

THE **ImpEE** PROJECT
IMPROVING
ENGINEERING
EDUCATION

Recycling of Plastics



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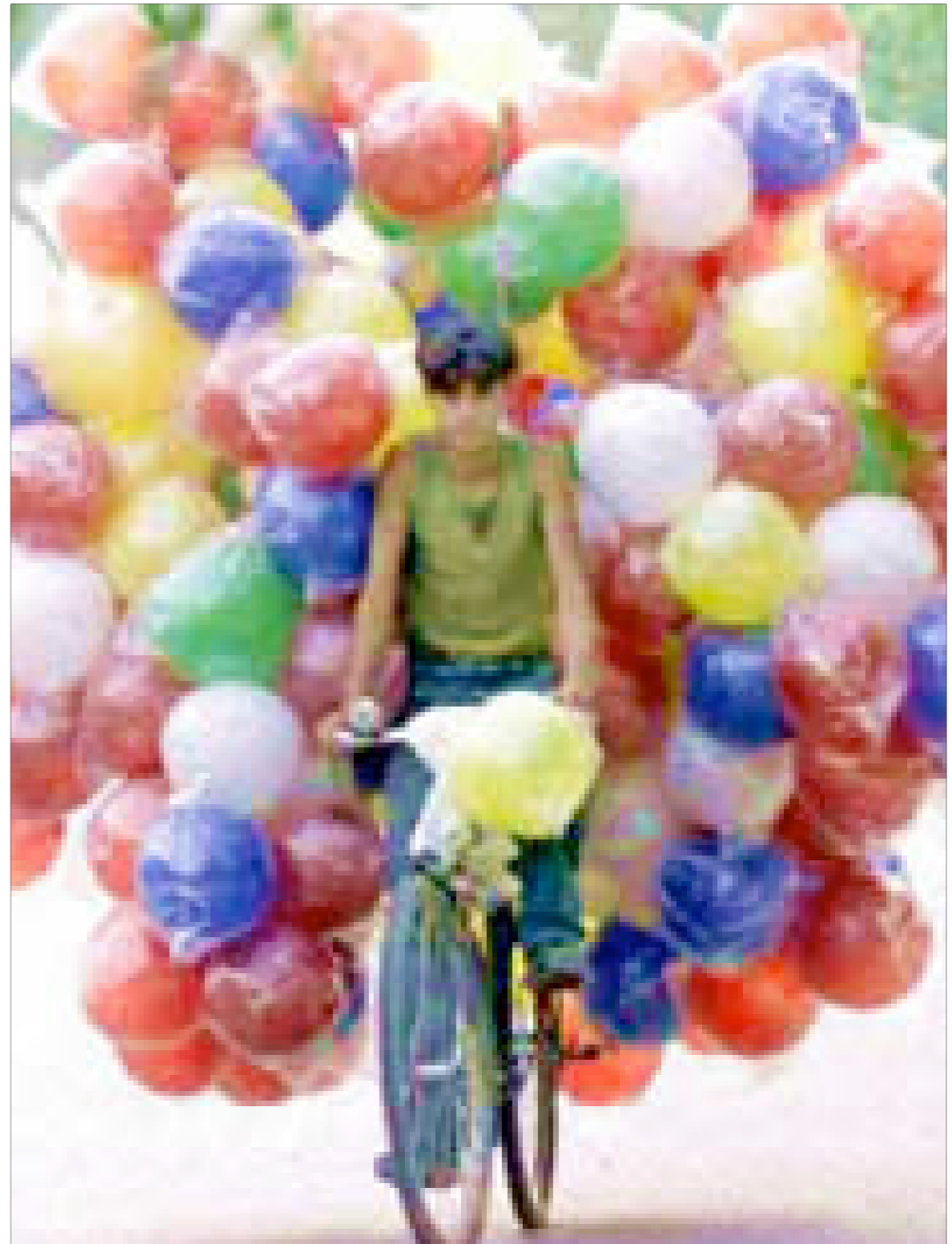


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Plastic waste in the UK

- 3 million tonnes of waste plastic are produced a year in the UK.
- 1 tonne = 20,000 plastic bottles
- 7% of this is recycled at present (2005)
- An estimated 9.2 billion plastic bottles are disposed of each year
- 200,000 tonnes of plastic rubbish is being sent 8,000 miles to China each year for recycling.



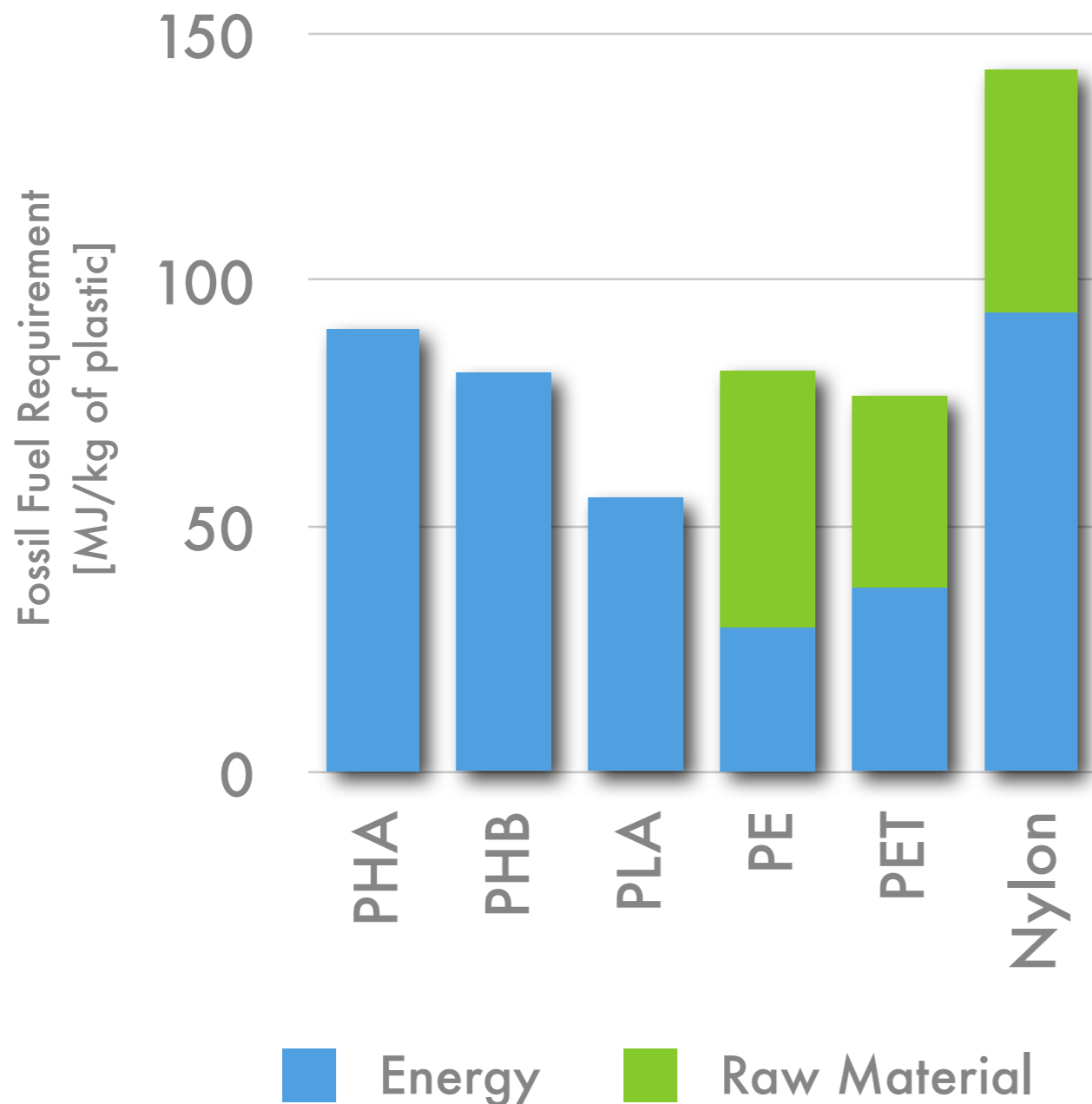
Things to think about...

- The basic raw materials for plastic are petroleum and / or natural gas.
- Although plastics only consume around 4% of the world's oil, supplies are becoming depleted.
- Many plastic products are reaching the end of their lifecycle, forming non-biodegradable mountains of waste plastic.
- 11% of household waste is plastic, 40% of which is plastic bottles



Biologically produced plastics

Energy consumption of Biological versus Crude Oil derived plastics



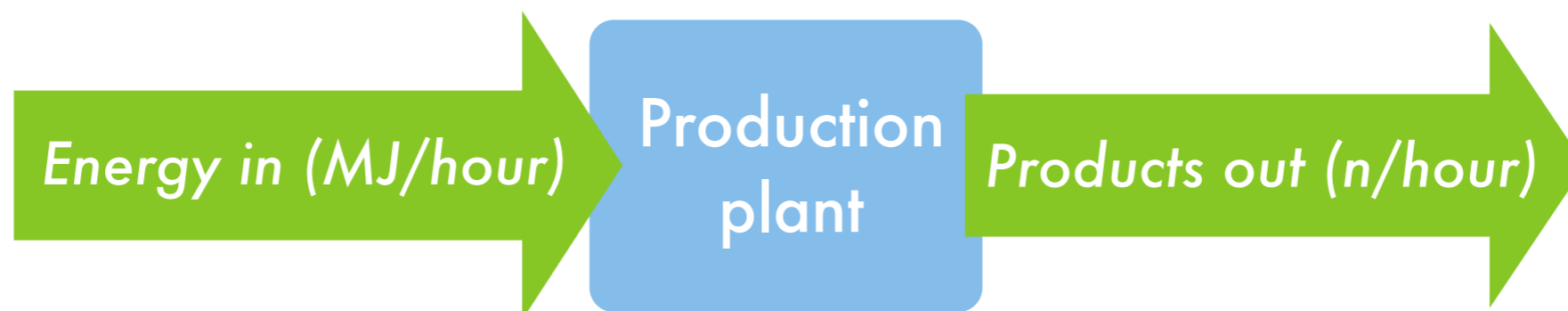
- PHA , PHB and PLA are biologically produced.
- Processing energy is relatively high.
- More fossil fuel energy is used in their production than for both Polyethylene and PET.
- So renewable plastics are not necessarily as environmentally friendly as they first appear.

Assessing embodied energy and CO₂ of plastics

The energy input during manufacturing is not calculated via thermodynamics because:

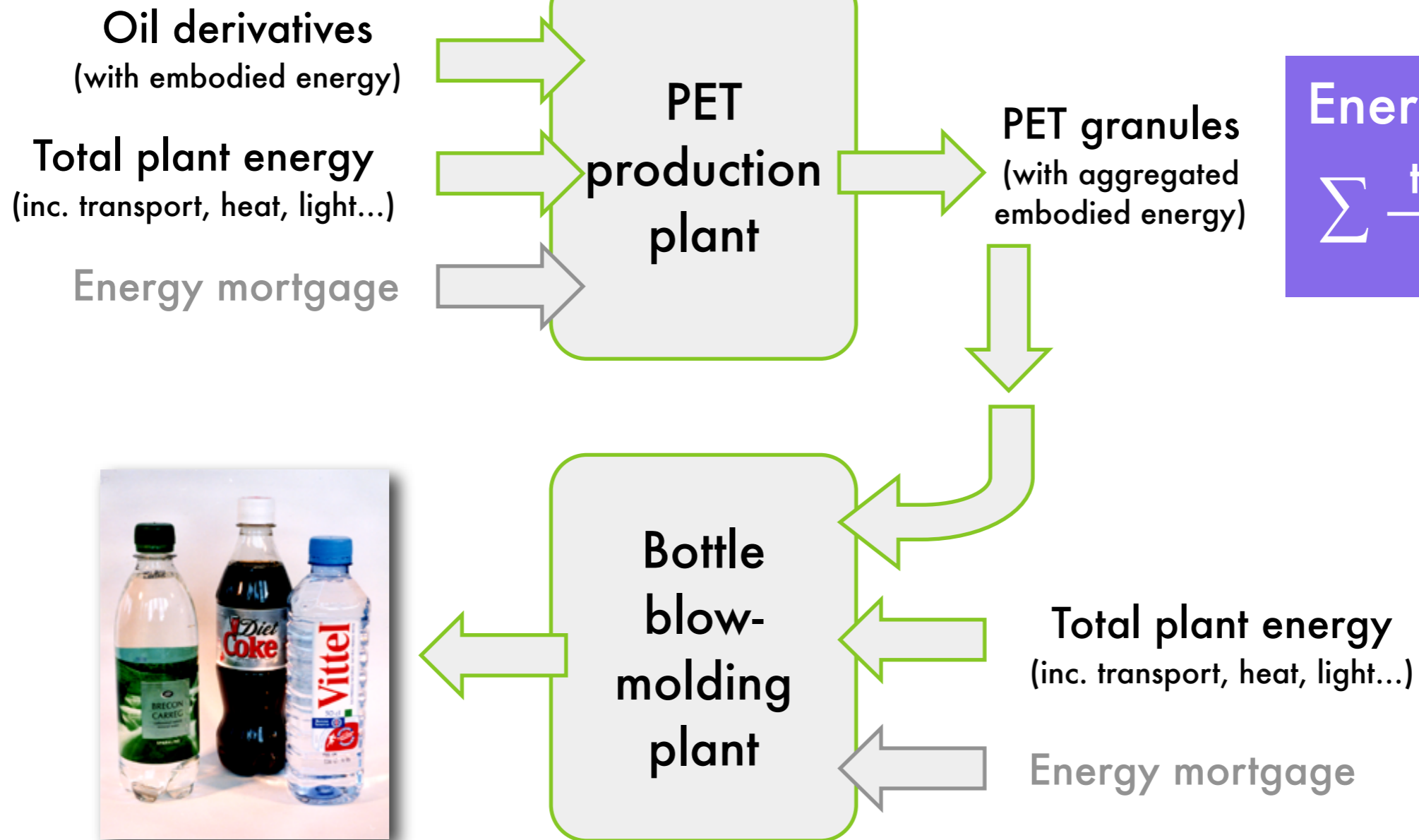
- Industrial processes have varying efficiencies ranging from a few % to about 50%
- The scrap-fraction ranges from a few % to 80% or more
- Some part of the energy to heat, light and maintain the plant must be included
- In any new enterprise there is an energy “mortgage” to be paid – the energy it cost to build the plant

Instead it is calculated by input-output analysis



$$\text{Energy/product} = \text{Energy in/Products out}$$

EXAMPLE: primary production of PET bottles



$$\text{Energy/kg PET} = \sum \frac{\text{total energy in}}{\text{kg of PET out}}$$

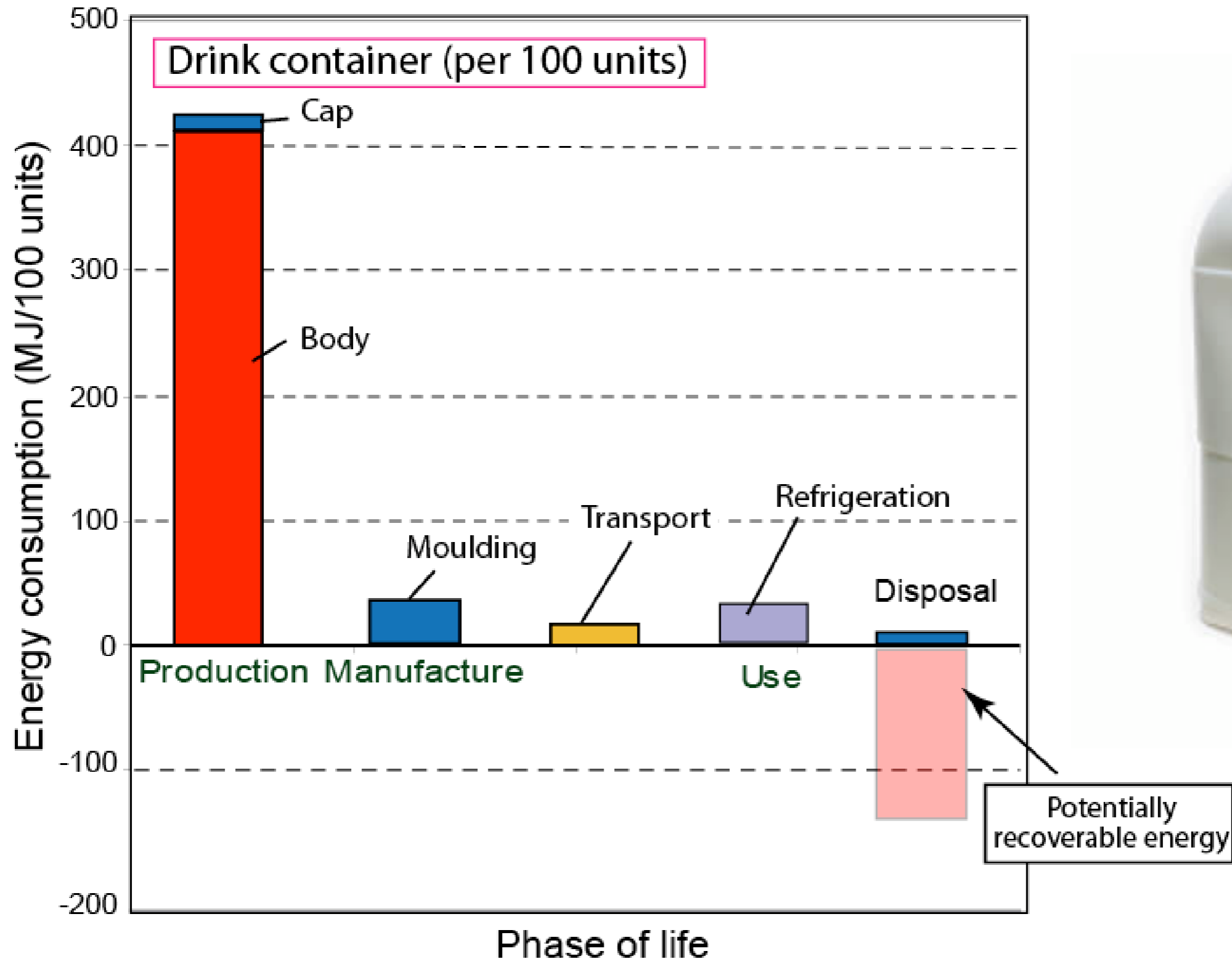
$$\text{Energy/bottle} = \sum \frac{\text{total energy in}}{\text{number of bottles out}}$$

Life-Cycle Analysis

- In addition to the energy embodied in the plastic during production and manufacturing, products also require energy during use and disposal.
- An analysis that considers this whole process is referred to as life-cycle analysis.
- The next slide shows the results of such an analysis of a plastic drink container.








Energy breakdown for PE bottle



Eco-impact per unit of function

Function: contain 1 litre of fluid

	Glass	PE	PET	Alu	Steel
Container Type					
Mass [g]	325	38	25	20	45
Mass/volume [g/litre]	433	38	62	45	102
Energy/Mass [MJ/kg]	14	80	84	200	23
Energy/Volume [MJ/litre]	8.2	3.2	5.4	9.0	2.4

The **winner** is steel.
The **losers** are glass and aluminium.

Recycling changes the picture a little – but not simple

Things to think about



- Plastics are not necessarily the waste and energy culprits that some people think they are. Plastics can be very energy efficient.
- It takes less energy to manufacture a plastic ketchup bottle than a glass ketchup bottle. And since plastics are lightweight, it takes less energy to transport a truckload of plastic ketchup bottles than a truckload of glass ketchup bottles.
- Up to 40% less fuel is used to transport drinks in plastic bottles compared to glass bottles

Why Recycle?

- In landfill, both synthetic and naturally occurring polymers don't get the necessary exposure to UV and microbes to degrade.
- Here they are taking up space and none of the energy put into making them is being reclaimed.



Photo of tip.

Why Recycle?

- Reclaiming the energy stored in the polymers can be done through incineration, but this can cause environmental damage by release of toxic gases into the atmosphere.
- Recycling is a viable alternative in getting back some of this energy in the case of some polymers.
- As petroleum prices increase it is becoming more financially viable to recycle polymers rather than produce them from raw materials.

Recycling of polymers: the reality

In-house scrap (generated at the source of production) is near-100% recycled already.

Recycling of used plastics (here PET bottles): few plastic recycling plants make a profit. Many have closed.

Why, if recycling is energy-efficient? And is it?

- Collection is time-intensive, so expensive
- Sorting of mixed plastic waste is difficult – contamination is inevitable.
- Removing labels, print, all but impossible at 100% success rate
- Contamination of any sort compromises re-use in “hi-tech” applications (a carbonated water bottle is a pressure vessel – a failure is unacceptable to the supermarkets that sell them)



The consequence: most plastic (apart from in-house) is reused in lower-grade applications

- PET: cheap carpets, fleeces
- PE and PP: block board, park benches

Problems with recycling plastics

- PET and PVC have many problems with cross contamination as the two polymers appear very similar to the naked eye and share the same specific gravity so cannot be separated by conventional float-sink techniques used in the plastic recycling industry.
- The correct separation of plastics is extremely important. Just one PVC bottle in a batch of 10,000 PET bottles can ruin the entire melt!

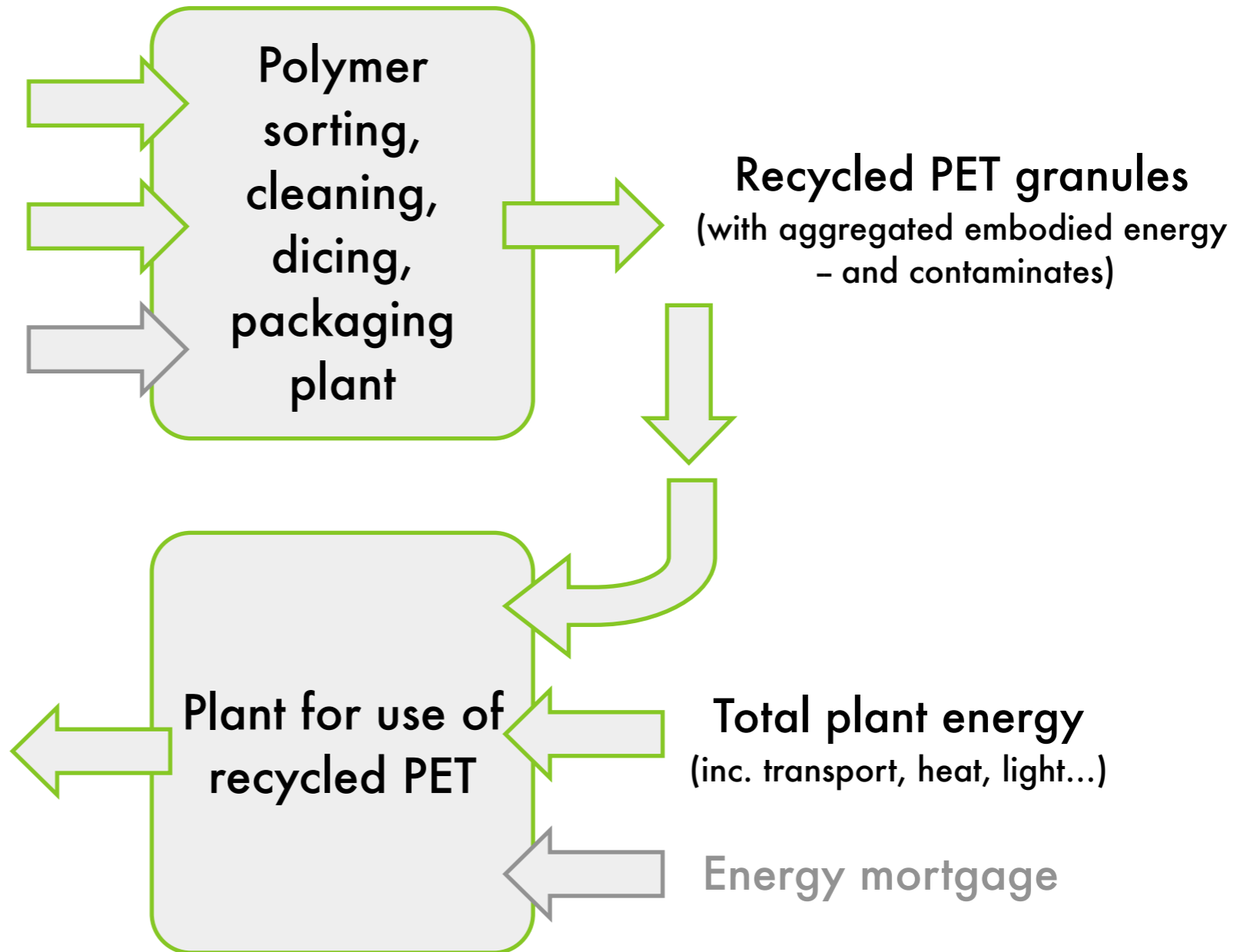
Energy (and use) audit of recycling of PET



Used plastic bottles
(inc. collection transport energy)

Total plant energy
(inc. transport, heat, light...)

Energy mortgage



Energy per kg of fleece =

$$\sum \frac{\text{total energy in}}{\text{kg of fleece out}}$$

Energies and prices of virgin and recycled plastics

Commodity plastics	Embodied energy, virgin material (MJ/kg)	Price*, virgin material (\$/kg)	Embodied energy, recycled material (MJ/kg)	Price*, recycled material (\$/kg)
HDPE	77 - 85	1.9 - 2.0	≈ 35 - 45	0.84 - 0.97
PP	75 - 83	1.8 - 1.85	≈ 35 - 45	0.99 - 1.1
PET	79 - 88	2.0 - 2.1	≈ 60 - 64	1.1 - 1.2
PS	96 - 105	1.5 - 1.6	≈ 40 - 50	0.75 - 0.86
PVC	63 - 70	1.4 - 1.5	≈ 35 - 40	0.77 - 0.99

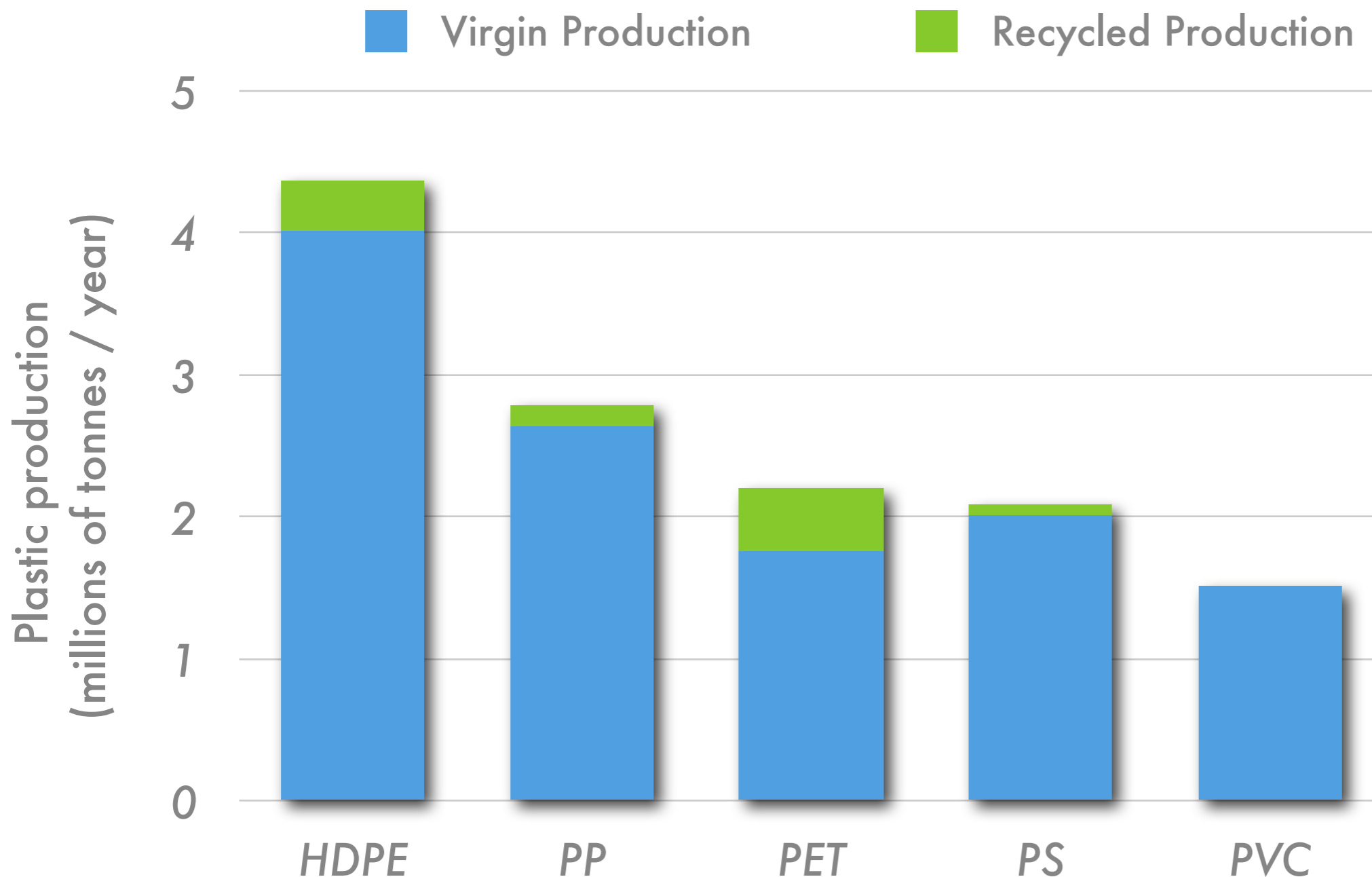
*Spot prices, November 2005

The messages:

- Both the embodied energy and price of recycled plastics are about half that of virgin material
- The lower price reflects the lower quality of the recycled material, limiting its use
- Because of this the contribution of recycling to current plastic consumption is small

Recycling of polymers: the reality

Because of the problems outlined on the previous slides, the contribution of recycling to current plastic consumption is small.



This bag contains a percentage of recycled polythene waste

Things to think about?








- Since most oil is extracted to be burned directly as fuel, is it so wrong to turn it into plastic first, and then burn it to recover the energy?



Things to think about

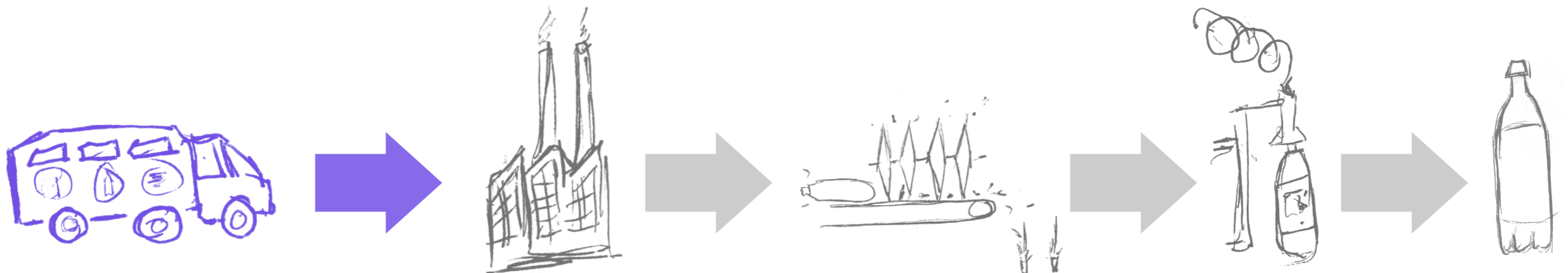
- China drives the global waste trade, importing more than 3 million tonnes of waste plastic a year.
- Western plastic companies are setting up in China, but some of the poorest people are employed to sort and recycle the plastic.
- Is it better to send rubbish to China to be recycled than to put it in landfill in Britain?

How plastics are sorted

Symbol	Acronym	Full name and uses
	PET	Polyethylene terephthalate - Fizzy drink bottles and frozen ready meal packages.
	HDPE	High-density polyethylene - Milk and washing-up liquid bottles
	PVC	Polyvinyl chloride - Food trays, cling film, bottles for squash, mineral water and shampoo.
	LDPE	Low density polyethylene - Carrier bags and bin liners.
	PP	Polypropylene - Margarine tubs, microwaveable meal trays.
	PS	Polystyrene - Yoghurt pots, foam meat or fish trays, hamburger boxes and egg cartons, vending cups, plastic cutlery, protective packaging for electronic goods and toys.
	Other	Any other plastics that do not fall into any of the above categories. For example melamine, often used in plastic plates and cups.

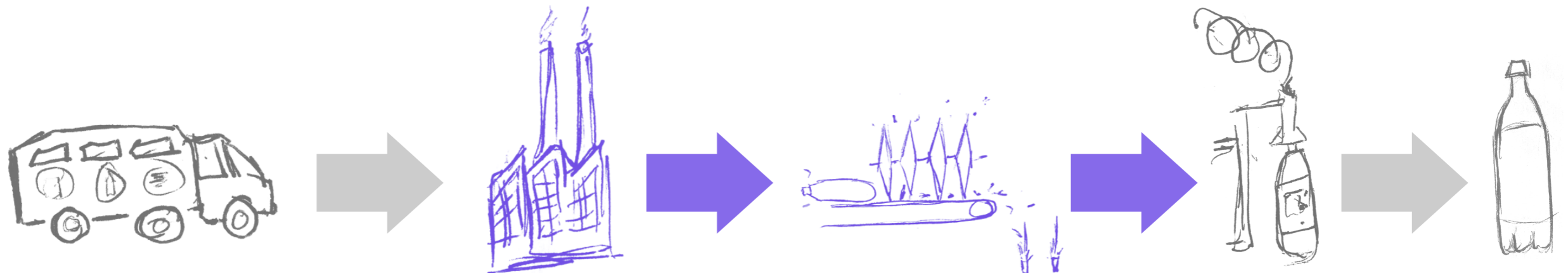
How the recycling occurs

1. The recyclables can be collected from individual homes or from collection points such as tips, schools and supermarkets. After transport to the recycling plant, plastics are hand sorted according to their recycling code. Some materials recovery facilities can mechanically sort different plastic codes. Each plastic type is processed separately.



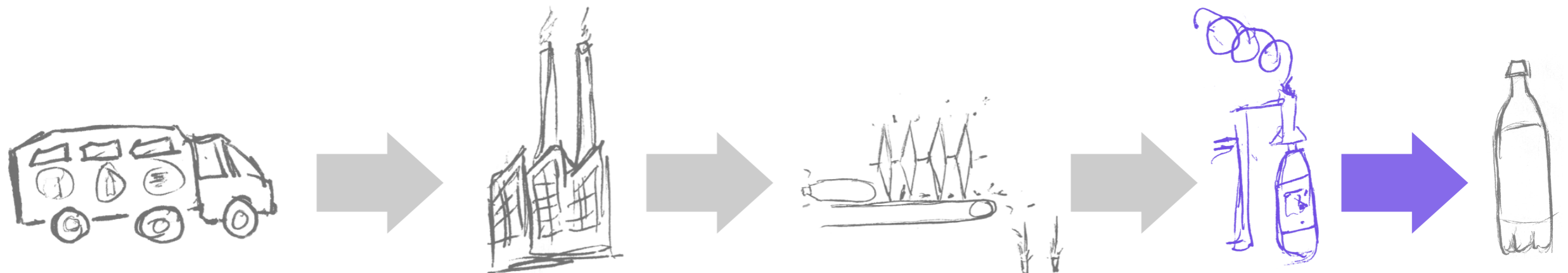
How the recycling occurs

2. The plastic is sliced into flakes and the flakes go through a washing process.
3. The clean plastic flakes are melted together, extruded through small holes, and chopped into pellets.



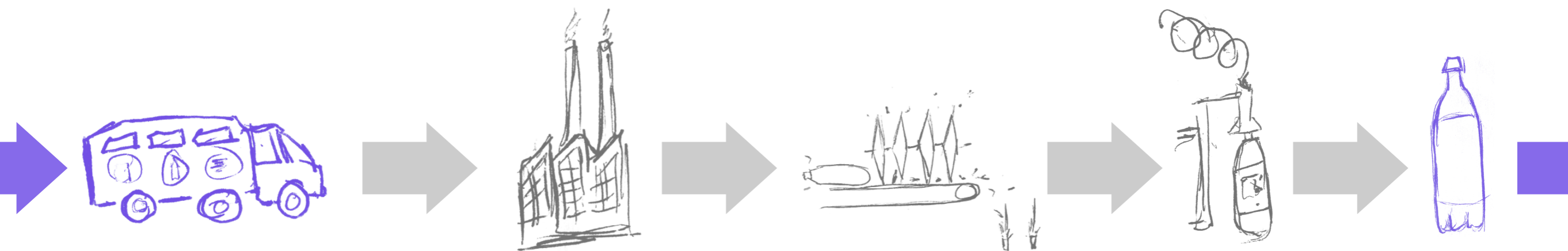
How the recycling occurs

4. The bags of recycled plastic pellets are taken to factories where they are melted and made into new products.
5. In the case of soft drink bottles the recycled pellets are combined with virgin material fresh from petroleum. These are then melted and moulded into preforms.



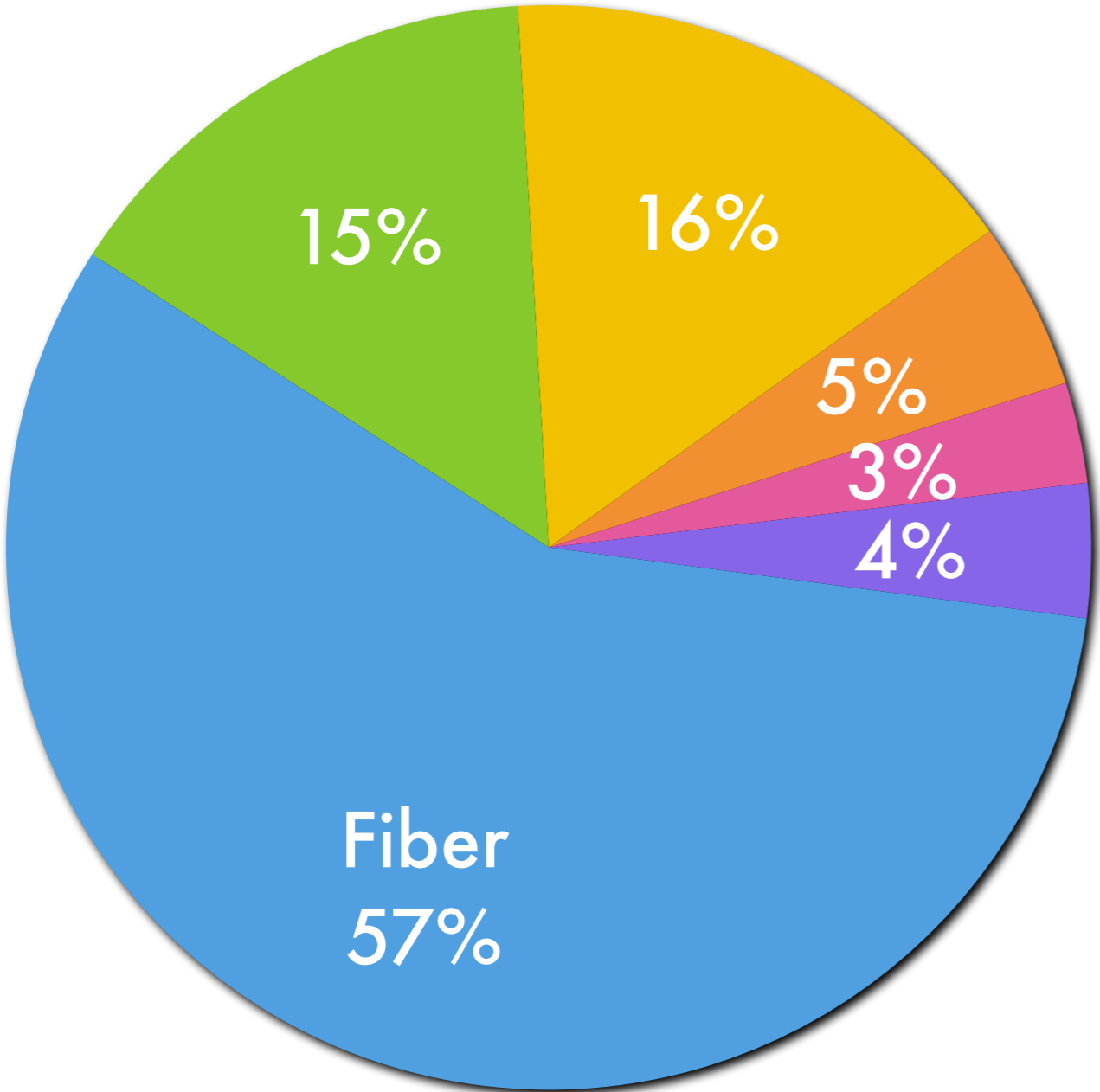
How the recycling occurs

6. The bottles are blown into another mould to form the full size bottle this is often done at the bottling plant where they are filled and sealed.
7. Once consumed they are delivered back to the recycling plant after household recycling.



Recycling Statistics

Where Recycled PET Ends Up



- Fiber
- Strapping
- Food/Beverage Containers
- Non-Food containers
- Film Sheet
- Other

Other includes: Compounded Resin (2%), Tolloed (1%), Clean Export (1%)

A different viewpoint...



- It takes one day to collect a kilo of thin plastic bags from a tip by hand
- For one kilo, the rag picker typically earns R1.5 in India
- Some cities in India are banning the use of thin plastic bags



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