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# A market overview on bio-based fuels and chemicals

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## This presentation provides a market overview for bio-based fuels and chemicals

What are bio-based fuels and chemicals?

Why produce them from lignocellulose?

How are markets growing?

What are the challenges, and how can they be overcome?

## Three main types of feedstock are used to produce biofuels

### Biofuels – Feedstocks

| "First Generation" feedstocks | "Second Generation" feedstocks | "Third Generation" feedstocks |
|---|---|---|
| **Food components:** Vegetable oil, sugar and grain and animal fats | **Non-food biomass:** Energy crops, waste biomass and agricultural arisings | **Algal biomass:** Algae grown for fuel use |

**This is what we mean by lignocellulosic biomass**

Source: Arthur D. Little; Images © Centre for Sustainable Energy and The New York Times

## A range of types of biofuel can be produced from these feedstocks – though not all have yet been commercialised

*Non-exhaustive*

**Types of biofuel**

| Types of biofuel | Feedstock: "First Generation" feedstocks | Feedstock: "Second Generation" feedstocks | Feedstock: "Third Generation" feedstocks | Fossil comparator |
|---|---|---|---|---|
| Bioethanol | Distillation and fermentation of grain and sugar | Range of biological and thermochemical treatments | | Petrol |
| Biodiesel | Transesterification of vegetable oil | Range of biological and thermochemical treatments | Extraction and processing of algal oil | Diesel |
| Biogas | Anaerobic digestion of food and agricultural waste to produce $CH_4$ | | | Natural gas |
| Others | Dimethyl ether, biobutanol, furanics, hydrotreated vegetable oil, pure vegetable oil… | | | |

**Legend:** Commercialised (green) | Not fully commercialised (yellow)

These are often called "advanced biofuels"

# The market for liquid transport biofuels is driven by regulatory incentives

## Biofuels – drivers

| Improving fuel security | Reducing carbon emissions | Using existing fuel infrastructure[1] | Lobbying from farming groups<br><br>Support for rural communities |
|---|---|---|---|

## Regulatory incentives

- **Mandates:** The EC requires 10% of transport fuels to come from renewable sources by 2020[2]
- **Incentives:** In the UK, fuel blenders buy Renewable Transport Fuel Certificates at point of duty, or pay a buy-out price[3]

1) Full compatibility in blends up to 5% of biofuel without vehicle engine modifications; in some cases up to 10% 2) Directive 2009/28/EC on renewable energy. 3) Renewable Transport Fuel Obligation, as described at http://www.dft.gov.uk/topics/sustainable/biofuels/rtfo/ November 2012

# Some "first generation" biofuels produced from crop waste materials have been successful

*Examples*

## "First generation" biofuels – success stories

### Waste vegetable oil

- **Argent Energy** in Scotland produces biodiesel from:
  - Old chip fat
  - Rendered abbatoir waste
  - Out of date packs of meat
- Some of this material would otherwise cost producers to dispose of

### Biogas from sugar beet pulp

- Sugar producers such **as AB Sugar** in the UK and **Suiker Unie** in the Netherlands use excess beet pulp in anaerobic digestion
- Methane can be supplied to the gas grid or used to generate heat and power

**However, other types of biofuel – particularly those produced from oil crops and grain – are dependent on regulatory incentives**

Sources: Arthur D. Little analysis; company websites

## However, biofuels produced from virgin food crops have faced significant challenges and some negative PR in recent years

| "First generation" biofuels from virgin food crops – challenges | |
|---|---|
| 1 Competition with food | ■ Demand for food is increasing<br>■ Agricultural productivity has not greatly improved in some oil crops used for biofuels<br>■ Together, these factors have resulted in direct and indirect land use change, for meat production and growing palm oil<br>■ Land clearance can mobilise soil carbon sinks in sensitive areas |
| 2 Fluctuating crop prices | ■ Crop prices have fluctuated considerably in recent years relative to the price of oil, with changes mainly due to poor harvests in some regions<br>■ As a result, some first generation plants are operating below capacity |
| 3 Dependency on regulation | ■ Some biofuels are reliant on regulatory incentives to be economically viable<br>■ These incentives are often changing! |
| 4 GHG reduction benefits | ■ Greenhouse gases emitted during manufacturing, transportation and use of biofuels |

Sources: Arthur D. Little, USDA

# Indirect land use change is being addressed – in part – through sustainability criteria for biofuels, though these do not currently address all the implications of biofuel production

1

## Competition with food and indirect land use change

**Measures are under development to improve the sustainability of biofuel production**

| Sustainability implications of biofuels | |
|---|---|
| **Environmental issues** | ■ Direct land use change<br>■ Maximising water use efficiency<br>■ Maintaining biodiversity |
| **Social and community issues** | ■ Fair land ownership<br>■ Labour rights<br>■ Effective agricultural extension |
| **Greenhouse gas emissions** | ■ Minimising transportation of bulk biomass and finished fuels<br>■ Mobilisation of carbon sinks |

**Measures to improve sustainability**

- Users of biomass and food crops for fuels now need to demonstrate:
  - A minimum GHG saving
  - That crop feedstocks are not being sourced from land of high biodiversity value or carbon stock[1]
- However, these basic criteria do not take into account wider sustainability issues at point of production
- Programmes such as Biopact and initiatives such as the NTA 8080 standard are under development, but are frameworks, rather than requirements

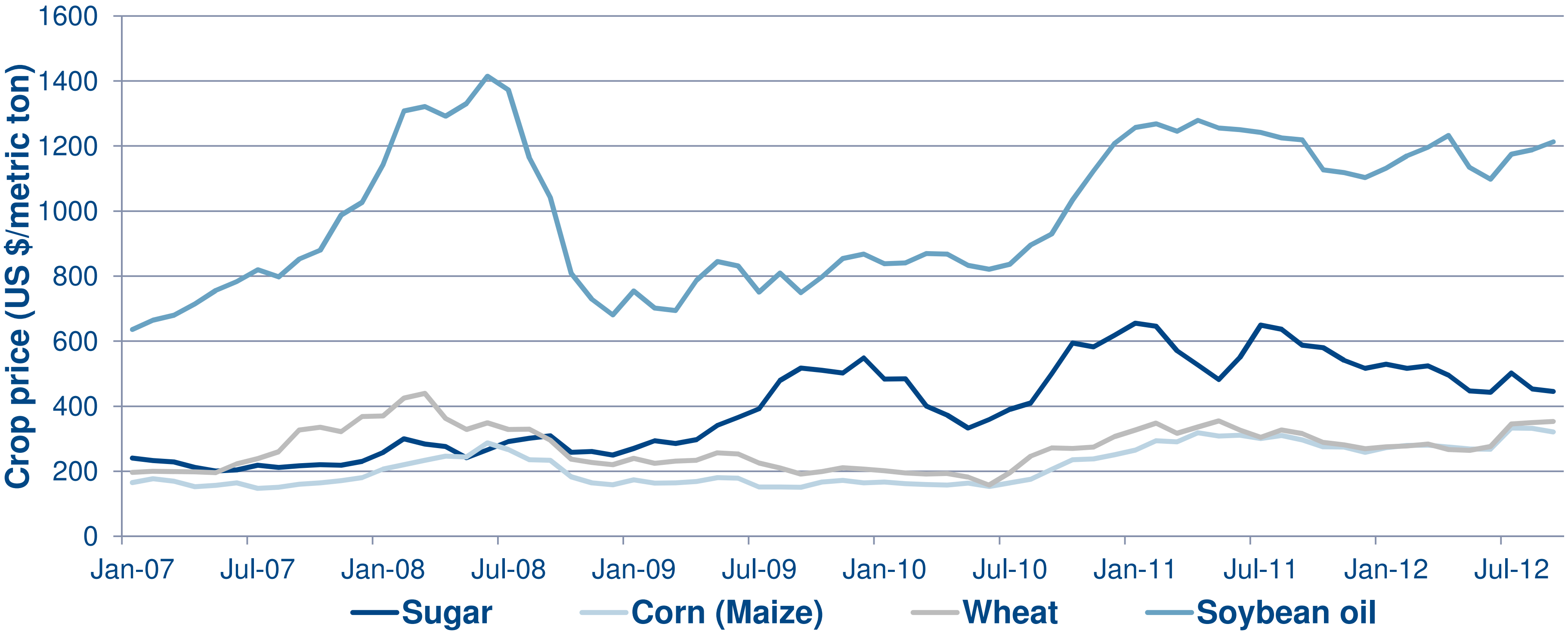
1) http://www.decc.gov.uk/en/content/cms/meeting_energy/bioenergy/sustainability/sustainability.aspx; http://www.dft.gov.uk/ topics/sustainable/biofuels/rtfo/ accessed November 2012.

# Crop prices for some of the main agricultural commodities – especially wheat – have fluctuated considerably in the last four years

2

## Fluctuating crop prices

### Global crop prices (US$ per metric tonne) 2007 – 2012




Source: http://www.indexmundi.com/commodities/ accessed November 2012

## The EC recently announced that it is considering capping the amount of biofuels produced from virgin food crops that can contribute towards renewable energy targets

3

### Dependency on regulation

*"We must invest in biofuels that achieve real emission cuts and do not compete with food"*

*"We are of course not closing down first generation biofuels, but **we are sending a clear signal that future increases in biofuels must come from advanced biofuels"***

European Commission announcement, 17th October 2012

**This suggests that lignocellulosic biomass is a key component of Europe's future transport fuels agenda**

Source: European Commission press release, 17th October 2012. available at: http://ec.europa.eu/commission_2010-2014/hedegaard/headlines/news/2012-10-17_01_en.htm

## Biofuels produced from lignocellulose bring four main advantages

**Make use of waste biomass and crop side-streams**

Avoids competition with food crops

**Higher yields obtainable within a given land area**

In terms of energy, where biomass crops are grown

**Biofuels from lignocellulose: Benefits**

**Processing technologies are already available**

Though not all of these are fully proven at scale using biomass as a feedstock

**Better GHG mitigation benefits**

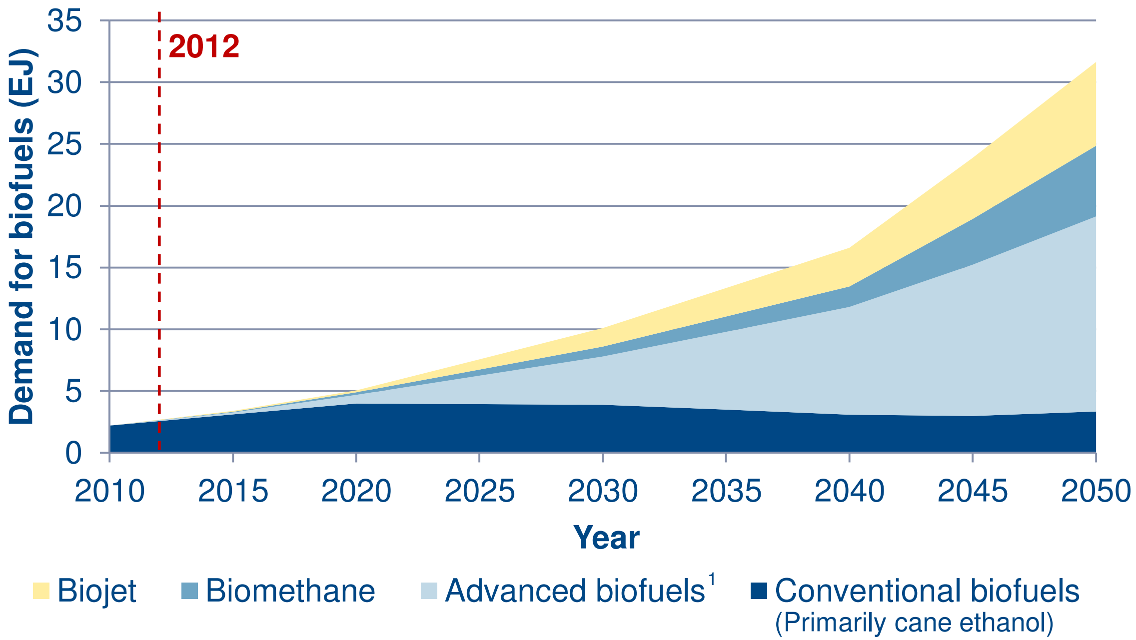
Compared to most[1] first generation biofuels

OECD / IEA, 2008. From first to second generation biofuel technologies: an overview of current industry and RD&D activities; Arthur D. Little analysis 1) Generally on a par with ethanol produced from sugar cane in Brazil.

## The market for advanced biofuels – which includes those produced from lignocellulose – is projected to expand rapidly, though there have been delays in commercialising them

### Biofuels from lignocellulose: Always the technology of the future…

#### Forecast global biofuel demand (2010-2050)




**By 2050, biofuels are projected to account for c. 27% of total demand for transport fuels, up from c. 3% today**

#### Interpretation

- Lignocellulosic biofuels are expected to become full scale commercial reality in the next 1 – 3 years

**However…**

- Forecasts are extremely variable
- Previous forecasts have suggested that this should have happened by now

**What's causing the delay?**

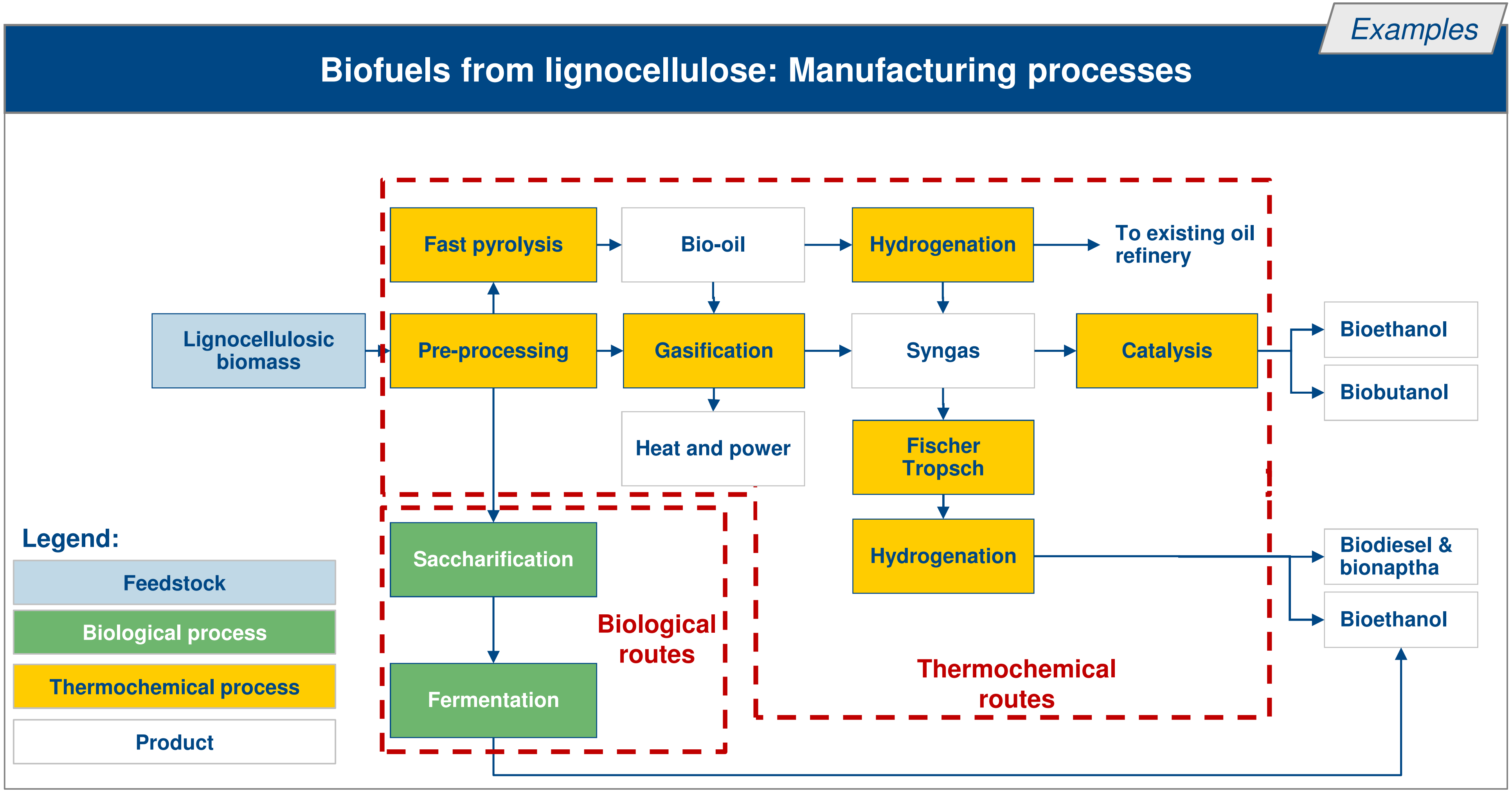
Source: Technology Roadmap - Biofuels for Transport © OECD/IEA, 2011. 1) Advanced biofuels includes those produced from lignocellulosic biomass, hydrotreated vegetable oil, and biofuels produced from algae

## Both biological and thermochemical routes can be used to produce biofuels from lignocellulose…

**Biological**

**Thermochemical**

# … both of which are under late stage commercial development

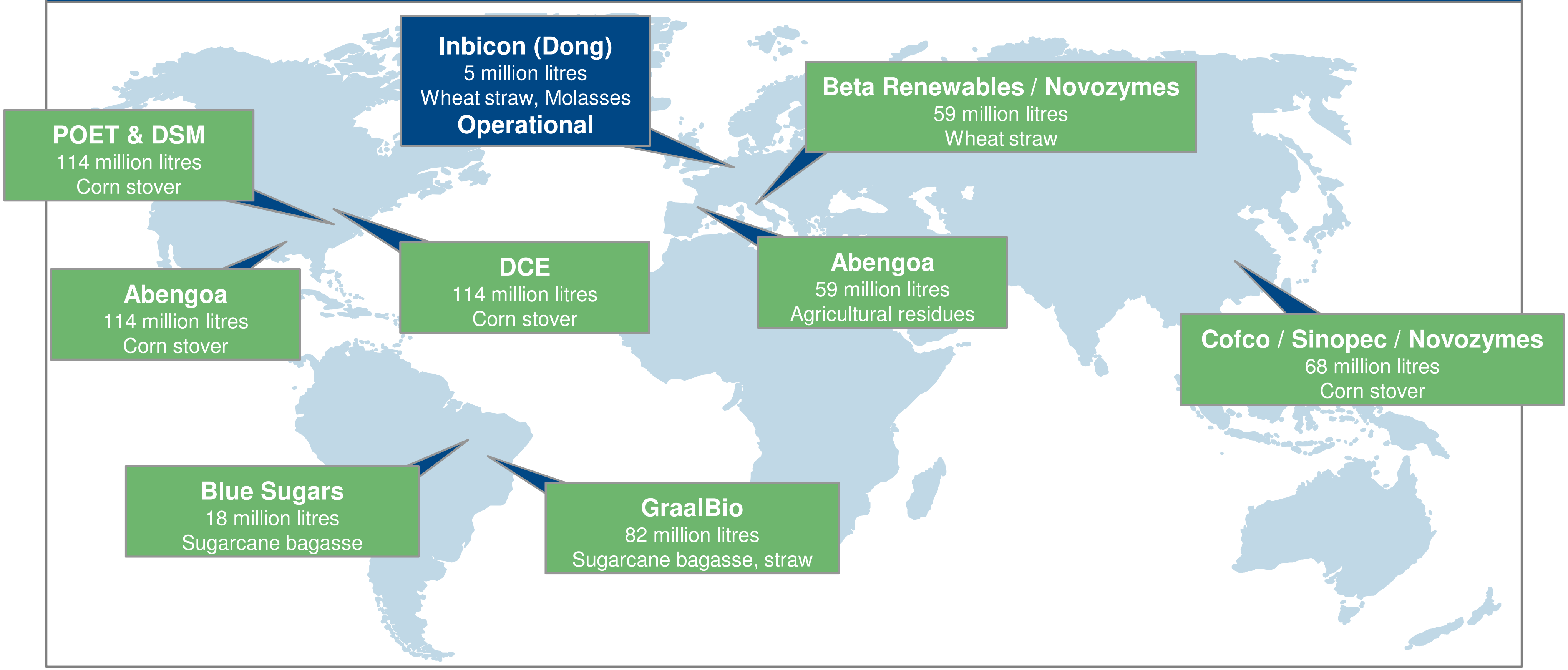



Source: Arthur D. Little, adapted from Van Thurjil, 2003; World Economic Forum, 2010. The future of industrial biorefineries

# According to company announcements, at least 500 million litres of production capacity are reportedly due to come online using biological routes within the next 2 years

*Non-exhaustive*

## Biofuels from lignocellulose: Planned biological facilities




Source: Arthur D. Little analysis of company announcements

## Some thermochemical plants are also about to begin operation – though some close-to-market opportunities have been stopped

*Non-exhaustive*

**Biofuels from lignocellulose: Planned biological facilities**


Source: Arthur D. Little analysis of company announcements

## Some producers closest to commercialisation using thermochemical routes have suffered recent setbacks, run out of capital and filed for bankruptcy

### Biofuels from lignocellulose: Recent setbacks

| | Range Fuels | Choren |
|---|---|---|
| **Company and technology** | ■ Syngas to ethanol and methanol<br>■ Wood chips | ■ Gasification followed by Fischer Tropsch biomass-to-liquids<br>■ Wood chips and agricultural waste |
| **Problems** | ■ Process found not to be economically viable<br>■ Encountered cash flow problems | ■ Delays in scale-up and commissioning of the gasifier |

**The US Government has reduced its mandate for second generation biofuels from 500 million gallons to 8.65 million gallons[1]**

Sources: Bloomberg, Biofuels Digest, company websites. 1) Congressional Research Service, January 2012. Meeting the Renewable Fuel Standard (RFS) Mandate for Cellulosic Biofuels. Available at: http://www.fas.org/sgp/crs/misc/R41106.pdf

## This suggests that the basic economics of biofuels from lignocellulose are a major issue – and one which could be improved by producing biofuels in an integrated biorefinery setting

### Biofuels from lignocellulose: Biorefineries and bio-based chemicals

Sources*

- Dedicated biomass energy crops
- Forest waste and agricultural arisings
- Established wood fibre supply chain

**Available biomass pool**

Uses*

- Existing technologies
  - Biomass heat and power
- Advanced technologies
  - Fischer tropsch diesel
  - Furfural

**Future synergies through "biorefineries": integration of power, fuels, heat and chemicals**

#### Biorefineries

- Biorefineries could help improve process economics by:
  - Sharing synergies in feedstock supply
  - Generating heat and power
  - Looking for added value products, such as bio-based chemicals
- Overall production costs could be reduced by 30%[1] in a biorefinery

**Biorefineries can also be used to produce bio-based chemicals from lignocellulosic biomass – though they have not yet been commercialised**

* Non-exhaustive. 1) IEA Bioenergy, 2012. Bio-based chemicals – value added products from biorefineries, citing an economic study of 12 biorefineries at Wageningen University

## Bio-based chemicals produced from lignocellulose can be classified into three main types

**Bio-based chemicals from lignocellulose**

**Extraction of novel molecules from lignocellulose**

Extraction of novel aromatics

**e.g. furans and phenols**

**Platform chemicals**

Production of chemical intermediates

**e.g. succinic acid, lactic acid**

**The main type today, and comprises:**

- Chemicals which are **direct substitutes** to existing petrochemicals
- Chemicals with **added functionality** such as biodegradability

**Direct use of lignocellulose**

Use of the lignin macromolecule as a structural fibre

**e.g. cellulose whiskers**

## The market for these bio-based chemicals is driven by pressure from customers and consumers, rather than by regulation

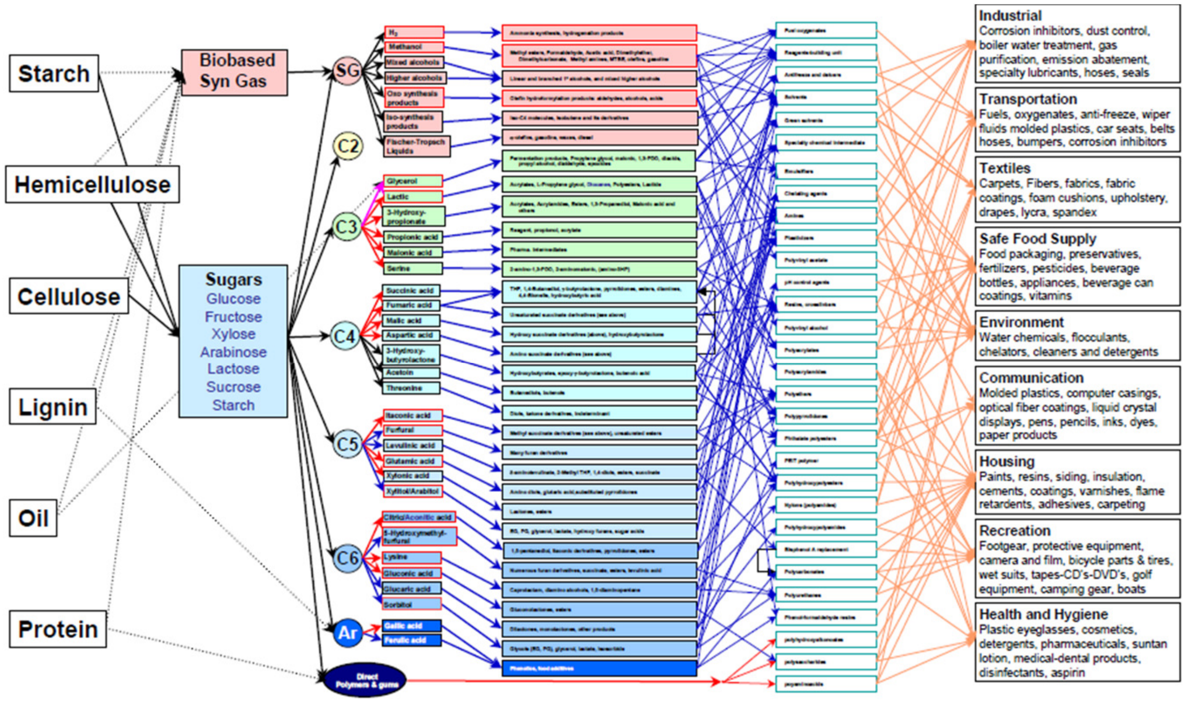
**Bio-based chemicals from lignocellulose: Drivers**

| Pressure from consumers for "green" products | Pressure from suppliers of consumers | Carbon footprint of products | Drop-in replacement for hydrocarbons |
|---|---|---|---|

**Regulation is not a major driver for bio-based chemicals – but in some circumstances it can act as a restraint**

## There is a vast range of bio-based platform chemicals and an even bigger range of production routes

### Bio-based chemicals from lignocellulose: Platform chemicals



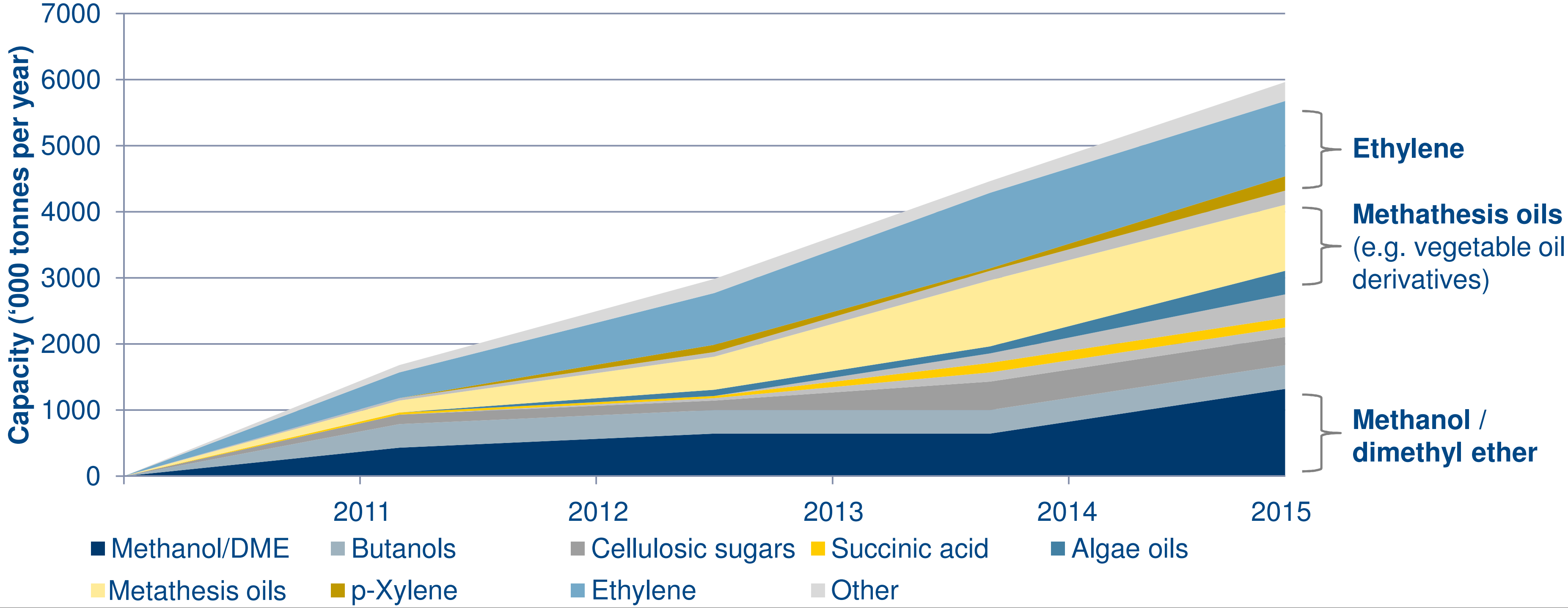

**The market for bio-based chemicals is complex, and highly fragmented**

Source: DOE, 2004. Top Value Added Chemicals from Biomass Volume I—Results of Screening for Potential Candidates from Sugars and Synthesis Gas

# Of this wide range of alternatives, production capacity is projected to expand for certain platform chemicals such as ethylene and methanol

## Bio-based chemicals: Market

### Planned global cumulative novel bio-based chemicals capacity (2011-2015)



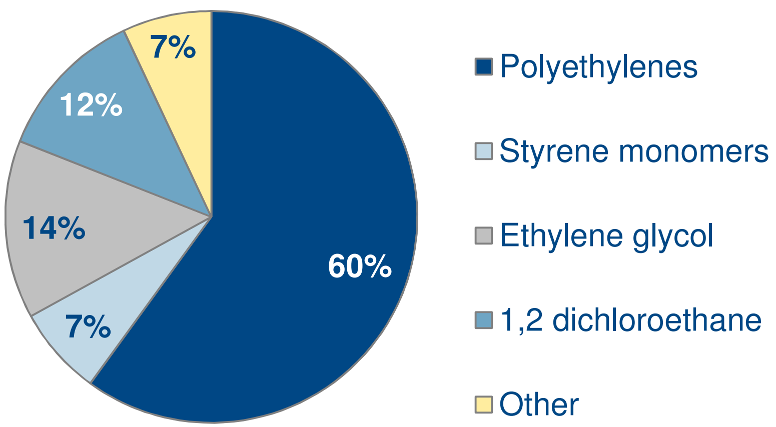

**If both first and second generation feedstocks are used, bio-based chemicals could account for up to 17% of the UK chemical market[1]**

Source: Adapted from ICIS / Nexant, 2012. Bio-based chemicals on the fast track to commercialisation. 1) Source: BERR / Arthur D. Little, 2009. Quantitative Modelling of Industrial Biotechnology and Renewable Chemicals. Figures from the "Knock on wood" scenario, which assumes that second generation biofuels will be successfully commercialised

# Bioethylene is one example of where synergies between second generation bioethanol production and the production of bio-based chemicals may lie in the future

## Bio-based chemicals from lignocellulose: Bioethylene as a platform chemical

### Bio-ethylene: Current derivatives




### Production

- **Bio-ethylene processing is well understood:**
  - Dehydration of bioethanol using an alumina catalyst
  - Cracking of bionaptha from Fischer Tropsch processing of biomass
- **Used as a building block for producing bio-based polymers,** especially:
  - Polyvinyl chloride from 1,2 dichloroethane
  - Poly-ethylenes
  - Polyethylene terephthalate
- **Some interest in bioethanol to bio-ethylene plants:** Dow plans a 300,000t plant in Brazil

**However, the economics don't quite stack up yet!**

Sources: Arthur D. Little analysis; IEA Bioenergy, 2012. Bio-based chemicals – value added products from biorefineries

## Across both bio-based fuels and chemicals there are considerable challenges – but none which we believe cannot be overcome

### Summary: Challenges and solutions

| | Agricultural production | Transportation and logistics | Equipment and process technology | Producers of bio-based fuels and chemicals | |
|---|---|---|---|---|---|
| **Challenges** | Improving yields of biofuel crops | Obtaining large quantities of sustainably sourced biomass | Handling heterogeneous feedstocks | Technology barriers at scale-up | Rise of competing fuel technologies |
| | | | Fragmented processing routes and end markets for bio-based chemicals | | |
| **Solutions** | ■ Target yield improvements for non-food purposes<br>■ Connect with producers<br>■ Optimise side-streams | ■ Use accreditation bodies where possible<br>■ Help develop sustainability standards<br>■ Look for supply chain synergies | ■ Find designs which can handle lower quality, variable feedstocks | ■ Partner with tech suppliers<br>■ Pursue biorefineries | ■ Aim for higher value chemicals (e.g. polymers)<br>■ Pursue specialty fuels markets (e.g. aviation) |

**Above all, it is vital to build the business case for any investment in this area to ensure you can make any money out of it**

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