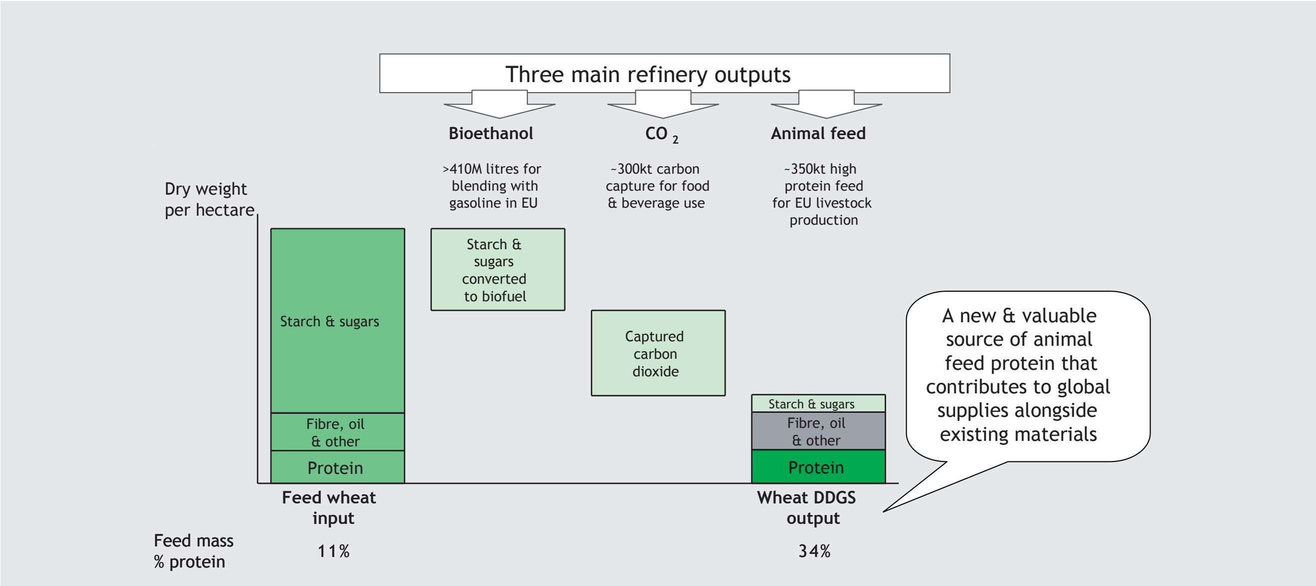

Figure 1. The biorefining process

– around 35 per cent. This co-product adds to European and global supplies of high-protein animal feed and it competes in the feed market on the basis of its nutritional value. Europe imports a great deal of soya meal for animal feed. The livestock industry globally is responsible for about one fifth of greenhouse gas emissions, and much of that stems from the production of feed and the conversion of high carbon stock land area required to produce that feed, especially in the tropics. DDGS makes an important contribution to sustainability in the livestock industry by reducing EU demand for imported soya meal from South America.

Second-generation technologies

Replacing more than about 20 per cent of global transport fuel energy will require second-generation biofuels. These will be made from cellulosic plant materials and may employ feedstocks other than sugar crops and grains; for example, grasses and woody energy crops, forest thinnings, wastes or algae. Second generation biofuels are typically more expensive than first generation biofuels because of the necessary additional capital investment, process operating costs and supply chain logistics costs per unit of fuel energy produced.

The ‘first-generation’ bioethanol industry provides a capital-efficient route to second generation bioethanol production, within existing biorefining facilities, and with no additional logistics costs, by converting cellulosic components in current feedstocks already in-process. It also provides a basis for new process developments that will pave the way for future second generation biofuel production pathways that can make economic use of new feedstocks and new biomass supply chains.

Grain biorefining has three very important benefits:

- it provides an immediate, highly sustainable contribution to achieving UK and EU targets on climate change and a greener food supply chain;
- it improves food and energy security, adding to global supplies of high-protein animal feed and transport fuel;
- it is an essential platform for future green technology development. ☐

Carbon dioxide - an age-old problem

Douglas Kell

There was a time, millions of years ago, when the amount of CO_2 in the atmosphere was even higher than it is today – about 10 to 20 times higher. The problem was solved by the evolution of trees and flowering plants that sequester carbon and by the laying down of coal. A great deal of research today is focussed on harnessing the power of plants that are good at sequestering carbon – bioenergy plants. Sequestering carbon in the soil as part of growing biomass crops is a vital part of reducing CO_2 in the atmosphere, and is an additional benefit to creating the biomass itself.

Professor Douglas Kell is Chief Executive of the Biotechnology and Biological Sciences Research Council (BBSRC). Professor Kell studied biochemistry and bioenergetics at Oxford University. He has worked on the development of analytical and computational models at the University of Aberystwyth. He later moved to Manchester as Chair of Bioanalytical Science. He also chaired the 2006 BBSRC review of bioenergy.

The amount of CO_2 in the atmosphere today is 385 parts per million by volume (ppmv). This is rising at a rate of some 2 ppmv per year. By comparison, the ‘pre-industrial’ level was 280 ppmv. Yet, if we could increase the carbon density in the soils of all the crops and grasslands in the world by 1 per cent through creating an extra metre of plant root, over 100 ppmv of CO_2 could be removed from the atmosphere.

Biofuel crops in the UK

Although the UK is relatively small, accounting for roughly 1 per cent of the world’s land area, it is the leading nation in plant sciences. Our researchers are looking at a number of potential

DISCUSSION

The risks in changing land use

If farmers are to commit to growing specific crops for biofuel, they will need safeguards against the risk of being overtaken by technological changes that necessitate a different crop or a different means of production. Other risks include continuing water shortages and efforts to restrict the use of pesticides. Whatever incentives may be put in place, there will always be the danger of creating perverse incentives leading to undesirable effects. Some people may resist crop change if it affects the landscape.

biofuel crops, some of which have both edible and non-edible components. They include waste in many forms, dual food/fuel crops such as cereals, straw and sugar beet, short-rotation coppice willow, and Miscanthus grass.

Because of our relatively small land mass, using the land effectively is a particular challenge. The UK comprises approximately 25 million hectares, with over 10 million hectares in England. When land in lakes, rivers, cities and other areas that cannot be used is subtracted, the total in England is under 8 million hectares. When other land that may not be usable is also taken out of the equation, for example national parks and areas of outstanding natural beauty, the total falls to less than 5 million hectares.

However, in England we have about 3.1 million hectares of agricultural land that is graded 3 or 4, representing among the least attractive land for agriculture. We need about 350,000 hectares to meet our transport biofuel obligations– or just over a tenth of the land that is of limited value for agriculture.

In addition, the proportion of land in the UK that is currently used for non-food crops such as forests is 12 per cent, whereas in Germany the figure is 30 per cent and in Sweden and Denmark it rises to 65 per cent. Thus in the UK we have a higher proportion of land area that we can still use for non-food crops, an opportunity not available in other European countries.

While having the land available is important, yield per hectare is also crucial. Most plants we grow have a photosynthetic yield of 1 per cent. In comparison, theoretical yields for C3 and C4 plants (which represent different kinds of photosynthesis) have been calculated to be 5 per cent and 7 per cent respectively. Based on these calculations it is clear that there is much potential to improve yield. Historically, we have improved our yield of grain by about 1-3 per cent every year and that is an easily attainable target for biofuels as well.

Yields vary typically between five and 15 tonnes per hectare. The variation is partly genetic and partly agronomic. We base our current yield calculations on 12.5 tonnes per hectare, and we are hoping almost to double that amount. The key to achieving this lies in genomics. We can now sequence anything we might wish to breed within a very small amount of time. In the beginning it took scientists many years to sequence DNA. By January 2009, we had sequenced 200,000 million DNA bases (approximately 60 human genomes). The same amount of sequencing now takes one week and requires one machine. Facilities such as the Sanger Institute and the Beijing Genome Institute have 100 of these machines each. The speed with which we can now sequence large numbers of DNA bases represents a very important breakthrough in genomics-driven breeding.

Using the knowledge acquired by sequencing to determine the traits we need to breed is a very important challenge for the future. We need to create multiple cultivars with the right traits; these include ease of breakdown as well as resistance to disease and drought.

A knowledge-based bioeconomy

For reasons to do with infrastructure, it is sensible to start by making liquid transport biofuels, whatever else we may do in the long term. Ethanol is the front runner at the moment, but its carbon:hydrogen:oxygen ratio is not particularly good. Other possibilities include making hydrocarbons from algae or other matter, which is how they were made first time around, millions of years ago.

When the oil and coal finally run out, and preferably before, we will need to use similar processes to make other products as well. In Europe this is called the knowledge-based bioeconomy. At its centre is the sustainable intensification of agriculture to fix carbon.

The BBSRC Sustainable Bioenergy Centre in Aberystwyth and elsewhere is conducting a trial planting of one of the energy grasses. The Centre is a 'virtual' research centre in which five universities and research institutes are involved. It has received funding of about £26 million from the BBSRC and a number of companies. It carries out research into ways of optimising yields by optimising each individual component – not only biomass growth, but also composition, deconstruction and fermentation. For example, the amount of sugar we can obtain from sugar cane could be much larger than it is now. The same is true of other, cellulosic biomass fuels. Improving the composition of these to maximise extractability is a vital part of our work.

Another promising area is that of novel enzymes. One of the classes of enzymes we are looking at comes from an organism known as a marine wood borer, or a 'gribble'. Unlike termites, which use bacteria in their stomachs to grind away wood, wood borers themselves encode and possess enzymes that make cellulases. The discovery of these enzymes is leading to some very exciting work.

Other research involves finding ways to improve yield, efficiency and extractability in the fermentation process – for example, by varying the temperature.

The ability to sequester carbon while creating vital biomass is a prize well worth seeking. Bioenergy crops are much better at sequestering carbon than are other crops such as winter wheat and oil seed rape. Soil contains twice as much carbon as the atmosphere. We must put policies in place that give farmers an incentive to plant bioenergy crops. We know that the plants we need exist – the rest is up to us. ❑

Audio and presentations from all the meetings of the Foundation for Science and Technology can be found on the website at: www.foundation.org.uk.