



Chemical recycling of plastics: Viability, environmental impacts and regulation

Friday 10 June | 1:15 - 2:45 pm | Room C

With: **Dr Andrew Rollison**, GAIA chemical engineer
Lee Bell, IPEN Mercury and POPs Policy Advisor and
Lauriane Veillard, ZWE Chemical Recycling Policy Officer

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'CHEMICAL RECYCLING' OF PLASTICS

What is it and what impacts
for the environment?



SPEAKERS



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Coordinator, IPEN | Moderator

**'Chemical recycling' of plastics – What is it
and what impacts for the environment?**



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CHEMICAL RECYCLING IS A UNICORN

YOU MUST BELIEVE
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BELIEVE INDUSTRY'S
CHEMICAL RECYCLING /
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FAIRYTALE



In Reality, Chemical Recycling:

- is old, outdated technologies, rebranded
- produces huge hazardous waste streams

"There is a residual solid waste stream of 10-30% that contains contaminant" – Chemical Recycling Europe (trade association)

The Basel Convention Plastic Waste Guidelines should not include

Chemical Recycling / Advanced Recycling

It is not an environmentally sound, commercially viable technology.



Visit us online for IPEN's research and projects that reveal hazardous substances in all stages in the life-cycle of plastics.

<https://ipen.org/policy/toward-a-plastics-treaty>





Andrew ROLLINSON

Independent Consultant,
Blushful Earth



'Chemical recycling' of plastics – What is it
and what impacts for the environment?



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Global Alliance for Incinerator Alternatives

‘Chemical recycling’ of plastics: viability, environmental impacts and regulation

The energy needs and environmental impacts of chemical recycling of plastics

Dr Andrew N Rollinson



Context



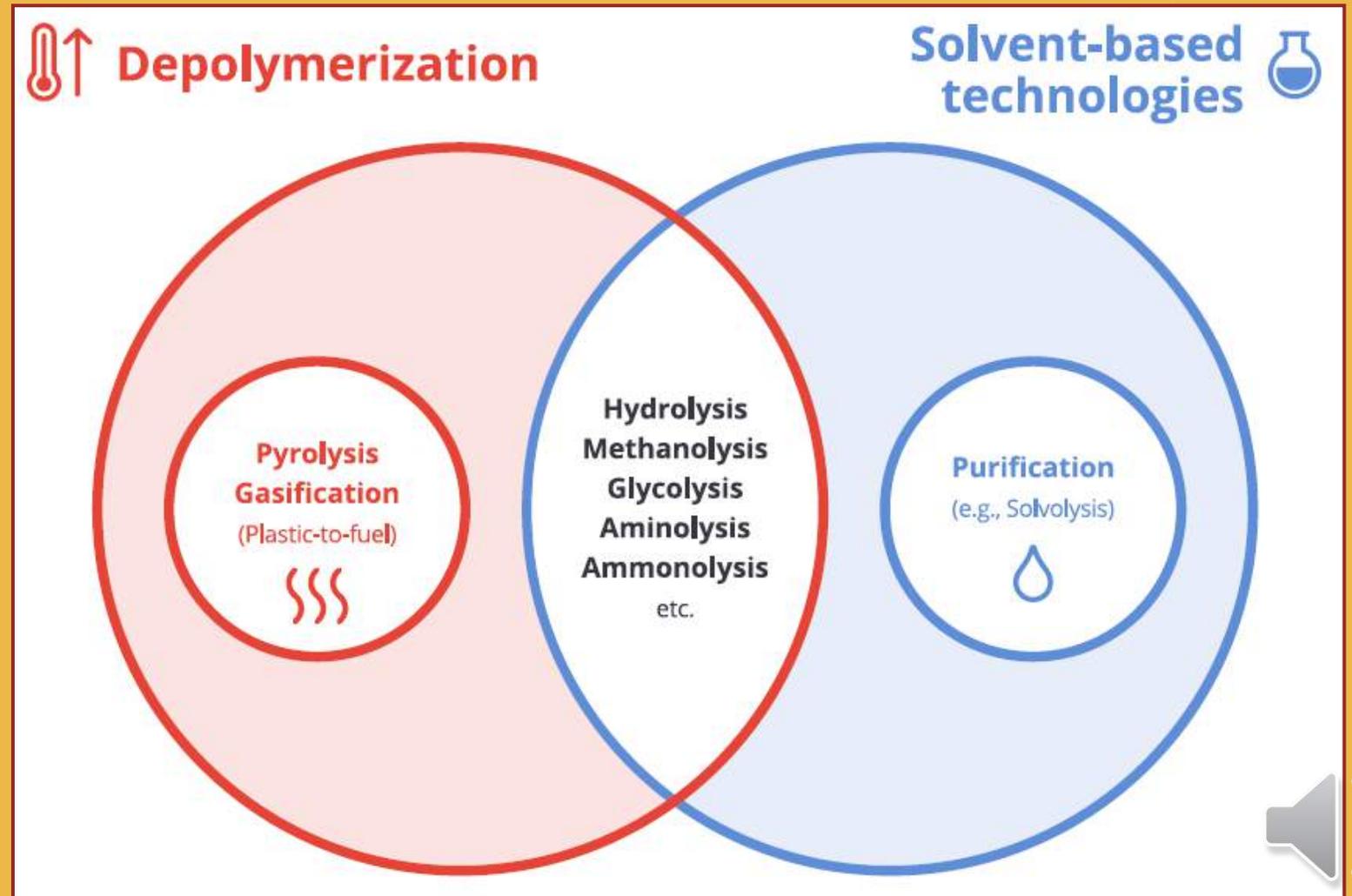
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LET THE PLASTIC INDUSTRY
TAKE YOU FOR A RIDE!



What is 'Chemical Recycling'?

- ❑ Lab' trials in 1950s
- ❑ Been failing commercially since the 1970s
- ❑ A collection of concepts, no accepted definition
- ❑ Molecular not mechanical process

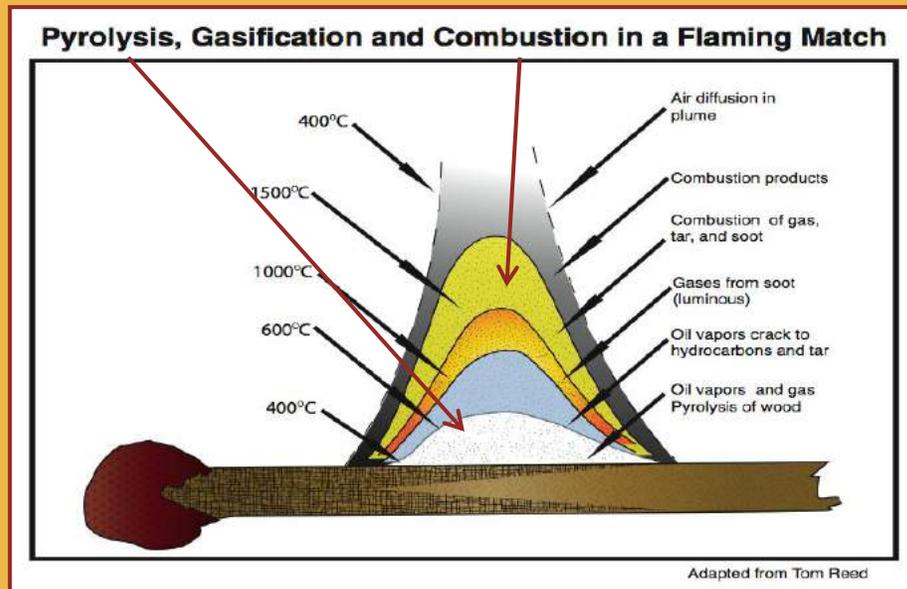


Depolymerisation



Pyrolysis and Gasification

- ❑ All organic matter when heated without oxygen will release a complex mixture of volatile organic molecules – this is **“pyrolysis”**
- ❑ Pyrolysis practised for thousands of years. Gasification technology developed in the 1800s



<http://www.gekgasifier.com/info/gasification-basics/gasification-explained>

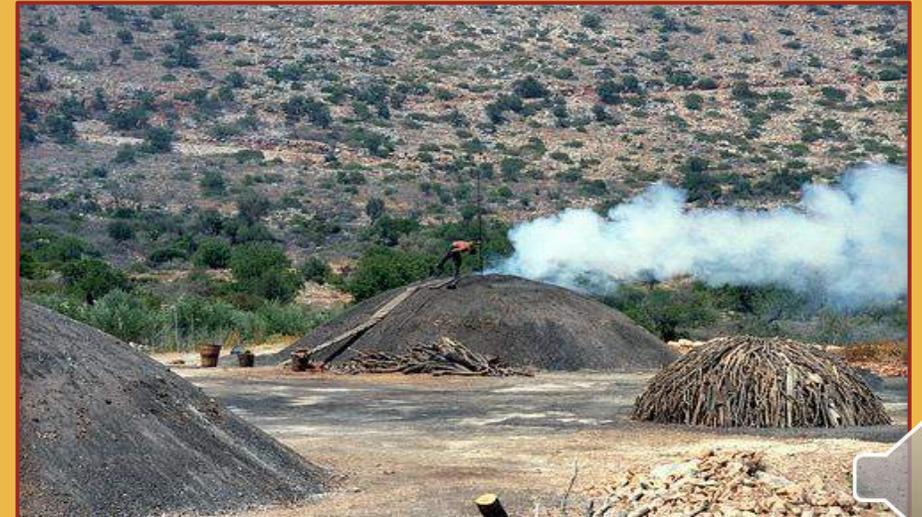


Photo creative commons: Lars plougmann



Pyrolysis and Gasification

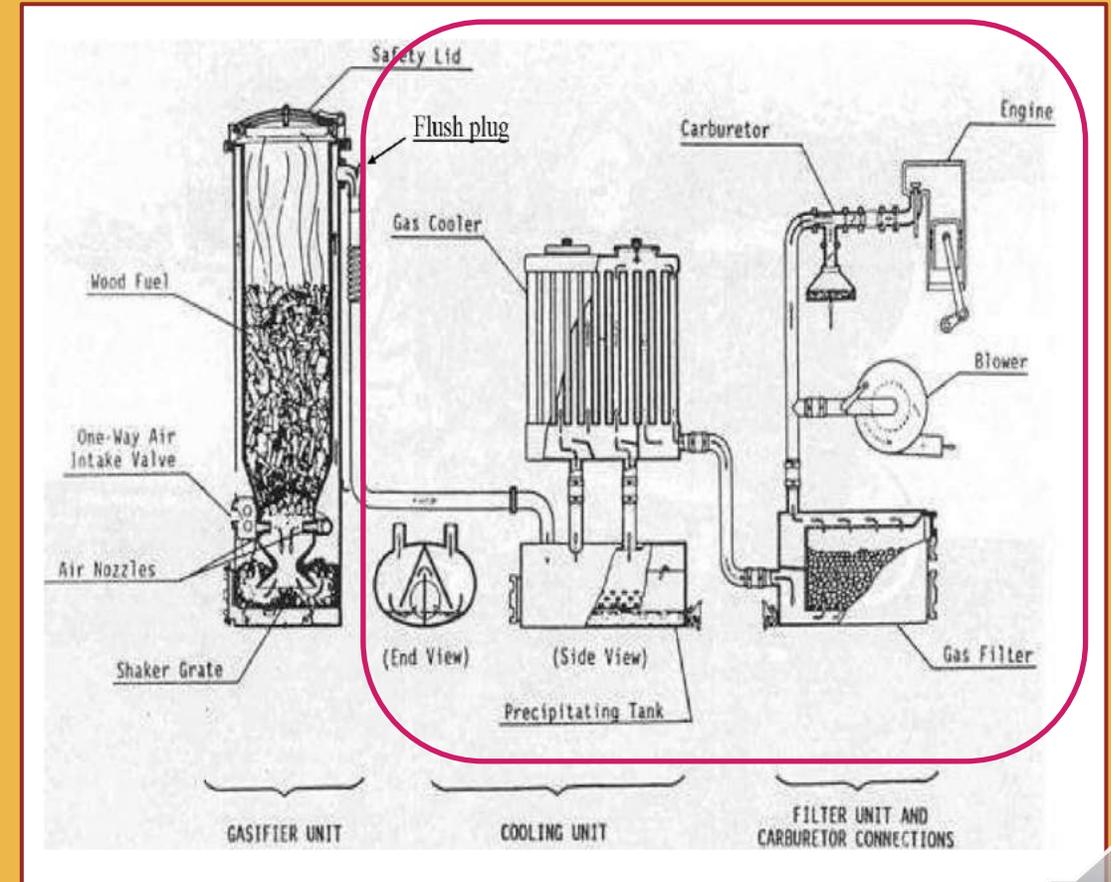


Attempts to manage dirty gases now 100 years old

- ❑ Incomplete combustion products, most of which are environmental toxins
- ❑ Polycyclic Aromatic Hydrocarbons (PAHs) – tar and soot



All Pyrolysis and Gasification Reactors produce tar!



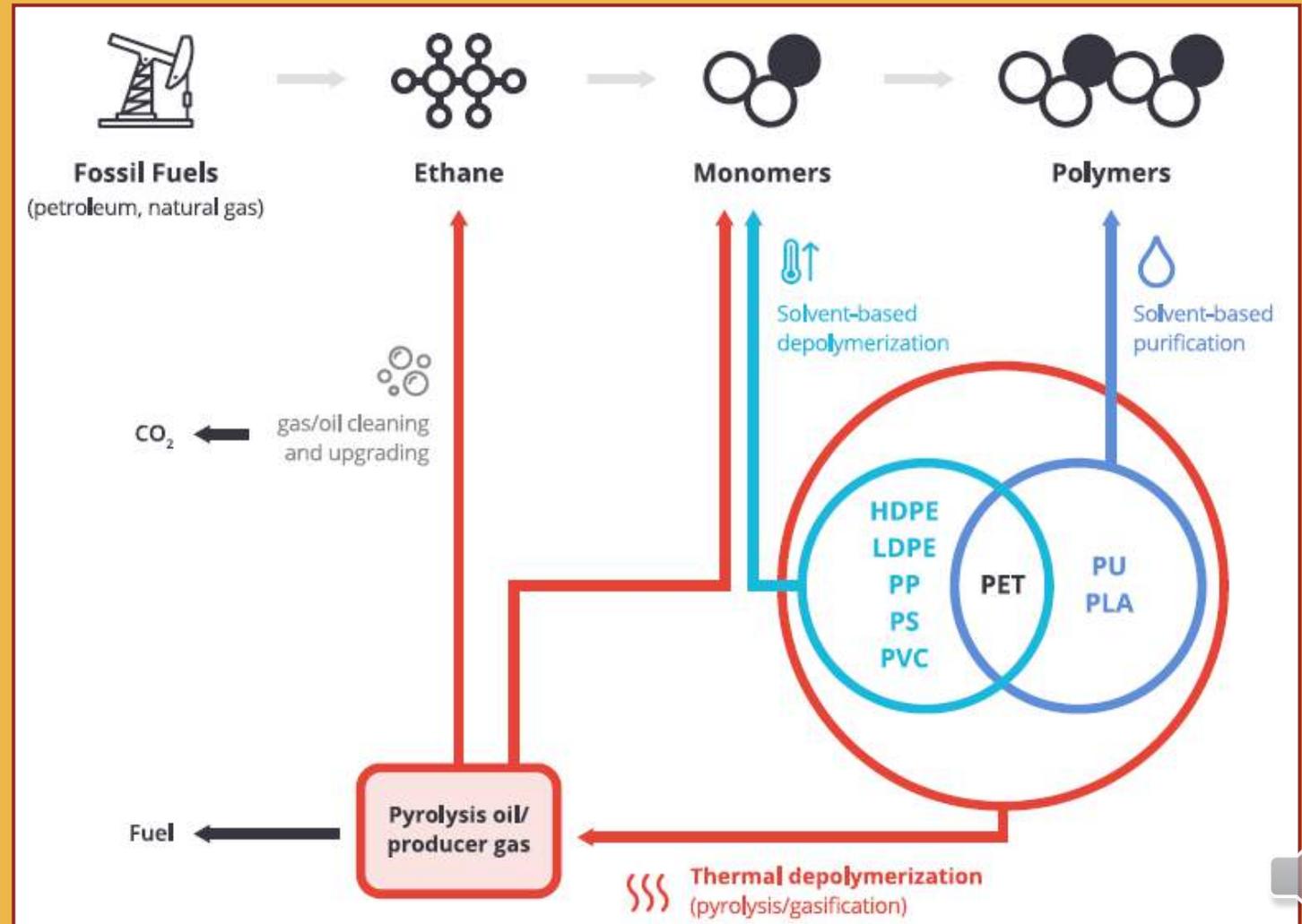
Adapted from: LaFontaine, H., Zimmerman, F.P. Construction of a simplified wood gas generator for fueling internal combustion engines in a petroleum emergency, (1989), Federal Emergency Management Agency: Washington.



Solvent-based Technologies



- ❑ High temperature
- ❑ Highly solvent specific
- ❑ Large volumes of toxic waste solvent
- ❑ Plastic toxins go into solvents and products



Findings: Environmental Impacts

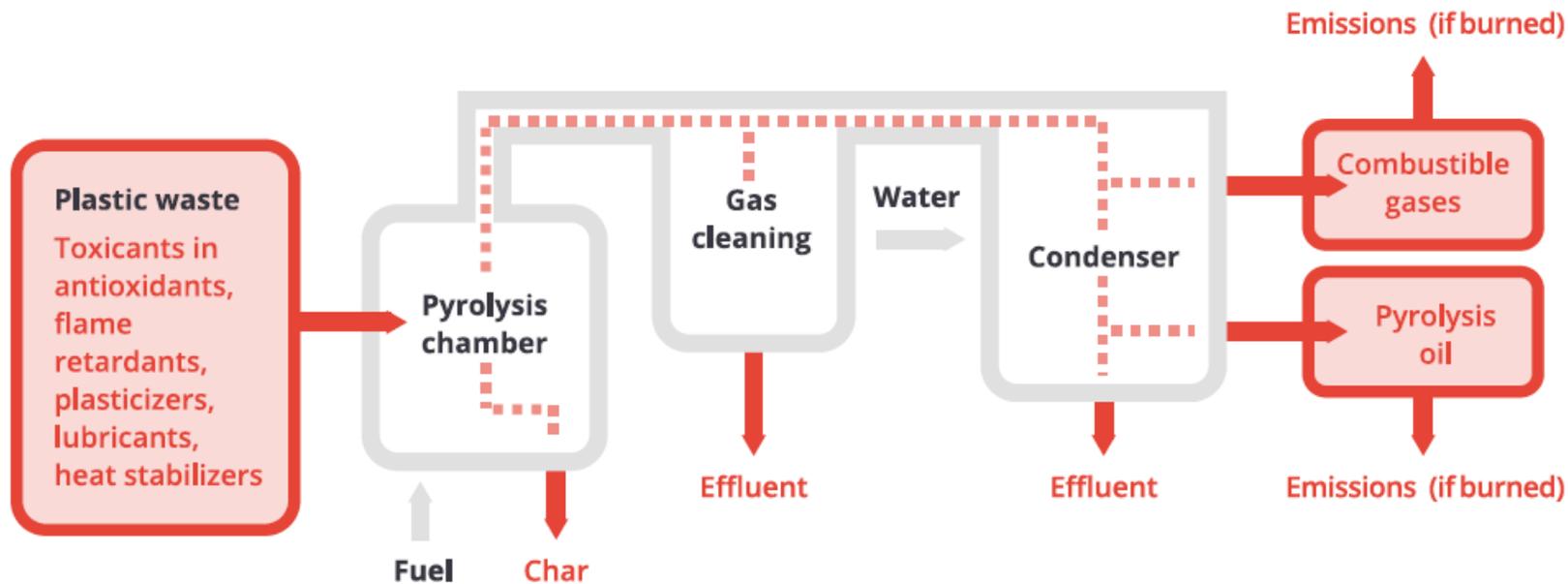


High energy intensity
High carbon emissions

“Pyrolysis oil should not be used as an energy source”

Mohr et al. 1997

Mohr, K., Nonn, Ch., Jager, J. 1997. Behaviour of PCDD/F under pyrolysis conditions. *Chemosphere*, **34** (5-7), pp. 1053-1064.



Toxicants include: phthalates, BPA, poly-brominated diphenyl ethers, toxic brominated compounds and poly-cyclic aromatic hydrocarbons (PAH), nitrated PAH (N-PAH), oxygenated PAH (O-PAH), and N/S/O – heterocyclic PAHs, As, Sb, Br, Zn, Cu, Hg, Cd, Dioxin, HCN



Findings: Environmental Impacts



- ❑ When plastics decompose it is not simply a reversible process
- ❑ Unwanted molecules are produced

“All these contaminants are known to cause corrosion issues, increase coke formation, destroy expensive reactor tubes, or deactivate catalysts in the separation section of a steam cracker.”¹

“In a nutshell, today the quality of crude plastic pyrolysis oils is unacceptable as feedstocks for industrial steam crackers”¹



Findings: Environmental Impacts



- ❑ Presence of banned substances and subsequent need to comply with chemical hazard regulations has been the primary cause of plant closure. ¹
- ❑ Common for polymer toxins (such as phthalate esters) to transfer into the solvent. ¹



Following a study of plastic pyrolysis, the resultant char was contaminated with heavy metals (As, Cd, Pb, Cu, Hg, Zn), and classified as both hazardous and ecotoxic. ²



1. Sherwood, J. 2020. Closed-loop recycling of polymers using solvents. *Johnson Matthey Technology Review*, **64**, pp. 4-15

2. Bernardo, M., Lapa, N., Gonçalves, M., Bardosa, R., Mendes, B., Pinto, F., Gulyurtlu, L. 2010. Toxicity of char residues produced in the co-pyrolysis of different wastes. *Waste Management*, **30**, pp. 628-635.

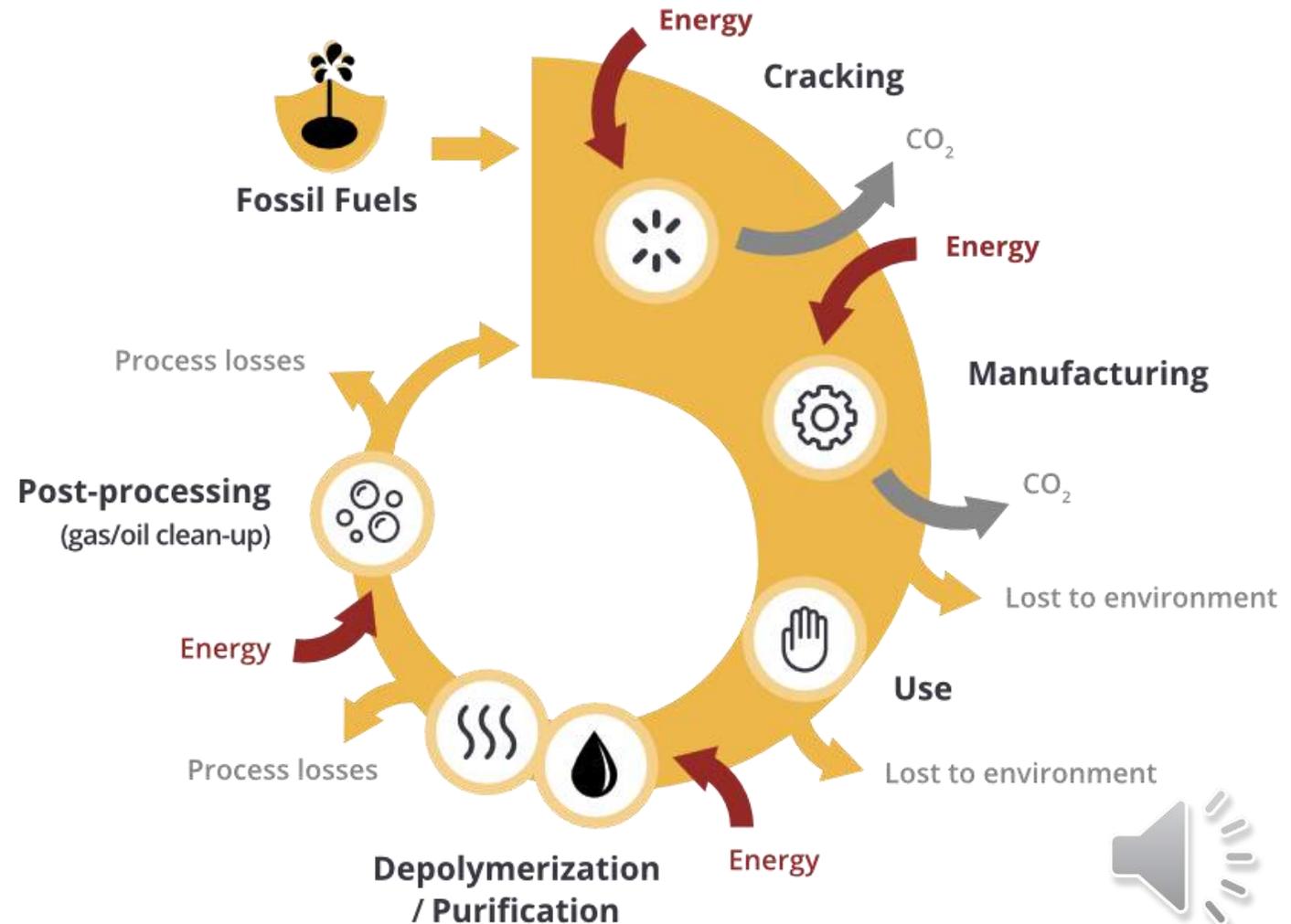
Findings: Energy



The leaky circular economy in plastics

- ❑ High fossil fuel consumption
- ❑ Little plastic makes the round trip

“No chemical recycling technology can offer a net-positive energy balance, even if the products/by-products are burned for energy”¹



1. Baytekin, B., Baytekin, H.T., Grzybowski, B.A. 2013. Retrieving and converting energy from polymers: deployable technologies and emerging concepts. Energy and Environmental Science, 6, pp. 3467- 3482.

Reviewed eight 'chemical recycling' facilities in the U.S.

- ❑ The majority of facilities are not recycling any plastics
- ❑ The facilities generate large quantities of hazardous waste
- ❑ They release hazardous air pollution



'Recycling Lies'

Nearly 500,000 pounds of hazardous waste were reported in 2019 from one “chemical recycling” facility alone.

Data from the EPA shows that Agilyx generated nearly 500,000 pounds of hazardous waste in 2019 alone, sending most of it off site to be burned (Table 2). This waste consisted primarily of benzene, along with other toxics such as lead, cadmium, and chromium (Table 2).²⁵

❑ *Hazardous waste sent off-site by Agilyx:*

Lead, cadmium, selenium, benzene, chromium, vinyl chloride, barium.

❑ *Hazardous air pollutants associated with multiple facilities:*

Styrene, benzene, toluene, mercury, arsenic, dioxins, ethyl benzene, xylene, naphthalene, acetaldehyde, formaldehyde, hydrochloric acid, hexane.



Investigation into public mis-information campaigns about the efficacy of recycling over several decades.



The screenshot shows the official website of the California Attorney General, Rob Bonta. The header includes the state seal, the name 'ROB BONTA Attorney General', a search bar, and a 'Translate Website' link. A dark blue navigation bar contains links for HOME, ABOUT, MEDIA, CAREERS, REGULATIONS, RESOURCES, PROGRAMS, and CONTACT. The main content area features a large blue headline: 'Attorney General Bonta Announces Investigation into Fossil Fuel and Petrochemical Industries for Role in Causing Global Plastics Pollution Crisis'. Below the headline, it identifies the source as a 'Press Release' and provides the date 'Thursday, April 28, 2022' and contact information: '(916) 210-6000, agpressoffice@doj.ca.gov'. A sub-headline reads 'Subpoenas ExxonMobil for information relating to decades-long plastics deception campaign'. The first line of the body text, starting with 'LOS ANGELES', is visible at the bottom of the screenshot.

 **ROB BONTA**
Attorney General

Search

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Attorney General Bonta Announces Investigation into Fossil Fuel and Petrochemical Industries for Role in Causing Global Plastics Pollution Crisis

Press Release / Attorney General Bonta Announces Investigation into Fossil F...

Thursday, April 28, 2022

Contact: (916) 210-6000, agpressoffice@doj.ca.gov

Subpoenas ExxonMobil for information relating to decades-long plastics deception campaign

LOS ANGELES – California Attorney General Rob Bonta today announced an investigation into the fossil fuel and petrochemical industries for



Industry



“...the pellet yield is only around 22 per cent of the original input material.” (Veolia Executive ¹)

EUWID RECYCLING AND WASTE MANAGEMENT 8.2022

1

Veolia executive questions the environmental benefit of chemical recycling for plastic waste

Group not interested in developing its own pyrolysis plants

‘It would be “optimistic” to suggest that chemical recycling will become a viable outlet for waste plastics inside the next decade’ ²

Pyrolysis has significantly larger carbon footprint than virgin plastic production ¹



2. Doherty, J. 2019. Chemical recycling of plastics '10 years away' (online). Accessed 2nd June 2022. Available from: <https://www.letsrecycle.com/news/latest-news/chemical-recycling-ofplastics-10-years-away/>

Conclusions



- ❑ No evidence that chemical recycling is 'Environmentally sound'. All evidence is to the contrary
- ❑ Energy balance is negative. Climate impacts
- ❑ Fifty years of commercial failure
- ❑ Large quantities of toxic residues produced
- ❑ Toxins go into products and by-products
- ❑ The operating facilities recycle little or no plastics
- ❑ Lock in to decades more fossil fuel consumption...
- ❑ ...hence heavily promoted by petrochemicals industry



Thank you for joining us!



Get in touch

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For media inquiries: claire@no-burn.org

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Read more at www.no-burn.org





Lee BELL



Mercury and POPs Policy Advisor, IPEN | Senior Researcher, National Toxics Network (Australia)



'Chemical recycling' of plastics – What is it and what impacts for the environment?



With the support of the
GENEVA ENVIRONMENT NETWORK

Chemical recycling of plastics: Viability, environmental impacts and regulation.

Pyrolysis and gasification:
Low viability with
high public relations potential.

Lee Bell

Mercury and POPs Policy Advisor

International Pollutants
Elimination Network

BRS COP June 2022 Geneva



Chemical recycling: Pyrolysis and Gasification

Feedstock recycling, also known as chemical recycling, **aims to convert plastic waste into chemicals that can eventually be converted into new plastic.**

- The vast majority of chemical recycling projects are based on these two technologies
- Waste plastics are heated between 400–800°C in pyrolysis and 1,200°C – 1,500°C in gasification plants under very low or no oxygen levels. The goal is that the polymer is thermally decomposed into hydrocarbon building blocks including monomers that can then be used again as a raw materials in chemical processes including plastic manufacture. The main outputs of the process are an oil product and carbon char.
- Neither of these processes are new or advanced and have operated, mostly unsuccessfully, for decades
- However, many plastics contain oxygen which lead to the formation of POPs in the processes.



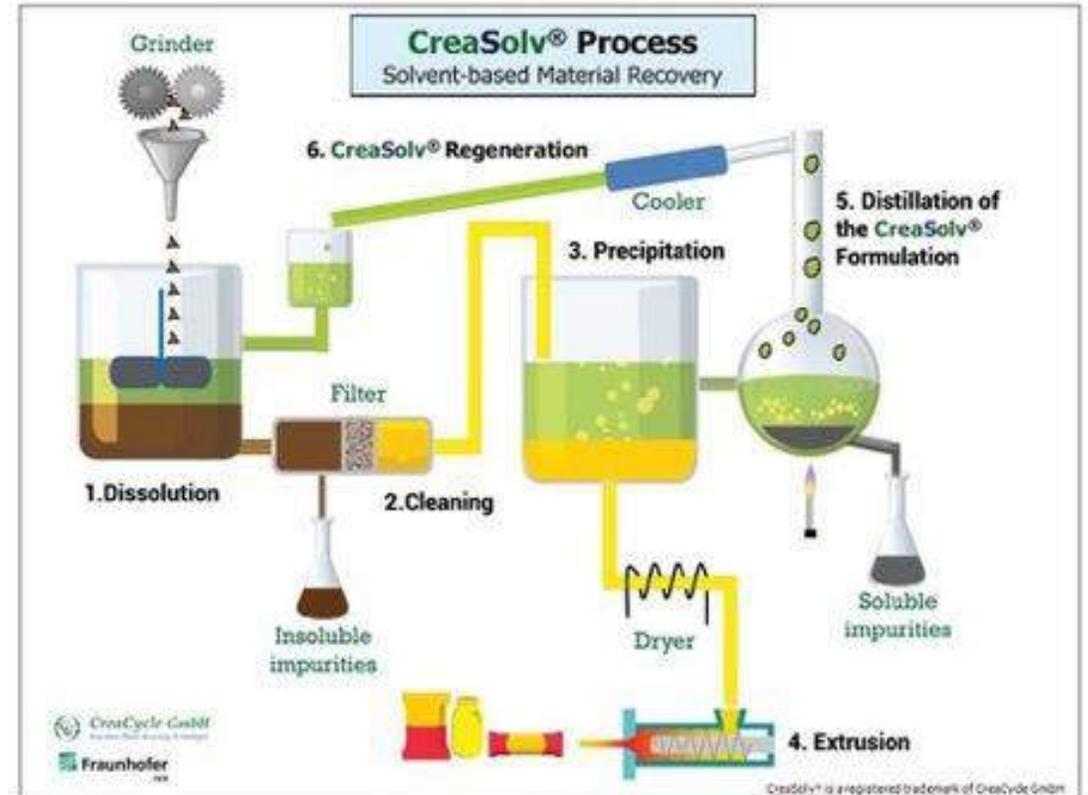
Chemical depolymerization

This chemical recycling process is essentially the opposite of polymerization and produces single monomer molecules or shorter fragments called oligomers. The process only operates efficiently with highly selective inputs requiring careful source segregation and is well suited to PET and purified terephthalic acid (PTA) but is also applicable to PA, PU, PLA, PHA, PEF, and PC and a range of polyesters.

AS WITH MOST CHEMICAL RECYCLING TECHNOLOGY THE TOXICITY, FATE, AND CHARACTERISTICS OF THE RESIDUES CREATED BY DECONTAMINATING THE MONOMERS HAS NOT BEEN MADE PUBLIC. THE HAZARDS ASSOCIATED WITH THE PROPRIETARY CATALYSTS USED IN DEPOLYMERIZATION HAVE NOT BEEN DISCLOSED.

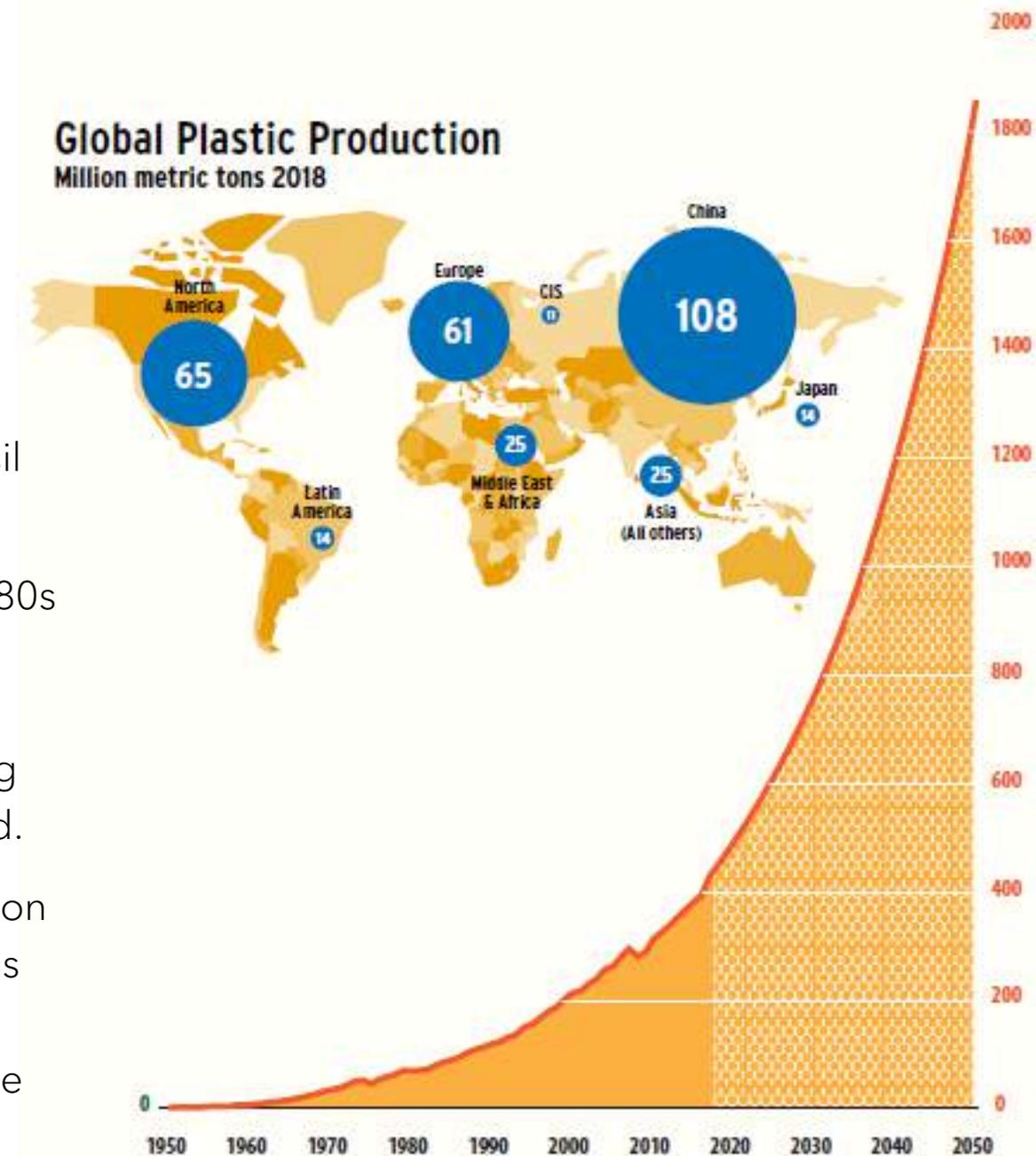
Solvolysis

- Solvolysis is a purification process based on dissolving polymers in proprietary solvents, separating contaminants and reconstituting the target polymer.
- In general, the solvent-based purification works by dissolving the polymer in a specific solvent followed by the removal of contaminants such as additives, pigments, and non-intentionally added substances (NIAS) through filtration or phase extraction, and then precipitating the polymer using an anti-solvent in which the polymer is insoluble (Crippa *et al.*, 2019)
- Its main application has been to remove brominated flame retardants and other additives from polystyrene allowing the target polymers to be purified and used as direct feedstock in new polystyrene production.
- This is very different to pyrolysis and gasification and could be supported, but also does have a waste stream generated by removing additives from the target polymers when large volumes are processed. It should be limited to polystyrene and not mixed wastes.

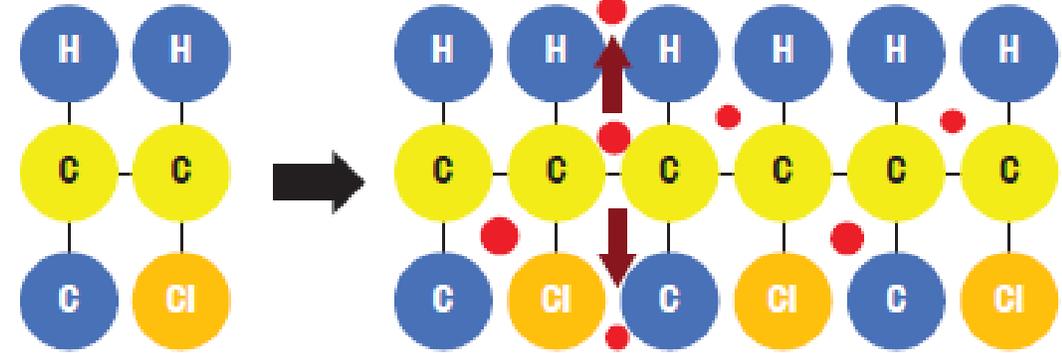


Why is it being promoted as the solution to global plastic waste solution?

- The fossil fuel industry is being forced to pivot away from fuel manufacture due to their carbon liabilities and are shifting fossil fuels in plastic production.
- Mechanical recycling of plastic was heavily promoted in the 1980s when the plastic manufacturers were last under major pressure over plastic pollution. It has failed to stem the tide of plastic pollution with only about 9% of all plastic ever produced having been recycled. The rest had either been dumped or incinerated.
- Plastic producers don't want limits imposed on plastic production but cannot now claim mechanical recycling will resolve the crisis and so are vigorously promoting chemical recycling as the solution that will allow plastic production and profits to continue unabated.



Additives in plastic waste generate a large hazardous waste stream from chemical recycling



- However, most plastics contain chemical additives, including POP, that may have functions as colorants, UV stabilisers, plasticisers, and fillers. These additives either go on to contaminate the output of the pyrolysis and gasification plants or become part of the hazardous waste stream from these processes. The more the outputs of these processes are purified the more hazardous waste is generated as solid waste or emissions. .
- The useful output of hydrocarbon chemicals from these processes can be oils, waxes and synthetic gases (syngas). In most cases these outputs are too contaminated to be used directly as feedstock. They are often too contaminated to be used as fuels. With further clean up they can be used as low-grade fuels. It is very expensive to clean them to the point they can be used as chemical feedstock.

Is chemical recycling viable?

IPEN argues that chemical recycling, particularly pyrolysis and gasification, is not viable due to:

- Its inability to compete economically with virgin plastics
- Costs of filtering out chemical additives in primary treatment and subsequent costs of post treatment purification of outputs.
- Low yields and high hazardous waste disposal costs.
- High energy consumption costs.
- High carbon footprint liability
- Need for clean homogenous plastic inputs
- Cost of emissions controls and compliance.
- Environmental impacts

<https://ipen.org/sites/default/files/documents/ipen-plastic-waste-management-hazards-en.pdf>



PLASTIC WASTE MANAGEMENT HAZARDS

WASTE-TO-ENERGY, CHEMICAL RECYCLING, AND
PLASTIC FUELS

Lee Bell
Professor Hideshiige Takada



International
Pellet Watch

IPEN
for a toxin-free future

Billions are being invested by plastic companies who need to be seen to have a solution to plastic pollution to avoid production limits.

Petrochemical and consumer-goods companies called the Alliance to End Plastic Waste, including Exxon, Dow, Total, Shell, Chevron Phillips, and Procter & Gamble, committed to spending \$1.5 billion over five years.



European plastics manufacturers plan 7.2 billion euros of investment in chemical recycling



Indorama to invest \$8 billion more

Published: March 30, 2022

Billion investment in plastic recycling in Sweden

Swedish Plastic Recycling (Svensk Plaståtervinning) is investing in building the world's largest and most modern facility for plastic recycling, Site Zero.

Chemical company, Eastman has announced they will be investing up to US\$1 billion in a material-to-material molecular recycling facility in France.

recycling and

European Government is not convinced.

“there is significant uncertainty about whether building a pyrolysis infrastructure to recycle plastics will actually lead to new materials, or only to fuels. Such a linear lock-in is clearly not in line with the basic principles of a circular economy and is one of the major concerns when considering the role of pyrolysis in the plastics economy” (European Commission 2018).



Journalists even less so...

REUTERS® INVESTIGATES | The Recycling Myth

A REUTERS SPECIAL REPORT

THE RECYCLING MYTH
BIG OIL'S SOLUTION FOR PLASTIC WASTE
LITTERED WITH FAILURE

NO DIESEL FOR DOW

SHELL PLANT 'REPURPOSED'

DELTA AIRLINES PROJECT GROUNDED

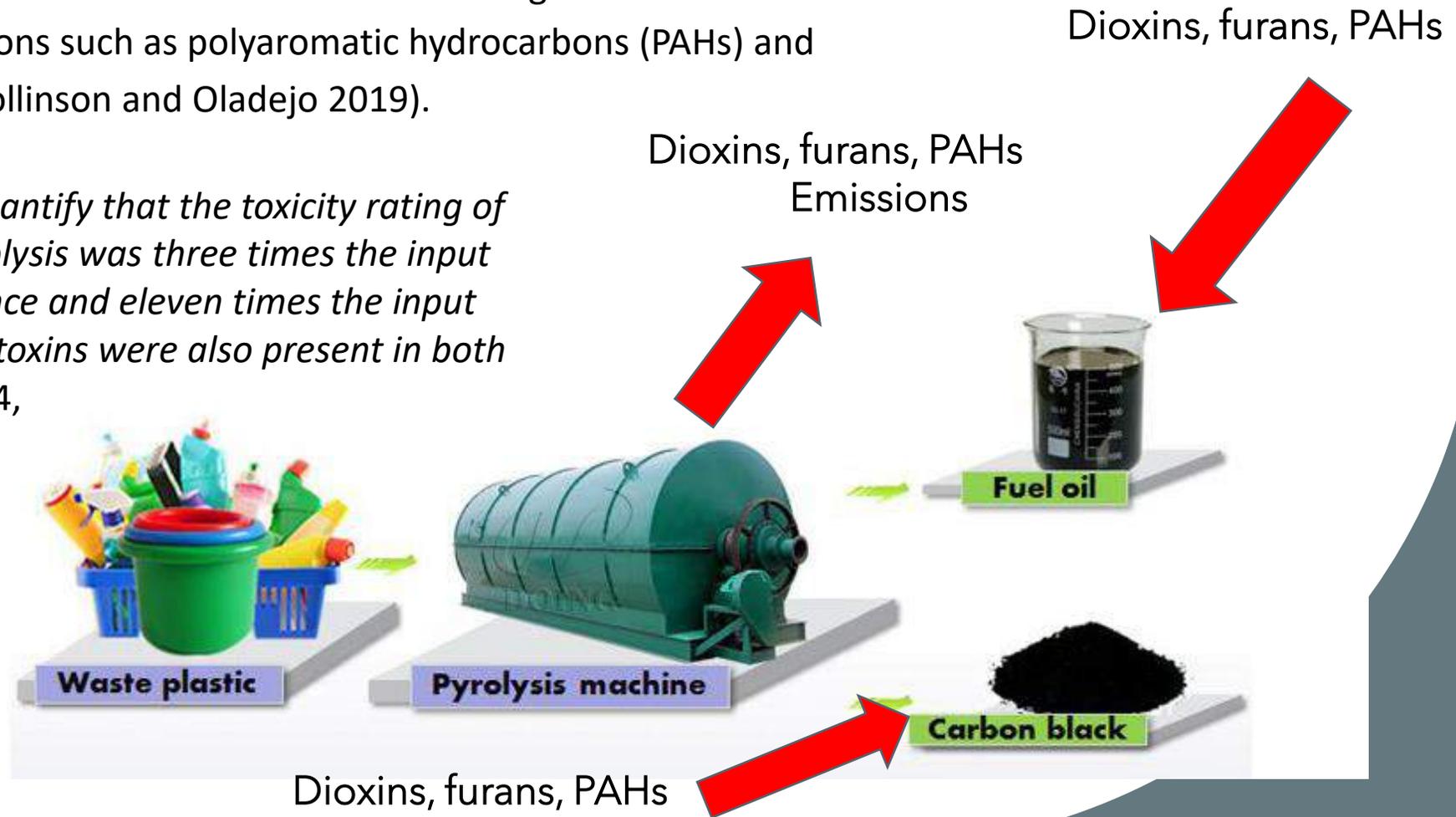
UNILEVER'S 'RADICAL RECYCLING' FALTERS

REUTERS® INVESTIGATES | The Recycling Myth

FROM SHELL TO UNILEVER, PLASTICS POLLUTERS BACK RECYCLING-TECH FLOPS

Low quality contaminated outputs expensive to decontaminate

- Using mixed inputs of plastic waste has been demonstrated to generate toxic substances in char and emissions such as polyaromatic hydrocarbons (PAHs) and dioxins (Crippa *et al.*, 2019, Rollinson and Oladejo 2019).
- Researchers were able to “quantify that the toxicity rating of PCDD/ DF products from pyrolysis was three times the input at full operational performance and eleven times the input at pilot scale, and that these toxins were also present in both gas and oil” (Chen *et al.*, 2014,



Plastic Additives 4-6% CAGR represents a massive waste stream if chemical recycling is widely adopted

Attractive Opportunities in the Plastic Additives Market



<https://www.marketsandmarkets.com/Market-Reports/plastic-additives-market-722.html>

Major waste industries understand the problem.

EUWID RECYCLING AND WASTE MANAGEMENT

Veolia clearly rejects the chemical recycling of plastic waste

Waste group does not want to pursue pyrolysis in particular

Euwid 15/2022, page 3. Euwid Recycling und Entsorgung weekly 15/2022.

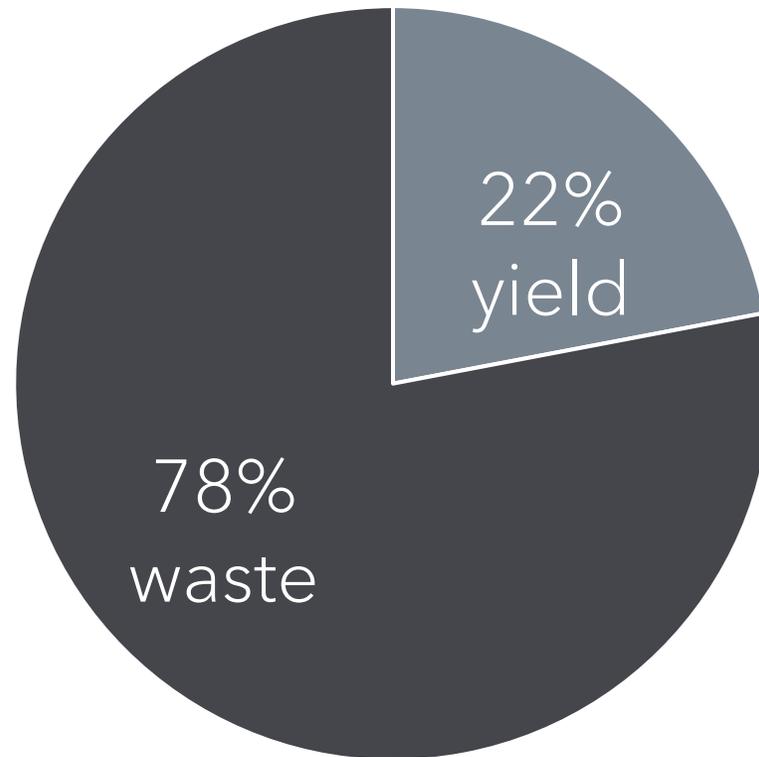
Markus Binding Veolia's
Managing Director for EVA
Verwaltungs GmbH – (Veolia)

"And this is precisely the risk for our industry: without proof of safe, reliable and sustainable mode of operation on an industrial scale, without a transparent database for life cycle analyses from sources that are as neutral sources as possible, without critical consideration of the proven and the new, **we run the risk of being used as a stirrup holder for a vision of the petrochemical industry,**"

"From the sequence of process steps in chemical recycling, the result is a material pellet yield of only about 22 percent,"

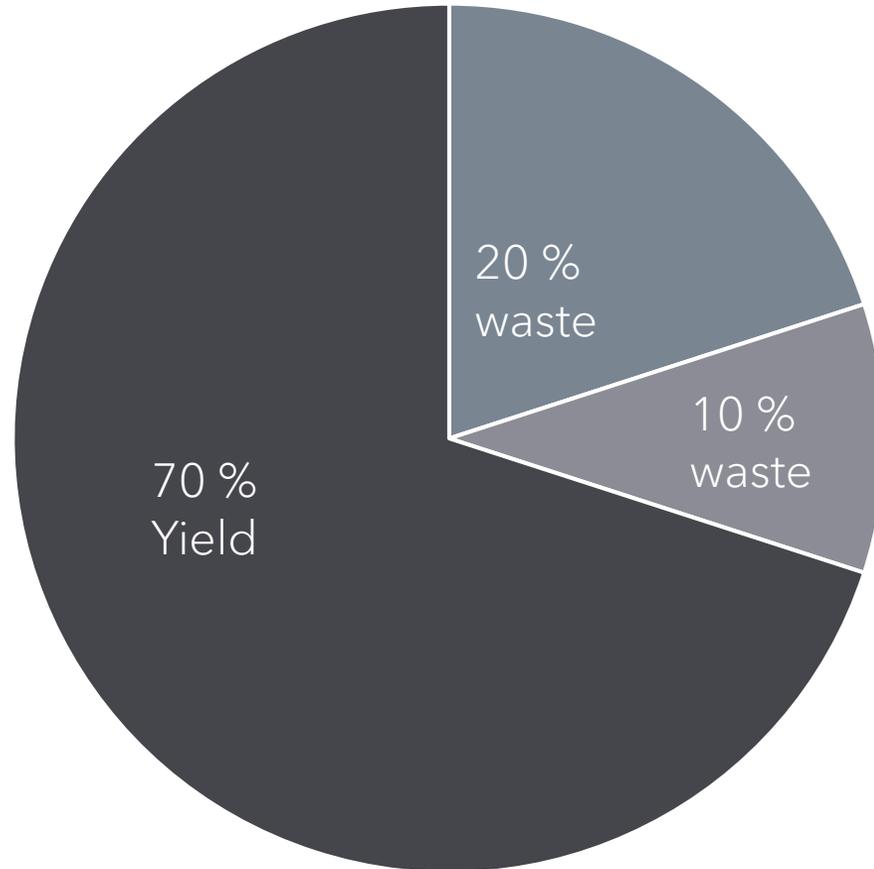
Veolia has publicly pulled out of chemical recycling

Veolia Germany quoted



Large toxic waste streams low yield

European Chemical Recycling Assoc.



■ 1 ■ 2 ■ 3

100 million tonnes of additives to be produced 2020-2025 could all become waste with 100% chemical recycling of plastic.



2020 – 17.1 M tonnes CAGR 4.4%



<https://www.plasticportal.eu/en/plastic-additives-market-will-reach-578-billion-globally-by-2020-%E2%80%93-allied-market-research/c/2233/>

Saviour technology or cynical public relations ploy?

Timothy Glaz, Head of Public Affairs - Werner & Mertz (Germany)

"Because it has been proven to harm the climate and the environment. This would give the Ministry of Economic Affairs a great opportunity to do something right for the environment and block a completely nonsensical technology."

"Pure lobbying project of the major plastic and chemical manufacturers"

IPENs View

CHEMICAL RECYCLING IS A UNICORN

**YOU MUST BELIEVE
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CHEMICAL RECYCLING /
ADVANCED RECYCLING
FAIRYTALE**



Thanks for your attention.



for a toxics-free future

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Lauriane VEILLARD

Policy Officer on Chemical Recycling and Plastic-to-Fuels, Zero Waste Europe



'Chemical recycling' of plastics – What is it and what impacts for the environment?



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Chemical recycling and recovery

Defining a legislative framework

Lauriane Veillard – Policy Officer on Chemical Recycling and Plastic-to-Fuels

June 7th 2022

lauriane@zerowasteeurope.eu

Zero Waste Europe

The European member of GAIA



**Support NGOs,
local groups and
communities**



**Change
European Policies**



**Mentor cities
towards a Zero
Waste transition**



What about chemical recycling and recovery?

There is a **significant lack of knowledge about the overall life cycle impacts** of chemical recycling on the environment. There are indications, however, that chemical recycling **works only under very specific and narrow conditions** and that it **consumes energy, water and chemical resources** that **increase the pollution of water, air and land**

European Environment Agency (EEA), 2021

<https://www.eea.europa.eu/publications/plastics-the-circular-economy-and/>



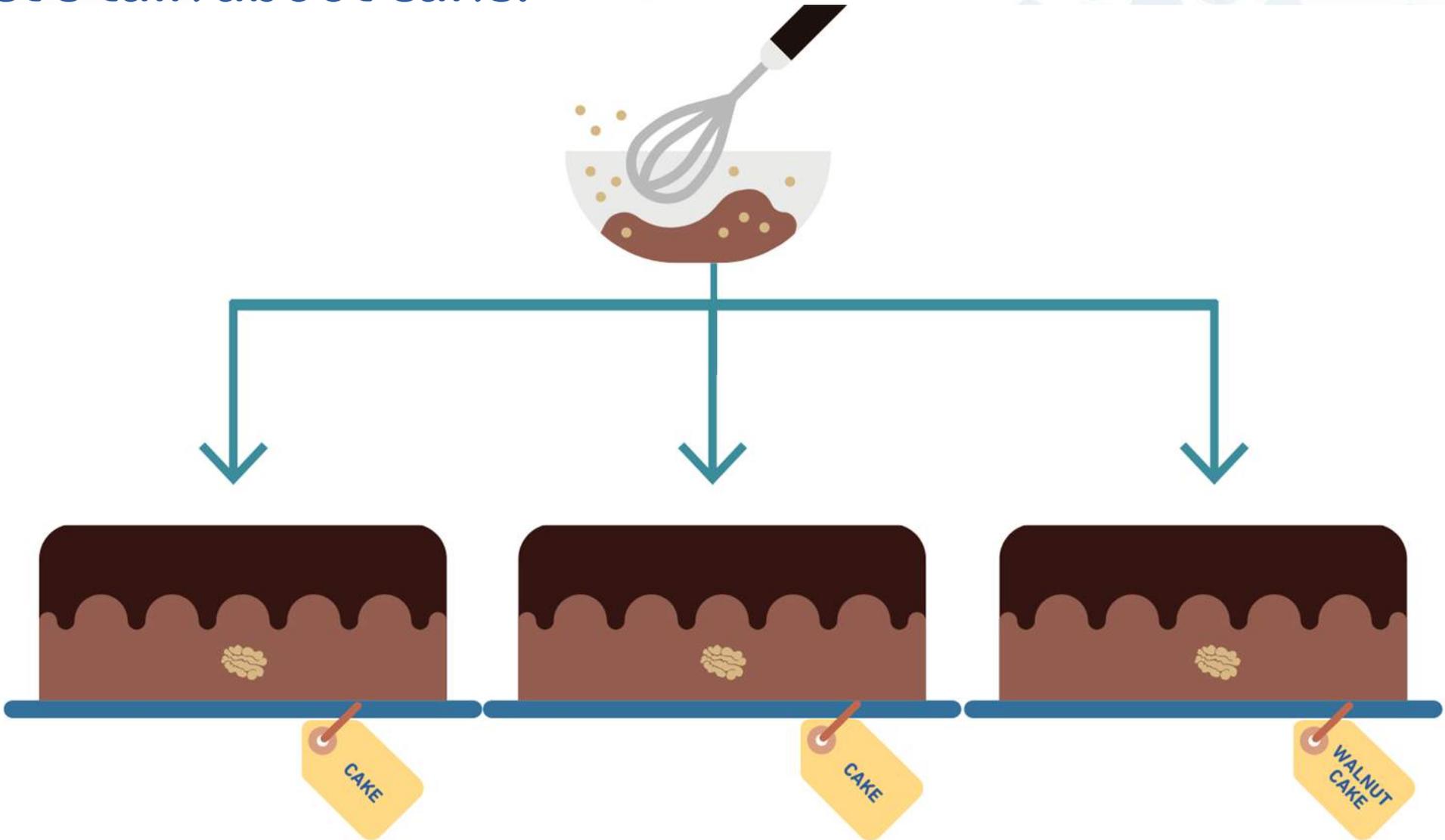
Definition and position in the waste hierarchy

- The term 'chemical recycling' has no formal definition and is used in different ways
- The term 'recycling' in the EU Waste Framework Directive does **not** include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations
- Harmonized legal definitions needed to distinguish between '**chemical recycling**' and '**chemical recovery**' in order to:
 - Clarify positions in waste hierarchy, with mechanical recycling being favoured
 - Exclude feedstock recovery from recycling targets
- Chemical recovery = pyrolysis and gasification technologies resulting in oils, syngas and feedstock recovery for the petrochemical industry

Definitions and position in the waste hierarchy must be based on well-founded scientific knowledge of environmental impacts



Now, let's talk about cake!



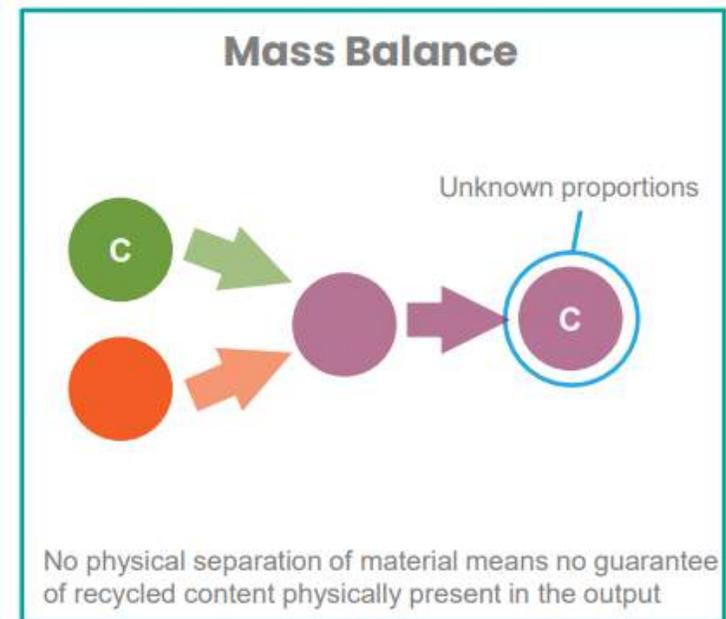
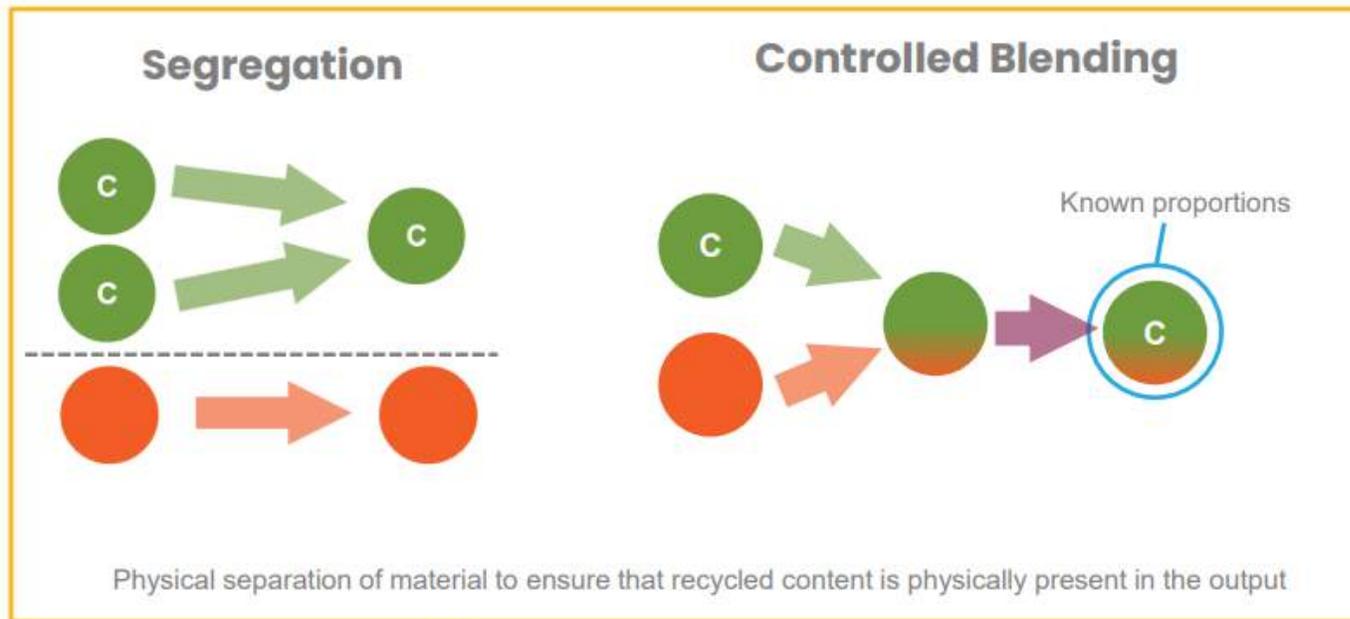
On the horizon: the 'mass balance approach'

Determining recycled content in plastic products

Chain of Custody (CoC) According to ISO 22095



Traceability, strength of claim, physical



On the horizon: the 'mass balance approach' - continued



Key policy recommendations

- **Environmental and health impacts** of chemical recycling & recovery need to be **evaluated at the industrial level** prior to incentivisation
- Review waste legislation to introduce definitions of recycling technologies that **exclude fuel production**
- A process **keeps at least 80% of the carbon content of plastic waste until the transformation into new products** in order to be qualified as a recycling technology
- Clarify the legal status of chemical recycling and recovery technologies in the **waste hierarchy**
- Put in place safeguards to **avoid competition with mechanically recyclable waste**
- Establish a **robust methodology for calculating the climate impact of chemical recycling**, including all indirect and direct emissions caused by the process
- Develop ambitious standards for determining the **actual recycled content** in plastics
- Chemical **recycling products are monitored to ensure toxic-free outputs** in line with the highest requirements of chemical legislative framework
- EU funds should **only support processes with a lower carbon footprint** than the production of plastic from virgin feedstock





Thank you!

Lauriane Veillard – Policy Officer on Chemical Recycling and Plastic-to-Fuels

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THANK YOU!



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International Coordinator, IPEN |
Moderator





WHAT'S NEXT?

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**The Basel Plastics
Amendments: The First
Year Report Card | BRS
COPs Side Event**

13 JUN 2022 18:15 - 19:45
CICG | Room 14 & Online
Basel Action Network

Chemicals and Pollution
 SDG3 | SDG12



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