Opportunities and challenges in the field of recycling of synthetic polymers

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MicPlaPROB

"ODPADNA PLASTIKA - SKRB IN PRILOŽNOST"

Webinar: PLASTIC WASTE – OUR RESPONSIBILITY AND OPPORTUNITY, 20th of April, 2022

The Academy of Applied Technical Studies Belgrade

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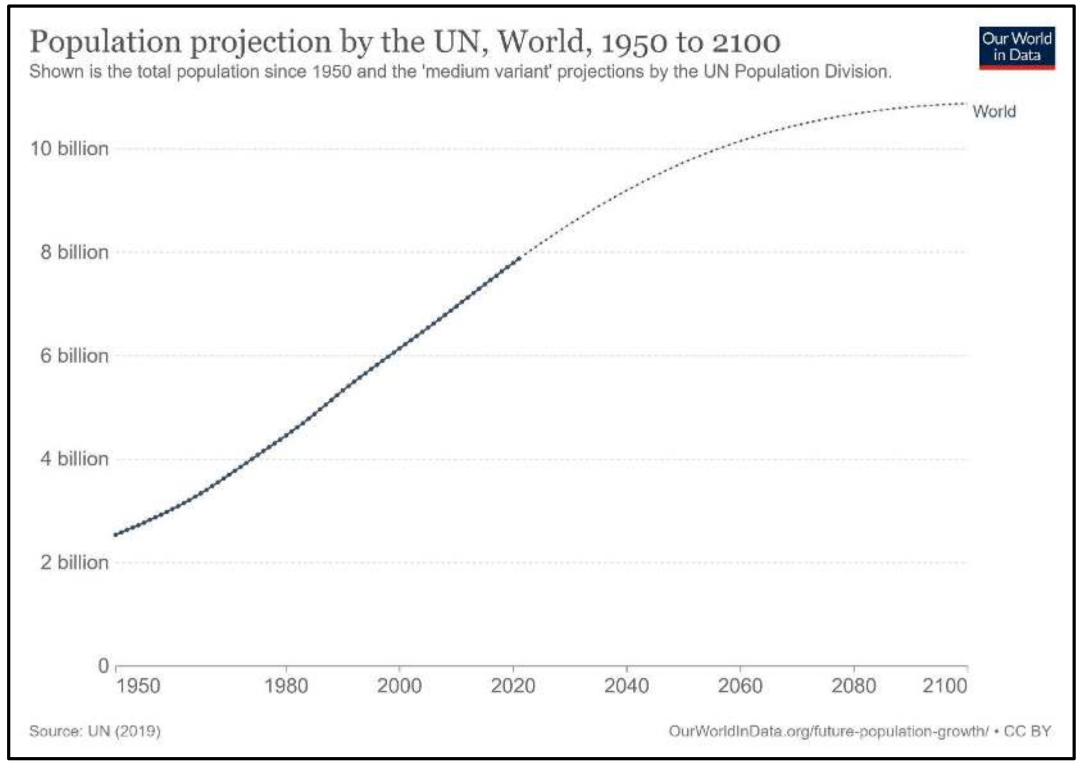
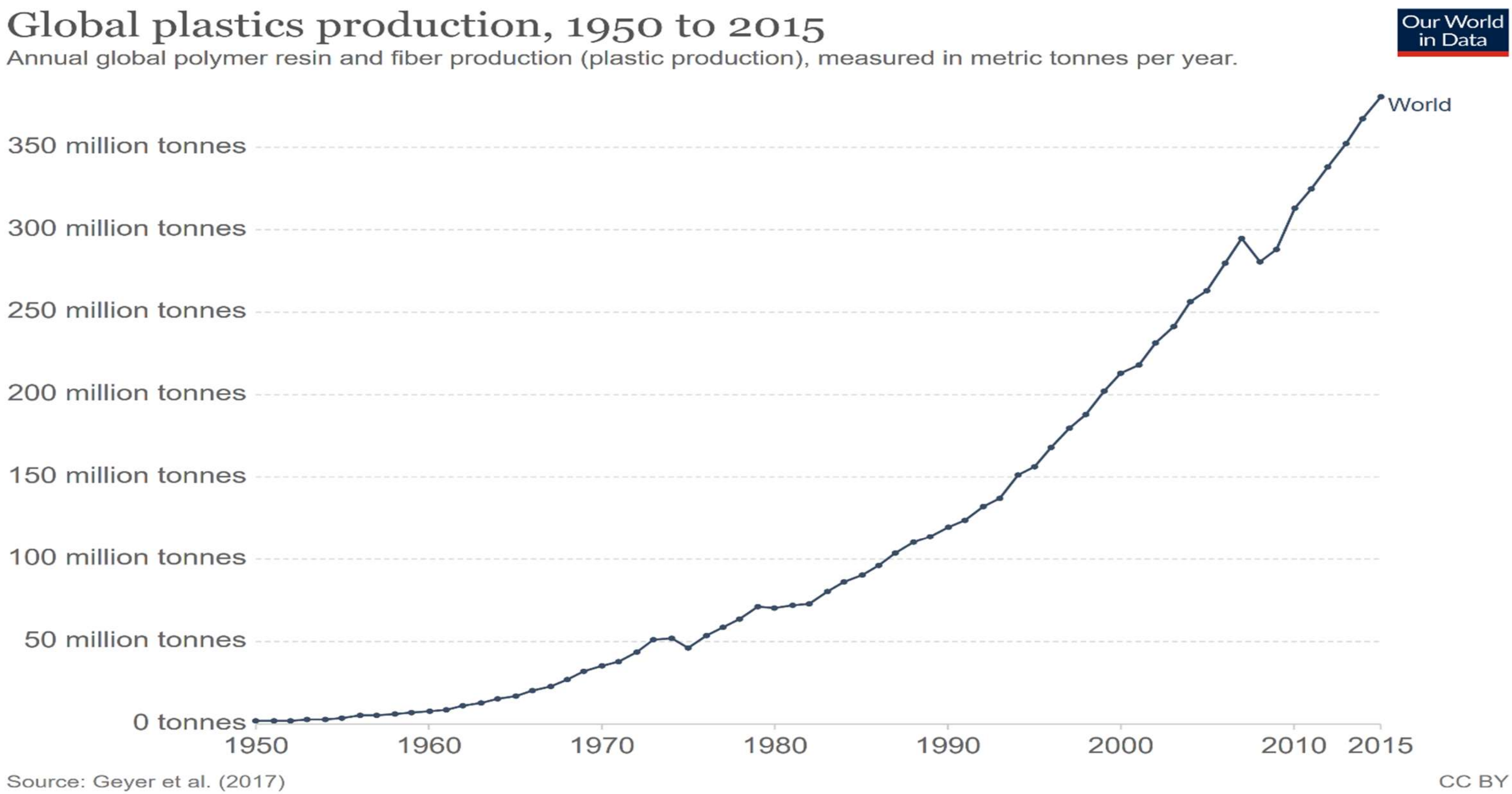
(UN)sustainable future

Population growth

Technological development

Globalization




Global plastics production, 1950 to 2015
Annual global polymer resin and fiber production (plastic production), measured in metric tonnes per year.
Our World in Data
World
350 million tonnes
300 million tonnes
250 million tonnes
200 million tonnes
150 million tonnes
100 million tonnes
50 million tonnes
0 tonnes
1950
1960
1970
1980
1990
2000
2010
2015
Source: Geyer et al. (2017)
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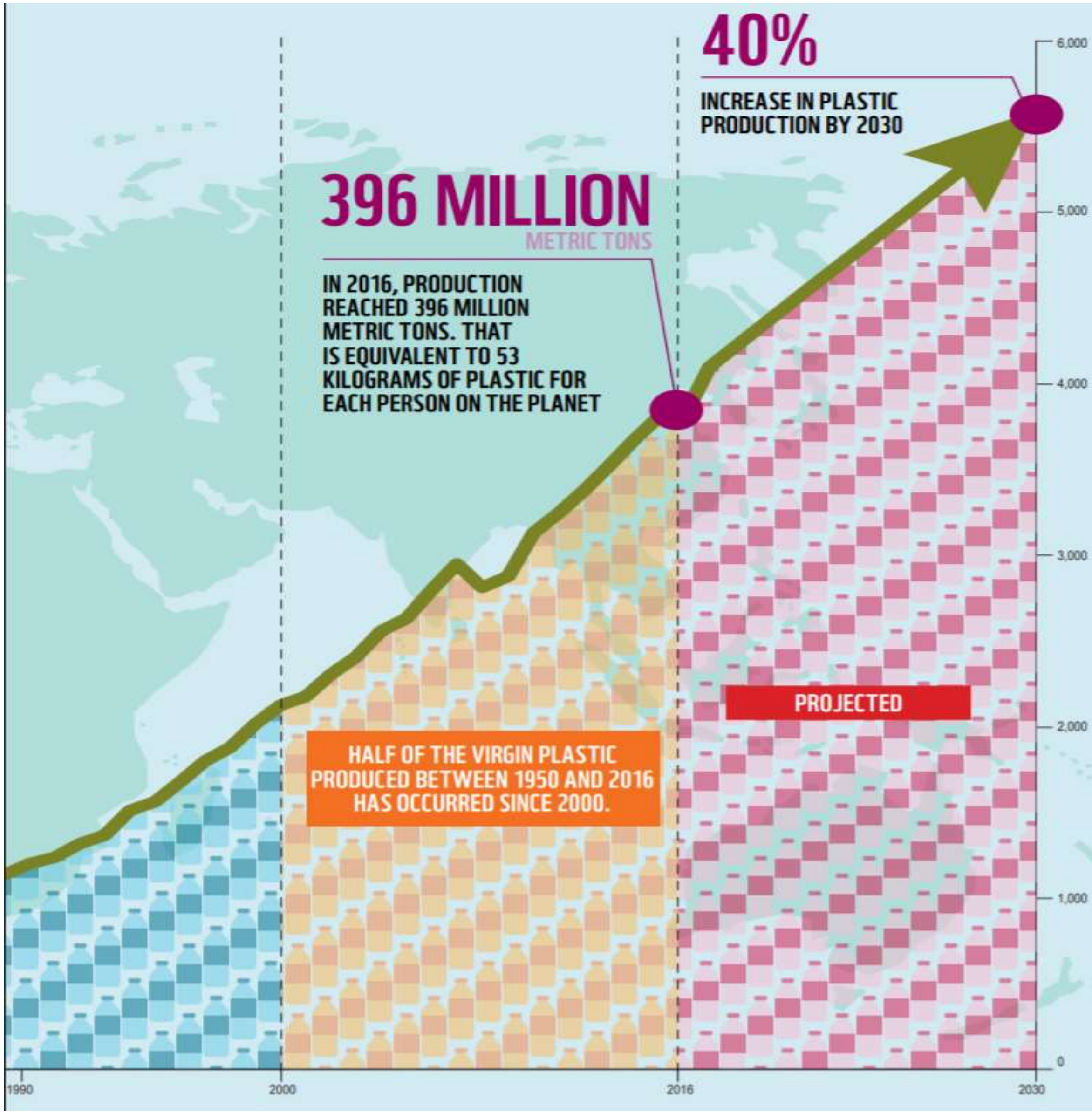
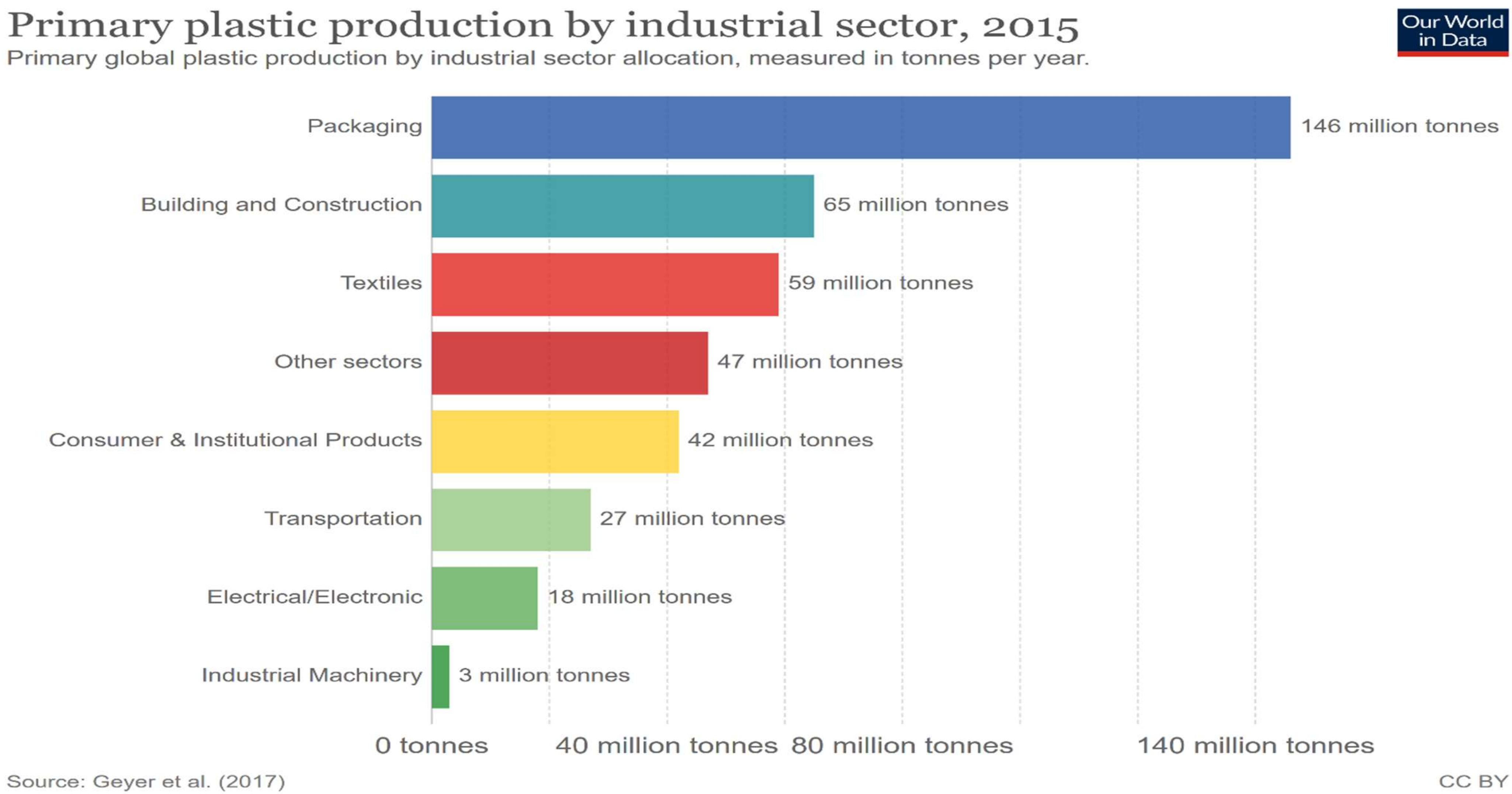


Source: WWF 2019

- Global annual production and consumption of plastic materials is steadily increasing, as presented previously
- Plastics are found **everywhere**, in packaging, textiles, hardware, and consumer products
- Synthetic polymers offer **solid performance at low cost**, sometimes with environmental benefit, for countless uses
  - Low density, durability, good processing capabilities and corrosion resistance
- However, most plastic packaging and too many plastic products are **eventually discarded only after one use**
- There is a **high demand** for plastics across the supply chains of packaging, automotive, agriculture, building and construction, textile, even medical industry …
- All materials are potentially recyclable, but **not** all materials are recycled
- **Recycling of plastic is limited !**
- Recycling involves BOTH collecting a *mixed* material, AND having an economic incentive to convert it into a product
- Many factors **limit** collection and economic incentives


Primary plastic production by industrial sector, 2015
Primary global plastic production by industrial sector allocation, measured in tonnes per year.
Our World in Data
Packaging
146 million tonnes
Building and Construction
65 million tonnes
Textiles
59 million tonnes
Other sectors
47 million tonnes
Consumer & Institutional Products
42 million tonnes
Transportation
27 million tonnes
Electrical/Electronic
18 million tonnes
Industrial Machinery
3 million tonnes
0 tonnes
40 million tonnes
80 million tonnes
140 million tonnes
Source: Geyer et al. (2017)
CC BY

GLOBAL CHALLENGES

- Global use of plastics (and other fossil fuel based materials) is steadily **growing**, despite of all the efforts
- A majority of the plastics used are **never recovered** — over 85%...
- According to some estimates, by 2030 **plastic production** will increase by **40%** and by 2050 expected increase in waste production is app. **70%**
- **The need to shift to circularity** is recognized, but the key actions are still to come. More investment is urgently needed to **support and scale transformational technologies**.

THINK GLOBALY ACT LOCALY...

- When plastics are collected, many countries/regions do not have the **recycling infrastructure** to properly and profitably sort, process and market much of this material.
- Manufacturers are challenged to use recycled plastics in the existing processes because they often do not perform as well as virgin plastics, due to **degradation or contamination**
- Without a bold shift in the current approach, the **mismanagement of plastics waste will worsen**, resulting in the loss of valuable materials and missed opportunities to recover and harvest the value of these resources.

Meet the synthetic polymers

The overall plastics market is dominated by the '**plastic big 5**':

- polypropylene (**PP**) – *yogurt containers, lids*
- polyethylene (**PE**)
  - Low-density (LDPE) – *plastic bags*
  - high-density (HDPE) – *detergent bottles*
- polyvinyl chloride (**PVC**) – *water pipes, medical equipment*
- polystyrene (**PS**) – *plastic cutlery, coffee cups*
- poly(ethylene terephthalate) **PET** - *water/soft-drink bottles*

- Together '**plastic big 5**' make up around **70%** of all manufactured plastics worldwide

Mechanical recycling of polymers

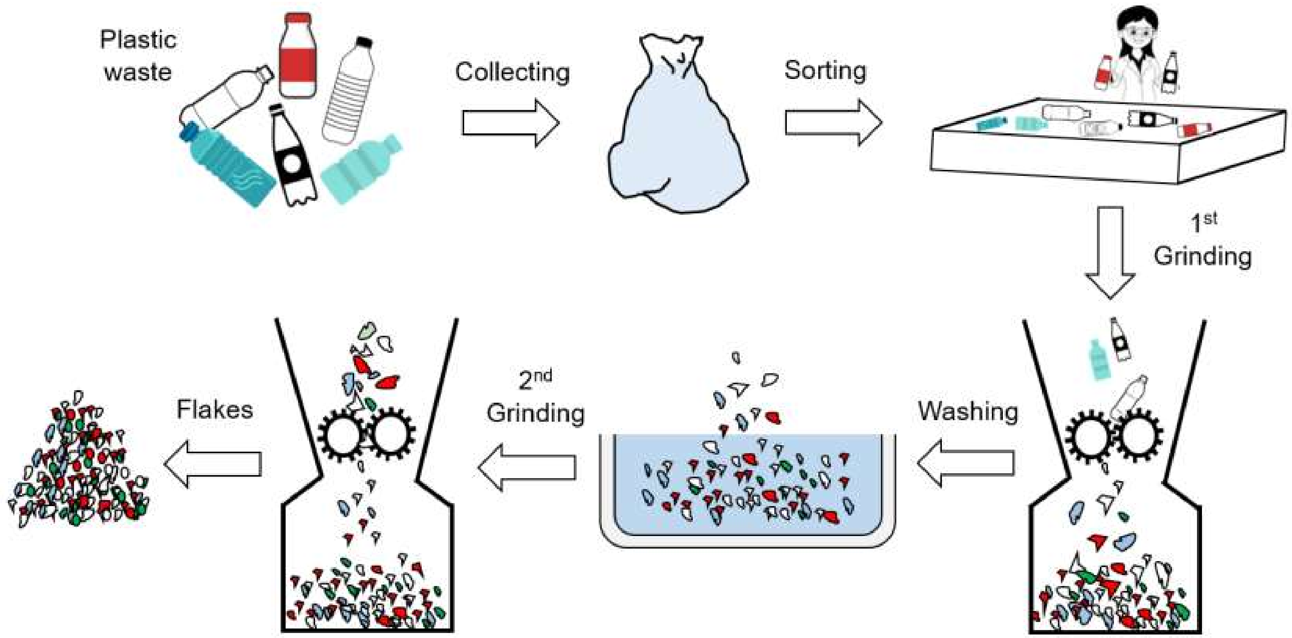


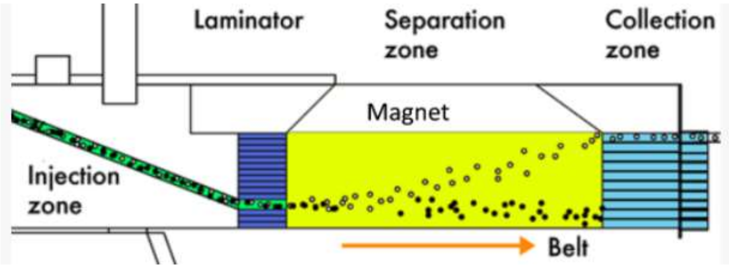
FIGURE 4. Scheme of the basic principal steps in a mechanical recycling process

Delva et.al, MECHANICAL RECYCLING OF POLYMERS FOR DUMMIES

Post-consumer plastic waste

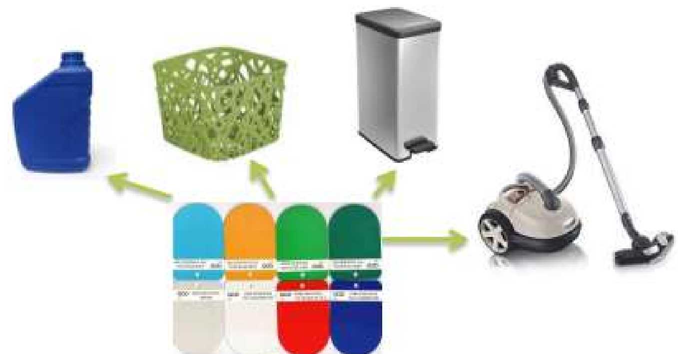
- ***Example*** - innovative processes for the purification of polymers from mixtures of post-consumer polyolefin wastes **packaging polyolefins represent 30% of the total polymer production*.
- **MDS** – Magnetic density separator
- MDS cuts the shredded mixed input waste into four different density ranges of polymer products
- Sink-float process using the difference in densities between plastics mixtures (PP, LDPE, HDPE, PS, PVC, etc.).
- A simplified layout of the prototype comprises a ferrous liquid and a magnet placed above it. different materials become lighter in weight than the liquid at different distances from the magnet, they can be separated by each other as they will be floating at different locations
- **MDS W2Plastics technology**
- https://youtu.be/8Fr54B8Qvtw

@TUDelft



QCP – The Production Process

QUALITY
CIRCULAR
POLYMERS



Shredding

Pre-washing / heavy removal

Wet grinding

Hot Wash

Sorting Centrifuges

Wind shift

Color flake sorting

Homo-genization

Extrusion / degassing / melt filtration

Compounding

WORLD MATERIALS FORUM

suez

LIMITS OF MECHANICAL RECYCLING :

- difficulties to handle multilayers products
- deinking / discoloration of plastics
- food contact for most polymers (PP, PE, PS)
- desodorisation of recycled plastics
- removal of forbidden substances (REACH, POP, RoHS)

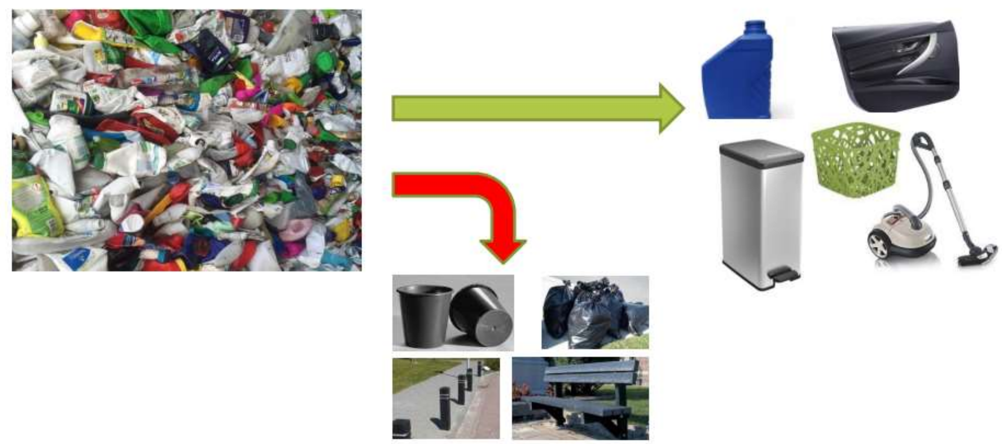
→ Need to find new processes to solve these issues

Higher Quality Needed

- polymer degradation (thermo-mechanical)

- the mechanical recycling of mixed polymers will inevitably lead to the formation of polymer blends

- it is compromising the mechanical properties of the product



Enter the ‚virgin like‘ compound market

Many examples of creativity, innovation …

Home » Changemakers » Sustainability in 3D Printing: How Closed Loop Plastics delivered a recycled filament without sacrificing quality

Sustainability in 3D Printing: How Closed Loop Plastics delivered a recycled filament without sacrificing quality

Feb 11, 2022

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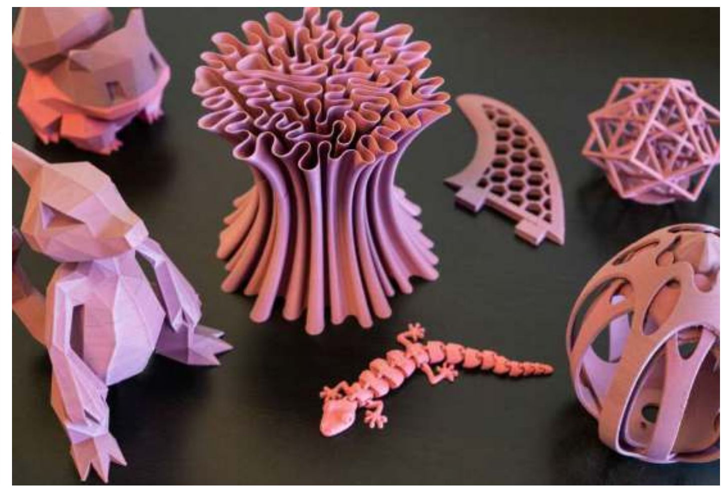


Photography by: UCI Beall Applied Innovation

Chemical recycling of polymers

- Collected plastic waste is **chemically degraded** into its **monomers** or other basic chemicals.
- The processes involved are, amongst others, **hydrolysis, pyrolysis, hydrocracking** and **gasification**.
- The output may be reused for:
  - **polymerization into new plastics**
  - the production of **other chemicals** or
  - as an alternative fuel

- **Challenges:**
- high investments
- high energy consumption
- high input levels, making only large(r) plants economically viable often.

Delva et.al, MECHANICAL RECYCLING OF POLYMERS FOR DUMMIES

Chemical recycling of polymers

“Plastic is still fantastic. But the end of life of plastic has not been thought through enough.

— ***Martin Stephan,*** *deputy CEO, Carbios*

Credit: Pyrowave

Pyrowave is testing a process that uses microwaves to break down polystyrene into styrene.

PURIFICATION : → involves dissolving plastic in a solvent
→ applicable for PVC, PS, PE, PP

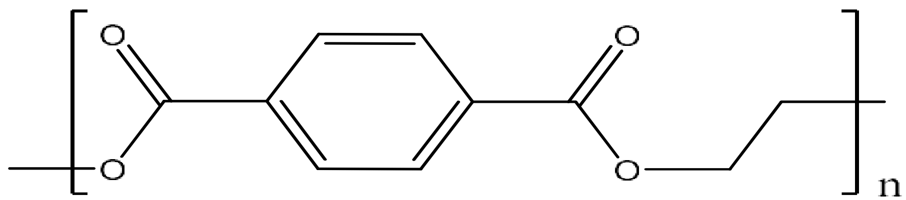
DECOMPOSITION (or depolymerisation) :
→ breaking molecular bonds to recover monomers
→ PET, PU, PA, PC, PEF

CONVERSION : → thermal depolymerisation and cracking (pyrolisis and gasification)
→ breaking further molecular bonds (liquids or gaseous hydrocarbons)

valorplast

Synthesis of plasticizers from waste PET

Waste PET – generic formula **A**:



A

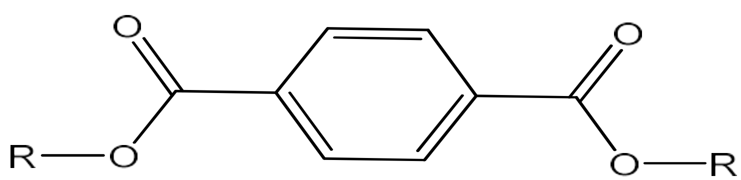
after purification (preparation) in the reactor we added alcohol, general formula **B**

R—OH

B

R: 2-hydroxyethyl, 2- (2-hydroxyethoxy) ethyl, benzyl group, di, tri and tetra functional alcohols, 2,3-dihydroxypropyl etc.

Glycolysates, derivatives of terephthalic acid are obtained, general formula **C**:



C

Thermoplastic composites from waste

- **Recycled (with % of virgin plastic often needed) synthetic polymer granulate:**
- high density polyethylene (PEVG), low density polyethylene (PENG), PVC, polypropylene (PP), acronitrile-butadiene-styrene (ABS), polystyrene (PS), polylactic acid (PMK)
- Fillers, e.g. **waste wood -** shredded, sifted, dried (sawdust, wood flour)
- **Additives:** binders, paints, UV stabilizers, antimicrobial additives, etc.
- **Application:** construction (66%), infrastructure (18%) and automotive industry (10%)

Panel core layer: Epoxy-glass fibre FRP-waste / recycled HDPE-plastic (70/30%)

Panel surface layer: Wood-Plastic-Composite WPC (waste wood / recycled HDPE-plastic 70/30%)

Illustrations in multilayer extrusions; panel dimensions 10x150 mm

CONENOR

Fillers and nanofillers in thermoplastic composites

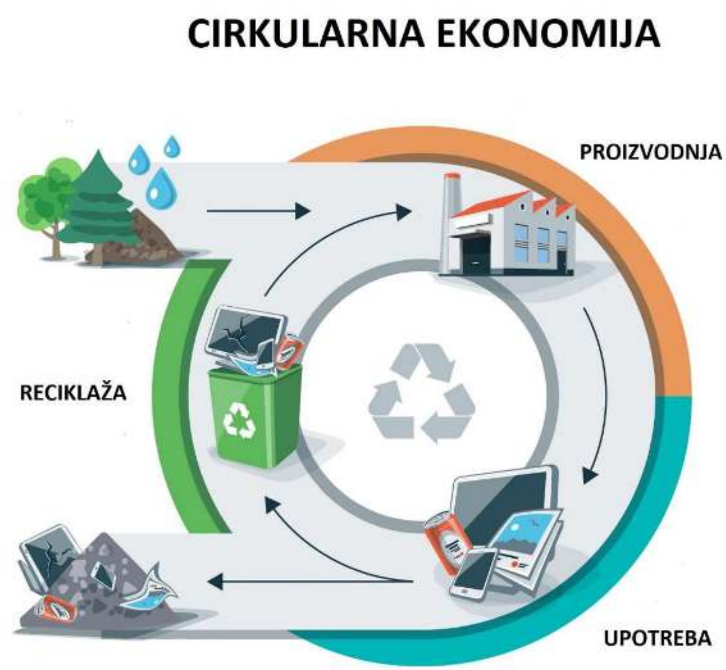
- **Examples of fillers**
- Calcium carbonate
- Clay
- Bentonite
- Glass fibers
- Ash
- Sawdust / wood flour
- Rubber particles

Wood flour

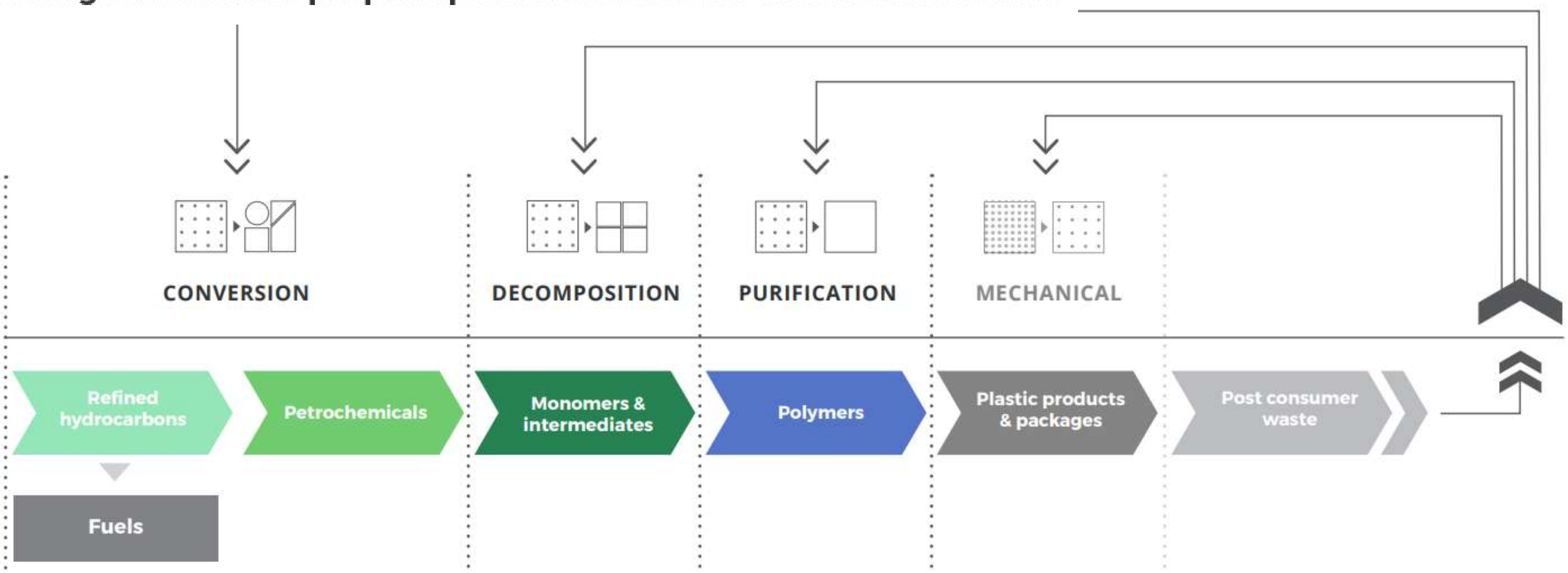
- **Nanofillers**
- Silicon dioxide
- Titanium dioxide
- Aluminum oxide
- Zinc oxide
- Silver nanoparticles
- Calcium carbonate nanoparticles
- Carbon nanotubes
- Nanocellulose

Nanocellulose

Linear → Circular economy

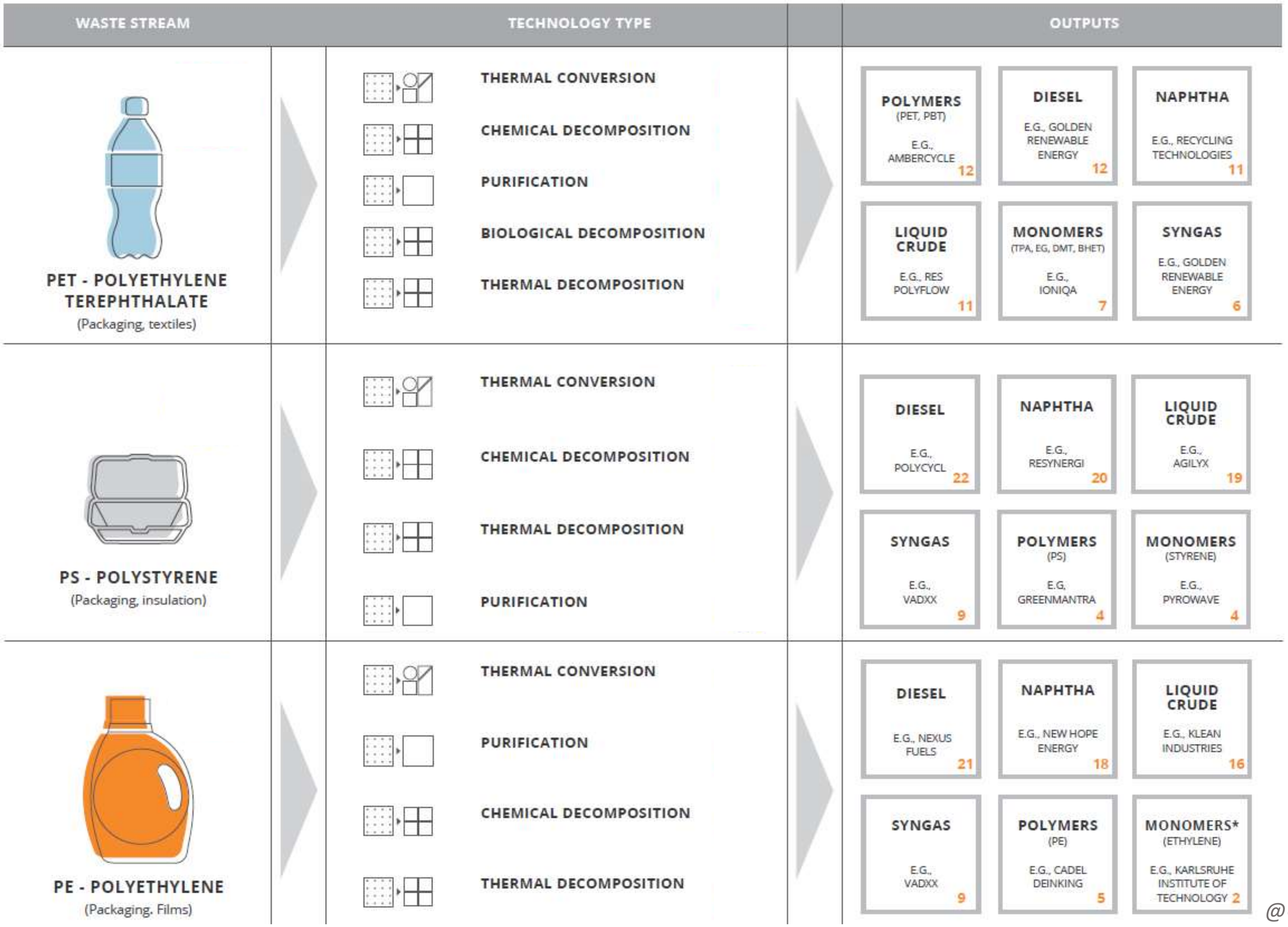


Technologies exist to repurpose plastics waste into valuable materials.



In this moment of technology transition from a linear to circular system, a fundamental question is: **How fast and how far can we go?** For investors, brands, and industry, the answer depends upon four key shifts that will be critical to success.

With growing interest and engagement coming from many different players in the system, **there is clear momentum for adopting and scaling** purification, decomposition and conversion infrastructure for waste plastics. Every sector of society is engaged in the broad challenges of climate change and the visible problem of plastics waste. The world's largest and most influential brands are taking ownership of the problem and looking at their own supply chains. Technology development is happening. There are solutions that are tackling key material types, producing materials in an environmentally beneficial way, attracting partners and capital, and becoming commercially viable.



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WASTE STREAM	TECHNOLOGY TYPE	OUTPUTS
PP - POLYPROPYLENE (Packaging, pipe, textiles)	THERMAL CONVERSION PURIFICATION CHEMICAL DECOMPOSITION THERMAL DECOMPOSITION	**DIESEL** E.G., JBI PLASTICS2OIL 21 **NAPHTHA** E.G., RENEW ELP 18 **LIQUID CRUDE** E.G., KLEAN INDUSTRIES 16 **SYNGAS** E.G., PLASTIC ENERGY 9 **POLYMERS** (PP) E.G., PURECYCLE TECHNOLOGIES 5 **MONOMERS*** (PROPYLENE) E.G., KARLSRUHE INSTITUTE OF TECHNOLOGY 2
MIXED PLASTICS (Packaging, other)	THERMAL CONVERSION CHEMICAL DECOMPOSITION THERMAL DECOMPOSITION	**DIESEL** E.G., RENEWLOGY 15 **NAPHTHA** E.G., RECYCLING TECHNOLOGIES 13 **LIQUID CRUDE** E.G., RES POLYFLOW 13 **SYNGAS** E.G., GOLDEN RENEWABLE ENERGY 9 **MONOMERS*** (ETHYLENE, PROPYLENE) E.G., KARLSRUHE INSTITUTE OF TECHNOLOGY 1
ELECTRONICS (Cell phones, electronic hardware)	THERMAL CONVERSION PURIFICATION	**DIESEL** E.G, KLEAN INDUSTRIES 5 **NAPHTHA** E.G, SIERRA ENERGY 5 **LIQUID CRUDE** E.G., JEPLAN 4 **POLYMERS** (PC, ABS, HIPS) E.G., GEO-TECH POLYMERS 3 **SYNGAS** E.G., KLEAN INDUSTRIES 2

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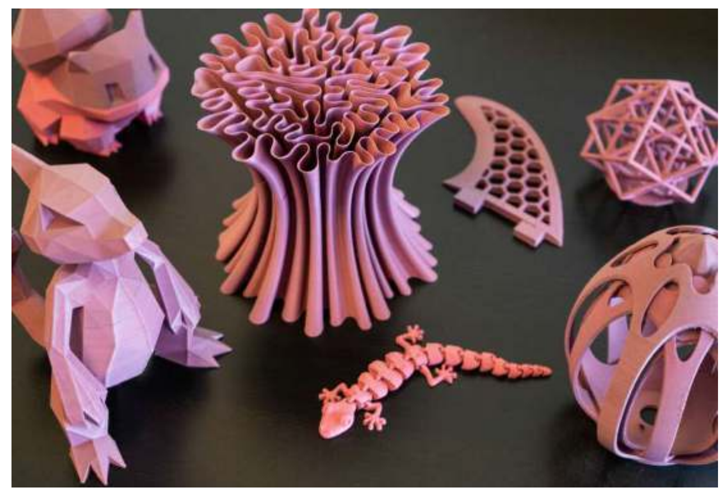
✓**Social benefits** of improved recycling:

1. New jobs → using waste provides 40% more jobs than disposing of it!
2. Environmentally conscious companies→ a new business culture
3. Better living conditions → cleaner water, air and soil
4. Education sector → raising awareness of the importance of responsible resource and waste management..
5. Innovative solutions!

So many ideas…

Recycled plastic bags ...



CONCLUSION

- Only circular economy leads to sustainable development!
- **~~Waste~~** streams → **materials** for reuse and utilization
- **recycling infrastructure** to properly and profitably sort, process and market underdeveloped
- Challenges to use recycled plastics in the existing processes due to **degradation or contamination**
- **Investments** needed: governments, investors and brands/industry must urgently invest to bring transformational technologies to scale and **stimulate markets**
- **Collaboration** to strengthen: brands and industry need to develop partnerships with technology providers to create **new business models** that will match the current technologies with the infrastructure of plastics and petrochemical manufacturing, waste management and recycling
- **Rethink** the current models. **Recycling (solely) is not a solution!**
- **Benefits:** social, economic, environmental.

Follow-up!

Plastic has become an integral part of our daily lives. And it's true - it makes many things easier.

Each of us can contribute to reducing the release of plastics into the environment by REFUSING or reducing the use of plastic bags, bottles, packaging and other plastic products, contribute to waste separation, recycling, reuse of plastic materials and more.

Raising awareness of the risks posed by chemical polymers to the environment, with potential consequences for human health has increased the efforts of a number of stakeholders, including plastics manufacturers, to contribute to reducing plastic emissions into the environment. A lot more is needed...

THANK YOU FOR YOUR ATTENTION!

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