

A load of rubbish ?



Dr Claire Barlow
University of Cambridge
Institute for Manufacturing
cyb@eng.cam.ac.uk

Outline

What is the problem with waste?

What are the options?

Is recycling worthwhile?

Can it be made more worthwhile?

Case study: Plastics

Zero waste solutions?

<http://www.wasteonline.org.uk>

Chronology of Waste

3000 BC - In the Cretan capital, Knossos, the first recorded **landfill sites** were created: waste placed in large pits and covered with earth.

2000 BC - **Composting** was part of life in China.

- During the European Bronze age **bronze scrap** recovery systems were in place.

Before 500BC - government officials in Athens opened a **municipal landfill site** and decreed that waste was to be transported at least one mile beyond the city gates.

1297AD - A law was passed to make householders keep the front of their house clear from refuse: it was largely ignored. However, most waste was burned on household **open fires**.

1354 - "Rakers" employed in London to rake rubbish together, load it into carts, and remove it once a week.

Early 1800s in UK: Anything of any value and anything combustible scavenged from waste (formalised as rag-and-bone men - common until late 1960s).

By **late 1800s**: municipal household waste collected daily; sorted by hand. **Glass** and **metal** returned to merchants; incinerated residue are used in building materials.

Post-WW2 years: **landfill** found to be cheaper than **incineration**. Landfill sites constructed at lowest cost and most convenient locations. Increasingly affluent society fostered throw-away culture; packaging increased.

1994 - EU Directive introduces producer responsibility for packaging waste.

2000 - Waste strategy for England and Wales is published, setting **national targets** for the **recycling** or **composting** of household waste: 25% by 2005, 30% by 2010, and 33% by 2015.

Summary of the waste problem in UK

Too many people

Too much waste

Landfill has been cheap and easy; little incentive for alternatives

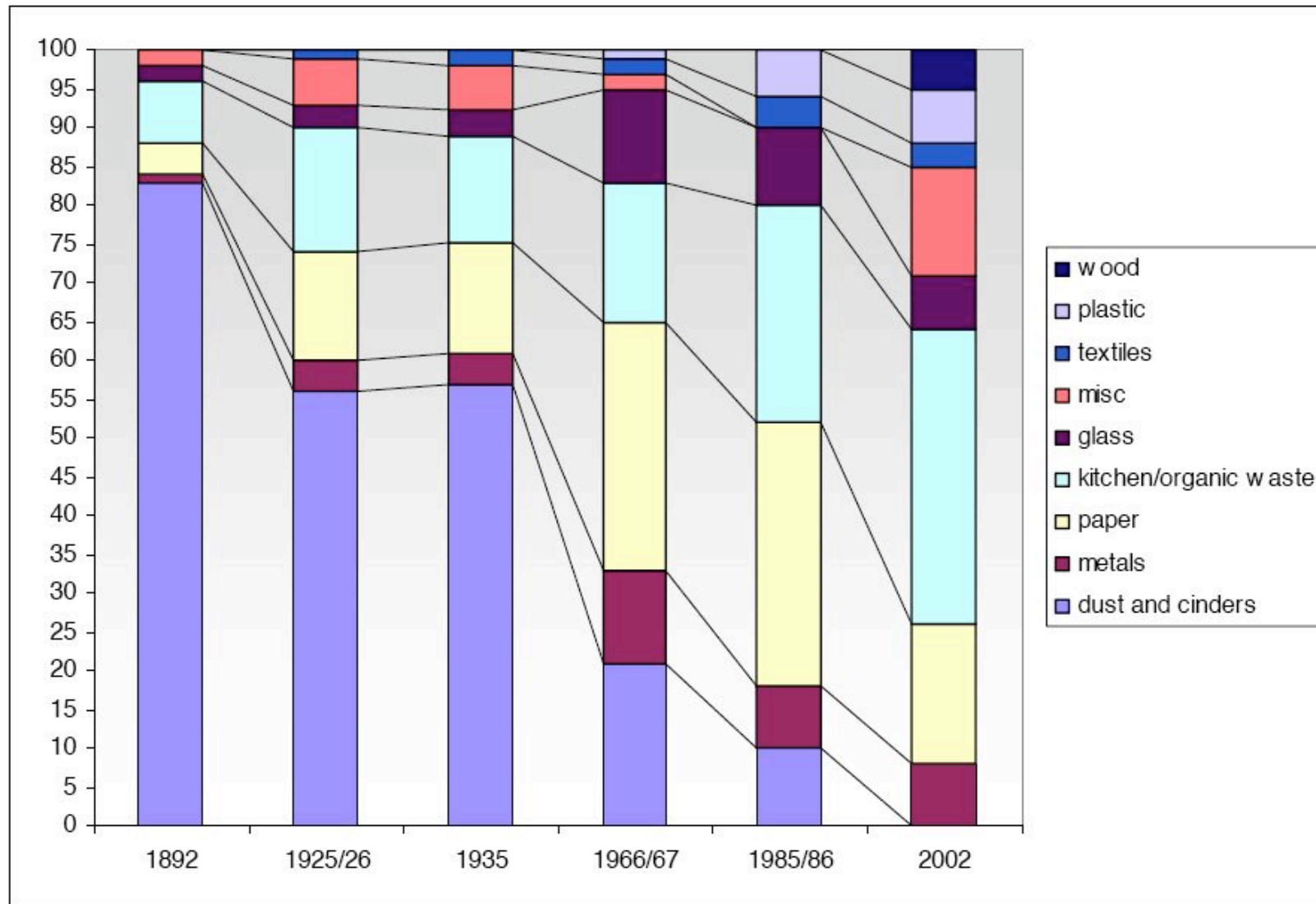
Culture and infrastructure for re-use and recycling have been lost

Labour costs too high for traditional hand-sorting processes to be resurrected and commercialised

Waste management legislation has contributed to stifling growth

Powerful NIMBY lobby fuelled by media

What's in your bin? Composition of domestic waste 1892-2002



Source: *Waste and Recycling: an exploration of contemporary environmental policy*, Page: 5

Sources: Atkinson, W. and New, R. (1993) *An Overview of the Impact of Source Separation Schemes on the Domestic Waste Stream in the UK and Their Relevance to the Government's Recycling Target*, Warren Spring Laboratory, Stevenage, Herts., Startegy Unit (2002) *Waste Not Want Not*.

Waste composition

Early waste was largely

- degradable (e.g. ash, iron)

- biodegradable (e.g. vegetable matter)

- safely combustible (e.g. wood, natural fibres)

- inert (e.g. ceramics)

Modern waste is more likely to contain

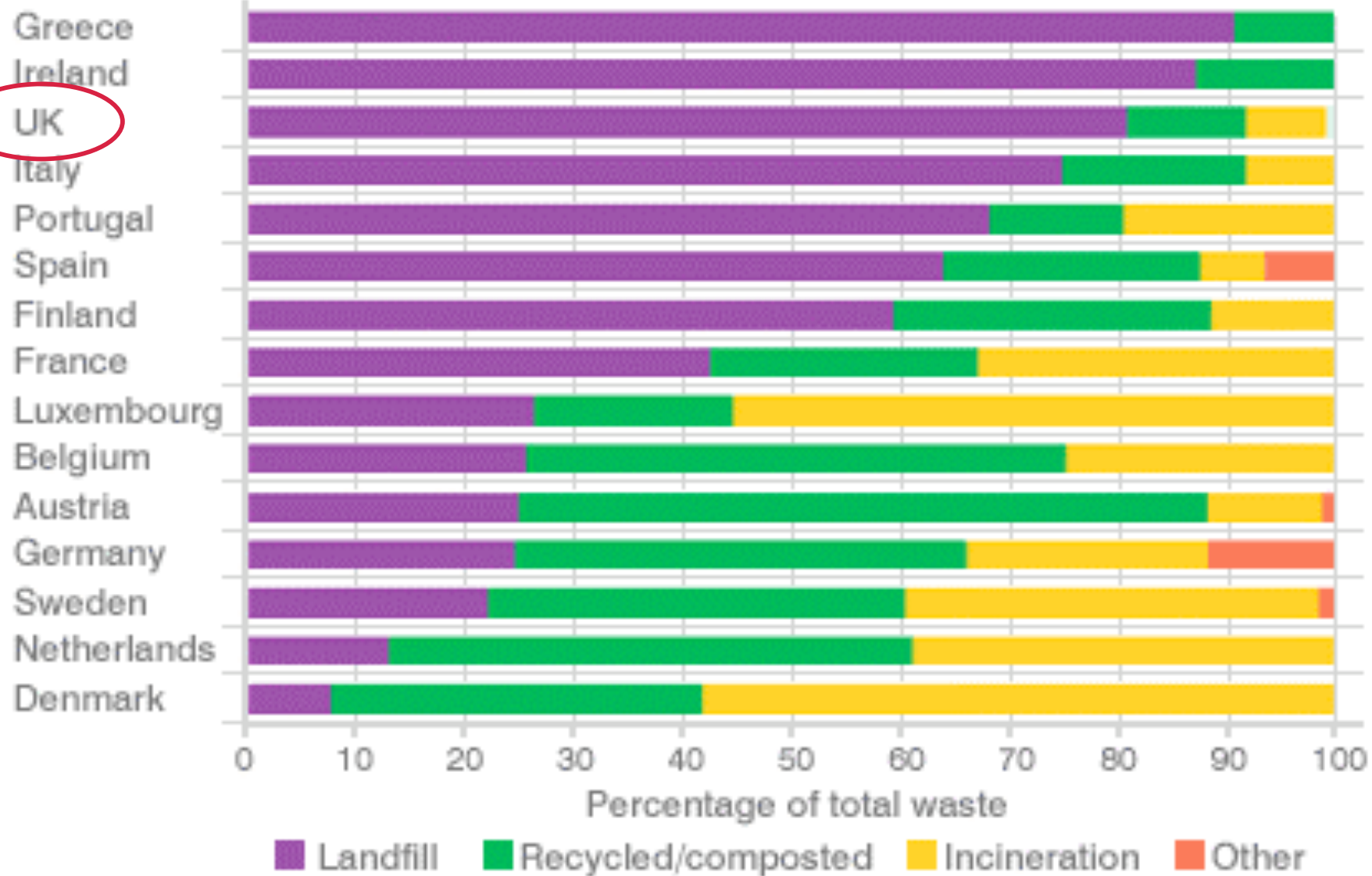
- toxic materials (e.g. solvents, heavy metal salts)

- mixed materials of unknown safety (e.g. textiles)

- organic waste (vegetable, meat etc)

- plastics

WASTE MANAGEMENT IN THE EU



SOURCE: Defra, 2004

Waste disposal

Landfill?

Incineration?

Recycling?

Re-use?



Waste disposal

Landfill

Incineration

Recycling

Re-use



Landfill

Originally old quarries, brownfield sites etc.

New sites now required.

Stringent safety and planning requirements:

- Only large sites economically viable

- Few and far between

- Intrusive

Local opposition.

Rubbish transported over large distances.

Methane emissions: (21 times more powerful greenhouse gas than CO₂).

Sites remain hazardous for many decades; danger of groundwater contamination.

BUT

‘Over 70% of methane from landfill can be harvested for energy.’

...leaving 30% of the methane to act as a greenhouse gas

Waste disposal

Landfill

Incineration

Recycling

Re-use



Incineration

Main technology: Incineration with energy recovery (electricity, sometimes heat as well).

Stringent safety and planning requirements:

- Only large sites economically viable

- Few and far between

- Intrusive.

Local opposition.

Rubbish transported over large distances.

Efficiencies low (20-25% without heat recovery).

Anxiety over gaseous emissions, toxic chemicals in residues.

Alternative techniques exist, but not yet commercially available:

- Small-scale incineration

- Gasification and Pyrolysis (recovery of gaseous materials plus energy; potential for high efficiencies)

Waste disposal

Landfill

Incineration

Recycling

Re-use



Recycling

Materials are re-used, retaining (some) value and reducing waste.
Promoted as responsible behaviour.

However:

Collection, sorting, reprocessing all require energy and resources.

Logistics are complex.

Many materials are degraded in some way by the recycling process.

Assessing the environmental impact of recycling is not easy.

Economics only favourable for a few materials.

Waste disposal

Landfill

Incineration

Recycling

Re-use



Re-use

Durable rather than disposable articles

Mend rather than discard

Examples at different scales:

Personal (e.g. re-usable shopping bags, charity shops, online Swap Shops)

Consumer (e.g. refillable bottles)

Industrial (e.g. pallets; reconditioned machinery)

Resources required for e.g. logistics, cleaning, storage

Needs a cultural shift from 'throwaway' to 'responsible'

Summary:

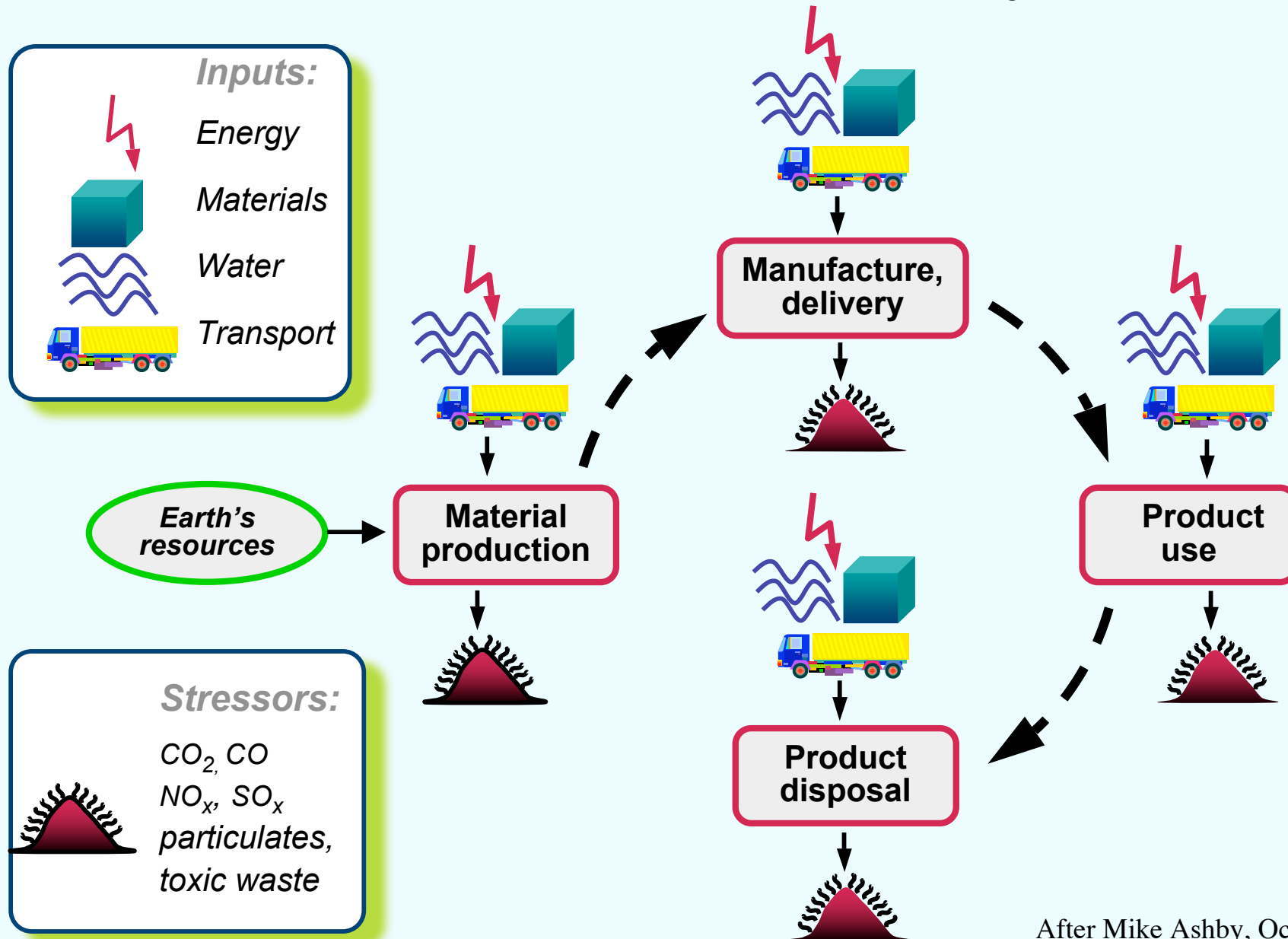
	Economics	Environment
Landfill	Cheap	Not good
Incineration	Viable	Controversial in UK Common in mainland Europe
Recycling	Material- dependent	Material-dependent; can be good
Re-use	Good	Excellent

Recycling

Potential for recycling depends on material

	Economics	Environmental impact of recycling	Technical viability of recycling
Cement	Low-value material	Would be good, if achievable	Low
Office paper	Medium value material	Quite good	Medium: material degraded
Metals	High value material	Good	Generally high

The material life cycle

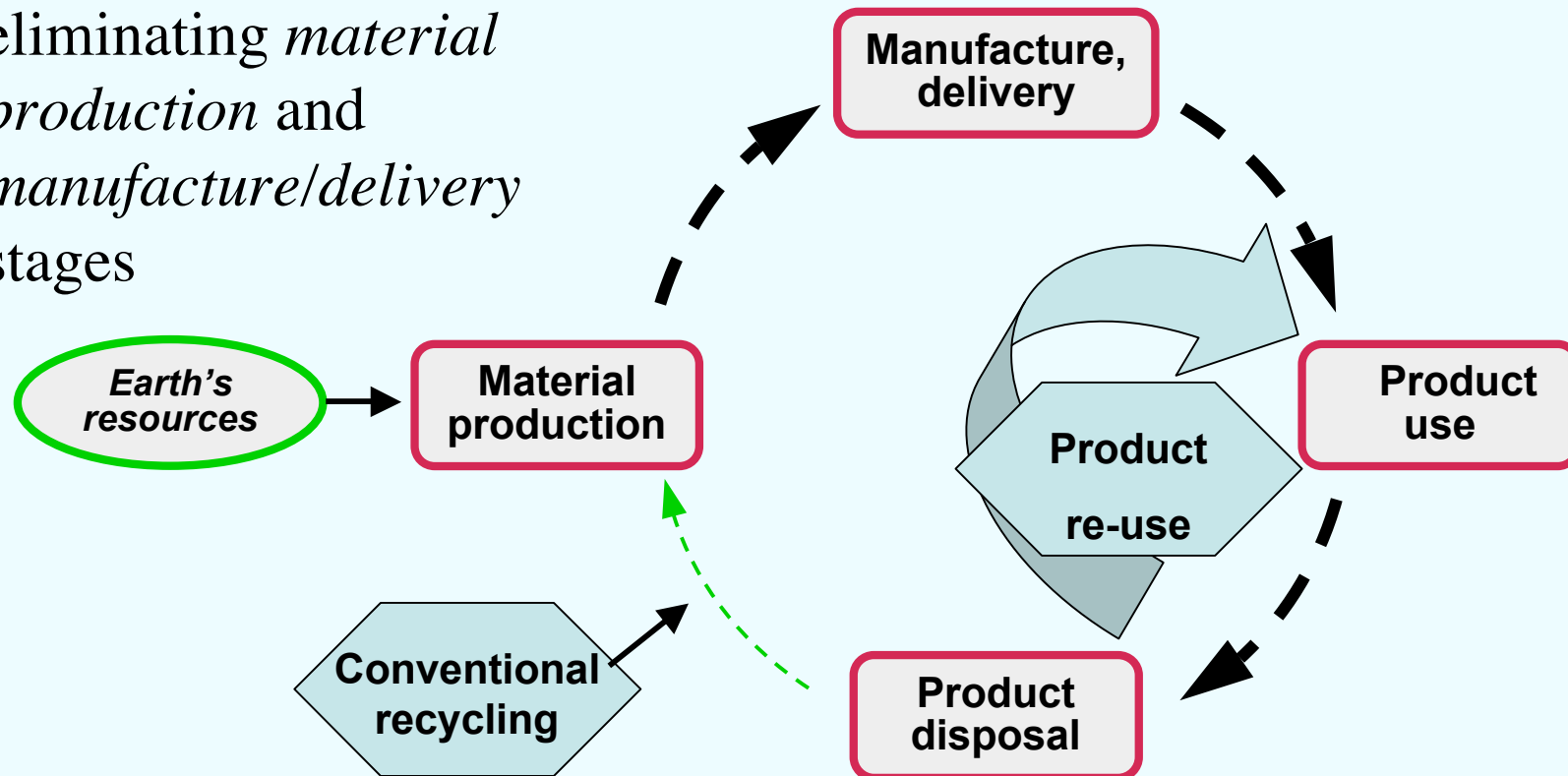


After Mike Ashby, October 2005

The material life cycle

Products re-used:

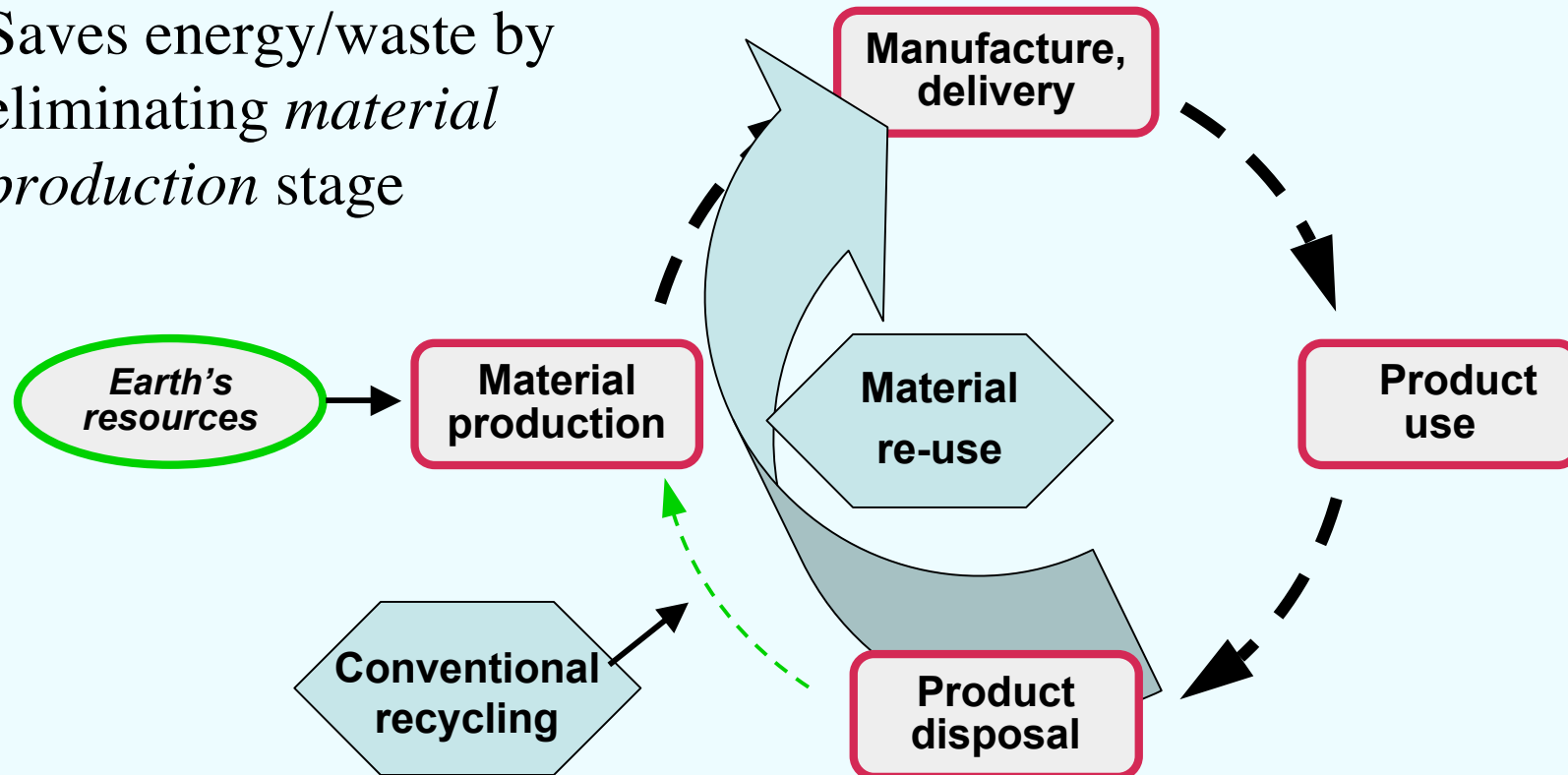
Saves energy/waste by eliminating *material production* and *manufacture/delivery* stages



The material life cycle

Material re-used to make new products:

Saves energy/waste by eliminating *material production* stage



How can recycling be assessed in environmental terms?

Need to assess impact of

- **Energy**
- **Resources**
- **Waste**

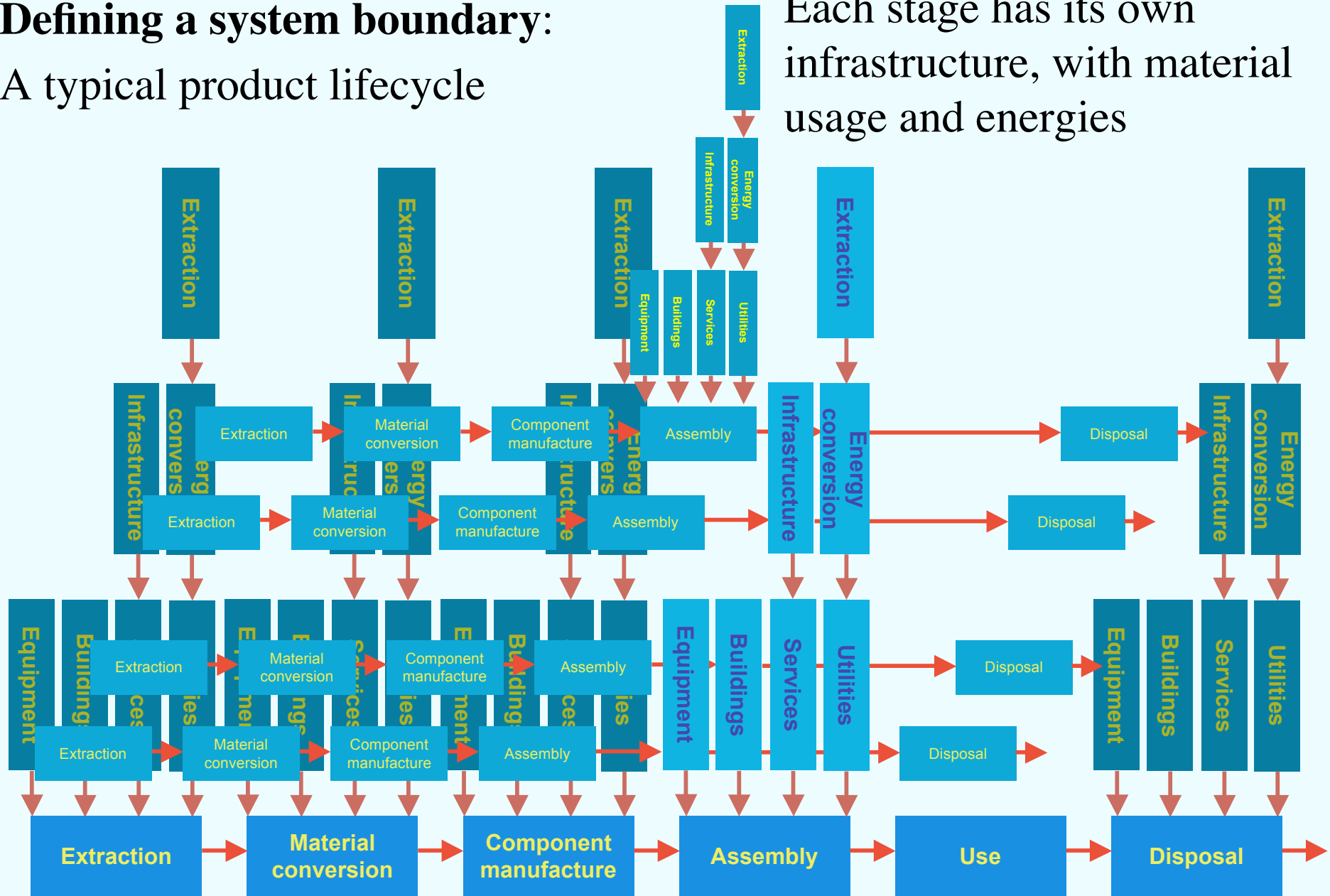
Complex problem:

Very disparate; relative weightings subjective

System boundaries crucial

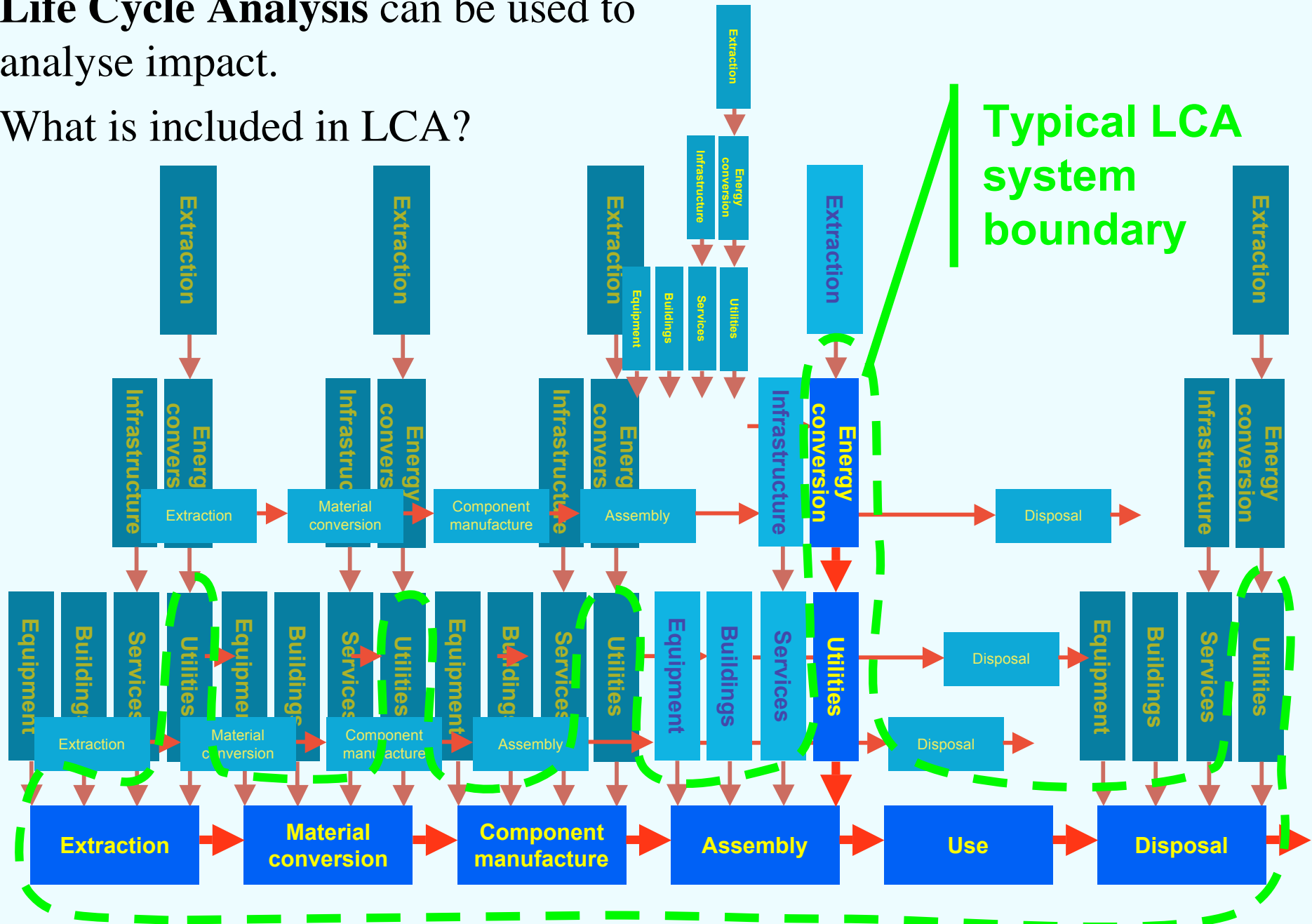
Defining a system boundary: A typical product lifecycle

Each stage has its own infrastructure, with material usage and energies



Life Cycle Analysis can be used to analyse impact.

What is included in LCA?



Courtesy Julian Allwood

Analytical techniques such as LCA are useful for comparisons

BUT

data can be manipulated to get any answer you want

Assessing full environmental impact of any recycling process is an inexact science

There is a great need for generally accepted and unbiased analytical tools

Case study: Polymer recycling

Thermoplastic polymers may be recyclable:

Low melting point

Regain mechanical properties
on cooling



But it's not so easy...

Properties dependent on chain configurations, additives, impurities

Polymers can't be purified

Full analysis difficult

Easily degraded on re-processing (*downcycling*)

Applications for recycled polymers limited (e.g. non-food)

Virgin polymers currently cheap; system won't tolerate any extra costs

Polymer Lifecycle and Recycling loops

Mechanical (Primary and Secondary) recycling:

Cleaned, ground up, re-used

Chemical (Tertiary) or Feedstock recycling:

Break down polymer to monomer (heat, catalysis); re-make virgin polymer

Energy Recovery (Quaternary):

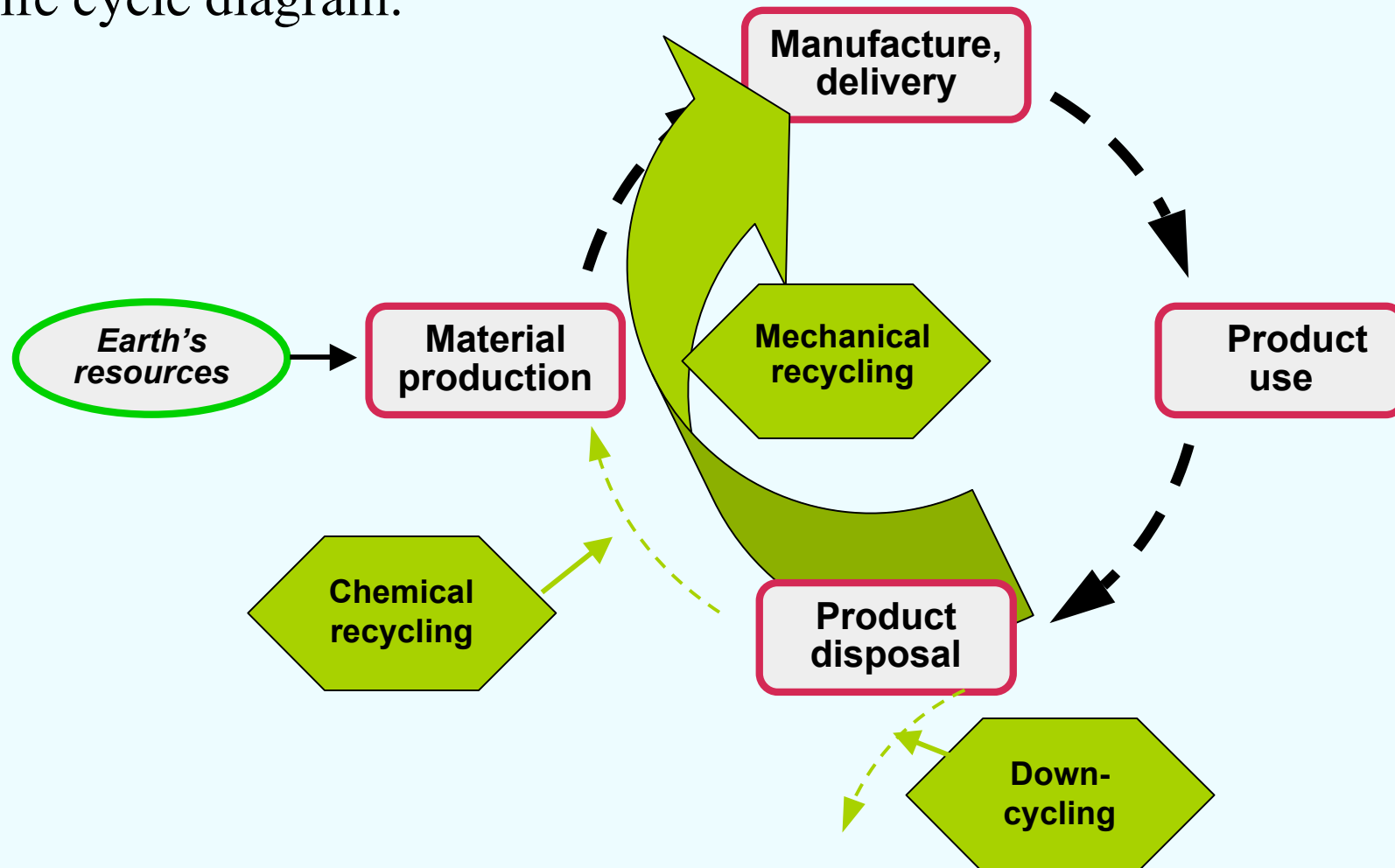
Burning. Being oil-based, polymers have high energy content.

Other disposal:

Ground-up polymers used as fillers, e.g. road or playground surfacing ('downcycling').

The material life cycle

Mapping polymer recycling onto the material life cycle diagram:



And the reality of what is happening now?

Mechanical recycling:

Primary Recycling (closed-loop): Standard practice in factories

e.g. Out-of-spec LDPE injection mouldings pelletised and immediately returned to moulder input

Secondary Recycling (post-consumer):

Viable for some specific products / polymers, e.g.

fleeces and other clothing from PET bottles: Patagonia™

household waste sacks from LDPE

bins, boxes, water-butts from HDPE

BUT only specific waste-streams are used for recycling: total fraction of polymers recycled may be as low as 3%...

And the reality of what is happening now?

Chemical recycling:

Pioneered in Germany

Plants are very large and costly

Prototype reactor in UK (Grangemouth, BP) not judged to be commercially viable; project was halted

Other reactors also being closed

So what really is happening?

Large amounts of waste plastics going to China

In other parts of Europe, incineration (Energy Recycling) is common

Current problems with polymer recycling?

Social:

Unwillingness to engage (both industry and domestic consumers)

Fear: Are recycled polymers safe? What are their properties? What's in them that could get out? What about dioxins? Is the recycling process safe?

Economic:

Oil prices still comparatively low so virgin polymer is cheap

Recycled polymer doesn't command high prices

Transport, sorting, shredding, cleaning etc all require energy

Technical:

Much effort is aimed at making secondary processes more robust: coping with mixed or contaminated plastics

Which problems are show-stoppers?

Social:

Changing, but not fast enough.

Influenced by economics: if it's not £valuable it's not important

Economic:

Stops a very high proportion of new ventures, once initial subsidies have ceased.

Economics is the real show-stopper at present

Technical:

Many processes are developed to prototype stage but aren't then reckoned to be economically viable

And the future?

As oil prices rise, recycling will increase

Thermoplastics:

‘Clean’ - Mechanical recycling probably the way forward

Mixed and contaminated -

Short-term: Incineration likely to remain best option

Medium-term: Development of robust recycling processes

Thermosets:

More incineration

Specialised pyrolysis will become common

Are Degradable Plastics the answer?



Oxo-degradable:

Breaks down over 18 months - 2 years (cf 1000 years for virgin plastics)

Virgin Polythene plus heavy metal additive

Degraded product: polymer fragments, contaminated with heavy metal

Bio-degradable:

e.g. “Compostable”: Aerobic decomposition

Product is environmentally benign



Are Bio-degradable Plastics the answer?

Source material: often biological (e.g. starch, cellulose), so from renewable resources

BUT

Still resource-intensive to manufacture (approx 80MJ/kg)

Suitable for commercial composting, but decompose slower than many other materials

Not really suitable for home composting

Not recyclable

Contaminants to conventional polymer recycling

Commercial realities

One way of increasing value of waste material is to link it to a specific product.

However, reliance on a single supplier or input stream is dangerous for a manufacturer.

Some diversification leads to a more robust operation.

A lot of product-specific SMEs are set up: to date, most have not survived. This will probably change.

Is the situation different for metals recycling?

- Metals recycling has always been performed
- Typical recycling processes closely related to manufacturing processes
- Analysis and purification of metals relatively easy
- Metals have relatively high value

BUT

- Collection, transport, sorting all cost money
- A surprisingly high proportion of metal is now being sent to China for recycling...

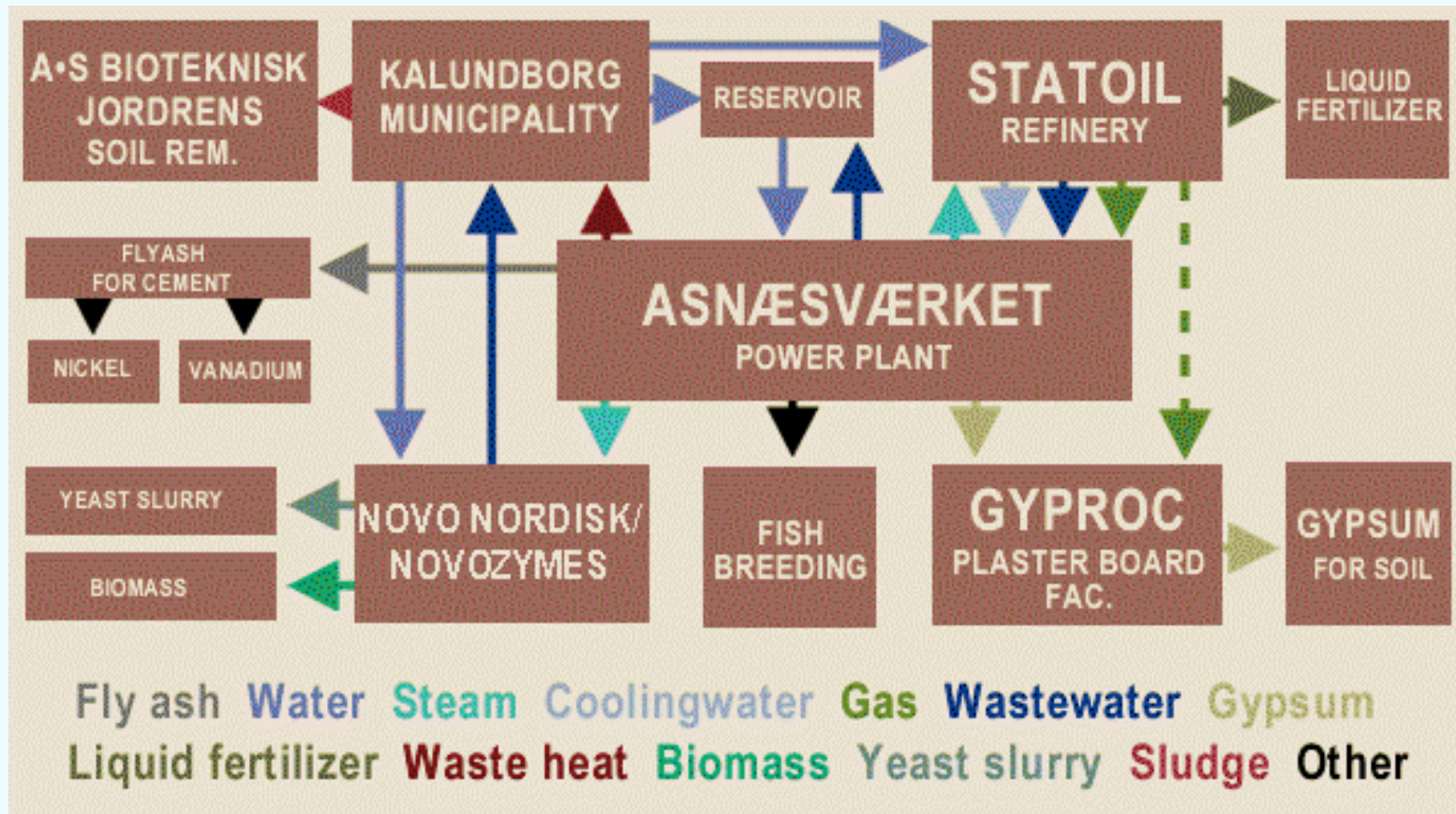
Industrial Symbiosis

Towards zero waste:

Waste output from one company used as raw material input for another.

Original networks in Pittsburgh (USA), and in Kalundborg (Denmark)

The Kalundborg Project



Industrial Symbiosis

NISP (National Industrial Symbiosis Programme) founded in 2003 in UK as the first National IS network in the world.

“Brokers” exchanges of information, expertise and materials between companies and organisations.

Immediate savings for participants (landfill avoidance; savings in virgin material costs; revenue from waste); many opportunities for new business generation

www.nisp.org.uk

Cambridge research projects: reducing recycling costs:

- **Minimise transport costs:**

 - Localised production

 - Small-scale processes

 - May involve compromise: economies of scale

- **Minimise energy required to recycle:**

 - Low-energy processes

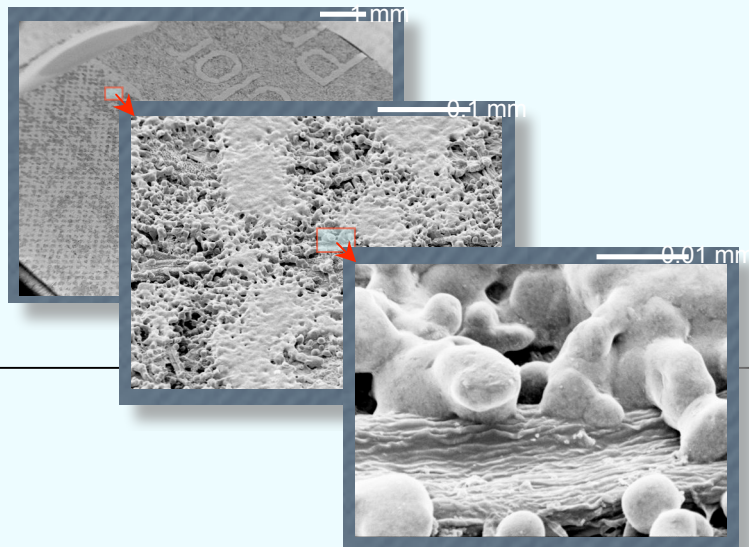
 - Short-circuit recycling processes

 - May involve compromise: quality of product

Novel recycling technologies: Research at Cambridge

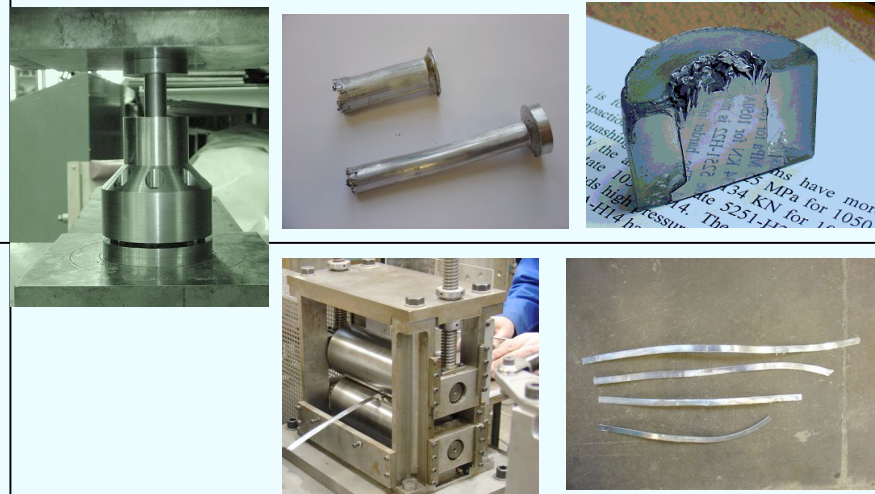
Recycling office paper on-the-spot:

Removal of photocopy toner to leave clean, re-usable paper



Recycling aluminium by cold bonding:

Squeeze and stretch aluminium scrap to regenerate bulk material



Recycling polymer in the factory:

Separation or robust processes to cope with mixed polymer



Section through sheet made from mixed "unrecyclable" polymer

Conclusions

Waste is a problem. Not a new one, but reaching crisis proportions in the developed world

Unbiased environmental assessment of processes is complex, but needs to be done

Recycling is increasing, but subject to greenwash

Plenty of scope for valuable research to improve production and recycling processes

Everything is driven by economics

So what should a responsible citizen do?

Remember the life-cycle loop: short-circuiting is good

Recycling is better than nothing, but best not to use resources in the first place;

Product re-use is more resource-efficient than recycling;

The truth about all waste disposal methods is complex: there are no simple answers;

There's lots of greenwash about, but recycling isn't all rubbish