feeding the world.

One potential solution which could become visible in cities lies in vertical farming - the practice of growing crops in vertically stacked layers.

It often incorporates controlled-environment agriculture, which aims to optimise plant growth, and soilless farming techniques such as hydroponics, aquaponics, and aeroponics.

While vertical farming aims to minimise water use and maximise productivity by growing crops hydroponically in small amounts of nutrient-rich water stacked in a climate-controlled building, high energy and labour costs mean it is not currently considered a sustainable long-term solution.

The University of Manchester start-up AEH Innovative Hydrogel Ltd has secured £1 million of Government funding through Innovate UK for the two-year Graphene Engineering Innovation Centre project to develop a unique, virtually maintenance-free 'vertical farming' system.

By using minute electronic sensors to monitor a plant's nutritional requirements, then automatically release nutrients to its root system, GelPonic has the potential to substantially reduce production costs and labour requirements.

GelPonic relies on a growth substrate – the surface or material from which an organism feeds – for indoor fruit-and-veg that improves performance in numerous ways. The hydrogel growth medium conserves water and filters out pathogens to protect plants from disease, while a graphene sensor allows remote monitoring, reducing labour costs.

See full AEH Innovative Hydrogel Ltd case study below.

STRATEGY FOR ADVANCED MATERIALS AND MANUFACTURING

Greater Manchester is at the heart of the UK's largest manufacturing and advanced materials cluster, and the city-region remains a hotbed of innovation – pioneering in world changing new materials like graphene and recognised as high potential investment opportunities by the Department for International Trade for light-weighting and sustainable and smart packaging.

Located at the centre of the largest aerospace cluster in Europe and the second largest automotive cluster in the UK along with specialisms in energy engineering and over 700 food and drink businesses, Greater Manchester has a robust and diverse ecosystem of thousands of supply chain companies feeding in components, raw materials, machine tools, semi-conductors and much more.

As we transition to the low carbon vehicles of the future, there are innovation opportunities for lightweight materials for structures and interiors, and powertrain technologies including batteries, supercapacitors and power electronics, along with opportunities in other sectors like sustainable packaging, medical devices, clean growth and digital.

All of these marry up with our Local Industrial Strategy – written in conjunction with national Government – which focuses on Greater Manchester's globally significant strengths in advanced materials and manufacturing, clean growth, health innovation and the city-region's commitment to carbon neutrality by 2038 – twelve years ahead of the rest of the UK.

Greater Manchester's Graphene, Advanced Materials & Manufacturing Alliance – GAMMA - is leading the delivery of the city-region's industrial strategy for advanced materials and manufacturing. The alliance is a strategic implementation arm of Innovation Greater Manchester, working with partners to drive industry demand for the city-region's nationally and internationally significant R&D assets, as well as helping to develop the conditions for securing future investments in the asset base and attract investment from industry.

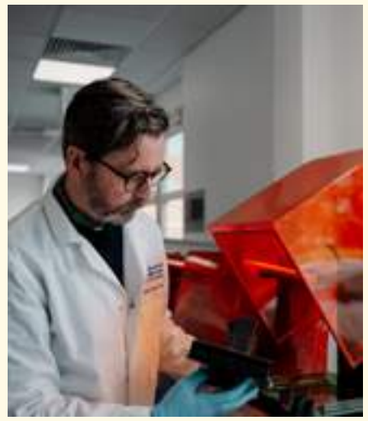
Chaired by Juergen Maier, former Chief Executive of Siemens UK and Vice-Chair of the Northern Powerhouse Partnership, GAMMA includes representatives from industry, academia and government working together to create the conditions to accelerate innovation across GM's advanced manufacturing base, to improve productivity and growth across the sector.

Recent research by GAMMA has provided a detailed understanding of Greater Manchester's advanced manufacturing and materials base including significant clusters of activity in coatings, technical textiles, graphene & nanomaterials, advanced machinery, and digital manufacturing. GAMMA working with industry champions to develop innovation networks, which will support these clusters with commercialisation and value creation.

GAMMA has a key role the development and application of advanced materials to achieve our ambitions in areas such as carbon neutrality, health and digitalisation. A strategic priority for GAMMA is improving productivity through digitalisation of manufacturing.

The Made Smarter programme in the North West is being led by Greater Manchester and is paving the way for the UK to be the global leader in the creation, adoption and exportation of advanced digital technologies. This Department for Business, Energy & Industrial Strategy sponsored programme has been hugely successful in enabling companies to get to grips with the technologies, expertise and skills needed to embed new tools and ways of working into their manufacturing processes. Going forward the programme will continue to emphasise the importance of the link between investments in industrial digital technologies and decarbonisation.

A key mechanism for delivering on the Industrial Strategy – and ensuring the whole of Greater



Manchester benefits – is Innovation Greater Manchester, a mission to drive economic growth across Greater Manchester and beyond to deliver increased prosperity, and longer and healthier lives for all Greater Manchester's citizens.

It's about taking the world leading research and ideas developed in the universities and facilitating the flow of this knowledge to local areas, where businesses can use it to grow sustainably, and targeted investment businesses at Innovation Zones across the wider city-region – delivering high value jobs throughout all ten Local Authorities of Greater Manchester.

Advanced materials are the building blocks for all products, and Greater Manchester is the UK's hub for advanced materials research and commercialisation – with the Henry Royce Institute coordinating national materials innovation and offering £330 million of advanced materials / manufacturing capability to help small and larger businesses innovate and accelerate the adoption of new materials.

Then there's The University of Manchester, whose Department of Materials is the largest in Europe, and Manchester Metropolitan University's surface engineering and 3D printing specialisms, and the University of Bolton's leading fire retardancy work. Overall the city region has invested over £500 million in research centres of excellence. Some of Greater Manchester's world leading specialisms include; light alloys, composites, technical textiles, surfaces & coatings, and materials for demanding environments.

Case Study 1 – AEH Innovative Hydrogel Ltd

An intelligent soil alternative that can sense and respond to a plant's nutritional needs is being developed by scientists using graphene, the 2D super material first isolated at The University of Manchester.

GelPonic could help address heightened global food security concerns following the coronavirus pandemic, drastically reducing the amount of energy and human interaction required to produce food using 'vertical farming' techniques.

While vertical farming aims to minimise water use and maximise productivity by growing crops hydroponically in small amounts of nutrient-rich water stacked in a climate-controlled building, high energy and labour costs mean it is not currently considered a sustainable long-term solution.

The University of Manchester start-up AEH Innovative Hydrogel Ltd has secured £1 million of Government funding through Innovate UK for the two-year Graphene Engineering Innovation Centre project to develop a unique, virtually maintenance-free 'vertical farming' system.

By using minute electronic sensors to monitor a plant's nutritional requirements, then automatically release nutrients to its root system, GelPonic has the potential to substantially reduce production costs and labour requirements.

GelPonic relies on a growth substrate – the surface or material from which an organism feeds – for indoor fruit-and-veg that improves performance in numerous ways. The hydrogel growth medium conserves water and filters out pathogens to protect plants from disease, while a graphene sensor allows remote monitoring, reducing labour costs.

Moreover, the production of the growth medium outputs significantly less CO_2 compared to traditional solutions and can also be used in areas with drought conditions and infertile soil.

Led by Dr Beenish Siddique, AEH Innovative Hydrogel has been supported by the European Research Development Fund's Bridging the Gap programme and was a 2019 prize-winner in the prestigious Eli and Britt Harari Graphene Enterprise Award, run by the University.

Bridging the Gap was developed to proactively engage with Greater Manchester-based SMEs and new ventures to allow them to overcome challenges, and explore and apply graphene and other advanced materials in a wide range of applications and markets.

The extra £1 million in funding announced by the UK Government is part of a broader £24 million spend to assist UK farming through pioneering technology.

"One of the biggest hurdles in controlled environment agriculture is operational cost, which makes it a low-profit-margin business," Dr Siddique explained. "The fact this system is almost maintenance-free could make a big difference to whether farms can be successful or not.

"We believe there is an opportunity here to change the future of farming not just here in the UK but around the world.

"Globally, around 70% of the fresh water available to humans is used for agriculture and 60% of that is wasted; agriculture also contributes around 20% of global greenhouse-gas emissions. Our system helps control that waste and those emissions, shortens germination times and could enable an increase of 25% in crop yields."

GelPonic is among the latest innovations to emerge from the Graphene Engineering Innovation Centre (GEIC) in Manchester. The GEIC is part of a £100 million investment in infrastructure to support the development of applications made possible by the isolation of graphene by scientists at The University of Manchester in 2004.

Graphene technology is already supporting research into new methods of water filtration, advances in healthcare, aerospace and automotive super light-weighting, and battery power.

Supported with £5 million of funding from Greater Manchester Local Enterprise Partnership and Greater Manchester Combined Authority, the £60 million GEIC specialises in the rapid development and scale up of graphene and other 2D materials applications.

The GEIC sits alongside the £61 million National Graphene Institute and both are part of the vision to create a Graphene City in Manchester, with scientific research conducted in partnership with industry to deliver prototypes then production. The £235m Henry Royce Institute, which has its headquarters in Manchester, will further boost the city-region's capabilities as the UK national institute for advanced materials research and innovation.

One of Dr Siddique's colleagues at the GEIC is commercialisation leader Ray Gibbs, whose role is to help to bring innovative ideas to fruition through launching start-up and early-stage companies such as AEH. He believes the pandemic, in tandem with net-zero targets, has sharpened the Government's focus on investment in innovation.

He said: "The COVID pandemic has demonstrated the fragility of the UK supply chains, none more so than food supply. Indoor farming allows us to grow food in the UK that would normally come from another part of the world. That contributes to self-sustainability, reduces food miles and means we're not so reliant on international markets for our food."

AEH is developing its system alongside project partners and subcontractors including Crop Health and Protection (CHAP), Labman Automation, Grobotic Systems and Stockbridge Technology Centre (STC).

CHAP's Innovation Network Lead Dr Harry Langford said: "There is a significant market demand for more sustainable hydroponic substrates. This project is an exciting opportunity to optimise and scale-up a novel hydrogel product and demonstrate this product directly to the end-user, within a highly innovative automated production system."

Case Study 2 – ProMake

How 3D printed body parts saved a man's arm and inspired an incredible business idea

Entrepreneur Jason Laing and his team are building a medical 3D printing business based on his personal success in overcoming horrific injuries. Founded in South Africa, it made sense for ProMake international to capitalise on Greater Manchester's strengths in health innovation and advanced materials along with the collaborative mind set Manchester has.

Jason Laing knows better than most the benefits of advances in materials science and healthcare innovation. Having suffered horrific life-changing injuries in a 2015 cycling accident, he became the subject of a personal experiment in the use of 3D printing for medical purposes.

Using 3D printing technology, Jason and his team were able to design, manufacture and repair parts of his body, saving his arm from the risk of amputation.

3D printing and virtual reality also helped with his occupational therapy and mental rehabilitation where he re-learned how to walk, talk, read and write all over again due to the head injury he also suffered.

Jason's journey has been documented through a TED Talk he did not long after his accident after learning to talk properly and memorising his speech.

That experience underpins the work of 3D printing healthcare manufacturing business, ProMake International Ltd, which established headquarters in Manchester in 2019 and is now being rebranded as ProMake LTD.

Through its advanced and unique product design, expertise in composite materials and progressive 3D printing technologies, the company assists inventors in developing and launching innovative products into global markets, particularly in the life science and aerospace industries.

Following Jason's successful recovery, ProMake's team have fully transitioned their expertise into the medical field by conducting facial reconstruction surgery using 3D printing.

In 2019, they completed the world's first inner ear transplant surgery to improve hearing by harmonically tuning the 3D printed implant with a patient's harmonics.

Since then, the ProMake team has also recently discovered that graphene – a 2D material first isolated in Manchester – is proving to be an even better medical solution for reconstructive surgery.

In leading their business from Manchester, they have been able to turn graphene into a functional form for their pioneering work by developing a unique way of 3D printing graphene polymers.

To support this application, Promake has been working - under agreements - with experts from Haydale and the University of Manchester's Graphene Engineering Innovation Centre (GEIC), which was funded in part by the Greater Manchester Local Enterprise Partnership.

COO and Co-Founder of ProMake Ltd, Jason says that his journey into 3D printing began with his experience as a jeweller, which included research into metallurgy, composite technology and computer-aided design.

That led him to work alongside his business partner Gavin Leggott along with maxillofacial surgeons, orthopaedics and veterinary care, merging that experience to develop innovative new healthcare solutions.

He discovered first-hand how they could work when a ProAm cycling accident left him with multiple injuries, including broken bones, dislocations, collapsed lungs and open fractures where bones broke through his skin.

Faced with the prospect of having an arm amputated, Jason says he worked with the surgical team to find ways that 3D printing might help.

He said: "We really took it to a new level because I also then gave full permission to take my life in my own hands essentially, and take the risk so that we can pioneer new developments that would then be used for medical research further on. So that's where 3D printing really came to play for me.

"3D printing itself excites me because of the possibilities that it can bring about, and what it has done for me already.

"The technology itself has not only given me a career but actually gave me my life back. And it helped me rebuild my own body. So now we are going to be able to take that technology, the research that we did on me as a patient and as a technician, and now be able to give that information back."

Jason says he is excited about the impact this work can deliver on a social level as well as a corporate level, meaning that patients will benefit too. The move to Manchester means access to research at the cutting edge of advanced materials in a city region renowned for health innovation and where people work well together.

He adds: "3D printing with graphene is a major game-changer. The 3D printing technology has not only rebuilt my own body but now as we also fuse this technology with graphene, we continue to unravel endless possibilities for medical innovation. We have recently introduced the world's first accessible commercial graphene 3D printing portal.

"Collaborating, experimenting and sharing ideas for greater humanity is at the heart of ProMake's ethos and that's why Manchester – alongside it being the home of graphene – is the perfect fit for our innovation mindset. "We want to sit alongside MedTech professionals locally and in all corners of the globe, and by working closely with unique scientific talent at the GEIC and along with our industrial partners such as Haydale within an ecosystem renowned for its long history of international engagement, we feel this is easily within our reach."

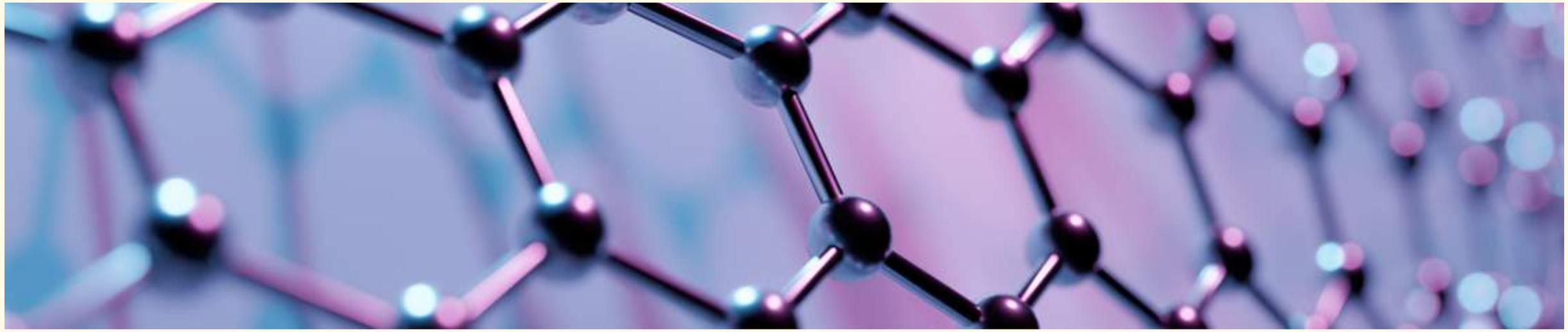
Working with the GEIC - via Bridging the Gap, backed by the European Regional Development Fund (ERDF) - has elevated ProMake's journey of discovery and they are also now realising the amazing benefits of 3D printing with graphene for external prostheses.

Graphene provides additional strength, superior thermal properties and enhances biocompatibility when added to biopolymers.

It brings other benefits for external prostheses: graphene is cooler, stronger, and enables sensory prosthetic mirroring for symmetry in motion and power release.

Looking ahead, the company has already begun to unearth the possibilities of 4D printing, which would enable them to programme materials to function in a certain way before they print e.g. anti-microbial, sensory, electric and hydro.

The Covid-19 pandemic has demonstrated how rapidly we can evolve under pressure and ProMake is a great example of a business that is grasping this opportunity to challenge the status quo and move with pace to deliver real change for the benefit of all.



Innovation Greater Manchester

Innovation Greater Manchester is a blueprint for a partnership with Government to stimulate R&D investment and level up the North, generating a £7 billion economic benefit and creating up to 100,000 jobs across the city-region.

Led by business, scientific, academic and local government leaders, Innovation Greater Manchester provides a blueprint for translating the world-leading research being done across the city-region into sustainable and growing businesses, and forms a key part of the Economic Vision – the plan to deliver a fairer, greener and more productive Greater Manchester economy beyond the pandemic.

Among its proposals are the creation of a single umbrella group bringing together local and national partners from the public and private sectors that have a stake in Greater Manchester's innovation ecosystem, and a six-year, multi-million pound Innovation Transformation Fund.

In advanced materials, the city-region is ready to build on the success and expertise of world-class facilities like the Graphene Engineering Innovation Centre, the National Graphene Institute and the Henry Royce Institute.

Collaboration supported by the Innovation Greater Manchester partnership would help commercialise the pioneering work done within these facilities, turning research into viable businesses that create high quality jobs and attract investment.

This would support Government ambitions for Global Britain by offering new opportunities for international trade while addressing challenges like climate change and health inequalities.

For researchers working on developing products like graphene-infused concrete and graphene-oxide membranes for filtering water, this could mean additional support for exploring the commercial applications of their products.

The blueprint also envisages a network of Innovation Zones that link labs to industry in city centres, town centres and advanced manufacturing parks across Greater Manchester.

Innovation Zones would ensure the growth fuelled by innovation brings economic and social benefits to every district, resulting in updated skills, good employment and places where people want to invest.

By bringing together local and national agencies to support an innovation 'supercluster' spanning the city-region, Innovation Greater Manchester could attract significant inward investment, close the R&D expenditure gap in Greater Manchester and the North, and advance the levelling up agenda through science and innovation.

Building Graphene City

Graphene City is an ambitious vision from The University of Manchester, that aims to create a thriving knowledge-based economy around this revolutionary discovery and associated research in advanced materials.

Graphene's vast potential will be fully realised by creating a critical mass of scientists, manufacturers, engineers, innovators and industrialists in Greater Manchester, the home of graphene. This innovation ecosystem has at its core the research-focused National Graphene Institute and the more commercially-facing Graphene Engineering Innovation Centre.

James Baker, CEO of Graphene@Manchester, said: "We are part of a Manchester model of innovation that is collaborative, meets global challenges and is inclusive – the graphene and 2D materials accelerator based at the University is an exemplar of how Greater Manchester offers a world-class model of translational research that will meet economic, environmental and societal priorities at a city-region, national and international level.

"Ultimately Greater Manchester is being recognised as an R&D partner of choice at a global level."

The National Graphene Institute (NGI)

£61 million has been invested into the NGI at the University of Manchester, which is focused on research into the applications of graphene. More than 90 companies are already working with over 350+ researchers, engineers and applications specialists shaping the material's future development.

The Henry Royce Institute

The Royce is the UK's national institute for matrials science research and innovation. It is the hub of a network of partners including the universities of Oxford, Cambridge, Imperial College London, Sheffield and Leeds. Research specialisms include 2D materials, advanced metals processing and atoms to devices. The Royce gives businesses access to state-of-the-art equipment and facilities and is continuing to grow available assets with its flagship building opening in 2021.

Graphene Engineering Innovation Centre (GEIC)

Opened in 2018 with funding from GM LEP and Masdar the GEIC is critical for the development of commercial applications for graphene and other 2D materials. The facility focuses on pilot production and commercialisation within industry. Companies take space in the GEIC allowing, for example, for the use of mixing labs, extruders and an autoclave to pilot produce composite components. Labs for battery production, printed electronics, membranes and sensors are also on site.

Advanced Materials & Surface Engineering Research Centre

Manchester Metropolitan University's Advanced Materials & Surface Engineering Research Centre develops materials for hydrogen fuel cells, batteries, sensors, electrolysers, amongst others, which can be screen printed or 3D printed. Specialisms include new catalyst materials for the low temperature removal of methane from diesel truck exhausts and photocatalyst materials; water treatment and disinfection or clean hydrogen from water splitting; along with surface coatings for low friction and wear, recyclable packaging and oxidation resistance, etc.

Made Smarter

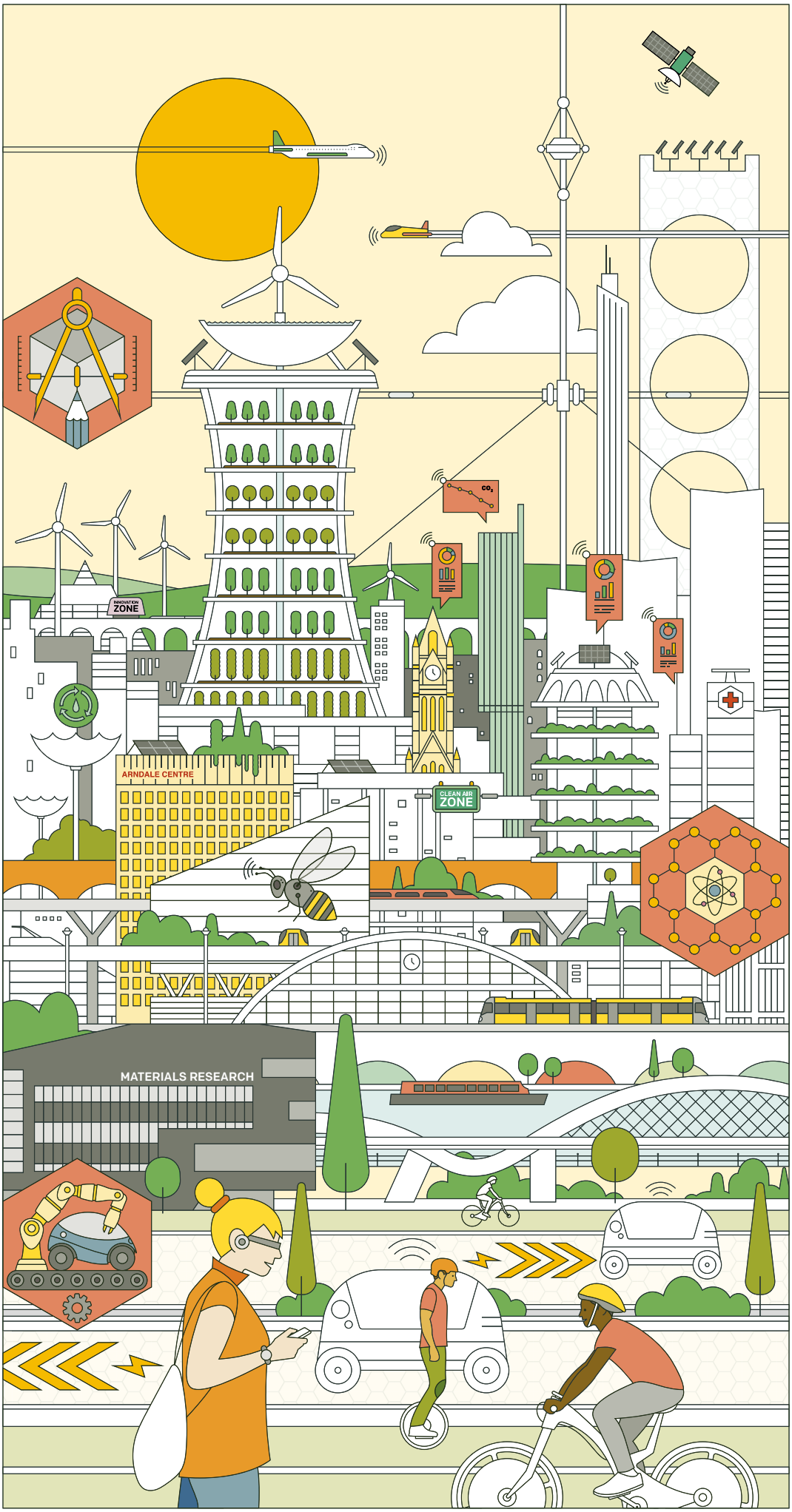
The Made Smarter programme in the North West is being led by Greater Manchester and is paving the way for the UK to be the global leader in the creation, adoption and exportation of advanced digital technologies. This Department for Business, Energy & Industrial Strategy sponsored programme has been hugely successful in enabling companies to get to grips with the technologies, expertise and skills needed to embed new tools and ways of working into their manufacturing processes.

Improving productivity through digitalisation of manufacturing is a strategic priority for GAMMA. Made Smarter is an exemplar intervention working with SMEs to map out their digitalisation journey and supporting them through grants, student internships, advice on workforce development, and developing the leadership and management skills needed to ensure that they achieve their maximum potential for innovation and growth. The programme has been extended in the North West and the model being rolled out in three other UK regions, over the next 12 months.

Resources

Video:

- **Made in Manchester: an intro to graphene**
  Graphene: Made in Manchester - Bing video
- **Inside the Graphene Engineering Centre**
  Inside the Graphene Engineering Innovation Centre - YouTube
- **Graphene@Manchester YouTube Channel**
  The University of Manchester – The home of graphene - YouTube
- **GEIC webinar series**
  GEIC webinars - Challenges and Opportunities in Graphene - YouTube



Manchester 2038 as imagined by illustrator and designer Barney Ibbotson.

A future of vertical urban farms; rainwater purification units utilising graphene membranes; road surfaces which defy potholes and charge the batteries in the driverless lightweight vehicles which pass along them.

The air is clean and people have a vast array of career opportunities in innovative industries that have not yet been imagined. Transportation is net carbon neutral, integrated affordable and efficient.

Drones - built in the image of Manchester's famous worker bees - buzz through the sky. The cityscape remains familiar but incredible new architectural structures are possible due to enhanced building materials which are lighter, stronger and conduct heat and power. The legendary space elevator is a reality.

Healthcare has been transformed by the ability to produce intricate replacement body structures.

As a result, Greater Manchester is a magnet for talent and investment and the city-region's efforts to tackle global challenges is supporting the fight against climate change.

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