The Bio-Economy
Where Do Materials Fit?

Dr John Williams
Head of Materials
NNFCC
June 2013
The Bio Economy

The aggregate set of economic operations in a society that use the latent value incumbent in biological products and processes to capture new growth and welfare benefits for citizens and nations.

These benefits are manifest in product markets through productivity gains, enhancement effects and substitution effects, additional benefits derive from more eco-efficient and sustainable use of natural resources to provide goods and services to an ever growing global population.

Source: OECD
Towards a low carbon economy

- Improve efficiency
- Fossil fuel substitution
- Replacement of oil based materials
- End of waste

Source: Adapted from ‘GHG Emission reductions with Industrial Biotechnology’: Assessing the Opportunities, WWF & Novozymes
The UK’s national centre for renewable energy, fuels, chemicals and materials

bio-economy development
EU Renewable Energy Directive

European Governments focussed on Bioenergy
Mandatory EU target of 20% renewable energy in overall energy consumption by 2020

UK Target – 15%

- 47% Electricity
- 33% Heat
- 20% Transport

![Graph showing EU Renewable Energy Directive targets for electricity, heat, and transport for 2020, 2006, and 2008/9.]
Interest in bio-based chemicals - Why now?

- Policy Support
- Technology Drive
- Market Demand
- Feedstock Pressure

Building sustainable supply chains
World biomass production
170 trillion tonnes

- Non utilised: 96%
- Utilised: 4%

Biomass utilised by humans
6 billion tonnes

- Food: 62%
- Wood (energy, paper, furniture, construction): 33%
- Non-food (clothing, chemicals): 5%

Source: Product overview and market projection of emerging bio-based plastics PRO-BIP 2009, Utrecht University
Ecosystem Services

• **Provisioning**
  • Food, water, energy, chemicals

• **Regulating**
  • Control of climate, control of disease

• **Amenity/cultural**
  • Recreation, spiritual

• **Supporting**
  • Biogeochemical cycles – C and N, Crop pollination, biodiversity
Renewable Energy Directive

Mandatory EU target of 20% renewable energy in overall energy consumption by 2020

UK Target – 15%

- Electricity: 47%
- Heat: 20%
- Transport: 33%

Graph showing the proportion of electricity, heat, and transport energy for the years 2006, 2020, and 2008/9.
Current energy supplies are compartmentalised – very little integration across sectors
Biomass can serve all sectors – integrated production of heat, power, fuels, and chemicals including recycling of bio-based chemicals and food/feed wastes. System is complex.
Biofuel supplied - 1,284m litres of fuel, 46% average GHG savings

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Volume, litres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oilseed rape</td>
<td></td>
</tr>
<tr>
<td>Palm</td>
<td></td>
</tr>
<tr>
<td>Soy</td>
<td></td>
</tr>
<tr>
<td>Sugar Beet</td>
<td></td>
</tr>
<tr>
<td>Sugar Cane</td>
<td></td>
</tr>
<tr>
<td>Tallow</td>
<td></td>
</tr>
<tr>
<td>UCO</td>
<td></td>
</tr>
<tr>
<td>UCO</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

Diesel Blend - Fatty acid methyl ester (FAME)

Petrol Blend - Ethanol
A wide range of biofuels can potentially be manufactured from bio wastes.
Bio-materials

- Global biofuel markets supported by subsidies or mandated targets
- No financial market support schemes for bio-materials
- Therefore
  - Evidence for sector interest?
  - Evidence for sector activity?
  - What factors are driving the development of bio-materials?
Interest from chemical producers

- Reduce exposure to crude oil prices
- Reduce process energy costs (industrial biotechnology)
- Potential for novel functionality
- Reacting to supply chain demands
- Green premium???
Crude Oil (petroleum)

Commodity Chemical Prices (spot market)

Source: ICIS Chemical Business
Crude oil (petroleum) and Agricultural Commodity Price index

Source: International Monetary Fund
NNFCC

Biobased will take a significant part of oil based chemistry

Investor Relations
Global Bio-based plastic Capacity Growth

- Crank et al 2005
- Crank et al 2005
- Pro-BIP 2009 Low growth
- Pro-BIP 2009 High growth
- Pro-BIP 2009 Company announcements
- Pro-BIP 2009 Company Expectations
- European Bioplastics 2008
- Consultant Data 2009
- Consultant Data 2009
- Consultant Data 2009
- Pro-BIP 2009 BAU
Epichlorohydrin from glycerol

- Solvay Epicerol® process
- Demonstration - Tavaux, France
- Commercial
- Plant location - Map Ta Phut
- Capacity 100,000 tonnes
- Glycerine demand – 120,000 tonnes
- Start Up - Q1 2012
Propylene glycol from glycerol

- ADM – Propylene glycol
- Plant location – Decatur, US
- Capacity 100,000 tons

DOW Chemical Company - Status unknown
Huntsman Corporation – Status unknown
Cargil/Ashland – Capacity 65,000 tonnes, location Europe
## Growth in US Ethanol

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Total Ethanol Plants</td>
<td>50</td>
<td>54</td>
<td>56</td>
<td>61</td>
<td>68</td>
<td>72</td>
<td>81</td>
<td>95</td>
<td>110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethanol Production Capacity</td>
<td>1701.7 mgy</td>
<td>1748.7 mgy</td>
<td>1921.9 mgy</td>
<td>2347.3 mgy</td>
<td>2706.8 mgy</td>
<td>3100.6 mgy</td>
<td>3643.7 mgy</td>
<td>4336.4 mgy</td>
<td>5493.4 mgy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plants Under Construction/Expanding</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>13</td>
<td>11</td>
<td>15</td>
<td>16</td>
<td>31</td>
<td>76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity Under Construction/Expanding</td>
<td>77 mgy</td>
<td>91.5 mgy</td>
<td>64.7 mgy</td>
<td>390.7 mgy</td>
<td>483 mgy</td>
<td>598 mgy</td>
<td>754 mgy</td>
<td>1778 mgy</td>
<td>5635.5 mgy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>States with Ethanol Plants</td>
<td>17</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>19</td>
<td>18</td>
<td>20</td>
<td>21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* operating plants
** 12,475.4 mgy capacity including idled capacity

<table>
<thead>
<tr>
<th>Country</th>
<th>Millions of Gallons</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>9000.0</td>
</tr>
<tr>
<td>Brazil</td>
<td>6472.2</td>
</tr>
<tr>
<td>European Union</td>
<td>733.6</td>
</tr>
<tr>
<td>China</td>
<td>501.9</td>
</tr>
<tr>
<td>Canada</td>
<td>237.7</td>
</tr>
<tr>
<td>Other</td>
<td>128.4</td>
</tr>
<tr>
<td>Thailand</td>
<td>89.8</td>
</tr>
<tr>
<td>Colombia</td>
<td>79.29</td>
</tr>
<tr>
<td>India</td>
<td>66.0</td>
</tr>
<tr>
<td>Australia</td>
<td>26.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17,335.2</strong></td>
</tr>
</tbody>
</table>

Source: RFA, F.O. Licht 2008 Estimates
Ethylene Value Chain

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

- **ETHYLENE**
  - Commodity Polyethylene
  - Styrene Monomer
  - Ethylene Oxide/Glycol
  - Vinlys Chain
  - Miscellaneous

- **Commodity Polymers/Rubbers**
  - Polyester
  - PVC
  - Vinyl Acetate
  - Alpha Olefins
  - Speciality Elastomers
  - Synthetic Ethanol
Bio-ethylene near market activity

- No technical hurdles for the production ethylene from biomass
- Braskem (Brazil)
  - Planned HDPE production
  - Capacity 250,000 tonnes/year Q4 2010
    - 1Mt end of 2012
- Dow/Crystalsev (Brazil)
  - Planned Polyolefin production 2011
  - Capacity 350,000 tonnes/year
- Solvay (Brazil)
  - Planned PVC and PVA

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

For a wheat price, typical of a balanced to long market, ethylene derived from bioethanol makes green polyethylene competitive with petrochemical derived routes in a high crude oil price world.

Current wheat price ~ £110/tonne
Current crude oil price ~ $75/bbl
DOE's Top 12 Bio-derived building blocks

- Succinic acid
- 2,5-Furandicarboxylic acid
- 3-Hydroxypropionic acid
- Aspartic acid
- Glucaric acid
- Glutamic acid
- Itaconic acid
- Levulinic acid
- 3-Hydroxybutyrolactone
- Glycerol
- Sorbitol
- Xylitol
Fumaric & succinic acid downstream potential

**Fumaric Acid**
- L-aspartic acid
- Unsaturated Polyester
- Alkyd resins
- Paper sizing
- Food and beverages
- Printing Inks
- Animal Feed

**1,4-Butanediol**
- Tetrahydrofuran
- Polytetramethylene Ether Glycol
- Solvent Uses

**γ-Butyrolactone**
- Pharmaceuticals
- Herbicides
- Foundry Resins

**N-Methyl-2-Pyrrolidone**
- Extraction Solvent
- Polymers
- Cleaning Agents
- Electronics

**2-Pyrrolidone**
- Pharmaceuticals
- Intermediates

**N-Vinyl-2-Pyrrolidone**
- Polymers
- Pyrrolidone

**Polybutylene Terephthalate**
- Copolyester Ethers
- Thermoplastic Polyurethanes
- Spandex Fibres

**Uses**
- Pharmaceuticals
- Intermediates

**Unsaturated Polyester**
- Polyester
- Alkyd resins
- Paper sizing
- Food and beverages
- Printing Inks
- Animal Feed
Butanediol economics

**Bio-BDO Indifference Curve for EU**
(Assumes Sugar at Intervention Price)

**Brazilian sugar - €150-200**

Wet milling of wheat and corn is limited in Europe with most sugar being sugar beet-derived. With a sugar beet price of circa €30 per ton then on an integrated basis it may be possible to support captive fumaric acid and butanediol production.
The race to commercial industrial bio-succinic acid

BASF and CSM announce joint production development of biobased succinic acid

LUDWIGSHAFEN, GERMANY, and DIEMEN, NETHERLANDS – September 30, 2009 – BASF SE and CSM nv today announced the cooperation between their respective subsidiaries BASF Future Business GmbH and PURAC for the development of the production of biobased succinic acid. Both partners have been working on the development of the industrial fermentation and down-stream processing of biobased succinic acid and will start production of commercial quality and volumes in the second quarter of 2010.

PRESS RELEASE

Bioamber Commissions World’s First Renewable Succinic Acid Plant

Pomacle, France, January 20th, 2010: Bioamber, a joint venture between US-based DNP Green Technology and France-based ARD (Agro-industrie Recherches et Developpements), announces the successful start-up and commissioning of the world’s first bio-based succinic acid plant. Since December 2009, the plant has been producing renewable succinic acid from wheat derived glucose.

DSM and ROQUETTE to commercialize bio-based succinic acid as of end 2009

Heerlen, NL, 09-Mar-2009 08:15 CET

Royal DSM N.V., the global Life Sciences and Materials Sciences company headquartered in the Netherlands, and the French starch and starch-derivatives company ROQUETTE confirmed during the international Life Sciences Forum, BioVision, that its bio-based succinic acid demonstration plant in Lestrem (France) will be operational by the end of 2009. The pilot scale production has proven that this biological route for producing succinic acid can be commercially viable. The first tests for customers are already underway with this ‘green’ succinic acid.
Lactic acid

• Polylactic acid - Worlds leading bio-based synthetic polymer

• European demand predicted to rise from 25,000 per year to 650,000 tonnes by 2025

• Global lactic acid production capacity > 400,000 tonnes

• Expanding number of additive packages increasing application areas

• Compostable packaging to textile fibres
Market confusion – bio means biodegradable

Samsung Reclaim M560 Phone, Earth Green (Sprint)

Contains 40% polylactic acid

According to the blogosphere - A biodegradable phone!
## What is bio?

<table>
<thead>
<tr>
<th>Origin of Material</th>
<th>Biodegradability</th>
<th>Example</th>
<th>The meaning of the prefix “bio-”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable</td>
<td>Biodegradable</td>
<td>Polyhydroxyalkanoate (PHA)</td>
<td>Biodegradable and bio-based</td>
</tr>
<tr>
<td>Non-renewable</td>
<td>Biodegradable</td>
<td>Polycaprolactone (PCL)</td>
<td>Biodegradable</td>
</tr>
<tr>
<td>Renewable</td>
<td>Non-biodegradable</td>
<td>Polyethylene (PE) from sugar cane</td>
<td>Bio-based</td>
</tr>
<tr>
<td>Non-renewable</td>
<td>Non-biodegradable</td>
<td>Polyetheretherketone (PEEK) for biomedical applications</td>
<td>Biocompatible</td>
</tr>
</tbody>
</table>

Adapted from: Taking bio-based from promise to market, EU Commission
Relevance of biodegradability?

DECEMBER 2, 2009 - COPENHAGEN DELEGATES WALK ON ECO2PUNCH® INGEO™ CARPET MADE FROM PLANTS, NOT OIL

Manufacture of this innovative performance carpet emits less greenhouse gas, reduces energy consumption, and demonstrates a new model for recycling.

COPENHAGEN, Denmark, December 2, 2009 - At the Bella Center where the United Nations global conference on climate change will be held, every one of the 15,000 dignitaries will stand, walk, and rest their feet on an ultra low carbon footprint Eco2punch® carpet made with Ingeo™ fibers from plants not oil.

Image courtesy of Natureworks

PLA provides end of life flexibility compost, incineration or recycling
Food packaging

- An estimated 8.3 million tonnes of household food waste is produced each year in the UK (source WRAP).
- Large quantities of food waste are packaged.
- Packaging increases the shelf life of products and reduces waste.
- Need an efficient system to deal with food waste.

Source: totals from Environment Agency annual report on landfill allowances produced from data provided by Local Authorities on WasteDataFlow.

Source: Defra.
The role for biodegradable packaging
England’s Official Information Portal on Anaerobic Digestion

www.biogas-info.co.uk
European Lead Market Initiative

- Standards, labels and certification
- Legislation promoting market development
- Product specific legislation
- Legislation related to biomass
- Encourage Green Public Procurement
- Financing and funding of research
Labels and standards

• Biodegradability - material function
  – Plastic products can provide proof of their compostability by successfully meeting the harmonised European standard, EN 13432

• Is origin of material is important?
• How do we communicate
Value to the supply chain

THE COCA-COLA COMPANY INTRODUCES INNOVATIVE BOTTLE MADE FROM RENEWABLE, RECYCLABLE, PLANT-BASED PLASTIC

TETRA PAK PLANS BIOPLASTIC TRIALS IN 2011
Dupont’s Propanediol platform

Zemea™ Propanediol

SmartStrand® Carpet with DuPont™ Sorona® Renewably Sourced Polymer
*Photo courtesy of Mohawk Industries*

Calvin Klein Golf jacket made with DuPont™ Sorona® polymer.
*Photo Courtesy of Calvin Klein Golf*
Propanediol Value Chain

100% bio-based content
- Zemea™ 1,3-propanediol
- Susterra™ 1,3-propanediol

100% bio-based content
- Cerenol® poly(trimethylene diol)

28% bio-based content
- Sorona® poly(trimethylene terephthalate)

30-37% renewable by weight
- Sorona® EP thermoplastic polymers

60% renewable content
- Pearlthane® ECO bio-TPU

X% bio-based
End Product

100% bio-based content
- Merquinsa
- DuPont

ASTM Standard D 6852: Standard Guide for Determination of Biobased Content, Resources Consumption, and Environmental Profile of Materials and Products
Bio-based content defined by C14 levels

Vinçotte announces proudly the first OK biobased certificates of a whole range of raw materials.
IF WE CAN

SHOULD WE?
Manufacture → Use → Disposal


Waste → Emissions → Waste → Emissions → Waste → Emissions

System Boundary
Significant fossil energy savings

**Primary Energy Inputs (MJ/t)**

<table>
<thead>
<tr>
<th></th>
<th>Price</th>
<th>Mass</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar Beet</td>
<td>46,709</td>
<td>32,852</td>
<td>45,110</td>
</tr>
<tr>
<td>Wheat Grain</td>
<td>41,659</td>
<td>33,421</td>
<td>35,699</td>
</tr>
<tr>
<td>Petro (PlasticsEurope)</td>
<td>72,300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**LLDPE Production (cradle to factory gate)**

- **Sugar Beet**
  - Price: 46,709
  - Mass: 32,852
  - Energy: 45,110

- **Wheat Grain**
  - Price: 41,659
  - Mass: 33,421
  - Energy: 35,699

- **Petro (PlasticsEurope)**
  - Price: 72,300

**NORTH ENERGY**
Significant GHG emissions savings

<table>
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<th></th>
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<th>Wheat Grain</th>
<th>Petro (PlasticsEurope)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>-481</td>
<td>-446</td>
<td>1,890</td>
</tr>
<tr>
<td>Mass</td>
<td>-1,372</td>
<td>-812</td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>-595</td>
<td>-470</td>
<td></td>
</tr>
<tr>
<td>Substitution</td>
<td>11,815</td>
<td>944</td>
<td></td>
</tr>
</tbody>
</table>
### Comparison with fuel ethanol

<table>
<thead>
<tr>
<th>Production Option</th>
<th>Energy requirement</th>
<th>GHG emissions</th>
<th>GHG emissions Petro equiv</th>
<th>% savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioethanol from wheat grain</td>
<td>0.597 (MJ/MJ)</td>
<td>0.044 (kg CO(_2) eq./MJ)</td>
<td>0.081 (kg CO(_2) eq./MJ)</td>
<td>46%</td>
</tr>
<tr>
<td>LLDPE from wheat grain</td>
<td>41,659 (MJ/tonne)</td>
<td>-446 (kg CO(_2) eq./tonne)</td>
<td>1,890 (kg CO(_2) eq./tonne)</td>
<td>124%</td>
</tr>
</tbody>
</table>
Findings of the Gallagher Review

• There is probably sufficient land for food, feed and biofuels

• The review has examined both the likely levels of future demand for agricultural land and how much land might be available. There remains much uncertainty.

• At present, feedstock for biofuel occupies just 1% of cropland but the rising world population, changing diets and demand for biofuels are estimated to increase demand for cropland by between 17% and 44% by 2020.

• However, the balance of evidence indicates there will be sufficient appropriate land available to 2020 to meet this demand......

• The review has not examined the situation beyond 2020 when current trends are anticipated to continue and climate change will affect land productivity. The long-term potential of bioenergy using land suited for agricultural production therefore requires further consideration.
### GHG savings per unit of land

<table>
<thead>
<tr>
<th>Land unit</th>
<th>Output</th>
<th>GHG savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioethanol from wheat</td>
<td>1 ha</td>
<td>66801 MJ 3181 litres</td>
</tr>
<tr>
<td>LLDPE from wheat</td>
<td>1 ha</td>
<td>1.4 tonnes</td>
</tr>
</tbody>
</table>

Using wheat grain for polyethylene delivers an additional 32% GHG saving over fuel ethanol.

<table>
<thead>
<tr>
<th>Land unit</th>
<th>Output</th>
<th>GHG savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLDPE from sugar beet</td>
<td>1 ha</td>
<td>2.7 tonnes</td>
</tr>
<tr>
<td>Product</td>
<td>GHG savings tCO₂ eq. per t</td>
<td>Land Use (ha per tonne)</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>acetic acid</td>
<td>0.3</td>
<td>0.14</td>
</tr>
<tr>
<td>acrylic acid</td>
<td>1.6</td>
<td>0.18</td>
</tr>
<tr>
<td>adipic acid</td>
<td>2.8</td>
<td>0.28</td>
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<tr>
<td>butanol</td>
<td>3.4</td>
<td>0.32</td>
</tr>
<tr>
<td>caprolactam</td>
<td>5.1</td>
<td>0.33</td>
</tr>
<tr>
<td>ethanol</td>
<td>2.7</td>
<td>0.27</td>
</tr>
<tr>
<td>ethyl lactate</td>
<td>1.4</td>
<td>0.30</td>
</tr>
<tr>
<td>ethylene</td>
<td>2.4</td>
<td>0.45</td>
</tr>
<tr>
<td>succinic acid</td>
<td>4.0</td>
<td>0.15</td>
</tr>
<tr>
<td>1,3-propanediol</td>
<td>1.4</td>
<td>0.36</td>
</tr>
<tr>
<td>PLA</td>
<td>2.9</td>
<td>0.18</td>
</tr>
</tbody>
</table>

NB: Production from corn starch

Adapted from: Medium and Long-term Opportunities and Risks of the Biotechnological Production of Bulk Chemicals from Renewable Resources, Utrecht University 2006.
Potential for high land productivity

- **Ethanol**  \( C_6H_{12}O_6 \rightarrow 2 C_2H_6O + 2 CO_2 \)

- **Lactic Acid**  \( C_6H_{12}O_6 \rightarrow 2 C_3H_6O_3 \)

- **Succinic Acid**  \( C_6H_{12}O_6 + 2 CO_2 + 2 H_2 \rightarrow 2 C_4H_6O_4 + 2 H_2O \)
French Biorefinery Development

- **FARMERS**: (Wheat, rapeseed, sugarbeet, alfalfa, barley, corn,...)
- **AGRO BUSINESSES** (CHAMPAGNE CEREALES...)
- **Cristal Union**: Sugar production
- **Chamtor**: Wheat processing

**Water Recycling**
- Biofuel Intermediates Surfactants
- Bioplastics, Solvents, Fine chemicals

**CSD**: Cogeneration of bio-based energy
- Steam & "Green" electricity
- Glucose synergy

**Cristanol 1 & 2**
- Alcohol for beverage
- Ethanol for gasoline (E85)
- Wet wheat feed for ANIMAL FOOD
- CO2 for industrial usage

**BIO AMBER**
- Succinic acid
- Diethyl succinate
- Succinate salts

**SOLIANCE**
- Natural and innovative cosmetic active ingredients

**Ecole Centrale Paris**
- Scientifically and technically engineers trained to the highest standard

**CIMV**
- Paper pulp from straw

**ARID**
- Agro Industries R & D

**Basins**
- Water purification

**Biotechnology Labs**
- Research laboratories for industrial applications

**Cosmetic ingredients**
- Amylic alcohol
- Bioethanol

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**Cosmetic ingredients**
- Amylic alcohol
- Bioethanol
Potential biobased material economy 2030

- nutrients returned to land, carbon feedstock for base materials
- draw down of atmospheric CO₂, replacement of fossil carbon
- reduced pressure on land, reduced emissions
- renewable carbon stored in materials 376-633 MtCO₂e
- platform chemicals, natural polymers, fibres
- Bio-based materials production 282-668 MtCO₂e
- polymers, additives, formulated products
- product life
- functional material
- base material
- recycle
- cultivation

Source: NNFCC & ‘GHG Emission reductions with Industrial Biotechnology’: Assessing the Opportunities, WWF & Novozymes
NNFCC’s role in development

- Market Pull
- Commercial Environment
- Technology Push

- The right conditions
- Engaged with UK and EU policy makers
- Raising awareness of retailers and the public
- Supporting UK R&D

building sustainable supply chains
Leadership Team

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*Biomass & Biogas*  
- Anaerobic digestion  
- Farming, forestry & waste  
- Feedstock planning

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- Biorefinery development  
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- Bioplastics  
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