Molecular Recycling

Closed Loop Partners

CLOSED LOOP partners

What is molecular recycling?

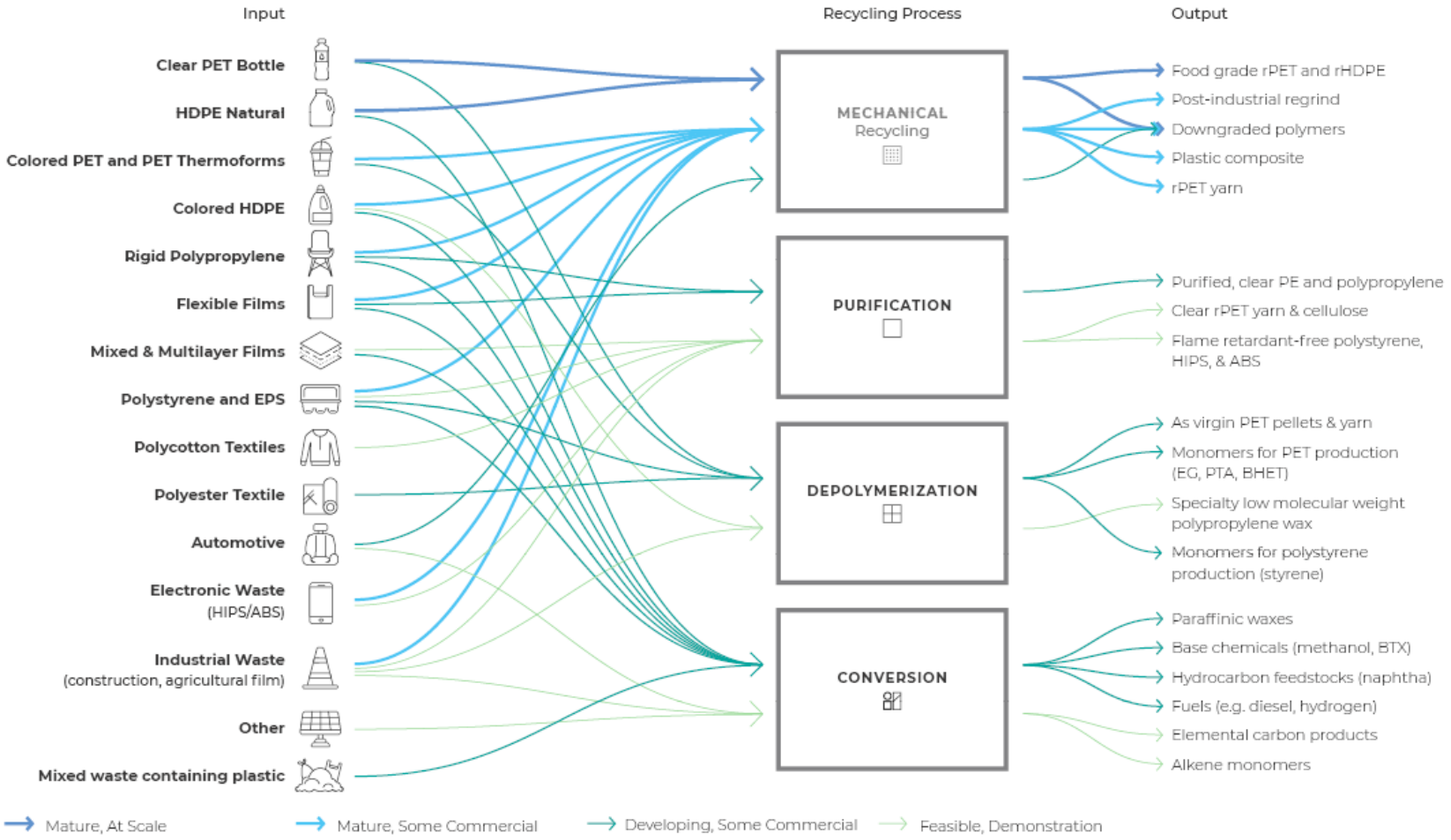
Technologies that use solvents, heat, enzymes, and even sound waves to purify or break down plastic waste. Whether they are circular depends on the supply chain they connect to downstream.

	PURIFICATION	DEPOLYMERIZATION		CONVERSION	
		Partial	Full	Partial	Full
Main Polymer Inputs	• Polypropylene (PP) • Polyethylene (PE) • Polystyrene (PS) • ABS Molecular homogeneity in input is preferred to ensure high output quality[1]	• Polyethylene terephthalate (PET) • PP • PE	• PET • Polyamide (PA) • PS • Polylactic acid (PLA) • Poly(methyl methacrylate) (PMMA) • Polyurethane (PU)	• Mixed (PE, PP, and PS preferred)	• Mixed
Features of Reaction	• Polymer bonds are not broken	• Limited chain scission • Limited side reactions	• Full chain scission • Usually chain-end scission reactions (where monomers are removed one-by-one)[2]	• Random chain scission • Side reactions such as cyclisation	• All bonds broken including C-C and C-H • Initial products of process are not hydrocarbons (e.g. syngas from gasification or carbon from flash-joule heating)
Typical Technology Outputs	• Colourless polymer flakes or pellets	• Oligomers • Polypropylene wax • Polyethylene wax	• Monomers, e.g. monoethylene glycol (MEG) & purified terephthalic acid (PTA) • Solvents • Polyethylene waxstyrenic polymers	• Crude oil • Naphtha • Paraffinic waxes • Alkenes (ethylene & propylene) • BTX • Diesel and other fuels	• Syngas (carbon monoxide and hydrogen mixture) • Methanol • Elemental carbon
Features of Products	• Molecular structure of polymers are unchanged from the input material	• Specific molecular products (oligomers, narrow distribution waxes)	• Specific molecular products (monomers)	• Products consist of mixtures of molecular species, often separated into fractions • Relatively wide distribution of product molecular weight	• Specific molecular products which are often fed directly into another reactor to produce other chemical products such as methanol or hydrocarbons
Technology Process Types	Solvent Extraction, De-inking	Enzymatic Degradation, Microorganism Degradation, Solvolysis (e.g. Hydrolysis, Glycolysis, Methanolysis, Ammonolysis), Pyrolysis, Hydrothermal, Microwave, Ultrasonic			Gasification, Flash Joule Heating, Plasma-arc Gasification

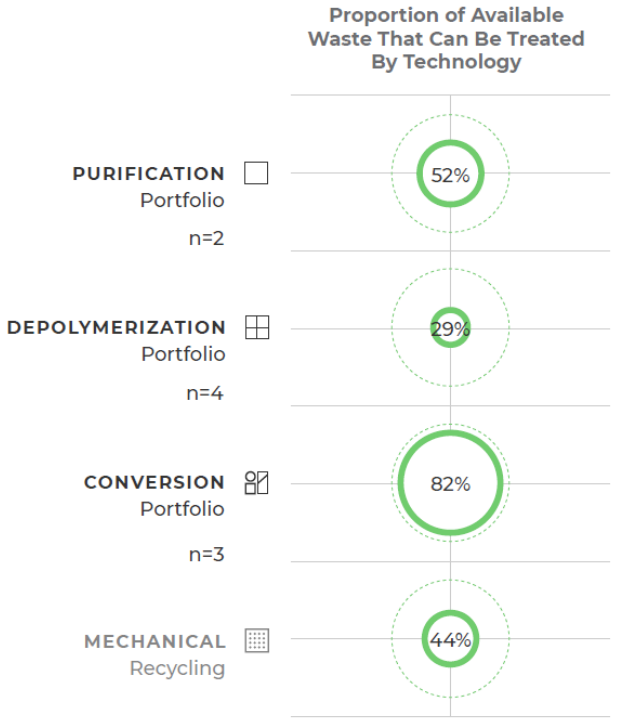
Source: Figure 6 in CLP's 2021 Report

What do these diverse technologies process?

MORE THAN PLASTIC PACKAGING WASTE



% OF PACKAGING EACH CATEGORY CAN ADDRESS



Sources: Figure 7 & 22 in CLP's 2021 Report

What are the environmental impacts to make recycled plastic again?

SUMMARY OF SYSTEM-LEVEL IMPACTS BY TECHNOLOGY CATEGORY

(i.e. the impacts when the outputs of these technologies are brought back to plastic resin)

		Total Natural Resource Energy [2] (NREt)		Climate Impact Potential (CO_2e)	
		MJ / kg Plastic Pellet	% Change vs Virgin System	$kgCO_2e$ / kg Plastic Pellet	% Change vs Virgin System
PURIFICATION					
	Portfolio average	28.8	↓ 59 %	1.6	↓ 20 %
	Range	22.0 – 35.6	↓ 47 % to ↓ 70 %	1.2 – 2.0	↑ 7 % to ↓ 45 %
DEPOLYMERIZATION					
	Portfolio average	46.7	↓ 38 %	2.5	↓ 12 %
	Range	18.0 – 68.1	↓ 17 % to ↓ 72 %	1.1 – 3.5	0 % to ↓ 36 %
CONVERSION					
	Portfolio average	35.8	↓ 47 %	2.8	↓ 7 %
	Range	12.6 – 59.1	↓ 14 % to ↓ 80 %	1.2 – 4.4	↑ 22 % to ↓ 26 %

Source: Table 1 in CLP's 2021 Report

What else is important to measure?

- **MASS YIELD OF TECHNOLOGY'S SUPPLY CHAIN**
- **CHEMICAL INPUTS AND PROCESSES AVOIDED**