Transport biofuels - drivers and options
Dr Elaine Booth
SAC BioEnergy Group
Contents

• Drivers for bioenergy
• Current transport biofuels
• Feasibility of different scales of biofuel production
• Environmental and feedstock issues
• Future options - new technologies
• Conclusions
Biofuels can have lower carbon emissions compared to petroleum products.

Coming up the UK agenda with rising oil prices and increasing geo-political instability.

Alternative markets for farmers.

Emphasis varies by country.
Factors driving transport biofuel development in the EU and UK

• Transport accounts for a significant, and growing proportion of energy demand
  – In the UK - 25% of energy demand

• EU Targets
  – biofuels should achieve 2% of transport fuels by 2005 and 5.75% by 2010 (currently - 0.3%) for member states
  – proposal to oblige public bodies to allocate 25% of procurement for heavy vehicles to environmentally friendly vehicles

• UK targets
  – Renewable Transport Fuel Obligation
    • proposed start 2008, 5% by 2010

• Cost and availability of mineral fuel
Current liquid biofuel types

- Renewable energy sources for transport are limited to 2 widely used types
  - Bioethanol - petrol substitute / additive
    - from starch/sugar crops, eg cereals, potatoes, sugar beet
  - Biodiesel - diesel substitute / additive
    - from oil crops, used cooking oil, tallow
Future UK government encouragement for biofuels

- Fuel duty rebate of 20p/l (fuel duty of 27.1p for biofuels) extended

- In addition, a Renewable Transport Fuel Obligation will be introduced. Buy out price (price paid by fuel suppliers who fail to meet obligation) will be 15p/l in 08/09

- Combination of duty incentive and buy-out price at 35p/l guaranteed for 09/10, but will reduce to 30p/l in 10/11
Transport biofuels – an easy introduction to bioenergy?

Production
• Agronomy well developed, no need for long term land commitment
• Production chain in place

Market
• RTFO - large transport fuel market
• With high mineral fuel prices and government incentives liquid biofuels can compete

Utilisation
• Convenient use in current engines
Bioethanol production worldwide

• USA - production since early 1980s using maize. 18 billion L in 2006.
• Brazil - production since 1975 using sugar cane. 16 billion L in 2006.
• Europe – 1.5 billion L in 2006. Spain biggest producer followed by Sweden, France, Germany. Other countries include Finland, Czech Republic, Ukraine, Poland. Feedstocks are wheat and sugar beet.
Processing required; wheat to bioethanol

Wheat grain
   ↓  \textit{milling}

Coarse powder flour & bran
   ↓  \textit{hydrolysis, fermentation and distillation}

Ethanol & stillage
   ↓  \textit{dehydration}  ↓  \textit{drying}

Bioethanol  animal feed & water
### UK bio-ethanol – many large scale plants planned

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Location</th>
<th>Size</th>
<th>Feedstock</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Sugar - bioethanol</td>
<td>Norfolk</td>
<td>70 ML</td>
<td>Sugar Beet</td>
<td>Being built</td>
</tr>
<tr>
<td>Greenspirit - bioethanol</td>
<td>Somerset</td>
<td>120 ML</td>
<td>Wheat</td>
<td>Finance in place</td>
</tr>
<tr>
<td>Greenspirit - bioethanol</td>
<td>Immingham</td>
<td>240 ML</td>
<td>Wheat</td>
<td>Early planning</td>
</tr>
<tr>
<td>Bioethanol Ltd – bioethanol</td>
<td>Immingham</td>
<td>120ML</td>
<td>Wheat</td>
<td>Early planning</td>
</tr>
<tr>
<td>Roquette - bioethanol</td>
<td>Midlands</td>
<td>120 ML to 240 ML</td>
<td>Wheat</td>
<td>Early planning</td>
</tr>
<tr>
<td>BP/Dupont - biobutanol</td>
<td>England</td>
<td>360 ML</td>
<td>Wheat</td>
<td>Early feasibility</td>
</tr>
</tbody>
</table>
Bioethanol production potential in Scotland

Feedstock
• Surplus barley gives a feedstock opportunity, but has a poorer conversion rate than wheat feedstock
• Wheat has limited production potential and trades at a premium
• No sugar beet grown, potatoes are for high quality seed

Scale
• Only large scale technology available with high capital requirement

Markets
• Threat of cheap imports could disrupt markets

Conclusion
• The case for bioethanol from wheat/barley in Scotland is poor
EU-25 bio-diesel production growing strongly - Germany dominates

Source: EBB (Feb 2007)
Processing required; rapeseed to biodiesel

Rapeseed
  ↓  *crushing*

Crude oil  &  rape meal
         (→  animal feed)

  ↓  *esterification (add methanol in presence of catalyst)*

Biodiesel  &  glycerol
           (→  petrochemical industry)
Biodiesel eg Germany, Austria

- removal of glycerol from vegetable oil prevents engine ‘coking’
- biodiesel can be used as a diesel substitute or blend in unmodified diesel engines
- frequently included as 5% blend to fit with engine warranties
Rapeseed oil as a biofuel (2)

- Pure Plant Oil / Straight Vegetable Oil (SVO), eg Ireland, Germany
  - Unaltered oil can be used as a diesel replacement, but engine modification needed
  - Now eligible for duty incentive in UK
  - Questions over long term engine performance
<table>
<thead>
<tr>
<th>Location</th>
<th>Size</th>
<th>Feedstock</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Argent - biodiesel</strong></td>
<td><strong>Motherwell</strong></td>
<td>50 ML</td>
<td>UCO Tallow</td>
</tr>
<tr>
<td><strong>Biofuels Corp – biodiesel</strong></td>
<td>Teeside</td>
<td>284 ML</td>
<td>Palm soya OSR</td>
</tr>
<tr>
<td><strong>Greenergy - biodiesel</strong></td>
<td>Imming -ham</td>
<td>113 ML</td>
<td>Palm, soya OSR</td>
</tr>
<tr>
<td><strong>DMF - rape crush (&amp; bio-diesel ?)</strong></td>
<td><strong>Rosyth</strong></td>
<td>140ML</td>
<td>OSR,(palm, soya)</td>
</tr>
</tbody>
</table>
Context of biodiesel production from oilseed rape in Scotland

• **Oilseed rape production in Scotland**
  – approx. 35,000 ha cultivation, third most widely grown crop, after spring barley and wheat
  – highest average yields in Europe
  – high oil content
    • due to northerly latitude and temperate conditions

• **Processing**
  – currently there is no crusher in Scotland
  – availability of wide range of processing scales
  – Scottish OSR prices lowest in UK
<table>
<thead>
<tr>
<th>OSR (tonnes)</th>
<th>Option</th>
<th>Scale</th>
<th>Product</th>
<th>Capital cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>355</td>
<td>1</td>
<td>Farm</td>
<td>Biodiesel</td>
<td>30.4K</td>
</tr>
<tr>
<td>15,000</td>
<td>2</td>
<td>Group</td>
<td>Biodiesel</td>
<td>3.86M</td>
</tr>
<tr>
<td>60,000</td>
<td>3</td>
<td>Medium</td>
<td>Biodiesel</td>
<td>10.2M</td>
</tr>
<tr>
<td>250,000+</td>
<td>4</td>
<td>International</td>
<td>Biodiesel</td>
<td>25M</td>
</tr>
</tbody>
</table>
### On-the-road price for 5 biodiesel options (p/litre)

<table>
<thead>
<tr>
<th>Option</th>
<th>Production cost</th>
<th>Retail margin</th>
<th>Duty</th>
<th>Sub-total</th>
<th>VAT 17.5%</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.68</td>
<td>0.02</td>
<td>0.28</td>
<td>0.99</td>
<td>0</td>
<td>0.99</td>
</tr>
<tr>
<td>2</td>
<td>0.60</td>
<td>0.10</td>
<td>0.28</td>
<td>0.98</td>
<td>0.17</td>
<td>1.15</td>
</tr>
<tr>
<td>3</td>
<td>0.45</td>
<td>0.10</td>
<td>0.28</td>
<td>0.83</td>
<td>0.15</td>
<td>0.98</td>
</tr>
<tr>
<td>4</td>
<td>0.41</td>
<td>0.10</td>
<td>0.28</td>
<td>0.79</td>
<td>0.14</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Note – mineral diesel at pump – £1.00 (Nov/07)

Note – RTFO buy-out price effect (£0.15 advantage)
• Commercial opportunity for **Scottish rapeseed** - biodiesel

- **Large scale** – lower cost/litre, but need to balance with availability of feedstock

- **Medium scale plant** (60,000t OSR crushed) (+ 10,000t oil) + esterified - produces 33ML of biodiesel
  - realistic estimate of share of osr production in Scotland vs economies of larger scale
  - 14% return with pay-back by year 6, but considerable inherent risks involved
  - mitigate risk through formation of joint-venture company
    - Farmers↔Processors↔Customers
Consider sensitivity of production costs

Budgeted production cost 41p/l

- Utilisation of capacity (+/-10% 2.4p/l)
- Cost of feedstock (+/- £10 1.8p/l)
- Value rapemeal (+/- £10 1.2p/l)
- Grant assistance (+/- £1M 0.9p/l)
- Value of glycerol (+/- £10 0.2p/l)
Small scale production of biodiesel

- Possibility for local fuel production?
- Equipment available and small scale production technically possible
- Opportunity for greater domestic benefits
- Look carefully at costs
- May be worthwhile for some:
  - Ready market for biodiesel
  - Utilise meal on-farm
  - Use existing buildings/labour
  - In area where diesel, feed particularly expensive
- SVO – lower costs of production – more suited to small scale?
<table>
<thead>
<tr>
<th>Option</th>
<th>Production cost</th>
<th>Retail margin</th>
<th>Duty</th>
<th>Subtotal</th>
<th>VAT</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVO</td>
<td>0.46</td>
<td>0.02</td>
<td>0.28</td>
<td>0.79</td>
<td>0.13</td>
<td>0.90</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>0.67</td>
<td>0.02</td>
<td>0.28</td>
<td>0.98</td>
<td>0.17</td>
<td>1.15</td>
</tr>
</tbody>
</table>

Note – mineral diesel at pump – £1.00 (Nov/07)

Note – RTFO buy-out price effect (£0.15 advantage)
Environmental issues relating to biofuels

Several factors need to be considered:

- energy balance
- greenhouse gas emissions
- feedstock - crop type and source
  - implications for biodiversity
  - social implications of production
Environmental indicators for biofuels

Energy balance

- **Biodiesel using UK oilseed rape**
  - positive, between 2 and 3 units out : 1 unit in
- **Bioethanol using UK wheat**
  - 1 - 2 energy units out: 1 unit in

Biodiversity implications

- heavy source influence
- little effect if from established farming rotation eg European osr, wheat
- potential large effect in the future if using virgin land, eg some tropical oils

GHG savings

- **Biodiesel**
  - Oilseed rape - 47%
  - Soya - 63%
- **Bioethanol**
  - Maize - 24%
  - Wheat - 47%
  - Sugar cane - 89%
Ensure positive environmental footprint for UK biodiesel

- Environmental credentials will be linked to RTFO
- N fertiliser accounts for a large proportion of energy input
- Opportunity to improve environmental credentials through management e.g. reduce N
Current biofuels - feedstock supply issues

RTFO in the UK - requiring 5% biofuels

- Will demand 2.5M tonnes of bio-fuel by 2010 (x 20 current UK bio-fuel sales)
- = 3Mt of wheat and 3Mt of oilseed rape!
- An issue particularly for rapeseed availability - present production of osr is 1.9 Mt

EU expected to **increase target for biofuel** to 10% transport fuels by 2020 ... ability to meet target with current biofuel types??
Second generation transport fuels - biomass crop feedstock

- Short rotation coppice
- Giant grasses
  - perennial crops - potential to offer benefits
  - reduction in use of energy and greenhouse gas emissions in establishment, over life of crop
  - grow on lower grade land
  - reduce food vs fuel controversy?
Second generation biofuels - processing

2 pathways - thermochemical and biochemical

• thermochemical
  – gasification → syngas, advanced catalyst conversion using Fischer Tropsch process → liquid transport fuel
  – or pyrolysis → bio-oil

• Biochemical
  – pre-treatment - biomass → cellulose, hemicellulose + lignin
  – breakdown of cellulose difficult - customised enzymes
  – fermentation of glucose → ethanol
Second generation biofuels pros and cons

Positives
- Enables whole plant to be used - more efficient
- Would enable greater quantities of biofuels to be produced
- Great potential for GHG saving compared to conventional liquid biofuels

Negatives
- Biomass feedstock is bulky for transport
- Parts of the technology are at development or demonstration stage
- Capital cost of plant currently x 3 or 4 corn grain bioethanol plant
- Timing for commercial viability - 10 - 15 years??
Conclusions

• Demand for transport biofuels around the world is being driven by need to reduce GHG emissions, address security of supply issues and to support domestic agriculture
• First generation biofuels use oilseed and cereal feedstocks - opportunity to get production chain established
• More expensive to produce than mineral fuels - need continuation of fiscal incentives
• Economies of scale offered by larger processing plants, but less local benefits
• Biodiesel - best option for processing in Scotland
Conclusions 2

• Current biofuels can offer environmental positives
  – GHG saving (biodiesel and bioethanol)
  – positive energy balance (biodiesel)
  – UK, and many European derived biofuels produced on established farmland appear to have little implication for biodiversity

• Second generation transport biofuels
  – potential to improve environmental gains and meet biofuel requirement
  – technology not fully commercialised
Environmental advantages of perennial bioenergy crops

- Diversity of landscape
- Local biodiversity
  - SRC provides different stages according to coppicing pattern
  - 3 tiers of habitats
- Lower pesticide use and less cultivations than conventional crops
- Better energy balance
  - eg 20 - 30:1 for perennials, compared to:
    - Biodiesel 2- 3:1
    - Bioethanol from temperate cereals 1:1
- Greenhouse gas savings, compared to use of fossil fuels
- ‘Disposal’ of ‘waste’ products – farm slurry, sewage waste water
How much biodiesel could a farm produce?

- 3t OSR → produces 1t biodiesel (1,136L)
- 25 ha (62ac) OSR → 100t OSR → 67t rapemeal → 33t biodiesel (37,500L) enough to run 18 small cars for 1 year
Biogas – anaerobic digestion of waste or crops to produce methane for heat and/or electricity generation

Source: www.biogas-nord.de
## Biogas

– potential output from different feedstocks

| Source: SAC |

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Net electric kWh</th>
<th>Net heat kWh</th>
<th>Electric Value @9.5p</th>
<th>Heat value @3.5p</th>
<th>Total value/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle slurry</td>
<td>30</td>
<td>56</td>
<td>£2.89</td>
<td>£1.95</td>
<td>£4.84</td>
</tr>
<tr>
<td>Food waste</td>
<td>77</td>
<td>140</td>
<td>£7.30</td>
<td>£4.91</td>
<td>£12.21</td>
</tr>
<tr>
<td>Maize silage</td>
<td>402</td>
<td>734</td>
<td>£38.16</td>
<td>£25.70</td>
<td>£63.86</td>
</tr>
<tr>
<td>Grass silage</td>
<td>133</td>
<td>243</td>
<td>£12.63</td>
<td>£8.50</td>
<td>£21.13</td>
</tr>
</tbody>
</table>
Biogas – frequency of energy crops in German biogas plants

Source: SAC
Anaerobic digestion summary

- Commercial operation of AD facilities are at an early stage in the UK and there is limited information on operation and efficiency.
- Economics are difficult to predict, but to be viable on animal manure only a plant needs to be of substantial size to cover costs.
  - Aided by double ROC payment for electricity produced.
- Crop products are of interest – need to evaluate viability for this use in UK conditions.
- Extra income potential from disposal of organic wastes.