The bioeconomy enabled

A roadmap to a thriving industrial biotechnology sector in Europe

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EXECUTIVE SUMMARY

Industrial Biotechnology-derived products are projected to offer significant potential for overcoming many of the socio-economic and environmental challenges facing the EU today.

The EU market for industrial biotechnology-derived products is expected to increase from 28 billion euro in 2013 to 50 billion euro in 2030, representing a compounded growth rate of 7% per annum. This growth will be largely driven by projected increases in the consumption of bioethanol and biobased plastics. New products such as aviation biofuels are likely to be commercialised in this period and gain market share. However, despite this very large projected market demand, significant barriers remain and hamper the full development of industrial biotechnology production in Europe. If such barriers are not promptly addressed, the EU based demand will end up being satisfied by non-EU based supply, thus representing a missed profit opportunity for the EU industry in the range of tens of billions euro.

The principal barrier to fully exploiting the industrial biotechnology opportunities in Europe relates to product cost-competitiveness, both compared to fossil alternatives and to equivalent products from elsewhere in the world. Cost-competitiveness is affected by many factors including the cost of feedstock, technology readiness level and the level of market support for biobased products. The competitiveness issue is compounded by difficulties in accessing finance for large-scale projects, an often low end-user awareness of IB-derived products and by a lack of skills and operational relationships to drive the sector forward.

The BIO-TIC project, funded through the European Commission's FP7 programme, has comprehensively examined the hurdles to industrial biotechnology innovation in Europe and identified actions which could be taken to overcome them. The results are based on an extensive literature review, complemented with over 80 expert interviews and 13 stakeholder workshops organised across Europe in 2013 & 2014. This report presents the most significant barriers to the deployment of industrial biotechnology in Europe, and outlines 10 pragmatic recommendations by which they could be addressed. These are to:

1. **Improve opportunities for feedstock producers within the bioeconomy.** Feedstock producers can play a vital role in developing the bioeconomy. Awareness raising of potential opportunities (both using existing and novel crops), ensuring a fair price for feedstocks and the development of infrastructure for collection, storage and transportation of biomass is required. The most effective routes by which these can be achieved are unclear and local measures will be crucial.
2. **Investigate the scope for using novel biomass.** Wastes and residues are favoured as routes to not compete with food production or land use, but little is known about how much of these wastes can be utilised without adversely impacting upon other markets. An assessment of sustainable waste flows is needed. Technologies need to be developed to deal with the inherent variability of waste and residue products. In some cases, national policies may need to be amended to ensure that wastes can be used in industrial biotechnology products.
3. **Develop a workforce which can maintain Europe's competitiveness in industrial biotechnology.** Industrial biotechnology is a highly specialised area. Existing skills do not match what industry is looking for. There is a need for personnel who can work across disciplines and who have business skills. New ways to teach need to be embraced. There is a crucial need to identify skills gaps and how these can be filled.
4. **Introduce a long-term, stable and transparent policy and incentive framework to promote the bioeconomy.** The EU policy environment is often criticised for not supporting innovative industrial biotechnology products sufficiently. A series of measures such as financial incentives or tax reductions could be used to help foster investments, whilst public procurement for industrial biotechnology-derived products could help create markets.
5. **Improve public perception and awareness of industrial biotechnology and biobased products.** Despite the environmental and social benefits which industrial biotechnology products can bring, customers and end users are not necessarily aware of what industrial biotechnology is or of the value proposition offered by its products. Targeted information campaigns to customers and end-users can help develop the market, but to ensure maximum impact, these should ascertain peoples' understanding first to identify gaps to address.
6. **Identify, leverage and build upon EU capabilities for pilot and demonstration facilities.** The EU has a number of scale-up facilities for industrial biotechnology processes. Some of these are in operation, some are idle. There needs to be a better understanding of what the capabilities of these plants are to help signpost people to appropriate facilities. The EU should develop existing infrastructures to create centres of excellence in scale-up in industrial biotechnology rather than invest in multiple redundant facilities.
7. **Promote the use of co-products from processing.** The smart and efficient use of biomass can help develop more products per unit of biomass. This means making the best use of biomass through a cascading approach where feasible, and making the most of co-products such as lignin which currently have a limited market application. The optimisation of separation technologies will be needed to recover potentially marketable co-products.
8. **Improve the bioconversion and downstream processing steps.** The optimisation of bioconversion and downstream processing of industrial biotechnology products could significantly reduce costs and improve efficiency of production. This would entail optimisation of microbial strains for the production of new products, making them resistant to contaminants present within lignocellulosic and waste feedstocks. There is a need to ensure continuous improvement of industrial biotechnology technologies to ensure competitiveness; R&D therefore needs to be funded across technology readiness levels, not just on emerging technologies.
9. **Improve access to financing for large-scale biorefinery projects.** The European climate for investment in large scale biorefineries is often considered to be challenging compared to other regions of the world. Public funding only covers part of the costs associated with project development and support from other sources need to be made available to cover the remaining costs. There is a need to improve the visibility and alignment of different funding schemes, and demonstrate how they can be integrated. A distinct European BioEconomy Strategic Investment Fund (EBESIF) could help pool resources from different financing mechanisms such as those available through the European Investment Bank and private funds, and help leverage Commission contributions.
10. **Develop stronger relationships between conventional and non-conventional players** Industrial biotechnology brings together actors from a wide range of backgrounds. There is a crucial role for cluster organisations in helping develop relationships between unconventional actors in the supply chain. A mapping exercise should identify existing clusters active in the industrial biotechnology area, and actions should be taken to facilitate the development of new ones where gaps exist.

Five product groups have been identified as being particularly promising based on their future market prospects, the potential for that product to introduce cross-cutting technology ideas, and to respond to societal and customer needs. These are:

1. **Advanced biofuels** (advanced bioethanol and biobased jet fuels), where the EU market could be worth 14.4 billion euro and 1.4 billion euro respectively by 2030. For biobased jet fuels, the proportion fulfilled by industrial biotechnology-based processes is unclear given the range of technologies available and their early stage of development;
2. **Biochemical building blocks** which can be transformed into a wide range of products which are either similar or offer additional functionality compared to fossil products, where the EU market could reach 3.2 billion euro by 2030;
3. **Biobased plastics** where the EU market could reach 5.2 billion euro in 2030;
4. **Biosurfactants derived from fermentation** typically used in detergents, where the EU market could reach 3.1 million euro in 2030;
5. **Novel products from conversion of fossil carbon dioxide by industrial biotechnology routes.** Given the nascent state of this market, no estimates for deployment can be given, but we expect some technologies to be ready for commercial production by 2030.

The size of the market opportunity for each of these product groups is addressed in this report, together with targeted solutions to overcome the hurdles affecting that sector.

In summary, this report presents a focussed action plan for tackling barriers to innovation within industrial biotechnology in Europe. It is based on three detailed reports covering market potential, research and development and regulatory/policy issues, available separately as appendices to this document and accessible through the project website at **www.industrialbiotech-europe.eu**

LIST OF ABBREVIATIONS

2,3 BDO	2,3-Butanediol
2G	Second generation (advanced) biofuel/chemical
BBI JU	Biobased Industries Joint Undertaking
BEUR	Billion euro
BIC	Biobased Industries Consortium
C12/C14	Carbon 12 isotope/Carbon 14 isotope
CAGR	Compound annual growth rate
CAP	Common Agricultural Policy
CBB	Biobased chemical building block
CCS	Carbon capture and storage
CCU	Carbon capture and utilisation
CEF	Connecting Europe Facility
CEN TC	European Committee for Standardization - Technical Committee
CO_2	Carbon dioxide
DSP	Downstream processing
EIB	European Investment Bank
EIP Agri	Agricultural European Innovation Partnership
ESF	European Social Fund
ESIF	European Structural and Investment Fund
ETP	European Technology Platform
EU ETS	EU Emissions Trading Scheme
FP7	Seventh Framework Programme
GDP	Gross domestic product
GHG	Greenhouse gas (ses)
GM	Genetically Modified
GMO	Genetically Modified Organism
GMM	Genetically Modified Microorganism
IB	Industrial biotechnology
ICT	Information and communications technology
IP	Intellectual property
ISPR	in situ product removal
ISSC+	International Sustainability and Carbon Certification Scheme +
JRC	Joint Research Centre
KEUR	Thousand euro
KET	Key enabling technology
LCA	Life cycle analysis
MEUR	Million euro
MOOC	Massive open online course
MTOE	Million tonnes equivalent
PET	Polyethylene terephthalate
PLA	Polylactic acid
PPP	Public private partnership
R&D	Research and development
R&I	Research and innovation
RED	Renewable Energy Directive
RSB	Round Table on Sustainable Biomaterials
RTO	Research and technology organisation/s
SME	Small and medium-sized enterprise/s
TRL	Technology readiness level

INTRODUCTION

Industrial biotechnology is not a new sector. For thousands of years, mankind has harnessed the power of microorganisms to develop well-known common household products such as wine, beer, yoghurt and cheese. In the past century, the applications for industrial biotechnology have expanded greatly thanks to advances in biochemistry, with industrial biotechnology used to produce many antibiotics, active ingredients for washing powders, nutritional substitutes and the wide use of IB in food and feed processing. More recently, industrial biotechnology has been harnessed to produce biofuels, such as bioethanol, as well as biobased chemicals and biobased plastics on a commercial scale.

World-wide, there is a recognition of the importance of developing the bioeconomy as a route to tackling some of the huge modern global societal challenges, including climate change, dwindling fossil fuel resources and the need for the development of a more sustainable and resource-efficient economy. Moreover, the work of biobased industries within the bioeconomy can have significant positive benefits for the renaissance of rural economies, promoting the efficient use of agricultural resources,as well as creating and safeguarding rural jobs. Since the adoption of the Bioeconomy Strategy by the European Commission in 2012, the visibility and importance of the sector has increased and industrial biotechnology has rightly been recognised as a key enabling technology (KET) for accessing the potential of the bioeconomy. Despite this focus, and the fact that industrial biotechnology is one of Europe's technological strengths, several hurdles continue to hamper the full exploitation of its potential.

The aim of this roadmap is to provide definitive recommendations on how to develop an internationally competitive industrial biotechnology sector in Europe. It outlines how the various stakeholders can work together to overcome the major current and future obstacles hampering the development of biobased industries in Europe. It draws upon three comprehensive roadmaps investigating:

1. Potential market developments;
2. Research and development (R&D) needs;
3. Regulatory and non-technological aspects.

The BIO-TIC project has examined what factors impact industrial biotechnology innovation, based on a literature review, complemented with over 80 expert interviews and 13 stakeholder workshops organised across Europe in 2013 & 2014. The three roadmaps are available separately as appendices to this document and accessible through the project website: **www.industrialbiotech-europe.eu**

1

WHAT IS THE POTENTIAL MARKET FOR INDUSTRIAL BIOTECHNOLOGY IN EUROPE ?

While it is generally acknowledged that the potential for growth of industrial biotechnology (IB) is huge, there is a lack of robust information on the size of the current IB market and its likely future development in the EU. The market estimates and projections presented below give the most up-to-date and comprehensive view on the current and potential future market[2] for IB products in the EU.

The EU market for the IB sector as a whole in 2013 was estimated at 28 billion euro (BEUR). By far the largest product segment was antibiotics (accounting for over a half of the market), followed by biogas and bioethanol respectively. Remaining applications, including amino acids, enzymes, biosurfactants, biobased plastics, vitamins, biosolvents and biolubricants, together accounted for less than a quarter of market demand in 2013.

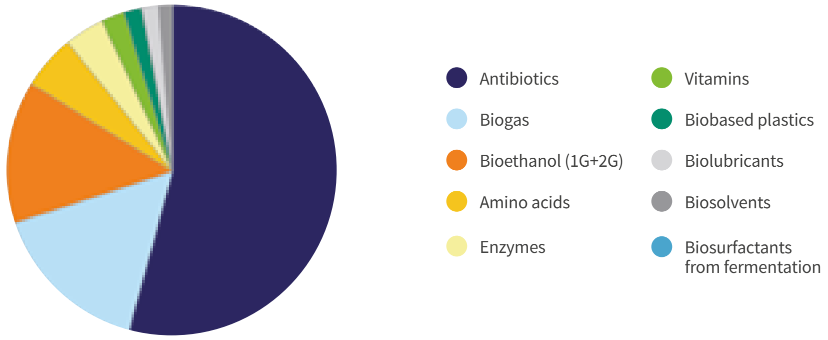


Figure 1 – Share of IB market demand in the EU (2013)[3]

The IB industry in Europe is driven by a multitude of factors including population growth, environmental issues, product differentiation and opportunities for cost reductions. The drivers often vary according to sector. For example, the biofuels sector is more policy and regulation driven, whilst the biopolymers sector is driven more by environmental legislation, brand identity and feedstock availability issues.

BIO-TIC's projections show that the EU market for IB products could develop from 28 BEUR in 2013 to 40 BEUR in 2020 and up to 50 BEUR in 2030. Excluding biogas and antibiotics, this represents a Compound Annual Growth Rate (CAGR) of 7% between 2013 and 2030.

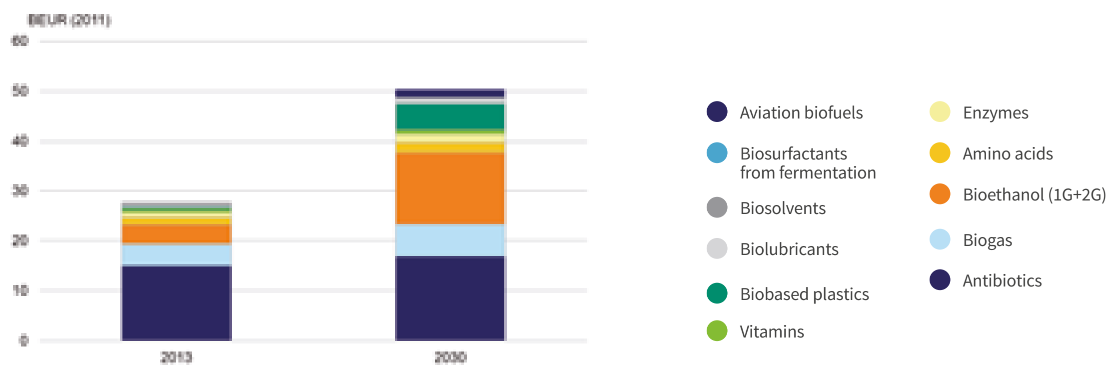


Figure 2 - Estimated IB market demand in the EU up to 2030[4]

[2] Market value is here defined as the value of consumption, i.e. production – exports + imports, in the EU.
[3] Based on results outlined in the market roadmap available at www.industrialbiotech-europe.eu
[4] Based on results outlined in the market roadmap available at www.industrialbiotech-europe.eu

2

HURDLES TO INDUSTRIAL BIOTECHNOLOGY IN EUROPE

IB offers significant potential for overcoming many of the grand challenges facing the EU today, including competitiveness, unemployment and sustainability concerns. However, despite this potential, significant barriers remain. This section briefly reviews the major technical and policy related hurdles hindering the development of a competitive IB sector in Europe.

2.1 Feedstock Supply

It is often questioned to what extent Europe can supply cost-effective feedstocks for large-scale production on a consistent basis throughout the year for biorefineries. **Costs of feedstock are often higher in Europe** due to regulations, climatic conditions and/or higher labour and operating costs.

In many parts of the biomass sector, supplies are currently limited as a result of a relatively **undeveloped infrastructure** for collection, storage and transportation. On top of this, **supplementing EU feedstock production with imports from elsewhere in the world is hampered by trade barriers** which artificially raise prices.

For sugar and starch crops especially, **the seasonality of EU production** means that feedstock price, availability and quality can vary significantly over the year as well as from year to year. In many cases, the cost and availability issue is compounded by the fact that there are **several alternative uses for feedstocks**. A high demand or subsidies in one market can mean that the prices are pushed up for other users.

Bio-wastes may be cheap and widely available in the EU at present, but their use requires significant technological innovation, especially to overcome **feedstock quality variations**. Furthermore their use is also subject to complex **regulations**. Once such technologies are developed, it is anticipated that the demand for such feedstocks will increase and subsequently so will their price. For all feedstocks, but especially bulky and heavy feedstocks (such as beet or straw), and novel alternative feedstocks such as carbon dioxide (CO_2), the **costs of transport can be high** over long distances, possibly requiring localised processing facilities for cost-effective production.

2.2 Production

Bioconversion is the conversion of biological or chemical substances into useful products either through fermentation or through biocatalysis where microbially-produced enzymes are used to catalyse industrial chemical reactions.

The **yield, productivity and robustness of many bioconversions are still too low** to make IB processing economically competitive for most IB products, except for notable examples, like lactic acid. In part, this results from a combination of the **poor yield** of microbes and biocatalysts (especially with feedstocks other than hexose (C6) sugars), a **lack of continuous fermentation** systems, **impurities** produced by bioconversion steps hindering downstream processing and the costs of water reuse.

The quality of the final product is paramount for consumer confidence and market uptake, however, it is generally agreed that the **properties of some biobased products are not adequate for all desired applications.** In addition, the attainment of a consistent quality product and waste streams is hampered by the use of **feedstocks which themselves vary in quality**, particularly for lignocellulosic and waste materials.

Several processes which need to be developed, integrated and reiteratively optimised during scale-up.

At present, each step is frequently developed and optimised separately from one another, leading to inefficiencies and **difficulties during scale-up.** There is also a **lack of predictive models** to aid the design of a more integrated bioconversion process.

2.3 Market

The costs of feedstocks and manufacturing have perhaps the largest impact on the cost competitiveness of industrial biotechnology products. **Without support, the market penetration of IB products may be limited** unless new functionalities, not offered by fossil products, can be exploited.

However, even if a competitive route to market can be established, IB products face a **long journey to commercialisation due to regulatory constraints** before they reach end users and consumers. **Consumer awareness of IB products is poor.** Their advantages and functionalities are not clear enough. Also, there is currently no agreed definition and a **lack of common understanding** about terms such as 'bioproduct' and 'sustainability'. Without a coherent strategy to promote the development of biobased products in the EU and one which recognises the benefits that these products can bring, **biobased products face a challenging route to market.**

2.4 Innovation Systems

The deployment of IB technologies is currently hindered by a **lack of access to finance** regardless of the size of company. Early stage and small companies such as spin-offs, start-ups and small and medium-sized enterprises (SMEs) face particular problems with the **high costs for patenting inventions,** the challenges associated with a **lack of harmonised intellectual property (IP) legislation** across the Member States, and **accessing finance for scaling-up IB projects** in Europe. In part, this can be attributed to the relatively risk-adverse European investment climate. However, IB as a sector faces particular challenges because it is an intermediate, enabling technology which touches upon several sectors and which does not always produce tangible and recognisable products, Subsequently the **lack of an overarching, long-term regulatory and policy** strategy for IB undermines investors' reassurance in the stability of the policy framework over the long timescales needed to develop, commercialise and recoup costs on such innovative technologies. Large multinationals also suffer from a **lack of public R&D funding for demonstration and commercial plants** in Europe compared to other regions of the world, and as a result, some have decided to invest outside of Europe, despite having developed their technologies in Europe.

More broadly, there is currently a **lack of collaboration** between the different actors in the IB value chain, with the **lack of operational alliances between industry and academia** a particular concern. This creates the risk that promising innovations in academia are not recognised by industry thereby stifling European competitiveness in this fast-moving sector. Moreover, it is acknowledged that there is a **lack of appropriately trained personnel** and actions to overcome this skill gap are needed.

3

TOP 10 RECOMMENDATIONS FOR DEVELOPING A VIBRANT INDUSTRIAL BIOTECHNOLOGY SECTOR IN EUROPE

In the previous chapter and the separate roadmaps we saw that there are several hurdles which impact upon Europe's potential to develop a world-leading IB sector. We also saw that there is a large range of potential solutions which could be employed to overcome these hurdles. But what are the most effective solutions? What action is needed to make them happen, by when and by whom?

This chapter outlines the Top 10 key recommendations for developing the potential of the IB industry in the EU, and has been based on evidence gathered about what is needed to overcome the identified hurdles and implement change for the successful uptake of IB solutions. The recommendations are not mutually exclusive, therefore there may be a high degree of overlap, or one recommendation may be dependent upon other recommendations. They are not presented in any order of importance.

The Top 10 BIO-TIC recommendations are to:

1. Improve opportunities for feedstock producers within the bioeconomy;
2. Investigate the scope for using novel biomass;
3. Develop a workforce which can maintain Europe's competitiveness in IB;
4. Introduce a long-term, stable and transparent policy and incentive framework to promote the bioeconomy;
5. Improve public perception and awareness of IB and biobased products;
6. Identify, leverage and build upon EU capabilities for pilot and demonstration facilities;
7. Promote the use of co-products;
8. Improve the bioconversion and downstream processing steps;
9. Improve access to financing for large scale biorefinery projects;
10. Develop stronger relationships between conventional and non-conventional players in the value chain.

3.1 Improve opportunities for feedstock producers within the bioeconomy

IB is often considered the key to the development of the bioeconomy. IB can also add value to industrial side streams such as CO_2, as well as biogenic waste streams, making valuable products from what might otherwise be considered either worthless or a cost burden. The bioeconomy begins with the efficient and sustainable production of biobased feedstocks. Without farmers' and landowners' support, the impacts of the bioeconomy in Europe will be limited. As a result, it is of paramount importance that farmers, landowners and forestry owners are fully aware and engaged with the potential of the bioeconomy.

The costs of EU feedstock can be high as a result of poor infrastructures for collection, storage and transportation of material. In addition, demonstration of the necessary environmental sustainability standards requires complex and time consuming procedures to demonstrate the biomass sustainability. In some cases, landowners may be unaware that they have different options for biomass utilisation, whilst in other cases, they may be aware of the opportunities, but may be reluctant to get involved as returns are deemed not worth the effort. A range of possible solutions to address these problems could be envisaged and are discussed below.

3.1.1 Ensure best use of biomass and wastes by landowners

The potential for using the residues of existing feedstocks, such as straw, forestry residues and wastes is immense, offering the possibility to develop biobased products without impacting upon land use whilst bringing in an additional income stream for farmers and landowners. In theory, wastes and residues are "cheap" feedstocks, however, many wastes and residues have existing uses, and care should be taken to ensure that the use of these materials does not adversely impact upon existing markets or uses and cause unintentional 'negative displacement' effects (see also Recommendation 2). Three approaches are proposed:

1) **Ensure that producers can make informed decisions on the use of their residues/wastes.** Farmers should know what options are available to them, and how they can be exploited, whilst still being able to meet the terms of cross-compliance measures stipulated in the Common Agricultural Policy (CAP) and any sustainability standards required by processors. As an example, there is currently a lack of guidance for farmers on the optimal use of straw as a soil improver. In this respect, the Agricultural European Innovation Partnership (EIP Agri) Farm Advice Service would appear to be the logical coordination point for this role, in collaboration with national and regional advisors. Furthermore, bio-waste producers may not necessarily be aware of the opportunities they have for using their product for bioprocessing.

As a result, there is a distinct need to raise awareness of IB amongst bio-waste producers to ensure that such synergies develop.

2) **Ensure producers are given a fair-price for collecting their wastes/ residues.** The IB industry requires access to competitive sugars as feedstock prices are a major determinant of the final product price. However, wastes and residues are rarely 'wasted' and may have valuable uses in other markets (see Recommendation 3.2). Producers need to be able to cover the costs of harvesting, collecting and storing the biomass and any inherent value that the feedstock brings. For example, for straw, the nutrients contained within the straw can be valuable depending upon the relative prices of nutrients, particularly phosphate and potash. The cost of biomass can vary significantly both in different areas and across the season/s. This variability in pricing can contribute to biomass producers deciding to sell on the open market rather than commit to forward contracts where the price may be held for several years. This can hamper the secure supply of biomass for processing. Options by which this could be facilitated need consideration. Regional development funding provides financial support to support this action, for example for establishing producer groups, knowledge transfer and capacity building, but the administrative burden associated with applying is thought to be disproportionate to the funding available. Routes to reduce the complexity associated with accessing such funding would be welcomed by landowners.

3) **Develop infrastructure for biomass collection, storage and transportation.** The ways in which wastes and residues are mobilised and who is responsible for this will be important in determining a fair price for producers. However, infrastructure and routes for mobilisation of waste and residues are currently lacking across much of Europe and there is a need to understand how this could be optimised, perhaps by learning from the well-established logistical chains within the forestry industry and for straw collection in Denmark. This is an active area of research in the EU; for example, the Biobased Industries Joint Undertaking (BBI JU) and some Horizon 2020 projects aim to address feedstock mobilisation and logistics by 2020 through a series of research, demonstration and flagship projects. There is no obvious solution to this problem and different solutions may need to be deployed in different regions. Financial incentives, cooperatives, obligations (or a combination thereof) may all be feasible options. Regional development funding should be used to explore which options best fit within different regions.

4) **Promote the availability of feedstock-related information.** In order to advance the bioeconomy in the EU, it is necessary to identify future feedstock availability by taking advantage of advances in IT and by developing methods and tools for managing; refining and utilising feedstock-related data so that necessary logistics and supply chains for biomass and waste streams can be established. Examples of such development include opening up previously exclusive feedstock statistics and inventory data and the utilisation of so-called big data (mining of large datasets to create business opportunities and to improve operations planning and decision making). Better information on e.g. the quality and utility value of feedstocks will benefit not only the producer but also other stakeholders of the value chain.

3.1.2 Reduce the complexity of sustainability reporting schemes

Ensuring that biomass is produced in an environmentally and socially sound manner is a pre-requisite for the development of a sustainable bioeconomy. However, there are a multitude of different schemes which biomass producers (especially in the agricultural and forestry sectors) must comply with. Not only do farmers need to ensure environmentally sound production to qualify for support payments as part of cross compliance measures under the CAP, but there are a plethora of schemes to certify sustainable production chain from biomass to final product including several directly related to IB and the bioeconomy including the International Sustainability and Carbon Certification+ (ISSC+) and Round Table on Sustainable Biomaterials (RSB). The multitude of different schemes and their different compliance criteria create an extra complexity for landowners, especially given that demonstrating compliance is time consuming and costly. A new Renewable Energy Package is due to be proposed in 2016-2017. This will include a new policy for sustainable biomass and biofuels as well as legislation to ensure that the 2030 EU target is met cost-effectively. The proposal will be based on an impact assessment in which the needs will be analysed and policy objectives will be clarified. This provides a good opportunity to see how the complexity associated with sustainability reporting schemes could be reduced.

3.1.3 Reinvigorate sugar beet production and processing capacity in the EU

Sugar beet is an excellent and sustainable feedstock for IB, with abundant and easily accessible fermentable sugars. Since the mid-2000s, there has been a reduction in sugar beet processing capacity in the EU. While in some countries production has been scaled-back, in other countries production has been lost entirely. The sugar reforms due in 2017 present an opportunity for reinstating this capacity at least in some areas of Europe, but landowners need to be assured that a market exists and they will get a fair price for their goods. Two approaches are proposed:

- **Improve sugarbeet IB-readiness.** Competitiveness of production for IB markets may be boosted through targeted research into how beet can be processed in a minimal way, so that sugars are available in a pure enough form for fermentation, but without the expense of being fully refined as for food grade sugar. Research is needed to ascertain whether this is possible and can be improved. A Horizon 2020 project bringing together the sugar beet processing chain and fermentation capability is encouraged and should learn from national research in this area.
- **Ensure efficient knowledge transfer in the industry.** On a local level, processors should work with potential growers to promote the opportunities for sugar beet cultivation in a specific locality, and agricultural extension services should ensure that best practices are deployed.

3.2 Investigate the scope for using novel biomass

In a future market economy, the most likely scenario for biomass supply for industry and especially for industrial biotechnology will be a mixed one, involving a diverse and variable mixture of feedstocks. In this way, simple feedstock (agricultural products such as sugar from sugar beet and sugar cane, starch from wheat and corn, plant oils etc.) and more complex feedstock (sugars from lignocellulosic materials such as straw, short rotation coppice, dedicated crops, residues or even algae and wastes) as well as advanced "non-biological" sources (such as wastewaters, municipal solid wastes, flue gases and direct air captured carbon dioxide) will coexist in the future.

Simple feedstocks are globally available at affordable prices for the bioeconomy of today, especially when oil prices are above 75 EUR/barrel. This is especially true for sugar from sugar beet, whose potential in Europe is set to increase after 2017 when the sugar quota regime will end. Thereafter, it is expected that sugar will be produced in the EU at even lower prices than today. Nevertheless, ongoing policy debates, together with well-established economic and supply chain security considerations from the industry, are driving intensive investments and development in the use of non-food based biomass sources. The key measures needed to unlock the potential of non-food based biomass sources are outlined below, while options to make full use of biomass are explored in Recommendation 3.7.

3.2.1 Facilitate the appropriate use of wastes and residues for IB processes

Wastes and residues could be used for the production of biofuels and biobased chemicals. However, there are multiple barriers preventing their use that need to be addressed in order to become a viable feedstock option for the IB industry in Europe.

1) **Identify what are truly wastes and residues[5].** The fact that a material or industrial stream is classified as a waste does not necessarily mean that such an item has no potential application or (hidden) added value. In some cases, wastes may have valuable applications, for example, tall oil from wood processing, often considered a waste, is a valuable chemical feedstock. There is little reliable information on the amount or existing uses of wastes and residue feedstocks and, consequently, to what extent their use for IB processes could result in unforeseen impacts. Therefore, there is a need to assess the waste biomass resources available. Differences in availability may occur on a regional and temporal level. As a result, an assessment of resources on a local scale would be useful in determining the sustainable supply of wastes and residues. Moreover, there is a need to ensure that any policy promoting the use of waste and residue biomass is cognisant of the subtleties associated with their use. Ideally, safeguards would be introduced to ensure that no negative, unintended consequences occurred through their use. A better classification of wastes and residues, supported by updated policies, would give confidence to project developers that they were using sustainable biomass sources.

2) **Encourage R&D on the processing of wastes and residues.** The use of wastes, residues or other side streams brings a series of technical challenges for IB processes. These include issues over the variability and availability of the material, the influence of inhibitory compounds and non-desirable competing microbes. Given the early stage of development of technologies for using waste and residue materials, the problems associated with their use are not yet fully understood. Focussed R&D is needed on using waste and residue feedstocks within a range of IB processes (either dedicated IB or hybrid thermochemical/ bioconversion based systems) to expand the variety of biomass sources available for the IB sector. Optimising bioconversion and downstream processing steps to overcome the issues associated with impurities present within the biomass is crucial.

3) **Introduce specific policy measures to facilitate the use of wastes for higher value applications.** Under the current waste hierarchy, as laid out in Article 4 of the revised Waste Framework Directive, the use of gasification, pyrolysis and other processes such as industrial biotechnology to produce new chemical materials from waste is not counted as being recycling. Instead, these technologies are counted as energy from waste applications and do not reflect the higher value applications that chemical production brings. However, Article 4 does allow Member States to take measures to encourage the options that deliver the best overall environmental outcome, based upon specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the generation and management of the waste. In some EU countries (e.g. the UK), such measures are not utilised, providing a barrier to companies wishing to invest in such technologies. Where applicable, this issue should be addressed on a national basis.

3.2.2 Continue to fund research and demonstration programmes on non-food biomass sources

A wide range of novel biomass sources exist which could be used as feedstocks for IB, including micro- and macroalgae, Miscanthus and *Arundo donax*. Their adaptability and resilience to marginal conditions could be improved to extend the cultivation area beyond current limits. This requires the input of plant breeders and research bodies from industry and academia using conventional and new technologies. A thorough assessment of the sustainability and a life cycle analysis (LCA) associated with novel biomass sources should be a necessity in any pilot and demonstration project utilising these resources at each stage of the project lifecycle.

[5] This recommendation is taken from IEEP 2013: «The sustainability of advanced biofuels in the EU»
http://www.ieep.eu/assets/1173/IEEP_2013_The_sustainability_of_advanced_biofuels_in_the_EU.pdf

3.2.3 Investigate routes for using multi-feedstock processing capability

The European IB industry is hampered in securing sufficient amounts of any one type of feedstock, on a consistent and economic basis throughout the year. It has been suggested that the development of facilities able to process multiple feedstocks (including food, non-food and waste biomass according to availability and cost) would help overcome some of the issues surrounding the variability of biomass supply. Significant R&D is needed to realise such facilities and their implementation is likely to be a longer term prospect. Nevertheless, funding should be allocated for R&D activities in this field now to ensure post-2020, plants have flexible processing capacity.

3.3 Develop a workforce which can maintain Europe's competitiveness in IB

It is generally acknowledged that while Europe excels at research, key competencies are needed to enable successful deployment of IB technologies. This entails an understanding of different scientific and technical skills, as well as business and personal skills that will allow professionals to easily adapt to new tasks, job functions or even different scientific areas. This will lead to efficient interdisciplinary work and effective collaboration with value chain partners. A greater focus on financial and business skills will also be required in scientific curricula in order to effectively turn ideas into business. A better balance between theory and practical training, more focus on cultural skills and cultural awareness (especially for emerging markets), strengthening knowledge and skills on business models and commercial aspects of the bioeconomy, and better project management skills are some of the other suggestions which should contribute towards enhanced innovation. It is clear that there will be no 'one-size-fits-all' approach here and innovative solutions will be needed to cover the complete value chain from farmers, forestry and landowners to end-user and capitalise upon regional strengths. IB is a rapidly developing sector, so there is a constant need to ensure that the skills and education provided to the sector are fit for purpose, take into account future skills needs and are adaptable to change. The EU has a world-leading academic sector, however, academia is often slow to react to specific skills needs of the industry, and such inertia can lead to mismatches in the skills taught compared to those needed by industry. Facilitating the timely and effective collaboration between industry and academia for skills development will be the key to maintaining European competitiveness.

3.3.1 Leverage education value from innovation projects

Using selected results from EU projects could effectively contribute to enhance skills for innovation in the short to medium term, at European, national and regional levels. Through better exploitation of the innovation outputs from successful projects, initiatives such as the SusChem "Educate to Innovate" programme[6] may support the systematic development of innovative learning resources. In this way such education programmes would become enriched in content with particular regard to case studies and real world examples. This would enable students to learn through failure as well as success, understand how and why decisions were made, with documented methodologies for problem-based studies, while at the same time being flexible in their implementation.

It should also be possible to integrate these into existing modules and curricula, whilst being adaptable by teaching staff at undergraduate and master degree levels as well for their use within lifelong learning courses. The effective implementation of such initiatives would require engagement of teaching academics at appropriate stages in the innovation project.

3.3.2 Encourage the development of training and teaching activities relevant to the needs of the IB industry

Industry-academia educational collaboration can be achieved at regional, national or European level and will include, for example, industrial masters and PhD studentships, industry placements for students, courses at pilot plants, and staff exchanges (both industry-academia and academia–industry). The skills developed through such learning activities should be recognisable and transferable. At European level, such activities could also be supported in the framework of the Horizon 2020 or BBI JU which could be used as a route for developing specialised training schools focussing on very specific elements of the bioeconomy, including IB, as well as in the framework of a possible future bioeconomy/IB focus at the European Institute of Innovation and Technology, in order to bring industry, research and teaching communities together at a pan-EU level.

The need for developing and maintaining specialised technical staff cannot be overstated, especially in the technically challenging and innovative IB sector. As people in such specialised roles 'learn by doing', such skills are not easily replaced.

Furthermore, innovative methods for delivering IB courses should be explored; especially for SMEs, since the time and cost associated with training can be discouraging. Massive Open Online Courses (MOOCs) offer considerable potential for broadening participation and knowledge exchange across borders and disciplines, allowing the transfer of European knowledge to less knowledge-intensive economies, and, similarly, helping improve European knowledge of applications worldwide. Evening courses are also encouraged.

[6] www.suschem.org/priorities/education/educate-to-innovate.aspx

3.3.3 Provide support funds to help develop IB-specific teaching programmes

Funding for IB-specific education actions may in the short term be achieved by integrating educational outputs into prospective project exploitation plans. In the longer term, an appropriate framework of project funding mechanisms should be identified or created to enable such courses. Significant expertise already exists in many cases; although it may be necessary to join these up, either within a single university/institution or by bringing several centres together . The administration associated with establishing and maintaining such interdisciplinary programmes across Europe should not be underestimated, and 'glue money' to develop and support such programmes should be provided to ensure continued impact and collaboration. DG Education and Culture has some relevant programmes under Erasmus+ (Knowledge Alliances), but they follow a bottom-up approach. Therefore, no sector or technology-specific calls can be envisaged, and the success rate is extremely low. Signposting of relevant funding sources would be beneficial here. The European Social Fund (ESF) which funds training and education within ESIF can also support cross regional knowledge sharing by using the new opportunity to use part of this funding (up to 15% of ESIF funding) outside of their region (e.g. for education, skills and know-how, etc.) and accelerate development of the bioeconomy within and across regions throughout Europe.

3.3.4 Develop an EU "observatory", supported by national bodies, to monitor skills needs from industry and monitor what skills are taught.

IB is a dynamic sector so the skill sets required may be expected to change quickly. Such an observatory, perhaps established through the European Sector Skills Alliance scheme under Erasmus+, or through the Bioeconomy Observatory, could identify current skills gaps and forecast future ones. In this way, academic and training programmes can be designed to best meet the needs of industrial players both now and in the future, and provide the crucial skills needed to maintain European competitiveness in this nascent but highly promising area[7]. Long-term support for such an initiative is essential. In order to ensure successful implementation, the input and opinion of university and other teaching personnel as well as from organisations active in the field of setting educational recommendations should be sought. They should be involved in the set-up and the development of an implementation concept for the results of the "observatory". The results of this observatory could then be used to develop a coherent education and skills plan for IB in Europe, thus helping to guide European activities for IB funding, incorporating academic training, skills retention and apprenticeships.

3.4 Introduce a long-term, stable and transparent policy and incentive framework to promote the bioeconomy

Whilst in February 2012 the European Commission adopted a strategy on the bioeconomy, a number of sectorial policies and funding mechanisms that have been put in place to support the development of industrial biotechnology and the bioeconomy still exist, to an extent, in isolation from one another.

At EU level, the European Commission promotes research and innovation (R&I) in the field of industrial biotechnology and the bioeconomy through Horizon 2020 and the BBI JU. The Common Agricultural Policy (CAP) allows Member States and regions to support initiatives that facilitate the collection and storage of biomass. IB has also been identified as a KET and biobased products were selected as one of the six priority areas, which should be supported by the new industrial policy. Several European Member States have also developed national or regional bioeconomy strategies. However, like the EU strategy, none are legally binding.

The European Union, its Member States and regions need a holistic framework which weaves the bioeconomy into the fabric of policy making across many sectors. To be successful, it is essential that the regulatory fragmentation across the range of policy areas that can enhance the bioeconomy is addressed. More innovation-friendly market framework conditions and incentives are therefore necessary to reduce the time-to-market of new goods and services, foster large investments in biobased production facilities with longer return on investment timeframes and to enable emerging sectors to grow faster. When adopted, legislation should also be stable in the long-term to secure investment.

To harness the potential of IB and the bioeconomy we recommend that the EU and national decision makers consider undertaking the following actions:

3.4.1 Introduce financial incentives for biobased products

Direct financial incentives or tax reductions could be granted to biobased industries that produce renewable chemicals in Europe from European renewable biomass. Renewable chemicals produced should include a minimum % of biobased content as calculated by the standard for biobased products (European Committee for Standardisation – Technical Committee 411 (CEN TC/411)). The financial incentives or the tax reductions could also be granted to industries buying renewable chemicals for the production of polymers, plastics or formulated products, or to industries buying renewable chemicals as polymers, plastics or formulated products. Given the national competence over taxation affairs, such a framework should be agreed at European level and implemented by the Member States.

Alternatively, direct financial incentives or tax reductions could be granted to biobased industries that produce renewable chemicals in Europe from European renewable biomass based on a selection of sustainability indicators (e.g. greenhouse gas (GHG) emissions, energy use, etc.). In order to set up such a framework, standardised, comparative life cycle assessments between renewable and non-renewable products should be developed.

[7] Work is underway in the UK to map the skills needed by the IB industry, and has been done in the Netherlands by the BE-BASIC consortium.

Optimisation steps of products should be included for new materials which are at their early stage of development.

Targets and incentives, mandates and bans can successfully support the introduction of sustainable and innovative alternatives on markets, although excessive market distortion should be avoided. Binding targets, such as the one adopted for renewable energy in transport in the Renewable Energy Directive (RED), help to ensure market development and create some long-term predictability for investors, hence securing "a business case". Similar targets could be adopted for certain product categories or applications. Progressive substitution schemes on less sustainable products are also effective in reassuring investors when it comes to investing in innovative products and technologies. In a similar way to the progressive ban on incandescent lamps which led to the LED revolution, substitution could be adopted on certain products where more environmentally sustainable, cost-effective biobased alternatives are being introduced to the market.

3.4.2 Support biobased products development through public procurement

The potential for increasing demand for biobased products through public procurement is huge, as European public authorities spend between 15% and 20% of the gross domestic product (GDP) on goods and services annually. Almost all product areas could potentially feature products made entirely or partly from renewable raw materials. Likewise, the production of almost all types of services could potentially benefit from biobased inputs.

A public procurement system for biobased products requires:

- Biobased products to be available;
- Information on products and products to be classified and compiled in database;
- Products to meet defined criteria and standards and to be recognisable through labels;
- Public procurers at European, national and regional level to be aware, convinced and trained to buy biobased products;
- Mandates, targets, political support and legislation.

In Europe, products are available and have begun to be classified and compiled in databases. These activities are currently being undertaken and should be coordinated. While several environmental labels exist (EU EcoLabel, national and regional labels), none recognise biobased as an indicator. Two European directives address public procurement. However, neither mentions renewability of feedstock as a criterion. While public procurement for biobased products is one of the priorities of the DG GROW biobased products expert group, most of the policy initiatives taken are modest and recent. Several upcoming policy initiatives such as the circular economy package and the new investment package launched by the European Commission in Autumn 2014 could be used to introduce ambitious legislation supporting innovative biobased products through public procurement.

3.5 Improve public perception and awareness of industrial biotechnology and biobased products

The average citizen's relatively low level of understanding and acquaintance with IB and IB-derived products can be misinterpreted as a lack of acceptance of IB by the public. However, this lack of awareness arises from the fact that IB is a technology which is difficult to explain and thoroughly comprehend, despite being commonly used to produce e.g. beer, cheese and bread. Moreover, it seems that the challenge extends beyond the complexity of the very subject of IB and touches upon people's general awareness of the origins of everyday products that originate from fossil carbon. Subsequently, it is all the more difficult for the public to picture how these very commonplace products could be replaced by biobased ones, enabled by IB.

The apparently limited knowledge on the subject is thus considered to contribute to consumer's lack of willingness to pay a bio-premium when biobased alternatives are more expensive than fossil based ones. That said, it is thought that there is a general appreciation for sustainability amongst many EU consumers and biobased products are increasingly being sold for the same cost as fossil ones with similar or even improved performance. Nevertheless, the lack of awareness of the existence of biobased products produced using industrial biotechnology, coupled with a lack of understanding of their benefits, still present a significant barrier to the creation of new markets for these beneficial and resource efficient products and processes.

Relevant output in this regard is expected from several upcoming Horizon 2020 projects, including BIOSTEP and CIMULAT.

3.5.1 Ascertain the public's acceptance level for IB and biobased products

Special Eurobarometer surveys from 2006 and 2010 have established that a large majority of Europeans have a positive opinion of IB. Yet, BIO-TIC stakeholders have found that the public acceptance of IB and biobased products could be further improved. We recommend introducing a public opinion study across Europe with regards to: 1) IB in general, including its technical aspects and 2) applications of IB: via e.g. a Eurobarometer survey. Such a survey could be funded via Horizon 2020.

3.5.2 Develop an EU wide campaign to improve public awareness and perception of IB and IB-derived products

Based on the results of the barometer study above, it will be possible to design an informed and effective communications campaign to (further) improve public perception and awareness of IB and biobased products. The risk perception indicators of the barometer study will determine the most relevant national bodies to supplement the EU campaign, and pinpoint if there is a need to create separate dialogues on more challenging subjects related to IB. The overall EU campaign could include:

- **A website outlining all there is to know about IB, building upon the input and structure provided by the BIO-TIC website.** It could include:
  a. An accurate scientific and agreed definition of IB, mentioning both biocatalysis and fermentation, and explaining the resulting processes with visuals rather than text;
  b. The policy context (IB as a KET, bioeconomy strategy, etc.) and directives which apply (contained use directive, food and feed directives, etc.);
  c. A showcase of examples by means of infographics to illustrate how IB acts as an enabler for the bioeconomy, the circular economy, carbon neutral processes, improving industrial processes and the array of available products, etc.
- **Promotional short films illustrating the benefits of IB products,** to be made available on websites and circulated through social media, possibly with "open licence", as well as on TV. The films should be application-oriented and focus on the sustainability, performance and environment-friendly aspects of biobased products. In order to increase familiarity with the word IB, the films should indicate that a product is made using IB by means of a recurring visual effect (e.g. a label or stamp saying "thanks to IB").
- **Educational material and tools** for all age categories about IB and the bioeconomy. All IB players should provide the opportunity to live the 'biobased experience' by organising open access days. The SusChem 'Innovate to Educate' programme mentioned in recommendation 3.3 may also be a useful model to replicate here.

3.5.3 Develop a campaign aimed at improving awareness of how IB products can aid industry

Within the larger aim of improving public perception and awareness of IB, it is also crucial to ensure that businesses are aware of IB solutions. The BIO-TIC project tools (e.g. the partnering platform and BIO-TIC website) can provide useful platforms and a sound basis to foster awareness of the IB alternative for businesses. The existing tools could be complemented and improved by:

- **Gathering European IB success stories as separate case studies to be made are accessible to IB companies throughout Europe for their communication towards brand owners.** A starting pool of examples for IB success stories can be found in the Bioeconomy Panel market group report. However, this work should be updated on an ongoing basis, possibly in the framework of the Joint Research Centre's (JRC's) Bioeconomy Observatory and should include national and regional examples in Member State languages.
- **Setting up an online brokerage tool based on properties and corresponding functionality of certain molecules produced with IB pathways,** e.g. an online database where European technology providers who are looking for customers could list their services' and products' specificities. An existing similar tool is IAR's Agrobiobase.
- **Setting up, for each Member State, a directory of IB and biobased companies, as well as chemicals companies.** The information could be gathered by national knowledge transfer organisations. They could simultaneously act as "matchmakers" and raise awareness about the existence of IB solutions for many types of industries, as from the recent UK-Norway action (UK-NO Directory 2014). These activities could be complemented by concrete help to find the suitable customer or partner, identify the corresponding funding (e.g. structural funds, European Investment Bank loans), etc.

More information on fostering industrial synergies and collaborations is given in recommendation 3.10.

3.6 Identify, leverage and build upon EU capabilities for pilot and demonstration facilities

The development of a new product requires several steps to take it from the lab scale to a commercial product. These steps are needed to test that the technology is scalable and reproducible outside of the laboratory environment and to provide data to prove to investors that an idea is commercially viable. Access to scale-up equipment is commonly cited as a barrier to the development of IB processes. Such equipment is costly and requires specialist staff to operate it. SMEs find it a particular challenge to finance trials at a large enough scale and to develop suitable data for investment decisions to be made whilst not compromising on IP rights. This results in the infamous 'valley of death' whereby innovative products at the lab scale fail to be commercialised. The risks and large capital outlay associated with scale-up mean that it is difficult to find private investors for these kinds of plants. Public funding therefore has a crucial role to play in helping bridge this gap.

3.6.1 Ascertain capacity, capability, funding models and client geography for European IB pilot and demo plants

A study of the IB pilot and demo plants in Europe to ascertain capacity/equipment, capability, funding models, utilisation and client geography would be useful in terms of helping identify the current capabilities for IB scale-up in Europe. This should include plants which are currently used as well as those which are currently idle. This study, which could potentially be funded through the BBI JU, would in turn help to:

- Signpost potential users and technology developers to appropriate facilities. An online information portal could act as a useful tool to provide information on location, capabilities, and the availability of the facilities, outlining for example whether the facility is operational or idle, and in the latter case, why and whether it can be used for other purposes. Pilot plant owners should be able to update the information about their plant to ensure it is kept up to date and useful. This tool should be advertised widely as the IB community is largely unaware of the facilities available within the EU.
- Identify existing capability gaps/vulnerabilities which need to be filled by investment in pilot scale equipment to help promote specific emerging technologies both now and in the future (see action 3.6.2 below). This should take into account the needs of the industry. As the IB sector is highly dynamic, this review should occur regularly to ensure that capability meets emerging needs.

Many SMEs are concerned that a host pilot/demo facility will claim IP rights over their results should the facility be used. As a result, it will be important to highlight the terms on which access is provided in such a study as it may be a crucial factor in determining whether a company chooses to use a particular facility or not.

3.6.2 Invest in infrastructure at pilot and demonstration scale to bring innovative European ideas to market

As a preference, funding instruments should seek to use existing facilities before new ones are created to ensure multiple, redundant platforms are not created in parallel. In particular, regional pilots should be avoided, unless they offer unique capabilities not matched elsewhere in Europe.

- Europe has several excellent open access pilot facilities (for example, Bio Base Europe Pilot Plant in Belgium, The Centre for Process Innovation (CPI) in the UK, Delft Bioprocess Facility in the Netherlands, SP Processum in Sweden, and the ARD Bio demo facility in France) which could play a key role in technology development within the IB sector. These plants have significant knowledge of process development, flexible equipment and highly-skilled, knowledgeable workers offering full support and capability. Ideally, should any additional infrastructure/equipment be required, this should be deployed at such open-access facilities where the investment cost and risk can be shared across multiple projects. This would also allow capabilities to be developed and retained in niche, highly technical areas whilst ensuring maximum value for money from the initial investment;
- In some cases, it may make sense to use idle facilities and retrofit them to a specific need. The impacts associated with their re-commissioning would need to be thoroughly assessed prior to funding to ensure that the specificities of different technologies are taken into account and that cost savings and environmental benefits are feasible. In particular, funders should seek to ensure that studies could not be performed at existing open access facilities before such ideas are financed;
- New facilities/equipment should only be funded so long as existing facilities and infrastructure are proven to be insufficient. End of life options should be outlined in funding proposals to ensure that large amounts of funding are not wasted. End of life options should be included at the design stage and give the possibility for the infrastructure to be dissembled and used by others at a later stage.

Anecdotal evidence suggests that funding for pilot and demonstration facilities is very fragmented, with several funding streams often needed to create a viable facility. In some cases, funding comes with significant barriers to access, either with use being restricted to companies from specific geographical areas, or limited to use for specific projects. Regional and cross-border funding can help bring regions together to develop joint facilities and mobilise other funding streams. Simplification of funding streams and ensuring that fewer conditions are attached to such funding would be positive moves in ensuring that pilot and demonstration facilities are open to those who need it.

3.6.3 Overcome fragmentation of scale-up facilities

Europe has a number of scale-up facilities at a range of scales, but these are largely disconnected at present. The development of a research infrastructure for IB could help address this problem by helping to connect complementary activities and speed up the innovation process, thus improving European competitiveness in a coherent manner. Such a network could help:

- Bridge the technology gap across Techology Readiness Levels (TRLs), providing a bridge between early stage research (TRL2) and later stage research (TRL6-7);
- Prevent undue duplication of activities by promoting cooperation between facilities, especially where there is complementarity in activities.

The development of such a network should draw upon the mapping exercise in 3.6.1 and could be based upon the model developed by the Seventh Framework (FP7) project Biofuels Research Infrastructure for Sharing Knowledge (BRISK), where a series of lab and pilot-scale facilities have cooperated to develop innnovative processes rapidly and effectively.

3.6.4 Promote development of predictive scale-up models

Predictive modelling and techno-economic assessment approaches of the production process and realistic models of reactor types could help identify potential bottlenecks prior to expensive piloting operations. Such models could greatly aid the extrapolation of lab results to large-scale processes and could leverage the development of computer-based systems already used in other engineering fields. Such a multi-KET approach could be of interest under the Commission's KET funding scheme.

3.6.5 Promote funding support for trials at dedicated pilot plant facilities

Piloting trials can be financially challenging, especially for start-ups and SMEs. In order to ensure that promising IB ideas do not fail due to the inability to test out processes, an appropriate level of financial support is needed. Support could take many forms and it is likely that no "one-size-fits-all" solution will apply. Such support could include competitively awarded innovation vouchers for a specific value or substantial tax credits for companies. The scale of funding will depend upon the nature of the work being carried out, but should ideally be between 30-50 KEUR for a small pre-pilot study, to around 250 KEUR for piloting and around 1 MEUR for advanced pilot scale tests. Alternatively, substantial tax credits for companies piloting at recognised facilities could be granted, for example French companies using the Bio Base Europe Pilot Plant are eligible for a 30% tax credit[8].

In order to ensure value for money, support should be provided to potential users of recognised centres of IB pilot/demonstration competence. Most of these facilities are based in Northern and North Western Europe due to the historical focus of these areas on IB. While many IB SMEs wishing to utilise such facilities may also be based in these regions, they should be accessible to companies from Eastern and Southern Europe too, taking different travel costs into account. Structural funds may provide an option on this matter, helping to support the training and education of people to develop the necessary 'know-how' for application in the host region. The possibility to use structural funds for such a purpose is not well known, and as a result, should be more widely publicised amongst the public. At a smaller scale, and for small duration visits, a dedicated programme for encouraging the use of recognised pilot facilities and exchanging information could be funded through Horizon 2020. The model developed by the Seventh Framework (FP7) project Biofuels Research Infrastructure for Sharing Knowledge (BRISK), which competitively awarded grants for EU researchers to attend laboratories with specialised thermochemical processing technologies, could be a useful model to follow.

3.7 Promote the use of co-products

The efficient use of co-products in a biorefinery is the most sustainable way to utilise the biomass and land resources. Co-products are manufactured alongside a primary product from the same feedstock in one process. Valorising co-products does not mean risking the main product of a biorefinery, but obtaining value out of the side-streams which are often underutilised. Co-production implies that different products are produced simultaneously in one biorefinery to enhance the use of biomass.

Highly integrated biorefineries have the target to minimise biomass losses and to find the best valorisation of all different biomass streams. They produce multiple product streams and optimise the value from a particular feedstock.

The aim should be to maximise the product streams from biomass because of value-added, resource efficiency and sustainability reasons. Thus, there has to be a framework to promote and finance this kind of biorefinery for biomass utilisation to ensure the build-up of some first facilities as a proof of concept. Optimised co-production and cascading use of resources should be supported and especially the material use of biomass, waste and residues in order to allow the full utilisation of biomass. For some sectors like the sugar and starch industry, the valorisation of all co-products in an integrated biorefinery concept has already been a reality for decades and should be used as a model.

[8] www.bbeu.org/sites/default/files/EN_BBEPP_Press%20Release%20CIR_27.01.15.pdf

3.7.1 Promote research into the utilisation of lignin

Effective lignin utilisation remains a key challenge for biorefinery projects. Lignin research is not new and there has been much research over the past 20 years on lignin from paper production processes. However, it is also acknowledged that lignin from different sources can vary quite significantly in terms of chemical properties and therefore its appropriateness for different downstream uses. Currently, the largest application for lignin is in its heating value; however, there are many higher value potential uses for lignin, including using it as a source of aromatic chemicals. The market is not yet developed, with low volumes and unstable quality. A pilot or demonstration facility is needed in order to produce enough volumes at a meaningful scale for industrial applications and to assess the quality differences at different types of biorefineries. The technology is at a too early stage for a standalone flagship plant. The valorisation of lignin would enable better fermentation processes (higher sugar yield), as well as help overcome the problems of dealing with the huge quantity of lignin side streams envisaged from the use of lignocellulosic materials for biofuels and biochemical production. Such a facility could build upon calls from the BBI JU on 'Advanced Products from Lignin and Cellulose Streams of the Pulp and Paper industry' and 'Fibres and Polymers from Lignin' and build upon the work of the Biorizon project and could be funded under Horizon 2020, LIFE or through the BBI JU.

3.7.2 Promote the cascading use of biomass

For some applications, biomass can be used, reused and then recycled before being burnt to produce energy. With cascading use – the sequential use of biomass in products and finally as energy– more biomass could be available for the bioeconomy and therefore also for IB processes. This means that the cascading principle closes the gap between biomass utilisation and the waste hierarchy and helps improve resource efficiency.

There are differing opinions on to what extent the cascading use of biomass should be promoted, but in general:

- Biomass as a raw material should be used in bioproduct (biochemical or biofuel) applications as much as possible. Biomass which is used for bioenergy (burnt) is lost for the cascade. This means, for example, incentives for bioenergy (such as pellets, as opposed to biofuels or other bioproducts) may hinder the most efficient use of biomass in higher-value material use. Cascading systems should be promoted by a level-playing field. The market, left to its own devices, will ensure the maximum value use of biomass alone. Where subsidies distort the market to the extent that this becomes a problem for other industries wishing to use the same biomass, the problem should be tackled at the regional or national level;
- Standards and norms should be developed for the classification and separation of heterogeneous bio-waste and its fractions to make it available in high amounts and at reasonable prices for the industry.
- The use of wastes is subject to complex regulations like the Renewable Energy Directive that should be revised to give access to these resources in a level-playing field.

3.7.3 Overcome quality problem of residues for high-value co-products

The valorisation of co-products requires significant technological innovation, especially to overcome feedstock quality variations. From a technical viewpoint, processing technologies have generally been designed to be optimised for one product, and not a range of co-products. For high efficiency co-production, a higher grade of integration is needed to valorise co-products which are currently considered as waste to minimise biomass and resource losses. Furthermore, novel technologies are needed to recover potentially useful compounds within the downstream processing step. R&D efforts supported by Horizon 2020 and BBI JU could represent a viable route for progressing in the co-production area.

3.8 Improve the bioconversion and downstream processing steps

Research and Development can strongly contribute to reducing the costs and environmental impact of IB processes, consequently increasing competitiveness. A number of R&D priorities may be required, in particular the improvement of the production (upstream) and purification (downstream) of IB products, especially when both of these aspects are considered together.

Two main actions may be pursued along these lines, including:

- European Centre of Expertise on BioProcess Development (EU CoE BPD), a virtual platform under the umbrella of the EU Joint Research Centre (JRC) network, bringing together relevant academic-based research groups, industry players and research and technology organisations (RTOs) to focus and speed up IB development;
- Increasing the number of grants dedicated to enzyme and strain development within Horizon 2020, in particular setting up dedicated SME Instrument call topics.

Both the desired Centre of Excellence and the increased Horizon 2020 funding should focus on the three critical areas of:

1. Developing novel microbial production systems and methods;
2. Ensuring that bioprocesses are developed as a whole system;
3. Promoting 'continuous improvement' in processing technologies.

Details follow in the sections below.

3.8.1 Develop novel microbial production systems and methods

The yield and productivity of current industrial microbial strains and robustness of fermentation and biocatalysis processes are often insufficient to enable cost-effective production of biobased products, especially when using second generation feedstock. Key R&D priorities may include:

- Engineering of microbes for an optimised usage of 2nd and 3rd generation feedstocks and tolerance to growth-inhibiting compounds present in the feedstock;
- Investigation of anaerobic fermentation processes and strengthening of related metabolic engineering and cultivation methods. In this way the benefit of these potentially less-costly processes may be increasingly exploited;
- Reduction of by-products excreted during IB processes that may inhibit productivity and complicate product recovery.

3.8.2 Ensure that bioprocesses are developed as a whole system

Many IB processes have been developed in discrete steps, through years of research on production being pursued without taking the following purification steps into account. As a result, even if each process step may work well in isolation, it may not be the case for the complete system. Process integration with upstream and downstream technologies is crucial to improve process yields, reduce inhibition in the bioconversion step and decrease production cost. The development of processes as part of an integrated system would require integrated optimisation of process intensification, in-situ product recovery (ISPR), continuous fermentation and petrochemical-sector-derived downstream processing systems. By doing this, continuous operations can be developed avoiding product inhibition and extensive steps in the downstream processing. It is important that microbial processes are developed by optimising bioproduction/bioconversion and ISPR together. The development of continuous and integrated processes can help reduce the water volumes that are commonly present in the downstream processing (DSP) of bioprocesses (and hence the cost for water removal) as well as help increase the use/re-use of by-products and waste streams, thereby increasing the value of these streams.

3.8.3 Promote 'continuous improvement' within processing technologies

Technologies within the IB sector are at different TRLs. Even if a technology is at a high TRL level, R&D on that technology should continue to be funded to allow continuous improvements in technologies over time and improve the competitiveness of the process, reducing costs and improving environmental impact.

3.9 Improve access to financing for large-scale biorefinery projects

Several public funding facilities are available for biobased industries in Europe. At the European level there are Horizon 2020 and BBI JU, LIFE 2014-2020, Connecting Europe Facility (CEF), INTERREG V, and at the transnational level there are EUREKA, ESIF, ERA-NET; and within Member States there are national, regional and local grants, etc.

While basic and fundamental research in Europe is mostly supported by EU and national/regional grants, certain countries have an increasing role in regional funding of flagship initiatives. Nevertheless, first of a kind and commercial scale biorefinery grants are not a sufficient instrument *per se*. At present, the most important contributions for flagship and commercial scale investments come from bank loans and investors.

The new Biobased Industries Public Private Partnership (PPP) (BBI JU) is bridging some of the funding gaps but cannot support all commercial scale projects. Although several instruments exist in Europe, access to funding remains an issue. Financing is fragmented and the procedures involved from one institution to the next, or from one region to another, are different, and the process of applying for funds can also be very long-winded and complex.

In order to improve access to financing for large scale biorefinery projects, the following actions may be envisaged, in order to decrease their complexity and increase their potential impact.

3.9.1 Increase grants awareness and stimulate cooperation, attract foreign investments, de-risk investments

At EU level, funding opportunities and public grants should be better highlighted. The JRC Bioeconomy Observatory may create an EU-wide portal for EU, transnational and national bioeconomy-relevant funding opportunities and grants within a European Commission-embedded website under the responsibility of the JRC Bioeconomy Observatory. All bioeconomy funding opportunities should appear in a searchable and sortable way, for example by opening and closing date, funding amount, funding %, topic, eligible sectors, eligible locations, and eligible parties.

3.9.2 Speed up integration of public grants from EU Horizon 2020, EU ESIF and national grants

At EU level, different public grants may be better complemented by the European Commission and regions. A step forward would be to set up dedicated Horizon 2020/ESIF Task Force with the objective of producing guidelines on how to better integrate Horizon 2020/BBI JU and ESIF funding. This could realised based on the Biobased Industries Consortium (BIC) Guiding Principles document[9].

[9] http://biconsortium.eu/sites/biconsortium.eu/files/downloads/Guidelines_BBI-ESIF-Final.pdf

3.9.3 Create an European BioEconomy Strategic Investment Fund (EBESIF)

At EU level, a strategic fund may be created by BBI JU and the European Investment Bank (EIB), including a novel synergy of public and private sources. The European BioEconomy Strategic Investment Fund's (EBESIF) mission should be to provide economically sustainable loans and loan guarantees (leverage 1-to-5) for large scale bioeconomy investments, learning from successful national investment funds such as the German High-Tech Gründerfonds. Biorefinery projects with a concrete business perspective are actively seeking loans. The main hurdle is risk-acceptance from the investing and loaning side. With the contribution of several other stakeholders the EBISIF could establish a portfolio of projects, including 20 to 30 new biorefineries to be awarded loan guarantee or loans. While a quarter of them may fail, 75% may succeed, and, following an "insurance" approach, Europe may kick start dozens of new biorefineries in less than a decade, corresponding to around 10% of the biorefineries required to keep up with the demand projected for Europe by 2030 (see chapter 4). Doing so, Europe would equip the market with clear European biorefinery benchmarks and strong business cases to follow. The envisaged EBESIF may be funded *via* any combination of the following items:

- **Stimulate Private Foundations, Charities and Families to donate money for the development of bioeconomy projects with high social return on investment.** A particular focus may be given to the rural development side of the bioeconomy, since this area is already within the scope of many local and global *pro bono* foundations.
- **Stimulate EIB's InnovFin focus on the bioeconomy.** The inclusion and allocation of a minimum share of InnovFin Large Projects for topics related to the current Horizon 2020 societal priorities, in particular to the bioeconomy, should be stimulated in order to improve access to risk finance for R&I projects with loans and guarantees from 25 MEUR to 300 MEUR to be delivered directly by the EIB. 500 MEUR would suffice to mobilise 20 to 30 biorefinery projects with a total value of around 4 BEUR, with a capital leverage of 5x, and an interest rate able to cope with a failure rate of 10%. EIB may be further encouraged to co-invest in the envisaged European BioEconomy Strategic Investment Fund (EBESIF).
- **Involve Public Pension Funds in the Bioeconomy.** Develop an EU Directive or Communication to inspire Member States in order to enable, encourage and discount pension system investments in strategic innovation sectors such as the bioeconomy. Pension funds have the timeframe and long-term interest to invest in the bioeconomy, for longer term return on investment and social return on investment. Such a directive should learn from the experience of the Danish PensionDanmark. Such pension funds may be further encouraged to co-invest in the envisaged European BioEconomy Strategic Investment Fund (EBESIF).

While specific fundraising milestones may be reached, the promoters should bind the European Commission to match the private donations on a 1-to-2 basis.

3.10 Develop stronger relationships between conventional and non-conventional players in the value chain

The eventual success of the biorefinery concept depends largely on the extent of integration that can be achieved. This has to take place at various levels, within a specific value chain as well as between different value chains. Relevant output on this regard is expected from the upcoming Horizon 2020 project BioLinX. Cooperation between farmers or forest owners with processing industries is a very simple example and shows the importance of the integration of the biomass supply sector with all downstream industries. At processing sites, integration of different technologies and processes is essential for the site to be able to work efficiently. Integration can also take place between two or more processing sites, where, for instance, sharing of utilities and waste treatment are common modes of cooperation, thus exploiting synergies for mutual advantage. An improved relationship between industrial sectors could also develop new opportunities, e.g. the pulp and paper sector with the chemical industry, or the food industry with the bioenergy sector. Currently there is not enough cooperation and knowledge exchange between different actors in the value chain, and one of the primary causes is that the actors in the different sectors are not accustomed to cooperating across industry sectors. Industrial policies can support the actors in the value chain to cooperate across sectorial borders to overcome the barriers between processing, feedstock supply and the food chain.

In addition, a critical disconnection between the industry and academic research institutions is slowing down the knowledge transfer process and thus innovation itself. In order to better align academic knowledge to industry needs, industry will need to develop an earlier understanding of the application potential of new technologies provided by academia. Similarly, academic researchers will need a sharper focus on industry's needs and specifications. To overcome the gap between applied and basic research a joint agenda between both stakeholder groups is urgently needed.

Finally, given the ever-increasing international linkage between science, business and society, the relevance of international collaborations and of the cross-border exchange of knowledge is rising. This also applies to the field of the bioeconomy and accompanying research. There are diverse arguments in favour of establishing a stronger (bilateral and multinational) network within the bioeconomy corresponding to the broad nature of the sector, which transcends regional or national borders and economic areas. The funding rules are also often specific to regions, which makes it difficult to collaborate with surrounding areas.

3.10.1 Set up or involve national and/or regional cluster organisations

Already today, many countries host a number of "biobased" regional clusters, regrouping companies, research institutes, funding agencies, investors, etc. In some cases, these clusters are real public-private partnerships (PPP) funding research and innovation projects. In other cases, the focus is more on networking or financing specific studies of common interest. These clusters can play a crucial role as they can stimulate, at national or regional level, networking, cooperation, partnering and knowledge exchange. Member States which do not have such cluster organisations should be stimulated to do so. A project should be set up, e.g. by the "Bioeconomy Panel", to map the European clusters, their activities and best practices, and to support the regions or Member States that do not yet have such a cluster organisations.

3.10.2 Stimulate clusters to set up national/regional public-private partnerships

As most of the clusters are a mixture of associations, regional authorities, companies, universities and research organisations, the formation of a PPP where all parties commit to invest their own resources, could strengthen cooperation resulting in targeted research and actions towards development and commercialisation of innovative biobased products. In addition, PPPs that stimulate the participation of companies and SMEs are more attractive for external funding and are also eligible for European funding. Clusters can facilitate access to investors and venture capital, which is beneficial to SME participation. Therefore, funding by local and regional governments should be strongly encouraged.

3.10.3 Support the creation of innovative value chains

To develop a competitive bioeconomy, it is important to create sustainable value chains (from feedstock production or supply, collection and logistics, conversion, production to market), and these do not necessarily have to be developed within one single region.

Often one region has a surplus of a certain feedstock and another region the technological know-how or the industrial expertise. An interregional platform, coupled with a web-based portal database would be very useful for stimulating co-operation between all stakeholders in the biobased field. Such an open web portal could be helpful in finding partners for new and innovative value chains. However it could also give an overview of all research and demo biobased activities in the different regions and existing interregional cooperation, calls for partners, etc. In addition, the web-based portal could contain a search engine for funding resources, including calls launched by government agencies, European funding programs and an overview of all business angels and potential investors.

In order to stimulate the collaboration between different industrial sectors (e.g. agriculture and forestry, food industry, chemical industry), projects should be set up (funded by the EU through, for example, Horizon 2020 or BBI JU, or by the Member States and the regions) in order to study and communicate synergies and complementarities between technologies, feedstock and waste (both availability and quality), and to bring representatives from the different sectors together in specific workshops or partnering events.

R&I programmes (be they European, national or regional) should cover the entire value chain (including feedstock supply, processing, logistics, pre-treatment, processing, compounding, side-product valorisation and product recovery, etc.) in order to obtain funding. By supporting research that covers the entire value chain – from feedstock to end-product – these programmes will stimulate integration of the individual bioeconomy sectors, facilitate innovation and encourage the uptake of its results by the industrial partners involved. In the longer term, we can expect not only a closer integration of the different sectors of the bioeconomy, but also between the different research areas across food as well as non-food commercial applications.

3.10.4 Stimulate collaboration between industry and public institutes

In order to better align academic knowledge to industry needs, industry will need to continue to develop an earlier understanding of the application potential of new technologies provided by academia. Similarly, academic researchers will need a sharper focus on industry's needs and specifications. Therefore, initiating specific bioeconomy networks at European and national level, building on existing sectorial networks such as European Technology Platforms (ETPs), industry associations, etc, and involving funding authorities, industry and academia, could be the key to overcoming the knowledge gap and competence hurdle that currently exists. Similar to, and in connection with ETPs, the bioeconomy networks could develop R&I roadmaps, organise matchmaking events and any other type of activity supporting closer relations between industry and academia/RTOs.

3.10.5 Stimulate innovation across disciplines

It is often stated that innovation happens across traditional disciplinary boundaries. IB innovation could also benefit from such interdisciplinary thinking. Innovations within the information and communications technology (ICT) sector are already helping to create tools which can improve processes within the bioeconomy. For example, the application of expertise in telecommunications is helping to assess forestry productivity, while microbial fuel cells can be used to power remote monitoring devices such as the ones monitoring water quality[10]. Such cross-disciplinary thinking can bring new ideas to the IB industry, stimulating innovation and competitiveness. Routes to promote such interdisciplinary thinking are needed, such as cross disciplinary partnering events or focussed workshops. The BBI JU and Horizon 2020 could prove potential routes by which such thinking could be promoted.

[10] www.researchgate.net/profile/Haluk_Beyenal/publication/7692918_Wireless_sensors_powered_by_microbial_fuel_cells/links/004635316d9dccaf71000000.pdf

4 HOW DO WE ENSURE THAT WE FULLY EXPLOIT THE POTENTIAL FOR INDUSTRIAL BIOTECHNOLOGY IN EUROPE ?

An additional aim of the BIO-TIC project was to identify which IB products could provide a competitive advantage for Europe and its economy and how markets for these products could be fostered.

Five product groups have been identified as being particularly promising based on their future market potential, the potential for that product to introduce cross-cutting technology ideas, and to respond to societal and customer needs.

Four of these are based on the use of biomass resources :

1. **Advanced biofuels** (bioethanol and biobased jet fuels, used in road and air transport respectively)
2. **Biochemical building blocks** (can be transformed into a wide range of products which are either similar or offer additional functionality compared to or better fossil products)
3. **Biobased plastics** (used e.g. in packaging applications)
4. **Biosurfactants derived from fermentation** (typically used in detergents)

The fifth product group includes products which can be obtained by the **conversion of fossil CO_2 into novel products by IB routes** (such as from power station smoke stacks). This could potentially be used to produce some of the same products which are currently produced from biomass but without any impacts upon land use.

The following section investigates the current market for these product categories, proposes a common vision on what the market for that product could be in 2030 and identifies the hurdles hindering and possible solutions for achieving this goal. Many of the hurdles affecting each of these product groups are common to all IB products and have already been described in the previous section; therefore the principal hurdles for that product category are briefly described, alongside a description of the solutions with specific relevance to that product group.

4.1 Advanced ethanol

What is advanced ethanol?

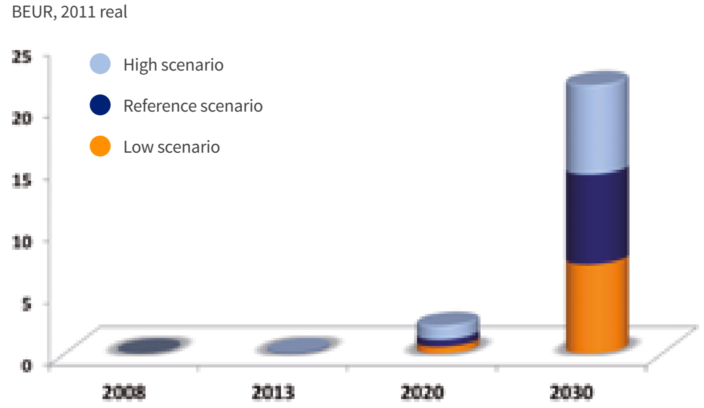
Advanced ethanol (often called 2nd Generation or 2G ethanol) is ethanol produced from lignocellulosic and bio-waste materials. The most well-developed production route is fermentation of the sugars, which become accessible by pre-treatment of the lignocellulose and subsequent hydrolysis of the sugar containing cellulose fibre and hemicellulose fractions. An alternative partially IB route is the gasification of biomass or non-recyclable municipal waste to syngas (which can also be obtained as a side product of industrial processes) and the subsequent fermentation of the gas to ethanol. Alternatively, ethanol may be produced using algae, although these routes are not commercially viable at present. Non-IB routes also exist.

What is the current situation?

The global production of advanced ethanol is still very low, but is rapidly increasing. In 2014 alone, four new advanced ethanol facilities became operational, mainly in the USA, with a nameplate capacity approaching 300 kton/year, using diverse feedstocks including bagasse, straw, corn stover, hemicelluloses, *Arundo donax* and organic waste (i.e., from the food industry). European ethanol production is driven by the RED (2009/28/EC) which gives an obligation for a 10% share of renewable energy in transport by 2020. More recently, an indicative 0.5% advanced biofuels target at national level by 2020 was set.

What could the sector look like in 2030?

The demand for advanced ethanol is expected to increase through to 2030. The reference, high and low market scenarios assume an advanced biofuel share of 1%, 2% and 0.5% of all road transport fuels by 2020 respectively, and the share of ethanol in advanced biofuels is assumed to remain constant at 30%. For 2030 it has been assumed that 10% of all road transportation fuels are advanced biofuels, whilst in the high and low scenarios, the shares are 15% and 5% respectively. The reference scenario would equal 1.4 million tonnes of advanced ethanol in 2020, worth approximately 1.1 BEUR and 13.1 million tonnes in 2030, worth approximately 14.4 BEUR.



Estimated market demand for advanced ethanol in the EU[11]

Such consumption estimates would correspond to around 185 new advanced ethanol biorefineries (70 kton/year) operating by 2030, an average of 10 new plants every year.

What is needed to develop a competitive advanced ethanol industry in Europe?

The principal hurdles for the development of an advanced ethanol industry in Europe relate to the **high production costs** (largely due to the immaturity of the technology) and a **lack of policy and regulatory certainty** which impacts upon investor confidence to invest in this promising sector.

The production of advanced ethanol is more expensive than for 1st generation plants. Achieving cost-competitiveness will entail the use of all products, which can bring in revenue and thereby reduce the cost of biofuel. The cost-competitiveness of advanced ethanol production could be improved by:

- **Increasing cooperation in the supply chain to improve large scale collection and storage of biomass.** When used for large scale, low value operations, added profitability of any operations will be low. Often it will be better just to burn forestry residues than to use them as a feedstock for biofuels or other low value 'chemical' products. Advanced logistic systems are needed to help improve the efficiency and costs of collection. This may require specialised harvest equipment and machinery for the transportation of agricultural residues. In some areas of the EU, efficient on-farm machinery and infrastructure is not yet available. EU rural development funds could be used to help finance such equipment. Moreover, financial incentives may be needed to collect residues (see also 3.1).
- **Developing high value applications for lignin and other co-products.** Lignin could be used in higher value applications. Several other additional product streams could be developed. In most cases, significant R&D is needed to bring such opportunities to the market (see also 3.7). Appropriate incentives should be in place (see below).

Unstable policy investments and prices do little to inspire investor confidence in this sector. Biofuels such as ethanol are a straight-forward way to achieve GHG reduction targets. Mechanisms to improve political and regulatory certainty could include:

- **Developing a supportive policy framework with appropriate long-term and stable measures to ensure investor confidence** in this area (see also 3.4). This could be done for example by:
  - Extending the targets for renewables in road transport to 2030 – having a specific share dedicated to advanced biofuels (recognising therefore their need for differentiated support); or
  - Mandating the use of advanced biofuels at the EU level by 2030. At present, national mandates are beginning to emerge; Italy for example has mandated that advanced biofuels will need to be blended in increasing shares in petrol and diesel over the coming decade, 0.6% from 2018, 0.8% 2020 and 1% by 2022. An EU mandate would be easier to implement than a series of national mandates.

In general, there is a lack of public acceptance of biofuels, especially first generation, which negatively impacts upon investor confidence. This could be tackled through:

- **A joint-fact finding mission** with NGOs and researchers contributing positively to the debate.
- **Focussing communications on the benefits of biofuels and the disadvantages of fossil fuels across society.** Actions could be envisaged such as education at school level, and improving the visibility of biofuels, for example through pump labelling.

[11] Based on results outlined in the market roadmap available at **http://www.industrialbiotech-europe.eu**

4.2 Biobased jet fuels

What are biobased jet fuels?

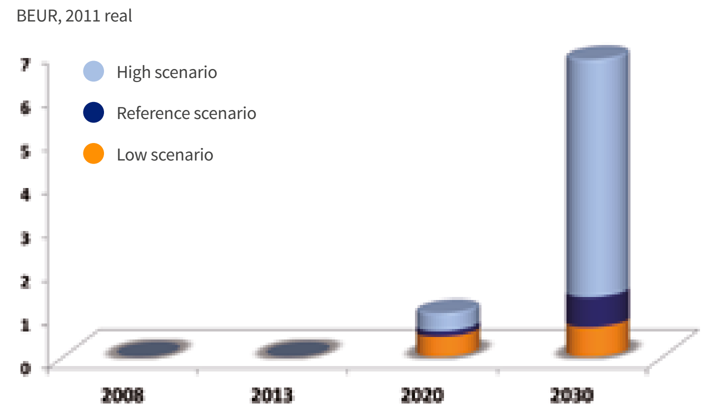
Biobased jet fuels (also known as aviation biofuels) can be produced from either oils (i.e., plant, animal or waste oils) or biomass (e.g. starch and agricultural residues). For the purpose of this roadmap, we assume that all aviation fuels must be 'drop-in' replacements for conventional fossil-derived kerosene as the development of new engines, aircraft, and infrastructure is very expensive and the existing infrastructure has a long lifespan. All aviation biofuels must comply with the strict quality requirements outlined in ASTM D1655 and ASTM 7566. There are both IB and non-IB based routes to aviation biofuels. The main IB route to aviation biofuels at present is the production of farnesane (2,6,10-trimethyldodecane), which can be blended with conventional kerosene fuel in a 10% blend. Other routes are thermochemical/chemical in their nature. Aviation fuels produced using the Fischer-Tropsch process and from HEFA (hydroprocessed esters and fatty acids), can be included in blends up to 50% with conventional kerosene.

What is the current situation?

At present, only HEFA-derived biobased jet fuels are used in commercial flights, and although the amounts used are not known, total use is expected to be minimal.

What could the sector look like in 2030?

The energy demand in aviation is expected to grow from the current 52 Mtoe to 59 Mtoe in 2030, but the potential for biofuels and that of fuels derived from industrial biotechnology based routes in particular is very unclear. Assuming 1%, 2% and 10% biofuel blends in the low, reference and high scenarios in 2030, the 2030 biobased jet fuel market would total 0.7, 1.4 and 6.8 BEUR respectively. No specific targets for IB-based processes can be given at this stage given their early stage of development and unclear competitive advantage compared to other biobased jet fuel processes.



Estimated market demand for biobased jet fuels in the EU[12]

Such consumption estimates would correspond to around 50 new aviation biofuel production plants (40 kton/year) operating by 2030, an average of 3 new plants every year.

What is needed to develop a competitive IB-enabled biobased jet fuels industry in Europe?

The principal hurdles for the development of an IB-enabled biobased jet fuels industry in Europe relate to high production costs due to the immaturity of the technology, but also due to the high feedstock costs and lack of policy and regulatory certainty which impact upon investor confidence to invest in this promising sector.

Biobased jet fuels have high production costs, in part due to high costs for feedstocks, but also because of the need to achieve the high quality specifications demanded for aviation. Several actions could be envisaged to reduce costs and hence improve the cost competitiveness of biobased jet fuels, namely:

- **Using waste lignocellulosic biomass as cheaper feedstocks could help reduce costs.** In the first instance, this could include waste lignocellulosic biomass from forestry as the logistics associated with their collection are already well established (see also 3.2);
- **Investigating the best ways of maximising the use of any co-products which can be produced and / or putting in place incentives for their use** (see also 3.7);

[12] Based on results outlined in the market roadmap available at **http://www.industrialbiotech-europe.eu**

- **Developing continuous processes for the production of aviation fuels and scaling-up of existing technologies** (see also 3.8);
- **Identifying routes by which hydrogen can be supplied cheaply.** Biobased jet fuels have a high demand for hydrogen in order to form pure hydrocarbons. Potential hydrogen production routes could include the gasification of wastes such as lignin, or through power to gas solutions, whereby hydrogen can be produced without producing CO_2 (see also 4.6).

With regards to the lack of policy and regulatory certainty, in addition to the aviation industry self-commitment to reduce its carbon emissions and develop aviation biofuels at a global level, potential actions could include:

- **De-risking investments** into biobased jet fuels production plants through loan guarantees and relaxing state aid rules (see also 3.9);
- Actions to **build a demand for biobased jet fuels.** These could include:
    - **Introducing an internationally binding fuel blending quota or mandate for a minimum amount of biobased jet fuel** to be used, for example for 2-4% by 2020 or 2025. This would ensure the commitment from airlines to buy biofuels and the cost issue described above would be less of an issue as all airlines would have the same costs for fuels so costs could increase across the board. These additional costs could be shared across supply chain or added to end user (passenger) costs (see also 3.4). This should ensure a level playing field between EU and non-EU carriers.
    - **Developing and encouraging voluntary initiatives:** Airline companies could introduce voluntary schemes to kick-off demand. The Dutch initiative by KLM, SkyNRG, Schiphol Airport and the Dutch Government is one example, and combined with effective marketing and consumer dialogue, such schemes could stimulate small scale demand for biofuels.
    - **Supporting aviation biofuels under international agreements.** An international agreement on emissions reduction in aviation is needed, including the introduction of CO_2 taxes for the aviation sector within the European Union Emissions Trading Scheme (EU ETS).

4.3 Biobased chemical building blocks

What are biobased chemical building blocks?

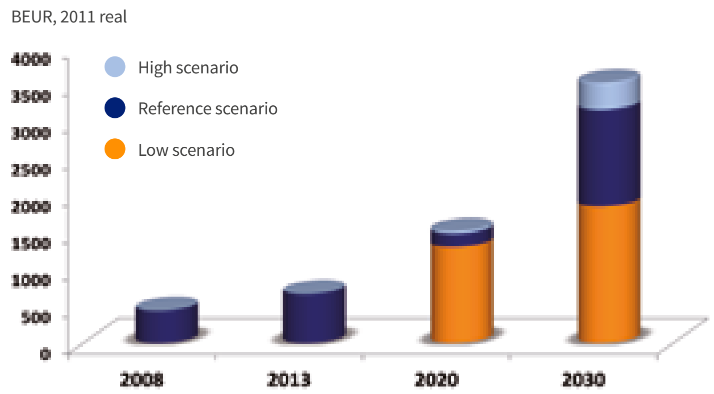
Biobased chemical building blocks (CBBs) can be classified as either 'drop-in' or 'novel' biobased chemicals. 'Drop-ins' are biobased versions of existing petrochemicals with existing markets, enabling a faster route to market. 'Novel' biobased chemical building blocks may offer unique properties which are unobtainable with fossil-based alternatives (i.e. biodegradability of the derived products), albeit at higher risk.

What is the current situation?

The EU demand for fermentation-based chemical building blocks was less than 700 MEUR in 2013. This is around 35% of biobased CBB global production. The market grew at a CAGR of around 10% per year between 2008 and 2013. The majority of new production facilities are currently being built outside of Europe, mainly in Asia and Brazil, principally as a result of the high operating and capital costs in Europe. Taxes, regulation and regulatory volatility are also perceived as hurdles in the EU. The potential impact of shale gas developments on the biobased chemical building block industry is unclear.

What could the sector look like in 2030?

The market value for IB derived biobased chemical building blocks in 2030 is expected to reach 3.2 BEUR in the reference scenario and 3.5 and 1.9 BEUR in the high and low scenarios respectively. With appropriate subsidies and regulations, the market could be even higher.



Estimated Market Demand for biobased CBB in the EU[13]

[12] Based on results outlined in the market roadmap available at **http://www.industrialbiotech-europe.eu**

Such consumption estimates would correspond to around 30 new biochemical building block production plants (50 kton/year) operating by 2030, an average of 1-2 new plants every year.

What is needed to develop a competitive biobased chemical building block industry in Europe?

The principal barriers to the development of a competitive biobased chemical building block industry in Europe are related to cost competitiveness, because both raw material and production costs are high in Europe. Raw material quality and availability is also a significant concern.

The availability of feedstock compared to elsewhere in the world is often perceived as a concern in Europe. However, Europe does have the potential to increase feedstock availability and the efficiency of feedstock without adversely impacting upon the environment or food production. Several measures could be envisaged including:

- **Opening up sugar markets for industrial use** (see also 3.1). Sugar beet is the most effective feedstock for developing biobased chemicals and is a crop which grows well in several areas of Europe. However, much of the sugar beet capacity in Europe was lost in the 2006 sugar reforms. By reintroducing this lost production and opening up the market for non-food use, this could improve the amount of sugar available for biobased chemical building blocks production;
- **Educating farmers, foresters and other land owners about the value of their products to the bioeconomy** (see also 3.1). Such collaboration could help increase the availability and decrease the costs for agricultural residues (i.e. by developing harvesting operations);
- In the longer term, **developing facilities which can process a number of biobased feedstocks efficiently at a single facility** so that the industry is not dependent upon any one type of biomass, thus potentially reducing costs by allowing the most cost-competitive feedstock to be used, possibly leveraging on biofuel biorefinery investments.

The cost-competitiveness of European production can be increased by improving the provision of feedstock, but also through several other factors, including:

- **Encouraging the integration of biobased chemical building blocks production with the conventional chemical industry** (see also 3.10) by using existing facilities or through exploiting industrial synergies, for example heat integration. Economic incentives would be welcomed to help the traditional chemical industry help establish IB based production routes. A close cooperation between different EU-funded programmes such as Horizon 2020, BBI JU and SPIRE will be beneficial in this regard;
- **Research and development into processing beet in a minimal way** so that the sugars can be used for IB without being completely refined;
- **Investigating the use of lignin for different end uses** (see also 3.7). Lignin is currently used for a wide range of low value applications, but higher value applications could improve the economics of the process considerably;
- **Improving the production efficiency** (see also 3.8). This can be achieved through:
    - **Developing more robust organisms** to overcome the impurities present in the feedstock. This will be a particular challenge when dealing with lignocellulosic feedstocks;
    - **Improving fermentation selectivity** to reduce the impurities present in the fermentation media or amending downstream processing steps to be more aligned with the contaminants produced by different organisms. Either way, this would help reduce the costs of downstream processing which can currently account for up to 50-66% of the processing costs;
    - **Pilot, demo and flagship plants are needed to optimise downstream processing steps in IB.** Downstream processing is the key cost element in processing, so technologies to improve downstream processing could therefore help improve the costs of production.

4.4 Biobased plastics

What are biobased plastics?

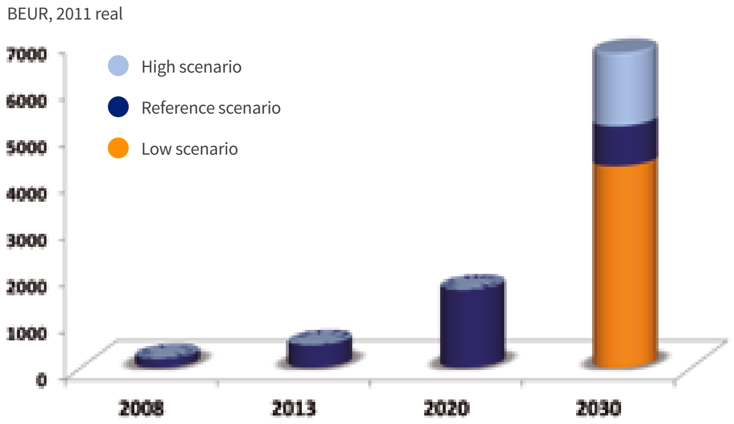
Biobased plastics are either totally or partially biobased polymers which may or may not be biodegradable. Biobased plastics may be chemically identical to fossil equivalents (known as 'drop-ins'). Biobased PET, for example, produced from sugarcane is the same as that derived from fossil sources and can be recycled in the same processes. Biobased plastics may also be completely novel, imparting new functionalities such as biodegradability, most often not possible with petrochemical feedstocks.

What is the current situation?

In 2013, the EU demand for biobased plastics was estimated at 45 MEUR, representing a CAGR of 20% between 2008 and 2013. In 2013, Europe was the largest biobased plastics consumer and producer, supplying around a third of the global biobased plastics output. However, the future production of biobased plastics is expected to be located in regions where feedstocks are cheaper and more readily available, e.g. Asia Pacific and Brazil. The development of biobased plastics in the EU is being driven by rising and increasingly volatile fossil oil prices, the potential for net environmental benefits compared to fossil plastics, and local and national regulatory actions such as bans on plastic bags. An increasingly positive consumer attitude towards biobased, biodegradable and compostable materials are helping to develop the market.

What could the sector look like in 2030?

The biobased plastics market value is expected to reach approximately 5.2 BEUR in 2030 in the reference scenario and 4.3 BEUR and 6.7 BEUR in the low and high scenarios, respectively. The main growth is expected in the specialty polymers and packaging applications. Market adoption in all applications is dependent on the adoption of mandates (for example supermarket plastic bags), biobased plastic cost competitiveness compared to conventional plastics and on consumer willingness to pay a bio-premium.



Estimated market demand for biobased plastics in the EU[14]

Such consumption estimates would correspond to around 45 new bioplastic production plants (50 kton/year) operating by 2030, an average of 2-3 new plants every year.

What is needed to develop a competitive biobased plastics industry in Europe?

The principal two barriers to the development of a competitive biobased plastics industry in Europe are **cost** and **branding issues**. These two hurdles and the potential solutions which could be envisaged to overcome them are explained further below as well as the potential impact they could have.

Many biobased plastics are more expensive to make than conventional ones, consequently, without initial market incentives, there is currently little hope for a quick market uptake regardless of their benefits. A notable exception is polylactic acid (PLA). Several actions to improve biobased plastics cost-competitiveness could be envisaged:

- **Funding R&D activities to improve product quality and reduce production costs** (see also 3.8) (e.g. conversion technologies and downstream processing). In this regard, there is significant similarity with the research challenges for biobased chemical building blocks. Significantly, anecdotal evidence suggests that there is currently no provision for the production of biopolymers at small scales, whilst others stressed the need for pilot, demo and flagship plants helping to understand how downstream processing affects polymer production.
- **Selective bans or taxes on non-biodegradable plastics where cost-effective biodegradable plastics have demonstrable environmental benefits** (i.e. shopping bags, agricultural mulching films, coffee cups and fast food packaging) could help improve the competitiveness of biobased plastics (see also 3.4).

[14] Based on results outlined in the market roadmap available at **http://www.industrialbiotech-europe.eu**

Branding and consumer perception are also a major issues for biobased plastics. Several actions could be envisaged here, including:

- **The organisation of information campaigns to increase awareness of biobased plastics** demonstrating their safety, environmental benefits and added value, and clarifying the different labels such as 'biodegradable' 'biobased' and 'bioplastics' that underly bioplastics (see also 3.5);
- The market for biobased plastics will be promoted by the development of new end use application. **R&D into new applications may be stimulated alongside the introduction of mechanisms to ensure that there is a better exchange of information between industry and academia.** This could be stimulated by the creation of an online network and technical event to showcase academic innovations and ensure that such advances are not lost because of a lack of communication between industry and academia. More widely, there is a need to acknowledge that as a nascent sector, the infrastructure for the use and reuse of biobased plastics still needs to be developed, for example composting and recycling;
- **Uniting resources and the development of a common agenda for sector development, encompassing both durable biobased and biodegradable plastics.** This kind of work could be led by European Bioplastics for example.

4.5 Biosurfactants from fermentation

What are biosurfactants?

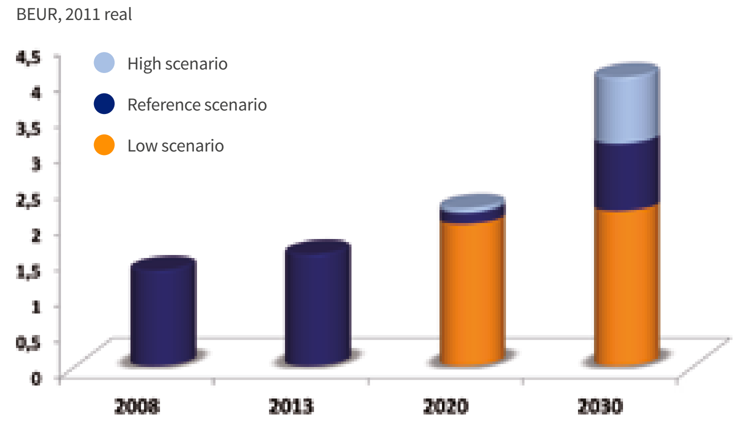
Surfactants are compounds active at the interface between two liquids, including: detergents, wetting agents emulsifiers, foaming agents, and dispersants. If wholly based on biogenic carbon or biomass, surfactants are defined as *biosurfactants*, with biobased carbon content equal or above 95%. Moreover, if derived through microbial processes they can be called *biosurfactants from fermentation*.

What is the current situation?

The EU represents the largest market for *biosurfactants*, corresponding to around half of total demand. The EU is also a leading producer of biosurfactants. Globally however, biosurfactants represent only a small share of the total surfactants market. The biosurfactants market is very concentrated, with the top five producers representing 90% of the market. The market is being driven by increased environmental awareness, new properties and fluctuating oil prices. The current market for *biosurfactants from fermentation* is very limited and thought to be less than 1% of the total biosurfactants market.

What could the sector look like in 2030?

The demand for *biosurfactants from fermentation* will depend strongly on household spending and industrial activity in detergents and cosmetics where environmental concerns are more evident and growth in these sectors is characterised by general economic development. The market for *biosurfactants derived from fermentation* is estimated to grow from 1.3 MEUR in 2013 to approximately 3.1 MEUR in 2030. In the higher and low case scenarios, the market value is expected to reach 4.0 and 2.2 MEUR respectively.



Estimated market demand for biosurfactants from fermentation in the EU[15]

[15] Based on results outlined in the market roadmap available at **http://www.industrialbiotech-europe.eu**

What is needed to develop a competitive industry producing biosurfactants using fermentation in Europe?

The main hurdles for biosurfactants from fermentation are technical hurdles and, related to this, acceptance of such products versus conventional products which may be cheaper.

The major hurdle is related to the performance of biosurfactants. Biosurfactants produced *via* non-fermentation approaches have been used for many years but have problems associated with their performance, limiting their applications to biocidal uses. Routes to improving the functionality of biosurfactants are needed and this will in turn help drive markets. IB routes can help here. Such measures could include:

- **Promoting cooperation within the value chain to match biosurfactant properties with end user needs (see also 3.10).** The characteristics of each biosurfactant need to be elucidated first.
- **Improving the downstream processing step for biosurfactant production (see also 3.8).** At present, each organism produces a mix of related molecules with different structures and properties, making downstream processing complicated, costly and adding to the cost of the final product.
- **Identifying to what extent waste materials could be used as a substrate for fermentation (see also 3.2)** (i.e. glycerol) thus enabling cost reductions.
- **Implementing research actions to improve conversion yields (see also 3.8).** Current bioconversion yields are too low for industrial production. Genetic modification of producing organisms has the potential to both improve yields and develop novel functionalities, but issues over public acceptance need to be addressed first (see below).

With regards to end user and customer acceptance, several measures could be developed to promote the market pull for biosurfactants. These include:

- **Demonstrating the added value for using biosurfactants in terms of superior properties and their sustainability (see also 3.5).** In particular there is a need to open the debate on genetically modified microorganism (GMM) use and how GMMs are a key technology for improving biosurfactant properties through appropriate tools. This may help:
  - Consumers to justify the higher price of such products compared to fossil alternatives (a green premium), especially in the higher value applications such as cosmetics where a price premium is more likely to be tolerated. This should be supported by an appropriate EcoLabel demonstrating the benefits and will be facilitated by the standard currently being developed by CEN TC 276;
  - Companies and end users to justify the time and expense in registering new products and gaining production permits in Europe.

4.6 CO_2 as a feedstock for IB

What can CO_2 be used for?

CO_2 is a well-known GHG but is less-known as a carbon source for IB or for its use as a feedstock for fuels, chemicals and polymers. CO_2 conversion technologies for fuels, chemicals and polymers have been gaining momentum in the past few years because CO_2 is an abundant source of carbon, and its use can help boost a low carbon society. Using gasses as feedstocks provides several advantages, such as no competition for land use, easy integration into existing chemical processes, less contaminations during fermentation and easier downstream processing.

What is the current situation?

In the last decade, carbon capture and storage (CCS) technology has received considerable attention. CCS involves the capture, compression, and injection of CO_2 gas into deep rock formations where it can be permanently stored. CCS is a commercial technology with several sites across the world. More recently, interest has grown in carbon capture and utilisation (CCU) technologies whereby the captured CO_2 is converted either chemically or biologically into useful products. In this way, CO_2 is considered to be a commodity rather than a pollutant.

Commercial CO_2 applications currently include carbonated beverages, fire extinguishers and cooling fluids, but CO_2 could also be used to produce biobased plastics and biobased chemical building blocks. The use of CO_2 for products benefits from being completely outside of the food chain. The first demo and commercial applications for waste gas fermentation processes to produce ethanol and 2,3-Butanediol (2,3 BDO) have already been commissioned. Availability of CO_2 is not deemed an issue for Europe as CO_2 is widely available from point sources throughout Europe.

What could the sector look like in 2030?

In 2030, we envisage that CO_2 will offer opportunities for new cost competitive chemical processes and applications, allowing chemical production chains to be reduced to 1 or 2 step microbiological conversions, and opening the possibility to produce completely novel chemical compounds. Moreover, we expect that Europe will have succeeded in integrating CO_2 bioconversion into existing energy and chemical infrastructures, making green energy available for CO_2 technologies and allowing the transformation of energy at peak load periods to chemicals and fuels. Competitive renewable energy prices could attract leading CO_2 technology developers to set up commercial facilities in Europe, making Europe a forerunner in this industry. Bacterial fermentation and microalgae technologies are expected to be ready for commercial production by 2030, but realisation of industrial scale facilities will depend strongly on the cost of CO_2 capture, the future political climate, and on the development of renewable energy prices and hydrogen. Other technologies, such as advanced biotechnological processes, bioelectrochemical systems and artificial photosynthesis technologies are forecasted to be at demonstration scale by 2030. Scale-up will be the key challenge in this sector.

What is needed to develop a competitive use of CO_2 by IB in Europe?

The key hurdles to the use of CO_2 for biobased products are technological, cost and regulatory barriers. The technology for CO_2 use with IB is at an early stage of development so substantial R&D is needed to overcome technical issues and reduce costs throughout the value chain. However, it is thought that the technical issues can be overcome and do not represent an unsurmountable stumbling block to the development of this promising opportunity. R&D needs should focus on:

- **Developing routes to enable the production of high value products (speciality chemicals), including identification of novel target molecules which could be developed through synthetic routes;**
- **The development of appropriate CO_2 conversion routes should include the whole process of IB and chemical catalysis processes.** In the longer term, CO_2 conversion with further chemical conversion in an integrated system can help obtain high value products based on the bioconversion products. More R&D is needed to find innovative applications and high value chemicals;
- **R&D into routes to overcoming impurities within the gas streams.** This includes identifying the most appropriate strains for different CO_2 sources and the development of downstream processing technologies which can tolerate such impurities. It is suggested that CO_2 use for fermentation is coupled with purification and preparation of the CO_2 stream so that impurities do not hinder fermentation and downstream processing steps;
- **Improving the development of non-IB related platform solutions to enable IB use of CO_2.** CO_2 is an inert, chemically stable compound. Routes which provide sufficient hydrogen, electricity or sunlight in a cost effective manner need to be developed in order to enable an energetically favourable biochemical reaction. This could include, at least initially, using energy-rich syngas or biogas, or locating the facility near to an oil refinery, if the costs of hydrogen could be reduced;
- **Developing cost effective routes to enable effective CO_2 capture, pre-treatment and *in-situ* conversion.** Though CO_2 is a waste and a cheap product, its capture and transportation is inefficient due to the low concentrations of CO_2 in the flue gas. This limits its application to over-the-fence customers.

Many regulatory barriers exist to the use of CO_2 for products. As a novel sector, this should be expected. In particular it should be noted that:

- **There is a need to develop recognised standards to enable the measure and certify the amount of waste CO_2 used for making CO_2 based products (see also 3.4).** Current standards are based on the measurement of C14 (biogenic carbon) and while this is ideal for biomass, it does not work for products derived from fossil carbon where C12 is the predominant carbon isotope. Several routes could be envisaged, including using LCA figures, reporting the CO_2 avoided compared to conventional supply chains.

A recognised standard could be used as an entry point for incentive schemes to help reduce product prices and thus create market pull:

- Tax credits could be envisaged to offset some of the costs associated with plant development against taxation (as in the USA for biobased chemicals);
- Alternatively, CO_2 based products could be promoted through the EU ETS scheme. Products made from CO_2 are currently not eligible for credits under EU ETS, however CO_2 sequestered through CCS is. The EU ETS enters its final stage in 2020-2025 so the inclusion of CCU technologies within any possible following scheme would be encouraged.

5 PERSPECTIVES

The market for IB-derived products within the EU shows a strong growth trend. By 2030, our estimates suggest that it could equate to a market value of 50 BEUR. This allows for the potential to valorise around 100 Mton of unexploited biomass without adversely impacting upon the environment or food production. Based on the estimated CO_2 benefits of future biorefineries, this is predicted to lead to more than 60 Mton CO_2 equivalent[16] savings, similar to the annual CO_2 emissions of a major city such as Paris, London or Rome[17].

The growth of the EU market for IB products, and the associated environmental and societal benefits that they could bring, could be even higher. However, in order to unlock this potential, several hurdles need to be overcome.

Most IB-derived products are based on the use of biomass resources. The availability of feedstock compared to elsewhere in the world is often perceived as a limiting factor for the growth of the EU biobased industries sector sector. However, Europe does have the potential to increase feedstock availability and the efficient use of this feedstock without adversely impacting upon the environment or on food production. In order to fully unlock the opportunities offered by this promising EU-based technology, as much biomass should be derived from Europe and its regions as possible. By 2030, our estimates[18] suggest a potential to valorise more than 100 Mton of unexploited biomass[19]. This will help secure much needed rural jobs and, as a consequence, help in the rejuvenation of rural economies, hence balancing industry's needs for a competitive feedstock prices with the needs of farmers to receive a fair price for their biomass/sugar.

Similarly, there appears to be no one-size-fits-all approach regarding the best way to access this material, as this will likely depend upon a range of variable factors including the strength of alternative markets, storage and transport costs. While reducing red-tape, improving access to new technologies, and improving education and training of landowners will all be important, further effort is required to ensure that biomass producers are aware of the opportunities offered by the bioeconomy. It is encouraging that several initiatives are looking at ways to help set up and foster co-operation mechanisms between agriculture/forestry and industry to guarantee a steady and reliable supply of renewable raw materials for the industry without compromising sustainability, and a fair income for the farmer and forest holders.

The use of waste and residues as feedstock offer significant potential for the EU but there are questions about the amount of residues which can be accessed in a sustainable manner. Moreover, some countries' interpretation of the Waste Framework Directive in its current form provides a barrier to the use of waste materials for value added products such as those derived from IB processes. This is a major barrier to accessing such resources should they be available.

Ongoing R&D is needed across all TRL levels, in order to improve performance and reduce costs, even with established and commercial technologies. The use of lignocellulosic materials and wastes is expected to bring a wide range of, as yet unforeseen technical issues which will need to be addressed in order to ensure that the use of these feedstocks is a viable option for Europe. Promotion of R&D into both bioconversion and downstream processing in integrated systems should be encouraged, in order to minimise potential technical issues when technologies are combined. R&D efforts in IB should leverage the existing EU scale-up facilities wherever possible, with incentives for SMEs to access facilities as needed.

IB projects carry significant investment risks. Dedicated instruments, such as the envisaged European BioEconomy Strategic Investment Fund (EBESIF), may support finance for large scale production facilities and thus help de-risk such investments by boosting the numbers of biorefineries and thereby create a critical mass of showcases to facilitate further plants. This should be reinforced by a supportive and long-term policy framework; encouraging long term projections of demand for IB products, backed up by supportive policy measures designed to kick start the industry.

It is clear that there will be a need to develop relationships between sectors which have not previously worked together. Dialogue needs to be promoted between the biobased industry and land owners. Industry needs to continue to engage with the public and NGOs by communicating the benefits of IB and by better understanding and responding to any causes of concern. Brokerage, round table discussions and trust-building is needed between all parties. Cluster organisations have a critical role in helping in facilitate such dialogue, especially at the local level where feedstock availability, logistics, site synergies and other supportive infrastructure will depend upon local actions.

The opportunity provided by Europe's value-adding IB industry is considerable across many sectors. Strong leadership and coordination is needed to ensure that this potential is recognised, harnessed and exploited. The EU needs to leverage its strengths and identify what its level of ambition is, especially in the view of the increasing global competition in this sector. Inevitably, new technologies take time to develop. A long-term sustained commitment is necessary to give confidence that the EU is seriously intending to leverage on its industrial strengths in IB and clean technology sectors in general. From this, a virtuous circle of investments, growth and innovation will then develop, generating additional direct and indirect jobs.

This roadmap provides support in developing an internationally competitive IB sector in Europe and provides a basis for the Bioeconomy Panel, Bioeconomy Observatory and national and regional bodies in the field to help inspire their activities.

[16] Based on extrapolation of CO_2 savings estimations of a 2nd generation cellulosic ethanol biorefinery by the US ministry of Energy i.e. **http://energy.gov/articles/project-liberty-biorefinery-starts-cellulosic-ethanol-production**

[17] **http://www.theguardian.com/environment/2009/mar/23/city-dwellers-smaller-carbon-footprints**

[18] Assumes that all market demand by 2030 is achieved by EU production of both feedstock and products. Our market demand equates to a number of biorefineries of 185 2nd generation ethanol, 50 biobased jet fuel, 30 biobased chemical building block and 45 biobased plastics.

[19] Assuming each plant uses 350 kton of biomass per annum.

ACKNOWLEDGEMENTS

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