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Industrial Symbiosis and Polymers

Dr Claire Y Barlow

Institute for Manufacturing

University of Cambridge

cyb@eng.cam.ac.uk

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Summary

Waste as a business opportunity

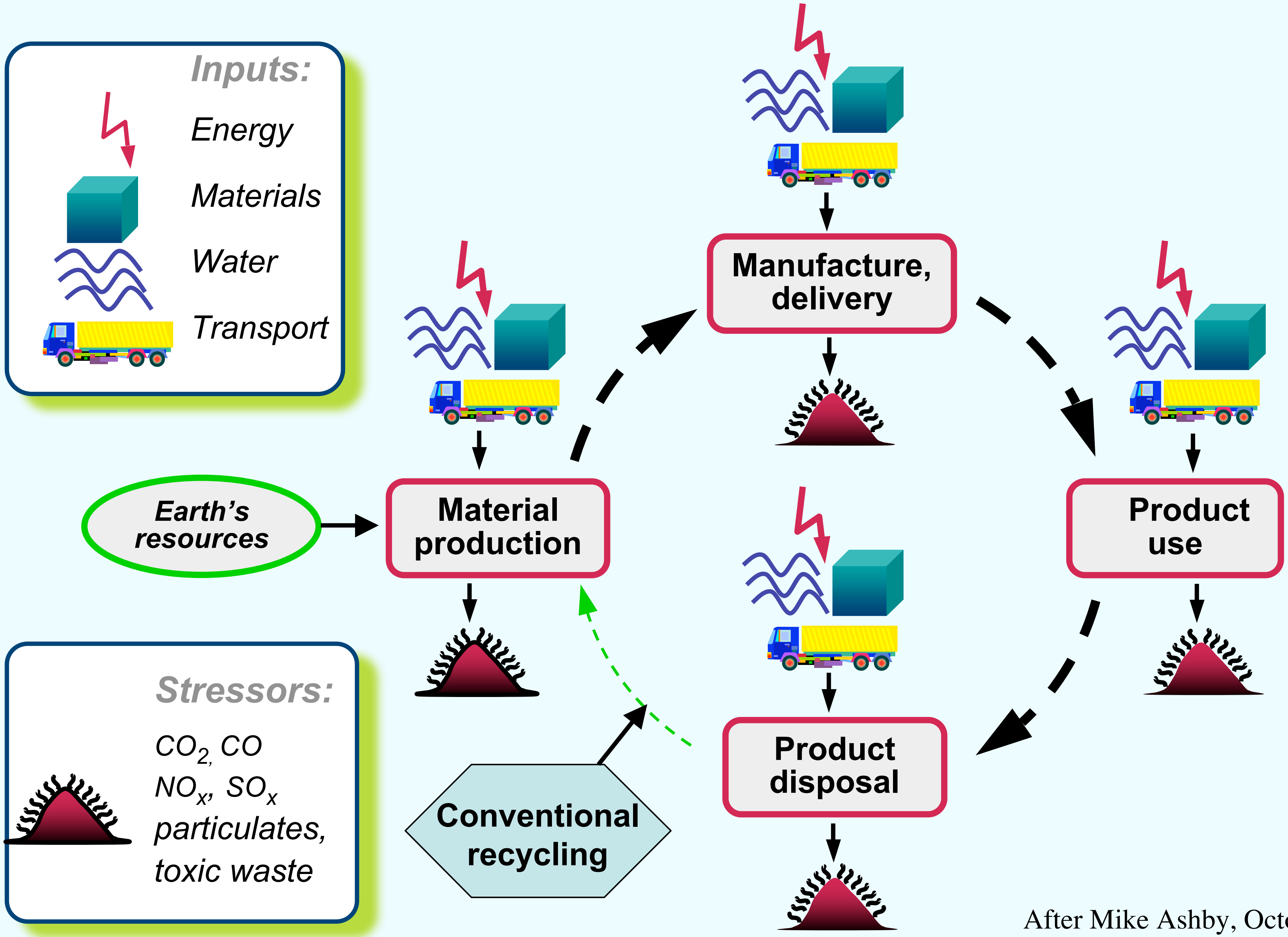
Polymer recycling

Current situation; problems; opportunities

“Intelligent Recycling”

Industrial Symbiosis: towards zero waste

The material life cycle

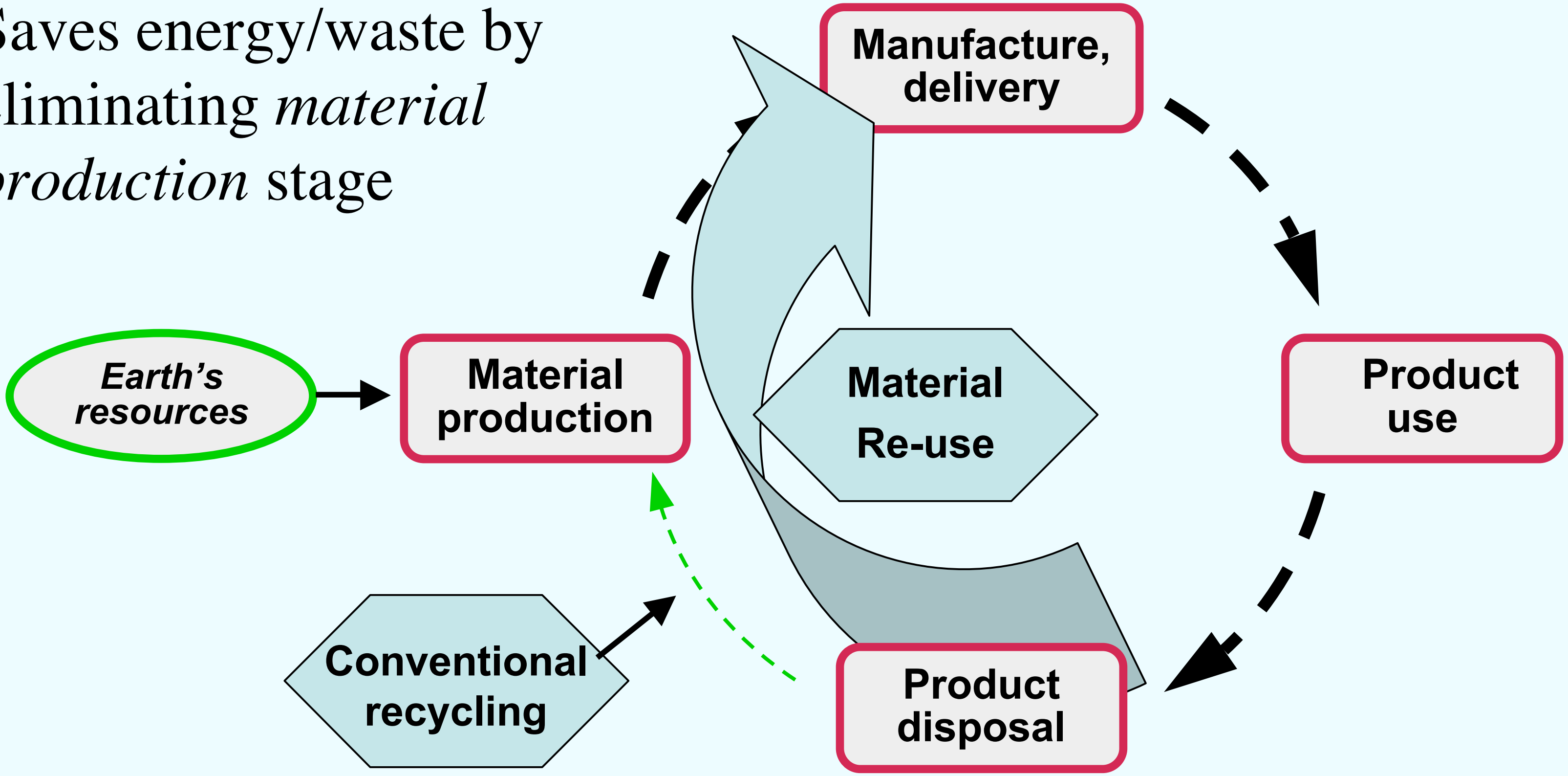


After Mike Ashby, October 2005

The material life cycle

Material re-used to make new products:

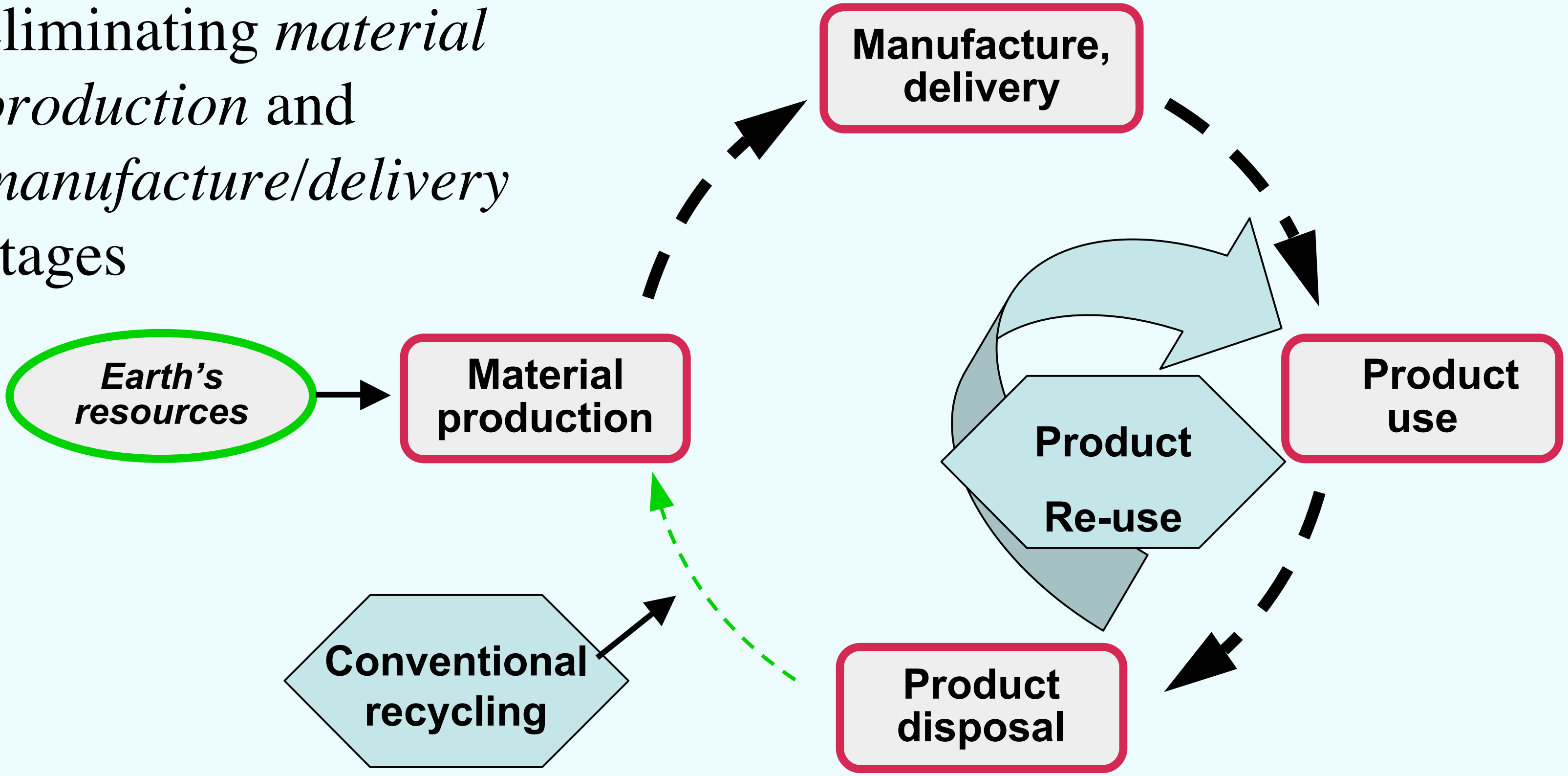
Saves energy/waste by eliminating *material production* stage



The material life cycle

Products re-used:

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



Polymer recycling

Thermoplastic polymers should (naively) be recyclable:

Low melting point

Regain most of mechanical properties on cooling

But its not so easy…

Polymer properties are very dependent on polymer purity

Easily degraded on re-processing (*downcycling*)

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

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

Why are polymers so difficult to recycle?

Polymer properties depend not only on ‘chemical formula’ but also on:

Chain length

Chain configuration (branching, position of sidegroups etc)

Polymer processing conditions similarly sensitive

Intrinsic Viscosity (IV) used as (crude) operative property measure

Nature and purity of polymer expensive to assess

Complex chemistry and tendency to decompose on heating means polymers cannot be refined or purified

Quality of input material is critically important to value of output

And more…

Why are polymers so difficult to recycle?

Most polymer products made from polymer which is tailored using additives to optimise it for that product, including

- Processing additives (e.g. reduce viscosity during extrusion)
- Property modifiers (e.g. increase stiffness of final article)
- Stabilisers (e.g. to oxidation in-service)
- Surface modifiers (e.g. barrier layer; metallising)
- Colouring

Consequences:

Polymer from every input waste-stream is different

Applications for output polymer either narrowly defined or not optimised

Conventional polymer recycling routes

In decreasing order or desirability:

- ❖ Product re-used (e.g. bottles washed and refilled)
- ❖ Material re-used for equivalent purpose (recycling)
- ❖ Material re-used for less demanding purpose (down-cycling)
- ❖ Material used for 'energy recycling'= burning

And a route which isn't normally regarded as recycling:

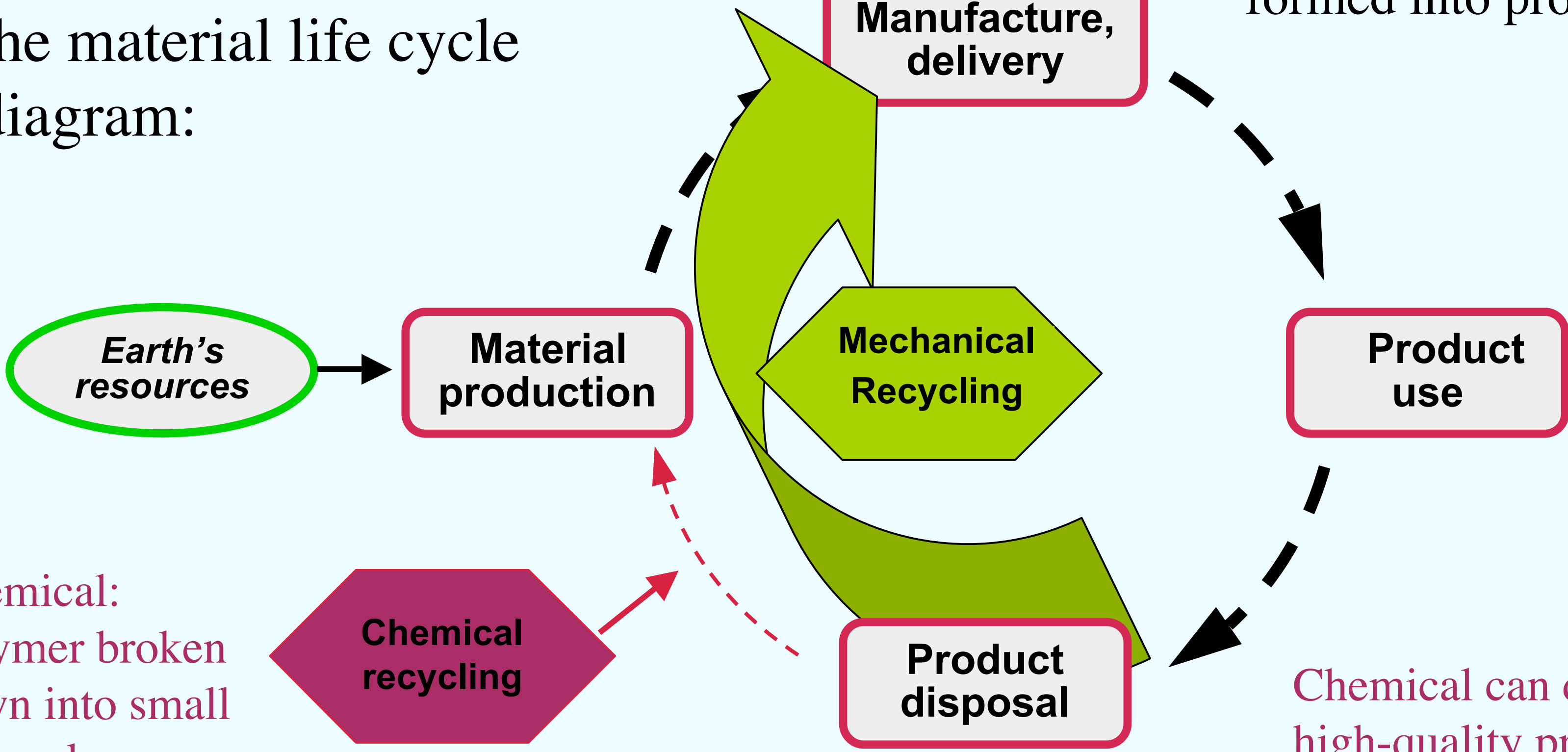
- ❖ Landfill (when no value is gained from the material).

(Footnote: there is recent interest in 'mining' landfill sites to extract metals. Polymers with are present are generally too contaminated to be recyclable, but may be used as a source of energy)

Polymer recycling and material life cycles

Two main routes to recycling: *mechanical* and *chemical*. Mapping onto the material life cycle diagram:

Mechanical: polymer ground up, cleaned, re-formed into product



Chemical: polymer broken down into small molecules; polymer re-manufactured

Chemical can deliver high-quality product, but is very energy-intensive

What is happening now?

Mechanical recycling:

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

e.g. Out-of-spec low-density polythene (LDPE) injection mouldings pelletised and immediately returned to injection moulder input

Secondary Recycling (post-consumer): Patchy…

Viable for some specific products / polymers,

e.g. fleeces and other clothing from PET bottles: Patagonia™

e.g. household waste sacks from LDPE

e.g. bins, boxes, water-butts from HDPE

BUT only specific waste-streams are currently used for recycling

What is happening now?

Chemical recycling (including pyrolysis):

Pioneered in 1990s as robust route for MSW (contaminated) polymers

Plants very large and costly; process is energy intensive

No current interest in use for MSW applications

Under investigation as part of the processing for niche materials, e.g.

- reclaiming fibres from carbon fibre reinforced plastic
- processing of tetrapaks (Enval)

So what really is happening?

Large amounts of waste plastics going to China (though import of post-consumer plastic bags banned as of 1 March 2008)

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

Mechanical recycling is probably the way forward, if recycling is done at all

Summary: What are the problems with polymer recycling?

x Recycled polymer quality variable so re-sale value low: downcycling.
x Recycling facilities don’t easily make money, so business is fragile
x Collection costs fall on local authorities, who resent having to pay

Other solutions are too easy:
x Polymers are basically oil, so fuel value is high
x Export is an easy option

How could the equation be altered?

✓ Government subsidies
✓ Oil prices rising, so re-processed polymer will become more valuable
✓ Fundamental changes to design of polymer articles: fewer polymers; think about joining methods; expect to use sub-optimised material. But these measures normally mean increasing weight of article, so using more material in the first place…
✓ Improved technology, low environmental impact, low-cost recycling?

Two approaches to improving the recycling equation balance (now for all materials, not just polymers):

Reduce cost of recycling

Improve quality of output

Reduce cost of recycling?

Intelligent recycling?

Minimise energy required to recycle:

Minimum intervention processes

Low energy, minimised processing

Minimise transport costs: localised processing

Benefits:

Transport eliminated

Storage costs reduced

Quality control of waste stream improved

BUT Processes must be small-scale; can lose economies of scale

High-value product: Increase output material value

- Improved sorting

Much identification and sorting of mixed polymers is still done by hand

Automated sorting technology exists, but is often more expensive and less reliable

Problems of contamination remain

- Improved robustness to "impurity"

Research into 'compatiblising' mixed polymers

e.g. Using shear process to break chains, generating new block co-polymers

Processes to 'neutralise' effects of impurities

e.g. Use calcium carbonate to absorb chlorine from PVC

e.g. make wood/polymer composite:

Street furniture, picnic tables etc…

Cambridge research projects: reducing recycling costs:

– **Minimise transport costs:**

Localised production

Small-scale processes

May involve compromise: lose economies of scale

– **Minimise energy required to recycle:**

Low-energy processes

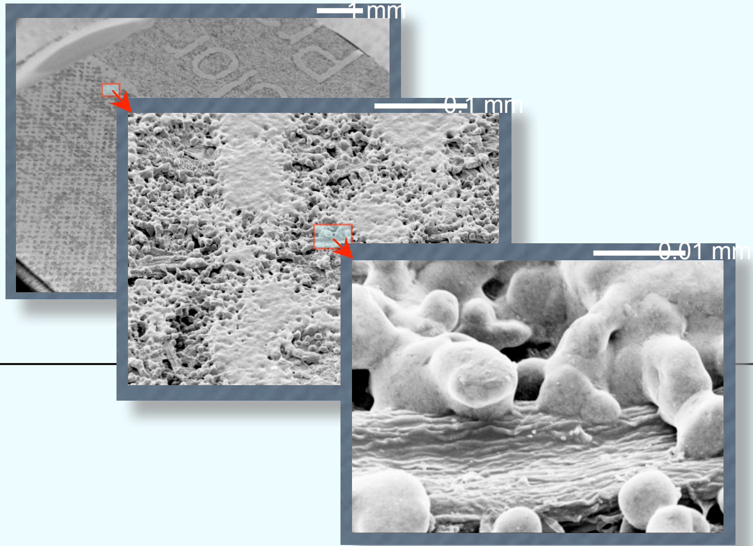
Short-circuit recycling processes

May involve compromise: quality of product

Novel local-scale recycling technologies: Research at Cambridge

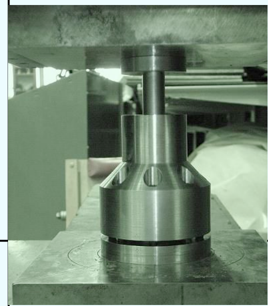
Recycling office paper on-the-spot:

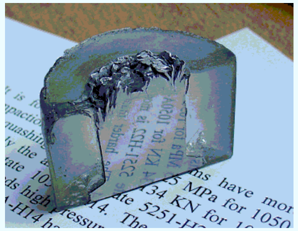
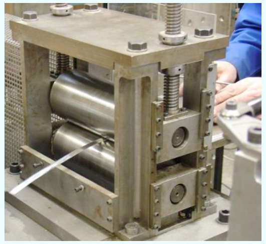
Removal of photocopy toner to leave clean, re-usable paper



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

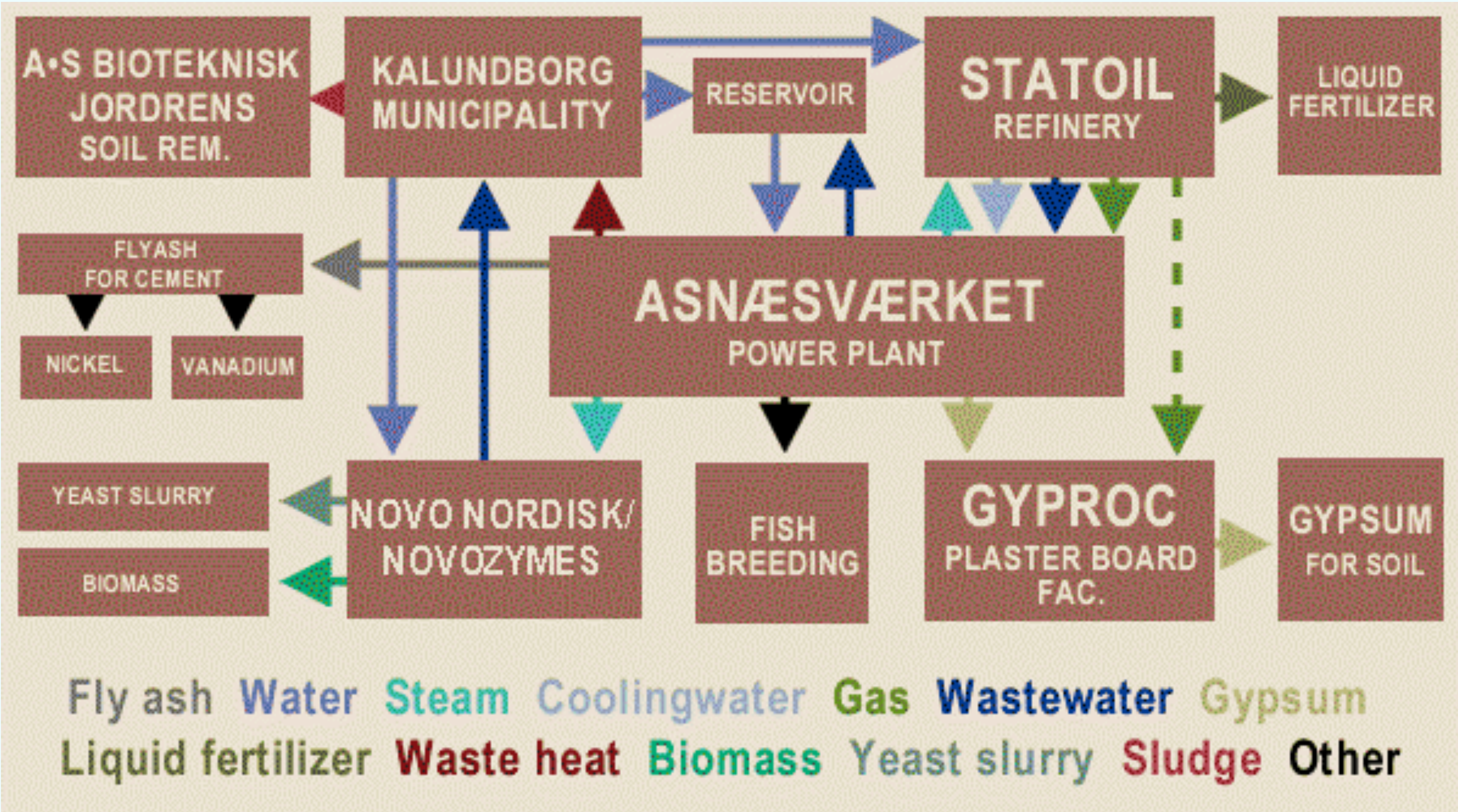
Industrial Symbiosis

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.

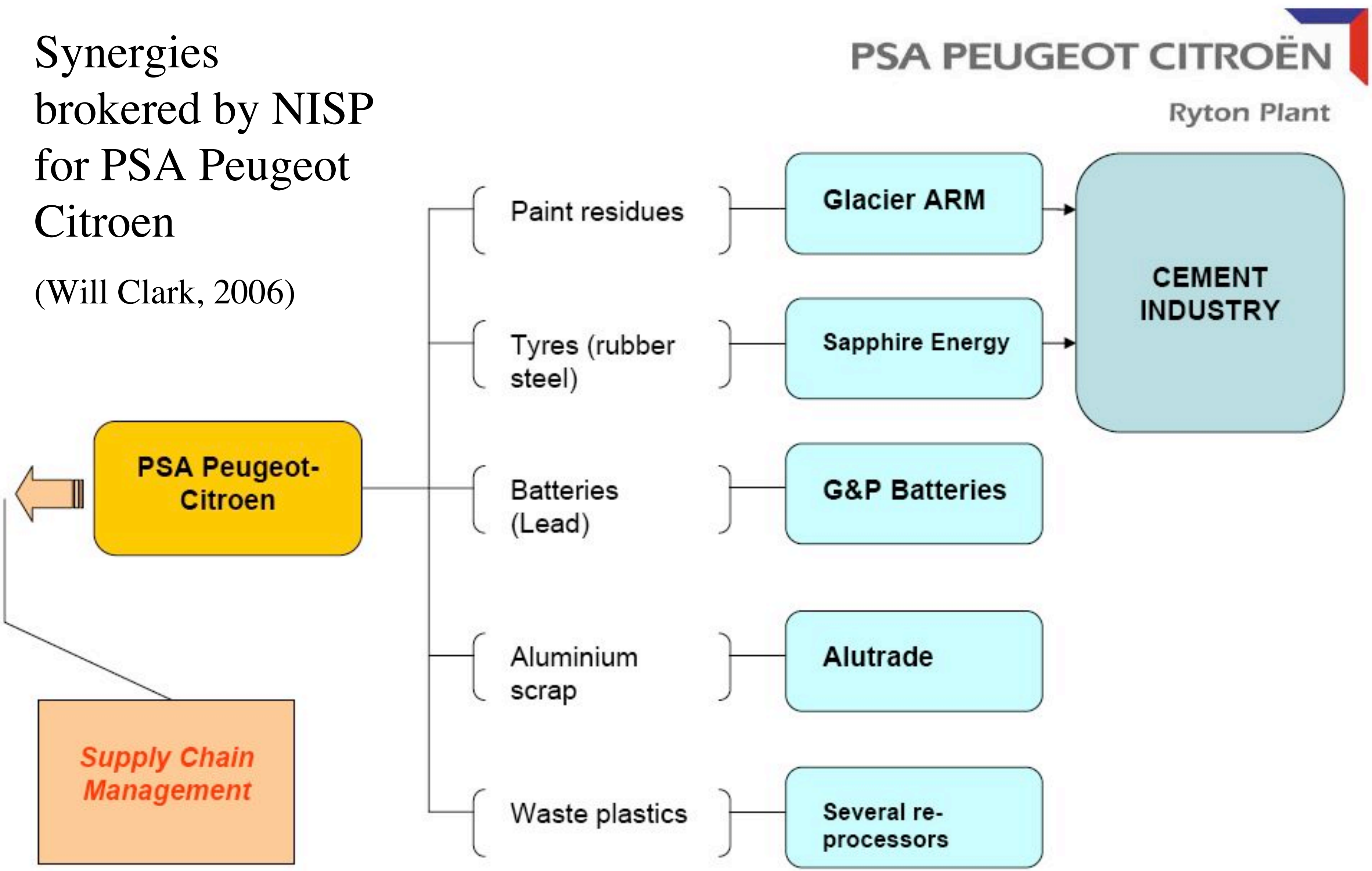
"Brokers" exchanges of information, expertise and materials between companies and organisations.

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

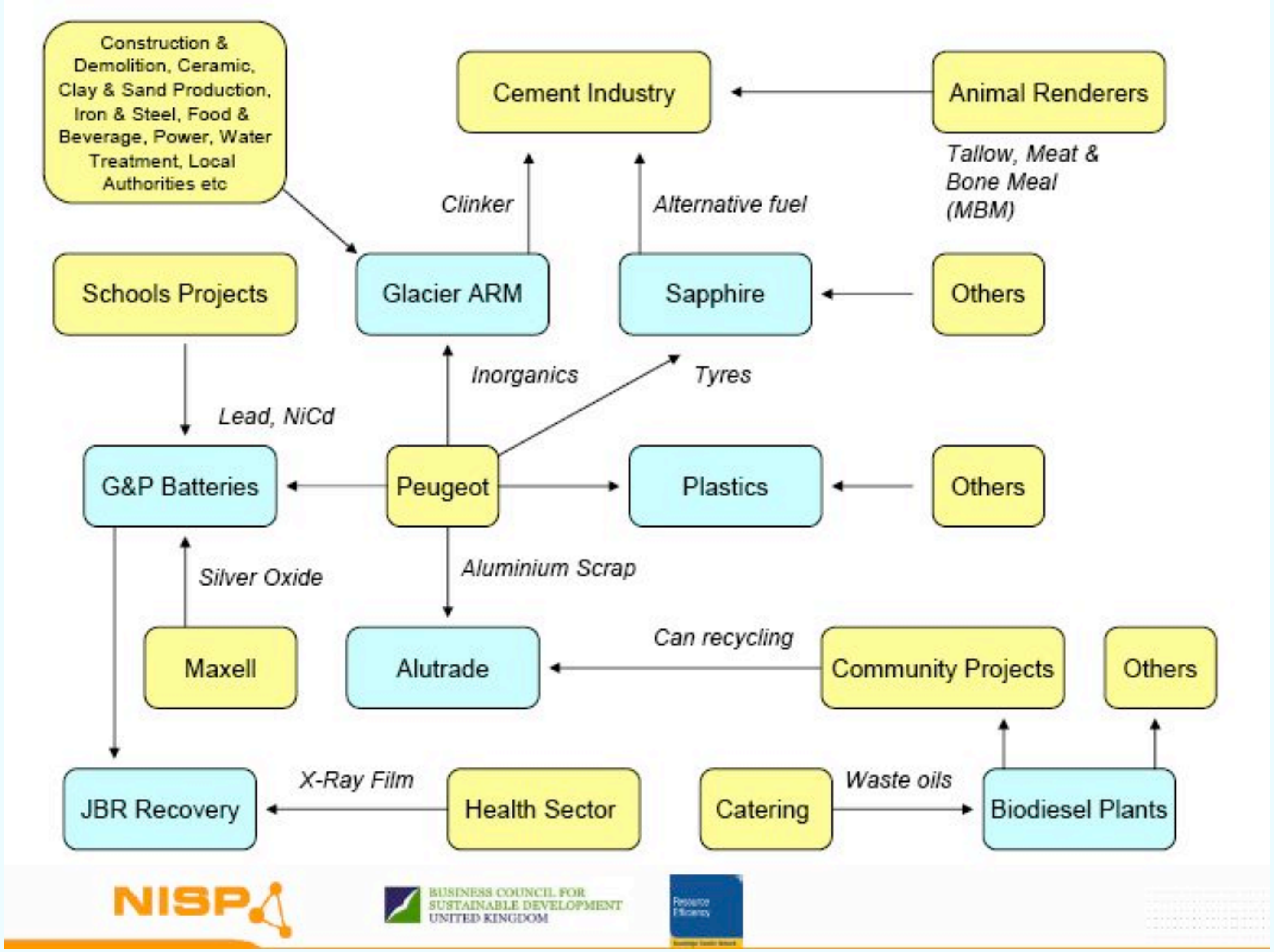
www.nisp.org.uk

Synergies brokered by NISP for PSA Peugeot Citroen

(Will Clark, 2006)



Peugeot synergies in the context of other synergies



Robust business models for receiving companies demand reliance on more than a single waste stream

Conclusions

Even when done well, recycling isn't 100% efficient

"Minimum intervention" reprocessing carries clear environmental benefits

Reprocessed material may have reduced strength compared with virgin, and reduced functionality

There is a compromise: environmental benefits traded off against mechanical properties

Decisions about where the most favourable balance lies will vary with different materials

Recycling opportunities for wastes are burgeoning