HM Government

Building a high value bioeconomy

OPPORTUNITIES FROM WASTE

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Ministerial foreword

We are seeing a bioeconomy revolution sweeping the globe. We are facing a number of challenges across the world to deliver economic growth sustainably and in tandem with protecting and improving the environment and reducing greenhouse gas emissions. New innovative technologies can enable us to respond to these economic, environmental and societal drivers. The UK often leads the world where innovation is concerned and the bioeconomy is no exception. There is a real opportunity for the UK and for our businesses to develop and harness new processes and business models and to export solutions to the global market.

Of course the UK is not alone in recognising these opportunities. We are part of a global race, and our challenge is to enable UK businesses to compete and grow in this global context and to deliver against the UK's growth ambitions. This means building an infrastructure that connects the innovation eco-system and enables effective exploitation.

A coordinated approach across Government and industry is a key factor to capitalise on these opportunities. We have focused our attention so far on the high value opportunities that are available from using waste as a feedstock and in doing so we have taken on the championship of the waste bioeconomy agenda through a joint-Ministerial role. This cooperative arrangement has supported a joined up approach in working towards a bioeconomy producing high value products from waste resources.

This report brings together for the first time the many actions Government, working with its partners and others, are already taking to support this emerging economy. It highlights the economic and international benchmarking studies that are underway to ensure Government has a solid evidence base to identify and develop the further actions needed to support the sector and deliver against our ambitions for a high growth, high value, bioeconomy with an initial focus in waste.

We would like to thank everyone who has contributed to the development of this report.

MATTHEW HANCOCK
Minister of State for Business, Enterprise and Energy

DAN ROGERSON
Parliamentary Under Secretary of State for Water, Forestry, Rural Affairs and Resource Management

Executive Summary

The context

The harnessing of biological resources or bioprocesses to produce food, fuels and chemicals is not new. For thousands of years wood has been used for energy, agriculture has focused on boosting and sustaining food production, and microbes have been exploited to produce ethanol. In the early 20th Century, we saw the introduction of commercial scale production of citric acid and penicillin via microbial fermentation.

More recently this range of endeavours has been grouped into a concept called the "bioeconomy"; the economic activity derived from utilising biological resources or bioprocesses to produce products such as food, energy, and chemicals. By considering a systems-level approach, we can address the complexity of the biobased systems that can be exploited sustainably for economic gain. This report looks at one part of this system, those pathways based on the UK's waste resources.

As scientific and technological advances have taken place, new opportunities have arisen within the bioeconomy to tackle some of the challenges that are facing society and industry in the UK and globally. One such opportunity is the potential to convert underutilised wastes into high value products. As an alternative to virgin materials, wastes could provide sustainable resources for the bioeconomy. Producing the energy, fuels and chemicals required to support modern life from waste derived feedstocks not only presents an economic opportunity for the UK, but provides a potential low carbon alternative to what are traditionally petrochemical, virgin material or finite resource based activities.

The Government agreed with the conclusion of the March 2014 House of Lords Science and Technology Committee report, 'Waste or resource? Stimulating a Bioeconomy', that there is an enormous opportunity for growing the bioeconomy using a range of feedstocks, including waste. We undertook to oversee the delivery of a long-term plan for realising a high value bioeconomy, with an initial focus on waste as a feedstock.

In driving forward this agenda, the Government has established a cross-Whitehall and public sector working group to ensure a joined-up approach. In tandem with this work, the Government has commissioned an international benchmarking study as suggested by the Lord's report.

The growth potential

The UK has a world-class science base in this area and many UK businesses are already leading the way to a more sustainable and efficient approach to resource use and management through innovative processes and technologies. Today there are at least 121 industrial biotechnology businesses established in the UK[1], and many more can benefit from the application of industrial biotechnology processes for non-fossil based feedstocks for product development. Commercial scale production facilities in the bioeconomy arena are becoming a

[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/298819/bis-14-p90-strength-opportunity-2013.pdf

realistic prospect across a range of thermo-chemical and (bio)chemical processes. However, there is clearly more to be done to realise the potential for new investment, supply chain regrowth and a step change in the contribution to economic growth and jobs from this nascent sector.

As the House of Lords report highlighted, it is not possible to be definitive about the size of the bioeconomy or of the potential contribution that waste can make to economic returns at this stage. There is, nonetheless, a shared consensus that the opportunity is in £billions not £millions. Our own estimated projection for the wider bioeconomy highlighted in the Lords report suggests that we could be looking at a total economic market of around £100 billion per annum, of which waste-based resources would make a significant contribution. Some other economic assumptions, which have not been formally evaluated are:

- The Chemistry Growth Partnership's 'Strategy for delivering chemistry-fuelled growth of the UK economy' identified scope to grow the gross value added of the chemical and chemistry-using sector from £195 billion to £300 billion by 2030, with the acceleration of innovation a key platform for achieving that growth. It highlights that utilising biomass or waste as a material could bring potential long-term benefits of £8 billion over the period to 2030 and is an essential focus for increasing the opportunity for innovation. Alongside these new materials the adoption of smart industrial biotechnology manufacturing processes is highlighted as playing a strong role in achieving the projected growth ambitions, with estimated economic potential of £4 billion to £12 billion per year.

- Figures captured in the Lords' report suggest the scale of opportunity might be:

  - Significant waste feedstock availability in the UK, including at least 100 million tonnes of carbon containing waste generated each year, and at least 14 million tonnes of bio-based residues from crops and forestry sources each year.

  - Of this, there is probably about 25 million tonnes of waste available which, with the right technology approach, could be converted into roughly 5 million tonnes of bioethanol with a potentially material impact on fuel supply with a value of around £2.4 billion.

Government, through its partners, is therefore working to substantiate the size of the economic opportunity from industrial biotechnology in the UK, including to identify the role that waste streams can play in realising that opportunity. This research will conclude later this year.

Environmental benefits and meeting our legislative obligations

Alongside the economic benefits, the advanced management of available carbon containing wastes and residues could help to reduce the use of petrochemicals, virgin materials and finite resources worldwide. This could contribute to reducing global carbon emissions and to increased sustainability and energy security.

Chemical companies may also be keen to de-couple their base and intermediate materials from virgin or fossil based sources. This can help reduce their carbon footprints especially for large volume production systems, e.g. monomers and surfactants.

Available evidence also suggests that we will need biofuels to decarbonise transport in the longer term. This is particularly true where other fuels may not be realistically deliverable (such as for aviation and HGVs).

The role of this report

This report acts as a starting point, articulating the opportunity as far as we can at this stage and identifying key components of the current landscape in England (waste policy is devolved), including:

- the legislative framework, the objectives behind it, the challenges of operating within the framework and the incentives that influence company investment;
- the existing strengths the UK has and how we are supporting their continued evolution so that they continue to support this emerging economy, especially the UK research base;
- the measures already being taken by Government and our public bodies to support the UK's commercial environment.

Next steps

We recognise that further work is needed by sector stakeholders and Government, using Government's Industrial Strategy model, to identify actions to support and build on the UK's existing strengths in this field and to develop a longer term plan to realise the economic and environmental potential of the bioeconomy, and the value of waste as a resource within it. The evidence from the economic analysis of the impact of Industrial Biotechnology in the UK will help to inform post-election priorities and Spending Review decisions for taking forward work in this area under the new Parliament.

Vision & Mission

Vision

1. By 2030, our vision is to see:

- the bioeconomy sector in the UK continuing to grow.

- a range of commercial scale plants fed by “wastes” operating across the country.

- entrepreneurial effort focused on areas of greatest scientific and economic potential, as well as those which deliver against our environmental and sustainability challenges. This includes our efforts to reduce greenhouse gas emissions, and to decrease the reliance of the chemical process and energy sectors on petrochemical, raw material and finite resource feedstocks and reduce their carbon footprints. This will assist in the long-term goal of decoupling economic growth from use of these finite resources.

- the UK as the location of choice for global investment in the bioeconomy.

- the UK become a global leader in gaining economic value and environmental, and societal benefit from utilising carbon-containing wastes and residues as resources in a vibrant bioeconomy, where appropriate, producing high value resource efficient materials, chemicals, and energy.

- UK capability built in advanced manufacturing which combines cutting edge R&D with industrial experience to demonstrate the potential of industrial biotechnology in promoting a bioeconomy.

- the UK as a major exporter of process technologies and business models, exploiting intellectual property abroad and retaining value for the UK while offering solutions globally and delivering against environmental targets.

Mission

2. To deliver against this vision, Government is:

- working with businesses, industry and local authorities to support the transition towards a more circular economy, encouraging a more sustainable and efficient approach to resource use and management, and ensuring that we make the best use of our materials and resources, and prevent waste, recycle efficiently, and deal with unavoidable waste properly.

- promoting the sustainable use of carbon-containing wastes and residues as important resources for developing a bioeconomy, working within the principles set out in the UK Bioenergy Strategy.

- supporting the underpinning research and development of an innovative and diverse pool of technologies and biorefineries with global potential to support a vibrant bioeconomy, and continuing to encourage investment in the development and demonstration of technologies, processes and facilities. This also includes the development of a skilled workforce at all levels to maximise the environmentally sustainable development of a bioeconomy.

- supporting businesses to lead the way in delivering growth and jobs while improving the environment, by ensuring the right policy and incentives framework is in place.

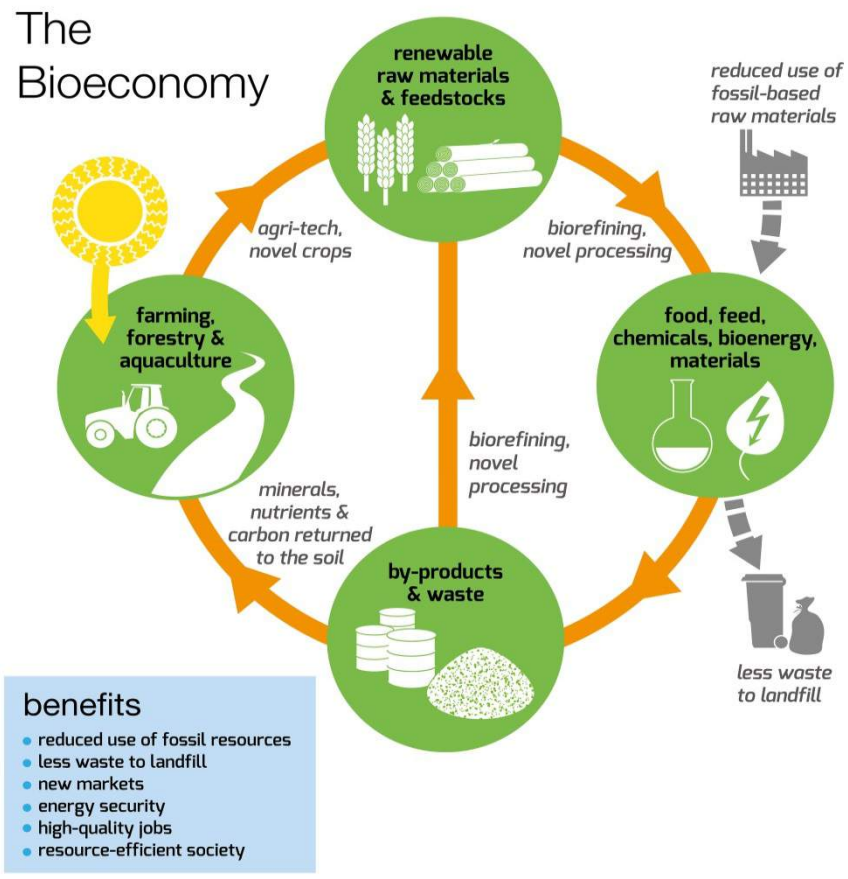
- ensuring that actions are coordinated across Government and aligned with policies around reducing carbon emissions, valuing our resources and reducing waste, bioenergy and biofuels, and science and innovation.

Context

Definition

3. In the context of this report, Government takes the term 'bioeconomy' to mean the part of the economy using biological resources (biomass[2]), or bioprocesses, for the production of value added products, such as food, feed, materials, fuels, chemicals, bio-based products[3] and bioenergy[4].

4. The terms bioeconomy and bio-based economy are often used interchangeably, but for the purpose of clarity within the scope of this document the use of 'bio-based' is reserved for products derived wholly or in part from biological resources.



[BioVale. © 2015 All rights reserved.]

[2] Material of biological origin excluding material embedded in geological formations and/or fossilized. (CEN/TR 16208:2011; CEN/TC 411/WG 1 2013)

[3] Bio-based products are products that are wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilised. (CEN - Report on Mandate M/429)

[4] Energy from biomass (CEN/TC 411 2012)

Raw Materials in scope

5. This report restricts its consideration of feedstocks for the bioeconomy to those not produced specifically as a product and focusses on harvest residues (classed as either co-products or by-products), process residues/by-products and biogenic components of industrial or consumer waste including bio-waste[5].

6. Specifically this includes:
   - Residues/By-products from agriculture, forestry, fisheries and aquaculture;
   - Residues/By-products from biomass based process industries;
   - Biogenic wastes produced from distribution, service industries or retail industries;
   - Biogenic fractions of municipal solid waste (MSW) and waste water.

7. Additionally:
   - Other by-products or wastes including flue gases (such as those from industrial manufacturing processes) generated from fossil feedstocks that are suitable for conversion to high value products using biotechnology based processes[6] are included.

8. In relation to waste, the revised EU Waste Framework Directive (rWFD) defines 'waste' as any substance or object which the holder discards or intends or is required to discard, including emissions of carbon dioxide and other carbon containing greenhouse gases. The waste hierarchy applies as a priority order in waste prevention and management legislation and policy: (a) prevention; (b) preparing for re-use; (c) recycling; (d) other recovery, e.g. energy recovery; and (e) disposal.

9. However, in the context of this report the term waste is used as a 'catch all' term rather than strictly referring to 'waste' in a legal sense[7], as set out above.

[Biorenewables Development Centre (BDC). © 2015 All rights reserved.]

[5] Bio-waste is defined as biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants. It does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood. It also excludes those by-products of food production that never become waste. Source; http://ec.europa.eu/environment/waste/compost/

[6] Note the resulting products from these processes would not be considered bio-based if the carbon source was fossil-derived.

[7] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69590/pb13813-waste-legal-def-guide.pdf

The Economic Growth Potential

10. There is a range of data that supports the assertion that this is an emerging sector of the economy offering significant growth and environmental potential. However, we do not currently have robust economic evidence to quantify the scale of the opportunity.

11. Some indicators of the size of the opportunity are:

- The European Commission notes that the EU bioeconomy (not restricted to waste feedstocks) already has a turnover of nearly €2 trillion and employs more than 22 million people, 9% of total employment in the EU. In addition, each euro invested in EU-funded bioeconomy research and innovation is estimated to trigger €10 of value added in bioeconomy sectors by 2025.[8]

- In the UK, the Government's Strength and Opportunity 2013 Annual Update[9] reports that the Industrial Biotechnology sector alone has shown a Compound Annual Growth Rate (CAGR) trend in turnover of 11% and in employment of 5% over the period 2009-2013.

- There are a wide range of market estimates on the potential investment opportunity for waste treatment capacity, which depends on the long-term availability of waste feedstock[10]. The Green Investment Bank (GIB) believes that 4.0-7.7 million tonnes of merchant waste treatment capacity (particularly from Commercial & Industrial sources) could be justified by 2020 based on the low and high case scenarios. This could support new energy from waste treatment infrastructure with a capital value of £3-6 billion. Against this, GIB has estimated there is likely to be an investment opportunity of £5 billion by 2020 in the UK waste market.[11]

- There is an opportunity for UK firms to capture part of the future global advanced biofuels market, worth up to £500 million to the UK in 2030. Even if export markets do not materialise there are gains from the conversion of domestically supplied low value waste to high value fuel, worth up to £130 million to the UK in 2030.[12]

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[8] http://europa.eu/rapid/press-release_IP-12-124_en.htm

[9] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/298819/bis-14-p90-strength-opportunity-2013.pdf

[10] See for example: Ricardo-AEA, CIWM Report (2013), "Commercial and Industrial Waste in the UK and Republic of Ireland"; and SITA UK (2014), "Mind the Gap – UK Residual Waste Infrastructure Requirements, 2015 to 2025".

[11] http://www.greeninvestmentbank.com/media/25376/gib-residual-waste-report-july-2014-final.pdf

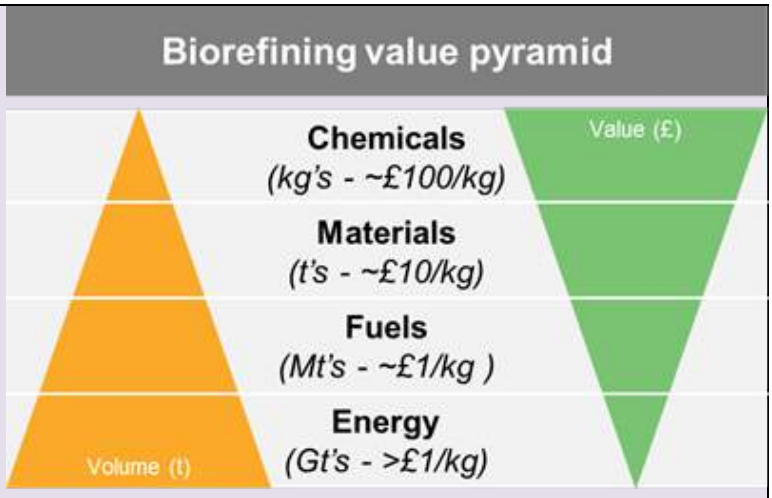
[12] https://www.gov.uk/government/publications/advanced-biofuels-demonstration-competition-feasibility-study

- The Technology Innovation Needs Assessment (TINA)[13], led by the Carbon Trust, indicates that the development of certain energy-from-waste technologies could save the UK billions of pounds. It also notes that 'domestic sources of wastes are estimated to supply ~100-170 PJ[14] to the UK'. While this is an opportunity, it is important that waste resources are managed in accordance with moving up the resource (waste) hierarchy, i.e. energy-from-waste only deals with waste that cannot be reused or recycled or valorised by other treatment options.

- Data in the House of Lords report suggests that there is 'a significant market for renewable chemicals, already estimated $57 billion worldwide and forecast to rise to $83 billion by 2018. The UK chemical industry currently has sales of over £60 billion per annum. The inquiry heard that around £6 billion of this might be replaced with renewable chemicals produced from waste materials.'[15]

CASE STUDY

Government continues to support the development of biorefineries given their role in maximising the value of feedstocks. For example, the Government funded Centre for Process Innovation (CPI) is delivering on a proposal for a National Waste Resource and Biorefinery Centre (NWRBC) in collaboration with Tees Valley Unlimited, a Local Enterprise Partnership in the North East. The aim of the Centre is to help to rebuild the capabilities of the UK Chemicals industry in parallel with wider activities such as Smart Cities, and to foster innovation to link waste and bio-processing. The NWRBC has the potential to generate substantial economic benefits for the UK and the Tees Valley, contributing in excess of £100 million in gross value added per annum and creating 350 direct jobs and 750 indirect jobs once fully established.



[Biorenewables Development Centre (BDC) © 2015 All rights reserved.]

12. The Biotechnology and Biological Sciences Research Council (BBSRC), the Engineering and Physical Sciences Research Council (EPSRC), Innovate UK, and the sector Council, the Industrial Biotechnology Leadership Forum (IBLF), have commissioned an analysis of

[13] http://www.carbontrust.com/media/190038/tina-bioenergy-summary-report.pdf

[14] The petajoule (PJ) is equal to one quadrillion (10^{15}) joules. 210 PJ is equivalent to about 50 megatons of TNT. This is the amount of energy released by the Tsar Bomba, the largest man-made nuclear explosion ever.

[15] http://www.publications.parliament.uk/pa/ld201314/ldselect/ldsctech/141/141.pdf

the economic impact of Industrial Biotechnology (IB) in the UK, including future economic projections (to 2025). The metrics against which the data will be gathered and the projections based, are:

- The UK position in the global market;
- The value of products and processes, including where possible an indication of the number of products and processes deployed;
- Market size and market growth projection in terms of sales and gross value added;
- Market maturity;
- Business investment in industrial biotechnology and bioenergy (IBBE);
- The number of jobs and value of employment to the UK economy;
- The value of exports and which nations were / are receiving the exports;
- Analysis of UK imports with a view to understanding how the UK might satisfy its own needs in the future.

13. **The commissioned analysis will provide a first step, although a partial view, of the economic potential of waste as a feedstock for the bioeconomy given industrial biotechnology represents a subset of the wider bioeconomy. Once published later this year, it will be a crucial contribution to the evidence base to help inform future policy decisions on how to build a high value bioeconomy.**

The Legislative Context

14. Regulation forms a key part of the bioeconomy landscape. It establishes minimum standards to protect human health and the environment and can also create markets by addressing market failures and providing a level playing field by which legitimate businesses can operate. We set out below the legislative context that impacts on the use of waste resources for bioeconomic activities, and the policy objectives which underpin that legislation. We recognise it is a complex landscape and as such this report also identifies the mechanisms that exist to support the sector in working with and benefiting from the legislation.

The legislation

15. There are a number of EU Directives which provide a framework for legislation within Member States and which have been transposed into UK law. Businesses and industry (and local authorities) which produce or handle waste, including importing, producing, carrying, transferring, keeping, treating or creating energy and products from waste, must comply with this legislation, designed to deliver our objectives on waste, climate change mitigation and sustainable products.[16]

16. It should be noted that while Wales, Northern Ireland and Scotland work within the same EU legislative framework, each Administration is responsible for their own waste policies and delivery. Therefore the geographical focus in this report is England only. However, all four Devolved Administrations work closely together, share and exchange relevant information and learn best practice.

Policy principles

17. The policy principles which underpin the complex set of legislation describe more broadly what we are collectively trying to achieve within the resource and waste management, energy and product sphere. The Government has published a number of strategic documents setting out our approach, including 'the Waste Review'[17], 'the Anaerobic

[16] Further information and guidance for businesses and organisations on waste regulation and what they need to comply with is available at https://www.gov.uk/waste-legislation-and-regulations, and https://www.gov.uk/browse/business/waste-environment/environmental-regulations

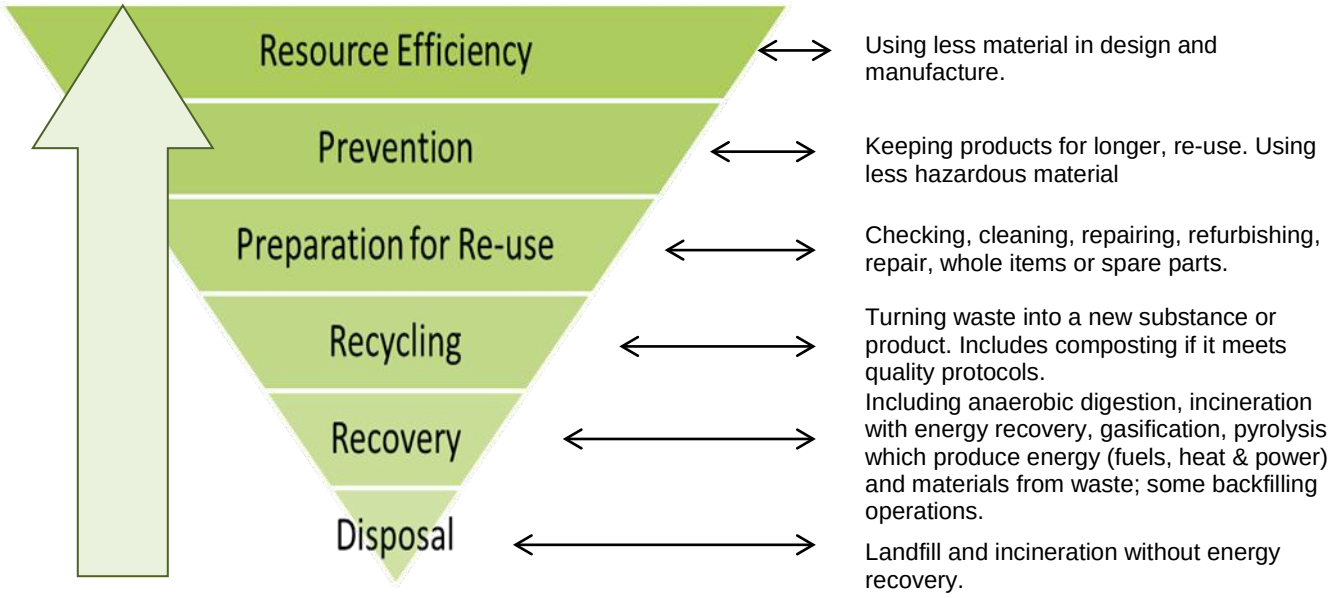
[17] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69401/pb13540-waste-policy-review110614.pdf

Digestion Strategy and Action Plan'[18], the 'UK Bioenergy Strategy'[19] and 'the Overarching National Policy Statement for Energy'[20].

18. The Government's objectives are to:

- move to a more circular economy; valuing and keeping our resources in circulation and applying the resource (waste) hierarchy, see figure 1 below. That includes the importance of resource efficiency as essential for economic growth, human health and the environment;
- ensure genuine greenhouse gas emission (GHG) reductions, and reductions of air pollutants including particulate emissions;
- protect the environment as a whole from harmful effects of industrial processes by applying the Best Available Techniques (BAT);
- promote the use of sustainable low carbon fuels in an attempt to reduce CO_2 emissions in the transport sector and increase the proportion of sustainable and lower GHG intensity fuels and energy used by transport;
- maximise the overall benefits and minimise the overall costs across the economy.

Figure 1 - Resource (waste) hierarchy



19. The Government remains committed to ensuring economic growth is compatible with our sustainability objectives; using wastes and residues as a feedstock supports these efforts.

[18] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69400/anaerobic-digestion-strat-action-plan.pdf
[19] https://www.gov.uk/government/publications/uk-bioenergy-strategy
[20] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/37046/1938-overarching-nps-for-energy-en1.pdf

We recognise that the primary use of agricultural land is for food production. Diversion for other uses such as development of bioenergy, chemicals, biofuels and other bio-based products, can impact on prices, biodiversity and other environmental objectives, as well as international development and poverty reduction.

20. The Government remains committed to ensuring economic growth is compatible with our sustainability objectives; using wastes and residues as a feedstock supports these efforts. We do recognise that the primary use of agricultural land is for food production. Diversion for other uses such as development of bioenergy, chemicals, biofuels and other bio-based products, can impact on prices, biodiversity and other environmental objectives, and international development and poverty reduction.

EU policy uncertainty

21. In July 2014, legislative proposals to reduce waste and improve resource efficiency were laid out as part of the Communication on the Circular Economy by the European Commission. On 16 December 2014, the Commission announced its intention to withdraw this package as part of the 2015 Work Programme Review with a view to replacing it with a more ambitious proposal on the whole circular economy in 2015.

22. We look forward to working with the European Commission, the European Parliament and other Member States to ensure a balanced package of proposals which has ambition, is evidence based, feasible and creates an environment that welcomes innovation. It could take over 2 years to conclude these negotiations.

Working with the legislation

23. As stated, we recognise that the landscape is complex. However, application of the resource (waste) hierarchy is not static. Over time emerging technologies can produce bona fide products for new markets rather than be deemed as waste recovery or disposal options, or they might be able to demonstrate a clearly better environmental outcome. For example, although anaerobic digestion (AD) is a recovery option, in the UK we count it as a recycling option when digestate is applied. This is because, based on current evidence from life-cycle analysis[21], AD with digestate as a fertiliser material is environmentally better for treating unavoidable food waste than composting or other recovery options.

24. There are circumstances therefore where the resource (waste) hierarchy can be flexible. The Environment Agency has an open process for recognising changing waste treatment processes and outputs[22] and over recent years has developed its thinking on how to

[21] http://www.wrap.org.uk/sites/files/wrap/Biowaste_CBA_Final_Report_May_2007.pdf
[22] Guidance on how the waste hierarchy should be applied can be found at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69403/pb13530-waste-hierarchy-guidance.pdf.

determine when a waste material can be treated to the point that it becomes a product that can be used without waste regulatory controls.[23] Supporting this, national planning policy on waste provides a positive framework for local authorities to drive resource and waste management up the hierarchy. It addresses waste as a resource and looks at disposal as the last option. It also ensures that the design and layout of new non-waste development supports sustainable resource management (including provisions of appropriate storage).

25. The Government and industry continue to work with the Environment Agency to assess how new technologies, processes and business models fit within the resource (waste) hierarchy. This supports and enables high value economic opportunities to be gained from waste resources, and for decisions to be made on treatment options for waste, ensuring that recovery/recycling targets are met.

Legislative challenges

26. We recognise that regulations and guidelines do not always keep pace with rapid developments in manufacturing and technological development. This could have the potential of limiting the adoption of innovative technologies.

27. Industry has told us of a number of areas where this is an issue. For example existing legislation does not cover the commercial development of technologies, such as Gas Fermentation, and does not include fuels produced from recycling waste carbon gases from fossil sources, such as those generated through the chemistry of steel making. Instead, current legislation focusses on renewable fuels under the Renewable Transport Fuel Obligation (RTFO). Under the RTFO, the Government incentivises biofuels derived from waste by providing them with double Renewable Transport Fuel Obligation certificates. At the European level, the possibility of an advanced biofuels sub-target is being examined as part of proposals to address indirect land use change (ILUC); the ILUC Directive is expected to be agreed in 2015.

28. The Government will continue to work with industry to ensure regulation is appropriate, ensuring innovation is not stifled while also supporting Government's commitments to protecting the environment.

Incentives

29. The energy sector is undergoing a massive reform to decarbonise our energy sources in a way which ensures security of supply and at a price which is affordable to those who pay energy bills. Energy from waste plays a role in delivering this reform, and we expect it to continue to do so.

[23] Guidance on this process can be found here https://www.gov.uk/turn-your-waste-into-a-new-non-waste-product-or-material

30. The reform is underpinned by European and UK law which sets targets to deliver 15% renewable energy by 2020, and an 80% greenhouse gas reduction by 2050. In order to achieve this, we have obligations in place and offer incentives that allow low carbon options to compete with their high GHG emitting alternatives. Incentives are therefore in place for large scale electricity (Renewables Obligation, Contracts for Difference), small scale electricity (Feed in Tariff), heat (Renewable Heat Incentive) and renewable transport fuel (Renewable Transport Fuel Obligation). These provide support for certain technologies which have the ability to use waste feedstocks, and which we believe require additional subsidy to deploy in the current market.

31. Emerging technologies, such as anaerobic digestion and advanced conversion technologies (gasification and pyrolysis), may make a useful contribution to the bioeconomy; through the production of energy and potentially through the future development of advanced fuels and bio-based products. They therefore receive a higher level of incentive, to compensate for the higher costs of energy production. In doing so, the incentives, along with R&D support, are serving to expand the market, increase the efficiency and reliability of the technologies, and help deliver cost reductions. This could provide a commercially viable route for anaerobic digestion and advanced conversion to contribute to the bioeconomy roadmap by readying the technology for future production on fuels and products.

32. The House of Lords report highlighted, however, that the 'plethora of incentives' is 'distorting the market and pushing waste towards lower value uses'; i.e. incentives have the potential to encourage the use of

[Pictures © Centre for Process Innovation Ltd (CPI) (www.uk-cpi.com) – All Rights Reserved.]

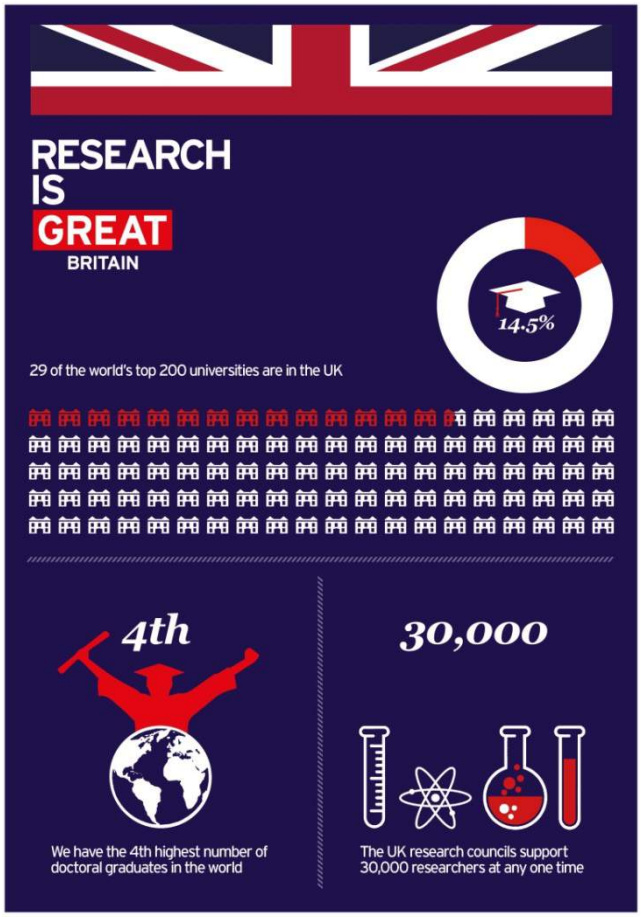
wastes at the bottom of the waste hierarchy rather than push materials into reuse or recycling options. The Lords report went on to suggest that this means that ‘it is unattractive for [investors to make] significant investment in high value chemical production.’

33. **To avoid unintentional distortion, regular reviews are undertaken on all incentive schemes to minimise risk of overcompensation. Further, according to the principles set out in the Bioenergy Strategy, Government takes into account evidence to consider the potential impact that market distortion could have on other industries that use the biomass feedstock.**

The Innovation Eco-System

Harnessing a Coherent Innovation Community

34. We have world class strengths in the biological, chemical, environmental and social sciences alongside a strong process engineering community. These equip the UK research base to provide the underpinning understanding and world-leading breakthroughs to advance the opportunities provided by the bioeconomy. The UK's innovation community is one of the key enablers in attracting inward investment. This strength provides the UK with a strategic advantage we could be better harnessing.



35. The primary mechanism of support for research and training underpinning the bioeconomy comes from the relevant UK Research Councils. Activities relevant to the advanced management of wastes feature in the strategic plans of a number of the UK Research Councils, which will continue to fund high quality academic research in this area. For example:

- Industrial biotechnology and bioenergy (IBBE) is identified as a key area in the recently refreshed strategic plan[24] of the Biotechnology and Biological Sciences Research Council (BBSRC). This highlights the potential of 'alternative feedstocks, including municipal waste, syngas, and industrial waste such as CO2, and approaches that integrate thermochemical and biological waste conversion technologies'.

- The Engineering and Physical Sciences Research Council (EPSRC) supports a range of related activities across its remit, primarily through the Manufacturing the Future, Engineering and Physical Sciences themes[25]. The Manufacturing the Future research theme, as stated in the EPSRC 2011-2015 Delivery Plan, aims to deliver 'research to enable the UK economy to develop and adopt sustainable, resource-efficient, low-carbon, low-pollution and low-waste manufacturing'.

[24] http://www.bbsrc.ac.uk/news/planning/strategy/priority-two.aspx
[25] http://www.epsrc.ac.uk/about/plans/deliveryplan/priorities/themes/challengethemes/

- For the Natural Environment Research Council (NERC), benefiting from natural resources is a theme within its new strategy, 'The Business of the Environment'. Two further NERC programmes of relevance are the 'Resource Recovery from Waste'[26] programme and 'Algal Bioenergy'[27].

- The Economic and Social Research Council's (ESRC) work in the bioeconomy is guided by its nexus strategy. This seeks to identify and examine the social-science challenges that cut across the energy-environment-food-water nexus[28].

36. In addition, Innovate UK fund, support and connect innovative businesses to accelerate sustainable economic growth, establishing seven Catapults which are technology and innovation centres where the best of UK businesses, scientists and engineers can work together on research and development.[29] The most relevant in the context of this report is the High Value Manufacturing Catapult.[30]

37. The Research Councils, working with Innovate UK, are best placed over the coming years to understand the research landscape across academia and industry. They can identify and act upon any critical research gaps to ensure the UK is well placed to support and gain value from using waste in the bioeconomy.

38. For example, a strong innovation community is important for the development and advancement of Key Enabling Technologies (KETs), i.e. technologies that enable the development of new goods and services and the restructuring of industrial processes. KETs will support the growth of the bioeconomy and are potentially deployable in multiple markets and regions, including internationally. UK innovation should therefore not be restricted to KETs of specific UK relevance. Process technology options should also not be restricted, and developments should not be limited or steered by UK raw material availability. The synergetic combination of process technologies leads to the development of advanced biorefineries where carbon-containing feedstock is converted by a combination of mechanical, chemical, and biochemical processes, into a range of materials, chemicals, and energy and the maximum value is achieved from each feedstock. Examples of KETs are:

    - biotechnology (e.g. fermentation [including gas fermentation], anaerobic digestion, biocatalysis, algal cultivation [photo and heterotrophic]);
    - chemical processing (e.g. catalytic reforming); and
    - thermochemical (gasification, pyrolysis, hydrothermal).

[26] http://www.nerc.ac.uk/research/funded/programmes/waste/
[27] http://www.nerc.ac.uk/research/funded/programmes/algal/
[28] http://thenexusnetwork.org/
[29] https://www.gov.uk/government/organisations/innovate-uk
[30] https://hvm.catapult.org.uk/

39. The Research Councils and Innovate UK also have wide ranging portfolios of multilateral and bilateral programmes which support collaborative research and development activities between UK academics and industries and provide access to international research infrastructure. Such programmes enable the UK research community to access expertise and facilities not necessarily available in the UK, thereby strengthening UK capacity and capability in research and development and positioning the UK as the global partner of choice. The Research Councils and Innovate UK will both continue to look for appropriate countries to partner with to ensure the best R&D, science, technology, engineering and maths is undertaken and opportunities for global impacts are realised.

40. Supporting the work of the Research Councils and Innovate UK, the Council for Science and Technology (CST) is currently investigating the UK's knowledge landscape via a series of expert seminars and an online tool to crowd-source data[31]. **The aim of this project is to build a picture of the whole research landscape in the UK and to develop a stronger evidence base. This will help to inform future strategic decision-making and help the UK to maintain and develop its excellence in research.**

Skills

41. For new sectors to grow and develop it is essential they are able to recruit appropriately skilled personnel. This means the skills base has to keep pace with the technology. The UK has well developed training mechanisms, from apprenticeships to masters and post-doctoral level. Many current industries also provide a workforce with skills transferable into a developing advanced waste management sector.

[31] https://www.gov.uk/government/collections/uk-knowledge-landscape

CASE STUDY

The Gatsby Charitable Foundation, a charitable trust set up in 1967 by David Sainsbury (now Lord Sainsbury of Turville) is working to increase the number of people with Level 3 and 4 Science, Technology, Engineering and Mathematics (STEM) skills. This will be achieved by promoting the status of science, engineering and IT technicians and supporting technician training pathways and qualifications that deliver real benefit to those who pursue them.

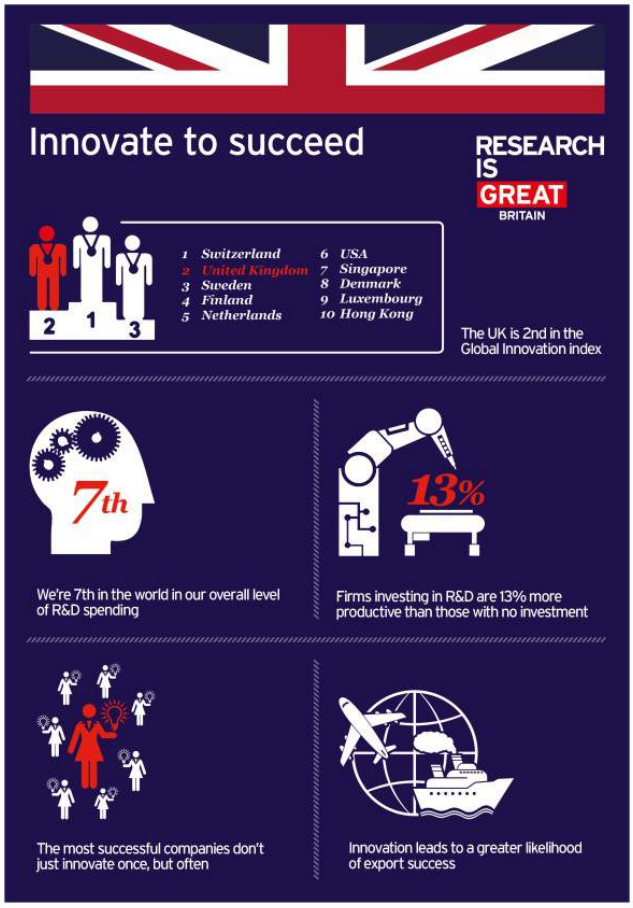
As part of this work Gatsby is supporting research to explore the current and future potential need for technicians within the biotechnology sector. These practical, problem-solving roles will be critical to the growth of the sector. The research is focused particularly on (i) how the technician skills requirements of the emerging biotechnology industry are captured and incorporated into training programmes and national standards; and (ii) how the requisite supply of future technicians will be generated. This work should inform support for further education (FE) colleges to ensure that the training they provide for technicians reflects the changing skills needs of the biotechnology sector, and give a higher profile among young people of career opportunities in biotechnology.

42. While not specifically focusing on the resource and waste management industry, the Cogent Sector Skills Council, acting on behalf of the Science Industry Partnership (SIP), has commissioned research to determine the advanced skills needs of industrial biotechnology, chemistry and engineering industries more broadly. Cogent is looking at t**he adequacy of current generic and specialist skills training in these areas, and any perceived gaps in training provision. This work will also establish if there is any need for modular approaches of training to address these gaps.**[32]

[32] http://www.cogent-ssc.com/general/news/22_09_14_Invitation_to_Tender_SIP_Industrial_Biotech_research.php

Supporting the commercialisation of research

43. The UK has consistently maintained a globally renowned science base, but we are less renowned for our commercial translation of innovation. The UK came 2nd in the Global Innovation Index (GII) 2014, moving up the ranks from 3rd place in 2013. The GII ranks countries in terms of their enabling environment for innovation and their innovation outputs. Our priority is to ensure that a 'well-linked innovation ecosystem' is embedded within the waste-based bioeconomy sector, including ensuring the infrastructure and support mechanisms are in place to enable smooth and integrated transition from the research base through to commercialisation.



44. There are three key components:

    (i) Building effective partnerships.

    (ii) Access to specialist processing and demonstrator plants.

    (iii) Finance

Building effective partnerships

45. There are a number of mechanisms in operation already to support good knowledge flows between academia and industry.

46. The Knowledge Transfer Network (KTN) Limited's primary role is to nurture, develop and scale up innovation within business, connecting companies with the wider knowledge economy across all significant sectors. Established by Innovate UK to build better links between science, creativity and business, the KTN provides impartial assistance to businesses to find them the right knowledge partner as well as the appropriate funding.[33]

47. The Biotechnology and Biological Sciences Research Council (BBSRC), working with the Engineering and Physical Sciences Research Council (EPSRC), has also established the

[33] http://www.ktn-uk.co.uk

BBSRC Networks in Industrial Biotechnology and Bioenergy (BBSRC NIBB). The aim is to promote greater communication and understanding between the UK Industrial Biotechnology and Bioenergy (IBBE) research and user communities, including communities investigating high value uses for unavoidable food waste, agricultural residues, C1 gases, and developing advanced anaerobic digestion[34].

48. In addition, through the Industrial Biotechnology (IB) Catalyst, a collaboration between the BBSRC, EPSRC and Innovate UK, Government has invested funding to build collaborations between academics and business to advance ideas from the academic lab to industrial application, including:

    - In 2014, the IB Catalyst invested £45 million into projects of relevance to the bioeconomy, supporting a number of projects specifically looking at taking one industry's 'waste' and turning it into a valuable commodity.

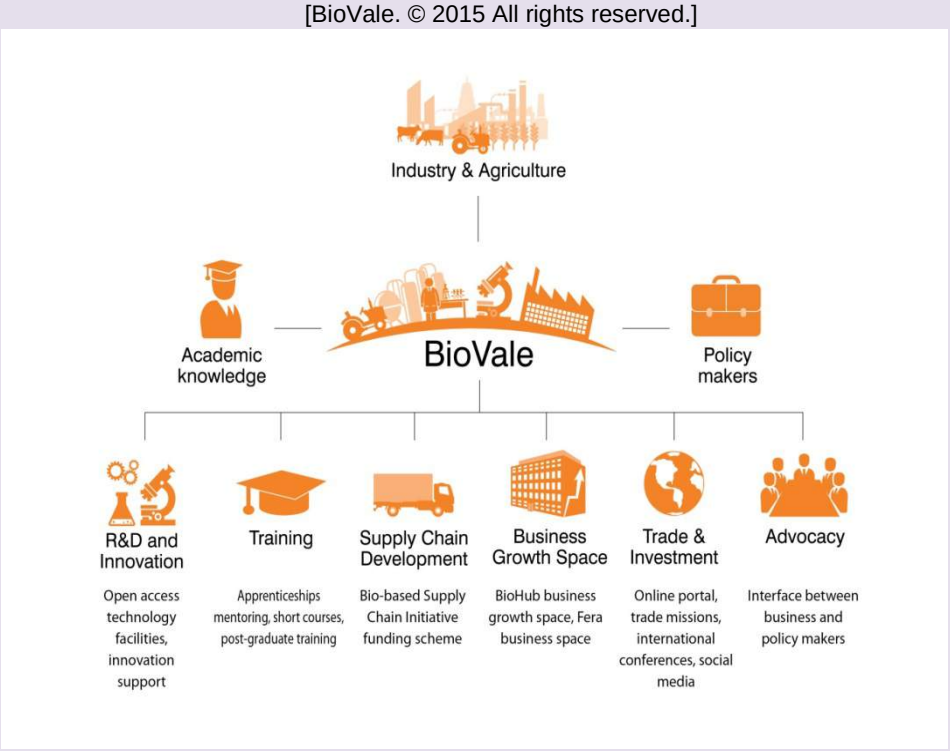
    - BBSRC, EPSRC and Innovate UK have shown their commitment to this scheme by providing an additional £40 million for investment in 2015/16.

49. The Industrial Biotechnology Catalyst funding partners, BBSRC, EPSRC and Innovate UK, will monitor the outcomes of the Catalyst to determine if this mechanism is adequate to support the early stages of a developing biowaste management sector.

CASE STUDY – BioVale

Yorkshire and the Humber has all the assets to become a leader in the bioeconomy, but these assets are not yet sufficiently integrated or linked together and gaps exist between the region's agriculture, industry and knowledge base. BioVale is a new initiative to respond to this by developing and promoting Yorkshire and the Humber as an innovation cluster for the bioeconomy, building on the region's unique combination of world-class science, innovative agriculture, and

[BioVale. © 2015 All rights reserved.]



[34] http://www.bbsrc.ac.uk/bbsrcnibb

bio-based industry.

City of York Council is a founding member of BioVale, and is working in partnership with the University of York (UoY), Biorenewables Development Centre (BDC), Food and Environment Research Agency (Fera), Askham Bryan College, and businesses in the region, including AB Agri, Drax, and Croda, to develop new supply chains and attract new investment in the bioeconomy. BioVale provides a 'one-stop-shop' bringing together business and academia to support the development of innovative, high value products and processes. It brokers a range of support mechanisms that include:

- open access R&D and demonstration facilities;
- training and exchange of skilled staff;
- development of business growth space;
- inward investment, trade and export;
- advocacy with policy makers.

BioVale will also work with the Local Enterprise Partnerships (LEPs) and central Government to deliver against the objective that universities should play a stronger role in economic development and that cluster strengths should be used to stimulate regional growth.

The BDC and UoY have already helped facilitate a Memorandum of Understanding between BioVale and Industries & Agro-Resources in France, and have brought forward a collaboration agreement with similar clusters based in Holland and Germany. This has led to joint research, sharing of facilities, and cooperation on developing new markets.

Investments in BioVale are expected to catalyse the creation and safeguarding of 45,000 new jobs by 2025, as well as over £2 billion per annum additional economic activity to create a bioeconomy of over £12 billion in Yorkshire and the Humber[35].

Although BioVale only formally came into existence in July 2014, it has already achieved a number of successes:

- Four companies have recently relocated to the region from other parts of the UK, and the US, in order to access regional facilities and expertise.
- BioVale and Askham Bryan College have started a major project to improve bioeconomy workforce skills and will deliver specialised skills support for over 200 trainees by Summer 2015.
- The Biorenewables Capital Grant Scheme has secured £1 million of funding, over half of which is from Europe, to help regional businesses invest in innovative new equipment.
- BioVale represents local companies as a member of the Biobased Industries Consortium: the private sector partner in the EU's Bio-based Industries Public-Private Partnership.

[35] Analysis of the economic opportunity offered by the bioeconomy for Yorkshire and the Humber. Report by the NNFCC, March 2014.

Access to specialist facilities

50. The costs of demonstrating and scaling up a new technology to make it 'commercial' can be prohibitive, particularly for SMEs. Having access to specialist processing plants at a range of different scales depending on the stage of development and the scale of the final commercial process is a critical piece of the ecosystem. It is also important to ensure the UK does not miss opportunities to maximise the value from locally generated ideas and feedstocks.

51. **The Biotechnology and Biological Sciences Research Council (BBSRC), the Engineering and Physical Sciences Research Council (EPSRC), and Innovate UK, have commissioned an analysis of the current availability and status of industrial biotechnology-relevant processing plants and equipment within the UK. Once published later this year, this analysis will identify options for future capital investments to prevent this being a barrier.**

CASE STUDY

The UK has a number of public funded centres to help companies de-risk investment. Among them, the Centre for Process Innovation (CPI) is the UK's flagship mechanism to support innovation in the process industries and is part of the Innovate UK funded High Value Manufacturing Catapult.

CPI specialises in scale-up scale-down programme development to de-risk bio-based products and processes in Technology Readiness Levels (TRL) 4 to 7, utilising in-house engineering, biosciences, modelling capability and £21 million of open access assets. This allows businesses to rapidly develop and validate techno-economic feasibility, to overcome the Valley of Death and build viable production facilities of their own.

[Graphics and pictures © Centre for Process Innovation Ltd (CPI) (www.uk-cpi.com) – All Rights Reserved]

Finance

52. Financing of technologies in the waste processing area is complex as their performance, costs and reliability are uncertain when they are in development. In addition to a supportive fiscal environment (e.g. R&D tax credits), and infrastructure support to accelerate the development and demonstration of new technologies to the point where risks are acceptable to financiers and project investors, access to finance is also a key factor affecting start-ups and SMEs across the sector. There are a number of Government mechanisms and schemes that provide direct support or help companies achieve commercialisation.

53. **Innovate UK** funds, supports and connects innovative businesses to accelerate sustainable economic growth. It seeks to support the ambition for the UK to be a global leader in innovation and a magnet for innovative businesses. Innovate UK runs themed competition programmes providing funding to promote innovation in areas with the greatest potential to accelerate economic growth. Relevant to the bioeconomy this includes Energy, Industrial Biotechnology, High-Value Manufacturing, Resource Efficiency and Biosciences including Synthetic Biology. Innovate UK addresses key market failures in these areas, such as business investment being too low and too late, the lack of visibility of long-term trends to some players (e.g. SMEs) and the need for collaboration along supply chains that will be disrupted by innovation.

54. Recent funding competitions from Innovate UK have covered commercialisation of UK biotechnology innovation (the Industrial Biotechnology Catalyst[36]), production of high value chemicals or materials from agri- or bio- waste (Recovering Valuable Materials from Waste[37]), and supporting the tools and services for a UK synthetic biology industry[38].

55. Innovate UK's energy programme alone will commit up to £35 million per annum to specifically help UK industry profit from the changes the world will have to make to address the 'trilemma' of energy security, affordability and sustainability. Energy is also one of the Knowledge Transfer Network's priority areas, working with the energy innovation community.

56. The **Green Investment Bank** (GIB) is a £3 billion Government led investment to accelerate investment in the UK's transition to a green economy and to create an enduring institution, operating at arm's length from Government. It provides debt and equity to projects on fully commercial terms and is currently funded under the Government's 2010 and 2013 Spending Reviews, with £3.8 billion over the period to 31 March 2016. To date they have made over 40 investments (including the Waste and Bioenergy team investing over £500 million across

[36] https://interact.innovateuk.org/competition-display-page/-/asset_publisher/RqEt2AKmEBhi/content/industrial-biotechnology-catalyst-early-stage-translation-round-3?p_p_auth=ZAjKsnu1
[37] https://interact.innovateuk.org/funding-competitions/-/competitions/view/recovering-valuable-materials-from-waste?p_auth=6bGrfQ28
[38] https://interact.innovateuk.org/competition-display-page/-/asset_publisher/RqEt2AKmEBhi/content/tools-and-services-for-synthetic-biology?p_p_auth=ZAjKsnu1

18 projects since its establishment in 2012), all of which are performing profitably. GIB expects to commit c.£700 million during 2014/15.

57. GIB is working with the changing market as technology becomes commercially proven to develop the solutions and accelerate deployment of a new class of projects, and there is ongoing work to broaden its investment portfolio.

58. The waste and resource management sector has been identified as a priority and GIB intend to make direct investment to address specific 'market failures'. It will use a knowledge based approach - debt, mezzanine, equity, credit enhancement, scope - to develop new products.

59. GIB continues to investigate the market dynamics of the sectors within which it invests and, where possible, to share these findings with wider stakeholders and the public. During 2013, GIB published a report on the issues facing the market within the anaerobic digestion sector, with the objective of identifying the opportunities and barriers for new investment. In July 2014, GIB published a report 'The UK Residual Waste Market'[39] setting out the main UK investment opportunities in the waste market, with a focus on the recent emphasis on processing commercial and industrial waste.

60. Over the next 6-12 months, the Green Investment Bank (GIB) will be exploring the potential investment opportunities within the UK recycling and reprocessing market in detail. Government will continue to challenge GIB to encourage them to develop their risk investment portfolio.

61. Another example of the funding support available to the sector is the £25 million **advanced biofuels demonstration competition**[40]. This was launched by Government in December 2014 and is supported by significant private sector investment. It aims to aid the development of a domestic advanced biofuel industry and achieve the construction of up to three demonstration-scale advanced biofuel plants in the UK.

62. An independent feasibility study into the project, published at the same time, found that gains from converting domestically supplied low value waste to high value transport fuel

[39] www.greeninvestmentbank.com/media/25376/gib-residual-waste-report-july-2014-final.pdf
[40] https://www.gov.uk/government/speeches/advanced-biofuels-demonstration-competition

could be worth up to £130 million gross value added to the UK by 2030, and potentially up to £500 million per year including exports.[41]

63. Awards under the Advanced Biofuel Demonstration Pilot will be made in 2015 and the funding will be available until 2018.

Global visibility of the UK innovation proposition

64. The UK is already building expertise in the bioeconomy to address future world challenges and growing market opportunities for UK business. We have a vibrant R&D sector, significant expertise in policy and strategy development and a proven track record in delivering technological innovation that makes better use of previously discarded resources (e.g. our recent advances in anaerobic digestion of food waste). The strength of the UK offer in this space is already attracting overseas opportunities and international collaborations. The UK capability in advanced manufacturing applications should be further built in order to develop as an exporter of process technologies and business models. This can include exploiting intellectual property abroad and retaining value for the UK while offering solutions globally and delivering against environmental targets.

65. However, the Government recognises that if we are to continue to grow the attractiveness of the UK proposition for inward investment, we need to understand the drivers behind industry investment decisions. There is a need to develop a clear picture of the UK's comparative advantage (to other countries) on the bioeconomy and, importantly, how we think this will evolve over the next decade. The Government is working through UKTI with industry stakeholders to do this, as well as to identify potential inward investment opportunities and to encourage investments decisions in favour of the UK. For example, there are a number of opportunities for companies to invest in the UK in developing systems and plants to collect and/or process waste streams into value added products.

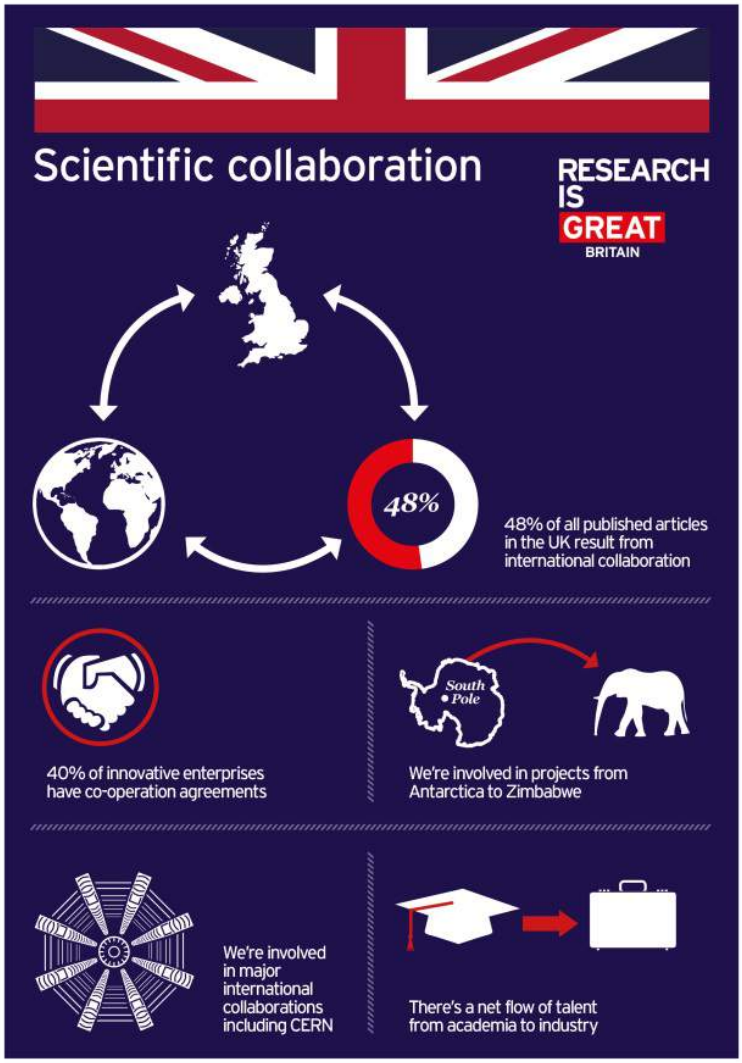
66. The Government continues to engage with industry to identify the economic drivers impacting inward investment decisions. This includes the future potential to increase UK exports of goods and services related to waste and the bioeconomy as part of Government's '2020 Export Drive', an ambitious programme to increase UK exports by 2020.

[41] https://www.gov.uk/government/publications/advanced-biofuels-demonstration-competition-feasibility-study

CASE STUDY

In 2011 Innovate UK signed a Memorandum of Understanding (MoU) with their Norwegian equivalent, Innovation Norway, to develop opportunities for collaborative working in the areas of industrial biotechnology and biorefining.

A report published by the NNFCC in May 2011, 'Capabilities and Opportunities for Joint Working on Biorefining and Industrial Biotechnology'[42] identified a series of both short term and longer term opportunities and synergies for both the UK and Norway: with marine waste, algae and wood as key feedstocks for the production of chemicals and fuels. These opportunities could only be realised through knowledge exchange and joint workshops to identify the research and innovation requirements and co-funded collaborative projects were seen as the way to achieve common objectives.



Four years on, we have seen a highly successful series of exchange visits that have examined specific technologies such as seaweed for biofuel as well as general networking activities to explore more serendipitous prospects. A total of 37 events have been held in both the UK and Norway, 9 opportunity reports have been issued and three joint funded Innovate UK run competitions, giving rise to 11 projects with a total investment of £3.4 million. Three new products - and 5 in the pipeline - with expected sales of approximately £100 million and 7 new or improved processes developed as a direct result of these collaborations. Added to this the patents filed or planned and new jobs predicted in the next 5 years, it was concluded at the 3 year review last year that expectations from the MoU had already been exceeded. Innovation Norway continues to co-fund UK competitions, supporting the first two rounds of the IB Catalyst as there continues to be no shortage of potential joint projects to support.

[42] http://www.nnfcc.co.uk/tools/capabilities-and-opportunities-for-joint-working-on-biorefining-and-industrial-biotechnology-may-2011-dr.-adrian-higson-and-dr.-claire-smith.-a-project-for-innovation-norway-and-technology-strategy-board

International benchmarking

67. The Government agreed with the findings of the House of Lords report that in developing a high value bioeconomy there may be valuable experience we can learn from other countries currently ahead of the UK in terms of extracting value from waste for use in the bioeconomy.

68. The Government undertook to review readily available studies, coordinate respective sources of data and commission further analysis as required. We have commissioned the Institute for European Environmental Policy (IEEP) to do this work.

69. We expect the IEEP to conclude the study by this Summer and to provide policy recommendations on what measures other countries have taken that might be relevant to stimulate a bioeconomy here.

Sustainability of the supply chain feedstock

70. A key challenge for developing and growing a commercially secure bioeconomy is a reliable and consistent feedstock. As highlighted earlier in this report, Government recognises that it is essential that we make the best use of our materials and resources, increasing their circularity and preventing and dealing with waste properly. Against the drive to bring down total waste arising, we recognise that there is a need to carefully consider the full breadth of available wastes, including gases, as well as the quality and long term availability of these resources and their use as a feedstock.

71. Whilst commercial and industrial supply chains are key in supplying critical feedstocks, local authorities are also important as the collectors of household waste materials (in England in 2012, households were estimated to generate 13.9% of all waste[43]). The 2011 Waste Review included a commitment for the Government to work with them to increase the frequency and quality of rubbish collections and make it easier to recycle. It also noted that while local authorities are working hard to improve recycling rates, they should also look to make the most of what residents put out for collection, all the while maintaining service quality. Separate household collections will be the default system from January 2015 for all waste collection service providers, except when separate collection is not necessary to provide a sufficiently high quality of recyclates economically, or where separate collection is not technically, environmentally or practicable.

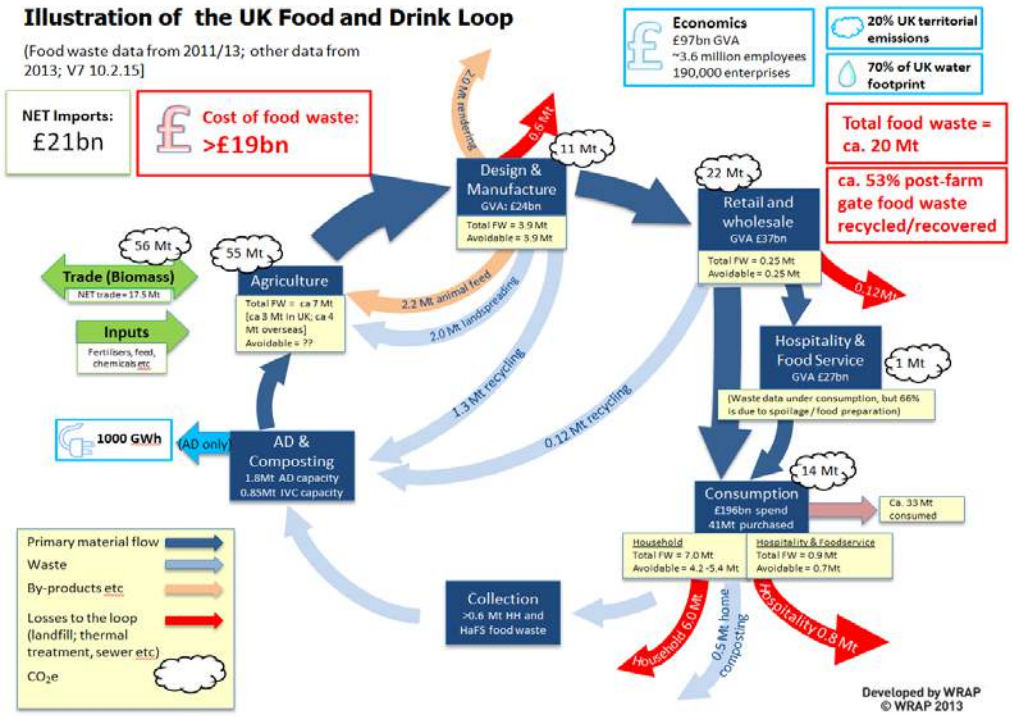
72. Anaerobic digestion (AD) provides a good example of both the challenge and opportunity of supply chain quality. The nature of the technology means that plants need a high quality feedstock, uncontaminated by physical elements such as plastic. Recent data from the Waste and Resources Action Programme (WRAP)[44] shows that only a very small fraction of the potential food waste feedstocks that are available are sent to AD facilities. Food waste

[43] Waste Statistics Regulation return 2012
[44] http://www.wrap.org.uk/content/survey-uk-anaerobic-digestion-industry-2013

is therefore either going to recovery routes such as direct land spreading or animal feed or, in the case of the majority of food waste from households, is being sent to landfill or energy from waste options. For this material to be captured and valued through AD or other processes that extract valuable compounds and chemicals there needs to be collection and supply mechanisms in place that ensure that the right quality materials are delivered to the processing facilities. However, these can be expensive to introduce and run, so potential end users would need to contribute to collection costs for them to be viable for local authorities.

Data availability

73. We have heard from the sector that is looking for waste materials to use as feedstocks for new processes that the availability and quality of data is key. We understand the importance of good data for judging the potential for industrial exploitation of innovative approaches, but also recognise that the nature of the data that we currently collect has been governed by our reasons for assembling data sets in the first place, i.e. reporting requirements, regulatory monitoring and policy development needs. This has meant that we have a great deal of data but at varying levels of detail and it is unlikely that we will ever have a complete picture of feedstocks for the emerging bioeconomy. For example, data on the food supply chain has been comprehensively collected and made publically available via a food waste portal[45], as can be seen in the diagram below. However, this is in contrast to the data collected to report statistics at an EU level is high level data covering a wide range of waste streams. Comprehensive mapping of resource streams would be a highly complex and an expensive task.



[45] http://www.wrap.org.uk/content/food-waste-resources-portal

74. Within the wealth of published data we also recognise it can sometimes be challenging to readily find the data of interest. Government therefore recently published (29 January 2015), a 'Digest of Waste and Resource Statistics'[46], a compendium of statistics on a range of waste and resource areas. Based on data published mainly by Defra, WRAP, the Environment Agency, Office for National Statistics and Eurostat, the aim of this Digest is to help the use of statistics by conveniently bringing together a wide range of key data on waste and resource into one publication. The Digest includes statistics on (i) resource, including flows and consumption of raw materials; (ii) waste generation, sources, destiny and composition of waste; (iii) food waste; (iv) economic characteristics of the waste sector; (v) waste infrastructure; (vi) environmental issues with waste; (vii) waste crime; and (viii) EU data on waste.

75. The Government also launched Edoc[47] in January 2014, an online system that provides an electronic recording of details of transfer of waste (domestic and commercial, i.e. not agricultural, gaseous or sewer treated materials) from one person/organisation to another. Government is committed to sustaining the Edoc system for the foreseeable future with a view to encouraging a digital by default approach across all businesses. As more and more businesses adopt Edoc the system has the potential to become a rich source of waste data. However, we recognise that the ability to use the system as a mechanism to understand quantities of all waste relevant to the bioeconomy in the future will largely depend on user uptake.

76. Through a technical advisory group (the Chartered Institution of Wastes Management (CIWM) and WRAP), the Government continues to work closely with industry to encourage and improve the uptake and user experience of Edoc. We will review the data that is collected by this system in terms of how it can be used by both Government and industry. If uptake of the system is poor, we will also consider whether a mandatory system would be appropriate, beneficial and economically viable for both the sector and for the Government.

77. We will also continue to collate our data for industrial sectors not covered by Edoc reporting and will increasingly look to industry to ensure that our knowledge of potential feedstock for the emerging bioeconomy is complete. The bioeconomy community should consider the use of data sharing portals in the future as a means of ensuring that there is good access to feedstock information.

[46] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/399502/Digest_of_waste_England_2015_-_final.pdf

[47] www.edoconline.co.uk

Conclusion

78. This report is a starting point. It reiterates the economic potential of this emerging economy. That is not in question, though there is still more evidence to be gathered; this is largely already in hand.

79. This report highlights that there are important things we can and are doing to support the bioeconomy sector and prevent barriers impacting on its growth, including:

    - Mechanisms to support the industry in managing the complex legislative framework governing this area, together with support for moving emerging technologies up the resource (waste) hierarchy when appropriate;
    - A strong incentives system that we keep under review to avoid distortions;
    - Maintaining a world-renowned research base and taking steps to ensure the skills supporting the sector evolve at the same pace as the sector;
    - Providing funding, finance and infrastructure support where the need for specific support has been identified;
    - Creating a strong innovation ecosystem whereby ideas flow smoothly from research through to commercialisation;
    - Publishing data on the UK feedstock supply chain, key for investment security, where available.

80. Following publication of a substantiated economic base and the findings of the Institute for European Environmental Policy's (IEEP) international benchmarking exercise later this year, work will continue with the Research Councils, Innovate UK, industry and other key sector representatives to maximise the opportunities of the bioeconomy sector to deliver against our economic growth and environmental objectives in the long-term.

Acknowledgements

81. As waste and bioecononomy policy cuts across many Departments, a cross-Whitehall and public sector working group was established to consider how we can further enhance the recovery of value from waste resources and to further promote the development of a sustainable bioeconomy. This group brought together the Departments for (i) Environment Food and Rural Affairs (Defra); (ii) Business, Innovation and Skills (BIS); (iii) Energy and Climate Change (DECC); (iv) Transport (DFT); and Communities and Local Government (DCLG), as well as public sector bodies, the Knowledge Transfer Network (KTN) and the Biotechnology and Biological Sciences Research Council (BBSRC). The Waste and Resources Action Programme (WRAP), a charity working with UK Government to support business, industry, civil society and local authorities to become resource efficient, and NNFCC Bioeconomy Consultants, a Research and Technology Organisation (RTO) providing technical, market and policy expertise, have also been integral members of the working group and key contributors to this report.

82. The Working Group sought views from a range of stakeholders from across the bioeconomy and resource management sectors. We have received a large number of contributions and it has not been possible to use them all in this report. They will however be used as part of work going forward in this area.

83. The Working Group has reported its progress to two primary governing bodies: the Defra-led Resource Programme Steering Group, which includes key Government Departments and delivery bodies, and the Industrial Biotechnology Leadership Forum (IBLF), which is co-chaired by Minister Matthew Hancock and Steve Bagshaw, Managing Director of Fujifilm Diosynth Biotechnologies. The Group has also engaged the Chemistry Growth Partnership and the Resource Efficiency Steering Group.

84. The production of this report would not have been possible without the interest and guidance from these Steering Groups or the contributions from the myriad of interested and informed stakeholders. The Working Group has tried to take account of the wide ranging and sometimes differing views on the future opportunity and to distil the key elements.

85. We would also like to thank WRAP, the Biorenewables Development Centre (BDC), BioVale, and the Centre for Process Innovation (CPI) for the pictures and graphics they provided for this report.

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