Safripol Sustainability Conference 2024

Title of talk: Chemical Recycling Landscape

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Designation: Senior Technical Specialist

Chemical Recycling Landscape

A big picture view

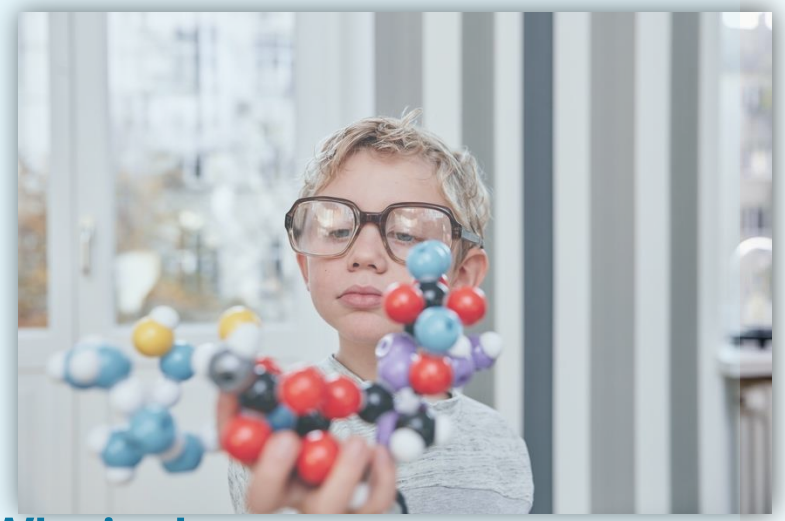




REFINERY/CRACKING → POLYMERISATION → PLASTIC CONVERSION → CONSUMPTION → WASTE PLASTIC


MECHANICAL RECYCLING

SOLVENT-BASED RECYCLING (PURIFICATION)



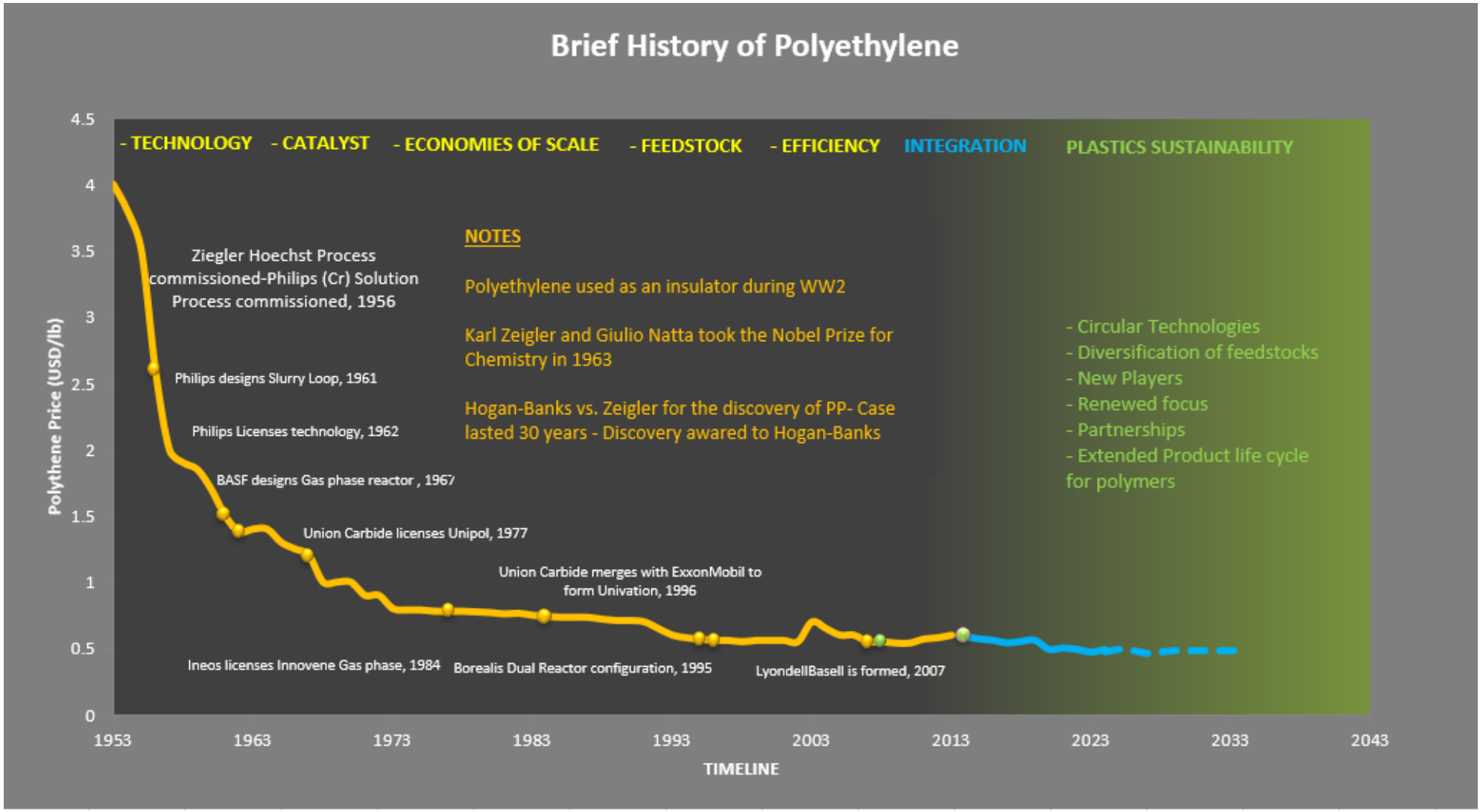
Why is the molecular/chemical structure of plastic so important ?

- Largest driver of the circular plastics system
- Modifies physical properties of waste plastics into a cleaner more usable item
- Limitations based on the inability to manipulate the molecular/chemical structure of plastic

PHYSICAL RECYCLING

SOURCES: https://www.recycling-magazine.com/2020/04/17/global-plastic-waste-management-market-with-slowdown-but-positive-outlook/, https://www.plasticsinfo.co.za/

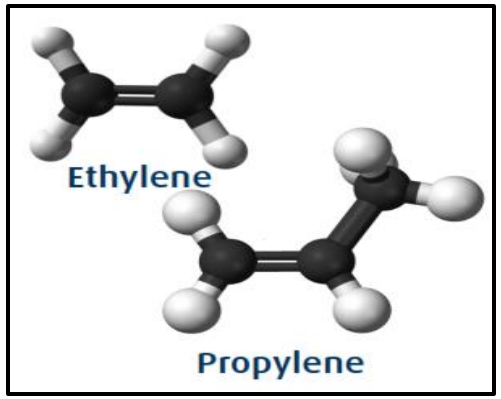
A brief history of plastics



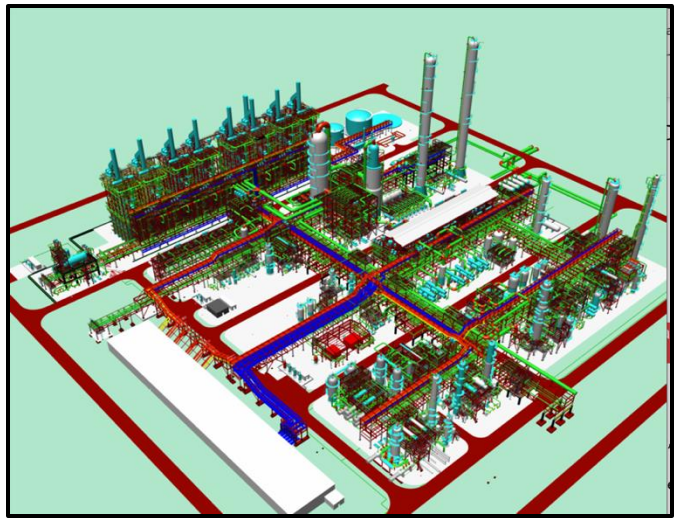
SOURCES: Chiven Manilall (Adapted from William Banholzer - AIChE Meeting 2014, Source: PCDB.Santefe.edu), T.E. Nowlin– The Business and Technology of the Global Polyethylene Industry, Mallpass/Elliot – Introduction to Industrial Polypropylene, https://www.chemistryworld.com/features/paving-the-way-to-polythene-/6675.article

Basic chemical processing mechanism

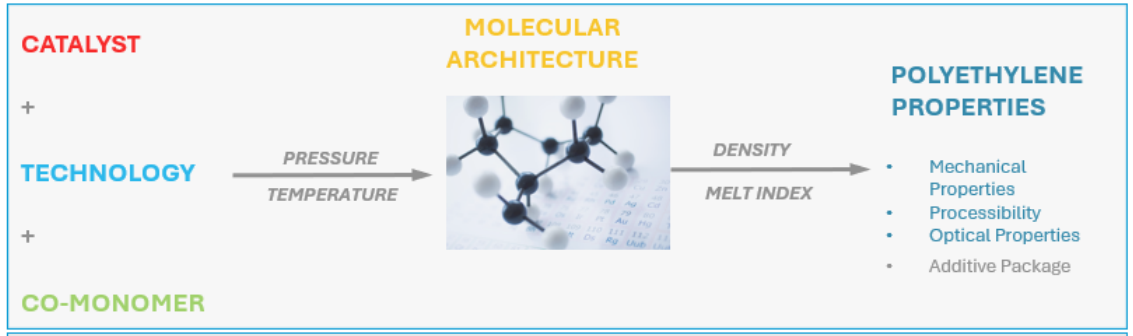
Monomer Production



NAPTHA CRACKER
ETHANE CRACKER
LPG CRACKER
CATCRACKERS



Polymer Production and Conversion (Fit for purpose)



- **Catalyst Types:** 3 (Ziegler Natta, Chromium, Metallocene)
- **Technology Types:** 6 (Technology Variations =20 +)
- **Co-monomer Types:** 10 + (Principally Butene, Hexene, Octene)
- 3 distinct types of PE: LDPE (High Pressure) & LLDPE/HDPE (Low Pressure)

Polyethylene is *tailored* into the desired characteristics

Important Properties

- Strength
- Weight
- Processibility
- Clarity
- Permeability
- Corrosivity
- Reactivity
- Flexibility

CONVERSION

Source: https://www.linde.com/clean-energy/industry-insights; https://www.plasticsinfo.co.za/, https://www.plastivision.org/blog/plastics-continue-to-make-cars-safer-and-fuel-efficien/

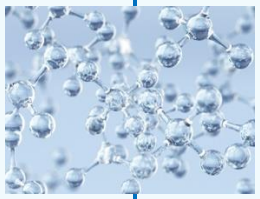
A big picture view





REFINERY/CRACKING → POLYMERISATION → PLASTIC CONVERSION → CONSUMPTION → WASTE PLASTIC


MECHANICAL RECYCLING




SOLVENT BASED RECYCLING (PURIFICATION)

DEPOLYMERISATION

PYROLYSIS/GASIFICATION

CHEMICAL RECYCLING

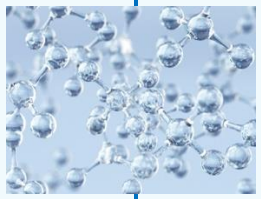
PHYSICAL RECYCLING

A big picture view





REFINERY/CRACKING → POLYMERISATION → PLASTIC CONVERSION → CONSUMPTION → WASTE PLASTIC




MECHANICAL RECYCLING

35% of collected waste

SOLVENT BASED RECYCLING (PURIFICATION)

10% of collected waste

DEPOLYMERISATION

PYROLYSIS/GASIFICATION

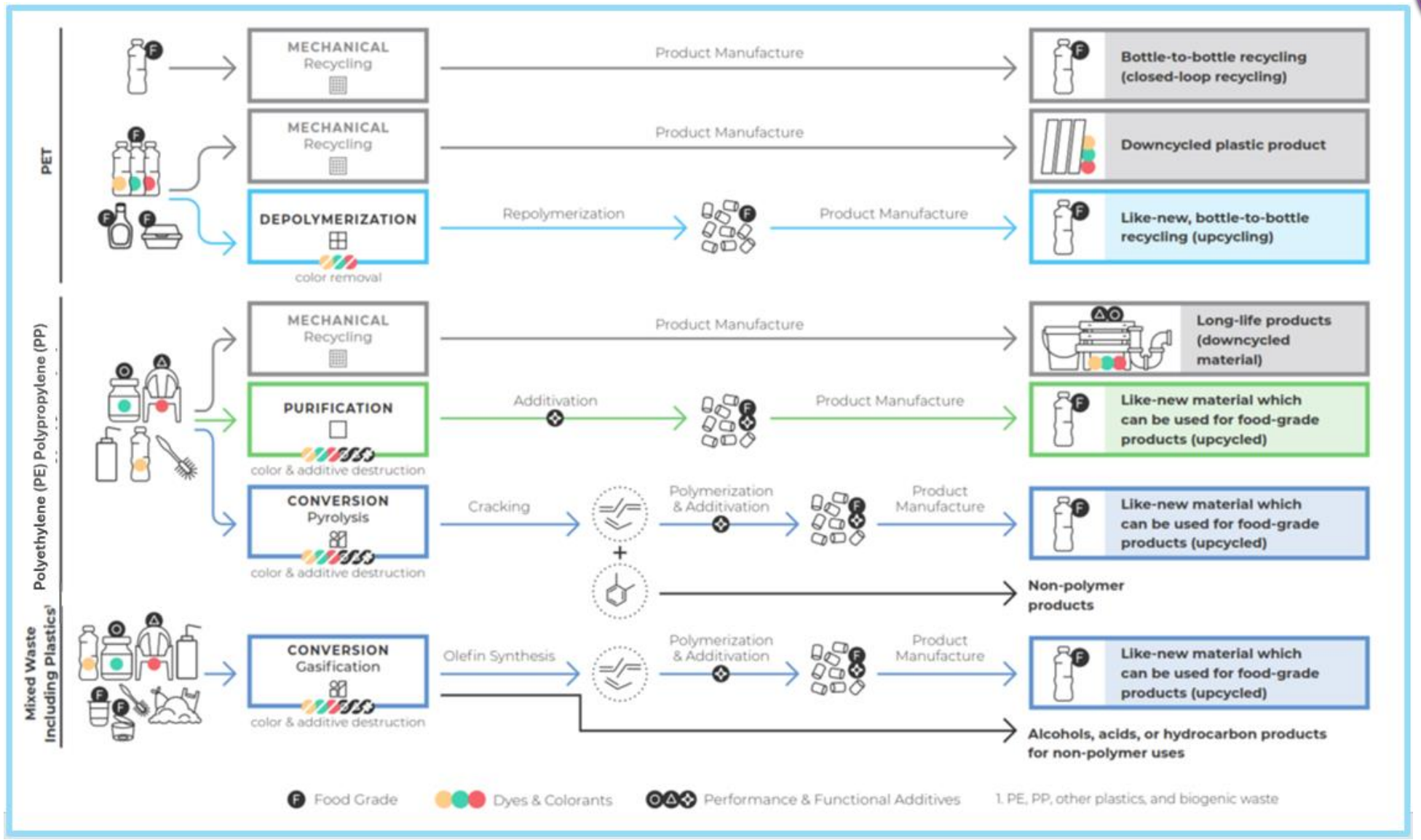
45% of collected waste

CHEMICAL RECYCLING

PHYSICAL RECYCLING

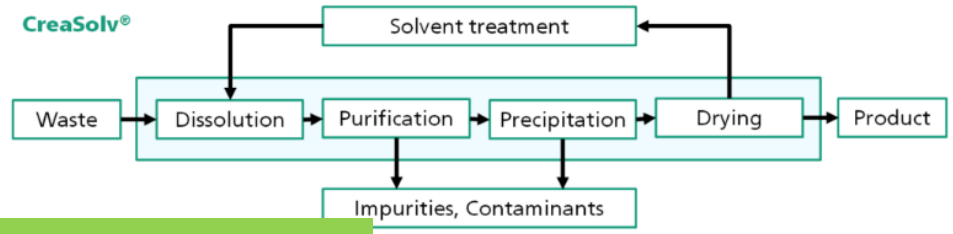
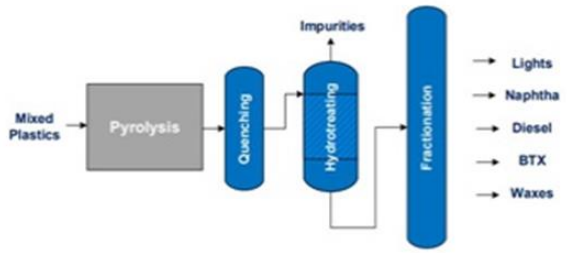
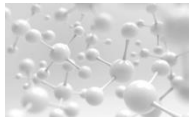
SOURCES: J.P Lange et al, Plastic recycling stripped naked – from circular product to circular industry with recycling cascade, ChemSusChem, 2024 [2] Elly Hoekstra, 20240307 - PD-EH-PRE - Plastics Analyses Dissolution

Value chain and technology overview



SOURCES: Assessing molecular recycling technologies US and Canada_ Closed Loop Partners_2023

Solvent based recycling versus Pyrolysis

 **SOLVENT BASED RECYCLING**	 **PYROLYSIS**
This process uses solvents to further extract color and additives without interfering with the molecular structure of the plastic mix.  	This process uses heat and catalysts to break chemical bonds within the plastic mix to produce a diverse range of hydrocarbons   
Evolving rapidly and is very easily coupled with conventional mechanical recycling technologies.	Conventional pyrolysis is easier to integrate into existing Petrochem facilities which reduces the need for large capital spend.
Much more energy efficient and has a lower carbon footprint than pyrolysis or gasification	Pyrolysis is the most popular form of chemical recycling and has a higher carbon footprint than most chemical recycling technologies.
New Cycle – Acquired by Lyondell Basel Pure Cycle Technologies – Partnered with Dow	Lyondell Basel – Moretec Technology Dow partners with Mura Technology
Carbon Footprint Range: 1 – 1.3 Tons CO_2e per ton	Carbon Footprint Range: 1.8 – 2.8 Tons CO_2e per ton

SOURCES: https://www.creasolv.de/en/the-process.html (Nontox), https://www.sulzer.com/en/shared/applications/mixed-plastics-pyrolysis, E.Hoekstra (PCF Calculations based on Sasol internal guidelines. Sept 2024)

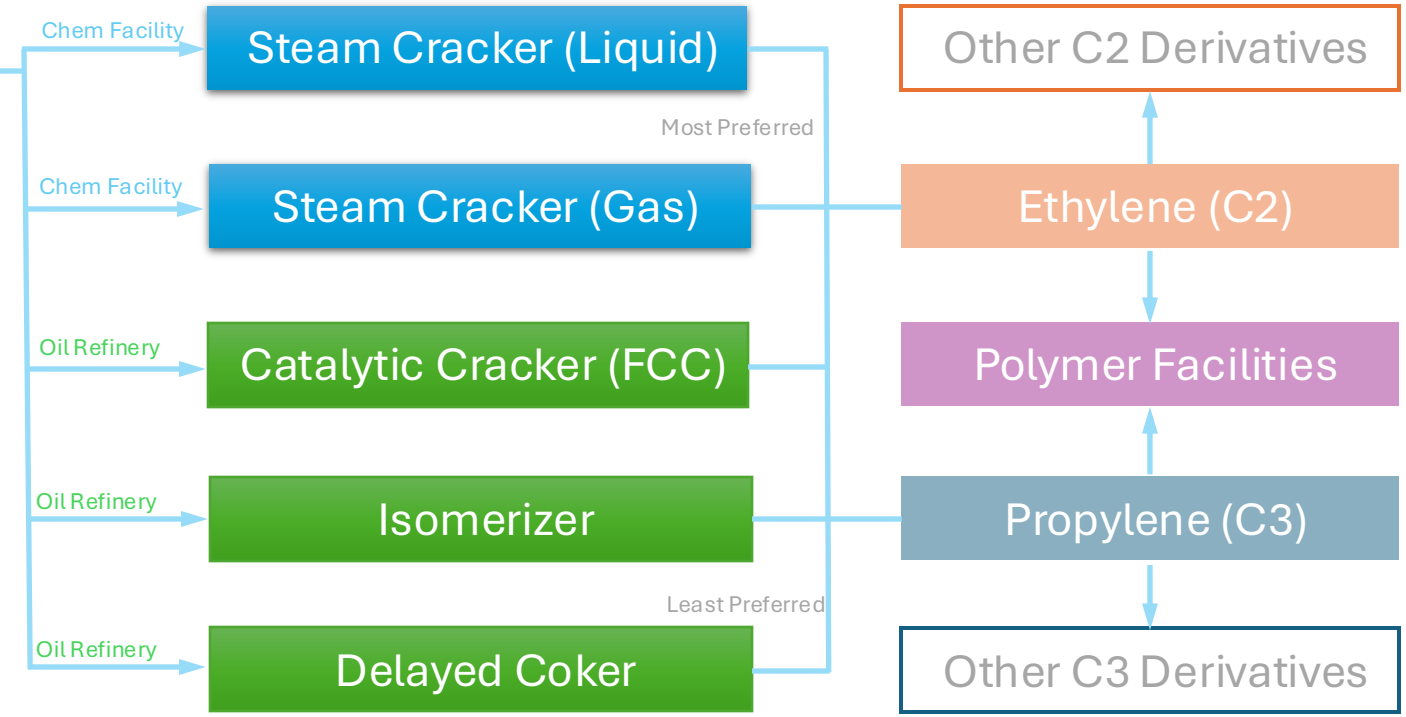
The importance of integration

New Process Facility

Plastics Pyrolysis - Hydrotreater

- A key advantage of Pyrolysis Oil (PO) is that it can be co-fed into existing large-scale crackers and refineries to produce fuels and chemicals.
- Building new processing plants specifically for PO can't be justified, because of its poor economics of scale: (20-100 KTA for PO versus MTA for cracker & refinery units).
- Feeding PO to a steam cracker is most preferable in terms of the production of base chemicals.
- Companies with liquid steam crackers have interest in PPO e.g.:
  SHELL (BlueAlp & other off take agreements) , DOW (Mura), Sabic (Plastic energy) LyondellBasell (Moretec)

Existing Process Facilities



Engineering companies are getting involved and are licensing technologies to third parties that want to get into the business . i.e., KBR is licensing Mura Technology's supercritical process, Lummus Technology is marketing New Hope Energy's technology, Haldor-Topsoe is offering its Purestep technology for pyrolysis oil upgradation, Honeywell UOP has unveiled its own process called UpCycle., TechnipFMC and Technip Energies have licensed various technologie s which includes Pyromax

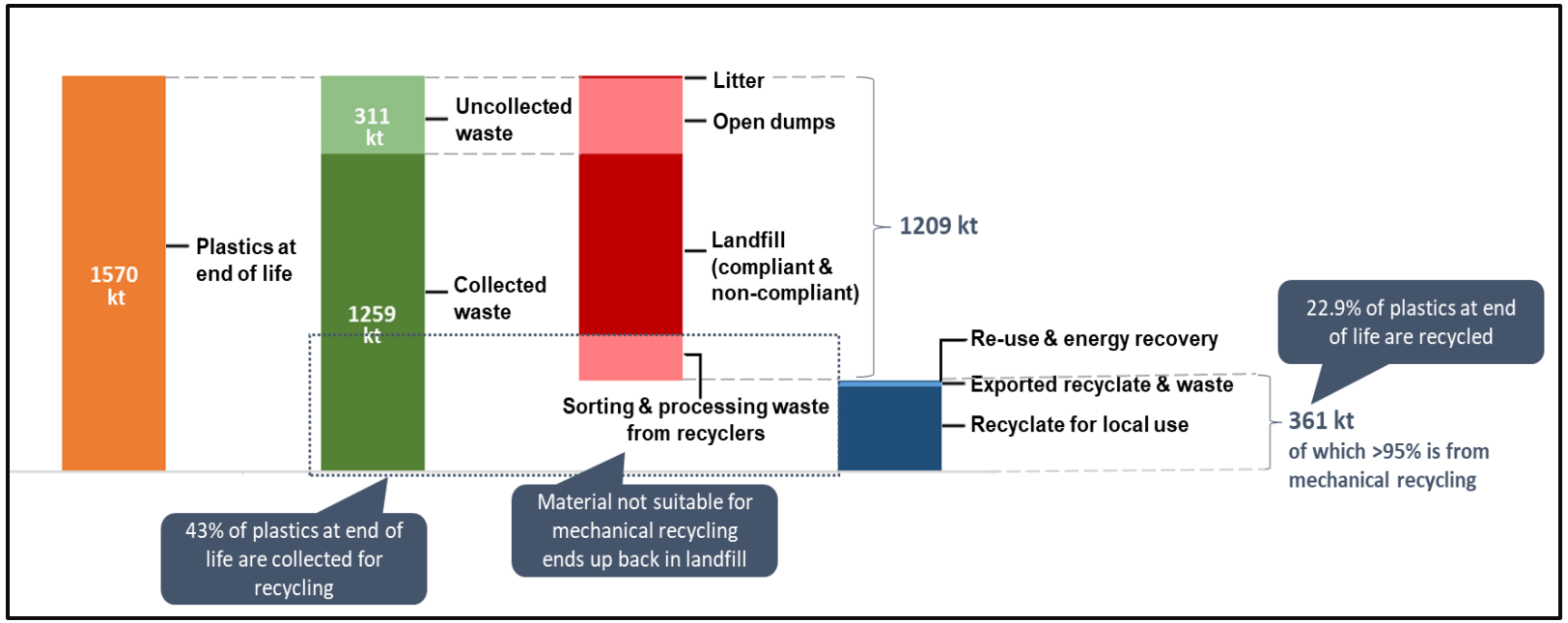
[1] PEP 199J, Base Chemicals from Pyrolysis Oil, 2023 [2] J.P Lange et al, Plastic recycling stripped naked – from circular product to circular industry with recycling cascade, ChemSusChem, 2024 [3] https://www.shell.com/business-customers/chemicals/chemical-recycling-tackling-plastic-waste.html#iframe=L3dlYmFwcHMvU2hlbGxfQ2hlbWljYWxzX1llY3ljbGluZy8, C. Manilall, Plastics analyses: industry analysis (draft), May '24 a) C-efficiency pyrolysis = 70-75%, C-efficiency cracker to ethylene, propylene and BTX is ~70%

The case for chemical recycling

What is Chemical Recycling ?

Chemical recycling, aka, advanced recycling, aka, molecular recycling are terms given to a group of technologies that can convert mixed and/or contaminated plastics into a 'virgin' like raw materials.

- It can produce recycled plastics from hard-to-recycle waste plastics that are highly suitable for complex- end applications like food contact or medical, or for safety critical applications (such as automotive) which is not always possible with mechanical recycling.
- Chemical Recycling compliments mechanical recycling and allows for a faster transition to a circular economy.
- Potential technologies involve depolymerization, pyrolysis and gasification.
- As per the 2022 RSA Mass balance, there is an opportunity to investigate for more chemical recycling potential.



Adapted from:
PlasticsSA, *Plastics 2022: An analysis of the South African plastics industry data,* July 2023

Conclusion

- Chemical recycling could play an important role in the circular plastics chain owing to its capability in transforming plastic waste into circular monomer and hence recycled polymer.
- The technology space is evolving at a rapid rate to produce more efficient and high-value product portfolios with hard to recycle plastic feeds.
- As it stands chemical recycling is a complimentary process to mechanical recycling and could accelerate the transition to a more circular economy.
- There is still a large portion of the RSA plastics value chain that's linear and chemical recycling could assist in changing this position.
- Collaboration amongst stakeholders is a key factor in enabling the use of chemical recycling in the RSA context.

Collaboration divides the task and multiplies the success

Acknowledgements

Thank you

End