Biorefining and the bioeconomy

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The bioeconomy features strongly in the desire to see a green recovery in the UK. It is also a main theme in the Government's Clean Growth Strategy, with a target to double the bioeconomy in the UK by 2030, from £220 billion in 2014, to £440 billion.

What exactly is the bioeconomy?

It could be described as the use of bioscience and biotechnology to provide chemicals, materials, food, energy & fuel and health or environmental benefits. But in fact, it is broader than this, and includes all economic activity derived from bio-based products and processes, so foresters, farmers and land managers are already engaged in the bioeconomy. It also includes the biomass energy sector. It also encompasses organic waste from industry or municipal sources. It also includes all upstream and downstream activities for these. Which goes some way to explain how the bioeconomy workforce in the UK reaches the reported 5.2 million jobs.

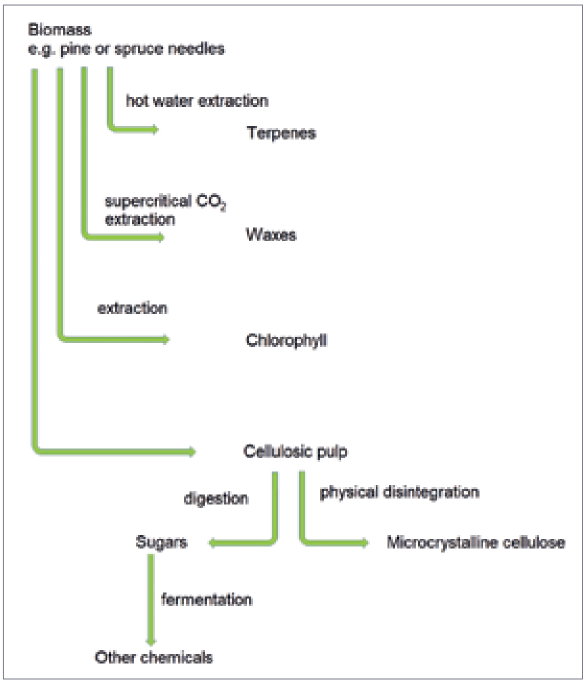
What we might look at instead is the Industrial Biotechnology (IB) sector, within the bioeconomy, which can use agricultural, forest or even aquatic residues in green and bio-based technologies. We also know that some nations are very advanced in IB, for example Finland and Sweden centred on existing pulp and paper activity to support high-tech development of regenerated cellulose, biocomposites, or new polymers. Or the Netherlands, where a large number of technologies are incubated through favourable support for start-up companies, new innovation, enzyme technologies and products frequently develop through to viable commercial systems. So, can this work in the UK?

In the BEIS/BBSRC report *Evidencing the Bioeconomy*, the direct output of the UK bioeconomy was £52bn in 2013, projected to rise by only 0.7% per annum to £58bn in 2030. This is the direct activity – agriculture and fishing, forestry and logging, water and remediation services, food and beverage manufacture, and IB and bioenergy (see chart). Changes in forestry are relatively minor in the projections, whereas agriculture is projected to decrease in value and the biotechnology and bioenergy sector increase substantially, giving the bulk of the growth. So, let's look at the biotechnology sector in a bit more detail.

How can forestry and wood be relevant for the biotechnology sector?

One important concept for biotechnology is the use of enzyme-based digestions or chemical reactions to break down biomass into a mix of useful chemicals. In fact, a set of 'platform chemicals' have been selected by industry as the most strategic and useful molecules for moving the chemical industry away from fossil-based resources towards synthesis of the many chemicals we need from bio-based resources. As we know, timber contains cellulose and hemicellulose. Both of these are polysaccharides, so can be broken down into sugars, and sugars can be digested further by microbes to create a range of different monomers, or to create new biopolymers through their metabolic processes. Another component of wood is lignin, which has long been a challenge to the pulp and paper industry to recover and convert into useful products. Increasingly there are strategies to convert lignin into bio-based adhesives for wood-based panels, or to create mouldable plastics, or to break it down into a range of phenolic molecules for chemical synthesis.

Another group of products is the 'value chemicals'. While the bulk of most agri-residues and wood is made up of cellulose, hemicellulose and lignin, a small component will be of other substances. Bark contains suberin, wax and many tannins and phenolic compounds; softwood timbers contain significant amounts of terpenes as well as waxes and resin acids; leaves contain a large number of chemicals, some with medicinal or health effects,



Simplified schematic of a biorefinery breaking down conifer needles into different products

BioPilots UK

There are four open access biorefinery centres collaborating in this scheme. Based at Aberystwyth (Beacon), Glasgow (IBioIC), Redcar (CPI) and York (BioRenewables Development Centre). The four organisations recognise the importance of partnerships to develop UK bio-based value chains. They allow new technologies to be de-risked through trials and scale up activities. For more information see biopilotsUK.com

Chemicals from food waste

GSK and Veolia working together with the BioRenewable Development Centre at York, have been looking at starchy food wastes as a resource for high value chemicals including antibiotics. Glucose will be derived and purified from food waste for use in the industrial processes.

Bio-resins from bark

Work at the BioComposites Centre with AW Jenkinson has looked at stilbenes as new chemicals for substitution into adhesives for wood based panels. Extracts of stilbenes were recovered from Sitka spruce bark, and used to produce resin for particleboard.

others giving flavours, aromas, and colours with potential in food. While these components may be present only in low quantities, their value lies in the specialist markets they are sold into, and the higher prices they may command. The economics of setting up a biorefinery frequently rely on selecting a feedstock with several of these value chemicals, and then developing the rest of the product mix from the digestion of the remaining pulp. Thus, in a biorefinery a biomass feedstock is fractionated into several separate products in sequence (see flow diagram), just as crude oil is separated into several distinct useful products in a petrochemical refinery. Biorefinery activity in the UK has a turnover of approx. £1.8bn in 2010, but is expected to grow to £12bn in 2025.

You can see that there are likely to be a huge number of different value chemicals available from different agri-crops, different forest residues (eg the bark, leaves or needles of different species of trees) and increasingly different micro or macro algae as well. As such, it offers a very interesting opportunity to the forest sector, to consider collection of brash to develop a value chain based on the dominant species. Others have looked at chemicals from bark (see above). Logistics will remain the key consideration for this – even if a biorefinery is established, its location near to suitable forest area and sustained supply of needles, brash, bark or other feedstocks across the seasons.

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An opportunity for forestry and wood

Over the past decades there has been a shift in the type of feedstocks targeted in biotechnology. The first-generation feedstocks (food crops including wheat, sugar beet, potatoes and other starchy crops) have given way to second-generation crops (wood, wheat straw, other agri-residues) to ensure that new technology is not competing with food, but is using co-products of food production. Hopefully it is also using the co-products of the timber industry not the primary crop. More recently a third generation of feedstocks have made advances, these are more varied, including the algae and seaweeds, but also bio-based municipal waste and industrial waste or food industry wastes.

This brings us to another concept – anaerobic digestion. This has moved relatively rapidly into mainstream as a solution to food waste from local authority collections and even water treatment. It uses microbes which grown in anaerobic conditions to digest and break down biomass into a rich mix of organic compounds and fibrous pulp. Conditions in the reactors can be controlled to favour production of gases such as methane, or to yield other products. There is interest in this technology to produce biopolymers for example, but the microbes used and the conditions in the reactor would be very different to the majority of industrial installations in place today.

From the forester's point of view, these developments in the bioeconomy are an opportunity, and also a sign that the way policy makers understand the role of trees is changing. It is great to see the mention of support for timber and cross laminated timber in construction in the text of *Growing the Bioeconomy*. This indicates that there is a desire to avoid the difficult situation of the first-generation feedstocks, where biofuels were seen as diverting food crops away from people. Timber should be used as timber first, but the emergence of biotechnology alongside timber offers scope for coproducts and residues, if the economics of collection can be stacked up favourably.

It is good also to see that the finite nature of land, and thus the limit on total biomass availability is acknowledged. The projected growth in the bioeconomy is primarily from advances in how the biotechnology is done, and how efficiently the value chain is put together, to supply higher value products, purer products or to deliver more of the transformation of the raw material into final product.

For more on the bioeconomy, see p56