Understanding the Value of Co-production of Biofuels and Biochemicals

Introduction

The transition from petroleum based fuels to biofuels will be driven by the co-production of biofuels and biochemicals[i].

Around the world significant steps are being taken to move from today's petroleum based economy to a more sustainable economy based on biomass. The transition to a bio-based economy has multiple drivers.

- The need to develop an environmentally, economically and socially sustainable global economy.
- The anticipation that oil, gas, coal, and phosphorus will reach peak production in the not too distant future and that prices will climb.
- The desire of many countries to reduce an over dependency on fossil fuel imports, so the need for countries to diversify their energy sources.
- The global issue of climate change and the need to reduce atmospheric greenhouse gases (GHG) emissions.
- The need to stimulate regional and rural development.

Fig 1: Lawter Mt Maunganui Resin extraction plant

The co-production of fuels, chemicals, combined heat and power and materials from biomass will allow economies of scale and revenue from multiple product streams that together will assist investors to gain confidence to enter the market.

A key factor in the realisation of a successful bio-based economy will be the development of integrated biorefinery systems allowing highly efficient and cost-effective processing of biological feedstocks to a range of bio-based products[ii], based on existing industrial activities e.g. pulp and paper, pharmaceuticals, wood processing etc.

Although global bio-based chemical and polymer production (excluding biofuels) is estimated to be around 50 million tonnes, the historic low price of petroleum based feedstocks together with optimised production processes has to date restricted commercial production of bio-based products. However, the continuing climb in oil prices and consumer demand for environmentally friendly products has now opened new windows of opportunity for bio-based chemicals and polymers. Industry is increasingly viewing chemical and polymer production from renewable resources as an attractive area for investment. Within the emerging bio-based economy there are significant opportunities for the development of bio-based building blocks (chemicals and polymers) and materials (fibre products, starch derivatives, etc). In many cases this happens in conjunction with the production of bioenergy or biofuels. The production of bio-based products could generate US$ 10-15 billion of revenue for the global chemical industry.

To assist understand the complexity of terminology a classification for biorefinery systems has been developed. This classification approach relies on four main features:

1. Platforms (e.g. core intermediates such as C5-C6 carbohydrates, syngas, lignin, pyrolytic liquid)
2. Products (e.g. energy carriers, chemicals and material products)
3. Feedstock (i.e. biomass, from dedicated production or residues from forestry, agriculture, aquaculture and other industry and domestic sources)
4. Processes (e.g. thermochemical, chemical, biochemical and mechanical processes)

The platforms are the most important feature in this classification approach: they are key intermediates between raw materials and final products, and can be used to link different biorefinery concepts and target markets.

The platforms range from single carbon molecules such as biogas and syngas to a mixed 5 and 6 carbon carbohydrates stream derived from hemicelluloses, 6 carbon carbohydrates derived from starch, sucrose (sugar) or cellulose, lignin, oils (plant based or algal), organic solutions from grasses and pyrolytic liquids. These primary platforms can be converted to a wide range of marketable products using mixtures of thermal, biological and chemical processes.

The economic production of biofuels is often a challenge. The co-production of chemicals, materials food and feed can generate the necessary added value. Within different markets all bio-based chemicals have potential as biorefinery 'value added products'. Already many products are either demonstrating strong market growth or have received significant industry investment in development and demonstration programmes.

The production of bio-based chemicals is not new, nor is it an historic artifact. Notably examples of bio-based chemicals include non-food starch, cellulose fibres and cellulose derivatives, tall oils, fatty acids and fermentation products such as ethanol and citric acid.

However, the majority of organic chemicals and polymers are today still derived from petroleum based feedstocks, predominantly oil and gas. Non-energy applications account for around 9% of all petroleum based fuel (oil, gas, coal) use and 16% of oil products. Global petrochemical production of chemicals and polymers is estimated at around 330 million tonnes. Primary output is dominated by a small number of key building blocks, namely methanol, ethylene, propylene, butadiene, benzene, toluene and xylene. These building blocks are mainly converted to polymers and plastics but they are also converted to a staggering number of different fine and specialty chemicals with specific functions and attributes.

From a technical point of view almost all industrial materials made from petroleum based resources could be substituted by their bio-based counterparts.

Today however, the cost of bio-based production in many cases exceeds the cost of petrochemical production. Also new products must be proven to perform at least as good as the petrochemical equivalent they are substituting and to have a lower environmental impact.

Historically bio-based chemical producers have targeted high value fine or speciality chemicals markets, often where specific functionality played an important role. The low price of crude oil acted as a barrier to bio-based commodity chemical production and producers focused on the specific attributes of bio-based chemicals such as their complex structure to justify production costs.

The recent climb in oil prices, the consumer demand for environmentally friendly products, population growth and limited supplies of non-renewable resources have now opened new windows of opportunity for bio-based chemicals and polymers.

Industry is increasingly viewing chemical and polymer production from renewable resources as an attractive area for investment.

However, not only the price of oil and consumer demand is acting as drivers in these areas. Emerging economies require increasing amounts of oil and other fossil based products, and are creating a more competitive marketplace. Also, security of supply is an important driver in biobased products as well as bio-energy. One reason why the chemical industry in more isolated areas such as Ireland never really became economic was due to the need to import chemical components and additives.

Island economies may be scaled up to global economies if the chemical feedstocks are available within a reasonable geographic region. Biomass possesses this inherent possibility.

Biorefineries and the bio-based economy

Around the world small but discernible steps are being taken to move from today's fossil based economy to a more sustainable economy based on greater use of renewable resources.

The transition to a bio-based economy has multiple drivers: an over dependency of many countries on fossil fuel imports, the anticipation that oil, gas, coal and phosphorus will reach peak production in the not too distant future; the need for countries to diversify their energy sources, the global issue of climate change and the desire to reduce the emission of greenhouse gases, and the need to stimulate regional and rural development.

Bio-based products (chemicals, materials) can be produced in single product processes; however, the production in integrated biorefinery processes producing both bio-based products and secondary energy carriers (fuels, power, heat), in analogy with oil refineries, probably is a more efficient approach for the sustainable valorisation of biomass resources in a future biobased economy. Biorefining can also be integrated with food or feed production, as is the case with first generation ethanol production.

However, the main driver for the development and implementation of biorefinery processes today is the transportation sector. Significant amounts of renewable fuels are necessary in the short and midterm to meet policy regulations both in- and outside Europe. Biofuels have to fill in a large fraction of this demand, specifically for heavy duty road transport and in the aviation sector where biofuels are the only reasonable alternative. Both conventional (ethanol, biodiesel) and advanced biofuels (lignocellulosic methanol, ethanol, butanol, Fischer-Tropsch-diesel/kerosene) generally cannot be produced in a profitable way at current crude oil prices. This implicates that they only can enter the market if they are forced to (governmental regulation) or if significant financial support is provided (tax reduction). This artificial market will not be a long lasting one. A significant reduction in biofuel production costs is required to create a sustainable market.

The added-value of the co-products makes it possible to produce fuels at costs that are market competitive at a given biomass resource price. Wageningen UR (NL) performed a study in 2010 in which 12 full biofuel value chains – both single product processes and biorefinery processes co-producing value-added products – were technically, economically and ecologically assessed. The main overall conclusion was that the production costs of the biofuels could be reduced by about 30% using the biorefinery approach.

A biorefinery will be designed around the feedstocks (e.g. agriculture, forest, marine and solid waste feedstocks), and conversion technologies (e.g. thermo-chemical or biochemical).

A biorefinery may be viewed as a concept, a facility, a process, a plant or even a cluster of facilities. A biorefinery is not a new concept; many traditional users of biomass, sugar, starch and pulp industries run biorefineries today. However, it is the rapid expansion in biofuel production and the need to derive value from all of the co-products which is driving the development of modern biorefineries at the moment. To be a viable proposition, the production of bio-based energy, materials and chemicals alongside biofuels should improve the overall economics of biorefinery operation and, in some cases, may even be the primary revenue stream.

Within the bio-based economy and the operation of a biorefinery there are significant opportunities for the development of biobased chemicals and polymers. At the global scale, the production of bio-based chemicals could generate US$ 10-15 billion of revenue for the global chemical industry.

A key factor in the realisation of a successful bio-based economy will be the development of biorefinery systems that are well integrated into the existing infrastructure. Through biorefinery development, highly efficient and cost-effective processing of biological raw materials to a range of bio-based products can be achieved.

Biorefineries – classification

Biorefineries can be classified on the basis of a number of their key characteristics. Major feedstocks include perennial grasses, starch crops (e.g. wheat and maize), sugar crops (e.g. beet and cane), lignocellulosic crops (e.g. managed forest, short rotation coppice, switchgrass), lignocellulosic residues (e.g. stover and straw), oil crops (e.g. palm and oilseed rape), aquatic biomass (e.g. algae and seaweeds), and organic residues (e.g. industrial, commercial and post-consumer waste).

These feedstocks can be processed to a range of biorefinery streams termed platforms. These platforms include single carbon molecules such as biogas and syngas, 5 and 6 carbon carbohydrates from starch, sucrose or cellulose; a mixed 5 and 6 carbon carbohydrates stream derived from hemicelluloses, lignin, oils (plant-based or algal), organic solutions from grasses, pyrolytic liquids.

These primary platforms can be converted to wide range of marketable products using combinations of thermal, biological and chemical processes.

Examples of biorefinery classification[iii] include:

- C6 sugar biorefinery yielding ethanol and animal feed from starch crops
- Syngas biorefinery yielding FT-diesel and naptha from lignocellulosic residues
- C6 and C6/C5 sugar and syngas biorefinery yielding ethanol, FT-diesel and furfural from lignocellulosic crops

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[i] This Information Sheet is summarised from the IEA Bioenergy, Task 42 report "Bio-based Chemicals – Value Added Products from Biorefineries".

[ii] Bio-based products – include all kinds of bio-based chemicals, bio-based plastics and additives – biodegradable and durable, bio-composites like wood plastics composites and natural fibres, reinforced plastics and insulation material, and also the traditional products of the timber industry. Bio-based products are used in construction and insulation, packaging, automotive and consumer goods.

[iii] Examples of how operating biorefineries can be classified can be viewed on the IEA Bioenergy Task 42 website: http://www.iea-bioenergy.task42-biorefineries.com