Circularity for Plastics : Challenges, Concepts and Fundamentals

AICHE Lecture Dinner Meeting, 25 January 2018

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This presentation is about…

- An new world full of apparent paradoxes
- New questions looking for out-of-the box answers
- A lucid virgin resin industry perspective :
  - « déjà vu » - long ago …
  - A new exciting role as key contributor

- ENGINEERS needed in the driving seat !!

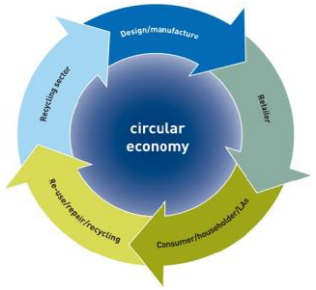
Stages of Industrial Maturity

Circular plastics industry

	LOW	MEDIUM	HIGH
Know-how basis	Practical, pragmatic	Applied technology inputs + documented experience	Fundamental science
Operation mode	Human intervention ; procedures = tips & tricks, indirect optimisation	Automated with human finishing ; standard operating procedures, good equipment	Fully automated ; operator = supervisor / controller & for abnormal situations
Product Quality	As good as possible ; low consistency	High but strong dependance on human intervention	Too high for human inputs, consistency by automation
Development	Trial & Error	Analysed test runs	**Science based** design and operation
Position of science	Basic, low awareness	Growing understanding **resulting** from documented experience	Deep mastering, **basis for** development

ENGINEERS reverse the position of science
from analysis to design

Two worlds, two types of professionals



Circular economy / Plastics waste & recycling

Entrepreneurs

Technicians

Lawyers

Waste sorters

Marine biologists

Civil servants

Lobbyists

Social workers

Politicians

Strategists

Logistic

Economists

Marketeers

Idealists

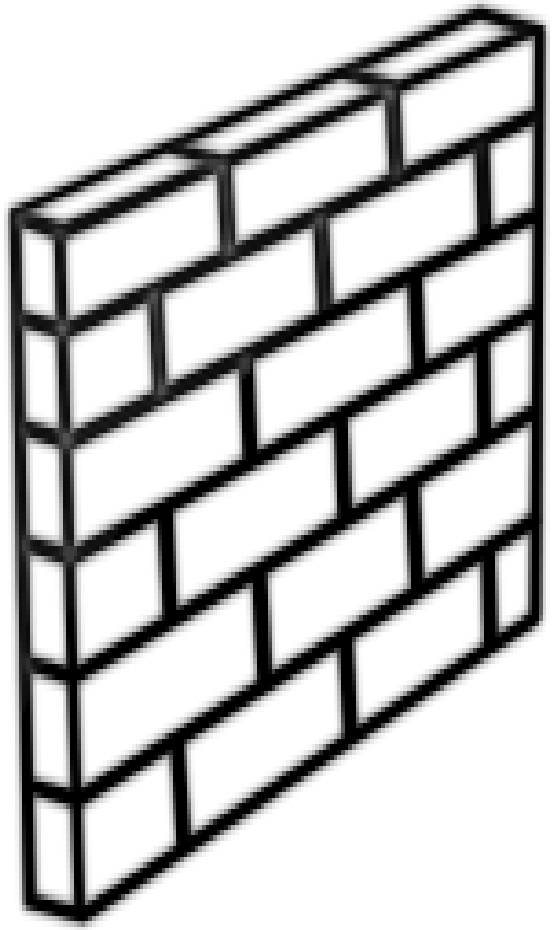
Financers

Environmentalists

NGO

Ecologists

Consultants



Linear economy / virgin resin production

Chemists

Engineers

Polymerists

Material scientists

Circular Economy
2010 Virgin plastics industry's perspective

Circular Economy

2018 Virgin plastics industry's perspective …

Circularity and virgin producers : plastics versus other commodities

Product	World market	Estim. Recycled content	Role of 'virgin' industry
Steel	1600 MT	60%	Key contributor to the circular chain : **Technology based enhancer** / stabilizer of recyclate for downstream use as recycled content, just like virgin material
Paper / Cardboard	400 MT	70%	
Aluminium	90 MT	45%	
Glass	55 MT	50%	
Copper	25 MT	35%	
Plastics (°)	**310 MT**	**~9%** (°)	**No significant involvement**
PET = exception	77 MT	25%	Active cooperation to strengthen recycling

(°) without PET : < 6%

Why do we care …?
new (virgin) materials segmentation !

Linear (« fossil ») materials :

- Single use lifetime ; end-of-life = in land or sea, or partly recovered as energy
- **Little or no good recyclate available**
  - landfilled
  - Incinerated
  - exported
- Impossible for converters and brand owners to combine virgin material with recycled content
- *Gradually de-selected, and **substituted** by circular materials, wherever possible.*

Circular materials :

- Multiple use lifetime ; waste = new feedstock
- **Plenty of good recyclate available, for use as recycled content**
- Structural cooperation between 'circular stakeholders', preserving the circularity.
- **Virgin** materials thrive as 'performance enhancer' for 'recycled content'
- *Growth, development, new technologies and competencies, gradually substituting linear materials*

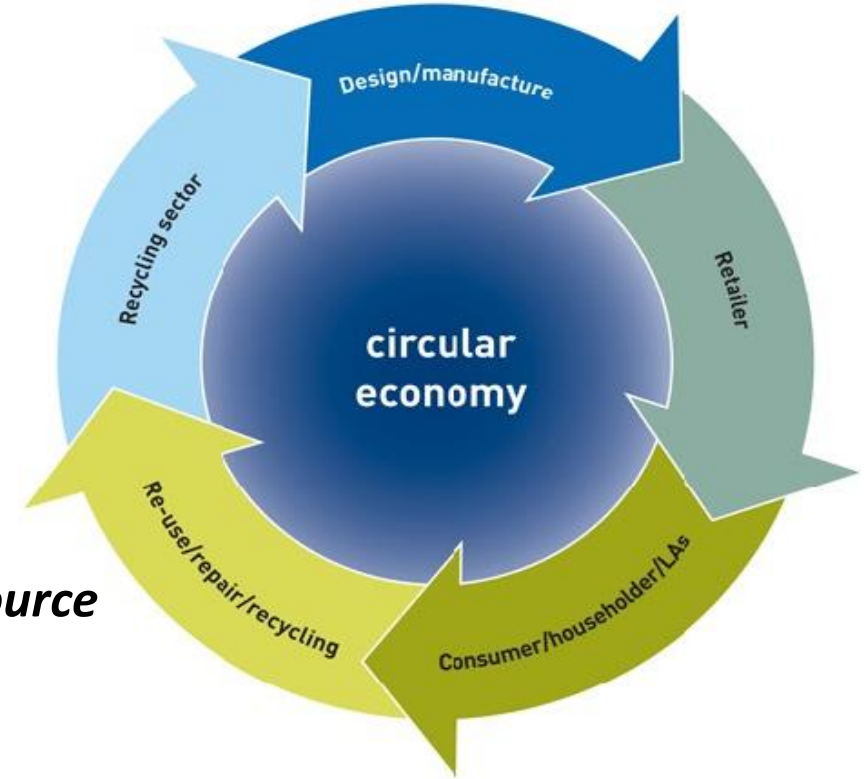
Circular economy : ‘the force’ indeed…

- Circularity = very strong concept : **simple and visual :**

  showing the direction where to go (over time)

  Umbrella citerium

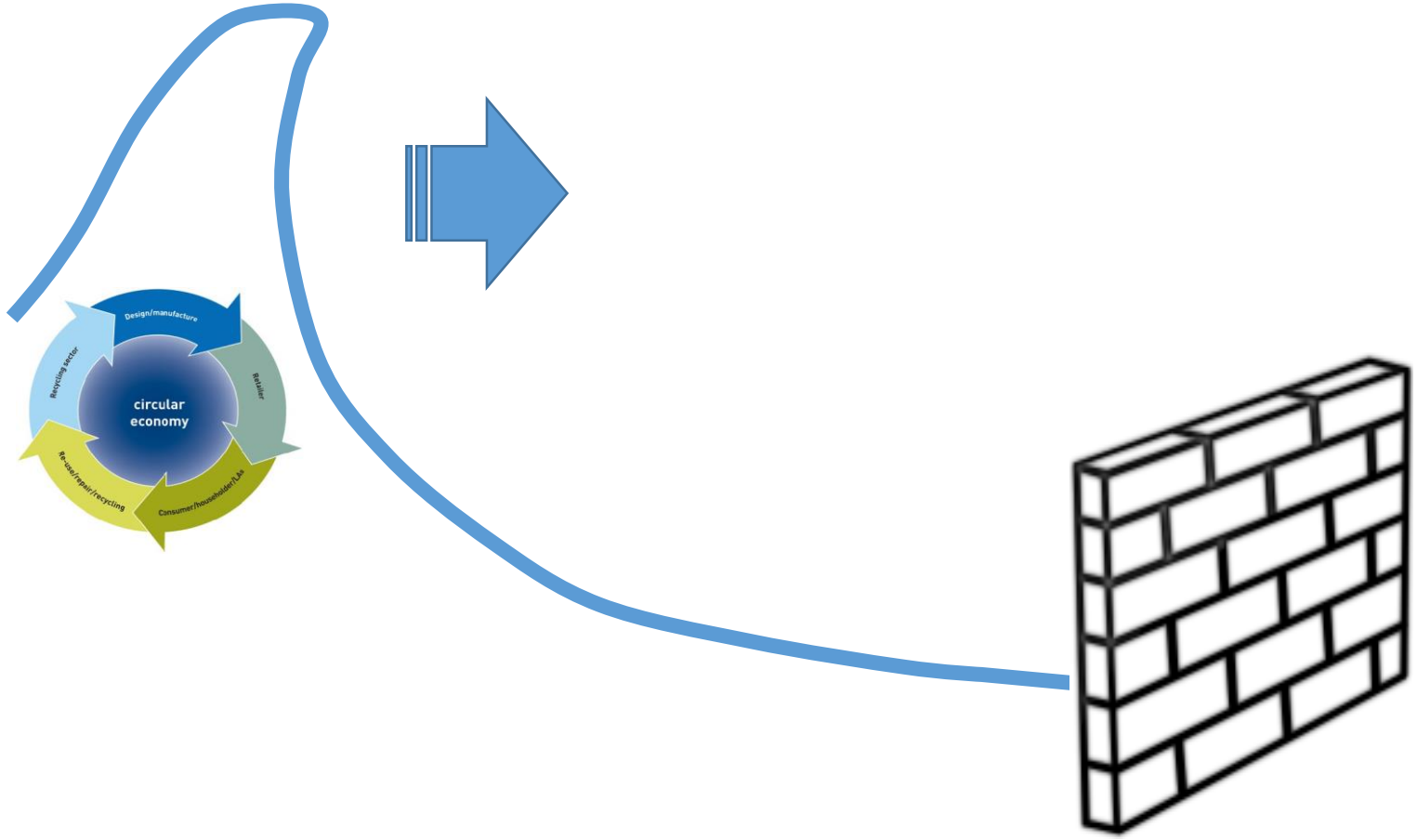
  No trade-offs, no confusion, easy to understand



- **Creates a new <u>hierarchy of priorities</u> !**
  - ***« OK to optimize costs, profitability, marginal CO2 and resource minimisation etc. but within boundaries of circularity »***

- Comparable to ‘Safety First’ criterium that revolutionized safety management in the industry since ~1980
  - *« OK to optimize cost and production, within boundaries of safety »*

Megatrend = TSUNAMI



Circular economy : What drives it really ?

Waste actors

Public | Private

Associations / EPR schemes

EU

National

Regional

Local

Authorities

KPI's | *Criteria*

Rules | *Achievements* *Constraints*

Industry

Material producers

Convertors

Brand owners

Distribution

Consultants

Political groups

Citizens

Voters

Waste producers

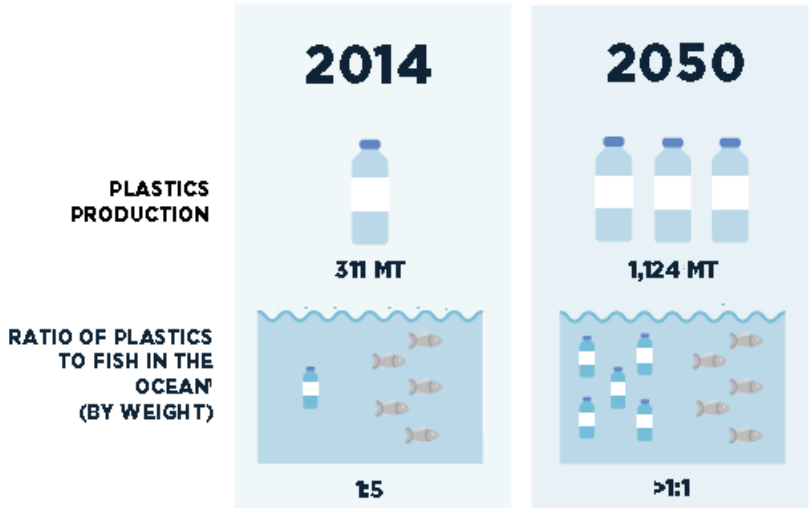
Investors

Customers

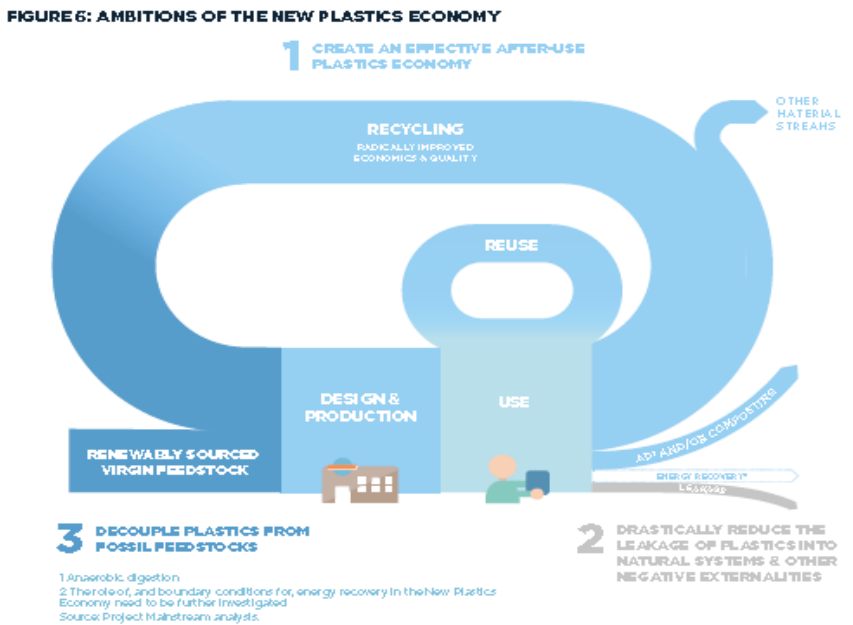
Central Driver =
capital of public sympathy for RECYCLING

Catalysing effect : Plastic Marine litter : from public concern …

To main policy driver !



« New Plastics Economy »



EU Recycling targets

for plastic packaging

75%

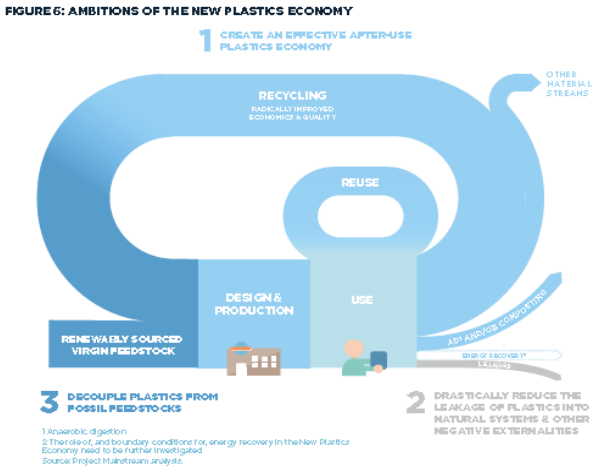
65%

55%

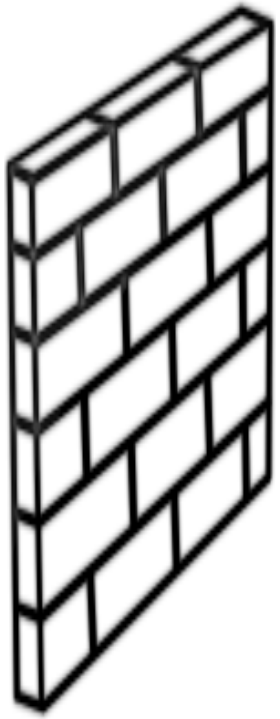
30% (2017)

Recycling = HOT : however, different perspectives

Design for Recycling



Criteria / Recyc-lability	Container (Main component)	Sub-components (Closure, lids, seals, inserts, tamper resistance, labels and sleeves)	Colour, print and adhesive	Identification	Residues	Mark level:
High	The container is made in mono-material (Either PET, PE, PP or PS).	Sub-components are made in the same mono-material as the container	No colouring and minimal print, e.g. date stamp. Adhesives are reduced to a minimum and are water soluble at 60°-80°C.	Labels and sleeves are made the in same mono-material as the container	No residues after use. Emptying only takes a rinsing in cold water.	
Good	The container is made in mono-material (PET, PE, PP or PS).	Sub-components are compatible with the container.	Minimal colouring and print. Adhesives are water soluble at 60°-80°C.	Labels and sleeves are compatible and does maximum cover 60 % on bottles and 60% on tubs, trays and pots.	Can be emptied in cold water or by use of a simple tool, e.g. a spoon.	
Uncertain	The container is in compatible materials.	Sub-components are compatible.	The container is coloured and printed. Adhesives are water soluble.	Labels and sleeves cover more than respectively 60% and 60% of the surface.	The packaging require separation to be emptied.	
Unfit	The container is composite of non-compatible	Sub-components contain metals and/or paper.	The container is coloured with carbon black or heavy colours. Adhesives are not	Labels and sleeves are in a different material than the container and cover the entire	The packaging cannot be emptied.	



Recycler's CEO :

"Our profession is ***cursed …***"

« The messages are OK, but reality goes <u>systematically</u> in the wrong direction »

« Every <u>innovation</u> creates new problems »

Eco - design = War zone !
recycling technology vs. packaging innovation

Packaging innovation :

- Multi-layer, multi-material
- New materials ;
- Sleeves in different material than bottle
- Carbon black, not seen by sorting equipment
- Foaming heavy materials, fillers in light materials

Disruptive innovation often justified by 'sustainability' rationale !

Felt as 'sabotage'

Design for Recycling today : pragmatic aproach

RecyClass™

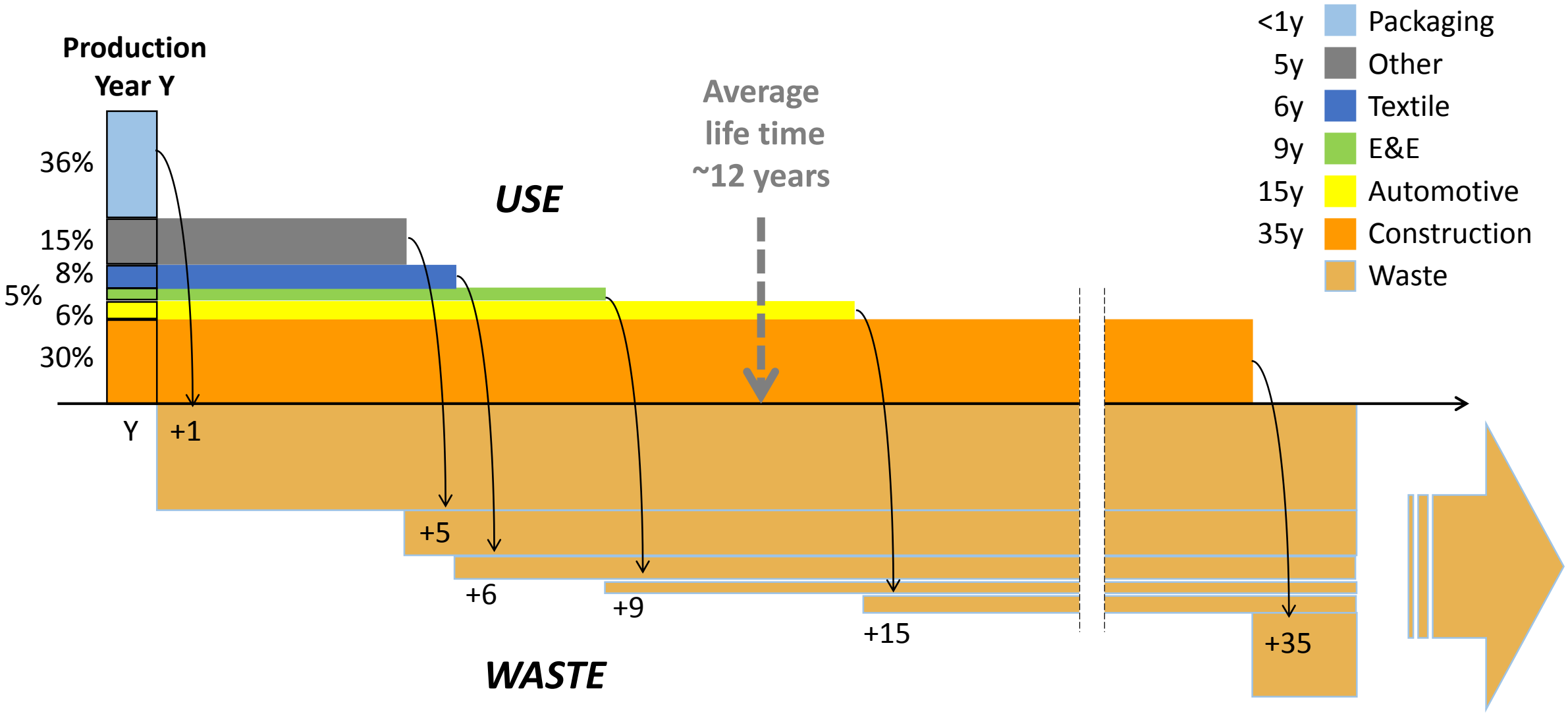
PE-HD Coloured Containers

	YES Full compatibility Materials that passed the testing protocols with no negative impact OR materials that hare not been tested (yet), but are known to be acceptable in PE-HD recycling	CONDITIONAL Limited compatibility Materials that passed the testing protocols if certain conditions are met OR materials that hare not been tested (yet), but pose a low risk of interfering with PE-HD recycling	NO Low compatibility
Container	PE-HD		multilayers PE-HD+ (PLA; PVC; PS; PET; PETG)
Colours	all colours	black inner layer	black
Barrier		EVOH ≤ 1%	EVOH > 1%; PA; PVDC
Additives			additives increasing the material density > 1 g/cm³
Closure Systems	PE-HD; PE-LD; PE-LLD; PE-MD	PP; PET; PETG; PS; PVC; PLA	foams with density < 1 g/cm³; aluminium
Liners, seals and Valves	PE-HD; PE-LD; PE-LLD; PE-MD	PP; PET; PETG; PS; PVC; PLA; removable aluminium fasteners	aluminium; foams with density < 1 g/cm³; metal; foiled paper
Sleeves	PE-HD; PE-LD; PE-LLD; PE-MD	PP; PET; PETG; PS; PVC; PLA	aluminium; metalised materials; heavily inked sleeves
Labels & Adhesives	PE-HD, PE-LD, PE-LLD, PE-MD labels; water soluble releasable adhesive (less than 40ºC)	PP and paper labels; PET, PETG, PS, PVC, PLA labels with water soluble releasable adhesives; pressure-sensitive labels	PET, PETG, PS, PVC, PLA labels with non water soluble releaseble adhesives; self-adhesive labels; aluminium; metalised materials
Inks	non toxic (follow EUPIA Guidelines)		inks that bleed; toxic or hazardous inks
Direct Printing	laser marked; production or expiry date		any other direct printing
Other Components	PE-HD; PE-LD; PE-LLD; PE-MD	PP; PET; PETG; PS; PVC; PLA	aluminium; foams with density < 1 g/cm³

Robust enough ?
Arbitrary ?
Survive innovations ?
Scientific basis ?

Waste and its science

Transformation from plastic to waste



Domestic plastic waste & recycling chain (packaging mainly)

Selective collection

Primary sorting by citizen

Trucks

Container parcs

Sorting

Manual

Mechanical

Belgium :
9 sorteing centers

Mono-material
« Bales »

trading

Recyclaging plants

Post-sorting,
Grind, wash

Fine sorting

Melt filtering,
(degassing)

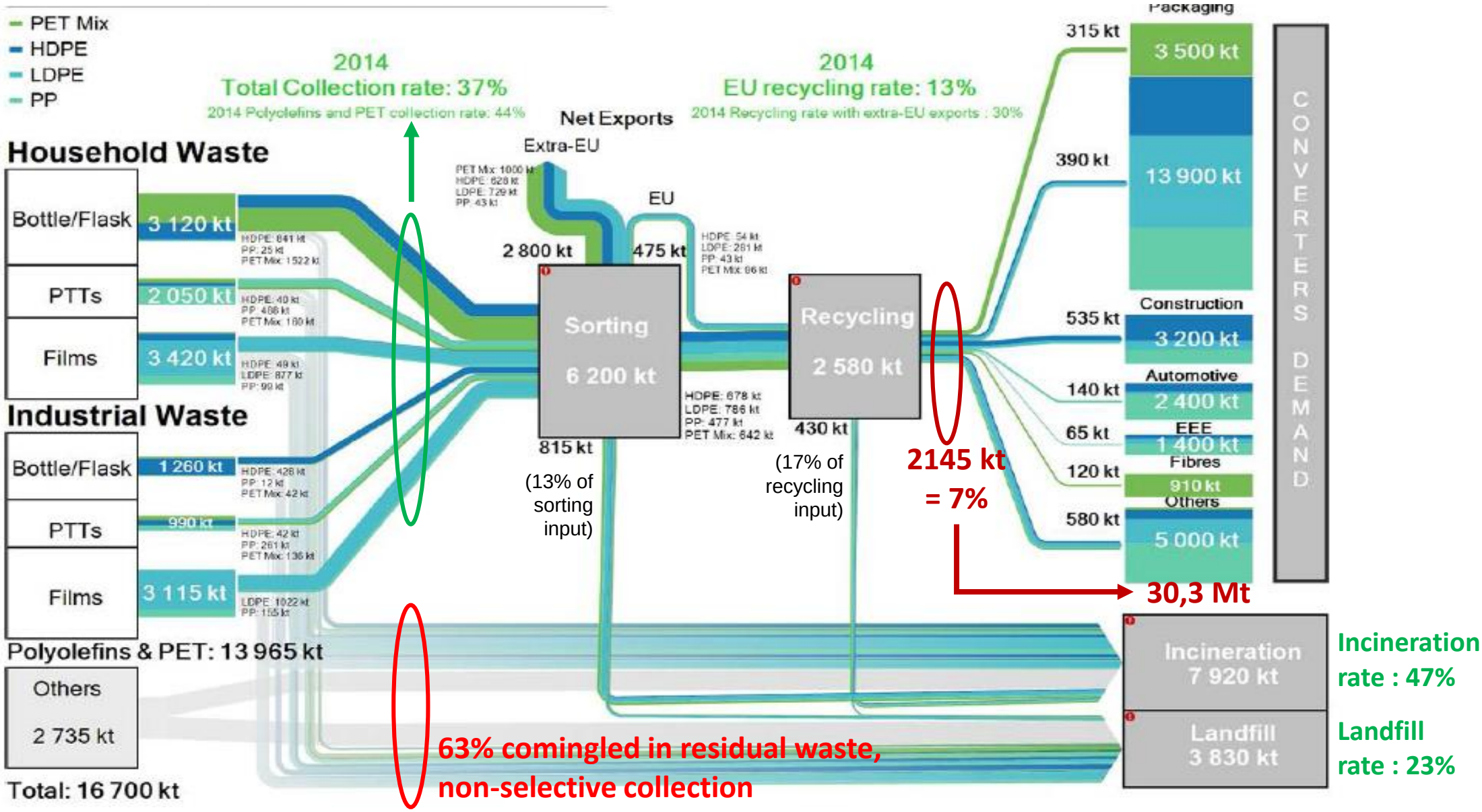
Post-Consumer Recyclate (PCR)

Washed
« Flakes »

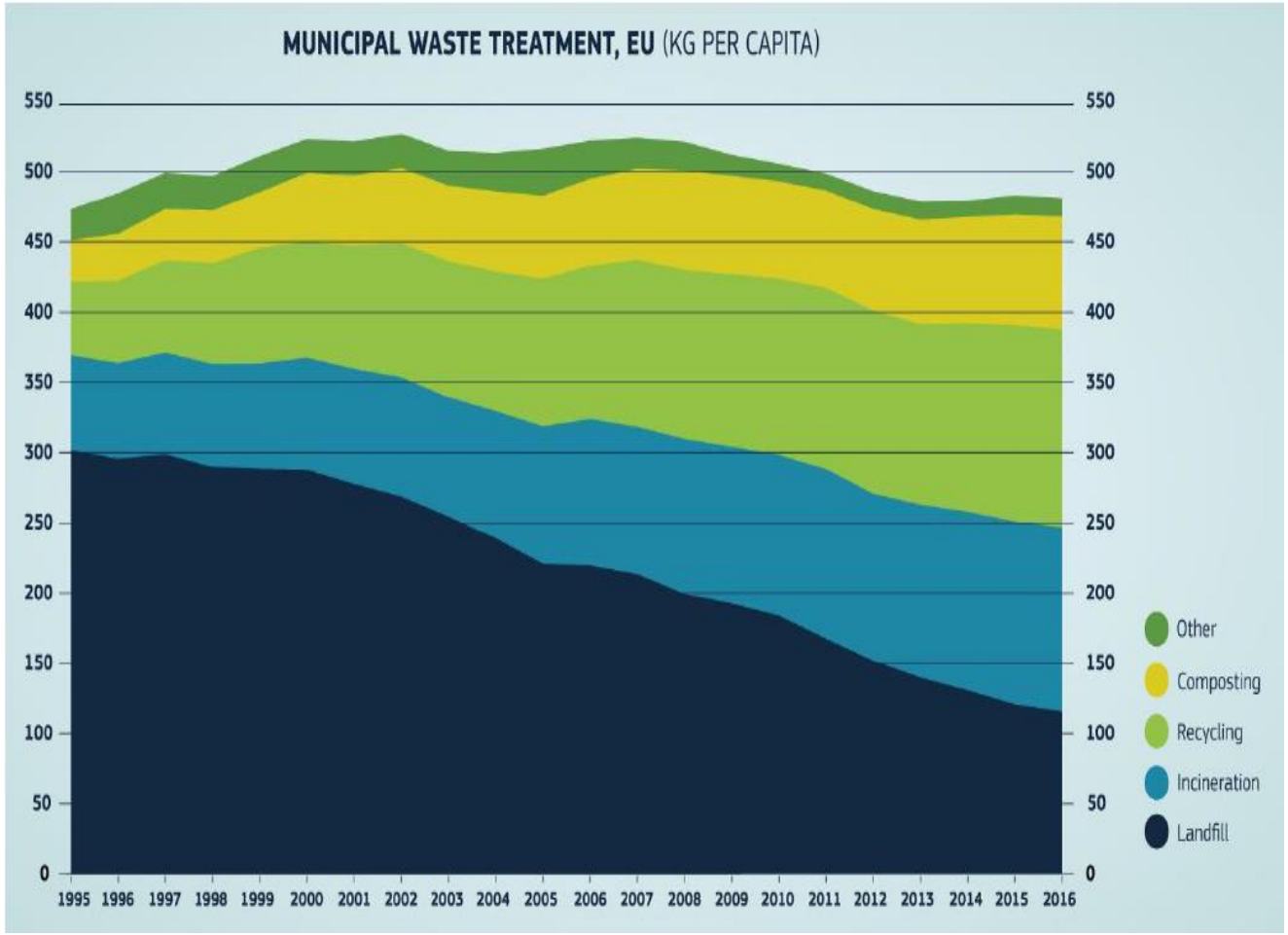
Pellets

EU plastic *packaging* waste streams 2014

Source : Deloitte - Plastic Recyclers Europe



Municipal waste in EU



'Waste' expressed in Tons : OK?

3 advantages of 'mass':

1) Easy to measure
2) It is not lost, can be followed through the chain
3) Estimation of potential economic value after recycling

Disadvantage : *mass is quite irrelevant to express the 'waste quality' …*

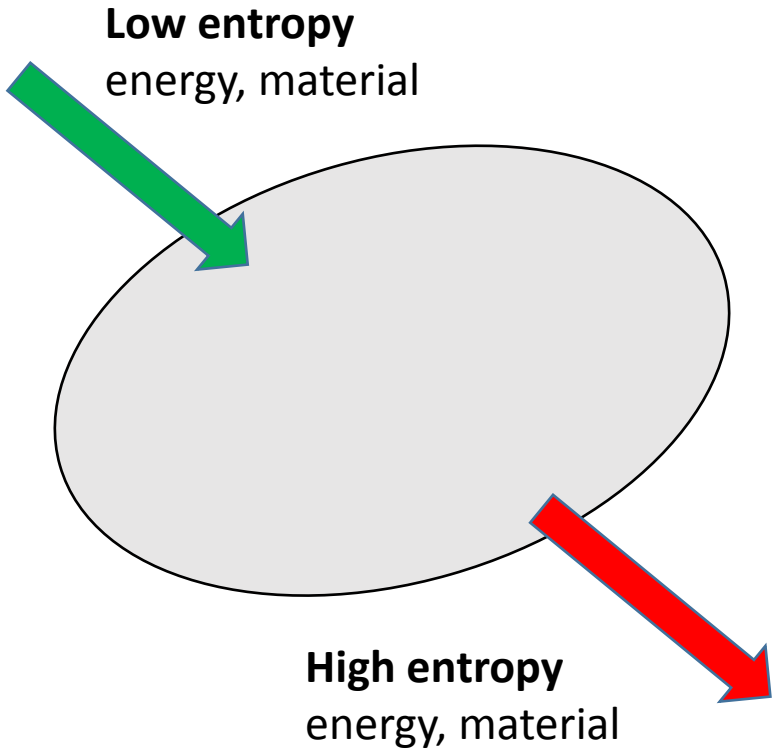
RUDOLOGY : the science of waste

Pioneers in 1970 - 1980

- William Ratjeh (Tucson, Arizona)
  - archelologist ; term « garbology »
- Jean Gouhier (France)
  - Teacher – geographer
  - Inventor of waste management concept
  - founder of 'Institut de rudologie' and 'Master Déchets et Economie Circulaire'
- Gerard Bertolini (France)
  - Economist specialised in waste ; directeur CNRS
  - « Waste = accurate as ID card or DNA »
- Ilya Prigogine (Belgium)
  - thermodynamics of « dissipative systems »
  - **Waste = high entropy**
  - 1977 Nobel Price Chemistry !

Remember : thermodynamic perspective on waste

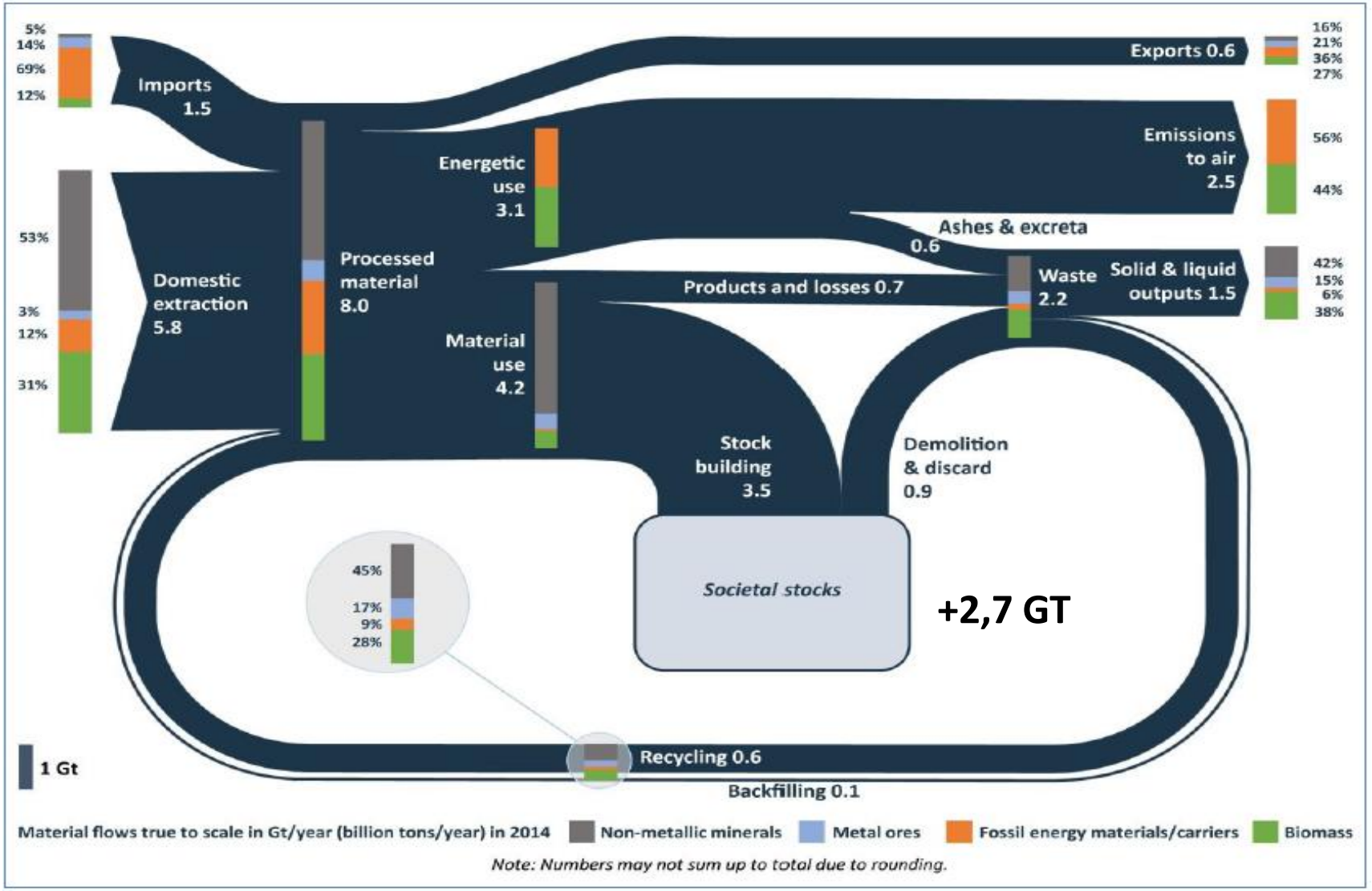
- Closed systems : evolve necessarily to maximum entropy level
- « Dissipative systems »:
  - Can maintain or reduce entropy (only) by importing resources and exporting waste
    - Resources = low entropy material and energy
    - Waste = high entropy material and energy
- Examples of dissipative systems:
  - Any living entity
  - The ‘anthroposphere’
  - Earth (open for energy, closed for materials)



EU material balance 2014

7,3 GT

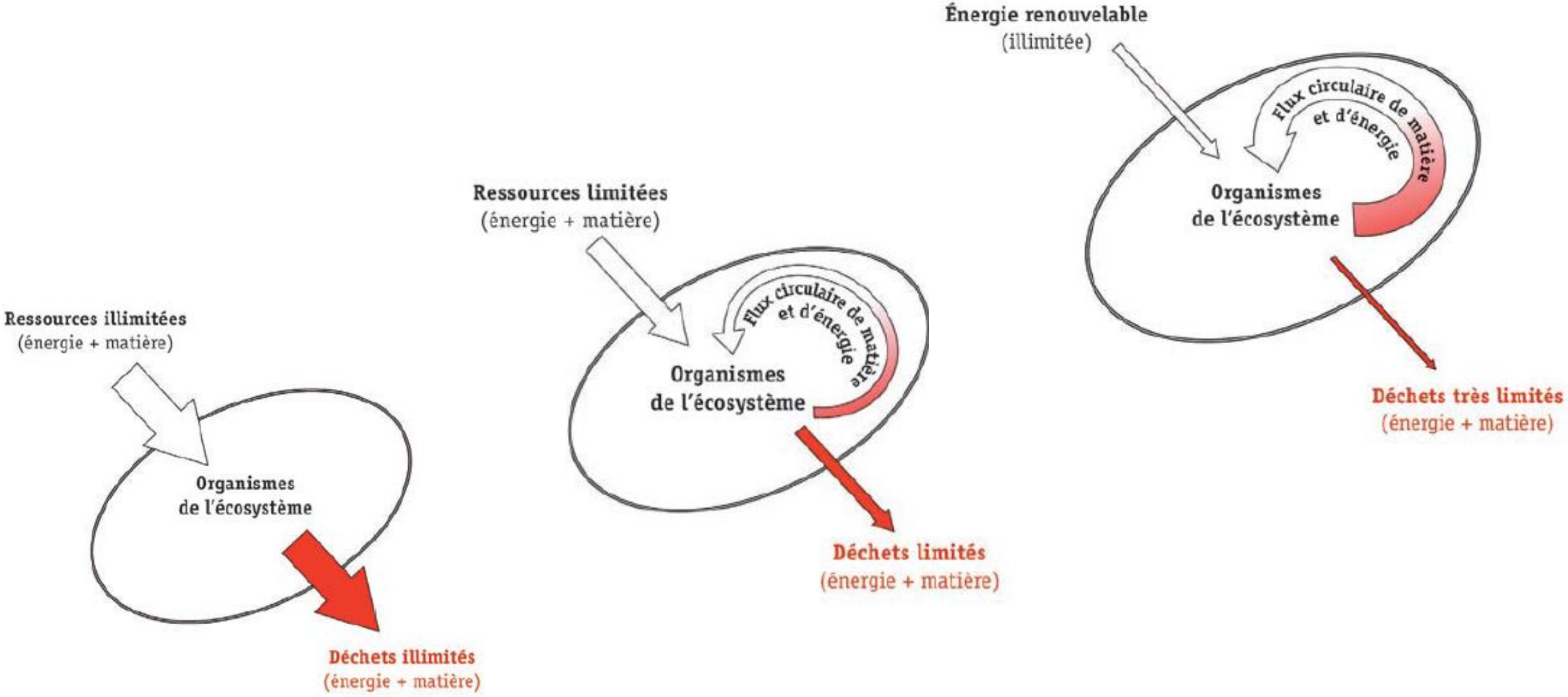
Low entropy



4,6 GT

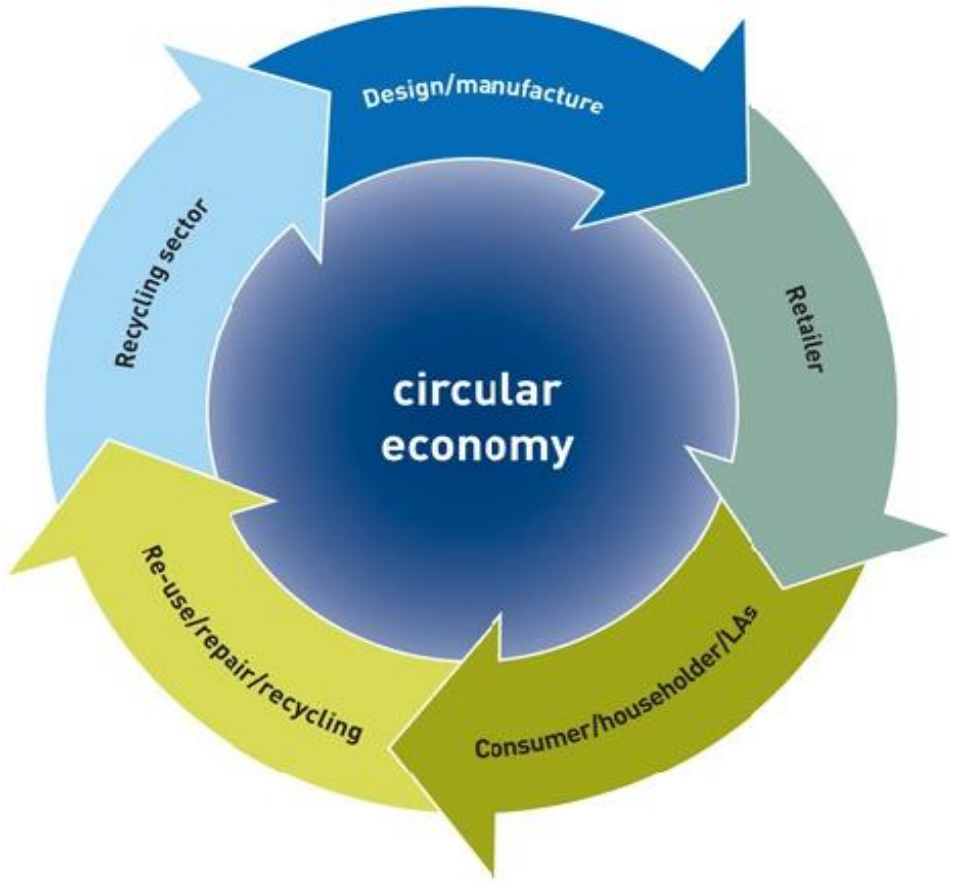
High entropy

Thermodynamic perspective on the Circular Economy



Source :
Les déchets – du Big Bang à nos jours

The EU Circular Economy's Aims



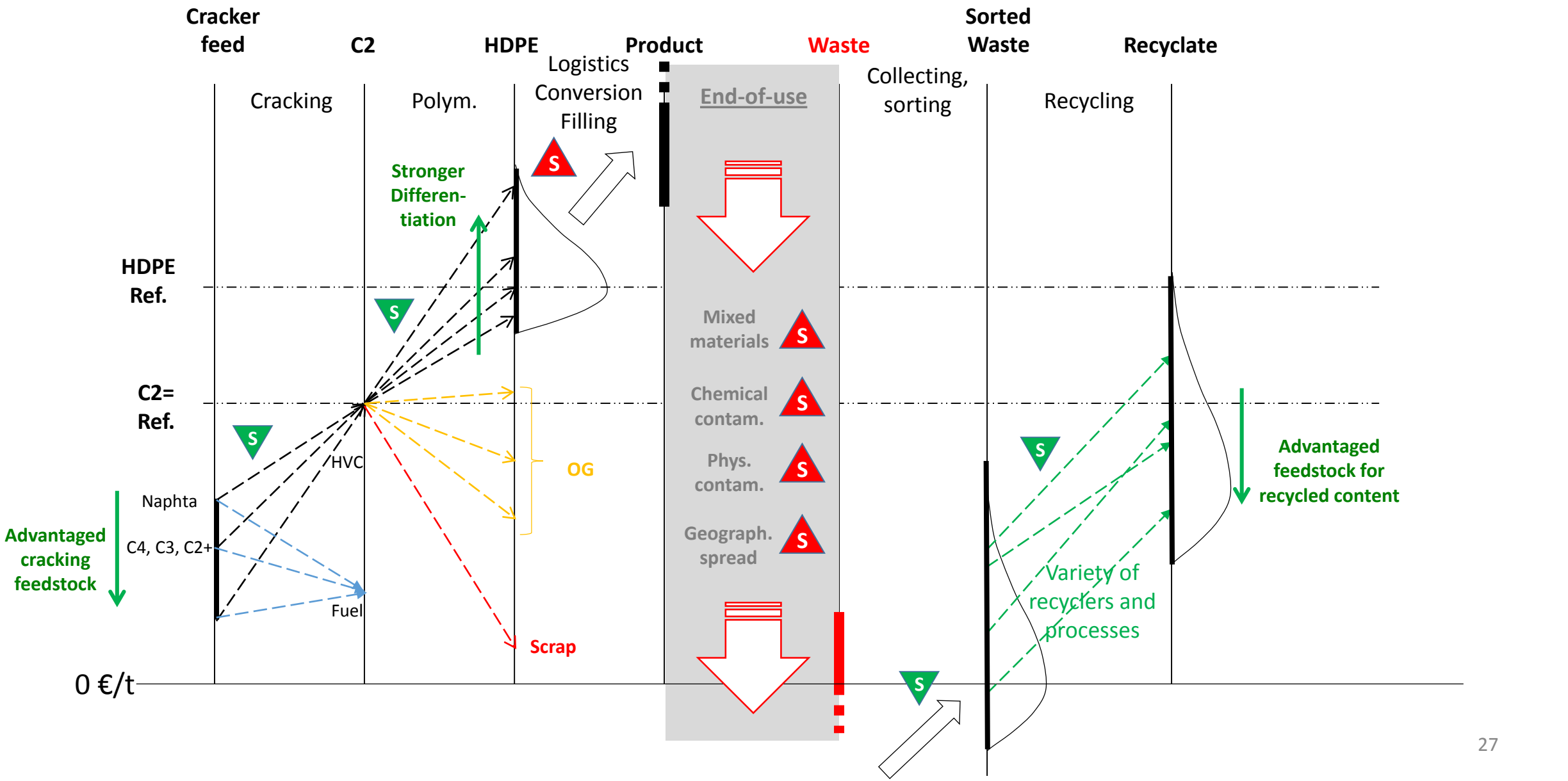
Since 20 years

- To develop a sustainable, low carbon, resource efficient economy
- To transform Europe's economy and generate new and sustainable competitive advantages

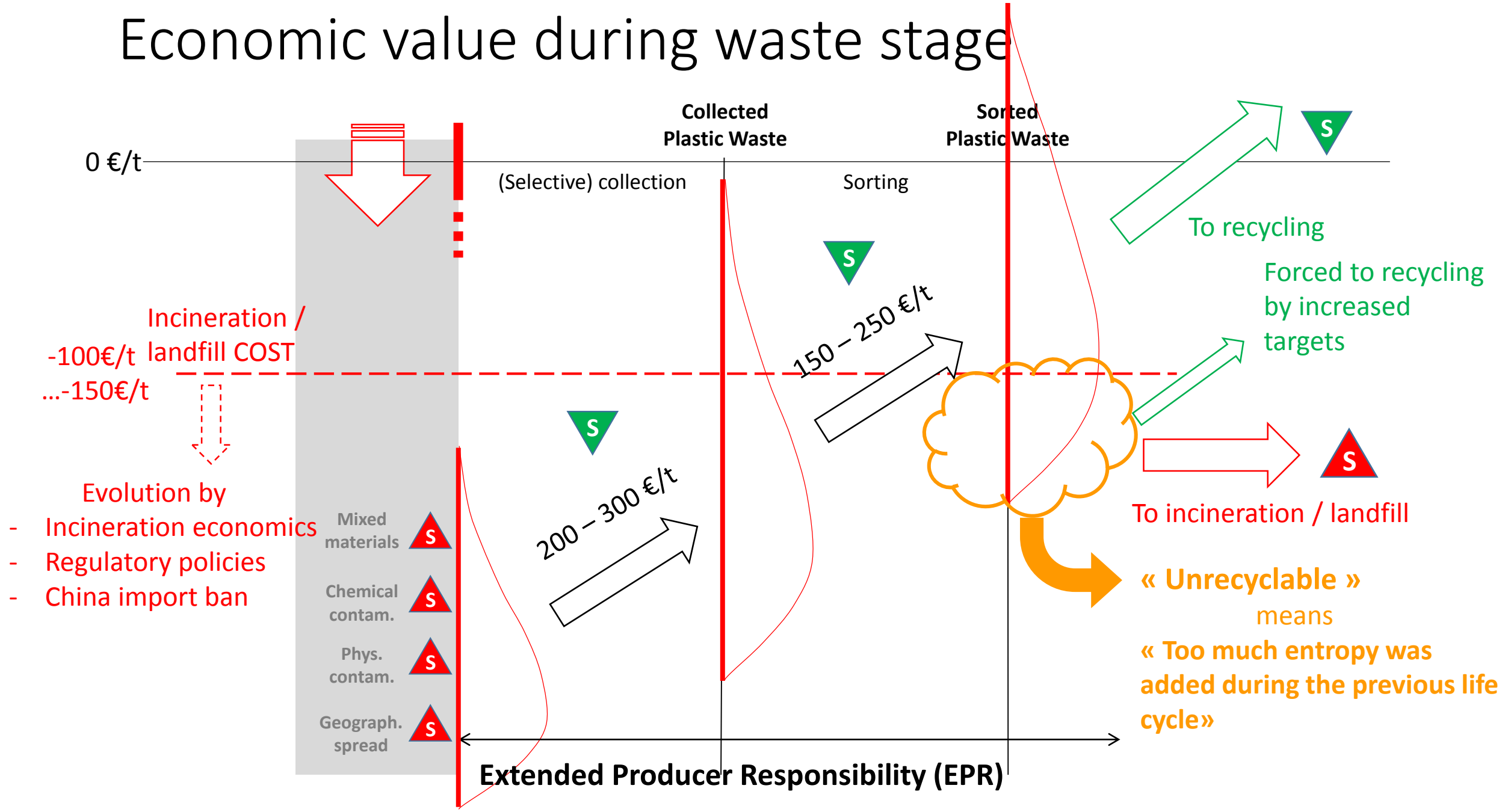
NEW

To maintain value of products, materials and resources in the economy for as long as possible while minimising waste generation

Economic value evolution of polymer molecules



Economic value during waste stage



Circular processes are low entropy proceess !

- Brake of a regular car : kinetic energy transformed into heat, then dissipated : strong entropy increase…

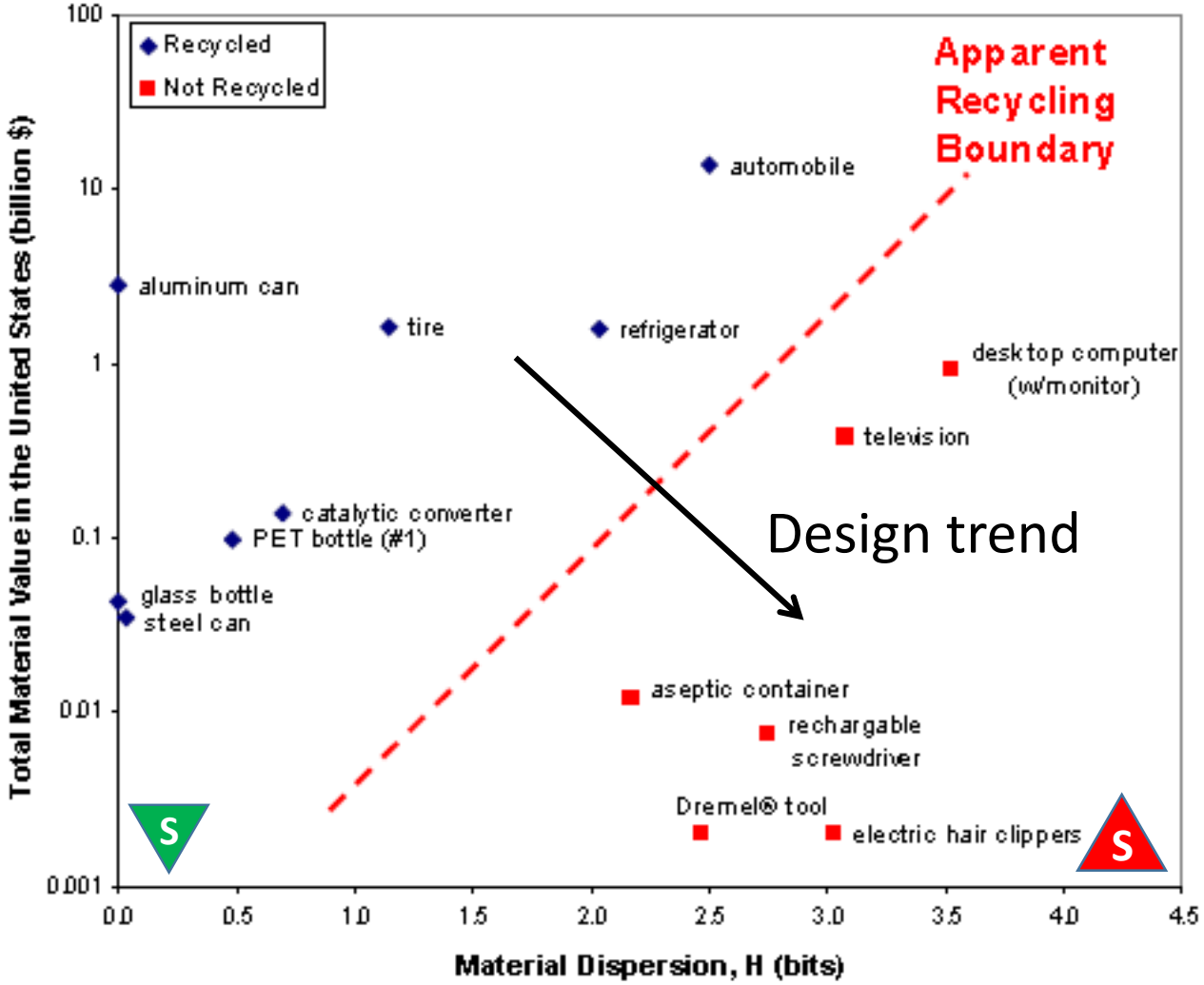
« LINEAR BRAKE »

- Brake of a hybrid car : kinetic energy transformed into electrical energy, then into chemical energy (battery), readily available for re-use : almost no entropy increase…

« CIRCULAR BRAKE »

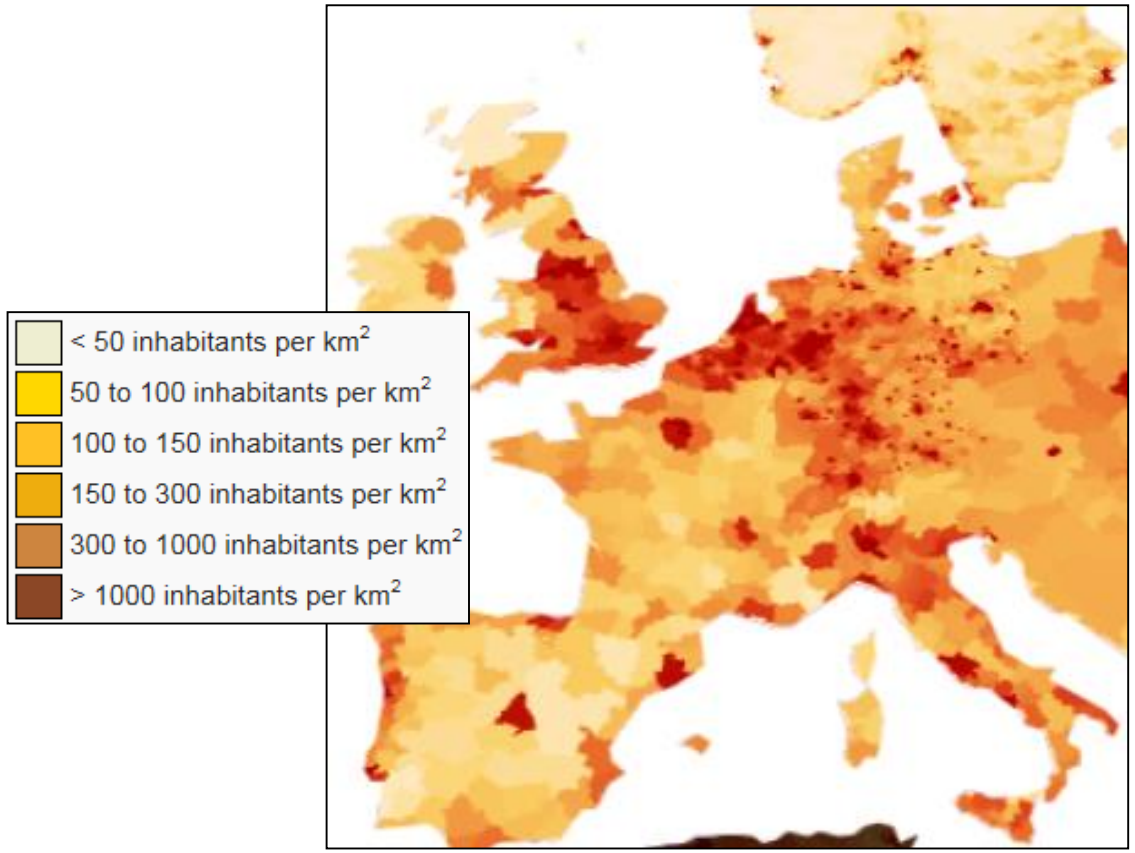
Entropy, recyclability and product design

- M.I.T. Paper ‘Mixing Entropy and Material recycling’
- Society recycles those materials with high ‘total material value’ and low dispersion
- Designers are constantly moving products to the lower right corner : using less expensive material and increasing functionality, often by more components



Source :‘Mixing Entropy and Material Recycling’,
Timothy G. Gutowski and Jeffrey B. Dahmus (MIT)

Waste generation map : cfr. oil & gas fields…



But… logistic entropy put limits to ‘economy of scale’ for high capex installations

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Enhanced Landfill Mining … Renewable Landfill …

- 500.000 landfills in Europe
- Organics have composted
- Plastics : in good shape ! No oxygen, no UV…
- Currently : focus on metals…
- 5-6 February : symposium in Mechelen

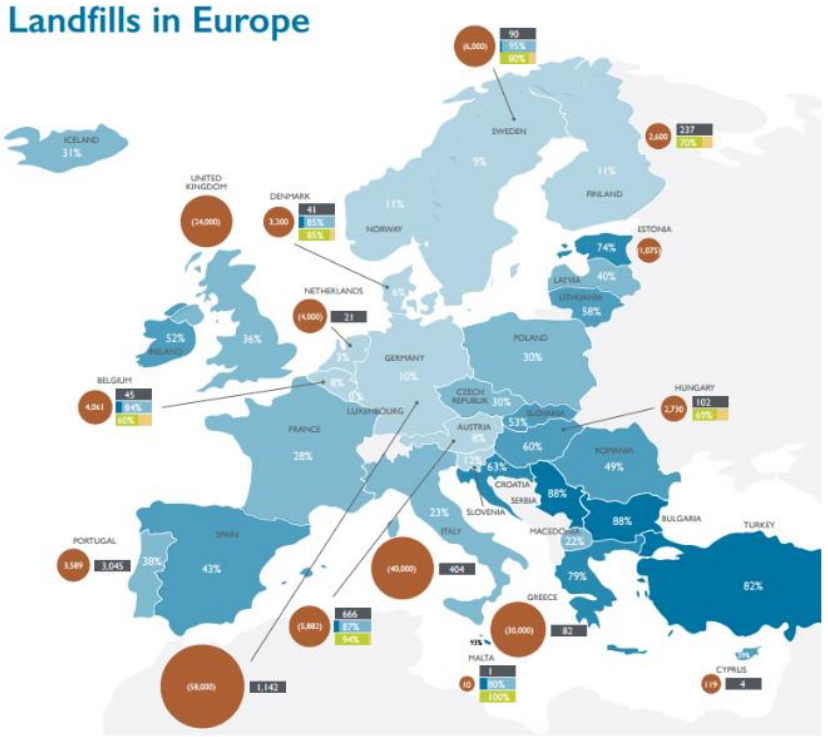


Image: EURELCO

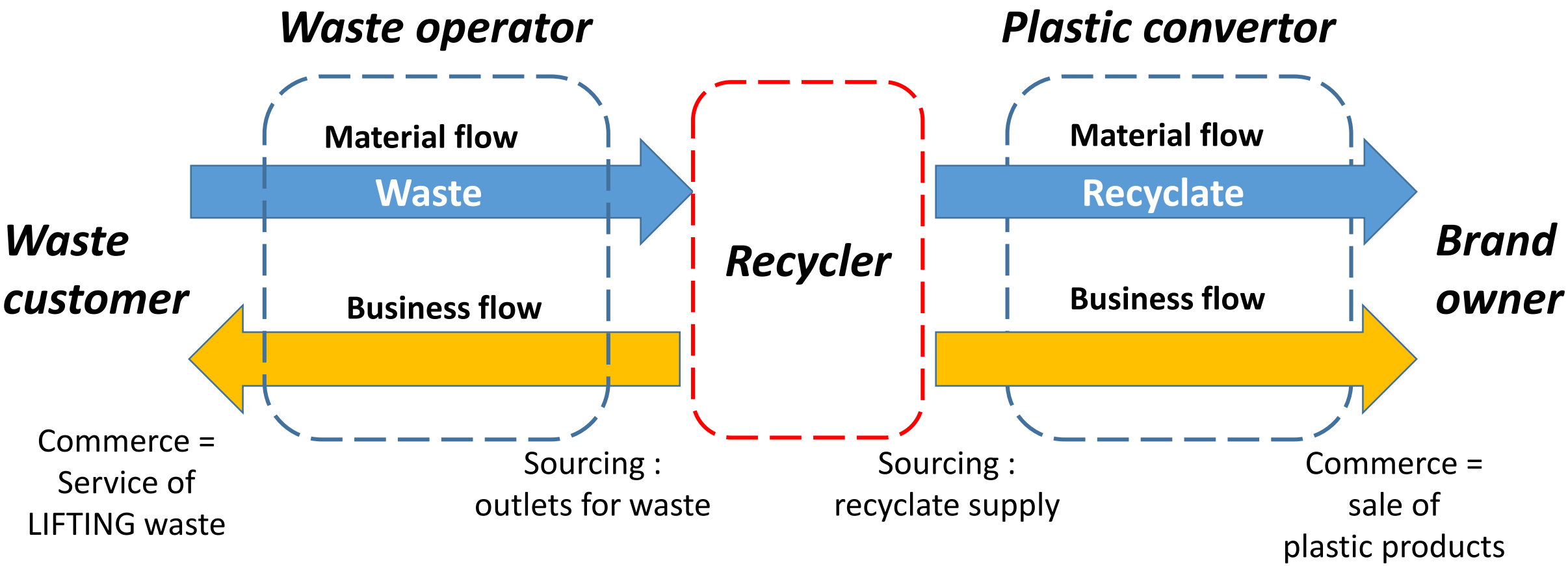
<u>Entropy opportunity :</u>

Logistic dispersion entropy already undone, logistic cost already spent.

Capital intensive activity, economy of scale : chemical recycling …!!

From waste to recyclate

The Recycler : Nobody's Customer…



Accessibility of P&G's market for *virgin* resins

Innovation from Consumer Insights

Consumer types

NO TRADE-OFF

Chooses recycled version if quality and price are the same

Niche
~17%
Highly engaged, will accept trade offs in cost and performance

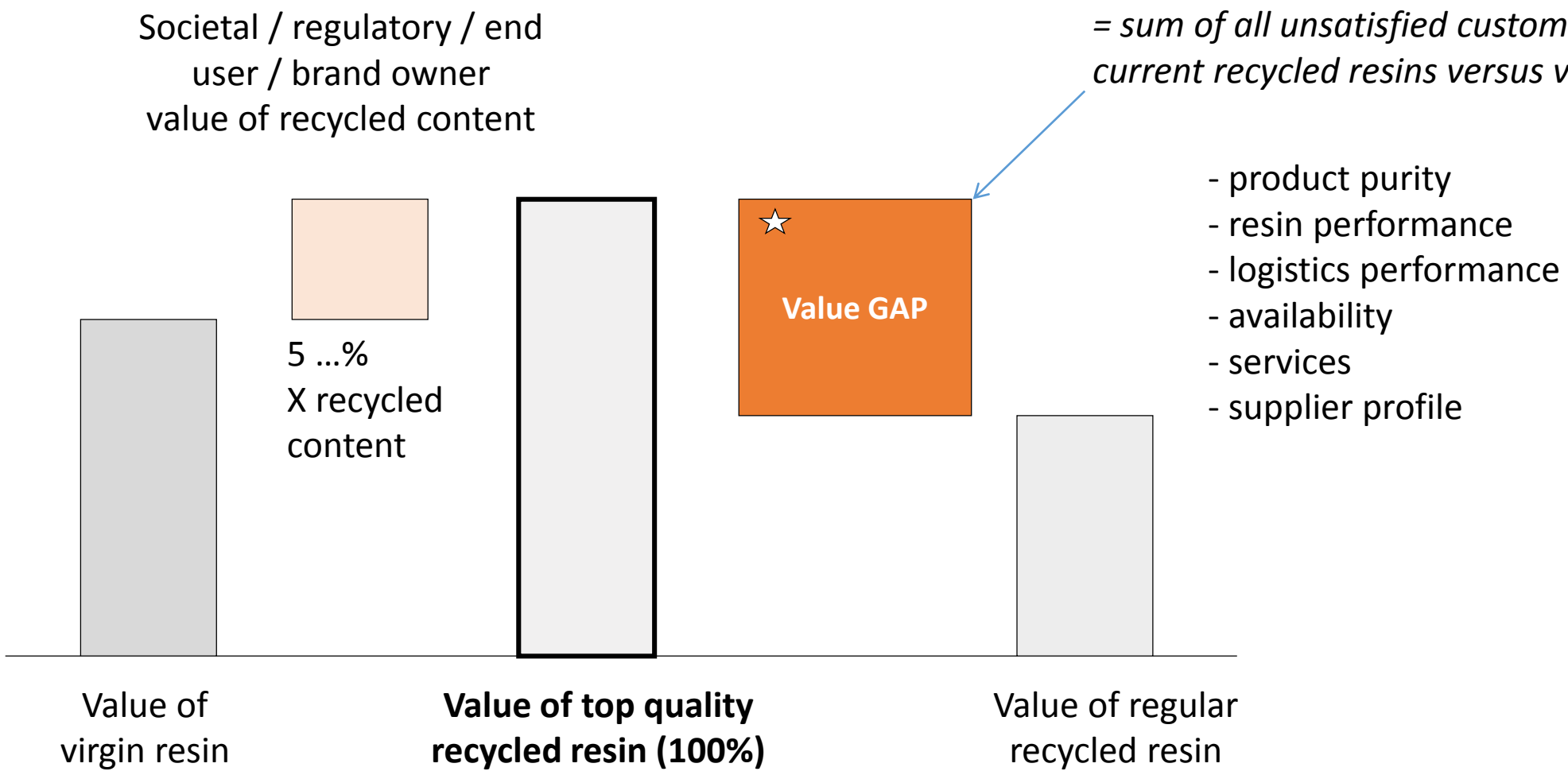
Sustainable Mainstream
~67%
Eco-aware, will not accept trade-offs in cost nor performance

Basic
16%
Indifferent to sustainability, value conscience

Virgin accessibility : only if recycled version not available

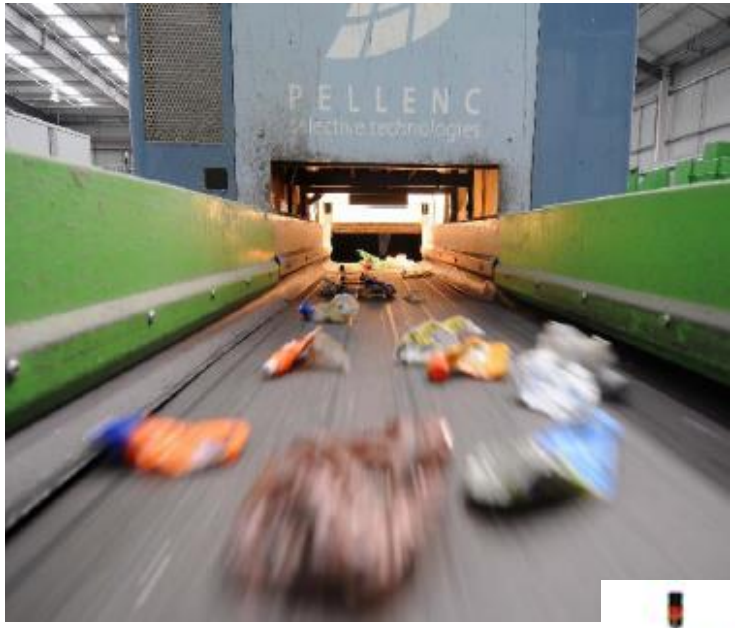
Virgin accessibility : only if price is lower than recycled or if recycled quality is worse…

Virgin / recyclate price difference :
reflects customer value gap, unsatisfied by current suppliers



Amazing sorting & recycling technology !

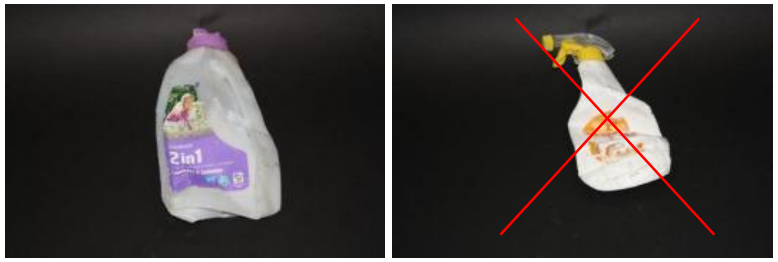
High speed bottle sorting per polymer



Multi-sensor flake sorting

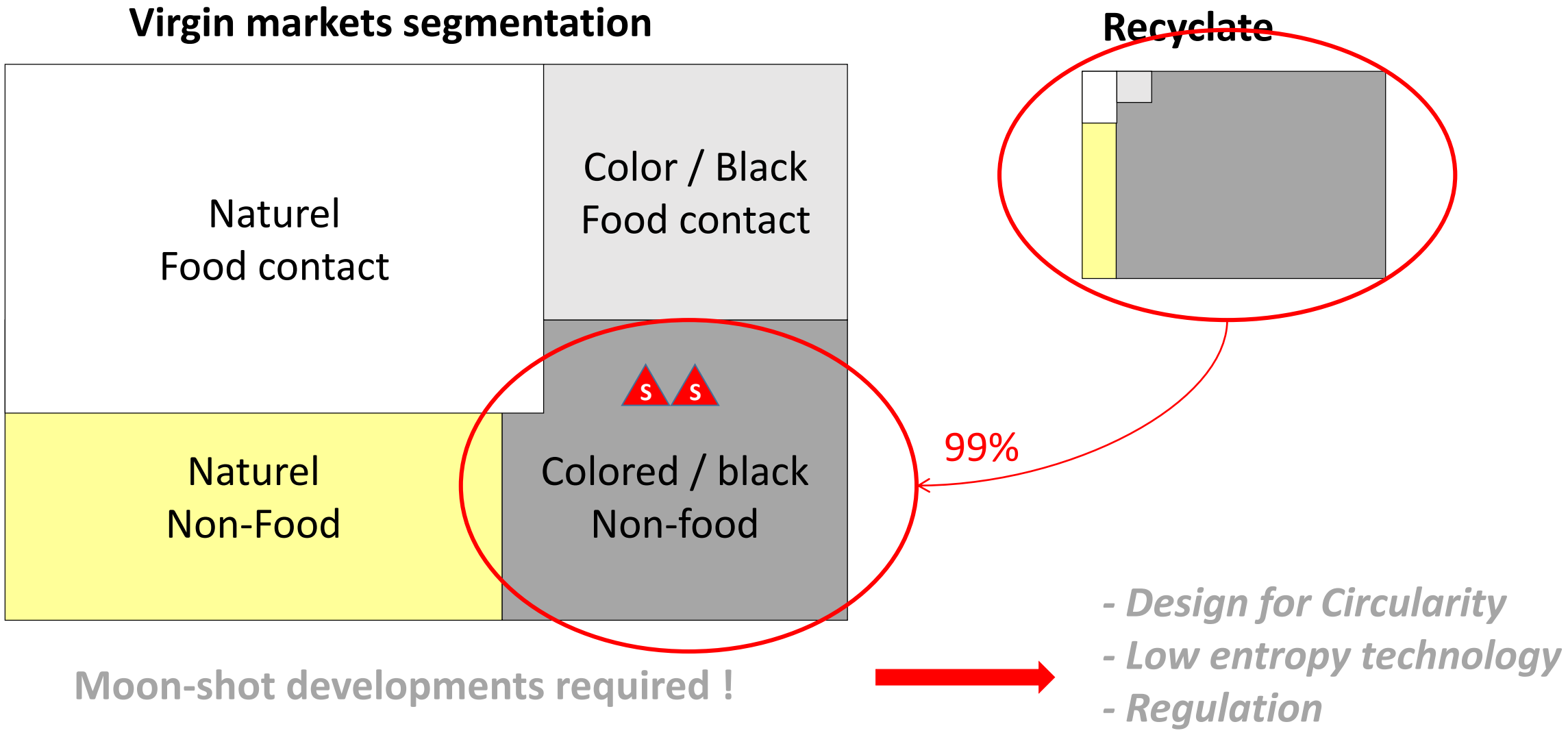
Near future :

Shape recognition



watermark sorting ! Food / non-food

Remaining barriers for recyclate to access virgin markets : *food contact* and *in-mass coloration*

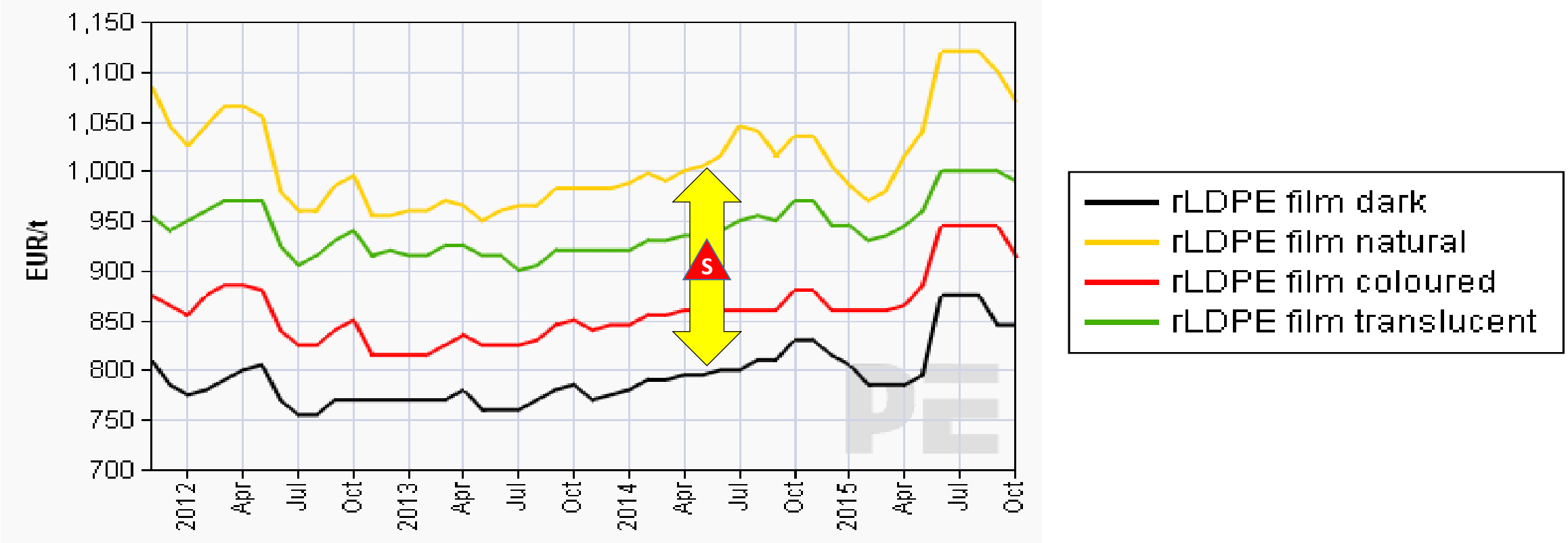


Natural packaging solution :

unique opportunity to inject value without subsidies

The practice to colour in the mass destroys a lot of ‘circular economics’ !

- Natural recyclate has 200 €/t more value than coloured recyclate : access to virgin markets
- Colour and marketing messages : concentrate on shrink film, removed at recycling



Coloured plastics : what sorting technology can do

Maximum valorisation potential ?

Most recyclers → After sorting light / dark, mixing the rest : Limited applications, extra pigment needed

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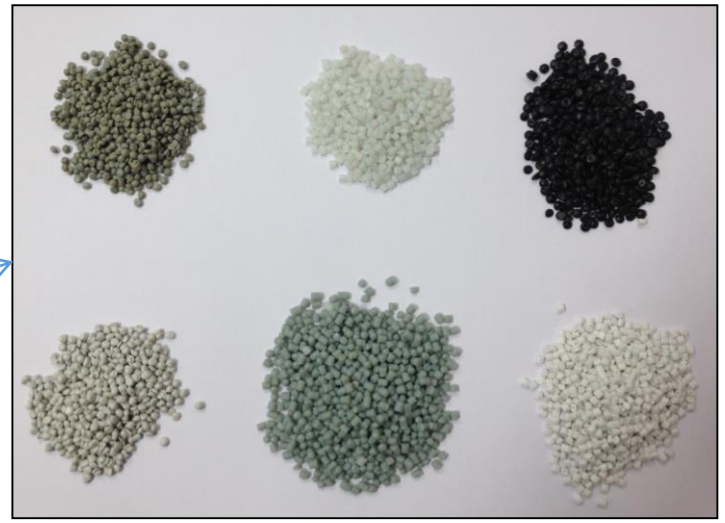

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US recycler ENVISION → On-purpose colour sorting : Selling pigment savings… (virgin + 20 … 50%)

(heritage from ex-virgin producer Union Carbide)

Apparent credibility gap

…Similar to virgin plastics in early period !!

Plastic = for toys

Plastic = fake, copy of real material

Strategic « non-communication »

Reason for not communicating on recycled content	#	%
Expected fear / rejection / uncertainty by consumers	6	35%
Lack of available information about recycled material	3	18%
Lack of certainty / fear of unexpected problem	2	12%
Avoid pressure from purchaser for special rebate	11	65%

Source : RECORD, France

History of plastics : from toys to high tech

INNOVATION

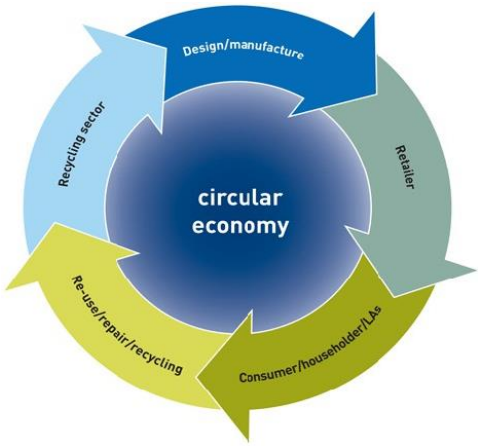
+

Building

credibility

« Plastic = for toys
Plastic = fake,
copy of real material »

New roles *and responsibilities* for economic actors ….



Waste service providers : become material suppliers

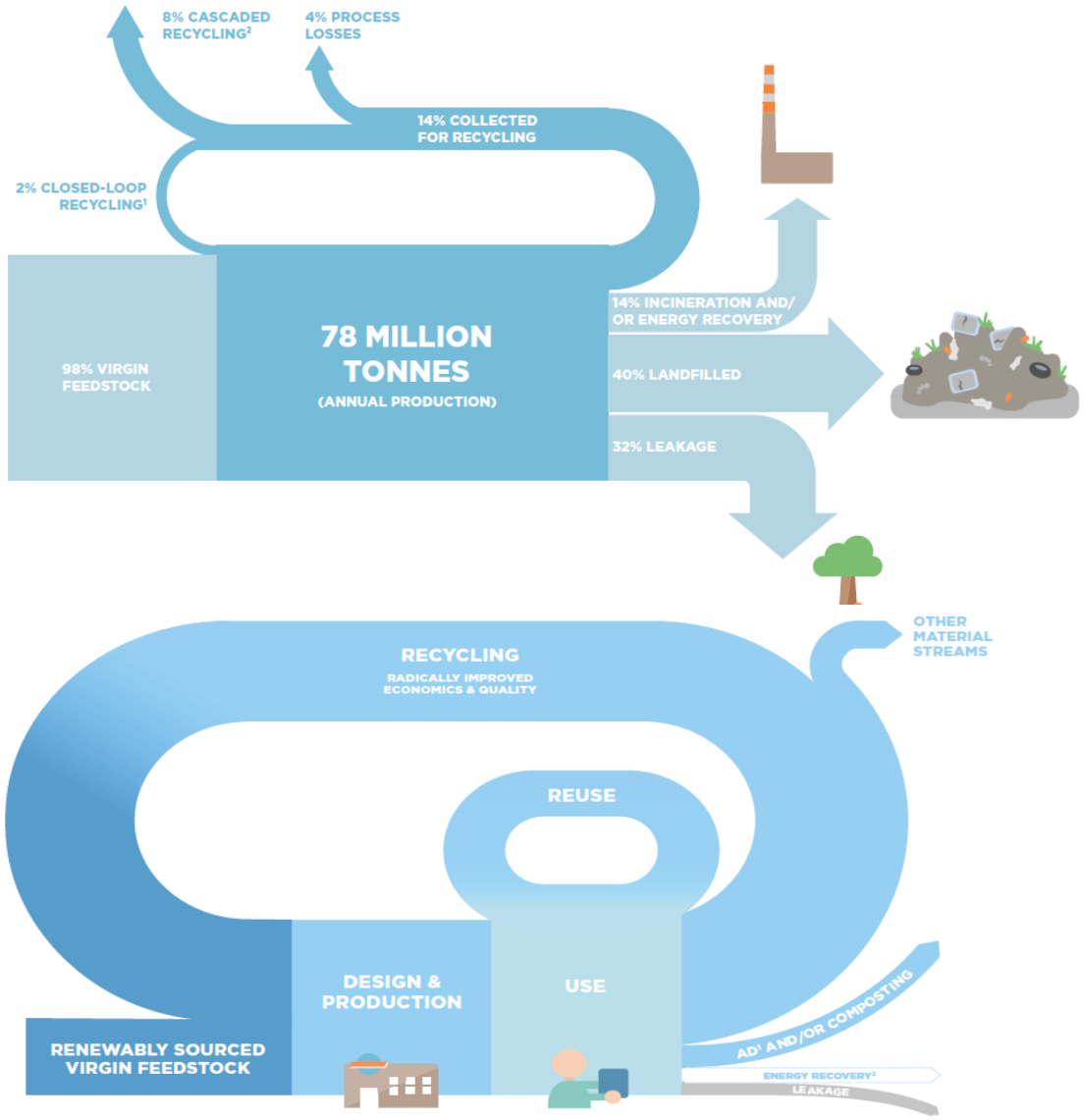
Packaging sector : privileged position !

- main source of secondary raw material ! >60% of all plastic waste
- short shelf life : predictable availability + regulatory compliance
- packaging design = key criterium for ‘circular potential’

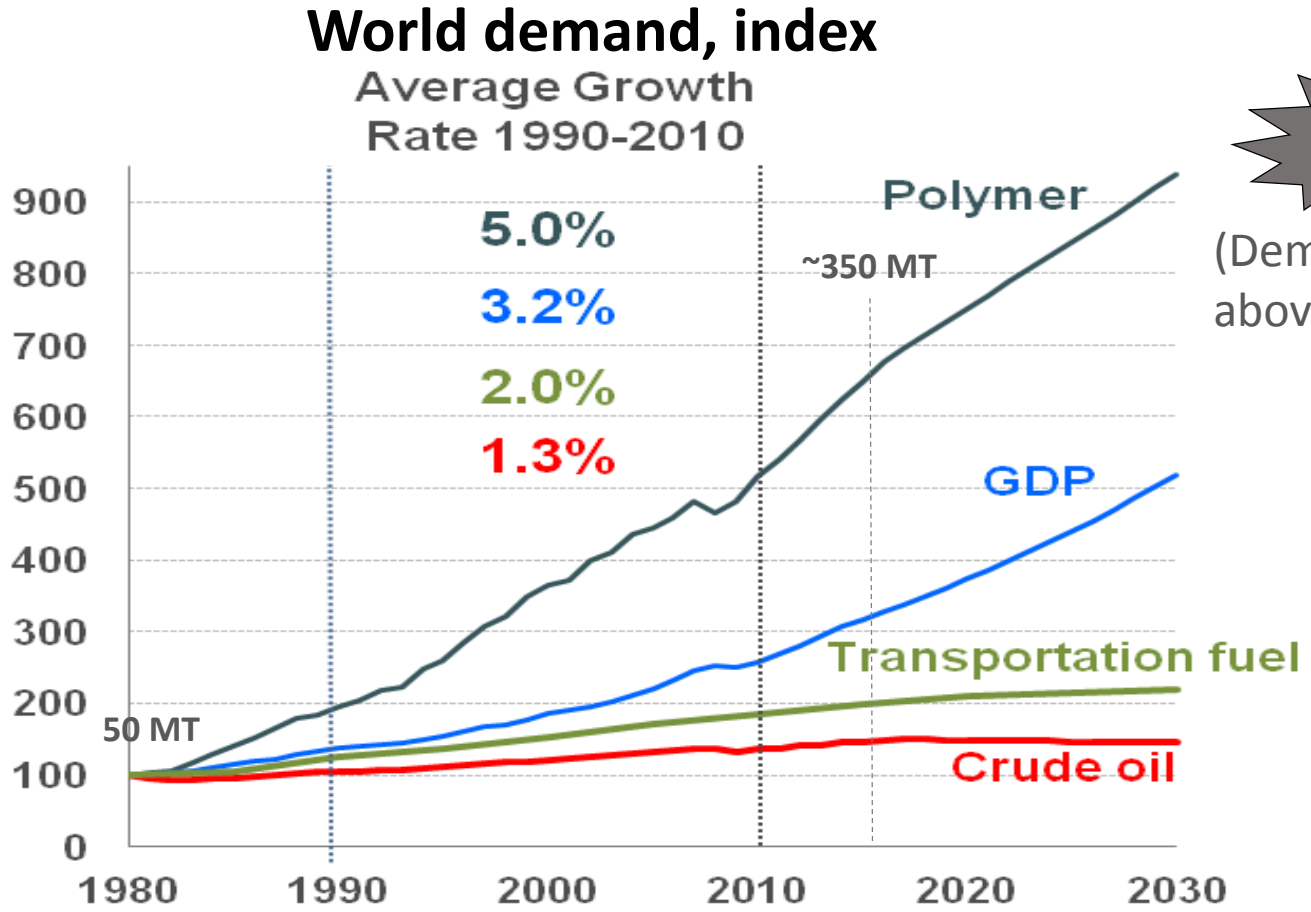
WHICH ROLE FOR A VIRGIN PLASTICS MANUFACTURER …?

Paper industry : growth by increasing circularity

- **1980 : linear, like todays plastic**
- **2018 : 70% circular**



Plastics historical success story :
relentless innovation focused on (linear) growth



!?

(Demand saturation above 1000 MT/y ?)

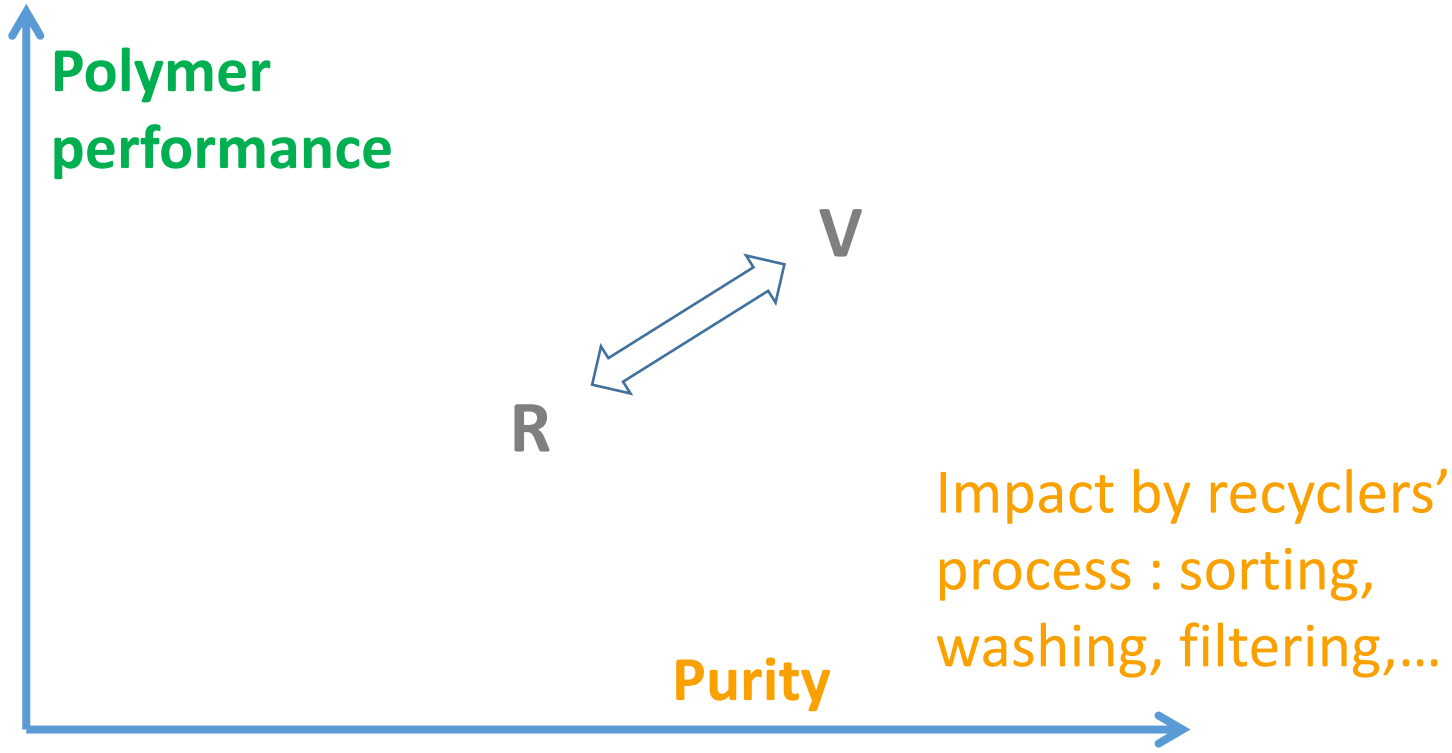
Can we, together, focus plastics innovation on *circularity* ?

Quality of recyclate (vs. virgin) : criteria divided in 2 distinguished dimensions

Impact : by compounding with superior virgin resin, designed on purpose to compensate for missing properties of chosen recyclate!

« Recyclate boosting » concept :
Unique contribution by virgin industry !

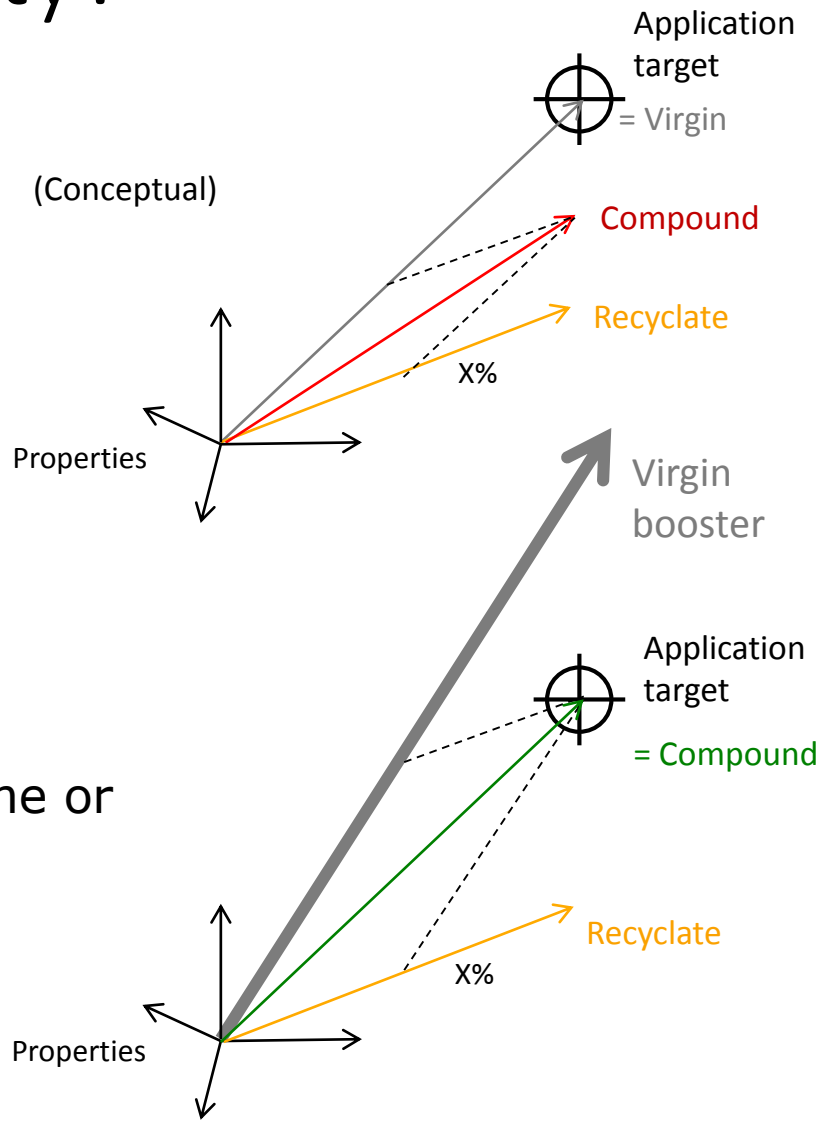
No other actor of the value chain controls the molecular design !



Has our industry technology sufficient spare to serve as engin of circularity?

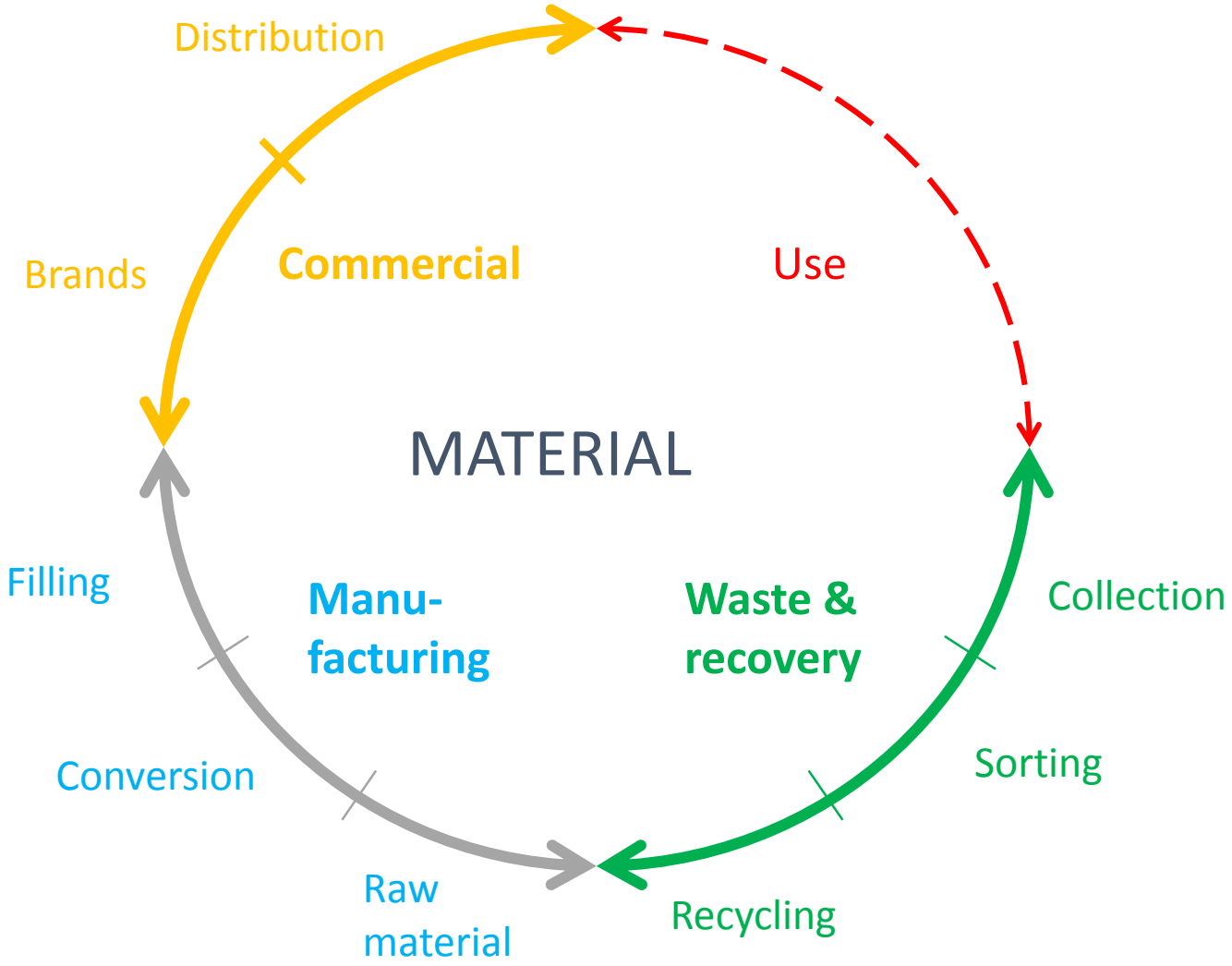
- Todays linear application:
  - Virgin design = **optimized** for the target application of the 1st life cycle
  - Virgin + recyclate = structurally inferior ; only applicable for less demanding applications

- Tomorrow's circulaire application:
  - Virgin design = **to boost recyclate** for use in (same or other) high technical application
  - Virgin + recyclate = **optimized** for the application



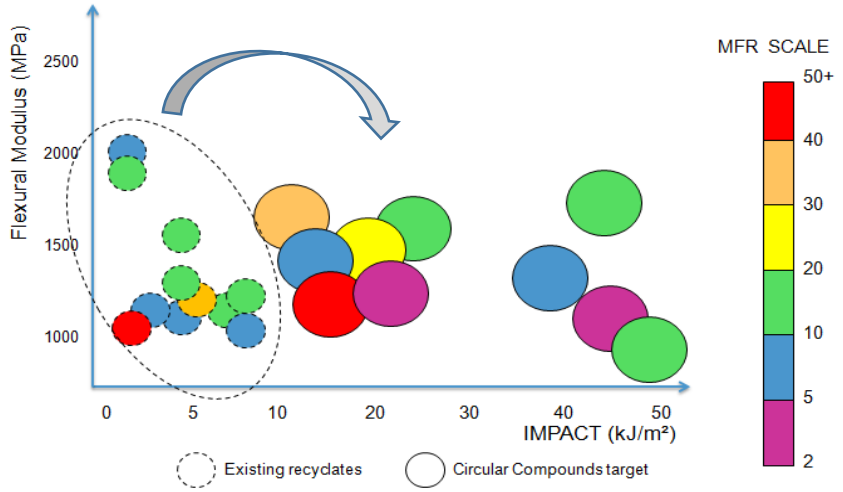
Circular Economy Platform : new effective industry configuration

- **Cooperation between all actors of the value chain : to make circularity ROBUST (sensitive to disturbance)**
- **High effectiveness in terms of**
  - **« material excellence »**
  - **Credibility towards society with circularity ambition**
- **Alignement of interest and goal = ‘low entropy’…**



4 Unique roles for virgin resin producers

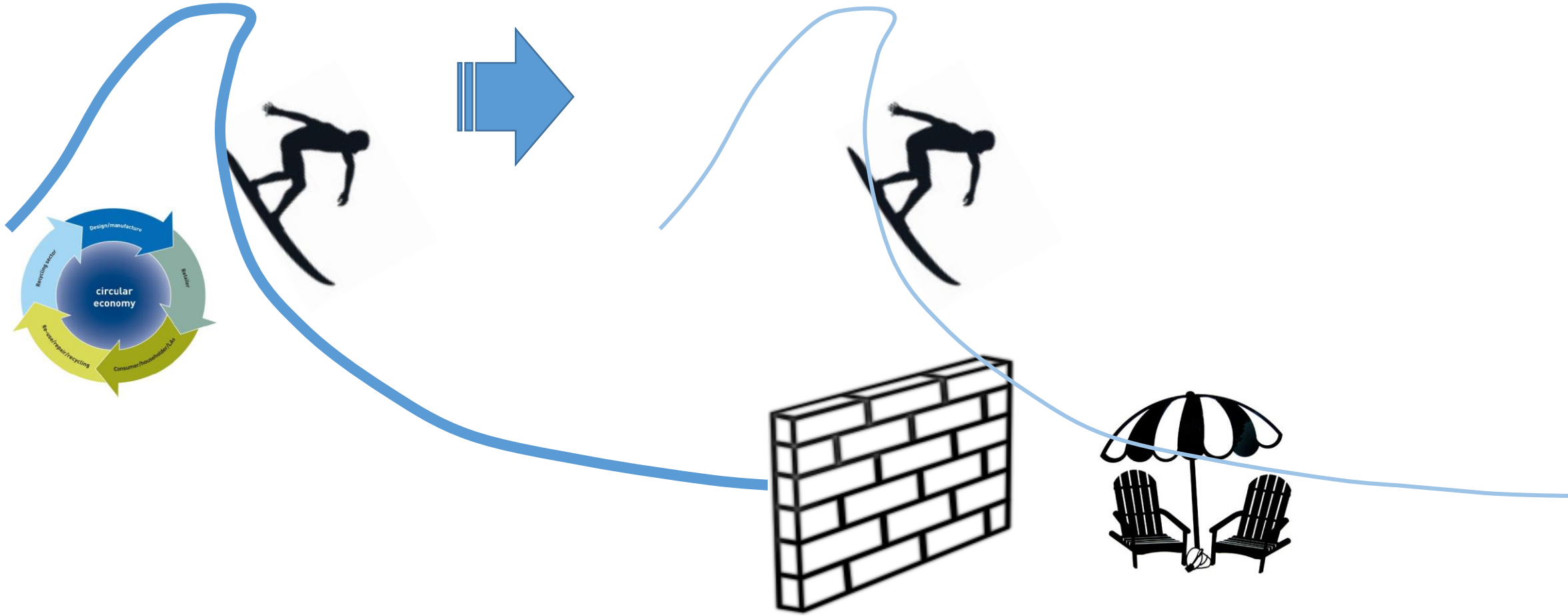
1. **Boost** recyclate with dedicated high performance virgin
2. New & enhanced **recycling processes**
3. Create and open up **markets** for (boosted) recyclate
4. Make plastics recyclate CREDIBLE as raw material



Takeways : opportuties and challenges

- Circular plastics are within reach of the industry
- The virgin plastics industry has to take up a key role as ‘engine of plastics circularity’.
- By the traject towards circularity, our industry will again become attractive to the young generations.
- Throughout the value chain, new rationale has to be developed, with Entropy as fundamental criterion for circularity.

Engineers are SURFERS on megatrends !




THANK YOU !