Developing supply chains from wheat as a feedstock

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Wheat for Biofuels, Bioenergy and High Value Bioproducts
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Bio-based isn’t new!

Volumes of renewable materials
- Vegetable Oils - 19.8 million tonnes
- Starch - 22.5 million tonnes
- Fibres - 28.4 million tonnes
- Wood pulp - 42.5 million tonnes

Applications
- Biolubricants
- Surfactants
- Starch Polymers
- Cellulose Polymers
- Natural Fibres & Biocomposites
- Fillers and adhesives
A Changing Landscape

Crude Oil Prices

Dollars per barrel

Forecast

OIL AND GAS LIQUIDS
2004 Scenario

The Economics of Climate Change
The Stern Review

CREATING VALUE FROM RENEWABLE MATERIALS
A strategy for non-food crops and uses
Two year progress report
**Why Wheat?**

**Europe’s dominant crop**
- UK production
  - ~1.8 million hectares
  - Yield ~8 tonnes/hectare (winter wheat)
  - 2007 harvest ~13 million tonnes
- European Potential
  - Large potential for increased yields in Eastern Europe
- Attractive cultivation costs per tonne of starch
- Source of starch, protein and lignocellulose
Beyond starch

- Processed starch is fit for purpose in many applications - but is function limited
- Requirement to convert natural polymers to flexible monomeric building blocks
- Access polyesters, polyurethanes, co-polymers etc
- Potential building blocks are well known
  - Ethanol
  - Lactic acid
  - Fumaric Acid
  - Succinic Acid
  - 3-Hydroxypropionic acid
  - etc
Supply Chain Considerations

Cultivation
- Impact on current supply chains
- New crop, new supply chain, land impact

Processing
- Technology Status
- Competition from existing production

Market Dynamics
- Market location
- Green premium?

End of life
- Waste infrastructure
- Waste policies
New Industry Dynamics

Bio-based polymers

- Bulk Volume Producers adopt Biotech
- Integrated Process Development
- New Supply Chain Agriculture + Chemical
- Chemical + Biotech collaborations
Bio-Based Polymers

European Market growth

- Biodegradables are expected to grow from 25kt in 1998 to 2-4 million tonnes in 2020

- By 2020 durables could account for 50% of renewable polymers

Most growth scenarios are based on crude oil prices <$50 bbl
Difficult to assess the impact of >$100 bbl oil and volatile agricultural markets
Commercial Activity

- Polylactic acid – PLA
- Developed by Dow Chemical and Cargill
- NatureWorks facility in Nebraska capacity 140 kt
- Good process and polymer properties vs conventional plastics
- One of only a small number of synthetic polymers that are fully biodegradable and compostable
- Claim - From cradle to resin, 68 percent less fossil fuel resources than traditional plastics (PET)
Susterra™ 1,3-Propanediol

- Produced in a collaboration between DuPont and Tate & Lyle
- Processing site in Tennessee - capacity 40,000 tonnes per year of PDO
- Applications
  - Sorona® Clothing, Carpets, Plastics
  - Zemea™ PDO for personal care

Energy & GHG emissions

- Energy – 63.9MJ/kg cf 111.0
- GHG’s – 2.18kgCO₂eq cf 5.0
Durable Polymers

- NGLs
- Refined Products
- Coal/Methanol
- Biomass/Ethanol

ETHYLENE

- Commodity Polyethylene
- Styrene Monomer
- Ethylene Oxide/Glycol
- Vinyls Chain
- Miscellaneous

Commodity Polymers/Rubbers
- Polyester
- PVC
- Vinyl Acetate
- Alpha Olefins
- Speciality Elastomers
- Synthetic Ethanol
Near Term Commercial Activity

- No technical hurdles for the production ethylene from biomass

- **Braskem** (Brazil)
  - Planned HDPE production Q4 2009
  - Capacity 200,000 tonnes/year

- **Dow/Crystalsev** (Brazil)
  - Planned PE production 2011
  - Capacity 350,000 tonnes/year

- Same economic considerations as fossil based production, feedstock cost and availability, construction and operating costs, access to market etc

- Can Europe reduce feedstock costs or leverage a technology advantage?
Assessing UK options

Market Attractiveness
- Local/European/Global Markets
- Profitability
- Competitive Intensity
- Partnering requirements
- Downstream development opportunities

Technical Feasibility
- Commercial development
- Capital Investment
- Ability to operate at world scale
- Technical Complexity
- Technology Access
- Environmental factors
Assessing UK options

Screening Matrix results indicate ten products in the desired attractiveness regime
Chemical Opportunities

1,4-Butanediol

γ-Butyrolactone

Polybutylene Terephthalate

Copolyester Ethers

Thermoplastic Polyurethanes

Spandex Fibres

Tetrahydrofuran

Solvent Uses

Polytetramethylene Ether Glycol

N-Methyl-2-Pyrrolidone

2-Pyrrolidone

N-Vinyl-2-Pyrrolidone

Pharmaceuticals

Intermediates

Herbicides

Foundry Resins

Unsaturated Polyester

Alkyd resins

Paper sizing

Food and beverages

Printing Inks

Animal Feed

L-aspartic acid

Fumaric Acid

Unsaturated Polyester

Alkyd resins

Paper sizing

Food and beverages

Printing Inks

Animal Feed

N-Vinyl-2-Pyrrolidone

Polyvinyl Pyrrolidone

Extraction Solvent

Polyaramids

Cleaning Agents

Electronics

Pharmaceuticals

Intermediates

Herbicides

Foundry Resins

Unsaturated Polyester

Alkyd resins

Paper sizing

Food and beverages

Printing Inks

Animal Feed
The End Game?

Figure 17 Generic Biorefinery Complex

Source: Mapping the Develop of UK biorefinery complexes (Tamutech Consultancy)
The Bigger Picture

Fig. 1. The fully integrated agro-biofuel-biomaterial-biopower cycle for sustainable technologies.

Figure from Ragauskas et al, (2006)
The Path Forward for Biofuels and Biomaterials. Science 311: 484-489