MATRIX
NORTHERN IRELAND SCIENCE INDUSTRY PANEL

November 2016

ADVANCED MANUFACTURING, MATERIALS & ENGINEERING

FINAL REPORT

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Acknowledgements

Without the enthusiastic participation of the many AMME companies, academics and other stakeholders who contributed so freely to the consultative phase of this study we would not have been in a position to capture the vibrant and thriving AMME sector portrayed in the report.

Matrix is indebted to those companies who participated in case studies, those who facilitated site visits and all who attended the AMME workshop sessions and subsequent round-table discussions. The insight and learning provided by all has been invaluable.

Thanks are also due to the DfE Permanent Secretary, Andrew McCormick and the Matrix Chair Dr Bryan Keating OBE for their participation in the consultative stage of the study, their willingness to visit and engage with a wide range of AMME businesses was much appreciated.

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Michael Cooper Photography

Manufacturing NI

MATRIX – the NI Science Industry Panel

The role of MATRIX is to help businesses inform and advise government policy by providing the business community - in partnership with the public and academic sectors – with a mechanism by which to collate that advice and communicate it to Northern Ireland's government. In this way we aim to support the region's policies on Research & Development, innovation and the growth of a knowledge-based economy. In parallel, MATRIX continues to promote the development of the economy through the exploitation of R&D particularly by guiding investments across the local scientific community and by promoting innovation across all sectors. We also seek to increase the opportunities for business' exploitation from the science and high tech sector by maximising the gearing and leveraging of public sector funding.

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"Taken together, whether as a sector / sub sectors/clusters/individuals, the contribution that AMME companies make to the Northern Ireland economy is impressive and a testament to the quality of our advanced engineers. Northern Ireland's Advanced Manufacturing, Materials & Engineering (AMME) capability should not be understated – it is a powerful force.

"Yes, manufacturing, by any definition has and will continue to face difficult times, but by and large, NI's AMME businesses survived the recession, have emerged more confident than before and are once again investing in growth.

"The challenges they identify, whether keenly felt in 2016 or anticipated for the future, should be considered in the context of a sector that can see enormous development opportunity.

"As such Matrix impresses upon government the need to respond in a comprehensive and timely manner to the recommendations within this report, so that in working together NI's full AMME potential can be realised."

Dr Rob Hardeman, AMME Chair (MATRIX Deputy Chair)

Foreword

Dr. Rob Hardeman

I am delighted on behalf of Matrix to present what I believe to be our most comprehensive report on Advanced Manufacturing, Advanced Materials and Advanced Engineering (AMME) in NI to date. Building on the 2013 UK Foresight Study - "Future of Manufacturing: a new era of opportunity and challenge for the UK", the report re-examines the future of advanced manufacturing in Northern Ireland and its importance to the local economy beyond 2016.

Over the course of this study we engaged with many AMME business leaders, academic partners, representative associations and government bodies – locally and nationally. What we learnt from that engagement, combined with the use of extensive data sets from a wide range of sources is that there is a surprising level of sustained activity and export achievement given many reports of the "demise of manufacturing". We have a strong manufacturing heritage, which still lies at the heart of industries in NI.

In fact, there is still a higher percentage concentration of manufacturing businesses here than there is in the UK as a whole. During the downturn, manufacturing industry here kept on track better than other UK regions. R&D didn't fall away and exports, largely speaking, remained strong. So we have a big and vibrant sector with a fascinating range of companies and products and the signs are good.

NI's AMME sector today is a leaner version of the one Matrix reviewed in 2008 and the most encouraging impression we take away in 2016 is that businesses, in being more flexible, have diversified and are better placed to adapt in a rapidly changing world. What we can see, in line with many other parts of the UK, is that companies have restructured their operations away from competing primarily on price and towards a greater emphasis on differentiation by product quality, knowledge, customer collaboration and brand. Yes, the recession was an incredibly difficult period for all manufacturers in Northern Ireland, but throughout the lowest points of the downturn advanced manufacturers continued to invest in R&D and that commitment to product and process, design and development has stood them in good stead.

Our decision to combine into AMME has been made in recognition of the levels of synergy and interdisciplinary working across those areas that we previously reviewed separately. Diversification has enabled lower-tier companies to serve multiple markets (and indeed many may not now associate themselves with any particular one) and innovation in any of the markets could spillover into others. Sub sectors and indeed sectors are becoming increasingly hard to separate.

We learned how success increasingly depends on collaboration and the network of partnerships that connect employees, suppliers, technical experts and academia. Nowhere is this 'Industrial Commons' more evident than in the UK government's commitment to the High Value Manufacturing Catapult. It is the Catapult's CEO Dick Elsy who makes the point that "it is no coincidence that the 2 industries that spend the most on innovation – aerospace and automotive – have seen the greatest productivity gains and continue to do well". Matrix couldn't agree more. "Innovation, after all, is the source of good, long-term business. And our role is to support a thriving business community here."

We also take note of a manufacturing resurgence in the US where government investment has been better targeted to strengthen the Industrial Commons by supporting cross- sectoral partnerships including academia, industry and representative organisations to produce ideas and capabilities that support commercialisation and scale-up activities across a wide swathe of firms

– this points to the renewed need for some centralised facilities to support smaller companies be that through training /testing/production line trialling..

Unquestionably, the current climate is challenging – manufacturing is changing at a pace which is relentless yet exhilarating. The link to Digital ICT through the use of big data and data analytics is but one example of that change. The number of devices connected to the Internet is predicted to double by 2020, to 30bn, nearly all of that growth will be accounted for not by laptops, tablets or smart phones, but by machines, products and sensors that primarily do something else. That explosion in the potential of technology, and the opportunity it provides to reinvigorate the manufacturing sector (often referred to as Industry 4.0) should not be underestimated. Another area where enormous challenge and opportunity lies is a realisation of the benefits of the circular economy in which we work to design in reusability as well as recover and regenerate products and materials at the end of each service life.

Perhaps however the greatest challenge we face as a region, along with many others is that of Skills provision – the availability of the right skill sets at the right time. At the outset of this study I reported that I'd be fairly confident that one conclusion will be that we need to work harder on the development of skills at all levels, from school leavers to PhD qualified engineers. That indeed remains the case. Skills are going to be vital to the continued growth of manufacturing here….and it needs to be right up there on every agenda.

The development of clear and sustainable objectives for AMME in NI needs to be aligned with the current strengths of the sector – of which there are many. There are strong clusters already in existence but not always highly visible. From Aerospace to Materials Handling, Polymers to Agri-engineering, and Construction products to Automation, with many highly specialised individuals in between, the sector is ready to take advantage of specific initiatives to enhance competitiveness and propel forward. Therefore, it is important that we put in place initiatives which have impact, that we measure progress against the recommendations and suggested actions in the report and that we respond to any hesitation in achieving what we set out.

NI AMME needs leadership and a voice. In terms of looking towards key opportunities for growth in the future, we need to identify, grow and compete in the global market on our key strengths – and to do that we need to, as a region, exploit that which differentiates NI AMME from its competitors. We need to shout from the roof tops NI's AMME reputation for innovative design and the world leading quality and reputation of our engineers. In the report we talk about NI AMME's 'strength in adaptability' – the sector has shown its ability to diversify and respond to the changing demands of manufacturing of the future, which when combined with an already high degree of specialism and excellent service, means NI AMME is ideally placed to take advantage of niche global requirements – always building on the great heritage and brand of NI engineering

With the draft Programme for Government of the next 5 years just published and a refocused Economic Strategy with a vision to 2030 to follow, Matrix looks forward to providing advice and support to Minister Hamilton and his officials in the Department for the Economy as we work together with NI's AMME business community, education and research institutions to build on what is already an incredibly impressive performance.

EPSRC's Production Nation blueprint for a creative, innovative, competitive economy has as a central pllar "Establish a new place for industry that is built upon a 'make it local, make it bespoke' approach." The evidence presented in this Matrix report tells us that NI's AMME businesses can do just that, and what's more, they can make it better!

Dr Rob Hardeman

AMME Chair

Executive Summary

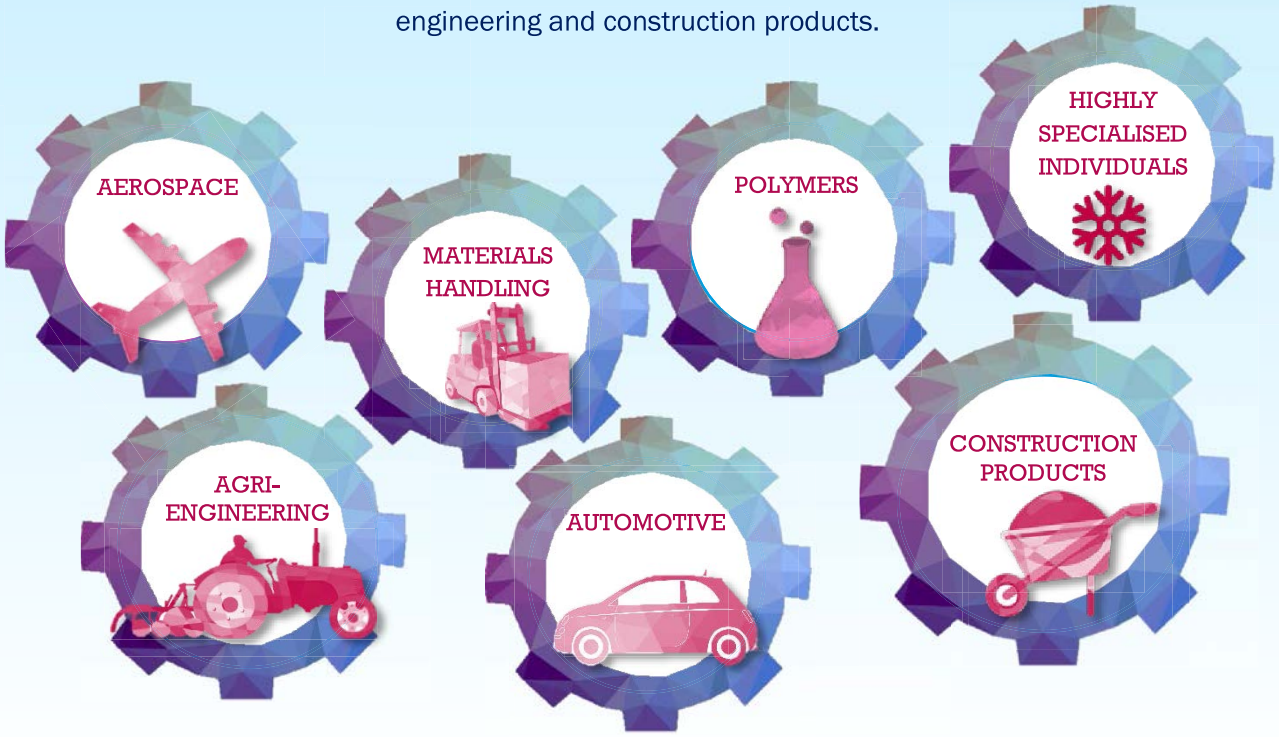
Matrix – The Northern Ireland Science Industry Panel.

Supporting Advanced Manufacturing, Materials & Engineering (AMME) businesses and maximising the impact of public funding by:

- *Promoting NI AMME*
- *Providing recognition and focus for the sector*
- *Encouraging research collaboration*

A Powerful Contribution to the Northern Ireland Economy

The NI Advanced Manufacturing, Materials & Engineering sector is diverse, with activities ranging from aerospace, automotive, pharmaceuticals, and chemicals to heavy plant, automotive, agri-engineering and construction products.



Since the 2012 recession, the NI manufacturing sector has created 6,500 new jobs – nearly 3 times the UK growth rate.

TOTAL NUMBER EMPLOYED IN THE NORTHERN IRELAND MANUFACTURING SECTOR IN 2016: **80,170**

TOTAL NUMBER EMPLOYED IN AMME IN NORTHERN IRELAND IN 2016: **44,170**

The outlook remains positive, but growth will be lower, reflecting the difficult international trading environment and the recent announcements at JTI, Michelin, Seagate and Bombardier (with the impact being most significantly felt in 2017 and 2018).

Geographical & Sectoral Spread

MATERIALS HANDLING

AEROSPACE

AGRI-ENGINEERING

POLYMERS

NI has AMME focus in Belfast, Craigavon, Derry~Londonderry, Dungannon, North Down and Antrim. There are strongly developed sectoral clusters in Aerospace and Polymers and looser groups in several other subsectors.

CONSTRUCTION PRODUCTS

AUTOMOTIVE

Highly Specialist Individuals

There are also several important specialist companies which don't fit within any of these groups, but which make up approximately one third of all AMMEs in Northern Ireland.

Whale® WATER SYSTEMS SPECIALIST

AVX A KYOCERA GROUP COMPANY

CATERPILLAR

SEAGATE

KELVATEK

SPHERE global

ulster™ www.ulstercarpets.com

lpe laser prototypes europe ltd

Key Findings

NI has a strong cohort of individual AMME companies making a very significant contribution to the local economy – these companies are competing globally and are Research & Development and Innovation (R&D&I) intense.

Critical mass :

AMME activity in NI (whether formally clustered or not) exists around three leading areas:-

- Aero, Defence, Security & Space (ADSS)
- Materials Handling (MH)
- Polymers

(together these 3 groups account for 39% of top AMME performers).

Strong performance:

In addition there is evidence of strong performance within:

- Automotive
- Construction Products
- Agri-Engineering

(together these three groups account for 29% of top AMME performers)

Significant and unique:

Individual companies classified within AMME as 'Highly Specialised Individuals' together account for over 30% of top AMME performers.

Heritage and innovation:

The ability of NI's AMME businesses to innovate successfully and diversify to pursue long-term growth paths is clear.

- **R&D intensity:** Investment in R&D over a prolonged period and sustained throughout the downturn is a clear signal that R&D is embedded across the top 200 AMME performers.
- **Longevity:** Many of NI's top 200 AMME companies (38%) are established 25years +; of which over a fifth can trace their roots back more than 40 years.

Respected and globally renowned – a strong brand:

Irrespective of the particular area of AMME they are employed in, NI's AMME professionals are globally respected, with NI engineering firmly reputed for excellence in quality, innovation and cutting edge design.

What AMME companies told us - what matters most to AMME companies in NI today?

Frequent and consistent themes:

Skills

Consistent with many other AMME communities, by far the most important issue concerning NI's AMME leaders is the availability of the right number of relevantly qualified workers at the right time.
Matrix wholly endorses the earlier findings of the 2015 NI Skills Barometer and the recent and proposed developments within NI Apprenticeships. In that context, AMME skills are considered in detail in the report, along with a number of suggested potential recommendations to Government, Industry and Academia.

Costs

As with skills, the issues raised are not unique to NI, and not all are of equal concern to each AMME company. However, when taken together, the key concerns around energy, foreign exchange, corporation tax, rates stability, logistics costs and others present significant challenge to a sector which has been under persistent threat over recent decades.
There is a general acceptance that some of these areas fall outside NI control. However, the recommendation to government is that, when policy is being developed, that the impact on NI's AMME businesses is front and centre of decision making. This report points to the recommendations relating to costs within the 2016 Oxford Economics report commissioned by Manufacturing NI.

Sectoral Development

NI's combined AMME strength is a formidable force, in any context. The companies have grown, diversified, survived the recession, sustained their investment in R&D and are now hitting global playing fields with renewed purpose. The impact of sectoral development already undertaken is evident (e.g. the Aerospace, Security & Defence Group (ADS) and SC21 for the Aerospace, Defence, Space & Security sector and the work of the Northern Ireland Polymer Association for polymer businesses).
With confident and ambitious leadership, NI's AMME combined capability can be further developed and promoted effectively – for the benefit of all. The report draws out specific recommendations pertaining to sectoral development.

Recommendations

SKILLS

- ✓ School children need practical, hands-on experience to be able to visualise AMME and its potential value in a way which they can relate to. An important first step would be the teaching of STEM through objects vs only through paper (i.e. practical vs theoretical learning).
- ✓ The role of colleges in the school/FE/HE education continuum providing vocational training for youth and continuing education for employees needs to be considered.
- ✓ Matrix should ensure that, as the NI Economic Strategy is refocused within the context of the new Programme for Government 2016-21, that the Department for the Economy is supported and encouraged to continue to build on the current STEM agenda and (important) small gains recorded. This is an essential step to ensuring the delivery of economically relevant skills and qualifications for the AMME sector in the future.

R&D & INNOVATION

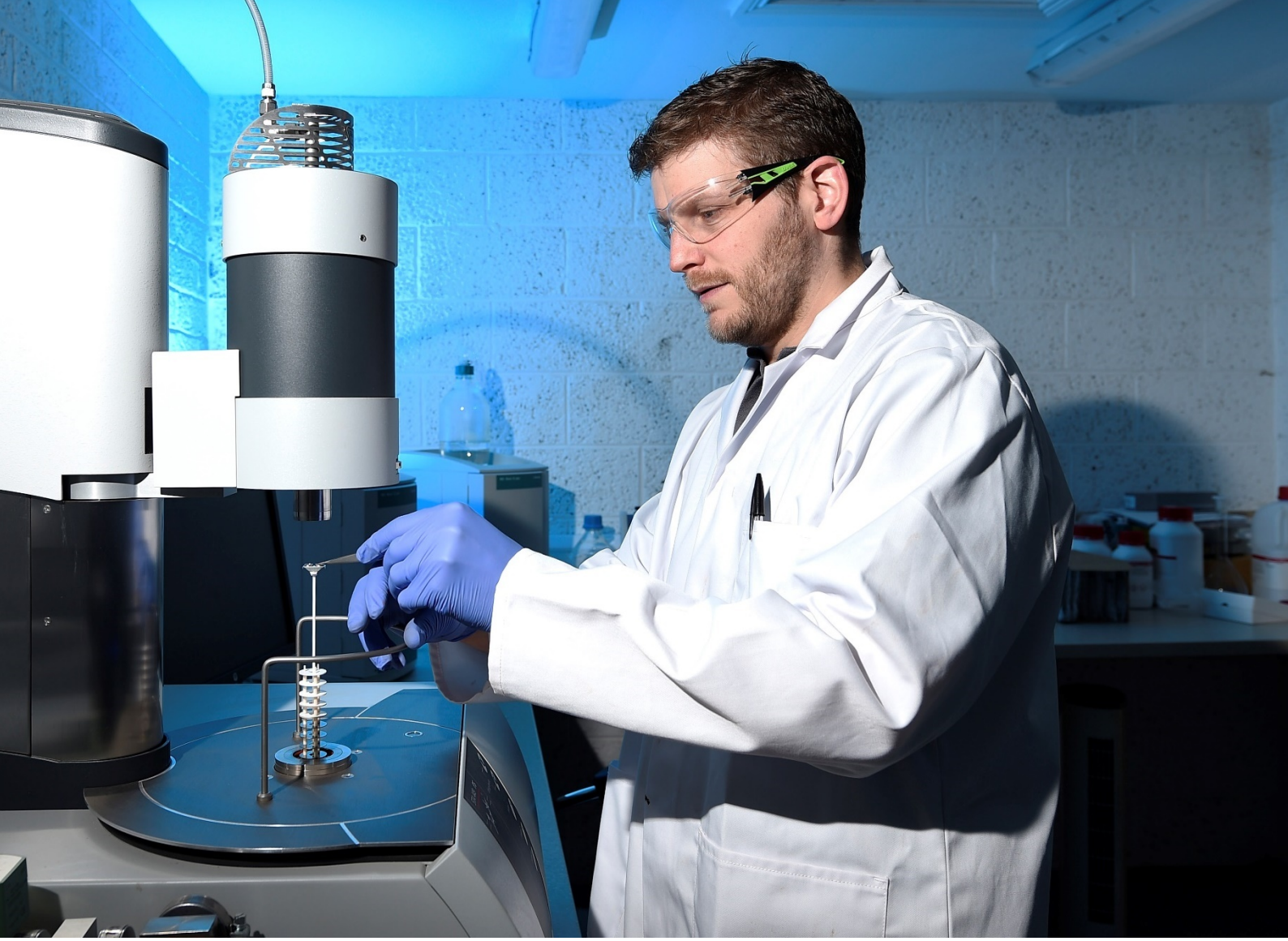
- ✓ Public funding of university-business collaborative R&D - Leverage and Value for Money: the development of metrics that identify and measure commercial outcomes as well as those for the university are important, not least in the context of constrained public spending environment.
- ✓ Mechanisms which streamline industry-university engagement should be reviewed in light of becoming more flexible and dynamic – to the benefit of all parties, taking into account ease of access to collaborative R&D for SMEs in particular.
- ✓ Businesses should be encouraged to seek out collaborative opportunities, wherever they lie, based purely on expertise and to look beyond localised networking, where appropriate, to avail of that expertise (e.g. explore HVM Catapult links).
- ✓ Regional funding for collaborative research should be directed to best meet the needs and growth of AMME businesses, irrespective of location of research partner.
- ✓ Additional HMRC resource available to NI businesses via its NI Corporate Tax Office (NIrCTO): DfE should renew efforts to ensure all eligible businesses are aware of the totality of support available to them under the HMRC incentives and reliefs – taking full advantage of NIrCTO's expertise and guidance.
- ✓ The opportunity to scope a government-led 'whole of AMME R&D&I solution' in response to industry needs within the established Catapult framework should be examined further.

SECTORAL DEVELOPMENT

- ✓ With regards scaling, the need to examine how some of the 'affinity groups' of AMME business could move into a form where their combined activity would move them to the next level is recommended. With the appropriate policy in place, Invest NI would be well-placed to work with companies to facilitate that movement.
- ✓ A potential pilot around the application of ADS initiatives to NIPA members would be an ideal starting point.
- ✓ Explore potential to develop a tailored AMME package of support (e.g. akin to Liverpool LEP advanced manufacturing initiative). Sector- specific and across full spectrum of R&D&I to include e.g. skills, trade, etc. and to incentivise AMME collaboration.
- ✓ The NI engineering brand should be developed and promoted and used by all relevant parties to promote NI as a location of choice to do AMME.
- ✓ To address issues relating to accessibility, a "See Inside Manufacturing" or "Manufacturing Day" initiative should be developed to help influence skills choices – "heads and hands".
- ✓ Develop a programme of education for the legislators. Prioritise the identification of a cross-party Executive 'Advocate for Engineering' – (e.g. the UK All-Party Executive Manufacturing Group model). Matrix can lead.
- ✓ Matrix 'loop and closure'. Need to set out the mechanism by which to bring AMME findings into the advice framework (evaluation of the model) and carry through the development of recommendations through a sub-group which would co-opt representatives from respective communities. Likewise, a conduit to UK government policy and funding should be formalised for NI AMME businesses – a continuing process which will provide feedback and input to next report. Matrix can work in conjunction with DfE to provide leadership.
- ✓ The 'clean and green' opportunity is an area which was initially identified in the first Matrix report and one which has been seen only to grow in the intervening period. NI's AMME companies should therefore be encouraged to explore and supported to engage further with the 'clean and green' opportunity, whether through education, the creation of shared value or the identification of partners.

“Manufacturing is evolving beyond simply making a product and then selling it. Manufacturers are increasingly using a wider value chain to embrace new sources of revenue, which will transform business models over time.”

The UK Government Office for Science, “The Future of manufacturing: A new era of opportunity and challenge for the UK”, 2013.



Introduction

Back in 2008 Matrix took a close look at Advanced Materials and Advanced Engineering in separate reports. The end of 2015 saw the panel revisit those reports and broaden their scope to undertake a comprehensive review of Northern Ireland's Advanced Manufacturing, Materials and Engineering (AMME) sectors.

Central to the work undertaken has been a period of extensive consultation with local companies; with their directors, technologists and scientists talking in detail about the challenges facing them in day-to-day industry, the concerns they have, the opportunities they see and the support they need going forward.

What follows within this report is a detailed summary of key findings, and a number of industry-led recommendations to government.

Manufacturing is entering a critical period

In its latest foresight report "The future of manufacturing: A new era of opportunity and challenge for the UK", the UK's Government Office for Science set out how manufacturing in the UK and the wider global manufacturing ecosystem will be faced with new or ongoing changes in a number of areas over the decades ahead.[1]

Looking forward to 2050, the UK report identified four key future characteristics of manufacturing that will have significant implications for both government and industry:

- Faster, more responsive and closer to customers
- Exposure to new market opportunities
- More sustainable
- Increasing dependence on highly skilled workers

These changes will combine to create major opportunities, and challenges, for manufacturers, irrespective of whether the manufacturing is carried out in Belfast, Leeds, Cardiff or Edinburgh.

This Matrix study uses the UK foresight report as a basis for understanding what the future might hold for NI advanced manufacturers and presents a snapshot of some of the findings of the UK foresight report and highlights where Northern Ireland AMME companies are already aligned with opportunities identified, in a wider global manufacturing context.

When the UK report published (October 2013) the authors concluded: "Undoubtedly manufacturing is changing at an impressive, if not daunting rate."[2] Today, those same authors have indicated that, even at this early stage, the importance of Industrie 4.0 and the evolution of smart factories has grown both in terms of extent of impact and rate of change to an even greater degree than was anticipated less than three years ago - an indication of the speed with which the face of AMME is changing. Smart factories will allow individual customer requirements to be met and mean that even one-off items can be manufactured profitably. Dynamic business and engineering processes will enable new levels of flexibility and responsiveness, and end-to end transparency over the manufacturing process, facilitating optimised decision-making.

'The future' may be upon us, much sooner than anticipated, but what is clear from the work undertaken in the course of this study is that NI's AMME community is responding to that change. During the downturn, manufacturing industry in NI kept on track better than other UK regions. R&D didn't fall away and exports, largely speaking, remained strong. AMME is beginning to now reap the benefits of sustained R&D investment through the worst of the recession.

AMME is one of Northern Ireland's richest assets, with a diverse range of talented companies and individuals driving innovation and growth across the whole sector.

[1] Foresight (2013), The Future of Manufacturing: A New Era of Opportunity and Challenge for the UK. Project Report. The Government Office for Science, London.
[2] ibid.

Economic Backdrop

Current Economic Climate – Northern Ireland

> Manufacturing is essential for long term economic growth and economic resilience.

This report is presented to Government at an important point in the region's economic development. The *Fresh Start Agreement* has been launched, the delivery of a new *Programme for Government* and *Refocused Economic Strategy* is imminent, and the countdown to the lowering of Corporation Tax has begun. The NI Economic Advisory Group has just published the first Northern Ireland (NI) Competitiveness Report setting out a strategic review of NI's competitive strengths and weaknesses, stating:

"If NI is to deliver upon the economic aspirations in the *Programme for Government* and the *Economic Strategy*, NI must play to its relative strengths and improve performance in a number of areas. This requires confident, challenged policy development in those areas over which we can bring influence to bear."[3]

Another countdown has also commenced and in due course Northern Ireland will be competing across the world from an, as yet undefined, position outside of the European Union. Matrix, in highlighting the challenges and opportunities facing NI's AMME sector and in setting out recommended actions, provides advice which, in the context of current economic conditions, is both entirely relevant and timely.

Wider UK Manufacturing Climate

In recent years, the relative share of manufacturing in the UK economy has declined more rapidly than in other developed economies, from 30% in the early 1970s to 10% in 2011, while the service sector has grown at a faster rate (consistent with growth in other developed economies including France and the US). This 'deindustrialisation' has also applied to UK manufacturing employment, with numbers reducing at a faster rate than in other developed economies, from close to nine million people in 1966 to below three million in 2011.

UK manufacturing performance has been weak relative to international competitors in some key areas:

- Expenditure on manufacturing R&D, especially with regard to new products;
- The level of investment in capital equipment; and the UK's share of global manufacturing exports.

However, this is not a complete picture. Whilst some of these figures are sometimes considered as clear indicators of the UK manufacturing sector being in inexorable decline, this is untrue. There are also many outstanding individual firms, and some important areas of relatively strong performance for manufacturing as a whole. The fall in the UK's share of goods exports has been accompanied by an increase in the export intensity (manufacturing exports as a proportion of manufacturing output), which rose from about 30% in 1991 to around 47% in 2011 (similar to France and higher than the US). [4]

In assessing the role of manufacturing, it is important to go beyond its direct share of GVA and employment. Evidence shows a more complex picture, emphasising that manufacturing is and must continue to be an essential part of the UK economy, with diverse benefits.

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[3] The EAG Competitiveness Summary Report, July 2016.
[4] Foresight (2013), The Future of Manufacturing, op cit

A powerful contribution to the NI economy

Advanced manufacturing, materials and engineering (AMME) is and must continue to be an essential part of the Northern Ireland (NI) economy. Its benefits include:

R&D: AMME businesses are more likely to engage in higher levels of R&D. In 2014 AMME businesses made up 32.7% of total number of businesses performing R&D, but undertook 51.8% of total business expenditure on R&D (£209.1m). (Annual Business Inquiry (ABI), NISRA, November 2015)

Innovation: AMME businesses are more likely to innovate. During the 2010-12 period 64% of AMME SMEs carried out product/process innovation compared with 54% of all manufacturing and 40% of all industries. For large companies that figure increases to 74% of AMME (compared with 60% of all manufacturing and 48% for all industries). (Annual Business Inquiry (ABI), NISRA, November 2015)

Productivity: GVA per AMME employee has increased by 25% since the onset of the downturn (2011), and is now 8% higher than pre-recession level and 17.5% higher than whole economy GVA. (Regional GVA: ONS)

Exports & sales: AMME businesses are export intensive with 80% of sales occurring outside of NI (79% for all manufacturing, compared with just 34% of all private sector industries). NI total sales of AMME goods in 2014 was £7.2bn - that is 39.6% of all manufacturing sales. (Broad Economy Sales and Exports, NISRA, December 2015)

Highly skilled jobs: In 2014, remuneration in NI AMME was 26.4% higher in comparable occupations compared with the average across all industries, reflecting the high level of skills required in modern manufacturing roles. (ASHE, NISRA, 2015)

Inter-industry linkages: Manufacturing performance affects other sectors through its wide range of input-output and other linkages.

Economic resilience: Economies with strong, export-led manufacturing sectors typically recover from recessions faster than those without equivalent manufacturing sectors.

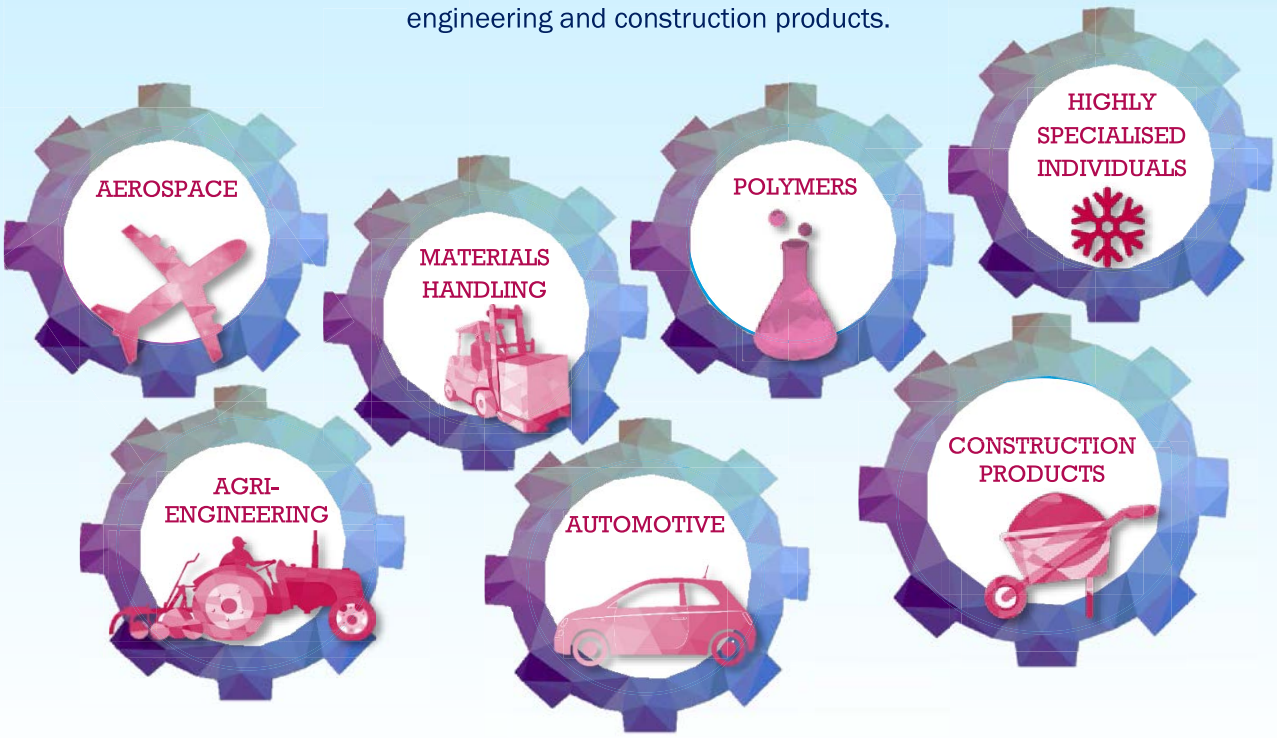
What is clear from the work undertaken during the past year is that manufacturing still lies at the very heart of business and industry in NI. The region's strong manufacturing heritage is in good shape, with a higher percentage concentration of manufacturing businesses in NI than in the UK as a whole. What is not always fully appreciated, however, is the breadth and depth of AMME activity in NI and its global impact.

The NI AMME sector is diverse, with activities ranging from aerospace, automotive, electronics, pharmaceuticals, and chemicals to heavy plant, automotive, agri-tech equipment and construction products.

NI has a strong and vibrant AMME sector and the signs are good.

A Powerful Contribution to the Northern Ireland Economy

The NI Advanced Manufacturing, Materials & Engineering sector is diverse, with activities ranging from aerospace, automotive, pharmaceuticals, and chemicals to heavy plant, automotive, agri-engineering and construction products.



Since the 2012 recession, the NI manufacturing sector has created 6,500 new jobs – nearly 3 times the UK growth rate.

TOTAL NUMBER EMPLOYED IN THE NORTHERN IRELAND MANUFACTURING SECTOR IN 2016: **80,170**

TOTAL NUMBER EMPLOYED IN AMME IN NORTHERN IRELAND IN 2016: **44,170**

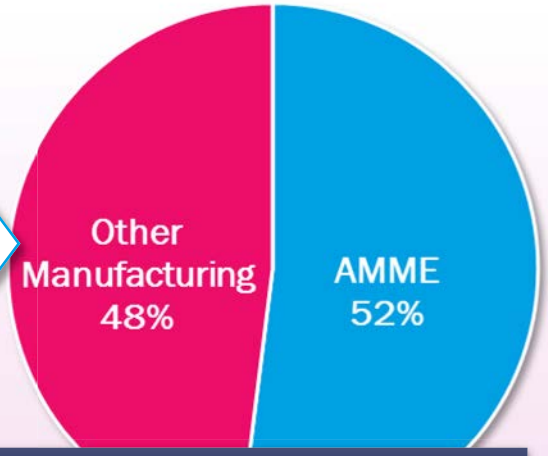
The outlook remains positive, but growth will be lower, reflecting the difficult international trading environment and the recent announcements at JTI, Michelin, Seagate and Bombardier, with the impact being most significantly felt in 2017 and 2018. (Source: UUEPC)

AMME's contribution to Northern Ireland's sales & exports

IN 2014, TOTAL AMME SALES BY NI COMPANIES WERE WORTH **£7.2bn**

AMME businesses make up **40%** of all NI manufacturing sales

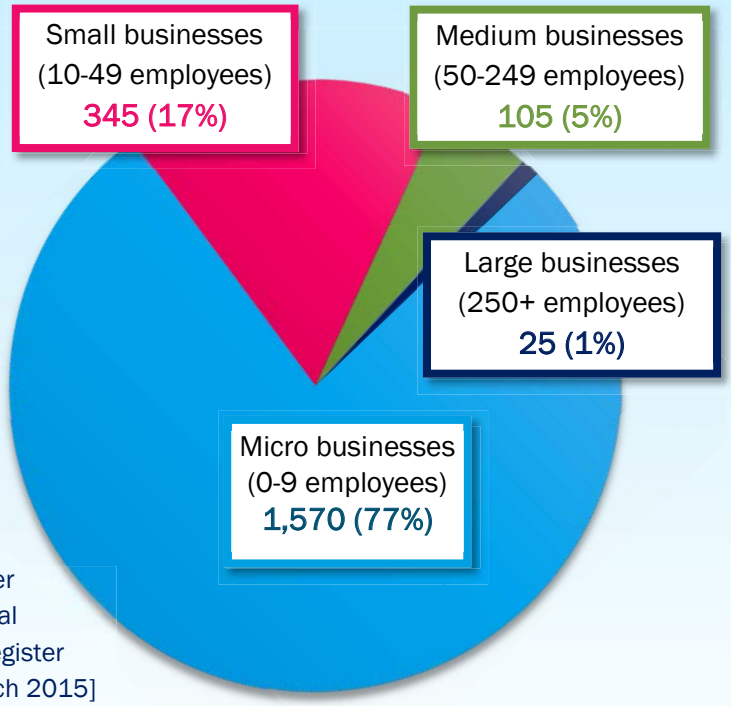
BUT AMME MAKES UP **OVER HALF** OF ALL OUR MANUFACTURING EXPORTS...



AMME is highly export intensive..80% of all NI AMME sales are external, compared to an 'all industry' average of 34%

Source: Broad Economy Sales & Export Sales, NISRA

Profile of AMME companies



[Source: Inter Departmental Business Register (IDBR), March 2015]

There are

2,050

AMME companies in Northern Ireland*

35%

of all manufacturing businesses.

*by Matrix AMME SIC classification – excludes LHS and Agri Food

AMME jobs are dispersed geographically across the NI region…

There are

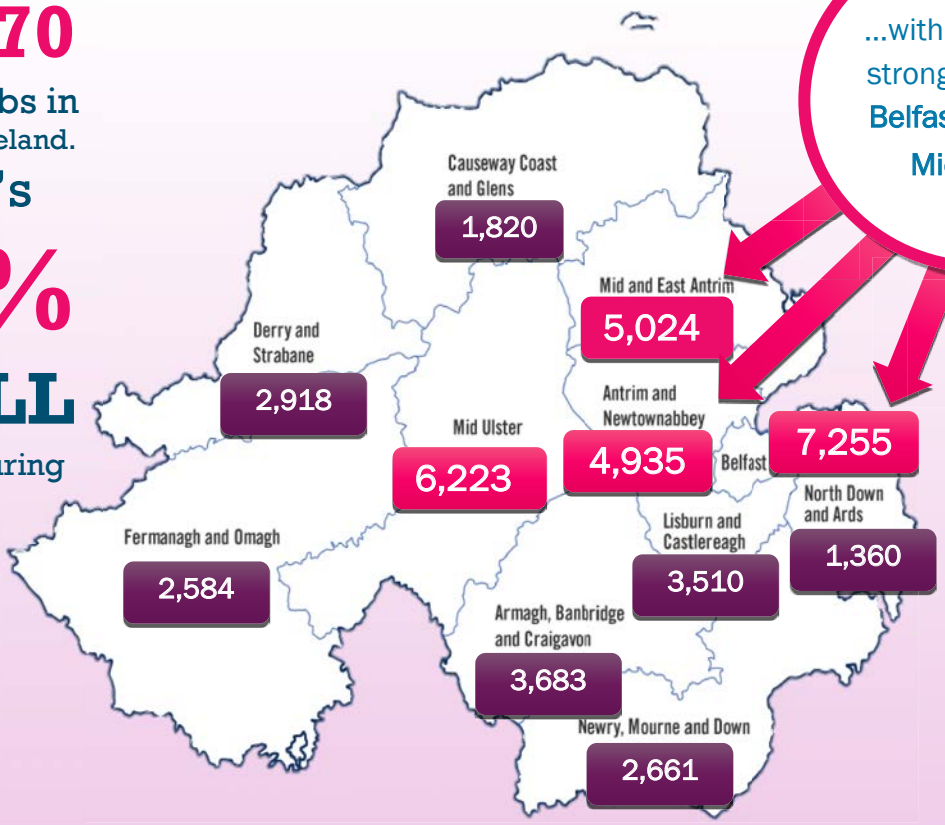
44,170

AMME jobs in Northern Ireland.

That's

55%

of **ALL** manufacturing jobs

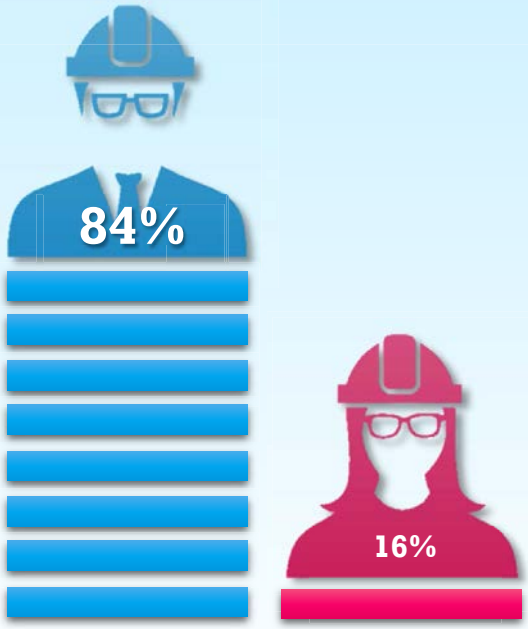


…with particularly strong clusters in Belfast, Antrim & Mid Ulster.

Source: NI Census of Employment (2013)

AMME workforce facts

AMME makes up more than half of all jobs within NI manufacturing. It is a male dominated sector with more than four out of every five jobs occupied by males (compared to an industry wide average of 48%).



Highly skilled jobs:

In 2014, the average AMME wage was £27,506; that is 15.2% higher than the average (in comparable occupations) across 'All Manufacturing' (£23,331) and 26.4% higher than the average (in comparable occupations) across 'All Industries' (£20,247).

But the gender pay gap is 26.7%.

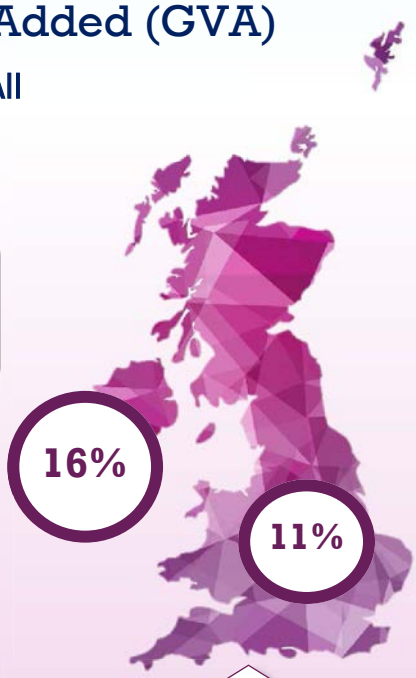
AMME Median gross earnings, ASHE, NISRA, 2015

Manufacturing Gross Value Added (GVA)

Over the period since last Matrix report, (2008-14) 'All manufacturing' NI GVA experienced growth of 29%.

In absolute terms, the contribution to NI GVA from manufacturing in 2014 was **£5.4bn**

The growth in GVA in NI manufacturing 2008-2014 is significantly greater than either NI industry or UK manufacturing. The AMME sector has been a key support for manufacturing growth in recent years. The size of the AMME sector increased at almost double the rate of the overall manufacturing sector over the 3-year period to 2013).



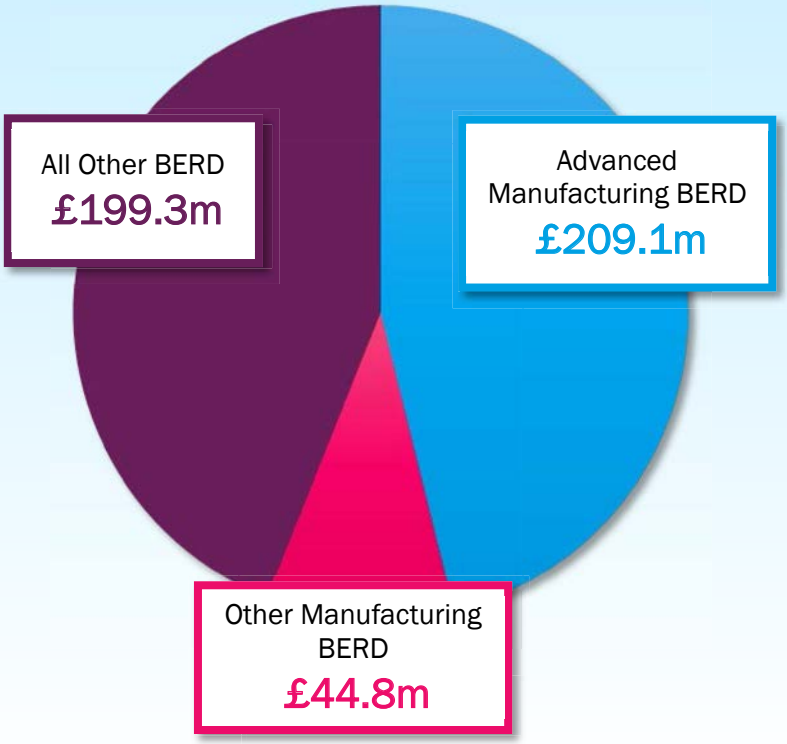
% of GVA that comes from manufacturing in NI compared to UK in 2014

GVA Growth 2010-13

ALL NI BUSINESS	UK MANUFAC-TURING	NI MANUFAC-TURING
9%	17%	29%

[Source: Regional GVA: ONS]

R&D Performance 2014



Advanced Manufacturing companies make up

32.7%

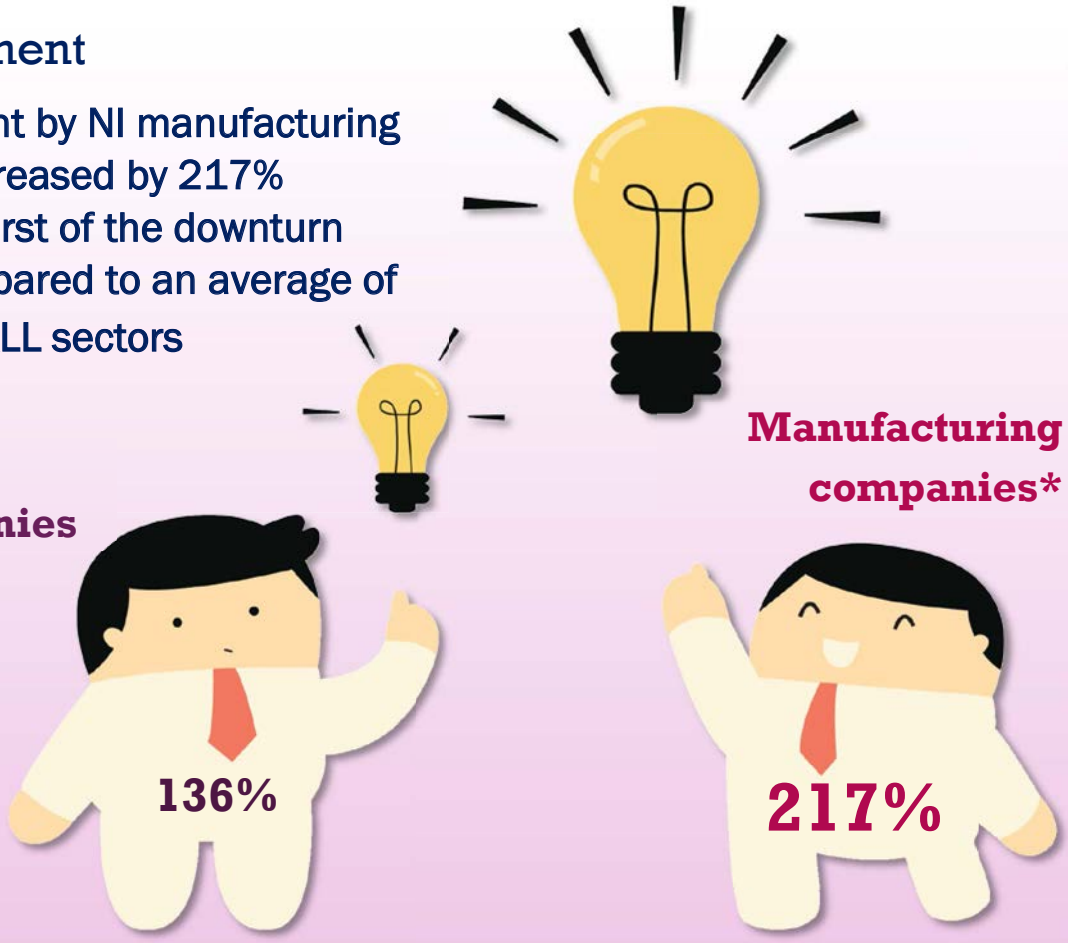
of the total number of R&D performing companies, but they undertook

51.8%

of the total BERD in 2014

R&D investment

R&D investment by NI manufacturing companies increased by 217% through the worst of the downturn 2008-14, compared to an average of 136% across ALL sectors



*Figures not available for AMME

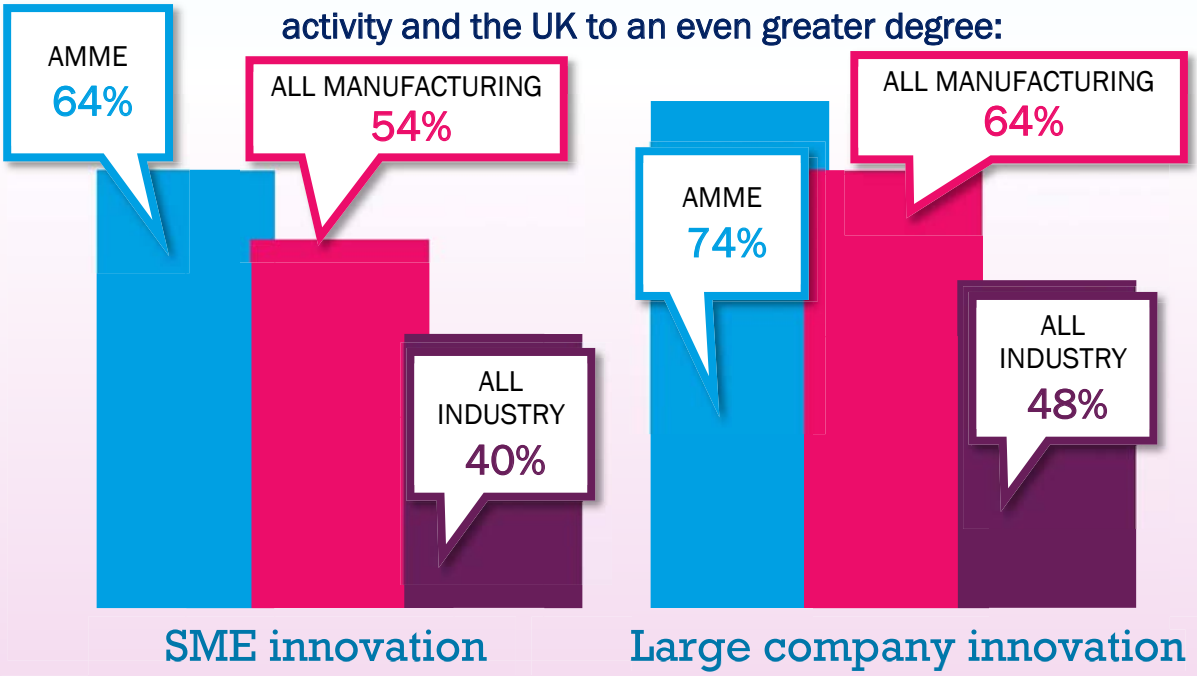
Source: NI R&D Survey, NISRA

AMME Productivity

The AMME sector in NI is overall more productive than the average across all NI industries, with productivity particularly high in the 'Manufacturing of Electrical Equipment' (£97,826) and 'Manufacturing of Computer, Electronic and Optical Products' (£84,890).

Innovation

NI's AMME sector out-performs the NI industry average in terms of innovation activity and the UK to an even greater degree:



- 64% of AMME SMEs are innovative, as are 74% of AMME large companies – higher than the comparative figure for 'All Manufacturing' (54% and 64%, respectively); and significantly higher than the NI industry average in terms of innovation activity (40% for SMEs and 48% for large companies).
- UK statistics broadly aligned to AMME classification indicate that NI's AMME innovation by industry out-performs (broadly equivalent) UK stats to an even greater degree (by up to about 10%).

Source: NISRA

Strategic Context

Northern Ireland

Programme for Government

The *Programme for Government* (PfG) sets the strategic context for both the Budget and the Investment Strategy for Northern Ireland.

Economic Strategy

The *NI Economic Strategy* sets out how the Executive plans to grow a prosperous local economy over the short, medium and longer term to 2030.

Regional Innovation Strategy

On 9th September 2014 the Northern Ireland Executive agreed the *Innovation Strategy for Northern Ireland* 2014 - 2025

NI R&D&I Funding Framework

- HMT R&D reliefs regime (R&D Tax Reliefs, Patent Box)
- Invest NI R&D assistance (Grant for R&D, KTP, Proof of Concept, Innovation Vouchers, Competence Centres)
- Invest NI business improvement intervention (Skills, Trade & Export, Lean Manufacturing, Technology Audit and IP support)
- Department for the Economy (Skills to Succeed)

Sector Support

- Aerospace, Defence & Security Group (ADS)
- NI Polymers Association (NIPA)
- NI Advanced Composites and Engineering Centre (NIACE)

Regional Research Initiatives

- Knowledge Economy Index
- Skills Barometer
- Competitiveness Scorecard

Strategic Context – UK

Foresight Report: The Future of Manufacturing: A new era of opportunity and challenge for the UK

Opportunities and challenges facing manufacturing up to 2050 and the impact these will have on government policy. (October 2013)

Eight Great Technologies and Industrial Challenges

Osborne's 'eight great technologies' where the UK can lead the world. The Chancellor announced an additional £600 million investment to support their development. (Autumn 2012)

"Our Plan for Growth: Science and Innovation" Innovate UK Delivery plan, 2016/17

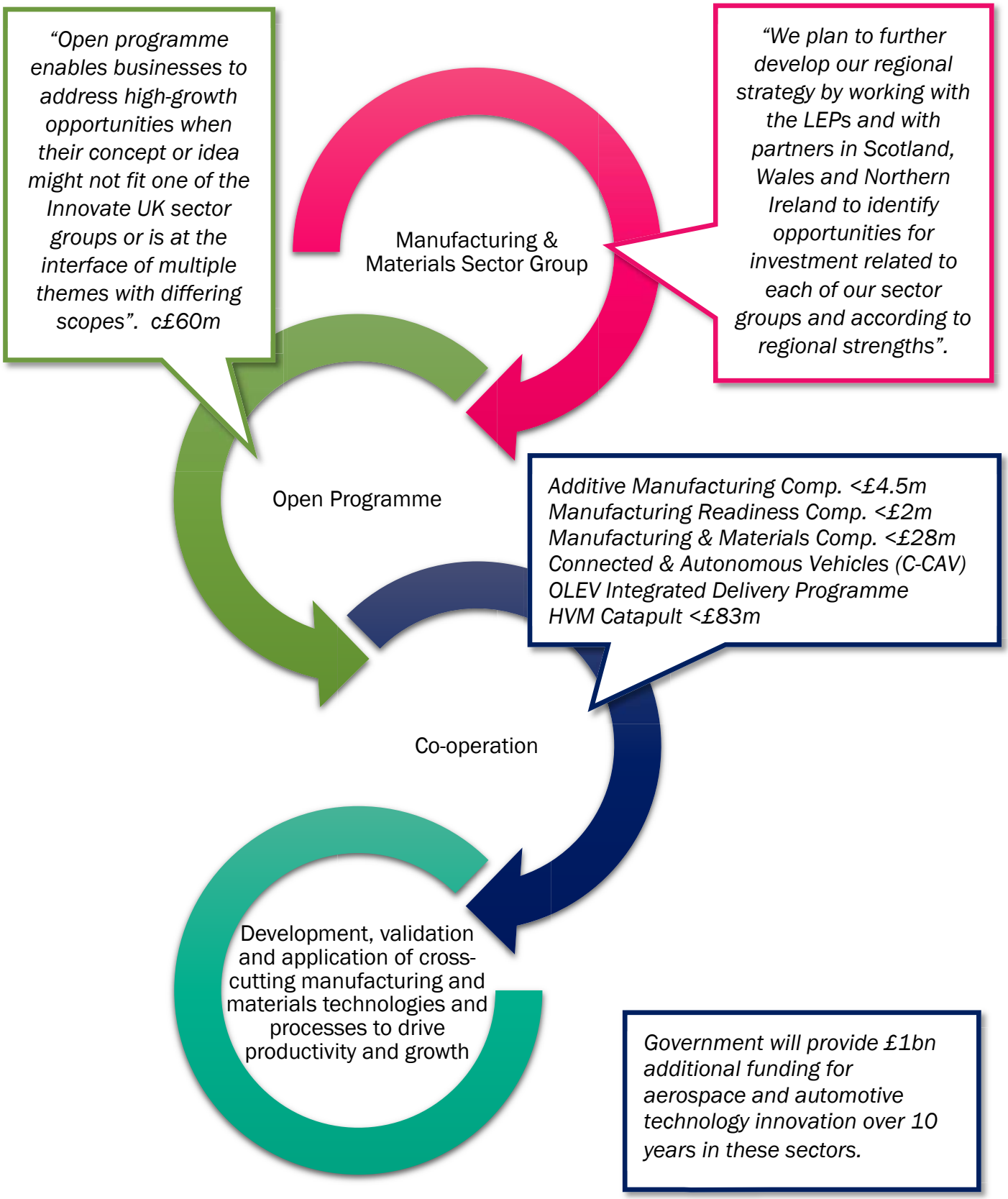
Innovate UK's plan to build on the momentum that Catapults have helped create in order to accelerate sector growth. Funding will be based on 4 sector groups, one of which is Manufacturing & Materials, plus an 'open' approach and Co-operation, (December 2014)

Department for Business, Energy & Industrial Strategy

Cabinet Committee on Economic and Industrial Strategy, August 2016

Following the creation of the new Department for Business, Energy and Industrial Strategy (BEIS), the creation of a new UK Government Cabinet "Committee on Economic and Industrial Strategy" will focus on achieving long-term improvements in industrial productivity and on encouraging innovations that will give the UK a competitive advantage. Key priorities for the department will be to develop a comprehensive industrial strategy; continuing to ensure the UK remains at the cutting-edge of science, research and innovation; tackling climate change; and ensuring affordable, clean and secure energy supply for the UK.

Figure 1: Innovate UK Delivery Plan 2016/17[5]



[5] Innovate UK Delivery Plan. Financial Year 2016-2017.

European Framework

"Manufacturing is seen as the engine of Europe for future growth and jobs and a vital element of the European industry renaissance".[6]

"I firmly believe that we need to maintain and reinforce a strong and high-performing industrial base for our internal market.... This should ensure that Europe maintains its global leadership in strategic sectors with high-value jobs such as the automotive, aeronautics, engineering, space, chemicals and pharmaceutical industries.

To achieve this we need to stimulate investment in new technologies, improve the business environment, ease access to markets and to finance, particularly for SMEs, and ensure that workers have the skills industry needs".

"A New Start for Europe: My Agenda for Jobs, Growth, Fairness and Democratic Change" - opening statement in the European parliament plenary session.

Jean-Claude Juncker
Strasbourg
15th July 2014

The policy debate on the future of industry and manufacturing in the EU has intensified over the last decades, but gained even more significance since the economic and financial crisis. Today the challenge is to arrest and reverse Europe's long-term industrial decline.

That challenge applies to UK manufacturing generally and in the context of this study, irrespective of the UK's position within or outwith the European Union. The question of access to EU framework funding in the post Brexit scenario remains to be determined. Vehicles exist for Associated countries (including Norway, Israel and Switzerland) currently and for non-Associated third countries under the "openness strategy". Whatever the exact nature of the UK's future relationship, EU funded or not, the focus and direction of EU R&D&I policy will continue to inform UK policy and will therefore remain important to NI's AMME community.

Aside from R&D&I policy, the question of barriers and tariffs in relation to the movement of people and goods will be important. Restrictions on access to skills from EU member states will need to be redressed via local skills provision, with increasing demand further enforcing existing skills recommendations, as set out in Skills Barometer[7] assessment (discussed further in this report).

[6] Key Enabling Technologies: Time to Act, Final Report, June 2015.
[7] op cit

The manufacturing challenge

Europe is confronted with a structural erosion of its manufacturing base and risks losing its competitive manufacturing capacity. As a result of economic and financial crisis and rapid geopolitical trends, Europe's manufacturing position is changing. The de-industrialisation of Europe and the progressive dismantling of its manufacturing sector, both in terms of GDP (from 18.5% in 2000 down to 15% in 2012) and employment (3.8m jobs were lost over same period), is well documented.

> "Significant investment programmes are profoundly altering economies, especially in Asia."
>
> KET

The rise of Asian economies, including China, Japan, South Korea and India is confirmed all along strategic industrial value chains. "Significant investment programmes are profoundly altering economies, especially in Asia".[8]

The resurgence of US manufacturing

Since the end of the recession, manufacturing in the US has added jobs and expanded at a historic rate. Manufacturing output has increased 30% since the end of the recession, growing at roughly twice the pace of the economy overall. Between Feb 2010 and Jun 2014, the US added 646,000 manufacturing jobs and restored its leadership position in attracting business investment.[9]

> "In the US manufacturing is being reinforced to regain competitive advantage and this appears to be helping productivity and related employment."

This was the result of recent ambitious policies (including the establishment of a national network of 45 manufacturing institutes over 10yrs) and the provision of incentives for manufacturing and insourcing to "make America a magnet for jobs and manufacturing". Flagship initiatives, such as Manufacturing Innovation Institutes and the reshoring initiative have been credited with reinforcing both the US technological infrastructure and manufacturing bases, leading to renewed manufacturing growth that has created millions of additional jobs across its supply chain. According to AT Keaney's 2014 FDI Confidence Index, the US surged past countries like China, Brazil and India to become the country with the top FDI prospects globally with significant investment in R&D.

The European manufacturing renaissance

It is against this backdrop that a number of Key Enabling Technologies (KETs) have been identified and are now at the core of political agendas and recognised by policy makers as strategic for the competitiveness of European industry, as well as for economic growth and job creation; as reflected in the EU strategy for KETs, the updated EU Industrial Policy and in the European Regional Development Fund, where they are recognised as an investment priority.

- **"Integrated Industrial Policy for the Globalisation Era: Putting competitiveness and sustainability at centre stage"** (Communication from the European Commission, 2010).
- **"A stronger European Industry for Growth and Economic Recovery: Industrial policy communication update."** Communication from the European Commission, 2012.
- **"For a European Industrial Renaissance".** Communication from the EC, 2014.

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[8] Key Enabling Technologies. op cit.

[9] Making in America. US manufacturing entrepreneurship and innovation, the Executive Office of the President. June 2014.

Subsequently, KETs are now a priority for the new framework programme for Research and Innovation (H2020), one of the investment priorities in the European Structural and Investment Funds and also in the European Investment Bank.

The European strategy for KETs (2009) identified, for the first time, key technologies that would have the potential of strengthening the EU's industrial and innovation capacity to address the societal challenges.[10] Six KETs were identified:-

- Advanced manufacturing
- Industrial biotechnology
- Nanotechnology
- Advanced materials
- Micro- and nano-electronics
- Photonics

Europe derives competitive advantages in many products and services and in multiple domains, many of which are driven by KETs e.g. in automotive, aeronautics, engineering, space, chemicals, textiles, building and infrastructures, agriculture and healthcare. KETs can revolutionise processes and help modernise manufacturing, reducing costs of production, reliance on finite materials, energy consumption, waste and pollution. The nations and regions that adopt these technologies and embed them into innovative products, processes and services will be the main beneficiaries in terms of growth, sustainability and jobs, with the global KET market estimated to be worth more than £1tn.

> "In the coming years, our capability to innovate in KETs will certainly be one of the most important factors for the success of the European manufacturing industry."
>
> **KETs: Time to Act, 2015**

NI AMME businesses are already competing in global markets (27% of AMME exports are to Rest of World, 50% to NI/GB/RoI, with the remaining 13% to Rest of EU)[11] and are well placed to take advantage of growing markets in KET areas, irrespective of the whether they are trading from a position within the EU, as is the case in 2016 or in the future, from a post-Brexit position.

[10] European Strategy for Key Enabling Technologies, 2009.
[11] Broad Economy Sales and Exports, NISRA, December 2015.

About this study / Scope of AMME

The Matrix study covers most areas of advanced manufacturing, but leaves out agri-food (widely considered to be a sector in its own right) and, for similar reasons, life and health sciences, the subject of an earlier Matrix report published in February 2015.[12]

Government statistics have been drawn from SIC codes (see Annex 1) to reflect the definitions of Advanced Manufacturing, Advanced Materials and Engineering – referred to as AMME throughout the study.

In total there are around 2,050 organisations of varying size and scale, employing 44,170 individuals and manufacturing a wide range of (often very specialised) products which fall within the scope of the AMME study.

Definitions

Advanced Manufacturing[13]

Advanced Manufacturing is:

"a family of activities that

a) depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or
b) make use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry, and biology.

This involves both new ways to manufacture existing products, and especially the manufacture of new products emerging from new advanced technologies."

Advanced Materials[14]

Materials types are labelled in variety of ways, often overlapping. Different types of materials can be defined or qualified in terms of:

- traditional categories (e.g. ceramics, polymers, alloys)
- material properties (e.g. optical, electronic, magnetic)
- application (e.g. materials for low energy technologies)
- the nature or scale of engineering (e.g. nano-materials, micro-materials) and
- sector (e.g. aerospace materials)

These categories are not intrinsically distinct. Some advanced materials could correspond to some or all of these labels. Furthermore, there a variety of labels used to qualify categories of materials, i.e:

- 'advanced materials'
- 'high value materials'
- 'modern materials'
- 'future materials'.

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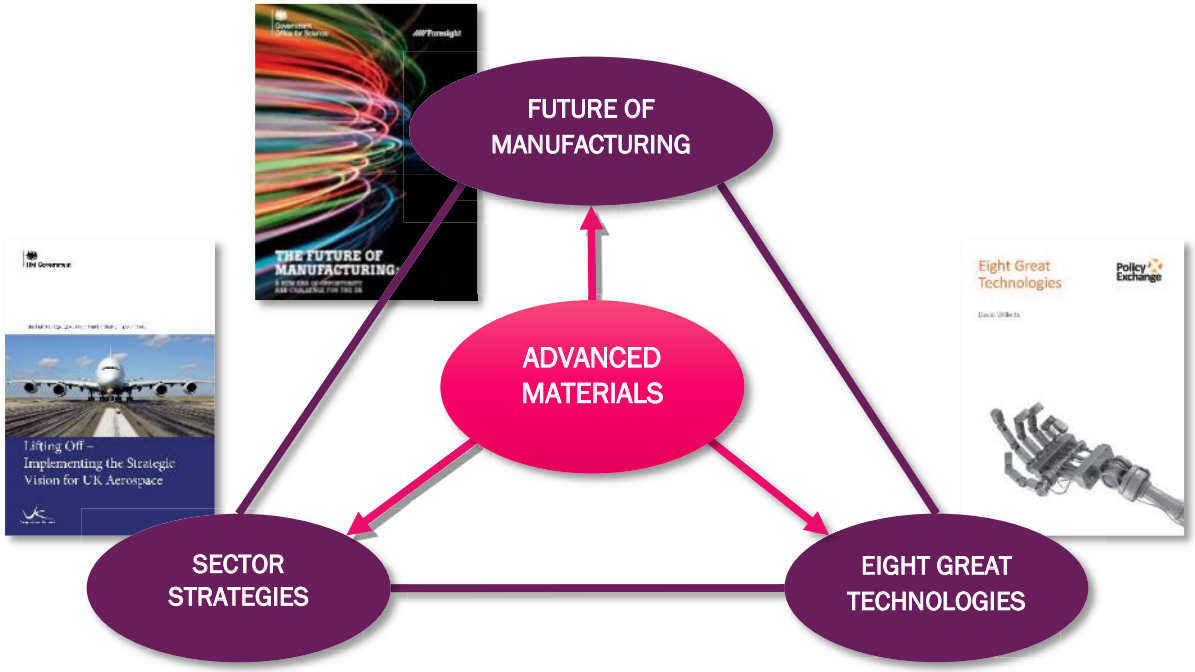
[12] Matrix, the NI Science Industry Panel - Reports
[13] The Advance Manufacturing Partnership 2.0 (AMP 2.0) report, President's Council of Advisors on Science and Technology on Ensuring American Leadership in Advanced Manufacturing
[14] A review of international public sector strategies and roadmaps: a case study in advanced materials. Dr Charles Featherstone and Dr Eoin O'Sullivan, March 2014.

Previously, Matrix dealt with Advanced Manufacturing and Advanced Materials in separate reports. The treatment of Advanced Manufacturing, Advanced Materials and Engineering in a single report this time around is not accidental. Most if not all of the companies falling within the AMME definitions are using advanced materials and for that reason, as is increasingly the case more widely, the disciplines are now considered together and not apart.

Figure 2: The importance of advanced materials to key technologies, sectors & production



Source: A review of international public sector strategies & roadmaps: a case study in advanced materials by Dr. Charles Featherstone & Dr. Eoin O'Sullivan[15]

[15] Op cit

Methodology and approach to data

Use of data

The research adopted a mixed-methods approach, with existing AMME data and literature on foresight and global trends and opportunities supplemented by primary research with AMME businesses and stakeholders. Primary research was undertaken during November 2015 – March 2016, with over 30 in-depth employer interviews conducted in addition to an online survey which was open to all AMME businesses and stakeholders.

While the SIC-based NISRA statistics enable us to draw a picture of the contribution of the sector to the local economy, for the purposes of this study – to facilitate being able to take a closer look at AMME specifically - companies falling within the AMME broad SIC classifications were ranked according to a range of high volume measures:

- R&D expenditure
- Collaborative R&D engagement
- Exports & sales
- Number of employees
- Turnover

A range of sources were used to provide the data for these measures, including NISRA and DfE (formerly DETI and DEL) published statistics (SIC code based), published company data including the Fame database, Bel Tel 100, Profit 200, LSE Group – Manufacturing and Engineering Insight ("Top 1,000 companies to inspire Britain") annual reports and sector body statistics. Data sets relating to publicly funded R&D allocated to NI private and HE/FE sectors were also utilized.

Public Funding Data Sources	Research Base Data sources
Invest NI	EPSRC
Innovate UK	UU, QUB
HMRC	University Business Collaboration/ HEFCE
DfE (formerly DETI/DEL)	

The culmination of these data sets along with qualitative evidence gathered during the consultation phase of the study facilitated the population of a Matrix AMME database, affording a unique level of granularity. This allows us to draw a more accurate and tailored picture of where AMME activity in NI is concentrated in 2016 and provides a detailed insight into the sector both in terms of overall trends, critical mass in sub-sectors and individual company performance.

The benefit of access to data at this level is two-fold:

- **NI decision-making:** Government can make better informed decisions with respect to future policy.
- **Policy alignment:** NI policy makers can feed through accurate information with respect to overall trends and areas of specialism within NI AMME, relevant to national policy initiatives.

Consultation phase

A range of individual companies contributed to the qualitative research undertaken during the course of the study, representing a cross-section of AMME companies by size, stage of development, product/market, ownership and business model. The evidence gathered during these company visits and interviews then informed a structured AMME workshop in March 2016, the culmination of which, along with key stakeholder engagement, led to the development of recommendations within this report.

Literature review

A comprehensive list of evidence papers reviewed during the course of the study is provided at Annex 2 and online via the AMME library section of the Matrix website. This includes recent NI regional research relevant to the study, e.g. the NI Skills Barometer and the Knowledge Economy Index reports.

Already mentioned in the introductory section is the use of evidence provided within the UK Foresight Report, Oct 2013[16] – the offer to 'pull apart and use freely' anything of particular interest within that work has made a valuable contribution especially to the "Future of Manufacturing" section of this report.

[16] Foresight (2013), The Future of Manufacturing, op cit

Key findings

NI has a strong cohort of individual AMME companies making a very significant contribution to the local economy – these companies are competing globally and are Research & Development and Innovation intense.

Critical mass:

AMME activity in NI (whether formally clustered or not) exists around three leading areas:

- Aero, Defence, Security & Space (ADSS)
- Materials Handling (MH)
- Polymers

(together these 3 groups account for 39% of top AMME performers).

Strong performance:

In addition, there is evidence of strong performance within:

- Automotive
- Construction Products
- Agri-Engineering

(together these three groups account for 29% of top AMME performers)

Significant and unique:

Individual companies classified within AMME as 'Highly Specialised Individuals' together account for over 30% of top AMME performers.

Heritage and innovation:

The ability of NI's AMME businesses to successfully innovate and diversify to pursue long-term growth paths is clear.

- **R&D intensity:** Investment in R&D over a prolonged period and sustained throughout the downturn is a clear signal that R&D is embedded across the top 200 AMME performers.
- **Longevity:** Many of NI's top 200 AMME companies (38%) are established 25years +; of which over a fifth can trace their roots back more than 40 years.

Respected and globally renowned – a strong brand:

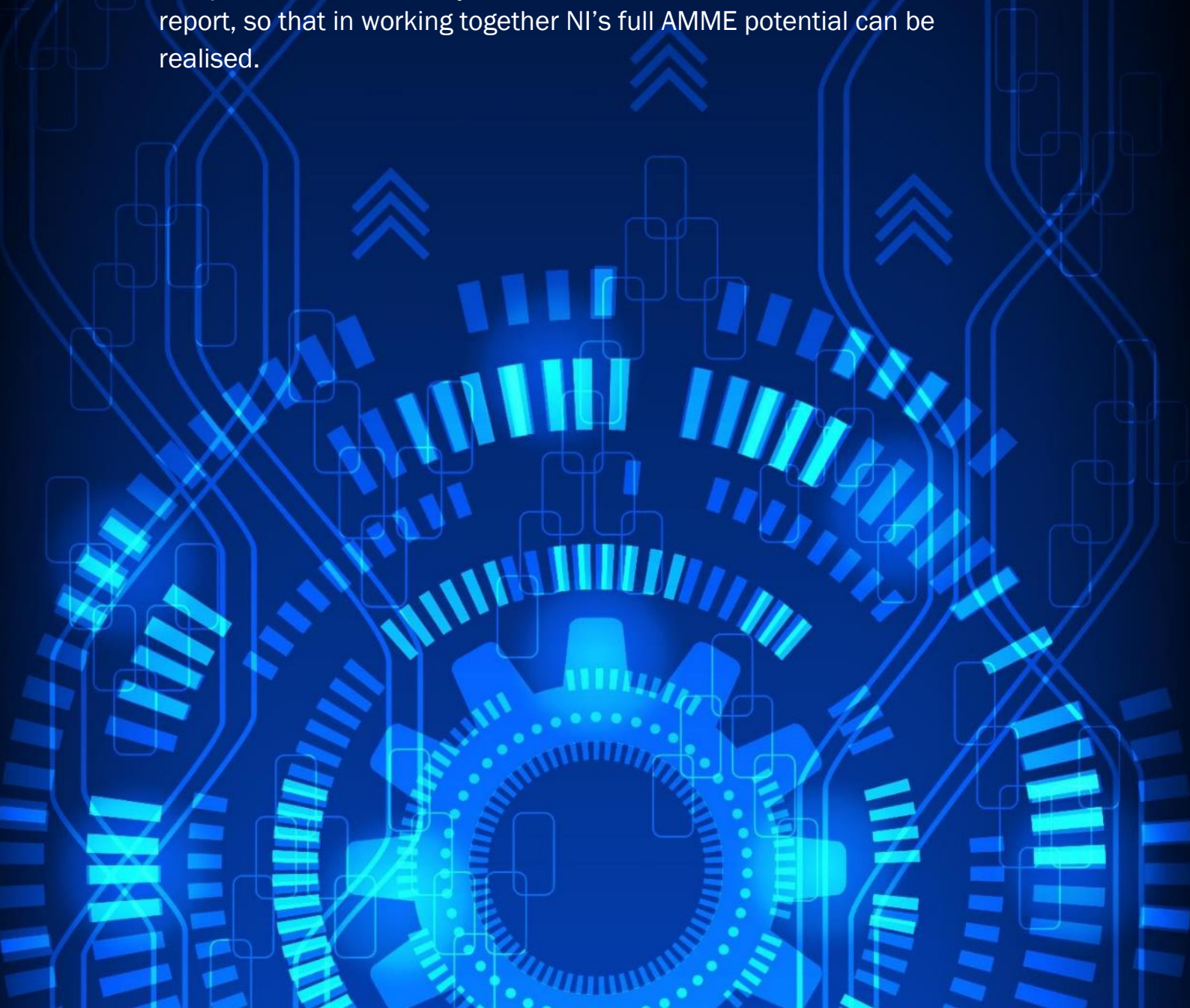
Irrespective of what particular area of AMME they are employed in, NI's AMME professionals are globally respected with NI engineering firmly reputed for excellence in quality, innovation and cutting edge design.

Taken together, whether as a sector, sub sectors, clusters or individuals, the contribution these AMME companies make to the NI economy is impressive and a testament to the quality of NI's advanced engineers. NI's AMME capability should not be understated – it is a powerful and formidable force.

Yes, manufacturing, by any definition has and will continue to face difficult times. But by and large, NI's AMME businesses survived the recession, have emerged more confident than before and are once again investing in growth.

The challenges they identify, whether keenly felt in 2016 or anticipated for the future, should be considered in the context of a sector that can see enormous development opportunity.

As such Matrix impresses upon government the need to respond in a comprehensive and timely manner to the recommendations within this report, so that in working together NI's full AMME potential can be realised.



What AMME companies told us - what matters most to AMME companies in NI today?

Frequent and consistent themes:

Skills

Consistent with many other AMME communities, by far the most important issue concerning NI's AMME leaders is the availability of the right number of relevantly qualified workers at the right time.
Matrix wholly endorses the earlier findings of the 2015 NI Skills Barometer and the recent and proposed developments within NI Apprenticeships. In that context, AMME skills are considered in detail in the report, along with a number of suggested potential recommendations to Government, Industry and Academia.

Costs

As with skills, the issues raised are not unique to NI, and not all are of equal concern to each AMME company. However, when taken together, the key concerns around energy, foreign exchange, Corporation Tax, rates stability, logistics costs and others present significant challenge to a sector which has been under persistent threat over recent decades.
There is a general acceptance that some of these areas fall outside NI control. However, the recommendation to government is that, when policy is being developed, that the impact on NI's AMME businesses is front and centre of decision making. This report points to the recommendations relating to costs within the 2016 Oxford Economics report commissioned by Manufacturing NI.

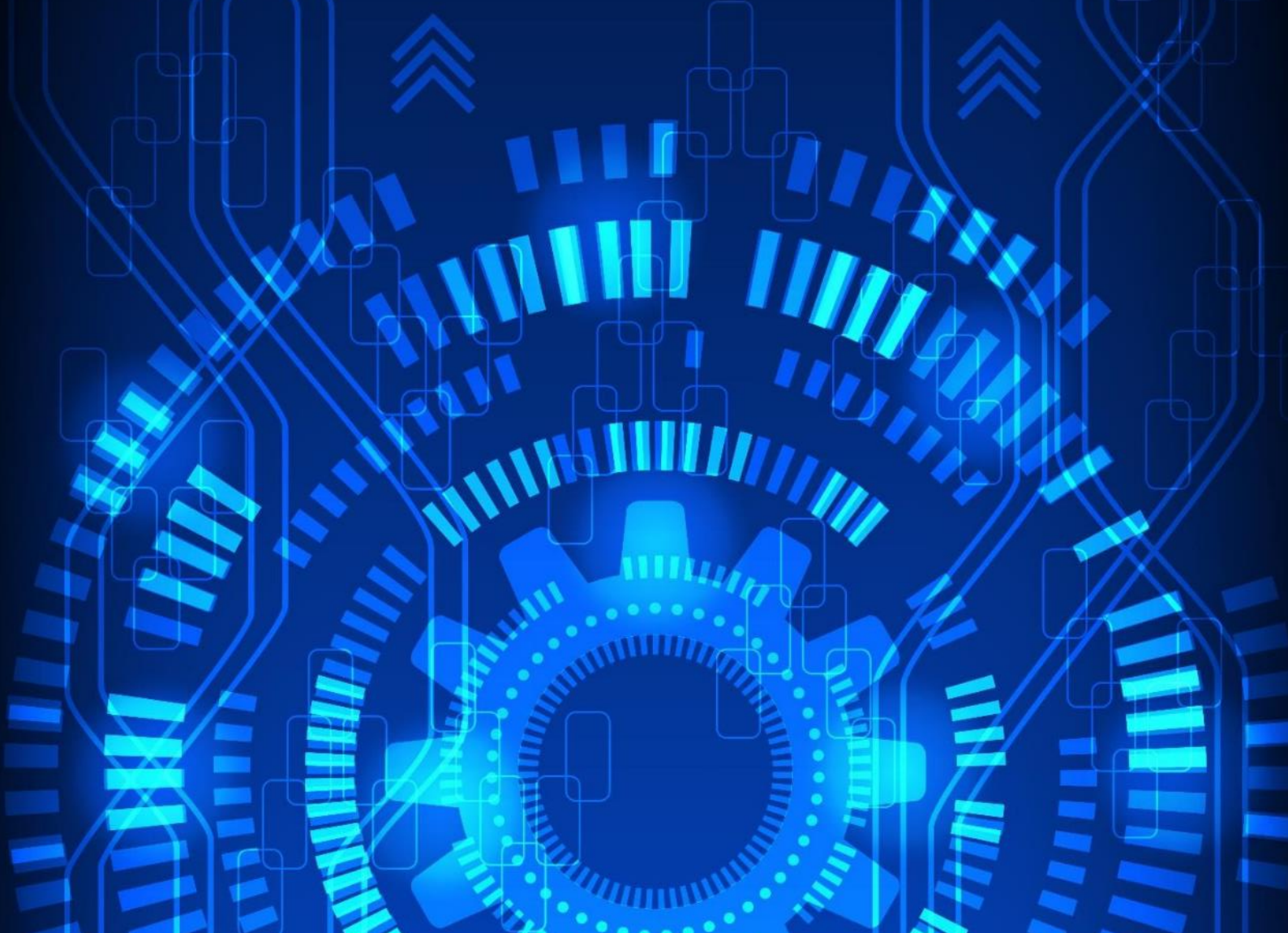
Sectoral Development

NI's combined AMME strength is a formidable force, in any context. The companies have grown, diversified, survived the recession, sustained their investment in R&D and are now hitting global playing fields with renewed purpose. The impact of sectoral development already undertaken is evident (e.g. the Aerospace, Security & Defence Group (ADS) and SC21 for the Aerospace, Defence, Space & Security sector and the work of the Northern Ireland Polymer Association for polymer businesses).
With confident and ambitious leadership, NI's AMME combined capability can be further developed and promoted effectively – for the benefit of all. The report draws out specific recommendations pertaining to sectoral development.

And what of the future?

When asked about the opportunities ahead, what was loud and clear from the consultation undertaken, irrespective of whether the company falls within a specific 'cluster' or 'sub-sector', or stands alone as a Highly Specialised Individual is that NI's AMMEs absolutely see the opportunities before them and the potential they can fulfil in an evolving Future Manufacturing market.

The following chapter focuses on the (rapidly) changing face of AMME and future trends and inherent challenges and opportunities, many of which we already see emerging within NI AMME.



The Future of Manufacturing

Identifying with UK foresight trends

This section contains a number of 'snapshot' summaries on topics including servitisation, the circular economy, personalisation, on/re-shoring and phoenix scenarios.

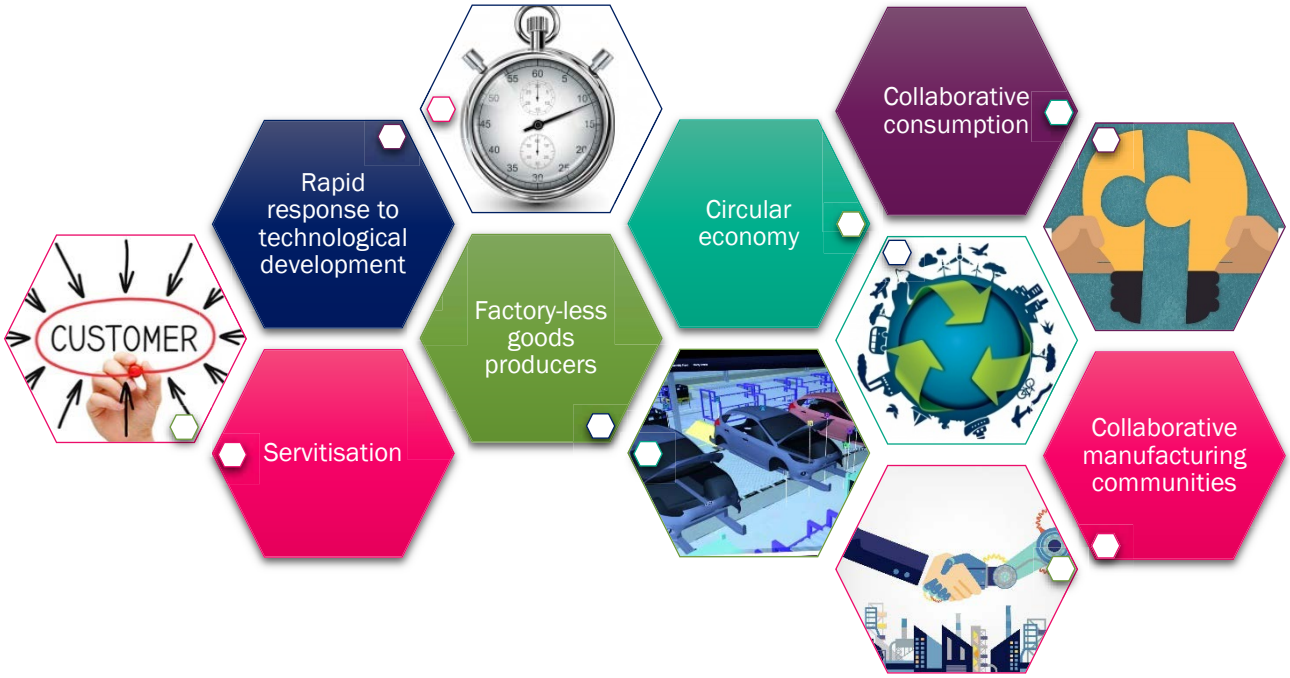
It also includes a more detailed review of the impact of technological change, to include:

- ***Primary and underpinning technologies***
- ***Industrie 4.0 / Smart factories***
- ***Factories of the future***

Introduction

AMME businesses are increasingly using a wider 'value chain' to generate new and additional revenue from pre- and post-production activities. Capturing value from manufacturing is therefore increasingly about capturing value throughout the lifecycle of products. Manufacturing will continue evolving in the future, with new ways of doing business placing greater importance on using new sources of knowledge and information, and establishing much closer, long-term relationships with customers.

Figure 3: Future sources of new and additional revenue for manufacturers[17]



- Selling services in combination with products much more extensively;
- Using products to generate new information about consumers and the usage of products;
- Becoming 'factoryless goods producers' - capturing value by selling technological knowledge and leaving production to someone else;
- Shifting to a 'circular economy' way of doing business, with end of life products remanufactured and returned to original specifications or better;
- Making use of changes in product ownership, by providing more robust products for 'collaborative consumption' as opposed to outright product ownership;
- Forming strategic alliances with manufacturers across sub-sectors, resulting in collaborative communities which may become more significant than networks dominated by lead firms;
- Using operational capabilities combined with greater entrepreneurial insight to respond rapidly to technological developments.

> "With servitisation, personalisation, circular economy and rental models becoming increasingly important in most sub-sectors in future decades as technological, economic, environmental and social trends force manufacturing firms in these directions … future manufacturing business model trends will be transformed."
>
> (Foresight, 2013)

[17] See Annex 3 for Summary table of future manufacturing business model trends, Foresight (2013).

Servitisation

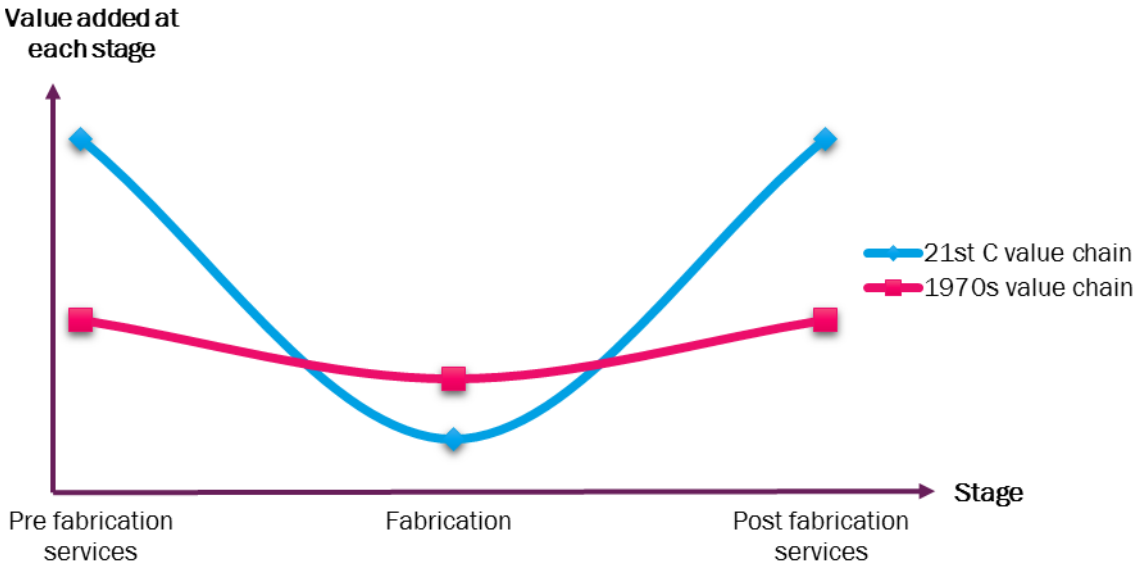
Locking in customers

Evidence suggests that services are added to generate extra revenue and to 'lock-in' customers. They can also make products and their maintenance more accessible, enable customer-specific uses and linkage to other products and provide the benefits of a product without exchange of owner. Reported manufacturers generating substantial proportions of revenue from services include Rolls Royce (49%), ST-Ericsson (38%), AtlasCopco (43%) and the Rolls Royce "power by the hour" offering, using capital equipment on an access basis, illustrates a model of what the future holds.[18]

Wider levels of servitisation are difficult to assess in terms of take-up. Based on the reality that most manufacturers provide some degree of services, the UK Foresight study underlines the requirement to distinguish between 'service enhanced' and 'service orientated' manufacturers.

Manufacturers aren't obliged to report service revenue separately. The limited reference to servitisation by NI manufacturers consulted during the course of this study suggests that, for now anyway, the focus is still very much on products. With some research suggesting that firm value will only rise once service revenue constitutes c30% of total revenue, perhaps the low level of focus on services at this stage is hardly surprising.[19] That said, the potential to generate extra revenue and to 'lock-in' customers should not be overlooked.

The 'smile curve' representation of the manufacturing value chain



[18] Neely, A. Benedetinni, O. & Visnjic, I. (2011)
[19] Fang, E. Palmatier, R. & Steenkamp. (2008)

CASE STUDY: WHALE PUMPS

Bangor-based Whale has been a leading manufacturer of pumps for the marine and caravan industries for many years, but the US-owned company is branching out in an entirely new direction. Whale bought its first 3D printer five years ago, established a business case and went on to purchase a couple of the very latest 3D print units in more recent years, setting up a dedicated Whale 3D division based in one of two buildings the company occupies on the outskirts of Bangor.

Whale 3D works closely with Stratasys, the US-based world leader in the production of large-scale 3D printing machines, and has partnered with Stratasys at exhibitions and shows to showcase the application of the technology within industry.

The Bangor operation also lays a strong emphasis on product quality. “We aren't the cheapest manufacturer in our marketplace,” says Richard Bovill, Whale’s Engineering Director, “But we think that we are the highest quality manufacturer around. Continuous improvement is part of the culture here.”

KEY FACTS

- Based at twin purpose-built sites in Bangor, Co. Down, Whale is now a £19.4 million turnover operation with a staff of 170, almost all of whom are based in Northern Ireland.
- The Bangor site employs a team of 40 engineers and has its own software development unit. This allows Whale to develop new product applications on its 12 injection moulding machines in the main plant.
- Whale exports to 52 countries worldwide and estimates an annual research and development spend of £1.5 million annually.
- Whale has over 100 customers in the aerospace, automotive, toy and even jewelry sectors in the UK, North America, China and Australia.

“Why did we get into 3D print technology? Because we could see it was a way for us to produce prototypes for seals, diaphragms, casings and other components for the R&D side of our own business.

“Before this technology was available, a prototype might take two or three weeks through design and production. On a 3D printer, we can produce what we need in 24 hours.

“That's a major advantage when it comes to speeding up the whole development process, and it can also reduce tooling costs.

“Even as things stand today, there's no doubt that 3D print technology speeds up research and development. But, in the future, the list of potential products that can be 3D printed is virtually endless.”

Jim Sergeant, Whale Pumps

Snapshot

Product Personalisation

Improvements in ICT + consumer-input + automation + additive manufacturing = increased potential for offering individually tailored products under conditions traditionally deemed unfeasible.

The prospect of mass product personalisation over the coming decades, 'make-to-stock' versus 'make-to-order' will be driven by advances in additive manufacturing, new materials, computer-controlled tools, biotechnology, and green chemistry. In addition, direct customer input at the design stage will enable companies to produce customised, affordable, high quality goods and services with shorter cycle-times and lower costs associated with standardisation and mass production.

Research suggests that customers in developed economies are already prepared to pay a premium of 10% for some degree of personalisation. This is a significant opportunity for manufacturers, and innovative technologies are already making this option more feasible. As consumers increasingly seek, and pay for, products and services that match individual needs more closely, technologies that enable precise requirements to be met (e.g. personalised clothing, newsletters, consumer goods and medicine) are beginning to emerge. Examples of personalised products already available include Nike footwear, Dulux tailor-made colour and VW cars.

Products are also likely to become increasingly 'information-dense' or 'informated', enabling not only the personalisation and services mentioned above, but also explaining the provenance and 'green' credentials of products as consumers seek easy access to data about what they eat, wear and buy. These products will also potentially, via sensors, be able to feedback usage data to designers to improve the next generation of the product, and to offer advice or comment to the user to optimise pleasurable use. A combination of improvements in ICT, consumer input, automation and additive manufacturing will increase the potential for offering individually tailored products under conditions that traditionally were seen as unfeasible.

Customerisation:

"The customization of products or services by using feedback obtained from personal interaction between a company and its customers. A company is customerised when it is able to establish a dialogue with individual customers and respond by tailoring its products, services, and communication on a one-to-one basis, according to specific customer preferences."

To exploit opportunities presented by mass personalisation, an understanding of consumer needs combined with strong design skills will be required to adapt products to rapidly shifting consumer tastes and trends. Similarly modelling and simulation are expected to play an increasingly important part in manufacturing at the stage of design and optimisation.[20]

Customerisation is an area where in NI we can already see evidence of the growth of many of these trends. There is a growing demand for manufacturers to tailor products to meet specific needs. The combined strength of the quality of NI engineers plus the ability to build lasting customer relations (built on trust and belief in the NI quality proposition developed over many decades) means NI AMME businesses are well-placed to exploit the opportunities in this area.

[20] Foresight (2013), Evidence Paper 6: Dickens, P. et al. (2013)

CASE STUDY: CREATIVE COMPOSITES

Creative Composites is one of those companies that goes into the 'hidden gem' bracket when it comes to advanced manufacturing in Northern Ireland .... a company not on many people's radar, but one at the very forefront of its industry.

Based at Knockmore outside Lisburn, Creative Composites – as its marketing tag line puts it – is one of the UK's most advanced composites manufacturers.

It makes finished composites products for use in high performance cars, in buses, in medical technology, in aerospace, in materials handling and in the rather more everyday world of vending machines.

And that's to mention just a few of its end product applications.

“High quality components are at the heart of what we do here,” explains MD Jonathan Holmes.

KEY FACTS

- Creative Composites started as the composites part of the highly successful Boxmore Packaging group. When the bulk of Boxmore was sold to US firm Chesapeake, an MBO took the composites division out on its own.
- Then based at a 25,000 sq. ft. facility at Blaris Industrial Estate, the firm moved to a purpose built composites manufacturing plant at Knockmore in 2005, doubling its production space at a stroke. Since then, it's been doubled again to 100,000 sq. ft.
- The firm has made everything from the full body shell of the ultra-lightweight Lotus Exige sports car through to a series of body components for other big brand name supercar makers.

“We have the flexibility to cater for composites projects with high, medium or low volume demand, and that has meant a substantial investment through the years in equipment.

“Our mission statement is clear cut. We set out to achieve better design, better manufacture and better service than our competitors. And we have to achieve that within the kind of short lead-in times that our customers demand.

“Believe me, if there is even a tiny blemish on the finish of the piece, our customers will reject it without any hesitation. So we have to get it right every time. The car industry, especially at supercar level, is all about weight reduction. So we also have to continually rise to the technical challenges that are set for us.”

Jonathan Holmes, Creative Composites

Using advanced technology to reduce energy, water and raw materials in manufacturing

Manufacturers who learn how to make their products with less energy, water and raw materials than their competitors will be more resilient during likely periods of disruption. The market for technologies and knowledge that enable resource-efficient production will grow quickly, with a potential role for government procurement in 'nudging' and stimulating developments, whilst avoiding unintended consequences.

The emergence of technologies that will help manufacturers use less resource to deliver value, for example lightweight materials and products, are likely to become more widely available over the next two decades.

Resource productivity:

"There's a very significant link between our ability to sustain and our ability to be productive .... and another dimension, the ability to be resilient as a nation.

"This is a really important resilience issue, to be productive at non-labour resources".

Professor Steve Evans, Director of Research in Industrial Sustainability, University of Cambridge.

At a recent Westminster Business Forum conference[21], Professor Evans, one of the authors of the UK Foresight (2013) Report again highlighted how "people and capital now account for about 10% of the cost of the manufacturing business and parts; raw material, energy, water, account for about 50%....there are going to be pressures on the education system to deal with resource productivity, not just labour productivity."

UK manufacturing activities must continue to adapt to best practice, particularly in the light of resource pressures.

[21] Westminster Business Forum, 14 July 2016 Keynote Seminar "High Value Manufacturing: the future outlook." Professor Steve Evans, Director of Research in Industrial Sustainability, University of Cambridge.

CASE STUDY:
banah UK

Right next to banah's name on its signage is the strap line 'cement reimagined' - and it's a little phrase that sums up the company rather well.

banah, its founder John Blackstock, his two sons and the rest of the small team at its base near Coleraine are doing something that no other company in the world is doing right now. They're pioneering and producing a revolutionary new type of cement.

The team's new product, banahCEM, is a unique new low-carbon cement based on a geopolymer binder system. It comes in two components – a powder and liquid – and it has a number of important advantages over traditional Portland cement.

It's much more environmentally friendly, it's resistant to much higher temperatures and it's also resistant to many more harmful chemicals. It's not hard, then, to see how banah's new cement might find applications in worldwide markets.

KEY FACTS

- banahCEM can offer an 80% reduction in CO_2 content. Its fire resistance is much higher than that of Portland cement and it is resistant to many chemicals. It gains strength much quicker than traditional cements (a key advantage in some construction scenarios such as tunnels).
- Academics working closely with banah include Professor John Provis, Professor of Cement Materials Science & Engineering at the University of Sheffield, Professor Marios Soutsos and Dr Sreejith Nanukuttan of the School of Planning, Architecture and Civil Engineering, QUB. banah has collaborated with both QUB and Sheffield to facilitate a KTP research associate.

"I had been working with cement for quite a while. It's a great product but it has its limitations and I was convinced that the future lay in geopolymers. One of the big drawbacks of traditional cement is that it is high in CO_2. In short, it's really not good for the planet. That was my starting point but a lot of reading, a lot of thinking and a lot of research has gone into it since then."

"So we're aiming for sales in what you might call the alternative cement marketplace worldwide. The potential is huge. Our main challenge? That has to be price. Our product may perform better but it's multiple times the price of traditional cement....and no one really wants to pay more."

John Blackstock, banah UK

Snapshot

Circular Economy

Sustainability and the circular economy: "clean and green"

A key driver of future manufacturing is likely to be a shift to more sustainable manufacturing, which uses less material, energy and other inputs, and a shift to a 'circular economy' way of doing business, with end-of-life products reused as inputs. This shift in thinking is likely to generate real competitive advantage and differentiation compared to the largely incremental changes in efficiency currently being considered in manufacturing practice. All subsectors will need to adapt to embrace sustainable technologies if they are to remain competitive.

The importance of shifting to sustainable manufacturing is a point which is re-emphasised often throughout the UK Foresight study and was also a recurring theme in Matrix' original 2008 Advanced Materials Report.

"In a fiercely competitive world of rising demand from consumers and dwindling natural resources, market forces will favour business models which create the most value per unit or resource. 'Circular' business models will be promoted further by resource scarcity and tighter environmental standards, urbanisation that concentrates flows of consumer goods and wastes, developments in track-and-trace ICT, new packaging systems and discrete shifts in consumer behaviour, where access is preferred over ownership."[22]

> "The circular economy offers an alternative pattern of resource deployment by creating more value from each unit of resource by recovering and regenerating products at the end of their service lives."
>
> **Ellen McArthur Foundation, 2012**

Examples of circular economy are inherently more productive than the traditional business models because they extract value from otherwise defunct resources. However, re-use and recycling requires different manufacturing capabilities and operational models, and will need new technologies to deliver globally competitive manufacturers.

The foresight study notes that the UK is currently considered an average performer in the development of clean technology in support of sustainable manufacturing, with significant barriers including a lack of support for R&D activities. This study detected similar limited appetite with some admitting that, in the absence of significant regulatory 'push', there was currently little incentive to pursue a true circular economy agenda. However, in the future achieving sustainability presents major opportunities for the UK manufacturing sector with significant potential economic, social and environmental benefits.

RECOMMENDATION

The 'clean and green' opportunity is an area which was initially identified in the first Matrix report and one which has been seen only to grow in the intervening period. NI's AMME companies should therefore be encouraged to explore and supported to engage further with the 'clean and green' opportunity, whether through education, the creation of shared value or the identification of partners.

[22] Ellen MacArthur Foundation (2012) The Circular Model – An Overview.

CASE STUDY: NI ADVANCED COMPOSITES AND ENGINEERING CENTRE*

Using advanced technology to reduce energy, water and raw materials in manufacturing

A NIACE-based Competence Centre project has brought together four NIACE participant companies with different sectoral backgrounds, who had never undertaken collaborative R&D with one another, along with Ulster University. Together they carried out collaborative R&D into a technical challenge that was defined by the companies and, importantly, was relevant to each company's future business growth.

The aim was to identify how big a role the recycling of advanced thermoplastics could play in their businesses. This was a challenging area for all four companies but the research necessary was not something any of the companies could have afforded (in terms of resources or finance) to do individually. Their participation in NIACE, provided the companies with an opportunity to form a collaborative partnership, with other companies who had also identified the significant role recycling could play in their business and with Ulster University.

Over the course of 13 months, the collaboration had discovered new information relating to the recycling of a highly advanced material, which actually translated into a potential saving of approx. £1M for one of the participant companies over the next four years. In addition, new business partnerships have been created as a result of the project. These partnerships are already developing into new and significant business opportunities that have the potential to lead to the production of tens of thousands of new components right here in Northern Ireland.

NIACE MEMBERS:

ADS, THALES, McFarland Associates Ltd, WRIGHTBUS, lpe, B/E AEROSPACE, CCP Gransden, base, eng-IT, BOMBARDIER the evolution of mobility, axis COMPOSITES, WIS GROUP, MJM GROUP, MILLS CNC, ENBIO, datum, SECO, denroy

Owned by the 2 universities (Queen's 70%; UU 30%), the NIAECC Competence Centre is based at the InvestNI /DBIS/ Bombardier funded NIACE facility which offers opportunity for academic researchers from QUB and UU to work alongside industry to deliver collaborative projects focused on developing innovative solutions in the advanced engineering sector.

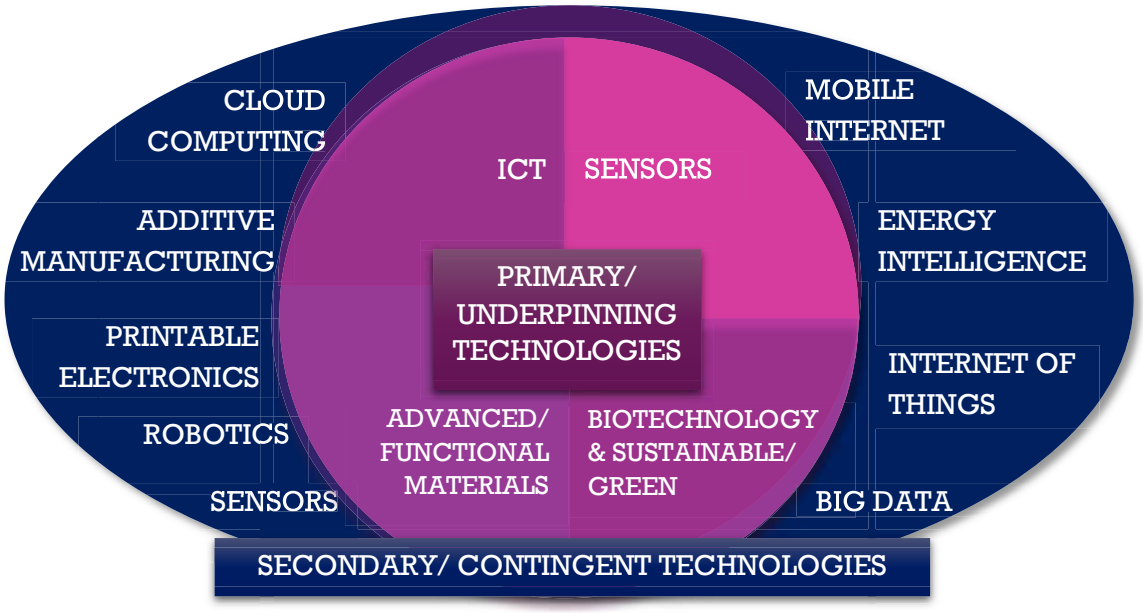
“Some of the value being created in 2050 will derive from wholly unanticipated breakthroughs, but many of the technologies that will transform manufacturing, such as additive manufacturing, are already established or clearly emerging.”

Foresight (2013).

AMME in the Future: Impact of Technological Change

Faster, more responsive and closer to customer – how technology will play a central role in driving change in manufacturing.

Figure 4: Technology & Innovation, Matrix 2016[23]



The figure above outlines:

- primary and underpinning technologies likely to become increasingly pervasive in products and processes; as
- secondary or contingent technologies make use of them;

to collectively facilitate:

- mass personalisation of low-cost products, on demand;
- a much more distributed local and global production base, with manufacturing done much closer to the customer and greater diversity in factories of the future
- 'digitised' manufacturing value chains, with digital connections between customers, manufacturers and suppliers increasing the speed and efficiency of manufacturing, and enhancing opportunities for international collaboration;
- greater freedom of design;
- delivery of innovative new products;
- higher performance and more flexible manufacturing systems delivering better quality and cost performance; and
- better customisation of products and services ('customerisation').

[23] Based on Foresight (2013), Table 1: Important pervasive and secondary technologies for future manufacturing activities

Primary or underpinning technologies

Technology has a central role to play in the competitiveness of advanced manufacturing, supporting innovation, driving product development and providing impetus for improvements in manufacturing performance.

- The potential global economic impact of twelve key technologies, including advanced robotics and energy storage, is estimated to reach US$14-33 trillion by 2025. This figure relates to new revenue that companies will generate and the value individuals will personally derive from an innovation they do not need to pay for.[24]
- Back in 1995, investments in automation alone were expected to comprise c8% of global ICT expenditure by 2020. The worldwide market for Internet of Things is now estimated to grow from around its 2014 level of $655.8bn to $1.7trn in 2020 with CAGR of 16.9%. Modules and sensors make up 31.8% of the total market for devices connectivity and IT services.[25]
- ICT is now applied to enable integration of data across functions (e.g. management of customer relationships, process control, product verification, manufacturing simulation, logistics, product traceability and safety systems).
- Over the next 20 years modelling and simulation is expected to become integrated into all design processes.

Technological developments will ultimately lead to new ways of doing business, for example using new sources of data to make products more tailored or personalised, or to sell complementary services. It will also bring new challenges in the protection of intellectual property, skills requirements and cyber- and biosecurity.

In these evolving conditions, to capture and stay in global markets those who innovate most effectively will succeed. For advanced manufacturers in Northern Ireland, this will include:

- creating products using low energy and low resource input;
- responding to customer needs for high quality, customisation and personalisation;
- decreasing time to market and product delivery time; and
- maximising complementary services.

> The establishment of "high performing and technologically advanced manufacturing capabilities, through the creation and/or acquisition of technologies that fully exploit an integrated approach to design, R&D and knowledge" will secure significant competitive advantage.
>
> **Foresight (2013)**

[24] Disruptive Technologies: Advances that will transform life, business and the Global Economy, McKinsey Global Institute (2013)
[25] Gartner, May 2015

Likely opportunities and challenges these new technologies present:

ICT

Today's manufacturing industries are concentrated along value chains in a smaller number of regions in Europe. Since less developed regions have little opportunity to participate in value creation, ICT allows the creation of 'virtual' value chains independently from geographical location, bringing in skilled labour from other regions, at lower cost.

This ever increasing reliance on ICT and the role of integrated telecommunications and computers means firms will need to adapt their underlying systems architectures and processes to cope with large amounts of data. Early adoption will enable businesses to more effectively stay ahead of the competition.

At firm level, a focus on incremental process improvements, means that relatively low-tech ICTs are prioritised over more powerful ones such as modelling and simulation, big data analysis and knowledge management. With top barriers including cost, lack of confidence, management buy-in and lack of skills, the opportunity exists to encourage an appetite for and uptake of high-tech ICT focussing on innovation.

Proposed actions at UK level have included: support to validate the use of high-end ICT in manufacturing activities; the provision of demonstrators (via High Value Manufacturing Catapult) to showcase the art-of-the-possible; sharefair/meet-the-buyer style and collaboration nation events to close the information gap between buyers and suppliers; 'hack weeks' in which digital and manufacturing companies are paired up and supported to work together intensively for a short time to develop a prototype digital solution to a manufacturing problem. At a practical level, this could include a focus on KTPs to drive their take up between associates from digital/ICT and manufacturers

With the recent addition of NI as a formal partner to the UK Digital Catapult new opportunities to showcase NI's world class capacity in areas such as advanced sensors, predictive analytics and cyber security will open up, whilst also providing a platform for local digital companies to engage with large companies across all sectors to pitch their solutions to meet those companies' needs. The Digital Catapult therefore presents a more than timely opportunity to work closely with NI's businesses to bring the best digital technologies and approaches to bear in AMME.

Advanced and functional materials

The added value of materials will expand as new materials such as graphene, carbon nanotubes, diamond-like carbon, composites (ceramic, metallic and organic) with shape memory and self-healing properties, and copolymers are used more widely in applications ranging from energy storage, smart phone displays to pharmaceuticals and aerospace and many other types of manufacturing. NI manufacturers have strong capabilities in a range of new materials expected to penetrate the mass market in the near future:

- Highly reactive nanoparticles (UU/SiSaf)
- Lightweight materials, including composites (Bombardier, Wrightbus, Creative Composites, MJM Marine)
- Multifunctional materials (AVX)
- Additive technologies (Whalepump, LPE)
- Biomaterials (NIO-BIO)

In the past, the key driver for new materials has been to achieve superior performance at high cost for the most elite applications, with some developments focused on low-cost applications.

While this is expected to continue, other drivers, including global resource scarcity and environmental concerns, will promote the use of sustainable materials and processes.

Sensors

Ubiquitous across the manufacturing sector, future development of nano-electro-mechanical systems is likely to support sensing and control of very small systems (e.g. in consumer electronics).

Development in sensing technology performance will continue. But it is the integration of sensors into networks of technology that is expected to revolutionise manufacturing, especially when coupled to simulation and additive capabilities, providing increasing levels of process autonomy.

> "Sensors will become very important for the future competitiveness of UK manufacturing over the medium and long term".
>
> Foresight (2013)

Manufacturers must develop their ability to transform this explosion of data into useful knowledge and value.[26]

Challenges therein:

Intellectual property (IP) protection and new technologies

As manufacturing changes, IP protection, to include strategic patenting (patent 'thickets'); increasing levels of worldwide litigation over IP infringement (related to cross-licensing/patent pools/issues around royalty stacking); and the introduction of new technologies (e.g. Internet of Things/embedded devices) present a new set of challenges.

Cyber security and counterfeiting

Likewise, cyber security and counterfeiting takes on heightened significance in context of the pervasiveness of the internet, as mobile communications allow equipment and systems to be connected and controlled in a seamless fashion, with every connected asset now a vulnerability for its owners or users. Most leading manufacturers are implementing multiple levels of security to ensure that entire networks do not succumb to security breaches. Advanced 3D measurement, digital modelling and rapid prototyping technologies enable improved product and process development. However, they also facilitate reverse engineering, cloning and the production of counterfeit products. Security technologies including digital traceability must stay ahead of illegal operations to protect legitimate businesses and minimise risks of product safety.

[26] Foresight (2013), Evidence Paper 6: Dickens, P. et al (2013)

CASE STUDY: INTELESENS

Intelesens is an innovator, developer and manufacturer of wearable, wireless, medical monitoring technology, much of it highly miniaturised, lightweight, unobtrusive and easily worn under clothing.

An Ulster University spin-out, it was founded in 2000 by three Biomedical-engineering Professors: the late John Anderson, Jim McLaughlin and Eric McAdams, who is currently based at the National Institute for Applied Science (INSA), in Lyon.

The company is based in East Belfast and was one of the first tenants in the Northern Ireland Science Park, focusing on developing new materials for electrode patch systems, designing novel wearable electronics and advancing a wide range of computational based algorithms.

Today, advanced manufacturing of these electrode systems along with supply chain management and validation and test are key aspects of the company's 40 strong workforce.

KEY FACTS

The mobile, wireless, sensor technologies produced by Intelesens:

- Provide clinicians with the opportunity to improve the speed of diagnosis and treatment of patients with cardiovascular and other acute and chronic illnesses.
- Provide access to affordable health monitoring technology to hospital patients who are currently unmonitored and to chronically ill patients living in the community.
- Assist in reducing hospital stays by improving clinical outcomes in acute care and making it possible to monitor those recovering from hospitals, or with chronic illnesses outside the hospital environment.

"Intelesens' success is a graphic demonstration of how Ulster University spin-outs are producing an impact on both the economy and people's wellbeing.

"NIBEC and our Engineering Research Institute have a tremendous track record of innovation and successful spin-outs.

"We are following and influencing the momentum that has been built up through government leadership as outlined in Northern Ireland MATRIX strategies and an important connected health DETI and DOH memorandum of understanding which outlined the technology roadmap for transforming our healthcare system.

"Our new and rapidly evolving Connected Health ECO system in Northern Ireland is also adding a strong collaborative element between clinicians, industrialists, government and academia."

Professor Jim McLaughlin, Intelesens

Smart Manufacturing

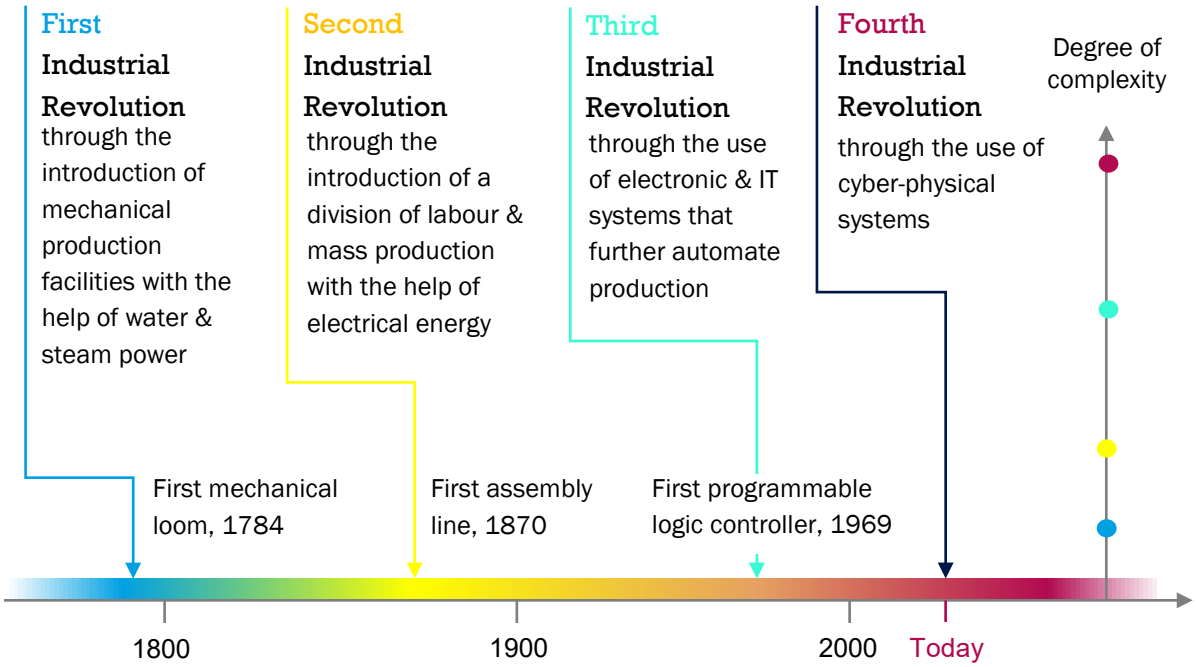
Industrie 4.0, factories of the future, de / re-industrialisation…

The underlying concept of Smart Manufacturing is to connect embedded systems and smart production facilities to generate a digital convergence between industry, business and internal functions and processes.

> "Simply put…industrial production machinery no longer simply 'processes' the product, but the product communicates with the machinery to tell it exactly what to do".
>
> **GTAI, Smart Products: Industrie 4.0**

Industrie 4.0 refers to a fourth industrial revolution (following water/steam power, mass production and automation through IT and robotics) and introduces the concept of "cyber-physical systems" to differentiate this new evolutionary phase from the electronic automation that has gone before. The concept of Industrie 4.0 is widely used across Europe and in particular Germany, where it encapsulates the government-sponsored vision for advanced manufacturing.

Figure 5: From Industrie 1.0 to 4.0

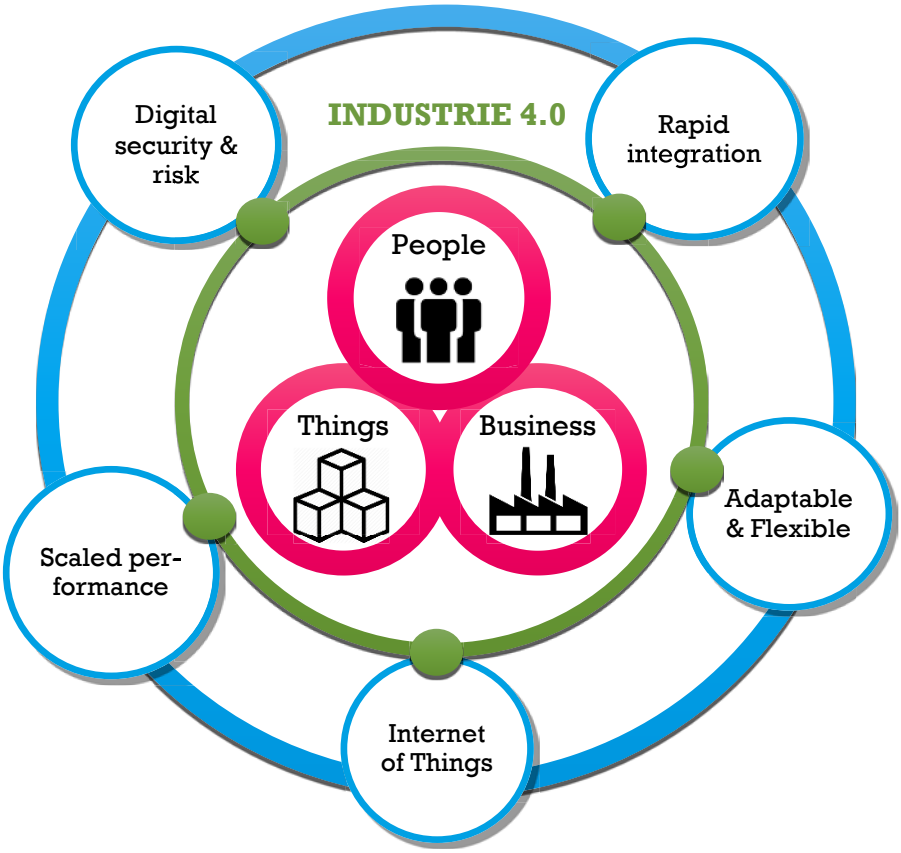


(Source: DFKI – German Research Centre for Artificial Intelligence 2011)

In the US and English-speaking countries more generally, commentators also refer to the Internet of Things, the Internet of Everything or the Industrial Internet. "What all of these terms and concepts have in common is the recognition that traditional manufacturing and production methods are in the throes of a digital transformation."[27]

[27] Industry 4.0. Challenges and solutions for the digital transformation and use of exponential technologies. Deloitte 2015.

Figure 6: The concept of Industrie 4.0



"The age of integrated industry" will only really materialise in next decade, but ... the IoT is finding its way into production... a world where intelligent ICT-based machines, systems and networks are capable of independently exchanging and responding to information to manage industrial production processes".

GTAI, Smart Manufacturing for the Future, 2012

UK's first Industrie 4.0 demonstrator

In September 2014 the UK's first digital factory demonstrator launched in the Manufacturing Technology Centre (MTC), Coventry (also known as Industrie 4.0 demonstrator) – designed to showcase how a 4th industrial revolution could shape the future of British manufacturing. A virtual 3D factory alongside physical production lines capable of demonstrating mass customisation of consumer goods – provides a platform for companies large and small to test and demonstrate their technology to potential customers and conduct research simulations. The facility is available for any of NI's advanced manufacturers to visit and share best practice.

L-R Brian Holliday, MD of Siemens Industrial Activities UK and Ireland, Alan Norbury, R&D Specialist Siemens UK, and Martin Donnelly the Permanent Secretary for the Department of Business Innovation and Skills pictured with a robotic hand on the shop floor of the MTC.

SEAGATE: FACTORY OF THE FUTURE

Significant effort is invested to continuing to advance Seagate Springtown manufacturing capabilities.

1. Factory modelling and simulation - A virtual model of the factory has been developed so the team can simulate the effects of modifications before implementing on factory floor. This enables the continuous tuning of tooling and labour resources for efficiency in manufacturing scheduling and development needs.
2. Big data mining and Real Time analysis - Creating increasingly complex algorithms to best utilise the huge amount of data generated during the manufacturing process and fed back to system for real time control.
3. Zero defect manufacturing - Traditionally the team has measured outputs from process to determine quality. With this new approach, the tooling input parameters are characterised so that defects can be anticipated before the product is even processed.
4. Multi-tool integration - Integrating multiple tools together onto a single handler. Enables improved process control as time lag between processes is better controlled and in some cases wafers are not exposed to the atmosphere between process steps
5. Handling automation - Some automation for wafer handling and lithography mask handling to improve control and reduce breakage. The nature of process limits levels of handling automation.

Factories of the future

As manufacturers have focused on labour and resource efficiency, adapted to new technologies including robotics and automation, and responded to opportunities in emerging economies, factories in developed economies and some emerging economies have undergone a transformation in recent decades.

The factories of the future will vary, depending on specific sub-sectors and products. But the majority will be influenced by common trends.

- Becoming more agile to respond quickly and flexibly to customer demands, and volatility in external factors, including access to resources.
- Becoming more open to support stronger manufacturer-customer relationships.
- Adapting to new product technologies as customer demands make products more challenging to manufacture with ever decreasing introduction times for new products.
- Embracing new manufacturing technologies as the value chain becomes digitised, with markets becoming more competitive and sustainability accelerating the rate of change.
- Harnessing the knowledge of skilled workers who may no longer be on the shop floor but working remotely, and developing new skills to adapt to advances in technology.
- Further blurring the boundaries between research, design, production and services.
- Establishing new more integrated working relationships through the value chain and across the product life cycle.

The table at Annex 4 summarises "The changing face of factories of the future", but high levels of diversity in the focus, scale and location of factories are already evident. This diversity will likely increase in line with the need for factories of the future to adapt to the range of changes highlighted above.

But what of the threat presented by many mass-manufactured products and automation in terms of employment and societal impact - and there are many well-rehearsed arguments to this point? One future-looking, local company ahead of the game is Sphere Global. Sphere is successfully exploiting the opportunities factories of the future present, designing the automation and building the infrastructure for the robots.

RECOMMENDATION

Catapult "knowledge missions" should be encouraged to exploit knowledge transfer and facilitate 2-way exchange between NI AMME companies and UK Catapult teams. (Invest NI's Trade Mission programme is an established model which could be adapted.)

CASE STUDY: SPHERE GLOBAL

Sean McNicholl doesn't need to be told about Industrie 4.0, its challenges and its opportunities. He has achieved more in six short years than a lot of entrepreneurs can hope to achieve in a lifetime of doing business.

The Campsie software and automation specialist returned home from working overseas and set up Cornerstone Automation Systems (later re-branded to become SPHERE) six years ago, and the industry automations specialist firm is already working with customers like Amazon and competing with Siemens and other giants of the industry.

SPHERE's business is the business of automation - helping customer companies to coordinate the flow of materials and supplies through large manufacturing operations, warehouses and distribution centres. The company's bespoke solutions are designed to minimise costs and to maximise efficiencies and accuracies through the process.

KEY FACTS

- Founded in 2010 with just four employees, SPHERE now has a team of 80 engineers and other staff and anywhere up to 50 sub-contractors at any given time.
- SPHERE is also in the early stages of planning a 100,000 sq. ft. extension to its Campsie plant, a move which would mean the recruitment of some 70-80 new staff.
- The company's bespoke solutions are designed to minimise costs and to maximise efficiencies and accuracies through the process.
- SPHERE has doubled or trebled its turnover every year since it started out in business.
- The customer list includes names like Dell, Amazon and Next.

"Our customers come to us with a problem. That's how this business works. It's down to us to provide a cost effective solution to those problems, whatever it is that they produce or distribute. Our technology is out there working with medicine, food, tyres and tablets at the moment.

"We have customer sites where robots are working alongside people, and we have others where we've taken automation to the leading edge of technology.

"We can talk to any piece of our technology anywhere in the world using our phones or laptops, and we can often solve problems wherever they are within minutes."

Sean McNicholl, SPHERE Global

On-Shoring/Re-Shoring

Trend or trickle?

Still "the yeti in the Himalayas – a subject of much discussion and speculation, but was something you hardly ever saw with your own eyes?"[28]

The UK study found "a relatively new trend that could gather pace [to be] the 'on shoring' (or 'reshoring') of production activities back to developed market economies". Many of the advantages that led to the rise of Asia Pacific as an important manufacturing location are now being challenged by wage inflation and the emergence of a large internal consumer market. Economic changes in countries in this region for example China, India, Bangladesh, and Vietnam coupled with volatility in energy prices have the potential to change the geography of global manufacturing in the decades ahead.

Typically, re-shoring/on-shoring involves repatriation of production from low cost locations, investment in onshore production to enhance capability, and sourcing of components from onshore, rather than from overseas. Since the 2013 UK Foresight report much has been written with regards Industrial Renaissance, with estimates of up to £30bn injection into the UK economy through reshoring by 2025. Analysis by PWC suggests reshoring has the potential to create between 100,000 and 200,000 extra UK jobs over the next decade in different sectors, including advanced manufacturing.

Detailed evidence on on-shoring is scarce, and has led to claims that it may prove to be a relatively minor process, and more of 'a trickle than a flood'. However, there is recognition that on-shoring is occurring in the majority of developed market economies in transportation goods, computers and electronics, fabricated metal products, machinery, plastics and rubber, appliances and electrical equipment, furniture, ceramics and textiles.

For reshoring, as with many other aspects of AMME today, the decision is about more than purely costs. Consistent with the EEF/GFK Make it Britain survey, work led by Professor Roy at Cranfield's manufacturing department in 2015 reviewed research into the past 25 years off-shoring and re-shoring and identified the top 3 key factors influencing decisions related to re-shoring[29]: -

1. Better supply service
2. Better quality
3. Innovation environment (R&D investment and R&D reliefs)

Cost is 7th on the list.

[28]John Cridland CBI, National Manufacturing Debate Report, 2015

[29] An analysis of the UK's capability to re-shore production, A White Paper by Cranfield University, 20th May 2015, National Manufacturing Debate.

Whilst it is still relatively less expensive to manufacture off-shore for many businesses, the cost-gap is closing with claims that "salaries in China are increasing at the rate of 13%pa on average – thus obviating any cost advantage in relatively few years". It is becoming possible for the UK to compete with lower cost locations on quality, delivery speed, customisation and sometimes price, with NI AMME companies indicating that, in their experience, the cost differential – for salaries, in any case - is narrowing to an even greater extent.

> "Salaries in China are increasing at the rate of 13% pa on average – thus obviating any cost advantage in relatively few years"
>
> **Sir Alec Broers, past President Royal Academy of Engineers**

Low cost, high volume electronics are unlikely to return but the most profitable parts of the value chain could be reshored – the start and the end of the manufacturing process R&D and after-sales service (increasingly dominant parts of the value chain), textiles may return as the level of automation increases and high value-added bio-pharma also is an obvious candidate.

Low volume products, for example automotive and aerospace parts, appliances and construction equipment in which labour accounts for a minor proportion of total costs, are considered the most suitable for onshoring. Examples include automotive where from 2012 UK vehicle manufacturers have already reshored over £1bn of purchasing.

In October 2014, a PWC survey of 384 Eurozone non-financial companies found almost 60% had reshored some operations, mainly production over the past year against 55% which had done the opposite), Italy (44 reshored companies) with others featuring prominently including RoI, Germany and Spain. In the US a small but growing number of firms are repatriating production, including General Electric, NCR and Caterpillar. Recent examples of UK on-shoring are provided at Annex 5, and beyond the US, Taiwan has recently reshored 44 manufacturing companies from mainland China.

Table 1: Key drivers relating to the onshoring of manufacturing activities, Foresight (2013)

Driver	Of particular relevance for	Potential spatial implications
Narrowing of differentials in labour costs	Production activities offshored to take advantage of lower labour costs	Onshoring of some production activity to the UK
Higher transport costs	Production activities offshored to take advantage of lower labour costs	Onshoring of some production activity to the UK
Need to be close to the market	Products customised to the market with short-term fashion cycles	Combination of manufacturing in high cost and low cost locations
Product quality concerns	All products, especially those with a premium placed on quality	Onshoring of some activities
Theft of intellectual property	Product innovation, process innovation less easy to copy due to tacit knowledge	Onshoring of activities where intellectual property is important
Economic downturn and reductions in size of orders	Large scale components orders from low cost locations	Opportunities for local suppliers willing to supply small batch orders
Advantages of co-location of design, R&D and production	Spatially separated activities	Greater co-location of activity in the UK and/ or outside the UK
Changing energy costs	Energy-intensive activities	Relocation to areas with low costs

Snapshot

Phoenix industries

There are prospects for 'phoenix industries' emerging in older industrial areas which offer advantages such as institutional networks and technical skills.

A recent analysis of US manufacturing argues that in order to understand where the potential for expansion of US manufacturing is greatest, there is a need to examine original 'manufacturing strongholds' to focus on rebuilding regional strengths. These strongholds include remnants of supply chains, and specialised knowledge in regional labour markets.

This has given rise to the idea of 'phoenix industries'. Firms that benefit from pre-existing personal networks, technical skills, and market knowledge which have developed over a long period. This argument is based around the strategic assets that old industrial regions still possess including specialised engineering departments and research programmes.[30]

> "A dynamic process of incremental, path-dependent renewal of technologies and local industries has enabled innovative, advanced manufacturing specialisms to emerge 'phoenix-like' from the ashes of old mass manufacturing industries in some locations in the UK such as Sheffield and in the US, encouraged in some instances by local sectoral policies."

"Often phoenix industries are made up of SMEs rather than large companies. They typically develop technologies used across a range of sub-sectors rather than make end products for one sector alone. In the future there will be more opportunities for the legacies of know-how, skills and institutions, including specialised engineering departments and research programmes, to help old manufacturing regions develop phoenix industries. Place-specific economic and non-economic factors, including history and place-associated brands, can play an important role in the competitive advantage of these new developments."[31]

There is some evidence of infrastructure for phoenix industries developing in the UK with the recent introduction of specialised training and research programmes by Sheffield University. As the Sheffield Initiative demonstrates, a university programme can act as an intermediary between industries developing from small-medium enterprises by advising policy-makers and the public of the advantages of advanced manufacturing, providing technical assistance and access to new technology, and fostering internships between graduates and local companies. In this context, given NI's rich engineering and manufacturing heritage, the region should be well-placed to identify and exploit potential pockets of resurgence. Recent activity within the technical textiles community has suggested potential for an emerging phoenix-like cluster combining traditional textiles manufacturers with leading edge technology.

UK Technical textile resurgence

The UK technical textile industry is an example of a phoenix industry, a high-value segment of the textile industry where the most innovative firms are creating products from engineering or scientifically advancing the fabric. The ripple of innovation is now spreading further across the traditional textiles industry, combining significant capabilities in yarn-spinning, knitting and weaving alongside growth in technical textiles, materials and composites.

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[30] Christopherson, S. (2009), Manufacturing: Up from the Ashes. Democracy: A Journal of Ideas.
[31] Foresight (2013).

Snapshot

Northern Ireland

For more than 200 years, Northern Ireland was a global leader in the manufacture of linen and was the heartland of Irish linen, with Belfast continuing to be referred to as Linenopolis until the beginning of the 20th century. Flax was grown, spun and woven into Irish linen, processed predominately by machinery, made by Mackies of Belfast, to produce a product which is still widely regarded as the best linen ever made, manufactured by some of the best machinery ever made.

Today, reinforced fibres in the form of bio-composites are becoming of increasing interest in aerospace, construction, filtration and transportation. Smart fabrics, in the form of wearables, are becoming increasingly important for personal protective equipment and survival equipment with embedded sensors, printed electronics, conductive yarns, phase change materials, non-wovens all able to combine with digital technologies. Digital manufacturing, 3D weaving, 3D knitting and near net shape production with zero waste are all areas of research with potential for growth.

Collaboration will be key to overcoming the market failures that exist due to decades of offshoring. The textiles community in Northern Ireland is committed to work together again in a new Technical Textiles Collaborative Network made up of 18 companies and academics, covering a broad range of expertise and capability.

NI AMME businesses are well placed to take advantage of opportunities like the Regional Growth Funds awarded to the Textile Growth Programme, which in 2013 awarded £32.3m in support to the UK textile industry, for projects awarded before end of March 2017.

Skills

"The stock and quality of education and skills in an economy is vital for economic growth. A highly skilled and dynamic labour force is more productive, innovative and attractive to foreign investors." (WEF)

"Knowledge oriented sectors are more export intensive, helping to generate additional income and grow the economy." (OECD)

“Lowering Corporation Tax will not be sufficient on its own to transform the local economy. If NI is to diversify its export base and maximise impact of lower Corporation Tax, it is imperative that the skills required to meet the needs of inward investors and growing local companies are available.”

The NI Economic Advisory Group, 2016

"People win business"

The quality of NI's engineers and design professionals has historically and continues today to earn worldwide respect. This combination of rich heritage and cutting-edge innovation sets Northern Ireland's AMME capability apart from the competition.

That said, primary concerns with respect to skills remain stubbornly persistent since Matrix last reported in this area in 2008. During the course of this study, when asked to identify the single biggest weakness they perceived and therefore potential barrier to future growth, AMME companies overwhelmingly identified "SKILLS". Regardless of company size, stage of development or sub-sector, skills constraints, (present and anticipated for the future) – at every level reached the top of AMME business 'threats'.

- Entry level
- 'Green' graduates
- Leadership & management skills for SMEs
- Marketing & sales skills for engineers
- Apprenticeships
- Upskilling existing workforce
- Commercial exploitation skills
- FE & HE

The issues raised are entirely consistent with UK, EU and wider international AMME research and broadly relate to:

1. **Supply and demand factors** (shrinking workforce / decreasing inflow);
2. **Quality of supply** (lacking and/or deteriorating skills); and
3. **STEM policy and action**

AMME skills for the future

The key enabling technologies of the future, whilst impacting positively on innovation and growth levels, pose a real challenge for the existing and potential workforce and for the education and training systems. New technologies bring new skills requirements. Across the sector, the increasing use of design packages and bespoke software in the manufacturing process is also requiring greater 'IT literacy' and skills in utilising specific CAD/CAM and CNC machining software.

> "New and emerging technologies will require a workforce with advanced skills to engineer in both the virtual and the physical worlds. Roles in supporting areas, such as cyber-security, will become increasingly important as manufacturing becomes ever more digitised".
>
> **Foresight (2013)**

Smart factories will require workers with the relevant production and I.T. know-how. Germany's Industrie 4.0 strategy points to the need for certified training courses in the future to take interdisciplinarity to a new and highly innovative level. The general shift to shorter, more tailored production runs, driven by both customer demand and the availability of more flexible production technology, is increasing demand for design skills.

Issue 1: Supply and demand factors 2015

Matrix fully endorses the finding of the NI Skills Barometer which undertook comprehensive analysis to enable the identification of an annual average supply gap in NI, across both HE and FE, by National Qualification Framework (NQF) level.[32] That is, in terms of total employment change, AMME subjects are prominent:

Figure 7: Top ten growth sectors 2015-2025 – total employment change

[32] NI Skills Barometer, op cit

Annex 6 illustrates sectoral demand data by industry sector and concludes:

- At NQF Level 6+, demand for Professional, Scientific and Technical (PST) and Manufacturing (along with ICT) peaks both in respect of the Barometer's baseline and high growth scenarios.
    - Manufacturing is 2nd on the list requiring 3,250 NQF Level 6+ individuals per annum: i.e. 1,800 replacement and 1,500 expansion.
    - PST is 6th on the list requiring 2,500 NQF Level 6+ individuals per annum: i.e. 900 replacement and 1,500 expansion.
- Again, at NQF level 4-5, *by broad subject area*: engineering and manufacturing ranks number one in terms of undersupply, with science and maths second (the approximate undersupply of graduates calculated at 275 and 230 respectively).
- No AMME-related subject areas appear in the top 15 over-supply subject areas.

The potential impact of even a fraction of the supply issues, identified within the Skills Barometer is even more heightened in the context of the skills required for a rapidly changing AMME sector.

Addressing AMME supply – education challenges

Through the course of the consultation period and workshop sessions business leaders, academics and AMME professionals identified a number of distinct areas which affect them most, areas which they would like to see government tackle. With regards sufficient supply of AMME employees, both in the immediate and longer term that crystallised around:

The low level of STEM take up at school – i.e. too few pupils go on to study AMME subjects

- First and foremost, the need for greater understanding of what drives millennials, particularly what makes them choose or reject STEM subjects. Without question, the impact of engineering not being promoted adequately in schools is paramount.
- AMME professionals feel strongly that practical hands-on experience of manufacturing and problem solving from an early age is of prime importance. Crucially, the majority of children leave school without ever having built or constructed anything.

> "Encourage children and students to make and solve".

The steady stream of young talent which leaves NI each year – "the brain drain"

Presently, some 35% of the region's 18-19 year olds leave NI to be educated in higher education institutions in England, Scotland, Wales, Ireland and further afield, making NI the only region in the UK that exports young people.

In order to reverse this "brain drain", the HE sector has made it clear that urgent investment is required to ensure that our people have the necessary skills and knowledge to support the growth of the regional economy and to provide an increased supply of skills which will attract new foreign direct investment to Northern Ireland.

Skills deficit

Skills deficit is unquestionably an area which is of real concern to all. In particular, NI's universities point to the structural funding deficit which exists in the higher education sector,

highlighting that NI is the only region in the UK which has divested from higher education in recent years.

Between 2009-10 and 2014-15, annual block grant allocations from the Department for Employment and Learning (DEL) to the Northern Ireland universities reduced from £214m to £185m – this equates to some 24% in real terms. The 2015-16 academic year saw a further 10.8% reduction in the higher education budget, totalling £16.1m. The impact of this funding reduction has required Queen's University to substantially reduce its undergraduate intake; by 2018-19 the university states it will have over 1,000 fewer places for local school leavers.

On 9 March 2016, the then Minister for Employment and Learning released "Securing a Sustainable Solution for Higher Education in Northern Ireland: An Options Paper". The paper highlighted that the student place reductions came at a time when skills forecasts indicated a clear under-supply of degree level skills in the Northern Ireland workforce. The report highlighted that, during the course of the previous Assembly term, a structural deficit in local higher education provision has emerged and grown.

With tuition fees uplifted only by inflation, and public investment reducing, a funding gap of between £900 and £2,500 per student (depending on the course of study) has emerged between Northern Ireland's universities and their counterparts in England – this amounted to some £39m by 2014-15. In addition, the further cuts of £16.1m in 2015-16 bring the current total structural deficit to some £55m.

If the ambition for the region's economy and wider society for the next 15 years, soon to be set out in the new Programme for Government and associated Economic Strategy, is to be realised - investment in young people is critical.

Suggested actions from AMME consultation

- Investment in young people is critical.
- Family friendly maker spaces to intrigue young people and parents – let children see the value of engineering.
- Roll-out initiatives like the ADS "Rocketry Challenge" and the Bombardier flight challenge more widely (i.e. beyond the engineering focused schools).
- Encourage teacher/industry placement programmes – a year out in industry for teachers so, through their teaching, they can introduce children to industry as opposed to focusing only on academic results.
- Initiatives like the "Skills Bus" need more investment – this is a highly regarded resource, but impact is limited by the fact that there is currently only one bus to serve the entire region.

RECOMMENDATION

School children need practical, hands-on experience to be able to visualise AMME and its potential value in a way which they can relate to. An important first step would be the teaching of STEM through objects vs only through paper (i.e. practical vs theoretical learning).

Snapshot

Apprenticeships

Apprenticeships and Youth Training Reform in Northern Ireland

A core element of UK strategy is to establish a high status system of vocational education. In order to fill skills gaps in critical STEM sectors the need to provide business led training with a direct line of sight to work, which young people will aspire to alongside traditional higher education is highlighted. The UK strategy is driven by (a) rapidly expanding higher apprenticeships up to degree and postgraduate level, and (b) creating National Colleges as high status, employer led institutions. The recent development of High Level Apprenticeships in NI point to a policy response to the needs of NI businesses and provides evidence of greater partnership between education and business.

Under the two complementary, Executive endorsed strategies: *Securing our Success,* the new Apprenticeship Strategy and *Generating our Success*, the new Youth Training Strategy, the Department for Economy (DfE) is implementing major reforms of NI's professional and technical education and training system. Piloting of elements of the new systems is currently underway in line with a phased introduction in 2017.

> "Apprenticeships are an excellent means by which employers can address skills gaps by providing vital skills and workforce development aligned to their specific organisational requirements as well as being assured that across the economy there is a critical mass of people with strong technical and employability skills".
>
> **Bryan Keating, Chair of MATRIX and Chair of the interim Strategic Advisory Forum on Apprenticeships.**

The overarching goal of the reform is to introduce a new world class system of professional and technical training that will offer a genuine alternative pathway to the higher level skills and qualifications necessary to grow the local economy. Underpinned by quality, breadth, progression and portability, the two strategies support the development of a highly skilled workforce, providing consistently high quality training leading to qualifications valued by all parties. Consistent with international best practice, the new model puts employers firmly in the driving seat. Through participation in a Strategic Advisory Forum, employers (and other stakeholders) play a key role in advising government across all aspects of apprenticeship policy. Through Sectoral Partnerships they will work with curriculum experts to design and agree the content for traineeships, apprenticeships and higher apprenticeships in each occupational area. Sectoral Partnerships are currently being piloted within manufacturing/engineering, ICT, agri-food, life and industrial sciences, financial services, hospitality and built environment industries.

Higher Level Apprenticeships (HLAs) are aimed at individuals who have completed 'A' Levels (or equivalent). They are designed to help those in work to develop higher skills ranging from level 4/5 – level 8 (Sub Degree to PhD). HLA pilots are currently underway in a number of sectors. With over 170 employers engaged, there are more than 240 higher apprentices undertaking their off-the-job learning across all six FE Colleges and Ulster University, in occupational areas which align closely with the findings of the Skills Barometer report. This includes HLAs in the following AMME areas: Mechanical / Mechatronics / Automotive and Advanced Engineering; Sustainable Construction; Renewables and Sustainability; and Automotive Management. An initial evaluation of the pilots highlights positive feedback from employers, apprentices and training providers alike, and it is anticipated that further HLA opportunities will become available from September 2016 as part of the phased implementation of the Apprenticeships Strategy.

CASE STUDY: APPRENTICESHIPS

The Apprentice of the Year Awards recognise apprentices who have made a significant contribution to their workplace.

Antrim's Lauren Gourley won the Apprentice of the Year and and Emmet Lagan from Omagh won Higher Level Apprentice of the Year for 2016. Lauren (20) is completing an Engineering apprenticeship at Larne Skills Development and is employed by Schlumberger, Monkstown; while Emmet (30) is completing an Engineering HLA at South West College, Omagh, and is employed by SSE.

KEY FACTS

- DEL established a number of pilot sectoral partnerships due to conclude in March 2017, including advanced manufacturing and engineering.
- Sector partnership and HLAs in engineering (Advanced, mechanical mechatronics), automotive management and automotive engineering – foundation degree/level 5 pilots have been established across Northern, NW, SE & SW colleges.
- Other finalists for the HLA of the Year 2016 in AMME disciplines were Thomas Haveron (Michelin), following an HLA in Advanced Manufacturing and Hannah Johnston (Wrightbus), following an HLA in Engineering . Both studied at Northern Regional College (NRC), Ballymena.

"I congratulate Lauren and Emmet on winning their respective Apprentice and Higher Level Apprentice of the Year categories and all the other finalists here today on their achievements.

"I wish them continued success in their chosen careers. These Awards highlight how Apprenticeships and the new Higher Level Apprenticeships are supporting our local economy by ensuring our workforce is getting the skills needed and valued by local employers."

DEL Minister Stephen Farry, March 2016.

Issue 2: Quality factors

AMME skills challenges are by no means unique to NI with countless other countries citing AMME skills constraints as a top concern (Australia, Germany, USA and Scotland to name but a few). The fact that NI companies are not alone in facing the skills challenges makes it nonetheless concerning.

> "Without the skills today, the chance of creating the jobs of tomorrow is substantially reduced".

At entry level, time again, employers emphasised the need for school leavers to have good essential skills – basic numeracy and literacy. Appreciating the value of the top 10% of high achieving engineers, AMME employers cautioned against ignoring the other 90% who should be viewed as potential technicians and a highly competent workforce which forms the engine of the sector.

At graduate level the quality of engineering graduates produced by NI's two universities is valued and recognised. In terms of broad, general engineering, AMME employers unanimously credit NI's education system with producing able, competent and intelligent young graduates, of a higher calibre than other regions/countries. Rather, the challenges which employers cite are concerned with the additional skills and experience required to deliver an *employable* graduate; i.e. interpersonal / communication skills, problem-solving and commercial acumen, among others.

Education and skills performance – NI's relative competitiveness

The NI Economic Advisory Group (EAG) recently published its inaugural regional Competitiveness Scorecard for the region. It presents a sobering assessment of NI's education and skills performance, and its position relative to comparator countries.[33]

NI's performance in the Education & Skills element of the Scorecard has deteriorated from 5.4 to 5.9 over the previous five years – the largest reduction of all of the competitiveness pillars. In absolute terms, NI's performance has improved in approximately half of the education and skills indicators and deteriorated in the remainder. In relative terms, other countries have improved more rapidly than NI, with the result that NI's comparative position has been eroded.

Participation rates rank well against competitor countries which provides a strong base in terms of the reach of education throughout the future labour force. For those completing their education, outcomes are average, or slightly below average for the countries analysed.

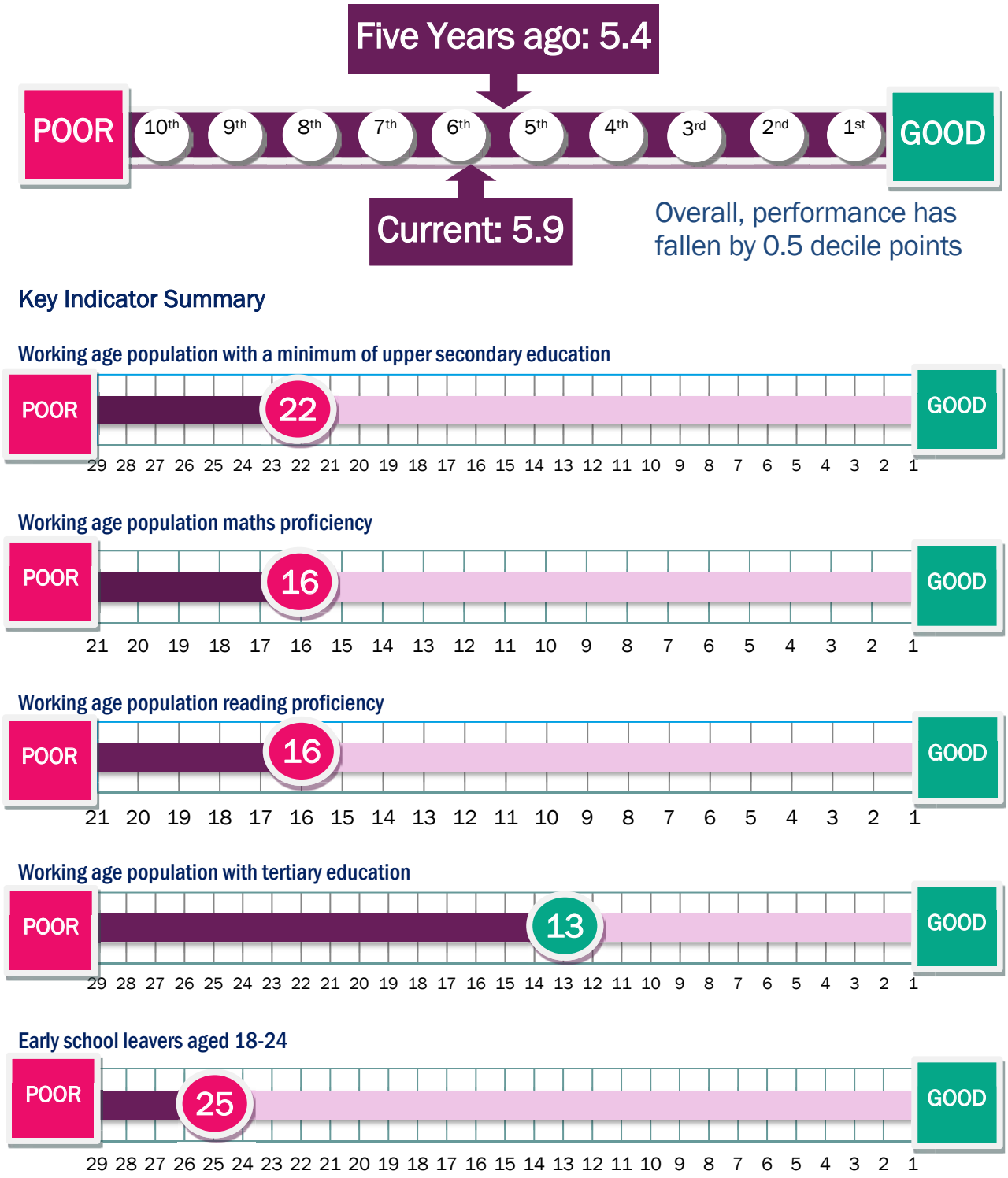
Literacy, as measured by PISA, presents some challenges, while scientific, mathematical and reading literacy of 15 year olds declined between 2009 and 2012. If this trend continues, it will result in difficulties for employers and economic development policy makers in future years.

The proportion of the population that have completed tertiary education has improved and NI ranks mid-table, although still well below the UK average and ROI. However, issues persist with a relatively large proportion of the population with only primary level education and a relatively large proportion of early school leavers suggesting that there are challenges within the education system for the less able pupils.

[33] NI Competitiveness, EAG Summary Report, July 2016.

The EAG Competitiveness Summary (published 2016) noted that in the years 2009-2014 Northern Ireland's overall performance across a number of educational and skills targets had fallen 0.5 decile points compared to other European regions.

Figure 8: NI Skills & Education: 2014 compared to 2009



Source: EAG Competitiveness Summary, July 2016

Assured Skills

"Access to skills is acknowledged as the pivotal factor in the location of industrial activities."[34]

Assured Skills is a joint programme between the Department for the Economy (DfE) and Invest Northern Ireland which seeks to ensure the delivery of a range of activities and interventions guaranteeing potential inward investment companies, or existing companies wishing to expand, that NI has the ability to satisfy their future skills and training needs.

Assured Skills helps companies find the talent they need and offers to train the candidates in skills useful to the companies using the "Academy Model" of pre-employment training support. This typically involves a short bespoke pre-employment training programme (between two and ten weeks) delivered to between 14-16 participants by a local college or university.

Academy entry requirements and course content are agreed with the company and a qualification, or units towards an accredited qualification, are normally included. A further option during the recruitment selection process is to include a psychometric assessment of the candidates. Companies interview onto the course, and agree the course content with the college or university. Candidates may receive a training allowance depending on the length of the Academy and, at the end of the training the companies interview candidates for an open position.

In the last four years, some 36 academies have been undertaken for a variety of companies with, in total, over 520 trainees completing the academies, and 85% securing ongoing employment with the participating companies. Assured Skills de-risks the recruitment process by allowing companies to assess candidate's skills and attributes before they become employees, and makes the new employees more productive from day one. The model is adaptable and has been used in a variety of sectors, including Business Services, Information and Communications Technology, Financial services, Engineering and Manufacturing. Recent DfE statistics report Assured Skills as having supported 2,311 jobs in STEM sectors when all jobs are realised.

When Caterpillar NI decided to introduce a material handler to their production line in 2015 (the plant until that point manufactured and exported electric generators to every part of the globe), new skills and expertise were required. Using the expertise of the regional FE Colleges, an Assured Skills programme tailored to the business' needs was introduced with training and upskilling carried out in the factory.

"The Assured Skills Programme was part of a package to make it attractive for a particular customer to look to NI as a place to do business with. We feel that we have come a long way in developing the whole workforce here." Enda McKeever, Project and Planning Manager, Larne Assembly Plant, Caterpillar NI.

CATERPILLAR

Caterpillar NI - Material Handling Assured Skills Academy, 2015

[34] Key Enabling Technologies, 2013 op cit

CASE STUDY: GREINER

When Dungannon company Greiner Packaging started to find it difficult to get the right people to work in its high-technology plastic packaging plant, it decided to take matters into its own hands.

The company, part of an international group with 35 manufacturing sites across Europe and the Americas, has designed and implemented its very own Greiner Gold Programme, an advanced form of high level apprenticeship combining comprehensive in-house training with day release classroom sessions organised by local FE colleges. A full four-year programme, it leads to a third level qualification and, crucially, means that participants are paid as full-time Greiner employees throughout the period.

“What we're offering isn't just normal jobs,” says Darryl McShane, Greiner's Senior Operations Manager. “This is a professional programme which leads to a recognised qualification but it's also an opportunity to come into engineering and manufacturing and make a real contribution right from the start.”

KEY FACTS

- Greiner Packaging employs around 220 staff in Dungannon (9,000 globally).
- Northern Ireland operation turns over £34.5 million.
- 85% of its markets are in GB with a further 10% in the Republic of Ireland.
- Processes used at Greiner include thermoforming, extrusion, injection moulding, injection stretch blow moulding, extrusion blow moulding and IML technology.
- Greiner Packaging manufactures a broad range of rigid plastic packaging for the food and non-food industries, turning out upwards of a billion pots every year for yoghurt, desserts and other products.

“We became aware several years ago that we were having problems recruiting people with the skills that we needed. Our answer was to tackle the problem ourselves, to bring in talent and provide the training ourselves, with help from the further education sector.”

“Good recruitment is key. We look for six GCSEs at Grade C or above or two A Levels, but more importantly, we're looking for young people with an interest in technology and in what they can learn from us, and young people who can show some evidence of leadership.

“The Greiner Gold Programme has been a major investment for us as a company but there's no doubt that it has helped to bring the Greiner name to the fore here in the mid-Ulster area, where there are a lot of big manufacturing companies in need of good people.”

Pauline Hillen, Greiner

Snapshot

Employability vs. employment

Different courses can deliver different skill sets. NI's AMME employers place high value on the quality of basic engineering education which graduates possess when they first enter the workforce. However, with 58% of graduate employers unlikely to recruit a candidate with no work experience they cite the following employability skills required:

- People management
- Team working
- Good communication
- Problem solving
- Critical/objective thinking
- Initiative
- Commercial acumen

Generally, a further two years training on the part of the employer is required, across a wide range of areas, to make graduates 'workforce-ready'. Raising student awareness about employability, above all else would help develop employability skills, as would the integration of employability as a clear, simple and deliberate goal of a degree course. It is more than 35 years since the UK's HEA first addressed the need to encourage academics to engage with employability. The 2015 NI Skills Barometer confirmed that the need remains unchanged. "Wider employability skills are essential to securing employment". "Employers indicate that not all qualifiers have the skills required to work at level equivalent to the qualification achieved" … potentially linked to the strong need for the employability skills outlined above. Policy comments within the NI Skills Barometer report emphasise that:

- Educational institutes must integrate the development of these skills into course delivery.
- Students must get appropriate exposure to meaningful work experience, typically through placement/internship to develop these skills and enhance employability.
- This can only be achieved by balancing the responsibility of educational institutes and the responsibility of the employer.

"The Schlumberger UK plc in Belfast is a manufacturing facility which has been based in Northern Ireland for almost 50 years.

"One of the reasons for establishing the facility in Northern Ireland was the highly skilled labour base. Finding high calibre graduates with practical application of mechanical and manufacturing knowledge continues to be important to us today.

"This is why we joined the Engineering Leadership Programme at Queen's University Belfast. The students we have engaged through this scheme have been high performers and during their placements have been involved in projects that require significant engineering competence.

"In return they gain insight into the realities of daily work in an engineering and manufacturing facility.

"In my view, the programme is delivering engineering leaders of the future and we look forward to seeing the benefits in the years to come."

Cate McCandless, Centre Manager, Schlumberger UK plc

The Engineering Leadership Programme is one example of extra-curricular activity being provided by QUB's School of Mechanical and Aerospace Engineering, albeit for only 10 of its top students in each year. Participating students benefit from additional development opportunities, delivered in collaboration with industry partners such as GSK, Aston Martin, Tayto, Glen Dimplex, BEAerospace to prepare them for the demands of the modern engineering workplace.

Addressing the quality challenge

Capacity within the sector between entry level and graduate entry is considerable, with many AMME employers stressing the need for a continuum of education for engineers. A systematic approach where students, from an early stage, can see a clear route to employment irrespective of the point of entry. In terms of upskilling the existing work force a number of polymers companies referenced the level of inflexibility in the system to accommodate bespoke, industry-led training.

One example quoted by a number of SMEs during the consultation was the recent proposition for a NI Polymers Academy in 2014/15. Facilitated under the umbrella of the NI Polymer Association (NIPA), the proposal presented an industry led initiative to cater for the needs of SMEs in NI engaged in polymer processing.

For reasons which still confound many of those businesses involved, the education and training system could not accommodate the proposed divergence from the status quo, irrespective of the needs and wishes of industry. Undeterred, as a result of the support of industry members, the NIPA Advanced Polymer Academy was established in 2015 and is now developing and delivering bespoke advanced training programmes to companies.

The launch of its new Diploma in Advanced Materials, Processes and Applications in 2016 marks a milestone in that the course is unique, having been specifically developed by the industry in order to fulfil an urgent need for polymers companies. Fully accredited and delivered by industry experts, the Diploma will be conducted in real industrial environments, enabling students to visit co-students' premises and experience best practice classes on state of the art processing equipment.

For many AMME businesses, irrespective of size or stage of development, "employability" and/or the role of placements also emerged as a key theme. While a one-year placement within a 3-4 year course was very useful in developing some of those skills, AMME employers do not consider NI graduates to be as well rounded as, for example, their German counterparts. German engineering courses are typically 6-7 years long, allowing plenty of time for placements but also the study and development of leadership and management skills.

- Good industry placements are highly sought after by undergraduates, but the timing and quality of the offering from industry must be just right (one year being optimal).
- Improved communication between businesses and universities/colleges around placements and formal structure is essential. Bureaucracy around placements is a major barrier for all parties, especially SMEs.

Both NI universities value industry placements. Queen's currently has 105 students (in one school alone) on placement across 69 companies. Some of the salaries secured for these placements reach as high as £21k, which goes some way towards underlining the value companies and the university place on people exchange and industry supported development of skills and knowledge. Queen's University is working with NI AMME companies to develop industry/market attuned graduates of the future; participating companies include:

Industry engagement

NI employers and academics alike have expressed concern that a broader range and larger number of schools don't currently engage directly with the world of AMME.

Lessons from the UK "industry partnerships initiative" (UKCES)[35] point to the need to support teachers to support students as key to success; especially in industries that are complex and less understood. Giving teachers the opportunity to visit local companies and see for themselves how modern businesses operate, providing them with resources that relate directly to their schemes of work, working with them to plan the programme of activity and helping them build their knowledge of new careers, are all important.

Education and employers should be better connected to prepare people for work. This means businesses engaging with education; schools, colleges and universities.

But the reality is that only 30 per cent of businesses actually offer young people work experience placements during education.

> "Successful employer engagement in schools should be long term, strategic and connect the classroom with the world of work."
>
> UKCES

Sir Ian Wood's *Commission for Developing Scotland's Young Workforce* aims to achieve this for all 363 Scottish secondary schools in the next three years.[36] Suggesting this is doable (on the basis that only 8% of the employers that do engage with schools experience any difficulties whatsoever), Scotland is developing a framework for coordinating education and business links at a local level.

Unquestionably, there is a wide range of excellent practice to build on such as Business in the Community's 'Business Class' and 'Inspiring the Future' run by the Education and Employers Taskforce, as well as the work of education business partnerships and employer bodies such as chambers of commerce and the CIPD.

The challenge now is to scale up activity at the local level, including bringing in smaller businesses, so that every school and college has a point of contact for business engagement and enterprise. This means stimulating the growth of networks in local areas and the development of new ones where they don't exist. This has the potential to create a national movement for inspiring young people about the world of work and will support them to make informed career decisions.

Sir Ian Wood's ambition for Scotland to achieve 100% school-industry engagement for secondary schools within three years is entirely relevant for NI - there are 832 primary and 271 secondary schools in NI and at least 2,050 AMME companies with a number of excellent programmes already in place across the region which could be deployed more widely.

One such programme is the School Employer Connections programme - a North-West based initiative established in 1999 to help give students real life insight and experience into the world of work which, in addition to a range of student-based events provides focussed workshops for teachers in key sectors. In addition to essential career guidance the programme supports curriculum requirements with experiential learning to increase student understanding, knowledge and build confidence and raise aspirations.

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[35] Industrial Partnerships Initiative, UK Commission for Employment and Skills, March 2015.
[36] Developing Scotland's Young Workforce – Scotland's Youth Employment Strategy, December 2014.

Suggested actions from AMME consultation

- The role of FE colleges in the education continuum providing vocational training for youth and continuing education for employees needs to be considered. In parallel, a more flexible approach which supports training delivered by industry to meet industry needs should be supported alongside fixed HE/FE delivery routes.
- A re-examination of the government training centres of the 1970s (considered a valuable source of employees).
- A focus to review and improve the system currently in place. A full review of the mechanisms for local AMME companies to offer placements to NI undergraduates with limited bureaucracy requirements on all parties and potential support to SMEs (e.g. revisit a model akin to the pilot mini KTP programme).
- Review German model and engineering course development over past 10-20 years: Core engineering degree + employability + placement extended over 3-6yrs.
- "Career Ready", a scheme offering 6 week internships for Level 3 students should be explored further.
- Communication – requires engagement on both sides. Establish an AMME forum for education and industry parties to come together.

RECOMMENDATION

The role of colleges in the school/FE/HE education continuum providing vocational training for youth and continuing education for employees needs to be considered.

Issue 3: STEM – Policy and action

At UK level, against the backdrop of no significant improvement in the UK's absolute performance in mathematics and science since 2006, recent government intervention has been in the form of Centres of Excellence.

Recognising that a strong mathematics education is vital for all pupils in enabling them to take advantage of the opportunities available in today's fast-moving education and employment market, a network of Maths Hubs across England backed by £11m of funding has been established. These Centres of Excellence implement elements of the Asian-style 'mastery' approach that has achieved world-leading success.[37]

> "Our science and innovation strategy can only be as good as the people that it can attract, educate, train and retain. Rigorous education and training add value to both individuals and the economy. We need to ensure that we make the best of all our talents – dismantling the sometimes invisible barriers faced by women and other underrepresented groups".
>
> **HMT/DBIS, December 2014**

Good teaching is vital if students are to achieve highly in STEM subjects. Subject knowledge for teachers in secondary schools is important for good quality teaching. However, last year, 26% of single physics hours taught to pupils in years 7-13 were taught by a teacher without a degree or PGCE in physics or a related subject. The corresponding figure for maths lessons was 17%. To redress this constraint, £67m has been allocated to new programmes to train up to 17,500 maths and physics teachers over the next Parliament, on top of existing plans. This will include programmes to recruit up to 2,500 additional specialist maths and physics teachers, through new schemes to attract more graduates, postdoctoral researchers and career-changers into teaching, and to add to the skills of 15,000 existing teachers through funded sector-led subject specialism training.

STEM position in Northern Ireland, 2016

NI AMME employers and academics observe that, given there are in excess of 1,000 STEM organisations in the UK – engineering professionals couldn't keep track of them all, therefore what chance would students have?

What became clear throughout the course of the consultation, was that no-one was sure who, if anyone, was in the lead with regards STEM in NI today. Added to which, the proliferation of national bodies meant that, while the profile of STEM may have been raised in recent years, the message was confused and the effect dissipated. The most telling view however was that, irrespective of whatever STEM policy was, is/might have been, little has changed.

Likewise, engineering and technology take-up in terms of gender remains stubbornly fixed, the table in Annex 5 refers to HE and FE take-up by gender and illustrates Engineering and Technology subjects remain male dominated both at FE (93.6%) and HE (82.9%). This is in line with UK stats which illustrate that only one in five 'A' level physics students are female – a figure that has remained unchanged in the last 20 years. Against this education backdrop, it is unsurprising therefore that the proportion of women in AMME careers has remained unchanged at 16% since the 2008 Matrix report (% of women in Manufacturing static at 22%; women in all industries static at 52%). Median gross earnings in AMME are 26.7% higher for males (£28,253) than for females (£20,717).

[37] Our plan for growth: science and innovation, HM Treasury /DBIS, December 2014.

Future NI STEM direction

The *Skills Strategy for NI* includes a STEM specific goal: to increase the proportion of people qualifying from NI HE Institutions with graduate and post-graduate level qualifications in STEM subjects (with an emphasis on physical and biological sciences, mathematical and computer science, engineering and technology) to 22.5% in 2020 from a baseline of 18% in 2008. The most recent statistics show that goal is on-target to be met with the proportion standing at 21.8% at the end of the June 2015.

The '*STEM Strategy for NI, Success through STEM*' which was agreed by the Executive in 2011 set out 20 recommendations for business and government to take forward to address the declining number of enrolments in STEM subjects. The recent stocktake of progress against the STEM Strategy highlights a number of key achievements across business and government, e.g.:

- 1,419 additional under-graduate and 234 additional PhD places in STEM and economically relevant areas;
- 17.7% increase in narrow STEM enrolments and 4.8% increase in broad STEM enrolments (at NI HEIs) from 2011/12 – 2014/15; and 24.9% increase in level 3-6 narrow STEM qualifications from FE colleges across the same period;
- 70.2% achieving grade C or better in GCSE Maths compared to 65.4% in 2010/11.

Suggested actions

A new mechanism WES uses "Sparxx" is based on the idea that you can have any amount of fantastic outreach that lights the spark, but unless you do something for a girl that gives the spark the oxygen to survive, then the spark will go out. Similarly, the teacher industrial partners' scheme is cited as a great mechanism for industry and teachers to get involved with stem careers.

> "You need constant contact to offer support and nudge them in the right direction".
>
> **Dawn Bonfield, WES President**

"In order to increase diversity, industries should ensure that they stipulate 50/50 male to female ratios for their outreach activities, however unpopular or hard the schools find it to achieve, as this is the quickest way to promote gender diversity."[38]

Good career advice is crucial – the lack of good careers advice in schools (especially where there is limited home support for STEM ambition) is one of the reasons why girls in particular fail to enter the engineering discipline, and this is something that Bonfield believes really needs addressing if we want to get more young people, and more girls in particular into engineering.

RECOMMENDATION

Matrix should ensure that, as the NI Economic Strategy is refocused within the context of the new Programme for Government 2016-21, that the Department for the Economy is supported and encouraged to continue to build on the current STEM agenda and (important) small gains recorded. This is an essential step to ensuring the delivery of economically relevant skills and qualifications for the AMME sector in the future

[38] Dawn Bonfield, WES, Materials World article, November 2015.

Skills Conclusion

The resource invested in human capital, particularly new recruits, is by and large the biggest single cost quoted by AMME companies. Clear and recognised technical and professional pathways are needed that go from school up to degree level and above, with stopping off points in between. This means closer collaboration between colleges, training providers, universities and employers to ensure that there are clear pathways between institutions and workplaces.

The importance of ready access to a highly suitably qualified and skilled motivated workforce cannot be over-stated. There is clear evidence that businesses are prepared to invest when they have greater control over how money is spent (the Greiner case study illustrates this). Strengthening workforce development must remain a high priority.

> "The image of FE must be considered the equal of HE, if all young people are to match their career choices with their abilities".
>
> NI Skills Barometer: Developing skills for tomorrow's economy, November 2015.

The skills and competencies of the existing workforce underpins competitiveness and growth, and upskilling the existing workforce is critical to keep pace with new technologies. Many SMEs in particular find it hard to balance the demands of short-term business pressures with planning longer term investment in skills, but by working together on developing their workforce– whether with government, skills providers or even with aligned cluster members, businesses can share knowledge ideas, risks and ultimately development costs. The ability of FE/HE to respond, flexibly, to the changing needs of industry in the context of factories of the future will impact significantly, on NI's AMME future success. Calls for alternative, more flexible training models and access to industry-focussed training akin to the 1970s training colleges for apprentices should be explored further.

The premise being that for SMEs to do it themselves would be fragmented, not to mention, resource intensive, but centres of excellence across the region to accommodate school leavers to address multi-sectoral needs (e.g. suggested clusters include 'sheet metal fabricators'), should be an option, where employers identify the need. This is especially pertinent in light of the cited example of the efforts required by NI polymer SMEs to establish a polymers processing academy to provide industry-led, commercially relevant training on their behalf.

Strong links between the departments of Education and Economy are vital to bridge the gap across the education path and ensure the departments are working towards common goals in this area. Throughout the consultation, almost inevitably, when discussing "what most impacts the choices children make (encouraged by parents)?" the image and general perception of engineering was pinpointed as the single biggest constraint. Better branding of engineering and a broader impression of a career in AMME was a consistent 'ask' by industrialists and educationalists alike. A theme which is explored further in this report under "Sectoral Development."

> "Learning is a dynamic process, in which successive stages of learning depend on skills acquired previously, particularly foundation skills of literacy and numeracy.... weak foundation skills limit initial learning, reduce career opportunities and lead to jobs that offer few opportunities for learning on-the-job, or other forms of upskilling. The implication is that career trajectories are much easier to launch favourably than to change for a stronger trajectory in later life".
>
> OECD Skills Studies, 2016.

Research & Development and Innovation Infrastructure

R&D&I efforts are seen as important drivers of non-price competitiveness as they can increase the capacity to create complex sustainable, customised and innovative products.

This section looks at R&D&I in the context of:

- The AMME business community
- The AMME research community
- The AMME business & research communities working together

“Business is far more likely to invest where there is an excellent, long-term and stable Engineering and Physical Science research base. Ready availability of, and access to, new ideas and skills gives industry the confidence to invest, and to take the risks that lead to innovative products and services, thereby creating jobs”.

(EPSRC Strategic Plan, 2015.)

Innovation is an inherently risky business. Many businesses, particularly SMEs, consider that risk more than they are willing to absorb. Government can, however seek to reduce barriers to innovation for businesses, by providing access to equipment, skills, networks, and funding.

R&D&I within the AMME business community

Creating the right environment and infrastructure provides a crucial foundation for private business investment. An environment that includes, amongst other things, a competitive tax environment, access to finance, the availability of appropriate support networks, and access to public funding, technical assistance and advice.

Tax and R&D Reliefs

As a UK region, NI has a highly competitive overall tax system. The current UK Corporation Tax rate is relatively low at 20%, the joint lowest in the G20 (and set to fall to 17% by 2020) and the Fresh Start Agreement announced plans to devolve the power to set the rate to the NI Executive, paving the way to implementing a 12.5% rate in NI which will significantly improve the region's competitiveness. In addition, there are generous incentives specifically for R&D.

R&D relief reduces the cost of qualifying expenditure by around 46% for a profit-making SME, 33% for a loss-making SME, around 29% for a large profit making company and 9% for a large loss making company. The Patent Box offers a 10% rate on profits derived from patents encouraging innovation to take place in the UK. R&D tax credits provided £1.4bn of relief to over 15,000 businesses, supporting around £13.2bn of investment in 2012-13. ***These reliefs put money into the hands of businesses making investment decisions.***

Over 470 NI firms benefitted from £0.58bn through the various R&D reliefs in 2013/14. If we apply the proportion of BERD which is undertaken by AMME companies to that £0.58bn total, we could (for illustrative purposes) assume that AMME companies availed of approximately £290m R&D relief in NI in 2013/14. Whilst official HMRC statistics are not available yet for the 2014/15 period, bearing in mind that the behaviour of a very small number of large companies can impact overall BERD results quite dramatically, care should be taken to ensure that, not only do the number of companies claiming these reliefs continue to increase, but that the amount claimed also continues to rise, or is at least maintained.

Whilst the level of Patent Box applications by NI companies remains low, there can be no question that HMRC Reliefs are more widely claimed than was the case when Matrix last looked at AMME – a significant factor when operating within a constrained public spending environment. (The R&D relief scheme, is an HM Treasury scheme, administered by HMRC, and funded centrally by Treasury, whereas 'Internal' assistance for R&D e.g. Invest NI's Grant for R&D programme is drawn directly from the NI Block Grant.)

The Invest NI figure for total Grant for R&D (i.e. all sectors) offers issued during the same period is £47.7m.[39]

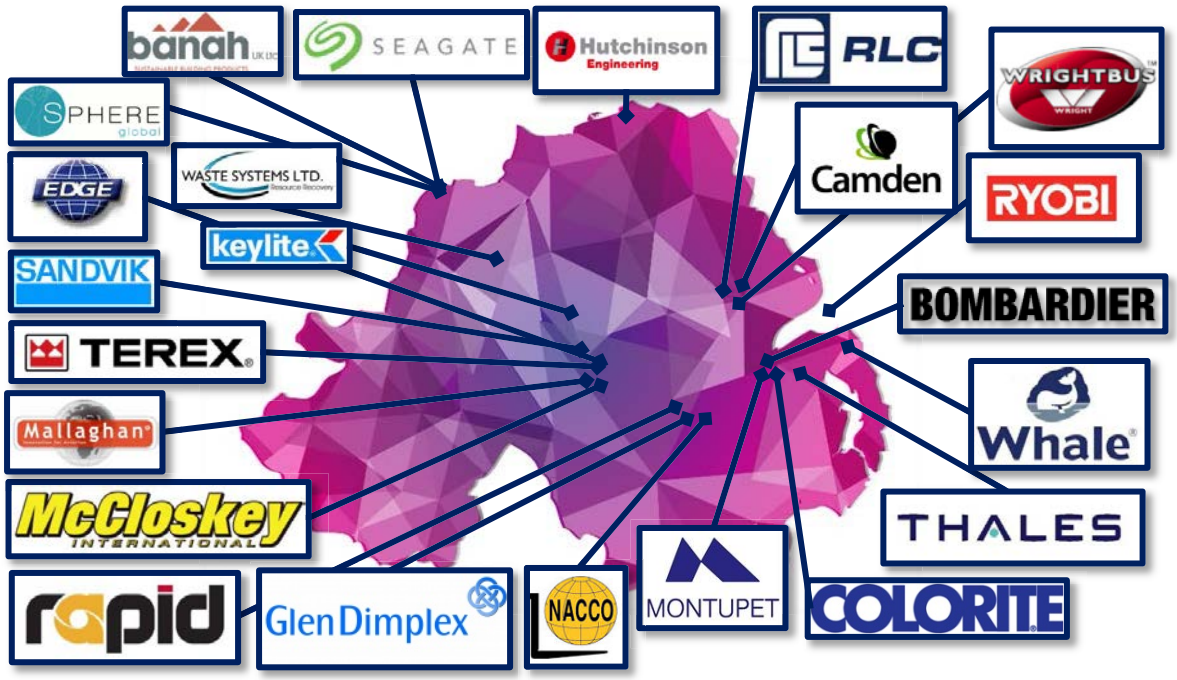
[39] Invest NI R&D Support

NI funded R&D grant assistance for AMME businesses

During the period since the last Matrix AMME report, some 385 AMME companies that is just under one fifth (19%) of all AMME companies (per Matrix classification) received financial support from Invest NI's Grant for R&D programme for over 700 projects, drawing down over £95m grant support against business investment for those AMME projects of just under £320m.

Despite government spending restrictions in recent years, the level of Invest NI grant assistance for R&D performing businesses in NI has been maintained. Significantly, over the final 2 years of this period (Jun 2013-Jun 2015), 46 of the 101 AMME offers issued (i.e. 44%) were to AMME companies 'New to R&D', suggesting positive level of 'churn' and R&D growth in the sector.

Figure 9: A range of some of Northern Ireland's key AMME R&D&I performers



'Ex-NI' financial assistance for AMME R&D&I

R&D&I is at the heart of the UK's long term economic plan with a total commitment of £2.9bn to fund large scale investments in science – via "grand challenges fund". Government support is delivered within the framework of its Industrial Strategy and concentrates on 3 main areas:

- Development of sector strategies for innovation-intensive industries, in partnership with business
- Catapult Centres - network of elite technology and innovation centres, that focus on sectors or challenges with large market potential and where the UK has a global research lead
- Support to universities in a 3rd mission to deliver economic growth, alongside their traditional roles of teaching and research

The 8 Great Technologies where the UK could lead the world in their development have been identified (drawing on advice from the Research Councils, Innovate UK and the foresight exercises of the Government Office for Science) and funding prioritised. Funding will be delivered via: HEFC & Research Councils; the UK Space Agency; National Academies; Innovate UK; and Government R&D departments.

The UK government has placed Catapults at the centre of its investment in innovation infrastructure, with the UK catapult centres increasingly used as the means to pull together many of the elements needed to help at sectoral level.

NI's AMME companies can access other funding from outside the region including Innovate UK's collaborative R&D and thematic calls (e.g. in transport, high value manufacturing or advanced materials) and EU competitions (e.g. H2020). These grant programmes are generally considered to be more competitive than internal NI assistance, which perhaps explains the relatively low level of participation by NI businesses.

Mainstream Innovate UK programme support for AMME – NI participation

During 2015/16, 59 AMME projects were initiated with an NI participant or lead, of which 28 were Knowledge Transfer Partnerships. Total grant assistance offered to the 59 projects amounts to just under £9m. This brings to over £50m the total mainstream Innovate UK programme assistance offered to 276 participants across the 2004-16 period for which Innovate UK data is available. [40]

Examples of direct UK funding include investment in Aerospace projects with Queen's NITC

The NITC at Queen's University Belfast is an industry facing research and technology unit aligned to the School of Mechanical and Aerospace Engineering, bridging the gap between academic research and commercial production to meet industry's needs. Working with local industry partners the NITC has facilitated consortium building to access funding from UK government programs, highlighted by the recent successes with the Aerospace Technology Institute; SCENIC (£5M) and FoAF (£1.4M).

Figure 10: Supply Chain Enablement for Increased Competitiveness (SCENIC) – NITC in partnership with NI AMME businesses

[40] Total number of distinct AMME projects 2004-16 is 290, across 327 NI partners. Details of grant assistance is only available for 276 of those partners (£50,893,765).

The SCENIC project aims to increase the competitiveness of the UK supply chain for aerospace metal structural components. The capital investment will establish an open access "manufacturing technology factory" encouraging and enabling increased research and development by UK industry, SMEs in particular. OEMs will participate, providing leadership and market need, while technology providers will support projects providing latest technical know-how. The capital investment will empower industry to pursue additional R&D project funding through Invest NI, Innovate UK, ATI and Horizon 2020. The project has a regional focus aimed at creating a platform for increased engagement with the wider research community in the UK and in particular the HVM Catapult facilitating wider interaction with leading OEMs and dissemination to the wider UK industrial community. The investment in high value manufacturing technologies, with regional access will help overcome a recognised barrier to SMEs increasing investment in higher value R&D and involvement with the HVM Catapult infrastructure.

Factory of the Future for Aircraft Wing Manufacture and Assembly (FOAF),

NITC is also a partner in the Airbus UK led national project involving NI companies Bombardier, Datum Tool Design Ltd and Eventmap Ltd – other partners include Cranfield University, the University of Sheffield, the Manufacturing Technology Centre, BAE Systems, Hexagon Metrology, Seco Tools and Aertec Solutions.

An ATI-funded project, Factory of the Future for Aircraft Wing Manufacture and Assembly (FOAF), led by Airbus Operations UK, will provide the facility, technology, testing and capability to validate the next generation of high-efficiency wing, and associated high-productivity manufacturing systems. The vision of the project is to develop a number of key outputs that will define a world class manufacturing facility. The £13.5 million project brings together 13 partners (six large companies, three SMEs, one Catapult and three universities), aiming to maintain and strengthen UK manufacturing capability for conventional and next generation airframe structures, ensuring that the UK remains a global leader in wing manufacturing and is integrated into a longer-term seven-year strategic target to generate a future factory vision. The project also has the capability to generate spin off technologies that could be transferred to other sectors.

Technologies developed as part of this project will boost business productivity by providing extra capacity to meet future demand and competitiveness to build complex aircraft components in the most cost effective way, ultimately securing future market share and highly skilled jobs across the supply chain in the UK. As a collaborative partner, the NITC will undertake key areas of research:

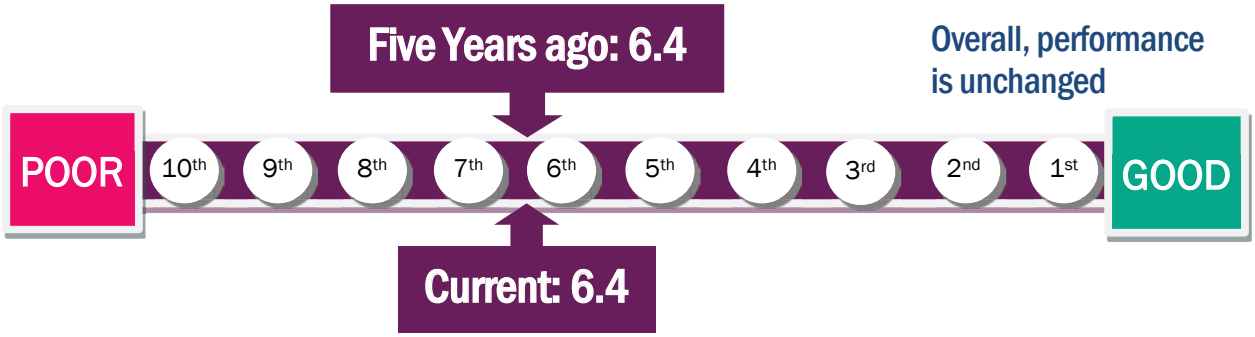
- Digital factory simulation focusing on the future high rate single isle production line
- Cost Benefit analysis to better understand the benefits of introducing new technologies
- Drilling studies through aerospace stack materials
- Innovative in-jig hole inspection techniques.

Every opportunity should be taken to encourage the NI AMME community to participate in national and wider funding competitions.

R&D&I performance – NI's relative competitiveness

As with Skills & Education, Innovation and R&D are considered key to regional economy development and therefore a significant pillar in the recently published NI Competitiveness Scorecard.[41]

Figure 11: R&D&I performance: 2014 compared to 2009 (full breakdown at Figure 38)



NI's R&D and innovation performance is one of the relatively weaker areas of the scorecard, scoring 6.4 in the decile placements, but remaining stable over the past five years. This means that two thirds of the comparator economies are ahead of NI in this pillar of the scorecard.

Whilst the Scorecard notes the level of innovation activity is relatively low within NI firms, it has increased - especially in manufacturing firms. We also know (see pp12-13) that AMME firms in particular perform consistently well across R&D&I measures, with an impressive track record in R&D, and the NI AMME sector out-performing the NI industry average in terms of innovation activity and the UK to an even greater degree.

The Scorecard nonetheless highlights particular areas of concern:

- NI's knowledge economy has grown quite rapidly over the past five years, and from a low base, is now 10th of the UK regions;
- Patent application rates remain relatively low;
- Number of PhD graduates has reduced and is set to reduce further in future years;
- Problem solving abilities of young people in technology rich environments are also relatively low when compared to other countries.

One area where NI has observed remarkable growth since 2008 is Business Expenditure on R&D (BERD), with the level of spending more than doubling. The figure did reduce markedly during 2014/15, with foreign owned firms reducing expenditure by almost £100m, or 29%; whilst notable, this should not be over-analysed on the basis of one year's performance.

BERD is particularly sensitive to the timing of individual projects within companies and, if larger projects are coming to an end, decreases until new projects are underway are not uncommon. However, domestic firms and Higher Education expenditure on R&D both increased, going some way towards replacing the reduced BERD.

Perhaps even more important is a significant rise observed in the number of companies involved in R&D. NI's R&D base has historically been concentrated on a relatively small number of firms, and the Scorecard commentary notes the latest R&D data signals a move to a much more diverse base which will benefit in the long run.

[41] NI Economic Advisory Group, July 2016, op cit.

Knowledge Transfer Partnerships (KTPs)

KTPs were cited most frequently by companies during the AMME consultation as the most beneficial form of university-related support. One company referred to the graduate programme as a "1-2 year interview process - for the company and the graduate". Of those companies who participated in the AMME consultation, the vast majority went on to employ the respective graduate – many of whom remain with the company years later. For some businesses, successful KTP projects mark the beginnings of an R&D culture within their daily business operations.

Both NI universities have been long-time, successful participants in the KTP programme, with the vast majority of these projects being with NI companies, mainly AMME SMEs.

Smiley Monroe KTP associate (with Belfast Met)

At a sectoral level the NI polymer sector has been important in terms of manufacturing KTPs in the UK, with 80-90% of around 50 NI polymer sector programmes awarded grades 1 or 2 (i.e. in top 5% -6% of all UK KTPs). These KTPs were considered to be outstanding or excellent in terms of contributions to (i) the company; (ii) the graduate associate; or (iii) the institution. Significant success at national award level includes Cherry Polymers (Best Overall UK KTP, 2012), Canyon Europe (Best UK Industry Impact Award, 2009) and UPU (Best Engineering KTP programme – RAE Special Award 2008).

Queen's University, in particular has an impressive track record in this area and continues to be the number one university in the UK for KTP projects, The University consistently tops the UK league table for both quantity and quality, having won 18 national awards in NI for its academics, associates and partner SMEs. Most recently, Bullivant Taranto Ltd, Tandragee was shortlisted in the "Innovation leading to New Markets" category of the Parliamentary Innovation Awards, 2016. The awards identify and recognise great SME innovation stories that inspire others and demonstrate significant impact on the economy.

KTP collaborations are recognised as a valuable part of the University's purpose, With the merited claim that "KTP at Queen's has become the standard-bearer for the whole of the UK", it is not surprising therefore that the University's strategy for identifying new opportunities and turning them into active partnerships has been shared and adopted on a national scale and is becoming a model for others further afield, with Dr Mary Flynn having recently visited South Africa as a guest of the British Council to talk about KTPs and their impact.

"If there is one word which sums up why KTP at Queen's has been so successful it is – understanding. We understand the local economy; we understand the development needs of local business".

Dr Mary Flynn, MBE, Head of KTP and Business Networks, Queen's University.

Snapshot

Bullivant Taranto Ltd, Tandragee

A KTP project between Queen's School of the Natural and Built Environment and Bullivant Taranto. This National Award winning Best Overall UK KTP project (2013) aimed at reducing energy costs and environmental impact, whilst also increasing the profit in the manufacture of pre-cast concrete products.

Bullivant Taranto Ltd is an SME with experience in design and manufacture of a range of reinforced and pre-stressed concrete products. This KTP started at a time of economic downturn in the construction industry and, not only did the company exceed the aims in the of the original project plan, they have driven the development of extremely low energy concretes with improved structural performance using locally sourced materials with the encapsulation of waste products such as PFA from Kilroot power station. The KTP partnership also resulted in expanding into new markets by the development of a novel vaulted floor system and new, patented pile connection which led to increased turnover, profit and a new client base. They are now at the forefront of the pre-cast concrete solutions, particularly the piling market, manufacturing and installing the patented Bullivant single reinforcing bar pile. The vaulted floor system resulted in a 66% saving in the self-weight compared with an equivalent flat slab system and represented a substantial cost saving with a significantly lower CO_2 with low energy concrete. Additional major impacts were:

- Development of low energy, self-compacting concrete (SCC) from locally sourced materials and in accordance with requirements of the new EU standards
- SCC removed the need for external vibration, reduced energy use, eliminated noise, reduced labour demand, the quality surface finish and increased durability
- Development of innovative patented products namely: structurally efficient vaulted floor and patented piling joint
- Cost of production reduced by 25%, energy reduction by 30% and reduction in cement/ replacement with waste materials which lowered CO_2 emissions
- Increased market share with regards to precast piling, including the expanding renewables market such as Carrowleagh Windfarm
- Extension of product portfolio, e.g. novel vaulted floor system with increased weight strength
- New markets entered in UK and Ireland including winning Ireland's largest ever underpinning contract

CASE STUDY: SMILEY MONROE

Smiley Monroe is one of the world's leading specialist manufacturers of 'endless' conveyor belts for customers in the mobile crushing, screening, washing and recycling marketplaces.

The company was featured in the London Stock Exchange's 2014 report '1,000 Companies to Inspire Britain', a celebration of the fastest-growing and most dynamic SMEs in the UK. The list highlighted the UK SMEs that have not only performed strongly since 2009 – an exceptionally challenging period – but have also outperformed their sector peers.

Research, development and innovation are all important to the company's continued development. Smiley Monroe has a current Knowledge Transfer Partnership with Belfast Metropolitan College which has resulted in the placement of a specialist researcher into the Lisburn operation.

The company also has a close association with the Polymer Processing Research Centre at Queen's University and with the Northern Ireland Polymers Association, headed up by Dr Gerry McNally.

KEY FACTS

- Established in 1979, Smiley Monroe now employs 125 people in Lisburn and a further ten at a satellite manufacturing facility near the Indian city of Bangalore.
- 80% of Smiley Monroe's revenues come from the manufacture of belting products for Original Equipment Manufacturers (OEMs) of screening and quarrying equipment.
- Between direct exporting and the export of equipment on which its belts are fitted, 95% of production from the Lisburn plant goes overseas to 42 different countries.
- The company has its own testing facility for both incoming raw materials and finished products.
- 400km of endless conveyor belts are produced each year, enough to stretch from London to Paris.

"It's an industry driven by innovation but the basics have remained the same. You can't really change much about the chemical process of vulcanization. But we can add value to our end products, we can manage our work flow, we can train our team in lean tools and best practices and we can involve everyone in our improvement programmes. The fact that we can offer competitive prices to our customers is partly due to the fact that we've adopted lean manufacturing principles and that we have a skilled and experienced supply chain team. In fact, when our US customers benchmark us against local suppliers of conveyor belts, we're still competitive.... even though we have to ship across the Atlantic Ocean.

"And we're problem solvers for our customers. We help them to find solutions based on years of field experience in conveying and screening applications in quarries, mines and cement plants."

Tim Monroe, Smiley Monroe

UK funding framework for AMME R&D&I

R&D&I is at the heart of the UK's long term economic plan with a total commitment of £2.9bn to fund large scale investments in science – via the "grand challenges fund". Government support is delivered within the framework of its Industrial Strategy and concentrates on 3 main areas:

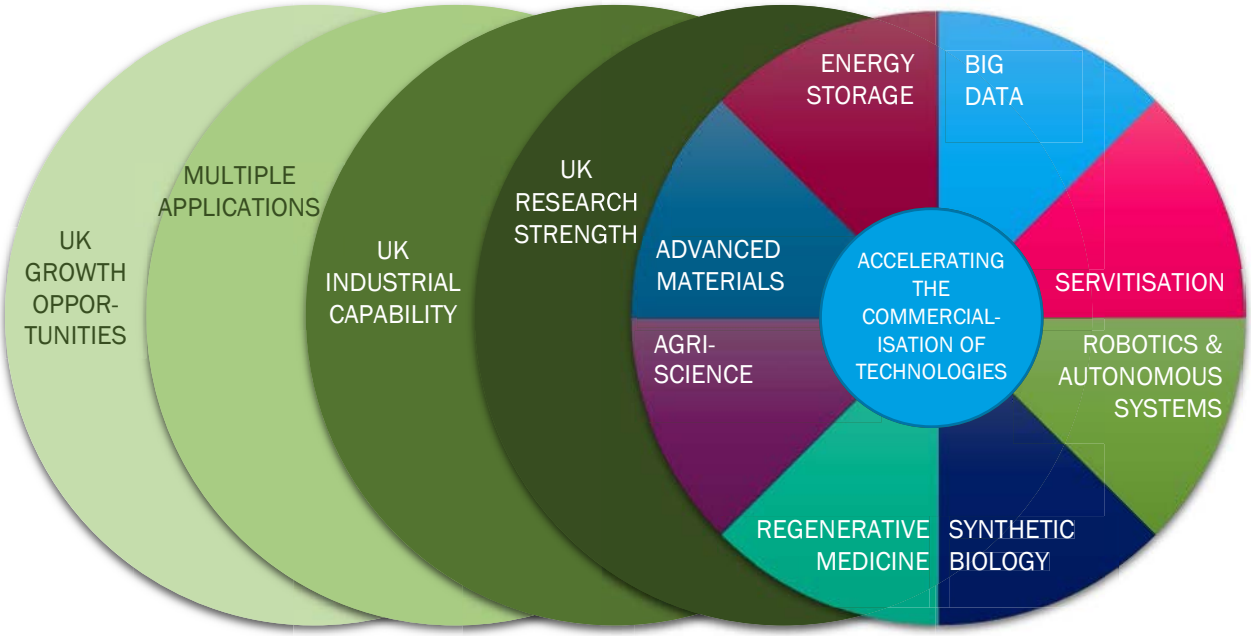
- Development of sector strategies for innovation-intensive industries, in partnership with business;
- Catapult Centres - network of elite technology and innovation centres, that focus on sectors or challenges with large market potential and where the UK has a global research lead; and
- Support to universities in a 3rd mission to deliver economic growth, alongside their traditional roles of teaching and research.

The 8 Great Technologies where the UK could lead the world in their development have been identified (drawing on advice from the Research Councils, Innovate UK and the foresight exercises of the Government Office for Science) and funding prioritised.[42]

Funding delivered via:

- Higher Education Funding Council & Research Councils
- UK Space Agency
- National Academies
- Innovate UK
- Government R&D departments

Figure 12: The Eight Great Technologies and their drivers



The UK government has placed Catapults at the forefront of its investment in innovation infrastructure; with the UK catapult centres increasingly used as the means to pull together many of the elements needed to help at sectoral level.

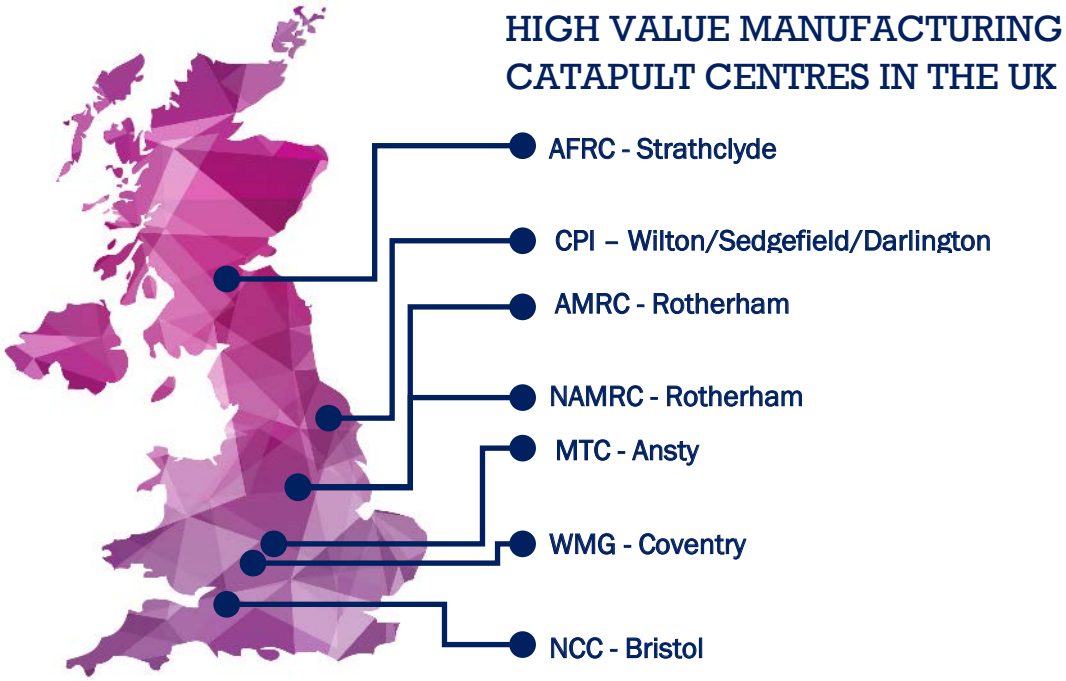
[42] The "Osborne 8 great technologies" which will propel the UK to future growth, January 2013.

Snapshot

UK Catapult Centres

This network of technology and innovation centres focus on sectors or challenges that have large global market potential and where the UK has a global research lead. The centres aim to assemble the best facilities and talent nationally to provide open access to businesses new to the technology areas and provide opportunities to build new business-university collaborations.

- £61m funding to the High Value Manufacturing (HVM) Catapult centres to meet increasing demand and provide outreach and technical support to SMEs[43]
- £28m investment in a new National Formulation Centre, as part of the HVM catapult, to drive manufacturing-based growth



Catapult access:

It would be unreasonable to expext a region of NI's size to be in a position to provide facilities on the same footing as the HVM catapult centres, but it can provide access to them. A Catapult mission programme – akin to the Invest NI trade mission programme (which many AMME businesses frequently referenced as a valued intervention) presents a simple model which could be replicated to kick-off an equally valuable flow of knowledge-exchange engagement. The invitation to participate has been issued at government level. Recent announcements relating to joint initiatives with NI's ICT Digital and Life & Health Sciences sectors are encouraging. The new NI centre for the UK Digital Catapult, based at Catalyst Inc will provide collaborative opportunities for business R&D and will also strengthen linkages between the NI digital sector with the GB market and wider UK catapult network. Belfast was also confirmed as one of the six centres of excellence in the UK Precision Medicine Catapult in 2015. NI's AMME businesses should be encouraged to follow-up, with whatever support is necessary and available, to facilitate early exchanges with the HVM Catapult network. As the developments within the other sectors demonstrate…with sectoral strength, leadership and persistence, this can happen.

[43] High Value Manufacturing Catapults

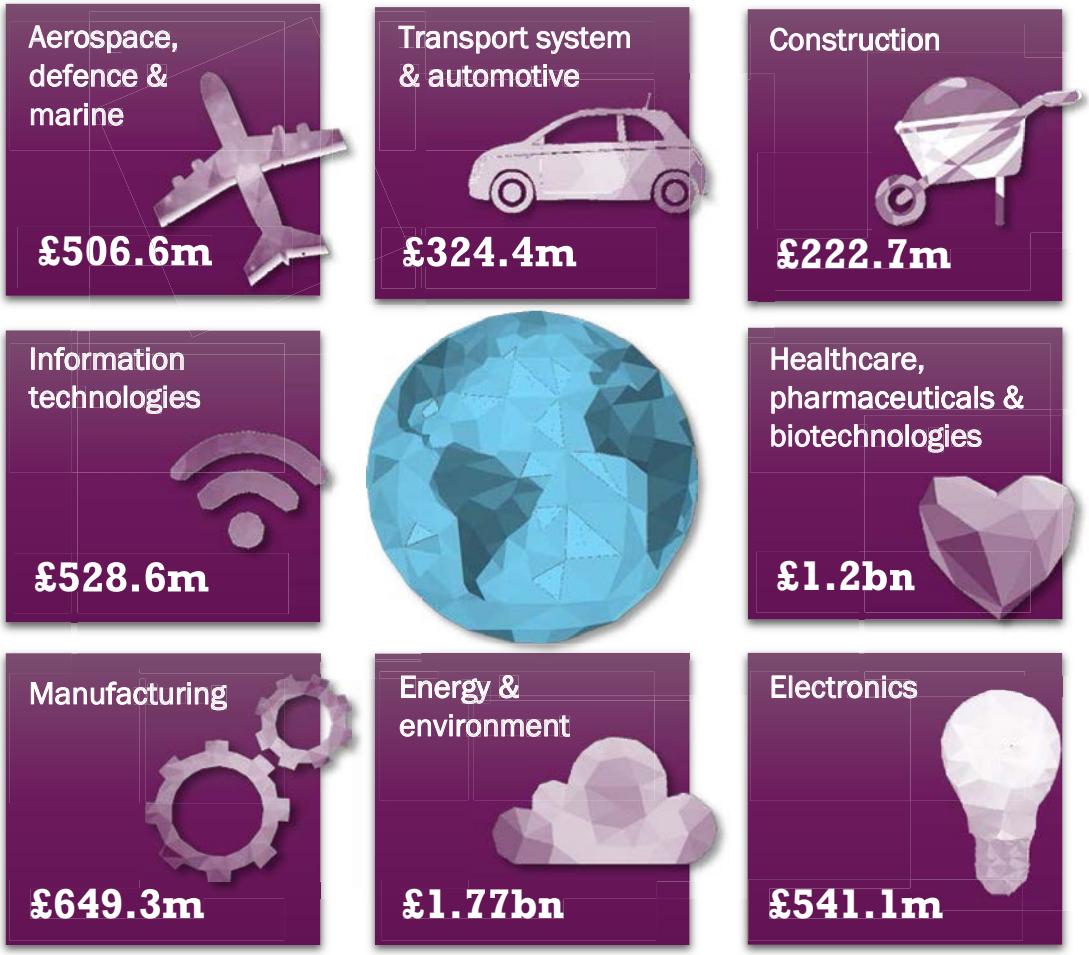
Snapshot

EPSRC

EPSRC, the UK's Engineering and Physical Sciences Research Centre promotes and supports high quality basic, strategic and applied research and related postgraduate training in engineering and the physical sciences.[44]

- For 2015/16, £2.5bn of EPSRC's portfolio has sector relevance, with £1.7bn directly relevant to the Industrial Strategy sectors (figure 12, below)
- All but one of the 'Eight Great Technologies' derive EPSRC sponsored research
- Of the Technology Strategy Board's £200m anticipated 2014/15 expenditure on its fourteen priority areas, £180m is linked directly to EPS
- Six of the seven Catapult Centres will build directly on and continue to benefit from engagement with EPS research

Figure 13: Current EPSRC Portfolio (2016) – Sector Relevance



- 12 framework ROs across the UK account for 51.64% of total (£2.69bn / 1,969 grants)
- 11 Strategic ROs account for a further 22.24% of total (£983.1m / 848 grants)

[44] EPSRC Strategic plan, 2015.

Research Environment for NI AMME

Without question, universities are a vital part of our innovation ecosystem. The UK research base is world-class and is second only to the USA for number of citations and has the most productive research base in the G8 (29 universities among the top 200 according to the Times Higher Education World Rankings are UK). Significantly, the Global Competitiveness Index ranks the UK 3rd for the quality of its research institutions. NI's AMME businesses have ready access to that research base, with many engaging with a wide range of subject specialists across the UK, including NI's two local universities who have significant strengths within a range of AMME related disciplines (see Annexes 4 & 5).

NI participation in EPSRC funded research

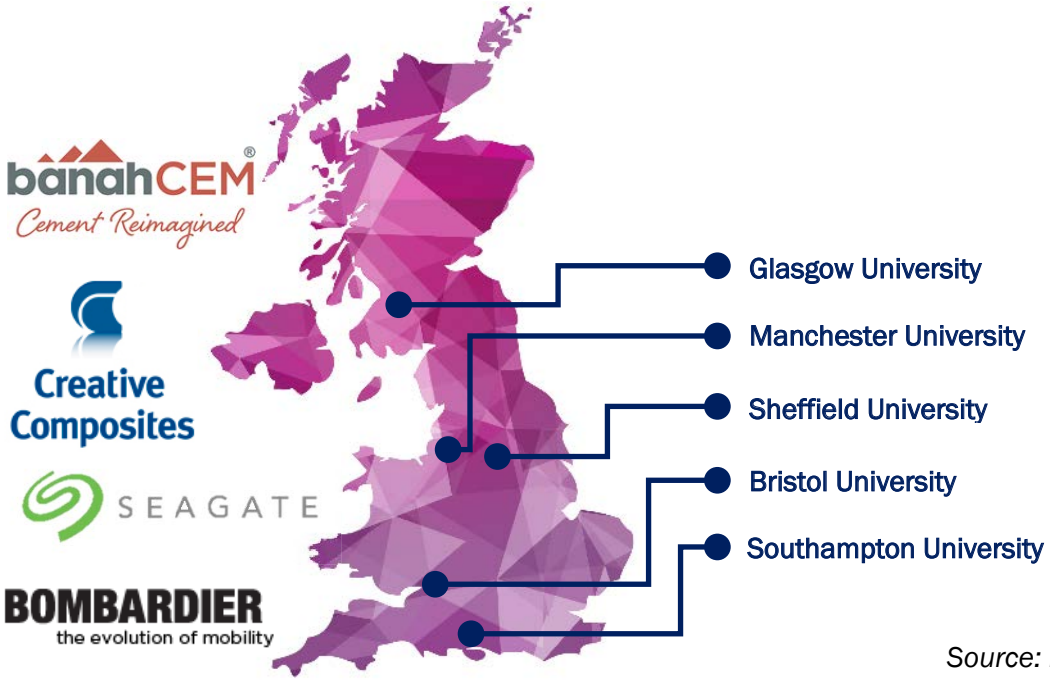
Neither of NI's universities is currently an EPSRC Framework or Strategic research organisation – automatically ruling them out of 74% of EPSRC portfolio. In terms of EPSRC's current portfolio Queen's University has secured an allocation of 0.781% of total (£35.3m / 56 grants), with UU being awarded 0.068% of the total (£3.1m / 9 grants). When broken down to AMME specific research - current EPSRC support (at January 2016) sits in the region of £11.4m (29 grants) and £528k (4 grants) to Queen's and UU, respectively.

This has not always been the case however, while Queen's is now sitting just outside the Strategic Partner cut off point, it was a strategic partner two years ago. Queen's firmly believes cuts from local government have significantly impacted on their ability to deliver in this area, citing the main cause of decline in EPSRC volume to the University firmly to be severe staff cuts during that period – an estimated 75 staff in the Engineering and Physical Sciences area. Nuances in the grant award calculations employed by ESPRC to determine Strategic Partner status, including for example Doctoral Training Centres (DTCs) which Northern Ireland has only had access to in recent years are also a factor.

Despite the current position, both universities remain committed to participating in EPSRC funding opportunities. In fact, in terms of early career research grants with EPSRC (EPSRC First Grant Awards), Queen's currently leads the UK for new awards, ahead of Imperial College London.

However, that isn't the full picture. NI's universities collaborate with ex-NI businesses, and likewise NI's AMME businesses collaborate with experts in their respective fields, irrespective of location; e.g. NI AMME businesses actively engaged with, among others, Sheffield, Southampton and Glasgow universities – all of whom are EPSRC's Framework/Strategic partners. Access to this level of research, whether from the local universities or further afield is important.

Figure 14: Examples of NI AMME businesses working with EPSRC Framework and Strategic Partners



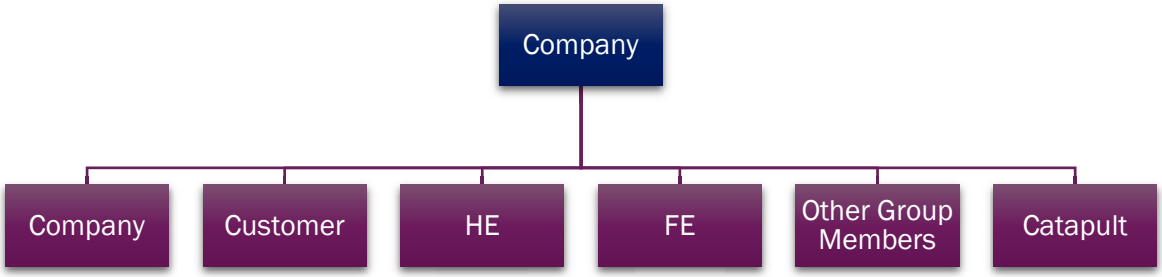
Source: EPSRC

Whilst NI's two universities will have linkages into the EPSRC core-funded universities, a number of NI's AMME businesses also work directly with a range of them, some of which are highlighted above.

Figure 15: Examples of ex-NI businesses working with NI Universities

NI AMME business and research communities working together

The options for potential collaborations are dispersed:



Collaborations may take the form of formal multi-million pound R&D projects with complex IP agreements through to simple £2k innovation voucher engagements, with many other layers of engagement in between. Local colleges and universities supply: access to research expertise, sub-contracted R&D, hire of equipment and testing which AMME businesses purchase; while the business in return also provides access to knowledge and industrial research expertise which can be applied directly to the business product/process development. Both Queen's and Ulster Universities point to significant investment in outreach activities during recent years, e.g. Queen's R&E directorate includes 28 staff solely dedicated to linking its research experts with industry and has also created a fund to reduce the cost to industry of engaging with research. Queen's has also created an Impact Development Fund, with funding from £5k to £50k, to support alliances with corporate partners.

The table at Annex 9 provides information taken from the government's Higher Education-Business and Community Interaction survey (HE-BCI), for all sectors, i.e. not just AMME and sets out Queen's and Ulster Universities' commitment to engaging with SMEs on research, consultancy and use of facilities. In addition, the universities also participate in collaborative R&D projects, often supported by public funding via Invest NI, Innovate UK or H2020.

As an integral part of the world's third-largest civil aircraft manufacturer, Bombardier Aerospace, Belfast looks to its involvement with the Royal Academy of Engineering's research schemes to make an impact on its operations and on the local community in its long-established base in Northern Ireland. Since 2001, in partnership with the Royal Academy of Engineering, Bombardier has funded a Chair in Aerospace Composites at Queen's University and also, since 2014 a Chair in Composites Engineering at Ulster University. Bombardier's links with higher education and with university research are strategically important to it on several levels, enabling it to achieve international competitiveness and to demonstrate commitment to the local community.

A more recent example of direct investment by business in university research is the "W-Tech" initiative by the Wrights Group.

BOMBARDIER
the evolution of mobility

ROYAL ACADEMY OF ENGINEERING

Snapshot

'W–TECH'

NI AMME business working directly with Queen's University, investing in R&D to stay ahead of the competition.

In September 2015 Ballymena bus builder Wrightbus announced that it is establishing an R&D Centre of Excellence in conjunction with Queen's University Belfast to develop driveline and composite technologies. 'W-Tech' - named after the Wrights Group's William Wright, the new project is a multi-million pound, ten-year research programme which strengthens the company's relationship with the University that goes back more than a decade. Wrightbus already undertakes all electric and hybrid bus simulations and modelling at the University, and a significant amount of driveline testing and development for the New Routemaster was conducted at Queen's Belfast.

The new programme which formally launched in November 2016 will extend the company's capabilities in near-term market opportunities and undertake research to develop longer-term innovations and technologies. It will incorporate laboratory and academic work, as well as prototyping and application study for commercial exploitation for the benefit of both the Wrights Group and the university.

As well as driveline technologies, composite material development will be a focus for the new partnership. Modern buses contain increasing proportions of composite materials in their construction. The New Routemaster features structural composite construction in its rear quarter using materials found in the holds of ocean-going racing yachts. In addition to Queen's Belfast, the Wrights Group collaborates on composite technologies with other organisations such as Bombardier, Caterpillar, Queen Mary University and Ulster University at the new Northern Ireland Advanced Composites and Engineering Centre (NIACE).

Celebrating the Wrights Group's special relationship with Queen's University, Minister for the Economy Simon Hamilton, Wrightbus founder and CEO Dr William Wright CBE and Queen's Vice-Chancellor Professor Patrick Johnston.

University funding to support sectoral growth

The majority of government QR funding ('mainstream QR') is distributed according to the universities' performance in the Research Excellence Framework (REF) 2014, under Graduating to Success the HE strategy for NI (summary at Annexes 4 & 5).

With QR funding for Academic Year 2015/16 in the region of £44.5m additional support is available to projects in the eligible areas of nanotechnology, sensors, telecommunications and energy/sustainability which fall under the jurisdiction of the NSF in the US. (c£1.4m 2016/17). H2020 contact points (which include advanced materials and transport technologies) and the HEIF fund (£3.96m per annum) - the underpinning funding for the universities' interaction with business. The long term aim of this funding is to improve Northern Ireland's innovation performance as a key element in raising productivity and delivering economic growth.

With over 40 staff related to AMME research throughout the university, the UU Engineering Research Institute has attracted over £35m funding over the past 15 years has engaged with a wide range of NI AMME businesses.

Figure 16: UU engagement with NI AMME businesses

Snapshot

UU working with NI AMME business – AVX Ltd

Small technology gives big business results.

A KYOCERA GROUP COMPANY

AVX Corporation works closely with scientists and engineers at UU using nanotechnology to improve the reliability of electronic components. AVX manufactures capacitors, components that store electrical charge, which are used in every electronic device including mobile phones, cars, and satellites. High-end electronics industries need components that meet stringent performance requirements and so manufacturers must devise innovative, higher specification products such as capacitors that provide greater energy storage efficiency, voltage capability, temperature dependence and reliability. The AVX facilities are very high tech with some of the most sophisticated manufacturing processes in the world. The electronic materials used in the manufacture of the capacitors are nano-particles, 10,000 times smaller than the width of a human hair, and nanotechnology is the science of manipulating matter at the nano-scale. The Nanotechnology and Integrated BioEngineering Centre (NIBEC) based at the UU Jordanstown campus is home to a range of world class nanotech facilities.

An initial project was highly successful with major improvements in nanoparticle dispersion which the company have now fully integrated into their volume production lines. This has had a major impact upon product development and business results. Building on the success of this collaboration, in 2012 AVX co-funded a second collaborative project with NIBEC specifically focusing on improvement of the base metal electrode (BME) system utilising nanoparticle nickel for MLCCs.

The NIBEC Team has been working with the engineers at AVX Ltd of Coleraine over many years and together they have made major breakthroughs. New projects will use state-of-the-art technology to help AVX create even more efficient and reliable components, increasing their market share and sales, and protecting jobs in Northern Ireland. Major research and development funding, which is backed by Invest NI and supported under the ERDF European Sustainable Competitiveness Programme will lead to further impact from this fruitful collaboration.

Professor Tony Byrne who leads the Ulster research said: “We are delighted to grow our collaborations with AVX and to see that our world-class facilities at NIBEC can make a real impact locally. This project will open real opportunities for science and engineering graduates and many of our students will learn from this research. Our collaborations with AVX have already made a significant impact, both for AVX and the University.”

“This work is an important example of how our Engineering Research Institute is impacting on the local economy with global and significant reach into the EU, USA and Asian aerospace, automotive and medical markets”, (ERI Director – Professor Jim McLaughlin). “The new nanoparticle developments within the AVX capacitor range and the characterisation techniques deployed are adding value, as well as helping with manufacturing production efficiencies”.

AVX Corporation, a subsidiary of Kyocera Electronics Corporation, has 9,900 employees and operates in the United States, Europe and Asia with sales of $1.545bn in 2012. The company has a plant based in Coleraine, Northern Ireland, where multilayer capacitors are fabricated and tested for a wide range of exports.

CASE STUDY: CCP GRANSDEN

CCP Gransden is one of the most active members of the Northern Ireland Advanced Composites & Engineering Centre (NIACE), the industry-led technology hub based next door to Bombardier's Belfast plant. Robert McConnell chairs one of the key committees at the centre.

The company has invested over £1m in automation equipment in recent years, and believes that investment in both equipment and R&D will continue as the company strives to win more contracts in the exacting aerospace and defence sectors.

Director Robert McConnell and his colleagues travel widely to present CCP Gransden's expertise to some of the biggest industrial names around. In the aerospace industry alone, relationships have been built with the likes of Airbus, Brazilian plane makers Embraer and NI-based BE Aerospace and, in recent months, CCP has made inroads with Jaguar Land Rover, one of the biggest UK operators in the automotive sector.

KEY FACTS

- CCP Gransden was established in 1896 as A.W. Hamilton Engineering on Belfast's dockside, repairing ships and acting as a contractor to the nearby Harland & Wolff shipyard. It has stayed in family ownership since then.
- In the 1950s and 60s the firm started to move from shot blasting and metal coating towards corrosion resistant plastics and composites. Customers back then included Michelin, Enkalon and Courtaulds.
- Today, CCP Gransden has two distinct areas of business, one of which is in the chemical field. Working now as the main local agent for chemical giants BASF, the firm is the market leader in the supply of flocculants used in the treatment of water, waste water and minerals.

"We work with a variety of advanced materials including carbon, glass, aramid and natural fibres. We can also select the best composite mix for specific applications using polyester, epoxies and phenolic and natural resins. We're very committed to research and development, to innovation and to collaboration with others in our industry sectors.

"Our future, we think, is as a highly flexible manufacturer working with a wide range of customers and our aim is to build on our reputation as an innovative producer of high quality finished products.

"R&D plays a vital role, but it's important to stress that R&D has to lead to workable solutions that can be implemented, resulting in real business improvements, something that's crucial to our competitiveness in the wider marketplace."

Robert McConnell, CCP Gransden

Invest NI funded industry-university collaboration

During the period since the last Matrix AMME report, of the 385 AMME companies who received financial support from Invest NI's Grant for R&D (GR&D) Programme for c700 AMME projects, 16 distinct AMME projects involving a business (or multiple businesses) + a university partner were pursued, that is, around two per annum.

At just 2.3% of total GR&D project numbers, the level of AMME collaborative projects remains proportionately low, albeit, at average of £318k, they are generally larger in terms of value of average GR&D offers (the higher support rate available for collaborative GR&D being a factor).

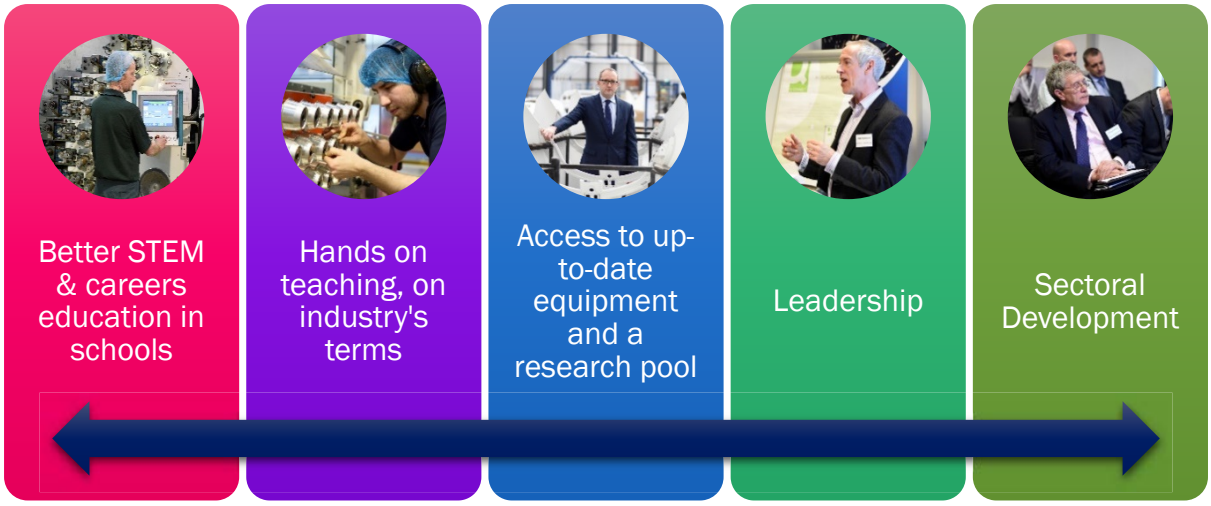
The ability to develop and commercialise new ideas, products and services is critical to NI's economic future and to creating wealth. How government invests in the knowledge base presents a crucial challenge, for all parties, not least in the context of a constrained public expenditure climate.

Within total collaborative GR&D offers, however, the value of AMME collaborative projects is significantly lower than for other sectors - Life and Health Sciences in particular. For the period January 2013 – October 2015 seven AMME collaborative projects accounted for 50% of the total number and only 23.6% of the total value of those projects supported. In fact, if one significant AMME project is excluded from the dataset, the 6 remaining AMME projects (i.e. 42.8% of total collaborations) drop to 10.4% of total value of collaborative assistance.

What's standing in the way of greater levels of AMME industry-university collaboration?

AMME businesses, by the very nature of meeting the definition of AMME, are pre-disposed to innovate. R&D is by and large embedded and many companies have the confidence and networks to access research expertise, from a wide range of sources. That said, and despite the fact that NI universities record significant effort over recent years to encourage increased levels of business collaboration, many AMME companies continue to consider academic collaboration a frustrating experience – or perhaps worse still, do not believe it has commercial relevance for large parts of the sector.

What do NI AMME companies say they need?



AMME businesses acknowledge the need to engage with the research base in order to remain competitive and grow in global markets. However, the level of bureaucracy which surrounds collaborative R&D support continues to provide negative responses (from not only businesses but also academics).

The decision to engage with Invest NI (or other government strands of funding locally) will bring with it additional burden and bureaucracy to ensure taxpayer value is delivered and obligations, such as State Aid and ERDF regulations, are met. Other sources of funding with less regulatory burden (and more competition) could be explored by industry, such as Innovate UK or EU H2020 (pending Brexit). These are funding streams that are designed for higher TRL levels and require industry leadership. Universities can be engaged to support and contribute to the research activity. Alternatively, industry can engage directly with universities, reducing significantly the need to engage in publicly funding-related obligations and allowing for more streamlined engagements based more firmly on industry requirements.

Some of the common delays in starting academic-industry partnerships such as recruitment of staff for example can be more easily overcome with shared risk in making appointments prior to Letters of Offer or Letters of Award, where there is government support involved in the R&D engagement. Or as above, dealing directly with universities creates greater flexibility to recruit more speedily. The INI Competence Centres, such as NIAECC, have begun to develop more flexible models, where 'pooled' researchers are recruited ahead of project approvals by the Centre Boards to minimise the delays in start-up.

The loss of experienced technology officers and similar support staff has also played a major part in the universities' ability to engage with the degree of agility that industry demands.

In addition to the whole burden of bureaucracy, industry frustrations are most frequently felt in relation to delays, projects overrunning or moving off-plan, mismatch of time scales and priorities.

Added to which, a number of businesses expressed frustration at the limited availability of research facilities outside the core academic timetable and the inflexibility of both HE and FE to respond to industry needs for just-in-time training, for example. “On their terms, in their silos” was a recurring theme.

Countless AMME businesses expressed that, based on their own experience, the universities, in their view, are not interested in the broader AMME sector. The perception being that schools within the university are increasingly being driven by a REF-focused agenda which doesn’t adequately recognise or incentivise industry-led industrial commercialization of that research.

The universities would contend that view is not universally true, a point which is clear from the range of case studies where the universities have engaged successfully with industry. REF now having a major component focused on economic impact means it is an imperative for universities to undertake work of value to the economy. Both institutions fared well in REF 2014 in this area. Recognition should be given to the importance of the impact agenda within universities and the fact that research funding is now directly linked to the socio economic impact that universities develop and deliver with non-academic partners. Both NI universities performed strongly in this regard in the last REF 2014, supported by work undertaken by companies in the AMME sector. The Research Excellence Framework, allied to incentives within universities for researchers to engage in commercial activity, is key to driving behaviour linked to economic outcomes.

Access to up-to-date equipment:

There is also a feeling that public investment in capital equipment is already too widely dispersed across FE/HE institutions, resulting in kit not fully utilised. Issues were also raised around access to equipment needing to be available on industry terms (i.e. not just during term time or core HE/FE hours).

Many AMME businesses recall a time when the R&D infrastructure available to them was better – high value equipment was up to date with specialised staff able (and available) to provide support and also to service that equipment. AMME businesses today quote unavailable equipment (either not available at all, or not at a time that meets business’ needs), uncompetitive costs and in one case a lack of confidence in the results as reasons why HE/FE facilities are no longer meeting the commercial needs of industry.

Regarding facilities access this is also an issue which the Universities feel and have expressed their frustration at not being in a position to meet short time-scale demands. The universities point to their “shrinking funding envelope” as a challenge which cannot be ignored in the context of pressures on equipment, meeting students’ demands and the ability to reinvest in facilities and maintain the appropriate staff base to support and maintain such equipment.

Access to industry research funding

A number of AMME businesses referenced a level of dissatisfaction with how industry engagement with the research base is funded and the way collaborative funding is typically channelled via the research partner in the first instance. Frustrations around industry being used as a conduit to access funding for universities were clear, with specific calls for direct research funding to industry - on the basis that universities are not the only source of commercially exploitable Intellectual Property.

The reasons for this are manifold. One may be the perceived imbalance regarding rates of assistance for collaborative funding. For example, projects supported by Invest NI's Grant for R&D are delivered under the European R&D&I State Aid framework, which restricts the level of assistance to industry (maximum support levels range from 25- 80%, depending on company size and the nature of R&D project – i.e. whether industrial research or experimental development). For the Jan 2013-Oct 2015 period support rates for AMME businesses range from 1-49%, whereas University costs were supported at 88-100%. Albeit, the universities would argue that despite grants awarded at 100%, in not recognising the standard UK University Full Economic Cost Model (FEC), Invest NI does not meet the full costs of research projects within either university. In fact, having factored in audit costs, additional administrative support and expenditure deemed ineligible, they would hold that many Invest NI-funded university-industry projects are loss making.

Some AMME businesses felt that projects which should really have been industry collaborations ended up being industry/university collaborations because of the funding mechanism but had ultimately failed. The "skewed" playing field therein was putting businesses off R&D collaboration of any kind. Taking into account the dispersed nature of knowledge and expertise which AMME business identify as most relevant to them, a more flexible or bespoke approach to government support for collaborations at all levels should be explored. It simply isn't the case that research organizations have a monopoly on the knowledge or expertise which is most relevant to all NI AMME companies today, therefore government should re-examine the support mechanisms in place to enable more companies to access the expertise they need, whatever or wherever the source of that expertise– on their terms.

The perceived mismatch in expectations and timescales (Industry requirement for a quick answer vs. university focus on publishing; or: solve problems that arise in day-to-day manufacturing opportunities vs. applied industrial manufacturing research) is not a new phenomenon, nor is it unique to NI's universities and AMME sector. But it does raise the question of whether the institutions are geared (whether through how they are funded or how research schools are resourced and incentivised) to respond flexibly to the needs of the manufacturers of the future.

“Innovation and advances in manufacturing research occur not only in academia, but also in established firms and in younger start-up companies. This research tends to be driven by the needs of product development and the launch of new products…not all innovations end up as patents or publications”.

“The experiences and insights gained from manufacturing activities at scale often trigger ideas for new innovations at the front-end. One of the main worries about separating R&D from production activities is that this feedback mechanism will be interrupted or dampened”.

Production in the Innovation Economy, MIT.

Fiscal incentives…grant assistance… access to research…access to industry expertise….

There can be no doubt, providing a framework where technical expertise and academic insight can come together in a flexible and industry-friendly framework is a significant challenge for policy makers, but one which offers significant potential value.

Taken separately, no one element provides the full solution for NI AMME companies' R&D challenges.

The final comments in this section relate to the opportunities which lie within business-university collaboration. Encouragingly, despite expressing high levels of dissatisfaction with the current position, many AMME businesses can still see the potential benefits to be gained from engagement with the research base, with technical members of businesses in particular valuing their engagements with research experts at an individual level. This pre-disposition on the part of industry to engage, whether within the constraints of formal collaborative university engagement or less formally, presents a huge opportunity for the sector and those with a vested interest in the commercialisation of research.

It should also be noted that, as is often the case with public support, dissatisfaction expressed widely across the sector in relation to overly bureaucratic processes or a lack of flexibility, (whether on the part of FE, HE, or Invest NI) was balanced, often by the same companies, with a deep appreciation of the contribution made by many individuals within the various institutions with whom they engaged.

Industry cases where government intervention was in the form of significant financial assistance, (e.g. Invest NI's GR&D programme) often cited the indirect support which accompanied the grant as the valued support element which made most difference to individual projects. Examples included support in the form of empathy/encouragement by a technology executive who understood the technical challenges of a proposed project; contradictorily, the discipline of the (oft-quoted "overly-bureaucratic" and "off-putting") appraisal process was recognised as having helped identify project planning issues at an early stage; or, in the case where the business is an NI subsidiary of a wider, global group – being able to demonstrate local support (often regardless of the actual pounds and pence value of the grant) has helped secure the allocation of group resources to the NI arm of the business.

Had the grant support not been available, would the majority of the companies consulted have gone ahead and undertaken the R&D project anyway? most likely; but most admit it would have been more challenging, especially given the economic backdrop of the past few years, it may have been at reduced scale, it would possibly have taken longer and it most definitely would have sent a dubious message about the level of regional commitment to the company's global HQ who in turn may have made a very different decision with regards allocation of group resources.

Taken together, the region can boast a comprehensive suite of R&D&I support –to help NI AMME businesses design, develop and commercialise new products and processes; and to attract and anchor foreign direct investment.

The over-riding impression is that elements of the R&D&I support infrastructure work well for AMME companies. Others, not so much.

- AMME businesses appreciate the constraints under which much of the assistance available to them is administered (e.g. EU State Aid constraints and the governance which accompanies grant assistance).
- AMME businesses also fully appreciate the need for and respect the REF-focused agenda within the universities; and for it to be adequately funded.
- Most importantly, however, for the purposes of economic development – they recognise the need for both industry and academia to work more closely together….

….but… and it's a big but, it needs to be on equal terms, with minimal bureaucracy. Otherwise, as is already the case, business will go ahead without the universities, potentially at greater cost to them and most certainly at a cost to the region – in terms of the lost opportunity from knowledge transfer – flowing in both directions – from the university to the business and vice versa, a vital spill over and wider economic benefit of collaborative R&D.

In concluding, in a harder and more competitive economic environment, the best exploitation of research for public benefit is more important than ever. In Europe this has resulted in recent calls to re-shuffle EU priorities and rebalance European funding toward technological research and product development, including technology infrastructures, industrial pilot lines and demonstrators for prototyping, testing and validating activities.

For many NI AMME businesses this would require the (perceived or otherwise) imbalance between an academic, publication-led REF focus and genuine university-wide interest in the commercialisation of R&D results to be addressed.

Consideration should be given to a number of R&D&I stakeholders who have as their raison d'être the development and support of industry-focused R&D&I. These include NIACE, ADS, NIPA and within the two universities a number of industrial research facilities, including the Engineering Research Institute's centres at UU (NIBEC, ECRE and Amfor) and at Queen's (NITC, PPRC, CenTACat, Quill, CEIAT and Ansin).

All have received government funding, whether resource or capital, or a combination of both. Given the criticism of current provision and bearing in mind the move at UK level to channel future strategic AMME funding via the Catapult network; the opportunity to develop a NI based AMME facility which builds on elements of existing provision (whether included above or not) to provide wider applicability across the broad AMME sector, in conjunction with the UK network should be explored fully. Given the convergence of sectors as AMME evolves and the reality that increasingly the high value add in AMME will occur at the interface of subsectors the opportunity to scope a government-led 'whole of AMME R&D&I solution' in response to industry needs within the established Catapult framework should be examined further.

CASE STUDY: SEAGATE

For Seagate's Springtown plant, size matters. As demand grows for data storage space, Seagate's researchers and engineers are charged with playing their part in making recording technology smaller....then smaller again. The plant's daily output - two million transducers - will fit neatly into a large jiffy bag.

And it's no quick process. From start to finish, the manufacturing process has some 1,200 individual steps and spans four months. It takes a further four months for the finished hard disk drive product to leave Seagate's downstream production plants elsewhere in the world.

The Springtown plant has two primary cost factors – its advanced engineering equipment and its people. Of the 1,400-strong workforce, a significant proportion are highly educated technical and scientific people - there are more than 100 PhDs on site.

The plant is currently working on a new generation of Heat Assisted Magnetic Recording (HAMR) technology.... a means of making the magnetic devices smaller without the risk of them becoming less stable.

KEY FACTS

- Seagate Technology (with around 40% of the global market) is one of three remaining large-scale manufacturers of hard disk drives in the world – the others are Western Digital (a further 40%) and Toshiba (20%).
- A world leading facility in every way and the biggest of its kind anywhere, the plant employs some 1400 people, runs 24/7 and ships some two million read/write transducers every day.
- The Springtown plant celebrated its 20th anniversary in 2013 and it's one of a network of worldwide plants run by the US-based parent company, an employer of some 55,000 people worldwide.

"Our customers want more memory but they also want costs to stay flat, so R&D is absolutely crucial to what we're doing here at Springtown.

"We're already working in atomic sizes, hundreds of thousandths of a human hair. And we're making a lot of progress. We're averaging a 15 - 20% growth in aerial density, which is the quantity of information bits than can be stored on any computer storage medium. But, at the same time, global demand has been growing by 30 to 40%. The past two years has seen another acceleration in demand, and we're expecting a tenfold increase by 2020. So you can start to see the challenge we face.

"It is very technologically challenging to work here; we're talking about engineering on an atomic scale. But it's that high level of technology that actually attracts a lot of really bright people to come and join us."

Brendan Lafferty, Seagate

RECOMMENDATIONS

Public funding of university-business collaborative R&D - Leverage and Value for Money: the development of metrics that identify and measure commercial outcomes as well as those for the university are important, not least in the context of constrained public spending environment.

Mechanisms which streamline industry-university engagement should be reviewed in light of becoming more flexible and dynamic – to the benefit of all parties, taking into account ease of access to collaborative R&D for SMEs in particular.

Businesses should be encouraged to seek out collaborative opportunities, wherever they lie, based purely on expertise and to look beyond localised networking, where appropriate, to avail of that expertise (e.g. explore HVM Catapult links).

Regional funding for collaborative research should be directed to best meet the needs and growth of AMME businesses, irrespective of location of research partner.

Additional HMRC resource available to NI businesses via its NI Corporate Tax Office (NIrCTO): DfE should renew efforts to ensure all eligible businesses are aware of the totality of support available to them under the HMRC incentives and reliefs – taking full advantage of NIrCTO's expertise and guidance.

The opportunity to scope a government-led 'whole of AMME R&D&I solution' in response to industry needs within the established Catapult framework should be examined further.

CASE STUDY: TEREX

The Tyrone-based Materials Handling sector might have achieved a strong reputation but it's not without its challenges, according to Kieran Hegarty.

"There are macro issues, but there are also micro issues around our own industry to think about too. We've taken the long-term decision to concentrate our efforts on mobile machinery rather than look at static units, as some have done. It's a clear policy decision to produce mobile machinery for the production of minerals around the world....and we think that it's the right decision for us."

A sizeable supply base has been built around the big materials handling players in County Tyrone, with small companies supplying everything from metal fabrications through to belting systems. The big ticket engines and advanced hydraulics still tend to come into Tyrone from big global-scale suppliers.

"We've seen the growth of a strong industrial sector based around materials handling and that's a good thing," he says.

KEY FACTS

- Terex sells 98% of its output externally and is owned by an international industrial corporation with its headquarters in Westport, Connecticut.
- The company has some 1,400 employees working across the three sites. The division also has plants in the US, Germany, Austria and Malaysia.
- Machinery built at the Terex plants in Omagh and Dungannon is shipped to destinations worldwide, including the UK, Western Europe, North America, Australia and India.
- Terex has five divisions, covering materials processing division, cranes, aerial work platforms, port/plant solutions and general construction equipment.

"We're only too happy to work with the universities but it's important that they become more proactive in the way that they engage with industries like our own. The aim has to be to increase the quantity of talent coming through education to industry. The quality is there, but the numbers are not. It's as simple as that.

"I think that some form of increased support for R&D would be very welcome. For a business like ours, R&D is everything. We've got to innovate and keep on innovating to win sales internationally.

"We also see huge potential in some new areas. A good example is the environmental recycling of construction waste – brick, metals and wood – which we reckon can be a major growth area as more and more legislation is introduced to encourage recycling worldwide."

Kieran Hegarty, Terex Corp.

So, what of NI's universities' vision of AMME beyond 2016? We asked, here is what they told us:

Queen's University, Belfast: Vision for AMME beyond 2016

"We have many excellent strands of research in individual disciplines and our big drive is to bring those together and form an integrated multidisciplinary research that reaches out right across the globe".

D^3 DREAM, DESIGN, DELIVER

A new multi-disciplinary research centre bringing together engineering and physical science research teams to tackle the global challenges facing society builds on the internationally leading capability in engineering and science at Queen's. D^3 Vision: "to make Queen's and Northern Ireland the leading global player in High Value Innovation, creating solutions that have rapid and direct impact on economy and society." Uniquely, psychologists and environmentalists work alongside researchers in technology and manufacturing. D^3 provides a focus for multi-disciplinary teams to develop the next generation of innovations built from cutting edge research.

D^3 will be unique in its global offering by having education, research and industrial partners all co-located. Working on a range of shared projects from high risk adventurous concepts to near term developments, with a focus on leading science and technology it will be built to be the state of the art for those who are only born today. "Those students of tomorrow need to be educated in tomorrow's technology rather than that which is already out of date. Having an integrated faculty which has capability to span from our deep history to our far future with those who can study our role and behaviour within it we will be well placed to deliver world changing research, and graduates who make a difference."

Embedded within the digital world, D^3 will blend intelligent autonomous systems, cyber physical systems and advanced manufacturing technology to enable instantaneous creation from ideas and dreams.

This will significantly strengthen mutual understanding and long term relationships by engaging in collaborative programmes and by encouraging mobility of staff and students across partners. Students and researchers can follow their work to fruition, and bring new challenges back to the centre creating a virtuous circle.

Building on the outstanding record of spin outs and industrial impact this facility will be an engine for the local economy generating direct economic benefit through increased sales and high value jobs. Queen's is committed to investing 30 academic posts with a total value of £7.5m over the next 5 years, to include outstanding early career researchers and established international leaders. This total investment will therefore significantly enhance the research facilities of QUB to continue its world leading research, and will encourage and strengthen strategic partnerships, stimulating additional investment in research and strengthening Queen's contribution to economic growth.

CASE STUDY: i-AMS

Queen's University Belfast has a bold vision when it comes to advanced manufacturing in Northern Ireland. The university already has a world-class reputation in the field of engineering, and it is now building upon that world-leading status by establishing, as part of the University's Vision 2020, a Pioneer Research Programme (PRP) in Intelligent Autonomous Manufacturing Systems (i-AMS).

i-AMS is being led by Professor Seán McLoone who is Director of the Energy, Power & Intelligent Control Research Cluster within Queen's University's School of Electronics, Electrical Engineering & Computer Science.

"The big challenge for us and industry here in Northern Ireland is how to take full advantage of Industrie 4.0," he says.

Described as the 'New Industrial Revolution' or 'Manufacturing's Next Act', Industrie 4.0 is the convergence of the so-called Internet of Things and Cyber Physical Systems, coupled with rapid advances in cooperative multi-robot and autonomous systems.

KEY FACTS

- The i-AMS programme at Queen's brings together an interdisciplinary team spanning electronics, electrical, mechanical and aeronautical engineering as well as computer science and even psychology.
- The PRP represents an investment of £1.06m over three years and includes PhD studentships and funding to develop links with key research centres in Europe, the US and China.
- The Queen's seed funding will initially fund 8 PhDs and 2 core positions to conduct underpinning research and provide a platform to engage with industry and leverage other sources of funding.

"Queen's ambition as part of its Vision 2020 is to contribute to tackling some of the key global challenges. The Faculty of Engineering and Physical Sciences has an important part to play in delivering the strategy, and through its support for i-AMS we are able to take a multidisciplinary and multi-departmental approach. What's important is that bottom up innovation needs to meet top down information in the push to create flexible new-generation factories. That means that our academic research and all the work that we do here has to be translatable to the factory floor. We want to be a contact point and a resource for industry and manufacturers and strong industry engagement is an important part of our mission. We intend to work closely with the Northern Ireland Technology Centre in this regard."

Professor Seán McLoone, Queen's University

Ulster University: Vision for AMME beyond 2016

Ulster will continue to serve the AMME community through its high quality research and education in the Faculty of Engineering & Computing. Our excellent student placement programme will continue to place our best engineers and computer scientists at the centre of our AMME industries to provide support for the sector and help shape our future graduate engineers and scientists. Undergraduate programmes will continue to provide a strong fundamental and practical education that will be topped off with industry driven and relevant subject options. This will allow us to respond quickly to the needs of the AMME sector without detracting from the necessary educational foundations of our degree programmes. Our research strategy for AMME beyond 2016 is encompassed in the strategies of the faculty's two research institutes with strong synergies between them. The growing links between Engineering and Computing create strong themes in virtual metrology, data analytics, manufacturing informatics, innovation in design & processing, and sustainable manufacturing. Advanced Materials and Advanced Manufacturing research is located within our Engineering Research Institutes with two core structures – ECRE/AMFOR leading structural materials and NIBEC leading on biomaterials through to nanotechnology. Underpinning strengths will be grown including materials characterisation; composites & metallurgy; advanced thermoplastics; plasma systems; nanomaterials, additive manufacturing (including rapid proto-typing) and device fabrication. Ulster University is currently investing in 5 new academic posts in engineering and the university has advanced plans to create further research led academic positions.

Engineering Research Institute - ECRE/AMFOR research:

Ulster University will base its future research in composites, plastics and sheet metal within NIACE - The Northern Ireland Advanced Composites and Engineering Centre. Post 2016 we will grow our composites and metals research to further strengthen areas such as complex 3D preforming and sheet metal forming technology development and to encompass new areas of strength in advanced thermoplastics for aerospace applications and in new materials and technologies for additive manufacturing. These are all areas of major interest to our local industry partners but also have wide appeal globally. We are now investing in the additional weaving machines, polymer processing equipment and metal forming equipment necessary to facilitate this research. We will also continue to grow our industry led research through the Northern Ireland Advanced Engineering Competence Centre and similar such centres currently under development.

NIBEC Research:

Ulster's core biomaterials and nanotechnology research will remain the pillars of research based within the Nanotechnology and Integrated Bioengineering Centre (NIBEC) complex. A new £7m biodevices rapid proto-typing laboratory will focus many of our activities on device development, thus enhancing our already strong innovation platform that has driven multiple spin-outs and strong industry interfaces. Industry led activity has allowed affiliated centres to grown such as CHIC, CACR and more are planned. Within NIBEC the new focus will be on growing our strengths in micro-plasmas, biomaterials fabrication, healthcare integrated sensor systems, and photocatalytic materials. In particular modelling materials that will lead to novel devices that can be integrated with photonic or electronic subsystems is core to healthcare technology and other monitoring projects going forward. We are investing in new surface science, additive manufacturing and rapid device proto-typing to create an environment that will allow platforms to grow international quality research and innovation. The centre will also focus on growing new PhD programmes with an industry and clinical focus.

Costs

The question of costs is one area where impact is felt in equal measure across all manufacturing generally and AMME specifically.

Costs – What matters most to AMME businesses today?

Second to skills, the issue of costs emerged within the AMME study as an area of concern. In particular, AMME businesses raised concerns relating to industrial de-rating and its long-term stability; logistics and the absence of a direct shipping route to North America; the impact of currency fluctuations; and also energy costs – namely poor infrastructure and issues relating to availability and access.

Well documented by other sources, most recently Manufacturing NI in its report supported by Oxford Economics[45], Matrix does not re-cover the whole area in this report. Instead, in confirming that the evidence presented during the course of the AMME study was entirely consistent with that already reported by Manufacturing NI in March 2016[46], Matrix accepts the findings and conclusions included therein and re-emphasises in particular the following Manufacturing NI conclusions:

> "Manufacturing faces a significant challenge in keeping its cost base in line with its competitors. Faster input costs as well as rising costs of employment has meant that costs in the sector have been rising faster than manufacturing in the UK as a whole and across the globe".
>
> "While rising cost is a concern in itself, it also reduces the capacity for the sector to invest. Reduced investment will reduce the amount of innovation and productive capacity that the sector can achieve in Northern Ireland, therefore limiting long-term growth. Any further pressure on costs, such as industrial de-rating, will intensify the challenges faced by the sector and provide a further obstacle to sustainable growth."
>
> "Manufacturing has a crucial role to play in the future performance of NI's economy. However, the sector is vulnerable to global shocks or changes in policy, which would threaten the sector's capacity to maintain its performance… on the flip side, if supported, manufacturing is well placed to capture the benefits of global growth".

[45] Manufacturing and the Northern Ireland Economy, A Report for Manufacturing NI, March 2016, Oxford Economics.
[46] Northern Ireland's Manufacturing the Engine of Prosperity. An Economic Analysis and Call to Action , Manufacturing NI March 2016.

Costs – consistent themes

Energy

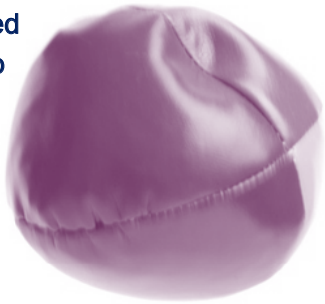
We need competitive electricity, gas and water prices plus good infrastructure – availability & access

Government

There are inconsistencies in employment law and greater agility in finance and taxation is required

Rates

Stability needed with regards to long-term industrial de-rating



Foreign Exchange

"Punishing.. but out of our control"

Infrastructure

Particularly trans-Atlantic logistics

NI AMME businesses are in what could be considered a “ready state”. Successful in their own right, they are hungry for leadership to maximize the region’s true advanced manufacturing, materials and engineering potential.

NI AMME companies are confident and capable, they are highly innovative and many are long-established with a deep embedded propensity to undertake R&D. Make no mistake, without coordinated and visionary government support NI’s AMME businesses will forge ahead.

By providing an over-arching ambition for AMME in NI, leadership could help cement an even brighter future for all, and in doing so maximise the impact of public funding via the provision of clearly coordinated AMME support framework.

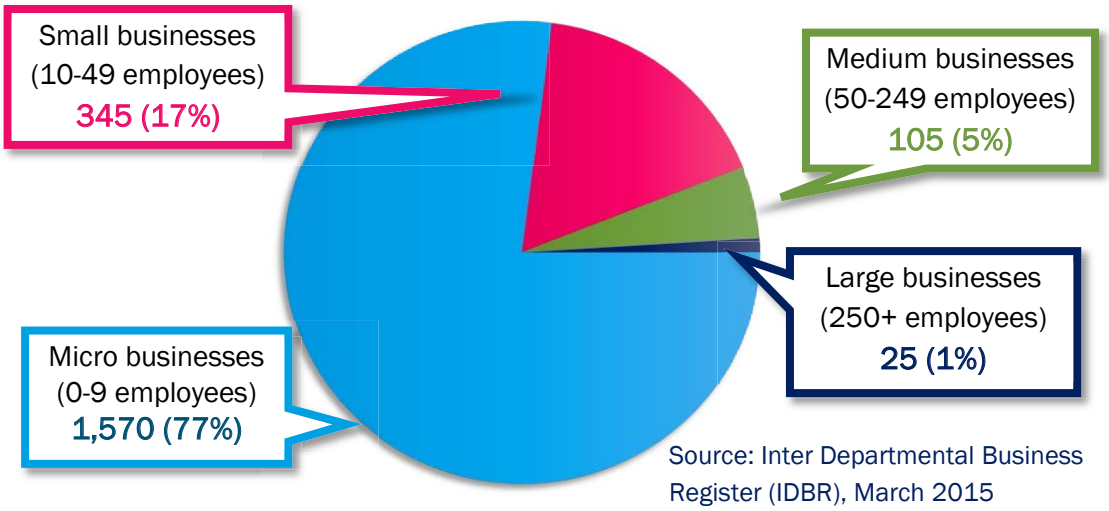
Sectoral Development

AMME is a broad and diverse sector; with significant stages of organisation within sub-sectors and an equally significant number of highly specialised individual businesses.

Sectoral overview

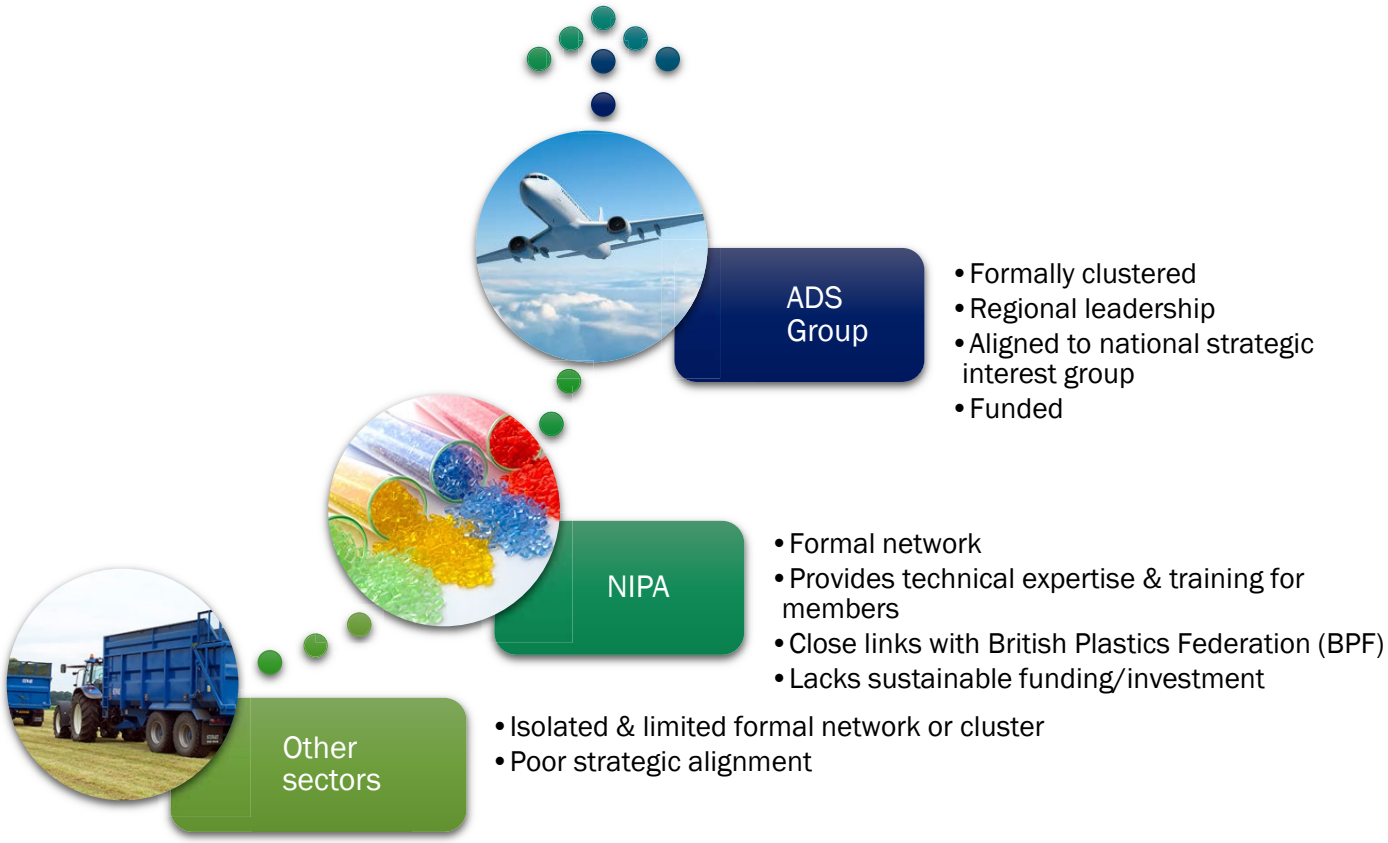
As is the case across all NI sectors, the region's AMME structure comprises a few very large individuals and lots of micro businesses, with a very small number of others in-between.

Figure 17: Breakdown of AMME businesses by size



This presents an obvious scaling challenge. With little evidence of lack of equity at start-up /early stage[47], the potential to develop merger & acquisition propositions, perhaps within the context of supply chain or affinity 'clusters' merits further consideration.

Figure 18: AMME sub-sectoral networks - overview



[47] The Future of Early Stage and Growth Finance in Northern Ireland, SQW Ltd, March 2015.

Each group represents a critical mass in relation to AMME activity, as classified for the purposes of this study, that is, they are businesses with high value-add, R&D is embedded, they are highly innovative, export intense.

Within these groupings we can already see, real benefits from varying degrees of 'organisation.' Whatever the nature and level of formal cluster development undertaken, the benefits to be gained from working together at a strategic level are clear.

ADSS

The Aero, Defence, Space & Security cluster –a sophisticated, mature, organised cluster in NI, with a number of key characteristics:

- Formally clustered
- Regional leadership facilitated under the Aerospace, Defence & Security Group
- Aligned to national strategic interest group
- Funded

KEY FACTS

- NI aerospace is a $1.6bn industry
- Europe's 8th largest aerospace region in revenue terms
- Over 44 ADSS companies in NI – 16 of which (employing 9,253) are in top 200 AMME. 7 of the 16 are established over 30yrs and 3 are established over 50yrs.
- Bombardier established 80yrs.
- Supply chain – mature & diversified

KEY PLAYERS INCLUDE…

Hutchinson Engineering

BOMBARDIER

THALES

RLC

survitecgroup

B/E AEROSPACE

NIPA

NI Polymers Association is, like ADS, an established, well regarded, organised cluster. However, it differs in many respects:

- NIPA leadership team provides technical expertise and hands-on training for its members.
- It lacks sustainable funding/investment
- It has strong links with a national body – the British Plastics Federation (BPF) – but the national polymers strategy lacks the profile that ADS enjoys

In common with ADSS, through their mapping of the region's capabilities and performance in their respective areas both clearly articulate the needs of their members and in doing so deliver a valuable service not only to their industry members, but also to government.

NIPA's ability to mobilise business within the polymer sector in NI, in particular, has brought together and given a voice to a very considerable number of highly diverse companies who, whilst individually significant, when clustered underneath NIPA present a combined strength which is formidable.

KEY FACTS

- 50+ polymers companies in NI; 23 in AMME top 200 (employing 3,040)
- The polymers sector employs 1 in 6 of Northern Ireland's manufacturing employees
- Polymers companies generate £1 in every £8 of NI total manufacturing output
- Almost two thirds of NIPA members each export to more than 30 countries worldwide
- Queen's Award for Enterprise success
- 11 of top 30 polymers companies established 40yrs+

MARKETS

- Solutions for medical devices & health care
- Marine
- Aerospace
- Automotive
- Teletronics
- Food & drink
- Textile markets

KEY PLAYERS INCLUDE…

Kingspan
Denroy Group Limited
Colorite
Canyon Europe
Whale

Materials Handling

KEY FACTS

- 38 MH companies feature in AMME top 200, employing 4,582.
- Long established MH heritage in NI – 10 of top 30 established 25yrs+ with the largest, Terex, tracing its roots back to 1966.
- 2016 Hyster-Yale saw 400,000th forklift truck roll off Craigavon production line – marking almost 35yrs of continuous production at the plant.
- CDE Global appear in LSE "top 1,000 companies to inspire Britain" 2015 and 2016.

MARKETS

- Quarrying & Mining
- Waste management/ recycling
- Cargo/ container handling
- Logistics handling
- Airport ground support equipment

KEY PLAYERS…

HYSTER-YALE
SANDVIK
TEREX
SMILEY MONROE
McCloskey INTERNATIONAL
Mallaghan Innovation for Aviation

Construction Products

KEY FACTS

- 38 CP companies feature in AMME top 200
- 6, 647 employees across the Construction Products 'top 200' companies (of which top 10 employ 70%)
- Combined turnover of CP 'top 200' is £33.5bn
- 74% of the top 38 companies are established 20yrs and 10 of those are established 35yrs+

PRODUCTS

- Windows
- Doors
- Fire Glass
- Ventilation

CONSUMERS

- Construction sector
- LHS

KEY PLAYERS INCLUDE…

CREAGH CONCRETE
banahCEM™ High Performance Geopolymer Cement
BRETT MARTIN
Keystone GROUP
McC fpmccann

Agri-Engineering

KEY FACTS

- 19 Agri-Eng companies in NI AMME Top 200 - employing 839 (66% of which are employed by top 5 companies)
- Only the top 2 companies employ 100+
- Combined turnover of Agri-Eng 'Top 200' is £42.6bn
- 8 of top 19 companies are established 20yrs+ and 6 of those are established 30yrs+

MARKETS

- Application in agriculture / forestry machinery and equipment

KEY PLAYERS INCLUDE…

NUGENT

Hill attachment

NC ENGINEERING WHERE QUALITY COMES FIRST

WALTER WATSON

FLEMING AGRI PRODUCTS

Automotive

KEY FACTS

- 17+ transport companies in NI AMME Top 200 – employing over 4,400
- Many other composites companies contribute to multiple sectors, including Automotive
- NI's leading composite companies supply Lotus, Jaguar, Land-Rover & other high end automotive manufacturers
- Leading global bus manufacturer Wrightbus, a pioneer of alternative public transport vehicles is NI's longest established automotive manufacturer (since 1946)

MARKETS

- Car manufacturers
- Trailer manufacturers
- Commercial passenger vehicles

KEY PLAYERS INCLUDE…

boomer

Creative Composites

AB PNEUMATICS

SMC

CHIEFTAIN

SCHRADER PERFORMANCE SENSORS

WRIGHTBUS WRIGHT

Highly Specialised Individuals

KEY FACTS

- HSIs account for around a third of top 300 AMME companies. The 70 HSIs employ c 9,000 (63% of which are employed by the top 10 HSI companies, with the top 2 HSI employers accounting for 36% of total).
- Many HSIs contribute to other sub-sectors, including Life and Health Sciences, Aero, Defence & Security, ICT Digital and Food and Drink.
- Highly innovative leaders: UK Energy Innovation Award winning Kelvatek features in the LSE top 1,000 companies to inspire Britain; Seagate employs over 100PhDs at its Springfield facility; and family-owned Ulster Carpets award winning weaving technology builds on 75 years of operation as it exports over 70% of its product from its County Armagh base.
- Combined turnover of top 70 HSIs is over £113.9bn.

KEY PLAYERS INCLUDE…

SEAGATE

ulster™ www.ulstercarpets.com

yelo

COONEEN GROUP

arbarr™ ENERGY STORAGE | LIGHTING | ELECTRONICS

KELVATEK

Whale® WATER SYSTEMS SPECIALIST

SPHERE global

survitecgroup

CATERPILLAR

ANDOR an Oxford Instruments company

Lpe laser prototypes europe ltd

AVX A KYOCERA GROUP COMPANY

MJM GROUP™

Sectoral development opportunities

The extent to which affinity groups within the sector are organised (whether through formal networking, clustering, strategic alignment, or none of the above) varies quite significantly. Given the broad and diverse nature of the sector, this is to be expected.

There are two key AMME areas where the benefits of formal sectoral development, however are indisputable: the aerospace, defence and security sector, with over 60 member companies ranging from Tier 1 to micro supply chain members networked under the ADS Group[48]; and the 50+ polymers companies networked under the NI Polymers Association (NIPA)[49].

As the UK's national association for the industry, ADS is an active participant in the Aerospace Growth Partnership (AGP) - a strategic partnership between government and industry which has been established to secure the future of the UK aerospace industry for the next 20 years and beyond. The NI branch of the group provides a point of coordination and a gateway into the wider UK Aerospace industry for NI member companies. NIPA is another obvious example of a mature cluster, already formally networked where further investment could make a significant contribution to the businesses within that area. NIPA also has strong links at national level with the British Plastics Federation (BPF) and its 400 strong membership network.[50]

In common, both groups in NI can proudly boast a vibrant membership with companies successful across a vast portfolio of products, services and capabilities. Both also present templates for 'organisation' which have huge potential with regards applicability across other AMME affinity groups.

The potential to customise and apply tried and tested ADS initiatives, for example integrated supply chain development, to meet the needs of other sub-sectors presents significant opportunities for NI AMME. Adapted to fit the needs of the polymers companies, the ADS model is entirely relevant.

NIPA, in turn, is a highly relevant, scalable model for other areas within AMME where there has been limited or no formal clustering to date. The ability to draw together businesses across bio medical, Life and Health Sciences, additive manufacturing (and many others) is paramount. Not least when we consider that, increasingly the value-add (exciting growth opportunities) will be found at the interface of disciplines/traditional sectors and sub sectors. The potential application of the NIPA model to Materials Handling, Construction Products and Agri-Engineering sub sectors is therefore worth detailed consideration or re-consideration, as appropriate.

The application of the NISP Connect (now Catalyst Inc.) model to the broad AMME sector is also an area worth considering. This might include, amongst other things, the roll-out of start-up, mentoring and/or springboard support specifically targeted at AMME businesses. The coordination of elements of Catalyst Inc. and NIACE is also an area worthy of further exploration, for example options to develop and provide, along with government funding, a focused package of AMME support.

The development and inclusion of the AMME sector as a metric within the Knowledge Economy Index would also be a welcome step. Consideration therein should be given to the need to review and identify more comprehensive and/or appropriate metrics than are currently available for the AMME sector, taking into account the work of the DBIS Manufacturing Metrics Expert Group.[51]

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[48] www.adsgroup.org.uk
[49] http://www.polymersni.com/
[50] http://www.bpf.co.uk/
[51] Measuring Manufacturing: Manufacturing Metrics Review Report, A Paper by the Manufacturing Metrics Expert Group, Feb 2016.

In addition, the need to explore generic themes of growing importance to the broad AMME sector is important. Specific interest groups/clusters/networks help generate a sense of common purpose and undeniably provide support and encouragement to SMEs in particular. Themes such as the rapidly evolving interface between AMME and ICT, digitisation and the use of digital infrastructures to capture value in AMME through design and development. There are recent examples of work already underway including SIB/Queen's data analysis workshops for the Materials Handling sector. This is an area which should be supported and encouraged not only in terms of understanding the value of own-company data but also of optimising supply chain integration via data analytics. There are many examples, too of initiatives in other regions focussing on AMME sectoral growth which may be relevant in NI. With similarities in terms of history, size, relationship to national funding and policy making, the Liverpool City Region "Making It" campaign is one which could be explored with a view to application in NI. In their 2014 report "making it" – Advanced Manufacturing in Liverpool City Region to 2020 the Liverpool City Region Local Enterprise Partnership sets out its vision for the region focussing on global growth opportunities[52]. Similarly, the Scottish "Materialising a Brighter Future"[53] template bears relevance to the NI AMME sector. Both examples are considered further in the snapshot at pages 115-117, alongside an insight to New England, USA where the region sets out its 2015 blueprint for a manufacturing revolution, akin to that in other US regions in recent years.[54]

In terms of mapping exercises, addressing the question of access to AMME infrastructure and support via a 'needs map' highlighting everything which is already available and identifying any gaps in provision would be a useful first step. The use of existing mechanisms with minimal bureaucracy is important. A stock take of relevant value chain opportunities would also provide direction in terms of future focus, with consultees suggesting this might include a review of RoI clusters in supply chain areas (for instance, the tooling cluster in Sligo).

A more in-depth review of best practice elsewhere, to include national and regional AMME sector strategies and benchmarking against comparator and exemplar AMME economies is also worth further consideration.

RECOMMENDATIONS

With regards scaling, the need to examine how some of the 'affinity groups' of AMME business could move into a form where their combined activity would move them to the next level is recommended. With the appropriate policy in place, Invest NI would be well-placed to work with companies to facilitate that movement.

A potential pilot around the application of ADS initiatives to NIPA members would be an ideal starting point.

Explore potential to develop a tailored AMME package of support (e.g. akin to Liverpool LEP advanced manufacturing initiative). Sector- specific and across the full spectrum of R&D&I to include e.g. skills, trade, etc. and to incentivise AMME collaboration.

[52] "Making it, Advanced Manufacturing in Liverpool City Region to 2020", Liverpool City Region LEP, 2014
[53] "Materialising a Brighter Future – Opportunities in Advanced Materials", Scottish Enterprise Technology and Advanced Engineering Group, 2012
[54] "Advanced to Advantageous: the Case for New England's Manufacturing Revolution", The New England Council and Deloitte Consulting LLP, 2015.

Tried and Tested Models/Elements

SC 21

A change programme designed to accelerate the competitiveness of the aerospace and defence industry by raising the performance of its supply chains.[55]

The programme is a collaborative effort with A|D|S leading the programme at a national level, working with signatory companies, primes, regional trade associations (RTAs), strategic partners and accredited training providers. A number of active work streams; groups of industry representatives also support the development of special areas of interest.

> "SC21 is driving real improvement in Bombardier's supply base. Suppliers who are genuinely active on the programme have demonstrated a 'delivery on time' performance which represents a 50% improvement over those companies that are not engaged in the programme. These are the suppliers with whom we would prefer to work and who are positioning themselves to develop their capabilities alongside us."
>
> **Stephen Cowan, General Manager, Supply Chain and Hawlmark Fabrication Facility, Bombardier Aerospace, Belfast.**

Sharing in Growth

The joint industry/regional growth fund initiative "Sharing in Growth" –an ambitious £250m transformation programme set up in 2013 to raise the capability of 64 UK aerospace suppliers in order to share in the growth of aerospace and other global markets. The scheme provides concentrated training and development programmes over a four-year period, tailored to the assessed needs of each supplier and targeted at world class standards of performance. The training and development covers all relevant disciplines, including lean operations, manufacturing processes, purchasing, cost modelling and leadership. [56]

Tried & Tested model / elements of model + tailored/customised to meet specific AMME needs of AMME sectors = enormous potential

These programmes would bear study to see whether they could be tweaked to form the basis of a tailored programme of support for broader AMME sector in NI. Either of which could be customised in conjunction with NIPA to suit the specific needs of its members. Invest NI funding to support companies through the programmes would offer a practical way to support SMEs, with minimal bureaucracy.

[55] Supply Chain 21
[56] Sharing in Growth Initiative

Regional Case Studies

Liverpool: LCR 4.0 – the Vision for Liverpool City Region:

> "A global manufacturing hotspot with the smartest networks, talent, technology and investment."

LCR 4.0 is a Liverpool City Region Strategy for Industrie 4.0 - an ERDF funded programme to 2019 delivered in partnership with the University of Liverpool, Liverpool John Moore's University, the Virtual Engineering Centre, the Hartree Centre which is STFC Daresbury and also the Sensor City Joint Venture. Based on existing competencies as identified in the 2013 Making It Report, several years ago and essentially tying those existing assets or competencies and strengths together to drive forward a step change in productivity, LCR 4.0 identified that one of the key ways to support manufacturers is to make it easier for them to collaborate with research institutions and innovate and become more resilient, more productive, employ more people and export more products.

LCR has modernised its manufacturing base and has developed an industry that is now vibrant and which can be globally competitive. It provides a platform for jobs and productivity growth for the UK economy as well as the local and regional economy, based on Short Term Opportunities that drive competency development and create competitiveness and Globally Competitive Competencies (building blocks for the future, 10yr development cycle). Recognising the potential of Advanced Manufacturing to create a high value return to the local, regional and national economy, the potential to create both jobs and economic growth, "Making It" has focused on bringing LCR's manufacturing community together to determine how to meet challenges and future opportunities. The Making It process has been led by the Liverpool City Region Local Enterprise Partnership with support from the Institute for Manufacturing, University of Cambridge (IFM ECS), BIS, Technology Strategy Board (TSB) and supporting LCR based companies. It mirrors work undertaken by the TSB in the production of its national strategy for Advanced Manufacturing.

> "Each of these competencies is relevant across the manufacturing sector and feeds into different elements of industry across the region. This provides a diverse base for growth. Resources will shape the products we make and the processes we develop and evolve. If we understand what is coming, we can plan and invest to make the most of the opportunity and to overcome the challenges."

LCR has worked with a number of partners within Advanced Manufacturing to outline areas where growth can be accelerated. With a shared ambition to stay ahead of the game short-term opportunities to be exploited have been identified and endorsed by the industry. Longer term competencies which will support LCR's ambition to be globally competitive will be progressed. Scheduled to be up and running from September 2016, a business will come to the LEP through its partners, whether that's Invest Liverpool, St Helen's Council, Wirral Chamber of Commerce, anyone in the city region who's a growth hub partner, and after an initial diagnostic they will be signposted to the most suitable type of business support. The hope being that for many manufacturers that will be LCR 4.0 – the region's flagship manufacturing growth hub project. The outcome? Companies that have got their own innovative products that they can use to grow their business and carry on. The LEP will have a better understanding of those businesses, their needs and what their growth patterns might look like in the future, what their barriers to economic growth might be.

Snapshot

Scotland: Materialising a Brighter Future

Scotland: *Materialising a Brighter Future* sets out a template for industry growth which considers academic strengths; company strengths; market drivers; opportunities; technology.[57] Essentially based on an enhanced asset review service, to include equipment asset/audit, the initiative is a comprehensive stock-take of the region's assets. In terms of applicability to the NI AMME sector - a mapping exercise which reviews infrastructure available across NI and within UK would provide a useful basis from which to promote sharing/open access across NI AMME. That review might also include the infrastructure available at UK level provided by Innovate UK and the HVM Catapult Centres, to include access to equipment, skills pool.

> "We are committed to supporting manufacturing businesses to grow and to invest in product, process and service innovation and will establish a new joint Manufacturing Centre of Excellence and Skills Academy."
>
> **John Swinney, MSP. Deputy First Minister**

A Manufacturing Future for Scotland also sets out the development and delivery of an extensive Smart Manufacturing Excellence Programme to realise the region's "increased ambition and desire to be world-class, competing on quality and efficiency rather than cost." Supply Chain Capability has also been identified as a key competitive differentiator. We want to support more Scottish businesses to achieve supply chain excellence and enhance how they manage and optimise their supply chains. We need to strengthen the supply chain capability of manufacturing SMEs to adopt new materials and processes that improve their ability to compete in global value chains. There are significant opportunities to increase Scottish content in both domestic and international supply chains including through re-shoring. It is perceived that large businesses are looking to improve their supply chain resilience and reduce cost by engaging with local and competitive suppliers.

At operational level, Scotland's Supply Chain Capability 2016 Workstream includes:

- Complete a review of sector and cross-sector supply chain capabilities and develop strategies to close critical gaps including FDI
- Launch two re-shoring pilot projects from sectors including Life Science, Chemicals, Oil and Gas, and Aerospace, Defence and Marine
- Review outcomes from re-shoring pilot projects and use to develop a re-shoring programme across all the main sectors of the economy
- As part of the new Trade and Investment Strategy, develop an international marketing and communications programme to promote Scottish manufacturing and associated innovation capabilities, to include using the new Innovation and Investment Hubs in Brussels, London and Dublin to increase profile and support collaboration.

[57] Scottish Enterprise Insight, Materialising a Brighter Future, April 2012

Snapshot

New England, USA

Advanced to Advantageous: The Case for New England's Manufacturing Revolution (The New England Council and Deloitte Consulting LLP, April 2015).

> "Advance, Advantaged, Added-Value and Accelerating – New England's 4 As of Advanced manufacturing."

Five categories of challenge + six areas of opportunity, that, if fully shared and applied across the region, could differentiate and serve as accelerators for advanced manufacturing growth = New England's Manufacturing Revolution. Despite the strength of the advanced manufacturing network in New England, the cluster identifies 5 categories of challenge:

- Region's comparatively high cost of doing business
- New England faces a shortage of qualified labour to sustain growth
- Advanced manufacturing in particular suffers from a lack of brand awareness that keeps talent at arm's length from meaningful employment opportunities
- SMEs struggle against market failures to scale effectively, innovate and adopt emerging technologies at the rate demanded by their larger colleagues throughout the supply chain
- Complex and ever-changing business regulatory environment diverts resources from their highest and best use (growth) towards compliance activities.

A cross-regional initiative has fashioned "responsive and innovative programmes, 'islands of excellence' that can be scaled". Six specific areas of opportunity are identified:

1. Creating comprehensive educational pathways: A fully connected system for students beginning in high school through a variety of HE institutions, technical education, vocational education, training and even internships and work experience. Credit is fully integrated and connected through all levels on the pathway.
2. Increasing industry partnerships and apprenticeships: Creating connections implemented and strongly reinforced between industry and educational institutions so that students are not only workforce ready, but new ideas from students permeate the industry, spurring innovation. Reinforce career progression and employee retention through paid internships and apprentice models which earn pay and college credit, leveraging funds available from state and federal grants.
3. Re-branding the industry – "Make It" a better brand: Moving away from the old view of manufacturing by changing the language we use for it – by calling it the "Maker Revolution" we change the brand of advanced manufacturing to reflect the high pay, critical thinking, advanced technologies and designs that define it. Support intake of interested students by helping them enrol in the programmes that will support their success in advanced manufacturing.
4. Secure a National Network for Manufacturing Innovation (NNMI) Institute.
5. Support to scale for SMEs.
6. Alignment of policy to the needs of industry.

> "A coordinated effort across a broad range of stakeholders – industry, government, educational institutions, and others – is necessary to take full advantage of the opportunity to grow".

Snapshot

Maker Space Platform - Inventions and ideas

The US manufacturing resurgence is worth a closer look in the context of policy intervention in the 4-5 year prior to 2016.

Similar to the UK, European and many other world economies the US faced challenges in terms of the perception of advanced manufacturing, citing AMME careers as being viewed as unattractive and unstable, which discourages some talented students from seriously exploring careers in them.

Efforts that aim to transform that perception and promote the opportunities and excitement of 21st century manufacturing have increasingly converged around what is known as the "Maker Movement".

The US government, in collaboration with the private sector, not for profits, foundations and skilled volunteers encourages support of the rapidly growing grassroots movement of "Makers".

Pointing to outcomes which include:

- Increased patent applications
- Increased initial product runs
- Increased levels of high risk R&D

The US Advanced Manufacturing National Programme Office provides an administrative mechanism to coordinate and manage cross-cutting manufacturing investments which are used to strengthen the industrial commons.

"Makers" engage in 'do it yourself' projects involving electronics, 3-D printing and robotics and the movement supports projects which inspire young people to excel in STEM and can also get them interested in advanced manufacturing.

"STEM coursework sufficient to succeed in today's advanced manufacturing environment"[58] is a major element of the US national strategic plan for Advanced Manufacturing with the need to supplement traditional academic education with the development of applied expertise front and centre.

A Northern Ireland Maker Movement, using creative professionals as the bridge to AMME is a potential initiative worth further exploration.

[58] "A National Strategic Plan for Advanced Manufacturing, Executive Office of the President National Science and Technology Council, February 2012".

Shared ambition…image…leadership…

Ambition

With many countries/regions setting out 20-35 year plans (UK-China) - where is NI's vision, even 10 years ahead?

Put another way, "what moves NI 12 years ahead of the 10 year plans?" Consistent throughout the study, across AMME business and education sectors was the very clear ask for an NI AMME vision to stimulate transformative and lasting impact over the next 20 years. The same capabilities and attitudes which the sector's rich engineering heritage was built on are evident today. The application of that heritage to AMME of the future is crucial. For many, a celebration and re-establishment of the NI Engineering brand is a must-do first step.

> "A project Kelvin for AMME is what is needed."
>
> **Maeve Gallagher, RLC (UK)**

In the way that Project Kelvin transformed NI business (particularly in the ICT sector) the same level of vision applied to AMME could have an equally transformative effect on that sector. A vision of how the sector could look in 10 years which, once articulated, would inform a blueprint from which every element of support to AMME would be driven, be that coordinated training schemes, open and shared technical capability, collaborative AMME recruitment exercises or combined marketing activity, and so forth.

Essentially AMME leaders desire a strong signal of government intent which they can identify with and which can represent the collective, impressive strength of NI's AMME and mobilise the broad sector around a shared ambition.

Image and brand - "The NI AMME distinction"

THE AMME sector has much to shout about. Not least its three distinct calling cards:-

People Win Business	World leading quality and reputation of its engineers and designers
Strength in Adaptability	Ability to diversify and respond to the changing demands of manufacturing of the future.
Customisation	There exists already a high degree of specialism and customization with NI's AMME sector, which when combined with 1+2 means NI AMME is ideally placed to take advantage of niche global requirements.

The potential value of a NI AMME image/brand which has wide-reaching influence across all stakeholders-whether through STEM take-up (children, students, teachers, parents) or Sector Development (customers, government) was a recurring theme throughout many aspects of the consultation. Both industry and academia place enormous weight on the impact of an overarching, globally-recognisable brand. For educators, the thrust of that quality brand identity would be to instil passion and ambition in students. STEM recruiters often cite the perception of engineering as having comparatively lower salaries as a constraining factor, along with a perceived lack of respect for the profession. Improved image to influence public perception would help redress this. Again, NIPA provides an example of foundations which are already beginning to bear fruit through the successful re-branding of the plastics industry in NI in recent years – it can be done.

Leadership

AMME businesses also seek help to make sense of UK / wider opportunities and represent NI's AMME strength at national forums in a coordinated, strategic and mandated fashion. This would also enable, in some cases, NI AMME influence being brought to bear at earlier stages of UK funding decision making processes. Assembly Members and policy developers should spend time with engineering companies to truly understand the issues. The Assembly Business Trust could play a part in this.

Overarching AMME leadership is therefore imperative on three fronts:

A. To articulate NI's considerable AMME strength and breadth around a clear and ambitious vision. An AMME subset of Matrix might provide a forum for all parties to come together (business/university/government), to embrace the ambition and vision for the sector and build leadership capability.
B. Once articulated, that brand should be communicated clearly and consistently across the broadest sphere of influence, i.e. from primary school age 4 right through to legislators and funders – internal and external alike.
C. To help NI AMME's précis /make sense of wider funding opportunities and represent NI's interests. Regular summaries of publications in commonly understood terms would help.

RECOMMENDATIONS

The NI engineering brand should be developed and promoted and used by all relevant parties to promote NI as a location of choice to do AMME.

To address issues relating to accessibility, a "See Inside Manufacturing" /"Manufacturing Day" initiative should be developed to help influence skills choices – "heads and hands".

Develop a programme of education for the legislators. Prioritise the identification of a cross-party Executive 'Advocate for Engineering' – (e.g. the UK All-Party Executive Manufacturing Group model). Matrix can lead.

Matrix 'loop and closure'. Need to set out the mechanism by which to bring AMME findings into the advice framework (evaluation of the model) and carry through the development of recommendations through a sub-group which would co-opt representatives from respective communities. Likewise, a conduit to UK government policy and funding should be formalised for NI AMME businesses – a continuing process which will provide feedback and input to subsequent reports. Matrix can work in conjunction with DfE to provide leadership.

Concluding thoughts

In the absence of a clear lead for the AMME sector the risk of fragmentation of resource, dilution of impact and lost opportunity, both within AMME and cross-sectorally, is very real.

The statistics in the introductory section tell their own success story. For NI AMME, the re-invention has begun. Now, to realise the opportunity that companies can clearly see, further growth potential could be supported with a fresh approach to overarching vision and partnership.

NI's AMME sector has already demonstrated not only a willingness to diversify, but the drive to do so, successfully, through extremely challenging trade conditions. Irrespective of product/size of business /market sector, the ability to differentiate on the basis of quality and to deliver a customised solution, built on customer relationship and understanding is unquestionable.

In terms of growing from research employees – to development, production and exports; increases in activity may take a number of years to feed through to economic outcomes. "It will be important to continue to invest in these activities, both to ensure projects underway come to fruition, but also that new and innovative products and processes take root in NI".[59]

What has changed in 2008-15 period?

"Many companies have restructured their operations away from competing primarily on price and towards a greater emphasis on product quality, knowledge, customer collaboration, brand and service… Generally, "the UK manufacturing sector is a leaner version of the one in the 1980s and 1990s, but it is more flexible and better placed to adapt to a rapidly changing world". [60]

> "In its most mature stage of development, a region could be at the highest risk of closing itself off to new growth opportunities"

Diversity within sectors provides the ability to withstand the impact of any one particular customer. Increasingly, too, the exciting opportunities that are emerging are at the interface of sectors/sub-sectors. "Through diversification, lower-tier companies can serve multiple markets (and indeed many may not associate themselves with any particular one) and innovation in any of the markets could spillover into others". New ways of looking at AMME in terms of future manufacturing should be encouraged.

"When manufacturing grows, the whole economy grows with it."[61]

Manufacturing NI's recent report focussing on manufacturing costs in NI concluded, "Businesses are investing and growing and the policy environment is proving conducive" "If supported, manufacturing is well placed to capture the benefits of global growth."

AMME is leading the way – highly innovative, investing in R&D and exporting to global markets. Continued and considered government support to build on the rich and varied sector which Matrix identifies in this report will not only cement the current position, but will provide a platform from which even greater success can be achieved, for the benefit of not only AMME companies, their supply chains and employees, but for NI economy and society as a whole.

Whatever the mechanism, the principles must be the same – a lean, just in time methodology with minimal paperwork. Funding that is too complex is of limited interest to businesses that are too busy.

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[59] NI Knowledge Economy Index,
[60] Backing Britain: A Manufacturing Base for the Future, 2014
[61] NI's Manufacturing the Engine of Prosperity, Manufacturing NI, March 2016

EPSRC ambition:

"Establish a new place for industry that is built upon a 'make it local, make it bespoke'. To grow the UK economy, reduce import dependencies and enrich local communities by supporting research that enables a decentralised approach to materials supply and methods of fabrication, with the final product manufactured close to the point of use."

Summary of Recommendations

RECOMMENDATION	OWNER	TIMELINE
School children need practical, hands-on experience to be able to visualise AMME and its potential value in a way which they can relate to. An important first step would be the teaching of STEM through objects vs only through paper (i.e. practical vs theoretical learning).		
The role of colleges in the school/FE/HE education continuum providing vocational training for youth and continuing education for employees needs to be considered.		
Matrix should ensure that, as the NI Economic Strategy is refocused within the context of the new Programme for Government 2016-21, that the Department for the Economy is supported and encouraged to continue to build on the current STEM agenda and (important) small gains recorded. This is an essential step to ensuring the delivery of economically relevant skills and qualifications for the AMME sector in the future.		
Public funding of university-business collaborative R&D - Leverage and Value for Money: the development of metrics that identify and measure commercial outcomes as well as those for the university are important, not least in the context of constrained public spending environment.		
Mechanisms which streamline industry-university engagement should be reviewed in light of becoming more flexible and dynamic – to the benefit of all parties, taking into account ease of access to collaborative R&D for SMEs in particular.		
Businesses should be encouraged to seek out collaborative opportunities, wherever they lie, based purely on expertise and to look beyond localised networking, where appropriate, to avail of that expertise (e.g. explore HVM Catapult links).		
Regional funding for collaborative research should be directed to best meet the needs and growth of AMME businesses, irrespective of location of research partner.		
Additional HMRC resource available to NI businesses via its NI Corporate Tax Office (NIrCTO): DfE should renew efforts to ensure all eligible businesses are aware of the totality of support available to them under the HMRC incentives and reliefs – taking full advantage of NIrCTO's expertise and guidance.		
The opportunity to scope a government-led 'whole of AMME R&D&I solution' in response to industry needs within the established Catapult framework should be examined further.		
With regards scaling, the need to examine how some of the 'affinity groups' of AMME business could move into a form where their combined activity would move them to the next level is recommended. With the appropriate policy in place, Invest NI would be well-placed to work with companies to facilitate that movement.		

RECOMMENDATION	OWNER	TIMELINE
A potential pilot around the application of ADS initiatives to NIPA members would be an ideal starting point.		
Explore potential to develop a tailored AMME package of support (e.g. akin to Liverpool LEP advanced manufacturing initiative). Sector- specific and across full spectrum of R&D&I to include e.g. skills, trade, etc. and to incentivise AMME collaboration.		
The NI engineering brand should be developed and promoted and used by all relevant parties to promote NI as a location of choice to do AMME.		
To address issues relating to accessibility, a "See Inside Manufacturing" /"Manufacturing Day" initiative should be developed to help influence skills choices – "heads and hands".		
Develop a programme of education for the legislators. Prioritise the identification of a cross-party Executive 'Advocate for Engineering' – (e.g. the UK All-Party Executive Manufacturing Group model). Matrix can lead.		
Matrix 'loop and closure'. Need to set out the mechanism by which to bring AMME findings into the advice framework (evaluation of the model) and carry through the development of recommendations through a sub-group which would co-opt representatives from respective communities. Likewise, a conduit to UK government policy and funding should be formalised for NI AMME businesses – a continuing process which will provide feedback and input into subsequent reports. Matrix can work in conjunction with DfE to provide leadership.		
The 'clean and green' opportunity is an area which was initially identified in the first Matrix report and one which has been seen only to grow in the intervening period. NI's AMME companies should therefore be encouraged to explore and supported to engage further with the 'clean and green' opportunity, whether through education, the creation of shared value or the identification of partners.		

ANNEXES

Annex 1: Summary of future manufacturing business model trends

Future Business Model Trends	Drivers of Change	Potential Impacts (Some already being seen)
The circular economy (involves products being re-used, 'repurposed', repaired, re-manufactured) and collaborative consumption (products or services are shared, rather than individual ownership).	• Desire for greater financial predictability of costs/revenue for customer/manufacturer • Customers not wanting the financial & environmental burden of product ownership • Material scarcity, oil prices, and extreme weather events	• Incentives shifted: as manufacturers bear costs of maintenance and repair, they are more likely to design products to reduce those costs. • Business models based on temporary or shared/collaborative ownership, with shifts from a linear to a circular economy, i.e. where products are re-used, 're-purposed', repaired, re-manufactured and recycled, rather than being used and discarded. • Re-manufacturing, whereby high-value or high-use parts of (typically) capital equipment are returned, repaired and re-sold. Already seen in aerospace, commercial vehicles, passenger cars and medical equipment. • Re-manufacturing being used as a market entry mechanism in emerging markets, for example by Volvo in India, where re-manufactured engines are 65% of the price of new engines. • Re-manufacturing institutionalised through standards, with more products designed from the outset with remanufacturing in mind.

Future Business Model Trends	Drivers of Change	Potential Impacts (Some already being seen)
Personalisation of products (technological advances enable products and services to be designed with much greater customer specificity)	• Technology & ICT, including sensors making it possible to identify and characterise individual people, places, organisations and things. • Information enhanced or 'informated' products are likely	• New connections between products, individuals, institutions and information become possible. As this occurs, new sources of value are created, and new business models are likely. • Increased ability to connect a physical artifact to information, for example through measuring usage and linking to the identity of a user, makes it feasible to operate non ownership-based business models. • Information-enhanced products and the wider ecosystems in which they exist offer opportunities for additional value creation. It will be important to understand the rights of those who create information, to protect ownership, and to safeguard the privacy of those to whom information relates.☐ • Personalised medicine aimed at individuals or segments of the population become established as prognostic and diagnostic information on patients becomes available.
'Factoryless goods producers' also known as fabless or virtual manufacturers (design and sale of products, typically hardware devices, with outsourcing of production)	• Typical manufacturing business models capture value created in development and design by the sale of products. • 'Fabless manufacturing captures value by selling a 'kernel' of technological knowledge, leaving production to someone else.	• Represents a major opportunity for manufacturers whose capability in production is made less distinctive as manufacturers in emerging economies gain these capabilities.☐ • These manufacturers will have to shift their reliance on recouping expenditure on R&D through selling products, to selling the design and development in its own right. • This requires a major effort in designing the product, and doing so in concert with the business models of relevant partners in the value chain.

Future Business Model Trends	Drivers of Change	Potential Impacts (Some already being seen)
Value through environmental sustainability and provenance	• Environmental sustainability emerging as an important component of product value. • Growing customer awareness of the environmental and social impacts of manufacturing and increased environmental regulation.	• Environmental sustainability will become an increasingly important component of product differentiation and value-creation. • Empirical evidence shows that environmental sustainability can reduce costs, with sustainable management of supply chains resulting in improved financial performance of a firm. • Environmental sustainability is likely to come to be measured and managed in order to provide clear information for consumers. This will be part of the mechanism for capturing value from sustainability. • There are several challenges, with sustainability issues difficult to identify and quantify within design, production and distribution. The National Physical Laboratory (NPL) and the Environmental Materials Information Technology Consortium are developing tools to allow the calculation of a product's CO_2 footprint and energy usage.
Business models that take advantage of 'infinite bandwidth/zero latency'.	• Advances in IT are expected to have profound implications for manufacturing business models, given it is a core technology within many products, affecting how products or services can be made available.	• Given the advances already seen in the data-carrying capacity of the internet, emerging practices are probably poor indicators of longer-term implications of IT. • Current developments include cloud computing, and wireless networks make it possible for organisations to connect with products embedded with sensors and other technology. • 'Infinite bandwidth/zero latency' (IBZL) would potentially remove obstacles to working across firm boundaries and distances, making data-transfer-

Future Business Model Trends	Drivers of Change	Potential Impacts (Some already being seen)
		intensive processes requiring telepresence more feasible (e.g. remote surgery, whereby a surgeon is able to operate via a robot which is able to provide real-time sensory feedback.) • Telepresence will affect development and production processes of manufacturing, as well as create opportunities for new types of services.
Business models that take advantage of new general-purpose technologies (technologies affecting an entire economy, e.g. the internet).	• General-purpose technologies create new opportunities for value creation through new properties.	• GPTs provide a basis for value creation, but the business model achieves value creation and value capture. Value creation depends on the ability to use GPTs to generate 'novel applications'. This goes beyond finding products in which new technology can be inserted as a replacement. • The most valuable future economic activity in biotechnology and nanotechnology is likely to not be in the manufacture of input materials, but in the application of these technologies.
Increasing interaction between firms to gain access to indirect capabilities	• IT is making it easier for activities to be organised between firms. • Increased collaboration causing sectoral fragmentation.	• The ability of firms to coordinate activity through collaborative, inter-organisational connections is likely to continue to increase as IT makes it easier to access the capabilities and resources of others. • The ability of firms to collaborate and access others' capabilities will become critical. • 'Co-production' between firms is likely to occur as collaborative communities of firms emerge, which may become more significant than tight networks dominated by a few lead firms.

Annex 2: Factories of the Future

The changing face of factories of the future

Spatial changes:

Factory locations are likely to become increasingly diverse and nearer to the customer's home. Facilities will include smaller, centralised hubs and more urban locations as the factory increasingly becomes a 'good neighbour' in terms of its environmental impact. Factories are also likely to be more distributed and more mobile, resulting in developments such as manufacturing at the bedside and in the battlefield. For complex products, some manufacturing activities will migrate to larger, more capital intensive 'super factories' while others will become reconfigurable units co-located and integrated with associated supply chain partners.

Technological developments:

Advances in additive manufacturing and other technologies will allow factories on a micro scale to become much more common, to the point where some people undertake manufacturing at home. Factories will become more agile and able to respond quickly and flexibly to customer demands due to their flexible machinery, staff and infrastructure, enabling the 'reconfigurable factory'. Factors such as fast progression from manual to automated manufacturing through greater process control are expected to play a growing role in the factory of the future. Factories will become more open to customers, supporting closer manufacturer-customer relationships.

New process technologies:

When allied with data-rich, mechanised production processes, these technologies will shift the key competences away from traditional production engineering and operational management to information processing and digital control. The role of the computer in managing complex and adaptable manufacturing systems, to support decisions concerning what is made where, and to feedback data from use, will change operational decision making. The huge increase in data fed back from users, combined with the increased competence of computer simulations to accurately model production processes and value chains, will allow manufacturers to model factory designs and alternative strategies before initial commitment, during implementation, and subsequent evaluation.

'Information-production engineers':

Manufacturers will compete on their ability to create value through the smart use of ICT. Employees will be hired for knowledge-based roles related to production, instead of those based on manual work. Information-production-engineers will design factories, re-configure them as required, and remotely assess output quality. They will design products to be made by 'listening' to customers as well as guiding their use and repair in the field. Workers with technical capability and a breadth of other skills including commercial competence and problem solving abilities will be in demand.

Data and digital technologies:

Firms will need to embrace new digital technologies to make sense of the proliferation of data, which will be important in remaining up to date with customer demand. The best manufacturers will use data directly captured from customers to offer a superior service. Consumers recognise this today in the surprising 'intelligence' with which loyalty cards target special offers. Out to 2050, second-by-second data on usage will allow manufacturers to alter products while in use (for example through the sending of a signal to stop the use of a phone which requires repair, or altering the software in a bicycle to provide feedback on training techniques appropriate to the customer's riding style). Firms will also take advantage of flexible automation and robotics which adapt processes in response to feedback.

People and culture:

Factories of the future are likely to be centres of creativity and innovation, operating in networks of relationships, for example with suppliers and universities, where skilled people use world-class technologies and processes to create new ways of adding value, often working remotely. The 'command and control' approach to management used by professional and technical workers will become outdated.

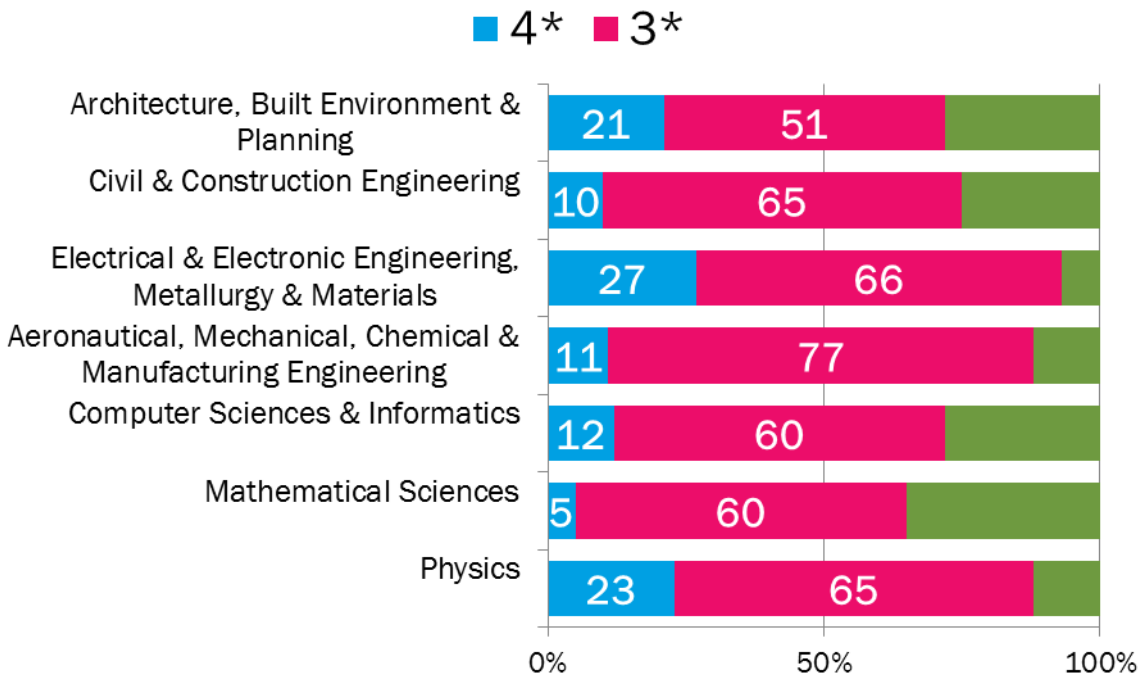
Annex 3: Key drivers relating to the onshoring of manufacturing activities

Firm	On-shored activity	Determining Factors		
Hornby plc	Returned 60% of model paint brand, Humbrol from China to UK in 2012.	To improve supply	Ensure high quality standards continue to be met	Proximity to HQ
Laxtons Ltd	Has returned design-driven yarn manufacturing back to Yorkshire	Improved lead times	Increasing control over quality and raw materials	Reduction of firm's carbon footprint
Bathrooms.com	July 2013 reallocated 50% of contracts currently held by Chinese manufacturers to UK firms in Midlands.	Decreased time from design through to production from four to six months to six weeks.		

Annex 4: AMME Research at Queen's

Queen's ranking amongst UK universities on a research intensity basis highlights the strength of research taking place at the University in areas relevant to the AMME sectors. Queen's was placed third, sixth and eighth in the UK in UoA 9, UoA 12 and UoA 13 respectively. The quality of the impact produced from Queen's research was also highlighted, with 100% of the research impact from UoA13 being considered world-leading or internationally excellent, against the UK average of 77.8%.

Figure 19: QUB REF scores

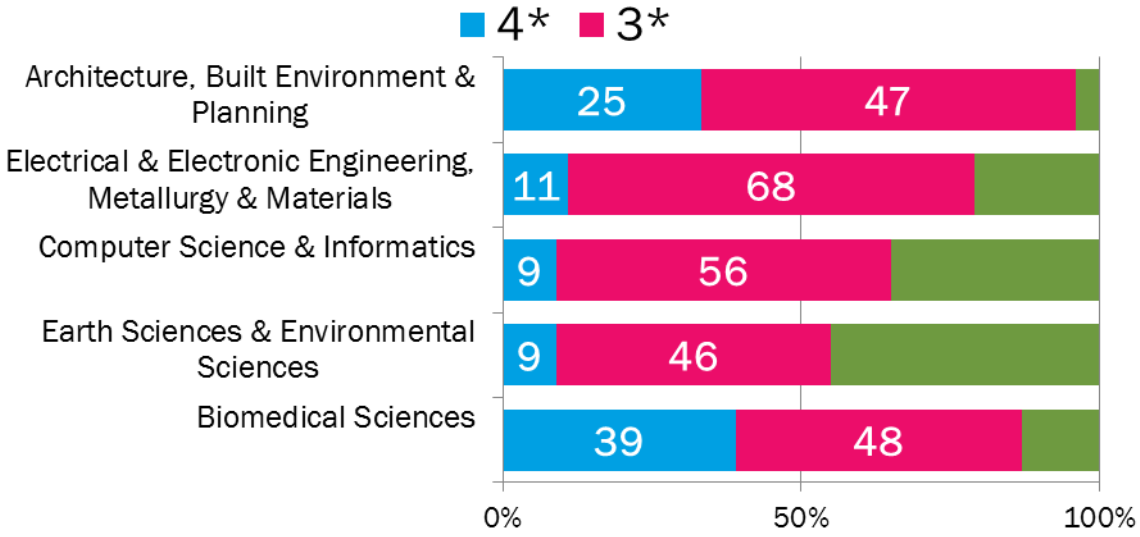


A review of funding awarded to Queen's for research in AMME related areas from August 2010 onwards reveals a total award value of £83.8 million. This research spans from work on novel materials for data storage to technology for large petrochemical refinery systems, and is funded from a variety of sources, including industrial partners, public funding bodies, and innovation agencies. Other ways in which Queen's supports local companies to gain knowledge and grow include: - the provision of consultancy services - signposting access to Innovation Vouchers and KTPs - helping in the licensing of intellectual property - partnering in research collaboration activities - offering a programme of events that provide a channel for knowledge exchange, including with leading national and international visiting speakers – and excellent networking opportunities - the provision of high end executive education and leadership training through the William J Clinton Leadership Institute. More recently (2014) Queen's launched a Leaders in Industry Programme aimed at talented individuals preparing for wider, more strategic positions within the Manufacturing sector.

Annex 5: AMME Research at Ulster

Ulster University's international reputation for research excellence has received world-wide recognition by the Research Excellence Framework 2014 (REF 2014).Engineering at Ulster is in the top 20 within the UK. 100% of UU research impact is world-leading or internationally-excellent and the university is placed in the top UK quartile across all research topics.

Figure 20: UU REF scores



Computing & Engineering Research at Ulster

Ulster's Computer Science Research institute (CSRI) conducts internationally excellent and world-leading research in intelligent systems, assistive technologies, next generation networks, and semantic analytics, across four highly active research groups and Centres:

- *Information & Communication Engineering (ICE)* focusing on knowledge engineering and data analytics, applications in healthcare modelling and computer vision, and increasingly, performance management of next generation networks, systems and services.
- *Artificial Intelligence & Applications (AIA)* focusing on pattern recognition, reasoning, and semantic analytics, with applications in text mining, intelligent document analysis, ambient assisted living, and security-based scenario recognition.
- *Smart Environments Research Group (SERG)* focusing on multi-disciplinary and collaborative research in sensor-based technologies, and applications in behavioural analysis, activity recognition, and assistive technologies for healthcare and independent living.
- *Intelligent Systems Research Centre (ISRC)* focussing on cognitive robotics, computational neuroscience, and biologically-inspired computation, with applications in robotic systems, neural modelling, and BCI.

Engineering Research Institute (ERI)

Over a number of years, the ERI has had a very high profile in research and impact associated with structural and advanced functional materials, relating to connected health, medical devices, tissue engineering, nano materials, plasmas, photocatalysis, coatings, sensors, composites and metal forming.

Variation in gender in terms of the regulated course subject area:

Across all subjects regulated enrolment shows a fairly even split in part-time provision, while in full-time provision, males (57.8%) are in majority in 2014/15 – across all subjects.

Yet, when STEM take-up is analysed, the position has remained stubbornly fixed:-

Further Education: In 2014/15 male dominated subject areas included "construction, planning and the built environment" (96.8%) and "Engineering and manufacturing technologies" (93.6%)

Higher Education: 50% of males (NI Domiciled qualifiers in UK HEIs) qualified in broad stem related compared to 43.4% females. Many fewer females however qualified in a narrow stem related subject, 14.5% (equivalent proportion of males = 33.4%). The proportions for qualifiers from NI institutions is broadly similar.

Table 2: "Dominated Course subject area" – by gender, 2014/15: NI Domiciled qualifiers in UK HEIs & (qualifiers from NI institutions):

NI domiciled qualifiers in UK HEIs and (qualifiers from NI institutions) 2014/15			
Females	%	**Males**	%
Subjects allied to medicine	83.6 (84.5)	Engineering & Technology	82.9 (80.1)
Education	71.9 (71.4)	Computer science	75.0 (76.2)
Languages	69.3 (71.3)	Architecture, building and planning	67.2 (66.4)

(Source: key points for (FE) Activity)

	Number of Engagements	Average Value of Engagements
SME Contract Research		
The Queen's University of Belfast	139	£15,986
Ulster University	57	£25,526
SME Consultancy		
The Queen's University of Belfast	3670	£1,017
Ulster University	3019	£1,635

	Mainstream QR funding	QR quality pot	QR funds for the supervision of PGR students (RDP)	Support element for charities research income	Research funding including charities
Queen's University Belfast	19,256,345	2,970,500	5,641,081	3,077,632	30,945,558
Ulster University	9,563,780	1,485,250	2,141,906	308,677	13,499,613
Stranmillis University College	57,383	0	0	0	57,383
Total	**28,877,507**	**4,455,750**	**7,782,987**	**3,386,309**	**44,502,553**

Annex 6: Queen's Industrial Research Centres

"We work collaboratively with companies of all sizes, locally and globally, helping them to access the knowledge, ideas and solutions that will allow them to thrive and reach their economic potential. In the last year alone, we worked with over 5,000 companies to deliver innovative solutions for industry."

Industrial Research Centres

- ANSIN, the advanced material research and development hub - ANSIN brings together the specialist skill-set and knowledge of Seagate Technology (Ireland) and Queen's to help advance materials, coatings, sensors and photonics for application across sectors.
- The Northern Ireland Technology Centre (NITC) –a technology and innovation centre specialising in design, knowledge engineering and manufacturing; bridging the gap between academic research and commercial production to meet industries needs and offer advanced solutions for customers in various sectors, such as aerospace, industrial equipment, energy, consumer products, manufacturing and packaging.
- Polymer Processing Research Centre (PPRC) –cross-disciplinary with Mechanical Engineering, Chemical Engineering and Pharmacy, established 1996.
- Centre for Theory and Application of Catalysis (CenTACat)– cross disciplinary with Mechanical Engineering and Chemistry & Chemical Engineering, est. 2003.
- Queen's University Ionic Liquids Laboratory (QUILL) – Established in 1999 to promote the industrial exploitation of ionic liquid technology, includes Chemistry & Chemical Engineering and Physics. Ionic solvents developed QUILL have been voted the most important British innovation of the 21st century in 2013.
- Centre of Excellence for Integrated Aerospace Technologies (CEIAT)- est. 2003.

Queen's University Spin-outs

Notable spin-out include, Catagen Ltd, founded in 2011 to develop a range of advanced catalyst ageing systems that would enable the automotive industry to carry out the required catalyst ageing tests at significantly reduced costs. The company built on research carried out at Queen's. The Belfast-based company now has customers in Fiat and General Motors, and was presented with the Best High Growth Company Award at InterTradeIreland's 2012 all-island Seedcorn Business Competition.

Likewise, Andor High Performance Cameras, relying on Queen's research expertise, Andor were able to develop the ROSA and Super-WASP instruments, which have contributed estimated annual revenue of £1.7 million to the company.

Other examples include:

- Blow Moulding Technologies
- Mercury Capture Technology
- EPSRC Centre for Doctoral Training in Photonic Integration for Advanced Data Storage
- Caterpillar Integrated Control Systems

- The Pioneer Research Programme in Intelligent Autonomous Manufacturing Systems (*i*-AMS PRP)
- Queen's Engineering and Physical Sciences Faculty has established a Global Research Institute in Electronic Communication and Information Technologies (ECIT) which builds on the outstanding work in Cyber Security, Wireless Communications and Electronic Systems. To support the next generation of key technologies three Pioneer Research Programmes (PRPs) have also been established in Sustainable Energy, Intelligent Autonomous Manufacturing Systems (i-AMS) and Advanced Interdisciplinary Research in Radiation. Bringing together teams which have generated over £75m in research income in the last 10 years and generated 6 spin out companies, £17m is now being invested in additional staff and equipment to accelerate these integrated teams.

Annex 7: Ulster University's Industrial Research Centres

Collaboration with industry is an integral part of the work of the ERI, including collaborations with a wide number of companies including Bombardier, Caterpillar, AVX, Seagate, SiSAF and TFX Medical. In particular, the institute has focused on its three research centres:

- Nanotechnology and Integrated BioEngineering Centre (NIBEC) - a multi-disciplinary focus for R&D in the areas of Connected Health & Sensors; TERM, Nanostructured Surfaces, Photocatalysis, Clean Technology and Dense Plasma Technology.
- Engineering Composites Research Centre (ECRE) - The Engineering Composites Research Centre (ECRE) has a unique blend of expertise in textile technology, polymer processing and engineering for research into polymeric and composites materials for use in a diverse range of engineering applications, in particular aerospace applications.
- Advanced Metal Forming (AMFOR) is at the forefront of materials characterisation and modelling for the sheet metal forming industries.

Ulster University Spin-outs

Technology transfer is a key objective and the Institute is one of Northern Ireland's leaders in intellectual property exploitation, with over 6 successful spin-out companies.

Annex 8: NIACE

Northern Ireland Advanced Composites and Engineering (NIACE Centre) was established to support and promote research focus and collaboration between academia and industry. Jointly owned by the Ulster University and Queen's University Belfast the centre, located next to Bombardier, was launched in January 2012, as a technology hub for the research and development of advanced engineering and advanced materials technologies across a range of industrial sectors. The centre currently has 17 fee paying membersfrom eight industrial sectors (Aerospace, Automotive, Construction, Defence, Environmental, Marine, Renewables & Space). These companies, combined with trade association ADS and the two local universities, collaborate to generate and share new knowledge, develop innovative solutions for real industrial challenges supporting the growth of local business and the NI economy.

Since formed, NIACE has been instrumental in Queens University and Ulster University (working with Bombardier and others) winning a combined total of £8M research funds from outside NI. In addition their partnership directly with NIACE was an essential precursor to the £5m NIAECC industry led R&D programme. This represents a fast track way for the academic research to enable industrial innovation.

The NIACE vision for the future is one where local Advanced Engineering, Materials and Manufacturing sectors achieve their full potential thereby having a positive impact on the local economy, a vision which NIACE believes it can play a significant role in achieving.

NIACE recognises the need for continued focus on ensuring its funding model is sustainable and attractive to companies, particularly SMEs, who can face particularly challenging resource difficulties.

To support our planned growth and our sustainability, we plan to develop and expand the physical size and capabilities of the centre. This will be led by our Participants and University Research Partners to ensure we provide a centre that continues to be of relevance and benefit to all involved, further increasing the capabilities of Northern Irish industry as a result. We will also add new capabilities, competencies, skills and knowledge that will be not only supportive to our R&D activities, but also enable us to offer new services such as consultancy, contract research, testing and training. This additionality will allow us to showcase local capabilities to national and international customers requiring the specialist support NIACE has on offer.

NIACE regularly interacts with other research centres across the national and international landscape. Over the past four years, NIACE has developed close relationships with the High Value Manufacturing (HVM) Catapult and in particular with the National Composites Centre. We will continue to develop this relationship to enable us to bring the full benefits of the HVM Catapult to local industry. Future development of NIACE will aim to position it as a Centre of Excellence offering participants the ideal environment to generate innovative solutions, through knowledge sharing and networking, to develop and grow local business and economic growth.

Annex 9: Charts

Figure 21: Breakdown of AMME companies by size (NI 2015)

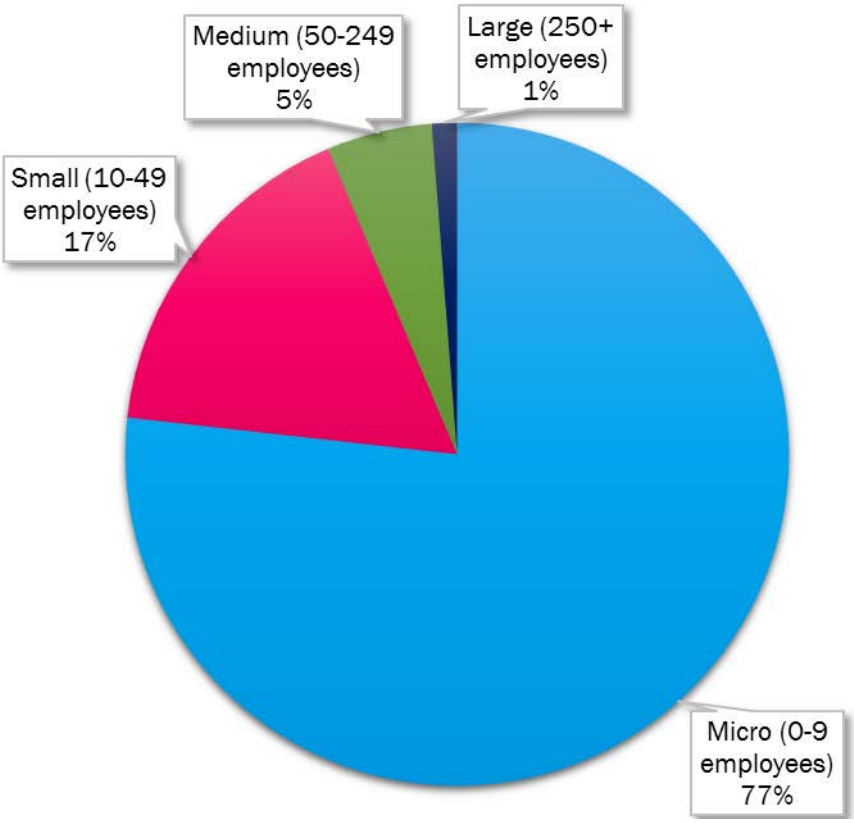


Figure 22: Proportion of NI manufacturing companies that are AMME by size (2015)

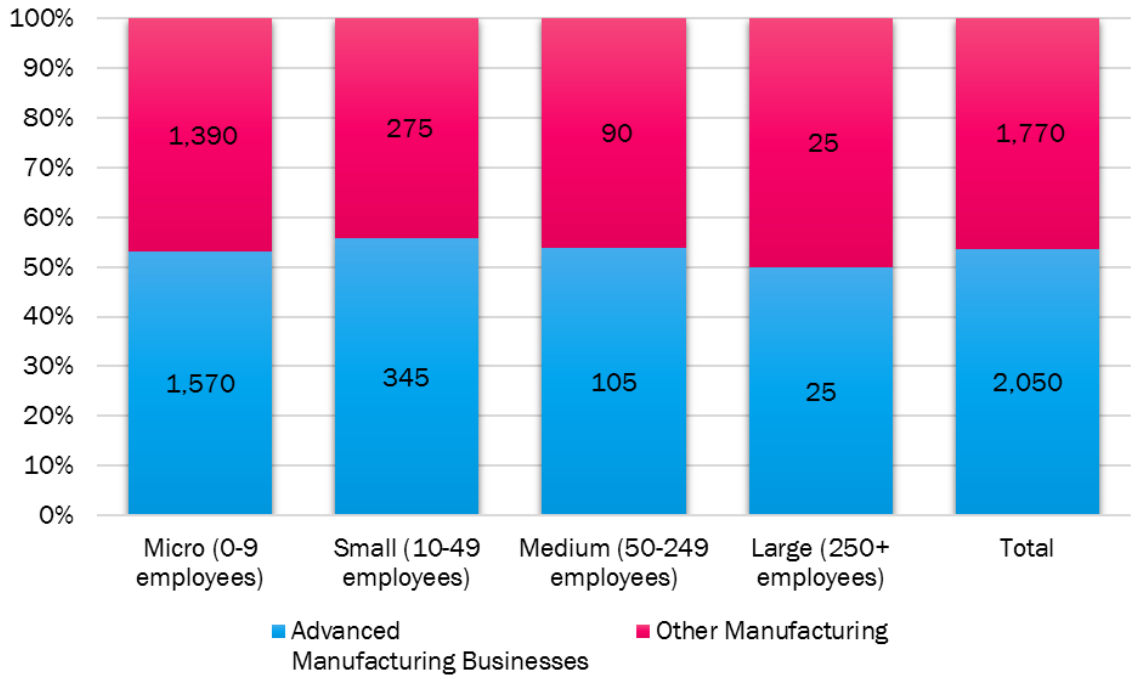


Figure 23: Number of VAT and/or PAYE registered businesses operating in NI by UKSIC (2007) industry, 20 March 2015

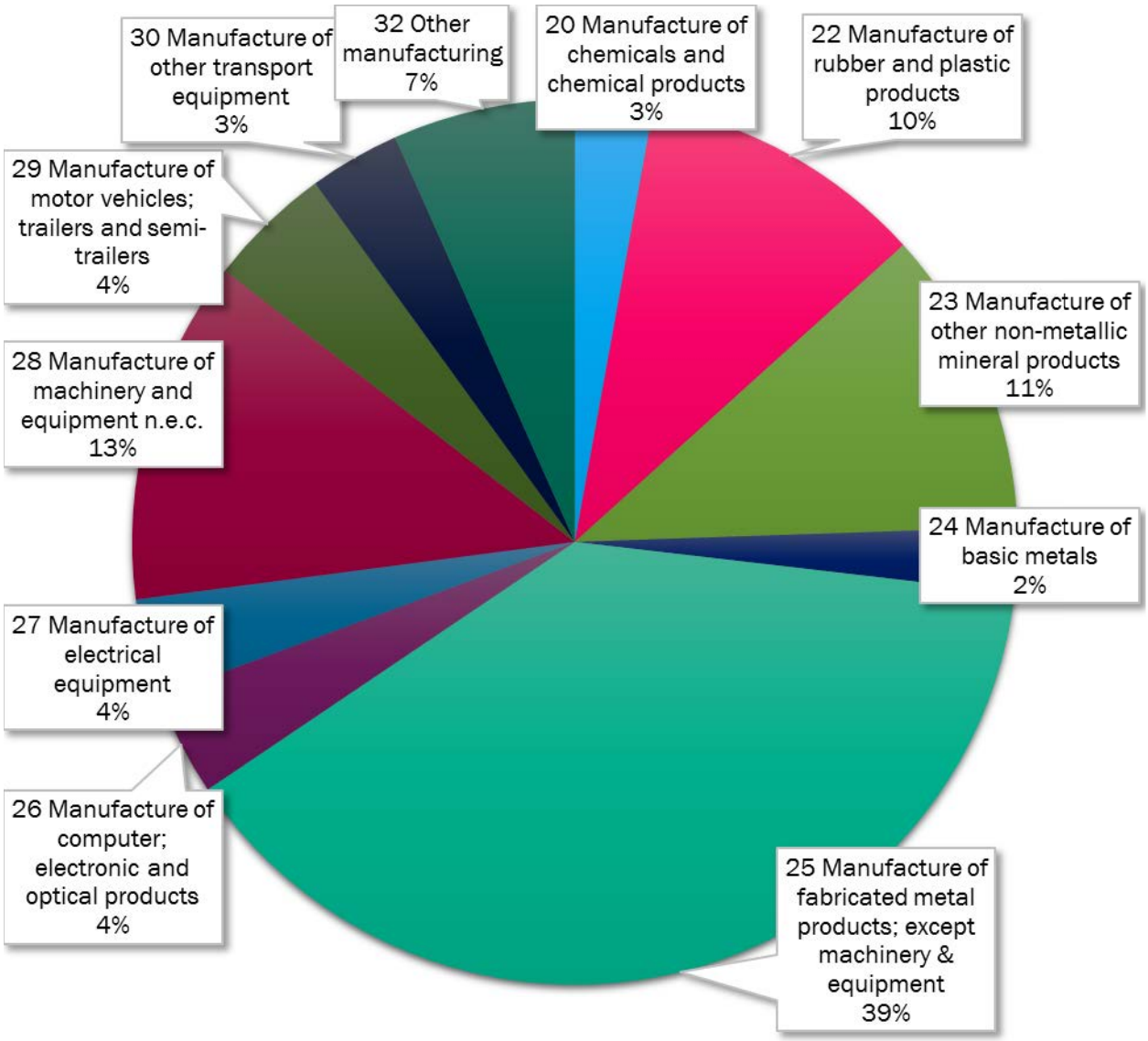
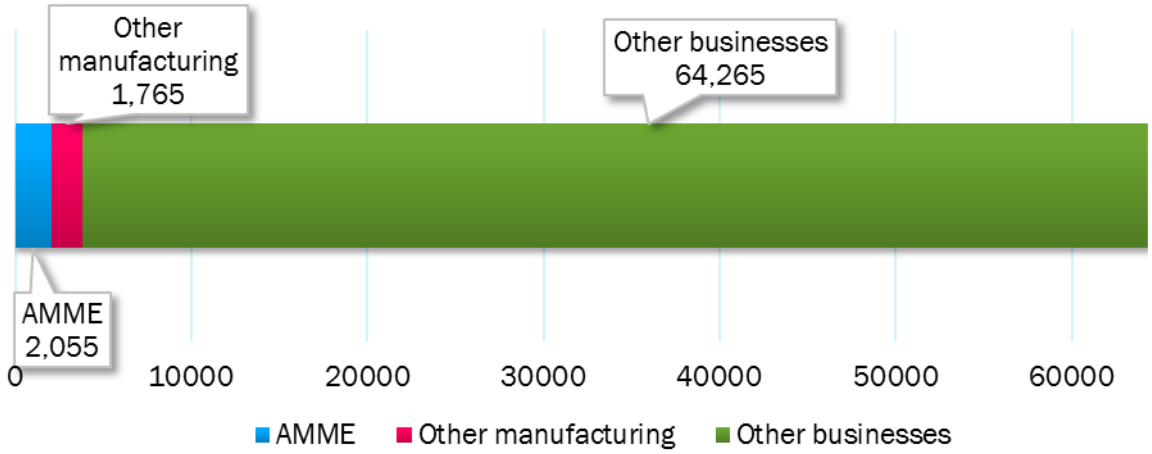
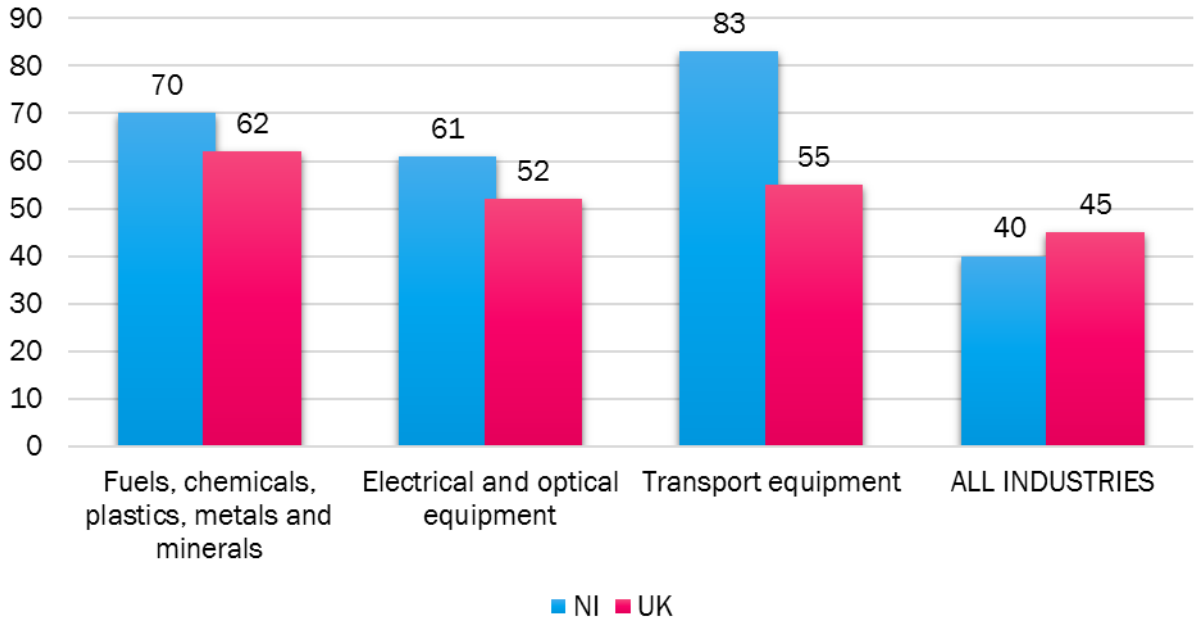


Figure 24: AMME as a proportion of other NI businesses



Innovation

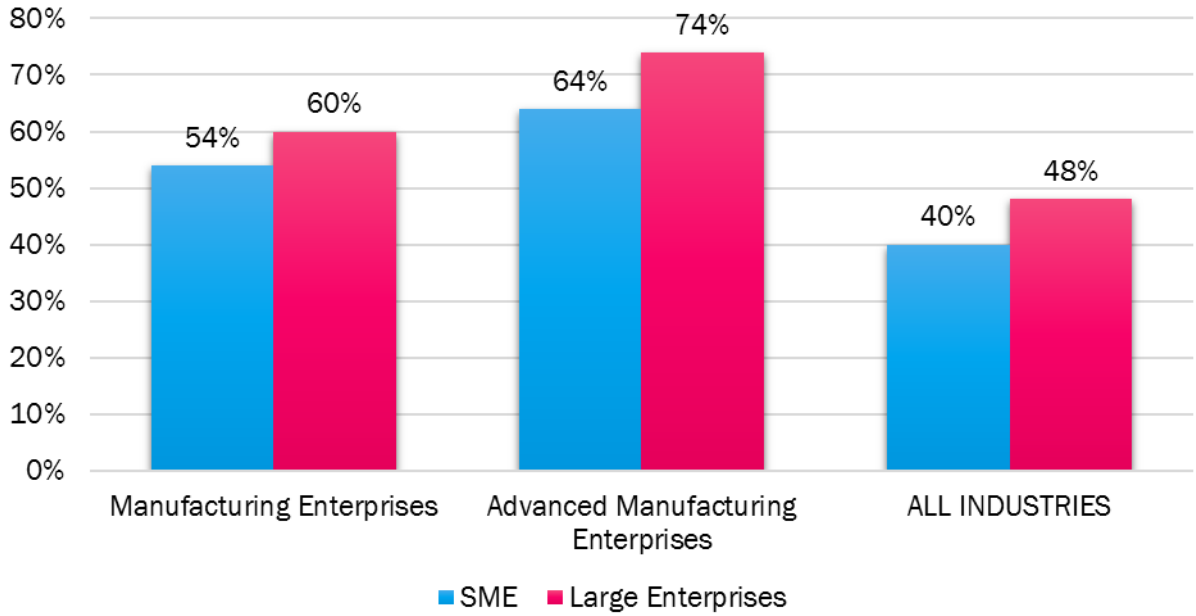
Figure 25: Percentage of companies considered innovative NI & UK 2010 - 2012



Accounts for majority of AMME sectors but also includes sic 19 (coke and refined petroleum products), sic 21 (manufacture of basic pharmaceutical products and pharmaceutical preparations) and sic 24 (manufacture of basic materials). It also does not take account of other manufacturing (sic 32)

The results would indicate that the AMME sector is relatively more innovative than the industry average, and even more so than the UK equivalent.

Figure 26: Innovation by industry - % of all enterprises (2010-12)



AMME sector well outperforms the NI industry average in terms of innovation activity.

Exports

Figure 27: NI AMME businesses - sales 2011-14 in £m

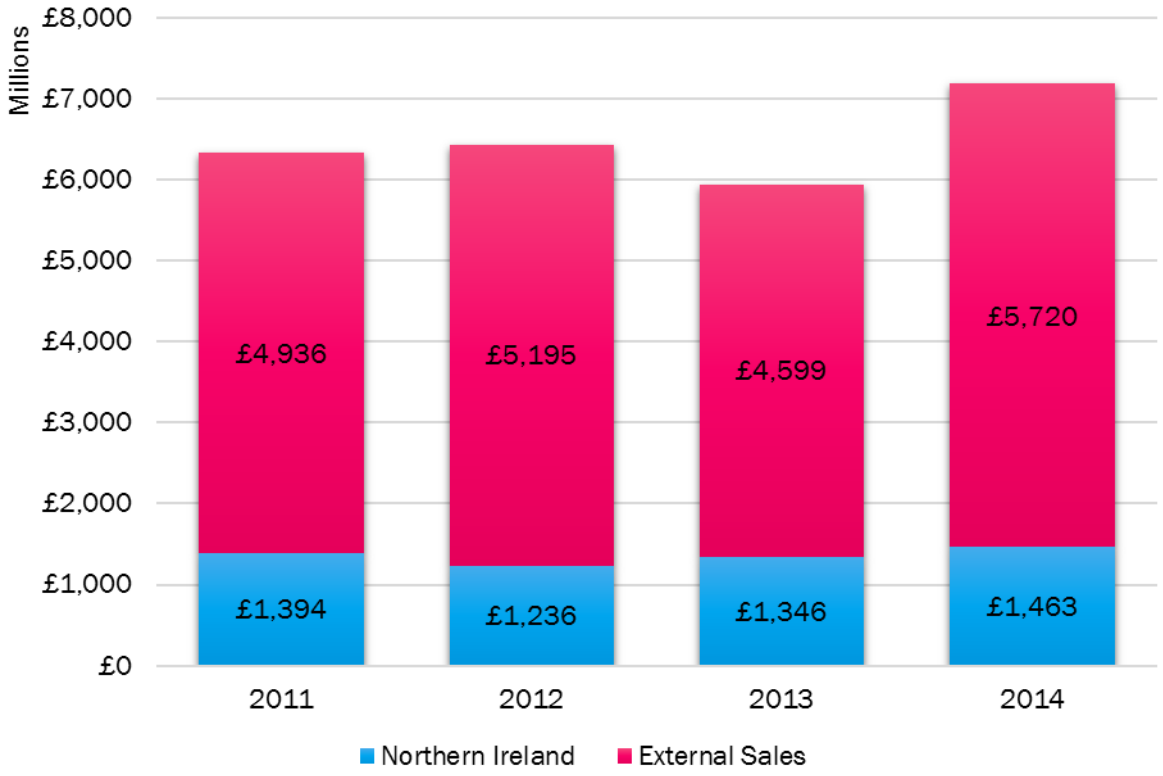


Figure 28: Growth in AMME exports outside EU as % of all manufacturing exports

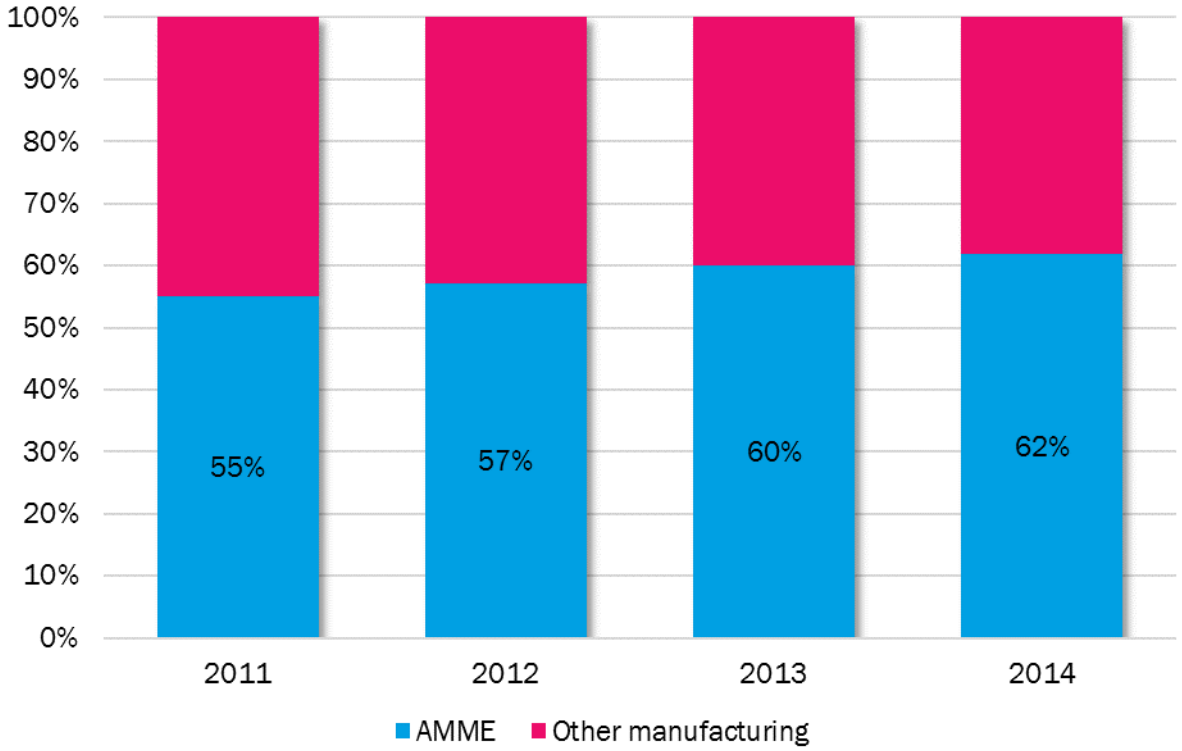


Figure 29: Proportion of AMME sales which are external compared to all manufacturing and all sales

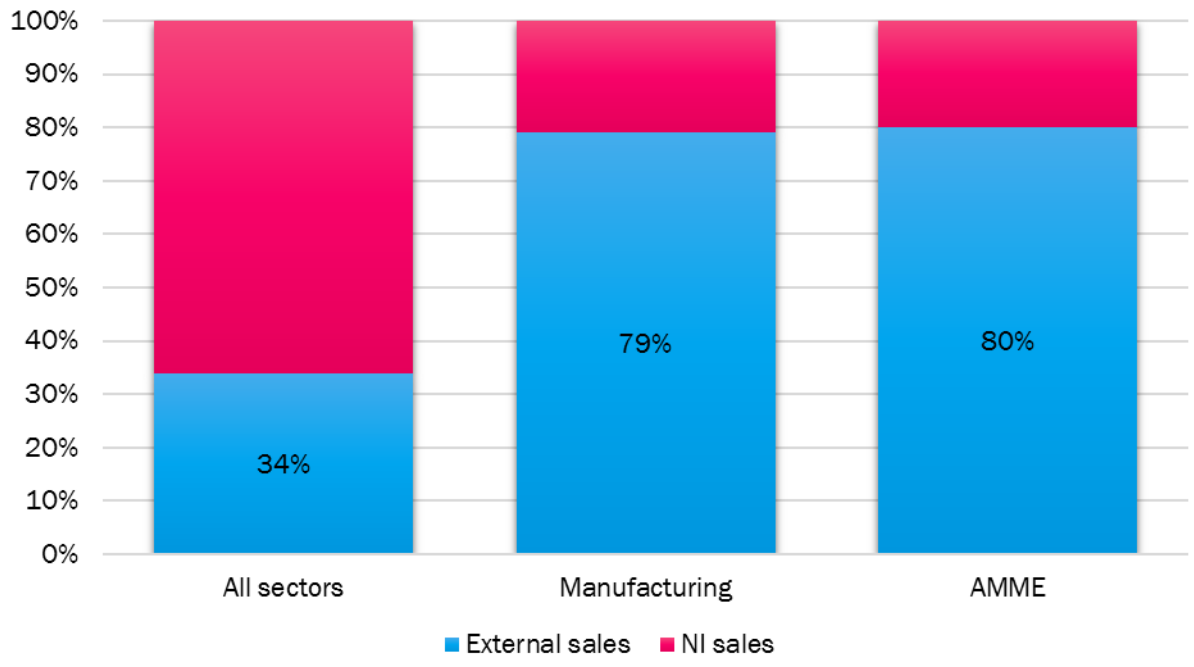


Figure 30: NI AMME sales as a proportion of all sales 2011-2014 (£m)

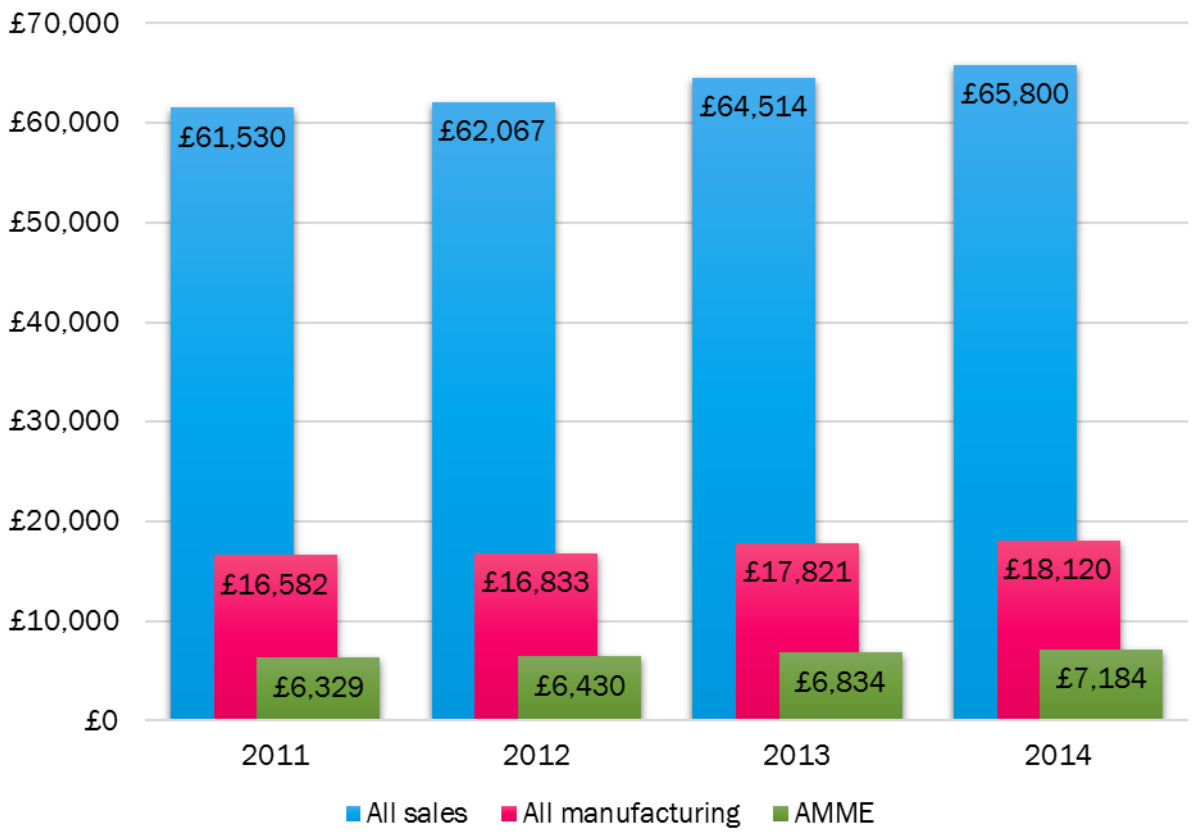


Figure 31: NI AMME external sales (outside NI) as a proportion of all external sales 2011-2014 (£m)

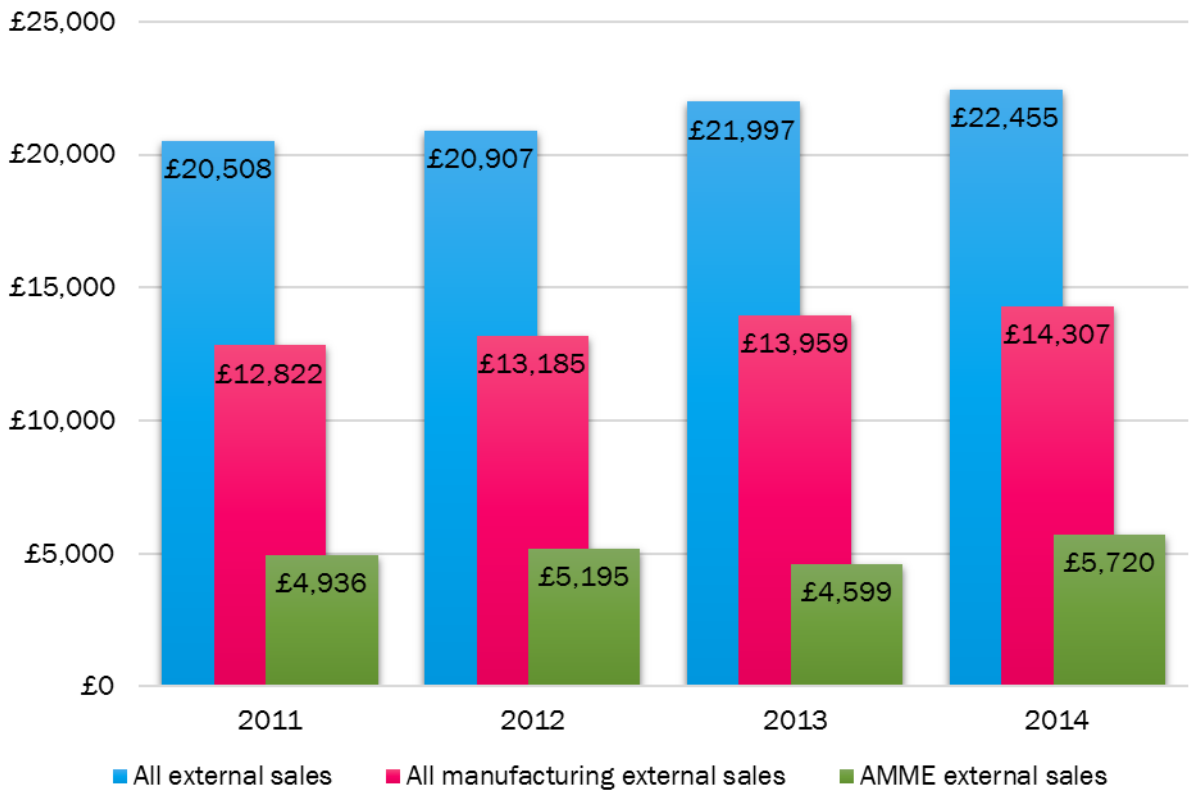


Figure 32: NI AMME export sales (outside UK) as a proportion of all export sales 2011-2014 (£m)

Figure 33: GVA

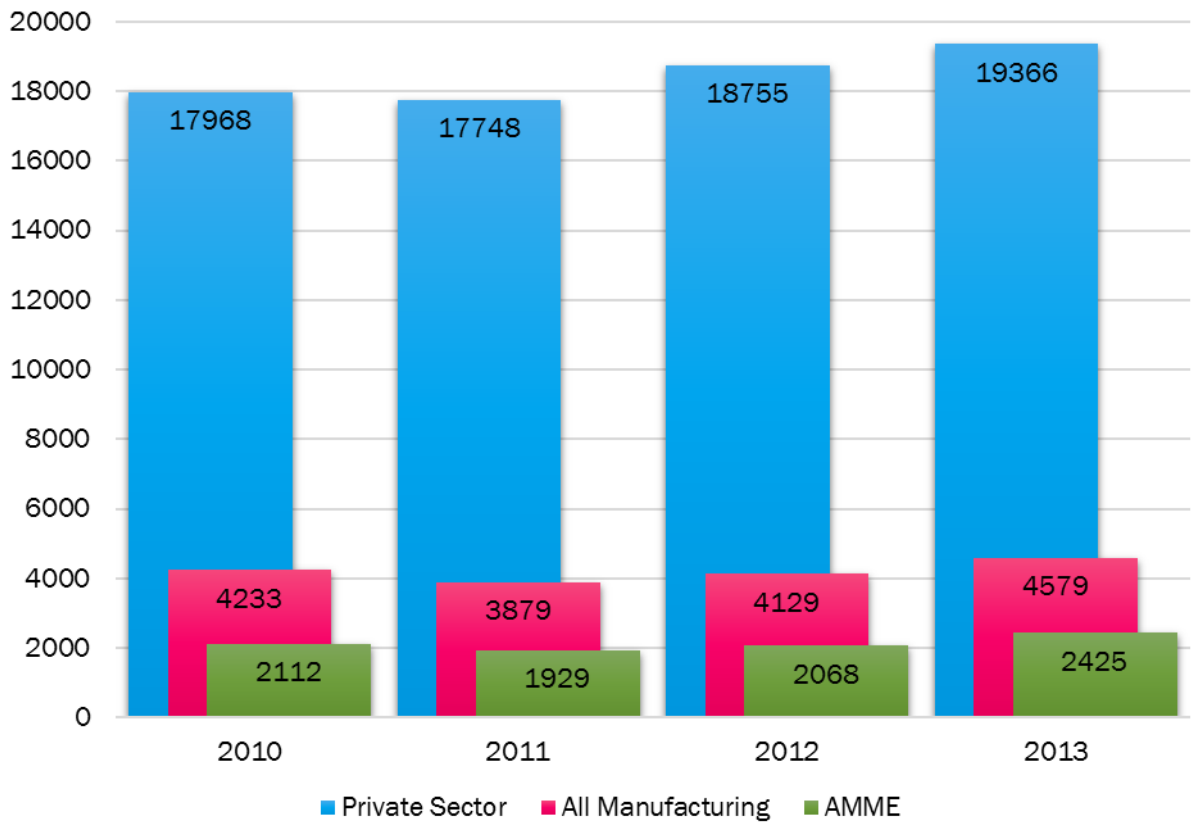


Figure 34: Women in AMME

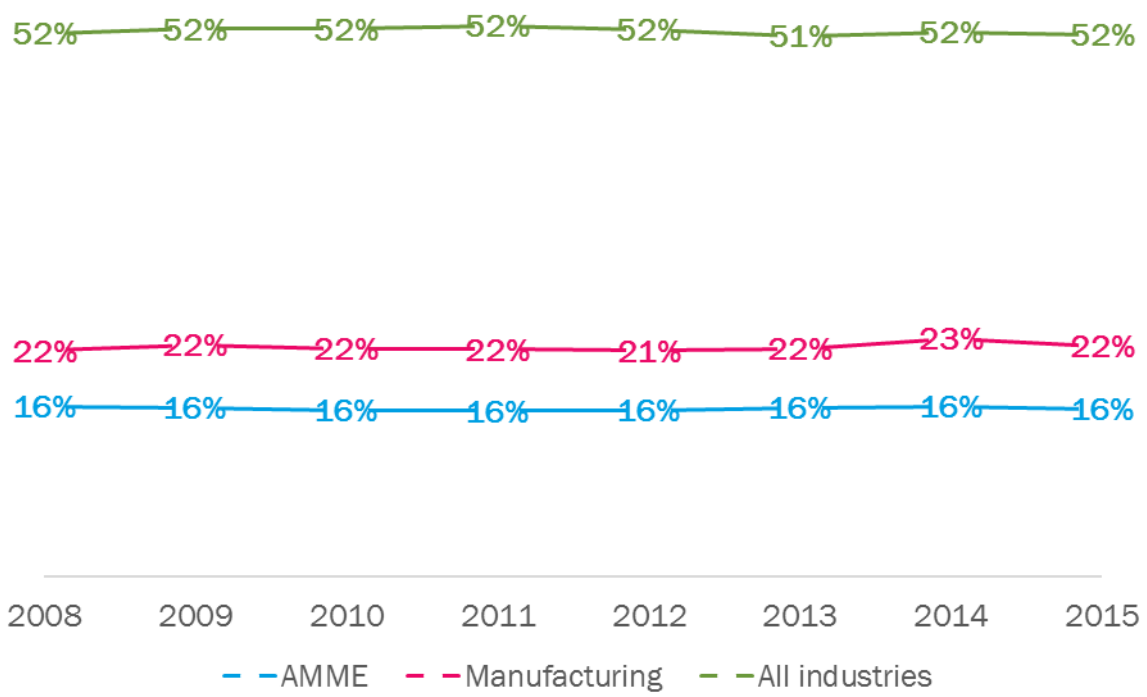


Figure 35: AMME jobs by district

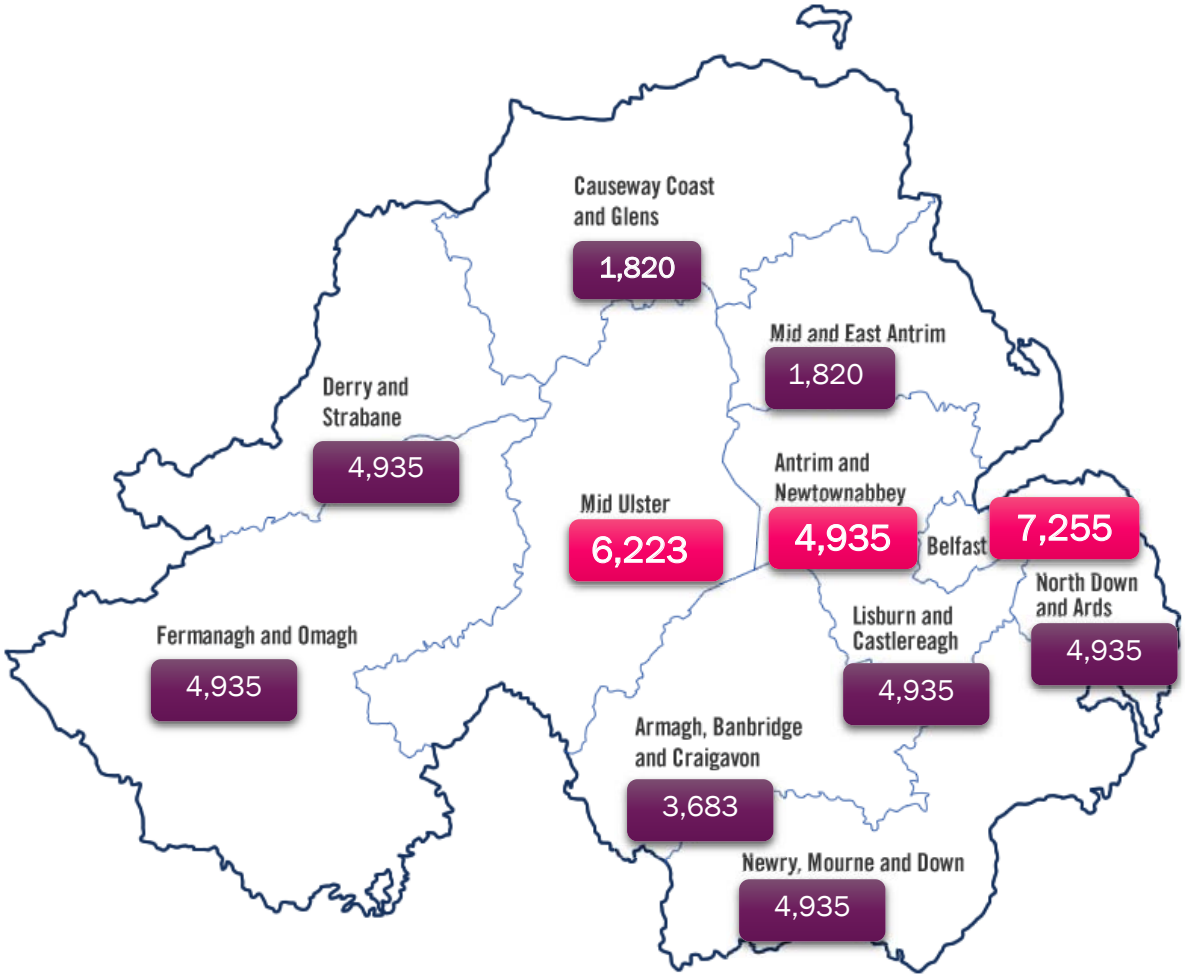
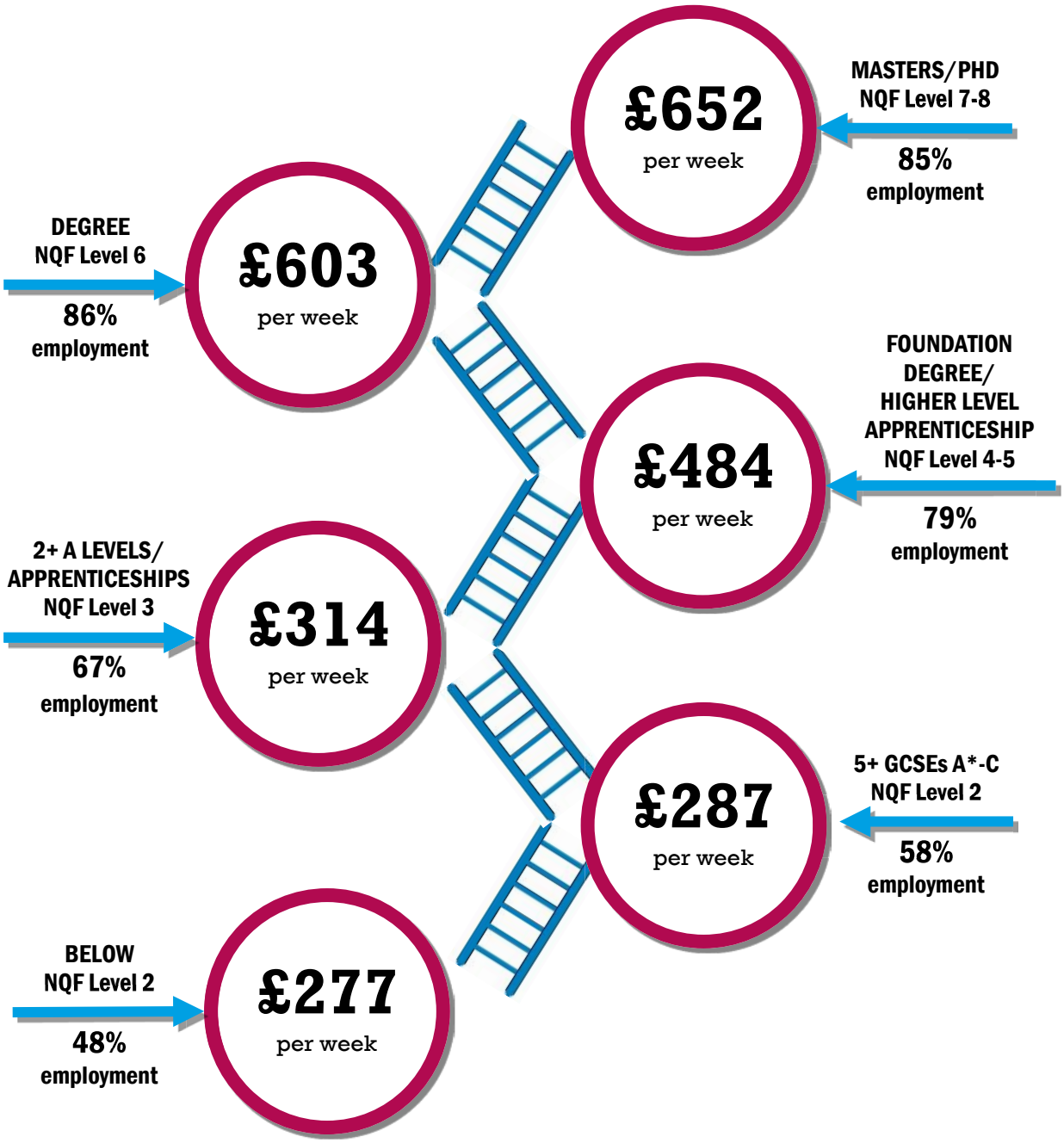


Figure 36: The Importance of skills – the more you learn, the more you earn



Demand by sector by level of qualification

The Skills Barometer analysis of demand by industry sector looks at the annual average net requirement (both from expansion and replacement) over the 2015-25 period.

Figure 37: Areas with the highest demand for graduates

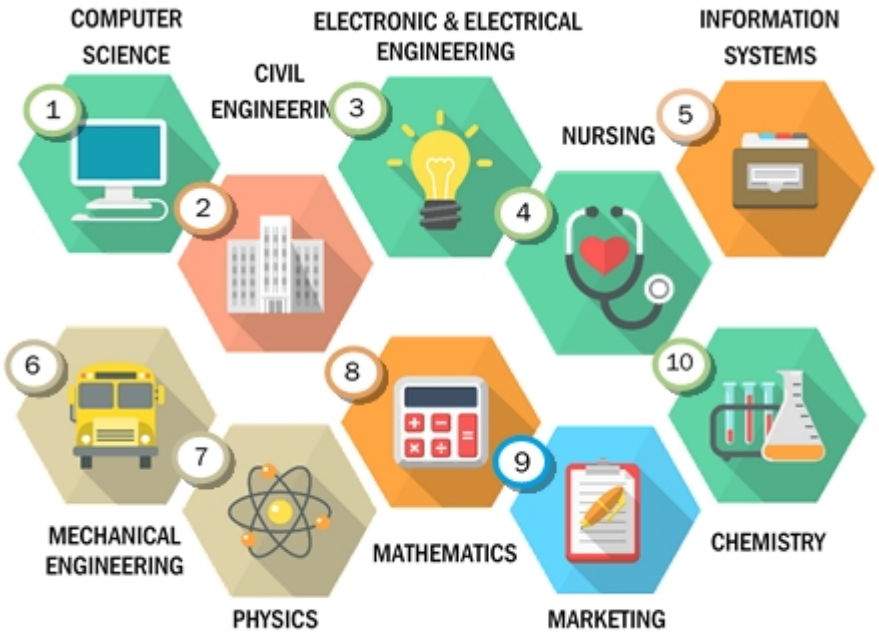
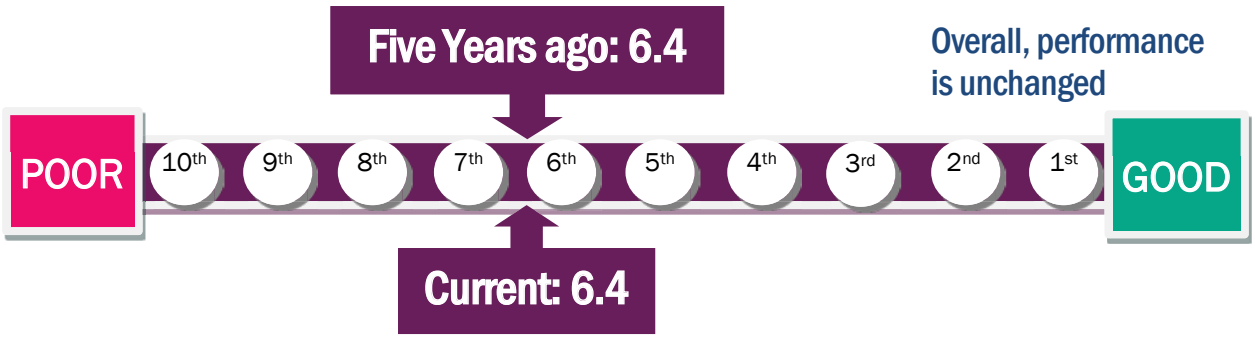


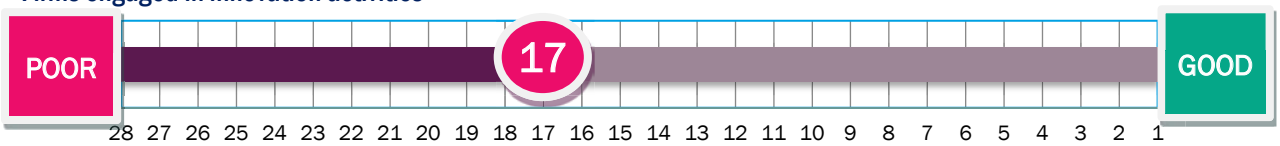
Figure 38: Areas with the highest demand for Foundation Degree Level/ Higher Level Apprenticeship

Figure 39: R&D&I performance: 2014 compared to 2009

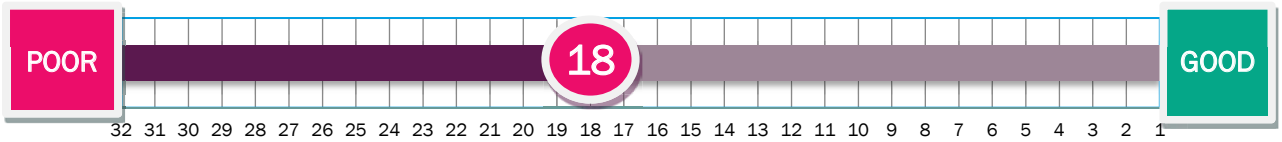


Key Indicator Summary

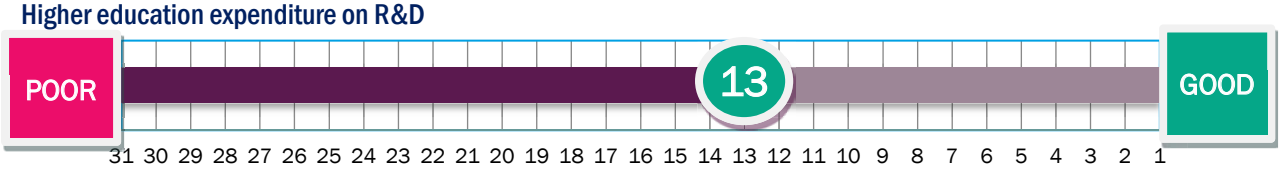
Firms engaged in innovation activities



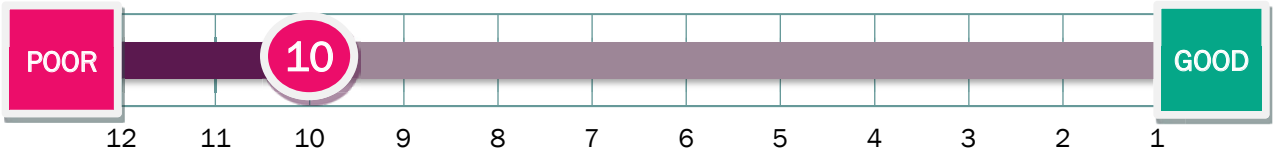
Business expenditure on R&D



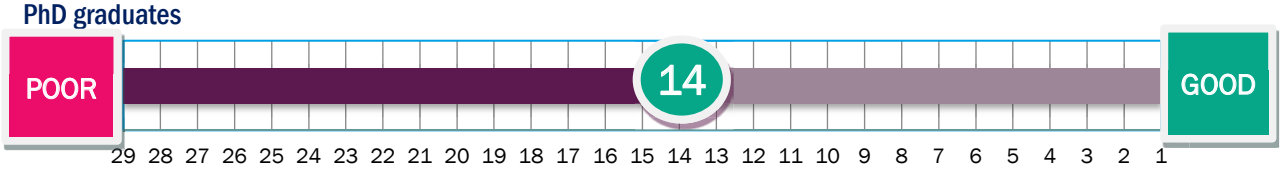
Higher education expenditure on R&D



Size of the knowledge economy



PhD graduates



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