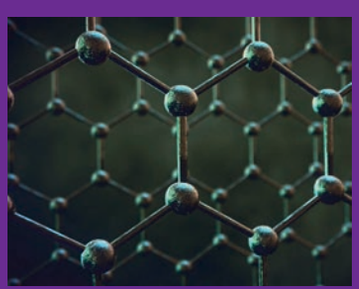
MANCHESTER 1824
The University of Manchester

GREATER MANCHESTER AND CHESHIRE EAST

A Science and Innovation Audit Report

sponsored by the Department for Business, Energy & Industrial Strategy



new economy
The Skills & Growth Company
GMCA GREATER MANCHESTER COMBINED AUTHORITY
Cheshire East Council
Greater Manchester Local Enterprise Partnership
Cheshire and Warrington 87 Enterprise Partnership
Department for Business, Energy & Industrial Strategy

Contents

Foreword

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

Juergen Maier
Chief Executive of Siemens plc

Connectivity put our region at the heart of the Industrial Revolution, when one particular innovation, the canal network, revolutionised the textiles industry. Today our industries may look a lot different, but one thing remains the same: the better our connections, the better our chance of a healthier, more successful economy and society.

Greater Manchester and Cheshire East are home to a high level of partnership and connectivity, not least in the areas of core strength: health innovation and advanced materials. We also have fast-growth opportunities in digital, energy and industrial biotechnology, with a wide range of science and innovation assets across all five areas.

Building on the interconnectivity between these is at the crux of the vision set out in this SIA. Synergies will accelerate the flow of scientific innovation to the market, boost productivity and potentially develop solutions to national and global challenges.

While acknowledging the demonstrable scientific excellence, dynamic workforce and business support environment of the region, as well our physical infrastructure and progressive governance, the SIA also shows us a number of ways forward in order to raise skill levels, drive innovative activity and more closely align industry and science. These will require strategic investment in future and existing assets, but also in developing, attracting and retaining talent, and in support for new and growing businesses.

The UK government has begun to demonstrate its support for a better connected north through the Northern Powerhouse initiative. It has also recognised the strengths of our infrastructure via the devolution of powers and budgets in Greater Manchester. This SIA shows a path which the government and our authorities can take to fully harness the potential within Greater Manchester and Cheshire East to bring benefits that spread through – and beyond – our region.

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

This Science and Innovation Audit, in partnership with central government, is an important step in helping us appreciate the strengths within Greater Manchester and Cheshire East. From the perspective of business it helps us to achieve a critical aim in ensuring that excellence in science is aligned as effectively as possible with opportunities for companies to innovate successfully.

This Audit has focused on identified specialisms around health innovation, advanced materials, energy, digital and industrial biotechnology, and identified a number of nationally important science and research assets. It has also demonstrated that innovation depends not just on physical assets but on people, talent, skills, and infrastructure. It positions existing companies and potential inward investors to capitalise on a dynamic and highly trained workforce, including a nationally significant concentration in clinical healthcare, a digital and technology cluster, one of largest graduate pools in Europe, and a concentration of STEM graduates and postgraduates.

Partnership working is underlined by strong governance arrangements. Greater Manchester was the UK's first Combined Authority, and has agreed a number of important devolution deals with central government, most recently on health and social care. This is underpinned by a strong public and private business support environment, including a Business Growth Hub, Manufacturing Champions Network, four Enterprise Zones, and growing incubator space, as well as strong physical infrastructure, including Manchester Airport.

This Audit provides a platform for ongoing engagement, so that we ensure that we support the innovation eco-system and extract maximum value from existing assets, as well as continuing to invest to maintain world-class excellence and stay at the forefront of international scientific development.

Juergen Maier
Chief Executive of Siemens plc

Executive summary

In autumn 2015 the UK government announced regional Science and Innovation Audits (SIAs) to catalyse a new approach to regional economic development. SIAs enable local consortia to focus on analysing regional strengths and identify mechanisms to realise their potential. In Greater Manchester (GM) and Cheshire East (CE), a consortium was formed to focus on our strengths in health innovation, advanced materials, energy, digital and industrial biotechnology. This report presents the results which includes broad-ranging analysis of GM and CE's capabilities, the challenges and the substantial opportunities for future economic growth.

Context

At the core of the industrial strategy for both GM and CE is the need to harness knowledge, innovation, skills and infrastructure to drive the local economy, create jobs and raise productivity. Realisation of the full potential from our science and innovation strengths will also benefit wider global societal challenges. These include climate change, energy security, transport efficiency, and a sustainable health and social care system. Informed by the results of our Smart Specialisation Platform analysis, emerging imperatives for growing the economy of the Northern Powerhouse and devolution of the health and social care budget to GM, we identified two 'areas' of focus for this Science and Innovation Audit (SIA):

1. 'Core strengths' in **health innovation** and **advanced materials**, where we have existing, internationally-recognised excellence.

2. 'Fast-growth opportunities' focused on the future potential of **digital, energy**, and **industrial biotechnology**, where our assets and capabilities offer real scope for future development.

Our guiding hypotheses were firstly that we have five areas of core strengths and fast growth opportunities which could be combined to release new synergies of innovation and productivity growth, and secondly that we would have to address gaps in our regional innovation ecosystem that are constraining our ability to do so in order to realise full potential. GM and CE's collaboration on this Audit is borne out of shared ambition, functional geography, talent and assets, and a strong history of working together in partnership, such as joint action to secure a future for Alderley Park[1] (home to 150 bioscience companies), and the £31m Joint Cheshire and GM Life Science Fund[2].

[1]https://moderngov.cheshireeast.gov.uk/documents/s31312/Alderley%20Park%20Development%20Prospectus%20-%20Appendix%201.pdf
[2]http://www.gmclifesciencesfund.com/

Vision

Our vision derives directly from our first hypothesis that we can create a global competitive advantage by driving synergies from our core capabilities. Our areas of excellence create additional positive spill-overs and value when combined. This inter-connectedness will enable us to co-develop applications in new technologies. It will be achieved by linking our unique clusters of excellence in fundamental science with an ability to put that scientific knowledge into application – bringing together local and national partners. Three key opportunities identified are:

i. Health – a globally leading centre for clinical trials

We have the largest concentration of excellence in health research nationally outside South East England. Key facilities in support of cutting-edge research and innovation are set in the context of a large and stable population exhibiting significant health challenges. Health devolution to GM (£6bn p.a.)[3] has created the unprecedented opportunity for a concerted push towards innovation for both health and economic benefit. We have put in place a platform, Health Innovation Manchester[4], to refocus our priorities around a system and place. Synergies with the digital sector (eg health informatics) allow us to drive towards becoming a globally leading centre for clinical trials.

ii. Materials – rapid accelerator to application

In advanced materials, the opportunities to develop 'Graphene City'[5] highlight the unique presence of world-leading science (eg National Graphene Institute[6]) engaged with business and producing start-up companies. The next steps are to systematise the pathway through higher technology readiness levels (TRLs) with the opening of the Graphene Engineering Innovation Centre (GEIC)[7] and hence to turn our discoveries to applications. Particularly important is the accompanying training programme.

This gives us a large concentration of graphene scientists with additional entrepreneurship training. The Sir Henry Royce Institute[8] will create a national focus to overcome traditionally long lead-times and act as a "rapid accelerator" through TRLs to application, notably in the manufacturing sector.

iii. GM as a full-scale test-bed and lead market to develop and demonstrate innovative technology

Our fast-growth opportunities, digital and energy, as with health, combine excellence in research and facilities with a particular competence in mounting large-scale projects in the community. This is illustrated by the large-scale demonstrators, CityVerve[9] and Triangulum[10], which enable whole systems to be tested and create multiple business opportunities. Industrial biotechnology is a capability of relevance for the concentration of related industries in the North of England. Focusing on synthesising new products and intermediates, it helps develop both sustainability and resilience in the move away from fossil fuels and feedstocks and offers the potential to address disease pandemics and tackle antimicrobial resistance.

Strengths: leading-edge science and innovation capabilities

The foundation for progress in GM/CE rests in part upon a critical mass of acknowledged Science and Innovation assets in each of the selected areas in both the public and private sectors:

Health innovation: eg Biomedical Research Centre (£28.5m, Sept 2016)[11], Academic Health Science Centre, Manchester Cancer Research Centre, Alderley Park Science Park, Medicines Discovery Catapult hub[12], Antimicrobial Resistance Research Centre, Citylabs, Precision Medicine Catapult spoke.

Advanced materials: eg Sir Henry Royce Institute, National Graphene Institute, Graphene Engineering Innovation Centre, BP International Centre for Advanced Materials (BP-ICAM)[13], Cockcroft Institute.

Digital: eg recognised as the UK's second digital hub through MediaCityUK, Farr Institute, CityVerve, Jodrell Bank, Hartree Centre (Sci-Tech Daresbury), and associated tech cluster[14].

Energy: eg National Nuclear Laboratory, Dalton Nuclear Institute, National Grid High Voltage Laboratory, Birchwood nuclear cluster, Amec Foster Wheeler's High Temperature Facility.

Industrial biotechnology: eg Manchester Institute of Biotechnology, Waters Corporation's Mass Spectrometry Facility[15], AstraZeneca's R&D facility, Antimicrobial Resistance Centre.

Demonstrated scientific excellence is also a key criterion. In health, the combined result of all health disciplines ranked The University of Manchester (UoM) 5th in the UK for research power[16], the highest-ranking institution outside the South East. UoM produced the second highest number of publications in the top 10% most cited in the field of advanced materials[17]. In our fast-growth opportunity areas UoM is consistently in the UK's top five both by volume of academic publication / share of top 10% cited papers[18].

A dynamic, highly trained workforce in the region includes a nationally significant concentration of training in clinical healthcare, one of the largest graduate pools in Europe, a strong concentration of STEM graduates/ postgraduates, and a long and successful history of entrepreneurship and industrial engagement[19].

Cityregion governance is conducive to

[3] *https://www.england.nhs.uk/2015/02/greater-manc-funding/*
[4] *https://www.healthinnovationmanchester.com*
[5] *http://www.graphene.manchester.ac.uk/explore/graphene-city/*
[6] *http://www.graphene.manchester.ac.uk/collaborate/national-graphene-institute/working-in-partnership/*
[7] *http://www.graphene.manchester.ac.uk/collaborate/geic/*
[8] *http://www.royce.ac.uk*
[9] *http://www.cityverve.org.uk*
[10] *http://triangulum-project.eu*
[11] *https://www.gov.uk/government/news/new-816-million-investment-in-health-research*
[12] *https://md.catapult.org.uk/*
[13] *http://www.icam-online.org/*
[14] *http://www.techcityuk.com/wp-content/uploads/2016/02/Tech-Nation-2016_FINAL-ONLINE-1.pdf?utm_content=buffer2e58f&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer*
[15] *http://www.waters.com/waters/en_GB/New-Mass-Spectrometry-Facility/nav.htm?cid=134653003&locale=en_GB*
[16] *Research Excellence Framework (REF) 2014 based on volume x grade point average*
[17] *ibid*
[18] *Scopus SciVal data for UoM ranked versus Russell Group comparators based on keyword field definitions*
[19] *"Mapping local comparative advantages in innovation", (BIS) 2015*

innovation and growth. Our history of strong local governance is exemplified by the creation in GM of the first Combined Authority in the UK, and a shared strategy to create economic growth. Four devolution deals have been agreed for GM, including control over £6bn p.a. of health spending with commitment to use this to drive innovation through Health Innovation Manchester to serve a patient population with major healthcare challenges. GM and CE have a strong and effective record of effective partnership.

A well-established public and private business support environment includes examples of mature business support networks eg GM Business Growth Hub, and the Manufacturing Champions Network; access to private equity (including Venture Capital and Business Angels in GM and CE); a strong underpinning financial and professional service sector; four Enterprise Zones (one at Alderley Park); and incubator and accelerator space spanning the region and joining up GM and CE assets.

Physical infrastructure is available for a globally connected high tech sector. The region has excellent air, road and rail connectivity (Manchester Airport directly serves over 210 destinations)[20], well-developed digital connectivity, and lower location costs for work/ living than London.

Gap analysis

Our analysis shows that in each sector we have globally competitive multinationals accompanied by clusters of innovative SMEs. In terms of skills and talent, a higher proportion of our area's workforce is employed in science, research, engineering and technology professions than the England average[21] but a significant share of the local population continues to have no qualifications at all. Around knowledge transfer and leadership, there are more firms in CE engaged in product or process innovation than the English average, and their level of business R&D expenditure per person one of the highest nationally[22]. Yet, across the whole of our geography, nearly half of firms are still not 'innovation-active'. Productivity levels remain below their potential, with GVA per capita in GM and average annual full-time pay significantly behind the England average[23]. In finance, although we have access to one of the largest private equity pools in the UK, access to venture capital remains behind the South East. Such access is needed to help bridge the equity gap from start-up to scale-up.

There is an outstanding offer of place assets, now linked more clearly as a system following this audit. Technology space and support services and institutions are situated in a continuum from MediaCity in Salford, through Corridor Manchester and Airport City to Alderley Park and the Cheshire Science Corridor. These form a globally competitive innovation district. There are strong examples of collaboration and networking across GM/CE, but we need to do more so that we can realise the full potential of our assets to drive innovation and commercialise our research locally. We must also support smaller firms to acquire and build the absorptive capacity to take advantage of the opportunities created by our science assets.

The audit shows that our innovation support system lacks some key elements in knowledge production (missing complementary assets), development of talent (addressing key skills and management deficits) and business support (improving the environment for innovative, growing firms). We need to increase productivity, raise skills and qualification levels across the workforce, and extend the benefits of our recent strong growth to the less favoured parts of our region.

Key ambitions

Following from our analysis of strengths and gaps we will follow two main lines of action:

1. Strategic investment to capitalise on the key intersections and opportunities

We must extract maximum value from existing assets and those under construction, but need to continue to invest (from our own and external funds) to maintain world-class excellence and remain at the forefront of international developments in our areas of smart specialisation. Notably this will exploit the synergies between our areas of strength in order to develop route-ways to the market.

Pankhurst Centre to bring together physical science capabilities for health benefit

We can reinforce inter-connectedness by making some important strategic investments. Central to our plans is the Pankhurst Centre for Research in Health, Technology and Innovation. This would be a path-breaking, cross-disciplinary Institute bringing together clinical research with materials science, informatics, engineering and computer science to address major health problems, and unlock synergies between our strengths of health and materials plus digital and biotechnology. Its 'bi-directional' nature means new discoveries will seek health applications and respond to health needs to find solutions. It will be both place-based and virtual, with a core of at least 100 research leaders from diverse disciplines working together, but drawing upon a wider group of researchers beyond.

Maintain the strength of our science assets with key critical investments

In the short-term, we have identified a small number of projects which address gaps and opportunities in our regional ecosystem and are strong candidates for investment to help do this.

2. Strengthening our innovation support ecosystem

Enhancing collaboration

We will drive alignment of our science assets with our local business base to maximise economic impact, stimulating a broader cultural change around interdisciplinary pathways to the market.

Nurturing talent

We must ensure the right local skills mix is in place to drive innovation, reinforce our identified scientific strengths and improve our ability to attract and retain talented individuals. GMCE needs to invest further in the development of the skills required to drive its key innovation sectors and assets, particularly higher-level technical skills. We plan to establish an **Institute of Technology**, which would work closely with GMCE's universities, enable progression from FE, will be driven by

[20] *Manchester Airport Group "Route Development at Manchester Airport", 2016*
[21] *"Mapping local comparative advantages in innovation", (BIS) 2015*
[22] *Ibid*
[23] *Ibid*

business demands and leadership, and foster innovation in SMEs.

Leadership and management capacity for our innovative sectors are also critical. We need investment in our business schools to ensure they can play a pivotal role through their research and training in guiding development of health devolution and of our advanced innovative sectors. We need to raise awareness of a diverse workforce to drive innovation.

Improving business support

As we build critical mass, there will be increased opportunity to ensure businesses gain access to diverse finance support to help them to scale-up. We need to realise the benefits of 'absorptive capacity' within SMEs, improving their ability to integrate new information for commercial ends. This includes increasing the provision of adequate space for both start-ups/ scale-ups and leveraging in smarter procurement practice from the public sector to incentivise innovative practice (eg through data-sharing initiatives such as GMConnect and Datawell).

Networking and collaboration

Our integrated governance, deep culture of collaboration between government, business, academia, and health, and strong partnership between GM and CE gives a powerful platform to implement the opportunities shown in the Audit. We will work with partners nationally (including across the North) and internationally as we pursue global export and inward investment opportunities.

The region is characterised by an exceptional level of partnership and connectivity. There are close strategic and operational collaborations between our universities, the business community, local government and public sector partners, health and social care providers, and charities. Connectivity is demonstrated by a series of strategic alliances, eg in healthcare and medicine (see strengths above); and national and international networks (eg EU €1bn Graphene Flagship[24], £20m Connected Health Cities[25], UK's only Internet of Things demonstrator (CityVerve), and other assets noted above). We already have strong international partnerships in each of the areas of strength identified and rapidly growing interest from global companies to have a footprint in GM (particularly at Citylabs) and CE (notably Alderley Park). Major multinational companies include NCC Group, NNL, NuGen, Hitachi, BP, Amec Foster Wheeler, Waters, Cisco and AstraZeneca.

The audit process has driven added-value in verifying our own internal assessments of strengths, weaknesses and opportunities; strengthening our collaborations across the region; building on our partnerships; and identifying future priorities, particularly for innovation and business development. During the process, we held 10 meetings with over 40 partners - including 20 companies and two workshops (health innovation and advanced materials). This led to the reinforcement of our strategy with other partners, introduction of industry partners to each other and important feedback, development of new collaborations and identification of areas that need to be strengthened. For example, UoM, Manchester Metropolitan University (MMU) and the University of Salford (UoS) are now working together on health education and innovation; while LEPS across the North are collaborating more closely on joint actions to understand and drive innovation.

The Audit has demonstrated a historic opportunity to develop our innovation ecosystem as an accelerated pathway to the market for regional and national social and economic benefit. It provides us with a platform for shared action going forward.

[24] *http://graphene-flagship.eu/project/Pages/About-Graphene-Flagship.aspx*
[25] *http://www.manchester.ac.uk/discover/news/chancellors-20m-to-use-cities-data-to-improve-healthcare/*

1

Introduction to Greater Manchester and Cheshire East

At the core of the industrial strategy for both Greater Manchester (GM) and Cheshire East (CE) is the need to harness knowledge, innovation, skills, and infrastructure to drive the local economy, create jobs and raise productivity. This report assesses key strengths, assets and capabilities in the region, and sets these in the context of an analysis of gaps and opportunities. Going beyond the economic narrative we recognise that the realisation of the full potential from our science and innovation strengths will also address wider societal challenges. These include several areas that are critical to our region, but also nationally and globally: climate change and the environment, combating pandemic infections and antimicrobial resistance, healthy living and ageing, and in support of these establishing a sustainable health and social care system that keeps more people economically and socially active for a longer time.

1.1 AUDIT PROCESS

GM and CE's collaboration on this Science and Innovation Audit is borne out of shared ambition, functional geography, talent and assets. There is a strong history of the two working together in partnership, exemplified by joint action to secure a successful future for Alderley Park, and through initiatives such as the £31m Joint Cheshire and GM Life Science Fund.

Over the past 15 years, GM has transformed into an international centre for knowledge-based and innovation-led service and manufacturing activity, exemplified by the designation of GM as the European City of Science in 2016 and the hosting of the EuroScience Open Forum. CE hosts a highly skilled workforce, significant industrial research and innovation capability, and a number of important academic innovation assets. The two together form a natural geography which also links beneficially to other parts of the North West and beyond.

For both partners, science, technology and the translation of discoveries through innovative practice into commercial applications are important drivers of economic growth, and both acknowledge this can bring wider social benefit. GM aims to transform itself from a net recipient of Exchequer funding to a net contributor, acknowledging that overall productivity is currently behind the UK average. We will therefore use this Audit to contribute effectively to the critical societal, national and global challenges. Such issues can be shaped only by the ability of places to build on knowledge networks to embrace innovative and disruptive technologies and bring them to market.

Undertaking this Audit has also galvanised local partners to come together and think about how we better leverage our assets and excellence to support the wider business base to drive economic growth and address notable gaps that inhibit delivery of our ambitions. It has also had the beneficial effect of supporting wider conversations with partners across the North to develop common policies targeted at both strengthening the innovation eco-system and driving smart specialisation. This includes working with Sheffield and Lancashire as part of wave 1 of the audits, in terms of better understanding the linkages around both the Sir Henry Royce Institute, and the Nuclear Advanced Manufacturing Research Centre. We have also supported colleagues in Liverpool City Region, York, and the Northern Health Science Alliance (NHSA) in their bids for wave 2.

Consortium Structure

The Audit has been led by a **Task and Finish Group**: UoM (as scientific lead), and Greater Manchester Combined Authority (GMCA) / Greater Manchester Local Enterprise Partnership (GMLEP) (as innovation lead – undertaken by New Economy).

It has been overseen by a **Core Membership** consortium of key local partners (see Annex A), including four universities (UoM, MMU, Bolton and UoS); the GMCA; two Local Enterprise Partnerships (GM, and Cheshire and Warrington); a number of science, health and innovation partnerships as well as wider public sector partners (Cheshire East Council, the Skills and Growth Company, Corridor Manchester, Health Innovation Manchester, Manchester Science Partnerships (MSP), the Manchester Academic Health Science Centre (MAHSC), the Northern Health Science Alliance and the national science and innovation campus, Sci-Tech Daresbury); and a group of large and small businesses with a local presence - including Arup, AstraZeneca, BBC North, the GM Business Growth Hub, BioNow, BP, BT, Cisco, Hitachi, Medtronic, MediaCity UK, NCC Group, Siemens, Unilever, and the Waters Corporation.

Enabling collaborators are drawn from universities and organisations both in the UK and overseas with which GM and CE have strong collaborations (see Chapter 5).

Focus on key areas

This Audit has identified five strengths which are the key focus of the study. They emerged from the analysis conducted for the 2014 EU Smart Specialisation Platform[26], and reflect a combination of genuine local scientific strength, current innovation opportunities, and the medium-term potential to deliver overall improvements in local productivity through ongoing investment. They also match the priority strengths identified as part of the Northern Powerhouse Independent Economic Review[27] and the 'leading innovation capabilities' for the North West as identified by the North West Business Leadership Team.[28] These are in two categories:

1. 'Core strengths' in **health innovation** and **advanced materials**, where we have existing internationally-recognised excellence.

2. 'Fast growth opportunities' focused on the future potential of **digital, energy**, and **industrial biotechnology**, where our assets and capabilities offer real scope for future development.

Hypotheses to be tested

The audit has been structured to explore and test two hypotheses:

1. that 'core strengths' and 'fast-growth opportunities', and critically the synergies between them, can be used better to accelerate innovation and productivity growth; and

2. that our regional innovation ecosystem is constrained by less than optimal key expertise and infrastructures which need to be defined and addressed.

Core strengths[29]

Health innovation: Recognising the major opportunity to drive private sector innovation and public sector reform as a result of the Health Devolution agreement for GM (DevoManc), our aim is to build on excellence in precision medicine, health informatics and bringing clinical research excellence and innovation into practice.

Advanced materials: To drive innovation in sectors such as environment, manufacturing, housing, transport, and biomaterials (to address health and well-being challenges), we will maximise the capabilities and networking of the key national assets in this domain situated in our region.

[26] *http://s3platform.jrc.ec.europa.eu/*

[27] *This identified four 'Prime Capabilities' at the level of the North: Advanced Materials, Energy, Health Innovation and Digital (including e-Health and Big Data)*

[28] *NWBLT, "Discovery to Delivery – NW England a premier location for science and technology innovation": (i) Advanced Materials and Molecular Manipulation; (ii) Energy Research including Nuclear Energy and Nuclear Engineering; (iii) Cancer Research and Health Innovation; (iv) HPC, Big Data and Digital Manufacturing.*

[29] *"Core strengths" are based on existing internationally recognised excellence; "Fast-growth opportunities" are based on current trajectory and potential.*

Fast-growth opportunities

Digital: This is a key enabling technology for the other sectors, and there are specific opportunities in Big Data, in our extended programme of demonstrator and test-bed projects in the domain of smart cities/Internet of Things (IoT), and via the dynamic creative, digital and media economy in the region.

Energy: Opportunities arise from our leading position in nuclear research, and in low carbon energy generation, transmission and storage.

Industrial biotechnology: The concentration of this sector in the North of England provide opportunities to drive technological advances in molecular biology and biotechnology to support drug discovery and development, as well as sustainable and clean production of chemicals for use in manufacturing.

1.2 OVERALL CEONOMIC PERFORMANCE AND CONNCETIVITY

Overview

GM is the UK's second largest city-region in both demographic and economic terms – bigger than Wales, the same size as the North East of England, and half the size of Scotland. With around £57bn GVA p.a., it is equivalent to almost 20% of the total economic output of the North of England and about 40% of GVA in the North West[30]. GM is also one of the largest economies (by GVA) in the EU.

CE's GVA in 2014 was ~£11.2bn, with average annual growth of 4.8% over 1997-2014[30]. Manufacturing and professional, scientific and technical services account for almost a quarter of jobs in CE, reflecting the presence of major manufacturing sites such as Bentley, AstraZeneca, Siemens, BAE Systems and Sanofi.

GMCE remains an important location for the manufacturing sector, accounting for about 137,000 jobs[31] , but has also seen its service sector develop as the dominant source of employment and driver of the economy. Hence it is now a key centre nationally for financial and professional services, higher education, and the creative and digital industries. However, overall productivity remains lower than its potential in GM (a current national gap of £3,600 per capita adding up to £10.4bn p.a.), while above the average in CE.

Governance

Along with the GM LEP, the GMCA provides a basis for collaboration and implementation of agreed strategy[32] in GM. This unique city regional governance enables us to take decisions of a strategic nature and places us in a strong position to make devolved funding decisions. For example, the DevoManc agreement (2015) provides greater local control over £6bn p.a. of health and social care spending, permitting far greater use of devolved and aligned commissioning and procurement. In CE, our governance is led by the Cheshire and Warrington Economic Prosperity Board, with business voice represented by the Cheshire and Warrington LEP.

Business base and labour market

GMCE have a combined GVA of £68.6bn p.a.[30], with over 126,000 businesses in 2015[33], and a strong track record in securing foreign direct investment (FDI) (eg £1.3bn in 2015[34]). In 2014 there were 14,225 business starts in GM (804/ 100,000 working age population); and 2,430 in CE (647/ 100,000) .

There are critical assets in GM's health and social care sector supporting 157,400 jobs and GVA of £4.5bn in 2014[36]. Outside London, GM is the UK's main centre of financial and professional services[37], employing over 294,000 people and generating almost £18bn GVA p.a. in 2014[36]. Our creative and digital sector accounts for 68,300 jobs, creating GVA of £3.4bn p.a. Education employs 119,000 people and adds GVA of £3.8bn p.a. to the GM. The low carbon and environmental goods and services sector already employs 38,000 people. Despite the decline of the manufacturing sector, 53,000 people now work in advanced manufacturing (including advanced materials) in the city region[36].

Overall GVA per capita in GM is currently £21k p.a. (below the UK average of £25k), but is £29k in CE (2013)[38]. Average annual gross full-time pay per capita in GM (£30k) is lower overall than for England (£34k, partly reflecting higher London wages) and in CE (£31k)[38]. The proportion of GM working age residents with no qualifications is higher (11.5%) than in CE (8.5%)[38]. 38.9% of residents in CE are educated to NVQ level 4 and 31.8% in GM (2013), compared to England average of 35%[38]. There are four universities with main campuses (UoM, MMU, UoS, University of Bolton) with over 96,000 students[39].

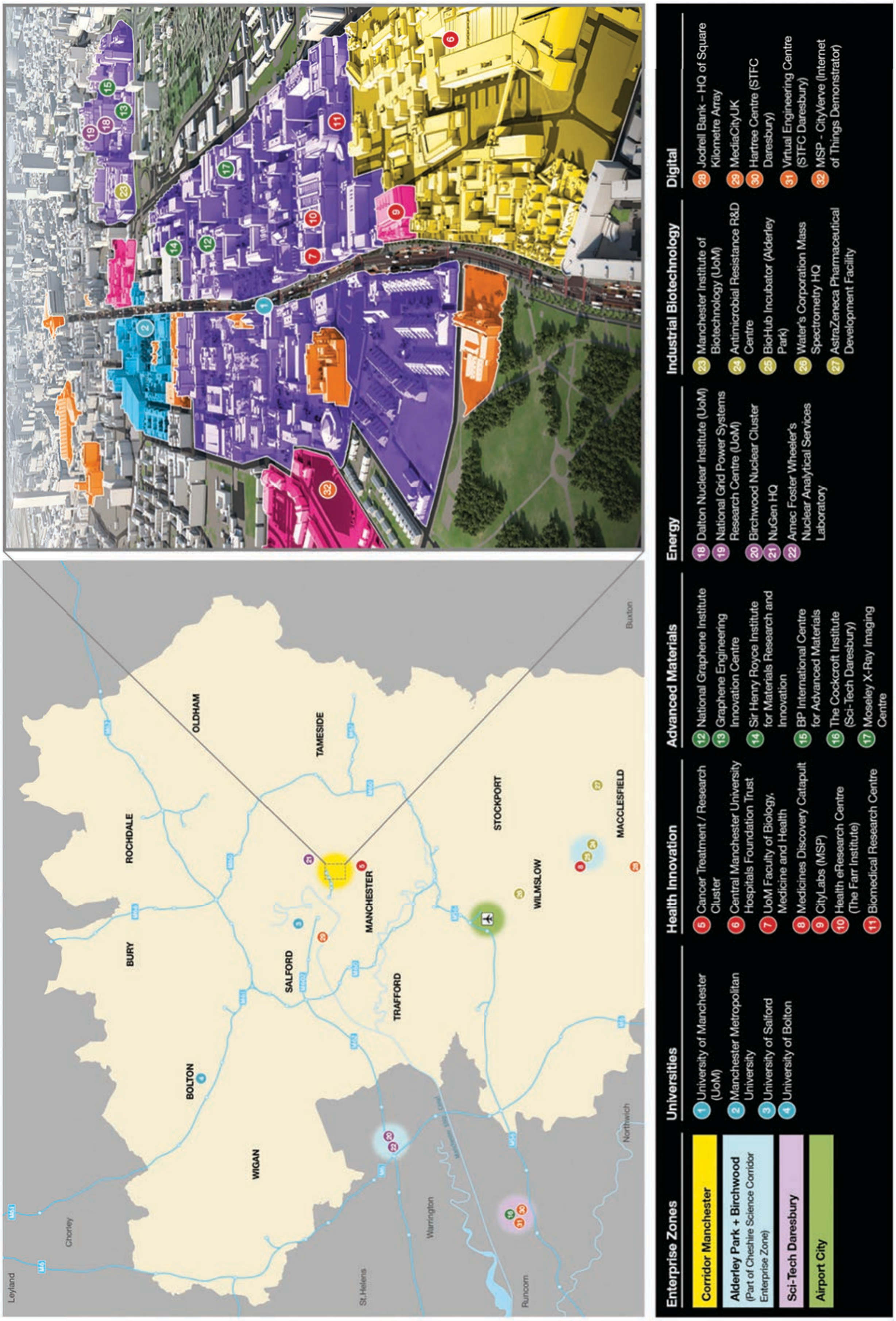
Connectivity

Connectivity is vital to stimulate innovation and collaboration and realise the full economic value from our existing science assets as well as to support future investments. GMCE have an extensive transport infrastructure that puts at least 5.2m people within an hour's commute of the core; the largest travel-to work catchment area of any conurbation in the UK outside London. Manchester Airport offers more direct connections than any UK airport outside London (over 210 destinations), and handles over 24m passengers p.a. It is also the only UK airport outside London to offer scheduled, non-stop direct routes to Hong Kong, China, and Singapore. It has multiple direct daily flights to the main US hub airports and European capital and regional airports.

GMCE sits on the main North-South and East-West UK rail and motorway links, and has the UK's largest light rail system. We are also at the heart of Transport for the North, which is bringing improved connectivity across the North. GMCE is home to one of the most advanced and competitive telecommunications and internet infrastructures in Europe – with excellent fibre networks both to Europe and North America, and 97% coverage of high speed superfast broadband to home and business.

[30] *ONS, Regional Gross Value Added (Income Approach)*
[31] *ONS, Business Register and Employment Survey*
[32] *GMCA/AGMA "Stronger Together: the Greater Manchester Strategy" (2009); "GM Growth and Reform Plan" (2013).*
[33] *ONS, UK Business Counts (Local Units)*
[34] *UKTI figures*
[35] *ONS, Business Demography 2015 and Population Estimates 2015. Calculations by New Economy.*
[36] *Greater Manchester Forecasting Model, 2015*
[37] *Northern Powerhouse Independent Economic Review, SQW, 2016*
[38] *"Mapping Local comparative advantages in innovation", BIS, 2015.*
[39] *2014/15 HESA data*

Map: GMCE Audit



2

Regional science and innovation assets

We already have a strong base of knowledge of our scientific and innovation capabilities based on our 2014 Smart Specialisation analysis (accredited by the European Smart Specialisation Platform)[40], work on sector 'Deep Dives'[41], and the GMCE Life Sciences Review[42]. In this section we review our science and research assets in the five areas with an emphasis on their relevance for innovation, and we summarise our human talent.

[40] *http://s3platform.jrc.ec.europa.eu/*
[41] *http://www.neweconomymanchester.com/publications/deep-dives-skills-reports*
[42] *http://www.gmclifesciencesfund.com/*

2.1 SCIENCE AND RESEARCH ASSETS

Assets - health innovation

Opportunities for innovation from DevoManc are being met by a new partnership, **Health Innovation Manchester,** which will speed-up the discovery, development and delivery of innovative solutions to the NHS. It is focused on health informatics and builds on GM's data capabilities and expertise in clinical trials and precision medicine. It is a unique strategic body with key local partners, including MAHSC, the Academic Health Science Network, the LEP and universities. As well as being tasked with increasing the scale and pace of innovation in health and care in partnership with industry, it will align GM's clinical excellence assets to address population health needs, accelerate the adoption and diffusion of innovations into GM Health & Social Care, and increase commercial engagement in the discovery, development and deployment of innovations.

GM has one of the six **Academic Health Science Centres** in England and the only one outside of the South East (a partnership between UoM and six NHS organisations three acute Trusts, two specialist Trusts and a Clinical Commissioning Group[43]) aimed at driving improvements in healthcare through research and innovation.

Devolution and the success of MAHSC have led to a **'One Manchester' approach to health research and innovation**. This is demonstrated for example by developing a single successful **Biomedical Research Centre** bid (£28.5m, the largest outside the South East), a single bid for a Clinical Research Facility and development for a single Clinical Trials Unit and R&D support office. More broadly, as the region became the first in the country to take control of its combined health and social care budgets, a sum of more than £6 billion, the opportunity has emerged to tackle health inequalities through a comprehensive approach to population health built on new systems and pathways operating at an unprecedented scale. Hospitals across the audit area offer treatment in all specialities and employ c255,000 people. GM has Europe's largest single-site clinical-academic campus on Corridor Manchester (see Chapter 4 and Annex C), a partnership between Central Manchester University Hospital NHS FT (CMFT), UoM and MMU, Manchester City Council and local business. This will be further strengthened by plans, which are well advanced, to unite the three major hospitals in the city into one NHS Trust[44] in 2017.

The population of GMCE is diverse, stable and accessible (outward migration is relatively low) but has significant health challenges and lower than average life expectancy. This population is therefore particularly suitable to sustain complex, long-term clinical trials, and our local data technology offers the potential access to around 2.8m patients for large-scale trials. Indeed, GM had the highest recruitment in England to commercial clinical trials in 2013-14[45]. This is underpinned by the largest concentration of clinical research nurses nationally (around 250) - trained and ready to support trials.

Case study:

The Salford Lung Study

The world's first digitally enhanced randomised clinical trial of a drug for chronic obstructive pulmonary disease (COPD), involving over 2,800 patients and carried out by GSK, Innoviva, North West e-Health, UoM and local hospitals[46]. The study showed that the drug Relvar Ellipta significantly reduced exacerbations in patients with COPD. Using electronic health records, GSK worked and studied patients in their everyday setting - monitoring all hospital admissions, outpatient and emergency department visits, and data from primary care providers.

Our strengths in precision medicine are based around cancer, genomics, proteomics, imaging, and biomarkers, with research attracting around £100m grant income in the past five years (MRC, EPSRC and industry) - with a major focus on immune-mediated conditions.

We have a long history of cancer research, stretching back to the early 20th century work on X-radiography and radium. The Christie NHS Foundation Trust is Europe's **largest cancer centre** and the largest **early-phase clinical trials** unit in the world, with around 400 trials taking place at any one time. It houses the biggest chemotherapy facility in the UK.

The **Manchester Cancer Research Centre** (MCRC) (£45m over the next five years) is a partnership between UoM, The Christie and Cancer Research UK (CRUK). Additional centres of excellence on site include the CRUK Manchester Institute (£24m p.a.); a CRUK Major Centre (currently £6m p.a. planned to rise to £9m p.a. 2017), one of only three such major centres nationally; CRUK Lung Cancer Centre of Excellence with UCL; and Prostate Cancer UK Fastman Centre of Excellence with Belfast University.

MCRC integrates world-class research and clinical expertise across cancer biology, translational research, drug discovery and clinical trials; it includes ~240 academics publishing on cancer and related areas, £145m live grants, and an extensive portfolio of industry collaboration eg leading the first human trials of the EGFR inhibitor, Iressa, and Arimidex with AstraZeneca.

MCRC is also the base for the **CRUK/EPSRC Cancer Imaging Centre** (with the University of Cambridge, ~£2m p.a. across both sites) which leads research to improve cancer diagnosis through magnetic resonance imaging, ultrasound, and positron emission tomography.

The **Proton Beam Therapy Centre** (£138m, with £7m research facilities, open 2018), one of only two such research and treatment facilities in the UK, will link to local academic research expertise in nuclear including at the Dalton Nuclear Institute, and use of the

[43] University Hospital of South Manchester NHS Foundation Trust, Salford Royal NHS Foundation Trust, CMFT, The Christie, Manchester Mental Health and Social Care Trust, Salford Clinical Commissioning Group

[44] North Manchester General Hospital, Wythenshawe Hospital and the Manchester Royal Infirmary.

[45] 2013/14 National Institute for Health Research Clinical Research Network, Greater Manchester Portfolio: 2,819 trials

[46] http://www.srft.nhs.uk/media-centre/latest-news/news-archive/news-2012/sls-update/

advanced particle accelerators at the Cockcroft Institute, Daresbury. In combination with the Stereotactic Ablative radiotherapy and Magnetic Resonance Imaging guided radiotherapy (operational 2017), this will be the first and only UK site with three advanced state-of-the-art radiotherapy delivery techniques.

UoM, The Christie and CRUK have invested £28.5m in a new cancer research facility, and are establishing the **Manchester Centre for Cancer Biomarker Sciences**, a national centre, which will link to the Precision Medicine and Medicines Discovery Catapults (see Chapter 4), and identify groups using proteomic, genomic, environmental, imaging and circulating tumour (liquid biopsy) biomarkers to lower future cancer risk – acting as a global hub that will pioneer personalised cancer treatment.

The **Health eResearch Centre (HeRC)** (£4m capital and £4m revenue from multiple funders) at UoM is one of four centres that make up the UK-wide health informatics research collaboration that is The Farr Institute. The collaboration involves UoM and Public Health England, alongside 19 other academic institutions/ health partners, to deliver advances in healthcare using 'Big Data', and has attracted £20m capital funding from government, research councils, and industry. HeRC will transform the delivery of health and social care through projects in areas such as self-care, integrated care, patient experience, and real-time monitoring using smartphones, wearable devices and accessible health-care records. As members of the NHSA[47], HeRC and GM partners are also working on the **Connected Health Cities** programme (government funding of £8m to GM), which will drive health careinnovation through the integration, analysis and use of data across primary, secondary and social care.

The **DataWell informatics project** (£6m over two years) at Citylabs links data across different health-care organisations to improve clinical care and patients' access to information. It is working with 12 health and social care organisations, and will extend its reach to cover the whole of GM by 2018.

The **Manchester Centre for Genomic Medicine** is one of the largest and most comprehensive genetics units in Europe, employing ~250 staff and with a national molecular testing role for around 50 services - developing new tests for the NHS as well as supporting the development of genetic services internationally. It handles 8% of all England's complex single gene diagnostics[48].

The **Stoller Biomarker Discovery Centre** (£18m funding, including £4m in private sector support) based at MSP Citylabs is among the largest clinical proteomics centre in Europe, and is linked to the Farr Institute to ensure rapid merger of clinical data.

The **UK Biobank**, hosted at UoM, is the largest repository in the world for over 500,000 human samples generating an important database for future research into major diseases, with the aim of improving prevention, diagnosis and treatment.

MMU has established a £2.5m strategic partnership with Nuffield Health to undertake research and workforce development around health, wellbeing and behaviour change - supported by four centres for health related research and knowledge, including ageing.

Alderley Park in CE (1.5m sq.ft. office and laboratory space, owned and operated by MSP[49]), is home to over 150 bioscience companies with specialist industry facilities and equipment for chemistry, bioscience, drug metabolism, mass spectrometry and nuclear magnetic resonance (see Chapter 4). Alderley Park is also home to important national assets such as the Medicines Discovery Catapult.

Medical education and training: GM trains 24,000 health professionals p.a. which is c.70% of new entrants to the NHS workforce. UoM, MMU and UoS are now working together to better integrate the training of health professionals and are working on plans for a new, joint independent international medical school.

Assets - advanced materials

Advance materials enables advances in technologies across multiple sectors, and is a world-leading scientific strength of the region, exemplified by the Nobel Prize for Physics (2010, Geim and Novoselov at UoM), and Regius Professorships in Physics (2014) and in Materials (2016). More than £120m in capital investment in the National Graphene Institute (NGI) and the Graphene Engineering Innovation Centre (GEIC) will reinforce our position as a leading knowledge centre in 2D materials (including, but no longer restricted to graphene) research and commercialisation, helping maintain the UK's world-leading position in 2-D materials. GM also has world leading capability and equipment in characterisation and imaging, crucial for advanced materials but also applicable to challenges spanning multiple sectors.

UoM's £61m **National Graphene Institute (NGI)** provides facilities for 250 scientists with 69 partner companies. It receives over >600 enquiries p.a. from companies large and small looking use graphene to produce the applications of the future with the potential to revolutionise healthcare, transport, and engineering. This is supported by investments in translational research; the £60m GEIC (see chapter 4) will bring 2D/graphene products closer to market by focusing on pilot production and characterisation to achieve higher TRLs. UoM is working closely with the UK's National Physical Laboratory to develop international standards for graphene and other 2D materials. UoM and NGI are now building strong links with China which is considering its own national graphene strategy, linked to NGI.

The EU €1bn **Euro Graphene Flagship** represents joint research on an unprecedented scale, with a core consortium of over 150 academic and industrial research groups across 23 countries. UoM has received >€4m to support the project, sits on the Executive Board as well as the Management Panel, and is leading work on spintronics,

[47] NHSA is a partnership of NHS and research organisations across GM and 7 other northern cities (see Table 1)
[48] UoM, "Global Challenges, Manchester Solutions", 2015.
[47] The MSP consortium (made up of UoM and Manchester City Council) own 35% of Alderley Park. The remainder is owned by Bruntwood and Cheshire east Council. Additionally, the UoM and Manchester City Council each owns a 12% share of the MSP site on Corridor Manchester.

enabling materials and health applications.

UoM also hosts the **Northwest Composites Centre (NWCC)**, a regional centre of expertise in supporting, evaluating and introducing innovation in manufacture, design, analysis and testing of advanced composites. The focus of the centre is around low cost, low energy, low cycle time manufacture of composites and more specifically structural textile composites, non-destructive and structural health monitoring with state-of-the-art X-ray tomography equipment in the **Henry Moseley X-Ray Imaging Facility** (£19m) and design and failure analysis of polymer composites. Currently there are over 70 PhD students and post doctoral research assistants with funding in excess of £5m from government and industry (aerospace, automotive, wind energy, marine, oil & gas). The Centre also houses the **National Composites Certification & Evaluation Facility**, serving the short term needs of the industry, which can lead to long term R&D collaboration. The facility generates commercial income of £400k p.a.

STFC Daresbury Laboratory is the central hub for the EPSRC National Facility for Aberration Corrected STEM or **SuperSTEM** (one of the world's most powerful scanning transmission electron microscope facilities), which supports multidisciplinary research through access to cutting-edge instrumentation, including electron microscopy and spectroscopy, allowing analysis at the level of single atoms.

The **Cockcroft Institute** at Daresbury (UoM with the Universities of Lancaster and Liverpool, and STFC's Accelerator Science and Technology Centre (ASTeC)) is the national centre in accelerator science. It offers expertise in the concept, design, simulation, construction and operation of accelerators for major science facilities such as the Diamond light source at the Harwell Campus in Oxfordshire. Science facilities such as Diamond are a key research tool to understand the fundamental properties, composition and function of materials at the atomic level. UoM has invested in guaranteed access to a full beamline at Diamond[50], which it uses for research spanning material science, biomedicine, and engineering (linking above to proton beam therapy for cancer). The Hartree Centre at Daresbury (see ASSETS - DIGITAL) provides supercomputing and data analysis infrastructures to deliver the modelling capacity for advanced materials.

Assets - digital

Building on the legacy of Alan Turing at UoM in the 1950s, and development of the first programmable computer (the 'Baby'), today we have strengths in computational science and the use of 'Big Data' which will help drive areas such as healthcare informatics, modelling for advanced materials, and Smart Cities.

UoM's **School of Computer Science** is amongst the largest and most highly rated for research in the UK (4th in the Research Excellence Framework 2014), with major strengths in 'Big Data', artificial intelligence and novel computer architectures – including the world-leading brain-inspired SpiNNaker machine. It has an outstanding track-record of technology transfer, from the earliest commercial computers to the spinout Transitive's virtualisation technology built into more than 17m computers world-wide. Building on these strengths, UoM's **Data Science Institute** brings together over 250 researchers in 'Big Data' from across the University, with strengths in data analytics, machine learning, statistical inference, numerical algorithms, information management, and cyber-security (particularly cryptography). UoM is also a lead partner in the **N8 High Performance Computing Centre** which operates Polaris, one of the 250 most powerful computers in the world.

UoM is also bringing together strengths across the university in cyber security in recognition of the growth in this area and major strengths and opportunities with many local companies in GM. In particular drawing on the university strengths in mathematics, computer science, and linguistics, which are all crucial for cyber security. The GM Local Growth Fund bid included a request for funding for a **Cyber Innovation Centre of Excellence** which would reinforce the impact of the government's National Cyber Security Strategy and exploit GM's rapidly expanding tech sector alongside a large financial and professional services sector (complemented by Fintech and IoT). It would aim to provide an incubation platform to attract, engage and connect entrepreneurs, talent, customers and investors and so support the commercialisation of research and IP. It would also provide collaborative research capabilities, and security intelligence, and also support businesses and the public sector to tackle cyber security and increase resilience.

The **Hartree Centre**, at Daresbury, is one of the world's most powerful supercomputing and data analysis infrastructures, and a leader in the Big Data revolution. It is helping UK industry gain a competitive edge by harnessing the power of Big Data, analytics, visualisation and data-centric cognitive computing. Since 2013 it has received £172m in government investment plus £200m from IBM to establish a R&D programme that will create the next generation of data-intensive systems - bringing people and skills together with the technology to support business developments. The Centre also has a long-term partnership with Unilever to support its R&D processes.

Jodrell Bank (part of UoM) has been designated the international headquarters of the Square Kilometre Array, the largest and most sensitive multi-radio telescope ever to be built. The project involves over 20 countries and will provide high resolution images 100 times faster than the world's current state-of-the-art instruments, helping to answer fundamental questions in physics. The project requires very high performance central super-computing engines and long-haul links in order to analyse the vast quantity of data generated. It will produce data-sets larger than any we currently deal with, pushing innovation in data-handling that will flow through from the 'big science' to industry application, offering an opportunity to locally exploit the know-how that will be developed.

Manchester won a national competition in 2015 (£10m from Innovate UK/government) for **CityVerve**, to demonstrate applications of IoT technologies in four key smart city areas: health and social care, transport, energy and environment within the Corridor Manchester Innovation District. CityVerve

[50] *Diamond Light Source is the UK's national synchrotron science facility, located at the Harwell Science and Innovation Campus in Oxfordshire.*

is based at MSP Central Campus and has 22 multi-sector partners led by Cisco and aims to develop a replicable model for other cities, to deliver more personal, efficient and flexible products and services. It will develop technical models for hyper-scalable cloud services, real-time data sharing, and interoperability of systems and build an IoT business innovation cluster through the incubator and open innovation programme at MSP.

The establishment of a data-sharing authority, **GMConnect**, will break down the barriers which stop public services sharing information. This centre of excellence will identify patterns of behaviour, trends and key relationships to allocate public resources as effectively as possible. The information will support the integration of health and social care in particular, as well as wider reform of public services, to ensure they are better connected and treat individuals more holistically.

The planned **International Screen School** at MMU will bring Science and Creative Innovation together in a new interdisciplinary Higher Education resource, designed and run with industry as partners in learning. Based in Corridor Manchester, it will create a valuable lynch pin for activities in the Creative Digital Sector and become the generator of a new interdisciplinary talent pipeline that will benefit the region and beyond. It will lead to >150 long-term direct/indirect jobs, and generate a GVA uplift of £13m per annum - providing places for 2,000 students over three years, with more than over 100 apprenticeships annually; as well as supporting 100 start-ups and SMEs across the creative and digital health sectors per annum.

Assets - energy

GMCE have a strong heritage in atomic research, building on the pioneering work of scientists such as Dalton and Rutherford. Current local scientific excellence lies in nuclear fuel; reactor design and construction; plant life management; decommissioning and radioactive waste characterisation; non-proliferation and medicine. Strategic partnerships include the National Nuclear Laboratory, EDF Energy, Amec Foster Wheeler, Rolls-Royce, National Grid, Siemens, Arup, Electricity North West, and BP. There is also a significant role in training nationally in the nuclear field. Manchester has the most full-time academics working on nuclear than in any other part of the UK[51].

UoM's **Dalton Nuclear Institute** (DNI) (>£100m research income since 2005; Queen's Anniversary Prize, 2012) exemplifies how GM has provided step-change leadership and investment to invigorate an important research field. Five years ago, research in civil nuclear energy within the UK had fallen to an all-time low along with few nuclear-trained graduates. Today, DNI offers the largest concentration of academic expertise in the UK, with >300 researchers, and 250 civil nuclear supply chain companies. It has 85 international partners/collaborators, 28 from industry and government, 22 from research organisations and 35 from academia. This includes a major R&D facility at UoM's Dalton Cumbrian Facility (holding the world's highest energy dual-beam accelerator system), permitting high-end research into the mechanisms and effects of radiation damage to materials. The Centre for Nuclear Energy Technology within the Institute is working with firms to develop their capabilities as suppliers to new-build nuclear programmes.

UoM is a founder of the National Nuclear Laboratory (NNL), including its flagship facility - the **Central Laboratory in Sellafield**. Once operational in 2018, this will provide a full suite of nuclear technology services making it the most advanced nuclear research facility in the world - including the commissioning of plutonium laboratories and high active alpha/beta/gamma cells.

Nuclear physics is also one of three core strengths of the research base at Sci-Tech Daresbury (see Chapter 4). The **STFC Council Nuclear Physics Group** there supports research in nuclear physics and applied projects in medical and security imaging.

UoM and Sheffield University lead the **Nuclear Advanced Manufacturing Research Centre** (NAMRC) with Rolls-Royce as lead industrial partner (£25m from government). Other founding partners include Areva, Westinghouse, Sheffield Forgemasters and Tata Steel. The Centre has dedicated laboratory facilities within DNI, and access to DNI's extensive manufacturing, testing and analytical resources, using GM's expertise in advanced materials to ensure nuclear reactors are able to withstand extreme conditions. This will be a core programme in the new Royce Institute.

UoM also works closely with National Grid, other UK electricity transmission and distribution network operators on research relating to the design and operation of the UK Electricity Transmission and Distribution Systems. The **National Grid Power Systems Research Centre**, at UoM, houses the largest and best equipped high-voltage (HV) laboratory of any UK university (the only HV lab capable of testing equipment for use on the 400kV network). It is used to support ~£7.5m research projects in energy network. The £13m Intelligent Energy Systems Demonstrator project is under construction at Thornton Science Park.

Triangulum is the €25m Horizon 2020 project to demonstrate cutting-edge smart city technologies and roll them out across the world, and involves UoM and MMU working with Siemens and European collaborators to demonstrate 'smart green growth' to reduce carbon emissions while boosting the economy. €9m will be invested in Manchester.

The **Salford Energy House** (£12m research income), at UoS, is the only full-scale building in an environmental chamber in Europe, and the only full-scale test facility in a controlled environment in the world. It aims to improve the energy efficiency of hard to treat buildings in collaboration with industry. This includes the development and testing of new materials, systems and products and studying human behaviour change associated with the adoption of energy efficiency measures in the home. It complements GM strengths in the development of advanced materials for use across the built environment. Key partners include the Department of Energy and Climate Change (now BEIS), GMCA, Danfoss, Siemens, Honeywell, Saint Gobain and Stelrad.

[51] *"A review of the Civil Nuclear R&D Landscape in the UK" (BIS/DRCC) 2013.*

Assets - industrial biotechnology

UoM has grant income in industrial biotechnology of >£100m, and partnerships with leading companies including GSK, Shell, Unilever and Pfizer to drive the creation of new bio-based chemicals. The work with GSK involves leading Europe's largest public-private partnership on manufacturing sustainable pharmaceuticals, CHEM21, bringing together six pharmaceutical companies, 13 Universities and four SMEs (€26m over four years). The work with Shell will harness the power of synthetic biology to propel chemicals/natural products production towards more sustainable manufacturing processes.

The **Manchester Institute of Biotechnology** (MIB) at UoM is one of Europe's leading industry facing research facilities. It focuses on green and highly efficient manufacture of industrials chemicals, bio- and second-generation fuels, with research covering atomic, molecular, systems, and organism levels. It houses 500 multidisciplinary researchers, and over the last decade has had more than 2,800 publications, produced eight spin-out companies and supported 51 patents. It collaborates with over 500 research partners in more than 65 countries.

UoM hosts **SYNBIOCHEM** at MIB, a UK/European Centre of Excellence (£10m BBSRC/EPSRC) for the synthetic biology of fine and speciality chemicals production (including new products and intermediates for drug development, agrochemical and new materials for sustainable bio-manufacturing), with 52 lead MIB investigators.

The **Centre of Excellence in Biocatalysis, Biotransformations and Biocatalytic Manufacture** has its core research facility at UoM and focuses on biocatalysis, looking in particular at engineering enzymes to synthesis new and specific molecules; whole cell biotransformations for rapid access to high-value fine chemicals; and biomimetic chemistry. It works alongside a biocatalytic engineering consortium to link together a wider set of universities.

2.2 SCIENCE AND INNOVATION TALENT

In GM we are embarking upon an ambitious set of reforms to our work and skills system in order to increase productivity and grow the economy. Employers will be at the heart of the system, incentivised to invest in and utilise the skills of their workforce. Developing higher level skills is a particular priority. This aims to ensure there is a seamless system where young people and adults routinely progress to achieve degree level skills and improves levels of graduate retention.

Human capital and talent

GM's four universities together generated almost 20,000 first-degree graduates (STEM and non-STEM) in 2013/14[52]. GM contributes to 7% of UK's doctorates overall, and almost 8% of England's STEM doctorates (11,000 students). The universities have over a million alumni across the world, and are in contact with a very large proportion, many of whom are in prominent positions in business, universities or governments. In STEM subjects, there are a total of ~43,000 students in GM (~32000 undergraduates and ~11000 postgraduates).

Apprenticeships

Through the GM apprenticeship strategy[53], we are developing an approach to significantly increase the number and quality of apprenticeships delivered. Ensuring a substantial increase in the number of degree and higher level apprenticeships in GM's growth sectors is of particular importance.

During 2014/15, over 1,000 digital apprentices started in GM workplaces across six frameworks and digital standards. In 2015, MMU launched its Digital and Technology Degree Apprenticeship programme[54]. The programme combines a focus on technical computing skills with units on business and enterprise. The first cohort of 60 apprentices included employees from twelve organisations (Barclays, AstraZeneca, Lloyds, and Thales and a range of regional SMEs). MMU also has further higher and degree level apprenticeships in delivery in Chemical Science[55].

Since 2013, UoS has delivered its Broadcast Engineer Degree Apprenticeship to 60 apprentices employed by the BBC[56]. It will launch its Chartered Surveyor Degree Apprenticeship in 2016. The GMCA, via the Greater Manchester Apprenticeship Hub, is also currently funding a project which aims to generate interest in careers in science amongst young people, stimulate the offer of high-quality apprenticeships amongst industry employers, and to develop provider capacity within GM.

Education and skills

GM has identified that it needs an education and skills system that delivers the higher level and technical skills needed to drive the productivity of our key growth sectors. The quality of Careers, Education, Information, Advice and Guidance (CEIAG) must radically improve to ensure that young people and their parents/teachers understand the range of education, training and employment opportunities available and are able to make informed choices about their future career. CEIAG will link young people's aspirations with labour market opportunities stimulating demand in key areas of economic growth eg STEM, and life sciences.

Clear vocational pathways for 16-19 year olds are also needed - in line with the government's Post-16 Skills Plan published in July 2016, alongside the independent review of professional and technical education led by Lord Sainsbury. After undertaking a broad and balanced curriculum until age 16, young people with follow either an academic or technical route. The academic route is already well regarded with universities sitting at the heart of the local skills ecosystem but we must ensure that technical education is of the highest quality, leading to progression into skilled employment. Young people following the technical option will undertake 1 of 15 routes covering college-based and employment-based education (apprenticeships) equipping individuals with the technical knowledge and practical skills valued by industry.

[51] "A review of the Civil Nuclear R&D Landscape in the UK" (BIS/DRCC) 2013.
[52] "Mapping local comparative advantages in innovation. BIS (2015)
[53] http://neweconomymanchester.com/our-work/skills-employment/gm-apprenticeship-hub
[54] http://www2.mmu.ac.uk/apprenticeships/students/digital--technology-solutions/
[55] http://www.mmu.ac.uk/news/news-items/2187/
[56] http://www.salford.ac.uk/news1/university-of-salford-apprentice-wins-bbc-accolade

3

Excellence in science and research

Rankings, Research Excellence Framework (REF) and research outputs

In the most recent international university ranking tables UoM rose from 41st to 35th in the world in the Academic Ranking of World Universities, and from 33rd to 29th in the QS rankings. The latest *Nature* review of improvement in research ranked UoM 18th globally, and 2nd in Western Europe[57].

The Audit area contains 4 HEIs and 19 FCEs[58]. The area locally accounts for 4% of the UK's REF-submitted university researchers. On research power the UoM was ranked 5th in the UK (83% of research activity world-leading or internationally excellent), and 92% of the impact was ranked outstanding and of very considerable reach and significance.

Citation evidence of excellence is presented for each of the areas[59].

Health innovation

In health, the combined result of all health disciplines ranked UoM 5th in the UK for research power in medical sciences, the highest-ranking institution outside the South East. UoM is particularly strong in allied health professions, dentistry, nursing and pharmacy; ranked 1st in the UK.

In a citation analysis based on publications containing health innovation keywords, UoM ranked 6th among Russell Group universities in the production of top 10% most-cited papers (335 publications). It is 6th in England for Medical Research Council awards and the only university outside the South East in the MRC Group 1 Universities (>4% of MRC total annual spends). It has >£300m in current live awards in health.

UoM and MMU have among the highest concentrations of research excellence in allied health research in the UK[60]. 100% of the impact of MMU's research in health was rated as internationally excellent and above. Since 2008, MMU has invested over £150m in capital projects to support health research, and is the top 'new' university for power of health research. MMU is using its recognised strengths as a vehicle to develop new approaches to the integration of health and social care.

Advanced materials

Citation analysis of publications with keywords corresponding to the EPSRC strategy for advanced materials showed UoM as producing the second highest number of publications in the top 10% most cited (171) among Russell Group universities, and the highest proportion of top decile papers.

UoM's submission of researchers in electronic engineering, metallurgy and materials represented 9% of the UK's REF submissions and hosts almost 10% of the strongest researchers in the areas across the UK. For aeronautical, mechanical, chemical and manufacturing engineering it has 5% of the UK total. UoM also leads the world in graphene citations and is amongst the world leaders in carbon capture and storage.

The materials group at MMU was named in the world top 10 (out of 3,000) in 2014 by Thomson Reuters on the basis of citations (25,000)[61]. Areas of expertise include antimicrobial anti-adhesive surfaces, additive graphene manufacturing and 3D printed batteries and supercapacitors.

Citations in fast-growth opportunity areas

In our fast-growth opportunity areas, UoM is consistently in the UK's top group both by volume of academic publications / share of the top 10% most cited papers (energy 3rd/3rd; industrial biotechnology 4th/5th and digital 5th/6th).

[57] *http://www.nature.com/nature/journal/v535/n7613_supp/full/535S49a.html*
[58] *Underlying data for local growth 2013-14. Higher Education and local growth. HEFCE (2015).*
[59] *Scopus SciVal data for UoM ranked versus Russell Group comparators based on keyword field definitions*
[60] *Research Excellence Framework (REF) 2014*
[61] *http://sciencewatch.com/sites/sw/files/sw-article/media/worlds-most-influential-scientific-minds-2014.pdf*

4

Innovation

Background

GMCE's key differentiating opportunities for growth, compared with other UK locations, is the proximity of major assets in other sectors (eg digital industries and the dense concentration of professional services) and the concentration of research and innovation assets within Corridor Manchester and into MSP's Alderley Park. This inter-relationship between sectors will be a major driver of growth and innovation. There are slightly more firms in CE engaged in product or process innovation compared to the England average (26%), with a higher average proportion of turnover from product or process innovation (28%)[62]. Nevertheless, we need to do more to ensure that we realise the full potential of our assets to drive innovation and commercialise our research locally. 52% of companies in the NW across all sectors are 'innovation active'; an increase from 42% in 2013, and are broadly in line with the England average (54%) in terms of improving goods/ services or replacing outdated products/ processes[63]. The level of business R&D expenditure per person in CE (£2716) is one of the highest nationally (2013).

As part of the GM Business Survey 2014[64], local businesses were asked whether they had engaged in innovative activities within the last three years. Of the 80% of GM firms that had engaged in Innovative activity in the last three years, the majority had invested in new machinery/plant, additional ICT equipment or additional software. Beyond identifying businesses engaging in innovative activities in GM, the GM survey also compares the profile of these innovative firms with non-innovative firms. The findings revealed that "innovation active" companies in GM are more likely to have reported increased turnover, employment and exports in the last 12 months, compared with non-innovation firms.

Innovative firms also tend to record greater levels of confidence about both future turnover and employment growth, and were more likely to access finance. They are also are more likely to be aware of, and have taken advantage of, local business support programmes, and to have used R&D tax incentives. However, significant barriers to innovation remain, with 30% of firms in the GM survey reported barriers to growing innovation. The main challenges identified were lack of finance to support innovation, lack the in-house knowledge and skills to develop and manage innovation; and, lack of knowledge of funding available to support innovation.

In this section we review the main business presence in each sector and identify the key assets oriented to the support of innovation. We also review the capacity for commercialisation of new technologies through place-based facilities, university technology transfer and business support. Illustrative case studies are embedded.

Place assets / National Enterprise Zones

Four government Enterprise Zones across the locality provide tax relief for small businesses, allowing all business rates growth within the zone to be retained and reinvested to support the local economic priorities and ensure that Enterprise Zone growth is enjoyed locally. The zones are especially tied to developing our local science assets:

Sci-Tech Daresbury has over 1,200 people on-site including >400 scientists working in fields including accelerator science, high-performance computing, simulation and data analytics and sensors and detectors. It operates large-scale facilities used by many UK universities and increasingly to industrial companies (eg IBM, Unilever, Bentley Motors, and BAE Systems). It includes STFC Daresbury Laboratory, The Hartree Centre, the Virtual Engineering Centre, Cockcroft

[62] *Technopolis Data (see Annex B)*
[63] *BIS: "Headline findings from the UK Innovation Survey 2015", March 2016.*
[64] *http://neweconomymanchester.com/media/1453/final-gm-business-survey-report-2014.pdf*

Institute and over 100 high-tech companies employing over 500 people in areas such as advanced engineering, digital/ICT, biomedical and energy and environmental technologies, varying from start-up companies to more mature SMEs to international corporates such as IBM and Lockheed Martin. About one in six are global multinational companies.

Corridor Manchester is home to an exceptional group of knowledge-intensive organisations and businesses. The area has consistently generated ~ 20% of the city's GVA, employing over 63,000 people within this large scientific and digital community, with over half these in knowledge-related sectors, and an anticipated 14,000 additional jobs by 2025. The area offers co-location opportunities for companies to access university research, the largest hospital in the region, laboratories, incubation and grow-on space with the additional benefit of Enterprise Zone status for two sites within the Innovation District. More than 70,000 students study in the area, with 25,000 of these studying engineering, medicine, computer science and biological sciences. The next ten years is a decade of opportunity for the Corridor Manchester area, with over £2.6bn investment planned up to 2025. The Corridor Manchester partnership has been in operation almost ten years and enhances economic growth through collaboration, leveraging assets and catalysing innovation.

Cheshire Science Corridor was awarded Enterprise Zone status in 2016, and encompasses many interconnected assets in advanced scientific analysis and research, pharmaceuticals R&D, pharmaceuticals manufacturing, chemical engineering, energy and nuclear engineering, radio-astrophysics and astronomy; including Capenhurst Technology Park, Thornton Science Park, Birchwood Park's Nuclear and Forensics Clusters, and MSP's Alderley Park.

Airport City Enterprise Zone is a 5m sq.ft. site development and involves a significant new business destination in the area immediately adjacent to the airport's terminals and ground transport interchange. Complementing this will be health and biotech-related research and development, and training facilities associated with 'MediPark', a new development linked to one of GM's major hospitals, which also benefits from the proximity of Manchester Airport. An £800m expansion of Manchester Airport is currently underway in order to create 'Airport City' (offices, hotels and logistics), in partnership with the Beijing Construction Engineering Group.

Health innovation assets

In terms of business clustering, there were ~260 companies operating within the biomedical sector in GM in 2015, employing 8,777 people. GM is home to 40% of all pharmaceutical, and biotechnology companies and contract research organisations companies in the NW. The GM sub-cluster maintains a strong offering across the whole range of competencies with particular strengths in biotechnology, CROs, diagnostics, analytics, medical technologies, and healthcare companies. Calculated GVA for the GM biomedical sector core companies is £245m[65].

The range of companies in our region encompasses global pharmaceutical companies (eg Actavis, AstraZeneca, Bristol-Myers Squibb, Medtonic, Sanofi-Aventis, Teva); a significant analytical and healthcare presence (eg Waters, Unilever, Thermo Fisher, Hologic, Qiagen Manchester, Advanced Medical Solutions); growing biotech companies (eg C4X Discovery, Epistem, Redx Pharma, Cyprotex, Premaitha Health); and many other spin-out and start-up companies.

MAHSC is working in partnership with Northwest e-Health and Hitachi to test new technologies in health informatics to deliver new services for the NHS. Hitachi has established its **European Big Data Laboratory** at Citylabs to start proof-of-concept projects for improving healthcare using informatics (see below under Digital assets).

Innovation support institutions, include the national **Medicines Discovery Catapult** (£5m initially from Innovate UK), based at Alderley Park, which will support industry to develop new technologies for the preclinical evaluation of medicines. It will operate at the earliest stages of medicines development, developing and validating new technologies for testing potential diagnostics and medicines ahead of human trials. This national Catapult will grow the UK's commercial medicines discovery capability to improve productivity in drug development and approval. This is complemented by the **MedTech Centre Incubator** based at MSP's central campus and which contains office and dry-lab facilities. It will also link to the Precision Medicine Catapult at the University of Cambridge through the UoM which is a recognised 'spoke' of this Catapult.

Case study:

Antimicrobial resistance (AMR)

The AMR Research Centre at Alderley Park is a major new facility to support the development of new antibiotics and diagnostics via an integrated development capability. It has major international funding, and with UK government support, will become a world leader in AMR[66].

The Centre will be a major partner in the new international Combating Antibiotic Resistance Bacteria Biopharmaceutical Accelerator – CARB-X. The Centre is expected to receive funding up to US$14m in year one and $100m in total over five years. The Wellcome Trust will also contribute funding. This will allow the Centre to focus £175m in total on helping SMEs progress R&D in support of clinical trials to address the global challenge of AMR.

The Medicines Discovery Catapult which is based at Alderley Park will contribute to the AMR agenda by developing new approaches for the discovery and early development of new medicines. Several businesses at Alderley Park are already working on developing new antibiotics, as part of a worldwide drive to find more effective treatments, for example, Redx Anti-Infectives Ltd. Corridor Manchester will reinforce this activity - including innovative work underway at UoM to consider the development of new antimicrobial surface coatings using graphene.

[65] *Bionow, "Biomedical Cluster Mapping Update for GM 2002-14", January 2015.*

[66] *http://cheshireeast.gov.uk/council_and_democracy/council_information/media_hub/media_releases/cheshire-east-joins-international-fight-against-antibiotic-resistance.aspx*

Citylabs 1.0 (MSP) is a commercial R&D facility for healthcare and medical technologies with 120,000 sq.ft. of office and laboratory space in the heart of the CMFT campus. Citylabs brings together business with the NHS and universities to accelerate innovation and growth in this leading healthcare and medical technologies cluster. Plans for Citylabs 2.0 and 3.0 are already well developed (an investment of £60m will bring in £100m GVA and create 750 jobs)[67].

Advanced materials assets

Businesses involved in the development and fabrication of advanced materials are mainly linked to the advanced manufacturing sector, with links to neighbouring geography in Sheffield and Lancashire. There remains significant investment by Siemens in GM focused on industry automation and drive technologies, low voltage activities and building technologies. There are a number of smaller electronic designers and contract manufacturers (including semi-conductors) such as Zetex and Ferranti, as well as a legacy of mass spectrometry businesses. TBA Electro Conductive Products Ltd in Rochdale is one of the first firms in the world to develop a product containing graphene through a sprayable transparent conductive coating aimed at the food, electronics, pharmaceuticals and petrochemicals sectors.

UoM is the hub for the £65m **BP International Centre for Advanced Materials** (BP-ICAM), which leads advanced materials research into fuels for the oil and gas industry by feeding research back into business operations, understanding impacts around safety, reliability and performance. It has seen a footfall of over 500 BP personnel since opening, and four senior BP staff are permanently on site in ICAM's on-site campus office. Satellite centres include the University of Cambridge, Imperial College London and the University of Illinois at Urbana-Champaign.

In addition to **NGI**, which is now fully operational, several world-class support institutions are under construction. The £60m **GEIC** (UoM, open in 2018) will bring 2D/graphene products closer to market by focusing on pilot production and characterisation, with application development in composites, energy, solution formulations and coatings, electronics, and membranes. It has received £30m from the Abu-Dhabi based renewable energy firm Masdar focused on the deployment of clean technologies[68].

The new £235m **Sir Henry Royce Institute for Materials Research and Innovation** will bring science together with business application to address societal challenges. It will encompass 14 areas of materials research across four themes – energy, engineering, functional and soft materials. The hub is based in UoM, with 'spokes' at the Universities of Sheffield, Leeds, Liverpool, Cambridge, Oxford and Imperial College London. This work is particularly supported by the institute's excellent imaging capability. The National Nuclear Laboratory and the Culham Centre for Fusion Energy are also key partners – recognising the need to test materials to withstand extreme conditions for applications such as nuclear new build.

The **Manchester Engineering Campus Development** (£350m capital investment from UoM) at UoM will bring together research, teaching, expertise and facilities of four schools and two research institutes into a single engineering campus, along with space to host industrial partners (76,000m^2 floor space, 1,300 staff members, 6,700 students). This will be adjacent to NGI and the Royce Institute. The co-location of a range of engineering disciplines facilitates collaborative inter-disciplinary working to tackle complex engineering problems and best prepares students for careers in industry.

Case Study:

Aerospace Technology Institute (ATI)

The NGI and the University of Central Lancashire (UCLan) Engineering Innovation Centre is partnering with engineering and advanced materials initiatives and facilities in GM and Lancashire to promote progression in skills and technology development in the aerospace sector. UoM and UCLan are developing a national technology road-map for the exploitation of graphene within the aerospace sector working with the ATI and a number of businesses in the aerospace supply chain, many of which are based in the region. They have produced a first prototype graphene-winged Unmanned Aerial Vehicle which achieved its first flight at the Farnborough International Airshow in July 2016, and are looking to develop a graphene aerospace strategy and programme of work to start in 2017. The development has potential for spin out into other sectors[69].

UoM, MMU, Manchester School of Art, University of Bolton and UoS collectively represent one of the largest concentrations of teaching and research into advanced textiles in the world. For example, the Institute for Materials Research and Innovation at Bolton leads applied materials science working to grow SMEs around the development of designer materials at the micro/ nano level in areas such as medical devices, biosensors, diagnostic devices, and energy fibres. It will operate out of the new £13m STEM building from 2017 in a facility designed to significantly accelerate SME Innovation and product development. Additionally, the textiles industry concentration in GM is almost three times the national average. Major local firms involved in Medical Textiles include Tamicare, Sterling Non-wovens, and Lantor UK. Tamicare has used R&D to develop the world's first-ever technology for creating 3D print finished textile products (bringing together digital with materials technology).

Digital assets

At Sci-Tech Daresbury, the **Virtual Engineering Centre** is the UK's leading centre for virtual engineering technology integration for commercial applications. This allows firms to develop and test virtual prototypes, therefore conducting R&D more quickly and cheaply than would ordinarily be possible, and accelerating the route to market. Key industry partners include JLR, Bentley Motors, Aston Martin and SME BAC Ltd, Schlumberger, Sellafield (energy), and Hitachi Rail (transport). At Sci-Tech Daresbury there is a growing cluster of businesses focused around data-centric technologies.

[67] *http://bruntwood.co.uk/news/citylabs-expansion-announced/*
[68] *http://www.manchester.ac.uk/discover/news/new-60m-engineering-innovation-centre-to-be-based-in-manchester*
[69] *http://www.graphene.manchester.ac.uk/latest/?archive=twelvemonths&id=16957*

MediaCityUK in Salford (GM) is the largest purpose-built media location in Europe (2,600 BBC staff including the base of Connected Studios, the BBC's digital R&D arm); ITV; UoS, and a University Technical College (teaching DCI and Entrepreneurship) and over 250 businesses. It also houses the largest HD studio complexes in Europe. The Sharp Project in East Manchester (200 sq.ft) hosts >60 digital entrepreneurs and production companies specialising in digital content production, digital media and TV and film production. The Space Project in Gorton (360k sq.ft) has facilities for large-scale TV and film production.

MSP's central campus on Corridor Manchester has >80 digital technology companies employing >1,500 people including many university spin-outs such as Telecity, and local scale-up companies (Metronet (UK), ANS Group). It also hosts Hitachi's European branch of Hitachi's Global Centre for Innovative Analytics at the **European Big Data Laboratory** with strong links to the US, as well as the Cisco CREATE UK R&D team. The campus is the HQ of Innovate UK's CityVerve IoT's City Demonstrator which is developing a business innovation cluster in the areas of IoT and Smart Cities along with Cisco's Mi-IDEA innovation centre to provide scale-up support to digital innovation businesses.

GMCE and Sci-Tech Daresbury together form a major business cluster in the digital and technology sector. Around 33,000 people are employed in the digital sector locally, contributing just over £2bn GVA p.a.[70], with an additional equivalent number in tech jobs[71]. Prominent business sectors are around EdTech, digital advertising and marketing, FinTech, and e-commerce. Significant firms include Apadmi, Cisco, Hitachi, Siemens, TalkTalk, UKFast, and Zen Internet. CE has more than 2,000 creative digital businesses (5,000 employees), with a mix of established multinationals and innovative SMEs, including the £1bn turnover company Cloud Imperium, McCann, Mobica and Think Positive. Barclays' UK Global Technology Centre (employs 4000) focuses on developing new FinTech technologies and applications, and supporting new technologies through 'FinTech accelerators'.

GM has a cluster of strengths around **cyber security**, which is recognised as a Tier 1 threat to national security, costing the UK economy an estimated £27bn annually in things such as fraud, extortion, intellectual property and data theft. This is complemented by supporting strategic strengths in FinTech and the Internet of Things. NCC Group (FTSE 250) is headquartered in Manchester and employs over 1,800 people worldwide. It is at the forefront of the fight for better cyber security. GM also houses the offices of global companies such as Raytheon, BAE Systems and Qinetiq, while UoM has significant activities in cyberphysical systems and self-defending networks. Other key components of the burgeoning cyber community include Barclays Rise and the soon to be launched 'The Vault', aimed exclusively at FinTech and cyber security companies. In addition there are significant public sector initiatives driving co-ordinated data sharing which will rely on, and support developments in, the high levels of cyber security.

Concentrations of technology/ digital business activity in CE are centred in Macclesfield and Wilmslow. A review of sub-sectors by the Skills and Growth company in CE identified particular strengths in IT and software, advertising, and design. It has major global companies, 80% of which are SMEs. The Siemens Digital Factory at Congleton supplies >1.2m variable speed drives into 78 countries. It has also adopted virtual reality technology – with Siemens' 3D cave helping it test product, work station and factory layout concepts in the virtual world before making them a reality[72]. Daresbury and MSP's central campus are additionally a growth point for the cluster of digital businesses which are growing up around the Hartree Centre and IoT city demonstrator respectively.

Energy assets

Key energy companies headquartered locally include Electricity North West, United Utilities, Certas Energy and Nuvia, Schneider Electric, Boulting Group, EA Technologies and Oliver Valves. Siemens' site in Congleton develops and supplies drive technology for use in hybrid buses, wind turbines and many other applications.

Birchwood represents a significant cluster of nuclear-related industry and expertise, especially around design engineering. This includes NNL facilities which lead on modelling and simulation, engineering, and environmental management, and the Nuclear Engineering Design Centre for Sellafield Ltd which reinforces local supply chain linkages. Other nuclear-related firms include Rolls-Royce Nuclear, Atkins, Amec Foster Wheeler, AREVA, and ACEOM – with expertise across new build, plant life extension and decommissioning. **AMCE's Nuclear Analytical Services Laboratory** is Europe's largest commercial radiochemical analysis laboratory and has a new High Temperature R&D Facility at the site for testing materials used in nuclear reactors. Other key sites for nuclear include Springfields Fuels (nuclear fuel production) near Preston; Capenhurst Nuclear Services Limited near Chester; and Redhall Nuclear in Cumbria.

Case study:

NuGen

NuGen is a UK nuclear joint venture between Toshiba and ENGIE (formerly GDF SUEZ) – scaling up to employ ~300 people by 2018[73]. Its Moorside project in Cumbria (potentially £10-15bn) will develop a new generation nuclear power station of up to 3.8 Gwatt. The reactors will use Westinghouse AP1000 technology and will come online from the mid-2020s, delivering enough low carbon electricity to power up to 6m homes. 14,000 to 21,000 jobs will be created over the lifetime of the project (from development to decommissioning).

NuGen has moved its UK headquarters from London to Manchester, offering the opportunity to develop strong industrial relationships with local companies, and draw upon local academic excellence in nuclear research.

Industrial biotechnology assets

MSP **BioHub Incubator** at Alderley Park is a life science incubator which provides office/ lab space with access to chemical and biological facilities, and virtual

[70] *Greater Manchester Forecasting Model, 2015*
[71] *Tech Nation 2016.*
[72] *Unlocking our potential, NWBLT, 2014*

workspace to allow scientists and small teams (who may not yet be ready to take on the costs of rented physical space) to benefit from being part of the community of over 90 incubator businesses.

There is an important cluster of biotechnology businesses in the region include Ai2 Absynth Biologics, Blueberry Therapeutics, Carbogen Amcis, Conformetrix, Oxyrane, C4X Discovery, Evgen, Epistem, F2G, Gentronix, Imagen Biotech, Intercytex Medicine, Molplex Pharmaceuticals and Thermo Fisher Scientific. Local spin-outs include C4X, PharmaKure, PeptiGel Design, and Spectromics working on AMR. 1,800 people are employed locally through AstraZeneca - 800 in a significant R&D facility developing new medicines in Macclesfield, most of which will remain after AstraZeneca's R&D relocation to Cambridge. The region includes AstraZeneca's largest pharmaceutical development team in the UK, with a £63m Pharmaceutical Development laboratory, complemented by AZ's biggest pharmaceutical manufacturing site in the UK, linking together innovation with the production of goods.

Case study:

Waters Corporation

The Waters Corporation in Wilmslow aims to enhance collaboration and drive innovation in mass spectrometry - from pharmaceuticals to food safety. Waters recently announced it had acquired Rapid Evaporative Ionisation Mass Spectrometry technology to investigate application in surgery, which could provide surgeons with diagnostic information about the tissue they are cutting into in real time[74]. Elsewhere, the Waters Open Access Analytics Lab (at Alderley Park) will offer state of the art liquid chromatography, mass spectrometry and informatics technologies to support the pharmaceutical and life science industries.

University innovation partnerships

UoM has an exceptional level of engagement with business, ranking top for the value of research contracts with UK companies over a two-year period[75] and consistently in the top 5 for all industrial engagement. It has a series of strategic partnerships with major UK companies, most of whom have a strong regional presence. The depth of partnership is illustrated by the fact that the University has the highest number of co-authored papers with Unilever and Syngenta, the second highest with Astra Zeneca (after work with its Swedish counterpart), the National Grid and EDF energy, and is in the top 5 for several more (Scopus data).

UoM's commercialisation subsidiary, UMI3, produces ~400 invention disclosures p.a., manages a portfolio of 28 spin-outs, has 100 inventions licensed in the past four years, and holds the UK's largest portfolio of graphene patents. Commercialisation via UMI3 is consistently ranked in the top four in UK in terms of viable spin-outs. UoM's Intellectual Property Premier Fund has invested £32m in late-seed, clean-tech, materials and medical technologies ventures. Examples of healthcare start-ups include Bioxydin (oxygen enhanced magnetic resonance imaging (MRI) biomarkers), Epistem (adult stem cells in oncology and commercialisation of a tuberculosis test), Spectromics (fast point of prescription test to guide use of antibiotics), and C4X Discovery (Nuclear Magnetic Resonance (NMR) technology-based design and drug development company). The spin-out Phagenesis was recently the subject of a high profile sale to Nestle health-care.

MMU generated 72 new business starts for 2013-14 and in 2016 was ranked 7th nationally for the number of Knowledge Transfer Partnerships it has created - an example is the work with the Stockport-based logistics company, ServicePower, to use expertise in digital and develop a quantum computing programme that can optimise the fastest routes for vehicle delivery.

The Industry Collaboration Zones (ICZs) at UoS are part of a £100m 5-year investment; £12m committed. ICZs are based around existing industry partnerships and areas of research across four sectors: Engineering and Environments; Health and Wellbeing; Sport; and Digital and Creative. They bring together academics, students, industry and communities, to create transdisciplinary and technology-enabled environments (physical, virtual and remote).

UoS was ranked 5th nationally for its activities with SMEs in the Witty Review (2013), working with 3,700 companies in the three years of the review. It assists in the creation of over 50 student start-up companies p.a. with >100 student start-ups still active. It has a portfolio of 10 spin-out firms[76].

Science parks and incubators

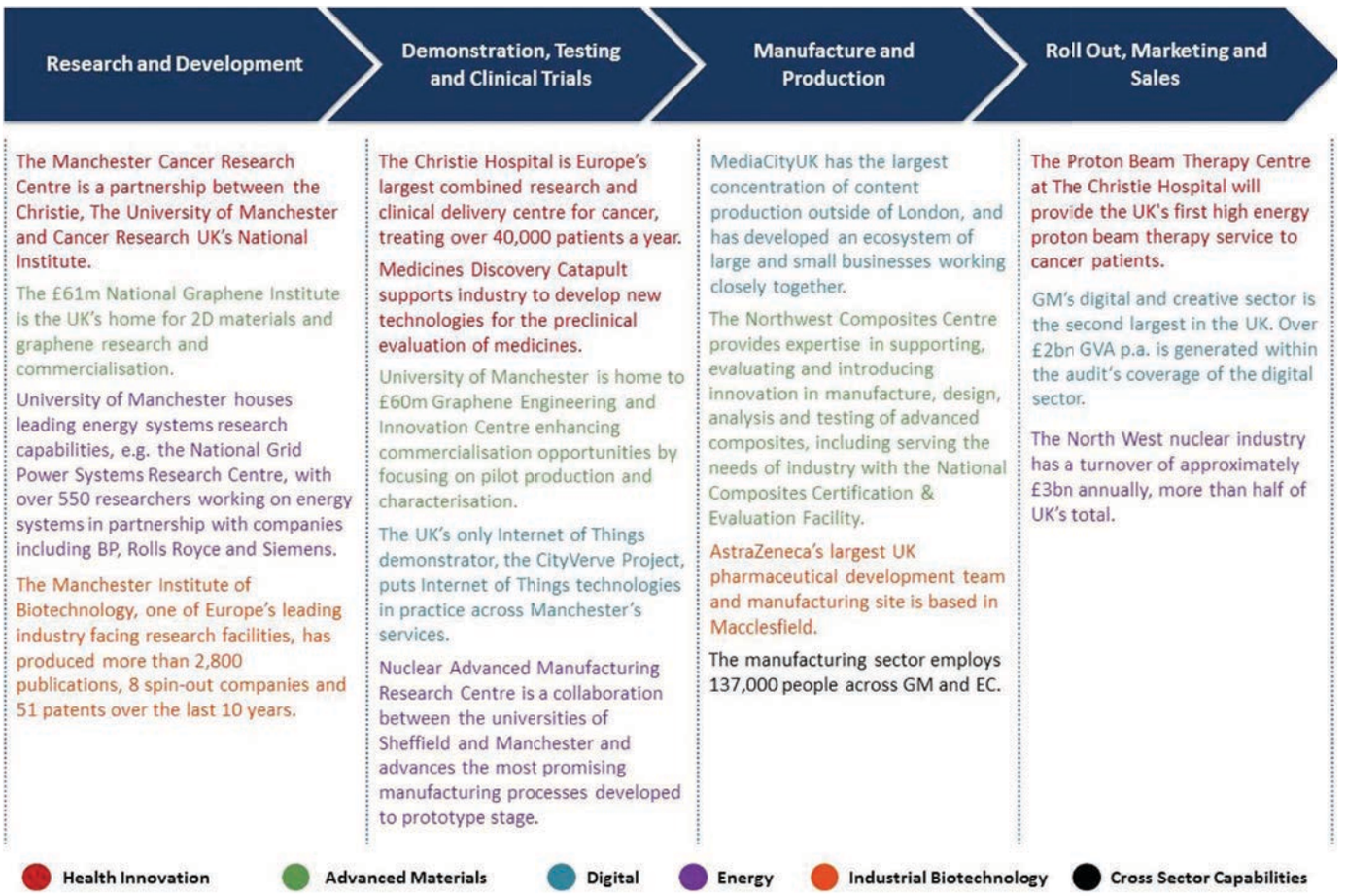
Manchester Science Partnerships is the largest science and technology park operator in the UK, providing infrastructure and innovation ecosystem to support the commercialisation of R&D and help companies to grow. It has 300 science and technology companies across its 2m sq. ft. portfolio, with the majority of firms it supports engaged in life sciences, and in Digital and Creative Industries. MSP is a partnership business established to grow the city's knowledge economy with shareholding split between Manchester universities, local authorities, NHS and private sector.

Sci-Tech Daresbury is a national science and innovation campus, with over 400 scientists in fields including materials and digital. It has 100 high tech companies employing >600 people and has developed c100 new products and services in 2015 alone. STFC's healthcare, innovation-focused Medical Technology Exchange Centre (MedTech) in particular - brings together expertise from STFC, the NHS and other related fields.

Local incubator space include the UoM Manchester Incubator R&D centre (87k sq.ft.) combines lab/office facilities for biotech start-ups, R&D satellites from pharmaceutical companies and service based companies; The Shed at MMU brings together start-up businesses, digital research and teaching while partnering the business incubation unit, Innospace (since 2007 it has supported >350 new businesses to create 500 new jobs); Barclays Rise in central GM (second site in the UK) is part of a global community to bring start-ups together to

[73] *http://nugeneration.com/*
[74] *http://www.waters.com/waters/library.htm?locale=en_PH&lid=134912089*
[75] *HESA data for 2013/14 and 2014/15*
[76] *Such as Salfordinsole (foot orthotic products) which has led to the sale of more than 50,000 pairs of orthoses to the NHS.*

Figure 1: Innovation from start to finish in GMCE



share knowledge and to support the development of the financial services sector (particularly fin-tech and digital) in GM with over 60 start-ups and is closely connected to the Barclays UK technology HQ in Knutsford. The space also hosts hundreds of events for the Manchester tech community and runs hackathons to support the development of new digital products for the Barclays platform. MSPs specialist incubators include the MedTech Centre and Mi IDEA digital innovation centre within the Corridor campus, and the BioHub incubator at Alderley Park.

Business Growth Hubs and business schools

The Business Growth Hub (part of the Manchester Growth Company) is working with partners to respond to the challenge of increasing investment in research and innovation in GM through improving access to expertise and facilities, including within the university base. It is working jointly with the four universities and MSP to simplify access to their expertise and facilities by providing the support of business development roles embedded in each and working as part of a coordinated Innovation Service. Funded jointly the roles will actively facilitate relationships between Innovation Advisors in the Hubs, businesses and those faculties with appropriate expertise, helping to build business confidence and overcome the barriers to collaboration, which can hold back innovation and the benefits of longer term relationships.

CE has established the Skills and Growth Company, which has an integrated model to stimulate the growth and productivity of major corporates and SMEs in high growth and priority sectors including digital, life sciences, energy and advanced manufacturing.

The region's business schools are playing a growing role in fuelling entrepreneurship and enterprise in the region through their training activities. Alliance Manchester Business School is directly engaging in action research with the sectors addressed in the Audit, including collaborative projects with the NGI, MIB and in Health devolution.

InnovateUK funding

Between 2002 and 2016, Innovate UK provided £80.8m of grant funding to 770 projects in GM. The majority of projects are based in Manchester and are academic research projects[77].

Beyond traditional grant funding, Innovate UK has also supported 769 live or completed Knowledge Transfer Partnerships (KTPs) with companies in the North West. This has been to the value of £8.2m (2010-16). Of these, 409 are partnered with MMU (172), UoM (146) and Salford (91). The KTPs, covering a range of areas of research, predominantly within the key sectors of advanced materials, bioscience, medicine and healthcare, and electronics.

Research & development tax credits

HMRC R&D tax credits are designed to encourage greater R&D spending, leading in turn to greater investment in innovation. They work by reducing a company's tax bill by an amount equal to a percentage of the company's allowable R&D expenditure. The data for firms in the North West of England (lowest area available) shows a total of £130m claimed in 2016, up 24% on the previous year. The North West is fifth in the UK rankings in 2016 on R&D tax credit claims, behind London, South East £410m, East of England £250m, and the West Midlands £180m. Data on the Patent Box Tax relief also shows a marked difference in companies claiming relief, with the North West making up just 1% of the UK compared to London 57%. The GM Business Survey asked respondents about awareness and uptake of R&D tax credits. Research by New Economy led to some key findings which indicated that firms were experiencing barriers to uptake of the credits. This included not properly understanding R&D tax credits, not being of the view that they will necessarily help the business, being unsure whether the firm qualifies for them, or finding them too complex to implement[78].

[77] *Available at https://www.gov.uk/government/publications/innovate-uk-funded-projects*
[78] *http:/neweconomymanchester.com/media/1453/final-gm-business-survey-report-2014.pdf*

5

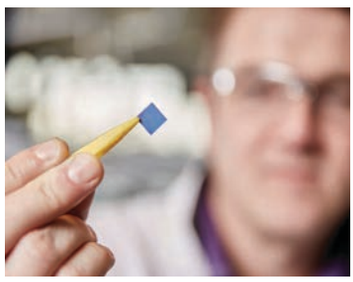
National and international engagement

There are several significant national and international collaborations and partnerships around science and research in our areas of strength involving partners in GMCE. Some examples are given in the table overleaf. It is not, however, intended as an exhaustive list of all activity.

Table 1: Examples of national and international collaboration

Asset / project	National partners	Asset / project	International partners
Health Innovation			
Northern Health Science Alliance (NHSA)	NHS and research organisations in GM and Durham, Lancaster, Leeds, Liverpool, Newcastle, Sheffield, York and Hull	Manchester Integrating Medicine and Innovative Technology (MIMIT)	1st International Affiliate of the Consortia for Improving Medicine with Innovation and Technology (CIMIT)
Connected Health Cities	NHSA + partners across north of England	National AMR Research & Development Centre	Combating Antibiotic Resistance Bacteria Biopharmaceutical Accelerator (CARB-X)
		National Centre for Genomics	Peking University
		Hitachi's Global Centre for Innovative Analytics	US and Japan
Advanced Materials			
BP-ICAM	Universities of Oxford and Cambridge	BP-ICAM	University of Illinois, Urbana-Champaign
Sir Henry Royce Institute	Universities of Sheffield, Leeds, Liverpool, Cambridge, Oxford, Imperial College London	EU Graphene Flagship	Partners across 23 countries
Cockcroft Institute	Universities of Lancaster and Liverpool, Diamond Light Source	NGI	Over 40 industrial partners from around the world
Digital			
HeRC/Farr Institute	Dundee, Swansea, UCL	Square Kilometre Array, Jodrell Bank	Over 20 countries
Energy			
National Nuclear Laboratory (NNL)	Cumbria	Triangulum	Eindhoven and Stavanger
Nuclear Advanced Manufacturing Research Centre	University of Sheffield	Dalton Nuclear Institute	85 international partners including Rolls-Royce, Sellafield, Amec Foster Wheeler, NNL etc.
Industrial Biotechnology			
Manchester Institute of Biotechnology	Including Chinese Academy Sciences (Beijing), ETH (Switzerland), Institution of Public Health (Belgium)	Manchester Institute of Biotechnology	Collaborations with over 500 institutions in over 65 countries

6



International developments in science and technology

Our core strengths and opportunities relate closely to the government's 'eight great technologies'. These are areas where the UK can lead the world based on analysis of the UK's scientific and business capabilities: Big Data and energy-efficient computing; satellites and commercial applications of space; robotics and autonomous systems; synthetic biology; regenerative medicine; agri-science; advanced materials and nanotechnology; energy and its storage.

Our five areas of strength demonstrate excellence in themselves, but it is clear that additional "spill-over" economic value is created when they combine together to create new innovations related to these eight great technologies. Research that addresses key societal, industrial and national challenges must be multi-disciplinary, and will not be solved within one discipline alone. The potential for inter-connectedness will enable GMCE to co-develop applications in new and disruptive technologies and respond to national and global customer demand (see Figure 1; Annex D includes a list of areas where partners have drawn together some ideas as a direct result of the audit work).

This is already happening locally in partnership with industry as a result of cross-disciplinary working. Our strong legacy of manufacturing, which we are working to reinstate, gives us a genuine opportunity to turn ideas into products. We also need to recognise that goods and services need to be tailored to serve the specific needs of customers in different parts of the world. It is also important to acknowledge that by their nature strengths in digital and advanced materials are cross-cutting and provide an "enabling" function.

In 2015 Elsevier published a comparator of various measures of research and innovation strength in Amsterdam along with ten other cities: Barcelona, Berlin, Brussels, Copenhagen, Dublin, Hamburg, Madrid, Manchester, Stockholm and Vienna. Despite not being a capital city (and with fewer national research facilities than Amsterdam), Manchester still came 5th out of 11 in scholarly papers/1,000. On academic-corporate collaborations Manchester was 6th and had the highest change in field weighted impact of publications from 2004 to 2013. Manchester came first in world download share from medicine.

Our areas of strength also address key societal as well as economic challenges:

Healthy living and ageing

Ensuring people are able to live healthier lives will not only reduce pressures on healthcare budgets (particularly where they facilitate prevention), but will help to ensure those people remain economically active for longer.

The UK spends >8% of GDP on healthcare, and the domestic healthcare technologies market (estimated £17bn) is set to grow.[79] There is a huge opportunity for advanced materials, physical sciences and informatics/digital to meet health needs. For example, customised biomaterials responsive to the body and its injuries will provide effective and long lasting personalised treatments. Health informatics (health interacting with digital technology) will also be crucial in supporting the next generation of scientific breakthroughs needed to tackle conditions, recognising that we need to be more sophisticated in predicting how patients will respond to treatment.

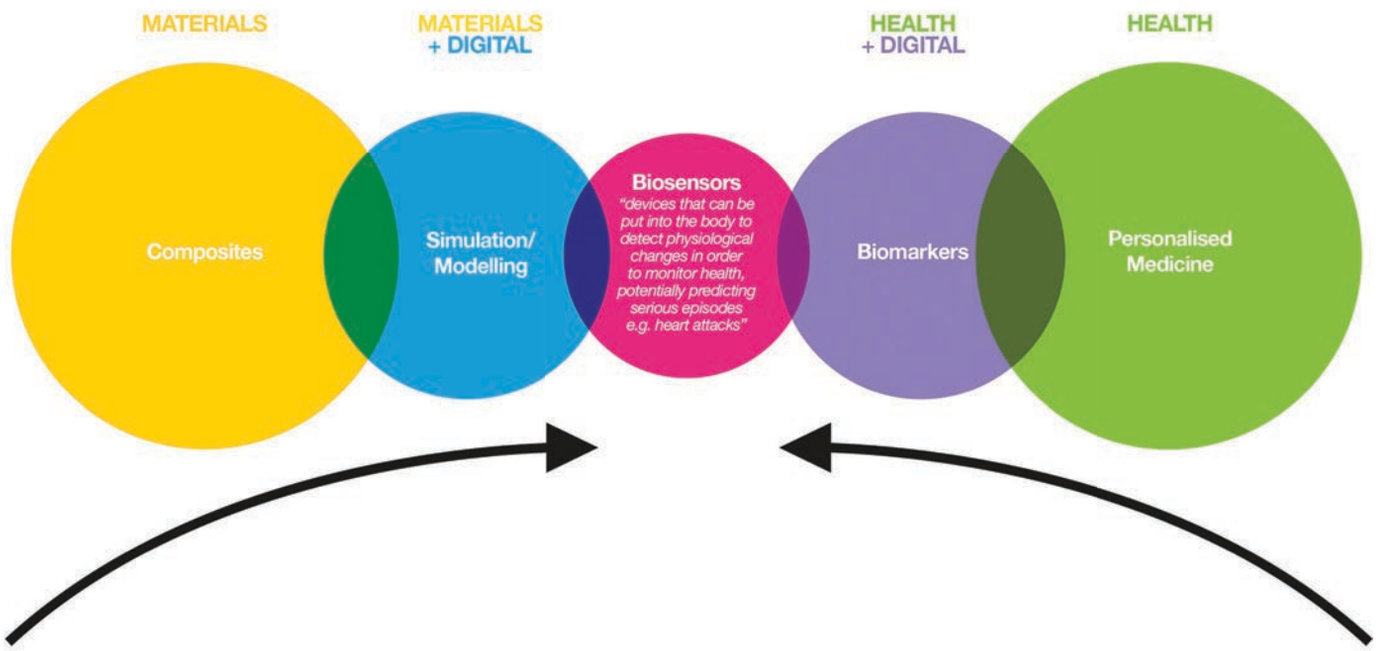
Globally, places like Massachusetts in the US have helped bring life sciences together with technology, for example the presence of IBM Watson Health at Kendall Square, Boston which has encouraged wider private equity investment in digital health start-ups.

GMCE are well placed to learn from places like Boston to better realise potential. DevoManc uniquely gives us the freedom, flexibility and governance to be able to design a new health and social care system (within the NHS) that is more sustainable and that provides the right care, right time and right place. The collaborative approach that we demonstrate, building on alliances such as MAHSC enable us to exploit our science assets in a combinatorial way to develop new sensors and monitors that will enable people to safely and effectively self-care

[79] *ABHI, Manifesto for Medical Technology 2015*

Figure 2: An example of related variety[80]

The inter-connectedness of our strengths allows us to develop applications in new and disruptive technologies that address major market demands as well as societal challenges.



and manage at home. This flexibility and common purpose is already attracting pharmaceutical and other Med Tech industry to explore new ways to develop medicines and diagnostics.

The size of our patient pool, and increasingly joined-up data systems (eg via Datawell and eResearch), are enabling us to design new 'real world' trials that are transforming the way industry looks at drug development (e.g Salford Lung Study). Such trials are faster and more powerful, demonstrating that treatments work in patient populations that are living and working in a real time normal environment. We have developed a unique expertise and workforce that is capable of delivering this. We are already attracting large corporates to the region (confidential discussions with several major companies are well advanced), and encouraging existing MNEs like AZ and Waters to invest locally. This will grow our cluster that will be attractive for entrepreneurs, investors and spin outs to develop new products and services faster and more in a more agile way. GM has a unique relationship with the NHS that means it is well placed to support SMEs on this journey around translational research. We are particularly well-placed to become the best place in the world to do clinical trials at pace and scale.

Climate change and the environment

Climate change is one of the most serious threats facing the world - a threat to the environment as well as to national and global security, poverty eradication and economic prosperity. Countries around the world came together at the Paris Climate Conference to agree a deal to cut global carbon emissions. Better energy storage offers one solution to the challenge of a clean, secure and cost-effective energy in sectors such as manufacturing and transport – while contributing to climate change and improved domestic energy security. The Carbon Trust estimates that improved UK energy storage could save £2.4bn p.a. system wide by 2030[81]. Additionally the concept of grid scale energy storage looks to use batteries at a range of scales from domestic to trans-national, and offers growth potential for high-value manufacturing and sectors such as automotive and aerospace. Developing grid scale storage additionally has the potential to reduce the costs of moving to a local carbon electricity system by £10bn p.a. by 2050.

The most critical and enabling aspect of energy storage devices are the materials from which they are made – therefore GMCE are well placed in connecting strengths in energy with those in advanced materials, while building on a strong manufacturing and engineering base. GM's research base in materials growth and characterisation, device modelling, measurement and circuit design offers an opportunity to generate innovation – drawing upon excellence in high performance materials such as graphene and other 2D materials. This offers an area for swift exploitation because semiconductor for processing don't require large scale capital intensive plants but rather draw upon diversity of high quality manufacturing techniques – of which GMCE sits at the centre.

[80] Jacobs, J. (1969) The Economy of Cities, New York: Vintage; "Related Variety" argues that cities with a diversified set of industries typically show high economic growth, because local diversity will spark creativity, new ideas and innovations.
[81] www.carbontrust.com/resources/reports/technology/energy-storage-report/

Our planned areas of strength address many areas of climate change and sustainability, from new materials that could offer improved energy storage, lighter materials and better computing, to industrial biotechnology which is driving more sustainable production of new chemicals and energy sources and our energy research on sustainability.

This is demonstrated by links to firms in our neighbouring geography. Johnson Matthey in Lancashire is a leading UK company in materials manufacturing and battery design/ assembly. Faradion in Sheffield is pioneering the next generation of advanced, low-cost batter materials include Na ion batteries). ITM Power in Sheffield specialises in the manufacture of integrated hydrogen energy systems (including electrolysis). Viridor in partnership with Highview Power are building a Liquid Air Energy Storage technology system demonstrator in GM. Firms with a local presence such as Siemens are advocates for radical energy storage for power to chemicals, as well as the end users in the automotive sector (JLR and Nissan are based in Liverpool).

Pandemic infections and antimicrobial resistance

The AMR task-force chaired by Lord O'Neill made a number of recommendations aimed at stimulating international cooperation to address the global threat posed by AMR, including the need to develop new antibiotics and to carry-out rapid diagnostics to ensure that antibiotics are used more selectively. The UK has a central role in this to use its science and research to develop new approaches for the discovery and early development of new medicines helping to transform ideas into commercial products and services.

Our plans in precision medicine, e-health, clinical trials and links to the important centre for antimicrobial resistance at Alderley Park, directly address these issue. Several businesses there are already working on developing new antibiotics, as part of a worldwide drive to find more effective treatments. For example, Redx Anti-Infectives Ltd, a company discovering and developing new therapeutics for the global pharmaceutical market. The Medicines Discovery Catapult to be sited at Alderley Park will additionally be the centre of national expertise for the discovery of medicines. Its role is to develop new approaches for the discovery and early development of new medicines helping to transform ideas into commercial products and services. It will develop and validate new ways of discovering new medicines and supporting the key UK strength in pharmaceutical, biotechnology and contract research organisations.

What markets do we target?

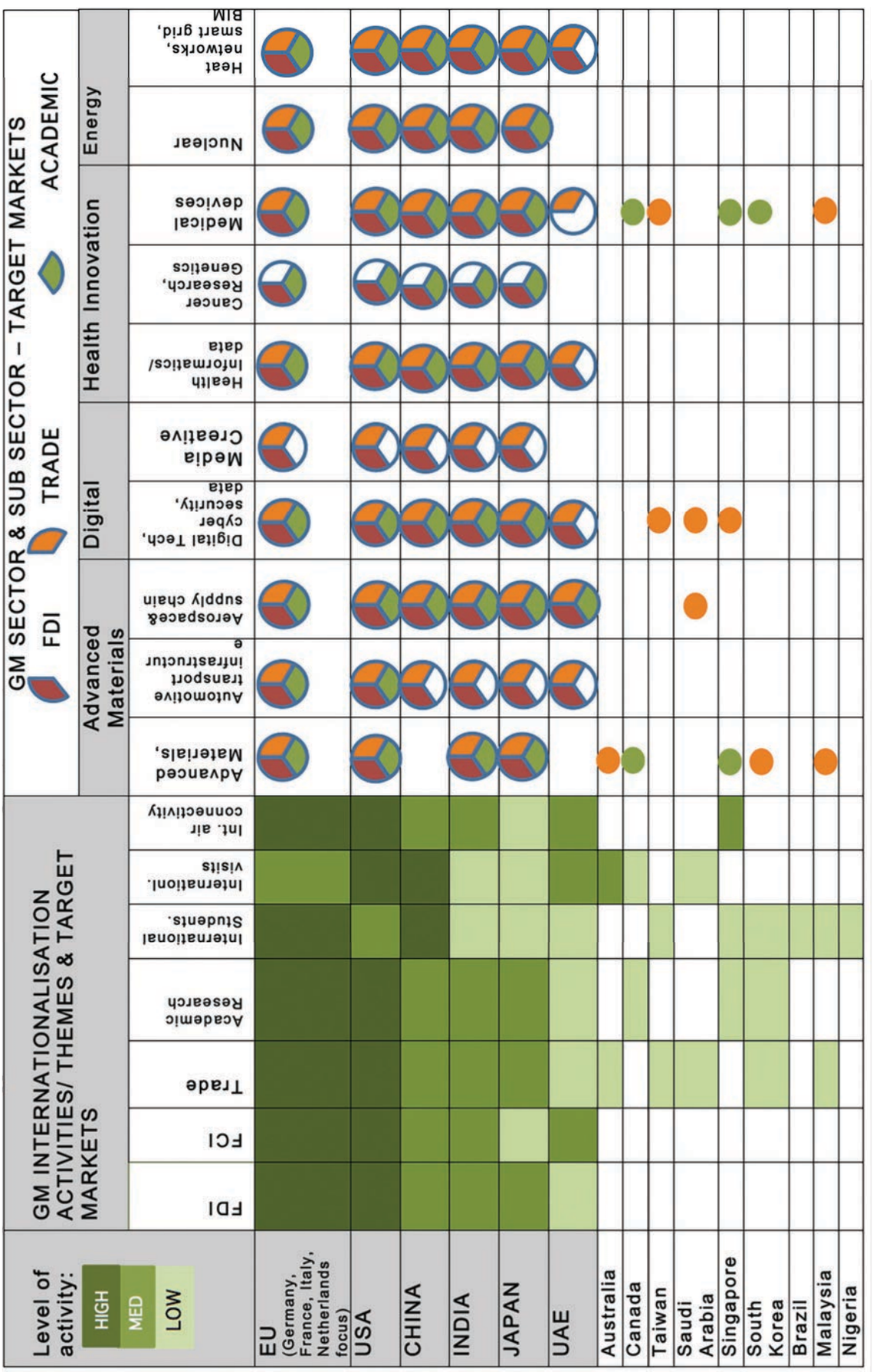
The GM Internationalisation Strategy 2017-2020 has built on our substantial sector intelligence and responds to extensive consultation[82]. The work we have undertaken during the preparation of the Strategy has highlighted the growing strength, depth and quality of our international networks across the public and private sectors, academia and key organisations, including the GM Chamber and Consulates. This is a significant competitive advantage that we aim to leverage and translate into a co-ordinated and integrated approach to implementation, working closely with the UK Department for International Trade (DIT).

As a result, the Strategy has helped us identify a number of specific key sub sector opportunities where GM has competitive advantage within target markets. These are set out in Table 2. The table shows a series of approaches through which GM proposes to engage actively going forward – including foreign direct investment (FDI) and capital investment (FCI), direct exports, academic links (both collaborative research partnerships, and attracting overseas students), as well improving city-to-city linkages via better connectivity.

The Strategy has confirmed that Europe and the USA remain the two largest and most valuable mature markets for visitors, trade, investors and students. The EU is our largest trade partner (led by France and Germany), and has provided the highest number of FDI projects to GM since 2013. China, India, Japan and the UAE offer clear growth potential and indicate where we are well placed to build upon existing trade, investment and other relationships based on our science strengths. Of these four, China, as the world's largest economy, offers the most significant opportunities where we can build upon existing connections and a strong relationship at government level. There has been a transformation in our relationship with China over the past three years – including the visit of the Chinese president to the NGI. The establishment of the Manchester China Forum as a coordination vehicle has proven to be a major success.

[82] *New Economy Baseline Data for the refreshed internationalisation strategy (2016) http://neweconomymanchester.com/news-events/presentation-slides*

Table 2: GM global market opportunities from science strengths (2017–20)



7

Conclusions

This audit has enabled our region to review our key strengths, assets and capabilities in science and innovation and to assess the gaps and opportunities that we need to address to go forwards. In so doing we have built on and extended the already cohesive networks existing in GMCE and sought to reach out to other regions undertaking or planning SIAs, particularly those in adjoining geographies. While our analysis of assets has inevitably looked inwards we have been seeking to develop an innovation and industrial strategy that equips us to take advantage of global opportunities and to deliver economic and social benefits both to our own population and to the UK as a whole.

This audit has enabled our region to review our key strengths, assets and capabilities in science and innovation and to assess the gaps and opportunities that we need to address to go forwards. In so doing we have built on and extended the already cohesive networks existing in GMCE and sought to reach out to other regions undertaking or planning SIAs, particularly those in adjoining geographies. While our analysis of assets has inevitably looked inwards we have been seeking to develop an innovation and industrial strategy that equips us to take advantage of global opportunities and to deliver economic and social benefits both to our own population and to the UK as a whole.

Health – a globally leading centre for clinical trials

The evidence has shown that we have a juxtaposition of the largest concentration of excellence in health research outside the South East, now hosting a new and cross-cutting NIHR Biomedical Research Centre linking the partners in our Academic Health Sciences Research Centre. Key facilities in support of cutting edge research and innovation are set in the context of a large and stable population exhibiting significant health challenges. Health devolution has created the unprecedented opportunity for a concerted drive towards innovation for both health and economic benefit. The synergies with the digital sector and in particular health informatics allows us to drive towards building on an already strong track record to become a globally leading centre for clinical trials, both of a conventional nature and increasingly in 'real-life' conditions. This in turn will attract inward investment and provide the basis for a growing ecosystem of innovative scaling-up firms.

Materials – rapid accelerator to application

In our second core strength, advanced materials the opportunities to develop 'Graphene City' highlights the unique presence of world-leading science in the NGI which is nonetheless closely engaged with business and producing a series of start-up companies. The next step is to systematise the pathway through higher technology readiness levels with the opening of the GEIC. Of particular importance is the accompanying training programme which gives us a large concentration of graphene scientists with additional entrepreneurship training. The wider spectrum of advanced materials research is also a core competence at the leading edge and the Sir Henry Royce Institute will create a national focus which is designed to overcome traditionally long lead-times and act as a rapid accelerator through technology readiness levels to application, particularly in support of the manufacturing sector.

GM as a full-scale test-bed and lead market to develop and demonstrate innovative technology

Moving to the fast-growth opportunities, digital and energy, as with health, combine excellence in research and facilities with a particular competence in mounting large scale projects in the community, in this case demonstrators as illustrated by CityVerve and Triangulum, allowing whole systems to be tested and creating multiple business opportunities. Industrial biotechnology is a capability of relevance for the concentration of related industries in the North of England and with its focus on synthesising new products and intermediates helps develop both sustainability in the move away from fossil fuels and resilience if raw material import costs rise. Alongside knowledge and expertise in cyber security meaning we have the opportunity to address this from the beginning of product and idea development instead of considering security as an afterthought.

Innovation strengths and weaknesses

In each sector we have globally competitive firms accompanied by clusters of innovative SMEs. There is now an outstanding offer of place assets, now linked more clearly as a system following this audit, which can trace a continuum of technology space and support services and institutions from Media City in Salford, through the Manchester Corridor and Airport City to Alderley Park and the Cheshire Science Corridor. In combination these form a globally competitive innovation district.

However, we also face important deficiencies. Only just over half of firms in our region are innovation-active. That proportion needs to grow and we need to ensure that firms acquire the absorptive capacity to take advantage of the opportunities created by the science assets. We have noted the need to increase GVA per capita, to raise the skills and qualification levels of the workforce and to extend the benefits of our recent strong growth to the less favoured parts of our region. We also have a regional gap in productivity, major issues of deprivation and of health inequalities.

To address these deficiencies and realise the benefits we intend to pursue three main lines of action:

1. Drive synergies from our core capabilities

Our areas of excellence create additional positive 'spill-overs' and value when combined. Drawing upon the principle of 'related variety' – this inter-connectedness will enable us to co-develop applications in new and disruptive technologies. This will be achieved by linking our unique clusters of excellence in fundamental science with the ability to put that scientific knowledge into application - creating a 'continuum' between local and national partners. For example:

Health/Materials/Digital – will respond to needs around improving health and social care outcomes and managing an ageing population, through the innovation of care pathways driven by integrated data to deliver precision medicine and the use of smart materials, specifically by monitoring care and treatments in real-time to create a learning health system. We are particularly well-placed to become the best place in the world to do clinical trials at pace and scale.

Energy/Materials/Digital - will contribute to tackling climate change and supporting energy security through whole energy systems and implementation of new materials and sensors in extraction, generation, storage, transmission and use resulting in low carbon solutions to areas such as transport and housing. Our advanced materials infrastructure is designed to provide the fastest possible acceleration through technology readiness levels to industrial application.

Digital/Health/Biotechnology/Energy – will harness innovative tech solutions and creative content to lead developments in areas such as diagnostic technologies, synthetic fuels and synthetic biology for novel vaccines, modified enzymes etc, with business leading the way in areas such as responses to antimicrobial resistance and pandemic infections.

2. Strategic investment to capitalise on the key intersections and opportunities

It is imperative that we extract maximum value from our existing assets and those under construction, but we need to continue to invest (from our own funds and external investment) to maintain world-class excellence and remain at the forefront of international developments in our areas of smart specialisation. Notably this will exploit the synergies between our areas of strength in order to develop 'route-ways to excellence', allowing us to incubate new niches, and help address society's wider problems. We recognise that two of our strengths – advanced materials and digital - are cross-cutting and have a broader 'enabling' function.

Pankhurst Centre to bring together health and physical science capabilities

There is potential to reinforce inter-connectedness by making some important strategic investments. Central to our plans is the Pankhurst Centre for Research in Health, Technology and Innovation. This would be a path-breaking cross-disciplinary Institute to bring together clinical research with materials science, informatics, engineering and computer science to address major health problems - unlocking the synergies between our core strengths of health and materials plus digital and biotechnology. Its 'bi-directional' nature means new discoveries will seek health applications and will respond to health needs and problems to find solutions; it will be both 'real' and virtual – with a core of at least 100 research leaders from diverse disciplines working together on the problems identified, but drawing upon a wider group of researchers beyond; and act as a major training centre to provide interdisciplinary experience for established as well as younger researchers. (see Annex H)

Maintain the strength of our science assets with key critical investments

In the short-term, we have identified a small number of projects which address gaps and opportunities in our regional ecosystem and are strong candidates for investment to help do this.

3. Strengthening our innovation support ecosystem

To capitalise on scientific strength and market opportunity we will need to strengthen our ecosystem to support innovation in the following areas:

Enhancing collaboration

We will drive alignment of our local science base with our local business base so as to maximise economic impact from our assets. This will include stimulating a broader cultural change to bring academics together from across disciplines more frequently and to better identify quality opportunities in which academics can interact with business people to foster market-led collaborations. We also see that the UK more widely needs to drive a collaborative rather than largely competitive culture if we are to compete with much larger economies with very much greater investment in research and innovation.

Nurturing talent

We need to ensure the right local skills mix is in place locally to drive innovation and to reinforce our identified scientific strengths, alongside improving the ability to attract and retain talented individuals.

This Audit and the Area Based Review have confirmed that GMCE needs to invest further in the development of the skills required to drive its key innovation sectors and assets, particularly higher-level technical skills. To this we plan to establish an Institute of Technology. Such an Institute would work closely with GM's universities, enable progression from FE, and be driven by business demands and leadership - acting as a magnet to foster innovation in SMEs. We also need to ensure that we have systems in place to encourage more young people to take up STEM subjects and engage actively in the science agenda. This means working with both primary and secondary schools, and investing in new facilities to support this where appropriate.

Leadership and management capacity for our innovative sectors are critical. We need to seek investment in our business schools to ensure that they can play a pivotal role through their research and training in guiding the development of health devolution and of our advanced innovative sectors. We also need to encourage collaboration and 'open innovation' to facilitate the transfer of knowledge, and raising awareness of the benefits of a diverse workforce to drive innovation.

Improving business support

As we build critical mass there will be increased opportunity to ensure that businesses gain access to diverse finance support at the right scale to help innovative businesses at all stages to invest in innovation, start-up and scale-ups, connect with research and subsequently generate economic growth.

As noted above, we need to realise the benefits of 'absorptive capacity' within small businesses, i.e. improving the ability to integrate new information for commercial ends. Including increasing the provision of adequate space for both start-ups/ scale-ups and leveraging in smarter procurement practice from the public sector to incentivise innovative practice (eg through data-sharing initiatives such as GMConnect and Datawell).

Moving forward with networking and collaboration

Our integrated governance, deep culture of collaboration between government, business, academia and health providers, and the strong partnership between GM and CE give us a powerful platform to implement the opportunities revealed by this Audit. In developing these we will work with partners from outside our geography, not only across the North of England (eg N8 and Northern Health Science Alliance partnerships, and linking to other current/ future Audit waves), but also nationally and internationally as we pursue global export and inward investment opportunities. This will maximise complementary strengths and ensure we continue to learn from best practice in research, science commercialisation, and innovation.

Annex A

Consortium structure and members

CORE MEMBERSHIP

***Purpose**: the Core Membership comprises representatives from public and private sector science and innovation organisations across the SIA footprint. Within this group, UoM will be the **Scientific Lead** for the delivery and implementation of the SIA; GM LEP/GMCA, through New Economy, will be the **Innovation Lead**, and ensure the audit is applied, business-facing and rooted in economic reality.*[83]

Members:

Arup
AstraZeneca
BBC North/MediaCityUK
BioNow
BP
BT
Cheshire and Warrington LEP
Cheshire East Council
Cisco
Corridor Manchester
Greater Manchester Combined Authority
Greater Manchester LEP
Greater Manchester Business Growth Hub
Health Innovation Manchester
Hitachi European Big Data Laboratory
Manchester Academic Health Science Centre (MAHSC)
Manchester Metropolitan University
Manchester Science Partnerships
Medtronic
NCC Group
Northern Health Science Alliance (NHSA)
Sci-Tech Daresbury
Siemens
Unilever
University of Bolton
University of Manchester
University of Salford
Waters Corporation

The Task/Finish Group

***Purpose**: The Task/Finish Group will ensure the SIA is delivered to time, budget and quality. It will be responsible for the day-to-day progression of the SIA.*

Members: UoM, New Economy and senior representatives from GMLEP

Enabling Collaborators

***Purpose**: Enabling Collaborators will be partners outside our SIA footprint but with whom GM and CE have links, to provide external challenge to our thinking and build national and international strengths and opportunities.*

Members: Other universities, research institutes, government departments and agencies and funders in the UK and globally.

[83] *The drafting of this report has been led by Professor Dame Nancy Rothwell, Professor Luke Georghiou (University of Manchester), Simon Nokes, Michael Contaldo, and Helena Crellin (New Economy).*

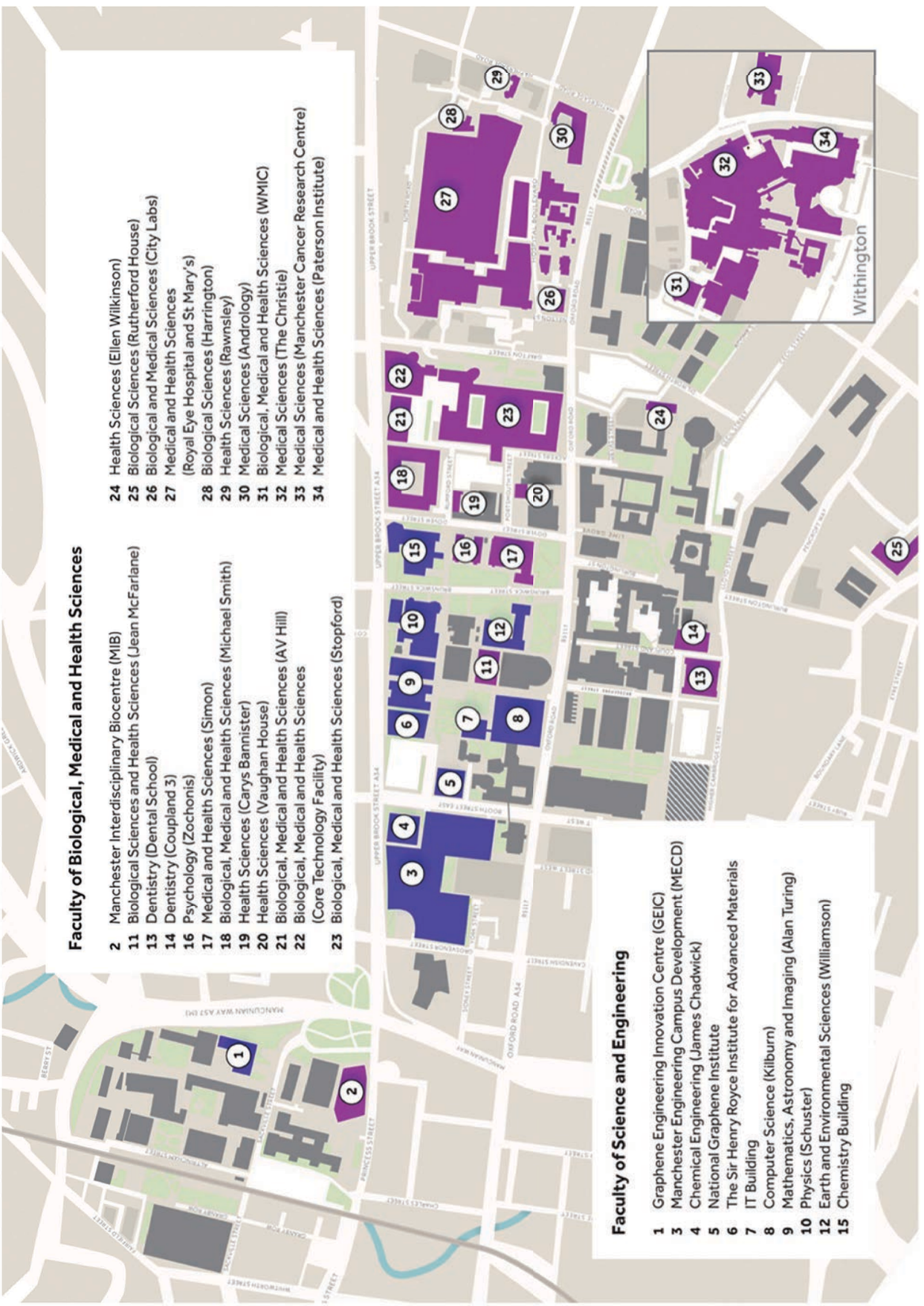
Annex B

Core data

	CHESHIRE EAST	GM	ENGLAND	TOTAL
UNIVERSITIES & RESEARCH ORGANISATIONS				
Number of research organisations (2015)				54
Number of Further Education Centres (2015)	6	13		19
Number of Higher Education Institutes (2015)	3	5		8
HUMAN CAPITAL & TALENT				
% workforce employed in science, engineering, technology and research professions (2014)	9.3	6.3	7.2	
% working population with no qualifications (2013)	8.5	11.5		
% working population with NVQ3 qualifications (2013)	15.4	16.9	17.2	
% working population with NVQ4 qualifications (2013)	38.9	31.8	35.0	
Retention of local graduate skills in region (2012/13)	68.7	81.7		
Number students getting a First with honours in a STEM subject (2013/14)	962	6,050		
BUSINESS DEMOGRAPHY/ PRODUCTIVITY				
Number of active enterprises (2012)	86,070	149,945		
GVA per capita (2013) (£)	25,477	20,724	24,091	
GVA per hour worked (2013) (£)	29.8	27.7	28.1	
Average annual gross full time pay (2014) (£)	30,640	30,358	34,197	
RESEARCH FUNDING				
Total value of UK research funding (2015) (£)				119,623,548
PRIVATE SCETOR INVESTMENT/ ENTREPRENEURSHIP				
Business R&D expenditure per person employed (2013) (£)	2,716	201		
Annual value of R&D tax credits claimed per person employed (2013) (£)				32 (NW)
Number investments by British private equity and venture capital members per person employed (2013)				213 (NW)
Foreign Direct Investment – % share of total UK FDI projects (2013)	0.7	3.3		
Total number of FDI successes (2013)	11	51	1,559	
Innovation activity as share of business turnover (2010) (%)	2.2	2.6	2.5	
INNOVATION ACTIVITIES				
% firms engaged in product/ process innovation (2010)	28	22	26	
Number of businesses (2014)	33,238	85,631		
Number of private sector jobs (2014)	287,750	833,378		
% of "fast growing" firms (2014)	13	16		
NATIONAL/ INTERNATIONAL ENGAGEMENT				
Number of local organisations participating in Framework Programme 7 (2015)				596
Local organisations participating in Framework Programme 7 – % share of UK total (2015)				3.4

Annex C

The University of Manchester on Corridor Manchester



Annex D

Table Showing The Potential For Inter-Connectedness Between Strengths

	Health	Advanced Materials	Digital	Energy (nuclear +)	Industrial Biotechnology
Health	• Precision medicine • Public health • Cancer • Health economics • Social care • Clinical trials	• Biomaterials • Smart textiles for assisted living • Biosensors Diagnostics • Regenerative medicine • Drug delivery • Tissue engineering • Implants-artificial joints, stents, transplants • Robotics	• Health informatics • Sensors • Internet of things. • Printable electronics from conventional to 2D • Robotics • In silico formulation - prediction of materials performance (Big Data). • Smart medical devices/wearables • Predictive models - eg drug behaviours. • Patient compliance	• Consequential impacts on health. • Relationship between energy and air quality. • Nuclear-proton beam therapy. • PET imaging.	• Biocatalysis/synbio for fine speciality chemicals manufacture for active pharmaceutical ingredients. • SynBio for newsynthesis of vaccines, biologics, enzymes, drug delivery, nano-responsive devices. • Biosensors.
Advanced Materials	• Self- care/ occupational health (eg polymer prototyping) • Transport • Construction • Sustainable materials		• Simulating properties of new materials • Modelling • Design • Materials for ICT	• 'Energy materials' including energy storage (batteries, supercapacitors and fuel cells) • Nuclear materials - fuel materials, fuel cladding, in core components • Oil and gas systems • Energy network materials • Materials for demanding environments • Corrosion • Sensing in extreme environments • Light weight composites • Smart sensors/coatings • Manufacturing • Predicting materials performance • Imaging of materials for energy industry • Materials leading to reduced energy use and reduced emissions.	• New feed-stocks; Green feedstock replacement • Fibres to smart coatings to photonics • Biomaterials including formulation and stabilisation • Biomimetics • Nano-storage • 'Smart' responsive materials and biosensors • Sustainability of production • New materials for biological syntheses

	Health	Advanced Materials	Digital	Energy (nuclear +)	Industrial Biotechnology
Digital	• Improving poorly integrated information systems • Creative industries	• Rapid triage and prototyping of bio-sensing and bio-augmentation requests, alongside a materials horizons communications programme • Predictive modelling • Analysis of new materials • Materials for ICT	• Cybersecurity • FinTech/ cybersecurity	• Whole energy systems / smart grids • Control of nuclear plants. Verification and validation, operator competency, cyber security, regulatory justification, supply chain management • Condition monitoring, sensors and data management • Autonomous systems for high hazard conditions • Analysis of energy use • Predictive modelling • Climate change • National grids	• Data storage in genomics and proteomics. • Protein design • Sensors • Wearables • Systems biology (complex analyses) • Synthetic biology • Predictions of behaviours of new molecules and systems
Energy (nuclear +)	• Integrated health and transport intelligence • Adaptivity for entire populations • Low/bio-powered implantable devices and wearable sensors for novel wellbeing and self-care	• Low-cost, low-power environmental sensor arrays • Self-organising networks	• Citizen digital avatar reflecting energy footprint • Social machines of energy use/ collective behaviours eg transport choices		• Bioenergy • Bioconversion • Network modelling • Synthetic biology for enzymes and bioprocesses • Bio-electrochemical systems for reversible chemical energy storage
Industrial biotechnology	• Microbiome-environment-behaviour interaction • Biopharms/ biologics production • Therapeutic enzymes/antibodies	• Allergic desensitisation / allergen presentation • SynBio/IB discovery of new materials • Sustainable manufacture • SynBio materials • New materials for deference/ advanced materials • Additive manufacturing	• Biotech process simulation • Computational design/machine learning underpinning biological design • Data/text mining	• Pathways to biofuels, scale-up of laboratory scales tests using pilot plant facilities and understanding of system level carbon benefits • New fuels (microbial engineering, propane, butane etc) • SynBio production of established materials (eg insulators)	• Design and formulation of biologics

Annex E

Glossary

Accelerator science – using beams of charged particles travelling at high speed to study, for instance, materials with applications in a range of sectors from health, engineering and materials science.

Advanced materials – research, developments and applications of materials designed to have superior properties (eg strength, weight, conductivity) or functionality than existing/traditional materials (see graphene).

Big Data – extremely large amounts of data that require advanced methods of capture, storage, processing and analysis.

Biomarkers – a gene or molecular characteristic that can identify a disease, eg specific proteins on the cell surface of cancer cells (see EGFR).

Computer architecture – the design of a computer system, which determines the technology and software it can support.

Devolution - the transfer of power by central government to a local or regional administration.

Epidermal Growth Factor Receptor (EGFR) – a receptor present on the cell surface that is activated when bound to epidermal growth factor and similar proteins; it is often overexpressed in cancers.

Foreign direct investment (FDI) - investment made by a foreign company or individual eg to establish business operations or acquire business assets in the other country.

Genomics – the study of the complete set of genes and non-coding DNA (the genome); it requires technologies for sequencing, analysis of Big Data and modifying organisms. Genomic information is important in identifying and understanding the genetic background to disease and producing personalised medicine technologies.

Graphene – the first 2D material to ever be discovered; it is a 2D sheet of carbon atoms, which are arranged in a hexagonal pattern, and has many astonishing properties such as being the strongest material ever measured and a very high electrical conductivity.

Gross Value Added (GVA) - the value of goods and services produced in an area, industry or sector of an economy.

Health informatic/analytics – information technology and information systems used in healthcare, including the storage, retrieval, sharing and use of health data (see Big Data).

Health innovation – research, development and technologies that further the understanding of biomedical sciences and their use to improve the provision of healthcare.

Industrial biotechnology – the use of biological processes, organisms and systems in industry, such as using genetically modifying microorganisms to produce drugs, as well as medical technologies (see synthetic biology).

Internet of Things – connecting everyday objects to the internet using sensors, allowing them to collect data and make decisions, for example smart energy meters that can adjust heating remotely in response to outside temperature, whether anyone is home etc.

Personalised medicine – also called precision medicine; it is the use of genetic, molecular, cellular and environmental information about the patient, to better diagnose and identify what treatments will be most successful. It also covers the technologies and procedures that are required to collect the specific data, and its applications to improve healthcare.

Proteomics – the study of the complete set of proteins (the proteomes) and the modifications they may undergo; this is important in fully understanding and identifying disease, as well as developing personalised-medicine technologies.

Spintronics – the study of the spin of electrons, the magnetic moment this creates, as well as their charge; this is important for applications in quantum computing.

Synthetic biology – the design and engineering of novel biological components, devices and systems as well as the redesign of existing, natural biological systems, such as the engineering of microorganisms to produce of materials such as bioplastics.

Annex F

Abbreviations

ASTeC – Accelerator Science and Technology Centre

ATI – Aerospace Technology Institute

BP-ICAM – BP International Centre for Advance Materials

CMFT – Central Manchester University Hospitals NHS Foundation Trust

CRUK – Cancer Research UK

DCI – Digital and Creative Industries

DNI – Dalton Nuclear Institute

CE – Cheshire East

EPSRC – Engineering and Physical Sciences Research Council

FDI – Foreign Direct Investment

FE – Further education

GEIC – Graphene Engineering Innovation Centre

GM – Greater Manchester

GMCA – Greater Manchester Combine Authority

GMLEP – Greater Manchester Local Enterprise Partnership

GVA – Gross Value Added

HeRC – Health eResearch Centre

IoT – Internet of Things

MAHSC – Manchester Academic Health Science Centre

MCRC – Manchester Cancer Research Centre

MIB – Manchester Institute of Biotechnology

MMU – Manchester Metropolitan University

MRC – Medical Research Council

MSP – Manchester Science Partnerships

NAMRC – Nuclear Advanced Manufacturing Research Centre

NGI – National Graphene Institute

NHSA – Northern Health Science Alliance

NNL – National Nuclear Laboratory

NWCC – North West Composites Centre

UoM – The University of Manchester

UoS – University of Salford

Annex G

Bibliography

- A Strategic Economic Plan for Cheshire and Warrington, C&W LEP, 2014
- Benchmarking Local Innovation: The Innovation Geography of the UK, Enterprise Research Centre, Enterprise Europe Network, BE Group, 2015
- Biomedical Cluster Mapping Update for GM 2002-14, BioNow, January 2015
- Building Local Advantage: Review of Local Enterprise Partnership area economies in 2014, The LEP Network
- Cheshire East Science Corridor: Opportunity Assessment, BE Group, 2015
- Collaboration between SMEs and universities – local population, growth and innovation metrics, ERC, 2015
- Deep Dives, New Economy (2016)
- Discovery to Delivery, North West England, a premier location for science and technology innovation, North West Business Leadership Team (NWBLT), 2015
- Encouraging a British Invention Revolution: Sir Andrew Witty's Review of Universities and Growth, October 2013
- European Structural and Investment Funds Investment Plan 2014-2020, GMLEP, 2015
- 'Exploiting The Excellence' – England's North West: where world-class science underpins wealth-creating innovation, NWBLT, 2014
- Exploiting the Growth Potential of Science in the Atlantic Gateway, SQW Ltd, 2016
- Global Challenges, Manchester Solutions, University of Manchester, 2015
- Greater Manchester Forecasting Model, Oxford Economics, 2014
- Greater Manchester Science and Technology Assets Map, New Economy, 2013
- Greater Manchester Science and Technology Review, New Economy, 2013
- Greater Manchester: Towards a RIS3 strategy, Williams, J. & Devaney, C., 2013
- Health North: Powering UK Health and Wealth Transformation, Northern Health Science Alliance, 2015
- Industrial revolutions: capturing the growth potential, Centre for Cities, 2014
- Localisation of industrial activity across England's LEPs: ERC Research Paper No. 15, ERC, 2013
- Mapping Local Comparative Advantages in Innovation, BIS, 2015
- Mapping Research and Innovation: Understanding Amsterdam's Competitive Advantage, UIN & Elsevier, 2015
- OCED Reviews of Regional Innovation: North of England, OCED, 2008
- Powering the Digital Economy, TechNation, 2015
- Research & Development in UK Advanced Textiles Manufacturing, New Economy, 2015
- Research Evaluation Framework, REF2014
- Sector Analysis report for Cheshire and Warrington, GM and Liverpool City Region LEPs, BioNow, July 2013
- Science and Innovation Audits Inception Report for the Consortia, Technopolis, May 2016
- Smart Specialisation in England, BIS, 2015
- Science and Technology – the Greater Manchester Story, New Economy, 2014
- Stimulating Business Innovation, Making Manchester a leader in enterprise innovation support, New Economy, 2011
- Strategic Plan Document for 2014/19, The Christie NHS Foundation Trust, 2014
- Strategic Vision to 2025, Corridor Manchester, 2015
- Stronger Together: Greater Manchester Strategy 2013, GMLEP and GMCA
- Technology Enterprise in Greater Manchester, Lusty, P. & McArthur, N., 2014
- The Digital Powerhouse: The innovation potential of tech clusters in the north, TechCity, May 2016
- The Independent Economic Review of the Northern Powerhouse, SQW Ltd, April 2016
- The Manchester Independent Economic Review, New Economy, 2010
- Turning Discovery Science and Knowledge into Jobs and Growth, GMLEP, 2013
- Unlocking our Potential: Solving the Productivity Puzzle in North West England and Nationally, NWBLT, 2016

Annex H

Pankhurst Institute

Our proposed 'Pankhurst Institute' brings together our core strengths and opportunities. Its core aim is to bring understanding, expertise and new discoveries in engineering, physical sciences and mathematics.

This proposal is timely because it will seize the unique opportunities offered by devolution of the health budget to GM, huge and growing strengths in health informatics and precision medicine and an explosion in the application of new materials.

It will benefit from and build on our proven expertise in such cross disciplinary areas:

- MIMIT - bringing engineering solutions to health problems;
- e-health - combining strengths in informatics, computing and health records;
- Industrial biotechnology where MIB has co-located biologists, computer scientists, physicists, engineers and mathematicians to address biologicals and health problems ('systems' biology and health);
- Bio-materials - already a major activity which is also a core theme of the Royce Institute which will be built with academic and industrial partners;
- Major industrial interest in these areas, with significant investment and co-location in the region.

It will also interact with the opportunities generated through the presence of new companies and infrastructure on our Science Parks at Alderley Park and at Citylabs.

Pankhurst will be:

- 'bi-directional' - new discoveries will seek health applications and will respond to health needs and problems to find solutions;
- Both 'real' and virtual' - We aim to establish a core of at least 100 research leaders from diverse disciplines, working together on the problems identified, but there will also be a much wider group of researchers within and beyond UoM engaging with Pankhurst;
- a major training centre to provide interdisciplinary experience for established as well as younger researchers;
- a strong interface with hospital and primary care providers;
- a key partner for industry.

M1759 11.16

recycle
When you have finished with this publication please recycle it

Mixed Sources
Product group from well-managed forests, and other controlled sources
www.fsc.org Cert no.
© 1996 Forest Stewardship Council