Advanced Plastic Recycling Update

PEP Report 199L

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Glossary

$/tonne	Dollars per tonne
°C	Degree Celsius
°F	Degree Fahrenheit
AEBP	Atmospheric equivalent boiling point
API	American Petroleum Institute
APR	Association of Plastic Recyclers
ARC	Advanced Recycling Cluster
ASTM	American Society for Testing and Materials
atm	Atmospheres
b/sd	Barrel per stream day
BCM	Billion cubic meters
BFD	Block flow diagram
BFW	Boiler feed water
BHET	Bis(2-hydroxyethyl) terephthalate
BHETA	Bis(2-hydroxy ethylene) terephthalamide
BLI	Battery limits investment
BP	Boiling point
Btu	British thermal units
Capex	Capital expenditure
CBAM	Carbon Border Adjustment Mechanism
CCC	Cyclyx Circularity Center
CCR	Conradson carbon residue
CFR	Cost and freight
CP	Contract price
cP	Centipoise
CSBR	Conical spouted bed reactors
CTA	Crude terephthalic acid
CW	Cooling water
DCU	Delayed coker unit
DGO	Distillate gas oil
DIDPP	Diisodecyl phenyl phosphite
DMT	Dimethyl terephthalate
DOE	Department of Energy
DRS	Deposit Return Scheme
EA	Environment Agency
EC	European Commission
EG	Ethylene glycol
EPA	Environmental Protection Agency
EPR	Extended producer responsibility
ETS	Emissions Trading System
FCC	Fluid catalytic cracker
ft^3	Cubic feet
FTR	Fired tubular reformer
g	Grams
G&A	General and administrative
GWP	Global warming potential
HCl	Hydrochloric
HDPE	High-density polyethylene
HEB	2-Hydroxyethyl benzoate
HGO	Heavy gas oil
h	Hour
HSFCC	High-severity FCC
HTC	Hydrothermal carbonization
HTG	Hydrothermal gasification
HTL	Hydrothermal liquefaction

HTS	Hydrothermal solidification
HWR	Heavy wax residue
IPE	Indomobil Prima Energi
ISCC	International Sustainability & Carbon Certification
JRC	Joint Research Centre
kg	Kilograms
kJ	Kilojoules
kPa	Kilopascals
kPaG	Kilopascal gauge
KPS	Koch Project Solutions
kta	Thousand metric tons per annum
kWh	Kilowatt hour
lb	Pounds
LCA	Life cycle analysis
LDPE	Low-density polyethylene
LF	Liquid fraction
LGO	Light gas oil
LHV	Low heating value
LLDPE	Linear low-density polyethylene
m	Meters
M	Thousand
mgal	Thousand gallons
MHET	Methyl-2-hydroxyethyl terephthalate
mlb	Thousand pounds
mm	Millimeters
MMT	Million metric tons
MPO	Mixed polyolefin
MRF	Material recovery facility
Mt	Metric tons
mol%	Molar percent
mPa	Megapascals
MWh	Megawatt-hour
NGO	Nongovernmental organizations
NIST	National Institute of Standards and Technology
Opex	Operational expenditure
OSBL	Outside battery limits
PAN	Polyacrylonitrile
PC	Polycarbonate
PCG	Petronas Chemicals Group Berhad
PCR	Postconsumer recycled
PA-6	Polyamide-6
PE	Polyethylene
PEP	Process Economics Program
PERN	Packaging Export Recovery Note
PET	Polyethylene terephthalate
PFAS	Per- and polyfluorinated alkyl substances
PFD	Process flow diagram
PLA	Polylactic acid
PMMA	Polymethyl methacrylate
PP	Polypropylene
ppb	Parts per billion
ppm	Parts per million
PPO	Plastic pyrolysis oil
PPT	Plastic packaging tax
PPWR	Packaging and Packaging Waste Regulation
PRN	Packaging Recovery Note

PS	Polystyrene
PSA	pressure swing adsorption
psi	Pounds per square inch
psia	Pounds per square inch absolute
psig	Pounds per square inch gauge
PTA	Purified terephthalic acid
PVA	Poly(vinyl) alcohol
PVC	Polyvinyl chloride
QCP	QC Polymer
RDF	Refuse-derived fuel
RO	Reverse osmosis
ROI	Return on investment
s	Second(s)
SCF	Standard cubic feet
SCM	Standard cubic meter
SCW	Supercritical water
SiPW-A	Phosphotungstic acid on a silica-modified support
SiWSi-A	Tungstosilicic acid on a silica-modified support
TBP	True boiling point
T_g	Glass transition temperature
TiWSi-A	Tungstosilicic acid on a titanium dioxide support
TPA	Terephthalic acid
TFC	Total fixed capital
t/d	Tons per day
t/y	Tonne per year
TSCA	Toxic Substances Control Act
UF	Ultrafiltration
UPR	Ultrapure recycled
vol%	Volume percent
w/w	Weight for weight
wt%	Weight percent
WTI	West Texas Intermediate

Abstract

A series of Process Economics Program (PEP) reports have been published on advanced plastic recycling processes. Due to the swift progress in this domain, novel processes, which were not covered in our previous reports, have been commercialized or are on the verge of commercialization. For mixed polyolefin plastic waste, the supercritical hydrothermal liquefaction of plastic has been gaining traction in mixed plastic waste recycling. Hydrothermal liquefaction uses supercritical water as the medium to help break carbon-carbon bonds in plastic waste. The liquefaction reaction occurs at around and above the critical temperature of water. Mura Technology has developed a process, called Hydro-PRT™ (Hydrothermal Plastic Recycling Technology), incorporating Licella Holdings' Cat-HTR proprietary hydrothermal liquefaction technology. The first commercial-scale plant using Mura's Hydro-PRT™ process, located in Teesside, UK, started up in 2024. It will process up to 20 kta of mixed polyolefin waste feedstock. KBR, Mitsubishi Chemical, Dow, LG Chem, and Chevron Phillips Chemical are among the major companies that have entered into licensing agreements or strategic partnerships with Mura.

Pyrolysis is the core technology of most commercialized advanced plastic recycling processes using mixed polyolefin plastic waste feedstock. However, a dedicated plastic waste advanced recycling unit can be costly, especially at a smaller capacity. In addition to the dedicated pyrolysis unit, equipment for fractionation, purification, and hydrotreating is required. Recently, there has been interest in using existing coking units in the refineries for the pyrolysis of plastic waste.

Enzymatic depolymerization of polyethylene terephthalate is being commercialized. Carbios (France) started construction of its first commercial-scale plant in 2024. The plant will be capable of processing 50,000 t/y of polyethylene terephthalate (PET) waste. Carbios uses an enzymatic depolymerization process to break down PET waste to form terephthalic acid (TPA) and ethylene glycol (EG).

In this report, we will review the current industrial status of advanced plastic waste recycling. A brief technology overview of several advanced plastic recycling processes will be reviewed. More in-depth analyses include techno-economic evaluations of advanced plastic waste recycling based on (1) a hydrothermal liquefaction process using supercritical water for mixed polyolefin waste based on Mura Technology, (2) pyrolysis conducted in a delayed coking unit for mixed polyolefin waste, and (3) an enzymatic depolymerization process for PET waste.

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