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International review of Bio-economy Strategies with a focus on waste resources

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Acronyms

BBE	Bio-based economy
BE	Bio-economy
BIG-C	Bio Innovation Growth mega Cluster
BMBF	Bundesministerium für Bildung und Forschung / German Federal Ministry of Education and Research
BMEL	Bundesministerium für Ernährung und Landwirtschaft / German Federal Ministry of Food and Agriculture
EEA	European Environment Agency
EIT	European Institute of Innovation and Technology
EU	European Union
EWFD	European Waste Framework Directive
FISCH	The Flanders Innovation Hub for Sustainable Chemistry
FTE	Full Time Equivalent
GBEV	Ghent Bio-economy Valley
GHG	Greenhouse Gas
HoL	Referring to the UK House of Lords
INTERREG	Inter-Regional-Cooperation also known as known as European Territorial Cooperation (ETC)
IWG	Interdepartmental Working Group
IWG BE	Interdepartmental Working Group for the Bio-economy (in Flanders)
KBBE	Knowledge-Based Bio-Economy
KIC	Knowledge and Innovation Communities
KIT	Karlsruhe Institute of Technology
MINA-raad	The advisory council on environmental and nature protection policy of The Flemish government
OVAM	Openbare Vlaamse Afvalstoffenmaatschappij (Public waste agency of Flanders)
PPP	Public-Private Partnership
R&D	Research and Development
RED	Renewable Energy Directive
SALV	The strategic advisory council for agriculture and fisheries
SME	Small and Medium sized Enterprises
SuMMA	Policy Research Centre for Sustainable Materials Management
SWOT	Strengths, Weaknesses, Opportunities and Threats
VIA	Vlaanderen in Actie / Flanders in Action
VISIONS	Valorisation of organic waste streams and technological development
VITO	Flemish Institute for Technological Research

1 Summary

This report provides a review of the approaches taken to date in realising the development of existing bio-economies,[1] exploring the enabling conditions that have led to these developments and identifies common themes that may help the UK to stimulate a bio-economy based initially on waste resources.

The focus on waste resources as a core component of the bio-economy remains underdeveloped in many countries, but the importance of waste in providing value-added resource streams is increasing. Governments in many countries are beginning to realise a shift in the main focus from bioenergy, which generally has been the primary market for biomass outside the conventional agricultural and forest sectors, to the broader bio-economy and higher value-added applications.

Underlying drivers

The drivers behind these changes are varied. Whilst fossil fuel prices are currently relatively low, the stability of supply of fuels from countries outside the EU has come into question in recent years with Member States looking to improve energy security and reduce greenhouse gas emissions. Many have looked at readily harvestable biomass as a source of renewable energy, although the sustainability of using biomass for energy on a large scale is being questioned in many quarters[2]. In parallel there is a growing focus on reducing reliance on imported industrial raw materials, increasing overall resource efficiency and making better use of wastes, with varying degrees of emphasis between countries. Industrial and economic policies in some countries have also sparked interest in developing new value streams from low cost or novel resources, such as wastes, while some are seeking to bolster the agriculture and forestry sectors. Innovation, stimulated by a mixture of public and private funding, has driven new investment in a number of industrial sectors although less rapidly than some had hoped. All these drivers contribute to the move towards a greener and more circular economy. The bio-economy forms a key part of this agenda.

Emerging strategies

Across the globe at least 34 countries have in place policies or strategies in relation to the bio-economy. These strategies vary considerably in their scope. Some, such as those in Germany and Finland, take a broad view, encompassing the whole bio-economy within a single strategy at the national level. Others take a regional approach, such as in Flanders, or focus on promoting certain aspects of the bio-economy deploying dedicated policies with a thematic focus, such as in Italy.

To date the outcomes of bio-economy strategies have been modest. Components of these policies have been in place for a number of years, but coherent bio-economy strategies are a relatively recent addition in the last five years. As a consequence the implementation of most bio-economy strategies is in its infancy and thus the results are not yet very clear.

[1] The term 'bio-economy' is used here to mean the *use of biological feedstocks to generate economic outputs'*

[2] Particularly as a result of indirect land use change resulting from the use of certain land-based biofuel feedstocks, and carbon debt and deforestation impacts of using woody biomass for heat and power production.

Scale of Bio-economies

While this was not the topic of this study, it is clear that Bio-economies are growing in size and the waste based fraction is increasing as well.

An analysis of economic developments in the knowledge based bio-economy (KBBE) sectors in Europe in 2009 suggested that bio-based applications generated an annual turnover in Europe of around €57bn, employing around 305,000 people, although this was a relatively small contribution compared to the food, agriculture, paper and forest industries. The latter accounted for an estimated annual turnover of €1,990bn and employed 21.2m (Clever Consult BVBA, 2010)[3].

The potential contribution of waste resources to the economy will of course depend on how those resources are collected and processed and the way in which they are utilised in the bio-based sector as new technologies, markets and policies emerge. Bio-chemicals are relatively small in volume compared to the volumes of biomass used for food and feed or for energy generation but command significantly higher prices (DeJong *et al*, 2009). Although relatively cheap in input terms, the value gained from utilising waste-based resources will depend partly on the ease in which they can be collected and how developed and efficient the technologies are to process them. However, the opportunities for using waste resources in the bio-economy are widely recognised as significant (HM Govt, 2015).

Biological feedstocks

Identifying the precise composition and volume of biological material utilised in different bio-economies presents a challenge. Whilst inventory information in traditional bio-economy sectors, such as agriculture and forestry, is well established, in others, in particular for waste resources, it is less so. The lack of data and comparable information sources has been highlighted by the European Environment Agency (EEA) as a major challenge for assessment in this area (EEA, 2013). Estimating the composition of the feedstocks employed for diverse bio-economies and the role of waste resources within them, relies on more qualitative assessments than on quantifications. However, initiatives to improve data capture are being put in place, such as the Flanders VISIONS project and the extension of waste data collection statistics in the region by OVAM.

Primary biomass production and imports continue to provide the major share of feedstocks particularly in the energy sector. The extent of waste resource use is more limited and highly variable. Most bio-economies utilise waste to some degree; often this is for bioenergy applications, particularly in the EU and in G7 countries. Within the EU, renewable energy targets for 2020 have stimulated considerable investment, in the generation of energy from biomass. Forestry biomass, largely in the form of wood pellets, continues to dominate bioenergy generation. Liquid fuel production from biological resources relies largely on agricultural crops, particularly maize and sugar for ethanol and, in Europe, oilseed rape for biodiesel. However, interest in utilising wastes for liquid transport fuels is growing and new

[3] The European Commission bio-economy observatory (https://biobs.jrc.ec.europa.eu) provides country specific details of the main economic indicators for different elements of the bio-economy value chain, such as the production of biomass or manufacture of bio-based products. However, the contribution of waste resources to these indicators is not disaggregated from the total figures provided.

industries are emerging. The inclusion of a list of various potential (waste and reside based) feedstocks that are eligible to contribute towards EU renewable transport energy targets has prompted development in this area[4].

Other commercial uses of biological waste resources have been largely, an adjunct to energy generation, although material and chemical applications are beginning to increase. This review has highlighted the Flanders region of Belgium as one of the leaders in the use of and promotion of waste resources in the bio-economy and one of the only jurisdictions to have dedicated actions and policies focussed on wastes. Yet even in Flanders wastes still form a relatively small component of the overall resource used in the bio-based and bio-economy.

Policy mechanisms to support bio-economies, particularly from wastes

Policy formulation in this domain, may be ad hoc or more systematic within a strategic framework. Various policy instruments are involved. These include regulatory measures concerned with waste management and material flows at different national, regional or sub-regional levels and associated initiatives at the city or municipal level. Good examples include the recent change in the Flemish waste act to become a materials decree, or the introduction of dedicated national sub-targets for advanced biofuel production in Italy.

Mandated or voluntary resource efficiency goals, including those related to the use of biological materials, as well as waste reduction and recycling targets, have helped to stimulate improved waste collection and separation activities.

The most widespread initiatives are those focussing on research, knowledge development and more practical forms of exchange. Research programmes to improve the valorisation of waste materials are evident in most of the country programmes covered by this study. Many involve public-private-partnerships, while cross border and international co-operation is quite widespread. The level of investment in research is also significant, in some countries. For example the German National Research Strategy for the Bio-economy 2030 (BMBF, 2011) alone provides €2.4bn of research funding supporting the bio-economy. Funding is aimed at companies, research institutes and universities, with participation from SMEs being particularly welcomed. Initiatives to increase the sharing of knowledge through industrial clusters and partnerships related to the bio-economy are increasingly extensive. These include the co-location of existing and related industries; the establishment of company matchmaking initiatives to link material chains; and the provision of shared demonstration facilities and infrastructure to close the gap between research activities and the commercialisation of products and processes.

Institutional issues are also important. The development of improved governance structures and the introduction of advisory panels and working groups has been realised in a number of countries. The Independent Working Group Bio-economy in the Netherlands, and the Germany Bio-economy Council are both notable.

[4] For example, Annex IX of COM(2012) 595 final. Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012PC0595&from=EN

Potential lessons from international experience

While bio-economy plans vary considerably and do not necessarily put a large emphasis on waste there are certain common themes that occur relatively frequently and therefore indicate some of the components that might help to make strategies to develop more waste based bio-economies successful.

1. Clearly defined objectives and guiding principles are necessary in order to guide policy, to enable those working in the bio-economy sectors to contribute to a common set of goals and to allow progress to be assessed.
2. The Bio-economy can be a useful forward looking framework through which to promote the better management and reduction of waste in society as well as establishing new value chains and economic activity.
3. However, the use of waste resources for new products should not inadvertently promote the unsustainable utilisation of wastes or other bioresources or create unsustainable supply chain.
4. Analysis of the potential nature, scale and dynamics of waste resources is valuable in order to improve understanding of the recovery potential for the bio-economy and the types of resources on which it should be based over relevant timescales.
5. Measures to promote research, knowledge exchange and significantly wider understanding of emerging aspects of the bio-economy, in particular new and novel technologies, generally are needed alongside established Research and Development programmes to accelerate progress in this sector.
6. Industrial clustering and industrial symbiosis should be explored and potentially promoted as an aid to the more effective utilisation of knowledge, resources and infrastructure in developing a waste based bio-economy.
7. Policies offering incentives for different economic uses of biomass – such as food, feed, bio-based products and bio-energy need to be aligned with strategic goals for the bio-economy. Regulatory frameworks may need to be reviewed. This is often a prerequisite for increasing the value generated from biomass, and for stimulating the value chains.
8. A range of measures can be used to help businesses to innovate, to utilise waste resources efficiently and to capitalise on existing regenerative loops. Elements in the policy mix often will include the development of dedicated infrastructure and planning mechanisms; the setting and implementation of policy targets promoting the use of waste and, where appropriate production of bio-based products; provision of targeted financial incentives, for example in the form of, investment aid, tax breaks or start up business loans; or other market enabling mechanisms, such as product certification or labelling.
9. Institutional adjustment can be critical in breaking the mould, crystallising new thinking and networks and bridging gaps that hold back development. For example consideration should be given to the development of an advisory body that not only provides advice but also helps to drive forward goals and coordinate activities in the development of the bio-economy based on waste. This can help to focus the needs of government, agencies and public bodies as well as of industry and other stakeholders.
10. The full range of stakeholders from industry, government, technical institutions and civil society should be included in the development of the bio-economy from the outset.

2 Introduction

This report provides a review of the approaches taken to date in realising the development of existing bio-economies, in a number of countries and exploring the enabling conditions that have led to these developments. It identifies some common themes that may help the UK to stimulate a bio-economy based initially on waste resources.


HOUSE OF LORDS

Science and Technology Select Committee

3rd Report of Session 2013-14

Waste or resource? Stimulating a bioeconomy

In March 2014, The UK House of Lords Science and Technology Select Committee reported on the findings of its inquiry into 'Waste opportunities: stimulating a bio-economy' (HoL, 2014). The Lords reported that the evidence they had received suggested other countries are currently ahead of the UK in terms of extracting value from waste. The utilisation of waste as a resource is affected not only by a country's desire to stimulate a bio-economy, but also in relation to differences in waste policy, infrastructure, culture, technology and investment. To this end, the Lords note that the deployment of waste in these ways may or may not be appropriate for the UK situation.

The Lords stressed the value in learning lessons from the approaches taken in other countries, both in terms of best practice examples to be aspired to, and practices that should be avoided. This could help the UK to develop a positive and proactive approach to policy development in making use of waste as a resource. The underutilisation of waste in the UK, and the relatively cautious approach that they considered the UK Government to have adopted now forms the basis of an opportunity to develop a sustainable waste-based bio-economy. Whilst some other countries have over-capacity in energy from waste facilities or anaerobic digestion, the UK has the opportunity to steer the development of the next generation of investment and infrastructure and in so doing make steps towards realising a high-value waste based bio economy in the UK.

The Lords report concluded that:

> *'In developing a long-term plan for a high value waste-based bio-economy, we recommend that the Department for Business, Innovation and Skills examines the strategies used by other countries to extract maximum value from waste, both successes and failures, and identifies approaches which would afford the UK the greatest economic opportunity.'*

In the Government's Response to the Lords' recommendations, the Department for Business, Innovation and Skills (BIS) agreed that there is merit in building a better understanding of international best practice and that they would review readily available studies, coordinate respective sources of data and commission further analysis as required. This report and the accompanying recommendations forms part of this response and of the evidence gathering for the production of a long-term plan to realise a high value bio-economy, with an initial focus on waste.

An outline of those countries identified as having a bio-economy strategy in place is given in Section 4, with subsequent sections and analysis focussing on those bio-economies that are based at least in part on waste and the role of waste within them.

3 Defining the bio-economy

The term bio-economy is used widely but not always consistently. The role played by waste in underpinning different bio-economies varies from country to country, with some sectors based entirely on waste and others where it plays no significant part. This section explores the way the bio-economy is defined in different countries, the relationship of waste to the bio-economy and to what extent the bio-economy is related to other concepts, such as the circular or green economy.

In this review we use the definition of waste as set out in the UK Government's view on the potential feedstocks for a bio-economy. Here waste is used in its most general sense to cover those materials *not produced specifically as a product and focuses on harvest residues (classed as either co-products or by-products), process residues/by-products and biogenic components of industrial or consumer waste including bio-waste* (HM Govt, 2015). It is important to recognise however that the fairly wide range of co or by-products in question are subject to different legislative and processing requirements in different countries. Clarity in the definition of wastes and straightforward legal requirements relating to their utilisation will be needed in the development of a bio-economy based on 'waste' in the UK.

3.1 What is the bio-economy?

In its broadest sense, the bio-economy addresses the production and use of biological resources for conversion into commercial products, ranging from food and feed to bio-based products and bio-energy. The bio-economy therefore encompasses agriculture, forestry, fisheries, food processing, and parts of the energy, chemicals and biotechnology sectors. As a system, the bio-economy has existed since humans first appropriated natural resources for their own gain, such as burning firewood or cultivating crops. In recent years there has been a renewed focus on utilising biological resources more efficiently, so as to reduce pressure on natural resources, as well as starting the transition away from finite fossil resources. There have also been technological advances that have allowed the use of biological resources in the making of plastics and other composite materials and chemicals. Collectively this new ambition has been termed the bio-economy.

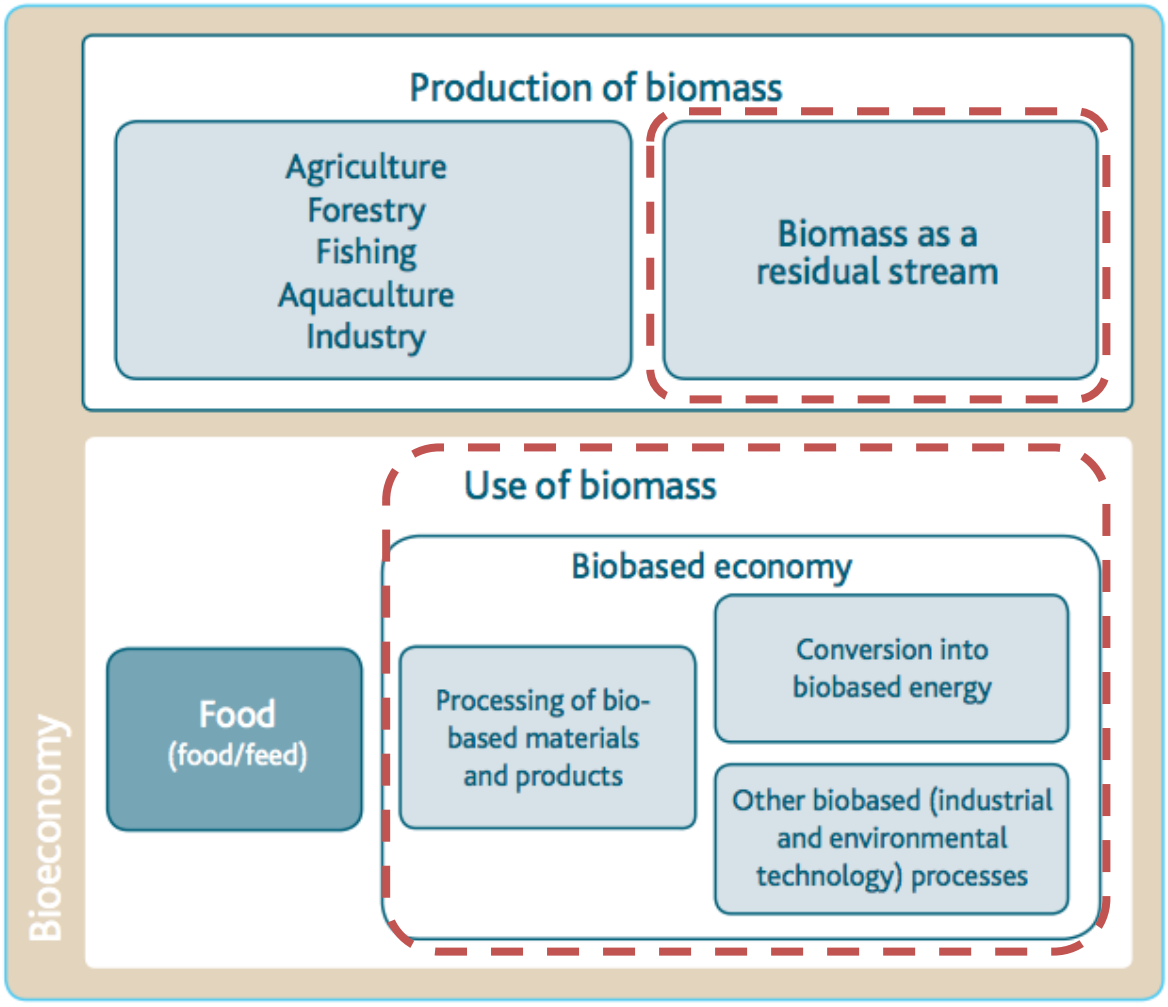
For the purposes of this report, we are using the definition of the bio-economy as set out by the UK Government, meaning 'part of the economy using biological resources (biomass[5]), or bioprocesses, for the production of value added products, such as food, feed, materials, fuels, chemicals, bio-based products[6] and bioenergy[7] (HM Govt, 2015). When comparing approaches to developing bio-economies in different contexts across the globe, it is important to recognise what is meant by the term bio-economy in those contexts and how this is applied in practice.
In the countries reviewed as part of this study a range of different definitions of the bio-economy have been used (Table 3 of Annex 1), as well as other complementary terms such

[5] Material of biological origin excluding material embedded in geological formations and/or fossilized. (CEN/TR 16208:2011; CEN/TC 411/WG 1 2013)
[6] Bio-based products are products that are wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilised. (CEN - Report on Mandate M/429)
[7] Energy from biomass (CEN/TC 411 2012)

as the circular, bio-based, and green economy often in a similar context. Where definitions of the bio-economy exist they are concerned for the most part with the feedstocks that form the component parts of the bio-economy, almost exclusively those of biological origin, and their ultimate end use. Similarly, the term "renewable", features in most of the definitions indicating that the bio-economy can be more sustainable in the long term than a finite fossil alternative.

The bio-economy (BE) and the bio-based-economy (BBE) warrant further explanation as they are used in a number of countries to make a distinction between different aspects that are the focus of different policies or sectors. Like the definitions of the bio-economy, the boundary between the BE and the BBE differs between countries, but in general the distinction is made in relation to the production and use of biomass, often with the exclusion of food and feed production. This is well illustrated in the Flemish case (Figure 1). Here the distinction is made between the bio-economy, which encompasses the production of biomass, either through primary production or through the collection of waste streams; and the use of biomass for food energy and material uses. The bio-based economy is a subset of the overall bio-economy and addresses only the use of biomass for materials, energy, chemicals and other bio-based processes, with the explicit exclusion of food.

Figure 1: Distinction between the bio-economy and the bio-based economy



Source: Vlamse overhead, 2013 in turn adapted from MINA-raad & SALV, 2012

Other conceptual definitions that differentiate between the BE and BBE are used without any consensus yet having emerged. The European Union identifies the bio-based economy as one that '…integrates the full range of natural and renewable biological resources, land and sea resources, biodiversity and biological materials (plant, animal and microbial), through to the processing and the consumption of these bio-resources' (European Commission, 2011). This definition of the concept focuses on the raw material rather than the conversion processes and is applied with the same meaning in Germany (BOR, 2011), Finland (Luoma *et al*, 2011) and Sweden (FORMAS, 2012). A number of authors have written on the conceptual definitions, such as Schmid et al (2012), Birch and Tyfield (2013), and Staffas et al (2013).

In the UK, the use of technology in the development of new aspects of the bio-economy is made explicit in the House of Lord's report on waste as a resource, '*[t]he growth of a bio-economy is underpinned by new technologies. This enables the use of a wider range of feedstocks, reducing dependence on non-renewable feedstocks, including fossil fuels'* (HoL, 2014). This takes a particular view about the use of technology and the inclusion of a wider range of feedstocks than most others[8]. Technology is not always referred to directly in the adopted definitions of bio-economy in other countries, although there are some exceptions. Technology features as a key, defining component in the American definition; as a central part of the bio-economy definitions in Italy, by reference to the biorefinery concept; in reference to knowledge-based use of biological materials in Germany; and explicitly as a necessary enabling tool in the Flanders vision.

Most bio-economy strategies make reference to the use of technology as a fundamental component of the transition towards a more bio-based economy. For example, the Netherlands places the emphasis on biomass production, innovation, sustainability and coherent policy, while Sweden is focusing on innovation, market introduction, support for SMEs (small and medium-sized enterprises) and general supporting policy. Germany has established a national Bio-economy Council with the focus on the economy, innovation, education and policy.

Whether or not the definition of the bio-economy makes reference to technology, it is clear that technological advances will play a role in helping to unlock certain value chains from a range of existing and future potential resource streams. Advances in technology are being looked at to help improve existing material pathways (such as food production or timber harvesting), making them more efficient or effective, as well as opening up new pathways involving wastes, residues and other materials that have proved more difficult to harness to date. The bio-economy will therefore need to integrate both technological enhancement in existing sectors, and simultaneously developing new ones.

3.2 Waste and the bio-economy

In Europe alone, 16 tonnes of material is used per person per year, of which six tonnes become waste. Although the management of that waste continues to improve in the EU, the European economy currently still loses a significant amount of potential 'secondary raw

[8] For example a bio-economy based on grown and harvested feedstocks, such as crops and timber.

materials' such as food, metals, wood, glass, paper and plastics through present waste streams. In 2010, total waste production in the EU amounted to 2.5 billion tonnes. From this total only 36 per cent was recycled, with the rest landfilled or burned. It is estimated that around of 600 million tonnes (37.5 per cent) of what was landfilled could have been recycled or reused.

Like the definition of the bio-economy itself, the term waste is used to mean a variety of different things in different contexts. In the legal sense of the word, the term waste has definitions in both EU and national law. For example, the European Waste Framework Directive (EWFD) defines waste as 'any substance or object, which the holder discards or intends or is required to discard'. A number of exceptions are made to what is considered waste under the directive, which encompasses some materials that may be desirable for use in a developing bio-economy, such as non-hazardous agricultural residues (Box 12).
Definitions embodied in legislation can be an obstacle to development. One of the identified barriers to developing the bio-economy in the Netherlands was that Dutch law considers certain residual material streams (e.g. wood processing residues) as waste, which makes it difficult to reuse (parts of) these streams in other applications (SIRA, 2011).

Whether or not a material is considered a waste does not necessarily prevent it from being used as a feedstock for the bio-economy, but it may influence the way in which it is permitted to be used. For example, a genuine waste as defined by the EWFD would be subject to the waste hierarchy. This is a set of principles preferring reduction, re-use, recycling, in sequence before energy recovery.
However, the use of other materials, not covered by the directive, may be such as to circumvent this hierarchy without falling foul of the legislation. Of course, in a system that seeks to maximise the contribution of waste to the economy, the longer a material remains in use or re-use the greater economic benefit is likely to be obtained from that unit of resource.

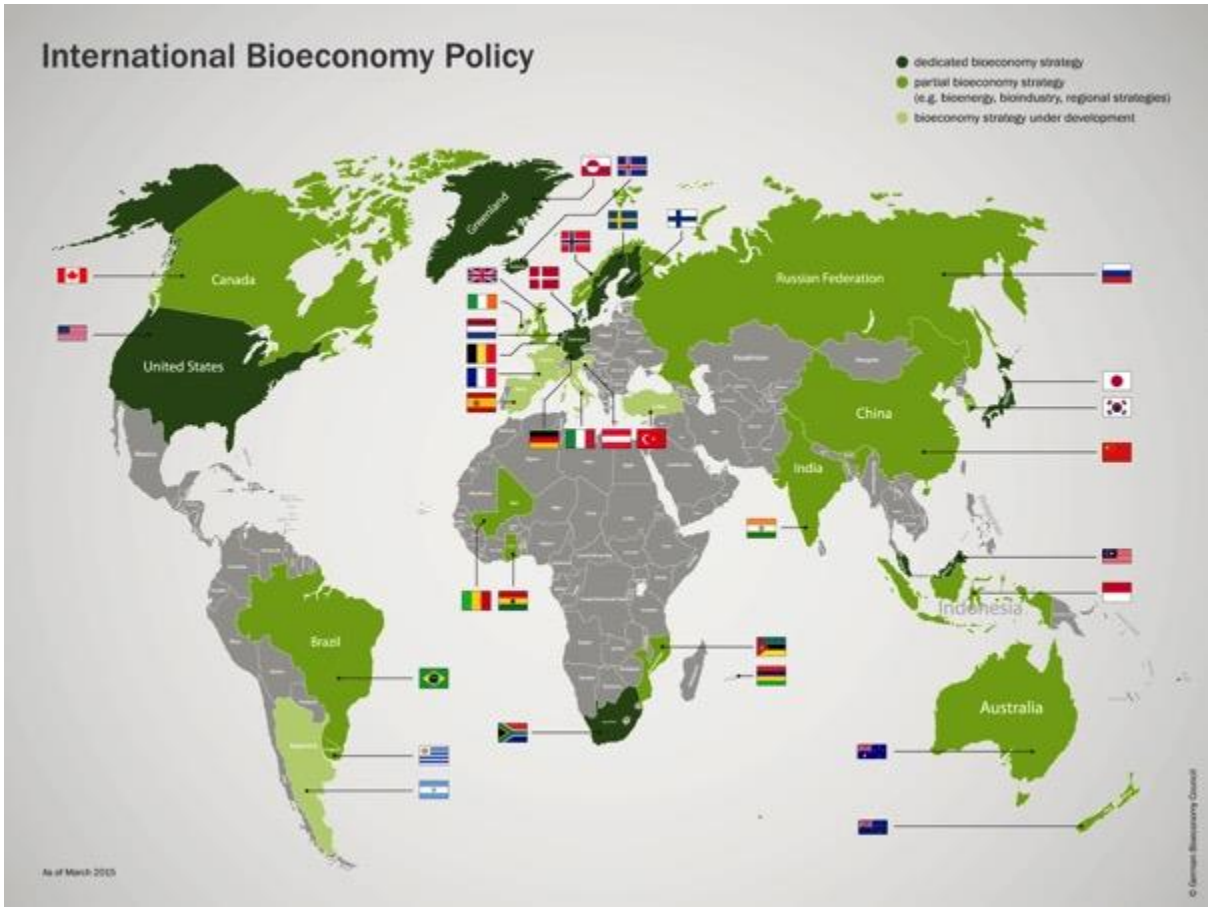
The less favoured conceptualisation of waste has undergone a significant change in recent years shifting from substances that are inherently undesirable and often problematic to deal with and so must be reduced to substances that are seen as more of a potential resource for a range of new and sometimes high-added value applications. The waste hierarchy, as set out in the EWFD, continues to promote the reduction of waste over its reuse, recycling, composting and energy recovery. However the markets and opportunities beyond conventional reuse and recycling are increasing, particularly with the drive towards improved resource efficiency and a more circular, bio-based and green economy. New concepts are emerging within this space to describe the more resource efficient use of materials, such as the cascading use concept, where material is used multiple times in successive use phases thereby adding value, and increasing efficiency. A variety of research initiatives in both the science and policy arenas are also helping to change perspectives and create new opportunities. This changing context is key to the development of the bio-based and bio-economy.

4 Strategies for waste-based bio-economies

This section describes some of the bio-economy strategies that have and are being developed in countries across the world with particular attention paid to those that utilise waste resources.

All economies have a bio-based component, whether that is the production and trade in agricultural crops or the more advanced development of refined bio-based products. Only a few countries however, have taken active steps to promote and develop their bio-economies through dedicated strategies and policies. In a recent global review, the German Bio-economy Council[9] identified 34 countries with existing strategies for the bio-economy (Figure 2).

Figure 2: Bio-economy strategies across the globe



Source: http://biooekonomierat.de, March 2015 **Note:** At number of these strategies are available for download http://biooekonomierat.de/en/bio-economy/international0/

These strategies vary considerably in their scope. Some, such as Germany and Finland take a broad view encompassing the whole bio-economy within a single strategy. Some, such as those in Belgium, the Netherlands and Sweden have placed more emphasis on promoting certain aspects of the bio-economy using strategies with a thematic or regional focus.

[9] http://biooekonomierat.de

Others, such as Italy, have a number of individual strategies without an overarching framework.
National or regional bio-economy or bio-based economy strategies are in place in several, but not all, the countries reviewed. For example, the Dutch government set up the "Bio-based Economy in the Netherlands" initiative; while in Belgium there is no counterpart national vision. However, in a strong regional approach the Flemish government established a Vision and strategy for a sustainable and competitive bio-economy in 2030. The regions of Wallonia[10] and Brussels have initiatives but not of a comparable strategic kind.

For this study we reviewed bio-economy strategies in eleven countries (Table 1) with a view to identifying those that involve planning for a significant use of waste. The policies and strategies for each of these countries are listed in Annex 2 (Table 4).

Table 1: Bio-economy strategies referred to in this study

Country	Document	Policy aim / contents	Year
Belgium *(Flanders)*	The vision and strategy of the government of Flanders for a sustainable and competitive bio-economy in 2030	The Strategy contains 5 strategic objectives providing the framework for the (further) development of a Flemish bio-economy	2013
Canada *(British Columbia (BC))*	BC Bio-economy	The finding of the Bio-economy Committee, established in 2011, are presented along with recommendations for action by the BC government on how to accelerate the development of BC's bio-economy.	2011
Denmark	No specific strategy	Bio-based solutions encapsulated within the Government's growth plan for water, bio and environmental solutions.	2013
Finland	Finnish Bio-economy Strategy	The Strategy contains 4 strategic objectives providing the framework for the (further) development of the Finnish bio-economy	2014
France	No specific strategy	A variety of individual initiatives in the area of the bio-economy	'07-'14
Germany	National Policy Strategy on Bio-economy	To develop a coherent policy framework for a sustainable bio-economy	2013
Hungary	The future landscapes of bio-economy: Hungary	To deliver insights into the Hungarian bio-economy scene	2014
Italy	No specific strategy	A variety of individual initiatives in the area of the green economy	'08-'14
Sweden	Swedish Research and Innovation Strategy for a Bio-based Economy	To provide a national strategy for the development of a bio-based economy and to propose a Swedish definition of the term.	2012
The Netherlands	The Bio-based Economy in the Netherlands	The document presents the aims and scope of several bio-based initiatives undertaken in the Netherlands	2013
USA	National Bio-economy Blueprint	To lay out strategic objectives that will help	2012

[10] The Wallonia region developed a cluster dedicated to the green economy, GreenWin, in the context of the framework 'Marshall Plan 2.0 Vert'. The cluster includes a specific focus on bio-based chemistry. In addition, ValBiom (an organisation that promotes the use of biomass for non-food applications) is very active in the study and promotion of the bio-based economy. Existing dynamic clusters in bio-economy related fuels, such as plastics (Plastiwin), renewable energy (Tweed) and agro-industry (Wagralin) have been set up. An on-going ValBiom-GreenWin-Awex project is called 'Le coq vert: towards a bio-based economy in Wallonia'.

		realise the full potential of the U.S. bio-economy	

Source: Own compilation. A more elaborated table detailing the principal documents reviewed can be found in Annex 2

Most bio-economy strategies include some form level of reference to waste, either by the identification of genuine waste streams, or through promoting the use of industrial side-streams, such as agricultural or forestry residues and paper pulp. The scale at which waste resources feature in these different strategies varies considerably. In some cases it is integral to the design of the strategy while in others it is more of a result of markets developing around available resources. Some initiatives involving wastes are well established, with supporting policy frameworks, such as those in Belgium; some are being developed around different sectors or facilities, like those in the USA and Italy; and others involve wastes as part of a much broader strategy, such as Germany and Finland. In some cases joint initiatives are being developed between countries to utilise common resource pools (including wastes), such as the memorandum of understanding on the bio-economy, between four neighbouring EU Member States[11] and the bio innovation growth mega cluster in Belgium, the Netherlands and Germany (Box 1).

Box 1: Bio Innovation Growth mega Cluster (BIG-C), Belgium, Netherlands & Germany

The Bio Innovation Growth mega Cluster (BIG-C), also known as Antwerpen-Rotterdam-Rhine-Ruhr (ARRR), was launched in April 2014 and is a cross-border initiative with the aim of developing the Flemish region (Flanders), the Netherlands and the German state of North Rhine-Westphalia into a leader of bio-based innovation.

This initiative focus is the following feedstock-to-product value chains:

- From lignocellulosic resources, i.e. agricultural waste, short rotation wood, landscape materials and green cuttings, into bio-based chemicals, materials and advanced biofuels;
- From agro-based feedstocks, i.e. dedicated crops or new crops producing chemicals, to the creation of new technologies and products;
- From industrial side streams, i.e. from the agro industry, the food processing industry, oleochemistry and the bioenergy sector, to high added value bioproducts; and
- From CO_2 and exhaust gases into bio-chemical products.

The mission of BIG-C is to stimulate bio-economic development in the area where the industrial mega cluster is located, focusing on fostering technological innovation and developing the production of high value added products. BIG-C builds upon a network of existing national public-private partnerships, such as CLIB2021 in North Rhine Westphalia (Germany), BE-Basic in the Netherlands, and FISCH in the Flanders region, and of companies involved in a number of bio-economy sectors.

CLIB2021 (DE-NRW) is an organisation including members from academia, SME, investors and public organisations fostering biotechnology in the chemical and energy industries. The cluster's members are from Germany, Europe, North-America and Russia. CLIB2021's aim is to develop and provide technologies for the production of bio-based products. **BE-Basic Foundation** (NL), the Biotechnology based Ecologically Balanced Sustainable Industrial Consortium, is a international public-private partnership including around 40 Dutch universities, knowledge institutes and companies involved in the bio-economy. Its aim is to develop bio-based knowledge and technology, in particular for the chemistry industry. Part of the BE-Basic funding comes from a research grant from the Dutch Ministry of Economic Affairs for executing the initial BE-Basic Program and part from industry and knowledge institutes; **FISCH** (BE-Flanders), the Flanders Innovation Hub for Sustainable Chemistry, is a public-private partnership with the aim of identifying and stimulating innovations in the chemical sector in Flanders. FISCH is funded by the Belgian Federation for the Chemical Industry and Life

[11] Belgium (Flanders), France, Germany and the Netherlands (European Commission, 2011)

Sciences, Essenscia Flanders, and VITO, in cooperation with various companies in the sector, Flemish university associations and the Flemish government.

Sources: Bio Innovation Growth mega Cluster (not dated) BIC-C – Flanders, The Netherlands and North Rhine-Westphalia http://www.errma.com/wp-content/uploads/2014/02/250314-BIG-C-position-paper.pdf; CLIB2021 website http://www.clib2021.de/en; BE-Basic website http://www.be-basic.org/; FISCH website http://www.fi-sch.be/en/

3

Driven in part by the Renewable Energy Directive (2009/28/EC), energy generation has been a major driver of waste use in the bio-economy in Europe. Wastes (of varying forms) are being converted into liquid or gaseous fuels, in some cases involving biorefineries or through direct combustion utilised to produce heat and power (examples from Belgium, Italy, USA, Finland and Germany can be found in Annex 5). However, with the advance of technologies and an increased focus on bio-based products Member States are starting to encourage the development of high-value products from wastes rather than energy generation, such as the production of bio-based raw materials and platform chemicals from wastes in the German Fraunhofer Center (Box 2), and the conversion of agricultural crops into platform chemicals as part of an initiative to launch the green chemicals sector in Italy (Box 3).

Box 2: Fraunhofer Center for Chemical and Biotechnological Processes (CBP), Germany

Based in Leuna, Sachsen-Anhalt, Germany, the Fraunhofer Center for Chemical and Biotechnological Processes (CBP) utilises forestry residues, straw and waste wood to replace oil as the base feedstock in the chemical industry. The CBP forms the core of the leading edge cluster "Bio-Economy" in eastern Germany with the aim of bridging the gap between the pilot plant and industrial implementation. By making infrastructure and plants available the Fraunhofer CBP makes it possible for cooperation partners from research and industry to develop and scale processes for utilising renewable raw materials up to an industrial scale.

The facility is supported financially (~€50m) by the German Federal Ministries of Education and Research (BMBF), of Food, Agriculture and Consumer Protection (BMELV) and for the Environment, Nature Conservation and Nuclear Safety (BMU) as well as the State of Sachsen-Anhalt.

Website: http://www.cbp.fraunhofer.de/en.html

Box 3: Biorefineries for the production of high-level bio-products, Italy

The Matricia is one of seven biorefinery plants being developed in Porto Torres in Sardinia, Italy. The development of these biorefineries is a joint venture between Novamont and Versalis to produce base chemical components (monomers and intermediates) from corn, wheat, potatoes, maize and vegetable oil (mainly sunflower oil). These chemicals form the basis for the production of more complex bio-products. Two additional plants are in development in the region that will have the capacity to produce bio-products from these base materials with a high added value, such as bio-lubricants and products for the cosmetics industry. Together the first three plants are expected to produce bio-products with a total capacity of 70,000 tonnes per year.

The overall project includes seven plants to be built in three steps, along with an R&D centre. The overall investment plan amounts to €450 million. The first two plants (amounting about €100 million in investment) are expected to employ 88 employees; the second two (about €50 million) will employ around 57 people; and the last three (about €300 million) will employ 126.

Novamont is a multinational chemical company operating in the bioplastic sector with a turnover of €89 million / year; Versalis (ENI) (50%) is a chemical company, a subsidiary of ENI, which manages the production and marketing of petrochemical products (e.g. basic chemicals, styrenics, elastomers, polyethylene). It also operates in the green chemical sector. ENI is a multinational company operating in the oil and gas sector with a market capitalisation of €68 billion.

R&D and the costs associated with the construction of the plants were financed by private funding. The initiative was supported by the Italian Government through the approval of legislation aimed at simplifying the authorization processes for building second- and third-generation biorefineries.

Source: Novamont website http://www.novamont.com/press/default.asp?id=732&id_n=35834 ; Versalis (ENI) webpage http://www.eni.com/it_IT/azienda/attivita-strategie/petrolchimica/polimeri-europa/polimeri-europa.shtml ; Bastioli *et al*, 2011

Yet despite the development of more advanced and novel processing of wastes to high-value products only a few of the countries considered within the scope of this review include dedicated bio-economy actions[12] that focus on promoting the use of waste resources for such applications. Amongst these countries the Flanders region of Belgium stands out as having the most developed strategic approach aimed at realising the potential from wastes. The remainder of this section focuses on the Flemish case.

[12] Including policies, dedicated strategies and enabling measures

5 A waste-based bio-economy in Flanders

The Flemish regional government of Belgium has had an overarching policy framework concerning the bio-economy in place since 2011[13], with a history of waste management and processing stretching back as early as 1989 with the introduction of a landfill tax (IEEP *et al*, 2012). Policy change towards the bio-economy in Flanders started with bioenergy policy, through the introduction of the Green Power Certificates system in 2002 with a gradual recognition of the importance of using waste resources, such as a study on the optimal energy valorisation of wood waste in 2003 (VITO, 2003) and development of biomass inventories in 2004[14] (VITO, 2011). Despite improving efforts around waste collection and management the real policy development around the bio-economy in Flanders did not start to emerge until a number of years later.

In 2011, the Government of Flanders designated 'Sustainable Materials Management' as one of the thirteen major societal challenges for the region, part of the Flanders in Action programme (Vlaanderen in Actie (VIA)[15]). Responding to this challenge, the VIA tasked the public waste agency of Flanders (OVAM) to transpose the EU Waste Framework Direct into a new materials decree, rather than revising the existing waste decree. This change in the conceptualisation of waste at the policy level has led to consideration of the entire materials cycle, from design, industrial symbiosis, to waste reduction and recycling. In 2012 the VIA prompted the development of the Flanders Materials Programme (OVAM, 2013)[16] and the creation of the Interdepartmental Working Group for the Bio-economy (IWG BE) in recognition of the cross-sector, cross-border and cross-policy nature of the bio-economy in the region. In 2013 the advisory council on environmental and nature protection policy of the Flemish government (MINA-raad) and the strategic advisory council for agriculture and fisheries (SALV) assessed the sustainable use of biomass in the bio-economy as a contribution towards the overall Flemish bio-economy vision (MINA-raad & SALV, 2013). In the same year, the first results of the IWG BE consultation with stakeholders, and the information provided by the MINA-raad and SALV review, formed the Flemish Government's vision and strategy on the Bio-economy in Flanders (Vlaamse overheid, 2013)[17]. This regional strategy sets the framework through which the waste-based bio-economy in Flanders is being developed.

The Flemish bio-economy vision is seen as a transition strategy to respond directly to the threat presented by the exhaustion and use of fossil raw materials. Additional drivers of the

[13] Following the publication of the Flanders in Action programme (VIA).
[14] A manure inventory was started four years earlier.
[15] The VIA was established by the Flemish council of ministers in 2006 - http://www.vlaandereninactie.be/en/
[16] The Flemish Material Programme (2013), a transition programme for sustainable materials management as promoted in the Flanders in Action (VIA) programme, identifies the bio-economy as one of nine key levers for coping with major societal challenges (i.e. reliance on fossil raw materials, climate change implications, dependence on imports) and leading to the development of a circular economy.
[17] The vision was informed by: a report 'How bio-based is the Flemish economy?' (U Ghent, 2010) which started to lay the groundwork for developments of more focussed research and action around the bio-economy; the work of the Flemish Interdepartmental Working Group (IWG) on the Bio-economy, created in 2012 and formally approved in 2013; of several discussions with stakeholders as captured by the joint opinion of 13 February 2013 of the advisory councils MINA-raad and SALV; and of the European strategy for the bio-economy.

vision include allowing the region to respond to major societal challenges such as population growth, climate change, the increasing pressure on ecosystems and economic development. Through the strategy Flanders hopes to provide opportunities for green growth and job creation, the further development of a circular economy, cross-border clustering, strengthening of competitiveness and the potential for research and innovation in Flanders (Vlaamse overheid, 2013).

Five strategic objectives drive the achievement of the vision in Flanders:

- SO1: The development of a coherent Flemish policy that supports and facilitates a sustainable bio-economy.
- SO2: To put Flanders at the top for education and training and research and innovation in future-oriented bio-economy clusters.
- SO3: Biomass is optimally and sustainably produced and used across the entire value chain.
- SO4: Strengthening of markets and competitiveness of bio-economic sectors in Flanders.
- SO5: Flanders is a key partner within European and international joint ventures.

Repeated reference is made to the fostering of links between resource using and processing sectors on the one side with waste producers and collectors on the other in order to close material loops and improve resource efficiency. In conjunction with establishing these links the cascading principle for biomass use is highlighted. In the Flemish case this term infers a hierarchy of uses in which biomass must be used, first to ensure food security, then material uses before final energy recovery[18]. Identifying and understanding these main (waste) resource streams and by-products being produced in the region that might be used in new value chains has therefore been a focus of initial research around the bio-economy in Flanders.

The VISIONs project[19] (Box 4) is one such initiative in this area, although the development of inventories for organic wastes has a much longer history (Vanaken, N *pers comm*). In 2015 additional research and development is planned that will cover wastes and residues as they relate to the bio-economy, for example the Biomass Residues Action Plan (forthcoming in 2015) aims to enable the transition towards a sustainable management of biomass residues to 2020 leading to an integrated and sustainable management of all biomass by 2030 based on the principles of materials hierarchy and cascading use. The Biomass Residues Action plan is being developed so as to be coherent with the Renewable Energy Action Plan for 2020 (also forthcoming in 2015), which sets out to establish similar standards around the use and prioritisation of materials.

Box 4: Valorisation of organic waste streams and technological development (VISIONS), Flanders (Belgium) 2011 - 2015

The VISIONS project started in September 2011 and has the aim of systematically listing all the main waste and residues streams in Flanders and assessing the most valuable bio-based applications. The project's duration is 4 years and includes developing a database and clustering waste streams and by-products that are available in

[18] This is different to the cascading principle as it relates to material flows, i.e. the use of a quotient of biomass multiple times in successive use phases.

[19] Value creation of organic waste streams – development of 2nd generation technologies

Flanders, as well as developing and testing 2nd generation technologies for lingo-cellulosic side-streams and waste oils at an industrially relevant scale.

The visions project covers the whole of Flanders. The Bio Base Europe Power Plant, where technological testing will take place, is located in the port of Ghent. The project includes 35 companies and clusters of companies in the bio-based economy, such as the Ghent Bio-Economy Valley and Essenscia. **The Ghent Bio-Economy Valley (GBEV)**, founded in 2005 under the name of Ghent Bio-Energy Valley, is a public-private partnership between Ghent University, the City of Ghent, the Port of Ghent, the Development Agency of East-Flanders and a number of industrial companies operating in the Ghent region. Set up initially with the aim of driving a substantial quota of biofuels production into the area, along with related investments, in 2008 GBEV moved on to the development of a wider range of bio-based activities, including bioenergy. **Essenscia Flanders**, the Belgian Federation for Chemistry and Life Sciences industries, is a multi-sectoral organisation representing the interests of nearly 800 companies including the pharmaceutical, biotechnology, agricultural, cosmetics and plastics sectors.

The €2.5 million VISIONS project is supported financially through a public-private partnership involving the Flemish Agency for Innovation by Science and Technology (IWT) (80%) and co-funded (20%) by a large consortium of companies interested in either valorising their waste streams or in finding alternative feedstocks for bio-based processes.

Sources: The VISIONS project website http://www.bbeu.org/sites/default/files/Bio%20Base%20projectfolder%20visions_web.pdf, the Ghent Bio-Economy Valley website http://www.gbev.org/en and Essenscia website http://www.essenscia.be/

The bio-economy strategy for the region, and related initiatives seek to improve resource efficiency in Flanders as well as delivering higher added value from wastes. The ambition of these initiatives and the framework within which they operate differs in the pre-2020 and post-2020 eras. For example, the Flanders biomass action plan will set the framework and targets to 2020. The main strategies of the action plan focus on closing the materials cycle, but also take into account the need for biomass as a renewable energy (RE) source in order to reach the 2020 RE targets for the Flemish region. However, beyond 2020 the policy landscape is likely to change considerably and the Flanders region will look to reassess its strengths and weaknesses in relation to the development of bio-economy initiatives focused on more materials recycling. Following the continuation of EU level renewable energy targets, albeit in a different form, beyond 2030 there is likely to remain attention on energy supply, however the role of biomass energy as part of this may change with a greater focus on solar and wind power and improved efficiency and consumption patterns (Vanaken, N. *pers comm*). How, and for what purpose biomass is subsidised remains an open question, but the strength and experience of Flanders in waste management and processing may see a greater focus on value-added from waste rather than energy consumption directly.

5.1 Balance of feedstocks in the Flanders bio-economy and the role of waste

With an area of only 13.5 thousand square kilometres[20] the land resources of Flanders are relatively modest compared to its population[21]. As such the potential for increasing the contribution of new domestic biomass supplies to the bio-based economy in the region is limited.

The advisory council on environmental and nature protection policy of the Flemish government (MINA-raad) and the strategic advisory council for agriculture and fisheries (SALV) assessed the sustainable use of biomass in the bio-economy as a contribution towards the overall Flemish bio-economy vision (MINA-raad & SALV, 2013). Their review

[20] Around two thirds the size of Wales

[21] Twice that of Wales, ~6 million inhabitants.

identified that the demands for bioresources would outstrip the ability of the region to supply them; that ensuring genuinely sustainable imports was challenging[22]; and that biomass is subject to a range of different policies and structures, which are not always harmonised in their aims and ambitions. Looking only at bioenergy potential in 2010, Belgium (as a whole) could, theoretically, generate six peta joules (PJ) of energy from its bioresources, giving it one of the smallest domestically sourced bioenergy potentials of all EU Member States (Böttcher *et al*, 2010).

As a consequence of the MINA-raad and SALV assessment and the existing expertise and capacity in the field of waste management in Flanders, residues and biological waste streams were identified as being some of the most suitable feedstocks on which to establish the bio-based[23] economy (Vlaamse overhead, 2013). Improving resource efficiency and closing material loops through improved cascades are seen as complementary activities in this area.

One of the leading principles applied in Flanders' to advance these goals is the separate collection of wastes at source. Separate collection is already well implemented in the region, including the collection and processing of post-consumer wood, although from a domestic perspective much of this relies on the public themselves taking wastes to collection facilities[24] (Vankanen, N *pers comm*) (section 6.6.1). With the ambition to focus the use of waste resources in the Flemish bio-economy there remains a shortfall in the generation or collection of waste compared to the potential to utilise that waste. For example, in 2008, wood waste supply in Flanders was 1.6 million tonnes (Mt)[25], while the theoretical demand was 2.9 Mt resulting in a 1.3 Mt, deficit (Carez *et al*, 2013).

Despite the impressive inventories of materials used and collected in Flanders[26], identifying individual sources and end uses in the bio-economy collectively, remains challenging. Inventories of waste production and collection are not always produced in connection with inventories of other biomass production, such as agricultural crops or timber, making aggregation difficult. The overall end use of those materials is then also hard to determine from a single source. It has not been possible within the scope of this report to combine existing datasets and information in order to make a fully comprehensive estimate of the balance of waste to non-waste resources used in the Flemish bio-economy. In fact uncertainties around the comparability and consistency of data has been noted as one of the barriers to more complete analysis in this area (EEA, 2013), particularly when comparing different forms of biomass[27]. Other pan-European studies, such as the '*resource efficient use of biomass'* study for the European Commission[28] are attempting to quantify the production and use of biomass resources, which should provide insights into this area for future research.

[22] Something that has been highlighted through the debate around the sustainability of biofuel feedstocks.
[23] Used in the Flanders case to describe the 'non-food' part of the bio-economy.
[24] For example each year, 160,000 tonnes of domestic wood waste are brought to and processed at container parks (recycling facilities) for use primarily in energy generation, but also for material use (such as fibre board).
[25] (1.2 million tonnes from industry and households, increased by import from abroad or from other regions)
[26] Such as the VISIONS project and the OVAM inventories
[27] Such as waste fractions or primary biomass (e.g. agricultural crops).
[28] Study number ENV.F.1/ETU/2013/0033

What can be said about the Flemish case is that there is a difference between the types and scale of waste streams available from domestic as compared to industrial sources. Efforts at the moment are focussed primarily on the collection and processing of industrial wastes given the relatively high volumes and collection infrastructure. One example of such initiatives is the focus on residual streams from the food industry, some of which contain high-value proteins and vitamins (for use in animal feed). The intention is to pass legislation in this area to ensure that such waste streams are collected and processed before disposal. Although, before any legislation is developed, the focus is first on research to understand which value-added products are important and whether or not legislation is required in this area (Vankanen, N *pers comm*).

Despite looking to its own strengths and resources, Flanders remains in part reliant on imported biomass to fuel developments in the region. This is one of the driving factors pushing Flanders towards the greater use of waste resource streams. The balance between domestic and imported biomass varies considerably between feedstocks. For example, for wastes and residues, in 2010 Belgian paper manufacturers used 0.6 million tonnes of fresh pulp, 40 per cent (0.2 Mt) of which was imported. This is far greater than the 0.4Mt (25 per cent) of wood waste that was imported as part of overall supply in the region of 1.6 Mt[29]. For primary biomass almost all of the rapeseed used in Flanders (2.1 Mt) was imported, yet most of cereal consumption came from domestic production (Carez et al, 2012).

Imports of both waste and primary biomass remain important for the Flanders bio-economy. These have been facilitated through good trading relationships with neighbouring agricultural producers in France and Germany and as a result of the major port infrastructure in Zeebrugge, Ghent, Ostend, and Europe's second largest port, Antwerp. In the period to 2020 imports of biomass to Flanders (and Belgium in general) are anticipated to increase. A review of the biomass needed to meet renewable energy targets in 2020 suggests that domestic biomass streams from agriculture and wastes would only provide 44 per cent of the total energy volume needed, with woody biomass, particularly from imports, being required (Carez *et al*, 2013) as well.

5.2 Actors in the Flemish bio-economy

The different actors present in the Flemish bio-economy[30] are hugely varied, ranging from individual householders through to multi-national organisations and businesses, research organisations and public authorities. Some however, are more relevant than others to the development of the waste component of the Flemish bio-economy. For example, as a response to increased dependence on imports, geopolitical relations, price fluctuations of raw materials, and the strain on the environments, some key industrial federations Agoria (technology industry) and Essenscia (chemical industry) demanded government action which has led in part to the development of a bio-economy strategy for the region (Paredis and Block, 2013). Key organisations in the waste-based part of the Flemish bio-economy include:

[29] Belgium is one of the top three importers of wood pellets from the US, alongside the UK and the Netherlands.

[30] Including those targeted by the regional strategy

Public bodies and organisations

- OVAM – the Flemish public waste agency. Established in 1981;
- City of Ghent Economic Development Authority;
- Port of Ghent – Established in 1999 as an Autonomous Municipal Company 'Ghent Port Company AMC' it became a limited liability company under public law (Nv van publiek recht) in 2014, allowing the company to have other partners than the city of Ghent;
- The Development Agency of East-Flanders (POM) in charge of executing the social economic policy in the East-Flanders province.

Private companies

- Abengoa - an applied technology organisation for biomass conversion (largely to energy) – 24,748 employees - €101m (~£65m) net income;
- **Bio Park Terneuzen** (Box 8). a Dutch cluster of companies composed of a range of companies operating in the food, chemical and energy sectors including:
    - Cargill (Multi-national organisation – 143,000 employees globally – $134.9bn (~£88.3bn) revenue in 2014);
    - Rosendaal Energy (Dutch biotechnology research organisation);
    - Royal Nedalco (a subsidiary of Cargill producing high grade alcohol for multiple industrial applications);
    - Yara (Norwegian agricultural and industrial development organisation – 12,073 employees in 2014 - 95.3bn NOK revenue in 2014 (~£8.44bn).

Research organisations and innovation hubs

- Ghent University;
- FISCH the Flanders Innovation Hub for Sustainable Chemistry a public-private partnership with the aim of identifying and stimulating innovations in the chemical sector in Flanders. FISCH is funded by Essenscia and VITO, in cooperation with various companies in the sector (http://www.fi-sch.be/en/fisch/members/), Flemish university associations and the Flemish government (Box 1);
- VITO, an independent research and technology organisation in the areas of clean technology and sustainable development.

Umbrella organisations and advisory councils

- Essenscia - The Belgian Federation for the Chemical Industry and Life Sciences
- MINA-raad - The advisory council on environmental and nature protection policy of the Flemish government;
- SALV - the strategic advisory council for agriculture and fisheries;
- The Interdepartmental Working Group for the Bio-economy in Flanders (see section 6.3)

5.3 Supporting the bio-economy in Flanders

The successful development of the Flemish bio-economy strategy has relied on a combination of incentives, private and public financing, industry/sector led initiatives and the development of public policy to overcome existing barriers.

The potential for new bio-economy applications, such as more novel materials or chemical uses, is limited currently; the principal focus is on more traditional uses, such as energy generation, composting, panel board and paper production. This is in part due to the existence of established industries in this area, such as two of Europe's largest paper plants[31] and in part due to the impact of renewable energy targets (Vankanen, N *pers comm*). Research initiatives, technological development, funding opportunities and industrial match making for new added-value products are being developed to overcome this issue. FISCH[32], CORE[33] and i-Cleantech Vlaanderen[34] are three projects in this area leading to the increased valorization of waste resources (PSI *et al*, 2014). These projects have led to practical initiatives, for example the SYMBIOSE platform[35], a matchmaking service platform for valorisation of waste and by-product streams, which promotes collaboration between producers aimed at reallocating one company's residues as another company's raw materials. Around 315 potential synergies have been identified so far, involving more than 190 different organisations and businesses.

Beyond the established industries and renewable energy polices, there are other barriers to the wider use of waste resources in the bio-economy. For example the chemicals industry, which is sizeable in the Flanders region[36], relies on the use of homogeneous biomass streams. Wastes, whether municipal, agro or silvicultural in nature, tend to be heterogeneous and require processing before they can be used in the chemicals industry. To this end, Flanders is looking to improve its waste collection and processing activities to provide more consistent streams of feedstock for use in a range of applications (see section 6.6.1).

Other barriers to the development of bio-economy activities relate to the infrastructure around fossil fuel resources and the current low fuel prices. Fossil based products remain relatively cheap compared to bio-based alternatives, particularly those based on new and emerging technologies. As a consequence there is little market space for the bio-based sector, or other forms of product recycling, such as plastics (Vankanen, N *pers comm*) at present. The bio-economy strategy for the region, and related initiatives[37] seek to overcome some of these barriers and to improve resource efficiency in Flanders as well as delivering higher added value from wastes. The ambition of these initiatives and the framework within which they operate varies, whether they are addressing 2020 goals or the post 2020 agenda. For example, the Flanders biomass action plan sets the framework and targets to 2020 with a focus on the use of wastes for energy generation more than for materials and chemical applications.

[31] The Finnish Store Enso facility located in Ghent producing 400,000 tonnes per year and the Lanaken Mill, owned by the South African Sappi group, which produces 510,000 tonnes per year)

[32] The Flanders Innovation Hub for Sustainable Chemistry (http://www.fi-sch.be) aims to identify, stimulate and catalyse innovations for sustainable chemistry in Flanders.

[33] The CORE project looks at Controlled Recycling and aims to match the competences of waste management companies to those of the plastics and textiles companies to turn waste into a valuable resource.

[34] I-Cleantech (http://www.i-cleantechvlaanderen.be/en) is a network organisation that aims to identify and stimulate development of cleantech instruments.

[35] http://www.fi-sch.be/nl/symbiose/

[36] such as the Antwerp harbour chemicals cluster

[37] Such as the Flanders Materials Programme

However, beyond 2020 the policy landscape is likely to change and the Flanders region will look to reassess its strengths and weaknesses in relation to the development of bio-economy initiatives (Vankanen, N *pers comm*). Following the EU level targets there is likely to remain a focus on renewable energy generation.

However the role of biomass energy as part of this may change, with a greater focus on solar and wind power and improved efficiency and consumption patterns. With a focus on greenhouse gas reductions rather than energy generation there may be opportunities for bio-based products to be supported on the basis of their GHG benefits, or as part of a sustainable public procurement programme (Carez *et al*, 2013; Vankanen, N *pers comm*). How, and for what purpose biomass will be incentivised remains an open question, but the strength and experience of Flanders in waste management and processing may see a greater focus on value-added from waste rather than energy consumption directly.

In the last five years, in conjunction with the development of the bio-economy strategy, a series of funding streams have been initiated, or refocused towards bio-economy initiatives. These come from a range of public and private sources. The Flanders materials programme identifies 24 differently sourced funding streams to help enable activities connected with better materials management. These range from modest grants of €2,500 in the case of local actions through a *fund for sustainable materials and energy* or the Enterprise Agency (AO) fund focussing on SMEs (€2,500 - €25,000) up to €1.5m available through the Participation Vlaanderen (PMV) initiative aiming to invest in start-ups and SMEs with a focus on sustainable materials management. Some funding is aimed particularly at consortia or groups of companies operating in this area, whereas other funding is aimed at individual entrepreneurs. European investment programmes including the Eco-innovation programme[38] and the Horizon 2020 research programme[39] are also cited. Tax incentives are another form of economic support, in particular for: research and development (13.5 per cent[40]); and reusable packaging projects (three per cent).

Economic instruments for the waste-based bio-economy in Flanders can also include disincentives certain practices to drive waste reduction activities, such as landfill taxes and pay-as-you-throw (PAYT) schemes. Instruments such as these are used relatively widely to help improve waste management, particularly in EU countries (EEA, 2013; IEEP *et al*, 2012). Full details of the funding opportunities available through the materials programme can be found at http://www.vlaamsmaterialenprogramma.be/aanbod (in Dutch).

5.4 Performance of the bio-economy in Flanders

At this stage in the development of the Flemish bio-economy it is not possible to assess the full impact of the strategies and policies put in place, or at least the results of such an assessment would only paint a partial picture. In fact of all of the published bio-economy strategies reviewed in this study were produced between 2012 and 2014, so there has been relatively little time for implementation or to detect emerging results. What can be seen from the information reviewed are the changes in national and regional policies that look to drive bio-economy development and the implementing measures and tools that accompany

[38] http://ec.europa.eu/environment/eco-innovation/apply-funds/call-proposal/index_en.htm
[39] www.europrogs.be/concepten/horizon-2020
[40] Or a staggered deduction rate of 20.5 per cent

them. Many of these are probably necessary for enabling conditions for the bio-economy to develop and are discussed in more detail in section 6.

Conceptual changes in the way waste is regarded has been one result of the various initiatives. The approach now is with the prioritisation of the use of biomass firstly for food, than for material use and leading only finally to energy recovery; this is accompanied by an emphasis on materials and resources rather than 'waste'. Improving knowledge and information about the bio-economy is evident in the newly developed information portals and research platforms (see section 6.5), and the setting up of advisory organisations for industry and government (section 6.3). Collaboration has been promoted as a result of the bio-economy strategy, through the development of industrial clusters (section 6.5) as well as multi-national research initiatives.

On the other side, the lack of funding aimed at developing new bio-based applications and materials was highlighted as one of the weaknesses of Flanders in its bio-economy strategy (Vlaamse overheid, 2013). Partly as a consequence of the strategy a range of dedicated funding streams have been promoted to support the bio-economy initiative in the region (section 5.3) and the inclusion of policy drivers has prompted industrial entrepreneurship and financing.

Some quantification of the scale and performance of the bio-economy in Flanders is available, although this relates to the bio-economy as a whole rather than purely to that component focussed primarily on waste resources. In addition, the timescales in question don't necessarily correspond to the implementation of policy measures focussed on the bio-economy. Some data is provided here (Box 5) for context and to indicate the potential economic significance of bio-economy activities in the region.

Box 5: Economic impacts of the bio-economy in Flanders

In 2010 the economic benefit provided by bio-products in Flanders equated to a gross margin of €1,315m, approximately five times as big as the value of bioenergy (€256m). In the same year employment was almost ten times higher for bio-products (8,249 full time equivalent (FTE) jobs) than for bioenergy (971 FTEs).

Excluding the primary production of raw materials from agriculture and the processing of bio-based materials into final products, 1.5 per cent (€1,571m) of the total Flemish gross margin and 0.8 per cent (9,215 FTEs) of all Flemish employment was generated by the bio-based economy in 2010. Almost half of the gross margin from the bio-based economy is attributed to the chemical industry (€829m). In terms of stability, the Flemish bio-based economy has seen an increase in gross margin by two per cent between 2008 and 2010 compared to a decline in the Flemish industry overall of six per cent. Employment in the bio-based economy declined by only one per cent over the same period, compared to a 10 per cent decrease in Flemish industry overall (Carez *et al*, 2012). With a foreseen shift in focus from renewable energy generation to bio-based products and services the economic potential of the bio-economy in Flanders looks likely to increase.

Source: Carez *et al*, 2013

6 Enabling conditions for the waste-based bio-economy

Based on the review of existing bio-economy strategies, this section sets out some of the conditions that have enabled the development of the bio-economy in a number of countries and ways of overcoming particular barriers. Having reviewed these different approaches, part of the research aim for this study was to extrapolate what approaches might work well in the UK context. This section provides the basis for that analysis.

6.1 Establish strengths and weaknesses

The development of bio-economy ambitions in the countries reviewed shows that in all cases, bio-economies are being developed around established rather than more novel industries[41]. The same conclusion was noted in the German Bio-economy Council's review of bio-economies in G7 countries 'They [the bio-economy strategies reviewed] are characterised by the prevailing industrial and economic profiles of the countries and by the amount of resources they have, especially by their natural resources potentials' (Bioökonomierat, 2015).

In some cases these economic or natural resource advantages can be obvious, such as the significant forest resources available in the case of Finland and Sweden, or the highly developed industrial and technology sector in Germany. Yet in principle the bio-economy and its cross cutting nature requires a more horizontal look at the strengths and weaknesses in a range of areas. An example of the strength, weaknesses, opportunities and threats (SWOT) analysis undertaken in the Flemish case shows the multi-sectoral examination undertaken and some of the drivers that focus the regional strategy on waste resources.

Box 6: SWOT analysis accompanying the bio-economy vision in Flanders

The analysis* for the Flemish bio-economy identified the following strengths, weaknesses, opportunities and threats:

- **Strengths:** knowledge base (biotechnology, process technology), (modern) agriculture, strong industry (food, chemistry, energy), well-developed logistics (land and waterways, port infra-structure), forerunner in collecting and recycling waste;
- **Weaknesses:** small geographic area, densely populated, high environmental pressure, poor exploitation of research, fragmented research landscape, extensive regulation and complexity of the Belgian constitution, few funding programmes aimed at developing bio-based applications;
- **Opportunities:** existing policy and initiatives, such as New Industrial Policy, transversal materials management action, biomass inventory, the IWG on food losses, innovation steering groups, cooperation with the Netherlands;
- **Threats:** little own technological development, growing competition from the cooperation of European clusters without the involvement of Flanders and other pilot installations, insufficiently coordinated regulations and policy.

Source: Own compilation. **Note:** * This SWOT analysis was carried out on the basis of UGhent, 2010 and Carez *et al*, 2012.

It should be noted that this study did not include a SWOT[42] analysis of the situation in the UK at present. Some of the strengths of the UK are highlighted in the House of Lords report on waste as a resource (HoL, 2013) and in the subsequent government report 'Building a

[41]

[42] Strengths, Weaknesses, Opportunities and Threats

high value bio-economy - opportunities from waste' (HM Govt, 2015). It is also recognised that the UK has systems in place currently that may be analogous to some of the key enabling initiatives that have been developed in other countries. For example the setting up of a dedicated advisory panel and cross-departmental working group is one of the tools used effectively in other countries. Such initiatives are not new to the UK, with WRAP and Zero Waste Scotland already providing advice to government and industry around the bio-economy and the cross-Whitehall and public sector working group set up by the Department for Business, Innovation and Skills (BIS) is helping to inform the development of the bio-economy agenda at the government level. ***As part of actions to promote the bio-economy, it is recommended that a SWOT analysis be carried out evaluating the UK's strengths and areas of competence to the using the type of criteria discussed in this report.***

6.2 Clear policies, aims and commitment

Clearly defined objectives and guiding principles are necessary in order to enable those working in the bio-economy sectors to contribute to a common set of goals and markets. E Emerging bio-economy strategies include a range of different objectives, such as reducing society's dependence on fossil resources; preventing biodiversity loss; creating new economic growth and jobs; reducing energy consumption; and mitigating climate impacts. However, such objectives are not always presented coherently and despite many being complementary, this is not the case generally.

As the bio-economy is subject to a wide suite of interests involving multiple actors (businesses, NGOs, policy makers), drivers (energy demand and renewables targets, material management, technological innovation, waste policy) and users (industry sectors, public etc.) it is important to articulate clearly the purpose and aims of developing a bio-economy to help actors coalesce around a common objective(s). This will help to steer investment, research and policy towards delivering those objectives in a cost efficient and environmentally responsible manner.

Coherence can be increased when the strategy as a whole addresses all aspects of the bio-economy. For example, the German national policy strategy on the bio-economy[43] sets out a series of guiding principles including amongst others:

- priority for food security; ensuring higher value-added is given preference during development;
- and improving environmental protection and sustainability. These guiding principles are used to inform three cross-sectoral and five thematic areas of action along with specific supporting measures. Other nationally coherent bio-economy strategies can be found in Finland, Sweden and the USA, amongst others (see Annex 2, Table 4).

The coordination effort required across the multiple sectors of the bio-economy should not be underestimated and in some countries, more targeted policies have proved effective in stimulating bio-economy development. Where there are dedicated strategies with a focus on a particular actor or range of actors emerging evidence suggests that having concrete agreements, objectives and indicative timeframes for action, can provide stimulus to

[43] Federal Ministry of Food and Agriculture (BMEL) (2014) National Policy Strategy on Bio-economy: Renewable resources and biotechnological processes as a basis for food, industry and energy.

implementation in practice (PSI *et al*, 2014). Flanders' regional approach to a bio-economy, with a significant waste component, provides cross-sectoral coherence in a specific thematic area, waste. As part of this initiative the Flanders' materials programme (OVAM, 2012) has engaged more than 33 different parties including research institutes, industry, NGOs and public authorities, all signed up to joint agreements on the bio-economy (Vlaamse Regering, 2012).

Other countries have chosen to focus efforts around specific areas of the bio-economy in order to stimulate investment and development. Italy for example, is pursuing the conversion of wastes, residues and dedicated biomass to bioenergy. Examples of clear policy objectives in this area include the promotion of advanced liquid biofuels through the enactment of a national decree law[44] that sets binding national sub-targets for advanced biofuels in Italy from 2018.

Some selectivity in incentives may be appropriate in the light of broader policy objectives but overall it will be important to establish a fairly level policy playing field for the different sectors utilising of biomass, such as food, feed, bio-based products and bio-energy. Incentives and policies supporting the production of renewable energy in order to meet binding EU and national targets currently drive biomass utilisation in the direction of bioenergy, particularly in the absence of any equivalent policies in the industrial materials, food or chemical sectors this will skew the development pathway for the bio-economy. A review of the incentives and regulatory frameworks governing and promoting biomass use will be an important prerequisite for increasing the value generated from biomass, and for stimulating new value chains.

This recommendation was made in the Copenhagen Declaration for a Bio-economy in Action that was agreed under the Danish presidency of the European Union in March 2012. At the European level, the proposal for an improved biomass policy as part of the 2030 climate and energy package, and the development of the circular economy package provide the opportunity to redress the balance of policies in this area; in the shorter term and beyond 2020[45].

6.3 Governance and structure

The development of an advisory body for the bio-economy has proved effective in providing advice and helping to coordinate activities in the development of the bio-economy in a number of countries. Advisory bodies, policies and strategies can be key enabling conditions to develop a leading position on the bio-based or bio-economy. Both the Flemish and the Dutch governments have set up advisory bodies (respectively, the Flemish Interdepartmental Working Group (IWG) for the Bio-economy and the Bio-Based Economy Programme Management) with the aim to provide impetus to the development of an integrated and cross-policy approach to the bio-economy or bio-based economy.

[44] Decree Law on Updating the conditions, criteria and procedures for implementing the obligation to release of biofuels for consumption, including advanced biofuels (August 2014)

[45] The point at which current renewable energy targets expire.

Despite similar aims, these two advisory bodies are structured differently. The Flemish IWG is comprised only of government departments and agencies[46] whereas the Dutch Bio-Based Economy Programme[47] Management includes other relevant stakeholders.

Guidance to government can be as important as the guidance provided to those industries and stakeholders which are developing the bio-economy. In 2009, the Federal Ministry of Education and Research (BMBF) and the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) established the Bio-economy Council as an independent advisory board to the German Federal Government. The central task of the 17 members of the Council, whose expertise covers the full spectrum of the bio-economy, is to search for ways and means for sustainable solutions, and to present their insights in a global context. The Bio-economy Council convenes regularly to prepare position statements and expert advice, organise events on relevant issues, and promote the future vision of the bio-economy to broader society. The activities of the Council are oriented both towards long-term objectives as well as current policy requirements.

6.4 Knowledge development (R&D)

Assembling and mobilising the appropriate knowledge, research and understanding of different aspects of the bio-economy, in particular of new and novel technologies to help utilise a wide range of bioresources, is seen as crucial in enabling a transition to a bio-economy in different countries. Countries with established or emerging bio-economy strategies are investing considerable research effort into this area both through public and private financing initiatives.

In Flanders, the Policy Research Centre for Sustainable Materials Management (SuMMa[48]) brings together five major research institutions[49] to work in cooperation with public organisations[50], which provide funding for writing research papers[51] or publications to create a knowledge base to underpin the bio-economy. In addition to collaborative research activities, funding is made available to support specific projects or research initiatives, such

[46] The IWG includes the Departments of Economy, Science & Innovation (EWI), Agriculture & Fisheries (LV), Environment, Nature & Energy (LNE), Work & Social Economy (WSE) and Education & Training (OV), together with the agencies VITO (Flemish Institute for Technological Research), ILVO (Institute for Agricultural and Fisheries Research), OVAM (Public Agency of Flanders), VEA (Flemish Energy Agency), VDAB (Flemish Employment and Vocational Training Service), IWT (Agency for Innovation by Science and Technology) and Enterprise Flanders.

[47] The BBE programme was set up within the Ministry of Economic Affairs, which had a coordinating role on the bio-economy economy among other governmental ministries.

[48] www.steunpuntsumma.be

[49] The Katholieke Universiteit Leuven, University of Antwerp, Ghent University, Hasselt University and VITO (https://vito.be/en).

[50] Such as the Department of Economy, Science and Innovation of the Flemish Government and the Public Waste Agency of Flanders (OVAM).

[51] Examples of such research papers include: Sustainable use of biomass in a bio-economy (MINA-raad & SALV, 2013) (in Dutch); International Discourses and Practices of Sustainable Materials Management (January 2014); Sustainable use of biomass – 10 principles (VITO, 2013) (in Dutch); How bio-based is the Flemish economy? (U Ghent); Sustainable use of and creation of value from renewable raw materials for bio-based industrial production (Carez *et al*, 2013); International benchmarking analysis of economic policy frameworks related to greening the economy (EWI, 2013) (in Dutch).

as the VISIONS project (Box 4). Applied research and innovation in the field of the bio-based economy is in part coordinated through the agency for innovation through science and technology (IWT Vlaanderen) for both research institutions as well as private companies In addition to IWT Vlaanderen[52] the not for profit *Flanders Innovation hub for Sustainable Chemistry* (FISCH) was created as a tool for facilitating the transition of the Flemish chemical industry towards sustainability. Dedicated private initiatives are also prevalent in Flanders, such as the initiative of Ghent University, which launched the 'Ghent Bio-Economy' spearhead in 2010, a multidisciplinary partnership involving 13 promoters from 5 faculties.

The use of public-private partnerships is common to the countries developing initiatives in this field around the bio-economy. In the Netherlands, public-private initiatives have been developed to help improve information exchange between researchers and those implementing new approaches as well as between research and innovation groups such as BioCab[53]. The Dutch Ministry of Economic Affairs actively promotes cooperation between businesses, knowledge institutes and the government through two platforms focused on generating new bio-based business cases – the Bio-renewables business Platform and the Agri-Paper-Chemical Platform.

Recognising the importance of coherent research activities, the German federal government has developed a national research strategy roadmap for the bio-economy (BMBF, 2011) (Box 7). The strategy sets out five priority fields of action: global food security[54], sustainable agricultural production, healthy and safe foods, the industrial application of renewable resources, and the development of biomass-based energy carriers.

Box 7: Research and development to support a bio-economy in Germany

The National Research Strategy Bio-economy 2030 (BMBF, 2011) is Germany's largest research programme for supporting R&D in the field of the bio-economy, providing €2.4 bn in funding. Funding is aimed at companies, research institutes, and universities with participation from SMEs being particularly welcomed. Project funding by the Federal Government is only considered if the work cannot be completed using the core funding of the research institutes and universities, or using private sector resources.

Within this strategy a number of sub programmes address waste issues. "BioEnergy 2021 Module A: Biorefinery of the Future" in particular covers the whole range of potential uses of different biomass feedstocks, including biological residues and waste.

Source: Own compilation

Moving from theoretical and applied research to commercial operationalisation is one of the major hurdles for any developing technology or industry. Countries with dedicated bio-economy research activities often have mechanisms in place to enable the transition of research into practice. In Germany this is promoted through the Industrial Biotechnology

[52] and in the framework of the targeted Flemish innovation policy and the New Industrial Policy of the Government of Flanders

[53] BIOCAB is a cooperative project in the Northern Netherlands, focused on the development of technology for the production of fibres (BIOFIB), chemicals (BIOSYN) and minerals (BIONPK) from agricultural residues. The project brings together partners such as Wageningen University, Smurfit Kappa and a range of other research and industry partners.

[54] Food production always takes highest priority in such research activities (BMBF, 2011).

Innovation Initiative[55]. This initiative aims to speed up the use of biotechnological processes at an industrial scale. Within this programme the Zero Carbon Footprint project is exploring the biotechnological utilisation of high carbon waste-flows, including sewage or flue gas from coal power plants. Flanders is utilising a common research infrastructure for demonstration projects, including complete dedicated funding stream, to enable this transition. An example of such infrastructure is the Bio Base Europe Pilot Plant (Box 8). This plant works according to the 'open innovation' principle, which allows companies to use the infrastructure in order to step up the pace of progress of their innovation projects as well as to complete them at a lower cost[56].

Box 8: Bio Base Europe Pilot Plant, Belgium

The Bio Base Europe Pilot Plant is a pilot facility that enables SMEs from North West Europe to test and develop bio-based products and processes. The total project budget was €13 million and construction of the plant started in January 2009, the operations themselves started in December 2010.

Located in the Port of Ghent, Belgium the BBE pilot plant is an independent pilot plant that operates from a laboratory level up to a multi-ton scale (up to a 25m^3). The research focus is on the conversion of biomass (i.e. agricultural crops and by-products) and industrial side streams (e.g. wastes) into biochemical, bio-materials, biofuels and other bioproducts. For lignocellulosic materials, the focus is on pre-treatment technologies and hydrolysis of biomass into fermentable sugars. A biorefinery approach is used in which the use and valorization of all fractions is considered. For waste oils and fats, a decision tree is developed to assist in designing refinery and conversion strategies towards fuel applications. New technologies, such as enzymatic production of fatty methyl esters, are evaluated for their profitability compared to conventional methods. The feasibility of higher added value oleochemical applications is explored as well.

The two key partners involved in the project are the Ghent Bio-Economy Valley and Bio Park Terneuzen. **Ghent Bio-Economy Valley (GBEV)**, founded in 2005 under the name of Ghent Bio-Energy Valley, is a Flemish public-private partnership between Ghent University, the City of Ghent, the Port of Ghent, the Development Agency of East-Flanders and a number of industrial companies operating in the Ghent region. Initially set up with the aim of driving a substantial quota of biofuels production into the area, along with investments, in 2008 GBEV moved on to the development of a wider range of bio-based activities, including bioenergy. **Bio Park Terneuzen** is a Dutch cluster composed of a range of companies operating in the food, chemical and energy sectors, i.e. Cargill, Rosendaal Energy, Royal Nedalco and Yara. The aim of the project is to maximise the exchange and use of each company's by-products and waste products that could be deployed as feedstocks, energy or utility supplements in other production processes.

The Bio Base Europe Pilot Plant is financed through public funding, namely the European Regional Development Fund (between Flanders and the Netherlands), INTERREG IV B, and supported by the Bio Base NWE, the Flemish Government Flanders in Action (VIA) programme and the government agency for Enterprise Flanders.

Source: Bio Base Europe Pilot Plant website http://www.bbeu.org/bio-base-europe-pilot-plant; Ghent Bio-Economy Valley website http://www.gbev.org/en; Bio Park Terneuzen website http://www.bioparkterneuzen.com/en/biopark.htm

In some cases, coordinated research activities are being developed by environmental groups and research institutes. For example, in Italy, the Green Chemistry Bionet[57] non-profit organisation was set up in March 2006 by Legambiente, an environmental organisation, and a group of academic and experts with the aim to promote and develop research and

[55] http://www.bmbf.de/de/16336.php (in German)

[56] More information can be found in the bio-based Europe Pilot Plant information pack available here: http://www.bbeu.org/sites/default/files/BBEPP_General%20Folder_Feb15_electronic%20version.pdf

[57] www.chimicaverde.it

industrial applications of raw materials from plants. The uses envisaged include, among others, energy, dyes, solvents, textiles, lubricants, bioplastics and cosmetics.

At the EU level, there is a range of funding and support mechanisms in place to directed at research and understanding in this area. Box 7 gives some examples of the types of research funding and support mechanisms that exist in this area.

Box 9: Examples of research tools and funds to help support the bio-economy in Europe

The European Commission's communication 'Innovation for sustainable growth: A bio-economy for Europe' (COM(2012)60 Final) considers ways of advancing this goal. A range of tools, research programmes and funds are available to help support the transition. Examples of these include, but are not limited to:

- Support for public-private partnerships on research and innovation for bio-based industries as a means to promote the development of integrated and diversified biorefineries, including their biomass supply chains. Support is ear marked through the Horizon 2020 research programme. Around €4.7bn has been made available for the Challenge "Food security, sustainable agriculture, marine and maritime research, and the bio-economy"[58]. Other Challenge funds are relevant to the bio-economy and can be found at http://ec.europa.eu/programmes/horizon2020/
- The European Innovation Partnership (EIP) is also envisaged to play a key role. EIPs act across the whole research and innovation chain, bringing together all relevant actors at EU, national and regional levels in order to: (i) step up research and development efforts; (ii) coordinate investments in demonstration and pilots; (iii) anticipate and fast-track any necessary regulation and standards; and (iv) mobilise 'demand' in particular through better coordinated public procurement to ensure that any breakthroughs are quickly brought to market. Rather than taking the above steps independently, as is currently the case, the aim of the EIPs is to design and implement them in parallel to cut lead times. More information can be found at: http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=eip
- Joint Programming Initiatives (JPIs) part of the European Research Area Network. JPIs aim to bring together research initiatives together, either within country or between countries, to make them more effective at tackling key societal challenges. http://ec.europa.eu/research/era/joint-programming-initiatives_en.html
- Climate-KIC is one of three Knowledge and Innovation Communities (KICs) created in 2010 by the European Institute of Innovation and Technology (EIT). The EIT is an EU body whose mission is to create sustainable growth. This is supported by the Climate-KIC which aims to address climate change mitigation and adaptation (and includes the bio-economy). This involves the integration of education, entrepreneurship and innovation aiming for connected, creative transformation of knowledge and ideas into economically viable products or services that help to mitigate climate change.
- In terms of enabling businesses to develop in this, and other areas of EU strategic importance, the EU has a programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises (SMEs) (COSME). Running from 2014 to 2020 with a planned budget of €2.3bn, COSME will support SMEs in the following areas: better access to finance for SMEs; access to markets; supporting entrepreneurs; more favourable conditions for business creation and growth. http://ec.europa.eu/enterprise/initiatives/cosme/index_en.htm
- The use of EU Cohesion policy funding to set up a node of catalysts or 'facilitators' at regional/national level across EU regions to connect companies and other actors including municipalities etc. to discuss how to move towards a circular economy, identify barriers and how they can be overcome etc. This recommendation was made in the context of developing a circular economy in Europe (PSI et al, 2014) - http://ec.europa.eu/regional_policy/what/future/index_en.cfm

Source: Own compilation

[58] COM(2011) 809/3

6.5 Knowledge exchange and capacity building

In developing a bio-economy strategy, there are clearly key roles for investors and innovators in critical industrial sectors, as well as for those with an interest in the sector and its impacts, whether these are environmental, social or economic. Arrangements for engaging stakeholders are important. In the Netherlands, stakeholder engagement was one of the key enabling conditions for the development of the bio-economy. The High Level Group Bio-based Economy and the Bio-renewable Resources Platform, both public-private co-operations, were asked to provide input on the future national bio-based economy strategy. Later in the development process, further engagement came from business and relevant NGOs which signed the "Manifest for the Bio-based Economy".[59]

6.5.1 Knowledge exchange

Given the complexities of the bio-economy and the need to build new networks and connections, the exchange of knowledge of different kinds is given considerable priority in many countries, especially where utilising wastes and residues is one of the goals. Information exchange and greater geographical connection between organisations, industries, and sections of the supply chain is already being used to enable resource and infrastructure sharing as well as developing new supply chains and industrial symbiosis between different industries. The dispersed location and availability of wastes and residues, the necessary processing infrastructure and supply logistics have been highlighted in a number of studies as being limiting factors in the development of bio-based industries, particularly those with novel applications (e.g. BMBF, 2011). Industrial symbiosis[60] and industrial clustering[61] are seen as potential solutions to some of these issues (e.g. PSI *et al,* 2014; Vlaamse overheid, 2014; European Commission, 2012; BMBF, 2006).

Industrial symbiosis here refers to where multiple industries may develop as part of a production chain, for example where one industry's waste/by-products can be used as raw material for another industry. This may take place around one major facility, such as is the case in certain wood to paper processing facilities in Finland and Wales[62], or around a group of countries, such as the Bio Innovation Growth mega Cluster (BIG-C) in Belgium, the Netherlands and Germany (Box 1). Indeed most bio-economy strategies involve establishing or supporting a specific cluster and/or public-private partnership at some level.

Clustering and symbiosis can be encouraged through support for regional infrastructure and for companies seeking to develop innovative recycling and recovery technologies. This might include the development of Business parks, Business Improvement Districts and other clusters of SMEs to facilitate collective long-term contracts for extracting value from waste,

[59] http://www.bio-basedeconomy.nl/2011/10/03/manifest-voor-bio-based-economy-2/

[60] Industrial symbiosis is defined as: the sharing of services, utility, and by-product resources among industries in order to add value, reduce costs and improve the environment (Agarwal and Strachan, 2008).

[61] Industrial clustering is defined as: the geographic concentration of interconnected businesses, suppliers, and associated institutions in a particular field.

[62] Such as the UPM Shotton materials recovery facility, in North Wales, that is paired with the UPM paper mill. For every 270,000 tonnes of recyclable material that are sorted at the facility, about 120,000 tonnes are newspapers and magazines that are used at the mill as raw material. UPM Shotton has partnered with external waste management experts to produce Fibrefuel. This is a unique pellet that constitutes mainly paper fibre retrieved from wet waste, which is then shipped back to Shotton for use in energy generation.

providing economies of scale and complementary infrastructure. However, realising these opportunities may not occur naturally without targeted, specific interventions, even at the regional or local level or the organisation and promotion of such opportunities through a dedicated agency or organisation, such as SUMA or IWT Vlaanderen. Further examples of bio-economy clusters in Germany, Finland and Sweden can be found in Annex 4.

Public-private partnerships (PPPs) are used frequently as part of developing knowledge clusters to leverage different funding streams and encourage commercially focused research. For example, the Netherlands has developed numerous public-private partnerships undertaking research programmes in the area of the bio-based economy (Table 2).

Table 2: Examples of bio-economy related public-private initiatives in the Netherlands.

Public-private partnership	Focus	Partners
Knowledge Centre of Vegetable Substances (Kenniscentrum Plantenstoffen, KP)	Knowledge centre focused on upgrading residues from horticulture and the production of high-quality extractives in horticultural crops. KP provides incentives for innovation projects, scans and provides assistance in regulations	Knowledge centre established by the government and the Commodity Board for Horticulture in 2011
BE-Basic	Industrial and environmental biotechnology focused on the development of biochemical and bio-materials. Research programme and Bioprocess Pilot Facility	12 Dutch and 3 foreign knowledge institutes, 14 companies
BIOCAB	Cooperative project in the Northern Netherlands, focused on the development of technology for the production of fibres (BIOFIB), chemicals (BIOSYN) and minerals (BIONPK) from agricultural residues	Wageningen University, Groningen University, and approximately 10 companies
ISPT	Promotes research and innovation concerning sustainable process technology, such as upgrading residues that contain ligno-cellulosic materials and proteins from agricultural residues	Joint venture between the process industry and knowledge institutes

Source: Own compilation

The knowledge needed to develop bio-economy activities is on an international scale (BMBF, 2011; Carez *et al*, 2013). Partnerships within clusters and in conjunction with PPPs increasingly include links with countries outside of a particular trading area such as Europe. For example, Norway and the United Kingdom have joined with Flanders through the ERA-Net Industrial Biotechnology work programme to undertake and share research in the field of industrial biotechnology and biorefining. Similarly, the French cluster IAR has formed official partnerships with the Wagralim cluster (Wallonia), CLIB2021 (Germany), and clusters from Canada, Finland and Hungary, while BE-BASIC (the Netherlands) has signed cooperation agreements with Brazil, Malaysia, the United States and Vietnam (Carez *et al*, 2013)

Clustering and PPPs are not the only activities that are available to improve information and knowledge sharing. This can be facilitated through other forums such as events, conferences and dedicated workshops. For example each year Ghent University organises an international conference on renewable resources and biorefineries[63]. The conference aims to provide an overview of the scientific, technical, economic, environmental and social issues renewable resources and biorefineries in order to give impetus to the bio-based economy and to present new developments in this area. The conference invites key delegates from university, industry, governmental and non-governmental organisations and venture capital providers to present their views on industrial biotechnology, sustainable (green) chemistry and agricultural policy related to the use of renewable raw materials for non-food applications and energy supply. International initiatives such as the international Knowledge Based Bio-economy (KBBE) forum, established in 2010, aim to enhance the research and innovation policy dialogue and scientific cooperation between the four partners[64] regarding the most important issues of the bio-economy.

6.5.2 Capacity building

In addition to improving knowledge of technologies and the bio-economy in general, a further priority is to improve the capacity of actors to understand the bio-economy, its character in economic, technical and other terms, their role within it and how they can contribute through their businesses.

Capacity building initiatives employed in the bio-economy activities in Flanders include, amongst others, improved eco-design tool kits and assessment audits to help identify material use within a company business model. These tools are aimed primarily at reducing material consumption, and therefore waste, but could be adapted in order to improve the design of products to enable them to be reused or reprocessed more easily. Examples include:

- a free audit, called a *materials scan* to give companies a view of their current material consumption and associated costs. This includes simulations to show how consumption and costs can be reduced (www.materialenscan.be);
- the OVAM SIS toolkit is a comprehensive design tool for integrating sustainability principles in innovation and design processes. The aim is to increase the value of a product and improve material use. Five pilots have been trialed with this scheme[65];
- the Ecolizer 2.0 – an eco-design tool aimed at designers and companies who want to identify and address the environmental impact of their products;
- and the EHO-Kit, to provide guidance to teachers, university academics, education coordinators and training councils to integrate eco-design in the courses of higher education[66].

[63] http://www.rrbconference.com

[64] The European Commission, Australia, Canada and New Zealand.

[65] Beneens, a general construction company; Janssen, a pharmaceutical company; Ontex a producer of disposable hygiene products; Tuperware, the plastic container company; and WinWatt a photovoltaic solar panel provider.

[66] Flemish design academies have signed an agreement in which they commit to incorporating sustainable design in their curricula (PSI *et al*, 2014).

Capacity building is clearly important for for industry and designers, but it also is valuable for many other actors in the bio-economy, including consumers who may benefit from improved labelling and advice, and responsible government departments and public agencies (see section 6.3 on advice to governments)

6.6 Analysing and mobilising resources

Bio-economies build on a large and probably expanding variety of different biomass streams used as feedstocks. Within some categories, such as wastes, there is a wide range of resources with different characteristics that can be mobilised in different ways. One of the first steps in determining a bio-economy strategy and building the implementing infrastructure to deliver it is to analyse and understand the resource base that is going to be used.

Clearly the composition of the resource base available within a country helps to determine the key feedstocks to be utilised in bio-economy chains. Countries that have somewhat similar bioresources compositions to those in the UK, such as Germany, Belgium and the Netherlands have sought to promote actively the use of agricultural residues (such as straw) and municipal and household wastes. In Finland and other countries with significant forest cover, the harvesting and processing of residues from the wood industry are more often favoured. The *valorisation of organic waste streams and technological development* (VISIONS), project in Flanders is an example of efforts to identify the main waste and residues streams in a particular country/region that would warrant further investigation in the case of the UK. In undertaking this type of analysis the consequences of different use patterns and in particular the scaling up of technologies, characteristics, costs and availability of sustainable feedstocks and environmental consequences of their use should be explored further. This is a key part of the planning process.

Having identified the potential of different biomass resources and related market opportunities, a particular challenge for waste based supply chains is to analyse the best means of , mobilising (collection and processing) those resources. Although wastes and residues are often seen as a free and abundant resource, mobilisation is not always as straightforward as it may appear. In a review of the opportunities for mobilising cereal straw for advanced biofuel production, IEEP identified five specific barriers affecting straw supply chains in the EU (see Box 10).

The Commission's Communication on the bio-economy reflects these findings, stating that 'Enhancing a productive and sustainable bio-economy requires more research, rural, marine and industrial infrastructures, knowledge transfer networks and improved supply chains'. It continues by stressing that 'various funding sources, including private investments, EU rural development or cohesion funds could be utilised to foster the development of sustainable supply chains and facilities' (European Commission, 2012).

Box 10: Barriers to the mobilisation of cereal straw in the EU

Despite the interest from farmers in increasing the market for straw as a feedstock for energy purposes and a demand from biorefineries for straw, a range of barriers currently affect the functioning of the straw supply chain between farmers on the one hand and processors on the other. These are varied in nature and any policy response needs to be sensitive to the specific conditions in the country. Five key types of barriers have

been identified as follows:

1) *Underdeveloped markets and lack of market information*: to a large extent, the lack of supply chains for straw for bioenergy purposes is essentially related to underdeveloped markets. With the notable exception of Denmark, the energetic use of straw is not an established practice EU wide. The marketing of straw for these purposes is at different stages of development in different parts of Europe and is still embryonic in many places.
2) *Competing existing uses of straw:* straw is not an agricultural residue for which there are no alternative uses. Not only does it play an essential role as a soil improver, but other markets have developed over centuries for straw that is in excess of on-farm needs. Sourcing straw for bioenergy purposes has to compete against these other established markets and, as a result of the underdevelopment of the bioenergy market for straw, in many places, farmers are still to be convinced that it is worth their while in the long term to change existing practices.
3) *Lack of guidance on optimal use of straw as a soil improver and associated farming practices:* while some farmers carry out detailed soil analyses as well as an analysis of the nutrient and mineral content of their straw to ensure optimal levels of incorporation, this does not happen in the majority of cases. This can lead to an unnecessary level of straw being incorporated into the soil, which then reduces the surplus available for extraction for other purposes.
4) *Lack of infrastructure:* one of the issues facing land managers who might be interested in supplying straw to biorefineries is the lack of appropriate on-farm machinery and infrastructure for straw handling and bailing to meet the requirements of the processors.
5) *Variability of straw supply*: from the processors' perspective, a major issue is the variability in the quantity and quality of straw available year to year and region to region, as a result of climatic conditions and fluctuating straw yields.

Source: Kretschmer *et al*, 2011

The approaches taken to overcome such issues are numerous and include investments in machinery, setting up of producer groups and funding of various kinds. In the case of agricultural residues, the Common Agricultural Policy, through Member State rural development programmes can help to provide funding and support in these areas (Kretschmer *et al*, 2012, p51). Co-financing to provide an economic incentive to supply can also be an effective tool. For example, in 2009, the US Government provided a matching payment up to $50 per dry tonne of biomass from agricultural producers selling to biofuel manufacturers.

6.6.1 Improved waste collection as a means of mobilising resources for the bio-economy

Unlike some land management and production residues, which often can be collected in the form of relatively homogeneous material, other forms of waste, such as municipal solid waste or industrial wastes, tend to be more heterogeneous. This can cause technical problems and create costs for processers that rely on uniform feedstocks of a certain quality. Therefore, ensuring that there is sufficient waste resource of the right quality and within tolerable levels of variation available for processing is a key enabling factor for encouraging investment in new process and supply chains.

The pattern of wastes and residues arising in Europe is driven by a combination of market forces and policy intervention. Three separate pieces of EU legislation and related targets have been driving waste reduction and recycling efforts in recent years and have helped to prompt the separate collection of certain waste streams. These are: the Landfill Directive and its landfill diversion target for biodegradable municipal waste; the Packaging and

Packaging Waste Directive and its recycling targets; and the Waste Framework Directive with its recycling target for household and similar wastes[67] (EEA, 2013).

Within the framework of these directives Member States have chosen to use a range of instruments to achieve their ambitions. The EEA identified different policy instruments used to promote the recycling of municipal solid waste in 32 European countries[68]. These include: waste management plans, landfill taxes, incineration taxes, landfill bans on organic wastes, mandatory separate collection, and economic incentives. Countries using a mix of these different instruments tend to have higher recycling rates than those focussing on one or only a few instruments. Of all the instruments reviewed, they found a clear correlation between the cost of landfilling and the share of municipal waste recycled in Member States, with gate fees and regulatory restrictions also playing an important role in shaping waste management decisions (EEA, 2013). Similar conclusions were drawn from an earlier report looking at economic instruments that can be used to promote better waste management in the EU (IEEP *et al*, 2012).

Several countries have, developed innovative approaches to waste management that have led to improved rates of recycling. Some focus on the consumer (i.e. householders), others on the municipality or government, and a third group on producers. On the consumer side, Finland, Denmark, Sweden and Austria have introduced the separate collection of waste paper from households, and Germany has introduced a separate recycling bin for metals and plastics. By 2013 eight countries had mandatory separate collection of non-packaging waste, and seven had some form of mandatory separate collection of bio-waste fractions[69]. Twenty countries have used some form of economic incentive[70] to encourage consumers to reduce, reuse or recycle more materials. For example, in Belgium, high household fines for failure to follow requirements to separate waste materials at the source and a maximum generation of residual MSW per capita[71], coupled with recycling quality standards, have helped to increase recycling of waste from domestic households. The Flanders region requires the separate collection of 11 different types of wastes from households and 18 different types of wastes from industrial premises.

In Luxembourg the approach has been more focussed on improving access to facilities and developing infrastructure, such as: design standards for separate collection in new households; the introduction of one container park (recycling facility) for every 10,000 inhabitants; and ensuring that 100 per cent of the population is covered by separate collection regimes. France has opted to take a slightly different approach. In addition to landfill bans, incineration taxes and economic incentives, the French authorities have also increased the requirements on producers (rather than consumers) by introducing a national

[67] There is a range of other relevant legislation in this area including the EU's WEEE Directive and Batteries Directive. For more details about the legislative instruments used to improve waste recycling in the EU, see IEEP *et al*, 2012.

[68] EU-28 with the addition of Iceland, Norway, Switzerland and Turkey

[69] It should be noted that the EU Waste Framework Directive requires Member States to implement by 2015 separate collection for at least the following: paper, metal, plastic and glass.

[70] Which pay-as-you throw schemes such as fees after weight, size, collection frequency other than just paying collection fee on the basis of property value, area of the property, household size or similar.

[71] Italy, Germany and a number of other countries have also introduced such an approach to limit waste generation per capita.

extended producer responsibility scheme for a variety of products such as non-packaging paper, textiles and furniture.

In some cases, very specific initiatives have been made to mobilise waste resources for bio-economy applications. One example is the waste-bread-round[72] in Vantaa, Finland.

Box 11: The waste-bread-round, Vantaa, Finland.

SITA Finland, a member of **Suez Environment Group**, has been working with St1 Biofuels to close the loop between waste bread and bioethanol production. SITA was one of the first waste management companies to collect bakery-waste and excess bread from local bakeries and supermarkets to use in the production of bioethanol.

SITA Finland collects (at no extra cost) out of date or leftover unpackaged and packaged bakery products* from bakeries and supermarkets in separate waste bins, 1-5 times a week depending on the store size. These are then delivered to an St1 Biofuels' Etanolix® plants where they are turned into fuel. Collection trucks operate on waste-based bioethanol fuel, which cuts local vehicle emissions.

The St1 Biofuel's Etanolix® plant utilising waste bread is located in SITA's waste treatment site in Vantaa, Finland, facilitates cooperation and synergies between the companies.

The Food Safety Authority in Finland requires registration by all animal-feed producers, and includes those bakeries and stores which provide left-over-products to farmers as animal feed. Registered animal-feed operators are responsible for the feed-chain and its traceability. Thus by diverting waste products into the energy supply chain bakeries and stores are released from the statutory registration and necessary controls applying to animal feed producers which is a bonus for them.

Source: Own compilation based on various sources **Note: *** Packaged & unpackaged bread and other bakery products; Baked waste dough; No mouldy products; No products containing meat or fish

Some brief case studies on the approaches to waste collection in different countries can be found in Annex 3.

6.6.2 Sustainable mobilisation of resources

Some strategies recognise that the bio-economy should be a framework through which to promote the better management and reduction of waste in society, by using waste as a feedstock for higher value products. Many bio-economy strategies are focussed on the use of bioresources for the production of specific materials, chemicals or fuels with potentially wide ranging benefits. However, there is a risk that the waste resources used to meet these objectives will be concentrated on those that are easiest and cheapest to collect rather than those that are a priority in terms of minimising impacts on the environment and contributing to wider resource efficiency targets.

The Flanders' Materials Programme (2013) is one example where better waste management is put at the core of materials management and accesses levers such as the creation of a bio-economy focusing on the use of the most suitable biomass (including waste and residues) for high-value applications or energy supply applications. This will be supported by

[72] http://www.st1biofuels.com/sustainability

the forthcoming Biomass Residues Action plan[73] (foreseen to be approved in 2015 by the Flemish government).

Clearly the use of waste resources to underpin a bio-economy should not inadvertently promote the unsustainable utilisation of wastes or other bioresources. Although a bio-economy may seek to maximise the utilisation and value of waste resources sourced from a variety of other sectors it should not serve to promote or incentivise an increase in the production of waste. Care will need to be taken in the way policies are developed to promote the utilisation of waste and the scale of deployment without leading to unsustainable development trajectories that would conflict with existing efforts to reduce waste. Similarly the review of existing bio-economies has shown that only in limited circumstances are biorefineries, bio-materials facilities or substantive new bio-economy sectors, based entirely on wastes or residues. For reasons of supply and economics, wastes often act as a supplement to, or are supplemented by other forms of biological resources, such as crops, wood pellets or other forms of biomass. An example is the combination of purpose grown energy crops utilised alongside agricultural residues in the Crescentino Biorefinery in Italy (Box 17, Annex 5). In such cases there is a potential risk that the promotion of the use of wastes may lead to the indirect promotion of the use of other bioresources beyond sustainable limits.

Steps to limit such adverse impacts have been taken in different countries. One example is the newly proposed set of rules in Denmark to report and limit the use of certain crops for biogas production that receives public support. As of August 1, plants receiving government aid will be allowed to use no more than 25 per cent of crops grown for energy production as part of their overall energy mix. The total will fall to 12 per cent as of August 1, 2018. However, agricultural waste or food waste will be excluded from such restrictions.

[73] The plan looks at achieving an integrated and sustainable management of all biomass by 2030, focusing on waste prevention and recycling, but also at valorising end products for the production of bio-based products or their use in bio-refineries. the action plan focuses on biomass in three sectors: the agricultural-food chain, open space (e.g. forests, natural reserves, parks, gardens,…) and the industrial and postconsumer wood streams. A separate chapter is dedicated to the contribution of Flemish biomass residues to the RE targets for the Flemish region. (Vanaken N, *pers comm*).

7 Conclusions

There is a series of common themes that occur frequently in those bio-economy strategies and initiatives being established in the range of countries reviewed in this study. These are presented here as preliminary conclusions to emerge from this review and as guiding principles which might be useful for the development of future bio-economy initiatives, including those based on waste resources.

It is important to recognise that there is already a large and functional bio-economy operating in the UK, one that encompasses both the more established biomass based sectors, such as food production, and more novel approaches to producing chemicals, energy and other products from bioresources. The guiding principles set out here could help to inform initiatives to further stimulate the development of key segments of this bio-economy. This would in turn support the extraction of the maximum value from wastes and afford a substantial economic opportunity whilst remaining sustainable, in line with the House of Lord's recommendations.

- ***Clearly defined objectives and guiding principles are valuable when building a bio-economy. The*** strategies being put in place in different countries include a range of different objectives, such as reducing society's dependence on fossil resources; preventing biodiversity loss; creating new economic growth and jobs; reducing energy consumption; and mitigating climate impacts. However, such objectives are not always presented coherently and while many of them may be complementary, this is not always the case. Given the potential diversity of actors and interests involved, it is important to articulate clearly the purpose and aims of developing a bio-economy. This should help actors to coalesce around a common objective(s) and to steer investment, research and policy towards a cost efficient and environmentally responsible outcomes. The guiding principles in the German national policy strategy on the bio-economy[74] are one example. These are used to inform three cross-sectoral and five thematic areas of action, along with specific supporting measures.

- *Incentives need to be aligned with these objectives rather than being based on previous priorities.* '***A level playing field must be created for the different uses of biomass – such as food, feed, bio-based products and bio-energy – by reviewing incentives and regulatory frameworks. This is a prerequisite for increasing the value generated from biomass, and for stimulating the value chains'***. This recommendation is taken directly from the Copenhagen Declaration for a Bio-economy in Action that was agreed under the Danish presidency of the European Union in March 2012. Some selectivity in incentives may be appropriate in the light of broader policy objectives but the balance at present is skewed in the direction of bioenergy.

- ***The Bio-economy can be a useful forward looking framework through which to promote the better management and reduction of waste in society as well as establishing new value chains and economic activity.*** Some of the greatest value in

[74] Federal Ministry of Food and Agriculture (BMEL) (2014) National Policy Strategy on Bio-economy: Renewable resources and biotechnological processes as a basis for food, industry and energy.

using waste as a feedstock in the bio-economy is to reduce the impact that waste generation has on society and the environment. Many bio-economy strategies are focussed on the use of bioresources for the production of specific materials, chemicals or fuels in order to provide new, high value commodities to society with less reliance on fossil fuels. Although this is to be applauded, there is a risk that the waste resources used to meet these objectives will be too much concentrated on those that are easiest and cheapest to collect rather than those that would contribute most to resource efficiency and environmental goals. The Flanders' Materials Programme (2012) is one example where better waste management is put at the core of materials management..

- ***The use of waste resources to underpin a bio-economy should not inadvertently promote the unsustainable utilisation of wastes or other bioresources or create unsustainable supply chains.*** Care will need to be taken in the way policies are developed to promote the appropriate utilisation of waste and the correct scale of deployment without leading to unsustainable development trajectories that would conflict with existing efforts to reduce waste. This review of emerging experience in different countries has indicated that only in limited circumstances are biorefineries, bio-materials facilities or substantive new bio-economy sectors based entirely on wastes or residues. For reasons of supply, technical considerations and economics, wastes often act as a supplement to, or are supplemented by other forms of biological feedstocks, such as agricultural crops, or wood pellets. The combination of purpose grown energy crops alongside agricultural residues in the Crescentino Biorefinery in Italy is one example. There is a potential risk that the promotion of the use of wastes may lead to indirect incentives for the extended use of other bioresources beyond sustainable limits. Steps to limit such impacts have been taken in different countries, such as the newly proposed law in Denmark to report and limit the use of certain crops for those biogas production plants that receive public support.

  Analysis of the potential scale, nature and dynamics of relevant waste resources in the UK should be undertaken in order to inform strategy for the bio-economy and help to focus interventions. Economic and environmental issues need attention as part of this exercise which needs to consider the implications of operating at different scales. The different variants of bio-economies reviewed in this study confirm that the specific composition of the resource base available within a country will be an important determinant of the appropriate strategy to adopt. Experience in a number of industrialised and densely populated countries such as Belgium, Germany and the Netherlands will potentially be relevant to the UK, as noted in Chapter 6. The *Valorisation of organic waste streams and technological development* (VISIONS), project in Flanders for example warrant further investigation.

- ***Measures to promote targeted research, knowledge exchange and significantly wider understanding of emerging aspects of the bio-economy, in particular new and novel technologies should be developed***. - The UK is home to world-renowned research and development institutions and established practice. There is an opportunity to capitalise on this foundation to foster the development of new technologies and approaches to utilising waste for high value applications. Research centres of excellence, funded research positions in universities and applied research facilities may all have a role and

justify selected support to help build the knowledge and technology for accelerated waste re-use. For example, in Flanders, the Policy Research Centre for Sustainable Materials Management (SuMMa[75]) brings together five major research institutions to work in cooperation with public organisations such as the Flemish Department of Economy and the Public Waste Agency. The latter provide funding for preparing research papers or publications to create a knowledge base to underpin the bio-economy. In the Netherlands, public-private initiatives have been developed to help improve information exchange between researchers and those implementing new approaches, as well as between research and innovation groups such as BioCab. The Dutch Ministry of Economic Affairs actively promotes cooperation between businesses, knowledge institutes and the government through two platforms focused on generating new bio-based business cases – the Bio-renewables business Platform and the Agri-Paper-Chemical Platform.

- ***Industrial clustering and industrial symbiosis should be explored and potentially promoted as an aid to the more effective utilisation of knowledge, resources and infrastructure in developing the bio-economy.*** In the classic case one industry's waste/by-products can be used as raw material for another industry but the right conditions for this to happen may depend on external help or prompting rather than arising through the market alone. For example, clustering and symbiosis can be encouraged through support for regional infrastructure and for companies seeking to develop innovative recycling and recovery technologies. This might include the development of Business parks, Business Improvement Districts and other clusters of SMEs to facilitate collective long-term contracts for extracting value from waste, providing economies of scale and complementary infrastructure. It would be timely to encourage join up between relevant sectors and waste processors. Free-to-business advice and networking programmes could be developed at a regional level to identify and pursue opportunities for advancing more exchanges between companies pursuing sustainable resource management solutions – e.g. the National Industrial Symbiosis Programme (NISP). Targeted, interventions may be needed at both the national and more local levels. A dedicated agency or organisation could help with this.

- ***Consideration should be given to the creation of an advisory body that also has a role in driving forward goals and co-ordinating the development of a waste-based bio-economy***. The development of advisory bodies is one of the key initiatives that has helped several countries to start to build leading positions in the bio-based or bio-economy. Advice can help to inform and support policy making as well as assisting the range of private and public bodies involved in the bio-economy. **The** German Bio-economy Council was established as an independent advisory board to the Federal Government in 2009 with 17 members whose expertise covers the full spectrum of the bio-economy. The central task is to search for ways and means to arrive at sustainable solutions, and to present their insights in a global context. Both the Flemish and the Dutch governments have set up advisory bodies designed to support integrated and cross-policy approaches. These bodies include relevant government Departments and related agencies, as well as knowledge institutes and relevant stakeholders. At the same

[75] www.steunpuntsumma.be

time there are good reasons to utilise and perhaps expand the capacity of any existing organisations which might benefit from having more of a bio-economy focus in the UK. Such bodies might include the Waste and Resources Action Programme (WRAP) and Zero Waste Scotland, which already provide advice, business and financial support to the resource management sector including in relation to the bio-economy. However, this is simply an example. It is not within our remit to analyse the role of different bodies within the UK.

- ***There is scope for helping businesses to utilise waste resources more efficiently particularly through innovation and partnership and to capitalise on existing regenerative loops.*** The options include:
    - *The development of specific infrastructure* which can help to accelerate innovation and lower costs. The Belgian Bio Base Pilot Plant is an example;
    - *The provision of financial incentives in the form of tax breaks or business loans* these could focus on the development of certain strategic elements of the bio-economy.
    - *The development of policy targets promoting the use of waste or production of bio-based products*, such as the Decree Law[76] introducing targets for advanced biofuel production in Italy from 2018.
    - *Introducing other market enabling mechanisms, such as certification or labelling, of products or process*. Although there is academic research into this area no information on labels and certificates for bio-based products was found in the countries reviewed.

- ***The full range of stakeholders from industry, government, technical institutions and civil society should be included in the development of a UK bio-economy.*** Development of a sustainable economy can not only involve a considerable number of actors with a direct stake in the process but have impacts on many more, with wider but legitimate interests in the economic, environmental and social aspects. Recognising this in the Netherlands, two public / private bodies, the High Level Group Bio-based Economy and the Bio-renewable Resources Platform, both were asked to provide input on the future national bio-based economy strategy. Later in the development process further engagement came from business and NGOs which signed the Manifest for the Bio-based Economy.[77]

[76] Decree Law on updating the conditions, criteria and procedures for implementing the obligation to release biofuels for consumption, including advanced biofuels (August 2014)
[77] http://www.bio-basedeconomy.nl/2011/10/03/manifest-voor-bio-based-economy-2/

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Annex 1 Definitions of the bio-economy and waste

This annex provides an overview of the different definitions of bio-economy used in ten countries.

Table 3: Definition of bio-economy used in different countries

Country	Definition and reference to waste	Source(s)
Belgium (Flanders)	**Bio-economy** includes both the production of renewable biological resources and the use of those resources and residual streams. These are used in processes and are processed into valuable products such as food, animal feed, (bio-based) products and bioenergy. '[i]n a **bio-economy** (sic) the building blocks for all materials, chemicals and energy are derived from renewable resources, instead of fossil resources such as petroleum. A bio-economy encompasses the entire value chain: production of renewable raw materials, industrial transformation into sustainable products and marketing them. The **bio-based economy** is the use and/or conversion of renewable raw materials for bio-based products and energy. **Waste** is one of the base materials utilised in a bio and bio-based economy	JRC, 2014a The Flanders materials programme (OVAM, 2013) EWI, 2012
Canada (Province of British Columbia)	**Bio-economy** refers to the utilisation of biological systems to achieve sustainable economic objectives. The word bio-economy covers a very broad range of activities, touching on nearly every aspect of society. For practical reasons, the Bio-economy Committee of Canada focussed its assessment of bio-economy opportunities in British Columbia by looking first at the utilisation of forest biomass, while remaining cognizant of major activities in other areas. No explicit reference is made to waste in the definition	Bio-economy Committee, 2011)
France	No official definition has yet been adopted.	JRC, 2014b
Italy	No official definition has yet been adopted. However, the Bioenergy Sector Plan defines the **bio-economy** as follows: '*[t]he bio-economy identifies new trends involving relocation and reorganization of production and processing, in relation to the natural resources of an area. This is possible, for example, through the development of biorefineries, understood as flexible technological systems able to use a wide variety of biomass to obtain, through integrated processes in the food sector and agro-industry, a wide range of products*.' The term **Green Economy** is more developed referring to '*an economy or economic development model based on sustainable development and knowledge of ecological economics*'. No explicit reference is made to waste in either definition	JRC, 2014c
The Netherlands	The Netherlands gives deference to the European definition of bio-economy (see above) but go on to define the bio-based economy. The **bio-based economy** is used to describe that part of the economy that is active in producing bio-based materials and products and bioenergy. In particular, the bio-based economy is '*an economy in which plastics, transport fuels, electricity, heat and all kinds of everyday products are made from vegetable raw materials (instead of fossil resources').* No explicit reference is made to waste in the definition	JRC, 2014d
Spain	**No official definition** has yet been adopted, although discussions around the development of a bio-economy are on going.	JRC ,2014e
Germany	**Bio-economy** is the *knowledge-based production and use of renewable resources*	

	to provide products, processes and services in all economic sectors, within the framework of an economic system, which is viable for the future. '*….the bio-economy encompasses all economic sectors and their associated service areas, which produce, work and process, use or trade with renewable resources – such as plants, animals and microorganisms and products made from them*'. Explicit reference to biogenic waste materials and residual materials is given in relation to the bio-economy. The cascading principle for material use is also considered, as is the materials lifetime in relation to its sustainability. The **Biorefinery** is also defined in conjunction with the bio-economy as an explicitly integrative, multifunctional overall concept that uses biomass as a diverse source of raw materials for the sustainable and simultaneous generation of a spectrum of different intermediates and products (chemicals, materials, bioenergy/biofuels), whilst including the fullest possible use of all raw material components. The co-products can also be food and/or feed.	BMEL, 2014 BMELV, 2012
Finland	The **Bio-economy** refers to an economy that relies on renewable natural resources to produce food, energy, products and services. The bio-economy will reduce our dependence on fossil natural resources, prevent biodiversity loss and create new economic growth and jobs in line with the principles of sustainable development. Explicit reference to waste is made within the Finnish strategy paper on the bio-economy in that '*in a sustainable bio-economy, **wastes** and industrial side streams will play an even more significant role than raw materials'*.	
USA	A **bio-economy** is one based on the use of research and innovation in the biological sciences to create economic activity and public benefit. No explicit reference is made to waste in the definition	The White House, 2012
Sweden	**Bio-based economy/bio-economy** are considered in the same context. These related to the '*…sustainable production of biomass to enable increased use within a number of different sectors of society. The objective is to reduce climate effects and the use of fossil based raw materials*. An increased added value for biomass materials, concomitant with a reduction in energy consumption and recovery of nutrients and energy as additional end products. The objective is to optimize the value and contribution of ecosystem services to the economy. Explicit reference is made to the use of ***by-products and waste***. A prerequisite of Sweden's definition of a sustainable bio-economy is that resources are used optimally. By-products and waste provide opportunities to generate energy or new products.	FORMAS, 2012

Source: Own compilation

Box 12: The European Waste Framework Directive (EWFD) definition of waste

The EWFD* (Article 3(1)) states that waste means 'any substance or object which the holder discards or intends or is required to discard'. However, several other aspects of the EWFD are relevant in defining what constitutes waste and how it is used in relation to defining certain bio-economy feedstocks. These are:

- Article 2(1)(f) explicitly excludes from the Waste Framework Directive's scope 'faecal matter, straw and other natural non-hazardous agricultural or forestry material used in farming, forestry or for the production of energy from such biomass through processes or methods which do not harm the environment or endanger human health'. In addition, Article 2(2)(b) excludes (to the extent that they are covered by other EU legislation) 'animal by-products including processed products covered by Regulation (EC) No 1774/2002, except those which are destined for incineration, landfilling or use in a biogas or composting plant'.
- Article 3(4) defines bio-waste as 'biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing

plants'.

- Article 6 offers a broad definition of when a waste ceases to be waste, stating that this is 'when it has undergone a recovery, including recycling, operation and complies with specific criteria to be developed'. However, these criteria are still in development. Although background work has been done on biodegradable waste (one of the main potential renewable energy feedstocks) this may not result in a proposal for specific end-of-waste criteria. It is also relevant to note that recovery of waste as defined by Article 3(15) encompasses operations that have as their principal result the useful substitution of waste for another material that would otherwise have been used to fulfil a particular function. Annex II of the Directive further clarifies that recovery includes 'use principally as a fuel or other means to generate energy', but only includes incineration if it reaches a specified energy efficiency threshold.
- There are no definitions of municipal or industrial waste provided within the Directive.

Source: Adapted from Kretschmer *et al*, 2013 **Note:** * Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives

Annex 2 Bio-economy strategies covered by this study

Table 4 provides an overview of the main bio-economy strategies and related activities covered by this study. Further studies and reports were reviewed and can be found in the bibliography.

Table 4: Countries promoting the development of a bio-economy

Country	Policy document	Aim of the policy / initiative
Germany	**National Policy Strategy on Bio-economy** (BMEL 2014)	To develop a coherent policy framework for a sustainable bio-economy
	National Research strategy Bio-economy 2030 – our route towards a bio-based economy (BMBF, 2010)	To Establish the conditions for the vision of a bio-based economy by 2030.
	Biorefineries Roadmap (BMELV, 2012)	To provide an analysis and preliminary assessment of future developments in the field of action of biorefineries
Finland	**Finnish Bio-economy Strategy** (Finnish Govenment, 2014)	To generate growth and jobs from the bio-economy
USA	**National Bio-economy Blueprint** (The White House, 2012)	To lay out strategic objectives that will help realize the full potential of the U.S. bio-economy and to highlight early achievements toward those objectives
Sweden	**Swedish Research and Innovation Strategy for a Bio-based Economy** (FORMAS, 2012)	To provide FORMAS with a national strategy for the development of a bio-based economy and to propose a Swedish definition of the term. This should cover R&D needs, initiatives for innovation, needs for coordination
Belgium (Flanders)	**Renewable Energy Action Plan 2020** (Forthcoming in 2015)	Establishes a framework for the transition of Flanders to renewable energy. It also covers the use and the sustainability of the available biomass sources and the search for the most valuable use for each energy sources. The cascading principle is in force for wood.
	Biomass Residues Action Plan (Forthcoming in 2015)	Sets a framework for • The transition towards a sustainable management of biomass residues in 2015 – 2020; • An integrated and sustainable management of all biomass by 2030; Relates to the following core principles: materials hierarchy and cascading principle.
	Bio-economy in Flanders. The vision and strategy of the government of Flanders for a sustainable and competitive bio-economy in 2030 (Vlaamse overheid, 2014)	The Strategy contains a number of strategic objectives providing the framework for the (further) development of a Flemish bio-economy 1. Development of a coherent Flemish policy that supports and facilitates a sustainable bio-economy; 2. Put Flanders at the top for education, training, research and innovation in future-oriented bio-economy clusters; 3. Sustainable and optimal use of biomass across the value chain; 4. Strengthening of markets and competitiveness of bio-economy sectors in Flanders 5. Flanders as key partner within European and international joint ventures

	The Flemish Material Programme (OVAM, 2012)	The Programme is led by the Public Waste Agency of Flanders (OVAM) and includes a transition project on sustainable materials management in the context of a green circular economy.
	Sustainable use of biomass in the bio-economy (MINA-raad and SALV, 2013) (in Flemish)	Opinion of the advisory council on environmental and nature protection policy of the Flemish government (MINA-raad) and the strategic advisory council for agriculture and fisheries (SALV) assessed the sustainable use of biomass in the bio-economy as a contribution towards the overall Flemish bio-economy vision
	Sustainable use of and creation of value from renewable raw materials for bio-based industrial production such as bio-materials and green chemicals in Flanders (2013)	Study to support the Flemish Government in developing its own strategy for a bio-based economy (BBE)
	Flanders in Action (VIA) (2011)	Social and economic action programme for the future of Flanders by 2020. The Plan identifies a number of societal challenges entailing the promotion of a long-term strategy and identifying several transitional priorities, amongst which **sustainable material management** (linking to smart product development and the re-use and recycling of materials).
Belgium (Wallonia)	**GreenWin cluster** (in French)	Presentation of the GreenWin cluster in Wallonia
Canada (Province of British Columbia)	**BC Bio-economy** (Bio-economy committee, 2011)	The report provides a snapshot of the activities underway across the province and around the world (Ontario, Alberta, USA, Europe and Finland). The finding of the Bio-economy Committee, established in 2011, are presented along with recommendations for action by the BC government on how to accelerate the development of BC's bio-economy.
France	**National Bio-economy Profile – France** (JRC, 2014b)	Summary of the major initiatives on the bio-economy in France
Hungary	**The future landscapes of bio-economy: Hungary** (Climate-KIC, 2014)	Deliver insights into the Hungarian bio-economy scene
	Decree Law on Updating the conditions, criteria and procedures for implementing the obligation to release of biofuels for consumption, including advanced biofuels (2014)	The Decree Law introduces binding sub-targets for advanced biofuels from 2018
	Sector Plan for Bioenergy (2014)	The Sector Plan provides strategic direction in the field of bioenergy. It is a strategic tool to engage and guide government and farmers towards the development of sustainable bioenergy. It also encourages the development of the bio-economy, as well as of the 'green chemistry'.
	National Strategic Plan for innovation and research in the agro-food and forestry sectors Draft version presented Rome in July 2014	The document presents the framework for action in relation to innovation and research. This was done in the context of the opening of the Italian Presidency to the EU and at the beginning of the programming phase 2014 – 2020.

	[*Piano Strategico per l'Innovazione e la Ricerca nel Settore Agricolo, Alimentare e Forestale*]	The Strategic Plan identifies various areas for further development, amongst which 'Sustainable use of biological resources for energy and industrial purposes'. This would be achieved through the development of a bio-economy
	National plan for renewable energy sources (2010) (in Italian) **[*Piano di Azione Nationale per le fonti rinnovabili di energia (PAN) (2010)*]**	The National Plan for Renewable Energy provides strategic direction on the measures to put in place, in the context of transport, electricity, heating and cooling sectors, in order to achieve the 17% renewable energy target established by the Directive 2009/28/EC for Italy.
	Industrial Biotechnology in Italy (2009)	The reports provides an overview of the state of play of industrial biotechnology in Italy, given that the Italian government has allocated funds to support R&D and has established an advisory committee
	Goals of Bioenergy in Italy. Report 2008	The report sets a number of priority for the development of the bioenergy sector in Italy
The Netherlands	**The Bio-based Economy in the Netherlands** (2013)	The document presents aim and scope of several bio-based initiatives undertaken in the Netherlands
Spain	**National Bio-economy Profile – Spain** (JRC, 2014e)	Summary of the major initiatives on the bio-economy in Spain

Source: Own compilation

Annex 3 Case studies on waste collection in four countries

This annex provides a summary overview of the different approaches to waste collection in three EU countries: the Flanders region of Belgium; Germany; and Italy.

1. Waste collection in Flanders

In Flanders, the Flemish waste legislation (VLAREMA 2012) requires the separate collection of 11[78] different categories of household waste and 18[79] different categories of industrial waste. Waste collection and management in the region relies on source separation as much as possible to ensure more homogeneous fractions of waste resources.

In some cases, waste that has the potential for high-quality material recycling, as well as wood waste, can be collected in the same container under the following cumulative conditions:

- it is dry, non-hazardous waste fractions where the merging of the groups sorting and does not obstruct the high-quality processing of individual waste fractions;
- the container is transferred to a licensed sorting facility where the fractions are fully sorted out;
- the waste producer about it has concluded a contract with a collector, dealer or waste broker, where the pooled fractions are specified.

For businesses the separate collection of waste is mandatory and requires a contract with a waste collection organisation (Article 6.1.1.4, VLAREMA 2012) unless the business waste is similar in nature, composition and quantity to that of a household[80]. Where businesses are co-located, such as on an industrial park or complex waste collection can be grouped into a single collection for all companies in the park.

In 2013 a total of 3.2 million tonnes of household wastes were produced in Flanders. 71 per cent of this was collected separately, reduced, recycled or composted. The remaining wastes were not subject to separate collection with 27 per cent being incinerated with energy recovery, two per cent being dried and separated, with the rest either burnt without energy recovery or disposed of by other means (De Groof and Vandecruys, 2013).

Further reading on waste collection in Belgium:

[78] Article 4.3.1 of VLAMERA 2012 (Household waste) hazardous waste from households; glass bottles and jars; paper and cardboard waste; bulky waste; green waste; textile waste; waste electrical and electronic equipment; waste tires; debris; asbestos-containing waste; PMD waste; wood waste; and metal. For households Wood waste and Metal waste must be separately presented and further kept separate during collection, or, if not demonstrably possible, subsequently sorted after collection.

[79] Article 4.3.2 of VLAMERA 2012 (Industrial waste): hazardous household waste of comparable industrial origin; glass waste; paper and cardboard waste; used animal and vegetable oils and fats; green waste; textile waste; waste electrical and electronic equipment; waste tires; debris; waste oils; hazardous waste; asbestos-containing waste; discarded equipment and receptacles that contain ozone-depleting substances or fluorinated greenhouse gases; waste agricultural films; waste batteries and accumulators; PMD waste; wood waste; and metal.

[80] limited to 4 bin bags of 60 litres or one container of 240 litres a fortnightly collection and that the maximum amount is collected in one round with household waste.

C. Gentil E (2013) Municipal waste management in Belgium. Paper prepared by the European Topic Centre of Sustainable Consumption and Production (ETC-SCP) for the European Environment Agency (EEA) under its 2012 work programme as a contribution to the EEA's work on waste implementation.

2. Waste collection in Germany

In Germany, source separation of organic residues from households, gardens and parks (i.e. biowaste) is one of the main measures in waste management. In 2010 approximately 64 per cent (8.2 Mt) of such wastes were collected separately from a total resource of 12.9 Mt. 3.85 Mt of this waste is from households via the biobin collection service, with the remaining 4.4 Mt originating from park and garden waste (Statistisches Bundesamt, 2010). Up to 80 per cent of all inhabitants (depending on the region) or 68.7 per cent of the total area of Germany is covered by separate collection of household, garden and park wastes via biobins (BGK/VHE, 2009).

The centrepiece of waste policy and legislation governing collection is the German Kreislaufwirtschaftsgesetz (KrWG), the law to promote circular economy and ensuring the environmentally friendly management of waste[81]. This law lays down the principles of waste management in Germany including the waste management hierarchy (prevention – recycling– disposal) as well as acting as the legal basis for different ordinances[82] regulating specific waste streams. With the introduction of this law and associated ordinances, German waste disposal authorities are required to separately collect organic waste by 2015.

The Gewerbeabfallverordnung provides the specific criteria commercial waste collection. In general, producers and proprietors of commercial waste (i.e. paper/cardboard, glass, plastics, metals and biodegradable waste (kitchen, garden, park waste and market waste) must store, collect and recycle those separately[83].

There are a range of other related instruments governing waste reduction, collection and re-use within German Law. These are summarised in IEEP *et al*, 2012 and include:

- ordinance on landfill sites and long-term storage banning the disposal of mixed municipal waste;
- pay-as-you-throw (PAYT) schemes where, largely householders, pay an increasing amount depending on the volume of waste being disposed of;
- national and regional waste management plans;
- and, producer responsibility schemes obliging producers and retailers to take back and comply with minimum recycling and recovery rates of certain types of waste (e.g. waste oils and waste packaging).

[81] http://www.gesetze-im-internet.de/bundesrecht/krwg/gesamt.pdf

[82] The Gewerbeabfallverordnung (ordinance on commercial waste); the Deponieverordnung (Ordinance on Landfill Sites and Long-Term Storage Facilities); the Verpackungsverordnung (waste packaging ordinance); amongst others.

[83] As an alternative, the waste need not be collected separately if the mixed waste is treated in a pre-treatment facility that sorts the materials and allows a recovery level of 85%.

Further reading on waste collection in Germany:

Annex 2 (Full Case Studies) of IEEP, Eunomia, BIO IS, Umweltbundesamt, Ecologic and Arcadis (2012) 'Economic instruments to improve waste management', Final report, Contract ENV.G.4/FRA/2008/0112, European Commission (DG ENV), http://www.ieep.eu/publications/2012/04/economic-instruments-to-improve-waste-management

Döing M (2012) Market Study Biowaste Bin. The market for separate collection and recovery of organic household waste in Germany. Report produced by ecoprog, Cologne, Germany.

European Compost network (ECN) (2010) Organic Resources and Biological Treatment - Country Report of Germany

Fischer C (2013) Municipal waste management in Germany. Paper prepared by the European Topic Centre of Sustainable Consumption and Production (ETC-SCP) for the European Environment Agency (EEA) under its 2012 work programme as a contribution to the EEA's work on waste implementation.

3. Waste collection in Italy

Based primarily on Ricci-Jürgensen, 2013
The separate collection of organic waste represents the largest portion of Italy's recycling industry. Intensive source- separation of bio-waste is a key-factor for gaining high recycling rates and is currently applied in 4,000 municipalities, involving around 40 million inhabitants

With over 4.5 million tonnes of biowaste – a combination of both food waste and garden waste - being collected each year in Italy, and used to produce some 1.3 million tonnes of quality compost used in agriculture, landscaping, and other activities, the sector is the country's largest contributor to recycling.

Surveys conducted by the Consorzio Italiano Compostatori (CIC) or Italian Biogas and Composting Consortium show that biowaste collected under optimised conditions and recycled in composting plants contribute significantly to Italy achieving both national and EU targets for recycling biowaste and reducing the amount of Municipal Solid Waste (MSW) sent for disposal.

Key to achieving this success has been the door-to-door collection of food waste, combined with compostable bags, which enables the best-performances in terms of capture and quality - i.e. the minimisation of non-compostable materials present in biowaste collections. Since the mid-90s CIC has been involved in developing and enforcing adequate recycling capacities for biowaste. In 1997 the Italian general Waste Act (Dlgs 22/1997) significantly altered the legal framework and vision for MSW management - the separate collection of biowaste became a strategic element to reach the recycling targets set out in the national law.

Italy's official data for 2011 shows that 4.5 million tonnes/year of biowaste was separately collected and recycled in composting or Anaerobic Digestion (AD) plants. This amount rose

to 4.8 million tonnes in 2012 and the CIC estimates that by end 2013 the amount will reach five million tonnes. In Italy biowaste is generally collected by means of two separate collection schemes: A scheme intercepting food waste, including both cooked and uncooked food-residues and including meat, fish, etc.; and a scheme intercepting garden waste, with lower frequencies than food waste collection and with different collection tools and schemes.

In 2011 biowaste from source separated municipal collections accounted for around 80 per cent of all organic waste recycled at Italian composting plants and 90 per cent of all input feedstocks to AD facilities. Source separation is a critical component of effective waste collection and ensuring feedstock suitability for AD and composting facilities.

Further reading on waste collection in Italy:

Ferraris M and Paleari S (2013) Municipal waste management in Italy. Paper prepared by the European Topic Centre of Sustainable Consumption and Production (ETC-SCP) for the European Environment Agency (EEA) under its 2012 work programme as a contribution to the EEA's work on waste implementation.

Maurano S (2010) Capannori, Italy: The first case of the application of the ‘zero waste strategy’ in Italy (and other measures to reduce our ecological footprint) Report produced by Centre for Social Studies, University of Coimbra, Portugal for the United Cities and Local Governments (UCLG) Committee on Social Inclusion, Participatory Democracy and Human Rights

Annex 4 Examples of different bio-economy clusters

This annex provides summary examples of different bio-economy clusters operating in the EU.

Box 13: Bio-economy clusters in Germany

Bio-economy Cluster
In the German 'Bio-economy Cluster' scientists from more than 50 companies and research and education institutes conduct closely interwoven research in 16 joint and 51 sub-projects along the wood and chemical value chains. Cluster partners such as the Fraunhofer Center for Chemical-Biotechnological Processes CBP, the DBFZ (German Biomass Research Center), the Helmholtz Centre for Environmental Research Leipzig and companies such as Linde Engineering, Ante-Holz and Homatherm act as instigators in the development of a strong, sustainable bio-economy on the basis of non-food biomass.

BIORegions: Launched in 1995 forming a number of national and cross border economic areas or bioregions in which biotechnology was being developed and commercialised. (BMBF, 2006). Several rounds of competitions have given specific regions access to private and public funding.

Source: Own compilation

Box 14: Bio-economy clusters in Finland

Finnish Bio-economy Forum/Cluster (FIBIC)
The Finnish Bio-economy Cluster has, today, activities in three different strategic focus areas. The areas are: Intelligent, Resource-efficient Production Technologies, Future Biorefinery and Sustainable Bioenergy Solutions. FIBIC is one of six strategic groups for science, technology and innovation in Finland (SHOK). FIBIC has the aim to turn science into sustainable bio-based industrial solutions. They offer businesses and research organizations a new way of generating, long-term cooperation and leveraging competences and resources. FIBIC has a number of research programmes in relation to waste. Website: http://fibic.fi/

Forest Cluster
A network of experts and businesses around the forest industry. Expertise and enterprises based on wood and wood processing. The forest cluster in Finland accounts for nearly 30% of all industrial production and net export revenues, employing nearly 200,000 people.

Green Growth, TEKES
TEKES is a publicly funded financer or R&D and innovation in Finland. Each year it finances some 1,500 business R&D projects, and 600 public research projects.
Its Green Growth programme works to identify new growth areas for sustainable businesses, with a focus on low energy consumption and sustainable use of natural resources. Part of the programme focuses on recycling, recovery of raw material and waste processing. Many of the projects they are financing could be considered to be part of the waste based-bio-economy. For example: http://www.tekes.fi/globalassets/global/ohjelmat-ja-palvelut/ohjelmat/green-growth/aineistot/ohjelman-esitykset/gg-projektikuvauksia_en.pdf

Source: Own compilation

Box 15: Bio-economy clusters in Sweden

The Biorefinery of the Future cluster
Since 2005 VINNVÄXT, the Swedish Innovation agency's (VINNOVA) programme for regional growth has been funding the Biorefinery of the Future project. Based in Örnsköldsvik, the Biorefinery of the Future cluster has the aim to accelerate development in the field of biorefining woody biomass, particularly using lignocellulosic feedstock. In recent years funds have been directed towards scaling up promising research.
Today the cluster has 21 member companies, mostly in relation to the forest, chemicals or energy sector. The average yearly turnover of SP Processum, who owns the cluster, has an annual turnover of 23.5 million SEK. VINNOVA spends 6 m. SEK each year on the cluster, with regional actors matching this investment, and 12 m.

SEK coming from EU structural funds, member companies, research funds, and additional EU funding (eg. FP7). The cluster now contains pilot and demonstration plants (note no commercial) worth in excess of 100 million Euros.

Waste Refinery
The "Waste Refinery" is a Swedish Excellence Centre established by the Technical Research Institute of Sweden. The centre is carrying out theoretical and practical research into the conversion of waste into high quality products, its research can be found here (Swedish only) http://www.wasterefinery.se/sv/publications/reports/Sidor/default.aspx

Source: Own compilation

Box 16: A Bio-economy cluster in Wallonia (Belgium)

GreenWin is one of Wallonia's six competition clusters and is dedicated to the green economy and sustainable development. The Cluster aims to support innovation and stimulate the development of collaborative R&D projects, with a view to growing the Walloon industrial infrastructure and creating jobs in new and changing markets. Working towards the marketing of more efficient environmental technologies, GreenWin focuses its action around three strategic areas concentrating on improving product life cycles by saving materials and energy, recycling and using renewable resources.

GreenWin brings together in a single network more than 150 members, with over 135 businesses, including universities, research centers, training operators and communities, all of which are involved in developing the green economy. The cluster has a dedicated operation unit, based on a network of experts in the area of its research. through this dedicated unit, GreenWin offers its members: a platform for dialogue; support in constructing projects; help in looking for funding and international visibility.

In 2013, activities within the scope of the cluster represented more than 45,000 jobs in Wallonia and Brussels. 21 projects were approved and funded by the Walloon Government for a total budget in excess of €60 million .

Source: Own compilation based on http://www.greenwin.be/en/pole

Annex 5 Biorefinery and bioenergy facilities using wastes

This annex contains boxed examples of different biorefineries and bioenergy facilities operating in part on waste resources.

Box 17: Crescentino Biorefinery for advanced biofuels and biochemical products, Italy

The first biorefinery for the production of second-generation bioethanol and biochemical products from non-food biomass was started up in September 2013. The plant is owned by the international joint venture (JV) Beta Renewables.

Location: The plant is located in Crescentino (province of Vercelli), Italy

Size: The plant produces 50 million litres of second-generation bioethanol per year, while its estimated maximum capacity is 75 million litres. Investments for R&D were 150 million €, coupled with 150 million € for building up the plant. The project created around 100-150 jobs directly linked to the running of the plant, plus additional 200 in related industrial sectors.

Feedstocks covered: The plant uses dedicated energy crops (*Arundo Donax*) and, to a lesser extent, agriculture residues (mainly rice straw) supplied from within an area of 70 km. The total biomass utilised is approximately 270.000 million tonnes / year, providing an output of around 13 million tonnes of bioethanol. No further information on the proportions of the feedstocks used in the production processes has been found.

Types of firms involved: Beta Renewables, the international joint venture owning the plant, is composed by the following companies:

- Mossi&Ghisolfi (M&S), world leader in the production of polyester polymers, develops and engineers bio-chemical technologies and processes based on non-food biomass through its subsidiary BioChemtex SpA (JV's share 67,54%). The company is based in Tortona (Alessandria, Italy) and has two Research Centres in Ravalta Scrivia (Alessandria) and Modugno (Bari). In 2012, Biochemtex had a turnover of 200 M €, employing around 250 people;

- TPG (Texas Pacific Group) Esch S.A.R.L. (JV's 22,51%) is a US-based private-equity investment firm, operating on the global market;

- Novozymes Bioindustrial Holding A/S (JV's 9.95%) is a Danish company is the field of bio-innovation. It employs over 6,000 employees globally.

Financing: R&D and the costs associated with the construction of the plant were financed by private funding. The initiative was supported by the Italian Government through the approval of legislation aimed at simplifying the authorization processes for building second- and third-generation biorefineries and, more recently, through the introduction of a binding sub-target for second-generation biofuel blending. A system of fiscal incentive for the production of bioethanol from agricultural feedstocks is also in place.

Expected benefits: The annual joint venture's turnover is estimated to be between €40 and 45 million.

Sources: BetaRenewables website http://www.betarenewables.com/crescentino/project; BioChemtex SpA http://www.biochemtex.com/ ; Francesca Baccino (2013) La rivoluzione verde di Mossi&Ghisolfi. 18-24 October 2013; E. Z. (2013) La nuova sfida è <<coltivare etanolo>> L'Informatore Agrario. 43/2013; Luca Zuccaro (2011) 40mila tonnellate/anno di etanolo con la canna sui terreni marginali. Terre e Vita. 40/2011

Box 18: Bee Power Gent (planned to be constructed), Belgium

The Bee Power Gent plant is to produce electricity and heat from biomass. It is under construction on the Ghent Coal Terminal site at the Ghent-Terneuzen Canal and is planned to become operational in the third quarter of 2017.

Location: The plant is located in the Port of Ghent, Belgium. The vicinity of the water is an asset as the biomass to be used in the plant will be supplied by seagoing vessels.

Size: The plant will produce around 215 MW of electricity and heat (approximately 2% of the entire Belgian market), and is considered the largest commercial plant in the world. The amount invested into the project will exceed 315 million €. The project is expected to create between 700 and 1,100 jobs during the construction phase and between 100 and 120 permanent jobs once the plant will become fully operational.

Feedstocks covered: The plant will be entirely supplied by short-rotation wood chips and agro-residues. No further information on the volumes of feedstocks used has been found.

Types of firms involved: The plant is owned by the Belgian energy company, Belgian Eco Energy (Bee), which is active in the development, financing, construction and operation of renewable energy projects and power and gas supply. The company is financed by Belgian industrial family capital.

Financing: R&D and costs associated with the construction of the plant have been provided through private funding. Public government support to the production of electricity from renewable sources has been provided through a system of Green Certificates. Producers are awarded one certificate for every MWh of renewable electricity produced.

Expected benefits: The plant will generate energy without the use of fossil fuels. Thanks to the district heating system approximately 100 MW of thermal energy will be distributed to industries and households in the port of Ghent and in neighbouring houses. No information could be found on estimated economic benefits.

Source: Abengoa website http://www.abengoa.com/web/en/noticias_y_publicaciones/noticias/historico/2014/11_noviembre/abg_20141105.html ;

Box 19: Syngas biorefinery based on straw (bioliq® Karlsruhe Institute of Technology (KIT)

The Syngas biorefinery in Karlsruhe, Baden-Württemberg, Germany, is a pilot scale biorefinery that aims to produce gasoline from agricultural lignocellulosic materials, in particular straw.

Feedstocks covered: Dry, lignocellulosic residual biomass (Straw, residual wood) from agricultural, forestry, and landscaping operations.

Why set up: The pilot plant was set up to produce high quality fuels or fuel components produced from sustainable biomass. De-centralised pre-treatment of biomass to obtain an intermediate energy carrier of high energy density (bioliqSyncrude), which can be transported economically over long distances to supply an industrial plant of reasonable size for synthetic fuel production. By chemical synthesis fuels will be produced which can be used as drop-in fuels or as stand-alone products completely compatible to exiting diesel or gasoline type fuels. Nearly any type of dry biomass can be utilized for this process; a focus is set on by-products and residues of agriculture, forestry or landscaping. The plant itself consists of four technical stages, in 2014, joint operation of the process chain is planned to produce gasoline from wheat straw for the first time.

Financing: The project was financed through the Agency for Renewable Resources e. V. (FNR), Ministry of Food and Agriculture (BMEL), European Union (EU), European Regional Development Fund (ERDF) and land of Baden-Württemberg

Source: http://www.bioliq.de/english/24.php

Box 20: Clariant cellulose ethanol pilot plant

***Country*:** Straubing, Bavaria, Germany

***Size*:** 1,000tn of cellulose ethanol from 4500tons of straw

***Feedstocks covered*: plant** waste – grain and corn straw

***Why set up*:** The plant, set up in 2012, uses Clariant sunliquid technology, which turns plant waste products, such as grain straw and corn straw, into second-generation cellulose ethanol. It is Germany's biggest pilot plant for the production of climate-friendly cellulose ethanol from agricultural waste

Financing: Gov/Private, set up by Swiss chemical company, Clariant. Cost EUR 28 m. Support from Bavarian government and the Federal Ministry for Education and Research

***Expected benefits*:** Studies show that Germany potentially has around 22 million tonnes of straw that could be used for energy production without compromising essential soil regeneration. This would be sufficient to cover around 25% of Germany's current gasoline requirements.

Source:
http://www.clariant.de/C12579EC0046869F/vwWebPagesByID/7735B0CFEF8CB077C1257A470028C3B2

Box 21: St1 Oy Hartwall Ab brewery's Etanolix® plant

***Country*:** Hartwall brewery in Lahti, Finland

***Size*:** 4 million litres of surplus yeast, rest beer and non-alcoholic liquids are funnelled to the plant producing 1 million litres of bioethanol annual.

***Feedstocks covered (name the wastes if known)*:** The bioethanol plant will use the by-products of local bakeries, breweries and mills as its feedstock. Previously the yeast left over from the brewery ends up in the animal feed industry. The Etanolix® process will separate the ethanol from the yeast, after which the remaining dry yeast matter can still go to make animal feed. Brewery waste contributes 1/3 of the feedstock, the rest comes from residues from bread and pastry production from bakeries and supermarkets nearby (*see SITA below*). Waste CO_2 from refining is fed back into the brewery.

***Why set up*:** Hartwall Brewery (Royal Unibrew) will forward any yeast and liquids left over from its drinks production to the bioethanol plant. Etanolix® units turn bio-waste and by-products from the food processing industry into 85% ethanol. This ethanol is then shipped to St1's dehydration unit in Hamina, Finland The 99.8% bioethanol produced at the dehydration plant can be mixed with petrol without any additional processing. St1 have aspirations to construct up to 15 Etanolix® plants in in Finland, which will be fed by a mixture of fermentable waste, particularly biodegradable by-products of bakeries, breweries and mills.

***Expected benefits*:** Not listed

***How financed*:** Cooperation between Royal Unibrew and St1

Source: http://www.st1biofuels.com/company/news/st1-opens-its-fifth-etanolix-bioethanol-plant-next-to-the-hartwall-brewery-in-la

Box 22: Nevada Cellulosic Ethanol Facility, DuPont

***Country*:** Nevada, Iowa, USA

***Size*:** 30 million gallons of ethanol per year, processing 375,000 tons of corn stover (waste) per year. The first commercial-scale cellulosic biorefiney in the world.

***Feedstock*:** Corn stover from surrounding 190,000 acres

***Why set up*:** Expected to be complete in 2015

***Expected benefits*:** Jobs: 85 permanent facility jobs, 1000 construction jobs, 150 involved in seasonal harvest, 500 local farmers to supply stover

***How financed*:** $225million financed by Du Pont, American Chemical multinational. Initial technology development with cost-share grant with Department of Energy. Demonstration facility in Vonore, TN in partnership with Genera Energy and the University of Tennessee Biofuels Initiative

Source: http://biofuels.dupont.com/cellulosic-ethanol/nevada-site-ce-facility/

Box 23: Sierra BioFuels Plant, Fulcrum Bioenergy

***Country*:** McCarran, Nevada USA

***Size*:** 10 million gallons of SPK jet fuel or diesel annually, with a fuel off-take agreement with Tenaska BioFuels

***Feedstock*:** 200,000 tons of prepared MSW (municipal solid waste) feedstock. zero-cost MSW feedstock agreements with Waste Management and Waste Connections, two of the largest waste service companies in North America,

Why set up: The biofuels plant will be capable of producing about 10.5 million gallons of low-carbon renewable fuel on an annual basis by processing 90,000t of MSW. The facility will also produce propanol, a chemical product used as an industrial solvent and chemical intermediate. The products from the plant will serve motorists in northern Nevada and California.

***Expected benefits*:** The project is expected to generate about 50 permanent jobs and about 450 temporary jobs. The technologies implemented at the plant will also cut down greenhouse gas emissions by more than 75% compared to the traditional production of gasoline from oil. Fulcrum BioEnergy is based in Pleasanton, California. The company plans to carry out projects in about 20 states with the aim of producing one billion gallons of ethanol on an annual basis by 2018.

***How financed*:** The total investment for the construction of the plant is estimated to be $120m. The project was selected by the Department of Energy for its Loan Guarantee Program in December 2011 – providing $75m of financing. The project also received a conditional commitment for a loan guarantee of $105m from the US Department of Agriculture in August 2012.

Source: http://www.fulcrum-bioenergy.com/facilities.html