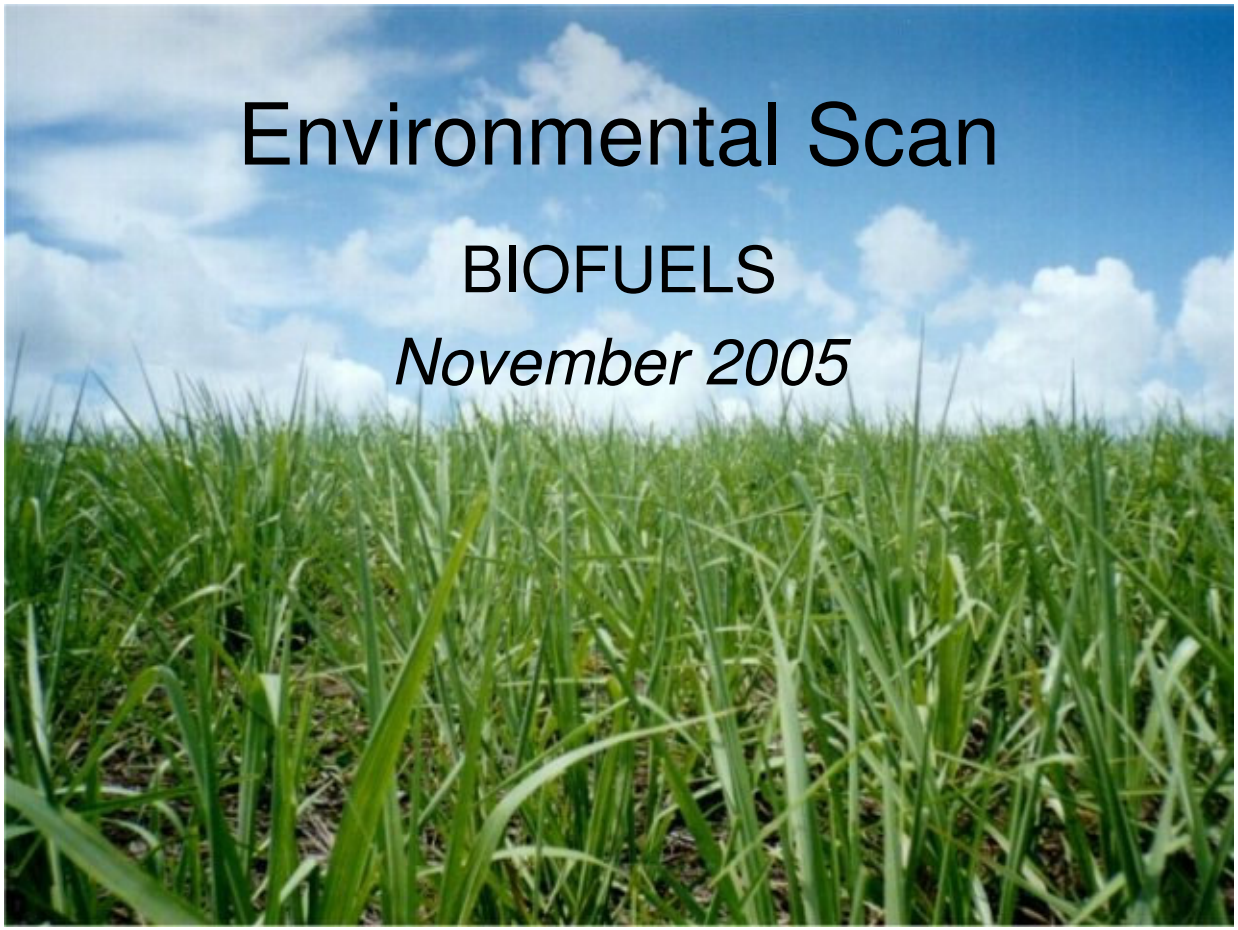


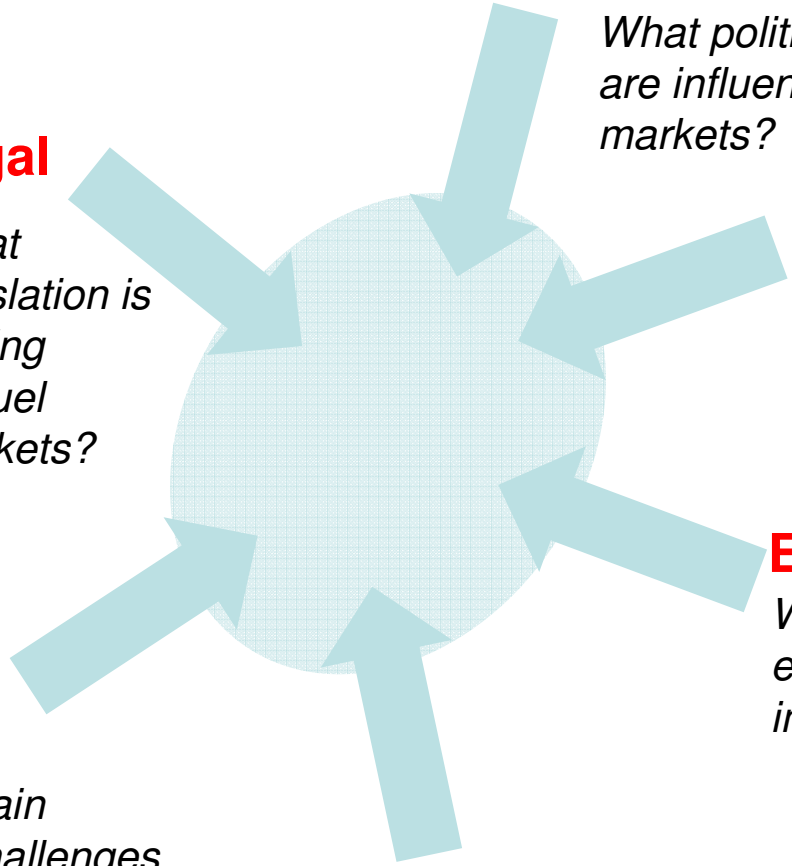
Why is ITI Life Sciences interested in liquid biofuels?

- Biofuels are an extremely hot topic and rightly so given the rising global awareness of climate change.
- ITI Life Sciences is keen to assess the scope for innovations within the **life sciences industry** which could add value in biofuels.
- While attention on biofuels intensifies, it is critical to assess the **real** market opportunities for Scotland under a commercially viable framework, targeting European and Global markets.
- Many technical challenges along the value chain remain, presenting the ITIs with potential opportunities to invest.
- Liquid Biofuels are potentially a great opportunity for Scotland's crop base to diversify and for Scottish academia and its industrial base to add value via collaboration.

Scope of this environmental scan

In order to assess biofuel opportunities in Scotland, ITI Life Sciences has broadened its focus based in part, on the framework opposite:

While we consider biofuels as a whole, each market segment is impacted by these forces to differing extents



Political

What political dynamics are influencing biofuel markets?

Economical

Does domestic production of biofuels make economic sense?

Environmental

What is the actual environmental impact of biofuels?

Sociocultural

Will social or cultural issues impact on biofuel adoption?

Technology

What are the main technological challenges the ITIs can help address?

Legal

What legislation is driving biofuel markets?

Biofuels **are** a renewable natural fuel source which have the potential to serve as an alternative to fossil fuels

Biofuels have the potential to:

- Meet climate change commitments

  Climate change is one of the greatest environmental threats facing mankind. Under the Kyoto agreement, the EU is committed to reducing CO_2 emissions by 8% between 2008 and 2012. Biofuels can produce up to 50% less CO_2 than conventional fossil mineral fuels.

- Reduce reliance on fossil fuels and dependence on foreign oil imports

  The UK Government is concerned at the decline of indigenous energy supplies. Biofuels can reduce a nation's reliance on imported oil and expand sources of imports, improve fuel security and diversity of supply while significantly improving the economies in rural areas.

Conventional biofuels can be processed from a range of natural sources by a number of long established methods including those below. At present, biodiesel and bioethanol are the principal commercially viable biofuels available.

To make biofuels production economically viable, the industry is faced with the dual challenge of procuring large quantities of biomass feedstock at an affordable price and making those processes simple and efficient enough

Biofuel	Conventional name	Production process
▪ Biodiesel from seeds ▪ Biodiesel from co-products (oils/fats)	▪ Biodiesel	▪ Transesterification ▪ Refining, transesterification
▪ Ethanol from sugar crops ▪ Ethanol from starch crops ▪ Ethanol from celluloses	▪ Bioethanol	▪ Fermentation, distillation ▪ Hydrolysis, fermentation, distillation ▪ Advanced hydrolysis, fermentation, distillation
▪ ETBE ▪ Diesel from bio-mass ▪ SNG from biogas	▪ Bio-ETBE ▪ Synthetic biofuel ▪ Biogas	▪ Synthesis from bio-ethanol and isobutene ▪ Gasification and synthesis ▪ Digestion, CO_2/H_20 removal

ETBE: Ethyl tertiary butyl ether SNG: Substitute natural gas

Bioethanol

Bioethanol mainly originates from the biological fermentation of sugars or carbohydrates derived from plant sources rather than petrochemicals.

Use of ethanol as transport fuel is not a new concept: Henry Ford's model T was designed in the 1920s to run on ethanol, or an ethanol petrol mix.

The large scale market for bioethanol emerged in 1975 from Brazil's National Fuel Ethanol Programme aimed at producing bioethanol from their vast sugar cane feedstock. Now one third of all cars in Brazil run on bioethanol using "flex fuel" engines able to use various blends of bioethanol with gasoline. In total Brazil produces around 13 bn/l/yr of bio-ethanol.

The USA are a major producer of bio-ethanol from grain, with around 6 bn/l/yr currently being blended to produce various grades of motor-fuels.

Main sources of bioethanol

A number of agricultural sources may be used for conversion into bioethanol including:

Sugars. When extracted from sugar-rich plants such as sugar cane and sugar beet, direct fermentation by yeast yields bioethanol after pre-treatment and enzymatic hydrolysis.

Starches. Upon conversion of grains such as wheat, maize and barley to sugar by hydrolysis, fermentation produces bioethanol.

The fermentation reaction and theoretical yield of bioethanol is c.50%. Significant industry focus remains on using improved enzymes to boost yields. Because ethanol has to be separated from water by distillation, energy intensity of the process and related CO_2 emissions are high.

$C_6H_{12}O_6$	⟶	$2C_2H_5OH$	+	$2CO_2$
glucose		**ethanol**		**carbon dioxide**
180kg		**92kg**		**88kg**

Cellulosic materials. Derived from agricultural waste, such as straw and molasses, grasses, wood and residue from forestry plantations. Specialist enzymes or harsh conditions produce sugar for fermentation.

The overall reaction for cellulose is 25% efficient. Efficient industrial production of bioethanol from lignocellulose remains one of the key technical challenges.

$(C_6H_5O_5)_n$	⟶	nH_2O	+	$nC_6H_{12}O_6$
cellulose		**water**		**glucose**
162kg		**92kg**		**88kg**

Biodiesel

Rudolf Diesel

Commonly derived from triglyceride sources such as oils and fats, biodiesel (alkyl monoesters) can serve as a substitute for any process using mineral diesel.

Vegetable oils have been used as a fuel for diesel engines since their inception by Rudolf Diesel in the early 1900s with small scale use since the 1930s.

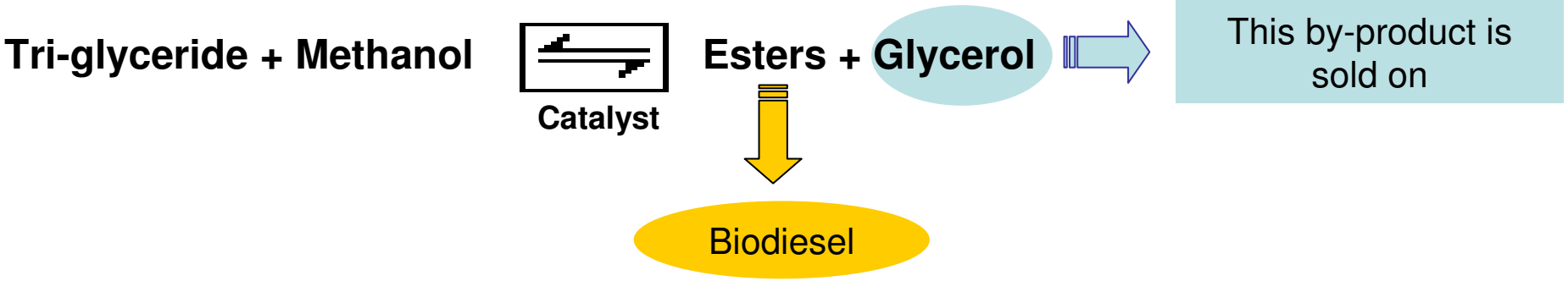
Biodiesel's importance emerged from the oil crisis of the early 1970s, as many countries sought to limit exposure to petroleum imported products. Reforms of the Common Agricultural Policy in 1992 arguably drove biodiesel to centre stage as farmers were encouraged to grow crops for non-food use, giving birth to large scale growth of energy crops and a commercial market for biodiesel.

European production of biodiesel reached approximately 2.6 m tonnes in 2004, and is set to double by 2008. In this context, the UK is also considering an ambitious mandatory target for 2010. Argent Energy currently produce biodiesel in Motherwell from tallow and waste vegetable oil.

In Europe, bio-diesel is mostly produced from rape seed and sun-flower oils. Animal fats and used cooking oil have the potential to provide significant additional quantities. The environmental foot-print of the feedstock used, and the impact of its specification on bio-diesel quality is a key element in selecting feedstocks.

Rapeseed for RME

Transesterification is the reaction of a triglyceride with an alcohol to yield esters such as Rape Methyl Ester (RME) and glycerol as shown below. The resulting biodiesel can be used in unmodified engines.



Hydrocracking *and* ***hydrogenation*** *of vegetable oil mixed with mineral oil at the refining stage could lead to the production of high quality biodiesel. A number of processes do currently exist, but are not yet commercially viable. The DTI has an open call out for proposals in this area.*

Its all in the blend

In Europe, only a maximum of 5% by volume of bioethanol or biodiesel can be blended into transport fuels without invalidating vehicle warranties. However, biodiesel produced to EU Quality standard EN14214 can be used in specified engines at 100%.

Additionally, the EU Fuels Directive 2003/17/EC and the UK Motor Fuels (Composition and Content) Regulations place limits on compatibility of materials and effects of trace by-products and other matters. It is likely that blend volumes in Europe will increase in coming years placing greater demand on producers and the industry as a whole.

Some regional limits for biofuel content are higher as summarised below*:

Territory	Blend	Comments
▪ Europe	▪ B5 ▪ B100	▪ Mostly from rape seed oil ▪ Available in Germany and Austria
▪ USA	▪ E5 ▪ E10 ▪ E70-E85	▪ A shift to E85 is possible ▪ 10% ethanol to standard gasoline is common ▪ Blend varies with region and season
▪ Brazil	▪ B20 ▪ B100 ▪ E25-E75	▪ Some use in Canada and USA ▪ Californians use neat biodiesel ▪ Possible via “flex-fuel” engines

*The biofuel constituent is indicated with a capital “E” for ethanol or “B” for biodiesel followed by the percentage blend.

The biofuel market continues to be driven by Global and European legislation

The EU has developed an integrated framework to promote bioethanol and other biofuels in Europe.

Directive 2003/30/CE of Promotion and Use of Biofuels was approved by the European Parliament and European Council to regulate the minimum useage of biofuels in EVERY member state.

- The directive states that by December 2005, biofuels should represent 2% of transport fuels, increasing to 6.76% by December 31, 2010.

  However, 19 member states have failed to legislate and 9 have not fixed targets resulting in a new target of 5.75% biofuel usage by 2010

- In addition, the EU approved the Directive of Taxation of Energy including **special fiscal regulation** of biofuels allowing member states to exempt biofuels from fuel tax.

- The European Commission will formulate a report at the end of 2006, and every subsequent two years, to review the progress in each member state and determine the need for further legislation.

The UK government RTFO initiative

creates a clear market need

In 2003, the UK Government made a commitment in its Energy White Paper towards reducing CO_2 emissions by 60% by 2050 and to assess the impact on the UK's wider energy and environmental policies. The assessment, published in 2004, included the conclusion that domestically grown biofuels could contribute around 33% of UK transport needs.

In 2004, the Government announced an intention to investigate the implementation of an Renewable Transport Fuel Obligation (RTFO) in its pre-budget report.

The UK government responded to industry demand for longer term certainty with the announcement of an RTFO policy (10/11/05).

- 5% of ALL UK fuel sold on UK forecourts will come from a renewable source by 2010.
- An RTFO could be introduced by April 2008.
- The introduction of an RTFO would give industry greater certainty to invest in biofuel production for the longer term and stimulate innovation and investment in new technologies and infrastructure where required.

Significant market opportunity

- Consumption of bioethanol in Europe in 2004 was 789,000 m^3 generating revenues of €374m and shows a growth rate of 72%. Over €4 bn of revenues are forecast for 2011. As bioethanol is blended with gasoline the consumption also depends to a large extent on the policies the oil majors adopt and the political or social pressures put on them.
- While a number of European countries have developed significant biofuel capabilities thanks to fuel tax rebates and economies of scale, the UK has lagged behind but is now picking up steam in biodiesel production.
- The recent RTFO announcement by the UK government creates a clear market need and is a major driver for the UK biofuel market going forward since biofuels must be sourced, though not necessarily in the UK.
- A large market growth is expected in 2005 and 2006 as all previous MTBE sites convert to ETBE and consume ethanol as feedstock. However, there is currently no bioethanol production in the UK.
- Biodiesel currently has a European market size of €1.5 bn and shows an accelerating double digit growth.
- Since 2004, UK capacity for biodiesel production has ramped up with further major capacity increases proposed by Greenenergy in partnership with Novaol, and Argent Energy for 2006, but scarcity of domestic source material remains an issue.

Mind the innovation gap

Aside from building infrastructure to satisfy production demand, it is vital that technology gaps related to life sciences are assessed to determine areas for innovation – this is where ITI Life Sciences seeks opportunities.

From our initial environmental scan the following challenges present opportunities :

Bioethanol

Bioethanol production is currently very inefficient due to a large number of energy intensive steps in the production processes. It is important to fully assess and address a range of issues including:

- The net energy balance of bioethanol production. Development of patentable processes, enzymes or any enabling technology to address the energy efficiency of bioethanol production is exciting.
- Suitable feedstock availability in the UK/Scotland. There is scope to improve feedstock for biofuel processing.
- Production yields of bioethanol from lignocellulose and other forms of biomass such as forestry products remain a major area for innovation and an area Scotland may be well placed to serve.

Mind the innovation gap

Biodiesel

Although biodiesel production is highly efficient thanks to room temperature processing a number of key challenges remain to be resolved for which ITI Life Sciences could contribute including:

- Improving oil yield from existing crops and investigate the development of new input crops
- Finding alternative high value added uses for by-products, an area that ITI Energy is actively exploring

Other liquid biofuels

The ITIs are also interested in other innovations that would relate to biofuels.

To be continued….

This environmental scan is the forerunner of the ITI Life Sciences foresighting report on biofuels to be released in early 2006, alongside ITI Energy's focused study on solid biofuels for heat and power.

To ensure that our foresighting is as comprehensive and rigorous as possible, and to determine if and where opportunities lie within liquid biofuels, we would very much welcome dialogue with our Members.

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