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The UK's National Centre for Renewable Fuels, Chemicals & Materials

End of Life Scenarios for Bioplastics

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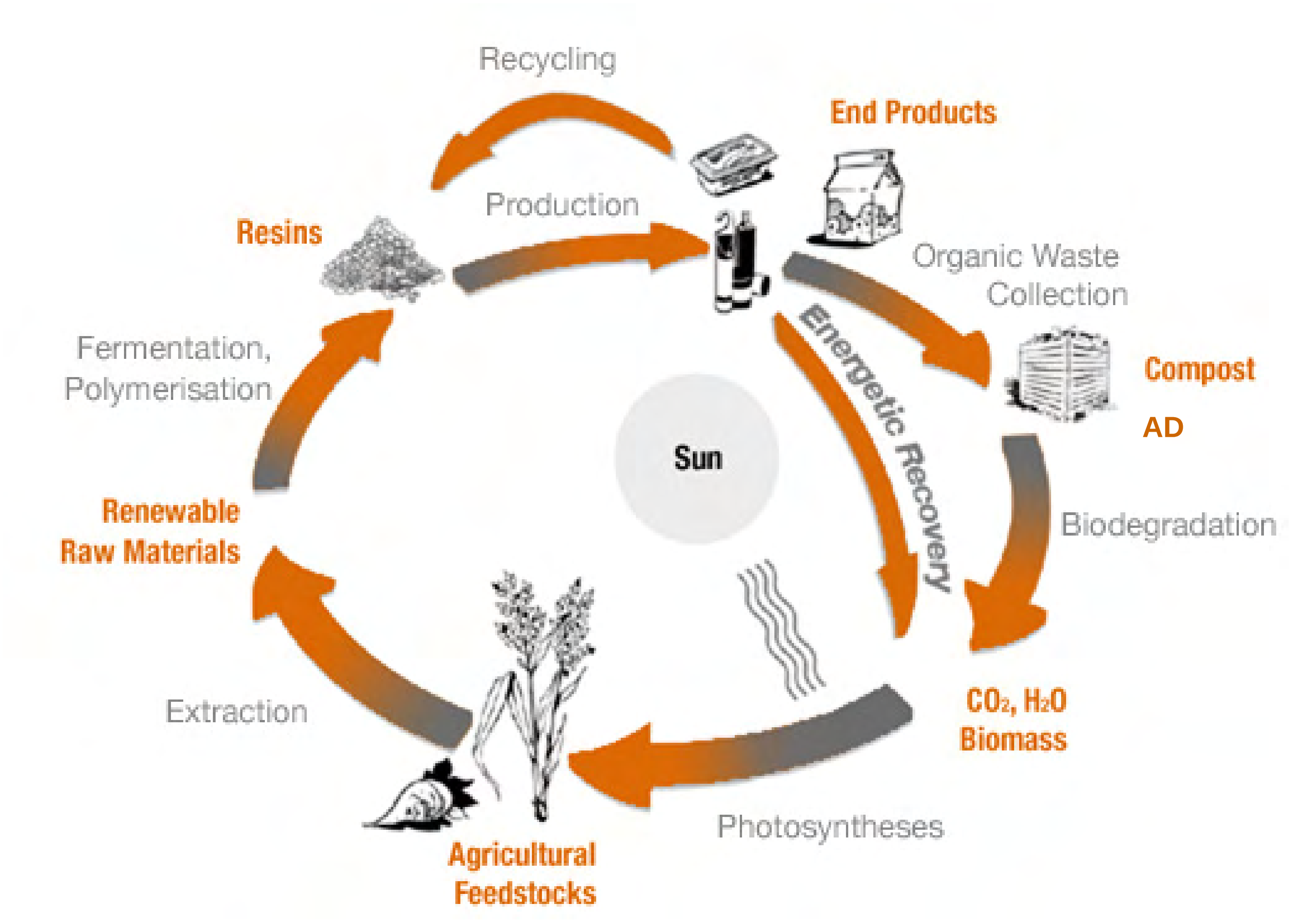
Content

- The key challenges for our world
- A circular economy as part of the solution
- Waste policies for a circular economy
- The role of compostable materials
- Conclusions

Idealised Closed Loop



Courtesy European Bioplastics

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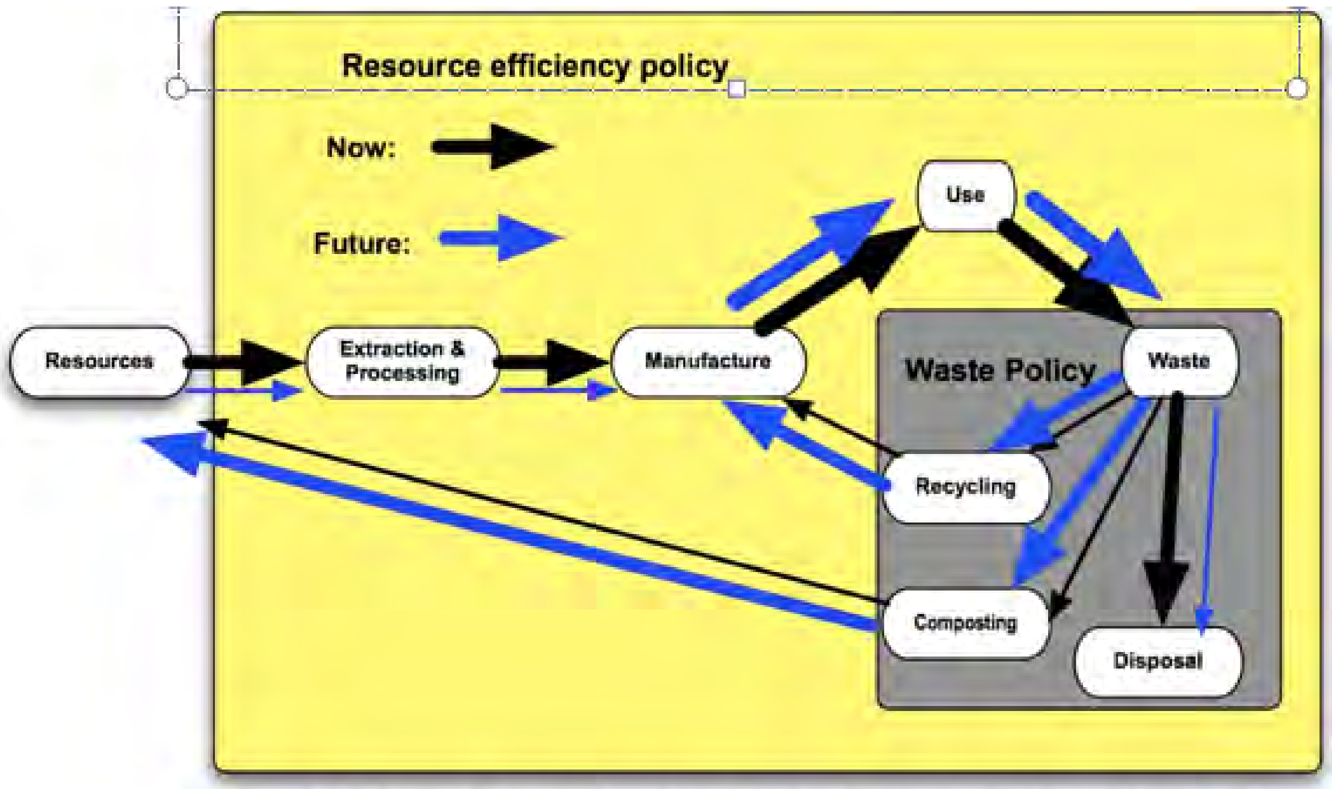
The Circular Economy

- **An economy where 'waste' does not exist, with 'end of life' resources re-entering the economy**
- **An approach focussed on maximising resource efficiency**
- **Waste policy is a key component of such an approach**
- **A simplified diagram:**

Waste Policy v Resource Efficiency



NB: There will of course be waste from extraction and processing and manufacturing; this waste is placed at the end of the system in order to simplify the diagram

Waste Policies to Maximise Resource Efficiency

- **The top of the waste hierarchy shows the way:**
  - Waste prevention - the best environmental option, avoiding resource use
  - Reuse - reduces need for resources and manufacturing
  - Recycling - reduces need for extraction and processing of new resources
  - Composting - returns nutrients and structure to soils; displaces other fertilizers; sequesters carbon; and, in the case of anaerobic digestion (AD), produces methane which can be used as a 100% renewable energy source.
- **Then we must phase out the rest - the residual waste, which is currently landfilled or incinerated**

Mechanical Recycling

Strengths ▪ High purity recyclate ▪ Simple process ▪ Value of polymer synthesis preserved ▪ Outlets for downgraded product ▪ Techniques for using recycled plastic in demanding applications	**Weaknesses** ▪ Hard to apply to post consumer waste ▪ Capital and labour intensive ▪ Requires clean, homogenous waste streams
Opportunities ▪ Recycle from manufacturing scrap ▪ Recycle from secondary and tertiary packaging in supply chain	**Threats** ▪ Biopolymers may be seen as a contaminant to more established materials

Chemical Recycling

Strengths	Weaknesses
▪ Produces a feedstock that can be used to create virgin polymer ▪ Relies on well established chemical engineering ▪ Will tolerate greater feedstock variability ▪ More tolerant to contaminants	▪ Capital intensive ▪ Needs a large plant to be cost effective ▪ Large scale chemical engineering needed – complex process. ▪ Never proven at full scale ▪ Only appropriate for some biopolymers
Opportunities	**Threats**
▪ Could handle post-consumer waste ▪ Could handle multi-material 'engineered' packaging ▪ Integrate biopolymers with general polymer waste stream	▪ Energy and transportation costs mean that process will never be viable ▪ Viable plants cannot handle enough feedstock variability to tackle post consumer waste

Incineration

Strengths	Weaknesses
▪ Handles all waste with a high carbon content ▪ Recovers energy from original fossil feedstock ▪ Carbon from biopolymers returned to the biosphere ▪ Efficient use of resources	▪ Capital intensive ▪ Pollution risk if poorly designed or operated ▪ Public suspicion fuelled by campaigns ▪ Swings in energy price could threaten viability
Opportunities	**Threats**
▪ Biopolymers contribute to renewable energy	▪ Public opinion blocks incineration

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Composting

Strengths	Weaknesses
▪ Dramatically reduces landfill ▪ Can cope with any biodegradable material ▪ Produces a commercial product ▪ Low energy input ▪ Returns carbon from biopolymers to the biosphere	▪ Requires careful separation of waste streams ▪ Cannot handle 'engineered' packaging that includes non-biodegradable polymers ▪ Treatment of kitchen waste requires new closed vessel composting
Opportunities	**Threats**
▪ Niches applications where composting can be guaranteed ▪ Major switch to compostable packaging	▪ Inadequate market for the compost ▪ Retailers won't label materials that will not compost at home ▪ Misclassification problem raises costs

Anaerobic Digestion

- **E.g. Greenfinch project in Ludlow, UK**
  - Government assisted
  - Strong public support
- **Recycles 5000 tpa of source-segregated waste into:**
  - Pasteurised fertilizer for local agriculture
  - Biogas, producing electricity & heat (100% renewable)

  www.greenfinch.co.uk
- **Anaerobic digestion of food waste from UK households could generate 0.4% of UK electricity demand [5]**
  - More could be generated if commercial food waste, or agricultural waste, was included.

Phasing Out Residual Waste

- **Ensuring that (eventually) everything can be reused, recycled or composted**
- **Mechanisms:**
  - Provision of collection systems
  - Development of processing capacity and markets
  - Regulations requiring recycling of complex materials
    - Including design for recycling
    - E.g. Waste Electrical & Electronic equipment Directive
  - A move to more recyclable plastics
  - **Expansion of compostable materials**

The Real World

- **The waste industry is conservative, and change takes time**
- **You will not get across-the-board transformation of systems in a short period**
  - due to e.g. lack of resources, long contracts & lifespan of equipment
- **The public has limited capacity and willingness to cope with complex waste systems**
  - Complex systems for consumer plastics sorting won't work
  - Compostability must be clear to the public, with a range of signals (labelling, product type, education etc)
- **Therefore, realistic plans must accept that much will remain the same - but there will be some changes**

Key Opportunities

- **Packaging materials that are hard to recycle due to complexity or lack of markets**
  - E.g. much food packaging material
    - Particularly where will be contaminated by food
    - Key need - compostable laminate systems
  - NOT materials that are recycled - e.g. replacing PET or HDPE in bottles
- **Products that may end up in environment as litter**
  - E.g. Carrier bags, Nappies
- **Products that will never be recyclable**
  - E.g. Nappies
- **Bags for compost systems**

Criteria

- **Feedstock:**
  - Sustainably produced (I.e. low/no pesticide inputs, low water use etc)
  - Non-GM
  - Ideally, a waste rather a food
- **Process:**
  - Energy efficient
  - Resource efficient (zero waste)
  - Green chemistry
- **End product:**
  - ideally home compostable, and must meet EU compostability standard
  - ideally anaerobically digestible
  - free of problematic chemicals, including any which would affect compost quality (including additives)

Sustainable Polymer/Renewable Polymer – A Working Definition

- Any polymer material extracted DIRECTLY or produced INDIRECTLY from the biomass.
- This idea automatically obviously covers Celluloses, Starches, Proteins etc.
- It also covers Polylactic Acid (PLA) and Polyglyconic Acids (PGA's) produced from naturally occurring monomers
- But it also includes:
    - Polyethylene produced from ethene, generated by dehydration of Bio-ethanol and;
    - Polypropylene produced from propene derived from Glycerol.

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Some Key Issues?

- Recycling / (Reuse)
  - Can the polymer be recycled?
    - E.g. Thermoset (NO) versus Thermoplastic (Yes)
  - How pure does the recyclate need to be?
    - With respect to polymer type e.g. PE, PP, PET, PLA PHA.
    - With respect to grade E.g. HDPE, UHDPE, LDPE etc.
  - How much effort is needed to ensure any material and/or grade purities necessary for recycling?
  - How much infrastructure is needed to facilitate recycling?
  - How much effort is needed to allow regeneration of the monomer or conversion to another feedstock e.g. Syn Gas?
  - Can we make use of less sorted, or even unsorted, waste?
  - **How much does the effort of recycling cost ?**

Some Key Issues?

- **Biodegradability:** For polymers this seems to be a catch all statement requiring degradation mechanisms involving enzymatic and/or microbial actions.
  - Note this definition does not specify:
    - Aerobic or anaerobic actions
    - Where the degradation is taking place (e.g. In a contrived or natural environment)
    - What the polymer is degrading to, for example; CO_2, H_2O, **CH_4**, biomass
    - The time scale over which any degradation occurs
- Consider the Questions:
  - Is wood biodegradable?
  - Is PLA biodegradable?
  - Is traditional PE biodegradable?
  - Do polymers need to be Biodegradable

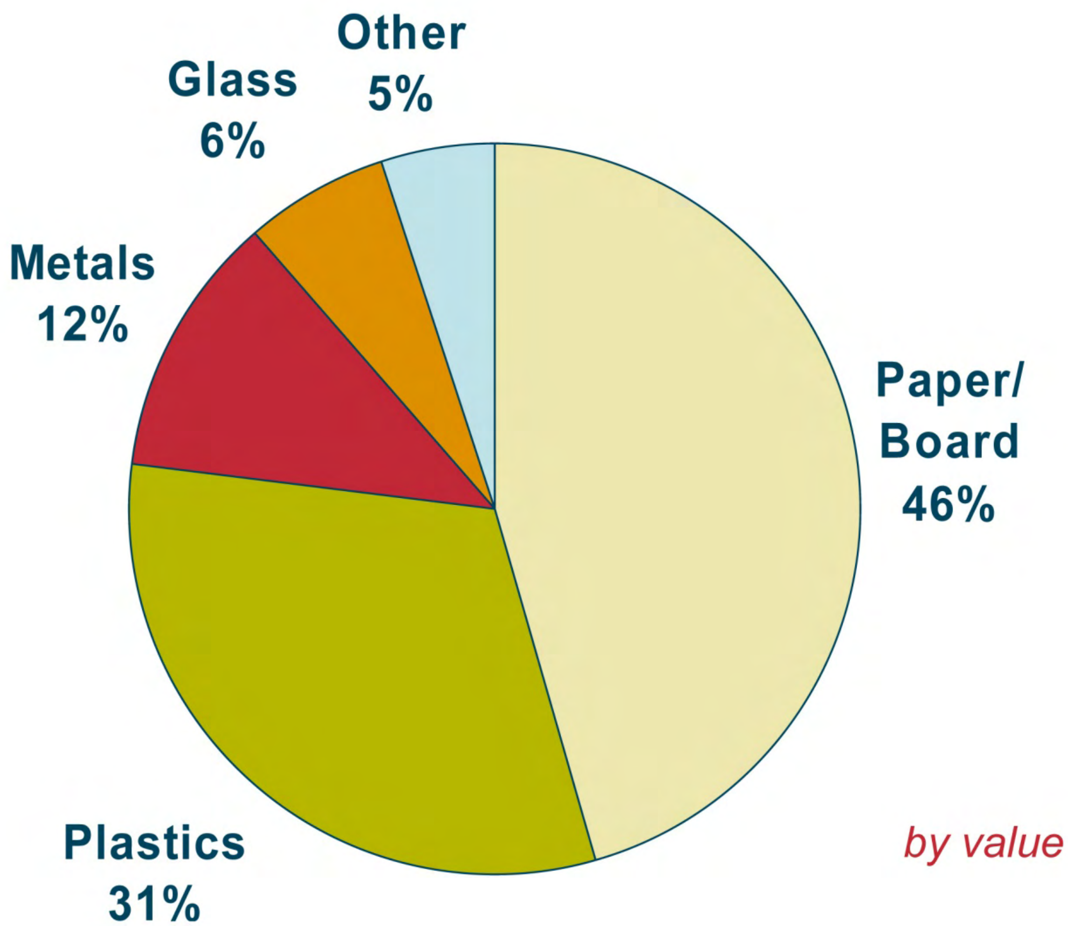

BASF – Ecoflex Film

Some Key Issues?

- Compostability: defined standards now exist e.g. EN13432.

- These standards typically define conditions, time scales as well as some outcomes, and required defined tests to be carried out before a claim can be made.
  - But they are specific to end use products not to polymer materials.
    - i.e. You cannot say PLA is compostable, and you can only claim, for example that 12µm thick PLA film is compostable after appropriate testing.
  - This second point often seems to be missed and compostability and biodegradability get confused.

Packaging Materials



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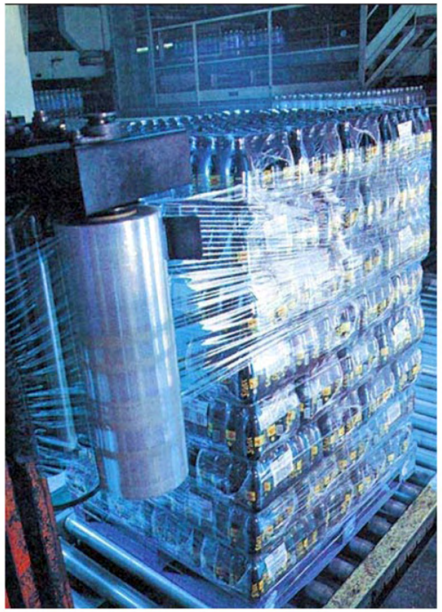
Primary packaging

Secondary packaging

Tertiary packaging



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Renewable Packaging

- Drop-in substitutes
- Increasing range of properties
- Meeting real user needs
- Price/performance gap
- Production scale
- Unique properties
- Performance data in use
- Transparent data on life-cycle impact
- Strategy for the use of biomass/waste

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Issues

- Renewable *not* biodegradable
- Need for independent advice
- Fragility of public opinion
- Labelling packing as compostable
- ‘Biodegradable’ plastics from petrochemicals
- Overestimating the impact of biopolymers
- Complex ‘engineered’ packaging
- Preparing for success
- Weight based recycling targets
- Incineration as a key part of waste management
- European focus on minimisation and recycling – not renewables

Conclusions/Opportunities

- Exploit interest in renewable polymers
- Learn from paper and board
- Develop the niches for renewable plastics
- Building renewable polymers into eco-design thinking
- Sell benefits of renewable feed-stocks
- Communicate benefits of ‘partial’ renewable polymers
- Composting & Anaerobic digestion
- Ensure waste management technologies do not exclude biopolymers

UKRPG

- Feedstock – scale-up issues, yields, processing, biorefineries, fermentation
- Polymer manufacture/processing – scale-up forecasts, adhesives, functional coatings
- Packaging – engaging retailers, composting trials, Standards discussion, UKRPG
- End of Life Options

Thank You

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Building sustainable supply chains