manufacturing Commission

INDUSTRIAL EVOLUTION

MAKING BRITISH MANUFACTURING SUSTAINABLE

October 2015

This report follows a nine month inquiry chaired by Chi Onwurah MP and Professor Steve Evans.

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‘It is absolutely vital that our ability to make things, and to make them well, is made stronger and more resilient in an increasingly volatile world’

Chi Onwurah MP

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Foreword

Chi Onwurah MP & Professor Steve Evans

Since the financial crash of 2008, the manufacturing sector in the UK has been firmly placed back into the political and popular spotlight. It provided a surprising and welcome bulwark of relative stability and good news while the financial sector seemingly imploded. The Coalition government undertook an active industrial strategy, foreign direct investment flowed in, and many companies started reshoring production.

And yet, this increased attention also began to highlight some uncomfortable realities: while our manufacturing prowess was once unrivalled anywhere in the world, other countries are now producing far more than we do. We have been suffering a skills shortage for a number of years. Energy and raw materials are becoming more volatile. Our productivity is sluggish. Much of our infrastructure is strained. Many of our most hallowed industries are struggling, and we are polluting the world we live in.

These issues, combined with rapidly advancing technological developments, have spurred on high quality research into what manufacturing may look like in the near and not-so-distant future. Many have focused on the possibilities afforded by additive manufacturing (3D printing), the internet of things (Industry 4.0), reshoring, automation, redistributed manufacturing and mass customisation. The Government Office for Science itself produced the comprehensive Foresight report The Future of Manufacturing: A New Era of Opportunity and Challenge for the UK, which took a strategic look at the manufacturing sector all the way to 2050.

We undertook this inquiry because we believe that none of this research has so far adequately addressed, from a policy perspective, some of the major vulnerabilities of present day manufacturing in the UK, or fully appreciated how we could take advantage of the complete range of opportunities on the horizon. Faced with a myriad of significant challenges, what would government and the sector itself need to do in order to survive and thrive?

Making British manufacturing sustainable means making it competitive over the long-term. It must have the right fundamental building blocks, from a solid skills base to a dynamic research environment that fosters new inventions and commercialises them into successful businesses. It must be resilient against external shocks, and have the right ingredients to grow. It must also work in harmony with the rest of the world.

As global prosperity increases, particularly in developing countries, so do the ranks of middle-class consumers and the total global output of produced goods to satisfy growing demand. The vast majority of those goods are single-use, many of their raw materials are getting harder to extract, and the processes used to make them are often highly polluting. UK manufacturers are used to fierce competition for market share at a global level, but may increasingly face the prospect of having to compete for access to critical raw materials. If we continue along the same path, there will come a time when we can no longer access the minerals and chemicals we need to make things, and our environment will be irrevocably damaged.

This report, compiled over the course of a nine-month inquiry with input from across business, academia, the public sector and the civil service, sets out how we can start redesigning our industrial system to make it more sustainable, improve our national security, and ultimately enhance our quality of life. The UK has some of the most efficient and productive factories in the world, and we have a wave of new production technologies emerging. But these are the exception rather than the rule. We believe that we must take advantage of this leadership moment to make the UK more resilient and a provider of solutions to the rest of the world. These recommendations are primarily directed towards policy-makers, though sustainable manufacturing simply will not become a reality unless it is embraced wholeheartedly by businesses as part of their strategic planning. We call on all Parliamentarians to embrace the potential of a thriving twenty-first century manufacturing sector, efficient, clean and resilient, and embedded in healthy communities around the country. By working with all the relevant stakeholders, the recommendations outlined in this report, and the exciting new manufacturing sector they allude to, are eminently achievable.

Britain gave birth to the Industrial Revolution over two centuries ago. In this new world of constrained resources, growing populations and planetary boundaries, we must fundamentally change the way we make things. We ultimately need another industrial revolution, based on a deeper understanding of the interaction between manufacturing and the physical world it takes place in.

It is time for us to recognise the economic, environmental and social problems that current methods of production engender, and begin leading the way in making manufacturing truly sustainable.

In short, it is time for an Industrial Evolution.

Chi Onwurah MP
Co-Chair

Professor Steve Evans
Co-Chair

Executive Summary

The long-term environmental constraints on the world's ecosystem pose specific challenges for the manufacturing sector, in addition to those that are shared by all inhabitants of the planet. These challenges go beyond climate change. Population growth and continued economic development amongst a new global middle class will put significant pressure on global supplies of resources and water. If UK manufacturers are to continue to survive and flourish in this future landscape, they will need to be responsive and resilient to these shocks, while also being at the forefront of developing innovative new ways of meeting society's needs.

Although many of the trends which will shape the future landscape for UK manufacturers are beyond our direct control, our response to these trends is not. UK manufacturers and policy-makers face the choice of whether to be reactive to threats like material insecurity, loss of competitiveness and worsening climate change; or proactive in recognising future challenges, taking decisive action, and seizing the opportunities that will arise from the necessity of a global shift toward sustainability.

In areas such as clean technologies, eco-design and new business models, the UK is well placed to be a world leader, and to take advantage of the growing global markets for more sustainable goods and ideas. While also serving environmental objectives, a sector-wide focus on productivity gains through energy and resource efficiency should equally be regarded as an economic priority. The global market for sustainable business operations is expected to reach between US $1.5 trillion - $4.5 trillion by 2020. Conservative estimates of the benefits the UK could gain through energy- and resource-efficiency amount to £10 billion per annum in additional profit for the sector, 300,000 new jobs and a 4.5% reduction in our total annual greenhouse gas emissions.

Many firms have already made staggering advances in their use of materials, water and energy. However too many others are not treating this as a strategic priority. On a number of different fronts, policy has a crucial role in helping to realise the economic, social and environmental benefits of a more sustainable industrial system. This report addresses this challenge through five key areas of focus for policymakers: Leadership, Resilience, Innovation, Collaboration and System Change.

The key determinant of firm-level performance on non-labour productivity is not so much technology, but leadership. There is overwhelming evidence of many 'green' initiatives that would raise, not lower, company profits. However, these win-win measures remain unrealised due to barriers and constraints around firm decision-making. Too many managers remain unaware of the extent of the benefits that could be achieved through greater efficiency. Too many firms are structured in such a way that responsibility for resource and energy efficiency is mired at middle-management level, rather than being a key consideration in the strategic direction of the company from the CEO on down. Too many firms are short-termist in their focus and their decision-making, rather than taking a long-term view of the shape of future markets and how they should position themselves to take advantage of this. Policy-makers must consider how they can focus management attention on these potential gains, and help to promote long-term strategic investment in sustainability.

Future challenges around material and energy security and decarbonisation efforts could prove hugely disruptive to the UK economy unless concerted efforts are made to develop resilience at a national level. China's decision in 2010 to restrict the export of rare earth elements – of which it produces 97% of global supply – brought the issue of critical materials to the forefront of many countries' minds in terms of strategic economic interest and national security. However, the UK currently lacks a coordinated and coherent approach to identifying its potential vulnerabilities, and developing long-term strategies to mitigate them.

With regard to new technologies, the UK must build an innovation system which is commensurate to the challenges and opportunities presented by industrial sustainability. The UK has for many years lagged behind its competitors on R&D expenditure, and on the scale and ambition of its public innovation system. The state must be an active player in the innovation process, not merely a passive corrector of market failures, topping-up the supply of basic research or nudging business incentives toward more R&D. Failure to support UK manufacturers at the same level as our competitors means that we will be less able to take advantage of the growing global markets for low-carbon technologies, and less able to address sustainability challenges ourselves.

Greater collaboration between companies and other actors must also be a central part of a more sustainable manufacturing system. Although there are great potential benefits to working together across industries, supply chains, with universities and with other intermediary institutions, doing so requires forging deeper institutional connections and personal relationships which sit outside of businesses' core focus. Policy can help the development of these linkages, and can act to convene various groups around particular challenges of sustainability, which are unlikely to be overcome through individual efforts alone.

Finally, manufacturers are increasingly experimenting with new ways of meeting customers' needs. This includes shifting from providing products to providing services, in a way that separates the use of a product from its ownership; or circular economy models where products are designed and manufactured for continuous reuse, and value is captured from 'waste' wherever possible. Policy-makers must be attuned to the possibilities that innovative business models present, and the ways in which policy can better support their emergence.

Recommendations

Leadership

1. The government should promote energy efficiency measures through the provision of low-interest loans, repaid through subsequent savings from efficiency gains.

2. Business expenditure on efficiency measures which build national resilience should be tax-deductible, expanding the R&D tax credit into a resilience, research and development (RR&D) tax credit.

3. Carbon reduction schemes should be redesigned to force top management attention on to savings opportunities through revisiting the Carbon Reduction Commitment (CRC).

4. Measures to decrease the knowledge gap on energy and resource efficiency, such as data sharing and 'sustainability champions' within the firm hierarchy, should be promoted.

5. Greater incentives for capital investment in low-carbon plant and machinery should be prioritised over cuts to corporate taxation.

6. Sustainability should be entrenched across the UK's education system, particularly in engineering and management courses, and measures to improve management skills among UK executives should be promoted.

Resilience

7. A new 'challenge-focused' Catapult should be established to examine and build our understanding around cross-sectoral areas of concern relating to resilience, and to convene relevant actors around addressing these issues.

8. Government should prioritise measures to increase the reliability of renewables and to mitigate their intermittency.

9. The Office of National Statistics should develop an enhanced data infrastructure for tracking material flows.

10. The Energy Intensive Industries 2050 decarbonisation roadmaps should be expanded into action plans.

11. An Office for Resource Management should be established within BIS to advise and coordinate policy-makers on the challenges and opportunities around resource security.

Innovation

12. The scale and ambition of the UK's innovation network should match that of our competitors, as well as the extent of the opportunities around sustainability. Publically funded R&D should be increased in order to place the UK economy on a more even standing with other OECD nations.

13. Government should make greater use of procurement to provide a market for sustainably manufactured goods, for instance through ensuring greater engagement with the Small Business Research Initiative (SBRI) programme.

14. Exemptions from the Climate Change Levy in the form of Climate Change Agreements should be reviewed, and consideration given to progressively shifting support towards R&D in clean technology and renewables.

15. The UK should take a lead in establishing standards for open data in energy and resource efficiency.

Collaboration

16. The industrial decarbonisation roadmaps undertaken by BIS and DECC should be expanded to other key industries, with a broader remit around long-term, strategic challenges faced by the sector.

17. The Competition and Markets Authority (CMA) should be tasked with working more closely with trade associations and business consortia to provide guidance at an earlier stage on data sharing and other forms of collaboration.

18. Government should expand efforts to foster voluntary agreements around the efficient use of materials and waste reduction.

19. The National Industrial Symbiosis Programme (NISP) should be refunded as a national initiative.

System Redesign

20. Government should consider tying support for energy- and resource-efficiency to other green measures. This can help counter the rebound effect by encouraging savings to be directed toward other projects that promote sustainability.

21. Responsibility for resource management infrastructure should be unified at a UK-wide level, and national infrastructure institutions must ensure that long-term investment decisions are consistent with sustainable manufacturing, and do not 'lock-in' unsustainable activities.

22. Government should promote alternative business models, and remove barriers to their development and adoption.

23. Government should work to reduce uncertainty around more sustainable manufacturing business models by establishing standards for remanufactured products and utilising government procurement to provide a market for such products.

24. Innovation and coordinating bodies should provide greater support to innovative business models.

List of acronyms

APMG	All-Party Parliamentary Manufacturing Group
APSRG	All-Party Sustainable Resource Group
BIS	Department of Business, Innovation and Skills
BSI	British Standards Institution
CCC	Committee on Climate Change
CCS	Carbon Capture and Storage
CEO	Chief Executive Officer
CME	Co-ordinated Market Economy
CRM	Critical Raw Material
DARPA	Defence Advanced Research Projects Agency
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
EII	Energy-Intensive Industries
EPSRC	Engineering and Physical Sciences Research Council
EU	European Union
GDP	Gross Domestic Product
GIB	Green Investment Bank
LEP	Local Enterprise Partnership
LME	Liberal Market Economy
LSE	London School of Economics and Political Science
NISP	National Industrial Symbiosis Programme
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
Ofgem	Office of Gas and Electricity Markets
ONS	Office for National Statistics
PGM	Platinum Group Metals
POLFREE	Policy Options for a Resource Efficient Economy
PSS	Product Service System
R&D	Research and Development
REACH	Registration, Evaluation, Authorisation and restriction of Chemicals
REE	Rare Earth Elements
RSA	Royal Society for the encouragement of Arts, Manufactures and Commerce
SBIR	Small Business Innovation Research
SBRI	Small Business Research Initiative
SME	Small- and Medium-sized Enterprise
TUC	Trade Union Congress
UCL	University College London
UNEP	United Nations Environmental Programme
UNIDO	United Nations Industrial Development Organization
VC	Venture Capital
WMS	World Management Survey
WRAP	Waste and Resources Action Programme
WTO	World Trade Organization

INTRODUCTION

Industrial Sustainability – Challenges and Opportunities

The Future Landscape for British Manufacturing

The long-term environmental constraints on the world's ecosystem pose specific challenges for the manufacturing sector, in addition to those that are shared by all inhabitants of the planet. Manufacturing is more intensive than the general economy in its use of energy and resources, and its emission of carbon into the atmosphere. Thus, as a responsible section of society, it faces a greater challenge than most in shifting to a mode of operation which is consistent with the needs of future generations.

The challenges faced by the sector go beyond climate change. Population growth and continued economic development in the global south will put significant pressure on world supplies of resources and water, heighten risks to biodiversity and contribute to air and water pollution. In addition to mitigating the adverse impacts of its own processes, manufacturing will need to be responsive and resilient to shocks and pressures which are beyond the control of any one economic agent or political authority.

Manufacturing also faces some fundamental shifts in what society demands of it. At a time when the world is witnessing the rise of a new global middle class of consumers, the way in which the material needs of the middle class have traditionally been met – readily-available consumer goods mass-produced within a linear system of production, ownership and disposal – is no longer fit for purpose. Furthermore, the needs of the future are not static, but will evolve alongside future challenges. Society will require not just that its demand for material goods be met in a way which does not endanger the global ecosystem, but that manufacturing plays a key role in providing solutions to the world's problems.

Although many of the trends which will shape the future landscape for UK manufacturers are beyond our direct control, our response to these trends is not. UK manufacturers and policy-makers face the choice of whether to be reactive to threats like material insecurity, loss of competitiveness and worsening climate change; or proactive in recognising future challenges, taking decisive action, and seizing the opportunities that will arise from the necessity of a global shift toward sustainability.

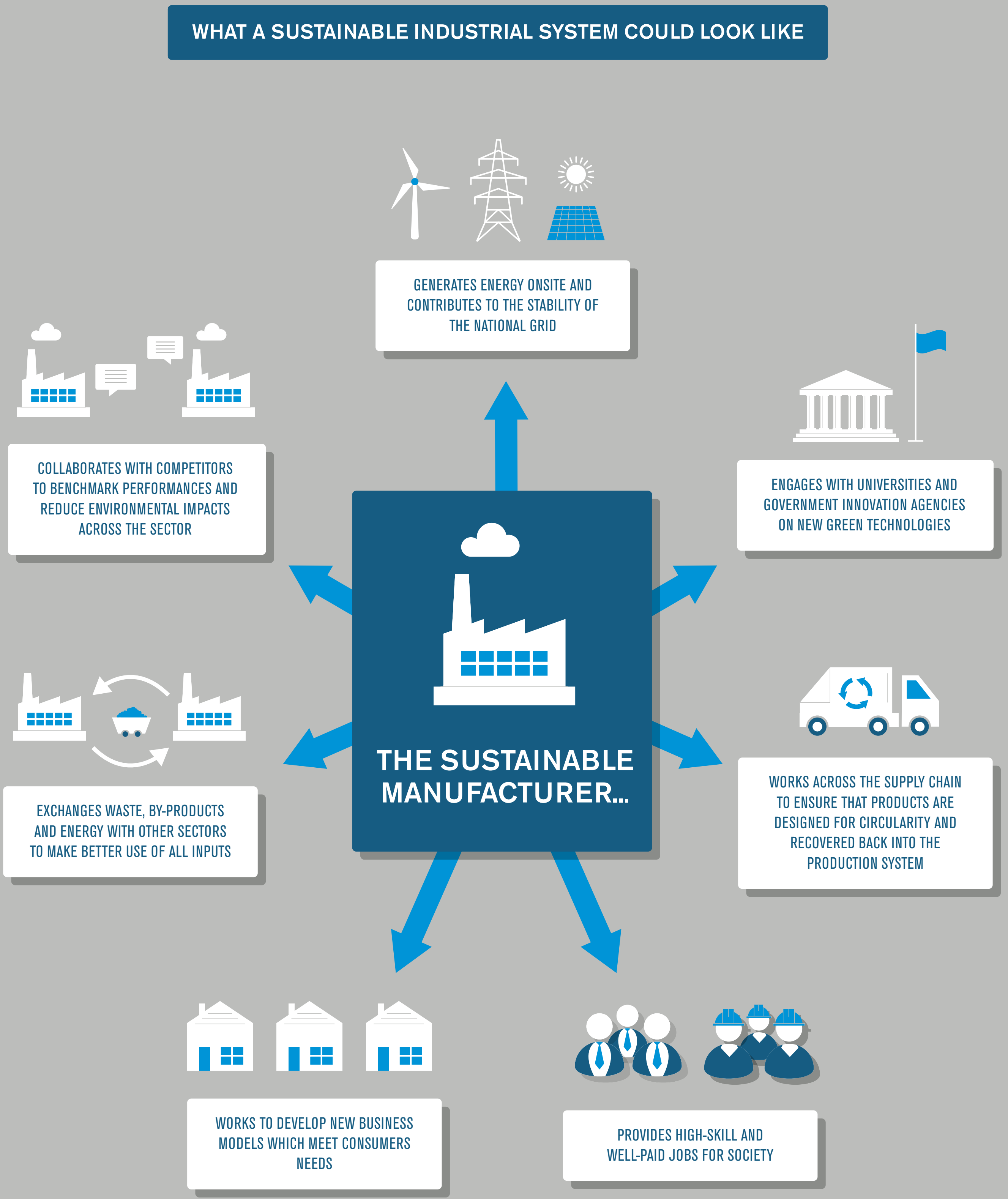

Fig.1 “What a Sustainable System Could Look Like”

Fig. 2 "Trends Influencing the Future Landscape for Manufacturers." Source: adapted from *Government Office for Science; The Future of Manufacturing*, 2013, p 149

As identified in the Government Office for Science's Foresight report, "The Future of Manufacturing" (2013), the circumstances in which manufacturers will have to operate in future will be very different. Environmental 'megatrends' in the form of climate change and population growth, and increased competition for energy, water, and materials, will necessitate significant shifts in the way manufacturers operate. In the face of these challenges, the reactive trends will be consumer demands for more sustainable products, and for government action in the form of higher standards around the impact and efficiency of production, and the increasing use of mechanisms to 'price' the impact of production on the environment. It should be understood that many of these challenges are interlinked: not only will they likely reinforce one another, but some options for addressing one challenge may also exacerbate others. For instance, policies that encourage switching to diesel-powered cars have had a positive effect on CO_2 emissions but have generated significant public health concerns as to the effects of other pollutants on air quality.

WHERE WE EXCEL

AREAS IN WHICH THE UK IS WELL PLACED TO BE A WORLD LEADER, AND WHICH WE SHOULD CAPITALISE UPON

CLEAN TECHNOLOGY

The global market for sustainable business operations is expected to reach between US $1.5 trillion - $4.5 trillion by 2020.[1] The UK has significant opportunities for growth in areas such as new materials, automation and fuel cells.

CREATIVE SECTOR

The UK's creative sector is well placed to play a role in addressing the challenges of sustainability within the manufacturing sector, and there has been a marked shift in university-level design courses in focusing on sustainability and system-wide design (as opposed to the creation of products for consumption).

ENERGY EFFICIENCY

The UK has some of the most efficient individual factories in the world. Just as the techniques that were pioneered in Japan in the 1980s have been copied by manufacturers around the world, and are synonymous with Japanese manufacturing, the same could be true for approaches created in the UK.

BUSINESS MODEL INNOVATION

The UK is a leader on thinking and analysis on how new business models can meet consumers' needs in more environmentally-friendly ways. Better implementation of these ideas could mean that they are something the rest of the world looks to the UK for.

The focus of this report is on the role of policy in fostering a transition towards a sustainable industrial economy. Here, policy moves from being an abstract feature of the business landscape to a being driver of change, and a determinant of both its rate and direction. As Schumpeter argued, economic transformations entail huge opportunities for innovators and disruptive new-entrants to the market, whether such transformations are technological, economic or social in nature.[2] This is the process of 'creative destruction'. Policy can help to shape the emergence of new markets and whole new industries for sustainable manufacturing, and can lay the foundations for greater private sector investment in skills, supply chains and infrastructure that are complementary to this direction of change.[3]

1 Tennant, M; "Sustainability and Manufacturing", 2013, 14.
2 Bowen, A and Fankhauser, S; "The green growth narrative: Paradigm shift or just spin?", Global Environmental Change, 2011.
3 Perez, C "Steering Economies toward the next Golden Age", Mission-Oriented Finance for Innovation, Policy Network, 2015.

Yet as much as we might be tempted to focus on the 'creative' aspect of 'creative destruction', the necessary corollary is that there will be losers as well as winners in this process. Furthermore, such transformations do not remain neatly confined to the economic sphere. Established economic relations are fundamental to wider social structures that shape peoples' lives; be it workers who have built up a skill-set specific to a threatened sector, or a local community that has developed a generations-long relationship with a local factory. Environmental and economic concerns demand that policy be designed to ensure that UK industry is at the forefront of the shift toward sustainability, ready to capitalise on the need for more efficient processes, products and business models. Yet at the same time policy must be concerned with mitigating the economic dislocation that might accompany this transformation. Change within the industrial economy will inevitably occur – it is up to us to determine what we make of it.

Opportunities presented by a shift to a Sustainable Industrial Economy

The Committee on Climate Change (CCC) projections call for direct industry emissions to fall to 65 MtCO2 by 2030 – a reduction of around 40% from 2012 levels.[4] In concrete terms, the central challenge of sustainable manufacturing is to shift toward production systems which continue to create the things society wants and needs, while using a fraction of the material and energy inputs.[5] Though often framed as a 'green' objective, this can equally be understood as a dramatic increase in multi-factor productivity; increasing the value derived from every tonne of material, litre of water and kilowatt of energy we input into the production process. Given the historical lag in UK productivity behind other developed nations, and the recent 'puzzle' of stalled GDP per worker since the global financial crisis, this is an opportunity the UK should embrace. A dedicated policy focus on resource productivity has the potential to boost per capita living standards while also enhancing wellbeing by fostering a more environmentally-friendly industrial system.

The benefits of moving to a broader adoption of best-practice efficiency methods, separate to the development and diffusion of new technology, appear to be substantial. It is difficult to accurately estimate the extent of the potential gains that could be made through improving non-labour productivity, and much more needs to be done to quantify this. However, the Next Manufacturing Revolution report found that a conservative estimate of the impact of such a shift amounts to:

- £10 billion per annum in additional profit for the sector;
- 300,000 new jobs; and
- A 4.5% reduction in the total annual greenhouse gas emissions of the UK

4 Committee on Climate Change; Fourth Carbon Budget Review: Chapter 4: Reducing emissions from industry. 2013, 90.
5 Evans et al. "toward a sustainable industrial system", 2009, 7.

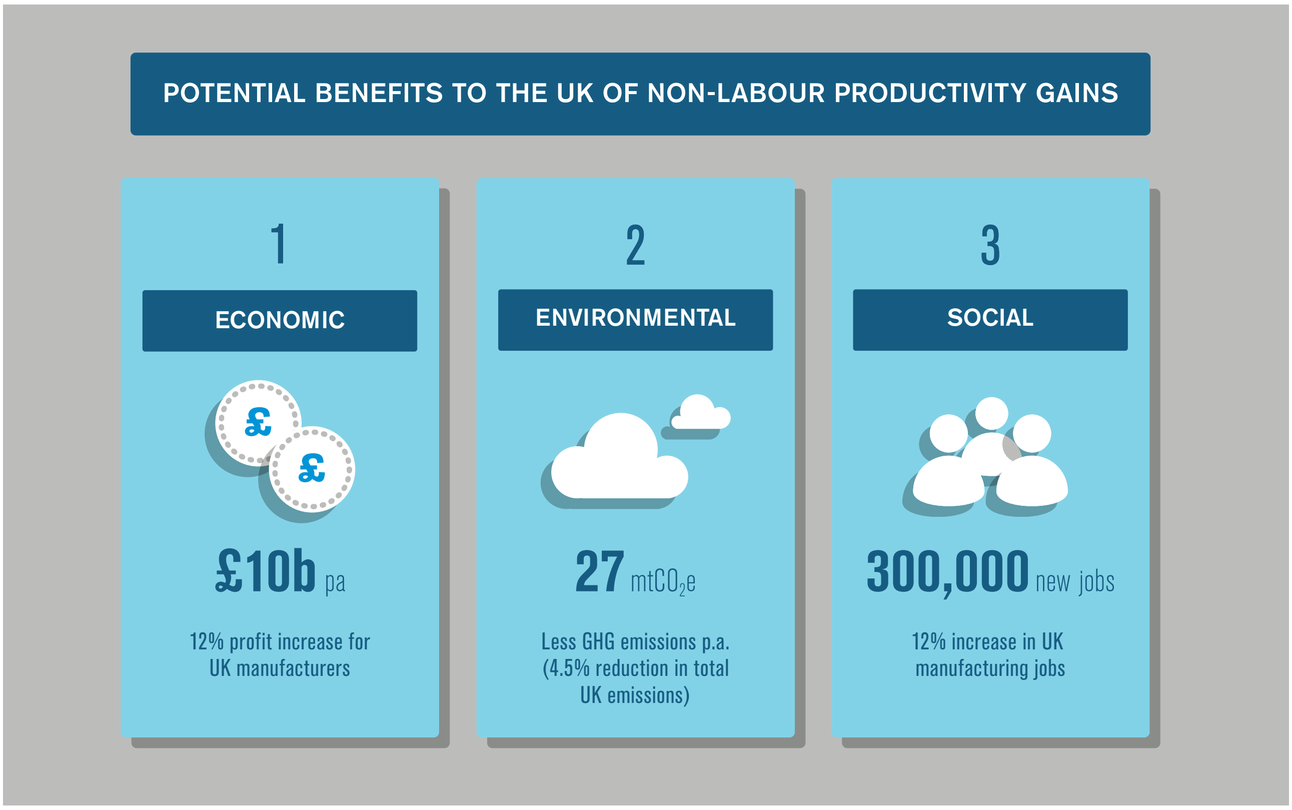

Fig. 3 Potential Benefits To The Uk Of Non-Labour Productivity Gains";
Source: adapted from Lavery, G. et al, Next Manufacturing Revolution, Lavery Pennell, 2degrees, Institute for Manufacturing, 2013.

Other benefits from a sustainable industrial sector are likely to include decreased pollution and resulting health issues, a reduction in the burden placed on transport infrastructure and the national energy grid, and reduced waste going to landfill or incineration.[6]

With the right alignment of incentives, market systems have shown themselves capable of such dramatic efficiency improvements in the past. Cumulative investment in labour-saving technology has seen labour productivity increase 15-fold in the US since 1870.[7] McKinsey Global Institute agrees that "there is an opportunity to achieve a resource productivity revolution comparable with the progress made on [labour] productivity during the 20th century".[8] However, market forces alone are unlikely to generate sufficient progress in material and energy productivity within a critical mass of manufacturing activities, at least until scarcity of those inputs reaches a stage which is disruptive to the economy as a whole, and resource-intensive industries in particular.[9]

6 5 Lavery, G et al, Next Manufacturing Revolution, Lavery Pennell, 2degrees, Institute for Manufacturing, 2013 11.
7 Maddison, A cited in United Nations Industrial Development Organisation (UNIDO); Green Growth: From Labour to Resource Productivity; 2013.
8 McKinsey Global Institute, Resource Revolution: Meeting the World's Energy, Materials, Food and Water Needs, 2011, 3.
9 Furthermore, so long as labour typically remains a relatively expensive input for manufacturers, compared to resources, market incentives will exist for firms to economise on labour, even if it means increasing environmental impacts. Sustainable Development Commission, Redefining Prosperity, 2003.

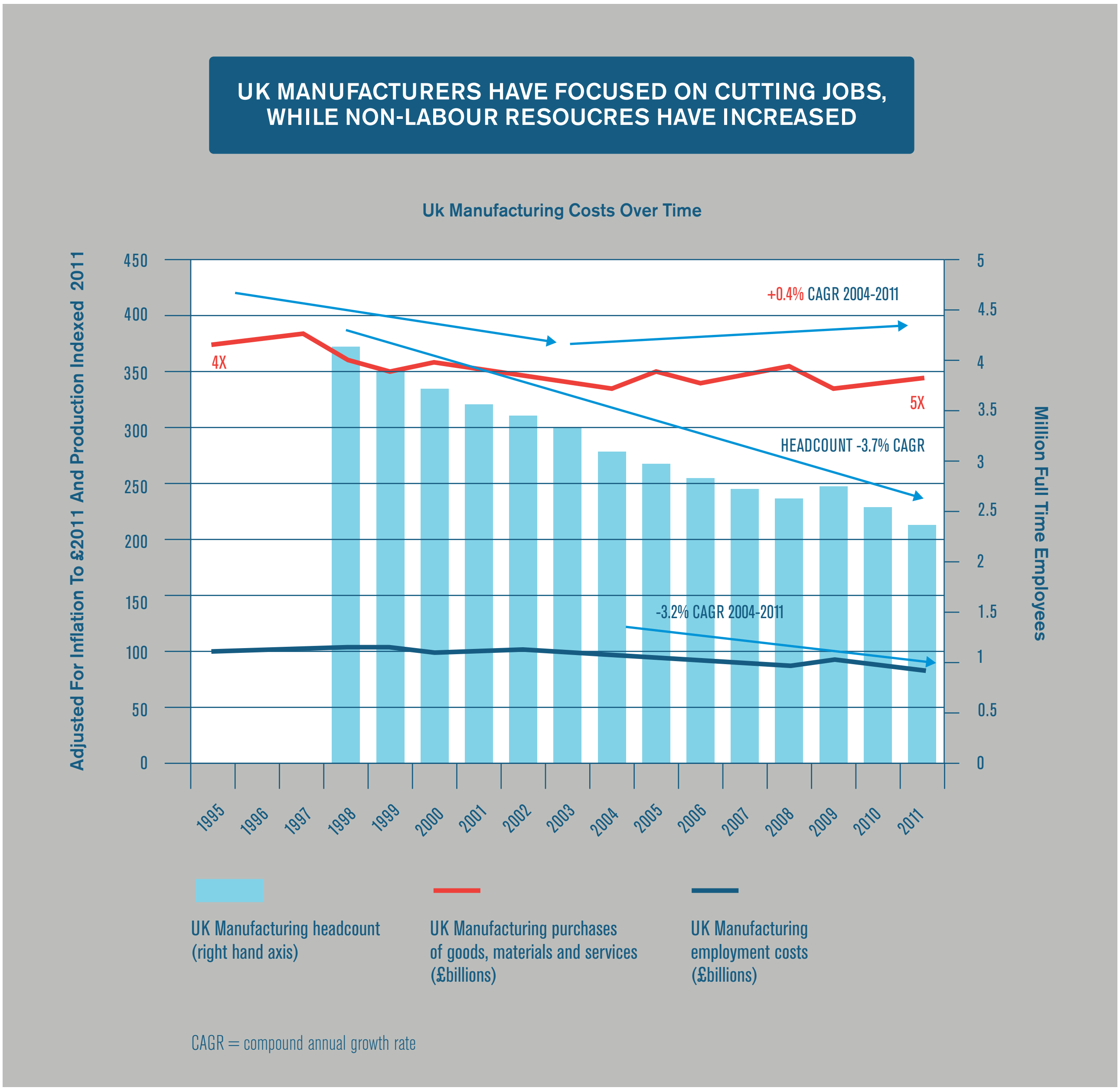

Fig. 4 "UK Manufacturers Have Focused On Cutting Jobs, While Non-Labour Resoucres Have Increased", source: Adapted from Lavery, G et al, Next Manufacturing Revolution, Lavery Pennell, 2degrees, Institute for Manufacturing, 2013

Figure 4[10] shows the aggregate costs of the UK manufacturing sector, divided into labour and non-labour costs, overlaid with a headcount of total employees in the sector. Total spending on labour costs have continued to decrease alongside total number of employees within the sector, which now number 1.5 million fewer than in the late 1990s. However, no progress has been made on non-labour costs in the years since 2004, with commodity price increases offsetting any efforts toward greater efficiency.

10 Lavery, G et al, Next Manufacturing Revolution, Lavery Pennell, 2degrees, Institute for Manufacturing, 2013.

The average manufacturer now spends five times more on non-labour costs than on labour costs. It is here that efforts to improve productivity should be focused.[11]

The benefits of realising such productivity gains are numerous. UK carbon emissions could be dramatically reduced through both decreased demand for energy and raw materials compared to current levels, and through creating less pollution during industrial processes. A reduction in resource requirements, or the substitution of less-scarce resources into the production process, would make UK manufacturing more resilient against future barriers to availability of resources. This includes price volatility and supply-shocks arising, for instance, from geopolitical turmoil, climate change-related extreme weather events or restricted access to rare materials on the basis of national competition.

UK manufacturing also has the opportunity to gain significant competitive advantages through efficiency gains and transformations within existing sectors, developing new green industries and innovative business models, and fostering economy-wide transitions which are complementary to 'greener' modes of production.[12] Analysis of patterns of green innovation shows that there are also opportunities for the UK to shift its comparative advantage[13] within certain industries if it is able to solve sustainability-related challenges better than its competitors.[14]

Competitiveness is a legitimate concern for public policy, without resorting to a crude understanding of global competition where every export is counted as a win and every import a loss. German-made solar panels are likely to work much the same as British-made ones. However, persistent current account deficits tend to have pernicious consequences,[15] and resource scarcity promises to exacerbate this. Manufacturing also employs some 2.5 million workers (as well as many more employed indirectly), who out-perform the general economy in terms of productivity and wages. Hence, there is a strong economic case, as well as an environmental one, for government to take an interest in the transformation of existing manufacturing activities and the emergence of new ones.

11 Baptist and Hepburn explore the relationship between intermediate inputs (of which materials are a considerable part) and economic growth. Our focus on measuring value - added – the value of output minus intermediate inputs such as materials and energy – in national accounts tends to obscure the potential of material efficiency gains to drive productivity. Looking instead at gross output, they find that firms that use intermediate inputs less intensively tend to have higher total-factor productivity (the residual impacts on output which are not accounted for by measured changes in the input of labour or capital). Baptist, S and Hepburn, C; "Intermediate Inputs and Economic Productivity"; Working Paper 94, Grantham Research Institute on Climate Change and the Environment; 2012.
12 Fankhauser, S et al, "Who will win the Green Race? In search of Environmental Competitiveness and Innovation", Global Environmental Change, 23, 2013.
13 i.e. what countries specialise in for trade.
14 Fankhauser, S et al, "Who will win the Green Race? In search of Environmental Competitiveness and Innovation", Global Environmental Change, 23, 2013.
15 Wolf, M; The Shifts and the Shocks, 2014.

Decoupling

What is needed is termed a *decoupling* of economic growth from environmental impacts. More specifically, relative decoupling means a decrease in the material/energy intensity of each unit of output, so that raw material and energy use increase at a slower rate than economic growth. Absolute decoupling requires that the trend lines of output and environmental impact move in opposite directions; that we are able to produce more with less in absolute terms.

Relative decoupling in material usage appears to be occurring on a global scale, with 50% more value being extracted per unit of material than in 1990. However, faster economic growth over this period has meant a significant rise in total material resource use, with global consumption surpassing 70 billion metric tonnes annually. This represents twice the level of extraction from the natural environment compared to 1980, and equates to around 46kg of consumption per person per day in advanced countries.[16] With anticipated population increases and economic growth, the United Nations Environment Programme (UNEP) predicts that without significant decoupling, global consumption of key material resources will be three times current levels by 2050.[17]

Analysis of domestic material requirements versus GDP can be problematic. Absolute decoupling at a national level, as appears to be happening in the UK for materials[18] and carbon,[19] could equally be facilitated by outsourcing of production as by improvements in efficiency. Changes in aggregate material use and carbon emissions for the UK need to be viewed within the context of changes to the make-up of the economy in recent decades; specifically the fall in manufacturing's share of GDP from around 22% in 1990 to around 11% today.[20] Similarly, significant 'onshoring' of production from overseas, or the emergence of new industries on a significant scale, could lead to an increase in these absolute numbers, while still being a net positive for the global environment as a whole. Policy-makers need to consider not only the UK's production emissions, but also its consumption emissions. While the former have fallen, the latter are still at 1990 levels and were trending upwards prior to 2007.[21]

16 OECD, Material Resources, Productivity and the Environment, 2015, 9.
17 UNEP, Decoupling Natural Resource Use and Environmental Impacts from Economic Growth, 2011.
18 DEFRA, Resource Management; a Catalyst for Growth and Productivity, 2015, 10.
19 Martin, R et al, Energy and the Environment: a cold climate for climate change policies? Centre for Economic Performance, 2015, 3.
20 BIS, Manufacturing in the UK, 2010, 2.
21 Martin, R et al, Energy and the Environment: a cold climate for climate change policies? Centre for Economic Performance, 2015, 4.

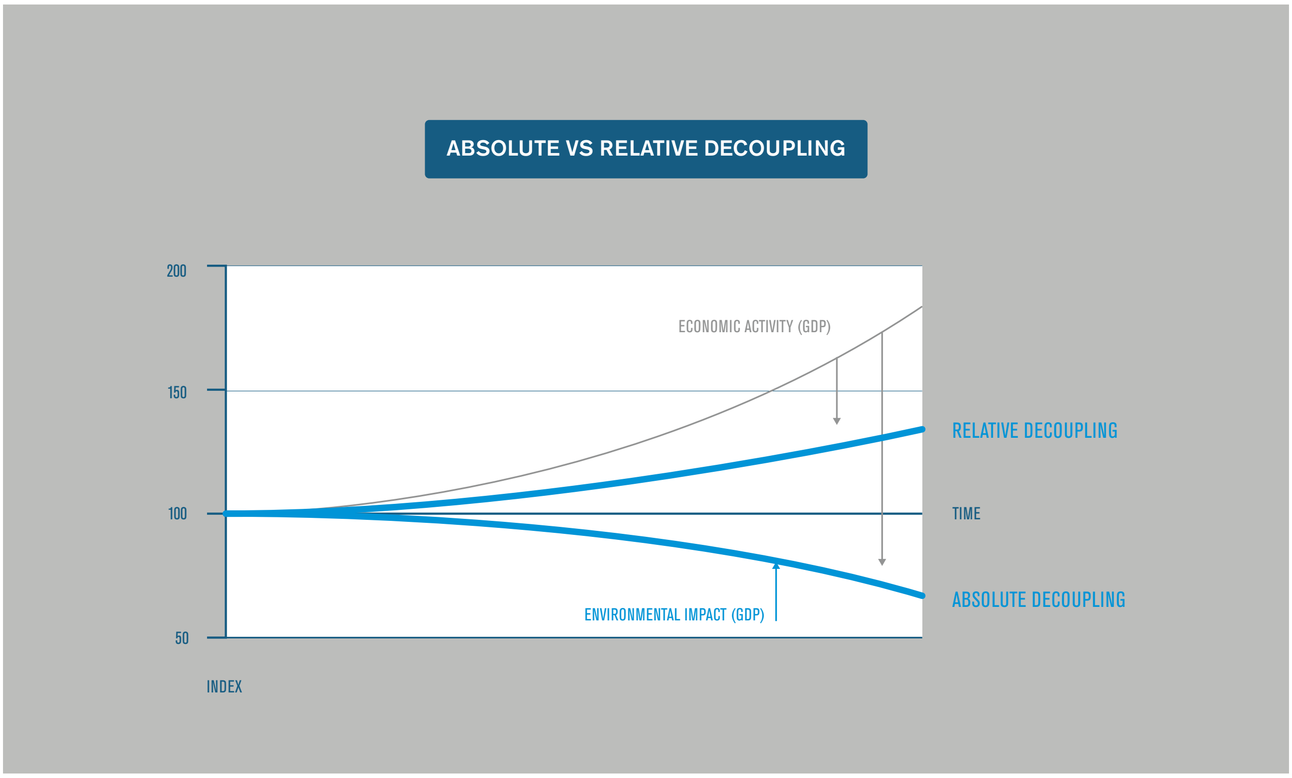

Fig. 5 "Absolute Vs Relative Decoupling", Source: Adapted from adapted from European Environment Agency; www.eea.europa.eu/publications/environmental-indicator-report-2012/environmental-indicator-report-2012-ecosystem/part1.xhtm

Moving toward Sustainability

The extent of the savings possible through efficiency measures differs across sectors. Energy-intensive industries, and those dealing in high volumes of materials, naturally have a much greater focus on such savings than the typical manufacturer. For instance, energy and material efficiency have historically been major concerns within the steel industry. The manufacturing sector as a whole has also been responsive to price changes, such as the increases in energy prices from 2002 which provided the background for considerable year-on-year improvements in energy intensity within industries like chemicals and automobiles.[22]

Yet in many industries, the largest determinant of efficiency improvements seems to be leadership and knowledge, rather than technical possibilities. The divergence in company performance within sectors is enormous – for instance, Toyota UK's cumulative reductions in energy use of 70% since 1993, compared to other automobile manufacturers which have achieved less than 10% over the same period.[23]

The attention directed toward the efficient use of energy and materials in any company is naturally linked to how much those inputs account for as a proportion of total costs. While energy-intensive industries (EIIs) account for two thirds of the UK's industrial carbon emissions and half of the sector's energy use,[24]

22 Lavery, G et al, Next Manufacturing Revolution, Lavery Pennell, 2degrees, Institute for Manufacturing, 2013, 22.
23 Ibid
24 Trade Union Congress (TUC), Building our Low-Carbon Industries, 2012, 3.

the remainder is due to non-intensive sectors, for which energy costs often amount to 5% or less of total costs.[25] For EIIs, even small incremental efficiency improvements will have a significant impact on emissions and energy/resource use, due to the volume of inputs and externalities involved in these processes. For non-EIIs, evidence suggests that the average firm is far from the efficiency frontier, and that unrealised, cost-effective gains across the manufacturing sector add up to a significant share of the sector's impact in aggregate.

Closing the efficiency gap between the best and worst performers is crucial, but sustainability within the industrial sector also requires that the frontier of what is possible be advanced through fostering innovation and the diffusion of knowledge throughout the system. This is particularly important for sectors that have already made significant gains in efficiency or whose emissions are substantially determined by the chemical reactions inherent in their processes (e.g. lime).[26] These industries will require new forms of technology (such as carbon capture and storage [CCS]) to meet the targets for emissions reduction set by the UK Climate Change Act.

A consistent and effective price on carbon and other externalities is an important aspect of incentivising sustainable transformation and levelling the playing field for greener alternatives. Yet such an approach on its own is not sufficient to overcome behavioural, organisational and informational barriers which already exist to more sustainable ways of doing business.[27] Additionally, decarbonisation of the energy grid is important not just from the perspective of carbon emissions generated through industrial use of electricity, but because of its potential to allow the electrification of heat generation for some industrial processes,[28] as well as sectors such as transport.

It is, however, unclear that efficiency and technological innovation alone will be sufficient drivers for industrial sustainability. This is partly explained by the rebound effect, or the so-called Jevon's paradox: advances in efficiency reduce prices, and increase consumer demand for a product, thereby undoing any reduction in total energy or resource use.[29] Any analysis of industrial sustainability would be incomplete without considering change on a system-level; of how society makes use of physical products, and the ways in which society's desired outcomes can be met through ways which are less damaging environmentally.

25 DECC, Energy Efficiency Opportunity in the UK, 2012, 19.
26 Orion Innovations UK ltd, Walking the carbon tightrope: Energy intensive industries in a carbon constrained world, report prepared for TUC, 2014, 44.
27 Fankhauser, S, "A Practitioners Guide to a Low-Carbon Economy: Lessons from the UK", Climate Policy, 2012, 12.
28 Such as in the paper and pulp, and food and drink sectors. BIS/DECC Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050; Cross-Sector Summary, 2015.
29 Allwood, J et al, "Material efficiency: providing material services with less material production", 7.

Examples of this line of thinking include:

- Better systems of reuse, remanufacturing, refurbishment and recycling;
- Better utilisation of waste;
- Product design for durability, easier repair and recovery of materials after use;
- Synergetic business relationships making better use of by-products and waste energy (industrial symbiosis);
- Circular economy models[30] which keep materials within the system of production and use, rather than discarding them;
- Innovative business models which deliver outcomes to consumers through means other than product ownership.

Such approaches face an inherent difficulty in trying to fit in to an existing system which has developed around the traditional, linear model of manufacturing. Evidence abounds that such models can deliver substantial economic and environmental benefits.[31] However no business operates in a vacuum, and new ways of doing things can often run contrary to established supply networks, infrastructure and consumer expectations. The question of how policy should seek to promote such measures within a complex system is far from straight-forward – yet it is an area which policy-makers can ill-afford to ignore.

The Role of Policy

The policy objectives which arise out of these observations require a multipronged approach: addressing barriers to wider adoption of known efficiency measures while also fostering an economic and social environment which is conducive to innovation, experimentation, new collaborative relationships and new, more sustainable ways of doing things. This report addresses this challenge through five key areas of focus for policymakers, which comprise the five core chapters of the report:

- Leadership;
- Resilience;
- Innovation;
- Collaboration; and
- System change

Although policy tools and approaches will be dealt with in greater detail in each of these sections, there are a number of core principles which ought to guide public policy formation in all of these areas:

1. Policy should be consistent as to its end, but flexible as to its means: Clear, consistent policy, backed by a credible and shared commitment amongst policy-makers to the end goal of sustainability, can provide certainty for private actors and encourage investment in efficiency measures and green

30 http://www.ellenmacarthurfoundation.org/circular-economy; RSA – The Great Recovery Project, Investigating the Role of Design in the Circular Economy, 2013.
31 McKinsey and Company/Ellen MacArthur Foundation, Towards the Circular Economy: Accelerating the scale-up across global supply chains, 2014; Preston, F, A Global Redesign? Shaping the Circular Economy, Chatham House, 2012.

innovation. However, the impact and interaction of different policy mixes is not always easy to predict in advance, and it should be taken as given that there will be unintended consequences accompanying policy measures. Government should therefore be unequivocal in its commitment to fostering a transition to a sustainable industrial economy, while also being flexible and reflective toward the measures it uses to help achieve this.

2. Policy should be coordinated: Sufficient market barriers to sustainability already exist without government adding to the challenge by having different spheres of policy working against one another. The division of policy-making functions and decentralisation of decision-making can allow for the development of specialised expertise and deeper linkages between public and private sector actors at the local level. A decentralised, more active policy approach to fostering sustainability also requires the development of policy-making *capacity* at all levels.[32] However, policy-making which is compartmentalised, both in focus and in structure, is likely to be an inadequate partner for the system-level change that is required for a sustainable industrial sector.

3. Policy should be conscious of the global dimension: The global nature of large sections of economic activity poses a significant challenge to policy-making at a national level. A policy approach which simply forces production elsewhere is counterproductive to environmental objectives (not to mention social and economic ones), particularly if the destination country imposes lower environmental standards than the UK. Carbon emissions and wasteful use of resources are no less damaging to the global system when they occur on the other side of the world. It is, however, easy to overstate the threat of 'carbon leakage', which in practice is likely to only apply to firms which have high decarbonisation costs in relation to output, and which face global competition.[33] For these industries in particular, the alignment of imposed costs and transitional support – at the EU level at least, if not the global should be a central consideration.

These principles presuppose that there is a role for government in shaping the outcomes of the market. Economic theory provides a number of arguments (and counter-arguments) to what can broadly be termed 'industrial policy', which underpin the analysis in this report, and are worth expounding from the outset.

32 Mazzucato, M, A mission-oriented approach to building the entrepreneurial state, Innovate UK, 2014, 17.
33 Fankhauser, S, "A Practitioners Guide to a Low-Carbon Economy: Lessons from the UK", Climate Policy, 2012, 11.

Economic Theory – Industrial Policy

It is hard to overstate the contribution of industrialisation to the level of material wellbeing now enjoyed by developed nations. Little wonder then that industry – its formation, expansion and retention within national boundaries – has been an issue of national importance and a focus for policy-makers as far back as Robert Walpole (Prime Minister 1721 – 1742) in the UK and Alexander Hamilton (Treasury Secretary 1789 – 1795) in the USA. For these leaders, and many others who sought to replicate the productive potential of the industrial revolution, industrial policy was seen as the ladder by which they, like the UK, would '[attain] the summit of greatness".[34]

A brief look at the economic importance of manufacturing illustrates why it has traditionally been central to the objectives of national policy around the world. Very few nations have reached 'developed' status other than through industrialisation – moving their workforce from farms and into factories.[35] Manufacturing has historically been the primary source of productivity gains for economies, and a key generator of new technologies and organisational forms, including those which have had significant benefits to other sectors of the economy.[36] Manufacturing is also intrinsically important for trade, as opposed to many service sector industries which require face-to face interaction and therefore do not easily cross national borders (haircuts being the classic example).

Modern connotations of industrial policy are much different, typically bringing to mind images of inefficient interventionism during the 1960s and 1970s: governments 'picking winners' through poorly targeted subsidies, and failed attempts to foster high-tech industries in the UK.[37] Alongside scepticism of the government's ability to improve on outcomes produced by market forces were concerns of 'regulatory capture'. This is the fear of policy decisions being based not on dispassionate assessments of national economic interests, but on interest-groups' ability to successfully lobby policy-makers. It was such concerns that underpinned the supply-side revolutions of the 1980s onward; specifically, the phasing out of subsidies and import protection, the deregulation of large parts of the economy, and pro-competition policies.[38] To the extent that government sought to promote manufacturing, it was through 'horizontal' means – such as education, national infrastructure

34 In the words of Prussian economic theorist Friedrich List, The National System of Political Economy, 1841.
35 Rodrik, D; 'No more Growth Miracles', Project Syndicate, 2012, available at http://www.project-syndicate.org/commentary/no-more-growth-miracles-by-dani-rodrik .
36 This includes agricultural machinery and pesticides, or inventory management techniques in retail stores - Chang, H Andreoni, A and Kuan, M; "International Industrial Policy Experiences and the Lessons for the UK", 2013, 11.
37 Crafts, N; "Creating Competitive Advantage: Policy Lessons from History", 2012, 8.
38 Crafts, N; "Creating Competitive Advantage: Policy Lessons from History", 2012, 9.

and support for science and innovation – rather than 'selective' assistance to individual sectors or firms.

Yet on some accounts, industrial policy in some form is inevitable. Chang, Andreoni and Kuan define it as "a policy that deliberately favours particular industries/sectors (or even firms) over others, against market signals, usually...to enhance efficiency and promote productivity growth, for the whole economy as well as for the targeting industries themselves".[39] Policy decisions such as the relative emphasis and funding between subjects within the education system, or where we invest in infrastructure and what type, can never be neutral between sectors of the economy which have such diverse requirements for these goods.

Such an understanding cuts across the horizontal/selective distinction, and has much in common with Karl Polanyi's understanding of markets as being *constituted* by states. What we might understand as the outcome of individual economic agents contracting with one another within a free market is, in fact, inevitably shaped by the boundaries which society has set for the market, and which are often taken for granted.

The challenges of the future that make a transition towards a sustainable industrial sector necessary, will not be met without the thoughtful application of a mix of policy mechanisms. This might involve relying primarily on the power of market competition in some areas while facilitating greater collaboration between competitors in others; coordinating consortia of different groups and organisations to look at the future resource needs of UK manufacturing, and how the economy as a whole can become more resilient to future shifts; or government working together with industry to help the development and diffusion of new, more sustainable ways of doing things. The state will have to take a more active role, while also being mindful that the existence of a market failure does not always imply a clear-cut and obvious policy intervention as a correction.

Justifications for Industrial Policy

The theoretical justifications for industrial policy are diverse and have varied in their prominence over time. At the root of the classical arguments for government intervention is the idea of market failure, which suggests that for all its productive potential, there are areas where the market does not work well. This includes a tendency to over- or under-produce certain goods in a way which is not ideal for society, or instances where players in the market lack the capability to coordinate, overcome risk or uncertainty, or take full advantage of areas of potential gain. This opens the door for policy to correct this failure in a way which allows society as a whole to benefit. Market failure theory is fundamental to much of what government does with regards to environmental regulations, funding research & development (R&D), building infrastructure and the provision of social services.

39 Chang, H Andreoni, A and Kuan, M; "International Industrial Policy Experiences and the Lessons for the UK", 2013, 9.

The most obvious form of market failure is that of externalities, the consequences of an economic activity which are shared or borne by society as a whole, not just those who generate them, and which are not reflected in the market price. Pollution from industrial processes is an obvious example of a negative externality. As the cost of pollution is imposed on society as a whole, and only partially falls on the party responsible for it, the market will tend to produce more than it would if the cost was solely borne by that producer. On a global scale, the same logic applies to climate change caused by the emission of greenhouse gasses, which the Stern Review described as a "market failure on the greatest scale the world has seen".[40]

Externalities can also be positive, such as knowledge from private R&D and skills training which 'spill over' into other sectors – these the market will tend to *under*-produce, because the producer does not capture the full benefit of his or her actions. New innovations have the potential to bring widespread benefits that are shared by society as a whole, meaning there is a good argument for governments to support greater R&D in cleaner technologies. A related concept to positive externalities is that of public goods, which everyone in society benefits from, but which no one is able to exclude others from. In such cases, individuals will have the incentive to 'free-ride' on others' efforts to provide or maintain this good, which will therefore tend to be under-provided. A clean environment, educated work force and basic research are all examples of public goods, which the state takes a significant role in providing beyond what would otherwise occur through the market.

Beyond Market Failures

While the classical arguments for addressing market failures underpin many 'horizontal' policy measures, which are often non-controversial, industrial policy which is more explicitly 'selective' relies on more complex systems-based accounts of innovation, diffusion and coordination. This approach focuses not just on actors within the economy, but also on the connections between them and the institutions (rules and norms) under which they operate.[41] Government inevitably plays a significant role in this system, and market failure theory on its own is an inadequate guide to the ways in which policy can influence the effective development, diffusion and utilisation of knowledge which might contribute to a more sustainable industrial system.

For instance, Mariana Mazzucato of the University of Sussex argues that while market failure theory is adequate for guiding policy which aims to 'patch-up' imperfections in already-existing market trajectories, "it is less useful when policy is needed to dynamically create and shape new markets".[42] This is particularly true for new technologies where there are high levels of risk and which require investment at a high level of capital intensity, something even venture capital has been unwilling to fund at sufficient levels.

40 Stern, N; Stern Review: The Economics of Climate Change, 2006, 25.
41 Crafts, N and Hughes, A; "Industrial Policy for the medium to long-term", 2013, 8.
42 Mazzucato, M "Beyond Market Failures: Shaping and Creating Markets for Innovation-Led Growth" in Mission Oriented Finance for Innovation, Policy Network, 2015, 149.

Transformative technologies such as the internet often take 15-20 years to mature to the stage of creating new industries. This level of patient funding is only likely to come from an infrastructure of supportive public institutions, interlinked with a strong network of private sector investors to capitalise on breakthroughs once the technology reaches the stage of commercialisation.[43] As Mazzucato has demonstrated, "every technology that makes the iPhone a 'smart' phone, was indeed picked and funded by government", including GPS, LCD displays and touchscreen technology.[44]

Yet the barriers to change are not just technological, but also behavioural and systemic. System failures can occur to inhibit shifts to new sustainable business models which require the reorganisation of infrastructure or the development of collaborations with new and unfamiliar partners. The diffusion of knowledge throughout the system can be undermined by weak connections between firms and other entities, and by the ability of different firms to absorb and take advantage of new sustainable approaches to production.[45]

> The 'Varieties of Capitalism' approach classifies the UK as a Liberal Market Economy (LME), characterised by certain complementary, interlinking institutions around corporate governance, education and training systems, inter-firm collaboration and labour markets. This approach suggests that such models tend toward more general and transferrable skills, market-based relationships and radical innovation, compared to the more coordinated alternative (Coordinated Market Economy [CME]), of which Germany is the archetypal case.[46]
>
> Many of the short-comings identified with LMEs – excessive short-termism in corporate decision-making and the provision of finance, a tendency not to incentivise long-term investment in sector-specific skills – are also likely to pose obstacles to the transition to a sustainable industrial system. These existing institutional structures, which are the result of many decades of cumulative interactions and policy decisions, naturally form the context of any future policy decisions. Yet such institutions should not be taken as given, and a key area of focus is the role of policy in facilitating a deep network of linkages between state, industry and 'intermediate' institutions (such as trade associations, unions and research/educational institutes).[47]

43 Majumdar, A, "Why We Need Public Endowments For Transformative Research", in Mission Oriented Finance for Innovation, Policy Network, 2015, 60.
44 Mazzucato, M, The Entrepreneurial State, 2013
45 Crafts, N and Hughes, A; "Industrial Policy for the medium to long-term", 2013, 15.
46 Hall, P and Soskice, D; "An Introduction to Varieties of Capitalism", in Varieties of Capitalism, 2001.
47 Chang, H Andreoni, A and Kuan, M; "International Industrial Policy Experiences and the Lessons for the UK", 2013, 15.

How should Industrial Policy be approached?

Although there is a strong theoretical argument for industrial policy, this does not mean that the design and implementation of that policy is always obvious or unproblematic. Much policy literature focuses on the many mechanisms which government might use to shape market outcomes, but equally important, according to Harvard economist Dani Rodrik, is the process through which such policies are formed. While its role in addressing market and system failures is often indispensable, government often has worse information than the private sector as to the source of market imperfections. It is therefore important that policy be formulated within an ongoing process of learning, exploration and reassessment between the public and private sector. This approach is termed '*embedded autonomy*', in which the flow of information into the policy-making process is facilitated by a broad network of private sector linkages, while at the same time ensuring that the state remains focused not on the particular interests of these private sector entities, but on the social objectives which will not be met by market outcomes alone.[48]

Government must also provide a clear direction for the formation of policy and for collaborative innovation. A sustainable industrial system should be a clearly articulated challenge for the sector as a whole to meet, both in terms of taking advantage of the opportunities for new and disruptive ways of meeting human needs, and of building resilience against future challenges related to sustainability.

A similar clarity must underpin the formulation of policy. Carlotta Perez of the London School of Economics argues that technological advances provide the potential for transformation, but the direction of that transformation is not predetermined. The state's role is to help grasp the rapidly rising opportunity within industrial sustainability, to shape market conditions in such a way as to enable investment opportunities in the direction of sustainability, and to foster the emergence of complementary industries, supply chains, skilled workers and consumers that reinforce this transformation.[49]

48 Rodrik, D; "Industrial Policy for the 21st century", 2004.
49 Perez, C; "Steering Economies toward the next Golden Age", in Mission-Oriented Finance for Innovation, Policy Network, 2015, 54.

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LEADERSHIP

The assertion that there are costless or near-costless measures[50] to improve energy and resource efficiency that have not been adopted by UK business seems rather odd from the perspective of neo-classical economics.

If these measures are worth doing, wouldn't they have been done long ago?

Yet firm-level performance on labour productivity varies wildly beyond what would be explained by levels of capital investment, and the evidence suggests that management practices account for a significant proportion of this.[51] As discussed previously, it appears that the efficiency with which companies use energy and resources is equally divergent – a gap which carries with it far greater implications from a sustainability perspective. Hence, there is good reason for policy-makers to consider how behavioural and organisational barriers to the wider incorporation of sustainability into business practices might be overcome.

Why would self-interested business not take up efficiency measures which economic analysis suggests ought rationally to be undertaken? The most straight-forward answer to this questions is that economic decisions are (generally) not made by computers, but by humans who are enmeshed in a complex array of institutions, social connections and organisational hierarchies that shape and constraint their decision-making. Additionally, and as behavioural economist Daniel Kahneman has demonstrated, there is a myriad of ways in which we are not perfectly logical creatures at the best of times, and frequently make decisions influenced by split-second impressions, excessive aversion to loss and cognitive bias. In this context, the collective failure to realise efficiency savings becomes somewhat more comprehensible.[52]

50 As is suggested by numerous cost curve analyses; for example tern, N; The Stern Review: The Economics of Climate Change, 2006; IEA; Summing up the Parts, 2011 and DECC, Energy Efficiency Opportunity in the UK, 2012.
51 Bloom, N and Van Reenen, J, "Why do management practices differ across firms and countries?" Journal of Economic Perspectives, 24: 1, Winter 2010, 203–224.
52 Kahneman, D, Thinking Fast and Slow, 2011.

The POLFREE project (Policy Options for a Resource Efficient Economy) suggests that businesses' progress on efficiency is hampered by a 'web of constraints' which includes inter-linking institutional, market, organisational, behavioural and technological barriers.[53] Policy-makers are understandably more comfortable dealing with factors external to the firm, rather than internal. However, it remains true that the most effective way of addressing the challenges of sustainability is for companies to internalise those challenges as part of their day-to-day business and long-term strategic planning.

> Johnson Tiles is a ceramics company founded in Stoke-on-Trent in 1901. Its floor and wall tiles contain recycled ceramic waste collected from other local manufacturers. This recycling system results in approximately 20, 000 tonnes of waste being saved from landfill every year, and has also allowed the company to make significant savings in terms of energy and water usage and carbon emissions. Their broader approach to sustainability includes working with suppliers to ensure they are minimising their environmental impacts, switching to inkjet printing and investing in new kilns to reduce flue gas emissions.[54] The characteristics of Johnson Tiles' approach, including a top-down emphasis on the benefits of sustainability and commitment to ongoing improvements year on year, should be highlighted and championed across the wider manufacturing sector.

Knowledge Gap

A number of submissions to this inquiry identified a gap in management awareness of the benefits of energy and material efficiency. While information on these is often freely available, this does not mean it is readily accessible and implementable for all companies equally. A key insight into this puzzle of unrealised efficiency gains is that measures which may seem costless – either in terms of net present value (NPV), or in a literal sense, such as shutting down machinery when not in use – are not costless from the perspective of management time and attention. Management 'bandwidth' is a scarce resource and sustainability measures are competing internally with other projects or courses of action in a way which is not purely based on economic returns.

53 Bastein, T. et al, Business Barriers to the uptake of Resource Efficiency Measures, POLFREE, 2014.
54 http://www.efficientenergy.net/n/102613.htm

Survey evidence from EEF suggests that over half of UK manufacturers have not considered remanufacturing, while a third have not considered selling services as well as products. Among those that have considered such measures, the uptake is remarkably high, with relatively few companies reporting that they had considered but rejected these approaches. There is also a clear pattern of smaller companies being less likely to engage in these practices.[55]

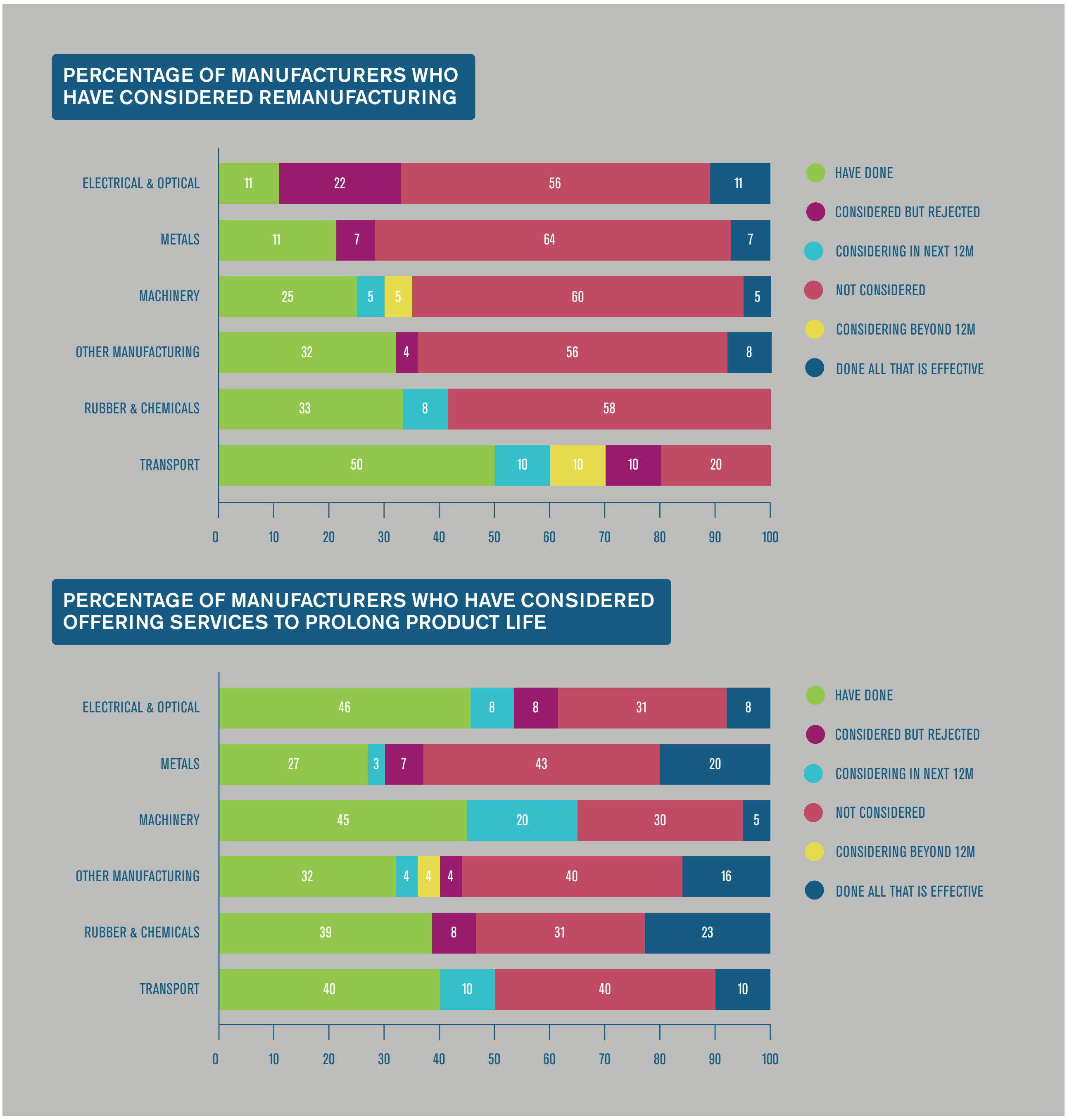

Fig. 6 Source: Adapted from Baker, S, "Systems Innovation In Industry: Trends Across Sectors", presentation to Conference of the Centre for Industrial Sustainability , July 2015

55 Electrical and Optical manufacturers are one exception to the high uptake of remanufacturing, with 22% having considered but rejected the option. Baker, S, Systems Innovation In Industry: Trends Across Sectors, presentation to Conference of the Centre for Industrial Sustainability , July 2015.

Special attention is warranted to the particular barriers small and medium enterprises (SMEs) face with regards to awareness of sustainable modes of manufacturing. Such businesses can face pressure from larger entities within their supply chain (often concerned with the overall environmental footprint of their products) to make improvements on environmental measures. Yet SMEs often lack the internal skills to take advantage of opportunities outside of their core business, or the scale to make external assistance (for instance, through a consultant) worthwhile. Schumpeter's theory of 'creative destruction' may have been correct in assuming that radical change would come from smaller, more nimble new entrants to an industry; however, many established smaller firms seem to find experimentation and innovation difficult when it comes to sustainability.

The EU-funded PrISM programme worked with 120 SMEs in the East of England between 2012 and 2015 and observed both a lack of appreciation for the potential economic benefits of incremental efficiency gains, and an acute sensitivity to upfront costs. A modest grant to fund electricity monitoring technology for 20 of these companies paid back within 6 months on average through cost savings and, more importantly, seems to have triggered an ongoing commitment amongst many of the companies involved to continue to improve efficiency under their own steam, once the benefits of sustainability were evident to them.[56]

56 Practical and Innovative Solutions for Manufacturing Sustainability (PrISM); Athanassopoulou, N "Reducing costs and carbon footprints: PrISMS case studies from SMEs", Presentation to Conference of the Centre for Industrial Sustainability, July 2015.

Leadership amongst UK Managers

What can analysis of the leadership capabilities of UK managers tell us about how policy should look to promote sustainability? The World Management Survey (WMS) found that the UK ranked mid-table in a cross-country assessment of management practices – ahead of developing economies and southern Europe but lagging behind the US, Germany, Japan, Canada and Sweden.[57] Its analysis of factors that tend to influence management performance emphasises that:

- Skills are crucial for managers and non-managers alike: the UK rates particularly poorly in this area, with a clear shortage of degree-holders in both categories;

- Market competition is associated with better management practices: this seems particularly true of global competition, where multi-national corporations generally outperform domestic firms.

- Firm ownership: Private equity-owned companies outperform family- and government-owned firms. Founder/CEO firms tend to be the worst performing on average, suggesting that there is a shift in the required management skills as companies move from being a start-up to a medium size business.[58]

Many of the good management practices emphasised in the WMS are likely to be important to a more sustainable industrial system – awareness and ability to adapt to new practices, long-term strategic thinking, and effective targets and tracking of performance.[59]

However, it is worth questioning whether the qualities of good management measured by the WMS overlap entirely with those which are required from the perspective of a more sustainable industrial sector. While greater management competencies might improve economic productivity, it is not clear that this will result in better environmental outcomes; for instance, if capital is used more intensively and energy and resource use increases. Thankfully, economist Nick Bloom and others found that good management practices are strongly associated with less energy- and material-intensive production processes, while still being more productive overall.[60] This connection could be reinforced by ensuring that sustainability is entrenched in educational programmes which are likely to be of relevance to managers within manufacturing, particularly engineering and business degrees.

57 World Management Survey, "Manufacturing Report: 2011"; http://worldmanagementsurvey.org/wp-content/images/2011/11/WMS_report2011_mfg_ENGLISH.pdf

58 The minimum number of employees for companies in the sample was 100. Homkes, R, What role will leadership play in driving the future of UK manufacturing?, 2014.

59 Homkes, R; "What role will leadership play in driving the future of UK manufacturing?", 2014, 37.

60 Bloom, N el al, "Modern Management: Good for the Environment or Just Hot Air?", The Economic Journal, 120, 2010.

Uncertainty and Organisational Barriers

It has been observed that energy efficiency measures often require high rates of return before businesses will invest in them, relative to other projects – which has been termed the 'energy efficiency paradox'.[61] 'Bounded rationality' – the limitations on resources available for accessing and interpreting information – is commonly cited as a barrier for such measures not being undertaken. Additionally, 'hidden costs' such as disruptions to production or staff time required to implement a measure, are felt to undermine the economic case for efficiency improvements.[62] Uncertainty can be exacerbated by factors external to the firm, including macro-economic conditions, policy fluctuations and the maturity of the technology involved in a project. Yet even accounting for these factors, it seems that many measures with high rates of return or little or no cost are not utilised[63] and the development of greater skills in this area appears to suffer from an assumption that the resulting solutions will be capital intensive.

The high hurdle rates businesses impose on efficiency measures in deciding whether to make an investment seem at best tentatively-connected to objective economic calculations. Rather than accurately reflecting the cost of capital and the perceived risk of a project, hurdle rates and payback periods[64] also act as means to structure firm decision-making within large complex organisations, or as useful 'rules of thumb' for organisations with fewer resources.[65] Furthermore, assessments of profitability (such as based on NPV) tend to occur once the proposal already has support, rather than being information on hand from the outset, meaning that there also needs to be a focus on how sustainability measures are championed and communicated within the firm.[66]

The structure of the firm appears to play a significant role in whether a company makes sustainability a priority. Energy efficiency tends to be the responsibility of middle, rather than senior management. This means that sustainability is less likely to be a key consideration in the strategic direction of the company, and also that senior management are less likely to be aware of the extent of the potential gains from efficiency measures.[67] A structure whereby the energy or efficiency manager is situated close to the Chief Executive Officer (CEO) in the organisation's hierarchy seems to be important in the implementation of sustainability measures. Yet the effectiveness of that communication is also likely to be fundamental to the decision-making process, which may open opportunities for policy to assist the relevant managers to make good business cases within their own organisations. Many companies which are recognised as leaders in sustainability have had a strong sustainability philosophy implemented from the top down – which can help generate a firm-wide focus on incremental efficiency gains, and ideas arising from the shop floor.

61 DECC, What are the factors influencing energy behaviours and decision-making in the non-domestic sector?, 2012, 7.
62 Baruah, P et al, "Firm Level Perspective of Energy Efficiency Barriers and Drivers in UK Industry – Indications from an Online Survey", BEHAVE Energy Conference, 2014.
63 Cooremans, C, "Investment in Energy Efficiency: Do the Characteristics of Investment Matter?", 2012.
64 Hurdle rates are the required rate of return on an investment: pay-back periods are the period of time in which the upfront cost of an investment is recouped from its returns.
65 Cooremans, C, "Investment in Energy Efficiency: Do the Characteristics of Investment Matter?", 2012.
66 DECC, "What are the Factors influencing energy behaviours and decision-making in the non-domestic sector?", 2012, 23.
67 DECC, "What are the Factors influencing energy behaviours and decision-making in the non-domestic sector?", 2012, 20.

Short-termism

A lack of long-term focus among businesses also seems to be a factor stymying sustainability measures. Pay-back periods of no more than two years on investments seem to be common, which excludes many efficiency and low-carbon investments which might have returns which are more heavily back-loaded. Such investments are sensitive to changes in discount rates – the extent to which current benefits are preferred over future benefits, and future values are 'discounted' over time to reflect this deferred gratification. Andy Haldane of the Bank of England has noted what seems to be excessively myopic focus on the part of investors and executives, which results in 'rational' investments not going ahead. A 2005 survey of executives found that shareholder expectations would drive them to reject a profitable (positive-NPV) investment which would lower quarterly profits below what was anticipated, while a 2011 PwC survey of FTSE-100 and FTSE-250 executives found a majority would prefer a £250,000 return tomorrow to a £450,000 return in 3 years' time.[68] This inclination has very broad implications for long-term economic performance, but from a sustainability point of view, the concern must be that so-called 'quarterly capitalism' is leading to economically, socially and environmentally beneficial proposals being tossed in the rubbish bin.

Is there a clear explanation for this short-termism which might guide policy-making on industrial sustainability? Submissions to the inquiry reported a greater degree of risk aversion amongst manufacturing businesses due to an uncertain economic climate, though this risk aversion was also identified as an issue over the longer-term due to offshoring and the diminishing weight of manufacturing in the economy. This is consistent with Haldane's findings of a shift to a statistically significant level of short-termism within the UK manufacturing sector from the mid-1980s to mid-1990s.[69]

Much attention has been focused on the rise of the finance sector at the expense of the real economy within developed nations, usually with reference to the financial sector's shift toward trading within itself and lending for asset purchases rather than business expansion.[70] However, the underappreciated aspect of this 'financialisation' is what has happened within the real economy itself. Anglo-Saxon liberal market economies that have increasingly prioritised the philosophy of 'maximising shareholder value' have tended to perform poorly with regards to patient reinvestment of profits, nurturing of skills and incremental innovation.[71] The prevalence of corporate share buy-backs, designed to boost share prices, at the expense of long-term investment amounts to firms 'eating themselves', according to a recent interview with Haldane.[72]

68 Haldane, A and Davies R; "The Short Long", Speech, May 2011, http://www.bankofengland.co.uk/archive/Documents/historicpubs/speeches/2011/speech495.pdf
69 Haldane, A and Davies R; "The Short Long", 2011.
70 Turner, A, "The Social Value of Finance: Problems and Solutions", in Mission-Oriented Finance for Innovation, Policy Network, 2015.
71 Lazonick, W and O'Sullivan, M "Maximising Shareholder Value: a New Ideology for Corporate Governance", Economy and Society, 29:1, 2000.
72 http://www.theguardian.com/business/2015/jul/25/shareholders-receive-too-much-money-from-business-says-chief-economist

This approach to business affects not only the company in question, but also its wider value network. Manufacturing unavoidably operates in an interdependent system of competencies and specialisations, which spreads well beyond a single entity. This includes suppliers, clients, workers, educational providers and related service systems.[73] The concern must be that the deficit in long-term focus and investment amongst companies leads to a withering of this inter-reliant ecosystem, and constrains the ability of other, smaller companies to grow and flourish.

The interaction between a shift toward more sustainable manufacturing and the typical investment cycle of manufacturers, poses some difficult questions. Equipment incorporating new technology tends to be more energy efficient than existing capital. However, the lifetime of existing capital imposes an effective limit on the rate at which the low-carbon plant and machinery will be purchased. Carbon-intensive equipment which has a lifetime of 25 years means that emissions reductions as a result of this investment will amount to 4% maximum, unless existing capital is to be scrapped ahead of time.[74] Investment decisions, however, are not made through recurring calendar reminders, but in response to perceived market conditions. Continued 'sweating' of assets during economic downturns, or the substitution of cheaper labour for capital, pushes back the rate at which low-carbon gains will be made through the investment cycle.

73 Chang, H Andreoni, A and Kuan, M; "International Industrial Policy Experiences and the Lessons for the UK", 2013, 14.
74 Fankhauser, S, "A Practitioners Guide to a Low-Carbon Economy: Lessons from the UK", Climate Policy, 2012, 4.

The Question of Finance

Shortages of capital are a commonly cited barrier to investment in efficiency measures, and is one of the most frequently-mentioned factors by firms themselves.[75] However, care is warranted in how we interpret this. UK non-financial corporations have been net-lenders since 2002, with the sector as a whole having large cash surpluses. With regards to many larger corporations at least, any failure to invest in efficiency measures is likely to be more a matter of internal decision-making processes and short-termism than actual shortages of finance. In such cases where internal finance is readily available, policy measures to increase the external supply of finance are unlikely to make much difference.

Where shortages of finance are more likely to be an issue is among SMEs. Through a higher degree of perceived-risk and lesser access to collateral, greater risk-aversion in the banking sector following the global financial crisis is likely to have a greater effect on SMEs than on larger firms. However, a deeper factor at play here is the pattern among liberal market economies of not relying on bank-financing.[76] Reluctance to take on additional 'gearing' – the ratio of equity to loan finance – for the company as a whole may result in efficiency measures being foregone, even when the required capital investment is relatively low.[77] Features of the institutional architecture of coordinated market economies, such as German local savings banks (Sparkassen), provide dedicated long-term finance to SMEs which allow investment in incremental efficiency gains with greater certainty.

Addressing this challenge should begin with the public institutions already tasked with providing financial support. The Green Investment Bank (GIB), having been criticised from the outset for its modest scale and lack of borrowing powers,[78] was still left with a considerable portion of its funds which could have been put to use in manufacturing. This suggests that work with both SMEs and the GIB on building business cases for efficiency measures (for internal firm purposes, as well the GIB's) could allow firms that do have capital shortages to make use of the funds available. The news as of June 2015 that the GIB is to be partially-privatised[79] adds to the uncertainty around the provision of patient capital to green infrastructure, efficiency measures and the diffusion of new technologies. It is unclear why a GIB backed by private finance would not be subject to the same shortcomings which made it necessary in the first place.

75 Baruah, P et al, "Firm Level Perspective of Energy Efficiency Barriers and Drivers in UK Industry – Indications from an Online Survey", BEHAVE Energy Conference, 2014.
76 Hughes, A, "Short-termism, impatient capital and finance for manufacturing innovation in the UK", 2013.
77 Sorrell, S et al, "Barriers to industrial energy efficiency: A literature review", UNIDO, 2011, 28.
78 Ekins, P et al, Greening the Recovery: the report of the UCL Green Economy Policy Commission, UCL, 2014, 128.
79 "Green Investment Bank to be part-privatised", BBC News, 25 June 2015, available at http://www.bbc.co.uk/news/business-33263710

A Vision from Government

Policy-makers quickly learn that there are limits on how much they can influence business decisions with words alone. Nonetheless, the tone which government sets through its actions and public pronouncement can send clear signals on policy-makers' commitment to sustainable manufacturing, and help to shape business expectations. As companies and their consumers begin to pay more attention to the overall environmental impact of products and industrial processes, the collective sense of whether the UK is looking to be a leader on sustainability is likely to increasingly affect decisions on inward investment and innovation.

> This inquiry heard evidence from AkzoNobel, a chemical and coatings manufacturer headquartered in the Netherlands, that slow progress on grid-decarbonisation was a major barrier to the company meeting its own sustainability targets, and that it was now making decisions on suppliers based on their carbon footprint. UK manufacturers, and the UK as a whole, risk losing valuable business if other countries are seen as being more proactive in promoting long-term sustainable thinking.

In September 2015, the Director-General of the Confederation of British Industry, John Cridland, warned that 'mixed messages' in the form of shifts in climate change policies "send a worrying signal about the UK as a place for low-carbon investment".[80] In 2012, GE Energy cancelled over £100m of investment in a UK wind turbine factory, citing "current uncertainty surrounding the government's renewable energy policy".[81] While there are many obstacles to business sector leadership on sustainable manufacturing, government cannot afford to be adding further barriers to green investment by projecting equivocation on its commitment to sustainability.

80 Cridland, J, "What a good climate deal will mean for Britain and the world", speech to BeyondParis, 22 September 2015, available at http://news.cbi.org.uk/news/what-a-good-climate-deal-will-mean-for-britain-and-the-world/
81 http://www.eaem.co.uk/news/cameron-cancels-pro-renewables-speech-industry-dismay

Policy Recommendations:

Recommendation 1

The government should promote energy efficiency measures through the provision of low-interest loans, repaid through subsequent savings from efficiency gains: this will help reduce uncertainty around efficiency measures through the public sector effectively taking on the perceived investment risk. Qualifying efficiency measures should be tied to Energy Savings Opportunity Scheme (ESOS) audits, which should also be expanded to SMEs (with the cost of the audit able to be tied and repaid through the loan scheme). This funding mechanism is similar to the model of the Green Deal home energy-efficiency scheme. To avoid the shortcomings of that scheme, finance should be made available at low-interest or interest-free levels, rather than having the positive externalities of greater efficiency be undermined by providing finance at commercial rates.

Recommendation 2

Business expenditure on efficiency measures which build national resilience should be tax-deductible, expanding the R&D tax credit into a resilience, research and development (RR&D) tax credit: like R&D, spending on energy efficiency entails benefits for the rest of society (positive externalities). R&D tax credits are a form of reporting that businesses are incentivised to do, and the benefits of the scheme can result in firm processes being structured around them. Expanding this scheme to include energy- and resource-efficiency will make these measures more central to management attention. This could be an alternative scheme to recommendation 1, or designed to work in conjunction with it.

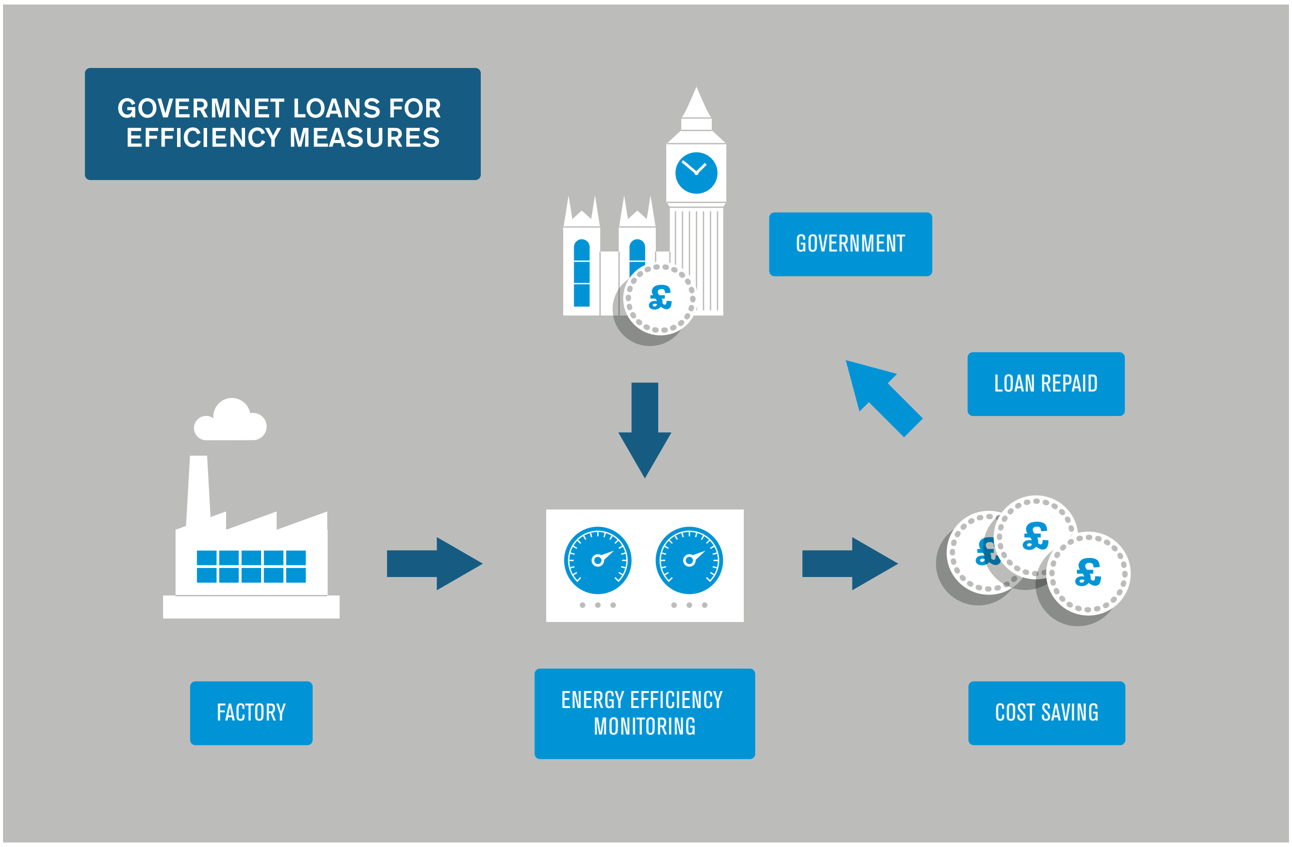

Fig. 7 "Recommendation 1: Government loans for Efficiency Measures"

Recommendation 3

Carbon reduction schemes should be redesigned to force top management attention on to savings opportunities through revisiting the Carbon Reduction Commitment (CRC): the Carbon Reduction Commitment (CRC) scheme[82] was applied to energy-intensive industries not covered by the emissions trading scheme from 2010. It initially included provisions for publically-reported league tables of firm performance, rebates to the best performers, and requirements that top management sign off on performance reports. However, these more innovative measures were dropped from May 2013 onward, leaving the scheme as mainly another carbon pricing mechanism. This approach should be revisited and combined with the climate change levy, with the benchmarking and rebate performance incentive measures expanded across the whole scheme. Publication of league tables would help narrow the 'knowledge gap' around efficiency measures, and provide consumers with greater information on the products they purchase.

Recommendation 4

Measures to decrease the knowledge gap on energy and resource efficiency, such as data sharing and 'sustainability champions' within the firm hierarchy, should be promoted. drawing attention to companies' relative standings in terms of efficiency will help close the knowledge gap. Additionally, efforts to encourage Chief Sustainability Officers or 'sustainability champions' within firms, sitting within top-management or reporting directly to the CEO, would make sustainable measures a management priority for a greater number of firms. These measures should be promoted and facilitated by intermediary institutions such as trade associations.

82 Later renamed the CRC energy efficiency scheme

Recommendation 5

Greater incentives for capital investment in low-carbon plant and machinery should be prioritised over cuts to corporate taxation: this would help bring forward new investments, and would also mitigate short-termism in corporate decision-making and encourage long-term investment. The existing Enhanced Capital Allowances (ECA) scheme, which allows investment is certain energy efficient machinery to be offset against taxable income, should be broadened. The Annual Investment Allowance (AIA), which was pegged at £200,000 during the 2015 summer budget, should be tied to the carbon budgets set by the Committee for Climate Change to discourage 'lock-in' of long-life, carbon-intensive investments.

Recommendation 6

Sustainability should be entrenched across the UK's education system, particularly in engineering and management courses, and measures to improve management skills among UK executives should be promoted: evidence suggests that good management skills correspond with better environmental performance at firm level, and that the number of degree holders at management level is a notable weakness of the UK. Measures to support post-graduate and part-time study[83] by executives might therefore result in better economic and environmental outcomes. This relationship should be reinforced by ensuring that sustainability is a key focus of higher education courses which are of most relevance to manufacturing – particularly engineering and business courses.

83 For a more comprehensive analysis of existing barriers, see the Higher Education Commission's report, *Too Good to Fail: The Financial Sustainability of Higher Education in England*, 2014

2

RESILIENCE

Known ecological limitations require a transition to a manufacturing sector which places much less of a burden on the natural environment than the practices and stock of capital inherited from previous generations.

Yet future challenges arise not just from the unsustainability of a business-as-usual approach, but from disruptions of an economic, political, social or technological nature which are often unpredictable, and beyond our direct control. Future trends around demographic shifts, climate change-related events and material shortages are likely to have a complex impact on national and global systems. Even harder to predict is the interrelated impact of these trends; how they will exacerbate or feedback upon one another.[84]

There is a tendency among observers of the UK economy to focus on mistakes and missed opportunities of the past; a pastime which led renowned US economist Robert Solow to quip: "Every discussion among economists of the relatively slow growth of the British economy compared with the continental economies ends up in a blaze of amateur sociology". There are undoubtedly lessons which can (and have) been learned from history. However, an excessive focus on avoiding a repeat of previous mistakes is not enough to secure a lasting and vibrant manufacturing sector if the challenges of the future are different from those of the past.

An industrial system which is resilient to future shocks is a prerequisite of a sustainable economy. An adaptive and flexible manufacturing sector can not only insulate itself from disruptions in the availability of key resources and inputs, but can also provide a ballast for the general economy in terms of economic activity and innovative ways of meeting society's needs. There is a pressing need for policy-makers and industry to work together to improve the resilience of the economy, in areas such as material and energy security, critical resources, and decarbonisation.

84 Tennant, M, "Sustainability and Manufacturing", 2013, 6.

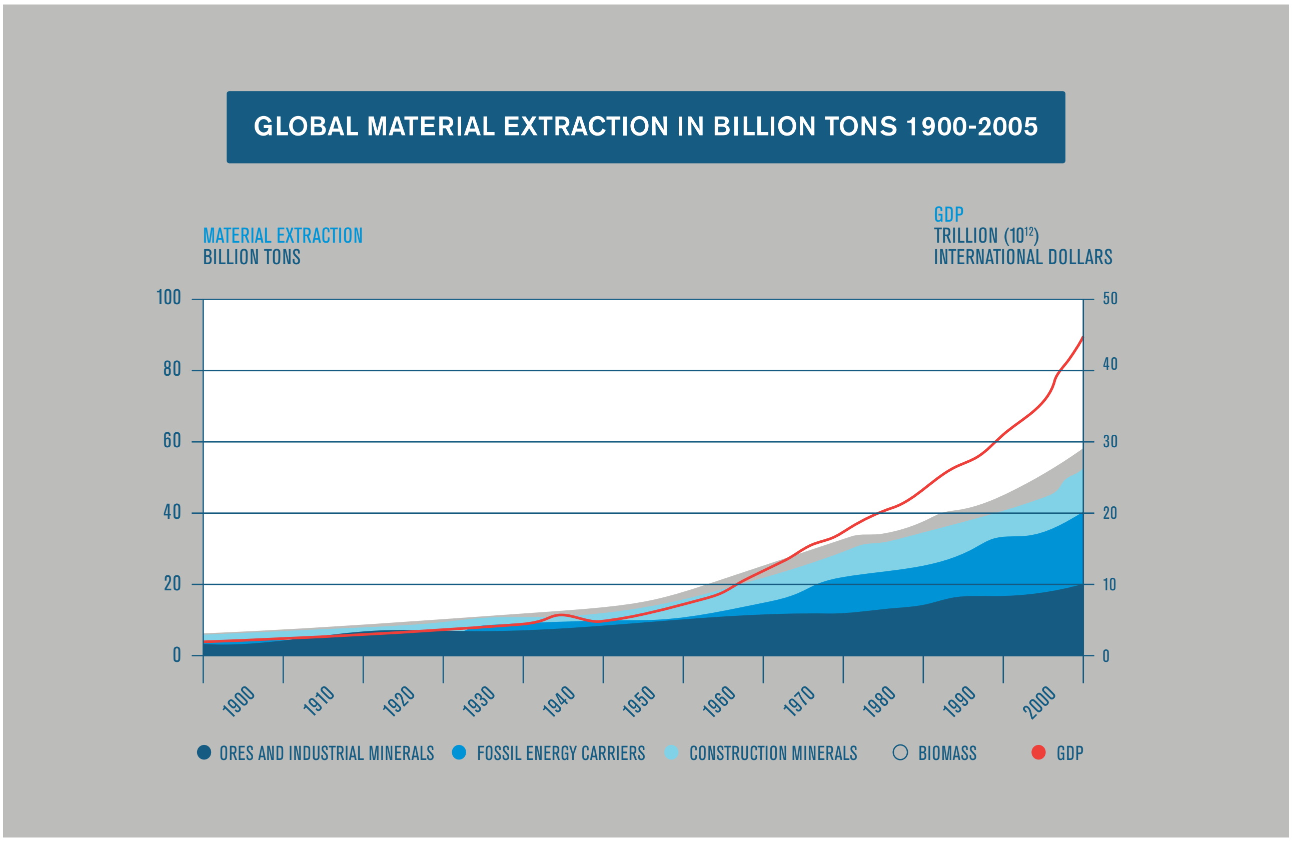

Fig. 8 "Global Material Extraction in Billion tons 1900-2005"
Source: UNEP, *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth, 2011*

Material Security and Volatility

The fact that the UK is an island nation has meant that it has relied on external sources of raw material inputs since world trade was in its infancy. Today, the EU remains the region of the world most reliant on the rest of the world for its raw materials.[85] The continued economic emergence of the developing world promises increases in material living standards for some of the world's poorest citizens, but also poses major challenges for the supply of raw materials for countries such as the UK.

Advanced countries use much more material per capita than the world average – approximately 60% more. The UK's material use per capita is among the lowest in the OECD, but that is true of other resource-poor and densely-populated nations. This is in part a consequence of off-shoring, which results in the UK importing finished goods which weigh much less than the raw materials used to make them.[86]A similar pattern of 'exporting' our overall environmental impact is evident in carbon emissions: while the UK's emissions from production have fallen since 1990, consumption emissions have seen no improvement over the same period – and were in fact increasing until the contraction of economic activity following the global financial crisis.[87]

85 Parker, D; *The Future Impact of Materials Security on the UK Manufacturing Industry*, 2013, 5.
86 OECD, The Material Basis of the Global Economy, 2015, 80.
87 Martin, R et al, Energy and the Environment: a cold climate for climate change policies?, CEP, 2015.

Industrialisation – the shift of a country's workforce from agriculture to industry – results in countries using much more non-renewable resources than renewable. Non-renewable resources such as construction materials, fossil fuels and metals now represent over two-thirds of total material extraction across the world, having accounted for around a quarter 100 years ago.[88] Population growth inevitably slows with continued economic development (and has been happening in both China and India), but the global population is still projected to reach over 9.5 billion by 2050, which could result in a tripling of global resource use.[89] Similarly troubling projections have been made for the increased global demand of water (an increase of 55% between 2000 and 2050) and for increased competition for land.[90] Given these trends, the continued ability of UK manufacturers to access materials and other inputs as readily as they have done cannot be taken for granted.

There are relatively few resources for which absolute depletion is an issue. The true risk for most materials is increased competition for resources and price volatility (through both demand growth and the exhaustion of more easily accessible supplies) and disruption to supply chains arising from extreme weather events or geopolitical unrest. These concerns are mirrored in the views of UK businesses. A 2012 survey by EEF the manufacturers' organisation found that access to raw materials was considered a business risk by 80% of senior manufacturing executives, while one in three considered it their top risk.[91]

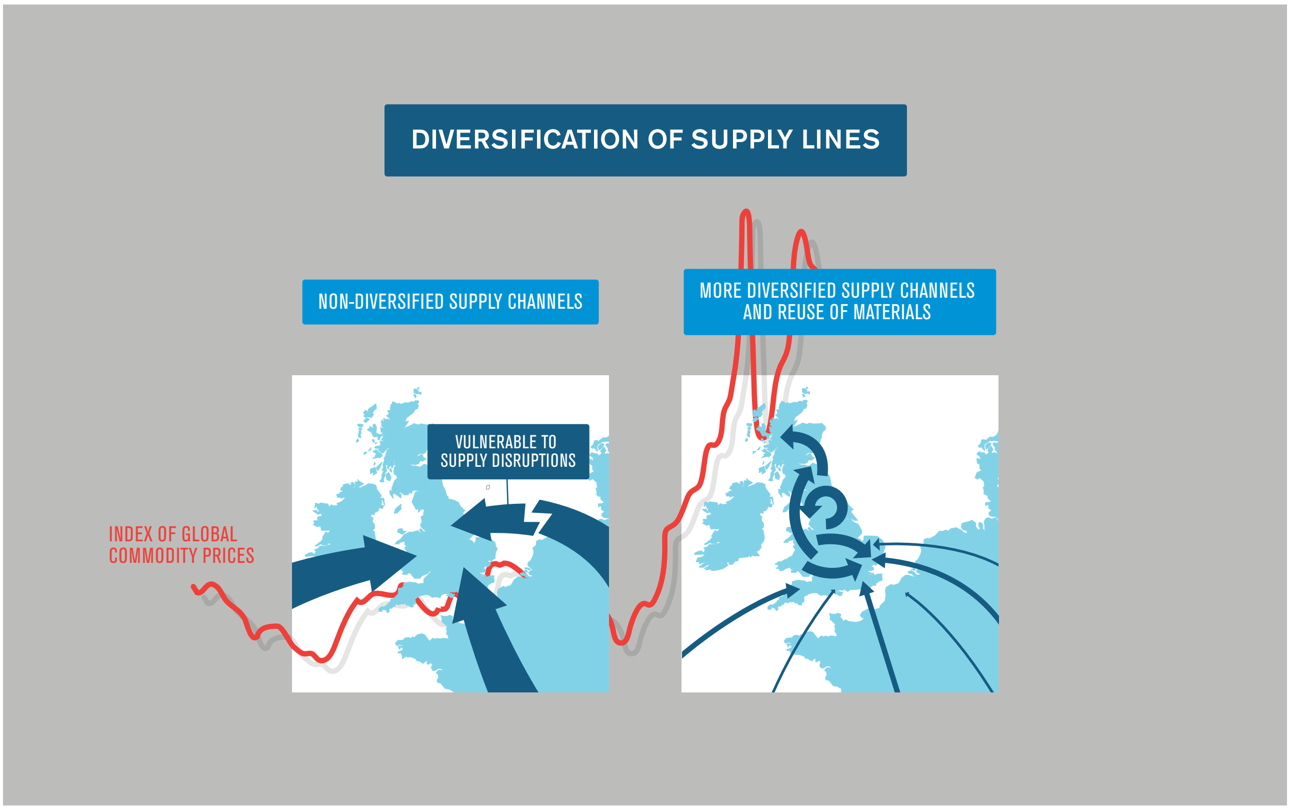

Fig. 9 "Diversification of Supply Lines"
Source: Commodity price trend line from McKinsey Global Institute Commodity Price Index, 1980-2014

88 OECD, *The Material Basis of the Global Economy*, 2015, 64.
89 UNEP, *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth*, 2011.
90 Government Office for Science; The Future of Manufacturing, 2013, 155.
91 EEF Survey – Available at http://www.eef.org.uk/about-eef/media-news-and-insights/media-releases/2012/aug/government-must-take-stronger-action-over-looming-raw-material-shortage

As globalisation has deepened the interconnectedness of economic relations across national boundaries, it has also amplified the degree to which shocks in other parts of the world reverberate within the UK. The potential impact of supply chain volatility was seen during the 2011 Fukushima disaster in Japan. The disruption in the supply of key automobile components resulted in a halving of production in some UK automobile factories during mid-2011, and the loss of some 22,000 cars during the year.[92] Trends in organisational practices toward lean or 'just in time' production have resulted in lower inventories, and greater vulnerability to shocks within global production networks.[93] The increased risk of extreme weather events, which can damage infrastructure, and disrupt the supply of materials, raises the importance of measures which allow manufacturers to mitigate and adapt to unpredictable future challenges.[94] This might include much greater collaboration in the face of severe supply disruptions, as occurred in Japan following the Fukushima disaster – for instance, plans to stagger production shifts and working days to relieve pressure on the energy system.

Fundamental approaches to building resilience in the use and sourcing of vulnerable inputs include:

- Greater efficiency: the barriers to greater efficiency have been discussed in Section 1 of this report. However, greater understanding of the risks associated with material security can help to shift efficiency measures from being an environmental or purely economic matter, to being a strategic consideration for an increasing number of firms.

- Better management and diversification of supply chains: this includes better inventory management, collaboration across supply chains, and localising/diversifying supply sources.[95]

- Light-weight or longer-life materials: estimates suggest that designing for lighter-weight products, prioritising minimal use rather than cost reduction, might save one third of material use.[96] Product redesign can contribute to slowing down material consumption through greater durability or easier replacement of critical components.[97] However, whatever benefits light-weight materials bring, must also be balanced against the difficulty they can cause for re-use, where they have trouble retaining their value.

- Material substitution: this includes replacing non-renewable with renewable materials in order to reduce pressure on finite resources, or generating innovative new materials.[98]

- Increased recycling and waste-minimisation: despite the established status of lean manufacturing and other waste-minimising approaches, analysis shows that yield losses across supply chains are still considerable in areas such as blanking and trimming of sheet metal.[99]

92 Pike, A et al, How does Manufacturing contribute to UK Resilience? 2013, 30.
93 Ibid
94 Tennant, M, "Sustainability and Manufacturing", 2013, 13.
95 EEF, *Be Prepared: Monitoring Supply Chains; Maximising Resilience*; 2012, 11.
96 Allwood, J et al; "Material Efficiency: Providing Material Services with less Material Production", Phil Trans R Soc A, 2013, 5.
97 Ibid
98 Tennant, M, *Sustainability and Manufacturing*, 2013, 23.
99 Allwood, J et al; "Material Efficiency: Providing Material Services with less Material Production", Phil Trans R Soc A, 2013, 5.

Improving material efficiency also has flow on effects toward reducing global energy use and carbon emissions upstream, as well as local benefits through less waste-processing and associated energy use.

Critical Raw Materials

Particular concern for resource security focuses around critical raw materials (CRMs), which are important to high-tech and strategic manufacturing activities. In 2014 the European Commission published an updated list of 20 CRMs from a European perspective, which are selected not just on the basis of economic importance and scarcity, but also on the risks associated with their supply.[100] China's decision in 2010 to restrict the export of rare earth elements[101] – of which it produces 97% of global supply – brought the issue of critical materials to the forefront of many countries' minds in terms of strategic economic interest and national security. These export quotas were lifted in January 2015 following a challenge at the World Trade Organisation. However, the prospect that access to other materials will be determined by national preference rather than market forces represents an area of significant uncertainty for UK industry and policy-makers.

Criticality of particular resources depends on a number of factors, including the potential for geopolitical unrest, diversity of suppliers and the ease of recovery of post-consumer material. For instance, the Democratic Republic of Congo produces 40% of the global supply of cobalt, which is used in batteries, alloys and catalysts.[102] End-of-life cobalt is recycled at a rate of 68%. Conversely, tantalum (which is an important input for the aerospace industry) has a more diverse range of supply sources, but is much more difficult to recycle from post-consumer engines and electronic scrap.[103]

CRMs are often used in low-carbon technology, meaning that supply shortages and disruptions may affect the UK's efforts at decarbonisation. Wind turbines rely on neodymium iron boron magnets, which contain the rare earth element neodymium. The pressing need to continue to cut carbon emissions could also put low-carbon industries in competition with other key manufacturing industries for the UK. For example, hydrogen fuel cells use platinum group metals (PGMs) as a catalyst. Increased demand for PGMs, however, could disrupt the automobile industry, which makes use of them in catalytic converters.[104] Like rare earth elements, the supply of PGMs is heavily concentrated. South Africa is the world's biggest producer, followed by Russia. Hence they are regarded as having a high supply risk.

Assessing the impact which CRMs might have on UK manufacturing is far from straight-forward, as it relies not only on a constant evaluation of material usage and geopolitical risks, but on an understanding of potential growth industries within the UK. Additionally, future demand for CRMs is dependent on the path of emergent technology, such as new innovations in transportation or the development of different polymers and alloys within the electronics industry. As the examples of Concorde, Betamax and the Sinclair C5 demonstrate, the market for different technologies can be difficult to predict in advance.

100 http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical/index_en.htm
101 REEs are often used in electronics and advanced technology.
102 Parker, D *The Future Impact of Materials Security on the UK Manufacturing Industry*, 2013, 16.
103 Ibid
104 Ibid

Recent OECD work attempts to project the landscape for CRMs in 2030 for the OECD as a whole, based on anticipated supply risks and shifts in economic importance of particular materials. In doing so, the work recognises that some aspects of what makes a material 'critical', such as low-substitutability and low-recycling rates, are not inevitable features of the future, but are the result of policy choices. R&D around material substitutes, investment in recycling capabilities and improving data collection on material use are all measures which will determine the 'criticality' of materials such as fluorspar, manganese, bauxite, copper and potash for future generations.[105]

Manufacturers can often be unaware of their reliance on CRMs elsewhere in the value chain, meaning identification of any supply risks is crucial to building resilience.[106] Other key measures include improving efficiency and waste-minimisation in the use of CRMs; identifying and developing potential substitute materials, products or processes; or (more radically) taking a strategic approach to the allocation of CRMs within the UK based on the importance or availability of substitute materials between sectors.[107] The circular economy and new business models (which will be discussed in section 5 of this report) will be of particular relevance to the retention and recirculation of CRMs. Estimates suggest that recycling rates for many rare metals are less than 1%, particularly owing to their use in small quantities in widely dispersed products, or in alloying, which makes them difficult to separate.[108] Furthermore, developing coordinated strategies for diversifying supply channels can contribute to resilience against supply volatility for materials generally, and CRMs in particular.

In countries such as the United States, Germany and Japan, governments have set out a coherent policy strategy on resource security, with coordinating institutions across relevant government bodies. In the UK, responsibility for material security is spread across at least seven government departments with no overarching responsibility. It was these concerns which led EEF, along with others, to propose an Office for Resource Management to be located within the Department for Business, Innovation and Skills (BIS).[109]

105 Coulomb, R. et al, "Critical Minerals Today and in 2030: An Analysis for OECD Countries", OECD Environment Working Paper No. 91, 2015.
106 Gardner, L, "Critical Materials and Resilience", presentation to Conference of the Centre for Industrial Sustainability , July 2015.
107 Parker, D, *The Future Impact of Materials Security on the UK Manufacturing Industry*, 2013, 32.
108 Graedel, T et al, "What Do We Know About Material Recycling Rates?", 2011.
109 EEF, *Materials for Manufacturing: Safeguarding Supply*, 2014, 7.

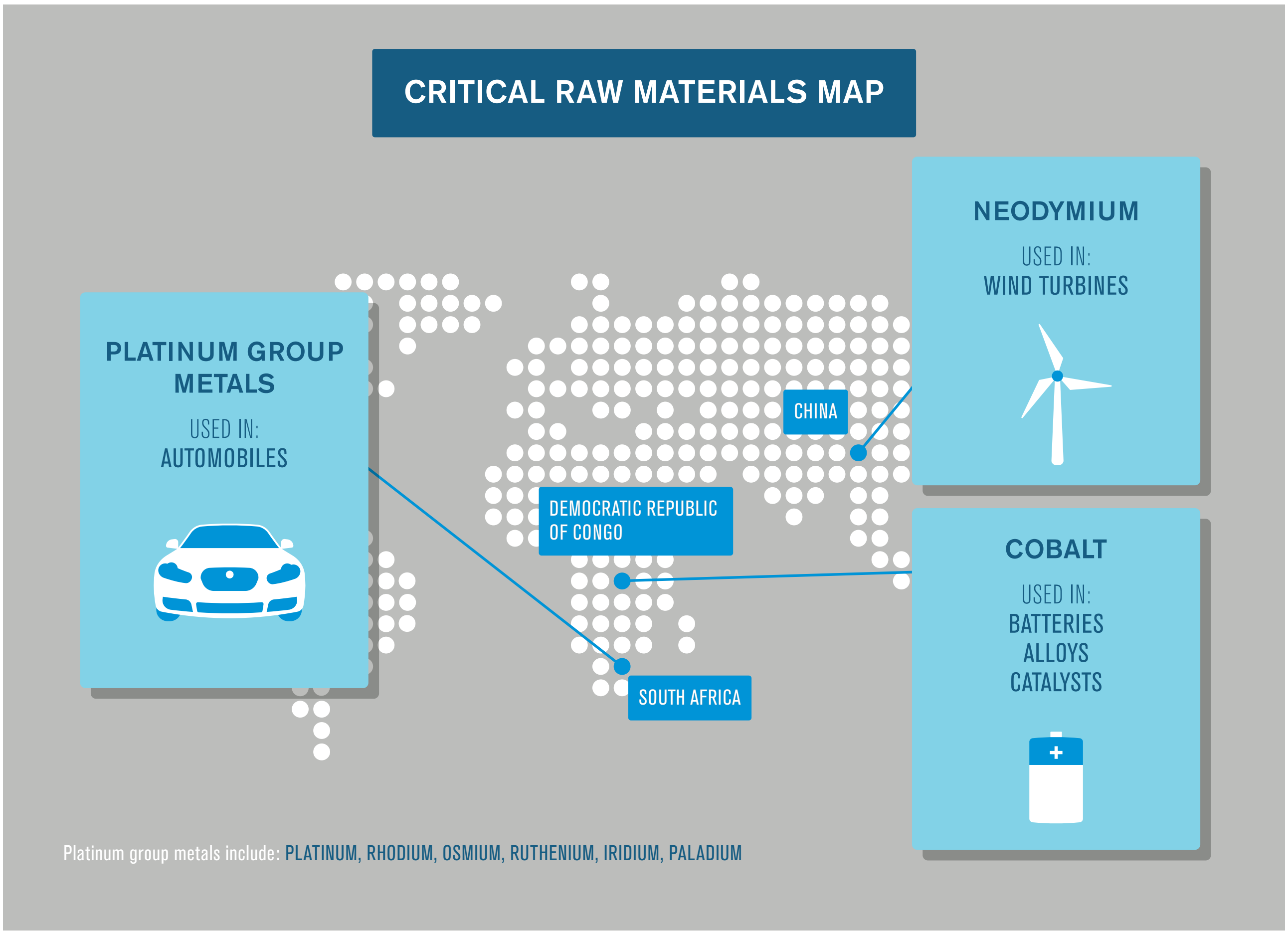

Fig. 10 "Critical Raw Materials Map"

Tracking Material Flows

As discussed earlier in this report, the fact that government often has worse information than the private sector does not mean that it should not have a role in correcting market or system failures. It does, however, mean that the flow of information between the public and private sector is paramount for the creation of effective policy.

The flow of materials throughout the system is determined by a complex array of social, economic and technical factors. Greater information on how these flows operate would allow for better policy-making from the public sector, and more opportunities for the private sector to identify unrealised gains and spaces for new enterprises.

Manufacturers, of course, collect and aggregate huge amounts of information as a matter of economic necessity and existing regulatory requirements; however the way in which they do so could be much better calibrated to helping develop resilience in our use of materials. As the UCL Green Economy Policy Commission noted, material flows are "still to a large extent unmonitored compared to the financial flows that they accompany, which are tracked through the accounts in great detail, resulting in sub-optimal decisions about materials management at every stage of their journey through the economy, but especially when they have become 'wastes'".[110] The Commission recommends that ONS be given responsibility for evaluating existing stocks of natural capital, and for creating more comprehensive accounts to track material flows throughout the economy. The development of effective policy to promote national resilience against future resource insecurity simply cannot occur when policy-makers are blind to the ways in which we use materials currently.

110 Ekins, P et al, Greening the Recovery: the report of the UCL Green Economy Policy Commission, UCL, 2014, 38.

Decarbonisation

Manufacturing accounts for approximately 30% of the UK's total greenhouse gas emissions (inclusive of indirect electricity consumption),[111] with the remainder largely split between transport and buildings. The UK Climate Change Act requires cuts of 80% to the UK's greenhouse gas emissions relative to 1990s levels. The decarbonisation roadmap set out by the CCC envisions an accelerating rate of decarbonisation from 3.2% per annum for the period 2008-2030, to 4.7% for 2030-2050 based on the assumption of falling costs of low-carbon technologies. This assumption itself assumes that such advances in low-carbon technology will be brought about by public and private investment in the decarbonisation of all sectors of the economy.[112]

111 CCC, Fact Sheet: Industry, available at https://www.theccc.org.uk/wp-content/uploads/2014/08/Industry-fact-sheet-2015-v1.1.pdf
112 Fankhauser, S, "A Practitioners Guide to a Low-Carbon Economy: Lessons from the UK", Climate Policy, 2012.

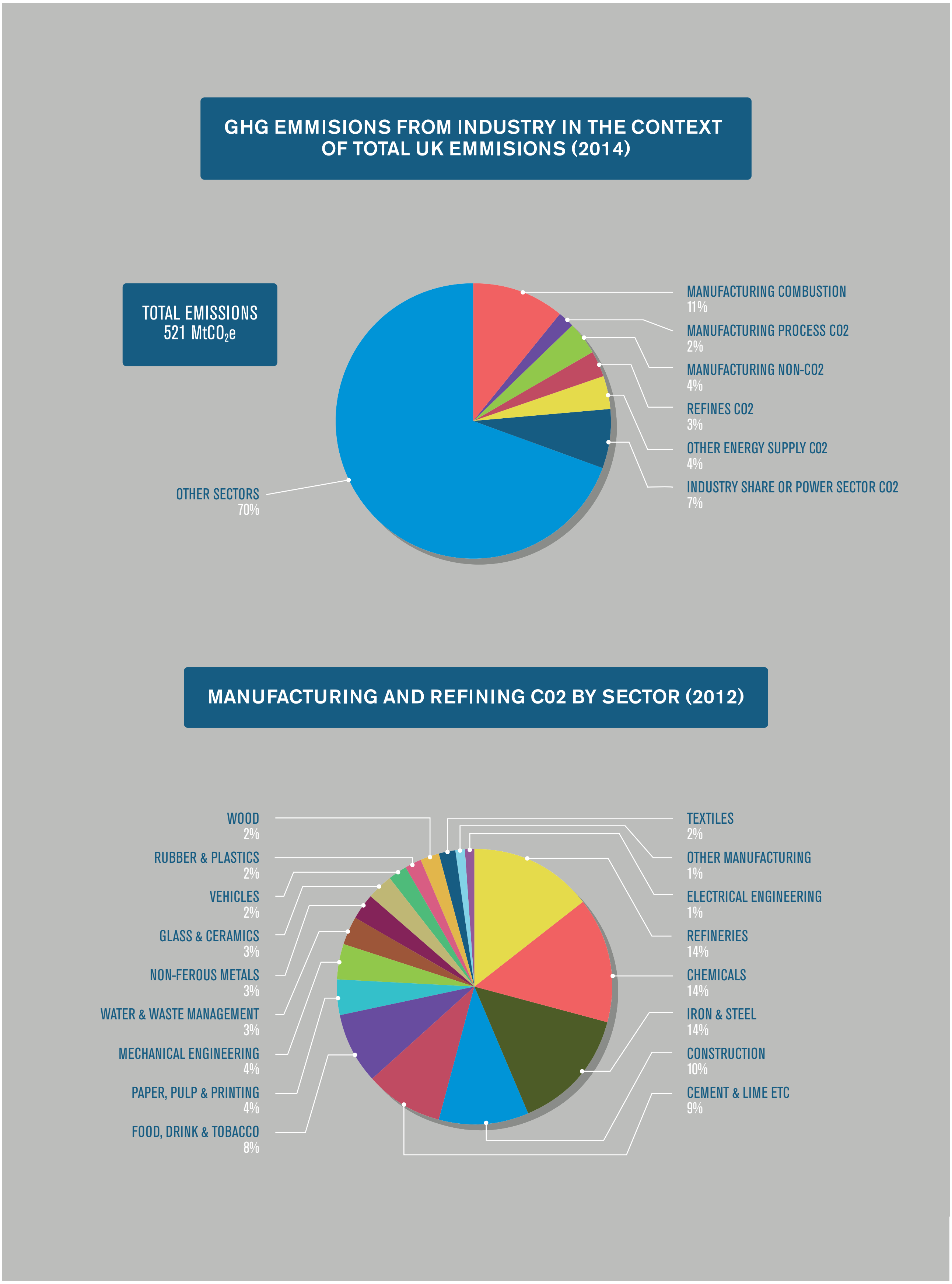

Fig. 11 “UK Manufacturing’s share of GHG Emissions, and breakdown by sector”.
Source: *Committee on Climate Change, Fact Sheet: Industry*

UK manufacturing's emissions fell by 20% during the first five-year carbon budget set by the CCC (2008-2012), and have continued to fall throughout the second, based on provisional estimates. Progress in industrial decarbonisation is occurring ahead of the CCC's trajectory indicators for both non-electrical energy intensity and the uptake of low-carbon heat.[113] However, this news should be tempered by the fact that this period coincided with a steep decline in economic output during the global financial crisis. A sustained economic downturn might have its advantages from a purely environmental point of view, but it could not be considered socially sustainable.

The collective need to transition away from one source of energy may generate significant scarcity issues in the alternatives. The BIS/ DECC decarbonisation roadmaps produced in 2015 for energy-intensive industries identified the replacement of fossil fuels with biomass as a key decarbonisation strategy for six out of the eight sectors examined: cement, ceramics, chemicals, food and drink, glass, and (most especially) paper and pulp.[114] The continued supply of agricultural biomass requires large quantities of land and fresh water, which puts the supply of biomass in potential competition with other demands associated with a growing global population, such as high-protein food and living space.

Current renewable energy obligations for the energy sector also mean that electricity suppliers are in competition for biomass, which raises the cost for manufacturers seeking to decarbonise their fuel sources. The cement industry has decreased its carbon intensity per tonne of cement by 22% since 1998, and now derives 44% of its fuel from waste and biomass. The need for consistent heat patterns limits the share of the sector's fuel that could be switched to alternative sources to around 80% (which means that new technology, particularly carbon capture and storage, becomes crucial).[115] The paper and pulp industry could potentially achieve reductions of two-thirds of its carbon emissions through replacing the fuel used in mills to generate steam with biomass.[116] However, increased competition for biomass makes it hard to see how such levels might be attained without a more strategic approach to the allocation of material to where its decarbonisation potential is the greatest – the so called 'cascade principle'.

113 CCC, Progress in Reducing the UK's Emissions: 2015 Report to Parliament, 2015.
114 BIS/DECC *Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Cross Sector Summary*, 2015, 16.
115 BIS/DECC *Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Cement*, 2015, 30.
116 BIS/DECC *Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Paper and Pulp*, 2015, 44.

Carbon Capture and Storage

Carbon Capture and Storage (CCS) is considered a key potential decarbonisation strategy for industries such as cement, chemicals, glass, steel and refining. It is also an important component of reducing the carbon-intensity of electricity production. It involves the capture and transferal of CO2 from industrial processes through compression, liquefaction or pipelines. The resulting carbon stocks can be stored in onshore or offshore geological formations or used as a feedstock in other chemical processes.[117]

The lack of progress on CCS presents a stark contrast to the importance which is placed on the technology in both the BIS/DECC roadmaps for UK energy intensive industries, and the European Commission's 2050 decarbonisation roadmap. Within the UK, the technology has reached demonstration stage within the energy sector, but remains uneconomical for commercial use within the manufacturing sector.[118] Hence, projections by the Committee on Climate Change suggest that CCS would at best be a medium-long term solution to decarbonisation (from 2030 onwards).[119]

CCS requires significant capital investment, and the price on carbon which would make it competitive with alternatives that emit carbon as usual is relatively high – though actual likely costs depend heavily on the purity and concentration of the CO2 which is produced, and vary considerably between industries.[120] CCS is a high-risk, high capital expenditure technology, the policy implications of which will be dealt with in section 3 of this report. It also requires significant investment in both transport and storage infrastructure, the latter of which is subject to a great deal of uncertainty as to the costs.[121] Interestingly, exhausted North Sea oil and gas fields and their remaining infrastructure might prove to be suitable for carbon storage.[122]

117 BIS/DECC *Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Cross Sector Summary*, 2015.
118 CCC, *Progress in Reducing the UK's Emissions: 2015 Report to Parliament*, 2015.
119 CCC, *Fact Sheet: Industry*, available at https://www.theccc.org.uk/wp-content/uploads/2014/08/Industry-fact-sheet-2015-v1.1.pdf
120 Green, R and Zhang, X, "The Future Role of Energy in Manufacturing", 2013, 15.
121 Bassi et al, "Bridging the gap: improving the economic and policy framework for carbon capture and storage in the European Union", 2015, 33.
122 Green, R and Zhang, X, "The Future Role of Energy in Manufacturing", 2013, 15.

Energy

Challenges to the resilience of manufacturing with regards to energy stem from price volatility and the reliability of supply. The industrial sector's share of total UK energy use has fallen from 43% in 1970 to around 20% in 2011 as the share of manufacturing in GDP has fallen. However, the energy mix within the sector's total consumption has also shifted, with gas and electricity use increasing at the expense of coal, coke and petroleum. Shifts in the make-up of the sector, as well as progress on energy efficiency, have also influenced the weight of manufacturing within the UK's total energy consumption.[123] Continued shifts in the mix of energy sources can be expected, as many industrial processes are electrified, and consumption switches away from gas - which is best considered an intermediate technology, as it is an improvement on other existing options but not sufficiently so to meet long-term carbon limitations without CCS.[124]

Accurate projections of energy prices are not necessarily straightforward, as they depend on the progress of new technology for decarbonisation, and on the efficiency efforts of other sectors of the economy. The most effective way that manufacturing can be resilient to price volatility is to increase the efficiency of their energy use at every stage, though firms' abilities to do so will vary depending on the measures available to them and progress which has been made to date. Over the short- to medium-term there is likely to be upwards pressure on energy prices due to increased reliance on early-stage renewable technologies and additional costs associated with CCS, though in recent times the falling price of fossil fuels have kept energy prices lower than they would otherwise have been. By 2020, such increases might amount to as much as 49% for a medium size manufacturing firm, which comes on the back of a 94% increase since 2002.[125] This naturally raises concerns around national competitiveness, job losses and 'carbon leakage' overseas.

It is important to distinguish shifts in cost competitiveness that arise from the internalisation of externalities from those that result from the uneven imposition of carbon prices. So-called Pigouvian taxes are intended to change the demand for some products in favour of others, as a reflection of the social cost associated with the more carbon-intensive option. However, policy measures which simply result in consumers switching to imported products that do not face equivalent carbon prices are counterproductive to environmental objectives, as well as social and economic one. Uneven carbon-price support between EU members in industries such as cement, lime, glass and ceramics is not desirable if it results not in innovation, but in the loss of jobs and the import of heavy products from elsewhere in the EU.

This asymmetry between national approaches to carbon prices and markets which are global in scale raises the possibility of evening out this tax treatment at the border. Though the common refrain is that this would be difficult under the World Trade Organisation (WTO), the issues here are more likely ones of politics and concerns around retaliation, rather than specific trade rules. In any case, it is not

123 Green and Zhang, "The Future Role of Energy in Manufacturing", 2013, 10.
124 Fankhauser, S, "A Practitioners Guide to a Low-Carbon Economy: Lessons from the UK", Climate Policy, 2012, 5.
125 Increase is for 2002-2012 period. EEF, *Business Productivity and Energy Efficiency*, 2014.

clear why the existing rules of one global institution on trade should be considered sacrosanct at the expense of global efforts toward combating climate change. Border levelling of effective carbon prices is likely to be a complex undertaking for some products with more diverse processes, but could be suitable for some products. In such cases it would be a preferable approach to free allocation of carbon allowances, which shift the burden of decarbonisation targets to the rest of the economy.[126]

Another potential risk to the resilience of UK manufacturing stems from the reliability of the supply of energy. Currently, the average UK consumer loses electricity supply for around 80 minutes per year through distribution problems or outages due to a shortfall in electricity generation, though industrial consumers are more vulnerable than the average UK consumer due to their higher energy requirements. The costs of these shortages can be substantial, with estimates suggesting that a four hour blackout in the West Midlands region on a normal working day would result in a loss of approximately £25 million pounds.[127]

The Office of Gas and Electricity Markets (Ofgem) suggests that uncertainty around electricity shortfall remains high from 2016-2017 onward as the retirement of older plants cuts into spare capacity.[128] The intended growth in the share of renewables within the energy system also raises the potential for greater unreliability, particularly from wind and solar which have only intermittent supply. This raises the importance of 'balancing' capacity of energy generation which can respond to short-term fluctuations in demand or supply, and in particular, the carbon-intensity of this back-up generation. The unreliability of some renewables also means that policy must be designed in a way which incentivises investment in capacity which will be idle more often than not.[129] The Electricity Market Reforms implemented from 2013 onward include a capacity market to address this issue, which has been criticised by the Energy and Climate Change Select Committee for keeping more carbon-intensive power stations online.[130] In light of this, other measures that can help the issue of renewables' intermittency, such as better energy storage technology and developing transmission links across the EU, should be prioritised.

Greater use of demand-side measures is one way in which manufacturing can contribute to a more resilient and reliable energy system. Many larger manufacturers already provide demand-response services to the National Grid, which involves the exchange of information between production systems and the electricity grid. This enables the intermittent switching-off of the electricity supply in a way that evens out short-term grid fluctuations without disrupting manufacturing processes. This presents an opportunity for manufacturers in the form of an alternative revenue stream, but requires a willingness to look outside of their core business model and collaborate with others in an unfamiliar area. Greater utilisation of this, and other measures such as capturing residual heat from industrial processes, can help square the circle of balancing spare capacity and decarbonisation. A more flexible approach from the National Grid in engaging with manufacturers on energy demand, rather than the current blunt approach to pricing, could help improve the stability of the energy system overall.

126 Carbon Trust, *Tackling carbon leakage: Sector-specific solutions for a world of unequal carbon prices*, 2010.
127 Green, R and Zhang, X, "The Future Role of Energy in Manufacturing", 2013, 24-29.
128 Ibid, 24
129 Fankhauser, S, "A Practitioners Guide to a Low-Carbon Economy: Lessons from the UK", Climate Policy, 2012, 5.
130 http://www.parliament.uk/business/committees/committees-a-z/commons-select/energy-and-climate-change-committee/news/emr-publication1/

Manufacturers are also building resilience to grid fluctuations and carbon pricing by developing onsite renewable capacity. A good example of this is the Hanson cement plant at Ketton, which has reduced its reliance on fossil fuels and electricity through a combination of on-site waste incineration and a nine megawatt solar energy farm.[131] Although a more sustainable industrial economy would be the end result of these measures, a more effective approach for government might be to encourage more companies to treat this as a strategic approach to mitigating future risks to production, rather than a matter of sustainability per se. As businesses are much more accustomed to anticipating and preparing for future market developments than they are the long-term challenges of environmental sustainability, the goal for policy-makers and business leaders is to ensure that these issues increasingly become one and the same conversation.

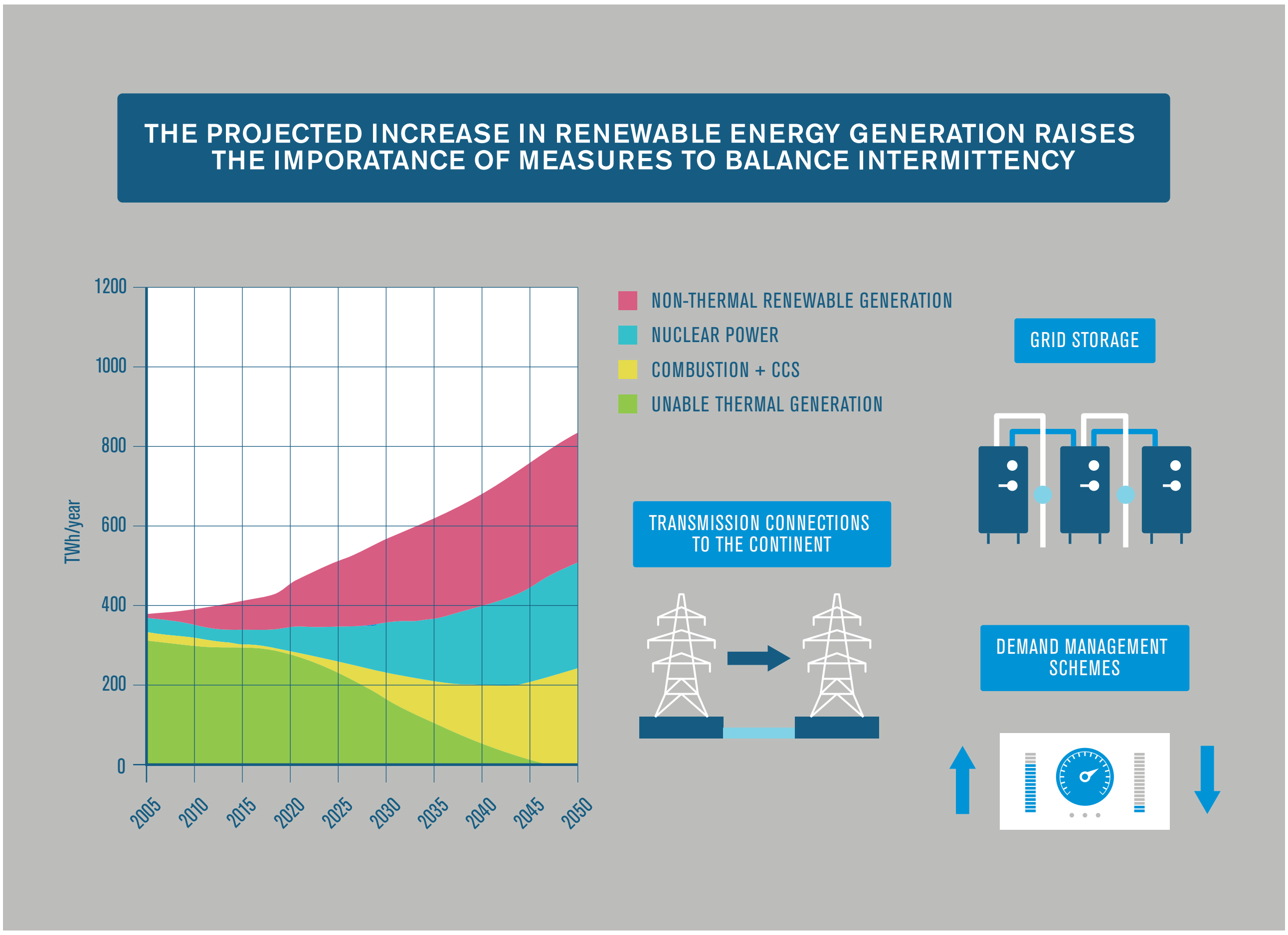

Fig. 12 “The Projected Increase in Renewable Energy Generation raises the Importance of Measures to Balance Intermittency”.
Source: Adapted from Pathway Alpha, “2050 Pathways Analysis”, DECC, 2010.

131 http://www.hanson.co.uk/en/sustainability/carbon-climate-change-and-energy

Policy Recommendations:

Recommendation 7

A new 'challenge-focused' Catapult should be established to examine and build our understanding around cross-sectoral areas of concern relating to resilience, and to convene relevant actors around addressing these issues. Although the existing Catapult centres are focused on coordinating businesses and universities around commercial opportunities, a similar model ought to be applied to convene key actors, such as professional bodies, academic institutes, skills providers and trade associations, around cross-sectoral areas in which could contribute to the UK's economic resilience, such as;

i. the strategic use of biomass for decarbonisation;

ii. the diversification of supply channels for key industries in order to reduce vulnerability to regional supply disruptions;

iii. the use of energy demand-management measures to contribute to national resilience within the energy system, and to develop contingency plans for dealing with future systemic shocks

Recommendation 8

Government should prioritise measures to increase the reliability of renewables and to mitigate their intermittency: this includes R&D efforts toward energy storage technologies, investment in longer scale transmission across the EU, and examining incentives for greener balancing capacity.

Recommendation 9

The Office of National Statistics should develop an enhanced data infrastructure for tracking material flows: as proposed by the UCL Green Economy Policy Commission, this would provide policy-makers with a much better basis on which to assess system-level issues in our use of materials, and open up new business opportunities to make better use of materials.

Recommendation 10

The Energy Intensive Industries 2050 decarbonisation roadmaps should be expanded into action plans: this is an area in which significant government support will be necessary, particularly in Carbon Capture and Storage (CCS) R&D and infrastructure. However, this support should be matched by corresponding commitments from industry.

Recommendation 11

An Office for Resource Management should be established within BIS to advise and coordinate policy-makers on the challenges and opportunities around resource security; in line with the proposal made by EEF and others. This should be matched by corresponding support elsewhere for issues around Critical Raw Materials (CRM), such as public R&D support for CRM substitutes and efforts to promote better recycling of products that use these materials.

3

INNOVATION

The industrial economy must be both a provider and a beneficiary of new green technology. The development of new industrial processes and business models, new low-carbon and energy-efficient products, and new materials designed for longer-life and circularity, is crucial to the challenge of continuing to meet the needs of society both today and in the future.

Additionally, manufacturing is but one part of a system which must collectively work towards a sustainable way of living, through a greener energy grid and infrastructure, a workforce attuned to new possibilities, and an innovation ecosystem which generates new technologies in a concerted and collaborative fashion.

The focus thus far has been on business leadership in sustainability with regards to known technology, and the building of a national manufacturing sector which is resilient to disruptions and shocks beyond our immediate control. Looking beyond these areas of opportunity, it is clear that new innovations are a pre-condition for the transition to a sustainable manufacturing sector.

The role of policy is to seek to shape this system in a way which maximises the possibilities of technological innovation, while providing a clear direction – a social purpose – to its utilisation and the development of wider economic structures. The state must be an active player in the innovation process, not merely a passive corrector of market failures, topping-up the supply of basic research or nudging business incentives toward more R&D. Radical innovations can have a transformative economic and social impact, but no crystal ball exists to guide investment in this direction, nor to anticipate whether new technology will serve wider societal objectives. A 'mission-oriented' approach to addressing society's most pressing technological challenges, such as grid-decarbonisation, carbon capture and storage, and material recovery technology, can serve to align public and private sector capabilities toward a more sustainable manufacturing sector.[132]

132 Mazzucato, M and Penna, C (eds),, Mission-Oriented Finance for Innovation, Policy Network, 2015; King, D et al, A Global Apollo Programme To Combat Climate Change, available at http://cep.lse.ac.uk/pubs/download/special/Global_Apollo_Programme_Report.pdf

Such an approach does entail greater government spending on innovation, but does not need to be excessively expensive for the public accounts. As discussed below, UK public spending on energy innovation is now a fraction of what it was during the cold war, and even a modest increase in spending in this area could generate significant advances while still constituting a small share of GDP. Nations which have fostered effective public innovation systems range from relatively high-spending Finland to the relatively low-spending United States. More importantly, effective innovation spending is an investment which generates high returns to the wider economy in terms of revenue, high-paying jobs and greater resilience to future shocks.

Arguments for Green Innovation Policy

As discussed previously in the economic theory section, traditional market failure and public good theories provide the basic, though incomplete, rationale for industrial policy directed toward green technology. R&D is a classic case of an investment resulting in externalities, as the benefit to society as a whole is significantly greater than that which accrues to the party responsible for the investment, mainly due to the spread of knowledge beyond that firm. Recent estimates suggest that the social returns for investment in science and innovation might be as much as two to three times higher than the private return.[133] This is the underpinning logic of public R&D spending, particularly in basic research which is conducted without a particular commercial end in mind. The impact on the atmosphere resulting from the mitigation of climate change is also a public good, which means that individual incentives are to free-ride on others' efforts to develop green technologies.[134]

An additional reason for government to promote green innovation is that current systems of pricing carbon are inadequate. The International Energy Agency estimates annual fossil fuel subsidies at $548 billion USD (£361 billion),[135] while the International Monetary Fund calculates that including what would be appropriate taxes to account for environmental impacts, implicit subsidies amount to $5.3 trillion USD (£3.5 trillion).[136]

The UK Climate Change Act 2008 has provided a clearly legislated target for cuts to UK greenhouse gas emissions (of 80% by 2050, relative to 1990) and an independent body (the Committee on Climate Change) to set binding 5-year carbon budgets. However, one of the key market-based mechanisms by which that goal is to be achieved, the EU Emissions Trading System, has been relatively weak, and has been supplemented and mitigated by a series of unilateral measures. These include the Climate Change Levy and exemptions from it through Climate Change Agreements; the CRC

133 Frontier Economics, *Rates of return to investment in science and innovation, report prepared for BIS*, 2014
134 Rodrik, D, "Green Industrial Policy", 2013.
135 Estimate is for 2013, and exchange rate is based on US$1 = £0.66; IEA World Energy Outlook, http://www.worldenergyoutlook.org/resources/energysubsidies/
136 Exchange rate is based on US$1 = £0.66; Coady, D et al, "How Large are Global Energy Subsidies?", IMF working paper, 2015.

energy efficiency scheme;[137] the fossil fuel energy carbon price floor, and various disjointed support packages to affected industries. As researchers from the LSE Centre for Economic Performance put it, "the complex interactions between different climate policies has resulted in considerable variability in the effective carbon price, and consequently in the incentives that different types of emitters face".[138]

Furthermore, there is evidence that the impact of price-based mechanisms is blunted by the direction of previous innovation. Although measures such as fuel duties can spur innovation in cleaner technologies, its direction is influenced by 'path dependency'. Firms which are used to innovating in a 'dirty' direction continue to build on past improvements, and the same is true for those exposed to past 'clean' innovations. As the current stock of industrial knowledge has developed down a resource- and energy-intensive path, there is a good argument for government to take a greater role in setting the direction of technological change and avoid the continued 'lock-in' of environmentally-damaging activity.[139] Importantly, earlier intervention can lessen the role that policy needs to play, as private sector research will continue to build on cleaner technology once it is sufficiently advanced.[140]

Public commitment to internalising the price of carbon must remain a priority for the UK at a national, regional and international level. Although there is growing optimism that the global climate negotiations scheduled to take place in Paris in late-2015 will result in an agreement, the likelihood is that a global carbon price is some way off. This will make it more difficult to strengthen the pricing of carbon to an effective level, and the failure to price carbon and other harmful activities adequately increases the importance of public support for competing low-carbon technologies.[141] This is particularly true for industries facing global competition, and which have already made significant advances in energy and material efficiency.

However, broad policy support for green innovation is equally important as an effective price on carbon and becomes even more important in its absence. A policy approach focused on incentivising the private sector through the pricing of externalities, feed-in tariffs and other such measures is unlikely to be sufficient without a coordinated and collaborative network of public and private institutions promoting investment in new sustainable technologies. An innovation policy which is adequate to the task of making UK manufacturing sustainable must take on a critical role as a partner to the private sector in the development of green technologies.

137 Initially the Carbon Reduction Commitment (CRC).
138 Martin, R et al; "Energy and the Environment: a cold climate for climate change policies?", Centre for Economic Performance, 2015.
139 Dechezlepretze, A et al, "Carbon Taxes, Path Dependency and Directed Technical Change: Evidence from the Auto Industry", Centre for Economic Performance, Discussion Paper 1178, 2012.
140 Acemoglu, D et al, "The Environment and Directed Technical Change". American Economic Review, 102:1, 2012.
141 Rodrik, D; "Green Industrial Policy", 2013.

How does the UK perform on Green Innovation?

The UK has well recognised strengths in its world class research base and ability to attract top research talent - as judged by its output and number of citations of academic papers.[142] However, its inability to translate this into commercialised products and national industries has been identified as an integral factor in the country's long-running productivity lag.[143] The UK has consistently underspent on R&D, which has accounted for approximately 1.8% of GDP for the past few decades. This compares poorly to the US (2.7%), Germany (2.8%), Japan (3.4%) and South Korea (4%).[144] With regards to business expenditure on R&D (BERD), industrial structure explains some of this gap –specifically the UK's specialisation in service sector industries. The long-term shift away from manufacturing as a proportion of the economy has resulted in fewer firms in R&D-intensive industries.[145] However, this long-term underinvestment is evident in public spending as well as private.

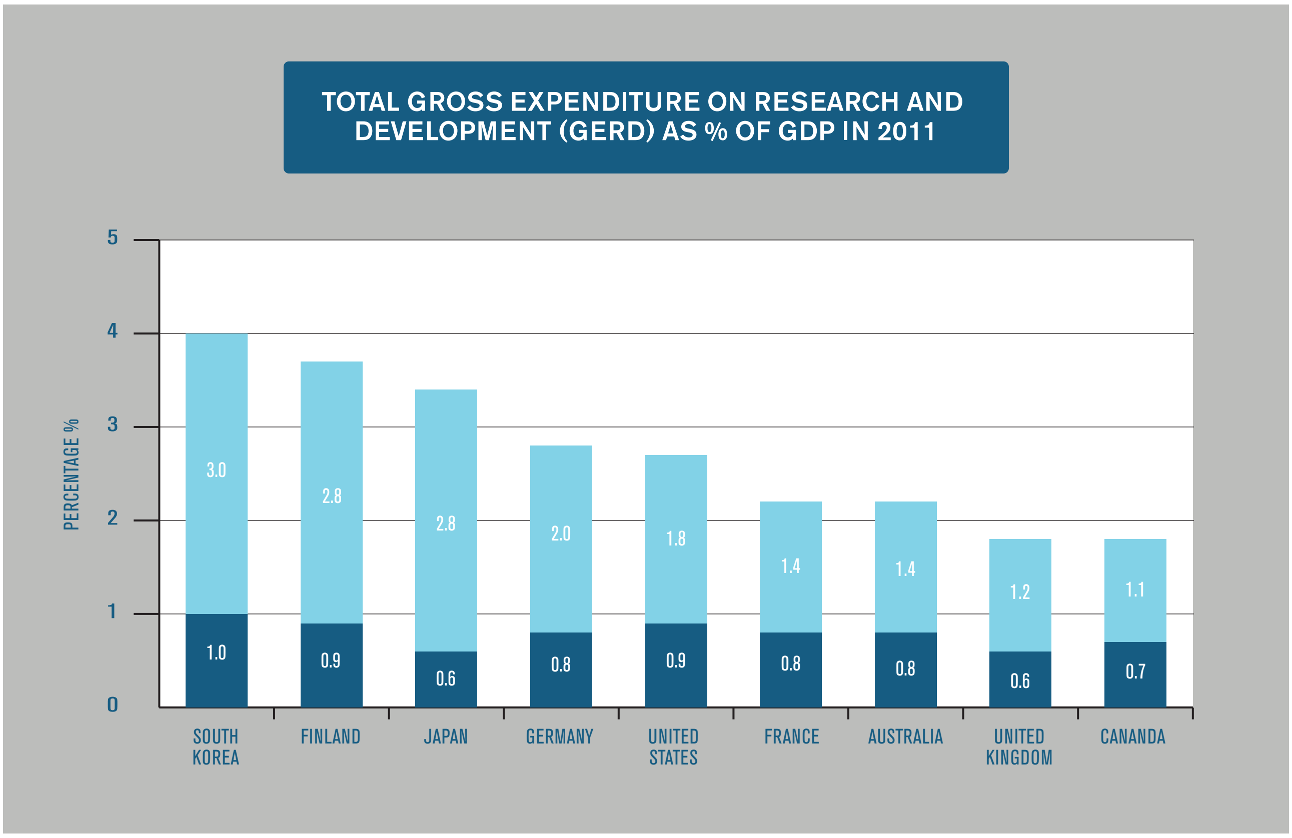

Fig. 13 "Total Gross Expenditure on Research and Development (GERD) as % of GDP in 2011"
Source: Allas, T: Insights from international benchmarking of the UK science and innovation system, Report to BIS, 2014.

142 NESTA, *Plan I: the Case for Innovation-led Growth*, 2012. 35.
143 Ibid
144 R&D figures are for 2011. Allas, T; *Insights from international benchmarking of the UK science and innovation system*, Report to BIS, 2014, 31.
145 Services do produce intangible assets which have an element of 'innovation', though not the sort measured by R&D – specifically technological or scientific advances; Allas, T; Insights from international benchmarking of the UK science and innovation system, Report to BIS, 2014, 36.

An international comparison of public and private R&D spending suggests little evidence that the state 'crowds out' private investment – rather, the two seem to be complements. While we should unquestionably be concerned with the quality of research as well as the quantity, there is little evidence to suggest that countries that are leaders on innovation are seeing diminishing returns from their investments.[146]

The UK also lags behind its competitors in measurements of patents per capita. Though the share of green technology as a share of total UK patents has increased steadily since 2000,[147] the UK has been outpaced in this area by other nations - particularly Japan, South Korea and Germany.[148] As a result, green patents now account for 3 times the share of the UK's innovation output that they did in 2000, but the UK's share of global green patents has actually fallen.[149] Within Europe, the European Eco-Innovation Observatory rates the UK relatively highly overall, due to high scores on resource efficiency and socio-economic outcomes, but the UK is the 7th worst performer on eco-innovation outputs – primarily patents and publications.[150]

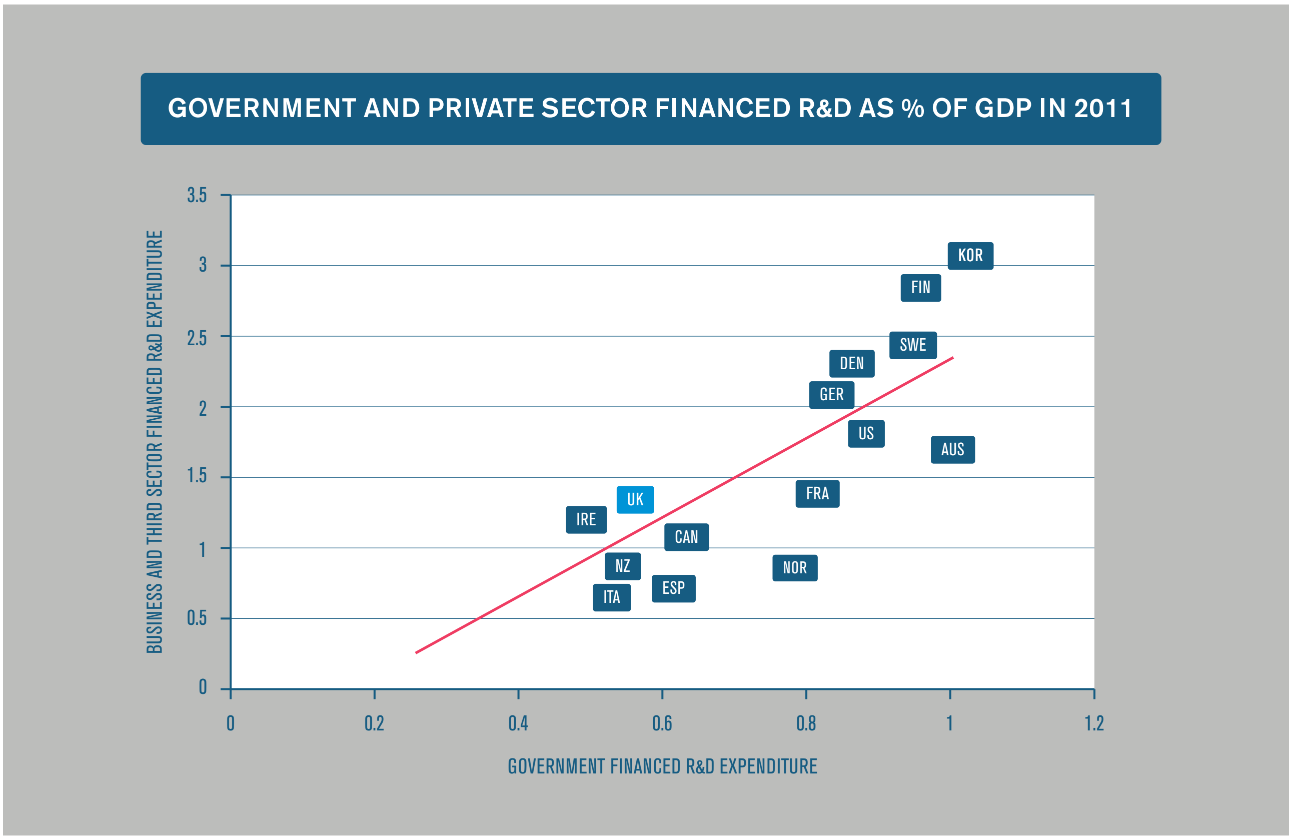

Fig. 14 "Government and private sector financed R&D as % of GDP in 2011"
Source: Allas, T, *Insights from international benchmarking of the UK science and innovation system, Report to BIS*, 2014.

146 Allas, T; *Insights from international benchmarking of the UK science and innovation system*, Report to BIS, 2014, 30.
147 Ekins, P and McDowall, W. Green Innovation: Industrial Policy for a Low-Carbon Future, TUC/UCL, 2014.
148 Fankhauser, S. et al, "Who will win the Green Race? In search of Environmental Competitiveness and Innovation", Global Environmental Change, 23, 2013.
149 Martin, R et al; "Energy and the Environment: a cold climate for climate change policies?", Centre for Economic Performance, 2015, 16.
150 Data for 2013; http://www.eco-innovation.eu/

Systems accounts of innovation would caution against a linear understanding of how new ideas get from the stage of basic research to commercialisation and diffusion. Instead, the emphasis is on the connections and feedback between different public and private sector actors, which allow new ideas to be generated, shared and made use of. This issue is linked to the familiar criticism of the UK as being good at coming up with new ideas but bad at commercialising them. However, it should be noted that on the evidence above, the UK is starting from a disadvantaged position in terms of the input of R&D spending into the system, even before weaknesses in the effective use of knowledge within this network are considered.[151]

The process of translating new ideas into implementable means toward a sustainable industrial economy is not just about the supply of innovation from R&D, but also the demand from innovative firms. This is not to say that there are not outstanding performers. ARM Holdings was recently rated the 5th most innovative company in the world by Forbes; however, the UK's total representation in the list accounted for only five companies in the top-100.[152] Not enough UK firms are taking a lead on exploiting new sustainable technologies, for reasons relating to firm-level decision making (as detailed in section 1), and the wider system in which they operate (which will be discussed in section 4). It is telling that while wind turbines were invented in the UK, very few are manufactured here currently. A stable and committed policy approach to supporting low-carbon innovation, and to championing the growth potential within these industries, is also a vital component of greater private sector investment in these areas.

Finance for Innovation

The UK has deep and well-developed capital markets, and is a significant global provider of financial services, so it seems strange to suggest that there is a shortage of finance for innovation. What is important in this context is not the quantity of capital but its type – specifically, a shortage of 'patient capital' that can remain committed to worthwhile projects through long technology development cycles. The uncertainty faced by investors in new innovations is not just related to what is technologically possible, but also includes market uncertainty (a firm's ability to make the technology work at scale and to drive costs down to a competitive level) and competitive uncertainty (fear that other market participants may create a better or cheaper product).[153]

Corporate innovation laboratories have historically been an important generator of private sector innovation, but have increasingly looked at odds with the trend toward financialisation. Exemplars of these institutions, such as the AT&T Bell labs and the Xerox PARC, would have a much harder time operating at such a level of R&D under today's prevailing focus on maximising shareholder value.[154] This demise of the vertically-integrated corporation, first in favour of leaner firms focused on 'core competencies', and then across globalised supply chains, led MIT

151 Mazzucato, M, *The Entrepreneurial State*, 2013, 52.
152 The other UK companies were Reckitt Benckiser, Capita, Experian and Smith & Nephew; http://www.telegraph.co.uk/finance/enterprise/11812335/Five-UK-firms-make-list-of-worlds-100-most-innovative-companies.html
153 Lazonick, W; "How Maximising Shareholder Value Stops Innovation"; *Mission-Oriented Finance for Innovation*, Policy Network, 2015.
154 Mazzucato, M The Entrepreneurial State, 2013, 24.

researchers to question "whether the separation of innovation from manufacturing will allow innovation to continue full-bore at its original home, or whether separation comes at the price of learning and creation of capabilities that might produce future innovation at the original home base".[155] For the UK in particular, the break-up and demise of two former innovation leaders, ICI and GEC, from the 1990s onwards, is indicative of the withering of the UK's private sector innovation capacity.[156]

Venture capital (VC) is usually identified as having the risk tolerance to bridge the gap between basic and applied research, and establishing viability for commercialisation. Indeed, VC has an important role in the development of new technologies, and the UK matches the US relatively well in terms of VC investment in clean energy technologies.[157] However, VC does not provide the level of patience which is often required for high-risk innovations; typically seeking to exit at the stage of commercial viability within 3 to 5 years. In this regard, it has followed the general private sector trend toward short-termism discussed in section 1. Additionally the VC model is unsuited to high-capital intensity projects. Within the matrix set out below, Ghosh and Nanda explain that VC tends towards the lower right-hand box, leaving a gap in the high-risk, high-capital intensity category.[158]

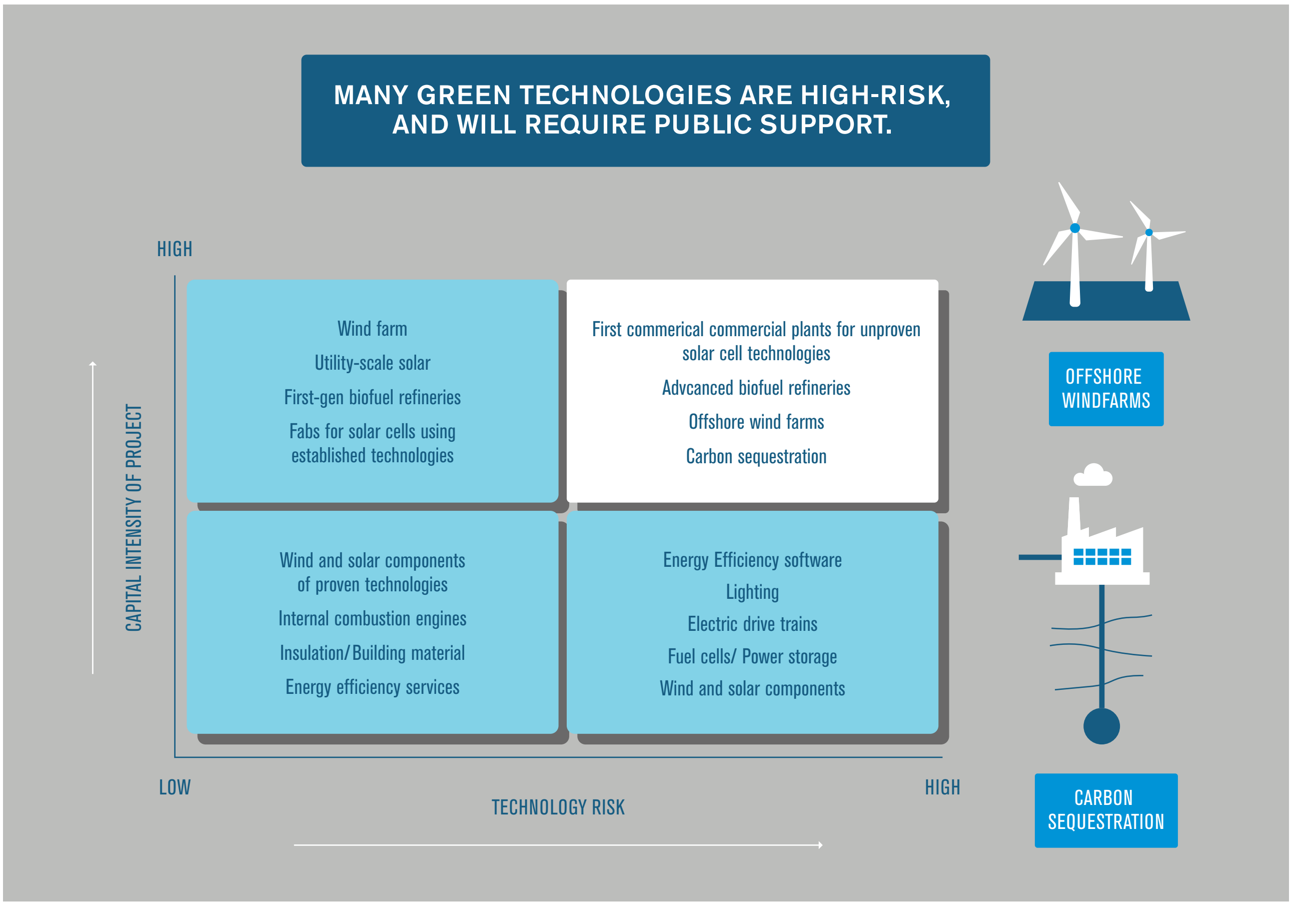

Fig. 15 Sub-sectors within Clean Energy;
Source: Adapted from Ghosh, S and Nanda, R, *Venture Capital Investment in Clean Energy Sector*",

155 "A Preview of the MIT Production in the Innovation Economy Report", 2013, http://web.mit.edu/pie/news/PIE_Preview.pdf
156 Jones, R, *The UK's Innovation Deficit and How to Repair it*, 2013, 6-7.
157 TUC/UCL, *Green Innovation: Industrial Policy for a Low-Carbon Future*, 2014, 31.
158 Ghosh, S and Nanda, R, "Venture Capital Investment in Clean Energy Sector", 2010, 7-10.

Many of the technologies which will be relevant for a more sustainable manufacturing sector in the future are located on the right side of the this matrix. Some are within the top-right category, putting them beyond the consideration of traditional funding avenues (debt or equity financing or retained earnings) as well as many VC models. CCS has been identified as a key decarbonisation technology for many energy-intensive industries, but this remains a high-risk technology and industry estimates suggest that it will double the capital cost of a new cement plant, which is currently in the region of £250-300 million.[159] The same could be said for the development of lighter weight, next generation materials with less through-life environmental impact.[160]

The Role of the State

The state's role in radical innovation is indispensable for two key reasons: its tolerance for bearing risk across long-term development cycles which radical innovations often require, and its ability to provide direction for technological revolutions which have a transformative effect on the wider economic system. Strong public commitment to horizontal industrial policy - skills, basic research and competition policy - should be non-negotiable; however, simply providing the background conditions for market players to operate is not sufficient to overcome the uncertainty and risk which accompanies many areas of innovation. Market failure-based approaches might be adequate (and indeed, crucial) for 'patching-up' incremental development within known technologies; however it does not provide us with a roadmap for the creation of new, transformative technologies which can drive a transition toward a more sustainable manufacturing sector.[161]

As Mariana Mazzucato has demonstrated, the state's historical role in the development cycle of radical technologies has extended well beyond the provision of basic research. In the USA, a broad-based network of public institutions have provided funding and collaborative support at all stages of the innovation chain, through applied research, early stage technology development, product development and production. In doing so, it has driven the development of the internet, nanotechnology and aeronautical technology; areas of high risk and uncertainty which may never have developed without the state providing patient backing and a bold vision of what might be possible.[162] Undoubtedly, the private sector has grasped these technologies and brought its productive and creative capacities to bear on the opportunity they provided. Nevertheless, the market opportunity was made possible by the state's willingness to choose and invest in the direction of technological change.

159 Ekins, P and McDowall, W. Green Innovation: Industrial Policy for a Low-Carbon Future, TUC/UCL, 2014, 31.
160 Grant, P, "New and Advanced Materials", Foresight Working Paper, 2013, 11
161 Mazzucato, M, *A Mission-Oriented Approach to Building the Entrepreneurial State*; Innovate UK, 2015; 8.
162 Mazzucato, M; The Entrepreneurial State; 2013, 62.

The state's role in the innovation system has been to a significant extent, the product of historical context. Many of the state-funded technological breakthroughs in the US during the 20th twentieth century fell under the rubric of defence spending, despite often making the greatest impact through non-military application of the technology. This level of funding and freedom to experiment – in what was effectively a large-scale industrial policy in all but name – reflected a strategic commitment to technological progress driven by the Cold War. This strategic approach to scientific research also explains why UK spending on energy research is now a fraction of what it was in the 1970s – at which point nuclear fission accounted for the bulk of research expenditure.[163] The challenges of making UK manufacturing sustainable are of a very different variety to the geopolitical challenges of previous decades. However, the urgent need to avoid the worst impacts of climate change and resource depletion surely warrants a strategic national focus on developing more sustainable technologies.

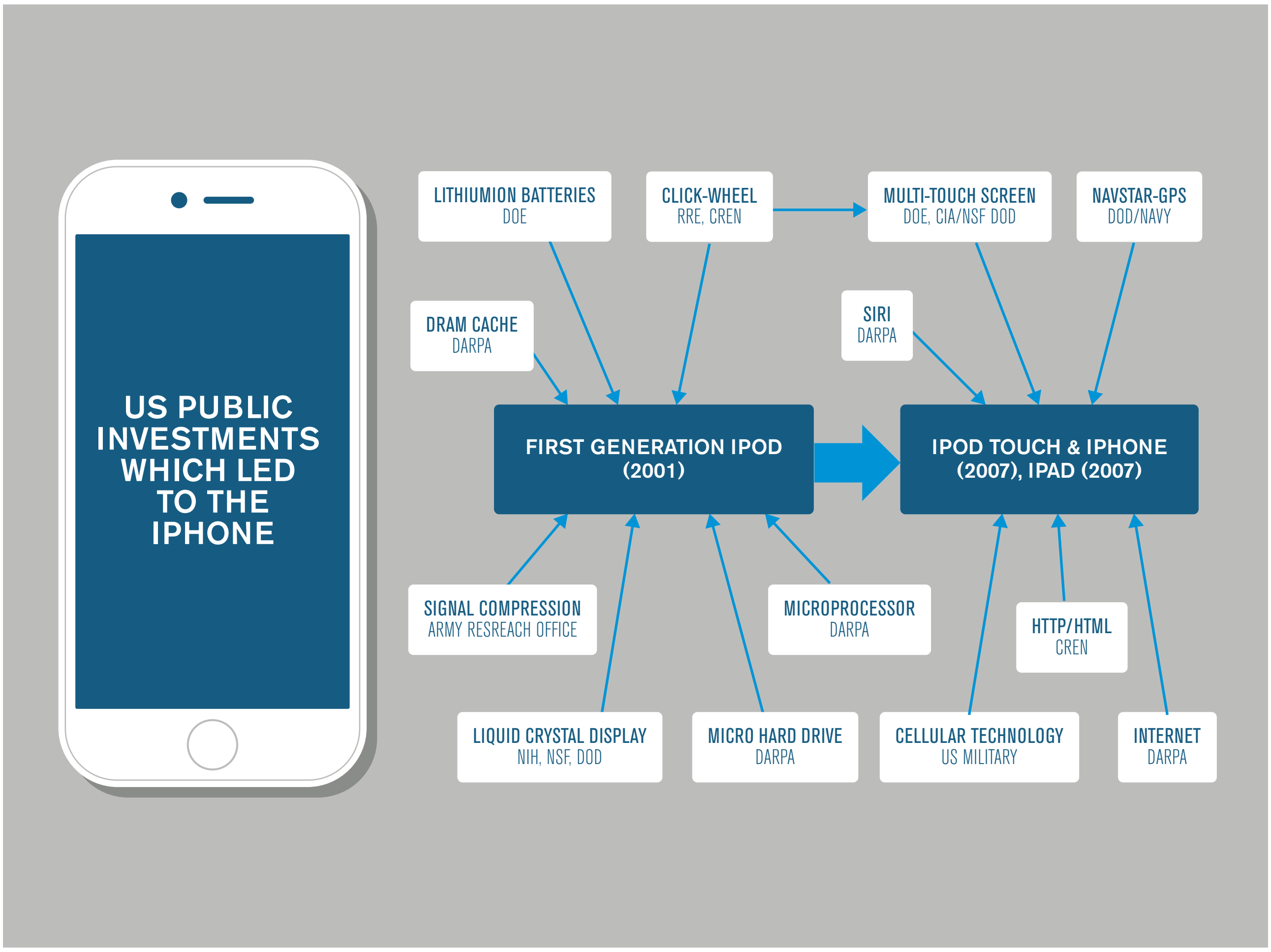

Fig. 16 Source: adapted from Mazzucato, M. *The Entrepreneurial State*. 2013.

163 UK Energy Research Council, http://ukerc.rl.ac.uk/ERA002.html;

Mission-Oriented Innovation

In the past, specific overarching objectives have underpinned national industrial policy. National security concerns justified government support for innovation during the cold war, while even horizontal industrial policy from the 1980s onward were driven by narratives of greater competition within a globalised market. In recent times, a number of thinkers have promoted the idea of focusing public policy around 'grand societal challenges', akin to John F Kennedy's challenge of putting a man on the moon by the end of the 1960s. Such missions can be purely technological, while others address broader challenges which extend beyond a single area of innovation.

An example of this approach, explicitly referencing the scale of the NASA moon missions, is the 'Global Apollo Programme to combat Climate Change' proposed by Sir David King and prominent members of the House of Lords. This project proposes a ten-year effort from a consortium of countries dedicating 0.02% of GDP to R&D on renewable energy, energy storage and transmission. The target is to spur on the advance of solar technology to the point that it is cheaper than new build coal energy world-wide by 2025.[164]

This is, of course, an attempt to hasten an already occurring trend in the price of solar-generated energy, which has fallen remarkably in the past decade. Even more remarkable is that this has been occurring when renewable energy accounts for only 2% of publically funded R&D globally – around $6 billion USD (£4 billion) per annum.[165] Public support for renewables globally, including among those countries that have had the most active industrial policies (such as Germany and China), has been heavily tilted toward support for deployment and investment in domestic manufacturing, rather than R&D.[166] In essence, industrial policy has been focused on getting a leg up on competitors, rather than advancing the capabilities of the technology. Concerns around gaining a competitive advantage for national industries are likely unavoidable, however the evidence does not provide great support for the theory that merely 'incentivising' private sector actors will generate technological advances at a sufficient level. As King et al note, "even in the major international companies which manufacture solar and wind equipment, the ratio of R&D to sales is under 2%, compared with over 5% in consumer electronics and 15% in pharmaceuticals".[167]

Industrial sustainability as a whole falls into a broader category of societal challenges, as it extends beyond a single technological objective or area of policy. For policy-makers it is more akin to the task of directing a 'techno-economic paradigm', a theory closely associated with Carlotta Perez of LSE. Sustainability within the manufacturing sector requires a reconfiguration of both production and consumption practices, but it also requires a clear social purpose towards which the possibilities represented by new technology – particularly information communication technology (ICT) - should be applied. According to Perez, such a transformation also serves sustainability in a social sense, as it "would create growing demand for equipment, infrastructure, and engineering, all redesigned in a green and sustainable direction, while enabling increasing production and innovation for the domestic and export markets in all countries".[168]

164 King, D et al, 'Global Apollo Programme to combat Climate Change', 2015.
165 King, D et al, 'Global Apollo Programme to combat Climate Change', 2015.
166 Grau, T et al, *Survey of Photovoltaic Industry and Policy in Germany and China*, 2011, 38.
167 King, D et al, 'Global Apollo Programme to combat Climate Change', 2015, 5.
168 Perez, C; "Steering Economies toward the next Golden Age", *Mission-Oriented Finance for Innovation*, 2015, 56.

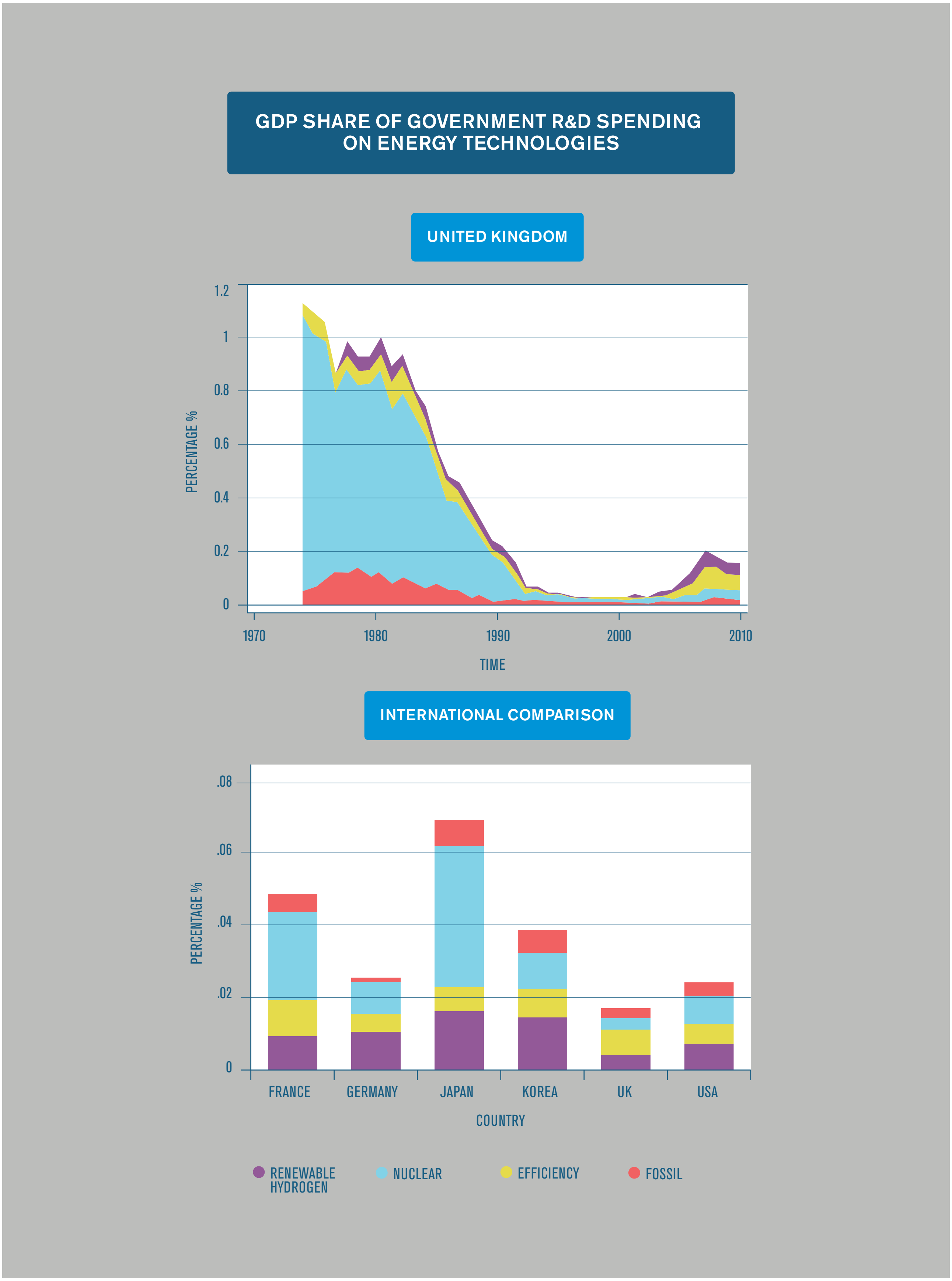

Fig. 17 "GDP Share of Government R&D Spending on Energy Technologies"
Source: Martin, R et al, Energy and the Environment: a cold climate for climate change policies? Centre for Economic Performance, 2015

The UK's Approach to Innovation Policy

Evidence submitted to the inquiry was largely positive about the model of Innovate UK and the wider innovation network (including the Catapult Centres, Knowledge Transfer Network and others). Specifically, the availability of grants through Innovate UK provided an additional spur for internal firm decisions on investment which might not have otherwise gone ahead. This is of particular relevance for multinational corporations, which are often in internal competition for investments to be made in the UK, rather than in other countries where the company might operate.

Innovate UK can also complement and add greater credibility to other government efforts to set higher industry standards. The provision of support and a platform for collaborative innovation can reduce industry opposition to regulatory challenges that businesses would otherwise have had to address on their own. Competitions or challenge-driven projects can also help to stimulate debate and innovation within industry. Innovate UK's work with the construction products industry, and around the Zero Carbon Homes plan (prior to its abandonment in mid-2015) are good examples of this. Estimates suggest that Innovate UK support has returned between £3 and £9 of added value for every £1 of public funds invested, meaning that significant value for money is being achieved through current investments.[169]

The wider context of innovation policy also includes the EU. The availability of funding through programmes such as Horizon 2020 provides important opportunities for collaborative innovation in areas which would benefit from scale beyond the UK alone. The potential benefits of EU-wide industry work programmes to develop sustainable innovations should be a key consideration of the UK's ongoing standing within Europe.

However, the scale of the UK's network of public institutions trails well behind more innovative competitors. Innovate UK funding for 2013 as a percentage of GDP was less than half what Germany spent on its equivalent Fraunhofer Society, while Finland spent close to 10 times as much on its Tekes funding agency.[170] In terms of specific innovation and technology centres, the 9 established Catapult Centres have some way to go to match the 67 Fraunhofer Institutes. The Sustaining Growth in Innovation Enterprises, led by Philip Shapira at the University of Manchester, found that the short-term approach to funding and support within the UK's innovation system was perceived by SMEs producing green products to be a barrier to the scaling-up of their operations. This is particularly true at the intermediate commercial viability stage – the so-called 'valley of death'.[171]

169 Cable, V; "Challenges And Opportunities For A Knowledge-Based UK Economy", Mission-Oriented Finance for Innovation, Policy Network, 2015, 80.
170 Allas, T; Insights from international benchmarking of the UK science and innovation system, Report to BIS, 2014, 30.
171 Uyarra, E Shapira, P and Harding, A, "Low carbon innovation and enterprise growth in the UK: Challenges of a place-blind policy mix", 2015, 28.

Procurement and Standards

The scale of the UK's public innovation network is but one aspect of the puzzle. Previous mission-oriented approaches to challenges, and models such as the Defence Advanced Research Projects Agency (DARPA) in the US, included measures for government procurement. In this way, the state effectively helped to create a market for new products, along with the products themselves. Within the UK, the relaunch of the Small Business Research Initiative (SBRI) in 2009 was aimed at providing this 'demand pull' alongside the 'technology push' of traditional innovation policy.[172] The SBRI directs government contracts to smaller R&D-driven companies through competitions. However, it has lagged behind its spending commitments for contracts awarded, and the failure of many government departments to engage with the system (or to direct contracts to universities rather than businesses) has blunted its impact.[173]

The UK government's total expenditure amounts to over 40% of GDP, which is a considerable degree of economic weight which could be used to promote sustainable innovation in manufacturing from the demand-side.[174] This is a lever for sustainable innovation which the government could make much better use of without breaching the non-discrimination principle of the World Trade Organisation (WTO). The WTO's Committee on Government Procurement does allow for the application of "technical specifications to promote the conservation of natural resources or protect the environment".[175]

The UK is in fact regarded internationally as a leader on some aspects of sustainable procurement, with standards such as BS 8903:2010, set by the British Standards Institution (BSI), providing a guide to incorporating sustainability into public and private sector purchases.[176] This ability of the UK to set globally recognised standards, as opposed to having to adapt to the standards established by other countries, is an underappreciated strength. Our ability to do so does require that the UK commit to a compelling vision of sustainability, and take concrete steps to back up that vision with credibility. This includes raising awareness and encouraging adoption of such standards wherever possible. Open data for energy and resource efficiency in manufacturing, as already occurs for buildings, should be an area which the UK specifically aims to take a global lead on.

Although government procurement does include consideration of externalities associated with different products and services, government departments' ability to take a longer perspective on sustainable manufacturing is limited by how far out their budgets are set. The practice of over-specifying government procurement requirements can also limit innovative responses that could meet the public sector's needs in new ways.[177] Doing more in this area across a range of products could not only save the taxpayer money (without compromising on function or quality), but could also help to stimulate the market for remanufactured goods and raise awareness across the wider economy.

172 This was modelled on the US' SBIR programme (Small Business Innovation Research).
173 Connell, D, Creating Markets For Things That Don't Exist: The Truth About UK Government R&D and How the Success of SBRI Points the Way to a New Innovation Policy to Help Bridge the Valley of Death and Rebalance the UK Economy, Centre for Business Research, 2014, 12.
174 HM Treasury, Statistical Bulletin: Public Spending Statistics February 2015, available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/407690/PSS_February_2015.pdf
175 Article X, WTO, "Revised Agreement on Government Procurement", available at https://www.wto.org/english/docs_e/legal_e/rev-gpr-94_01_e.htm
176 UNEP, Sustainable Public Procurement: A Global Review, 2013, 25.
177 Ibid

It is here that US programmes such as SBIR (Small Business Innovation Research) have played a vital role, with estimates suggesting that such public support amounts for between two and eight times as much as VC funding at the same stage.[178] The UK also lacks public support for the deployment of new technologies on the scale of the German KfW or Chinese Development Bank. It is these sorts of institutions that have done much of the heavy lifting, in terms of providing patient capital, for large scale renewables projects worldwide.[179]

A more active policy approach to driving radical innovation within sustainable manufacturing necessarily entails a greater degree of risk. Supporting projects across all stages of the innovation chain involves working in conditions of extreme uncertainty, as innovation is by nature an unpredictable advance in our cumulative understanding of what is possible. This means that support for innovation is a discovery process, and involves experimentation for the public as well as private sector.[180]

For policy-makers seeking to promote a sustainable direction for technological progress, this requires supporting a broad portfolio of individual projects in a decentralised, bottom-up manner. There needs to be a tolerance of the possibility of failure for a significant proportion of this portfolio. If there was sufficient certainty as to the likelihood of success prior to investing in an idea, the state's involvement would not be necessary in the first place. As Dani Rodrik has argued, "under an optimally-designed program of industrial policy, some firms that receive public support will necessarily fail. In fact, if every subsidized firm were to prove financially successful, this would likely indicate that the program was vastly under-performing".[181]

Concern as to the wasteful use of public funds is both natural and justified, but without proper context, there can be an excessive focus on the failures of government support without weighting them against the successes. Witness the backlash in the United States for the failed public investment in the solar company Solyndra, as opposed to the similar investment which helped the emergence of Tesla. What is important is that policy-makers continue to engage in the fruitful exchange of information with the private sector, and have confidence in their combined ability to shape new industries and markets beyond any single failed project.

A greater role for the state at the riskier end of the spectrum of technological possibilities also requires a commitment to developing capacity among those responsible for making decisions on public investment in innovation. A broad, experimental, portfolio-based approach to supporting innovation is also probably better served by a more decentralised innovation system, which requires that greater capacity and responsibility for innovation be developed within local enterprise partnerships (LEPs). The issue of the UK's underdeveloped regional innovation networks has been recognised elsewhere,[182] and the depth of similar networks evident in countries such as Germany and Italy takes time to develop. Additionally, more decentralisation of innovation support raises legitimate concerns over coherence and coordination of policy, across what is already a diverse landscape of agencies.

178 Mazzucato, M; The Entrepreneurial State; 2013, 48.
179 Climate Policy Initiative, The Global Landscape of Climate Finance 2014, 2014, 19.
180 Mazzucato, M, *A Mission-Oriented Approach to Building the Entrepreneurial State*; Innovate UK, 2015; 16.
181 Rodrik, D; "Green Industrial Policy", 2013, 14.
182 Ekins, P and McDowall, W. Green Innovation: Industrial Policy for a Low-Carbon Future, TUC/UCL, 2014, 28.

However, policy-making in this area should be understood as being about diagnosis as much as implementation, at the level of regional networks and specific industries. A sufficient degree of 'embeddedness', or understanding of the specific challenges that firms are facing and the support they require, will require a strengthening of institutions at a regional level. Connections between these organisations also need to be deepened, so that policy-makers can learn from successes in other regions.

Policy Recommendations:

Recommendation 12

The scale and ambition of the UK's innovation network should match that of our competitors, as well as the extent of the opportunities around sustainability. Publically funded R&D should be increased in order to place the UK economy on a more even standing with other OECD nations. This greater funding power should be accompanied by an explicit remit to push technological change (and economic growth) in a sustainable direction. The innovation network as a whole should have greater scope to pursue a portfolio approach to supporting innovation; funding a wide variety of projects in an experimental, bottom-up and mission-led manner. This approach requires a tolerance of the possibility of failure in some projects, and an emphasis on learning and re-evaluation so that the portfolio as a whole can make a difference in transformative technologies. Greater innovation capacity should be developed at a regional level, including through Local Enterprise Partnerships.

Recommendation 13

Government should make greater use of procurement to provide a market for sustainably manufactured goods, for instance through ensuring greater engagement with the Small Business Research Initiative (SBRI) programme. Greater reporting of government purchases of remanufactured goods, and road-mapping targets for such products as a percentage of total purchases, would provide greater certainty for manufacturers looking to shift towards more sustainable manufacturing practices.

Recommendation 14

Exemptions from the Climate Change Levy in the form of Climate Change Agreements should be reviewed, and consideration given to progressively shifting support towards R&D in clean technology and renewables.

Recommendation 15

The UK should take a lead in establishing standards for open data in energy and resource efficiency: the trend toward open data is one that the UK should be ahead on, and establishing ourselves as a leader in recognised standards for data-sharing on efficiency.

4

COLLABORATION

Collaborative approaches to addressing sustainability challenges can yield opportunities, solutions and breakthroughs that may never have otherwise occurred. Deeper connections amongst competitors, across supply chains or between separate sectors or non-market entities can help the spread and enhancement of knowledge to the benefit of all.

With so much focus on the physical and ecological constraints facing the manufacturing sector, it is in some ways comforting to think that "knowledge is the only resource expanded by utilisation".[183] The accumulation of knowledge, skills and innovation capabilities is recognised as central to improving productivity.[184] It is unusual to come across a manufacturing-focused policy document which does not encourage greater cooperation between firms. Yet due to various market and system failures, opportunities for greater cross-sectoral collaboration and sharing of knowledge are not being realised. The failure to take advantage of opportunities to collaborate represents a loss to the UK in terms of profitability, employment and environmental benefits, and successfully addressing this failure is crucial to the task of fostering a sustainable manufacturing sector in the UK.

Knowledge can effectively spread throughout the economy via direct market transactions or by indirect means. The former can involve the purchase of knowledge (in physical or intangible forms) from parties external to a company, or the sharing of knowledge through formally agreed collaborations. Non-formalised transfers of knowledge are known as *knowledge spillovers*, arising when a firm learns and benefits from the investment of others.[185] Both forms of knowledge transfer are crucial to the broader adoption of sustainable manufacturing practices and the development of new ways of doing things. Yet both are likely to be underprovided with a passive approach to industrial policy.

Sustainable manufacturing also requires that waste materials and energy be captured and made use of wherever possible. Collaborations are crucial to the development of effective systems of waste utilisation and circular economy, and also present opportunities for new synergistic industrial arrangements built around making use of others' by-products and lost energy.

Industrial Commons

A new idea is only as useful as the structures and relationships around it allow it to be. Changes in the structures of firms toward lean organisations focused on 'core competencies' has meant that new innovations are much more dependent on capabilities external to the organisation in order to reach their potential. Thus the innovation process within the manufacturing system is best understood as a collective undertaking, from the point of conceptualisation and commercial

183 Seliger, G, Technische Universität Berlin, Presentation to Conference of the Centre for Industrial Sustainability , July 2015.
184 Crafts, N; "Creating Competitive Advantage: Policy Lessons from History", 2012, 1.
185 Bascavusoglu-Moreau, E and Li, Q,, "Knowledge spillovers and sources of knowledge in the manufacturing sector: literature review and empirical evidence for the UK", 2013.

start-up to the stage of scaling-up and making incremental improvements to new products.[186] This so-called 'industrial commons' argument recognises that "production and innovation capacities of a given economic system depend on the presence of multiple resources, such as R&D know-how, engineering skills, technological capabilities, and specific manufacturing and prototyping competences.... many of [which] are scattered across a large number of manufacturing and services companies as well as other organisations".[187]

The academic literature here stresses not only the interactions between those with different capabilities, but the importance of retaining a critical mass and diversity of mature manufacturing firms. Complementarities between a wider value network of suppliers, distributers, designers, service providers and customers are integral to our ability to make the most of new ideas, as well as the better utilisation of knowledge attained from interactions with foreign companies. The Massachusetts Institute of Technology 'Production in the Innovation Economy' project emphasises the importance of developed economies maintaining a core of advanced manufacturing capacity and suggests that the "ongoing connections between innovation and production, throughout the product cycle, are key to our continuing ability to innovate and thus to grow the economy".[188]

186 Locke, R and Wellhausen, R, *Production in the Innovation Economy*, MIT Press, 2014, 8.
187 Chang, H Andreoni, A and Kuan, M; "International Industrial Policy Experiences and the Lessons for the UK", 2013, 14.
188 Locke, R and Wellhausen, R, *Production in the Innovation Economy*, MIT Press, 2014, 6.

Clusters

With greater globalisation of trade, supply chains and production, and the prevalence of information communication technology, knowledge has become less constrained than ever by national borders. The transfer of knowledge from overseas, via international trade, foreign direct investment (FDI) or the operation of multinational corporations in the UK, in fact greatly outweighs the contribution of domestic R&D.[189]

At the same time as global connectivity is enabling the spread of information, the location of industry continues to matter. Competitive benefits from 'clusters' of specific or complementary industries in a particular area have long been recognised in the form of cheaper transport costs, greater depth of specialised skilled workers and suppliers and the spread of knowledge. Lancashire cotton mills, ceramics in Stoke-on-Trent and Silicon Valley are all recognised examples of 'external economies of scale'. With regards to knowledge spillovers in particular, close proximity of industries can enable the diffusion of knowledge through labour mobility, greater direct personal interactions and easier opportunities for comparison and assessment.

The need to shift manufacturing processes toward more sustainable modes of operation provides additional possibilities for clustering. The BIS/ DECC decarbonisation roadmaps undertaken for the UK energy intensive industries identify opportunities for the reuse of waste heat in other industrial processes. This could be enabled by greater clustering of industries with demand for low grade heat near those that produce it in excess. This is of particular relevance to the paper and pulp and chemicals industries. Clustering could also have benefits with regards to the utilisation of biomass and carbon capture and storage infrastructure.[190] The Teesside Collective, the business case for which is currently being explored, would be the EU's first CCS-equipped industrial cluster.

From a policy perspective, it appears that it is considerably easier to identify an existing cluster than to generate new ones. Although examples such as Silicon Valley were significantly shaped by government policy (specifically, defence policy),[191] there still seems to be a significant element of spontaneous evolution to clusters which active policy measures have not been particularly successful in replicating.[192] However, policy support for existing clusters may be beneficial in strengthening network connections and facilitating R&D, patient finance and specialised skills training. Other areas of policy, such as planning laws, can act as barriers to clusters.

Clustering on the basis of energy or carbon reductions carries additional complications in that it entails a greater degree of interdependence between companies than a typical commercial relationship. Relocating factories for this purpose is unlikely where there are considerable sunk investments in existing sites – however, new enterprises or manufacturers 'onshoring' their processes back to the UK could be presented with significant opportunities for clustering in order to share heat or carbon sequestration infrastructure with existing factories.

189 Crafts, N; "Creating Competitive Advantage: Policy Lessons from History", 2012, 2.

190 BIS/DECC; *Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050*, 2015.
191 Mazzucato, M, *The Entrepreneurial State*, 2013, 63.
192 Uyarra, E and Ramlogan, R, "The Effects of Cluster Policy on Innovation", NESTA, 2012.

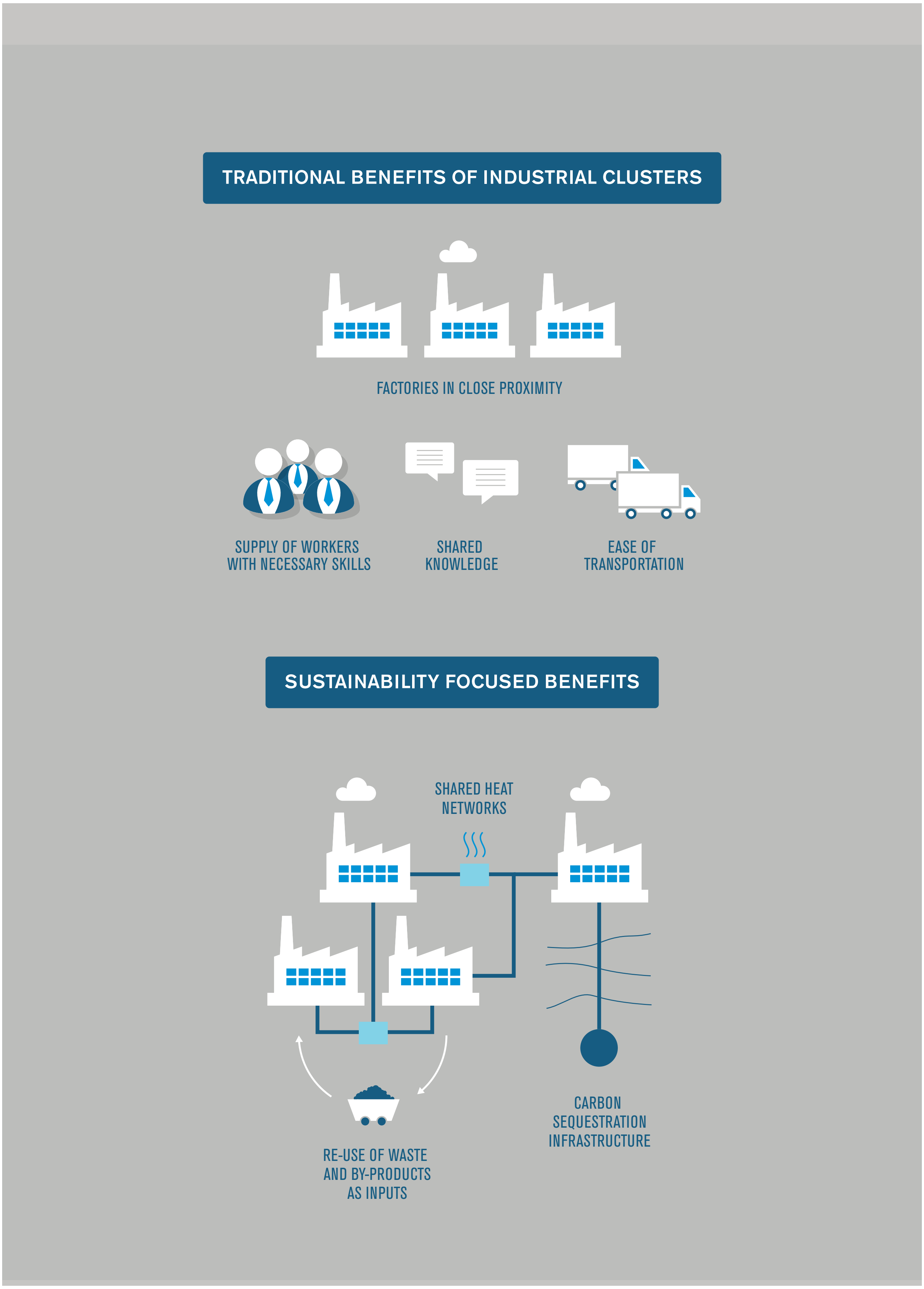

Fig. 18 "Traditional and Sustainability-Focused of Industrial Clusters".

Formalised Collaborations

Despite the importance and potential benefits of working with others to incorporate new ideas into a company's production processes, various factors prevent this from occurring more often. Collaboration entails a significant degree of uncertainty, whatever its form, and more radical partnerships require companies to look outside of their core business and commit resources towards often unpredictable possibilities.

Firms can collaborate vertically within a supply chain, or horizontally across a wider value network.

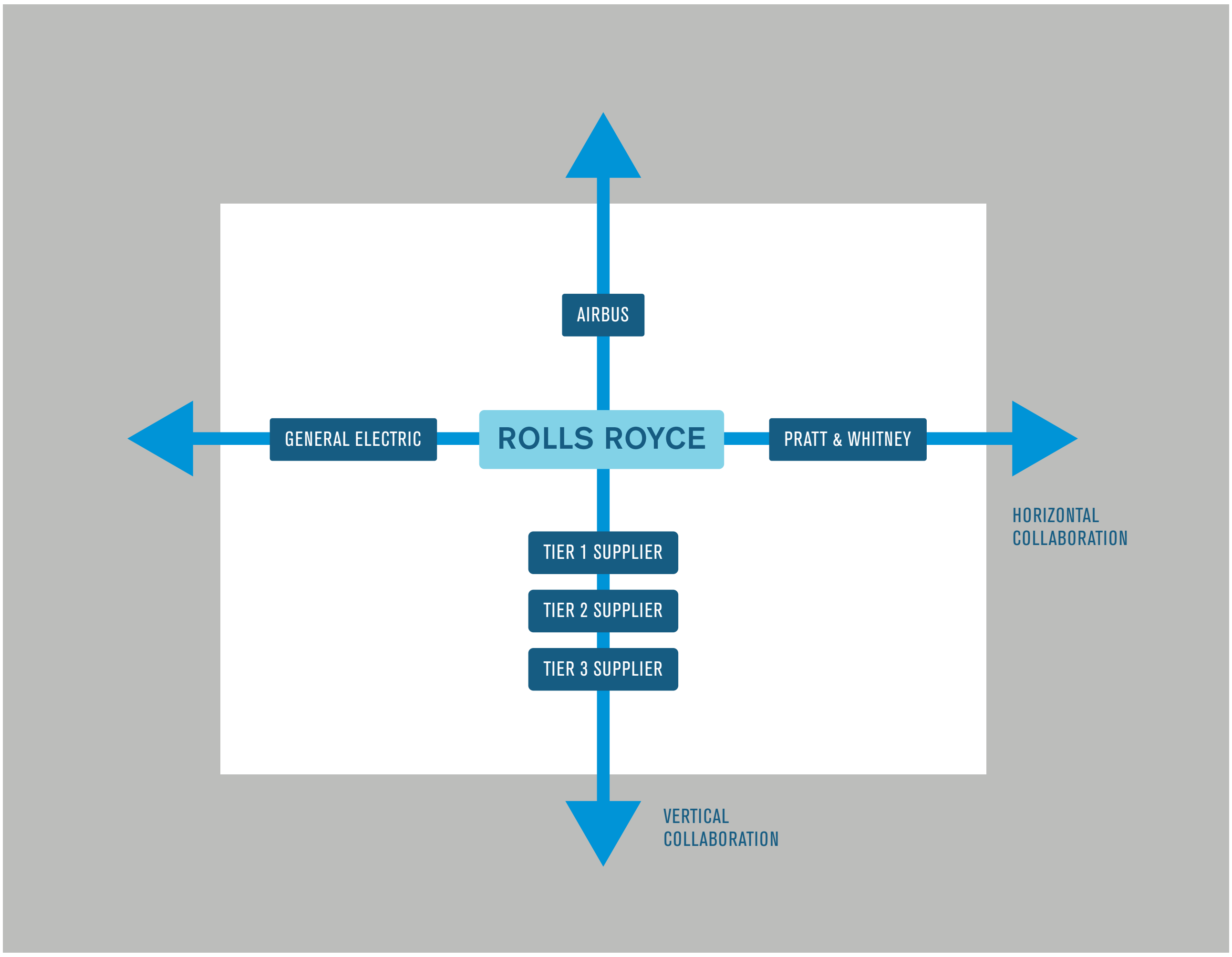

Fig. 19 'Horizontal vs Vertical Collaboration'

Customers are identified as a key source of knowledge, and UK firms have tended to be more willing to engage with the end users of their products than with other possible collaborators.[193] There are certainly areas in which consumer demand can be effective in pulling companies in a more sustainable direction. However this potential driver may be limited by a lack of consumer information.

193 Bascavusoglu-Moreau, E and Li, Q, "Knowledge spillovers and sources of knowledge in the manufacturing sector: literature review and empirical evidence for the UK", 2013, 20.

Transaction costs and information asymmetries often beset collaborations with other commercial entities, and increase the uncertainty which firms must deal with in working with others.[194] Suppliers are also a frequent and important partner for collaborations. However, despite the potential benefits of increasing efficiency and reducing environmental impacts through collaborative relationships across the supply chain, these transactions do not occur in isolation from relationships of market power. Smaller players in particular may face reduced incentives to redesign their products or processes if unequal bargaining power is likely to result in the lion's share of the gains being claimed by others. From this perspective, vertically-integrated firms are likely to have an easier time working together on sustainable products and processes on a system-wide level, provided that decision-makers within these organisations are able to overcome the organisational barriers discussed in section 1. On the other hand, some suppliers can secure their market position by offering tailored solutions to their customers, though ownership of intellectual property rights is an inherent transaction cost.

Collaboration and Varieties of Capitalism

Although we should be cautious in viewing existing institutions as immovable or in any way pre-determined, it would seem likely that collaborative approaches come more naturally to firms within Coordinated Market Economies such as Germany than to firms in the UK, which is an archetypal Liberal Market Economy.[195] Coordinated systems are characterised by "institutions [including] powerful business or employer associations, strong trade unions, extensive networks of cross-shareholding, and legal or regulatory systems designed to facilitate information-sharing and collaboration".[196] Within systems like the UK, these sorts of connections are less developed. Instead, arms-length, market-based relationships tend to prevail. Hence, UK firms are more likely to face the prospect of having to develop connections and relationships where none existed previously, if they are to take advantage of the benefits of collaboration around sustainability.

Voluntary Collaborations

It is difficult for market players, however big, to have a complete view of the supply chain, and of how a system as a whole might be improved in a way which is more environmentally sustainable and more profitable.

Collaboration between *competitors* can assist the spread of knowledge and enable costs sharing, though concerns about market competition and competition regulations can stymy this. The

194 Bastein, T. et al, Business Barriers to the uptake of Resource Efficiency Measures, POLFREE, 2014, 41.
195 See the discussion of the Varieties of Capitalism framework in the economic theory section.
196 Hall, P and Soskice, D; "Introduction to Varieties of Capitalism" , in Varieties of Capitalism, 2001, 10.

possibility of competitors working together does bring in additional concerns around their space to operate under competition policy. This can foil or delay collaboration on research, best practice sharing or common standards, even if the reality of legal barriers is far less onerous than is often perceived.

Throughout much of the EU, competing companies engage in much greater levels of collaboration than is typical in the UK, despite operating under the same EU competition laws. For example, Dutch companies commonly engage in data-sharing to benchmark their efficiency performances. Established and well-proven processes, such as the approach taken by WRAP (Waste & Resources Action Programme), can help ease these concerns. Nonetheless, these concerns are an additional transaction cost which prevents opportunities from being realised, and it can take time for companies to feel comfortable within a more collaborative operating space. Even successful sector-wide UK initiatives, such as the Courtauld Commitment on waste within the grocery sector (which was brokered by WRAP), took time to build up the necessary level of trust among the participating firms. This model, prioritising environmental gains but able to demonstrate the economic case to individual actors, has had some other notable successes (such as the Sustainable Clothing Action Plan) and is worth expanding upon.

However, there will be areas in which the gains are more elusive or vague, or where other barriers exist to an agreement being reached. In these situations, the threat of government regulation can provide impetus toward industry agreements which might not otherwise have occurred. Depending on the level of broad engagement with a voluntary agreement, there might also be a good argument in some cases for entrenching such agreements within legislation. This balance of using the 'carrot' or 'stick' in some combination goes directly to the 'embedded autonomy' approach discussed earlier in this report. Policy-makers must be attuned to the concerns of industry, and the (quite legitimate) complications that formulating standards and other such measures can entail, while also being able to send a clear and credible message that change will have to occur in some way. Well-designed regulation, or the threat of regulation, can be a driver toward industry turning its mind to innovation and collaborative agreements, rather than efforts to oppose government action.

Sources of knowledge

Bascavusoglu-Moreau and Li's evaluation of UK innovation surveys (UKIS) found that market-based sources of knowledge (suppliers, clients and competitors) were the most common resource for manufacturers to work with. Professional and industry associations were reasonably well utilised, while government and higher education institutes were the least well-utilised, with less than 10% of manufacturers engaging these sources. Higher technology manufacturers, larger companies, multi-national corporations and exporting businesses were more likely to take advantage of external knowledge sources.[197]

Indirect Knowledge Transfers

As knowledge is a non-exhaustible resource, it has the potential to help drive a transition to a sustainable manufacturing system within all industries and within all countries. Its ability to do so is determined by the depth of the connections through which knowledge can flow between different actors, and their capacity to make effective use of the information. Knowledge spillovers include the ability to replicate the success of others, learn from their mistakes, or benefit from the tacit knowledge of workers that is not easily codified.[198] Knowledge spillovers are a positive externality, as the returns to the initial investment are not fully captured by the party that made it. This means that society in general would benefit from more of this investment than is likely to occur absent a strategic policy approach.

The intrinsic difficulty of an externality is compounded when the challenges of sustainability are taken into account. All manufacturers would benefit from collective efforts to reduce carbon emissions from production and to expand the scope of human knowledge in which all can share; however, all (or at least most) would prefer that others bear the weight of these efforts.[199]

Absorptive Capacity

The effective spread of ideas and technology related to sustainable manufacturing, via strong inter-firm and cross-sector connections, also requires that firms on the receiving end of these flows are able to make use of it. ‘Absorptive capacity’ is defined as a firm’s “ability to recognise the value of new external information, assimilate it, and apply it to commercial ends”.[200] There are numerous factors which might affect this, but skills and education, investment in R&D and organisational capabilities are among the most important.[201]

There is evidence that firms that are best able to take advantage of external sources of knowledge have higher proportions of graduates, particularly those who specialised in STEM subjects (science, technology, engineering and mathematics). However, the process of accessing, interpreting and applying new information to an existing business model is likely to require the availability of a diversity of skills at different stages. Tera Allas, in a report for BIS, suggests that “scientific and technical skills may be needed to absorb external

197 Bascavusoglu-Moreau, E and Li, Q, “Knowledge spillovers and sources of knowledge in the manufacturing sector: literature review and empirical evidence for the UK”, 2013, 37-51.
198 Ibid, 20
199 Rodrik, D; “Green Industrial Policy”,2013, 2.
200 Cohen, W and Levinthal, P, “Absorptive Capacity: A New Perspective on Learning and Innovation”, Administrative Science Quarterly, 35:1, 1990.
201 Crafts, N and Hughes, A; “Industrial Policy for the medium to long-term”, 2013, 15.

knowledge whereas process, production and design skills may be required to create firm-specific innovations".[202]

Unsurprisingly, smaller firms often face difficulties with regards to the technical skills required to make use of external knowledge, or in having the resources to devote significant time to the task ahead of day-to-day operations. Evidence submitted to this inquiry suggested that smaller firms tend to rely more heavily on their relevant trade association for guidance on sustainability. That may be true in some sectors, but in aggregate the UK innovation survey (UKIS) data finds that smaller firms rely on similar mixes of knowledge sources as larger firms – it is just that far fewer of them do so regularly. While trade associations may have a significant role in assisting firms with sustainability, their potential impact is likely limited by having to take into account the different absorptive capacities of their members.

Intermediary Institutions – The State as Broker and Facilitator

Intermediary coordinating organisations can help deepen the connections between different actors in a way that reduces risk and uncertainty and helps facilitate the spread of knowledge. They are therefore an important focus for policy in the UK as the need to develop more sustainable forms of manufacturing becomes more pressing. Organisations such as Innovate UK and its associated networks, the various Research Councils, and programmes such as the RSA Great Recovery project and WRAP are crucial not just as a means of 'correcting' market failures in the form of insufficient innovation within the UK economy. They also have a vital role in creating a vibrant ecosystem of connections and supportive institutions which can help the spread of sustainable innovation and expertise, and help create new markets for sustainable manufacturers.

A clearly defined direction for innovation policy does not necessarily mean a top-down process for pursuing this goal. In the US, a broad, decentralised system of public agencies has long worked to foster a network of collaborating actors across universities, corporations and other intermediary groups. These organisations have considerable operational autonomy to pursue specific challenges collaboratively. This model is typified by the Defence Advanced Research Projects Agency (DARPA), but also includes the National Science Foundation (NSF), the National Institute of Health (NIH) and the Small Business Innovation Research Programme (SBIR).[203]

Fred Block describes the role of this 'Developmental Network State' as not only directing resources towards technological challenges, but also one of "opening windows, brokering, and facilitation". 'Opening windows', as an approach, recognises that narrowly defined government objectives might exclude otherwise beneficial ideas and that the state should "create multiple windows to which scientists and engineers, working in university, government laboratories, or

202 Allas, T; *Insights from international benchmarking of the UK science and innovation system*, Report to BIS, 2014, 12.
203 Mazzucato, M, The Entrepreneurial State, 2013.

business settings, can bring ideas for innovations and receive funding and other types of support".[204]

Brokering reflects the idea that public agencies with a broad overview of this network might be in a unique position to connect different groups in a way which might not otherwise have occurred. Mutually beneficial relationships can form around the exchange and cross-pollination of ideas, or the linking of the right innovation with the right business group or investor.

Facilitation is best described as a role for the state in reconciling new ideas and existing systems. For more radical innovations, this can include investment in necessary infrastructure (as was required with the railways or the internet). It can also involve considering the impact of existing standards or regulations, which might have unintended consequences when it comes to new products and ideas.[205] A common complaint heard by this inquiry related to regulations around the transportation of waste, particularly the EU's REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulation, which was not designed with sustainability in mind, and is a perceived obstacle to increased recycling and the circular economy.

This convening role for the state is not necessarily one which comes naturally to it, at least in the case of the UK. While the depth of existing institutional linkages in Germany might provide a better basis for the fostering and sharing of knowledge around sustainability (particularly on a regional level), the UK has actually come a long way in recent decades, and the existing system is worth building upon. Projects such as Innovate UK's collaborative R&D projects can serve as a platform for new relationships or consortia, and can focus the talents of various actors around a grand societal or technological challenge. Similarly, the establishment of the catapult centres, technology-focused institutes that are focused on connecting researchers and businesses and facilitating the commercialisation of new ideas, is an important development for the UK's ability to develop sustainable innovations.

The space in which collaborations emerge and develop is an important feature of an innovation system, particularly with regards to realising cross-sectoral opportunities that might exist beyond the social or economic interactions which occur in the normal course of business. 'Kissing frogs' is the common shorthand among proponents of industrial sustainability for unusual collaborations that might result in worthwhile opportunities and partnerships; a textbook example being Marks and Spencers' clothes recycling project with Oxfam.

204 Block, F, "Swimming Against the Current: The Rise of a Hidden Developmental State in the United States", 2008.
205 Block, F, "Swimming Against the Current: The Rise of a Hidden Developmental State in the United States", 2008.

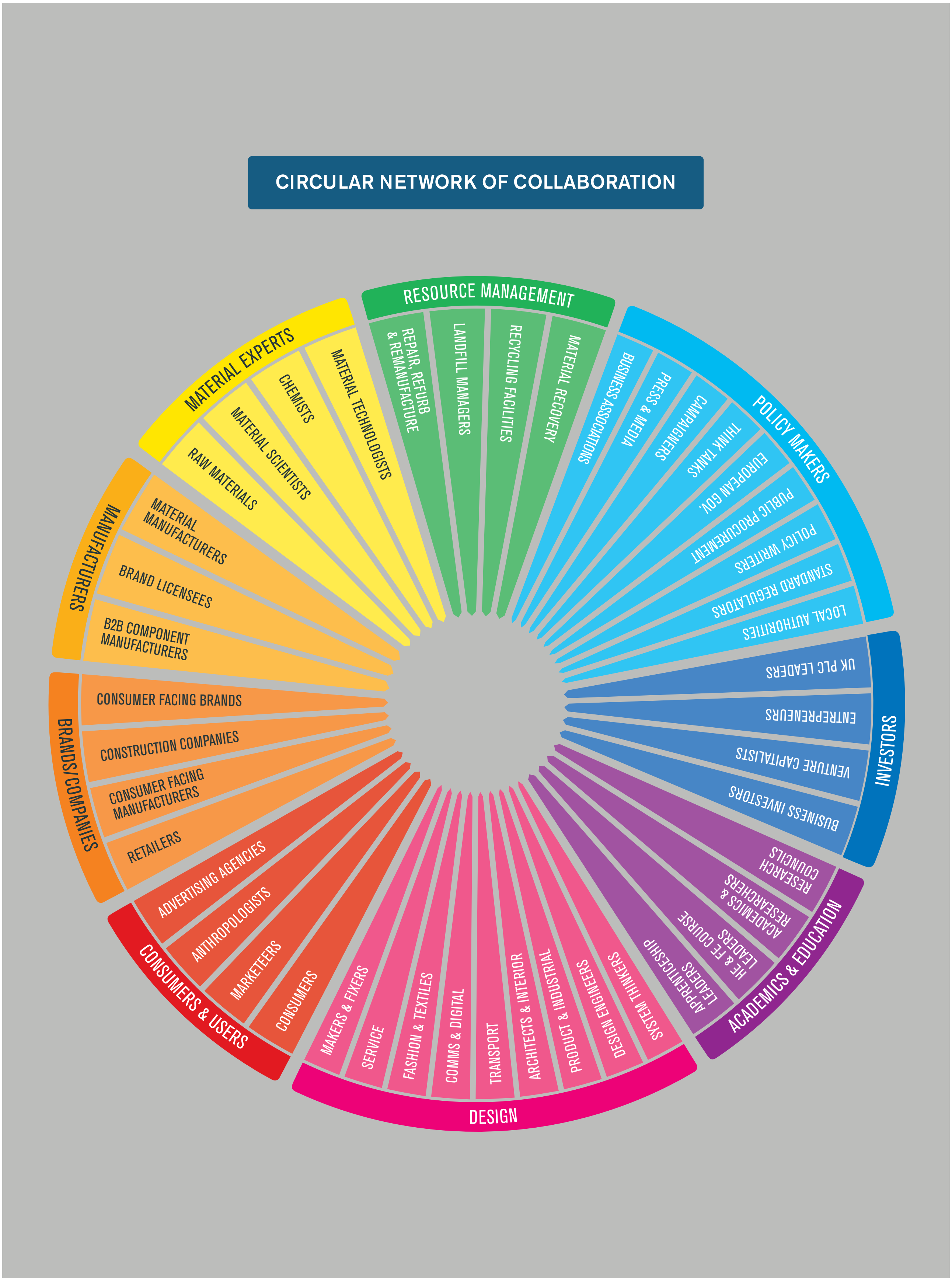

Fig. 20 “Circular Network of Collaboration”;
Source: RSA, The Great Recovery, The Role of Design in the Circular Economy, 2013

Organisations like the Catapults therefore need to continue to build linkages across academia and industry, and to develop into spaces in which intractable problems stumble across unexpected solutions. The broad provision of multi-faceted support which characterises the German Fraunhofer model is not just a matter of institutional design, but of developing capacity and networks of relationships. It has also been noted that the Fraunhofer system tends to generate commercialised innovations within established companies (owing to Germany's broad and well-established industrial base) rather than helping the emergence of new companies.[206] The Sustaining Growth in Innovation Enterprises project involving the University of Manchester found that fast-growing firms in green industries tended to be engaged with universities as sources of public support. However, it also noted that the impact of these 'triple helix' connections with universities and government was muted in comparison to the US.[207] This suggests that the catapult centres have not yet reached the same level of maturity as comparable American networks.

The challenge for the UK's innovation system is also to broaden the involvement of the private sector in the exchange of knowledge around sustainability. The availability of Innovate UK grant funding, and the work of organisations like the Knowledge Transfer Network, have undoubtedly widened private sector involvement in collaborative innovation. However, the engagement of companies with these organisations is inevitably tilted towards those that already have an inclination toward looking outside of the firm for opportunities to collaborate, or which have the resources to devote to filling out a grant application. Wider use of schemes such as innovation vouchers could be an important component in helping younger companies in particular access academic, technical or design expertise and support.

If deeper collaborative connections across the system are considered to be important, a key question for the purposes of sustainability then becomes: what is the best forum around which to convene a broader engagement with the challenges of sustainability? Given that significant change within industries is likely to be handled better by some companies rather than others, trade associations may not be the best option for this, as it potentially conflicts with their representative function on behalf of the whole industry.[208] Professional bodies, such as the different engineering institutions, working with government, could potentially play a greater role in convening a critical mass of manufacturing firms around a particular challenge. Dealing directly with one industry enables policy-makers to develop a depth of understanding of sector-specific challenges. However this must be balanced with a recognition that sustainability entails challenges that are not neatly confined to one sector.

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206 Connell, D, *Creating Markets For Things That Don't Exist: The Truth About UK Government R&D and How the Success of SBRI Points the Way to a New Innovation Policy to Help Bridge the Valley of Death and Rebalance the UK Economy*, Centre for Business Research, 2014, 11.

207 Shapira, P; "Sustaining Growth for Innovative Enterprises: Transatlantic Comparisons and Implications for the UK"; Workshop on Innovation and Local Growth Enterprise Research Centre, Warwick Business School, 2015.

208 Although the Green Building Council is an example of industry organising itself around concerns for a more sustainable built environment.

Industrial Symbiosis

Although firms have clear incentives to be efficient within their own core processes, by-products, surplus energy and spare capacity frequently occur. This raises the possibility of synergistic collaborations to make use of these resources as inputs in a different industry, through approaches such as 'industrial symbiosis'. This can result in the generation of new revenue, saving on waste treatment expenses or landfill taxes and the more efficient use of resources. The realisation of such opportunities on a system-wide level faces particular barriers. However, greater public support for facilitating these linkages could help the development of an industrial system that is more than the sum of its parts in terms of energy and resource efficiency.

It is by now a well-worn theme of this report, but the mere fact that profitable collaborations exist in theory does not mean that they are taken-up in practice. Successful cases of industrial symbiosis require an understanding of the waste or by-products of others, or the suitability of one's own unused resources as input for other industries' processes. Even after this knowledge gap has been overcome, uncertainty as to the benefits of collaboration, frictions in coordinating the schedules of separate processes and the proximity of the facilities involved can frustrate what would otherwise be rewarding relationships.

Industrial symbiosis can occur within planned initiatives such as eco-industrial parks, but its utilisation on a wider scale can be better promoted through a facilitating agency. The National Industrial Symbiosis Programme (NISP), which operated as a national programme until 2014,[209] is a well-known example of this model, which has been recognised by the OECD and European Commission. Facilitating here involves not just the exchange of information between firms, but the provision of expertise which can assist in identifying opportunities and overcoming technical issues. The inherent challenge of facilitation for industrial symbiosis is that the connections are between companies from different sectors (akin to the 'kissing frogs' analogy above). Hence, industrial symbiosis involves trying to identify and develop relationships that would not 'naturally' occur.

NISP generated a good return on public investment of between £5-£9 of value for every £1 put in. Calculations of reductions in water and material use, CO2 emissions and waste going to landfill show that this occurred at a cost of less than £1 per tonne.[210] Additionally, industrial symbiosis collaborations can generate positive externalities which the system as a whole benefits from. These include not only the benefits of greater material efficiency, such as resilience against resource insecurity and environmental benefits, but also high levels of (cross-sectoral) innovation and knowledge spillovers.

The challenge for this model in terms of having a major impact on sustainability is to be able to facilitate industrial symbiosis at scale. Dealing with a broader range of companies most likely means dealing with greater levels of corporate inertia and uncertainty, and also requires more workers with the skills to recognise and expedite opportunities for industrial symbiosis. Policy changes which might assist industrial symbiosis having a greater impact include higher carbon prices, better data on material flows and removing regulatory barriers to the exchange and reuse of waste. Maintaining the diversity of the UK's manufacturing base is also important in terms of ensuring potential synergistic matches.

209 NISP is now run as a commercial entity by International Synergies Limited.

210 Ekins, P et al, *Greening the Recovery: the report of the UCL Green Economy Policy Commission*, UCL, 2014, 153.

Policy Recommendations:

Recommendation 16

The industrial decarbonisation roadmaps undertaken by BIS and DECC should be expanded to other key industries, with a broader remit around long-term, strategic challenges faced by the sector: these plans should act to inform the policy-making process on sector-specific detail and provide a basis for negotiated agreements on what support government will provide, and what expectations will be placed on industry to commit to longer term collaborations. This may include, for example, joint funding for dedicated training and research facilities within universities.[211] These agreements should then be advanced either through existing industry leadership councils, or by acting as the basis for new councils along the same lines. These forums could then work to inform the catapult focused on cross-sectoral challenges, outlined in recommendation 7.

Recommendation 17

The Competition and Markets Authority (CMA) should be tasked with working more closely with trade associations and business consortia to provide guidance at an earlier stage on data sharing and other forms of collaboration that might otherwise be frustrated by uncertainty around competition policy.

Recommendation 18

Government should expand efforts to foster voluntary agreements around the efficient use of materials and waste reduction, while providing a clear signal to industry that regulations will be imposed if a suitable agreement is not reached within an acceptable timeframe.

Recommendation 19

The National Industrial Symbiosis Programme (NISP) should be refunded as a national initiative, accompanied by a broader review of policy measures which can assist in scaling up its impact.

211 Such as the Centre of Excellence for Food Engineering at Sheffield Hallam University (https://www.shu.ac.uk/research/food-engineering/).

5

SYSTEM REDESIGN

The prevailing model of raw material extraction, production, use, and disposal is not the result of any immutable economic laws. Rather, it is the historical legacy of a course of economic expansion which developed largely unrestrained by planetary limitations, and which is embodied in our existing stock of capital and systems of production. New sustainable business models have the potential to be both profitable and far-less environmentally burdensome through focusing on meeting consumer's needs in new ways, retaining and reusing products and material in a circular (or closed-loop) rather than linear system of use and production.

This report has thus far dealt with barriers to greater business leadership on sustainability; the need to develop greater resilience to future disruptions to the supply of materials, energy and other inputs; the state's role as a partner in green innovation; and how we can drive greater collaboration between all parties in society to promote the spread of knowledge and higher standards as a means to a more sustainable manufacturing system. On a longer time scale, sustainability will also require shifts in the way that businesses do business: the manner in which they provide value to their customers, and capture value for themselves through new models of economic activity.

The UK is, in fact, a leader on thinking around new business models. Among the most prominent examples of work in this area are:

- The work of the Ellen Macarthur Foundation on the circular economy, including in conjunction with McKinsey & Company
- The RSA Great Recovery Project, particularly with regards to design in the circular economy
- The work of International Synergies and the National Industrial Symbiosis Programme (NISP)
- Charities such as Green Alliance and WRAP which conduct research and various initiatives on recycling and new business models

- The Scottish Institute of Remanufacture at Strathclyde University, Glasgow

- EPSRC-supported work on industrial sustainability, through-life engineering, Product Service Systems and servitization

This report does not seek to add to that body of knowledge of what is conceivable for businesses, but rather to focus on the role of policy in enabling the broad emergence and adoption of new ways of meeting consumers' needs in more sustainable ways.

Government will undoubtedly make little headway in trying to prescribe business models to the private sector or to consumers. As economist/philosopher Amartya Sen has argued, the freedom to engage in economic transactions and exchange is worth treasuring in itself, regardless of any arguments as to the efficiency of markets.[212] While society can put reasonable restrictions on the ways in which individuals conduct their business, in line with social norms or objectives, such restrictions should be imposed with caution.

Instead, sustainable businesses models must be demonstrated as being economically viable, at scale, in a world of constrained resources. This viability is not just a function of the business models themselves, but of the wider system in which these new enterprises will need to operate. Established regulations, forms of capital investment, national infrastructure and supply chains all contribute to a lock-in effect, or a degree of path dependency, which can serve to lock-out other ways of doing business. The same is true of cultural norms around how we fulfil our material needs. For example, consumers will need to adjust to new manufacturing approaches which increasingly separate the use of a good from its ownership. Government has an indispensable role in reducing consumer uncertainty and promoting the development of new markets for sustainable business models.

A parallel can be drawn with the 'new economic geography' account of globalisation. As global transport costs and barriers to trade fell throughout the late 20th century, manufacturing businesses did not all rush to the lowest-wage economy at one time, but were held in place by the availability of inputs and proximity to markets (and still are, in many cases).[213] However, each firm that did offshore reduced the cost for subsequent firms to do so by contributing to the development of similar complementary networks in the country of destination, pulling more and more firms towards developing economies.[214] A similar tipping point can be envisioned for sustainable business models, whereby the development of a more effective resource management infrastructure, complementary regulations and financing options, product design for circularity and willing consumers will encourage more and more firms to adapt their businesses practices to a circular economy. The more

212 Sen, A, *Development as Freedom*, 2000, 26.
213 These are, essentially, 'clustering' effects of the sort discussed in section 4.
214 This is the Krugman-Venables model of agglomerations.

government can tilt institutions in a direction which is more conducive to sustainable manufacturing, the more the UK will benefit from the social, economic and environmental advantages offered by this transformation.

What do we mean by System Redesign?

Sustainable business models include a broad range of ideas. Some are specific to production within manufacturing, while others focus on wider social ('slow fashion', environmental stewardship, transparency) or organisational structures (social enterprises, wider stakeholder models).[215] A common thread throughout these ideas as they relate to the industrial system is the rethinking of how manufacturers create and capture value, and how this can be better aligned with wider social and environmental goals.

Some of the most promising avenues of business model innovation blur the line between manufacturing and services. Servitization can range from the provision of assistance after the sale of a product to ensure longevity and continued performance,[216] to the delivery of a function derived from a physical good while the manufacturer retains ownership of it (Product Service Systems [PSS]). Some of the most well-known examples of innovation in the latter category include Rolls Royce's 'power by the hour' provision of engine use and Xerox's shift from selling photocopiers to providing 'document management solutions', where they are paid per print or copy.[217] This shift reflects the fact that we *primarily* value goods for the outcomes they make possible – what they contribute to our wellbeing – rather than the mere fact that we own them. The director-general of the Confederation of British Industry recently noted that when these trends are taken into account, manufacturing's contribution to UK GDP might be as much as 19% - approximately twice what is normally reported in national accounts.[218]

Applying these insights to business practices opens up opportunities for higher and more stable revenue streams, attaining competitive advantages and capturing value at the service-end of the product's lifecycle – all while producing much less on the basis of pure volume. Servitization can potentially result in significant decreases in resource use, and can also better align the firm's interests with the long-life and efficient performance of the manufactured good, as well as its reuse.[219]

Other areas of sustainable business models for manufacturing focus on generating value from waste in both products and processes; recirculating used goods and materials back into the production

215 Bocken, N et al, "A Literature and Practice Review to Develop Sustainable Business Model Architypes", *Journal of Cleaner Production*, 65, 2014.
216 Such as through-life engineering services; see EPRSC Centre for Innovative Manufacturing, "Making Things Work: Engineering for Life – Developing a Strategic Vision", 2015.
217 Baines T, et al, "The servitization of manufacturing; a review of literature", in *Journal of Manufacturing Technology Management*, 20:5, 2009.
218 "Manufacturing worth 19% of UK economy, according to CBI chief" The Manufacturer, September 2015; http://www.themanufacturer.com/articles/manufacturing-worth-19-of-uk-economy/
219 Bocken, N, et al, "A Literature and Practice Review to Develop Sustainable Business Model Architypes", *Journal of Cleaner Production*, 65, 2014.

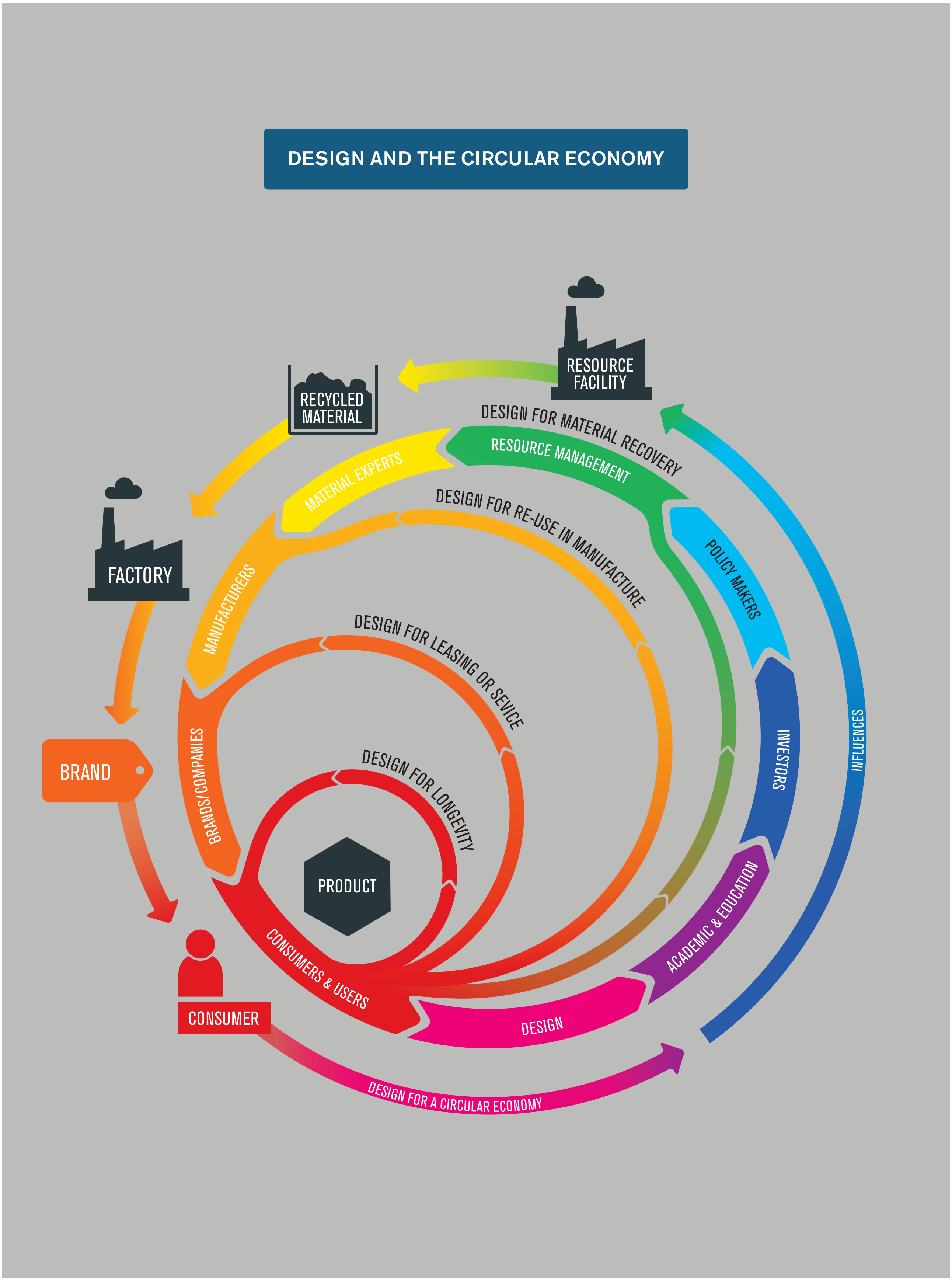

Fig. 21 "Design and the Circular Economy"
Source: RSA, The Great Recovery, The Role of Design in the Circular Economy, 2013

cycle to break the link between manufacturing and raw material extraction.

Examples of this line of thinking include:

- Circularity[220] is an approach which stands in contrast to the 'linear' account of traditional production and consumption ('take-make-dispose'), and involves the joining up of the value chain so that end-of-life products are reused as inputs, and waste is utilised as a resource wherever possible. This requires the system-wide design of products for durability, repair, upgrade, reuse and recovery.[221]

- Industrial Symbiosis is the utilisation of waste and by-products from one process as inputs in another.

- Remanufacturing is "a series of manufacturing steps acting on an end-of-life part or product in order to return it to like-new or better performance, with warranty to match".[222] It is a similar but distinct concept from reuse, refurbishing, repair and recycling.

Why are new business models necessary?

As noted, there are good economic reasons why businesses would consider developing sustainable business models, regardless of their benefits from an environmental point of view. What makes sustainable business models an area of particular interest for government is not just these potential environmental benefits, but also the limitations of addressing sustainability purely from a supply-side approach. Although the unrealised economic gains from efficiency are considerable, it is not clear that this alone would be sufficient to get us to a truly sustainable system without a radical change in how consumers make use of manufactured products. The same is true for technological change, which must advance (and be widely implemented) at a rate sufficient to counter the trends of world population growth and economic development.[223]

This is explained by the rebound effect, or Jevon's paradox, which says that the gains from efficiency improvements can be partially or wholly offset by increases in the demand for the relevant product as a result of lower prices. This is true of energy as well as products, and can occur through either greater consumption or through consumers choosing more material or energy-intensive products. This is a key factor undermining the absolute decoupling of growth and environmental impact, as whatever progress we make in environmental impact per unit is undone in absolute terms by the sheer weight of increased output.

220 Other similar concepts include closed-loop, cradle-to-cradle, industrial ecology, biomimicry, natural capitalism and the performance economy. Circular economy is used here for consistency.
221 RSA – the Great Recovery, *Investigating the Role of Design in the Circular Economy*, 2013.
222 This is the definition proposed for adoption by government in the All-Party Parliamentary Sustainable Resources Group (APSRG)/All-Party Parliamentary Manufacturing Group (APMG) report, *Triple Win: the Social, Economic and Environmental Case for Remanufacturing*, 2014. It is currently being considered for adoption by the EU Commission.
223 Tennant, M, "Sustainability and Manufacturing"; 2013, 30.

This, it should be recognised, is part of a feedback loop of increasing supply and demand through productivity gains which has underpinned advances in human wellbeing at a level that would have been inconceivable just a few centuries ago. The consequences of the industrial system continuing to operate in an unsustainable manner mean that that connection is irrevocably severed.

Evidence suggests that the rebound effect differs between products.[224] However, its effect is difficult to anticipate in advance as it depends on what consumers choose to do with the savings from more efficiently produced products. Many of us would be content with just one vacuum cleaner, no matter how much its cost has fallen. As income increases, consumption tends to shift toward more services, as people's material needs become satiated. This may mean that savings from cheaper manufactured goods are redirected to less environmentally-taxing options. The corollary of this is that the rebound effect is higher for lower income households, which have greater unmet material needs.[225] New innovations in the ways in which manufacturers meet the needs of the market offer the potential to escape this paradox.

What are the Opportunities from Sustainable Business Models?

Materials and Resilience

Sustainable business models would enable a dramatic decrease in material and raw resource consumption. Estimates from the Ellen MacArthur Foundation, which quantified these potential benefits for durable goods at an EU level, suggest that savings would be in the range of $320 billion - $630 billion (£211billion to £416 billion) per annum by 2035, depending on the scale of their adoption.[226] The largest potential gains are in the automotive, machinery and equipment, and electrical machinery sectors, as well as significant potential gains in consumer goods such as packaged food, beverages and textiles.[227] WRAP estimates that the circular economy could result in 20% less waste generated, and a decrease of 30 million tonnes of material input into the economy by 2020.[228]

The recirculation of materials within the economy can help to build national resilience to resource price volatility and supply shocks by reducing manufacturers reliance on imported materials. The work of the Green Alliance identifies metals, phosphorus and water as key priorities for resilience-driven circularity.[229] Business models such as PSS that allow firms to retain ownership of the physical product are potentially vital measures to ensure the continued access and availability of CRMs. These models can help firms overcome the challenge of recovering CRMs at the end of life, where it does

224 Sustainable Lifestyles Research Group; papers available at http://www.sustainablelifestyles.ac.uk/projects/economy/mapping-rebound-effects
225 Sussex Energy Group, "Mapping rebound effects from sustainable behaviour", http://www.sussex.ac.uk/sussexenergygroup/research/recent/mappingrebound
226 Exchange rate is based on US$1 = £0.66; Ellen MacArthur Foundation, *Toward the Circular Economy*, Vol 1, 2012.
227 Ellen MacArthur Foundation, Toward the Circular Economy, Vol. 2, 2013.
228 WRAP, "WRAP's vision for the UK Circular Economy to 2020", available at http://www.wrap.org.uk/content/wraps-vision-uk-circular-economy-2020
229 Green Alliance, *Reinventing the Wheel: A Circular Economy for Resource Security*, 2011.

not occur already due to their wide dispersal in low quantities.[230] Models which rely on continued use of the product rather than sales should also provide greater incentives for manufacturers to prioritise durability, in-use product efficiency and design for re-use or recovery.

Employment

In addition to the environmental benefits of sustainable business models, such radical innovations can have beneficial knock-on effects for employment and society at large. Innovation creates new industries, new market players, and correspondingly new jobs. However, as with all social and economic transformations, there will be winners and losers, and some industries will find it easier than others to apply new business models to what they do.

With regards to employment, the services sector is more labour-intensive than manufacturing, so in theory the shift toward servitization raises the potential for greater job growth within firms. Whether this turns out to be a general trend toward more high-quality jobs depends on how much employment is cannibalised from existing manufacturing-related services (such as repairmen). Low-carbon electricity is often regarded as having high job-creation potential, but this partly reflects the fact that renewables are still a maturing technology.[231] As such, these jobs are likely to be relatively low-productivity ones. The same is likely true for labour-intensive recycling jobs.

The employment implications of a circular economy naturally depend on the extent of its penetration within the economy. WRAP and the Green Alliance provide estimates based on a number of potential scenarios, and conclude (cautiously) that a circular economy has the potential to provide low- to intermediate-skilled employment in some regions of the UK that have suffered from high unemployment in recent years, and to offset projected declines in mid-level employment.[232]

Much of the employment benefits of a wide-scale shift to a greener economy are likely to come about indirectly. New approaches to manufacturing also require shifts in suppliers, infrastructure and skills providers. In past technological revolutions (such as railways, mass production or ICT), it is in these 'induced activities' around complementary businesses and economic structures that the major job creation has occurred.[233]

Barriers to Sustainable Business Models

Regulatory

Policy often has unintended consequences, which are a natural outcome of seeking to codify complex real world behaviours into restricted and

230 Parker, D "The Future Impact of Material Security on the UK Manufacturing Industry", 2013, 32.
231 Fankhauser, S "A Practitioners Guide to a Low-Carbon Economy: Lessons from the UK", Climate Policy, 2012, 12.
232 WRAP and Green Alliance, Employment and the circular economy Job creation in a more resource efficient Britain, 2015.
233 Perez, "Steering Economies toward the next Golden Age", Mission-Oriented Finance for Innovation, 2015, 58.

unrestricted categories. Much of our current regulation was not created with sustainable business models in mind. The potential for radical change in the way many manufacturers operate means that policy-makers need to be engaged with developments in the private sector. This involves being proactive in updating regulation to suit contemporary needs (while still addressing the underlying social objective of the regulation), as well as being efficient in the accreditation of new innovations when this is necessary. Examples of regulatory barriers to the circular economy and other sustainable business models include:

- Labels: the RSA Great Recovery report on bulky waste noted that used furniture which had had their fire labels removed were not able to be resold by re-use organisations, meaning that these otherwise valuable goods tended to end up in landfill;[234]

- REACH regulations at the EU level were not designed to promote the take back and recycling of chemicals and can prevent circularity with regards to used paint, for example.

- WRAP provided evidence to this inquiry that one company looking to buy and resell used televisions needed separate VAT calculations for each unique item, rather than being able to average out profit margins. This effectively imposed a heavy transaction cost on each unit, and heavily increased the administrative burden the company faced.

While the enactment of these regulations was undoubtedly based on good intentions, some may unintentionally curtail the development of promising new business models. While it may be true that some of these barriers are far from insurmountable, they do contribute to the perception of difficulty around changing the way manufacturers operate, and pose a particular obstacle for SMEs that might have less internal capabilities to dedicate to compliance in this area.

Responsibility for policy areas of relevance to sustainable business models cuts across BIS, DEFRA, DECC, HM Treasury as well as the Department for Communities and Local Government (DCLG). Thus there are a large number of entities which need to coordinate on the task of facilitating business model innovation within the UK's policy framework, not to mention private sector and intermediary organisations. Additionally, much of this change is better addressed at an EU-wide level. This would provide the opportunity to establish a larger market for new manufacturing models to operate within, while providing support to local-level experimentation through organisations such as Innovate UK, WRAP, the RSA Great Recovery project and the Knowledge Transfer Network. At the time of writing, the EU Circular Economy package first announced in January 2015 has not been finalised. There are, however, hopes that this will ultimately result in a broader focus across the value chain on areas other than waste, including product design and markets for secondary raw materials.[235]

It should also be noted that there are political economy issues at play here. Business model innovation which emerges from disruptive new-entrants to a

234 RSA The Great Recovery, *Rearranging the Furniture*, 2015, 23.
235 APSRG, *The EU Circular Economy Package: Policy Priorities for the UK, Post-Event Briefing*, July 2015.

market may face regulatory barriers of the sort discussed above. However, such firms are likely to have less power to make sure that their perspectives are heard by policy-makers and taken into account, compared to incumbent market players.

Infrastructure

For someone wishing to start a new, linear manufacturing business in an established market, there are plenty of considerations to take into account. However, in many ways, much of the thinking has already been done for them. They will likely have the benefit of established supply chains which operate at scale, and have evolved technologically and organisationally to provide inputs in a more or less convenient form for manufacturers. Infrastructure exists at a national and international level to allow them easy access to resources and components, and the required industrial machinery is likely to be technologically advanced and suited to high-volume production. At many levels, the established structures around firms determine what makes economic sense in terms of how they operate.
It is little wonder then that resource-intensive modes of manufacturing continue to dominate.

Conversely, those seeking to develop a business which makes use of waste streams and recirculates material are confronted with a much different picture. Although materials and goods that could theoretically be reused are all around us, they are rarely in a form that is easy to make use of. Secondary materials are often widely dispersed, not easily separated from other waste or from complex products, and require considerable work to get to a useable state. Material complexity may bring many benefits (including from the point of view of more sustainable industrial processes), but the development of new alloys and polymers ahead of our ability to take products apart and recover these materials poses a significant barrier to the circular economy.

In some ways, these difficulties are inherent to the reuse of waste. Although by-products can be reutilised within the firm to create new streams of revenue,[236] business models that seek to make use of end-of-life products are typically dependant on waste companies, local collection and recycling systems, and (crucially) consumers themselves. Takeback schemes and deposits can and have worked well for some products, such as British Gypsum's plasterboard take-back programme.[237] However these approaches are less well suited to smaller and lower-value products. As an illustrative example, large high-value permanent magnets in wind turbines tend to be recycled, while the magnets in mobile phones do not. Difficulties of the sort detailed above mean that it becomes uneconomical to sort and recycle many lower-value materials. The end result is a system which results in many waste streams being too costly, difficult or unreliable to utilise as an input, while competing supply sources derived from raw materials have advantages of both scale and efficiency that have been built up over many decades.

For potentially reusable products, the existing recycling system is ill-suited to recognising and recovering value. Although the 'waste hierarchy' places reuse as a higher priority than recycling, legislative targets around the latter mean that it tends to dominate within the operation of waste management companies, and there are few financial incentives for waste contractors to facilitate business models around reuse.[238]

236 AB Sugar is a well-known example of this.
237 http://www.british-gypsum.com/about-us/sustainability/plasterboard-recycling
238 RSA The Great Recovery, *Rearranging the Furniture*, 2015, 17; APSRG/APMG, *Triple Win: the Social Economic and Environmental Case for Remanufacturing*, 2014.

These inherent difficulties are exacerbated by the way the UK goes about waste management. There are some bright spots within resource management policy at a national level, including the ongoing work of WRAP, and the impact of the landfill tax escalator.[239] However, the fragmentation of responsibility for waste between district, county and borough councils and unitary authorities across England, Scotland, Wales and Northern Ireland[240] results in a complex regulatory landscape for companies wishing to secure the return of used products and materials.

Devolution of powers has resulted in more active approaches to waste in Scotland and Wales, which have advanced ahead of the rest of the UK.[241] However, the lack of a coherent national approach is an obstacle to a more sustainable system as a whole, and also makes it more difficult for manufacturers to provide consistent advice to their customers on the return or recycling of products. The ongoing national debate on further devolution of powers needs to take into account what impact this will have on efforts to facilitate a system-wide change in our use (and re-use) of materials.

Measures such as long-term contracts for waste-to-energy plants, which guarantee these plants access to certain quantities of municipal solid waste, may be an improvement on landfills. However, they risk locking-in investment in less sustainable uses of waste, which leads to the ongoing incineration of materials that could otherwise be recycled (such as paper). A similar problem might occur with manufacturers going down the route of developing and using more light-weight materials, which may reduce resource use but potentially poses challenges from a circular economy point of view as it can be more difficult to recover this material.

The UK's long-term underinvestment in infrastructure is well-recognised. Additionally, from the point of view of economics, the provision of infrastructure is complicated by its public good characteristics, network externalities and lack of competition, which mean that there has always been a strong rationale for government

239 The landfill tax has had a significant impact on the landfill of municipal solid waste in the UK, and has also resulted in a considerable (and largely coincidental) reduction in methane gas emissions. See European Environment Agency, *Municipal Waste Management in the UK*, 2013; Fankhauser, S "A Practitioners Guide to a Low-Carbon Economy: Lessons from the UK", Climate Policy, 2012, 11.

240 This is not to mention Waste Collection Authorities and Waste Disposal Authorities.

241 FCC Environment, *Mapping the Politics of Waste*, 2015, 2.

Closed Loop Environmental Solutions

Closed Loop Environmental Solutions is a company based in the UK and Australia, and was the first to construct a factory for the reprocessing of polyethylene terephthalate (PET) and high density polyethylene (HDPE) bottles back to food-grade plastic. They helped the recovery rate of plastic bottles in the UK rose from around 3% to over 50%, diverting millions of bottles from landfill and reducing CO2 emissions by an estimated 52,500 tonnes annually.[242] Dealing with a widely dispersed and low-value product Closed Loop Environmental Solutions relies on wider collection and sorting systems, which often don't do a good job of extracting value from waste and enabling the reprocessing of materials.

Closed Loop Environmental Solutions is a partner in the consortium Simply Cups, a paper cup collection and recycling system. Here, there is a similar challenge of there being no good business case for waste companies to sort and bale low-value materials. Disposable paper cups are a multi-material but theoretically-recyclable product, made from high grade paper with a plastic film coating. They are a classic example of a product that consumers likely assume will be recycled if they place in the recycling bin, but which the system fails to make the best use of. Instead, responsibility for the product is passed down the chain and much of the material ends up in incineration. The landfill tax provides an opening for Simply Cups to operate as a paid collection service for a supply chain-wide consortium of manufacturing, hospitality, vending and catering companies (which arose out of an Innovate UK competition). Expanding the project to the level of a paper cup recycling facility would require the broad engagement of enough companies to allow sufficient scale in the supply of material.

242 http://www.closedlooprecycling.co.uk/about-us

to take an active role in this area.[243] There is an urgent need to avoid carbon lock-in through long-life investment in transport, energy, water and telecommunications infrastructure that will prove ill-suited to the needs of more sustainable manufacturing models, as well as of future generations. One prominent example is the gas distribution infrastructure. Investments in this network should be directed toward adapting it for greener gases such as hydrogen, rather than continuing to invest for the purposes of natural gas which is inconsistent with long-term carbon targets.[244] The importance of CCS to achieving the necessary reductions in industrial carbon emissions further adds to the need for an effective institutional framework for infrastructure.

A long-term, strategic approach to the direction of this sector is vital. The coordination, maintenance and development of a wider system that is sufficient to fulfil the potential of more sustainable business models ought to be a strategic economic priority for the UK.

Finance for New Business Models

As with the wider economy, the financial system has evolved in a way that reflects the traditional, linear approach to manufacturing. As manufacturers continue to develop new sustainable business models, there is the potential that entrenched approaches to lending may pose a barrier to the more widespread adoption of new ways of doing business.

The broader trend within finance has been a move away from financing new business investment and increasingly towards real estate lending. Financing manufacturing naturally poses a greater challenge for bankers than mortgage lending, as it requires analysis of a much broader range of questions than just credit-worthiness and the value of the collateral property. As Adair Turner has written, “left to itself, the banking system will overprovide credit for real estate purchase and for real estate investment, and will underprovide credit for business investment, business development, and business innovation”.[245]

New business models pose some particular challenges for traditional approaches to the provision of finance. PSS-type models rely on revenue through long-term ongoing contracts rather than one-off sales, and it is here, rather than in the value of the asset itself, that the profitability of the company lies. Financial institutions must adapt to recognising the retained or potential value in assets and materials, which is central to the circular economy, rather than applying valuation models which would write those assets down to zero (or to scrap value).[246] ‘Financial innovation’ has become somewhat of a loaded term, but finding creative ways to fund and support new business models is a vital component of a more sustainable future.

243 Ekins, P et al, *Greening the Recovery: the report of the UCL Green Economy Policy Commission*, UCL, 2014, 120.
244 Ekins, P et al, *Greening the Recovery: the report of the UCL Green Economy Policy Commission*, UCL, 2014, 132.
245 Turner, A “The Social Value of Finance: Problems and Solutions”, *Mission-Oriented Finance for Innovation*, Policy Network, 2015, 27.
246 ING, *Rethinking Finance in a Circular Economy*, 2015, 38.

Consumer Preferences

The fostering of markets for new manufacturing business models is an under-examined area of focus for policy-makers. Consumers are, of course, well-used to being confronted with new products. However, uncertainty around new ways in which products are produced or how functions are delivered may pose a barrier to new business models flourishing in the market. Concerns as to the quality of goods that are remanufactured, or produced with recycled materials, are something that government can help mitigate through the effective use of standards – particularly championing them on an EU-wide level. This is particularly important in order to ensure that low-quality goods are not weakening consumer confidence in these classes. Government procurement can also help attest to the quality of these goods, as well as providing an additional demand-side pull for sustainable manufacturers. For instance, the UK military is a significant purchaser of Caterpillar's remanufactured machinery.[247]

Particular challenges face the more widespread use of servitization models. Consumers in general are accustomed to owning most of the goods they use, and a broad-based shift away from this norm might encounter resistance. It therefore becomes even more important that such goods remain consistent with consumer expectations in other areas, particularly product quality. Greater collaboration and data sharing by firms on market research could help identify specific barriers to new business models and assist their broader adoption.

Awareness has also been identified as a significant barrier to servitization.[248] Government procurement approaches which are better suited to servitization, such as changing the way CAPEX and OPEX budgets are determined for government departments, could help avoid the lock-in of more resource-intensive approaches (as well as saving the taxpayer money). Local authorities would likely benefit from more procurement through servitized manufacturing models, but financial uncertainty around their budgets can pose a barrier to this happening.

247 APSRG, Remanufacturing: Toward a Resource Efficient Economy, 2014, 3.
248 Aston Business School, Servitization Impact Study, 2013.

Policy Recommendations:

Recommendation 20

Government should consider tying support for energy- and resource-efficiency to other green measures. This can help counter the rebound effect by encouraging savings to be directed toward other projects that promote sustainability. For instance, the funding mechanism set out in recommendation 1 could include the option for businesses to dedicate a portion of their loan repayments toward other measures that reduce environmental impacts, such as onsite renewables or product redesign.

Recommendation 21

Responsibility for resource management infrastructure should be unified at a UK-wide level, and national infrastructure institutions must ensure that long-term investment decisions are consistent with sustainable manufacturing, and do not 'lock-in' unsustainable activities: with debates as to further devolution still ongoing, it is crucial that any steps in this direction take into account its impact on efforts to facilitate a system-wide change in our use (and re-use) of material products. Institutions shaping national infrastructure must also ensure that all future investments are consistent with the needs of more sustainable manufacturing, and avoid locking future generations into an unsustainable trajectory. This would be best served by an independent Infrastructure Strategy Board[249] with an explicit remit for future-proofing infrastructure for sustainability. Alternatively, Infrastructure UK, which sits within HM Treasury, should prioritise this function.

Recommendation 22

Government should promote alternative business models, and remove barriers to their development and adoption; Manufacturers, particularly smaller ones, need to see more clearly the benefits of adopting circular business models and be shown examples of how it can be done profitably. Despite the prevalence of one or two poster companies for the circular economy, the common view is that this is a niche area applicable only to high value goods. More pilots need to be conducted and case studies developed in order to highlight successful transitions and provide evidence of how companies have overcome the challenges in doing it. It is important that these pilots work with manufacturers of all sizes, exploring different business models and across a number of different sub-sectors. Regulatory barriers to more sustainable business models should be removed. This should include the UK taking a lead on measures at an EU level on issues such as standards for recovered materials. It is important that regulatory clarity extends to the reuse, repair and remanufacture of products and spare parts as well as materials and recycling.

249 Along the lines of the recommendation of the LSE Growth Commission; *Investing for Prosperity: Skills, Infrastructure and Innovation*, 2013.

Recommendation 23

Government should work to reduce uncertainty around more sustainable manufacturing business models by establishing standards for remanufactured products and utilising government procurement to provide a market for such products. Government buying standards should also be reviewed to make sure that practices are consistent with models such as Product Service Systems. This should include piloting PSS schemes at local government level to promote its application.

Recommendation 24

Innovation and coordinating bodies should provide greater support to innovative business models. Despite the clear environmental and business benefits that can be achieved through remanufacturing, it has traditionally received little innovation support. Facilitating supply chain discussions with relevant stakeholders on how to design for the circular economy and implement new business models can also help accelerate their deployment.

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Steering Group & Secretariat

Inquiry Steering Group

The Co-Chairs would like to thank the inquiry steering group, all of whom have committed substantial time to this inquiry, both through the evidence gathering process, and in supporting the drafting of this report. The recommendations made by this inquiry do not necessarily reflect the views or opinions of individual steering group members, or the inquiry's sponsor.

Susanne Baker – EEF
Professor Nick Crafts – University of Warwick
Peter Digby – Xtrac
Professor Sam Fankhauser – Grantham Research Institute on Climate Change and the Environment,
Sophie Thomas – Royal Society for the encouragement of Arts, Manufactures and Commerce (RSA)
Kresse Wesling MBE – Elvis and Kresse

Secretariat

The Manufacturing Commission is powered by Policy Connect, the leading network of Parliamentary groups, research commissions, forums and campaigns working to inform and improve UK public policy.

Michael Folkerson – Manager, Manufacturing, Design and Innovation
Toby Moore – Senior Researcher, Manufacturing Commission

Evidential Submissions

Evidence Sessions and Interviews

Session One: 15th May 2015
Dr Greg Lavery, Lavery Pennell
Professor Nilay Shah, Imperial College London

Session Two: 22nd May 2015
Andy Brown, British Printing Industries Federation
Paul O'Donnell, Manufacturing Technologies Association
Jane Thornback, Construction Products Association
Dr Richard Leese, Mineral Products Association

Session Three: 9th June 2015
Arjan Geveke, Department of Business, Innovation and Skills

Session Four: 24th June 2015
Ian Collier, High Value Manufacturing Catapult
Ben Peace, Knowledge Transfer Network
Dr Richard Miller, Innovate UK
Peter Goodwin, Closed Loop Recycling

Session Five: 14th July 2015
Alan Norbury, Siemens
David Cornish, AzkoNobel
Vicky Pryce, CEBR
Peter Laybourn, International Synergies

Additional Interviews

Professor Mariana Mazzacuto, University of Sussex
Lord Adair Turner, Institute for New Economic Thinking
Dr Antonio Andreoni, School of Oriental and African Studies
Keith James, WRAP
Gerard Fisher, WRAP
Adrian Tautscher, Jaguar Land Rover
Professor Tim Jackson, University of Surrey

Written Submissions

AzkoNobel
British Coatings Federation
British Geological Survey
British Printing Industries Federation
British Glass
Crafts Council
Dr James Colwill, Wolfson School of Mech. and Manf. Eng., Loughborough University
Dr Mike Tennant, Centre for Environmental Policy, Imperial College London
Dr Winifred Ijomah, Scottish Institute for Remanufacture, Strathclyde University
Professor Eileen Harkin-Jones OBE, University of Ulster
High Value Manufacturing Catapult
Innovate UK
Interface Solutions
Knowledge Transfer Network
Mike Baunton CBE
Mineral Products Association
International Synergies Ltd
The Centre for Sustainable Design, University of the Creative Arts
Professor Peter Childs, Dyson School of Design Engineering, Imperial College London
Steve Hope
UCL Sustainable Resources Institute
Unite

About the Manufacturing Commission

About

The Manufacturing Commission is a Parliamentarian- and industry-led body which conducts high-level research inquiries aimed at driving new thinking around industrial policy in the UK. It is cross-party and cross-sectoral, and makes recommendations to government and industry in order to instigate positive change in the UK manufacturing sector.

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