



Exhibition of Advanced Manufacturing and Engineering
EAME08, Hethel Engineering Centre

Closed Loops for Sustainability and Profit

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What is Closed-Loop Manufacturing

The classic supply chain is considered to be 'Open Loop'
In fact, the anthrosphere is part of a vast Closed Loop linked to the ecosphere

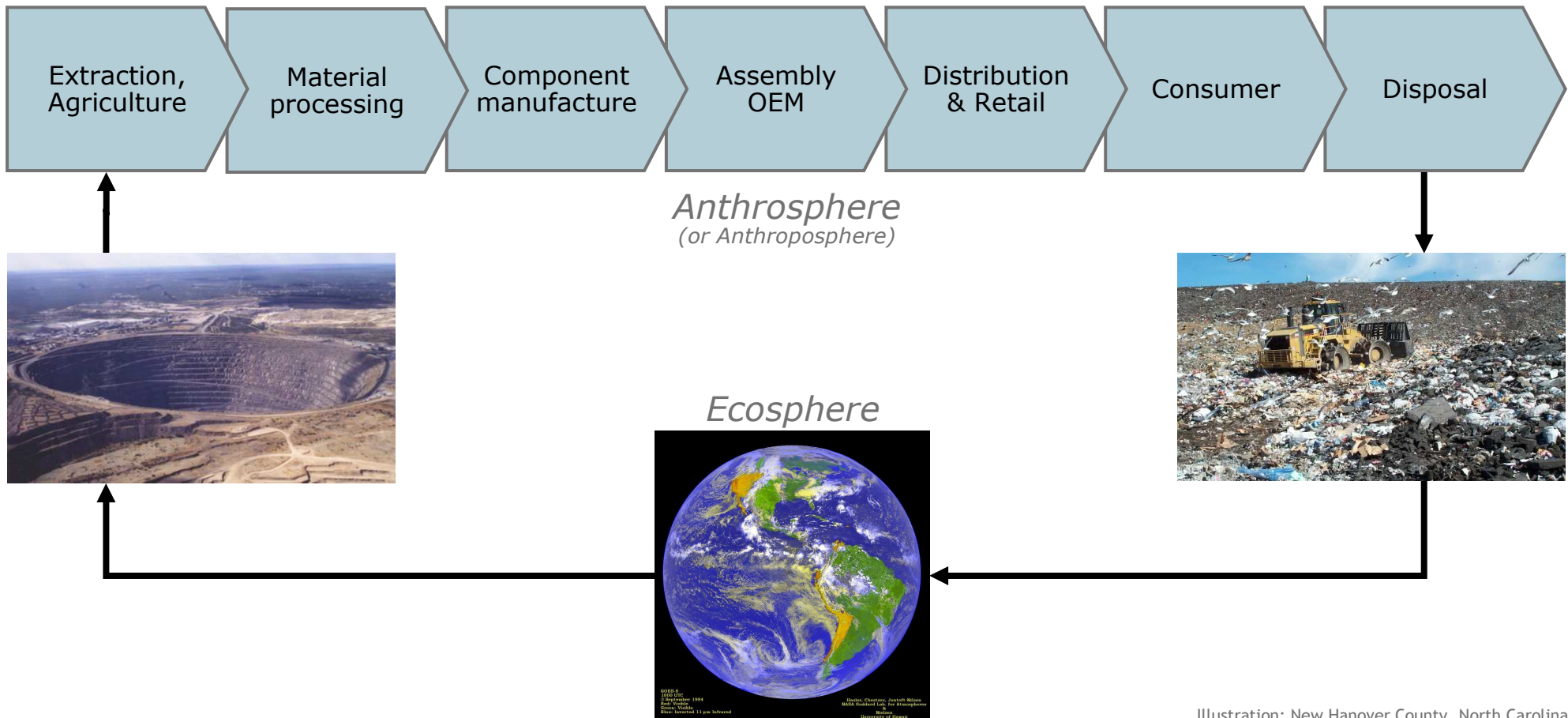
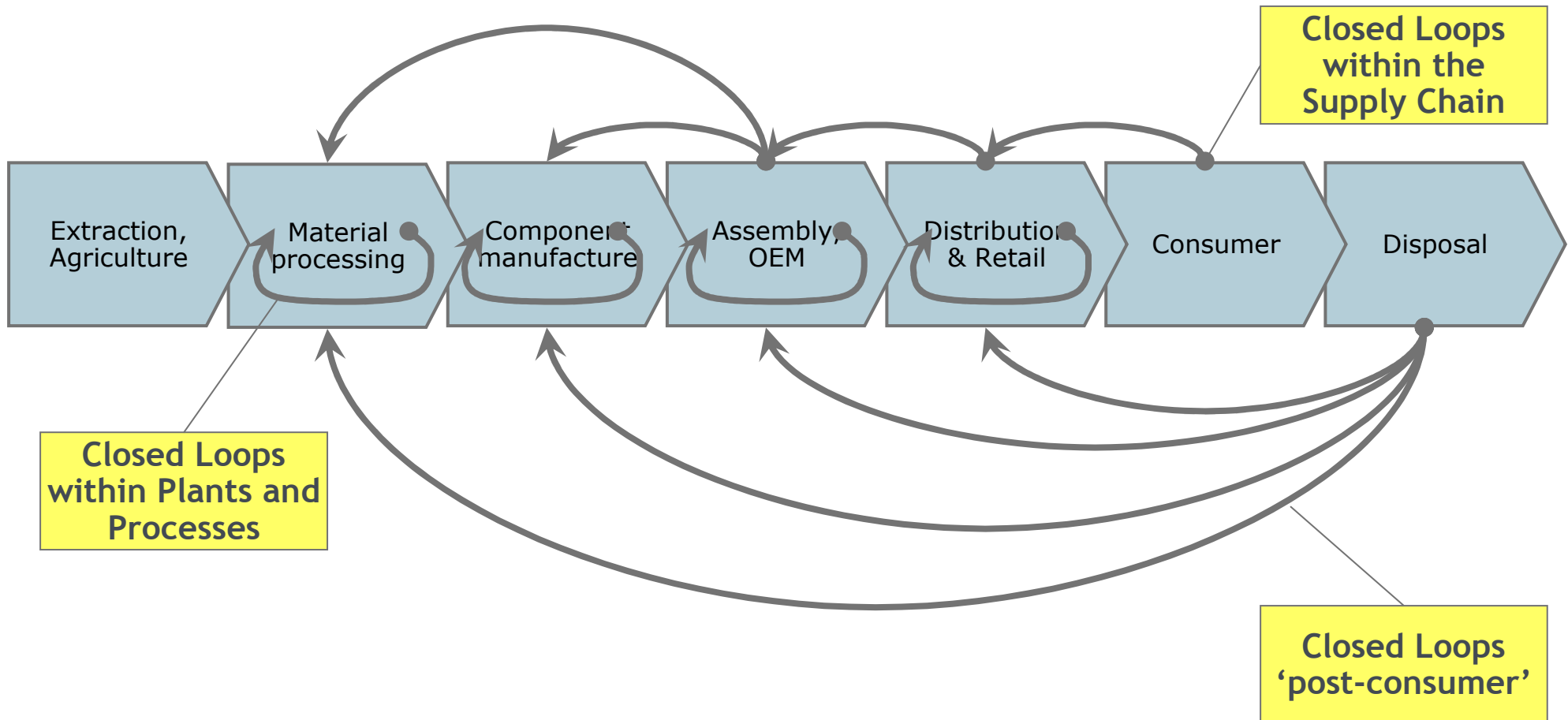


Illustration: The Palabora open pit, South Africa's leading copper producer

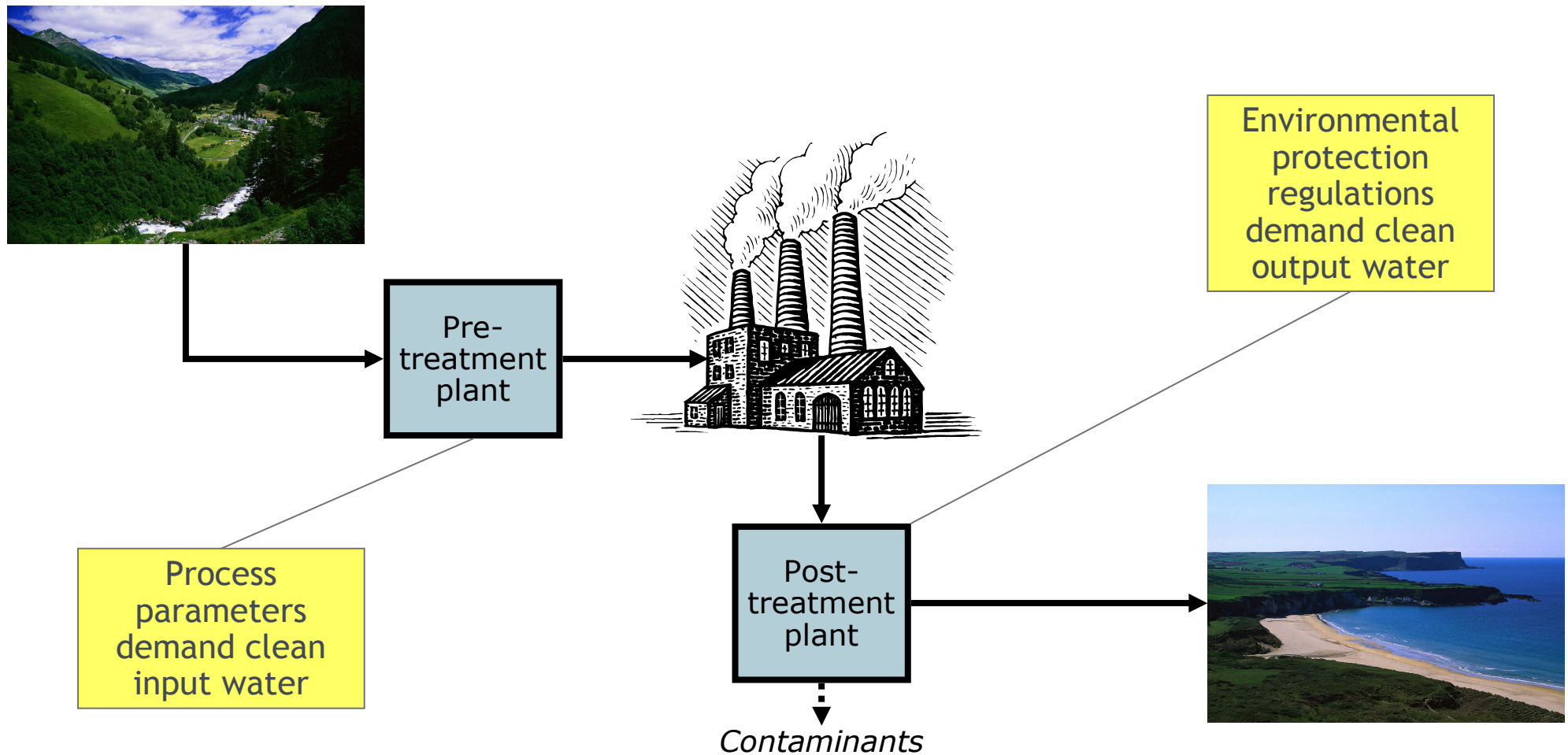
Illustration: New Hanover County, North Carolina
Secure Landfill opened in 1981 as the first lined landfill in the state

What is Closed-Loop Manufacturing

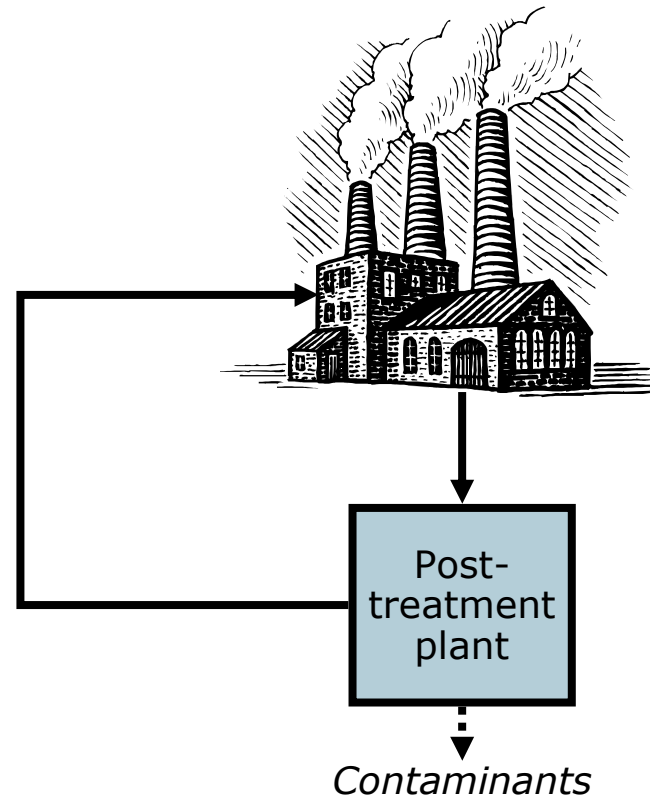
Closed Loops can allow the value invested in materials to be conserved



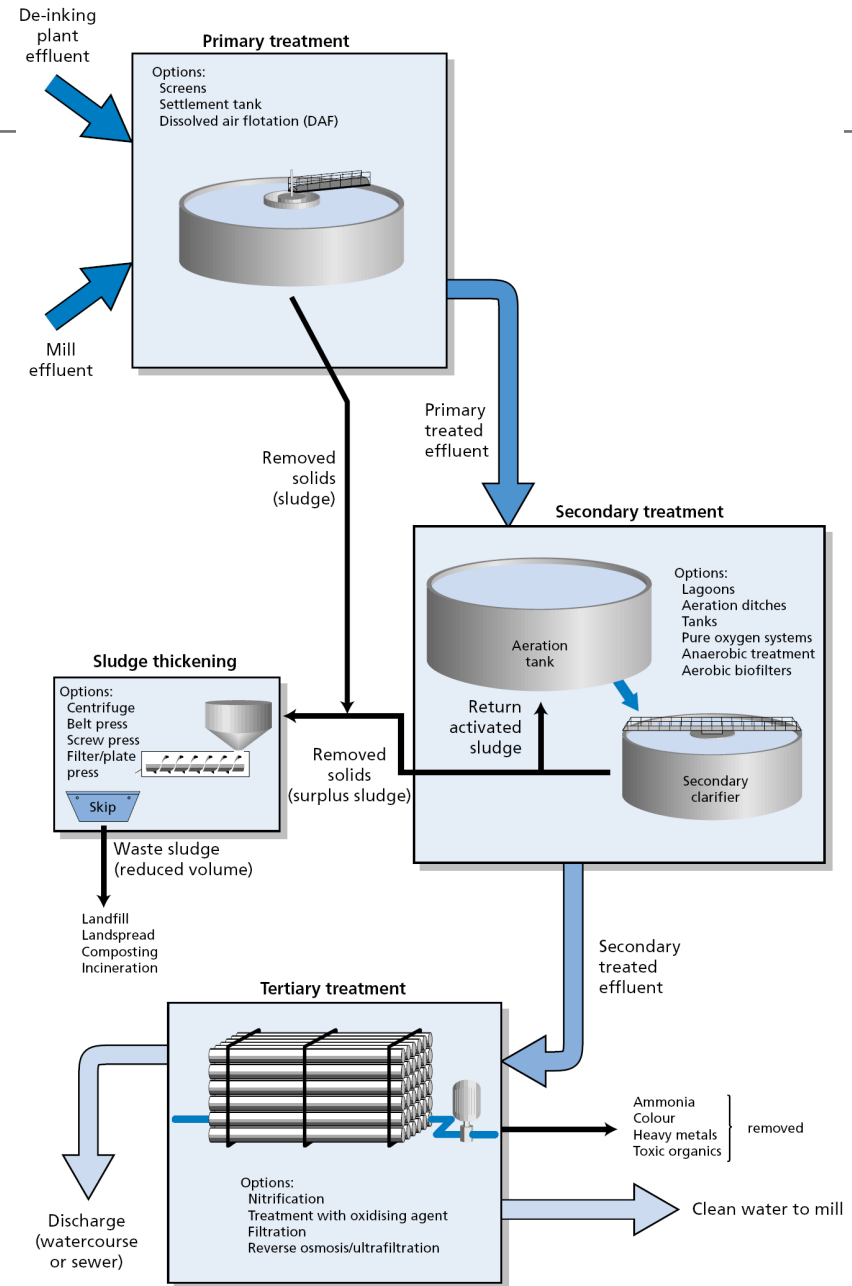
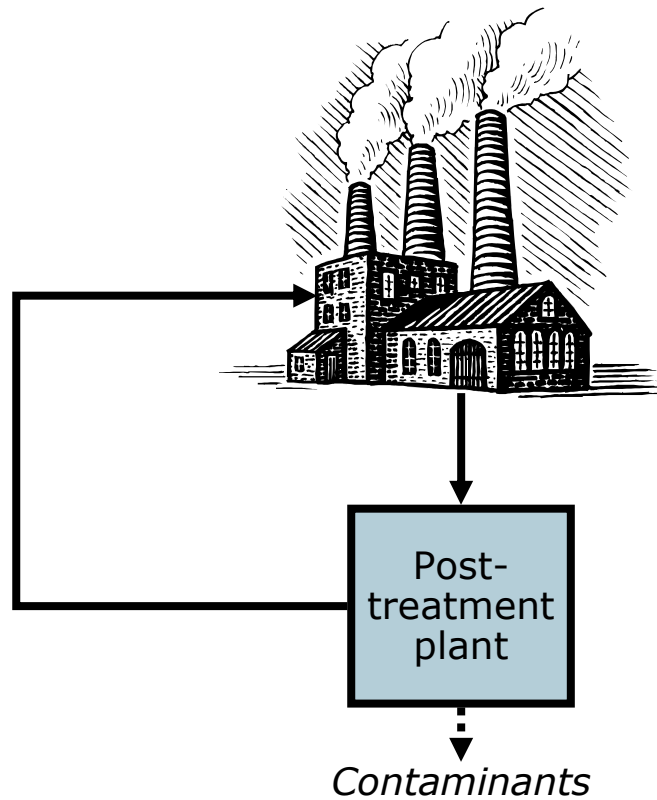
Closed Loops within Plants and Processes Water use



When the cheapness and availability of water are not the main consideration, process designers gain the freedom to select a better solvent and location



Closed Loops within Plants Water use



Source: Environmental Technology Best Practice Programme 'Cost-effective Effluent Treatment in Paper and Board Mills' GG156 Fig. 1 Effluent treatment overview

Reusable transport packaging can work well in closed loop shipping systems

- Reusable transport packaging is most likely to work well in specific situations:
 - Large volumes and consistent flows that make planning easier
 - Transportation and logistic arrangements that can be set up without adding significant cost
 - Large or bulky products or easily damaged or high-value items that must be protected
 - Community of regular customers, who are willing to cooperate and return packaging
 - Suppliers and customers that are grouped near one another
- Packaging may cost more initially, but should last longer, protect products better, reduce waste handling costs, allow better ergonomics and presentation, and provide other savings and benefits



JT9D Turbine Engine Container



Plastic crates



IBC container (for liquids)

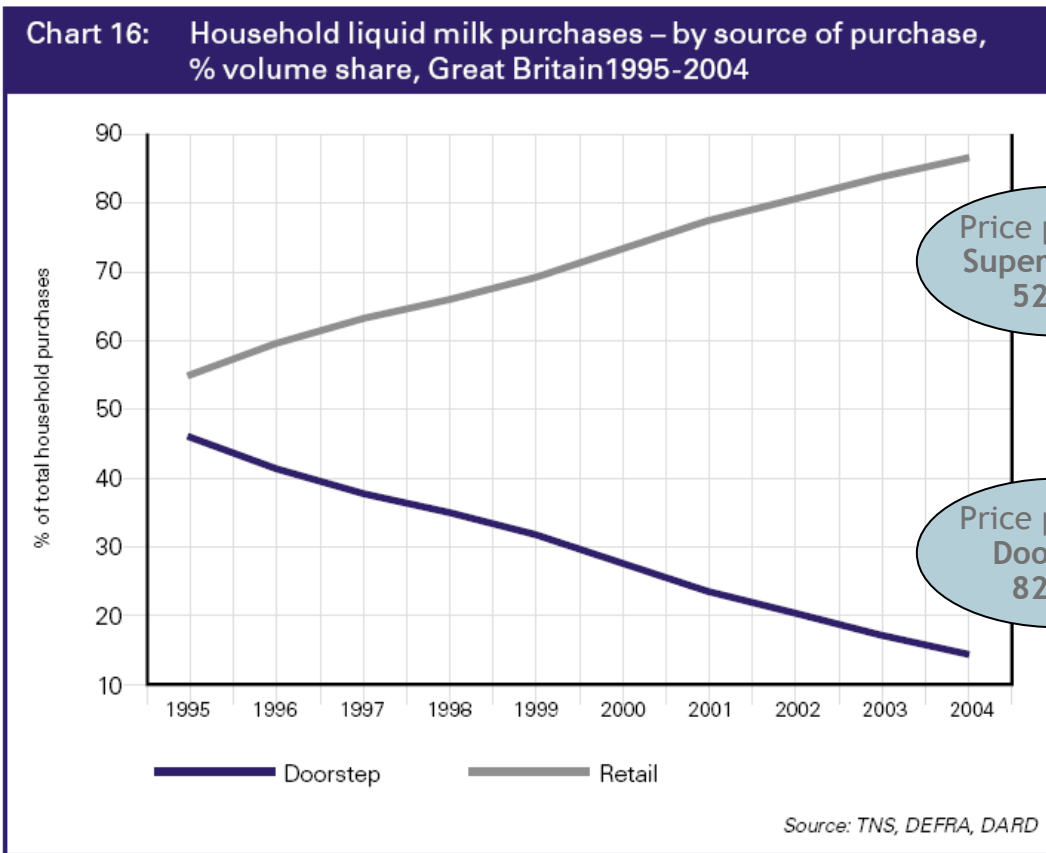


FoldyPac wooden containers



Open-head plastic drums (for solids)

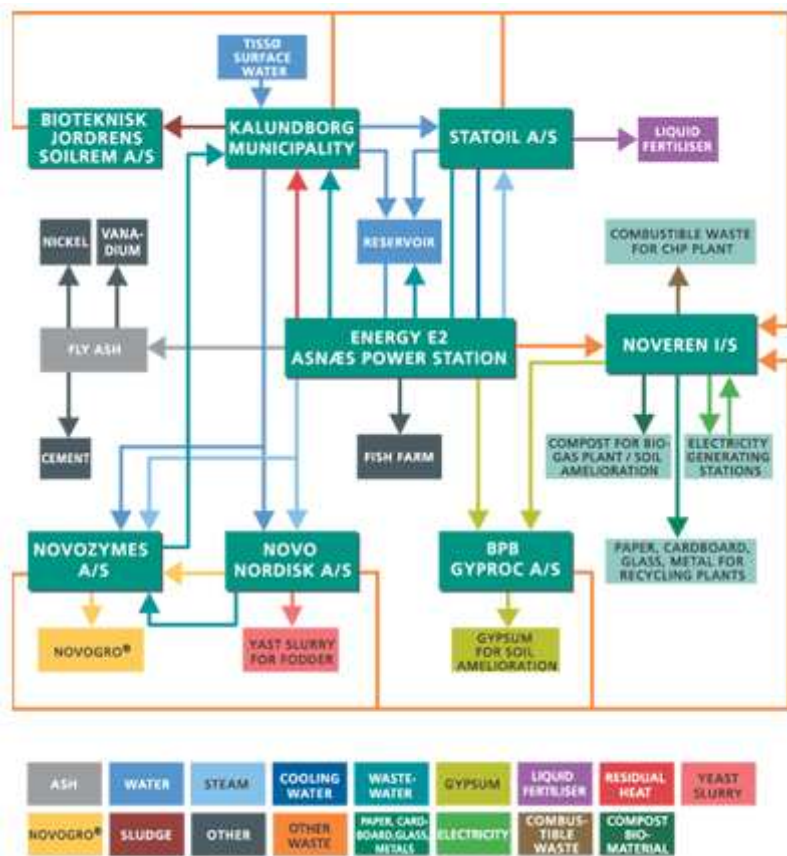
Doorstep delivery of milk has declined as prices have become uncompetitive, so reusable glass bottles have been replaced by one-trip polythene containers



Source: Milk Development Council 'Dairy Facts and Figures 2004'
Prices per litre at January 2006

Closed Loops within the Supply Chain Kalundborg

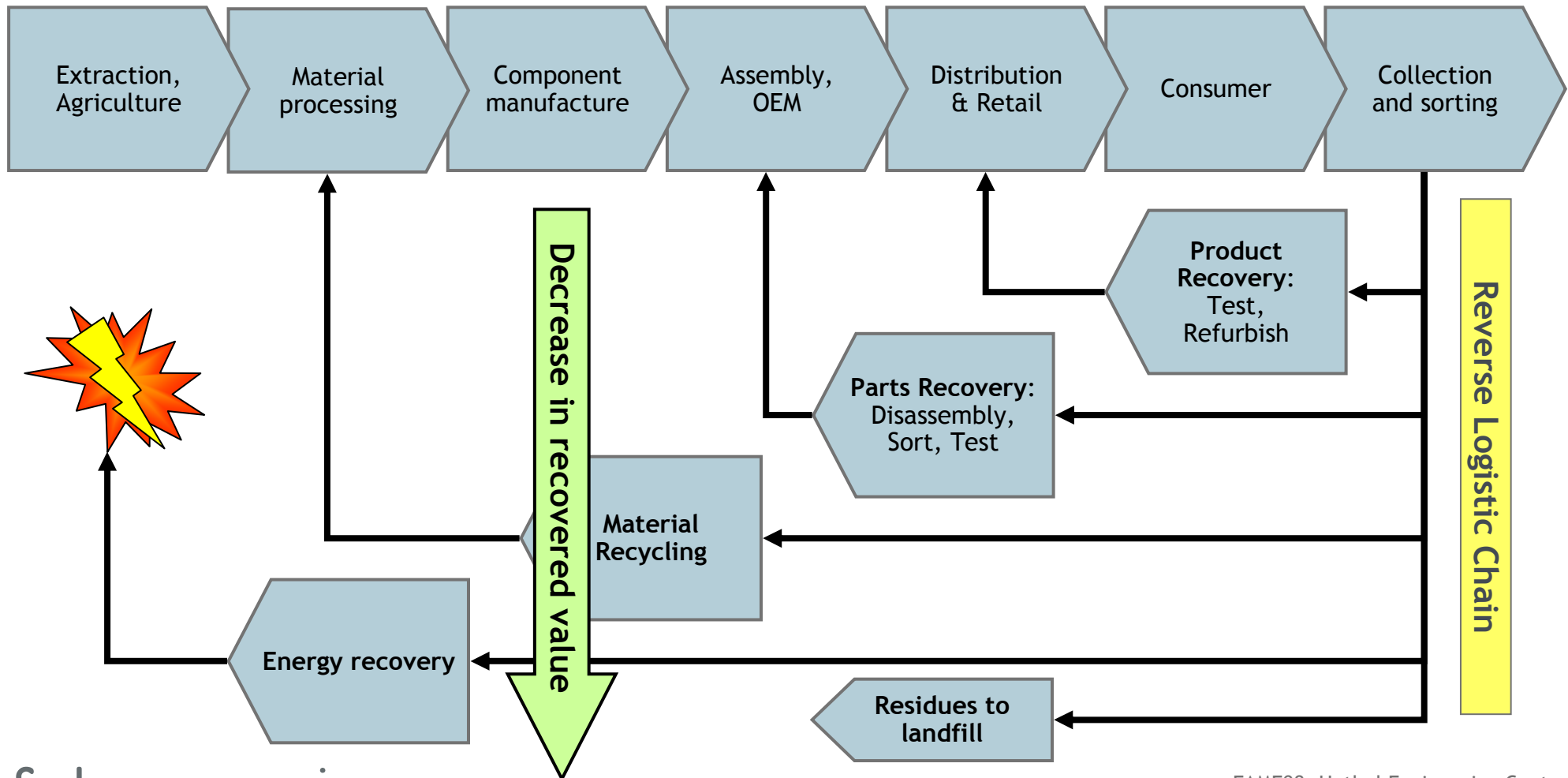
In Kalundborg, Denmark, some 20 symbiosis projects between industrial companies and the Municipality exploit each other's residues and by-products



Source: www.symbiosis.dk

What	Annual saving / benefit	How
Water consumption	Reduced 25%. 1.9 M m3 ground water and 1 M m3 surface water	Recycling the water and circulating it between individual Symbiosis partners
Oil	Reduced 20,000 tonnes; 380 tonnes of SO ₂ emissions	Novozymes A/S, Novo Nordisk A/S and Statoil use process steam from Asnæs Power Station.
Ash	80,000 tonnes	Ash from combustion of coal and orimulsion at Asnæs Power Station used in the construction and cement industries and the extraction of nickel and vanadium.
Gypsum	200,000 tonnes	Gypsum from Asnæs Power Station used in the production of plasterboard
NovoGro®	20,000 hectares of farmland.	NovoGro® from Novozymes A/S substitutes the use of lime and part of the commercial fertiliser
Wastewater	Reduced environmental impact	Wastewater treatment collaboration between Novozymes A/S, Asnæs Power Station and Municipality
Sludge	Expenditure savings and improved economy	Sludge from the treatment plant brings reduces production time at A/S Bio-teknisk Jordrens Soilrem
Newspaper and cardboard	13,000 tonnes	Sold to cardboard and paper consuming industries in Denmark, Sweden and Germany for new paper, new cardboard, egg boxes and trays for e.g. the health sector.
Rubble and concrete	7,000 tonnes	Used for surfaces after crushing and sorting
Garden and park refuse	15,000 tonnes	Delivered as soil amelioration in the area
Bio waste	4,000 tonnes	Bio waste from households and company canteens is used in the compost and biogas production
Iron and metal	4,000 tonnes	Resold after cleaning for recycling
Glass and bottles	1,800 tonnes	Sold to producers of new glass

There tends to be a decrease in recovered value, as approaches become cruder. Variability makes Reverse Logistic Chains difficult to manage



Plastics in principle should be easy to recycle, but in practice are difficult to handle, so ‘down-cycling’ or energy recovery may be better options

- Thermoplastic polymers *should* be easy to recycle, as they have lowish melting points and regain most of their mechanical properties on cooling. *But ...*
- **Regulations** prohibit the use of recycled polymers in some applications, e.g. food contact materials
- **Virgin polymers are currently cheap** (though rising with the price of oil), allowing little scope for extra costs
- Properties are very dependent on **purity** and are easily **degraded by reprocessing**
- Polymers **cannot be refined** or purified due to complex chemistry and a tendency to decompose on heating
- Polymer properties depend not only on chemical formula, but also on chain length and structure (branching, crosslinking, position of side groups, etc). Intrinsic Viscosity (IV) is a key property
- Most plastics contain necessary **additives** that affect reuse:
 - Processing additives (e.g. reduce viscosity during extrusion)
 - Property modifiers (e.g. increase stiffness of final article)
 - Stabilisers (e.g. to prevent oxidation in service, UV stabilisers)
 - Surface modifiers (e.g. barrier layers; metallization)
 - Colouring, ink, labels
- Every waste-stream is different, and expensive to assess: **variability** is a problem
- Better options may be to ‘**down-cycle**’ (i.e. reuse in a less demanding application), or **recover energy** using combustion, although this is opposed



Source: Dr Claire Barlow, Institute for Manufacturing, University of Cambridge

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Many different ownership transfer models exist to provide incentives to return materials for recycling

EXAMPLES

Donation model	Users give items for recycling at end of life	Bottle banks, charity shops
Incentive model	Government or buyer provides positive incentive to recycle	Tax breaks, grants, rewards, subsidies, advantageous pricing, purchasing preference
Coercion model	Legal penalties and charges force users to sort and submit items for recycling	'Chipped' wheelie bins, Landfill Tax
Deposit model	Items remain the property of supplier. A deposit is charged that is forfeited if lost	Returnable packaging
Buy-back model	Supplier pays for items at end of life	Car batteries, trade-in discounts on white goods, cell phones
Mandatory take-back model	Law requires maker to take back items at end of life and carry the cost of proper disposal	German Packaging Ordinances for extended producer responsibility
Dustman model	Third party is paid to dispose of items, perhaps recovering value by recycling	Tyres, scrap cars, skip hire, domestic refuse, toxic waste
Steptoe model	Third party recycler buys items and recovers value by recycling	Waste paper, scrap metal, antiques, toner cartridges, rags-and-bones
Lease model	Goods are leased or hired to user. Ownership is retained by supplier	Photocopiers, car lease, electric vehicle batteries, construction plant
Service model	User purchases a service not an item. Ownership of the 'tools' for supply is retained by supplier	Public transport, airlines

Multiple ownership models can be found for one commodity

Non-returnable bottle: UK	Ownership passes from supplier to customer. No incentive to return ownership to supplier. Scrapped, maybe recycled.
Returnable bottle: Germany	Ownership passes from supplier to customer. Deposit provides an incentive for return to supplier. Reused. Reverse logistics!
Glass in a pub	Ownership remains with the supplier. Supplier is responsible for 'maintenance'. Reused.
Glass at a Beer Festival	Ownership passes from supplier to customer at entrance. Supplier is <u>not</u> responsible for 'maintenance'. Retained as a souvenir
Jug filled for pub 'take-out'	Ownership remains with the customer (or may be sold by pub to customer) Customer is responsible for 'maintenance'. Reused.

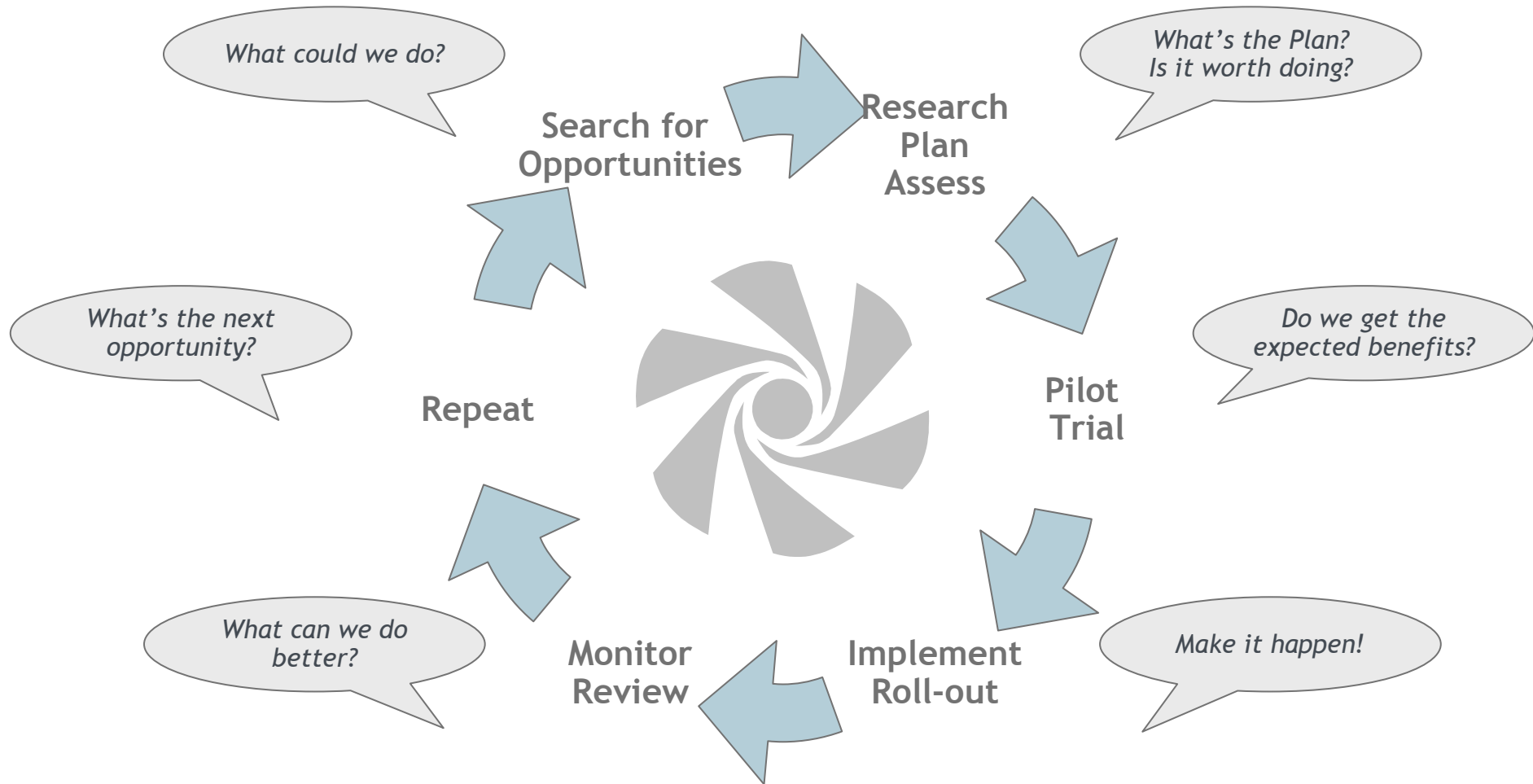


Illustration: The bar at the Eight Bells, Chipping Campden

Closed Loops are just one way to improve resource efficiency, but some of the approaches can be contradictory

Strategies			Side effect
Reduce	Eliminate the use	<i>"Is your journey really necessary?"</i> ^[1]	Also removes need to reuse
	Use less material	<i>"Any car which holds together for more than a race is too heavy."</i> ^[2]	May reduce value for recycling, weaken for reuse
	Greater simplicity	<i>"Simplicate, then add lightness"</i> ^[2]	
	Substitute materials with less environmental impact		May increase initial cost May reduce value for recycling
	Manufacture with less environmental impact		May reduce product life
Reuse	Extend the product life	<i>"Built to Last"</i>	May need to invest more materials
	Promote secondhand use	<i>"Preloved"</i>	Implies greater residual value, longer life, repairability
	Repair, Refurbish	<i>"Make-do and Mend"</i> ^[1]	Need to design for repair May increase complexity Need to establish repair infrastructure
	Design for Disassembly and Remanufacture	Whole life cycle approach	May increase costs Need to establish salvage infrastructure
Recycle	Material re-used for equivalent purpose		May be costly to establish and operate
	Design for easy recycling e.g. markings, segregate materials so separation is easier		Need to get consumer to sort waste stream Variability is a challenge
	Substitute materials that recycle easily		May need to compromise on properties/design
	Material re-used for less demanding purpose e.g. PET bottles to fleece	<i>"Down-cycle"</i>	Value is lost. Economics may become difficult
Reduce impact of disposal	Design so that energy can be recovered		May limit choice of materials
	Select materials that degrade easily and benignly	<i>"Biodegradable"</i>	

Businesses should systematically and persistently seek opportunities for savings



Closed Loops offer scope for financial and resource savings, but there is no single approach that is right for every situation

- The classic Open Loop supply chain is part of a vast Closed Loop connected to the 'ecosphere'
- Closing the loop within a process can enable new ways of doing things
- Within a supply chain, reusable packaging can offer benefits in the right situation
- Substantial symbiosis projects are possible, but are challenging
- Product refurbishment and reuse; parts dismantling and salvage; materials recycling and energy recovery can all play a role in post-consumer Closed Loops
- A wide variety of Ownership Models exist to provide incentives to participate in the Closed Loop
- Closed Loops are just one way to improve resource efficiency
- Action should be systematic and persistent



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Futureneering is an advisory business assisting emerging technology ventures with strategy and commercialisation

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