3m2: Circular food packaging

Biobased polymers for circular packages

April 12th 2022, Ulphard Thoden van Velzen

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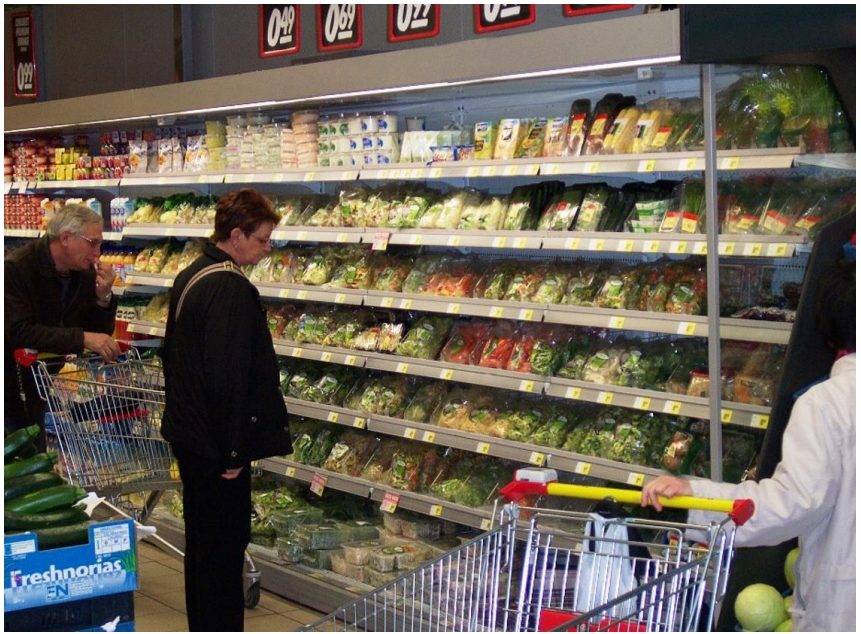
Plastic food packaging

- Friend & foe: Societal enabler & source of pollution
- Quick fixes do not exist
- Towards circular & sustainable food packages

Plastic packages

- Most protection
- Lightweight
- Enables convenience products
- Transparency
- At limited cost...



But plastic (packages) have downsides

- Greenhouse gas emissions
  - Advanced LCA tools
- Littering and plastic soup
  - Crude estimations

Magnitude of the environmental impact of waste

- Landfilling biowaste and not recycling plastic waste in the EU is a major source of GHG
    - 150-250 Mton CO_2 eq. reduction potential by diverting biowaste from landfill and recycling plastics!

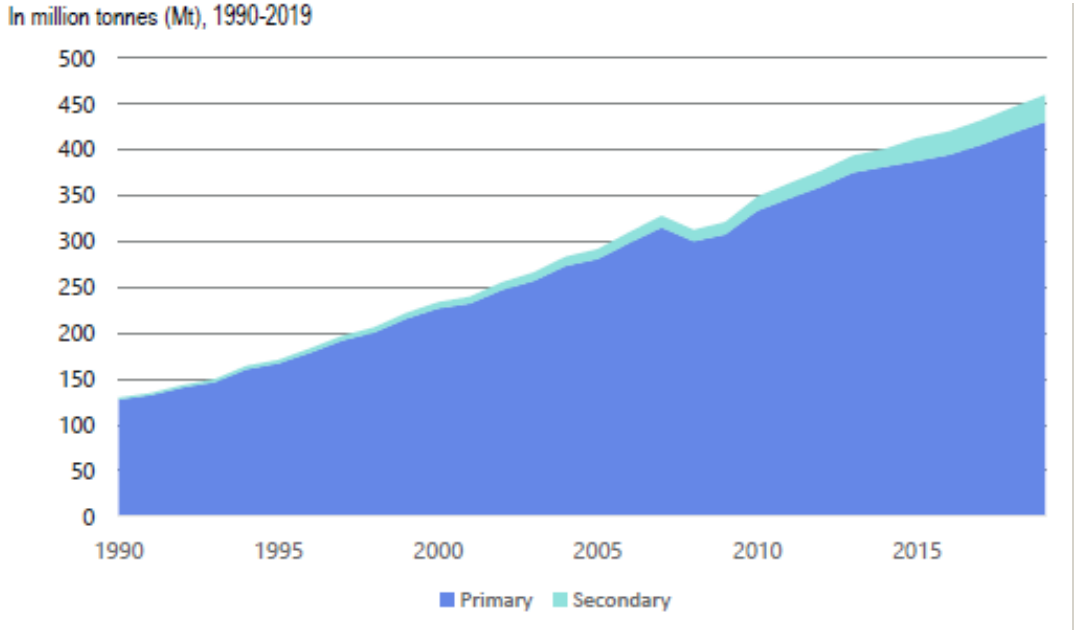
→ Large direct investments in Central European waste industries!

Source: Prognos, IFEU, INFU, Oct. 2008

And the global production keeps on growing

- Growth in Asia
- Stagnation in Europe

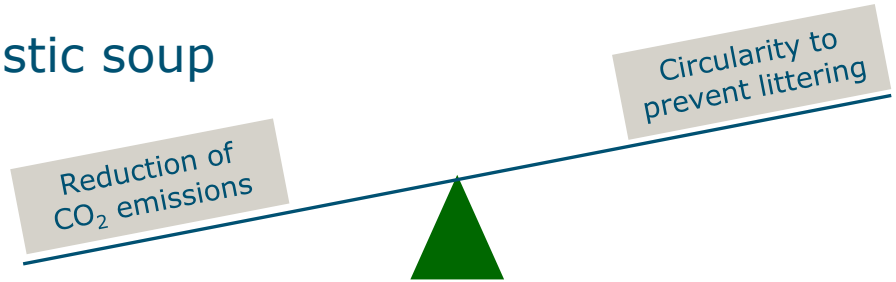
- Recycled plastics ~6%



OECD Global plastics outlook, 2022

Plastic soup as a game changer

- Shifting perspectives on sustainability of plastics
- 1970-1990 Material reduction, global warming potential
- 1990-2010 Shelf life extension, feed the world
- 2000-2015 Food waste, optimise waste management
- 2015- Plastic soup



On the origin of plastic soup

1. Fishery

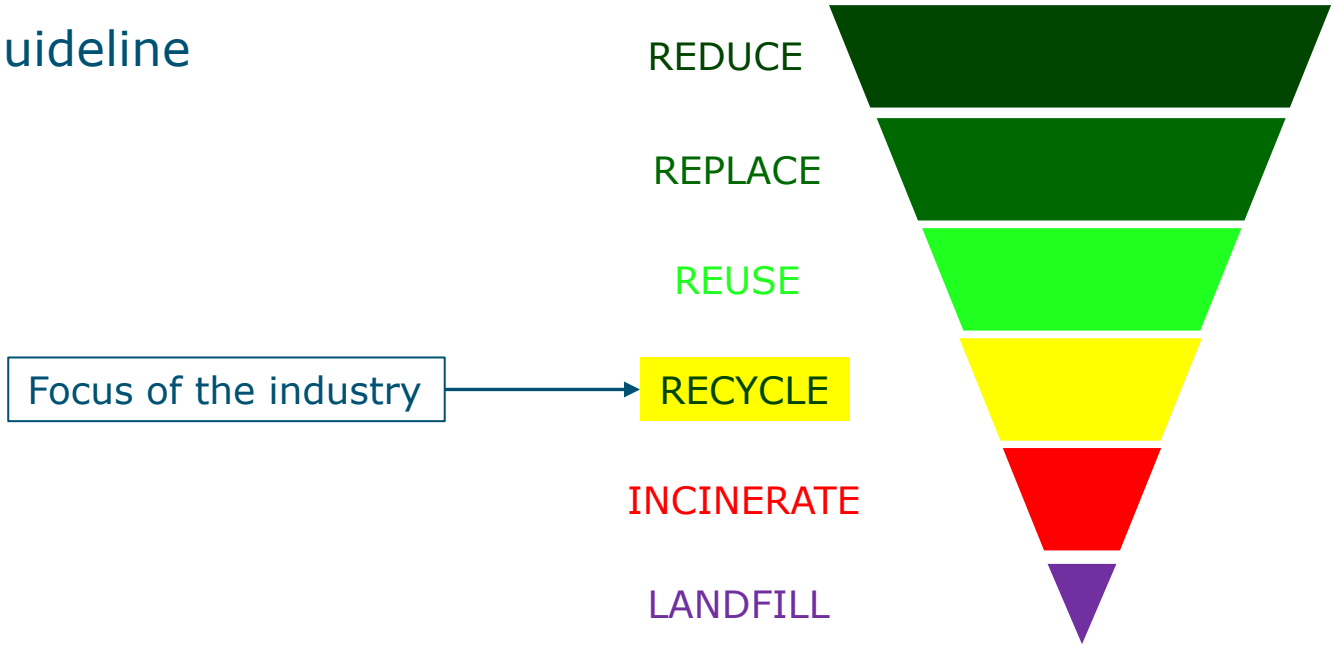
2. Lack of waste management infrastructure in most of the world

3. Human littering behaviour

4. Crooked laws in developed countries to register exported plastic waste as ‘recycled’

Classical solutions: waste hierarchy

- Simplified guideline



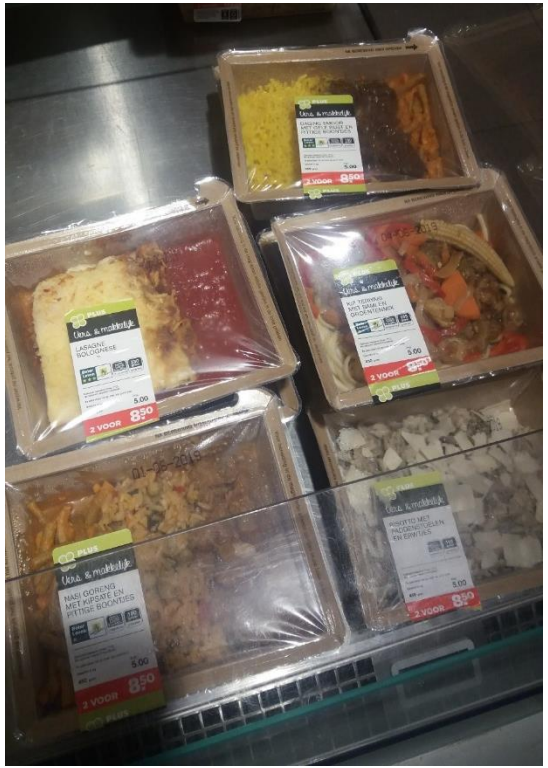
1. REDUCE

- Consume less!
- Remove plastic packages
    - Applicability is limited to a few fresh whole products
- Trade-offs
    - Food waste
    - Marketing
    - Channels: perfect for markets, less so for retail & e-tail

2a. REPLACE

- With Metal / Glass -> often more GWP

- With Paper & Board
  - Perfect for undemanding products
  - But chemistry is needed for water, grease & gas barriers
    - Beware of regrettable replacements
    - Ingredient X



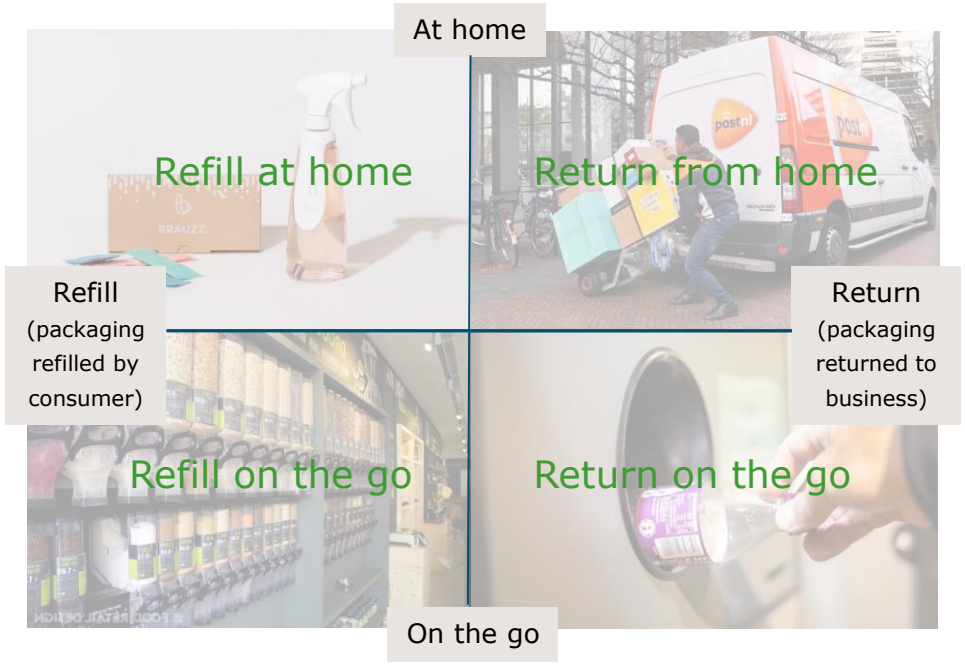
2b. REPLACE

Koehler paper / Ritter Sport

- Promising new developments with:
- Coated paper products
    - Oxygen barriers added to paper for dry products under dry conditions
    - Recyclable with paper: dissolves
- Biobased and biodegradable plastics
    - Opposition and system lock-in (*)

3a. REUSE

- Multiple business models
- Most require intensive collaboration with partners & large investments



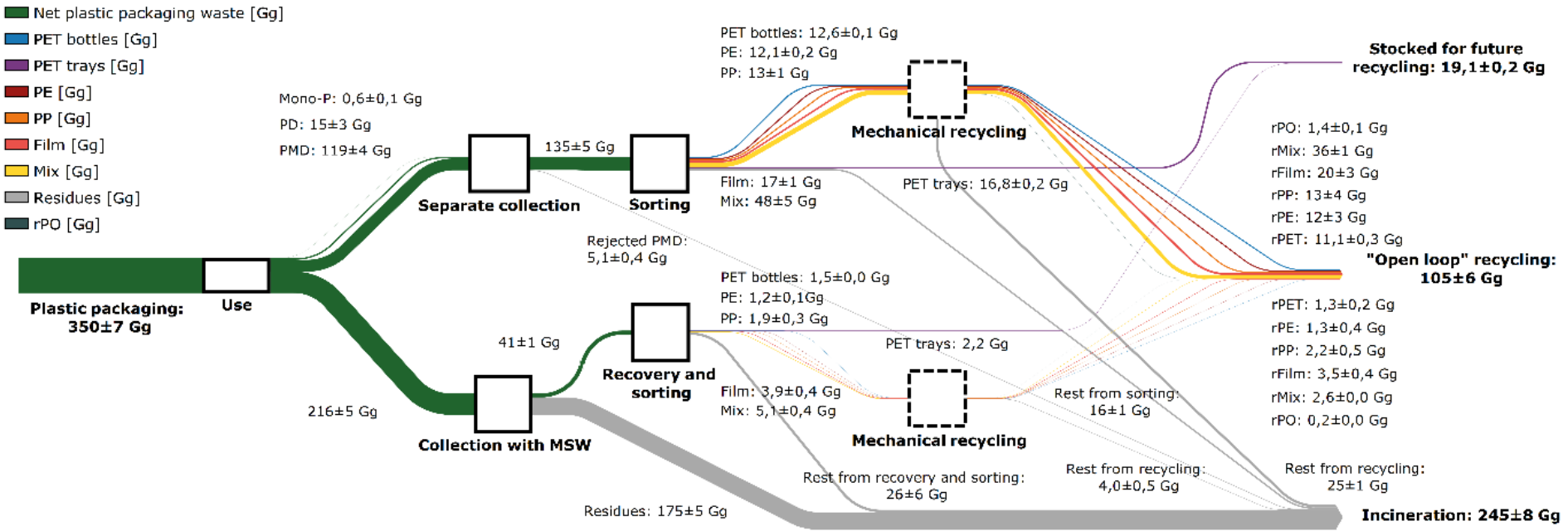
3b. REUSE / Return on the go

- Food-safety: only glass & stainless steel
- All companies with an existing reusable glass bottle system want to maintain it
- Large barriers to set-up a new reuse system
    - DRS – high collection rates / retail commitment
    - Standardised pool bottles – minimal distances
    - Decentralised production – minimal distances
    - Non-viscous beverages / products – easy cleaning

4. RECYCLING

- Current focus of the food industry
  - “Least difficult” to set-up
    - separate LWP collection, no retail involvement
    - Open-loop recycling hardly requires design changes and investments

Post-consumer plastic waste recycling NL 2017



- Brouwer et al. Waste management, 2019, 100: 112-121

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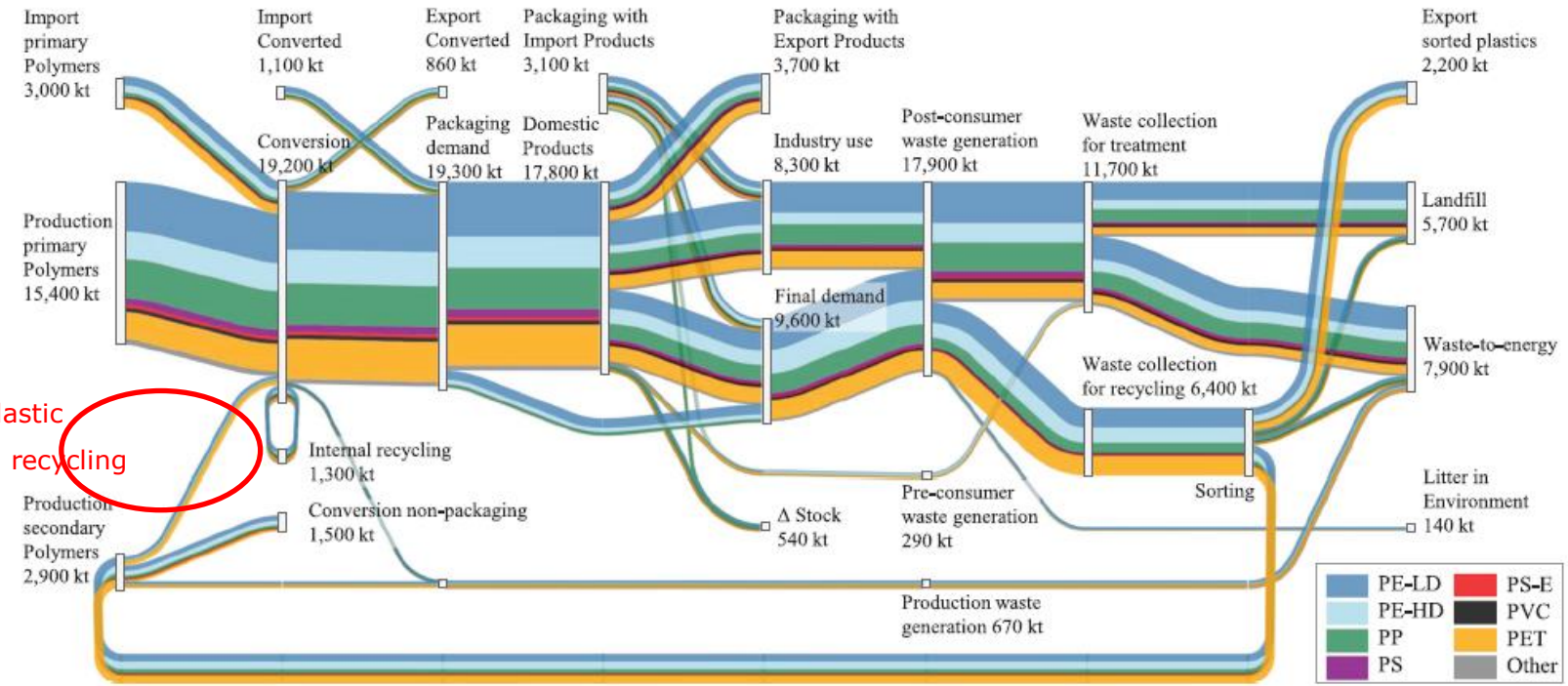
Plastic packaging flows in EU-28 for 2014



Circular plastic packaging recycling

Cimpan, C., et al. (2021). Plastic packaging flows in Europe: A hybrid input-output approach. *J Ind Ecol*, 1–16. https://doi.org/10.1111/jiec.13175

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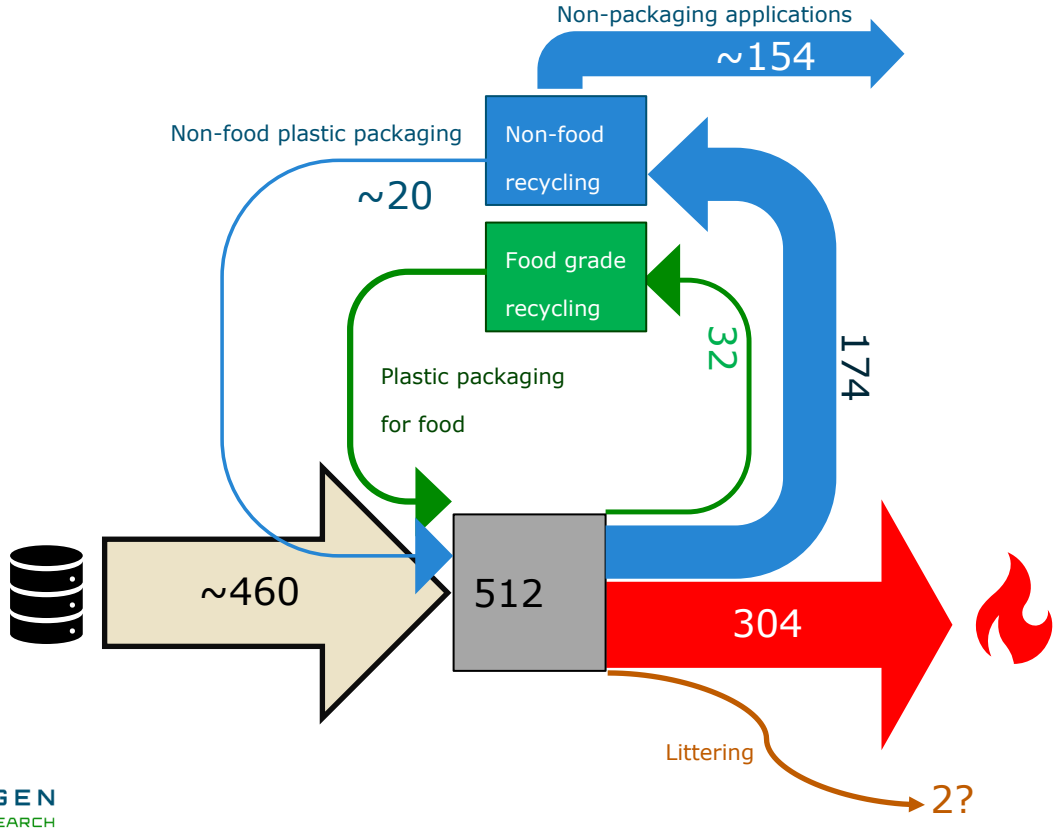
Recycling of plastic packages in NL, 2017

kiloton



Doi:10.3390/su122310021

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Diverging views on the status quo

- Producers / Dutch government
- Recycling target is achieved
- Littering fund is paid

- The most advantageous system internationally

- NGO’s / EU Commission
- This system leaks and is too limited
- Too reliant on fossil feedstock

- We need to make the system “circular”

So how does our recycling system work?

The 3 most abundant types in LWP in 2022

PET trays, cups, blisters

~12%

PP trays, cups, blisters

~10%

PE films

~7%

And the next 3 types

PET non-beverage bottles ~4%

PE non-beverage bottles

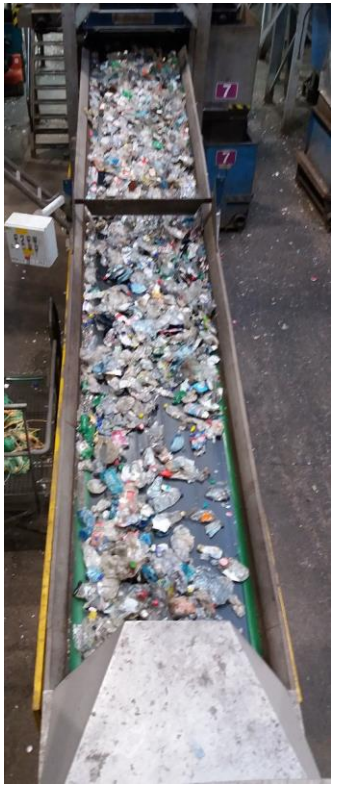
~4%

PP films

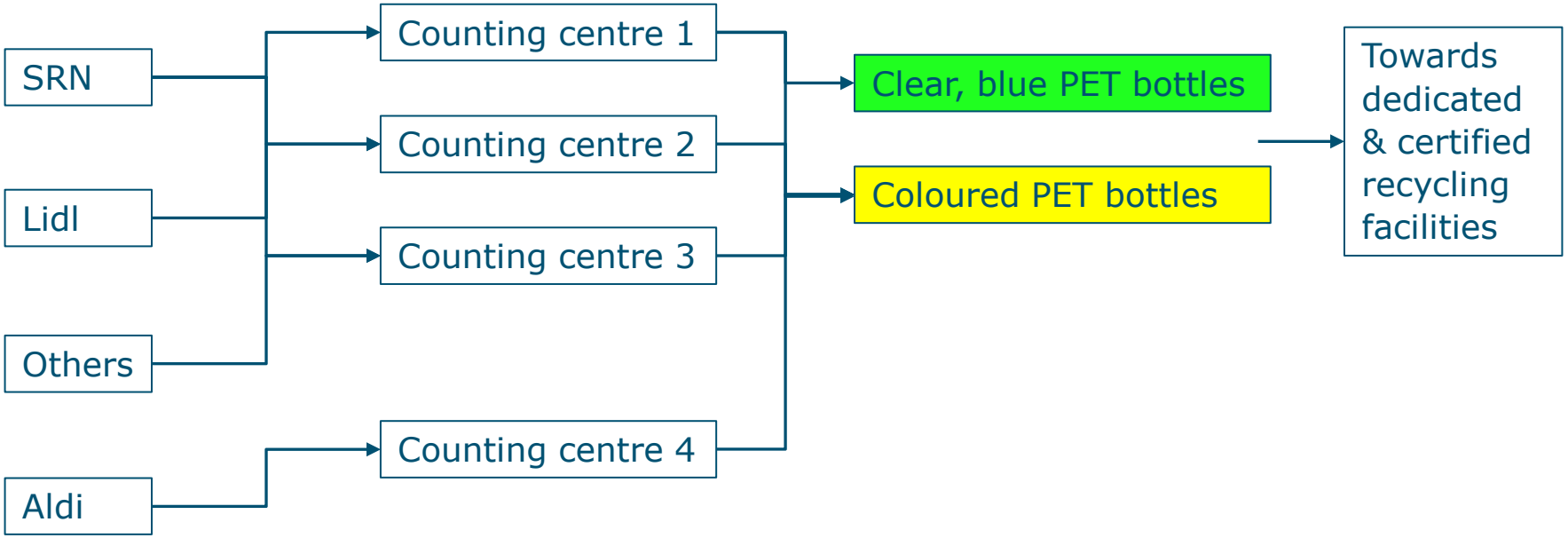
~3%

Deposit refund systems

- Suitable for few types of packaging: 10%
    - PET beverage bottles, cans...
- High return rates 90-99%
- Close co-operation between bottlers and recyclers
    - All bottles are designed-for-recycling
- Currently mostly bottle-2-bottle (food-to-food)
- Unpopular with retailers



PET bottles in the DRS



Separate collection lightweight packaging waste

Operated by the municipalities
Many different collection systems: drop-off, kerbside, PAYT, Wheelie bins, bags...

Separate collection lightweight packaging waste

- Net collection yield = participation rate * selection rate
- Participation rate varies from 30 – 100%
- Selection rates are fairly stable at 70 ± 10%

- Issues
  - Costs
  - Managing ‘non-targeted contributions’

DOI: 10.1016/j.wasman.2019.04.021

13 years of experience in NL

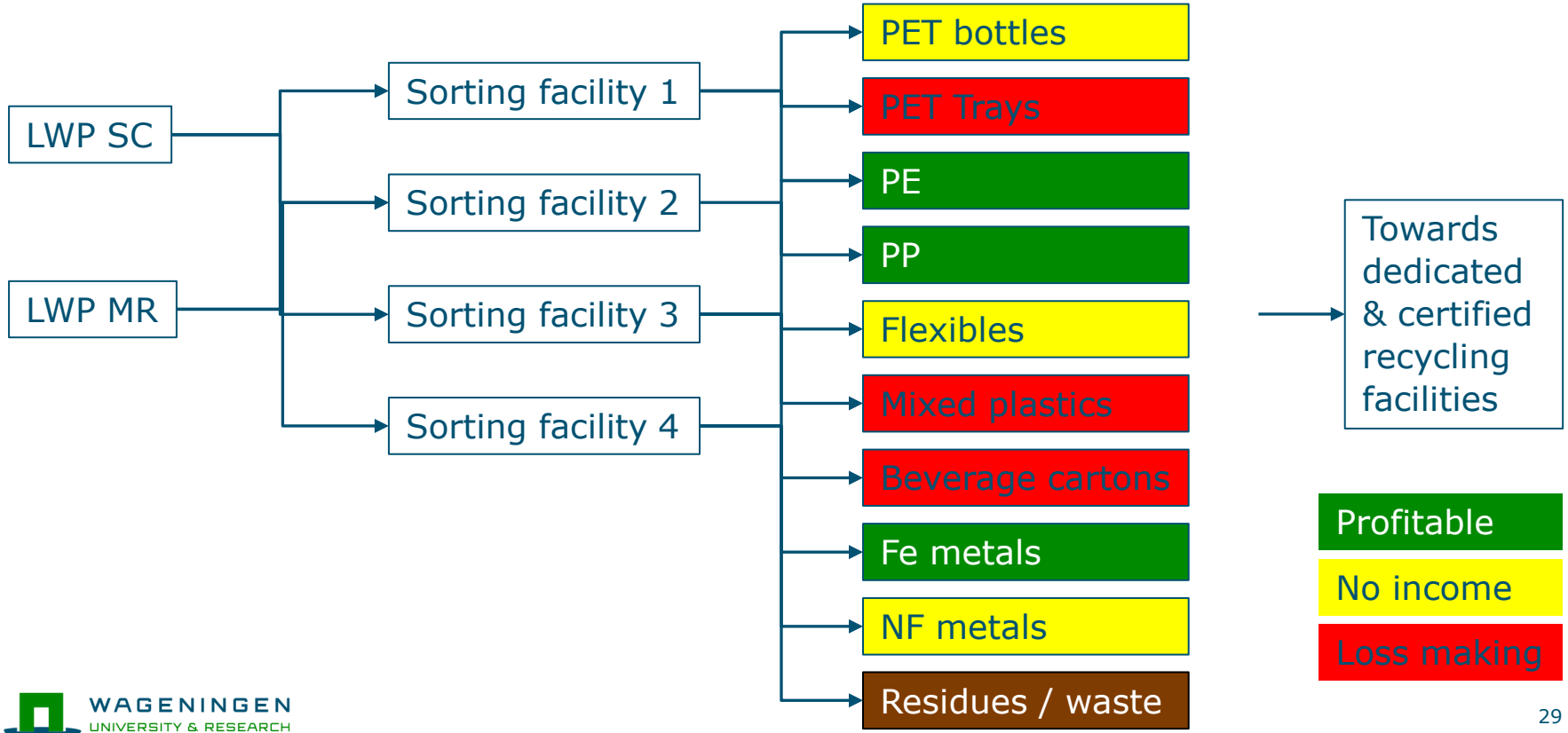
- Rural municipalities
  - Kerbside LWP collection in wheelie bins
  - PR 90-100%

- Urban municipalities in Holland, Groningen
  - Drop-off LWP collection failed (PR < 25%, NTC > 30%)
  - Mechanical recovery of plastic packages from MSW

Mechanical recovery from MSW

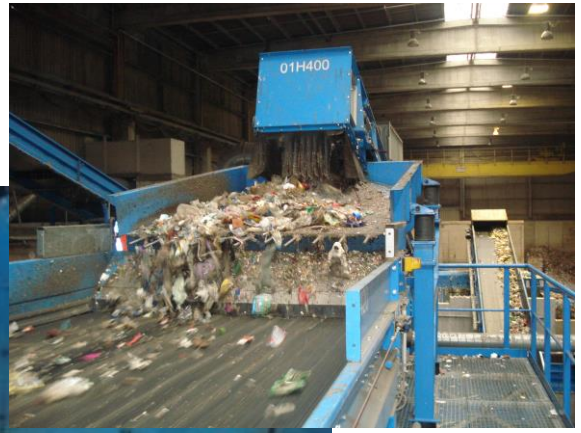
- Relatively new in EU & NL (FR, ES, PL, AT, UK, CY)
- Rapidly developed in NL
- Dependant of the waste processor
    - Execution, composition
    - Large central investments
- Maximum recovery yields ~ 70%
    - More common 60%

Dutch LWP is sorted at 9 products

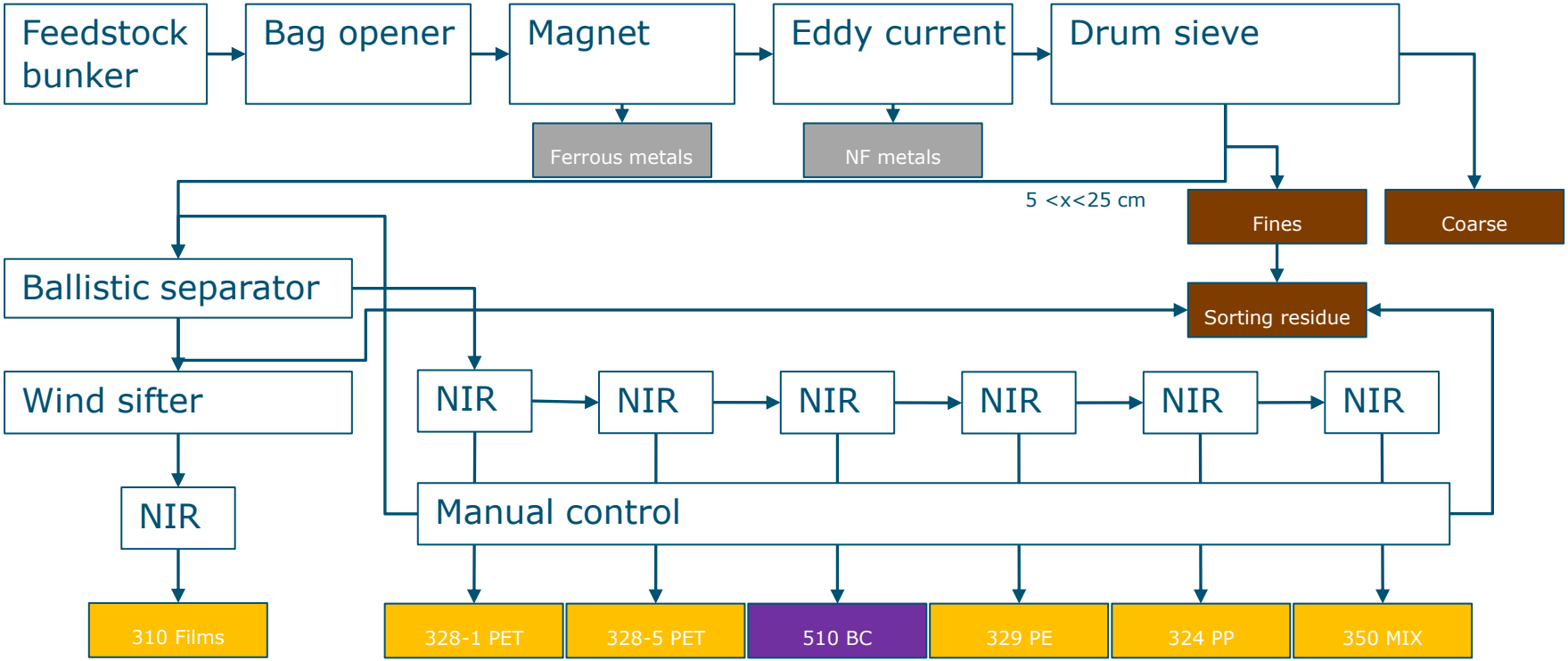


Sorting technologies

- 4 sorting facilities in NL
- 4 sorting facilities in DE
- All are different
    - 25-100 kt/a
- Noisy & dirty



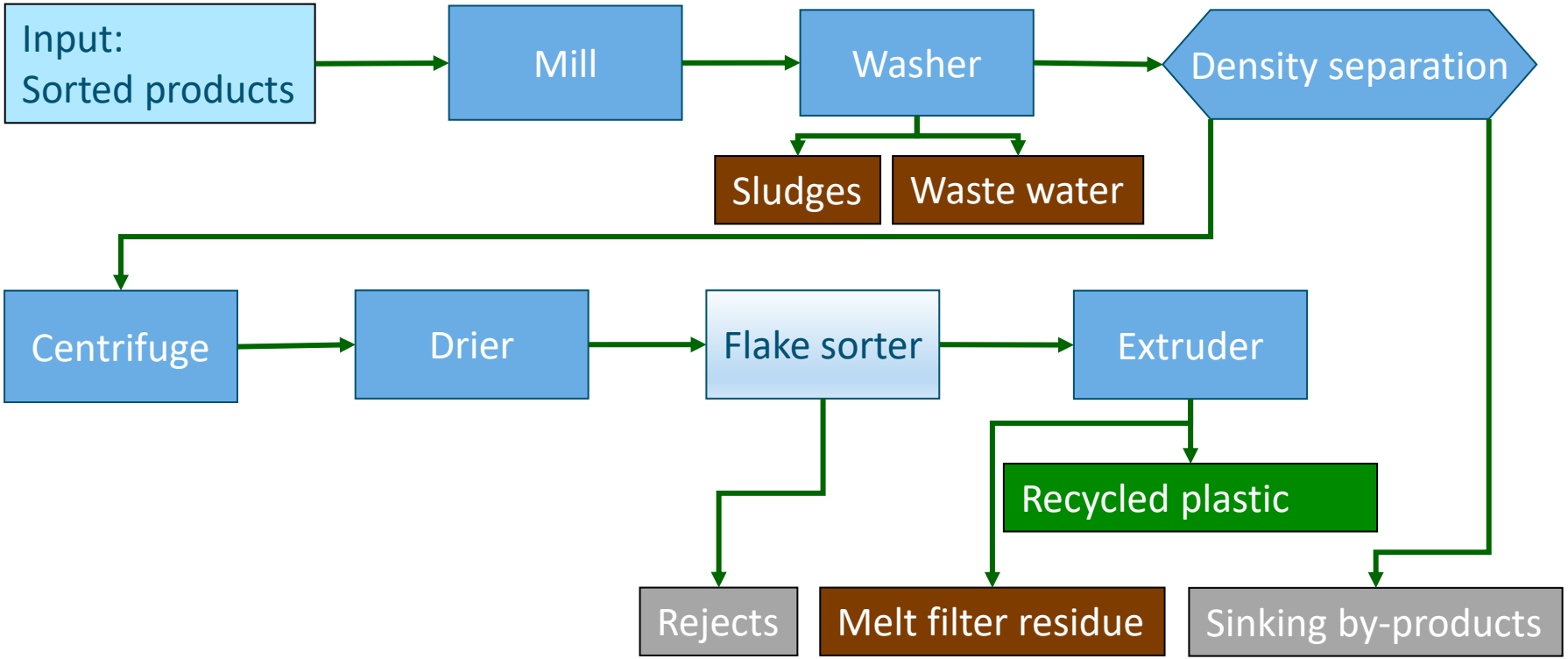
Sorting LWP – General set-up



Mechanical recycling technologies

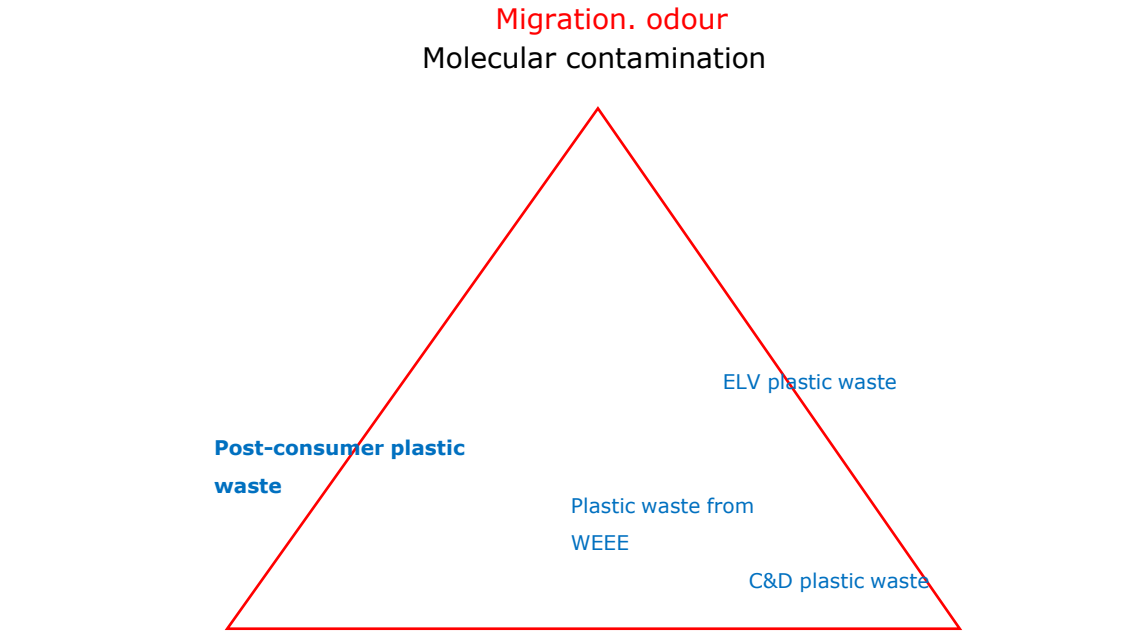
- ~500 plastic recycling facilities in Europe
- ~200 certified
- Dedicated for specific feedstocks and products
- 25-100 kt/a

Simplified set-up of mechanical recycling



Why is plastic recycling not circular?

2008: 3 main quality decay mechanisms



DOI: 10.1002/mame.200700393

Quality of recycled plastics

Sorted product	Recycling process	Molecular contamination	Polymeric contamination
PET bottles	Standard	Low after SSP	~0.1 – 1.0%
	Advanced	Low after SSP	<0.1%
PE DKR 329	Standard	Very high	5-10%
	Advanced	Very high	1-3%
PP	Standard	High	5-10%
	Advanced	High	1-3%
Film	Standard	Very high	8-15%
	Advanced	Very high	1-3%

Not suitable for food applications

Not suitable for packaging

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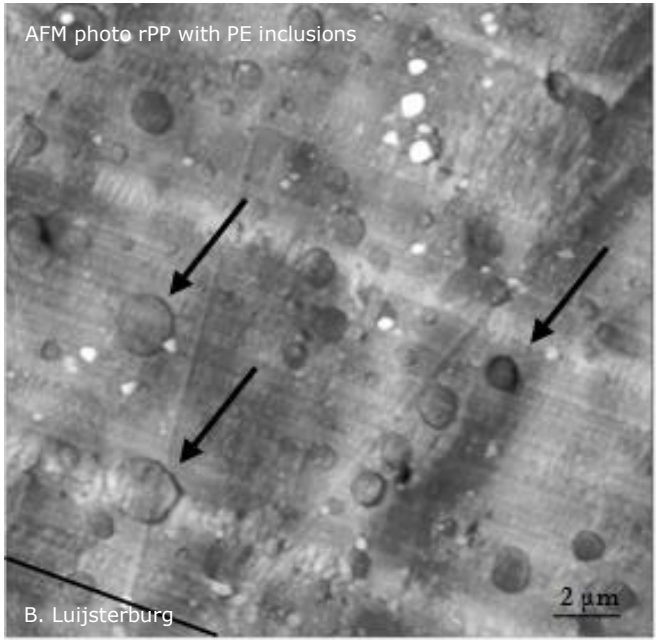
Polymer contamination results in blends

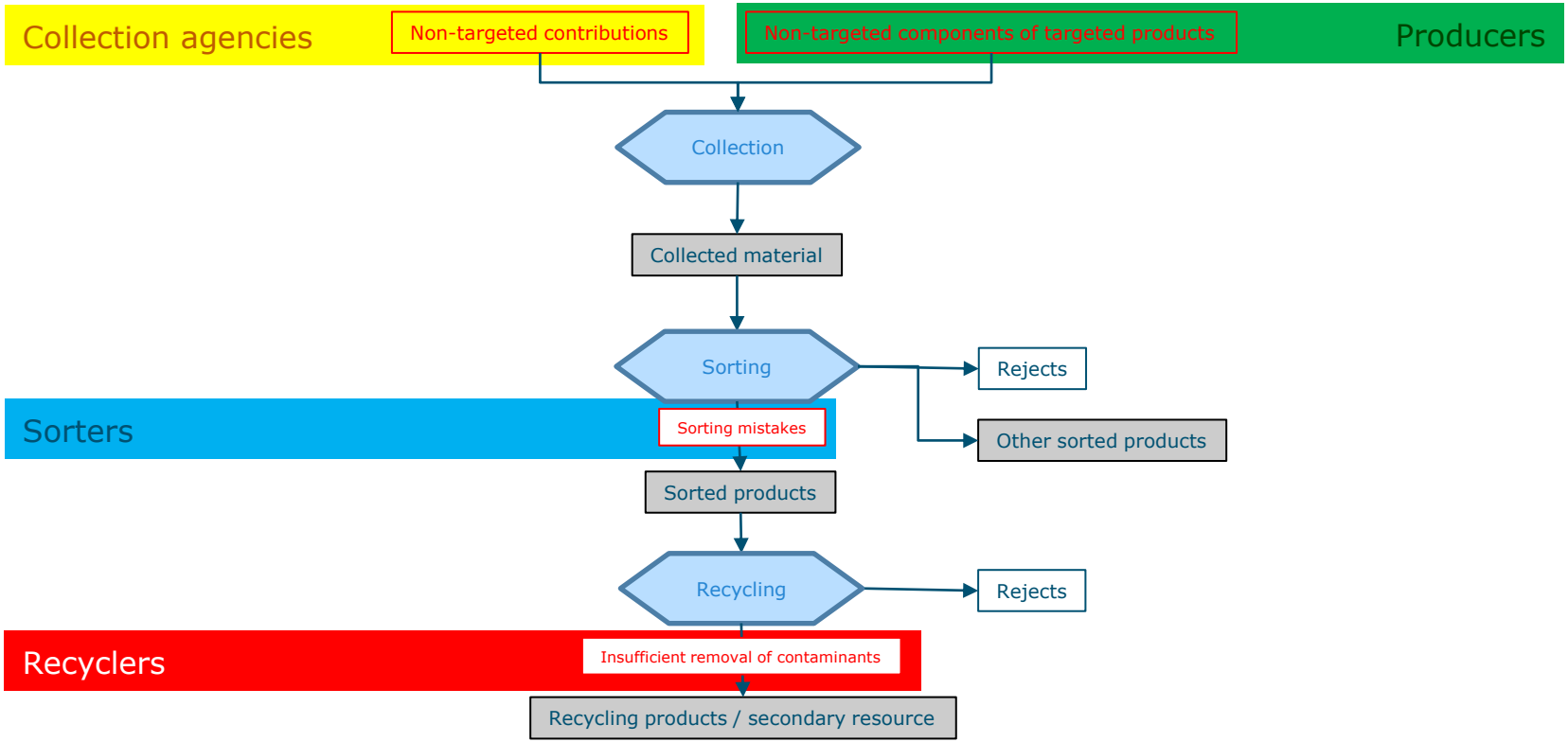
- Most recycled plastics are blends !
- Most common particles are other polymers
- But also inorganic particles are found



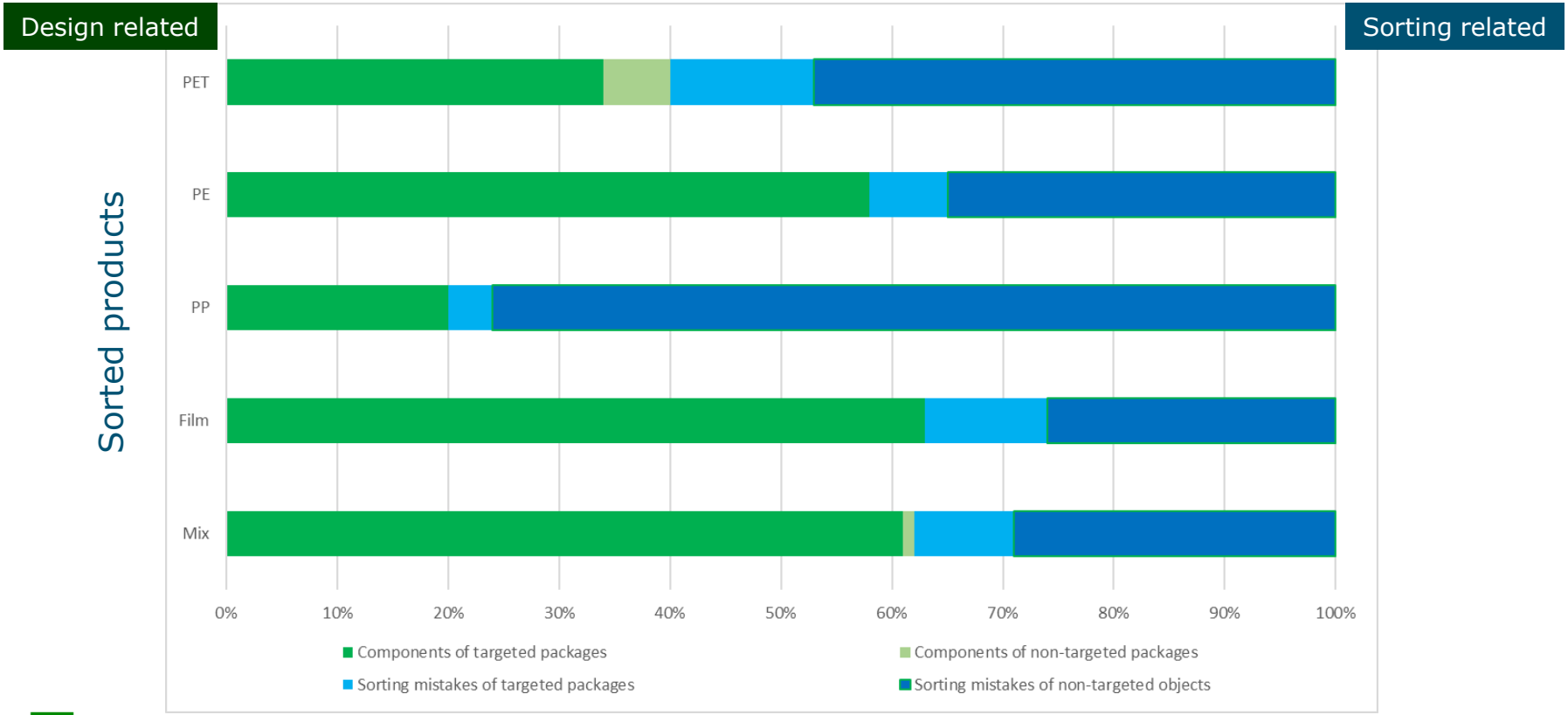
Particle & polymer contamination

- Inorganic inclusions -> SEM EDX (Al, Si, K, Ca...)
- Black spots -> SEM EDX / Micro-IR -> C (burnt paper?)
- PET -> partisol
    - Virgin ~ 10 million particles/gram
    - Recycled > 100 million particles/gram
- Results in haze, holes, reduced impact strength, etc.

Quality: Origin of contaminants

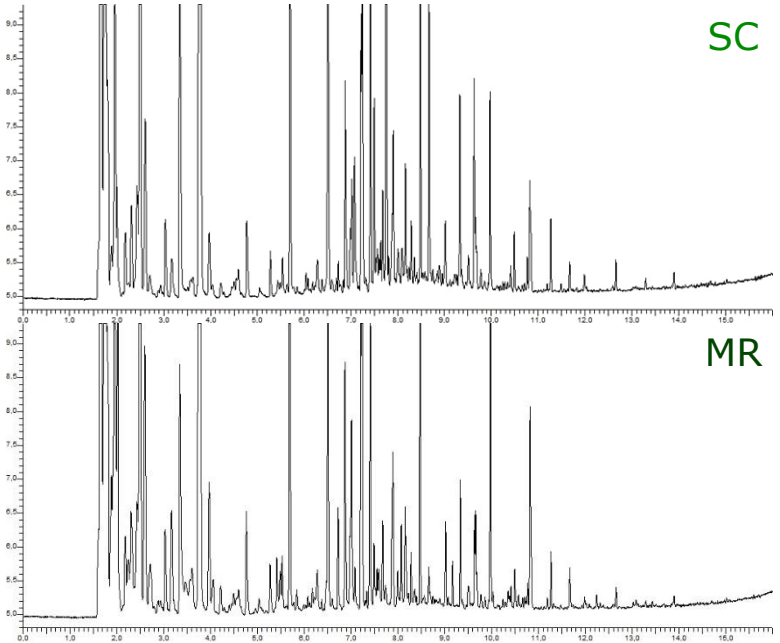


Source of polymeric contaminants



Molecular contamination

- Headspace GC of volatile compounds from recycled film made from separately collected (SC) plastic packaging waste and mechanically recovered (MR) plastic waste.



Molecular contamination – an overview

Type	Type of molecules (MC)	Relative concen-tration	Odour activity	Food safety relevance
Oligomers & degradation products	Homologous series of alkanes and alkenes	High	Hardly	Mostly negligible
Additives	Anti-oxidants (Irgafos), anti-slip agents (calcium stearate, Erucamide)	Limited	Non to hardly	High for amides
Additives from prints and labels	Plasticiser (DEHP, etc.), BPA, MOSH, MOAH, photo-initiators, phenols	Moderate	Non to hardly	EDC's
Incidental contamination with product residues	Strongly varying, for example: + paint residues (pinenes) + food (oleic acid, limonene) + pain relief lotion (menthyl salicylate) + odorants (linalool, ionone)	High	Varying	Varying
Microbiological metabolites and degradation products	Strongly varying: + Geosmine, 2-methyl-isoborneol, etc. + Short chain fatty acids, butyric acid + methyl sulphides and amines	Very low	Very high	Most negligible but also natural toxins

Types of molecular contaminants

- Systemic (OR>90%) originate from the package itself, the collection, sorting and recycling
- Incidental (OR<5%) originate mostly from consumer abuse
- Neo-formed are formed during recycling (thermal treatments)

- Intentionally Added substances (IAS): systemic additives
- Non-Intentionally Added Substances (NIAS): all

OR = occurrence rate

For example rPET from beverage bottles

- IAS, systemic: 2-aminobenzamide
- NIAS, systemic: acetaldehyde, 2-methyl-1,3-dioxolane, ethylene glycol, limonene
- NIAS, incidental: trichloroethene, acetone, lindane...
    - Are sufficiently removed during recycling (SSP)
- NIAS, neo-formed: benzene

Why is recycling not circular?

- Most packages are **not** designed for (circular) recycling — Producers
  - Polymeric contamination -> opaque, hazy, brittle
  - Molecular contamination -> odour, food safety
- Lack of efficient decontamination technologies — Recyclers
- Much too strict legislation
  - Based on a triple worst case risk assessment — Government

Legal blockade on food-safe recycled plastics

- EU 282/2008 deals with food-grade recycling of plastic packages
- Recycling company petitions for a positive opinion at EFSA with a description of the feedstock & recycling process.
    - Challenge test has to prove sufficient removal efficiency
- EFSA has granted > 100 positive opinions in favour of approval (mostly on PET bottle recycling)
- EC has approved none

Risk evaluation by EFSA

- The current risk assessment is still very strict, based on a **triple worst case approach:**
  - potential contamination levels (worst-case)
  - migration model (worst case)
  - exposure scenario's (worst-case)
- A revision is under discussion, but there is no sign of more realism
- Only one less strict assumption will enable circular recycling
- (Within the USA, the circular recycling is enabled by NOL of FDA)

DOI: /10.3390/su14020824

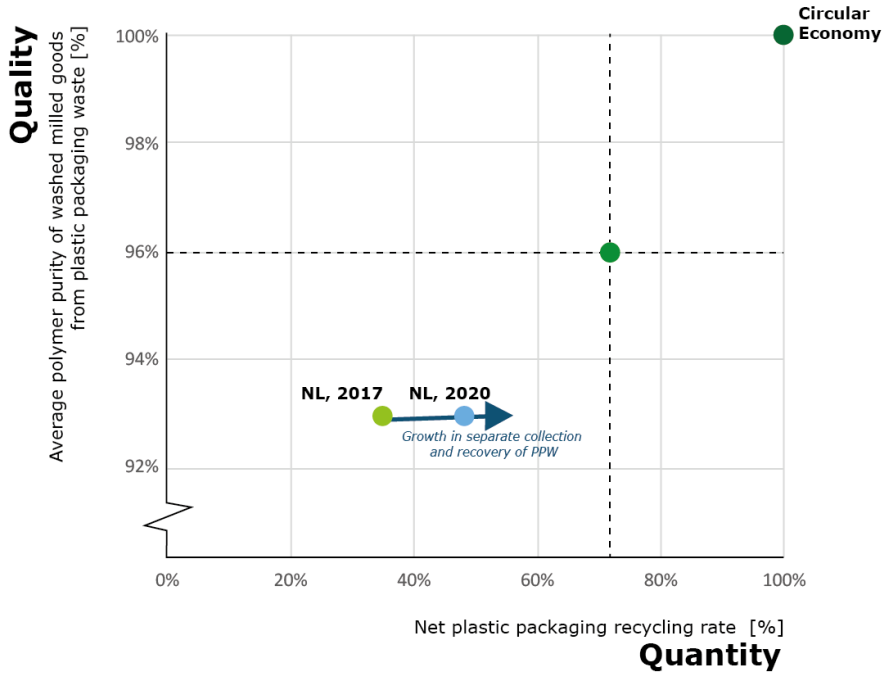
So we can’t reach circularity

Recycling of PPW, progress in NL 2017-2020

Status 2020*:

- Recycling rate: ~48%
- Average polymer purity: ~93%

Higher separate collection rates and additional recovery of PPW resulted in a higher recycling rate.



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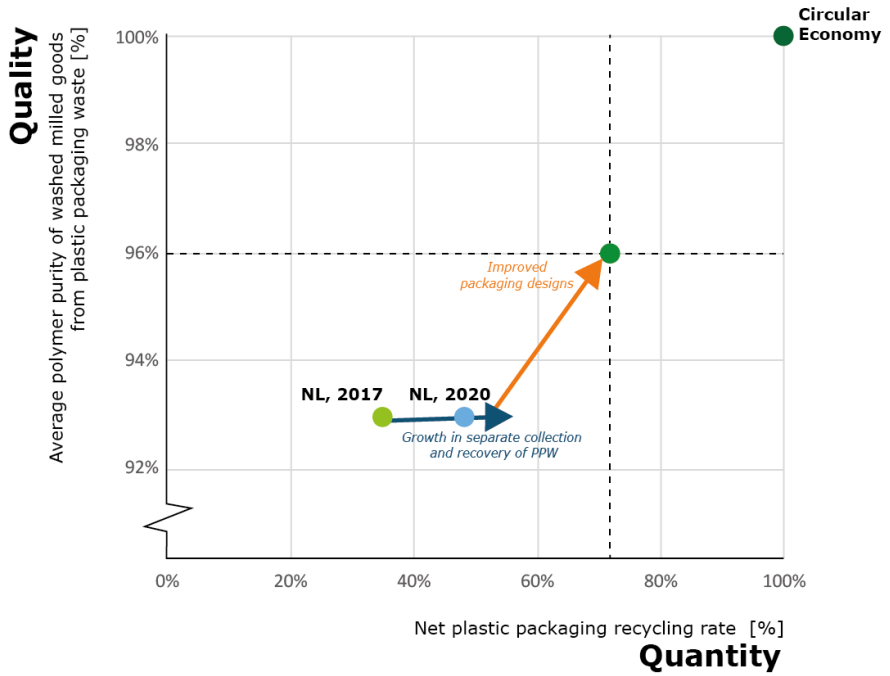
*calculated estimate

More circular recycling

- The recycled plastics resulting from this system are of **insufficient quality** for the application packages and consumer product

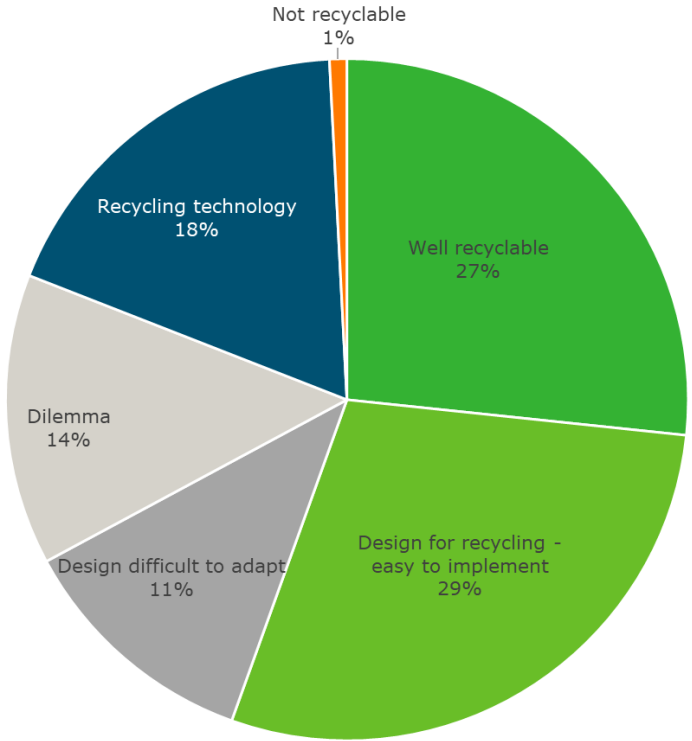
Design for recycling:

- improves the quality of the recycled plastics
- improves the chain efficiency



Design for recycling opportunities

- Status 2021: 27% well-recyclable
- Only 1% is not recyclable
- 72% improvement window
    - 29% easy to implement
    - 11% difficult to adapt
    - 14% dilemma’s (food waste)
    - 18% recycling technology



Easy to implement (29%)

Packaging components that cause impurities (16%):

- Pump & spray mechanisms

- Unremovable (paper) labels

- Metal caps, silicone rings, etc.

Easy to implement (29%)

Big labels & sleeves (~3%)

Black packages (~7%)

Difficult to adapt (11%)

Small packages

Dilemma (14%)

Laminated films and rigids (~7.5%)

Beware of regrettable replacements

PP films (~6%)

Blisters for pills (~0.5%)

Challenge: medicine legislation

Recycling technology (18%)

- PET trays (2021 started)

  Solution: develop recycling technologies, redesign packages

- PS packages

  Solution: replace by PE, PP or PET, or use as feedstock for pyrolysis

General challenges

- Dilemmas: disadvantages of alternative packaging like reduced shelf life, higher cost, less convenience, marketing factors, etc.
- International production chains; differences between countries.
- Confusion about what is recyclable.
- Regrettable replacements: “natural-looking” packaging that is not recyclable. For example paper / plastic combinations

Dilemma 1: PVC push through blister

- Chewing gum:
  - PET of PP-blister
  - Pots
- Drugs
  - Non PVC packages in new applications
  - Redesign large products

Dilemma 2:Laminated flexibles

- Reduce vs Recycling
- Technology recycling still absent
- Proposed alternatives might not be recyclable as well
- Incinerate in the residue for the time being

Dilemma 3: Hand pumps & spray guns

- Ease vs Polymer contamination
- Source of POM, ABS, glass balls, metal springs
- Solutions:
  - Body of PE in stead of PET
  - Separate collection of body and pump / spray gun

Dilemma 4: PET-PE trays

Modified atmosphere trays for

meat, cheese, fish, meat-replacers

Large market size

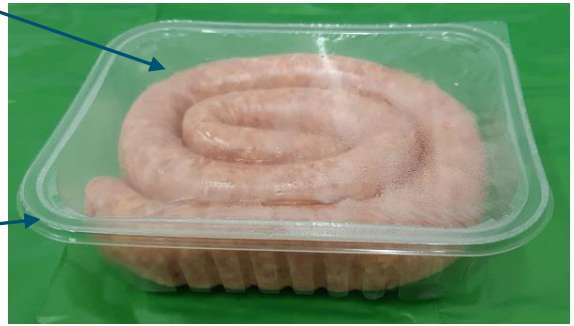
So let’s elaborate

Modified atmosphere packaging for meat...

- Prolongs the shelf-life of meat, fish, cheese and meat replacers
- Invented 1964, Early adopters 1975, Mass adaptation 1999

Protective CO_2 / O_2 rich atmosphere

CO_2 / O_2 gas barrier package



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Modified atmosphere packaging for meat

- Higher direct costs +0,07 €/pack
  - Packages, gasses, machines…

- Lower indirect costs -0,10 €/pack
  - Longer shelf life
    - Less shrinkage in shops (8 -> 5%)
    - Less night shifts
    - Lower delivery frequency ….
    - Larger product portfolio

But PET-PE MAP-trays are not-recyclable!

PA / EVOH / PET containing top-films

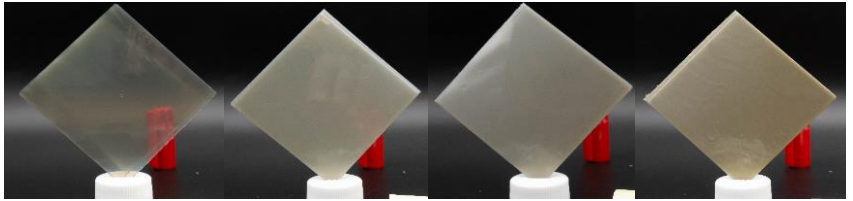
PE or PET-G sealing layer

Non removable labels

Purge absorbers with glue

Recycling tests

Tray 0 Pure | **Tray 1** + Seal | **Tray 2** PET-PE | **Tray 3** Seal & Top



Tray 0 Pure | **Tray 1** + Seal | **Tray 2** PET-PE | **Tray 3** Seal & Top

The presence of seal-medium and top-film causes blend formation. Hence, the rPET is hazy, for which there is limited market.

DOI: 10.18174/526914

Possible Solutions?

1. Developing recycling processes for PET trays,	RECYCLING
2. Using PLA trays	COMPOSTING / RECYCLING
3. Flowpacks with multilayer barrier films	REDUCTION
4. Reusable packages	REUSE

Recycling processes in development

- 4PET / Faerch, mechanical recycling -> turbid rPET for CPET trays
- PRA -> slightly dark rPET in ABA structure for near-transparent trays
- Indorama Verdun -> only accepts mono-A-PET trays to make transparent rPET
- CURE, depolymerisation process development -> operational 2024

PLA trays

- Promessa tested PLA trays from 2019-2020 for organic meat
  - Received much negative responses from VA...
  - Leak chance increased to ~1% (food safety hazard)
  - Double prices
  - Top-films were formally compostable, but contained PVdC
    - Improved top-films required

Flow-packs for minced meat

- In 2020 several meat companies tested with PP/EVOH/PP films
- Weight reductions of 70-80%
- Lower costs but new machines
- Films are currently recycled with MIX and hopefully in the future via pyrolysis

Reuse attempts

- In 2017 tests with Reusable PET trays were executed at BONI
- Then too low return rates
- Not all returned trays were cleaned by consumers, resulting in a potentially non-hygienic situation in the shop and in malodours

- Attempts were stopped

Dilemma 5: Snack tomatoes

Should supermarkets reduce or replace plastic packages?

PET shaker S1

PET shaker S2

PP shaker S3

Carton PET Shaker CS1

PP pouch SP1

PP, PET bucket B1

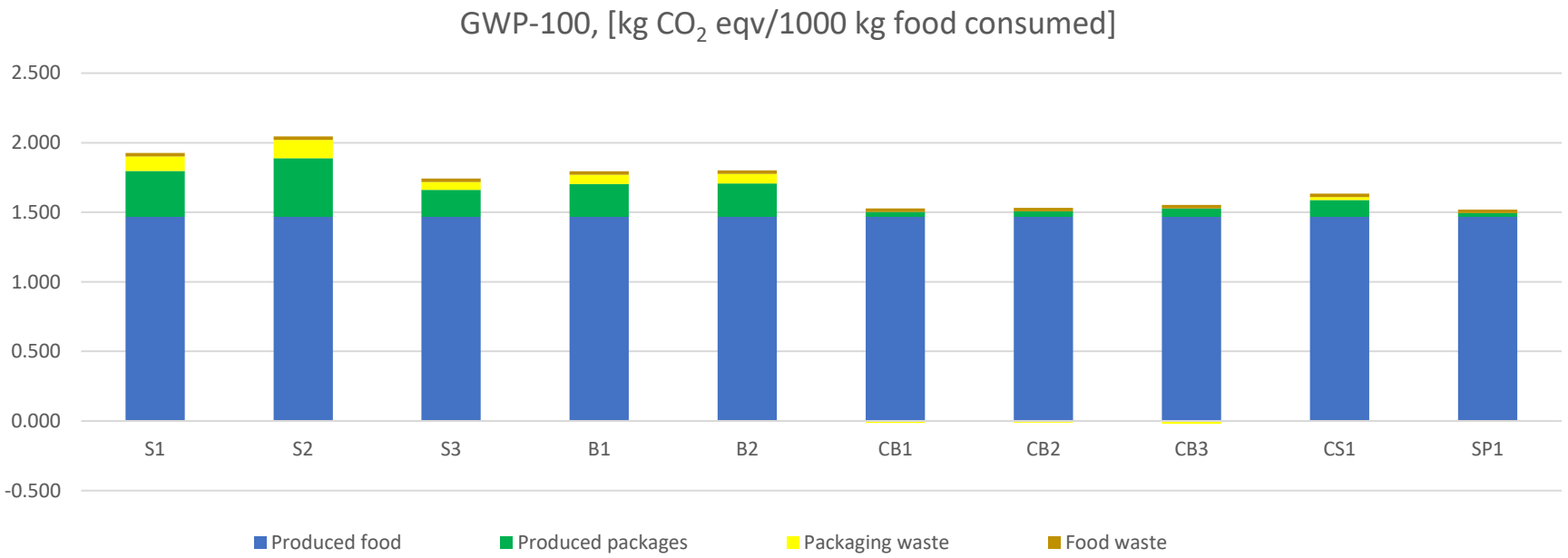
PP, PET bucket B2

Carton box CB1

Carton PLA box CB2

Carton PLA box CB3

GWP-100


GWP-100, [kg CO_2 eqv/1000 kg food consumed]
2.500
2.000
1.500
1.000
0.500
0.000
-0.500
S1
S2
S3
B1
B2
CB1
CB2
CB3
CS1
SP1
Produced food
Produced packages
Packaging waste
Food waste

Conclusions snack tomatoes I

- GWP-100:
  - is dominated by tomato production,
  - the relative contribution of packages is small, but can still be minimised with cardboard packages.

- Consumer perception: cardboard packages is most environmental friendly
- But the sales in optical transparent (plastic) packages is the best

Impacts

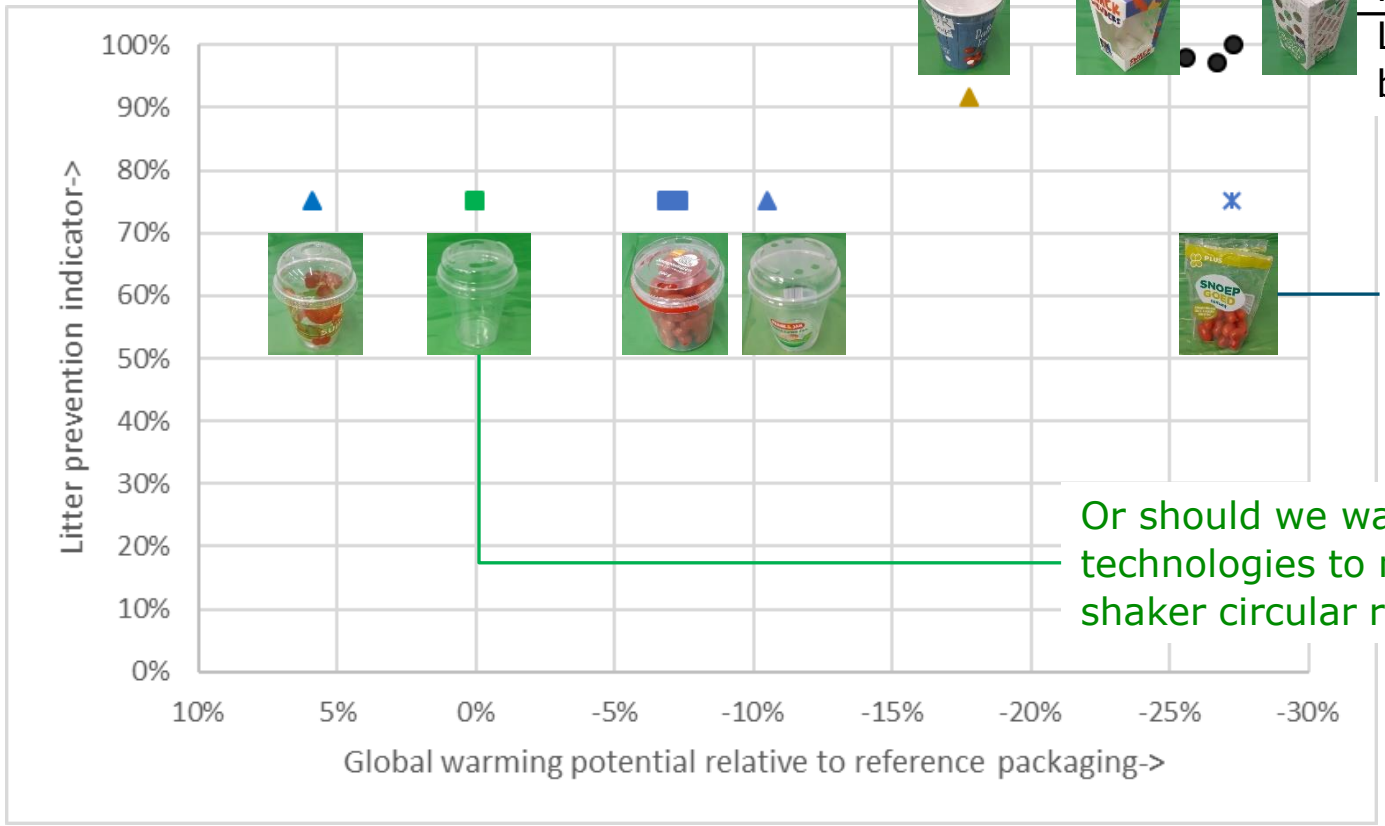
Pack	GWP-%	Recyclablity	Circularity	LPI
S1	100%	0/99%	0/99%	75%
S2	106%	0/99%	0/99%	75%
S3	97%	67%	0%	75%
B1	94%	82%	0%	75%
B2	95%	82%	0%	75%
CB1	79%	100%	0%	100%
CB2	80%	87%	0%	97%
CB3	80%	90%	0%	98%
CS1	88%	67%	0%	92%
SP1	79%	100%	0%	75%

LPI= littering prevention indicator

Conclusions snack tomatoes II

- Potential recyclability of the packages is fairly high
    - For PET shakers the development of a recycling technique for non-bottle PET is very important
- Circularity
    - None of the packages is currently circular recyclable.
- Litter Prevention Indicator
    - The cardboard based packages prevent littering the best

The snack tomato case



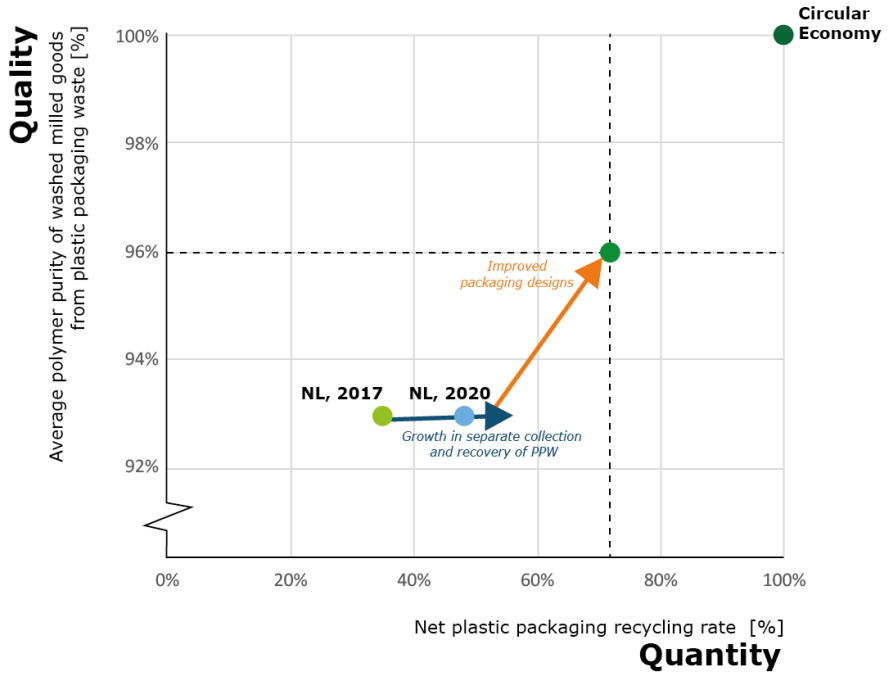
So what would happen if all plastic packages were designed for recycling?

And if we would recycle all plastic packages with the best current technologies?

The technical limit

Design for recycling maximised with the current mechanical recycling technologies

- improves the quality of the recycled plastics
- improves the chain efficiency



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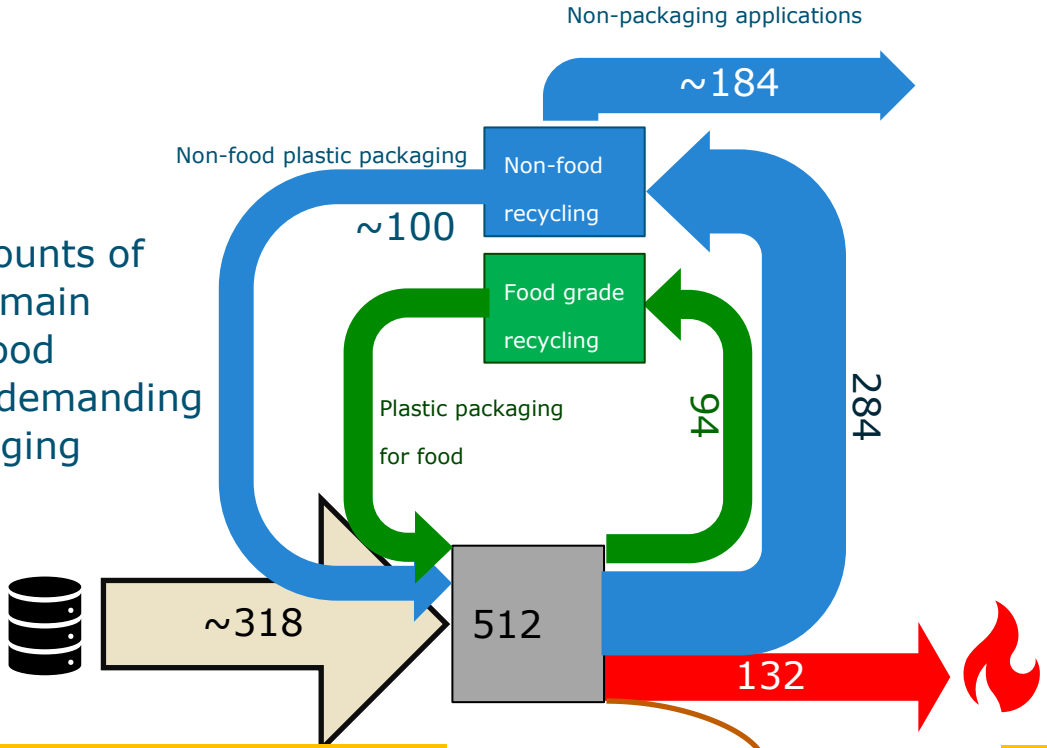
Circularity potential with current technologies

kiloton

Substantial amounts of virgin plastic remain necessary for food packaging and demanding non-food packaging



No decoupling from fossil feedstock

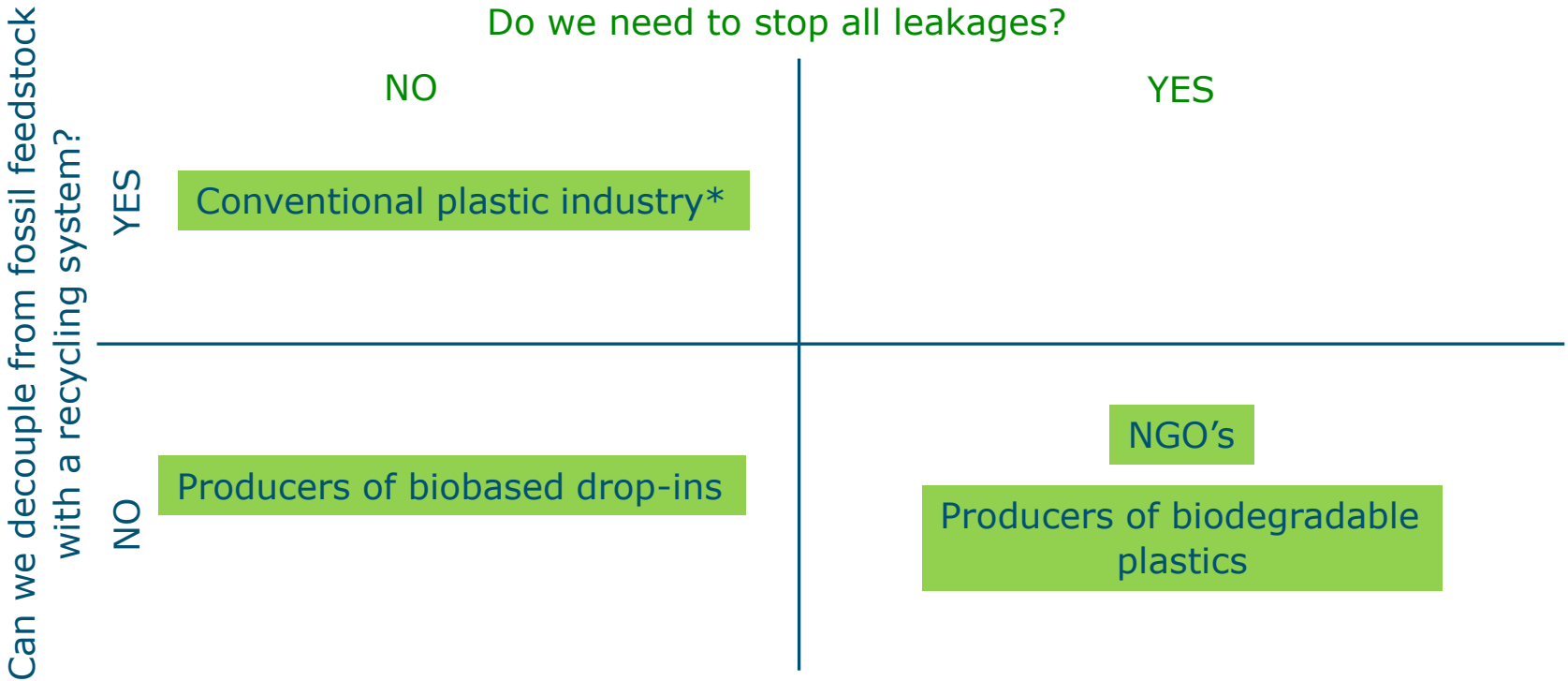
Potentially no solution for leakage

Diverging opinions of stakeholders

- Can we tolerate some leakages of plastics from recycling systems in the future?
  - YES: maintain status quo
  - NO: leakages have to be stopped: we need bans and to move towards biodegradable plastics

- Can we decouple from fossil feedstocks with a recycling system?
  - YES, maintain status quo
  - NO, we need to move towards biobased feedstock

Stakeholders' opinions



*:Systemiq 2022, "Reshaping plastics"

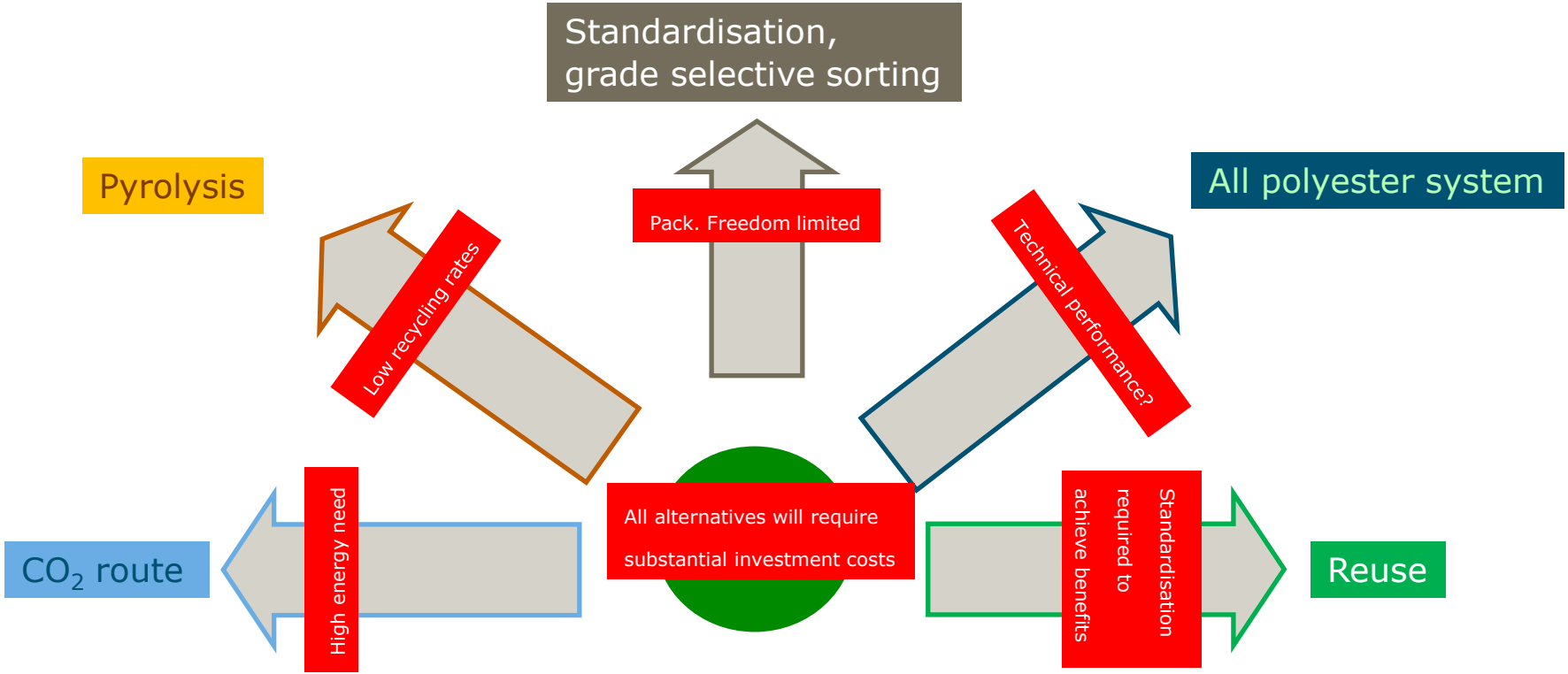
The vision of the conventional plastic industry

Steps	Circularity %	GHG emission Mt CO_2 eq.	Fossil oil use Mt
1 Base	14	112	44
2 Current actions	33	92	37
3 Reduce & Reuse	52	68	29
4 M&C Recycling+	69	41	24
5 3+4	78	33	20
6 5 + CCS + H_2	78	25	20
7 6 + biobased	78	0	11

1% mismanaged plastics is deemed inevitable

*:Systemiq 2022, "Reshaping plastics"

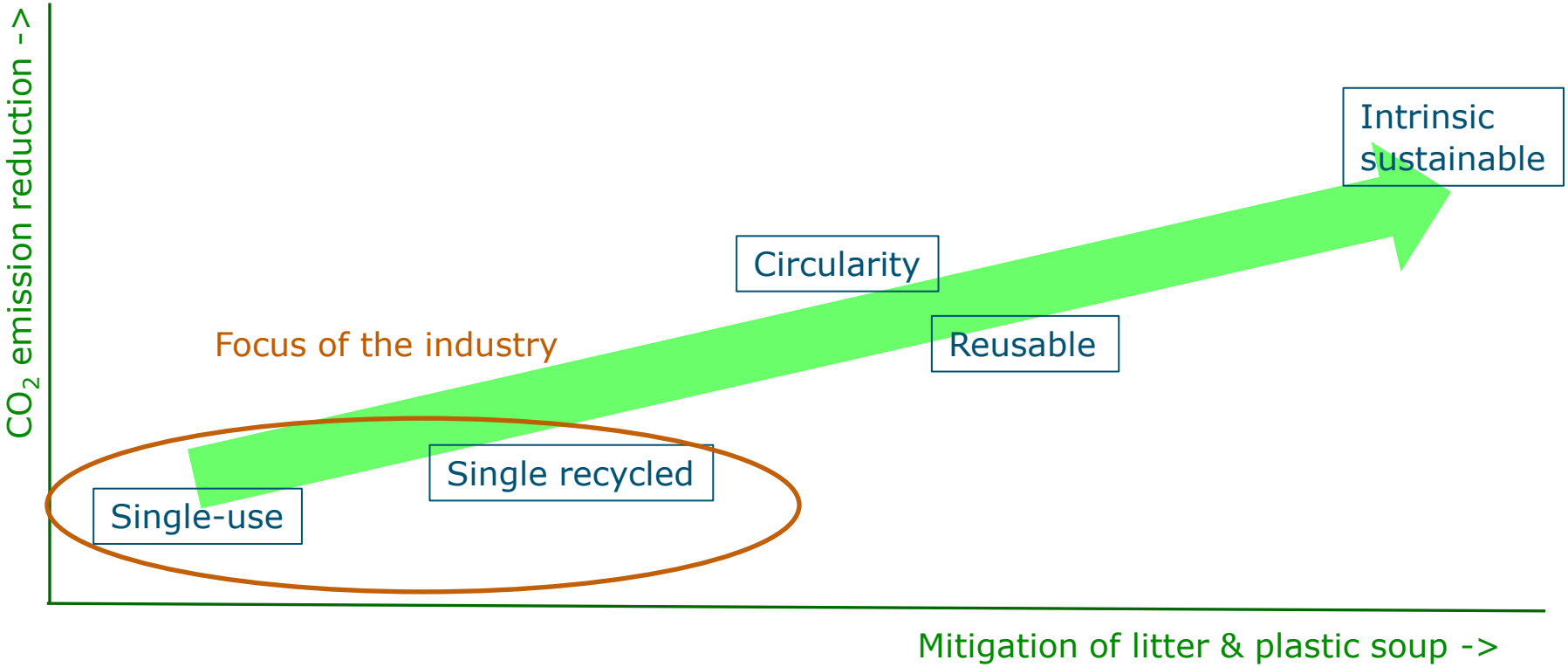
Diverging opinions between stakeholders



Governmental responses in the EU

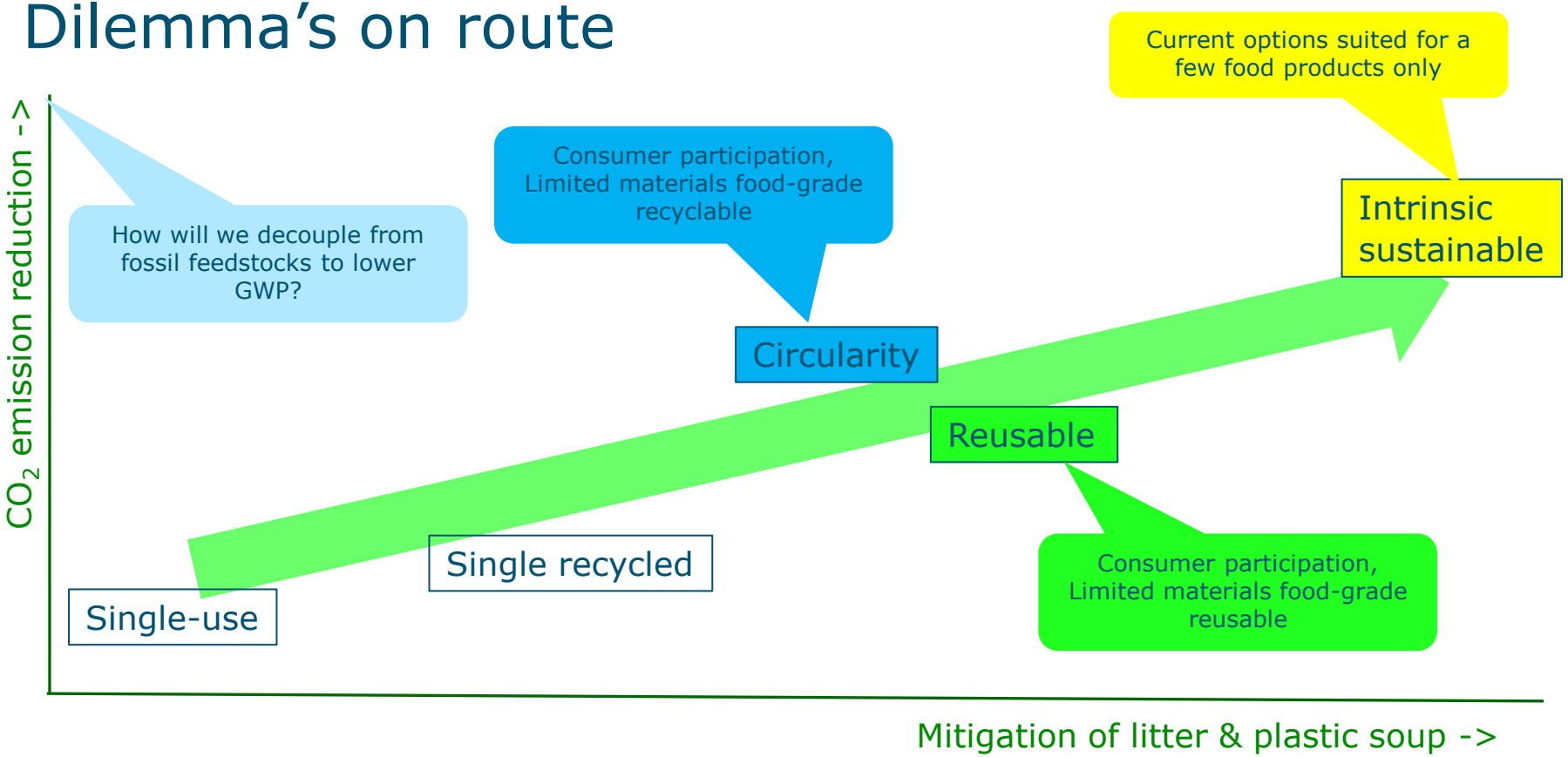
- EU 1994/62 Packaging waste directive -> PPW RR 22.5%
- EU 2008/98 Waste framework directive
- EU 2008/282 Directive on FCM made from recycled plastics
- EU 2018 Plastic Strategy
- EU 2018/852 Revised packaging waste directive -> PPW RR 50%
- EU 2019/ SUP directive
- *New revisions, taxes, bans, RC content policy, reuse targets*

Scientific perspective on sustainable packaging



KIDV, State of Sustainable Packaging, 2020

Dilemma’s on route



KIDV, State of Sustainable Packaging, 2020

Eventually we will need a system reset

- We need plastic food packages that protect foods, are recyclable, reusable, cheap and simultaneously:
- Biobased to decouple from fossil feedstocks – lower GHG emissions
- Biodegradable in nature - to minimise the impact of littering

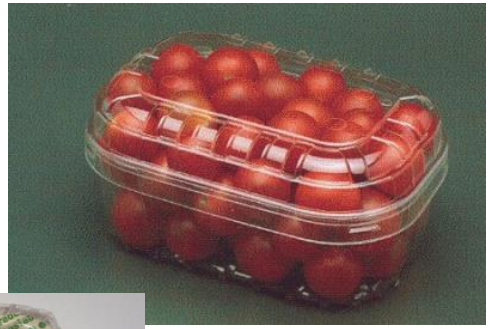
Biobased & biodegradable plastics

- Total market is currently estimated to be ~1% of plastics
- Heterogeneous group with many polymers and properties

DOI: 10.18174/408350

Bioplastics in food packaging

- Multiple bio-based & biodegradable materials are used / were tested



Furthermore, they offer potential solutions for currently non-recyclable objects

DOI: 10.18174/555442

Lessons learned with food packaging

- Technically multiple food products can be packaged successfully
- Current market share < 1%, because of a mixture of reasons:
    - Costs
    - Performance
    - System lock-in
        - No system for bioplastics currently present
    - Confusion over what bioplastics are and how they fit
    - Stakeholder opposition / defensive responses

A good possibility: PLA trays for salads

- Performance is well suited to pack products like salads
- Sufficient margin to pay a few cents extra on the package
- Opposition from:
    - Waste companies
    - EPR organiser
    - Recycling companies
    - Retailers

Opposition from waste companies

- It is getting more challenging to produce compost
  - Pollution in organic waste is rising (metals, glass, plastics)
  - Acceptance levels in compost are reduced
- Simultaneously composting times have been reduced
- Strong defensive response against compostable plastics, with the exception of: waste collection bags, tea pouches, coffee pads

- Although PLA composts faster than waste collection bags

DOI: 10.18174/514397

Opposition from the EPR organiser

- System lock-in. Afvalfonds qualifies PLA as non-recyclable, because
  - It is currently present in too small amounts in LWP,
  - Sorting companies do not invest in sorting equipment for PLA
  - And therefore it remains “non-recyclable”
  - High rate in the eco-modulation scheme

- Whereas it can be sorted efficiently and also recycled efficiently

Doi:10.1177/0734242X211003969
Doi:10.1177/0734242X18798448

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Opposition from PET recycling companies

- PLA cannot be removed by elutriation and could end-up in PET
- Only true for very rudimentary PET recyclers, most have flake sorters now

- Concentration in recycled PET is currently below 0.02%
- Even if 1% PLA would end-up in PET the impact on the properties of rPET would still be negligible when the PET is properly processed

Doi:10.1002/pts.2633

Opposition from some brand-owners / retailers

- "If it would already end-up in the organic waste and would be composted then it would just add CO_2 to the atmosphere"
- Feedstock policies to keep up materials in the current loops

- No urgency felt to decouple from fossil feedstocks to lower CO_2 emissions
- Unable to influence / orchestrate collection & recycling value chains

Role of the Dutch government

- *Transitieagenda Kunststoffen*
  - Strives for 15% biobased input in the plastic system

- Letter to the parliament of June 10th 2021
  - Limit the use of biodegradable plastics to where they offer additional benefits
    - Concerns that they will pollute organic waste, LWP and result in more littering

Our challenge

- We need to reset the system and somebody has to orchestrate it
- Stakeholders have different visions for the future
    - There is no common understanding of the environmental impacts
    - Many lack a sense of urgency
- The governments do not understand that they stifle progress

For intrinsic sustainable packages we need:

- Alignment & active participation of all stakeholders
    - Civilians, FMCG industries, Waste companies, Governments
- Credible pathways to integrate biobased & biodegradable plastics in the recycling & waste management systems
- Prove that we can sort and recycle them in large scale with the common impurities
- New materials that have sufficient performance, are recyclable or reusable and bio-degradable when littered

Thank you

Plastic packages will remain in focus for the coming years

There are no quick fixes

But we all could start...

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