International Solid Waste Association

China's Ban, Marine Litter, Artificial Intelligence and the future of recycling

Antonis Mavropoulos
ISWA President
@amavrop

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@ISWA.org

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www.iswa.org

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ANNUAL REVIEW 2017

WORKING TOGETHER TOWARDS A CLEANER, HEALTHIER PLANET

Contents

- China’s Ban: the end of recycling as we know it
- Marine litter: time to rethink our plastic matrix
- 4.0 Industry gets into recycling
- Big Data &The Big Challenge for Artificial Intelligence

Before China's Ban

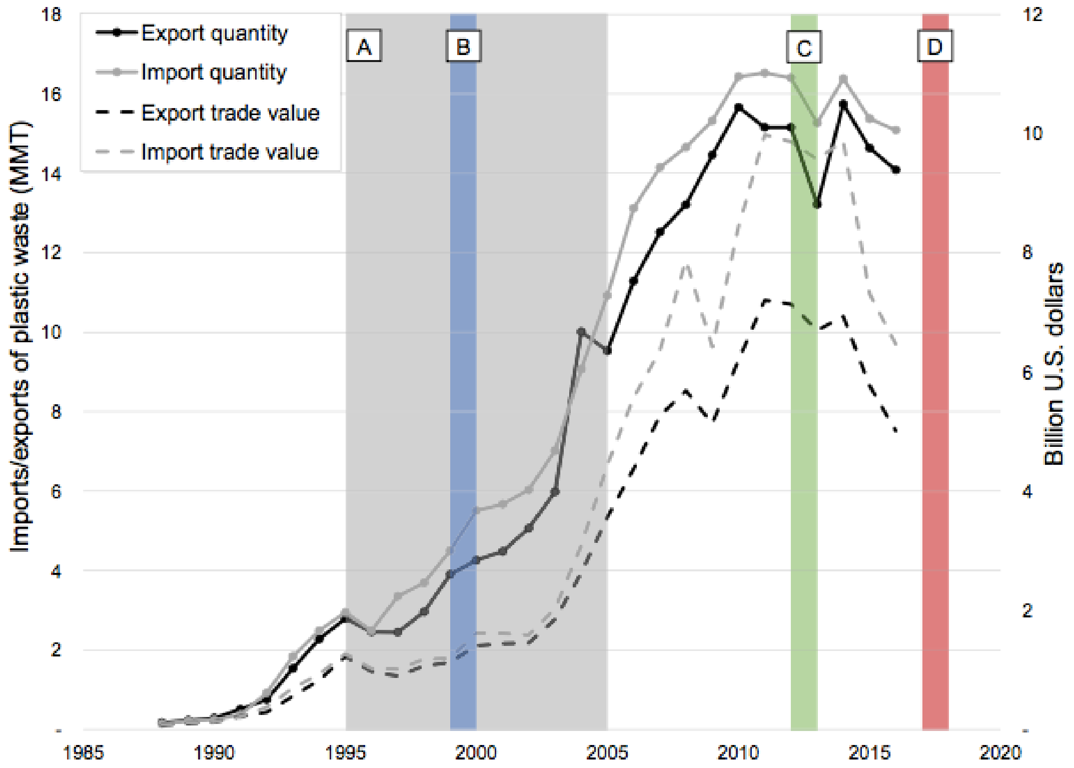
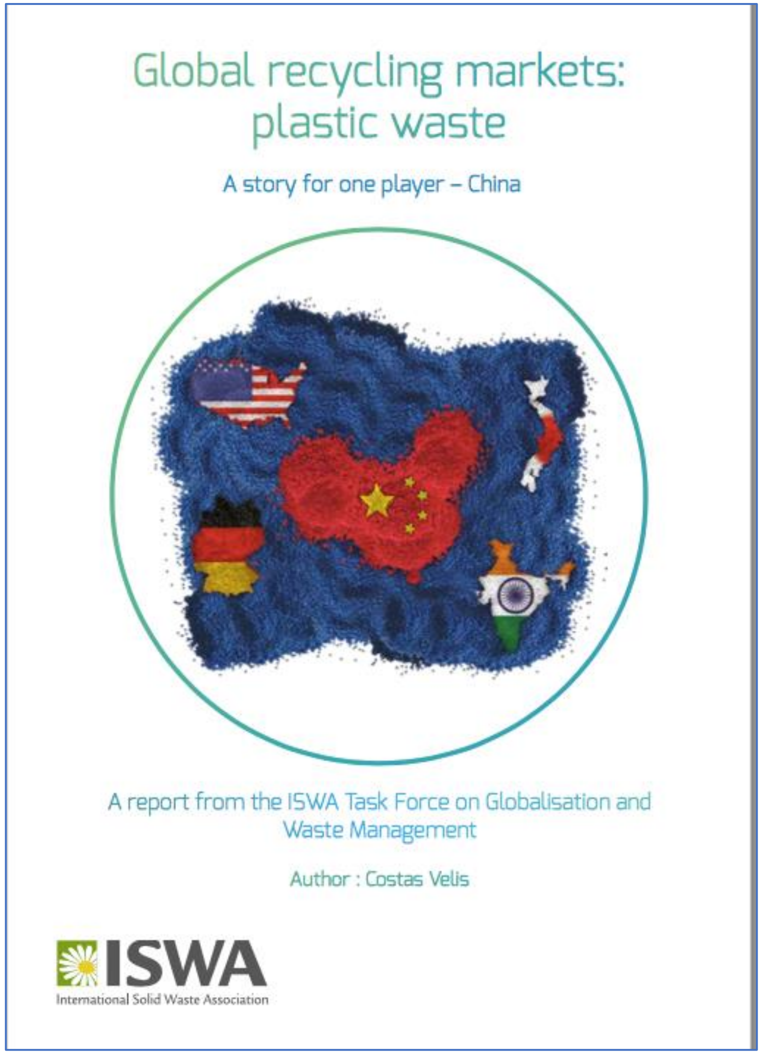


Fig. 1. Trade of plastic waste in mass and trade value (UN Comtrade data). (**A**) Advances in Municipal Recovery Facility (MRF) technology resulting in expansion of commingled recycling, especially single-stream recycling in the United States (1995–2005) (see the Supplementary Materials). (**B**) Surge in globalization, supported by the World Trade Organization and the International Monetary Fund (*29*–*31*). (**C**) Implementation of temporary Chinese import restrictions (Green Fence) (2013). (**D**) Implementation of the new Chinese policy banning the import of nonindustrial plastic waste (2017).



Source: Brooks, Wang, Jambeck, The Chinese import ban and its impact on global plastic waste trade Sci. Adv. 2018;4:eaat0131 20 June 2018

What ISWA said?

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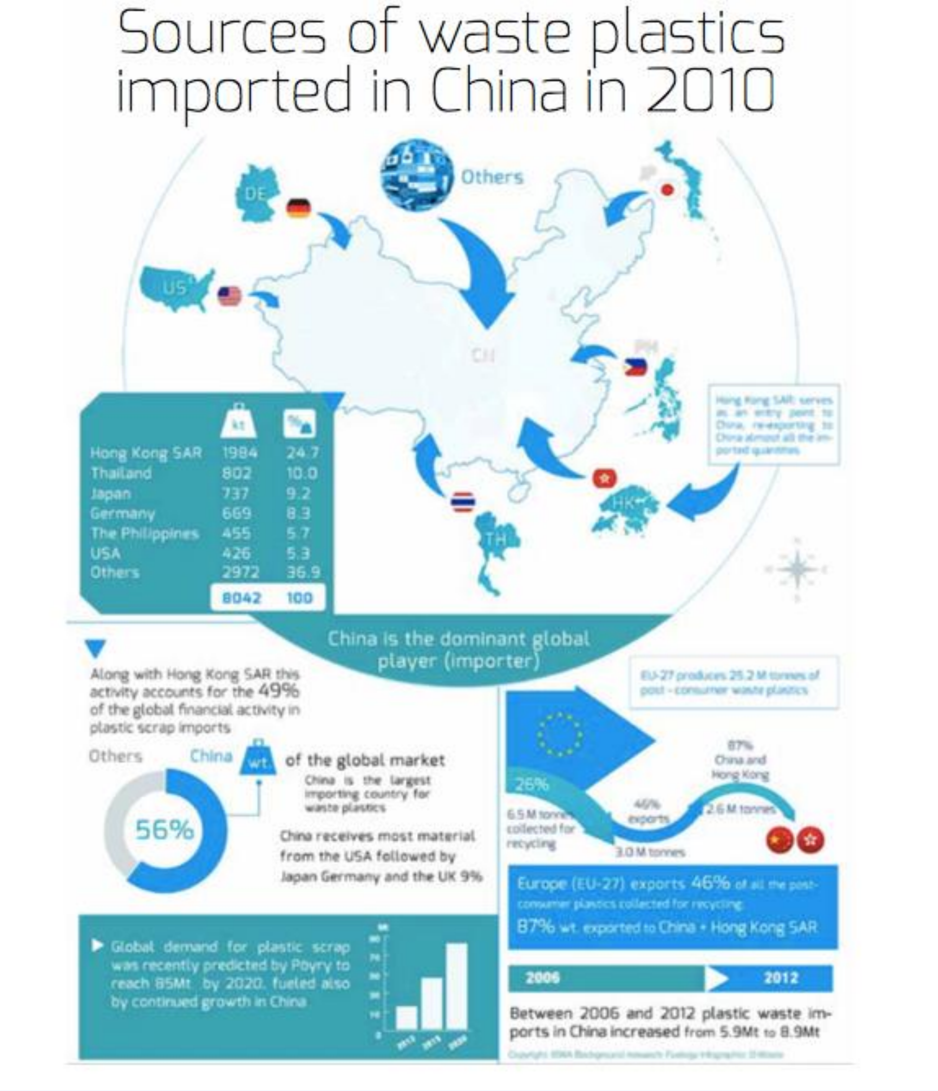
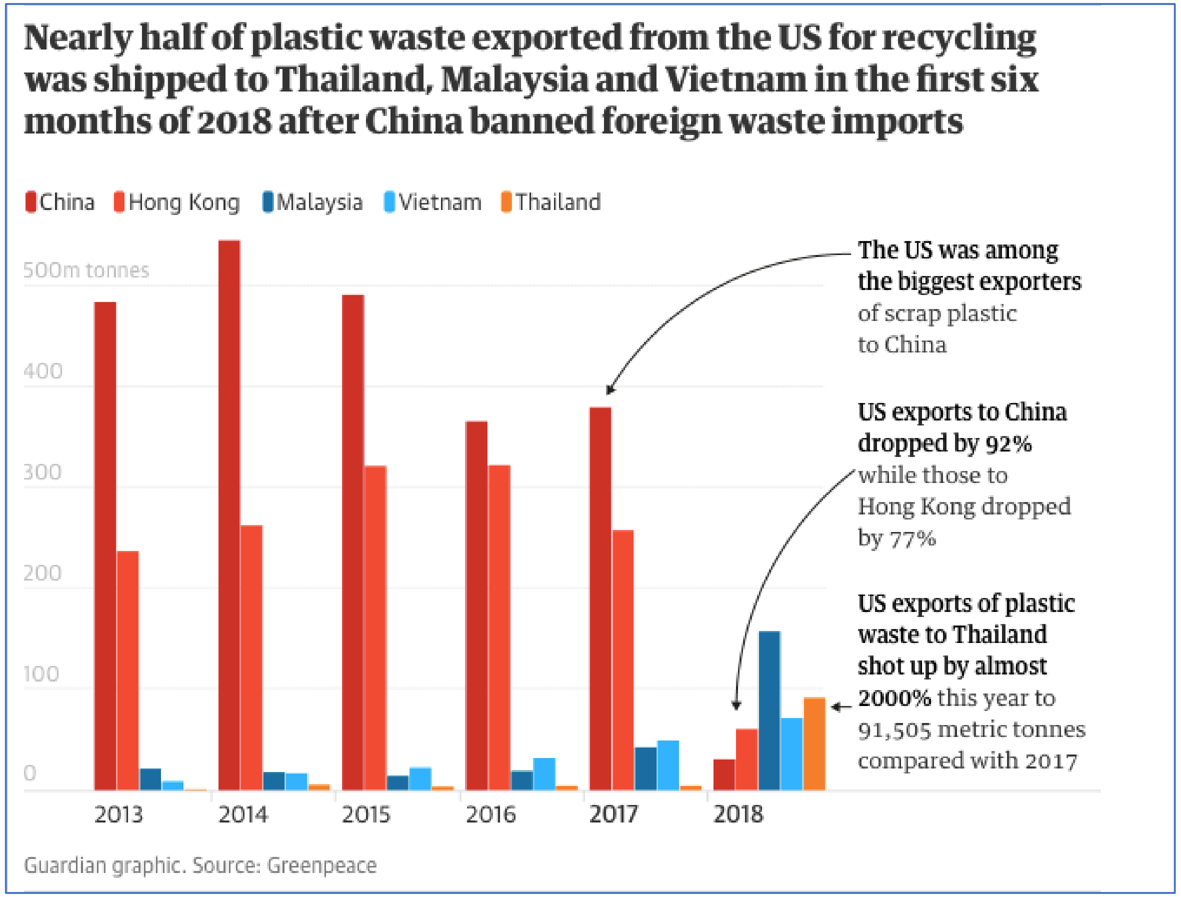
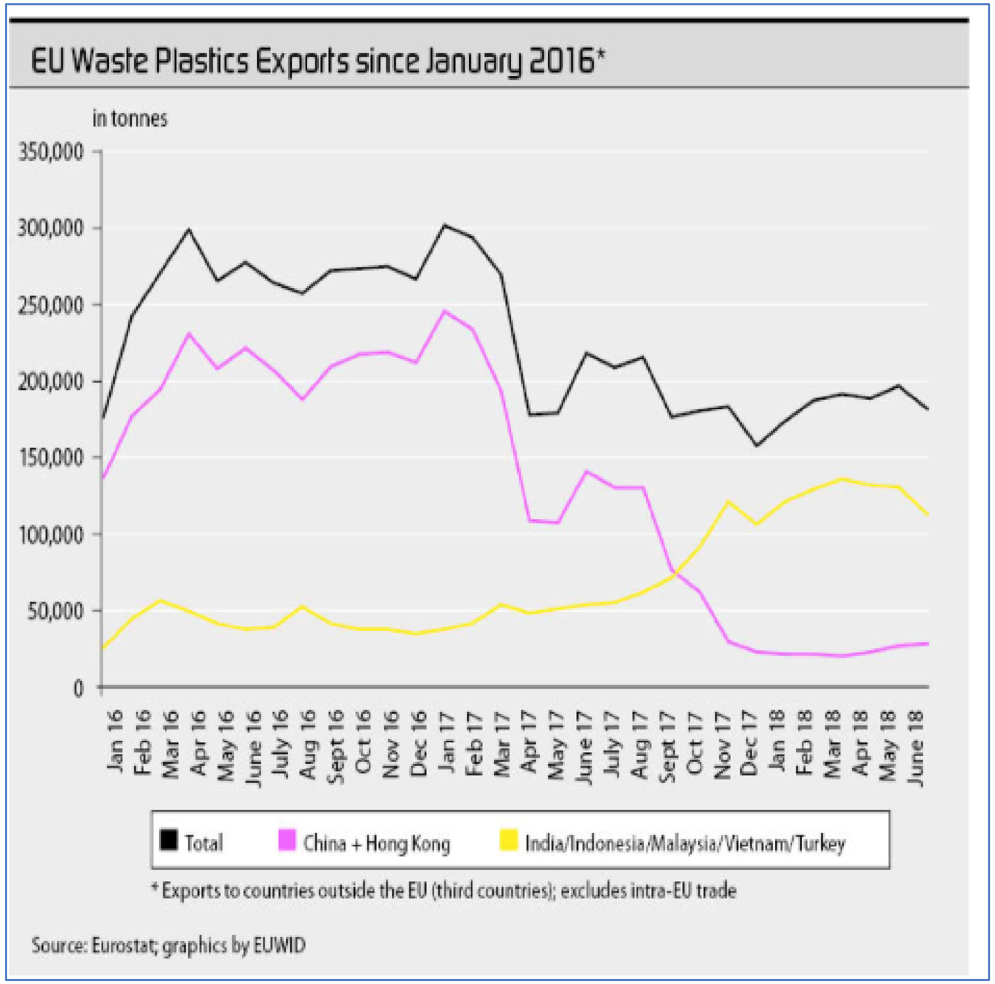
Is dependence on a single importing country a risk?	Yes, for two reasons. First, China may in the medium- or long-term become self-sufficient in high-quality secondary plastics. Second, advanced recycling collection schemes in Europe/ N America etc. were created aspiring to achieve sustainable resource recovery. However, this is questionable when almost half of the collected plastics are exported to countries with lower environmental standards. Global plastic recycling markets in themselves may not lead to the required balance between environmental protection, clean material cycles and resource utilisation.
Should exporting countries be investing in local re-processing capacity for recycled plastics?	Yes, over-dependence on a single exporting country is risky. However, a balance is required. Quality, segregated polymers, e.g. clean PET from bottles, are increasingly sought-after commodities on the global market, with manufacturers in the US, Europe and China competing for a limited supply. So some export is normal - provided a 'level playing field' in terms of environmental standards can be assured.
What then should be done with mixed / unrecycalble plastics?	Segregate further and near the source to prepare a higher quality feedstock for recycling. Or develop innovative processes and invest in local capacity for mixed plastics recycling. Or consider waste to energy - high efficiency combined heat and power (CHP) plants cab be a sustainable solution for the non-recyclable plastics (e.g. thermosets), particularly in countries that have high dependence on landfill disposal.



China's Ban shifts markets, impacts & opportunities





Virgin plastic & environmental impacts

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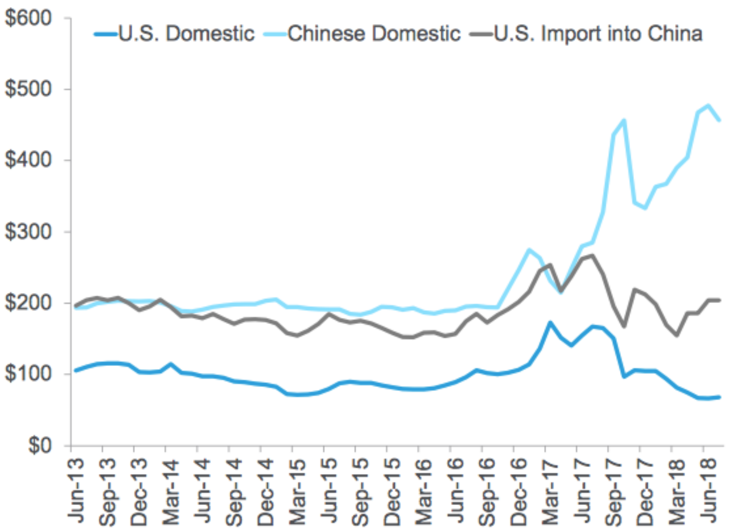
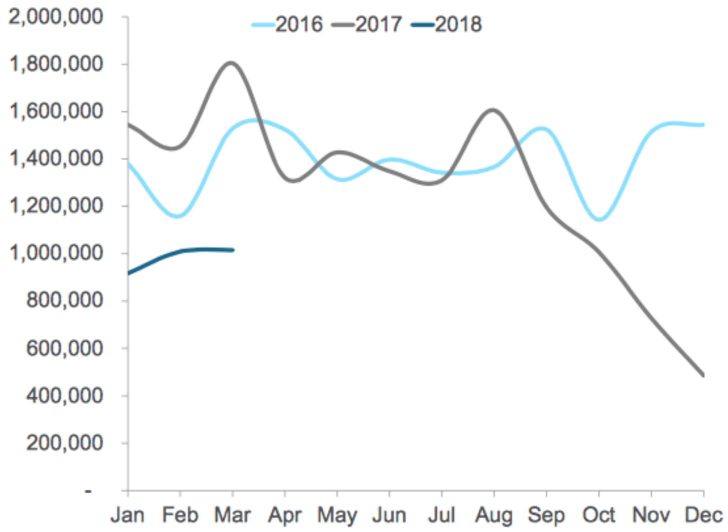
Figure 28. U.S. and China OCC Prices ($/ton)



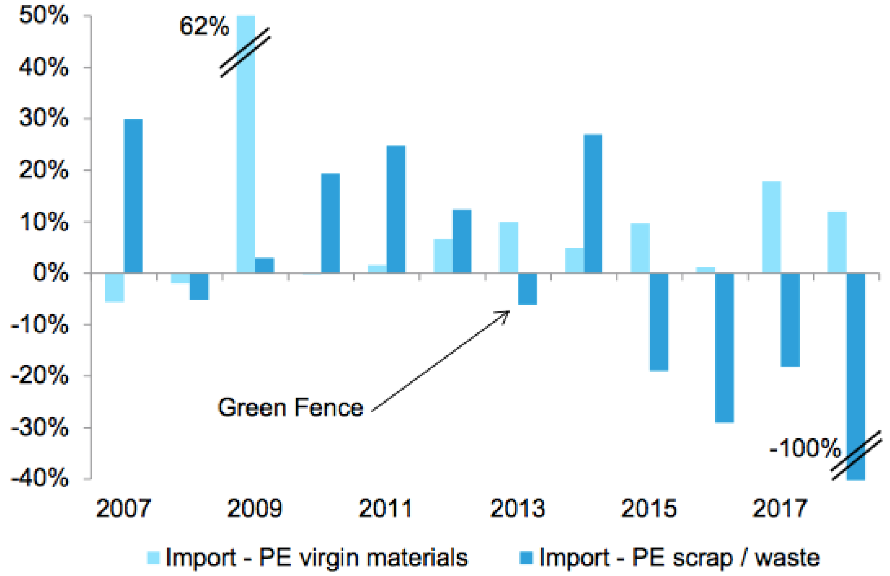
Source: Citi Research, RISI

Figure 29. Monthly OCC Imports From U.S. to China



Source: Citi Research, RISI

Figure 35. China Virgin and Scrap PE Import Growth



Source: China Customs, Citi Research

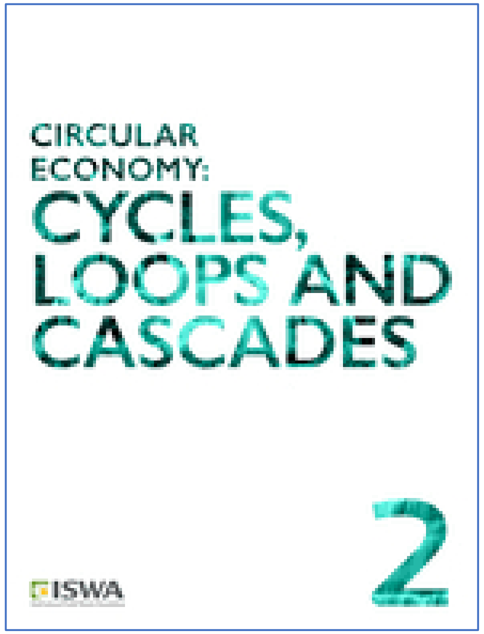
100-110 million tones of plastic waste should find another destination between 2020-2030

Source: CITIBANK, RETHINKING SINGLE-USE PLASTICS - Responding to a Sea Change in Consumer Behavior

In brief...

Conclusions on China Ban - 1

- There is no sustainable solution without a shift to redesign
- Quality recycling is more resilient, less vulnerable but also more difficult
- Need for local & regional closed loops → Developing the domestic markets and outlets is a key-element
- Adaptation and resilience instead of continuously growing targets → Local or regional closed loops → Local or regional environmental impacts and economic benefits
- The dominant business model that was based on extensive exports of low-quality materials is over. Other countries will soon follow China's example. Adapt or collapse…
- Key-point: **plastics are the big problem**



Conclusions on China Ban - 2

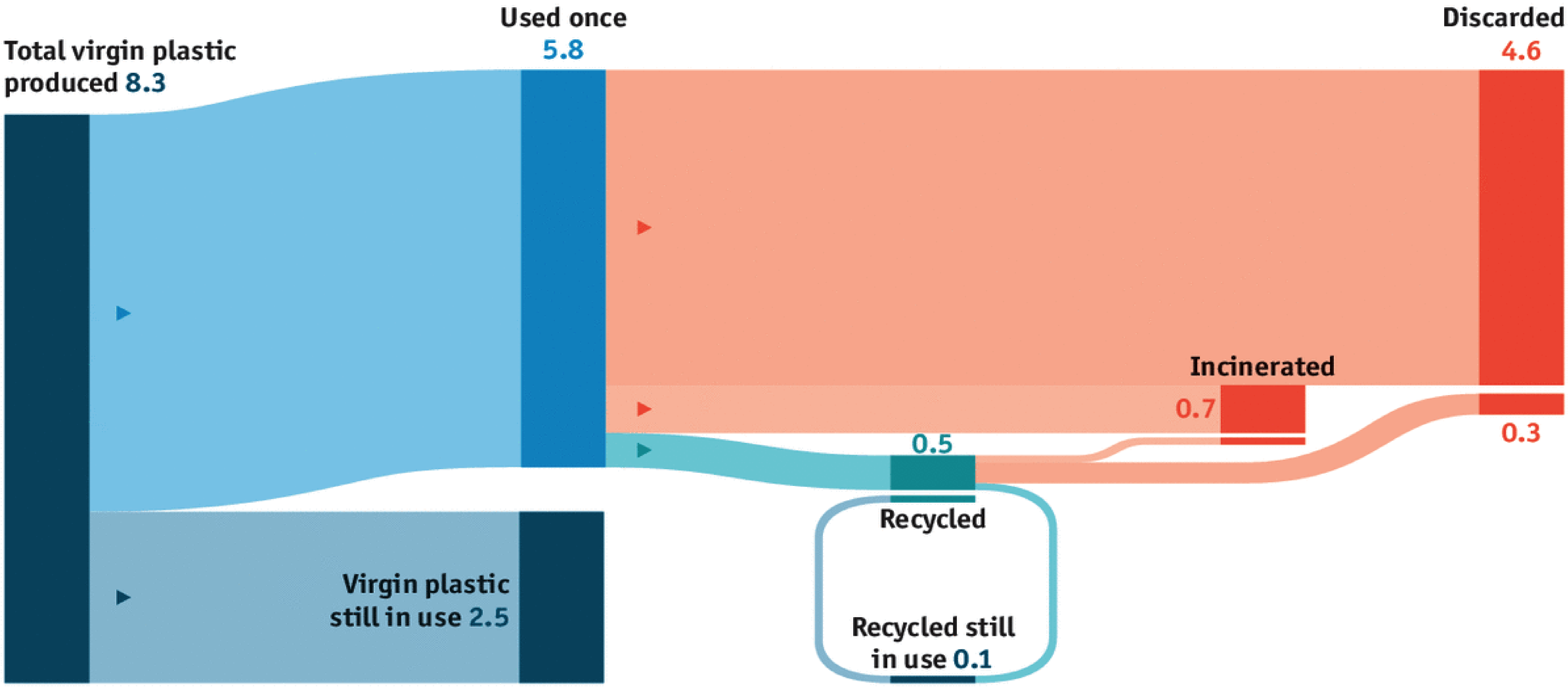
Pursuit of Appropriate Goals / Doing Right Things

	Inefficient	Efficient
Effective	Pursuing right goals, but inefficient (costs are high)	Pursuing right goals and efficient (high-ROI, cost-efficient)
Ineffective	Pursuing wrong goals and inefficient (not producing enough and are expensive)	Pursuing wrong goals but is efficient (not producing enough but low-cost)

Use of Resources / Doing Things Right

The end of all things

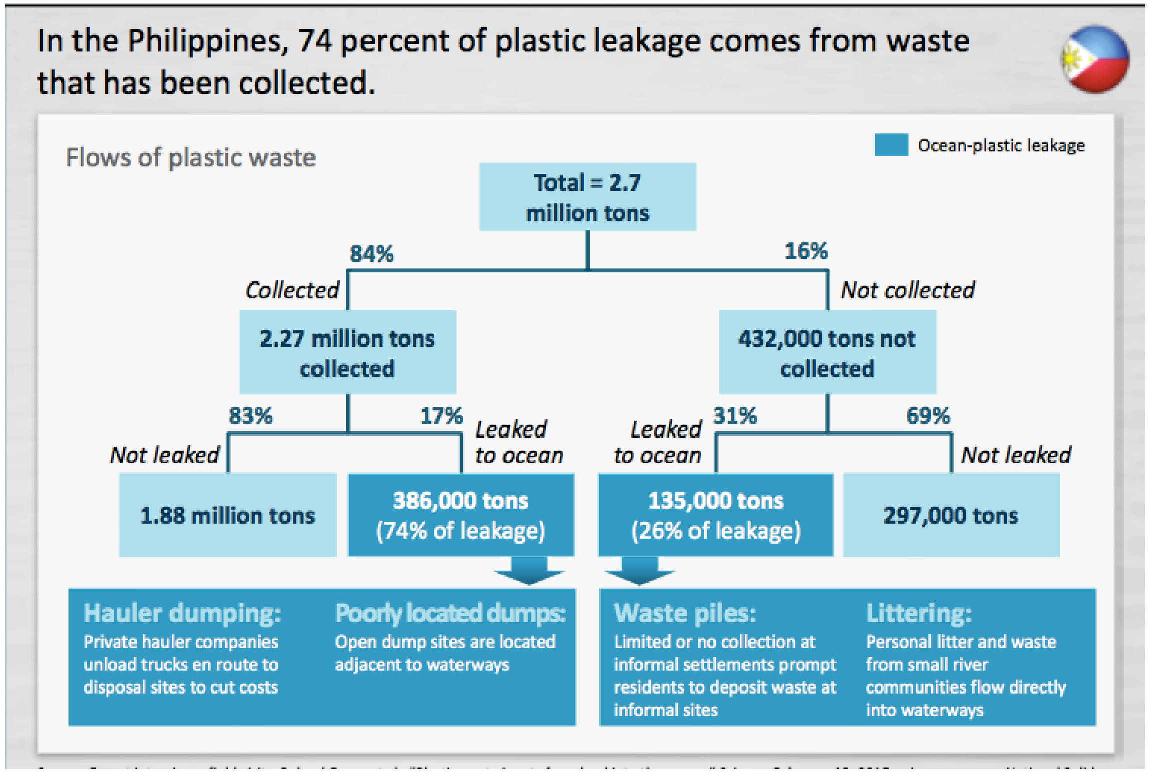
Global plastic production and use, 1950-2015, tonnes, bn

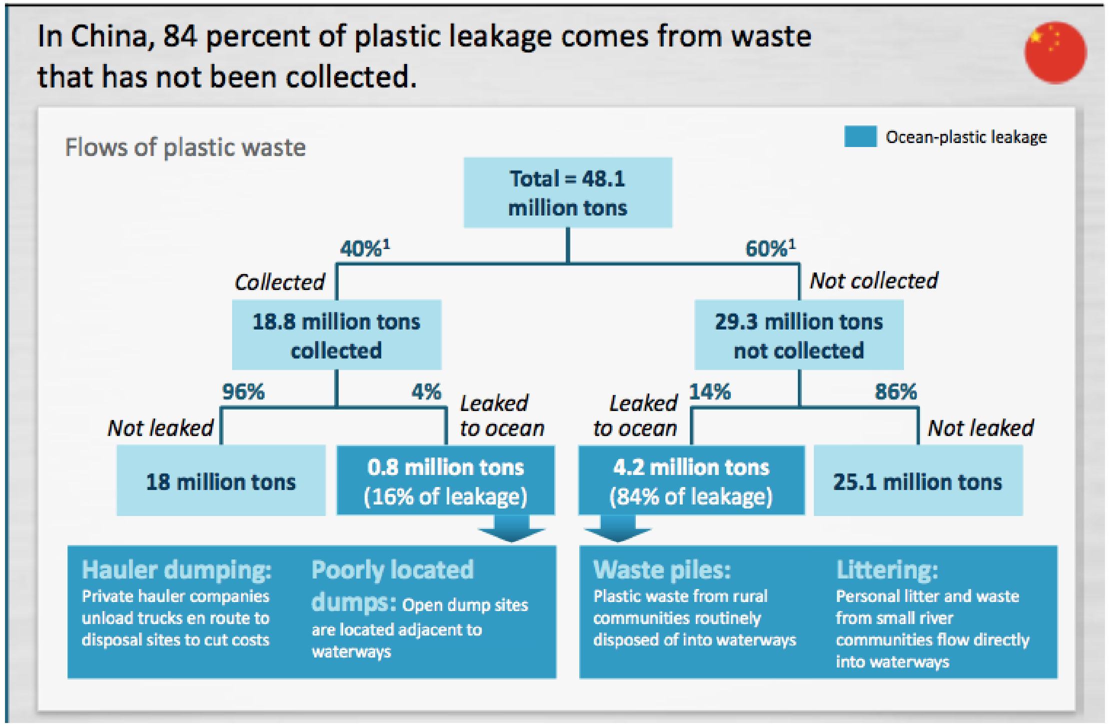


Source: “Production, use, and fate of all plastics ever made” by R. Geyer et al., *Science Advances*

Economist.com

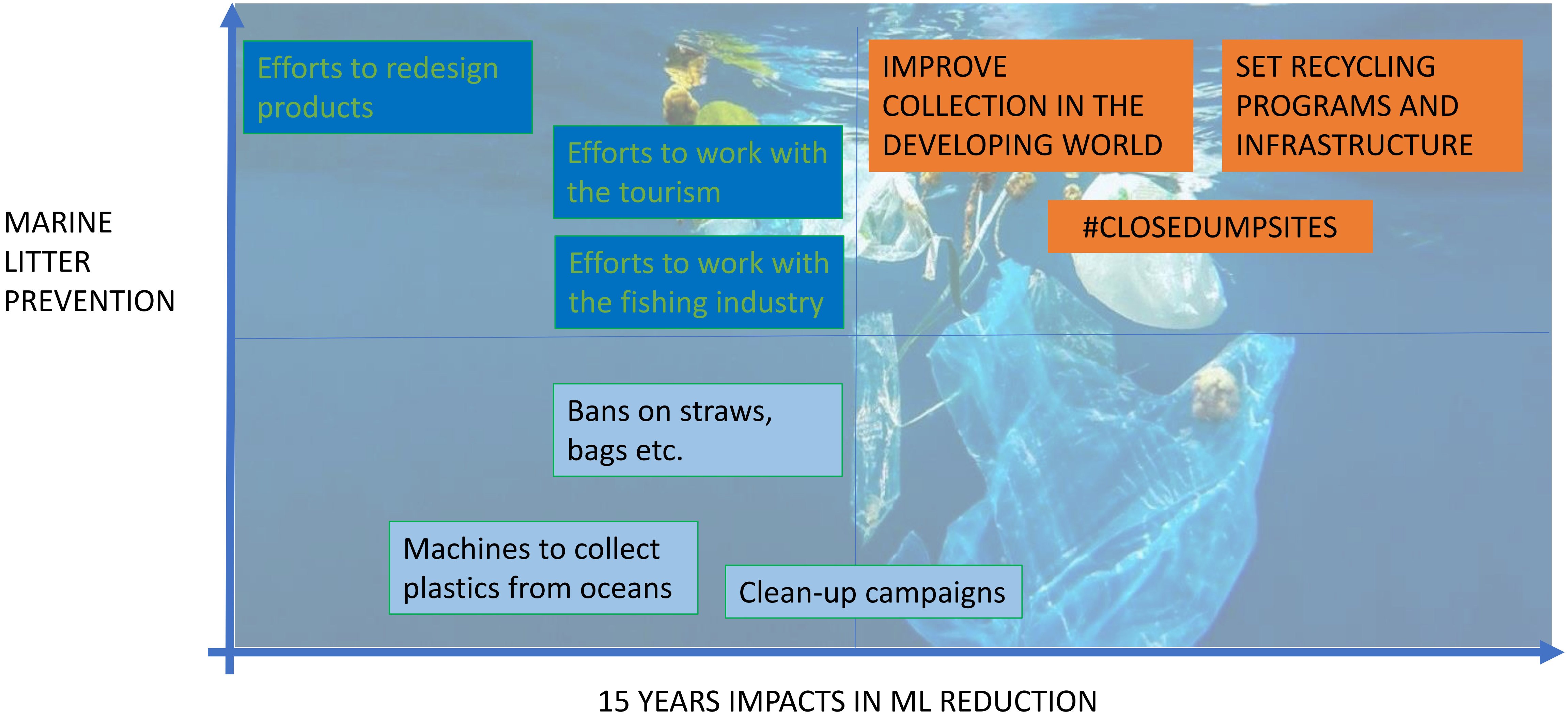
But…





Source: Ocean Conservancy, Stemming the tide, Land-based strategies for a plastic free ocean, 2016

Effective Vs Efficient again



So what? More science, less convenience

Conclusions on Marine Litter

- Marine litter is becoming a global challenge similar to Climate Change – let’s hope for a better response
- We are too dependent to plastic to find an easy fix and too damaged by ocean plastics to delay it
- Plastics are too successful and convenient but we must put an end to our dependence on the continuous expanding plastic matrix
- The dominant business model of the plastic production and consumption has come to an end – we can’t continue like this.

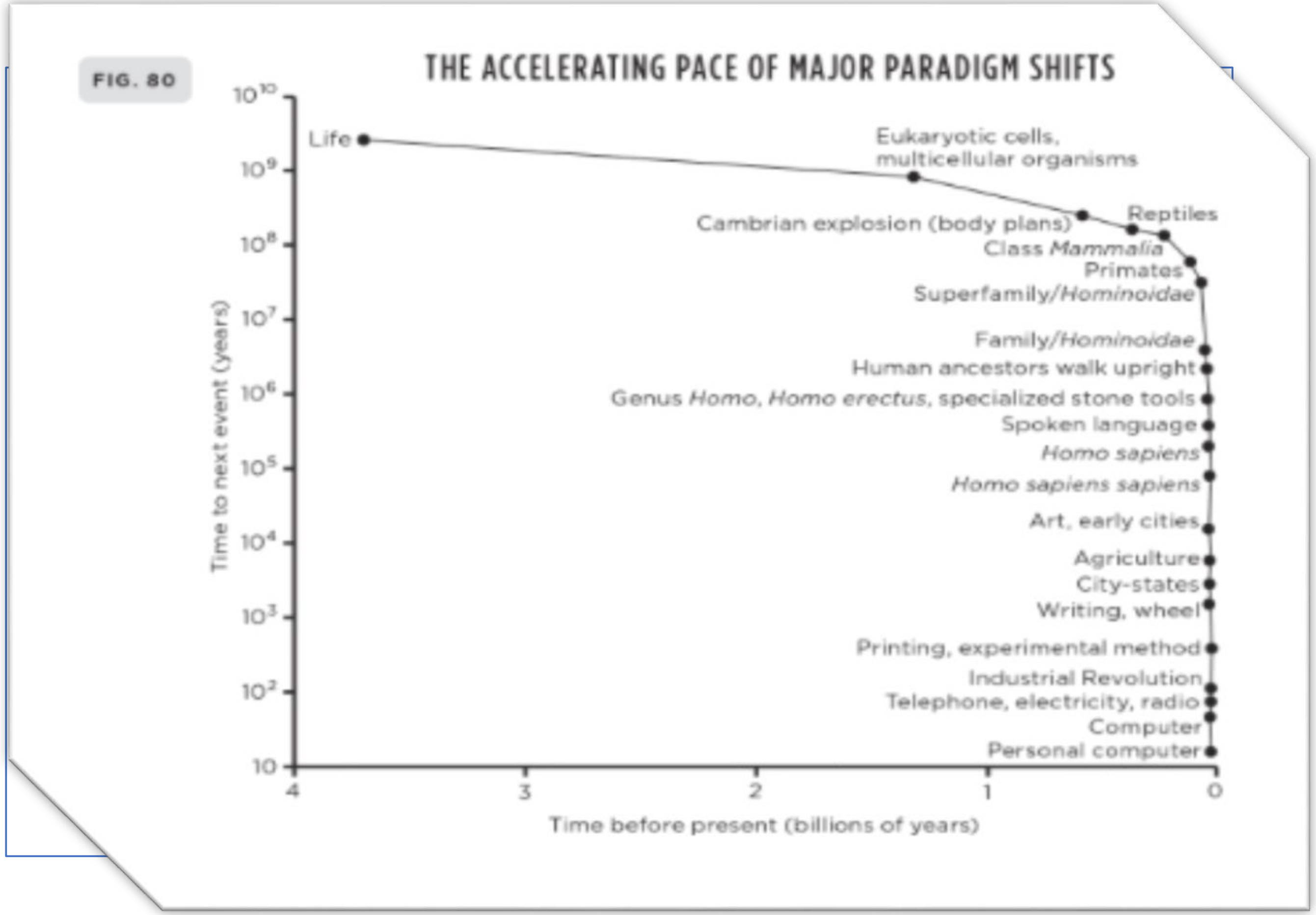
What’s common between China Ban and Marine Litter?

- They are both about plastics
- They both create global environmental impacts
- They both highlight the end of dominant business models
- They both need a serious shift in the global economy and in the plastic industry
- They will not be resolved without radical technological and business innovation

Here comes the 4th Industrial Revolution

ARTIFICIAL INTELLIGENCE AT THE CORE OF INDUSTRY 4.0

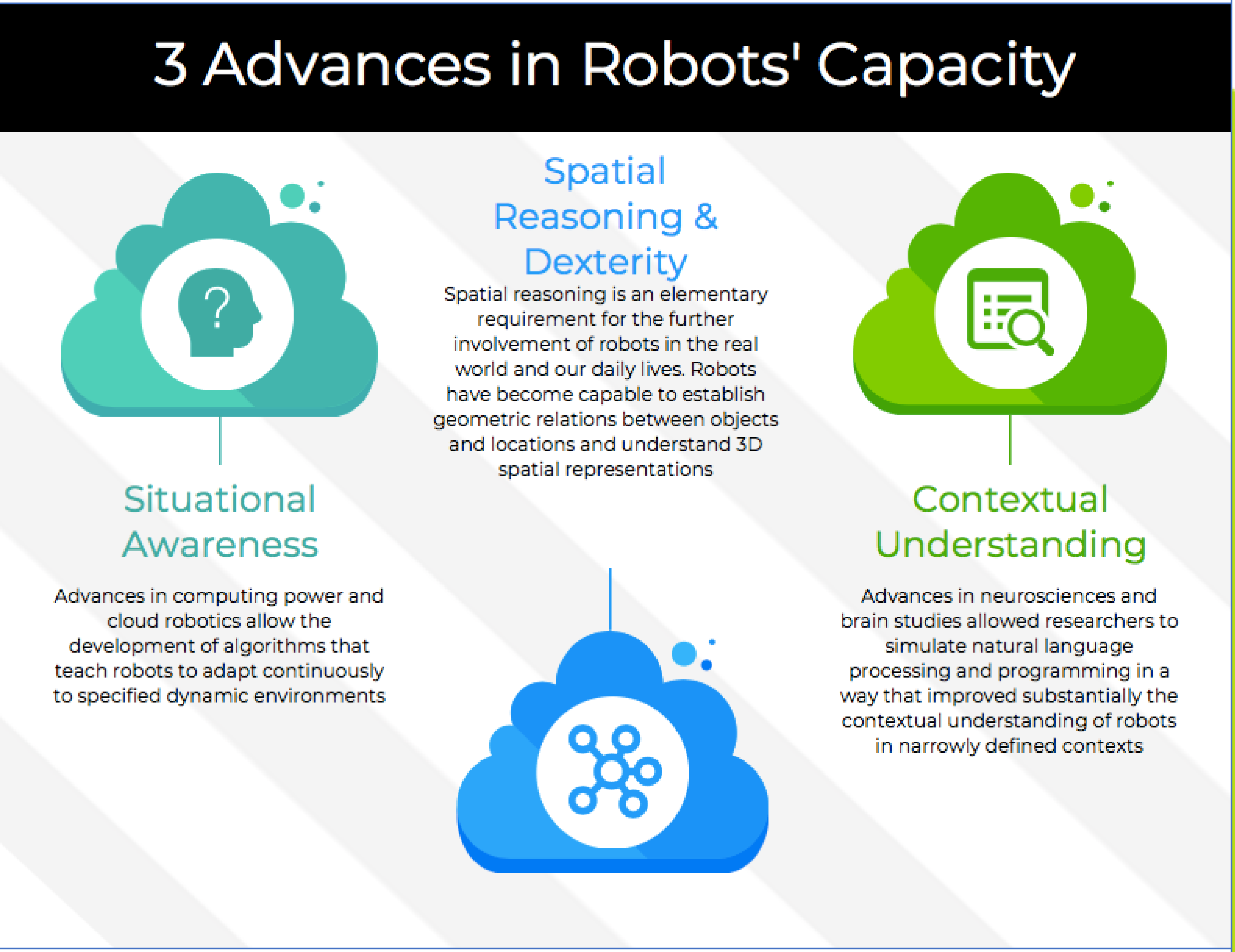
Progress & evolution are not linear!

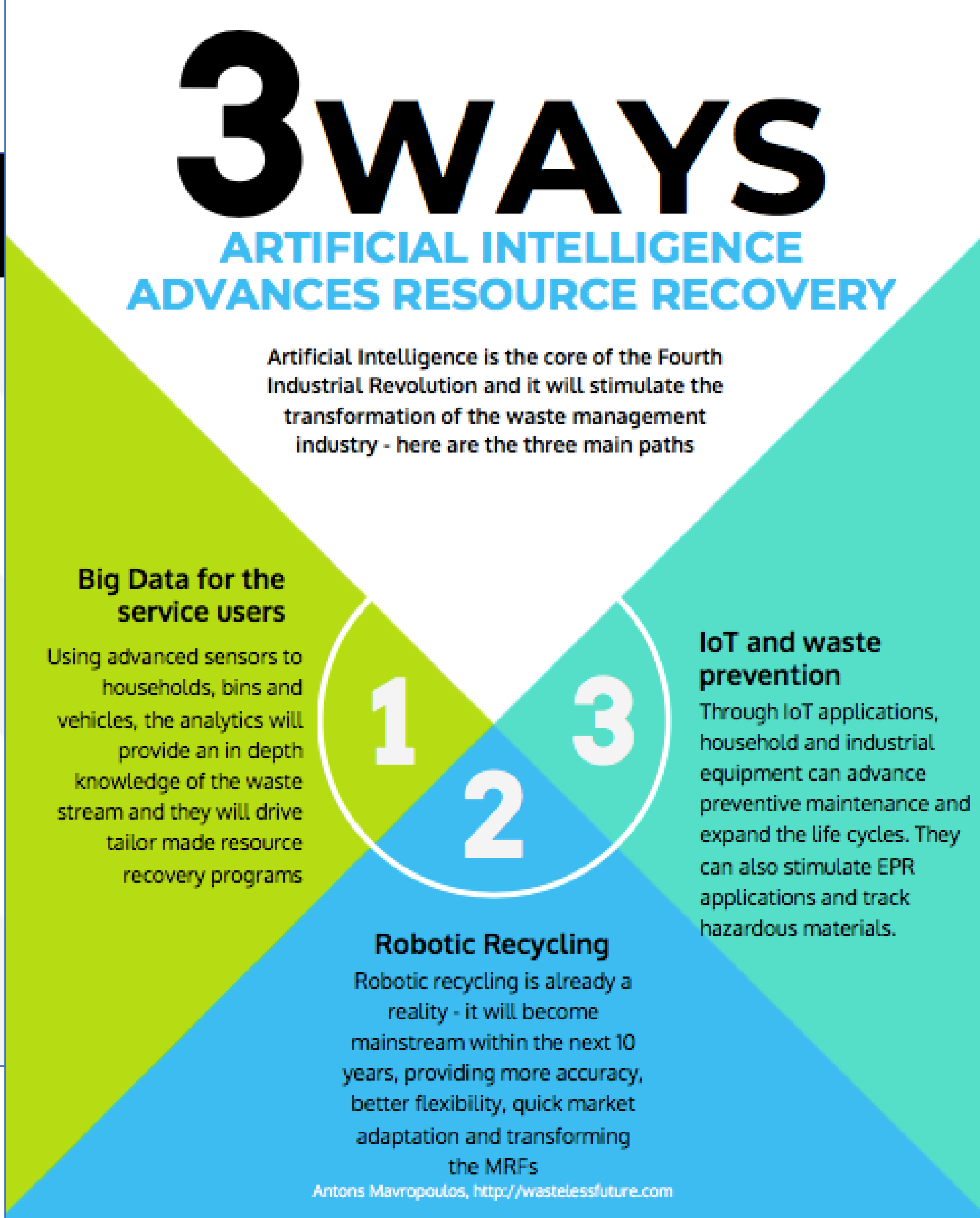


- Technology accelerates at faster paces in more advanced societies than in less advanced societies.
- By 2000, our rate of advancement was five times the average rate in the 1900's.
- At this rate, another century's advancement will be achieved by 2021.
- By the 2040's, a century's worth of progress may be achieved multiple times in the same year.

Source: Geoffrey West, Scale, The Universal Laws of Life, Growth, and Death in Organisms, Cities, ad Companies

Source: Ray Courzweil, "Laws of Accelerating Return" in Human History


3 Advances in Robots' Capacity
Spatial Reasoning & Dexterity
Spatial reasoning is an elementary requirement for the further involvement of robots in the real world and our daily lives. Robots have become capable to establish geometric relations between objects and locations and understand 3D spatial representations
Situational Awareness
Advances in computing power and cloud robotics allow the development of algorithms that teach robots to adapt continuously to specified dynamic environments
Contextual Understanding
Advances in neurosciences and brain studies allowed researchers to simulate natural language processing and programming in a way that improved substantially the contextual understanding of robots in narrowly defined contexts


3WAYS
ARTIFICIAL INTELLIGENCE ADVANCES RESOURCE RECOVERY
Artificial Intelligence is the core of the Fourth Industrial Revolution and it will stimulate the transformation of the waste management industry - here are the three main paths
Big Data for the service users
Using advanced sensors to households, bins and vehicles, the analytics will provide an in depth knowledge of the waste stream and they will drive tailor made resource recovery programs
1
2
3
IoT and waste prevention
Through IoT applications, household and industrial equipment can advance preventive maintenance and expand the life cycles. They can also stimulate EPR applications and track hazardous materials.
Robotic Recycling
Robotic recycling is already a reality - it will become mainstream within the next 10 years, providing more accuracy, better flexibility, quick market adaptation and transforming the MRFs
Antons Mavropoulos, http://wastelessfuture.com

AI & Waste Prevention

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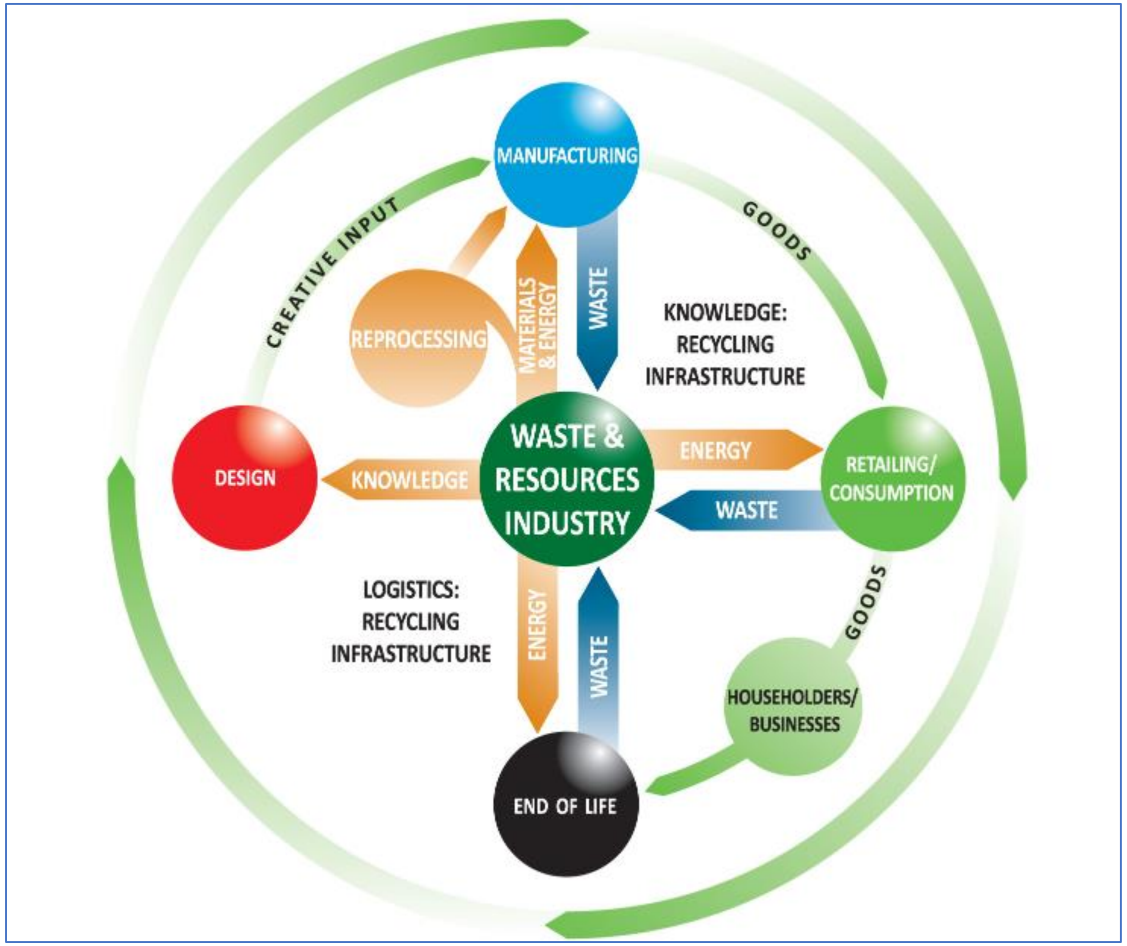
1. AI & IoT can drive EPR
2. AI & IoT can prolong life cycles through preventive maintenance
3. AI & IoT can optimize products for their specific use and drive resource and energy efficiency
4. AI & IoT can stimulate fit for purpose new materials



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Robotic recycling is becoming mainstream

1. Manual sorters will fade out – they will take with them accidents and health problems related to working conditions
2. Adjustments on the sorting lines will become easier and faster, based on the robotic vision and big data systems
3. There will be a much more accurate and precise knowledge of the incoming materials streams
4. Facilities will become more flexible and their response to market changes will be immediate
5. In the beginning we will use robots and AI to optimize the current process – but then, as it became with other sectors, they will redefine the meaning and the design of the recycling plant in ways that its difficult to imagine.

But here are some questions


WASTELESS FUTURE
Antonis Mavropoulos

Home Vision Meet Antonis Speaking

Five questions about Robotic Recycling

Antonis Mavropoulos
January 26, 2017
Circular Economy, recycling, Robots, Sensors, Wasteless
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We have just started to discuss and try to understand what will be the potential impacts of the rise of robots in our lives and societies. But, the pace of change is too fast and very soon we will have to deal with the real consequences rather than the potential ones. As I use to say in my lectures "Fasten your seatbelts, the fourth industrial revolution is already here and disruption is the rule, not the exception".

Robots for Recycling or for CE?

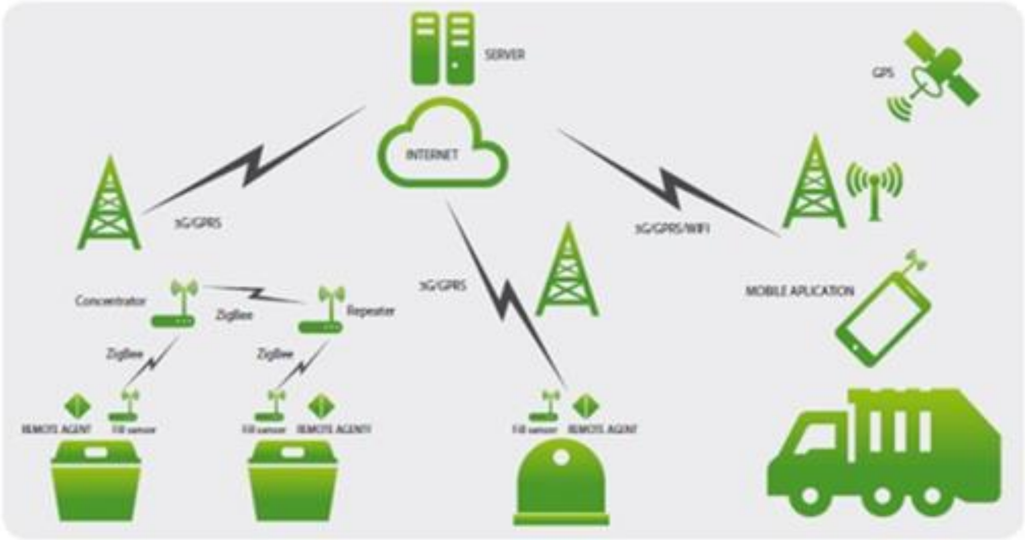
Robots for more or less public engagement?

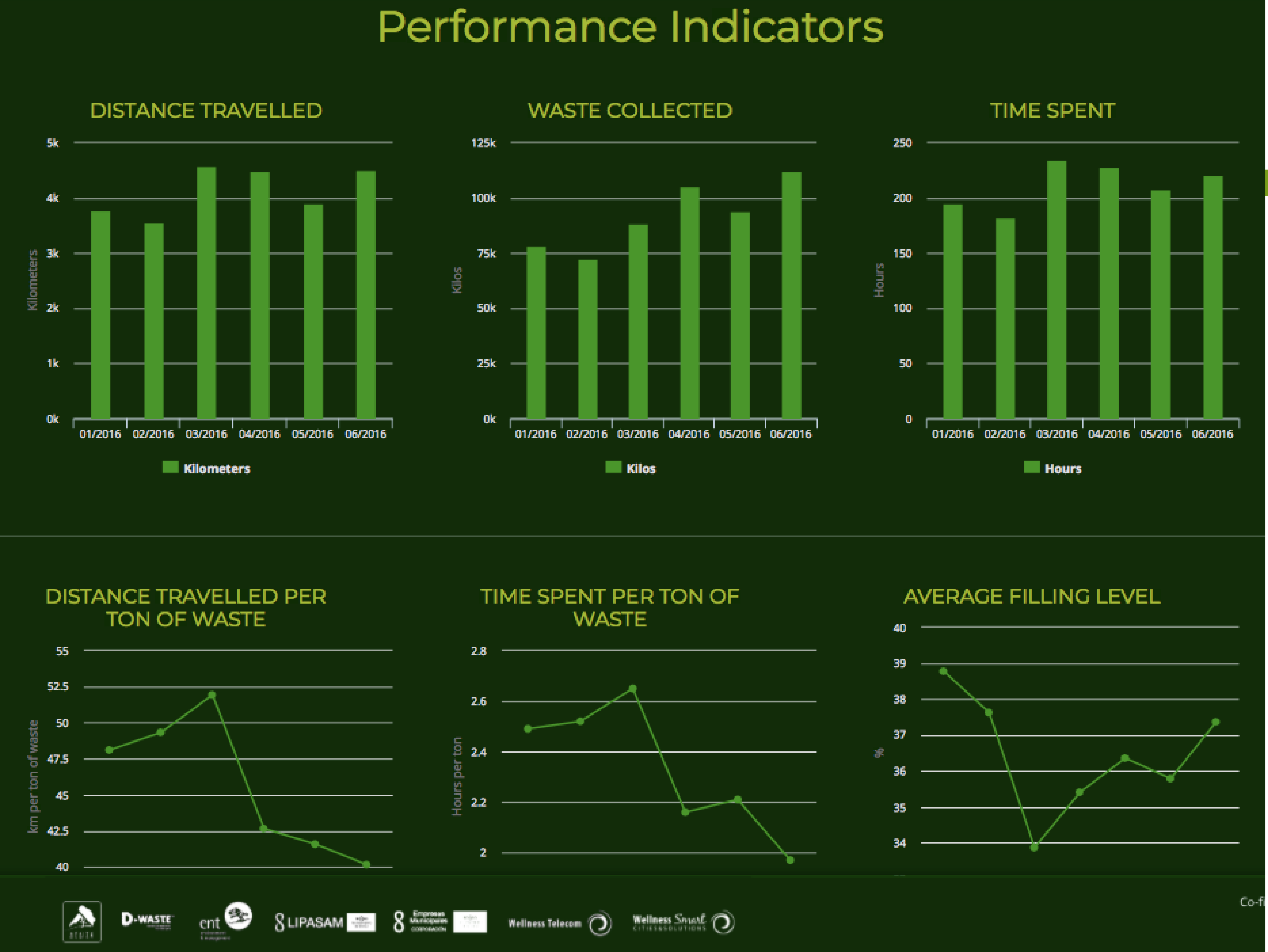
Robots designed for reuse or for becoming the new e-waste?

EPR for Robots?

AI & Waste Collection

1. Advances in situational awareness, contextual understanding and spatial reasoning will soon create robots for emptying waste bins
2. Driverless waste collection is already tested
3. The combination of the previous with mobile apps, cloud computing and sensors in the bins will deliver the first generation of hybrid networks where humans, vehicles, bins and waste data are integrated in a single network that continuously optimizes waste collection procedures.
4. Less cost, more safety and more resource recovery are expected





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The impact will be further obvious with robotic bins directly connected to collection systems

Data is the new soil

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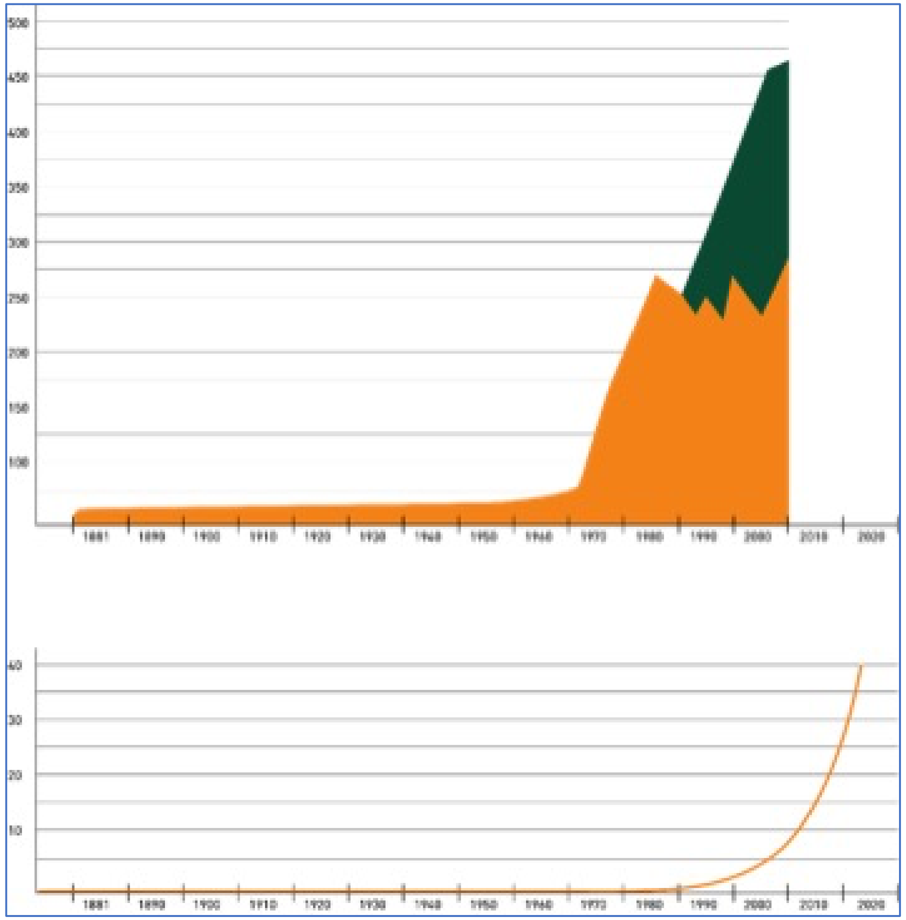
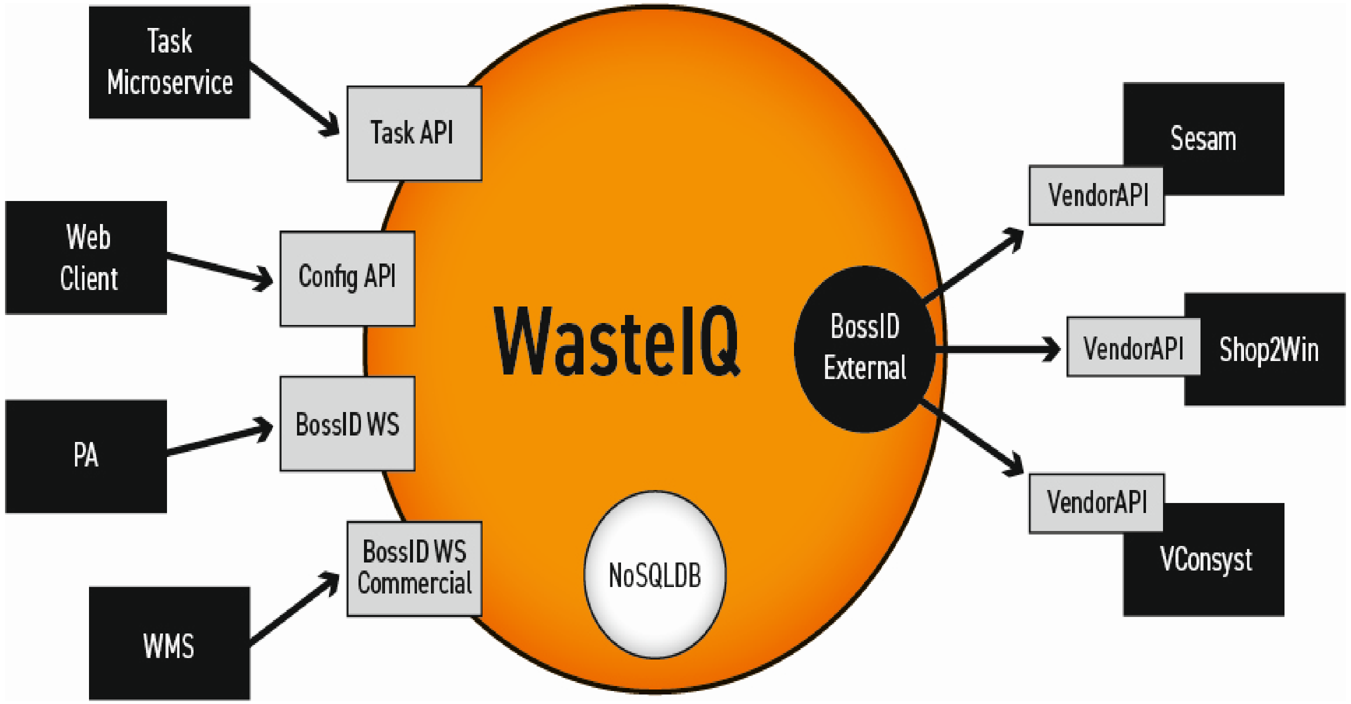
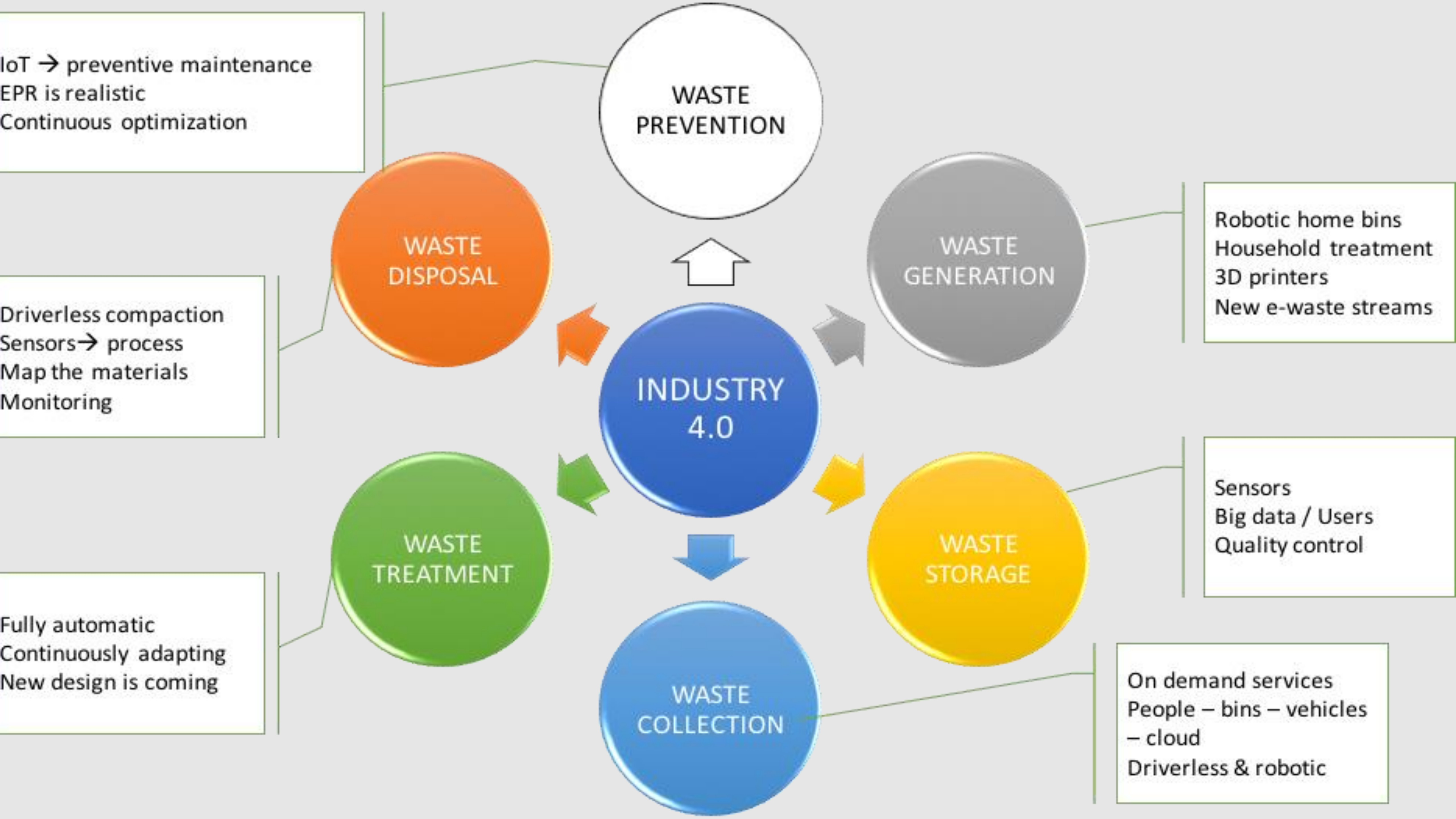
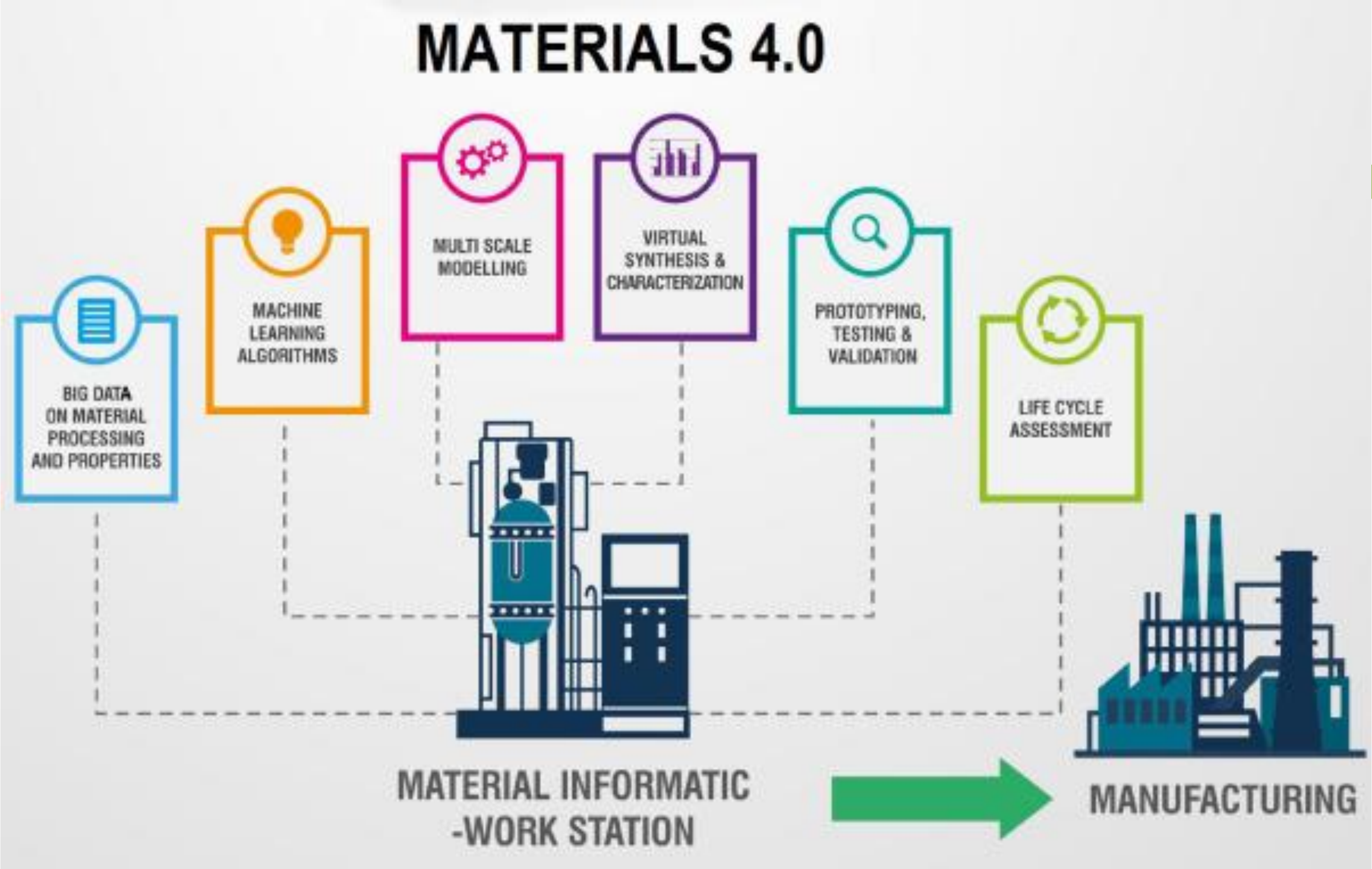




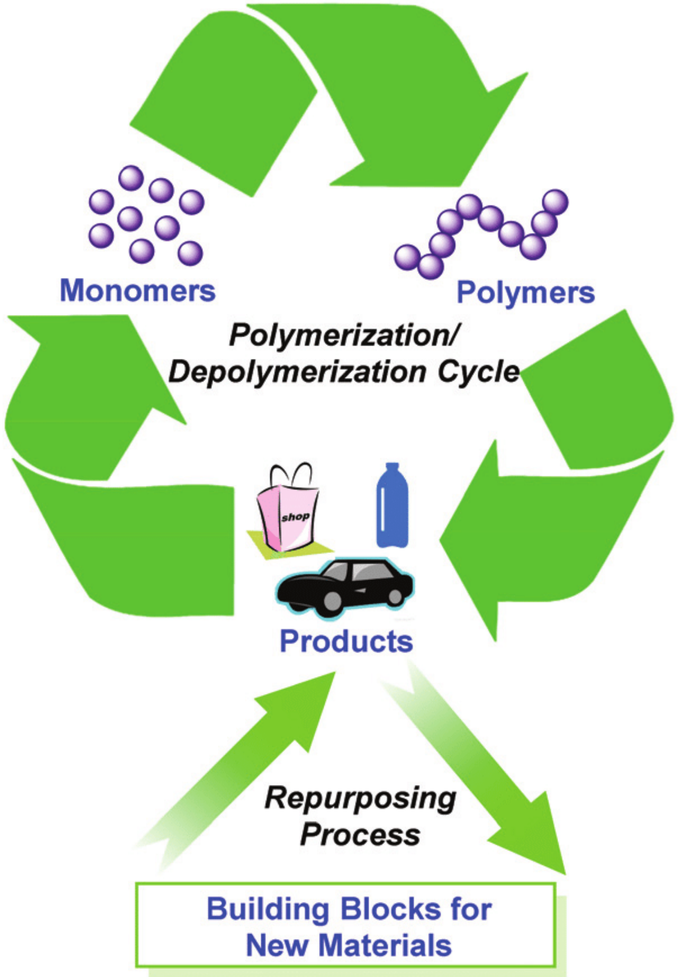
Source: Toralf Igensund, BIR, The 4th Industrial Revolution in practice Waste IQ the open waste management platform, ISWA Blogs


IoT → preventive maintenance
EPR is realistic
Continuous optimization
WASTE PREVENTION
Robotic home bins
Household treatment
3D printers
New e-waste streams
WASTE DISPOSAL
WASTE GENERATION
Driverless compaction
Sensors→ process
Map the materials
Monitoring
INDUSTRY 4.0
Sensors
Big data / Users
Quality control
WASTE TREATMENT
WASTE STORAGE
Fully automatic
Continuously adapting
New design is coming
WASTE COLLECTION
On demand services
People – bins – vehicles – cloud
Driverless & robotic

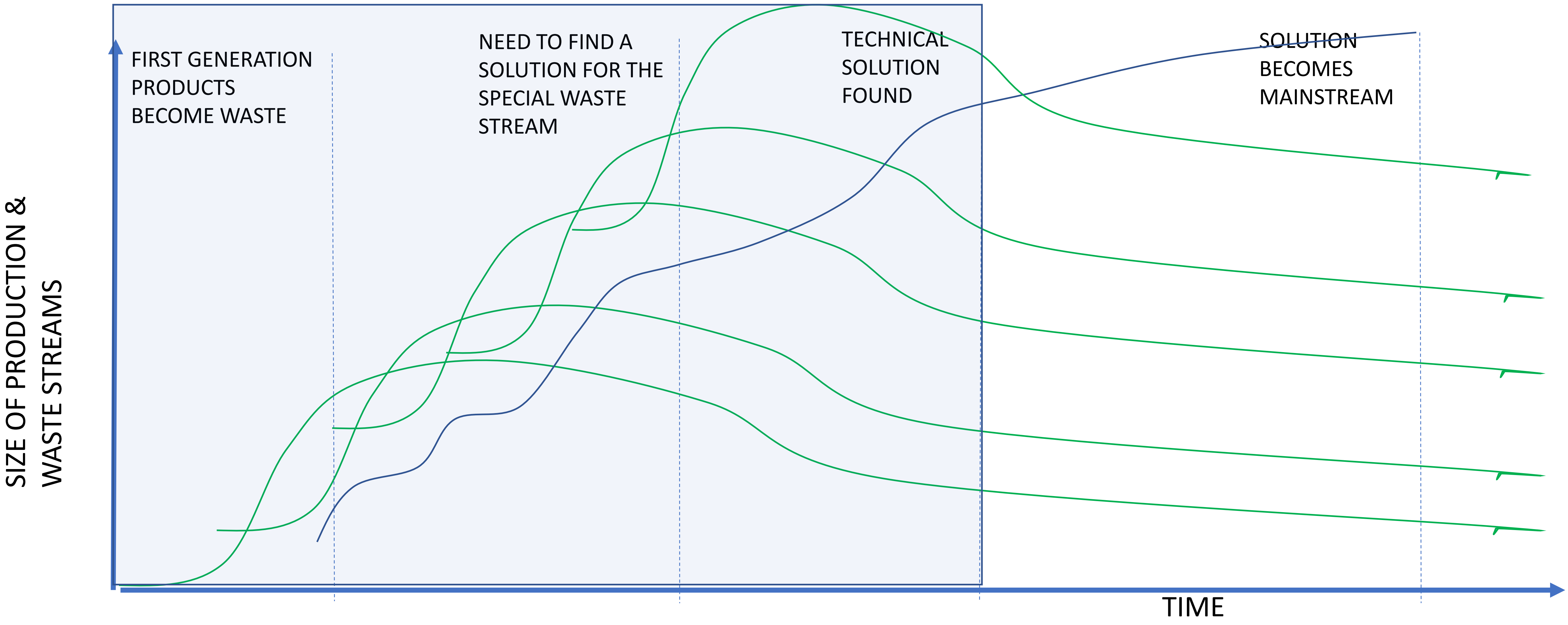


Source: Materials 4.0: Materials big data enabled materials discovery Rajan Jose Seeram Ramakrishna, APPLIED MATERIALS TODAY, Volume 10, March 2018, Pages 127-132

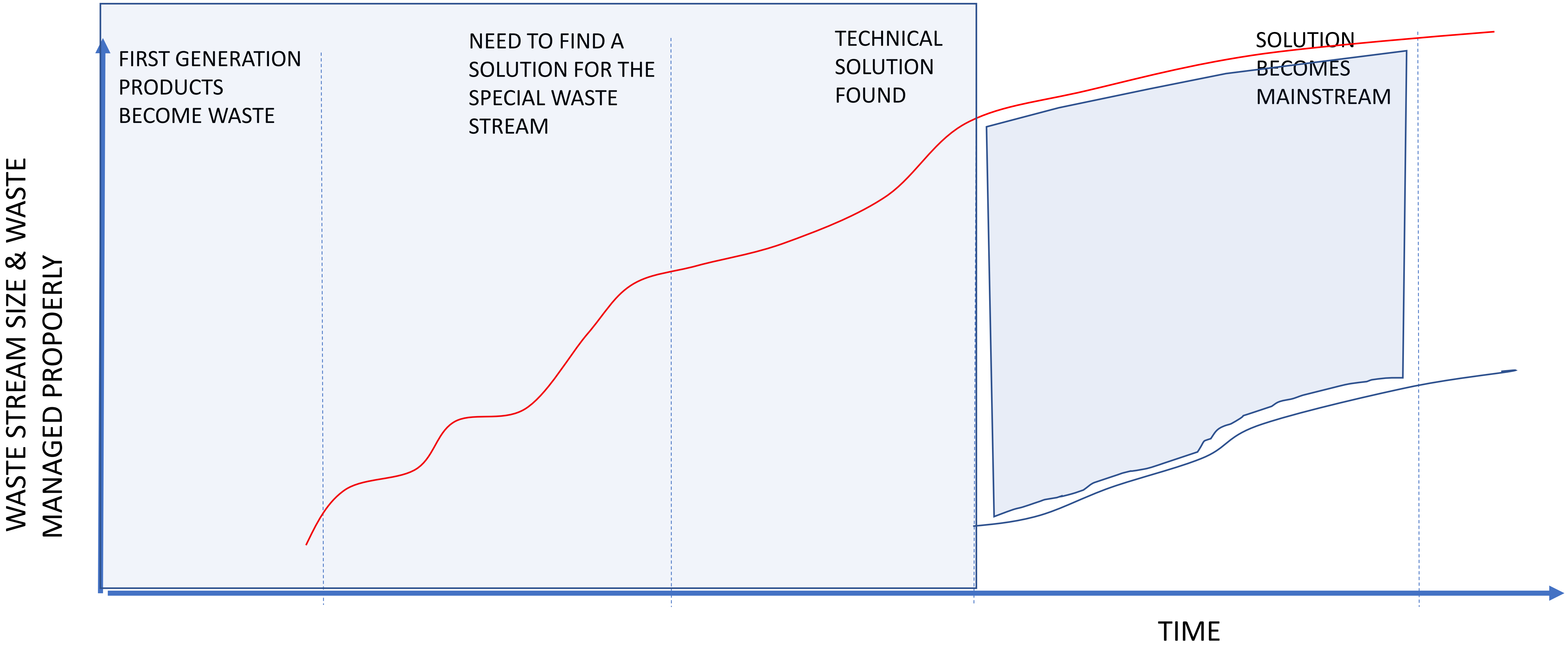
CHEMICAL RECYCLING

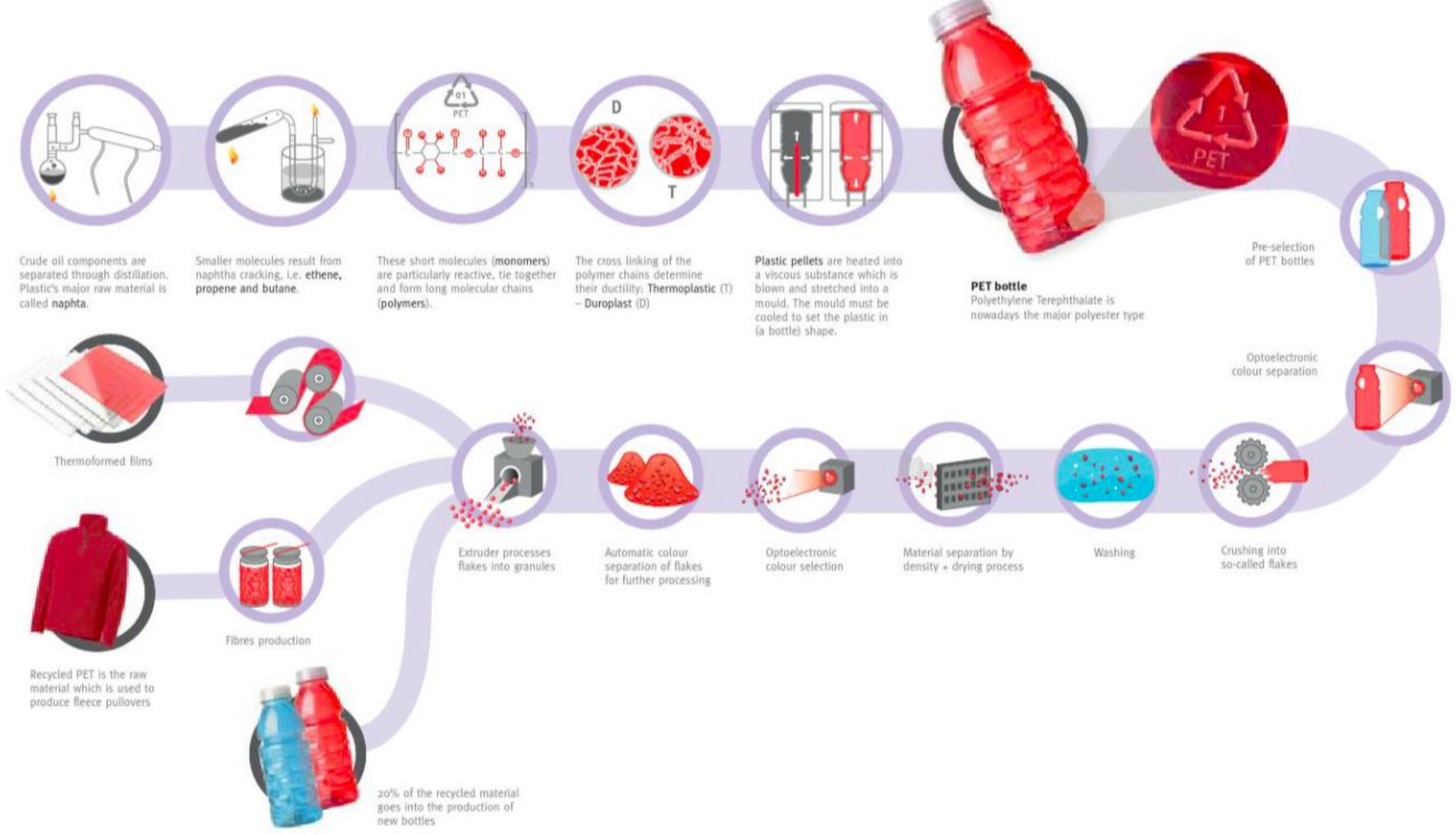


AI can't resolve Product Cycles dynamics



It's a systemic characteristic




01
PET
D
T
1
PET
Crude oil components are separated through distillation. Plastic's major raw material is called **naphta**.
Smaller molecules result from naphtha cracking, i.e. **ethene, propene and butane**.
These short molecules (**monomers**) are particularly reactive, tie together and form long molecular chains (**polymers**).
The cross linking of the polymer chains determine their ductility: **Thermoplastic** (T) – **Duroplast** (D)
Plastic pellets are heated into a viscous substance which is blown and stretched into a mould. The mould must be cooled to set the plastic in (a bottle) shape.
PET bottle
Polyethylene Terephthalate is nowadays the major polyester type
Pre-selection of PET bottles
Optoelectronic colour separation
Crushing into so-called flakes
Washing
Material separation by density + drying process
Optoelectronic colour selection
Automatic colour separation of flakes for further processing
Extruder processes flakes into granules
Thermoformed films
Fibres production
Recycled PET is the raw material which is used to produce fleece pullovers
20% of the recycled material goes into the production of new bottles

Do we have the right focus about recycling?

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Table 2.1 Elements regarded as critical and technologies (JRC, 2013)

Element	Rating	Associated Technology
Rare Earths: Dy, Pr, Nd	High	vehicles, wind
Rare Earths: Eu, Tb, Y	High	lighting
Gallium	High	lighting, solar
Tellurium	High	solar
Graphite	Medium-High	vehicles
Rhenium	Medium-High	fossil fuels
Hafnium	Medium-High	nuclear
Germanium	Medium-High	lighting
Platinum	Medium-High	fuel cells
Indium	Medium-High	solar, lighting, nuclear
Rare Earths: La, Ce, Sm	Medium	vehicles
Rare Earths: Gd	Medium	lighting
Cobalt	Medium	vehicles, fossil fuels
Tantalum	Medium	geothermal, fossil fuels
Niobium	Medium	CCS
Vanadium	Medium	CCS
Tin	Medium	solar
Chromium	Medium	desalination

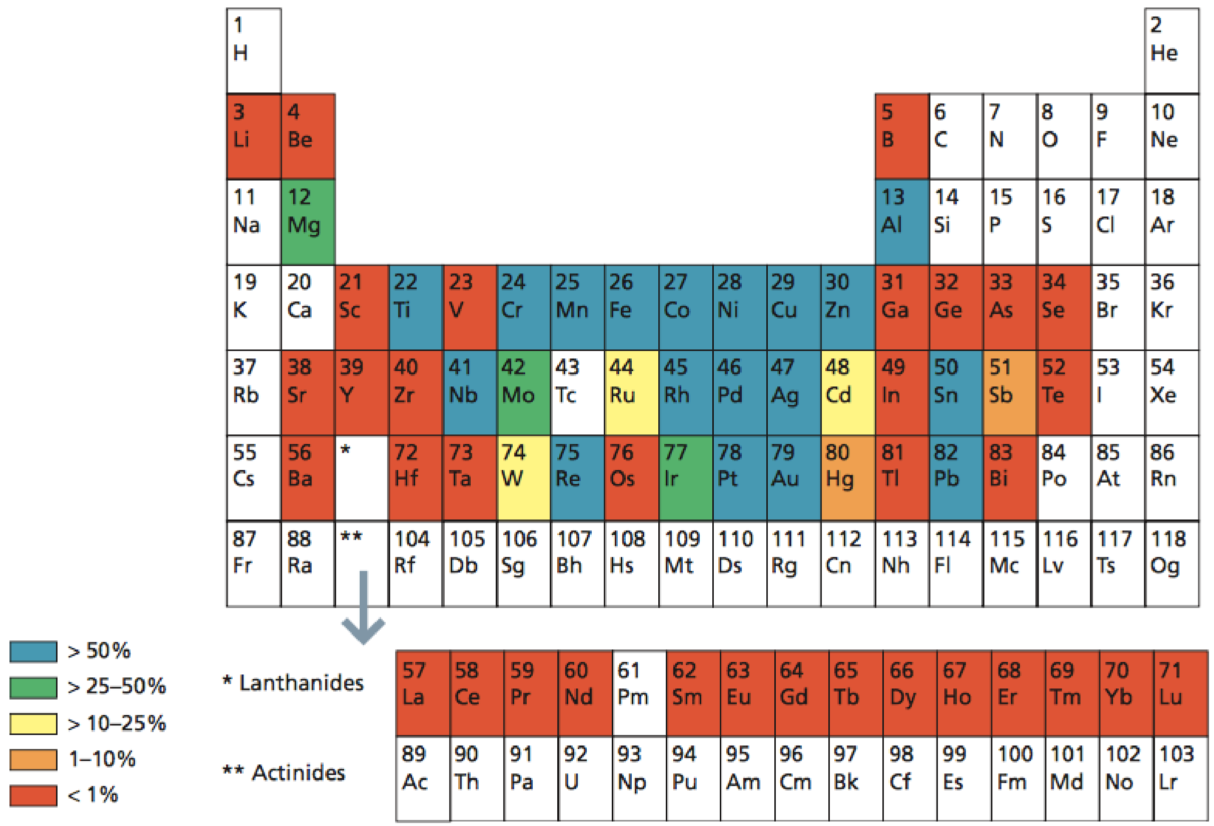
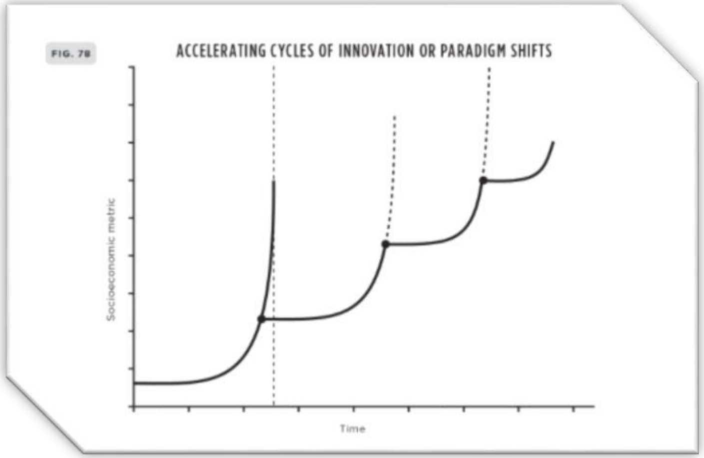


Figure 3.1 Recycling rates for critical materials (UNEP, 2011).

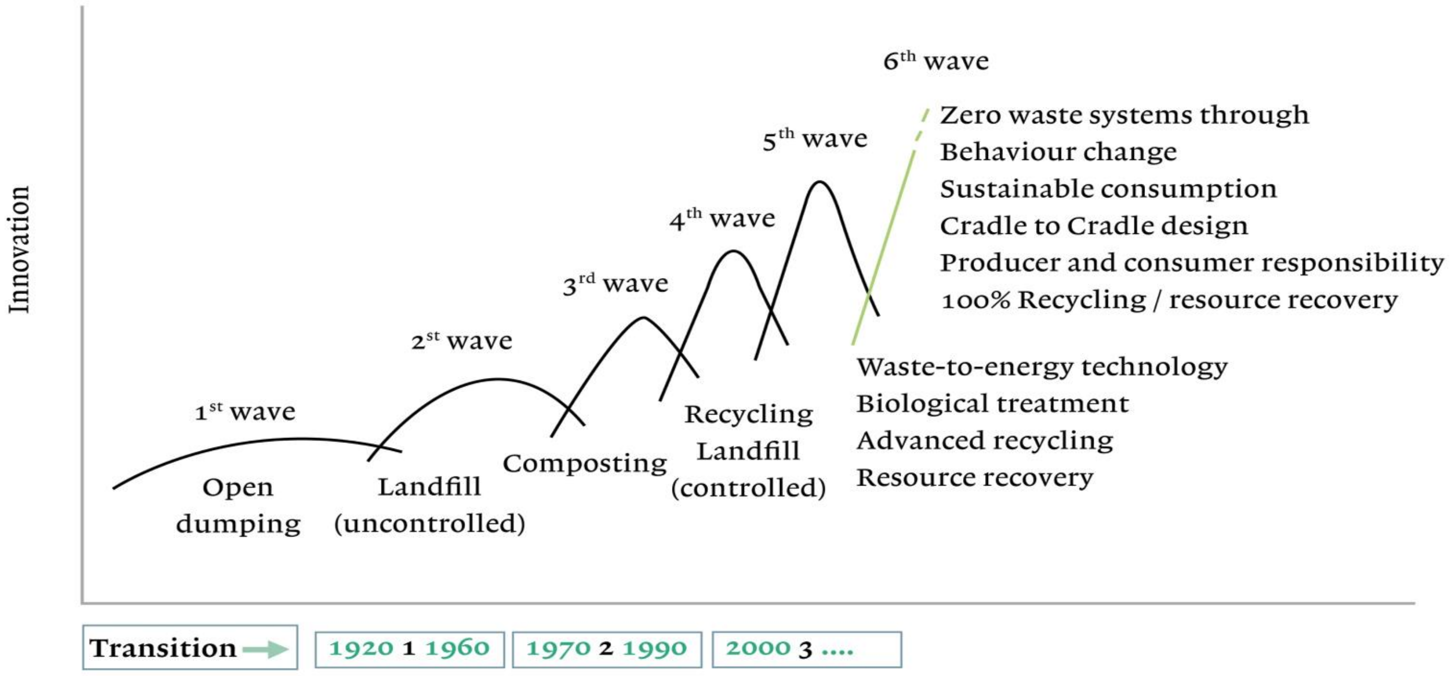
Source: EASAC, European Academies, Priorities for critical materials for a circular economy, 2016

Waste Management Change is the rule!

The previous 30 years are not a measure for the progress of the coming 30 ones – exponential progress can't be comparable with the linear one



Source: Geoffrey West, Scale, The Universal Laws of Life, Growth, and Death in Organisms, Cities, ad Companies



Source: Ad Lasink, Waste Hierarchy as a Legal Instrument, presentation, Workshop on the Waste Law, Beirut, September 2018)

Wasteless or wasteful?

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