TOGETHER WE CAN

Introduction to Plastics Recycling, Chain of Custody Models and the Mass Balance Approach

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THE UK PLASTICS PACT

Session plan

- Setting the scene
  - The work of the UK Plastics Pact
  - Defining recycled content & recyclable
  - Plastics conversion technologies
  - Recycling processes
  - Tracking recycled materials
- Chain of custody models
  - Identity preservation
  - Segregation chain
  - Book and claim
  - Mass balance
- Mass balance
  - Components of mass balance
  - Models considered for the Plastics Packaging Tax

Mass

Mass

Mass can be defined as the amount of matter present.

Law of conservation of mass

Without nuclear reactions mass can neither be created or destroyed in closed systems but the chemical structure and physical forms can change.

Mass balance

Mass balance follows the laws of conservation of mass and can simply be considered an accounting of all the material in a system or process.

Setting the scene

The UK Plastics Pact

WRAP’s mission

‘A world in which resources are used sustainably’

To accelerate the move to a sustainable, resource-efficient economy through:

- **Re-inventing** how we design, produce and sell products
- **Rethinking** how we use and consume products
- **Re-defining** what is possible through re-use and recycling.

Environment impacts

- **8 million tonnes** of plastic leaks into the ocean – equivalent of dumping one refuse truck every minute
- If no action is taken, this is expected to increase to two per minute by 2030 and four per minute by 2050

PLASTIC v FOOD WASTE

UK Plastic Packaging waste

2.2 million tonnes per year

UK Household Food & Drink waste

7 million tonnes per year

The UK Plastics Pact's Vision

A WORLD WHERE PLASTIC IS VALUED AND DOESN'T POLLUTE THE ENVIRONMENT.

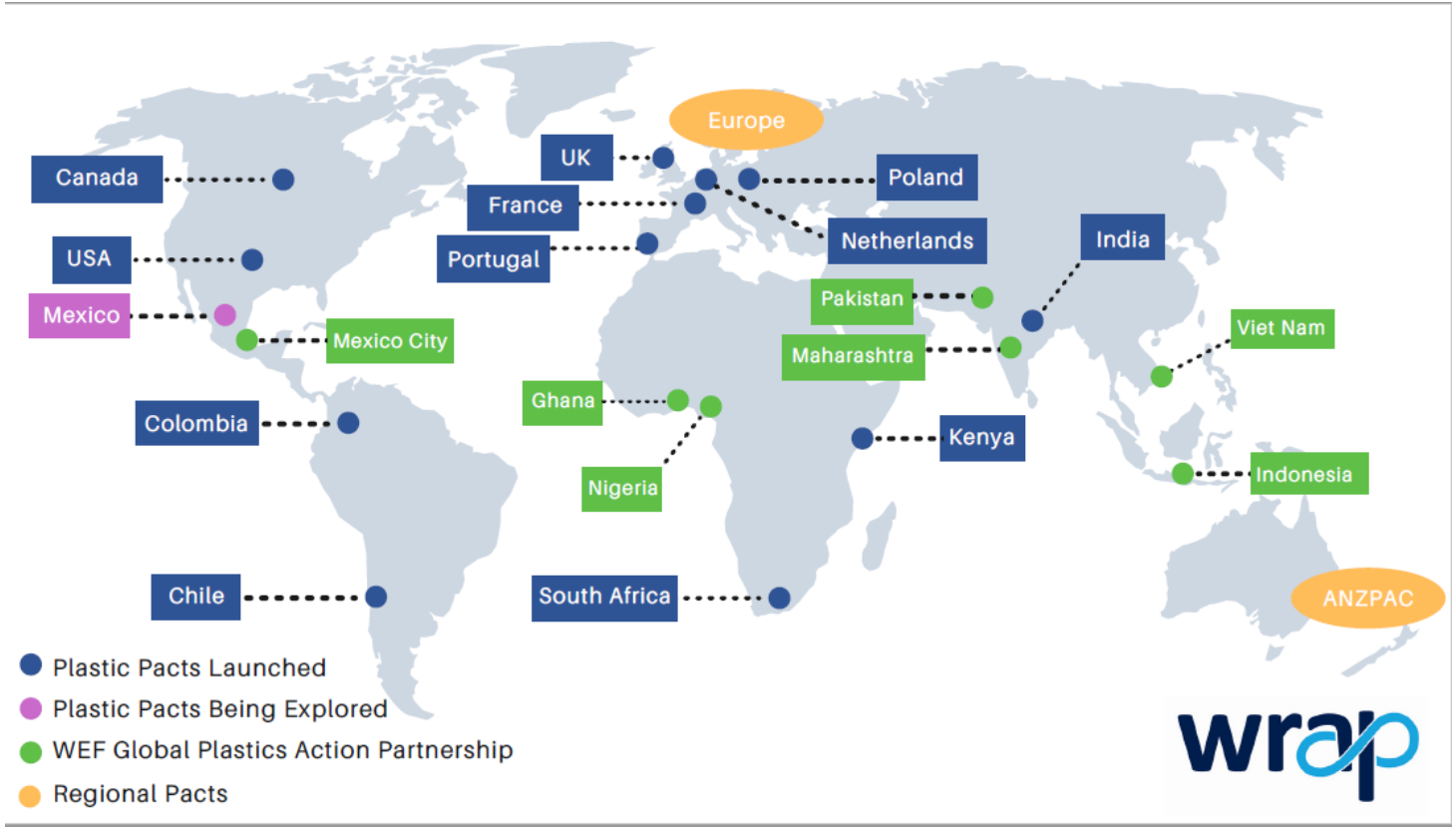
Tackling plastics at a global and national level

- Global issue that requires global and national level action.
- The first of a global network of national initiatives.
- All under the umbrella of the Ellen MacArthur Foundation's global initiative – New Plastics Economy.
- With other countries are following suit.

ELLEN MACARTHUR FOUNDATION

NEW PLASTICS ECONOMY

WRAP's **global plastics** work .....



UK Plastics Pact Membership

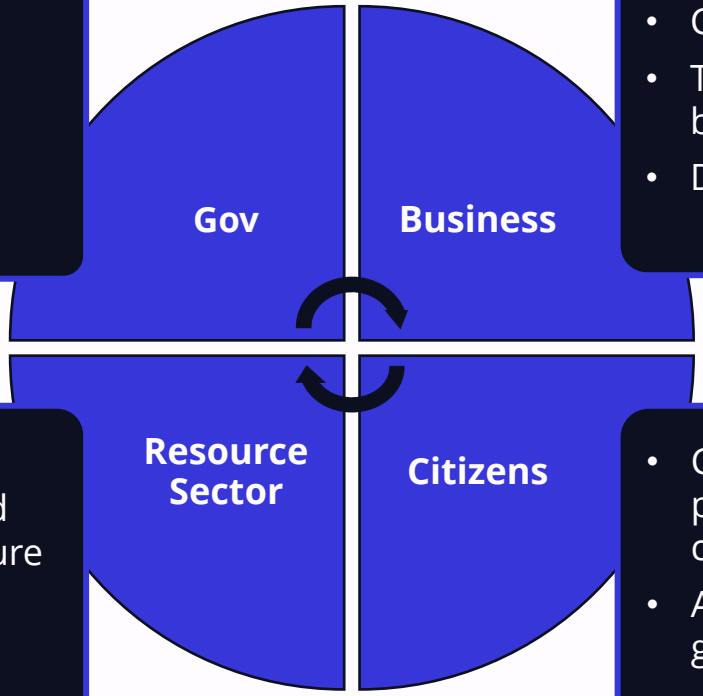
100+ business members from across the value chain

40+ supporting members amplifying messaging and extending reach

>95% UK grocery market

2/3 of all household plastic packaging placed on the UK market

- Regulatory reform
- Citizen behaviour change campaign
- Government leadership



- Critical mass of businesses
- Targets embedded in business processes
- Demand for recycled plastic

- Investment in sorting and reprocessing infrastructure
- Availability of quality recycled plastic material

- Citizens engaged with prevention, recycling and correct disposal.
- At home, work and ‘on-the-go’


BY 2025
100%
of plastic packaging to be reusable, recyclable or compostable
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BY 2025
ELIMINATE SINGLE-USE PACKAGING
Take actions to eliminate problematic or unnecessary single-use packaging items through redesign, innovation or alternative (reuse) delivery models.
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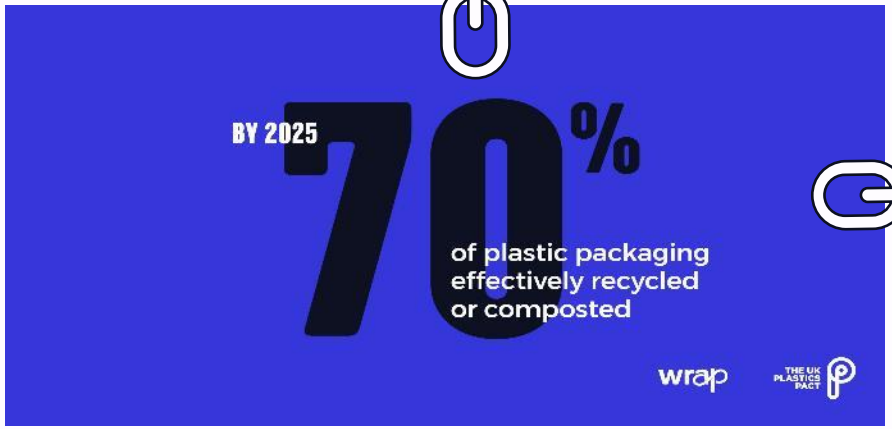
BY 2025
70%
of plastic packaging effectively recycled or composted
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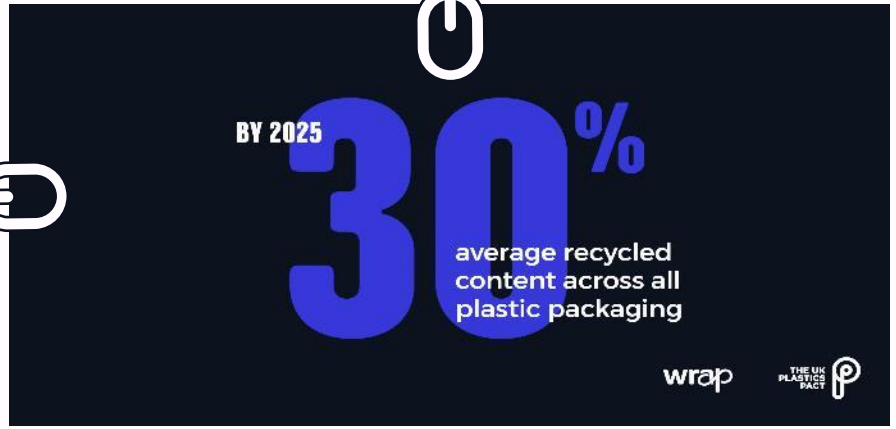
BY 2025
30%
average recycled content across all plastic packaging
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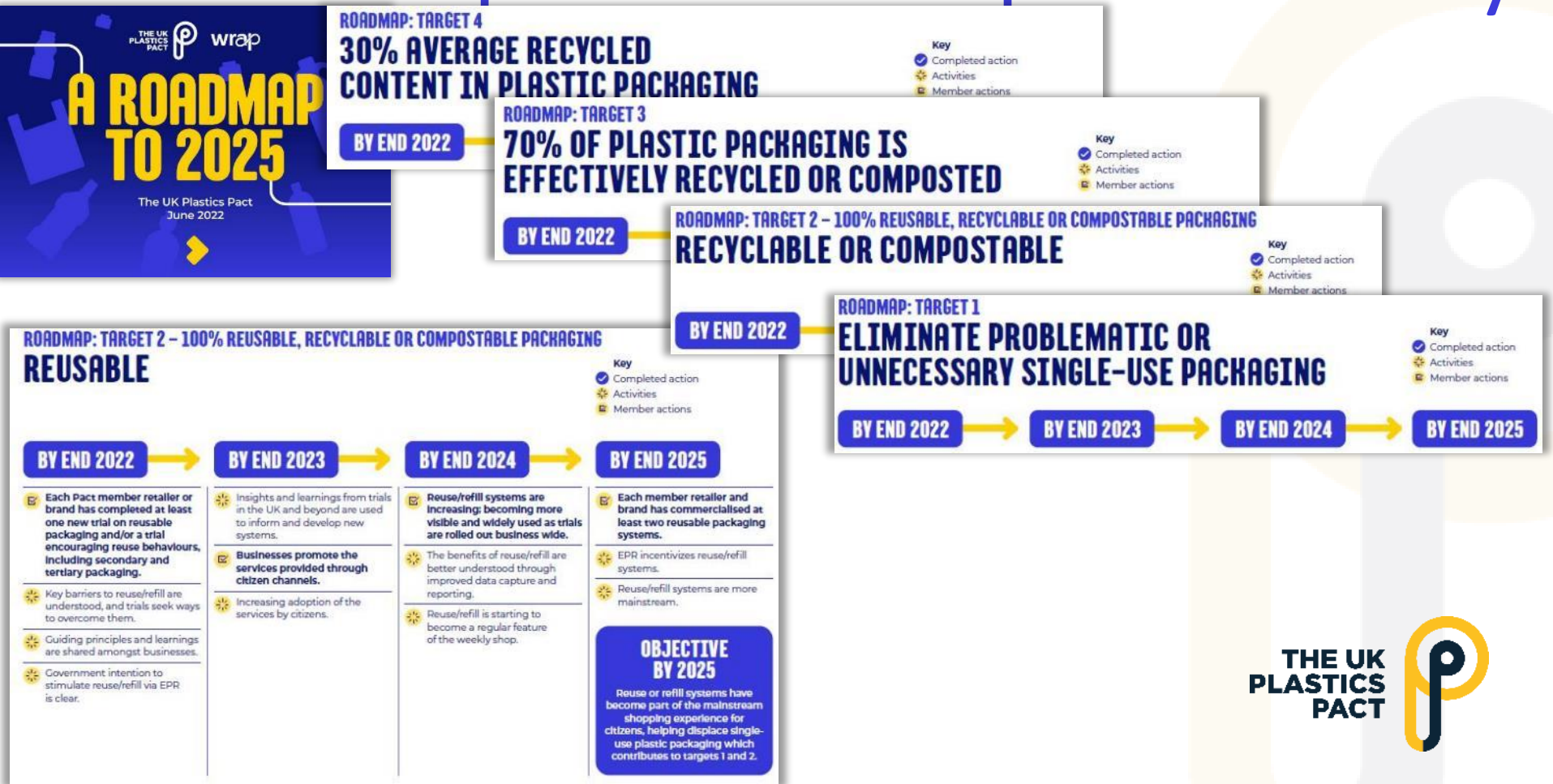
UK Plastics pact: roadmap for delivery



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UK Plastics pact: progress to date

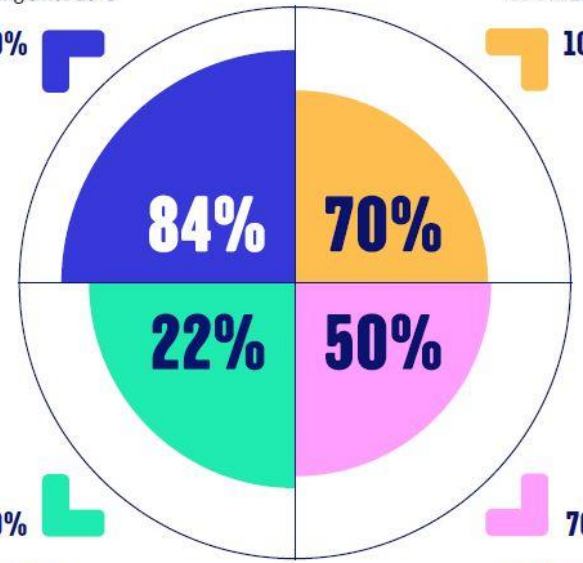
6%
reduction in plastic packaging placed on market[1]

92%
of rigid plastic packaging is recyclable, up from 81% in 2018

22%
increase in the amount of plastic packaging recycled in the UK rather than exported in 2020 vs. 2021

9%
reduction in CO_2e since 2018, equivalent to taking 119,000 cars off the road[1]

2021 DATA



TARGET 1
84% reduction in problematic and unnecessary plastic packaging since 2018[1]
100%

TARGET 2
70% of plastic packaging is recyclable - up from 66% in 2018
100%

TARGET 4
22% average recycled content, up from 8.5% in 2018
30%

TARGET 3
50% of plastic packaging is recycled - up from 44% in 2018
70%

TARGETS TO 2025

106 full business members, **35 associates** and **48 supporters** have committed to four ambitious targets. By 2025:

TARGET 1
Eliminate problematic and unnecessary single-use plastic.

TARGET 2
100% of plastics packaging to be reusable, recyclable or compostable.

TARGET 3
70% of plastics packaging effectively recycled or composted.

TARGET 4
30% average recycled content across all plastic packaging.

View the full list of members here.

[1] Based on members who reported in both 2018 and 2022 to provide a meaningful data comparison

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TARGET 1: contribution

THE ORIGINAL EIGHT

PROGRESS TO DATE

10%
reduction in consumer packaging between 2018 & 2020.

80%
The most significant reduction has been achieved in PVC packaging, which has fallen by more than 80% since 2018.

46%
reduction in problematic and unnecessary plastic items since 2018 to 398 million items (numbered 1-5 in the list). The tonnage of all items has reduced by 42%, from 22,700 tonnes to 13,100 tonnes[3].

Further information on progress including examples of member action can be found in The UK Plastics Pact Annual Report.

1. Disposable plastic cutlery
2. Disposable plastic plates and bowls
3. Plastic straws
4. Cotton buds with plastic stems
5. Plastic stirrers
6. Household polystyrene packaging
7. Oxo-degradable plastic products
8. Polyvinyl chloride (PVC) packaging

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TARGET 1: contribution

THE INVESTIGATION LIST

- Multi-layer non-recyclable plastics (e.g., pet and baby food pouches)
- Tear off tamper evident strips on containers
- Excessive headspace / oversize packaging
- Bottle tops/caps

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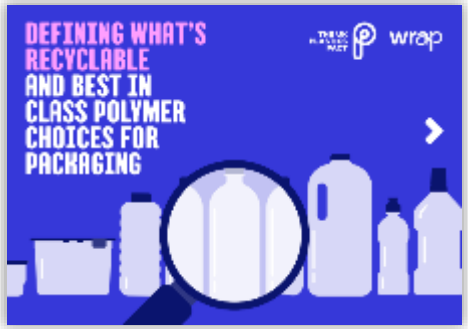
TARGET 2: contribution



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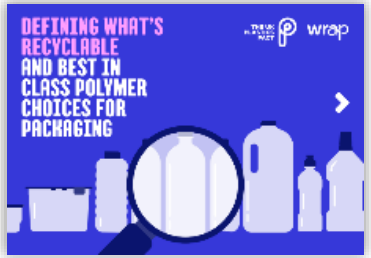
TARGET 2: Good design



CLASSIFYING WHAT'S CURRENTLY RECYCLABLE

PACKAGING PREFERRED MATERIALS AND FORMATS GUIDELINES

RED	AMBER	GREEN
Materials or formats that are disruptive to recycling in the UK and/or considered not recyclable.	To be used where functional requirements are not met by materials or formats in the green listings. Please note that not all of these items are currently widely recycled.	Preferred for recycling in the UK via kerbside collection or retailer front of store collection points.
	ls: PE flexible film, including OPP etectable colours, preferably lighter colours and ing red for PET – which affects future PET jazz uses s: nets if 100% PE c yokes for cans and bottles -layer, multi polymer films and complex laminates, ding pouches k sleeves with greater than 40% coverage. Sleeves d also weigh <5% of the pack (to adhere to recyclable ition) **and** the sleeve should be easy to remove during cycling process (to ensure that the bottle isn't directed jazz stream) er evidence items should be designed to be retained e container uld labels (e.g. for margarine tubs) should minimise verage	Materials: – Rigid PET (aPET and rPET), PP, HDPE or LDPE – all clear or natural in colour (excluding household, DIY and garden chemicals, such as bleach, turpentine and weed killer) – PE film recycled via retailer front of store collection points – cPET: move from dark to light colours in cPET trays, the use of white or natural should be avoided because this can be detected as clear and contaminate the PET stream. The use of recycled jazz cPET materials in packaging should be recognised along with their contribution to the circular economy Formats: – Mono material pouches (exc. from DIY products) – Mono lidding film[3], same material as tray when permanently attached[4]

BEST PRACTICE GUIDANCE

BOTTLES (NON-FOOD OR DRINK)

Recycled content ambition	2022	2025
PET	20%	40%
HDPE	20%	40-45%
PP	10%	20%

Further details on coatings and components etc. can be found here.

	Best in class material choice	Best in class colour choice	Why?
Bottle	rPET/rHDPE/rPP	Clear (uncoloured) PET (light blue tinted is also acceptable) HDPE not natural or white – any NIR detectable colour PP any NIR detectable colour	Using clear PET provides the greatest opportunity to be recycled into packaging, as well as other products For HDPE – food and non-food contact packaging is primarily sorted on the basis of colour, and this is important to meet legislative requirements. Keeping food packaging in natural and non-food packaging in (NIR detectable) colours aids this in HDPE. White HDPE can be detected as natural. There is potential here to use colours containing carbon black for bottles containing household, DIY and garden chemicals, such as bleach, turpentine and weed killer
Cap/pump/ trigger	HDPE or PP	Minimise colours in caps	Minimal use of colours in the caps creates more options for reuse when recycled
Label/sleeve	HDPE or PP label covering less than 40% of the bottle (if a full-body sleeve is necessary the sleeve material should be the same polymer as the bottle)	n/a	Labels commonly do not get recycled therefore the smaller the label, the better. Ideally less than 40% in order to ensure the bottle material is correctly identified. Sleeves should also weigh <5% of the pack (to adhere to recyclable definition) and the sleeve should be easy to remove during the recycling process (to ensure that the bottle isn't directed to the jazz stream)

On-pack messaging to include:
- Rinse
- Flatten
- Cap on
- www.recyclenow.com

Latest OPRL Labelling Rules available at: www.oprl.org.uk

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TARGET 3: contribution

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Target 4: The route to target 4

Target 4: progress to date

- Progressing well to 2025's target
- We need to continue driving increased inclusion
- We can't be become complacent
- Significant challenges must be overcome to maintain progress including:
  - Films & flexibles
  - Food contact PP&PE
  - PET tray to tray recycling
  - Jazz inclusion
  - Caps and closures

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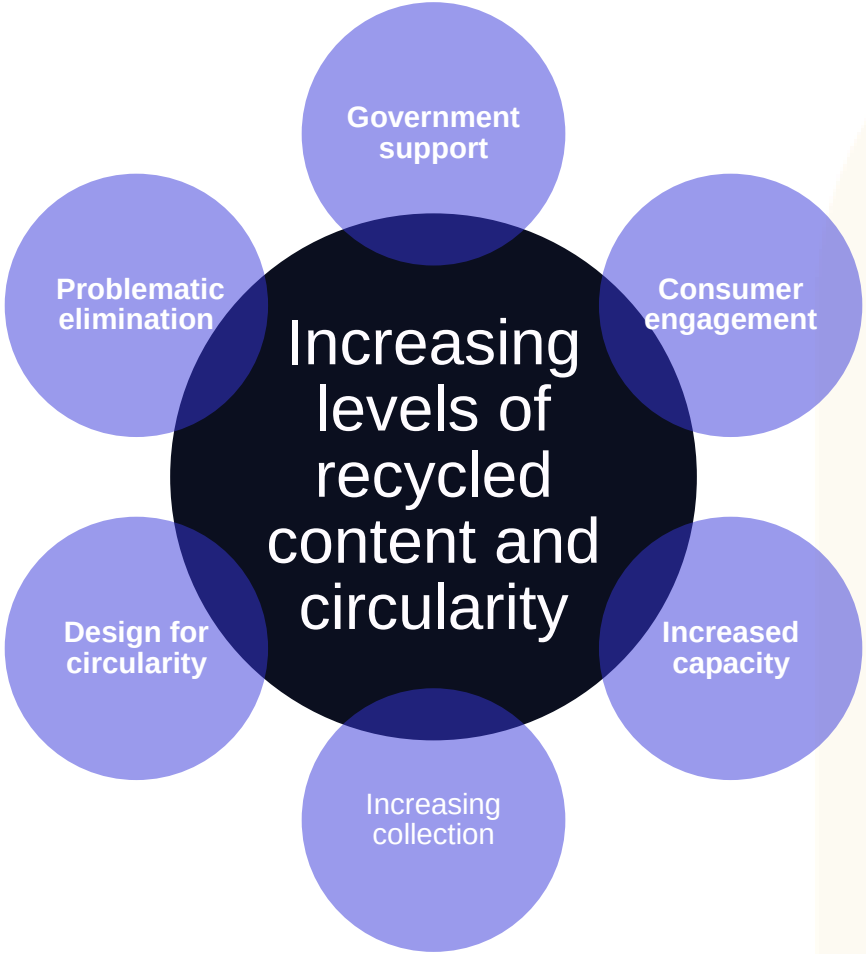
End result



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Setting the scene

Defining recycled content

Recyclable definition

The UK Plastics Pact is aligned to the Ellen MacArthur Foundations' definition set out in the New Plastics Economy Global Commitment: A packaging or packaging component is recyclable if its successful post-consumer collection, sorting, and recycling is proven to work in practice and at scale.

A package can be considered recyclable if its main packaging components, together representing >95% of the entire packaging weight, are recyclable according to the above definition, and if the remaining minor components are compatible with the recycling process and do not hinder the recyclability of the main components. 'At scale' is considered a 30% recycling rate.

Recycled content definition

To define recycled content first you need to understand what is not classed as recycled content. In the context of the UK Plastics Pact virgin materials and process scrap[1] do not count towards recycled content

Virgin material

Is material generated from sources that can be fossil or bio based.

Process scrap

Process scrap is defined as material resulting from production, engineering, maintenance, and R&D activities that is not be generated by end users of the product, examples would be:

1) Skeletal waste
2) Process scrap
3) Product produced during R&D & maintenance activities that cannot fulfil a packaging role
4) Out of specification that cannot fulfil a packaging role
5) Unfilled customer returns

process scrap cannot contribute to the recycled content percentage, unless it's input material included recycled content[1].

[1]If the input material that generated the process scrap itself had a percentage of recycled content, this can be included as recycled content. For example a thermoformed tub is first made with 40% recycled content and 60% virgin with a scrap rate of 10%. The next run has 40% recycled content 50% virgin and 10% scrap, the recycled content the level would be 40% plus the amount of recycled content in the scrap in this case 40% of 10% so 4% giving a total recycled content level of 44%.

Recycled content definition

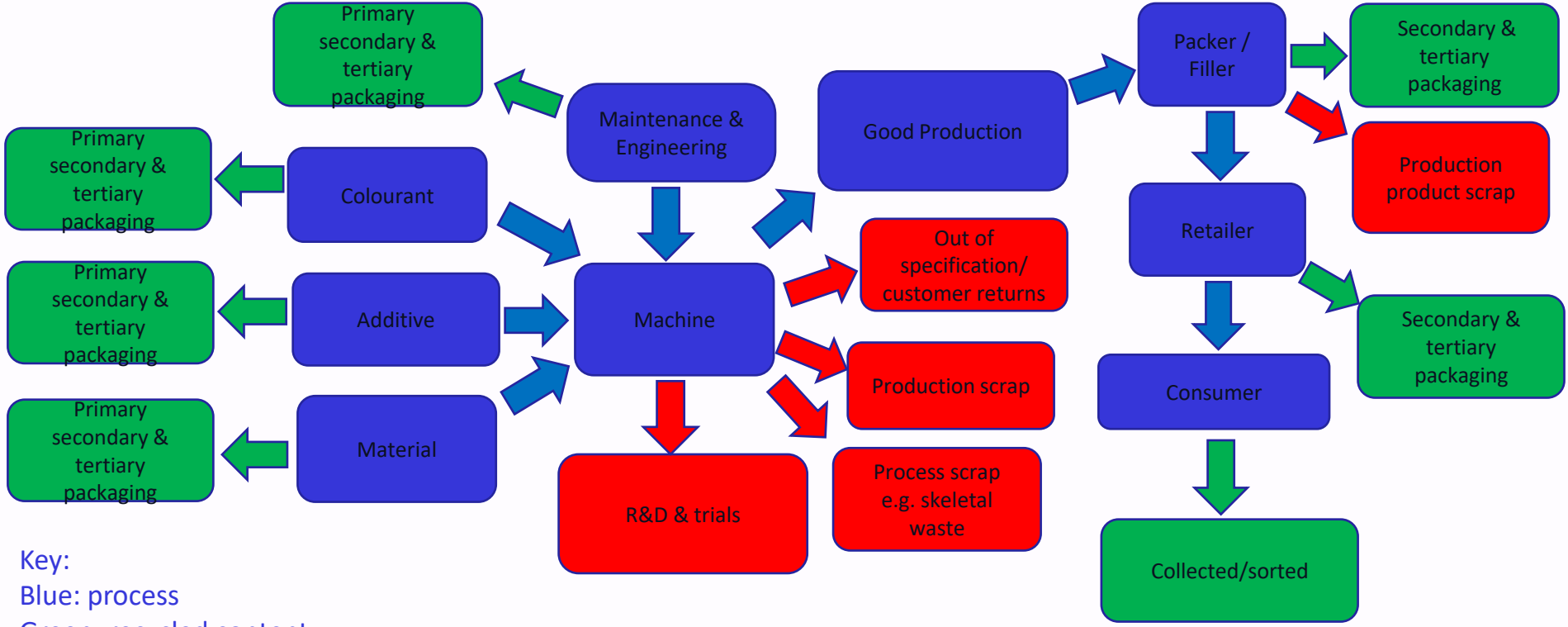
Recycled content

In the context of the UK Plastics Pact we align with ISO 14021's usage of the term that clarifies post-consumer material as material generated by households or by commercial, industrial, and institutional facilities in their role as end users of the product which can no longer be used for its intended purpose. This includes returns of material from the distribution chain.

This material can be generated by:

- **Mechanical** – a physical process of recycling, the material is generally granulated/shredded, cleaned and either supplied as flake or extruded into pellets.
- **Non mechanical** – can be segregated in 2 main areas:
    - Feed stock generation – the structure of the material is broken down to provide building blocks for new materials in processes such as depolymerisation, pyrolysis, gasification.
    - Cleaning - the chemical structure is maintained but impurities are removed with processes such as solvation.

Overview of recycled content generation

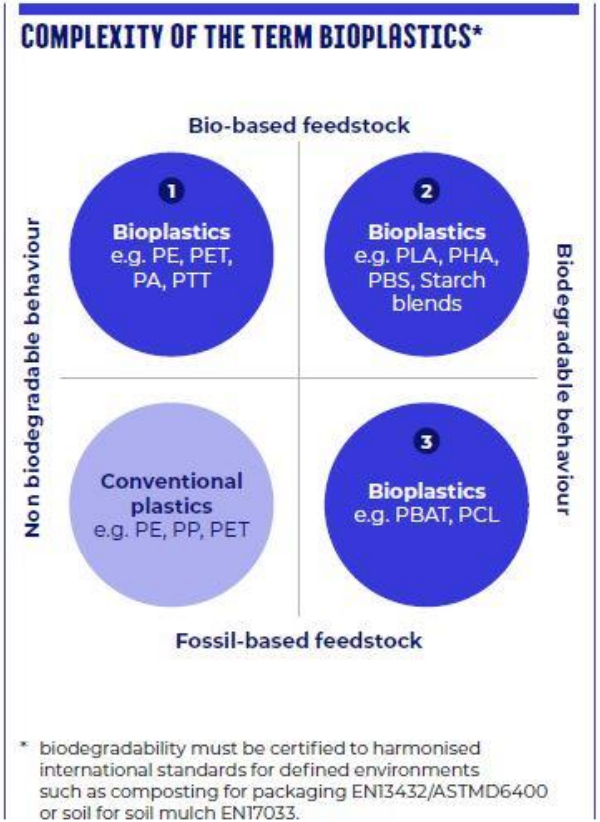


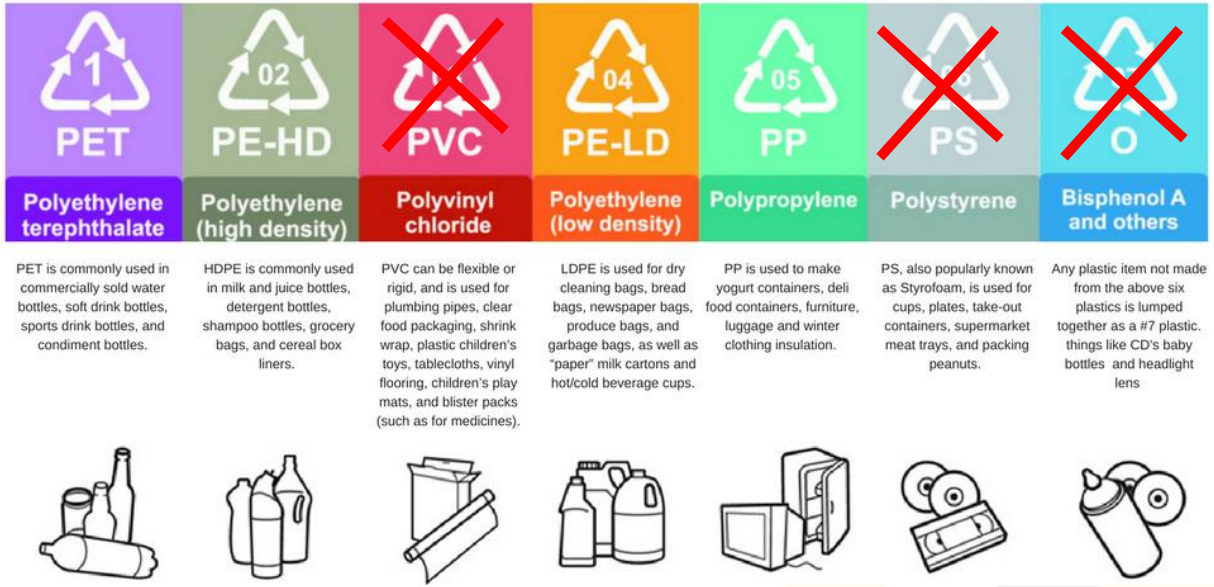
Key:
Blue: process
Green: recycled content
Red: process scrap not classed as recycled content

Setting the scene

How packaging is made

Polymer types and packaging





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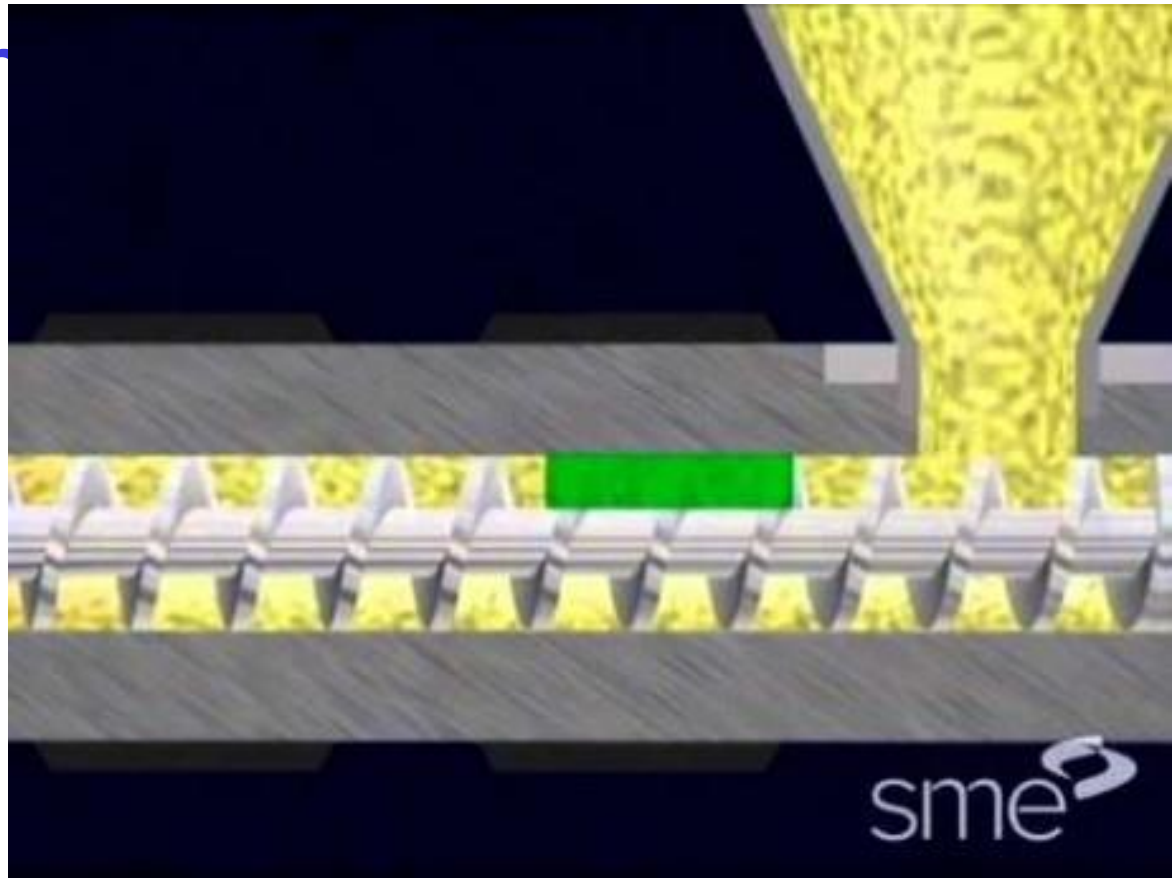
Polymer types and packaging mar



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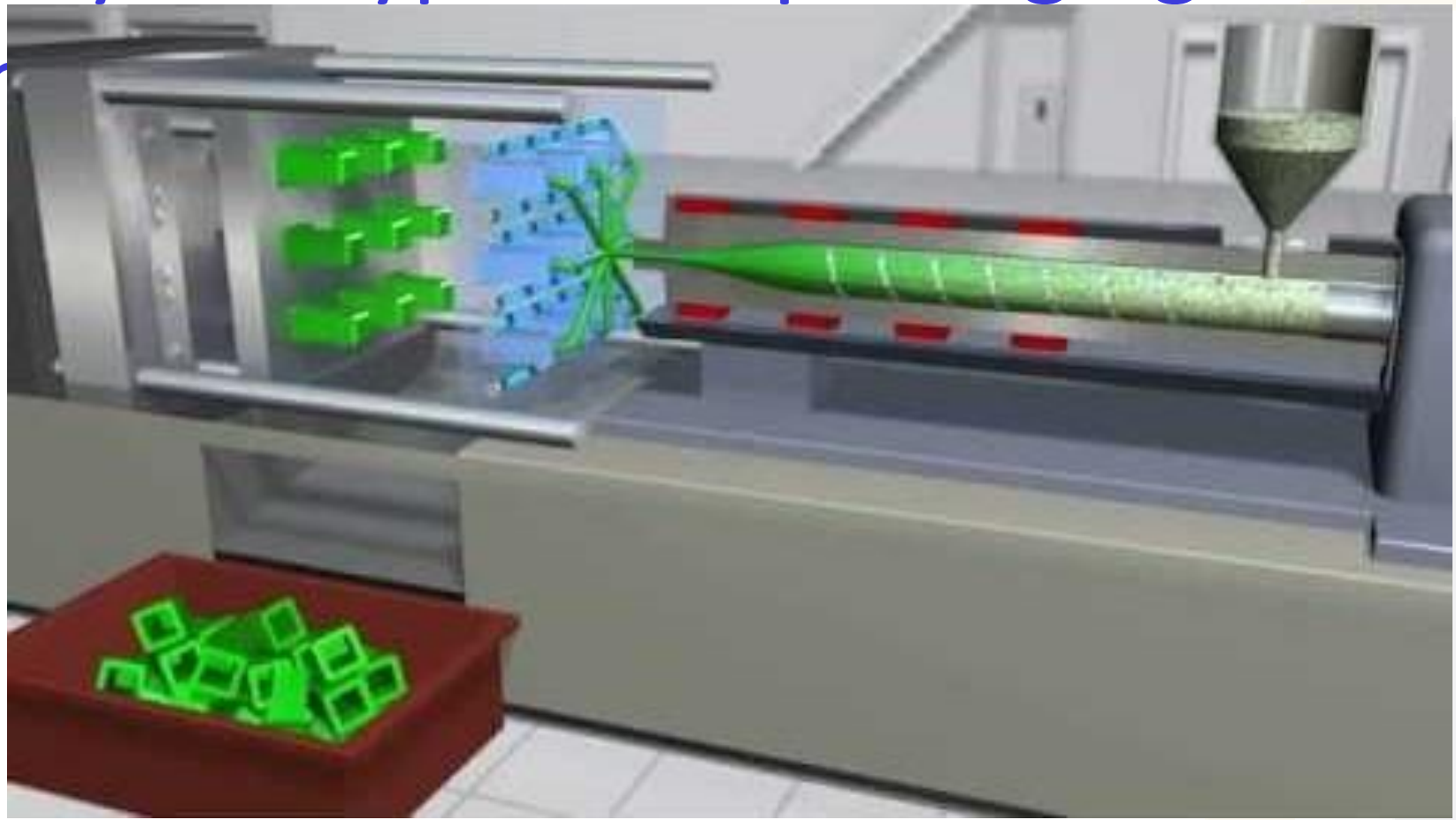
Polymer types and packaging m



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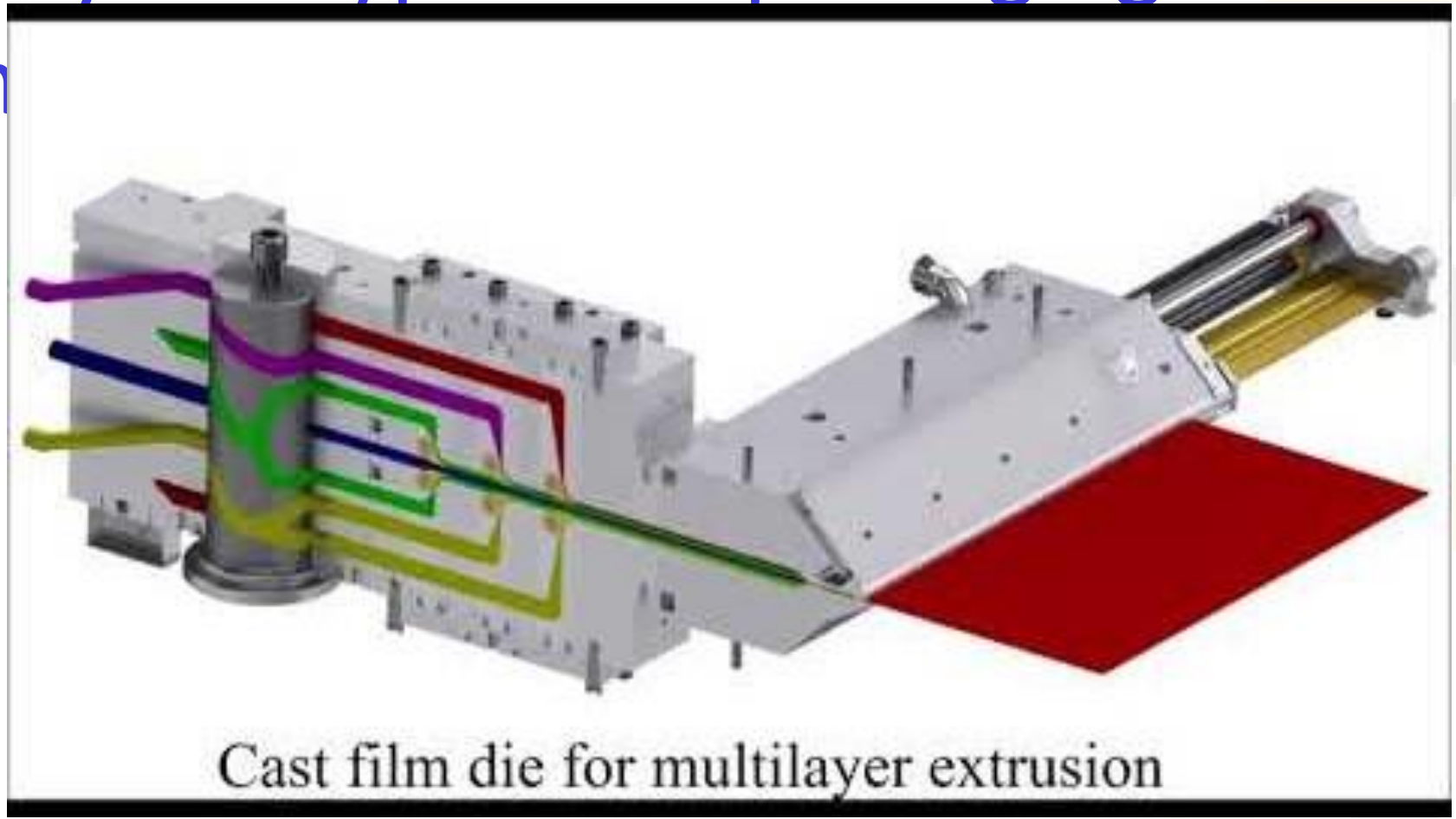
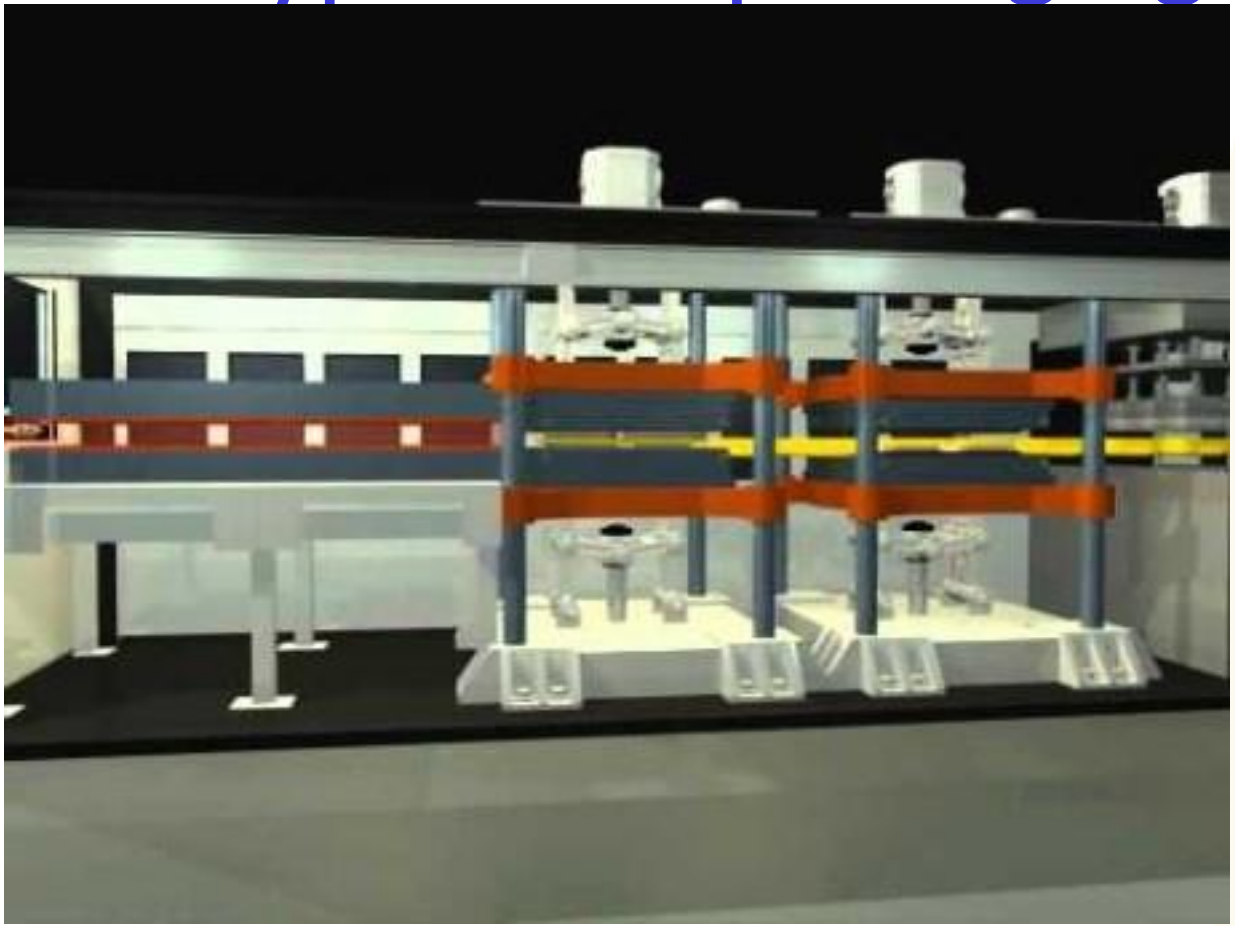


Cast film die for multilayer extrusion

Polymer types and packaging man



Setting the scene

How packaging is recycled

The Waste hierarchy

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How packaging is recycled

Depending on the local authority collecting the recyclable materials, bins of either mixed or separated waste are collected by the local authority waste collection team.

This material is taken to a local MRF (Material Recovery Facility) to be sorted. Materials are separated automatically using NIR (Near-Infrared Radiation) and checked for contamination manually.

Recyclable plastics are separated automatically and baled together (as seen below).

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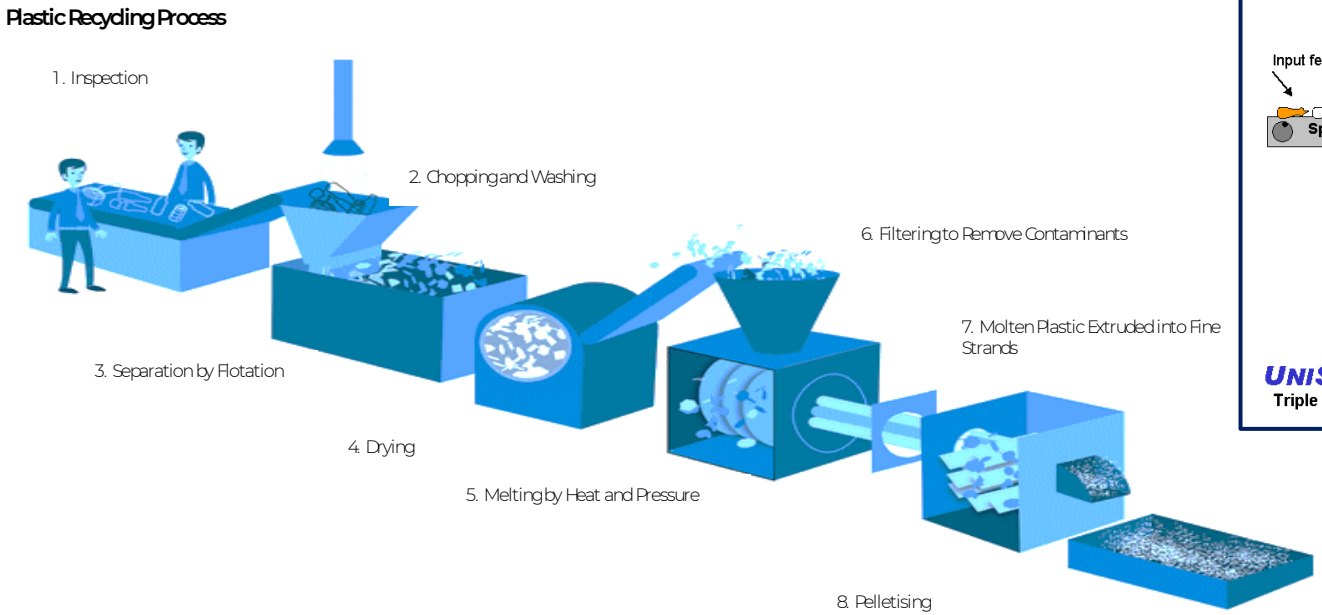
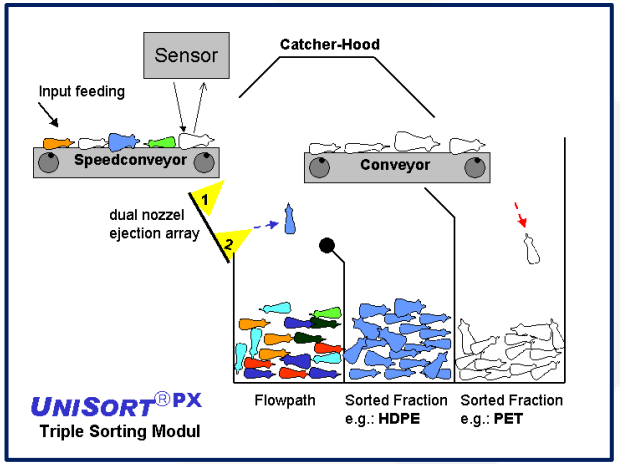
How packaging is recycled

How packaging is recycled





Recyclable

Recyclable at specialist points

The most widely recycled plastics in the UK are rigid PET, HDPE and PP.

Other plastics such as PVC and PS are only recyclable at specialist facilities for non-consumer packaging or process scrap. LDPE, HDPE, and PP post-consumer films and flexibles are only currently collected by a small number of local authorities, supermarket front of store collection points or specialist schemes.

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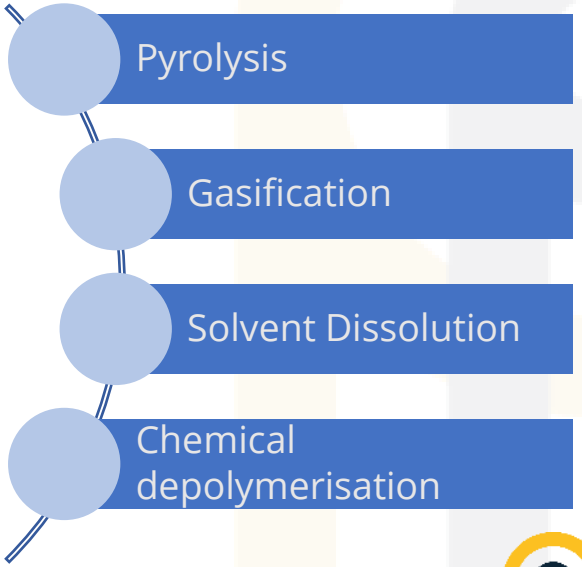
How packaging is recycled

How packaging is recycled

Non-mechanical (Chemical) recycling process

- Mechanical recycling is the standard recycling method widely used today.
- Mechanical recycling has a number of limitations, however the primary one is the inherent inability to produce a virgin comparable product.
- Non-mechanical recycling, sometimes termed Chemical Recycling or Feedstock Recycling, may be able to overcome this issue.
- Non-mechanical recycling can be broadly grouped into 4 categories.
- Each one uses a different process and is suitable or has been developed for different polymers.
- The different process can also have different outputs.



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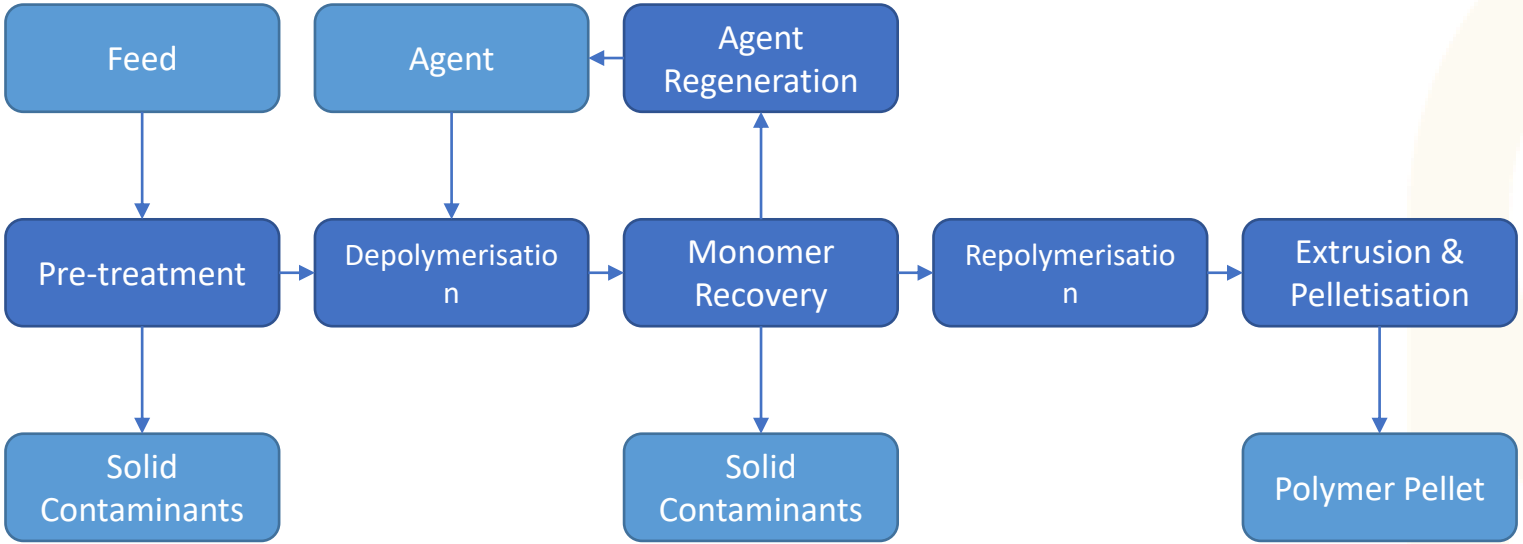
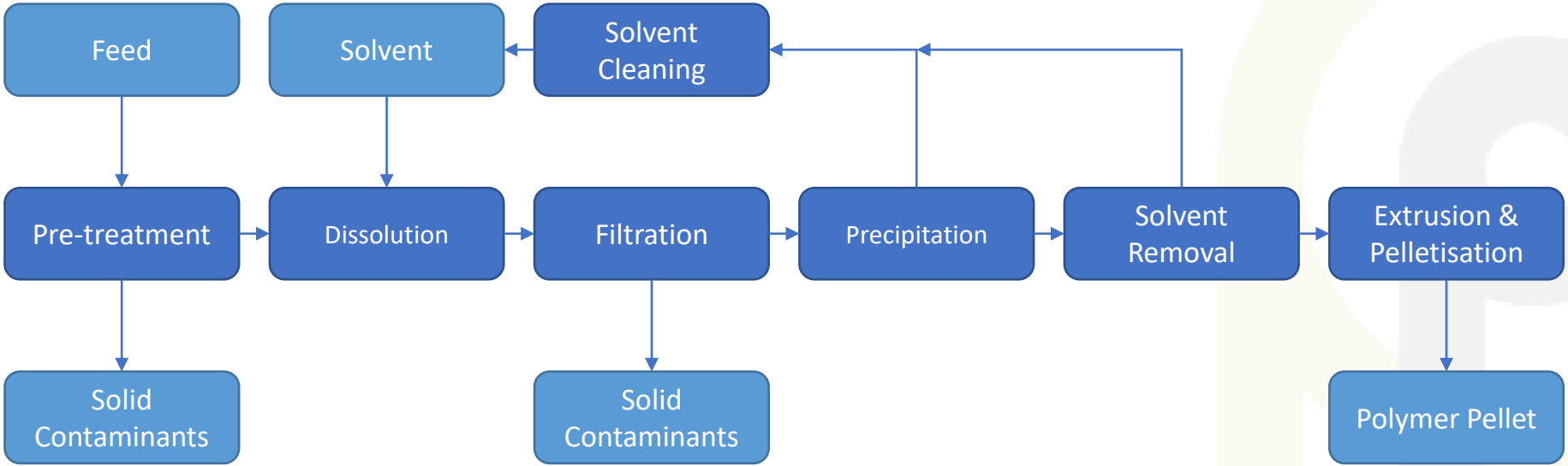
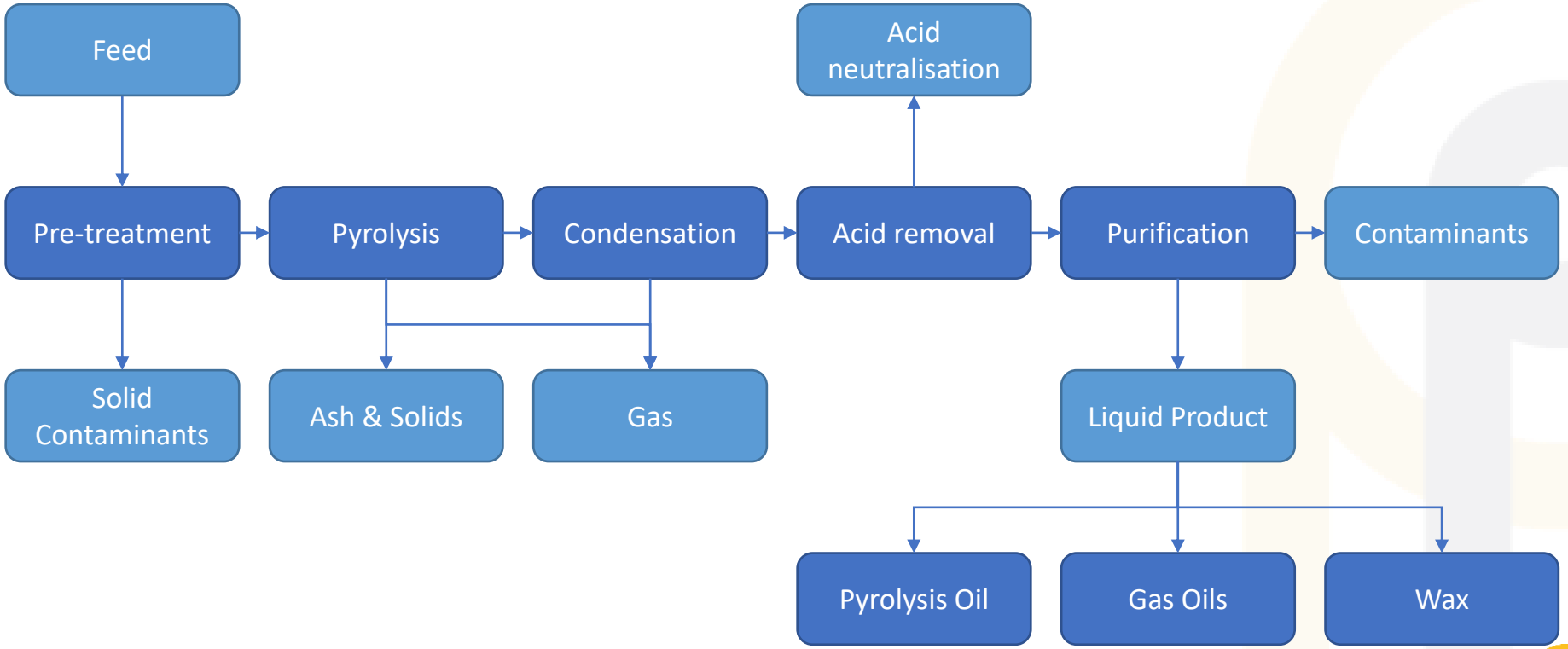
How packaging is recycled - Depolymerisatio



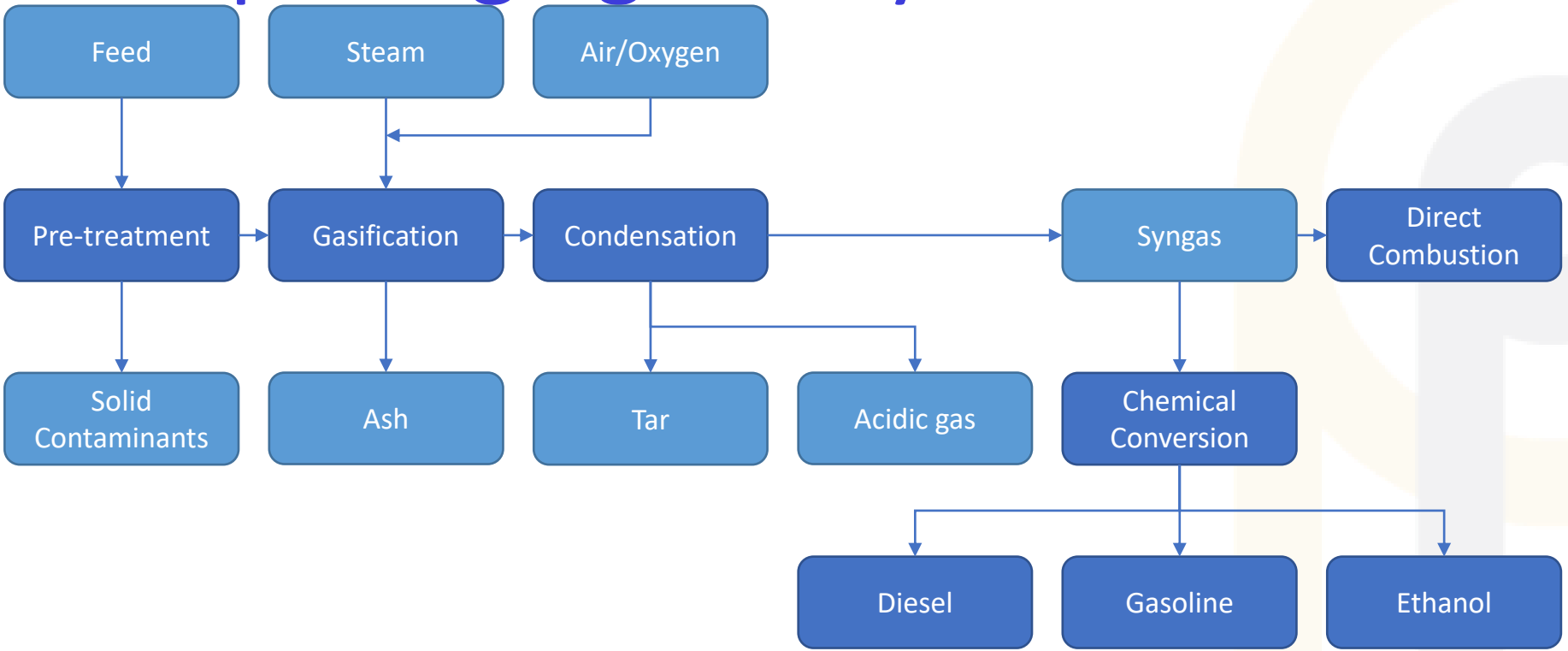
How packaging is recycled - solvation



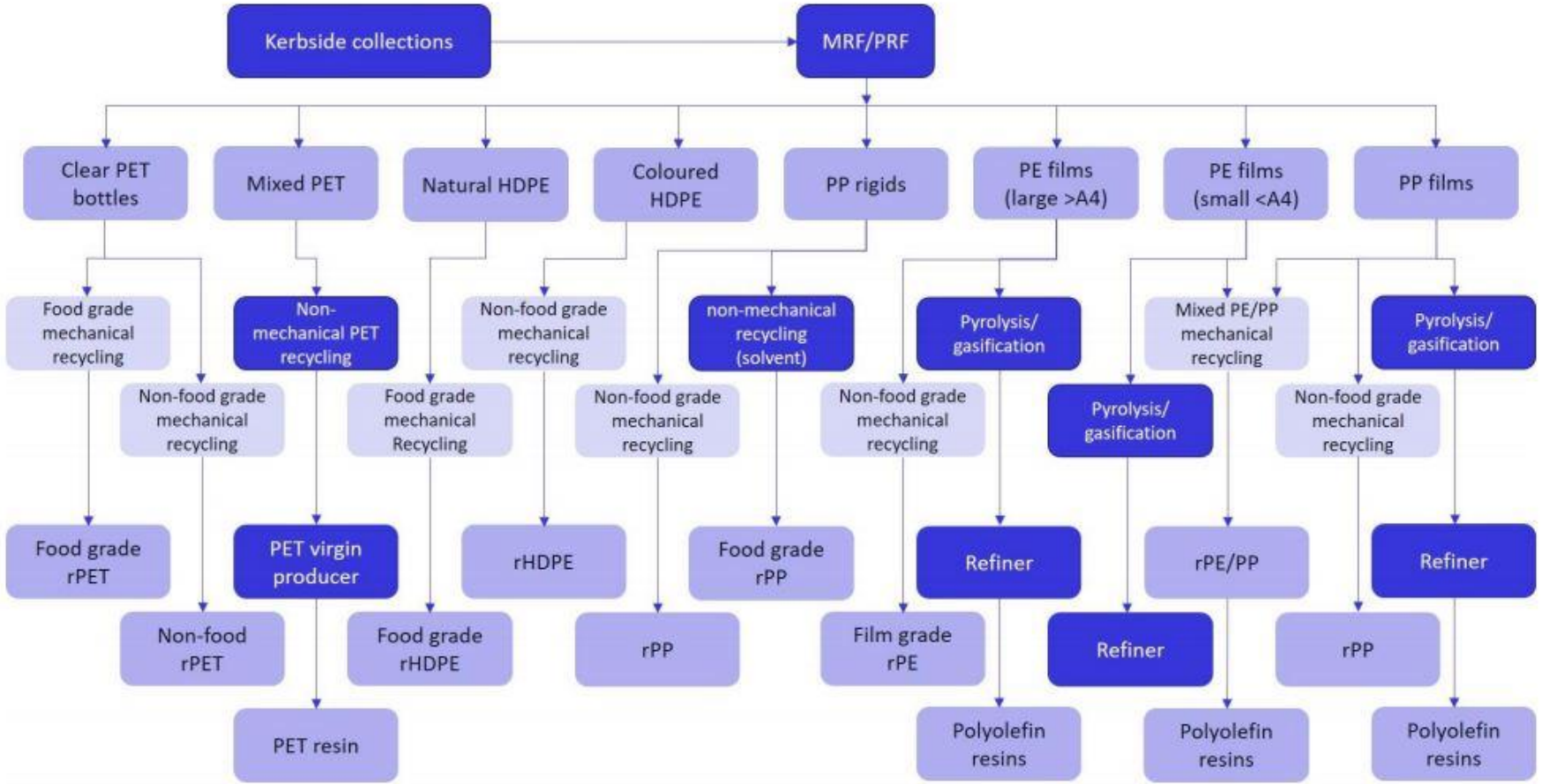
How packaging is recycled - pyrolysis



How packaging is recycled - Gasification



How packaging is recycled - flows



Setting the scene

Legislation

Waste & resources strategy

Designed to:

- Preserve resources
- Minimise waste
- Promote resources efficiency
- Minimise environmental damage
- Drive the circular economy

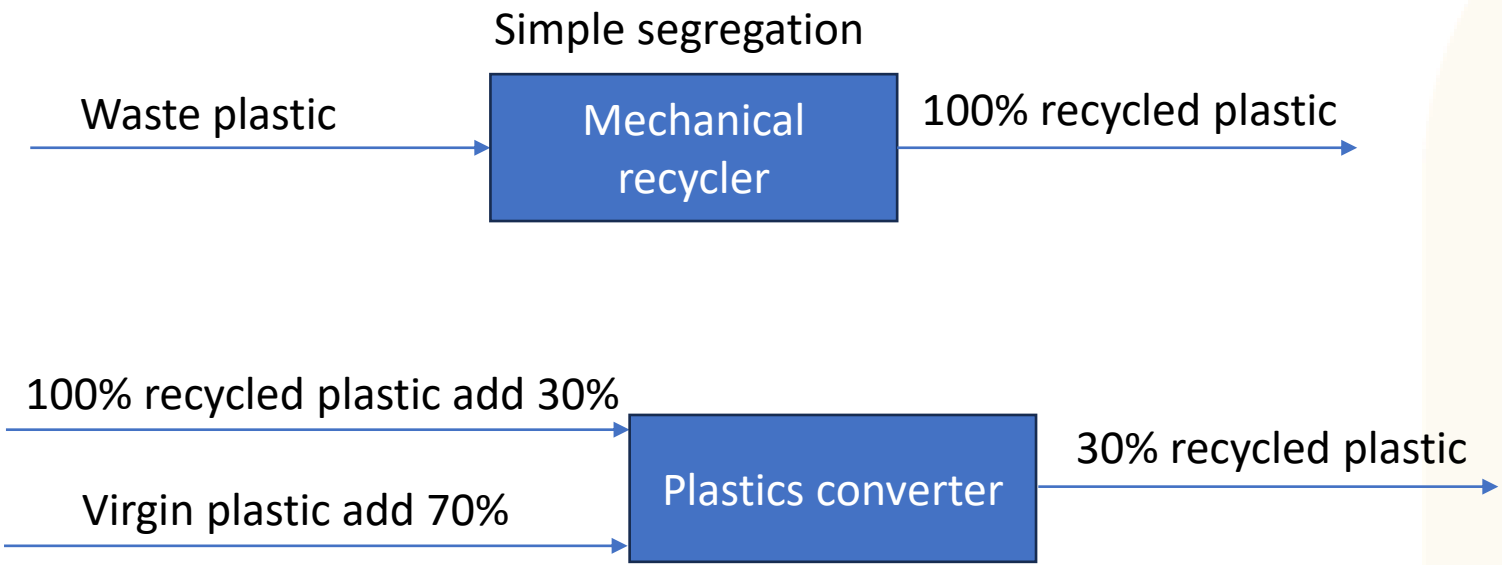
Key elements:

- Single use restrictions plastic straw, stirrer and cotton bud ban
- Deposit return scheme
- End user producer responsibility
- Consistent collections
- Plastics tax

Setting the scene

Tracking recycled materials

Mechanical recycling



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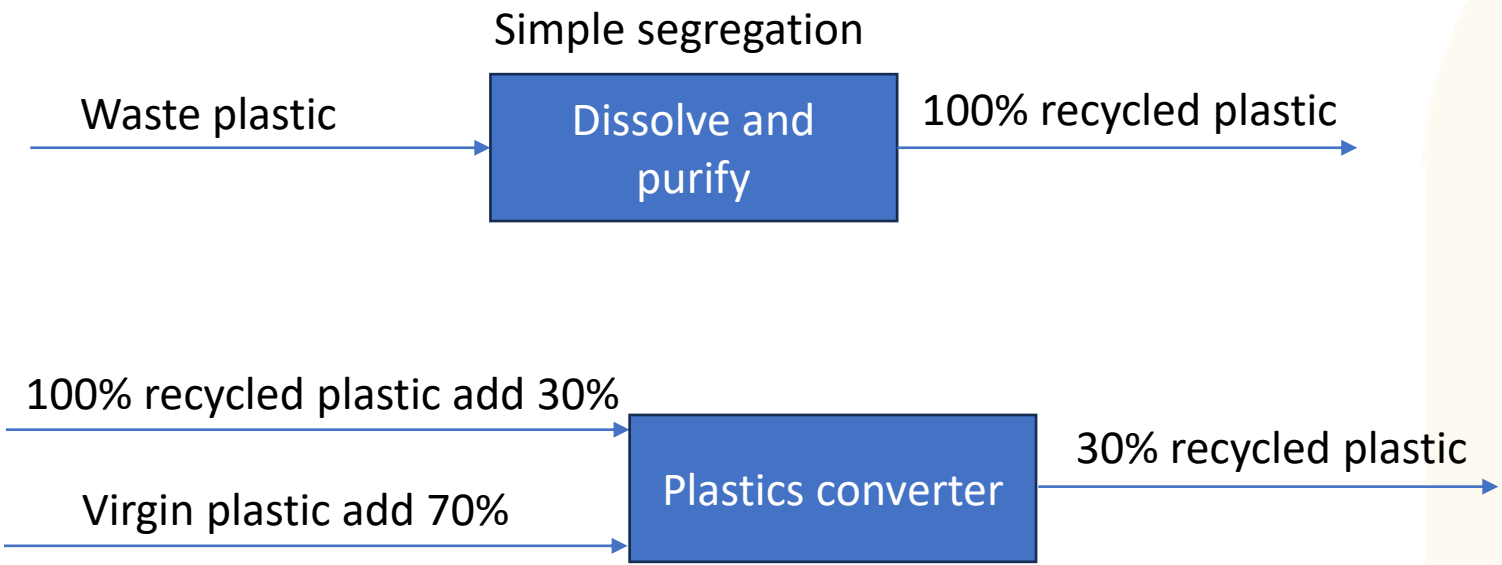
Non - Mechanical recycling Solvation



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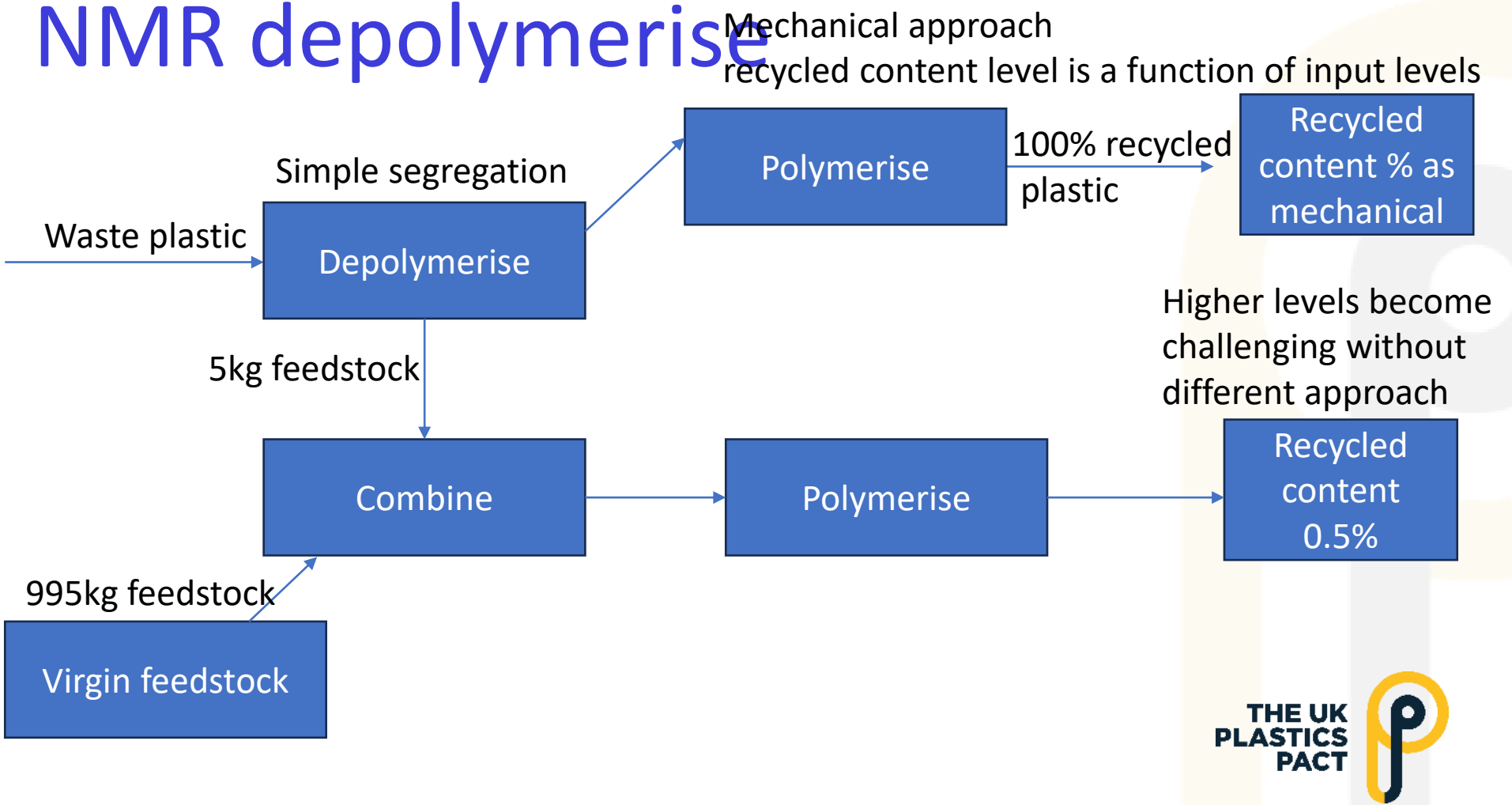
NMR depolymerise



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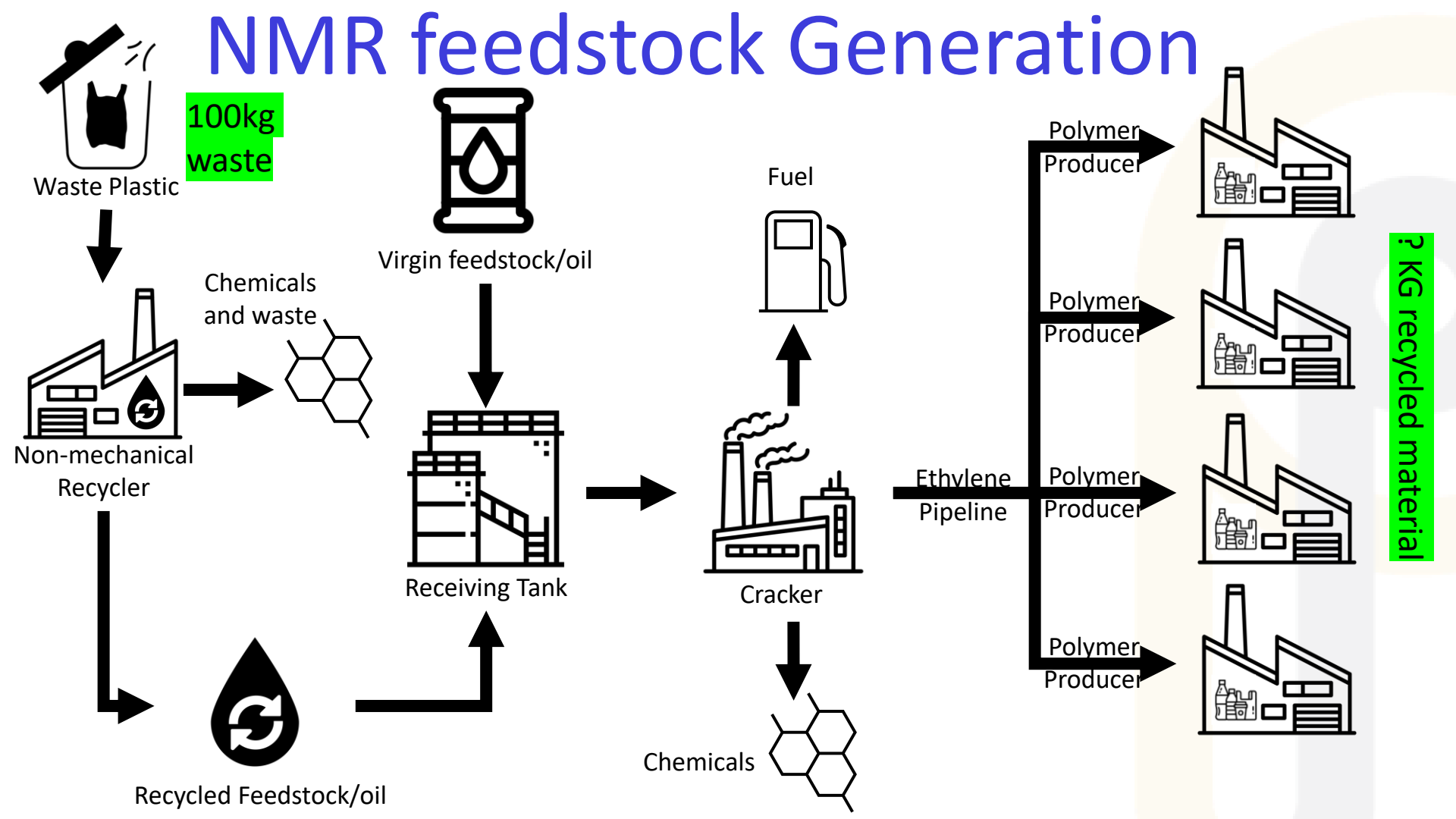
NMR feedstock Generation



Chain of custody models

Sourced from: Four chain of custody models explained (circularise.com)
Network Projects - White Papers & Articles (ellenmacarthurfoundation.org

Chain of custody overview

Chain of custody is simply the process of following materials through every step of the supply chain including:

- Sourcing
- Production
- Processing
- Shipping
- Retail

Chain of custody is achieved through:

- Procedures,
- Technologies
- Documents.

to track products from source to sale, this provides insights into the products

- Origin
- Components
- Processes
- Handlers

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Why have a Chain of custody?

Consumers demand a greater ESG focus on their impacts including:

- Ethical impacts
- Environmental considerations
- Sustainability benefits
- Regulatory compliance

Companies need evidence for sustainability claims and are used to collect evidence on:

- Material sources
- Processes used
- Suppliers used

The chain of custody can also support product recalls

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Chain of custody Models?

There are four main chain of custody models split between those that

- Track specific batches through a process
- Those that balance the input and output of a process

These can be grouped into 2 main areas:

- **Identity preservation** and **segregation** models should be employed particularly when sourcing materials that could potentially come from conflict zones or places where human rights abuse is common.
- **Mass balance** and **book and claim** models can be almost entirely decoupled from real processes in physical material flows, making them a great solution for chemical production and green energy

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Identity preservation

Identify preservation tracks the individual molecules through the supply chain from producer to consumer.

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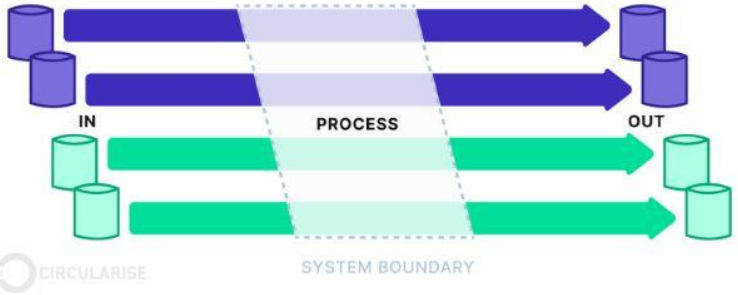
Identity preservation



Advantages of identity preservation:

- Less need for additional testing
- Transparent and inspires the most trust
- Ensures the most uniqueness and value is captured and maintained
- Able to extract a premium due to its added value
- Brands are able to tell customers the stories of the items involved in the production

Disadvantages of identity preservation:

- Most logistical effort as it requires strict physical separation from other sources
- Complex system of standards, records and auditing throughout the entire process
- Most expensive
- More limiting due to stringent requirements and handling processes

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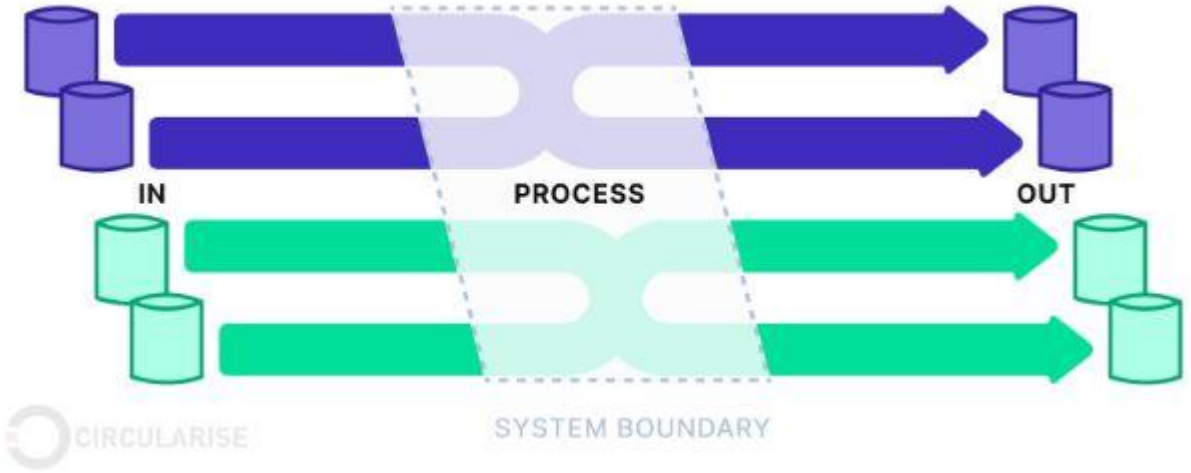
Segregation



Segregation keeps certified and uncertified sources separate it is similar to identity preservation but allows certified sources to mix.

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Segregation

Advantages of segregation:

- Transparent and inspires more trust
- Ensures uniqueness and value are captured and maintained
- Able to extract premium due to its added value
- Less need for additional testing

Disadvantages of segregation:

- More logistical effort as it requires strict physical separation from other sources
- Complex system of standards, records and auditing throughout the entire process
- Limiting due to stringent requirements and handling processes
- More expensive

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Mass Balance

Mass balance is design to track the amount of sustainable content through a production system but does not guarantee the output is generated from the input.

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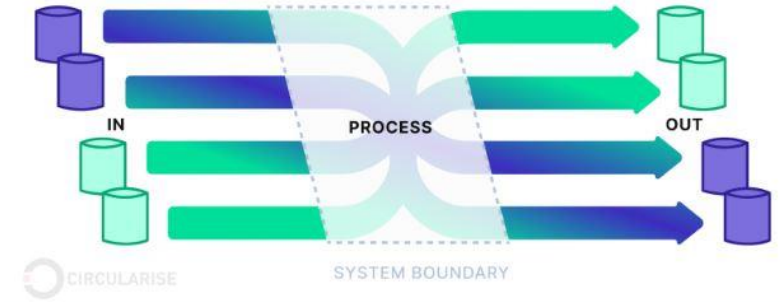
Mass balance



Advantages of mass balance:

- Low-cost barrier to entry
- Fast and easy to get started
- Can support large-scale production
- Flexibility in sourcing for materials
- Helps companies gradually transition to sustainability

Disadvantages of mass balance:

- No physical traceability involved
- System can more easily be abused to make false claims
- Complex system of certification, records, reconciliation and auditing required
- Sensitive information could be at risk in certain industries
- Time-consuming to maintain as it scales
- Easy to make costly mistakes

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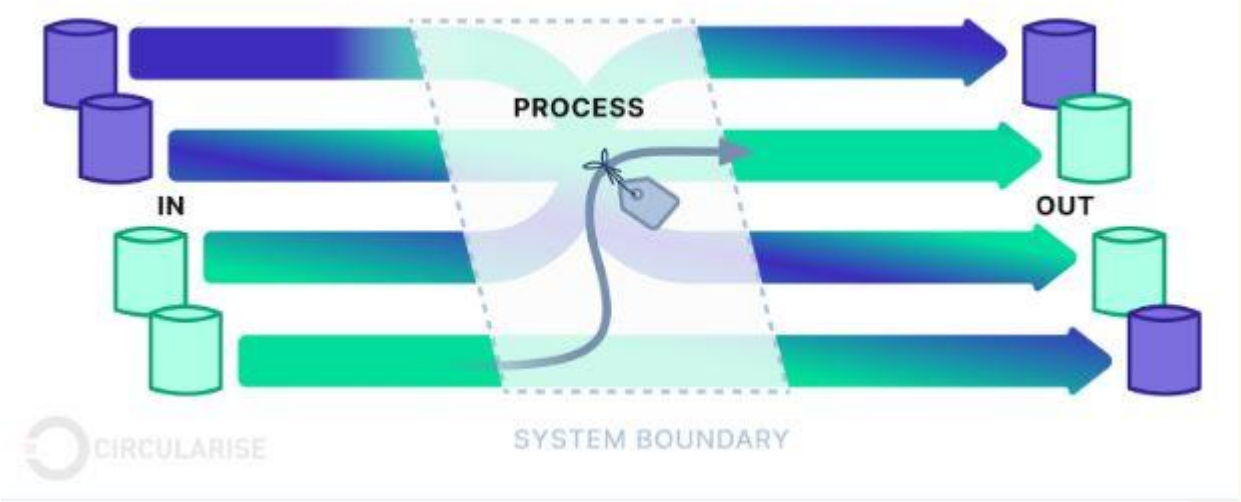
Book and Claim



Certified and non-certified materials flow freely thought the supply chain with no traceability or physical connection, sustainable credits are traded on a separate marketplace.

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Book and Claim

Advantages of book and claim:

- Lowest cost barrier to entry
- Easiest to get started
- Can support large corporations and productions
- Useful for when local demand exceeds local supply
- No transportation costs involved

Disadvantages of book and claim:

- Not a truly sustainable solution
- Sustainability claims can be made without sustainable practices
- System is easiest to abuse for greenwashing
- Least credibility and accountability

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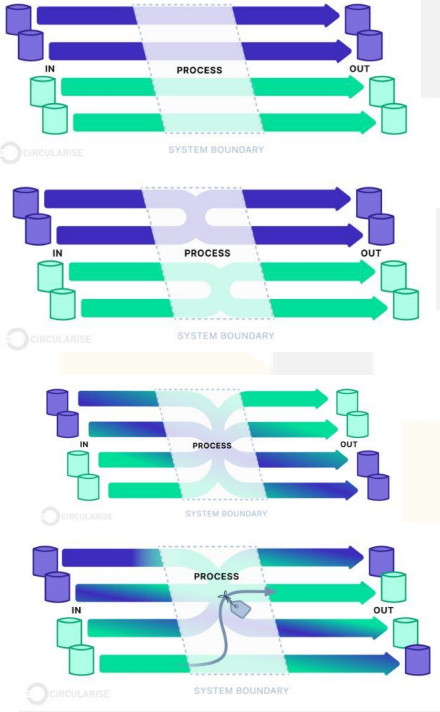
Chain of custody summary

	Identity Preservation	Segregation	Mass Balance	Book & Claim
Ensures the output of certified materials does not exceed the input	Yes	Yes	Yes	Yes
Possible to verify fair and ethical practices	Yes	Yes	Depends	No
Physical traceability is possible	Yes	Yes	Depends	No
Origins of final product or product component can be identified	Yes in specific detail	Yes less detail	Depends	No can be linked to location or region
Mixing of certified and non-certified materials	No	No	Yes	Yes
Reconciliation over a specific time period required	No	No	Yes	Yes
Administrative and logistical cost and effort	Highest	High	Medium	Lowest
Credibility	Highest	High	Medium	Low

Chain of custody examples - coffee

Claim made	Chain of custody example
Individual fairtrade organic farmer	**Identity preservation** ensures the beans you receive are the ones grown by that farmer and have been individually processed
Organic beans	**Segregation** ensures the beans you've bought are all organic and have been processed separately
Country/bean specific	**Segregation** ensures the beans supplied are of the type/region quoted
Fairtrade	**Mass balance is ideal** consumers are paying for the fair wages not the exact beans, so providing the proportion can be shown as fairtrade
Carbon offset of production	**Book and claim** would allow the offsetting of GHG emissions but has no impact on the product supplied.

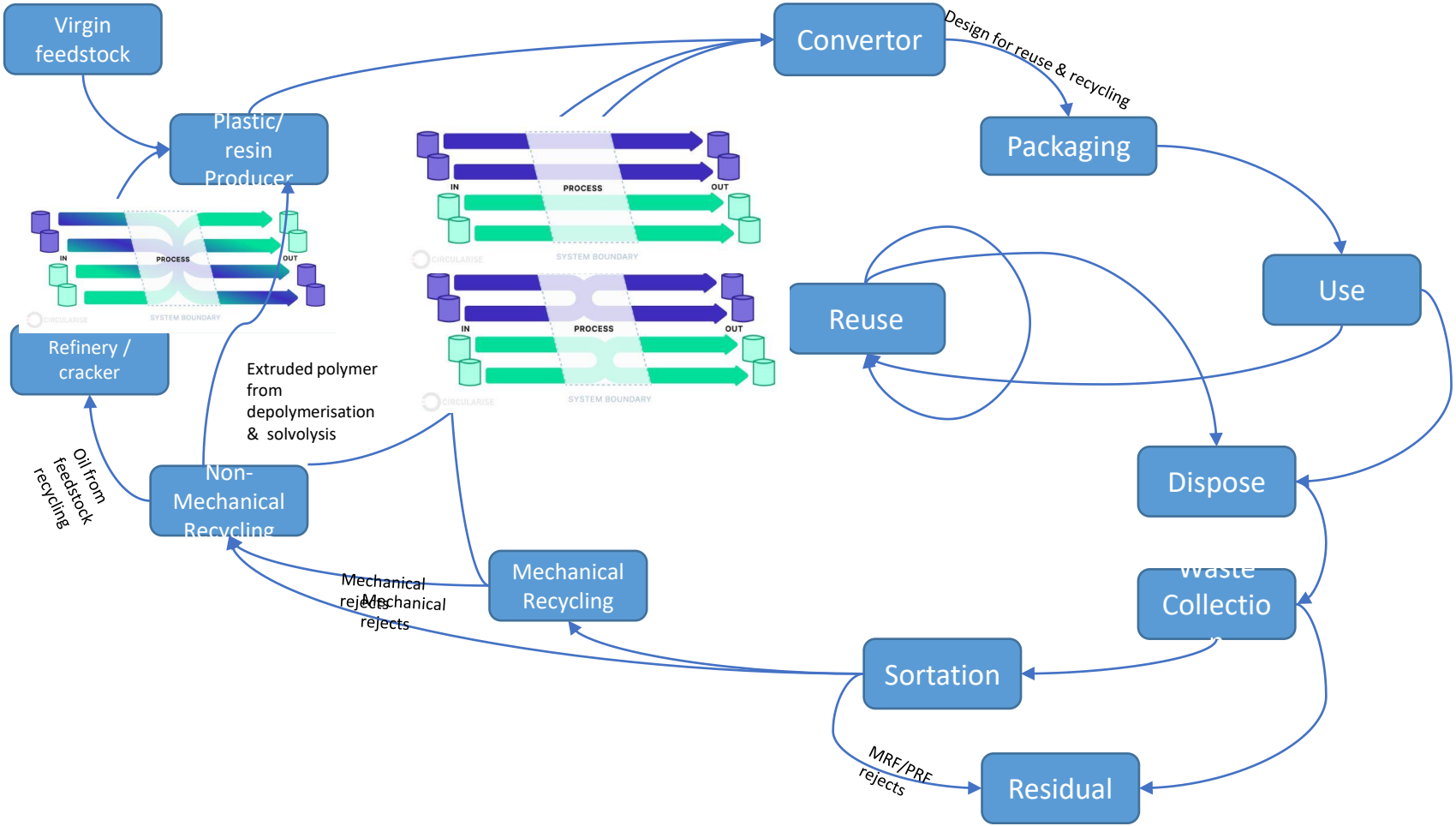


Chain of custody examples

Product	Label Certification Organization System	Traceability Model Allowed[a]				Year of Introduction
		Identity Preserved	Segregation	Mass Balance	Book and Claim	
Palm oil	RSPO	X	x	x	X	2004
Soy	RTRS		x	X	X	2006
	ProTerra	x	X	X	X	2012
Sugar	Fair Trade	x	X	x		1997
	Bonsucro		x	X	X	2006
Cotton	Fair Trade	x	X			1997
	Better Cotton Initiative	x	X	X		2005
Marine Fish	MSC		X			1997
	This Fish	X	X			2010
Aquaculture Fish	ASC		X			2011
Timber	FSC	x	X	x		1993
	PEFC	x	x	X		1999
Biofuels EU Market	15 Different Schemes	x	x	X		2009
(non) GMO Crops	EU		X			1997/2004

Product	Label Certification Organization System	Traceability Model Allowed[a]				Year of Introduction
		Identity Preserved	Segregation	Mass Balance	Book and Claim	
Biofuels	RSB	x	x	X		2007
Agricultural Products	IFOAM	x	X			1972
	Rainforest Alliance	x	X	X		1987
	Organic Label US and EU		X			1990/1991
Tea	Fair Trade	x	X	x		1997
	UTZ	X	X			2002
	Ethical Tea Partnership		X			2009
Cocoa	Fair Trade	x	X	x		1997
	UTZ	x	X	X		2002
Coffee	Fair Trade	x	X			1997 (1988)
	UTZ	x	X			2002
	4C Association	x	X	x		2006
Meat	GRSB	X	X			2016

Recycling model/Where it fits in



Mass balance approaches

Sourced from: Four chain of custody models explained (circularise.com)
Network Projects - White Papers & Articles (ellenmacarthurfoundation.org
Plastic packaging tax - chemical recycling and adoption of a mass balance approach - GOV.UK (www.gov.uk)

Mass balance models

The mass balance approach is a chain of custody model used to track materials through the supply chain.

The mass balance approach has 4 key components:
Level of mass balance
Allocations method
Balancing period
Units of measurement

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Level of Mass balance

The level of mass balance is the system boundary or geographical area a mass balance approach calculation can be applied to. This can be at:

- batch level
- site level
- group level (also known as company level)

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Allocation methods vs recycling metho

Non mechanical recycling falls into 3 primary areas:

- Preservation of polymer structure
  - Can be accounted for with chain of custody
- Depolymerisation to building blocks
  - Can be accounted for with chain of custody or
  - Via simple mass balance approach
- Feedstock generation for cracker
  - Needs a more complex allocation approach of mass balance

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Allocation methods

The output products from the cracking process can be used for a range of products including fuel. There are currently 4 known allocation methods that can be used to allocate the recycled feedstock input into the cracking process, to the output products. The allocation methods that can be used are:

- free allocation
- proportional balance (also known as technical balance)
- fuel exempt
- polymer only

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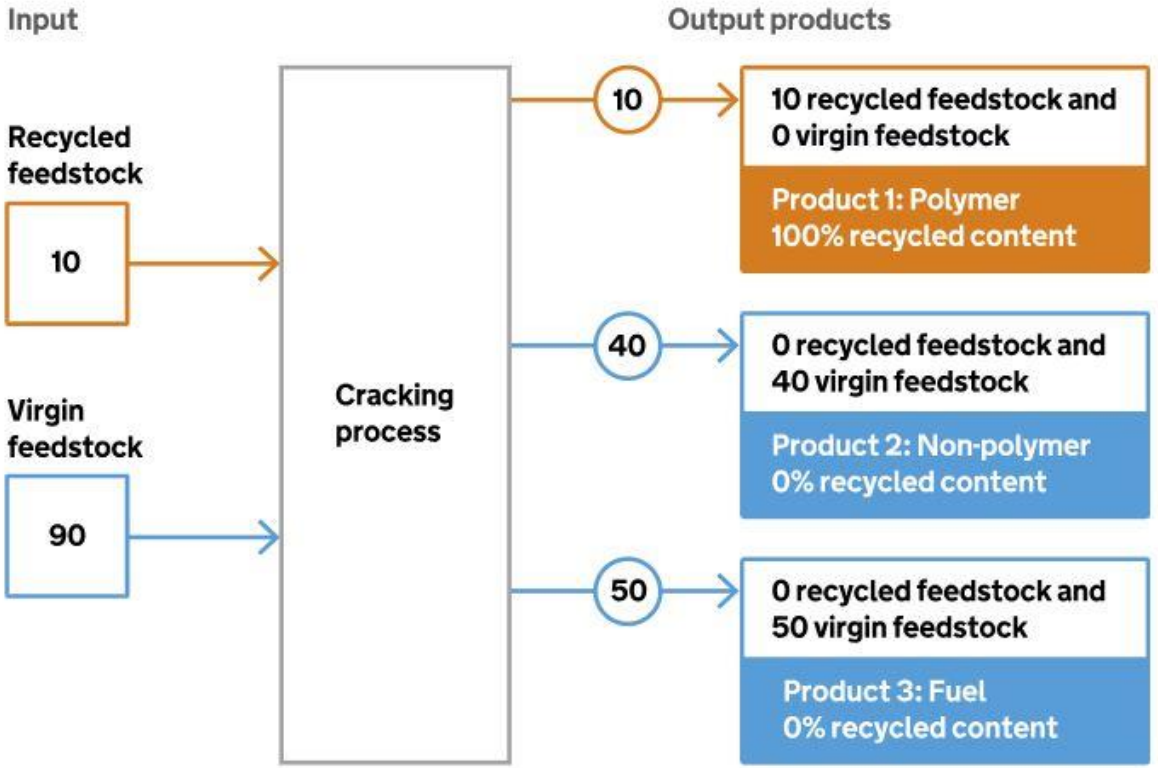
Free allocation method

Figure 1: Free allocation method



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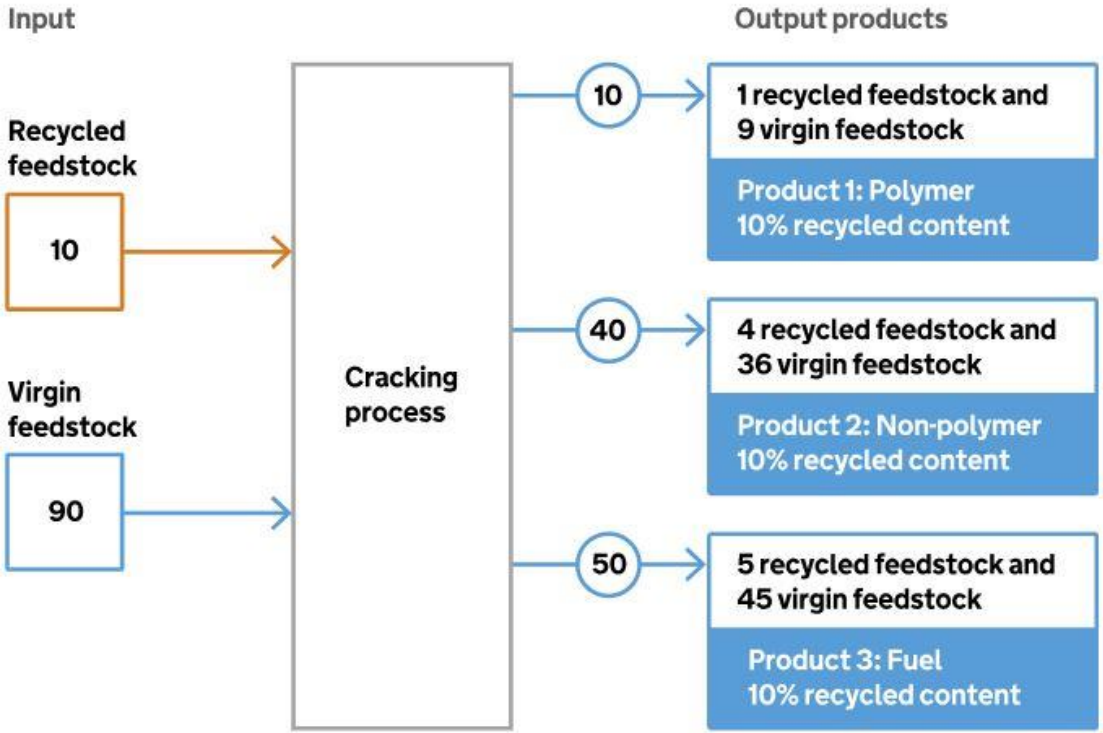
Proportional balance allocation metho

Figure 2: Proportional balance allocation method



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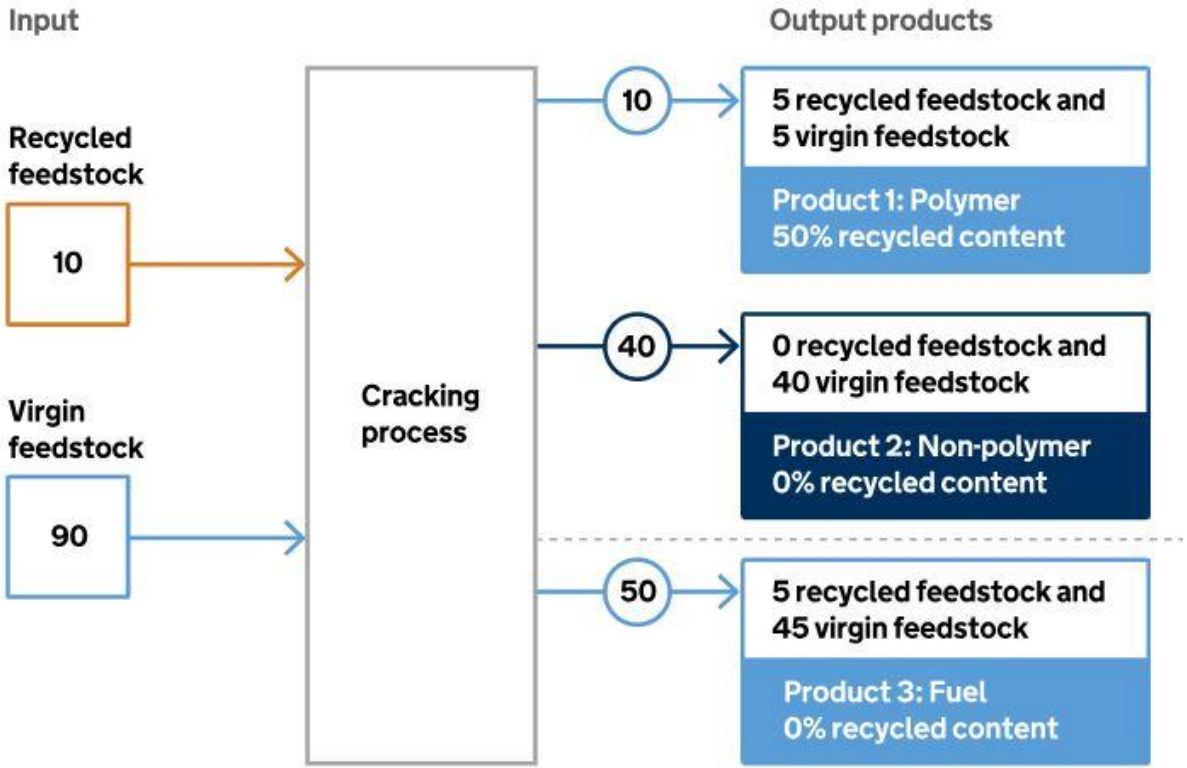
Fuel exempt allocation method

Figure 3: Fuel exempt allocation method



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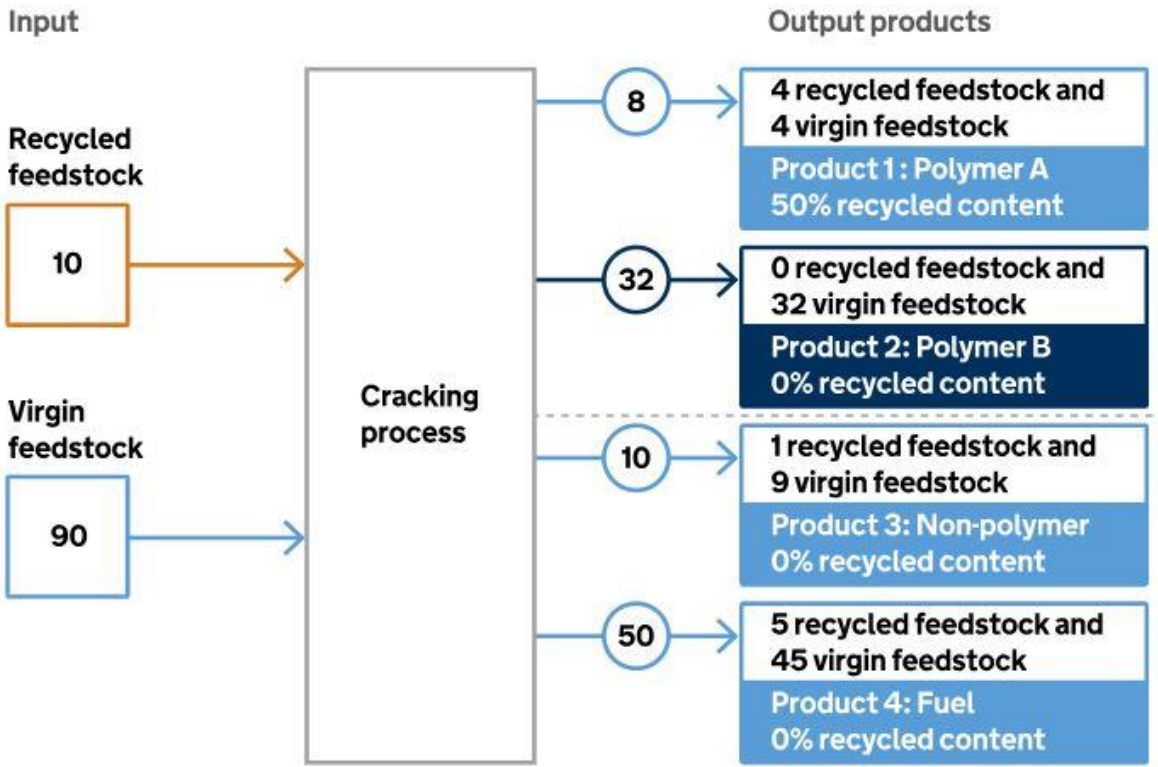
Polymer only allocation

Figure 4: Polymer only allocation method



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Balancing period

The balancing period is the maximum period a business is allowed to equate the proportion of recycled feedstock it receives for input into its cracking process, to the claims it makes for the proportion of recycled material in its output products.

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Measurement units

A reliable unit of measurement is needed to calculate the inputs and outputs from a cracking process. We have identified 3 units of measurement that can be used for a mass balance approach calculation. These are:

- mass
- molecular units
- lower heating value

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Standards

Level	Initiator	Example	Application
Global	Government or country	The International Electrotechnical Commission: IEC 62368-1:2018 ISO International Standards organisation	Standard for defining the safety of electrical and electronic equipment within the field of audio, video, information and communication technology
Regional	EU member states through national mirror committees or EU Commission mandate.	CEN - European committee for normalisation	Organisation establishing voluntary Standards applying in European Union. They are sometimes supporting Directive implementation in the context of harmonised regulations. EC 715/2007 : European Emissions Standard for defining the acceptable limits for exhaust emissions of new vehicles sold
Country	Accredited standards organization. National mirror committee of international standards.	ANSI, BSI, NEN, AFNOR, AENOR, JIS...	National standards development. Can integrate Regional / International standards in National collection thanks to mutual recognition agreements.
Organization	Innovators	Microsoft, Intel, IBM: USB port	Universal Serial Bus (USB) for improving interface between personal computers and peripheral devices

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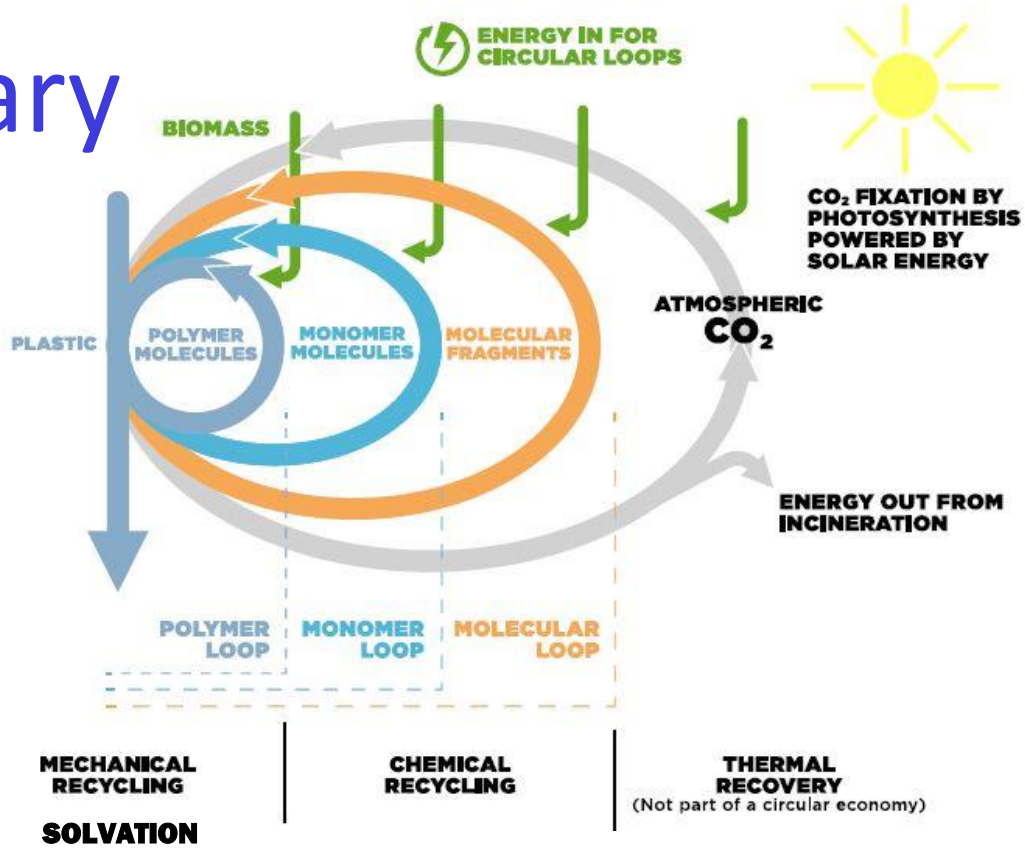
Summary



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TOGETHER WE CAN

Thank you

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