March 2024

Sector Insights

Sector: Plastic Recycling

Industry Group: Waste & Recycling

AGRICULTURE & FOOD | ENERGY & POWER | MATERIALS & CHEMICALS | RESOURCES & ENVIRONMENTAL MANAGEMENT | TRANSPORTATION & LOGISTICS | WASTE & RECYCLING

ENABLING TECHNOLOGIES, BUSINESS MODELS, AND THEMES

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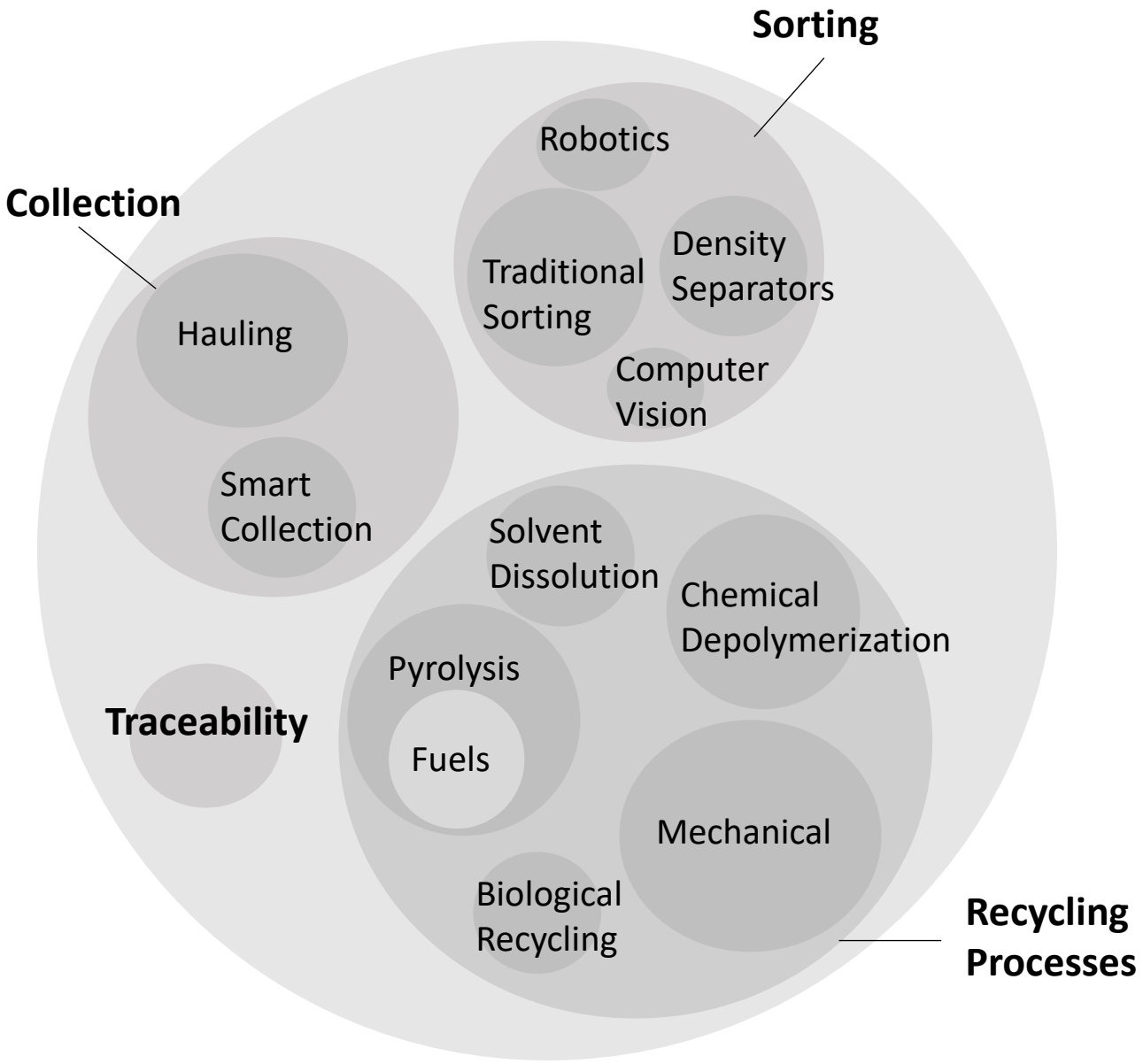
Plastic Recycling Sector



Key Segments & Sub Segments

Plastics recycling falls within the waste management branch of Cleantech Group's taxonomy. End products from recycling have diverse applications including fuels, chemicals, building materials, and packaging. There are 329 relevant companies on i3.

Pretreatment

- **Collection**: Waste collection technologies, which optimize collection and some presorting.
- **Sorting**: Washing and sorting technologies to remove contaminants, sort plastic types, and prepare materials for recycling process. Key innovations in image recognition software, AI analytics, and robotics.

Treatment

- **Recycling Processes**: Specific chemical and mechanical recycling processes will vary depending on plastic feedstock, purity of plastic, and desired end-product.
- There is increasing hybridization between processes to upcycle compounds using catalysts or solvents.

Executive Summary: Plastic Recycling

Advanced recycling offers several solutions to improve plastic recycling, reduce pollution

- Plastic recycling traditionally diverts waste from emissions-intensive landfilling and incineration, using it to produce new plastic
- The recycling status quo uses **mechanical recycling for 90% of all recycling,** creating several issues:
  - Mechanical recycling requires expensive, manual sorting
  - Mechanical recycling only accepts PET, HDPE, PP, LDPE and produces mixed resins
  - Recycled plastic is often contaminated and low quality, limiting applications and offtake partners
  - Current recycling rate is just 8% of all plastic waste due to technical process limitations, uncoordinated waste handling, and lack of demand
- **Advanced recycling offers promise:** it **accepts all plastic types,** produces **higher quality products**, and accepts **cheaper feedstocks**
- Advanced recycling targets three primary offtake markets:
  - Plastic-to-fuel: Usually pyrolysis or gasification (Plastic Energy, Brightmark)
  - Plastic-to-chemicals: Extracted from deconstructed polymers following pyrolysis or depolymerization (Anellotech, GreenMantra, MacroCycle)
  - Plastic-to-plastic: Technically possible across technologies, but solvent dissolution most effective and targeted (Polystyvert, APK, PureCycle)
- Solvent dissolution can be used to extract pure, uncontaminated polymers such as PP and HDPE from packaging products (31.2% of annual plastic volume)
- Solvent dissolution can be integrated into mechanical recycling, **increasing profits** and **creating circular plastic packaging** today

Figure 1: Plastic Production by Type (400M Tons)

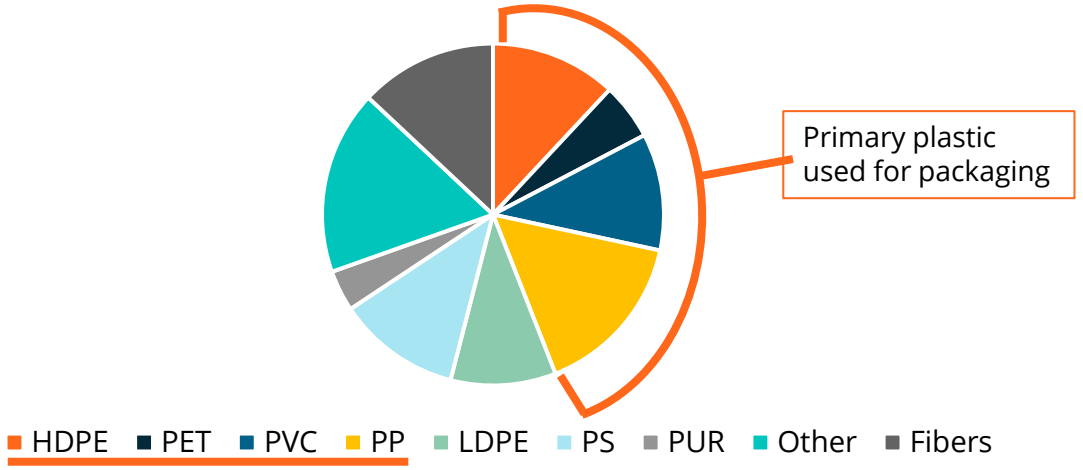
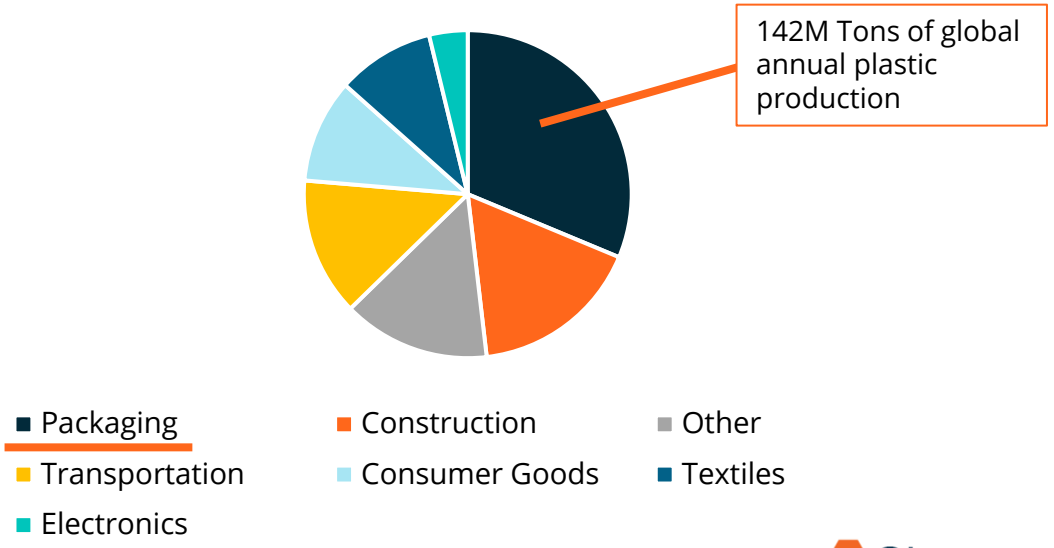


Figure 2: Plastic Production by Industry



Source: OCED, 2022.

Plastic Recycling: Setting the Stage

Advanced recycling improves recycling rates but must reduce environmental impacts through innovation

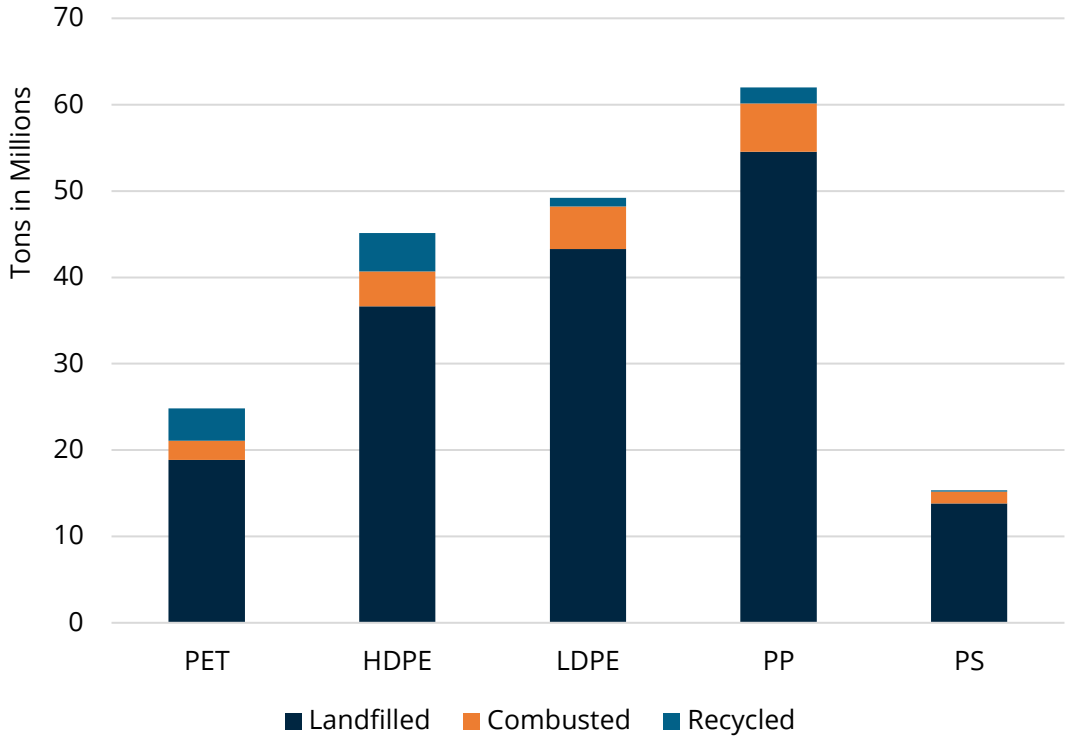
Description

- Plastic recycling refers to the commodification of plastic waste, primarily into plastic but also textiles, fuels, or specialty chemicals
- Primary problematic plastics:
  - 75% of the primary packaging plastics have recycling rates below 10% (Figure 3)
  - **Packaging plastics represent 44% of all plastics manufactured each year**
- Structural issues impacting low recycling rates:
  - Plastic recycling plants are concentrated in countries with established waste collection and material recovery facilities (U.S., EU, Australia); only target high value plastics (PET)
  - Asia produces 52% of global mismanaged plastic waste (UN), requires most aid
  - Poor sorting, labeling, education outside of the EU limits recycling efficiency

Impact of Advanced Recycling

- Makes plastic a circular resource, can reduce emissions and pollution
  - Advanced recycling increases recycling rates by accepting all plastic waste
  - **Advanced recycling reduces need for new fossil-based plastic, oil exploration**
  - Depolymerization, solvent dissolution, catalytic pyrolysis **lowers GHG emissions by 43% compared to incineration of films like HDPE and LDPE** (Yale360)
  - GHG emissions from plastics set to double by 2060 otherwise (Figure 4)
- Tradeoffs
  - **Advanced recycling is more GHG intensive than mechanical recycling** - it should be used selectively on difficult to recycle waste
  - Initial Lifecycle Assessments (LCAs) show that standard pyrolysis generates **carcinogenic air and water pollution**, GHG emissions equivalent to virgin plastic
  - Solvent dissolution can pollute air, food, and water if toxic byproducts leak
  - Depolymerization is energy intensive and can leak toxic compounds like methanol

Figure 3: Disposal of Plastic Types



Note: Types 3 (PVC) & 7 (Other) are excluded from the NREL study as rate of recycling is approximately zero. Total tonnage is approximated using recycling rates and OCED reported tonnage.
Source: National Renewable Energy Laboratory (NREL) 2019 Plastic Landscape Assessment, January 17, 2024.

Source: Cleantech Group

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Drivers – Advanced Recycling More Sustainable, but Economics Remain Barrier

Advanced recycling is necessary to curb emissions and pollution from virgin plastic, increase recycling profits

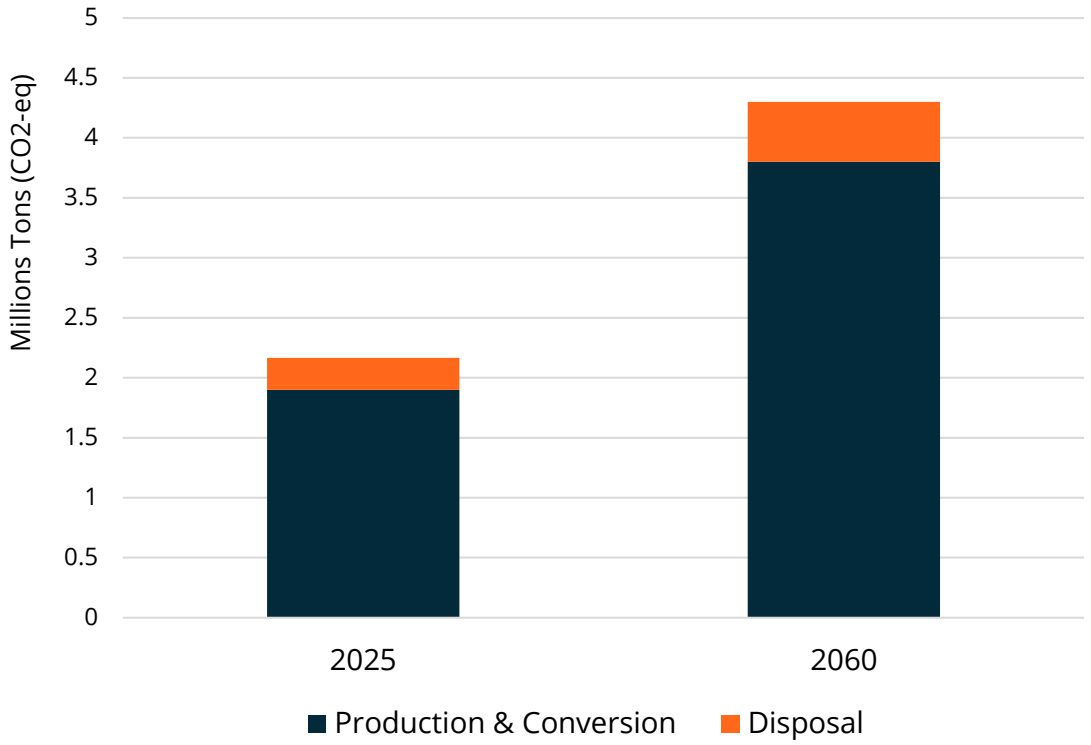
Economic Motivators of Demand

- **Cost of production**
  - Depolymerization and Solvent Dissolution
    - Energy consumption, disposal of toxic byproducts too expensive for stand-alone deployment (excluding handful of glycolysis plants)
    - Solvent dissolution can remove adhesives and contaminates prior to mechanical recycling, reducing pre-processing and equipment damage
  - Catalytic pyrolysis lowers energy requirements by half of standard pyrolysis
- **Revenue**
  - Base chemicals, polymers, fuels are far more valuable than mixed plastic pellets from mechanical recycling
  - Advanced recycling improves standard recycling's material recovery **25-50%**
  - **Layering in advanced recycling alongside mechanical recycling commodifies previously discarded material, increases profits**

Market Conditions

- Policy promoting recyclability, waste-to-fuels, and sorting infrastructure can accelerate recycling rates, reduce virgin polymer production. Extended Producer Responsibility (EPR) legislation financially penalizes plastic manufacturers, packaging companies using plastic with low or no recyclability
  - Banning plastic waste exports creates domestic treatment, sorting (EU 2021)
  - Subsidizing plastic waste to fuel utilization (IRA, EU fit for 55)
- Only thermal treatment, glycolysis is profitable today
  - Price of recycled resin higher than virgin resin across recycling processes
  - Successful value chains can be co-opted by future depolymerization, dissolution
- **Waste collection companies are positioned to vertically integrate collection, sorting, and recycling, benefitting from economies of scale**

Figure 4: Plastic Lifecycle GHG Emissions



Source: OCED

Source: Cleantech Group

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Challenges – Displacing Plastics Emissions Still Requires a Green Premium

Pyrolysis best positioned for immediate profit; all recycling processes suppressed by cheap virgin resins

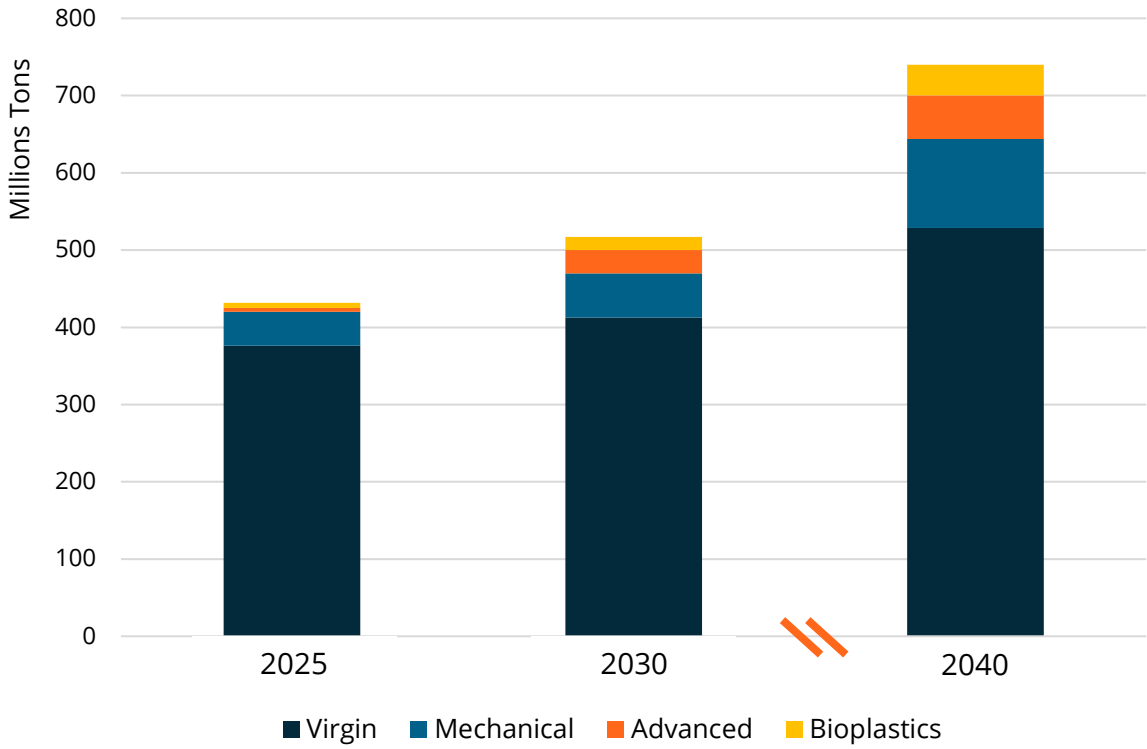
Technical Barriers

- Input issues
  - Solvent dissolution and depolymerization treatments for mechanical recycling increase overall energy requirement by 2-10x
  - Expanding existing Material Recovery Facilities (MRFs) to include treatments like solvent dissolution is often not possible due to space constraints, offtake contracts
  - 90%+ purity feedstocks maximize material yield, not available at commercial scale
- Offtake issues
  - Refining infrastructure does not exist at a commercial scale for solvent dissolution
  - Pyrolysis does not integrate easily into existing refining, often requires new refineries or substantial retrofitting
  - Commercial repolymerization controlled by chemical companies (**Suez, SK**), creating bottleneck while chemical incumbents scale refining

Economic Barriers

- **Increasing costs and green premium across recycled materials**
  - Feedstock bales are increasing in price while price paid for recycled resin is falling (46% decrease for HDPE, 8% decrease for PP in one year) (SMP)
  - Small margins (sometimes < 1%) due to high processing costs
  - Virgin resin is cheaper than recycled resin across all plastic types
- **Scaling issues:**
  - Full vertical integration most successful model, impossible for producers other than commercial waste managers (e.g., WM, Republic Services)
  - Refining plants for pyrolysis oil, solvent dissolution are usually $50M+ investments
- High competition in PET depolymerization, pyrolysis due to established offtake
- **Bioplastics will directly compete against recycled plastics** (Figure 5)

Figure 5: Plastic Production by Source



Source: NREL, World Economic Forum, and Cleantech Group.

Source: Cleantech Group

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Value Chain/Landscape

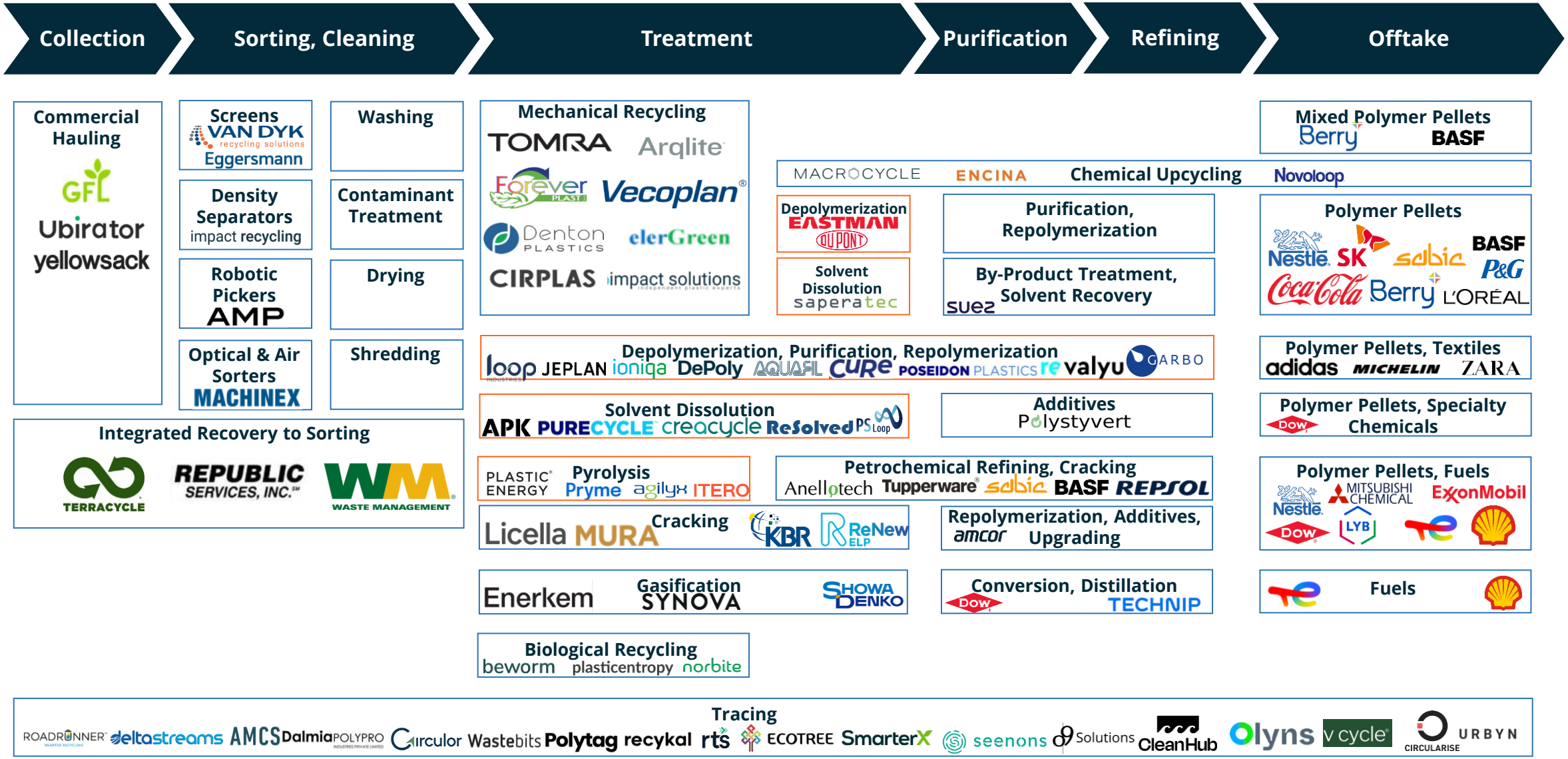

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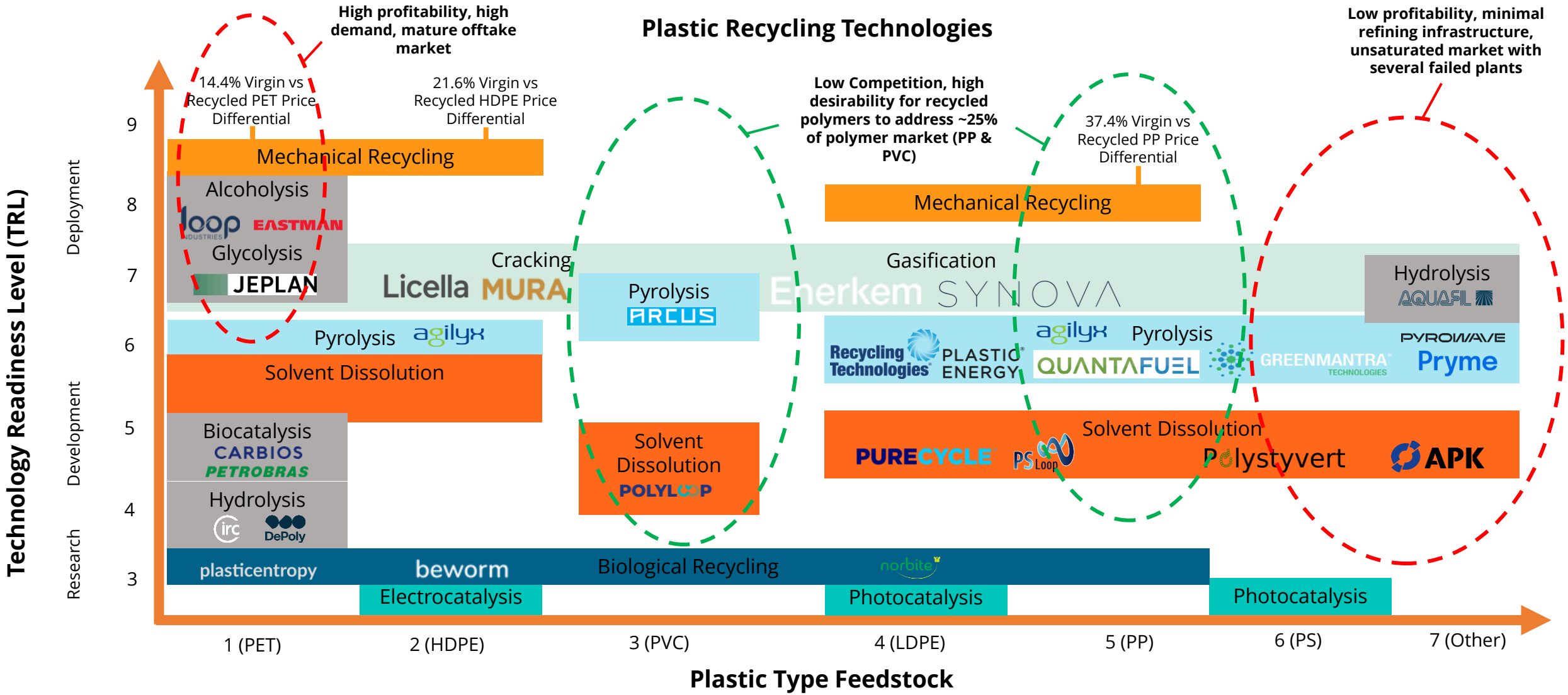
Figure 6: Recycling Process Maturity

rPET through depolymerization, mechanical recycling pairing is the model for sustained growth



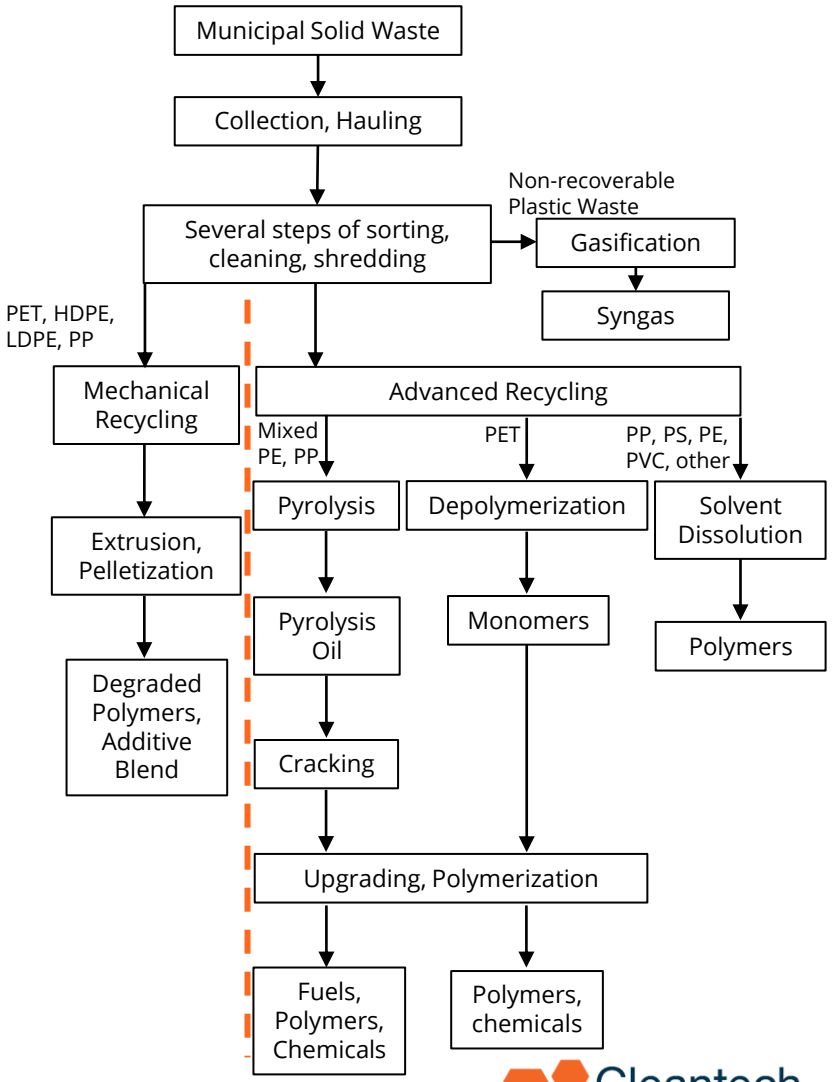
Source: S&P, Cleantech Group.

Key Innovations

Solvent dissolution and depolymerization compliment mechanical recycling, pyrolysis offers more immediate profits

- **Mechanical recycling**
  - Feedstock: Mixed plastics to produce pelletized mixed polymers
  - Technical issues: Mixing plastics dramatically lowers strength, functionality and therefore reduces end-uses and markets
  - Innovation: Chemical pretreatments to remove contaminants or posttreatments to extract polymers
  - Off-taker: Large plastic manufacturers (Berry Global, BASF)
- **Pyrolysis**
  - Feedstock: Mixed plastic, preferably PP or PE
  - Technical issues: Production is exponentially more toxic than virgin plastic, refining pyrolysis oil requires several steps and is often not suitable for repolymerization, optimal reactor has still yet to be determined
  - Innovation: Catalytic pyrolysis start-ups (Anellotech, Braskem) improve efficiency with single-step reactions and may eventually compete with mechanical recycling in total energy requirement
  - Off-taker: Oil and gas (ExxonMobil, TotalEnergies), large plastic manufacturers (SABIC, Braskem)
- **Solvent Dissolution**
  - Feedstock: Mixed plastic, usually high (90%+) purity PS
  - Technical issues: Solvents must be recovered for process to be profitable, requires thorough feedstock testing to maximize value extraction
  - Innovation: Machine learning to optimize solvent choice, STRAP system to dissolve several layers of plastic
  - Off-taker: Packaging manufacturers (COEXPAN, Nestle, L'Oréal), chemical companies (SK)
- **Depolymerization**
  - Feedstock: PET, limited PE, PA, and PU
  - Technical issues: Requires high purity feedstocks and expensive reactor metals due to corrosiveness of reactions, can create hazardous byproducts requiring careful treatment
  - Innovation: Can be used for chemical upcycling to create new value from certain polymers, complimentary technology for non-PET mechanical recycling
  - Off-taker: Food and beverage corporates (Coca-Cola, Starbucks), textile manufacturers (Seibu Sogo, Adidas)
- **Biological Recycling** uses several species of worms, bacteria, and other organisms to digest plastics
- High purity HDPE, LDPE mix is best recycled through **gasification** and **cracking** to produce platform chemicals
- Gasification and cracking are integrating conversion steps in new pilots, directly competing with pyrolysis
- Higher volume and purity of sorted plastic waste increases advanced recycling profitability and lowers energy requirement

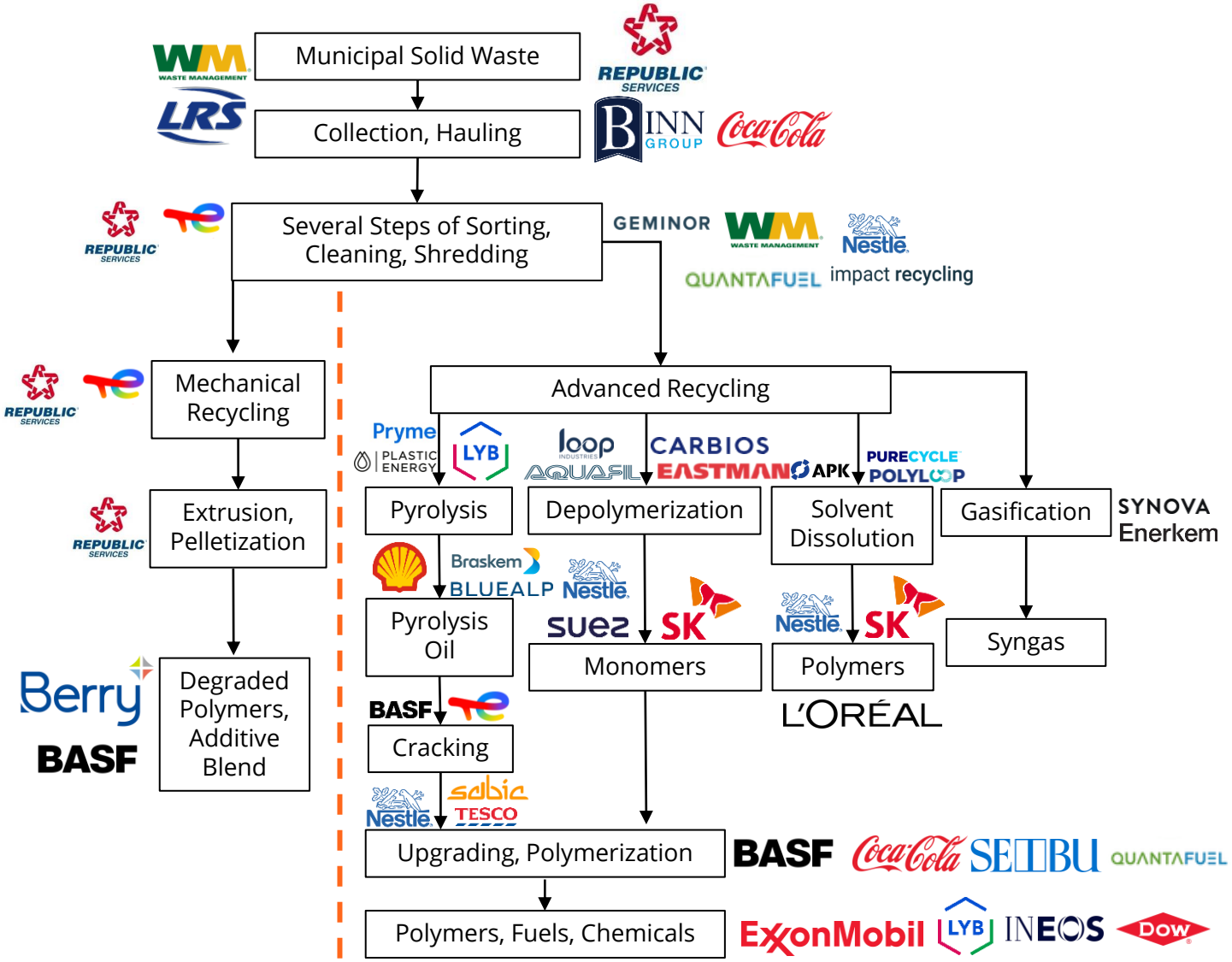
Figure 7: Incumbent (Left) vs Innovator (Right) Recycling



Source: Cleantech Group

Key Trends: Supply Chain Engagement

Figure 8: Incumbent (Left) vs Innovator (Right) Recycling



Highlights

- High demand for end products but limited corporate engagement with advanced recycling innovation, corporate engagement concentrated in downstream refining
  - Chemical companies with established refining (Shell, SK, Suez) are often initial development partners for pilot and commercial facilities due to their existing refinery infrastructure
  - Jet fuel (Sustainable Aviation Fuel, or SAF) offtake agreements from pyrolysis, cracking, and gasification have been slow but are expected to grow alongside sorting due to strict chemical requirements (Quantafuel, Enerkem)
  - Following depolymerization and upgrading, primary offtake partners for rPET have been Coca-Cola, PepsiCo, L'Oreal, BASF
  - Textile industry engages exclusively after BHET is extracted from PET, room for greater collaboration here
- Oil and gas industry varies in supply chain engagement, but are concentrated in pyrolysis refining or pyrolysis-to-fuel offtake agreements
  - TotalEnergies has investments in pyrolysis, offtake agreements, waste sorting, as well as mechanical recycling suggesting a desire to vertically integrate several technologies with their refining
  - Shell has capitalized on their refining infrastructure while building out their own pyrolysis facilities and securing feedstocks
  - ExxonMobil, Chevron moving slower, looking to replicate Shell's strategy
- Waste managers (WM, Republic Services) are gradually integrating vertically but have shown apprehension toward perceived risk of unproven advanced recycling processes
- Investing in sorting unpopular and expensive, but produces downstream quality improvements and integration possibilities

Source: Cleantech Group

Plastic Recycling: Regional Drivers, Sources of Innovation, Pilots

United States

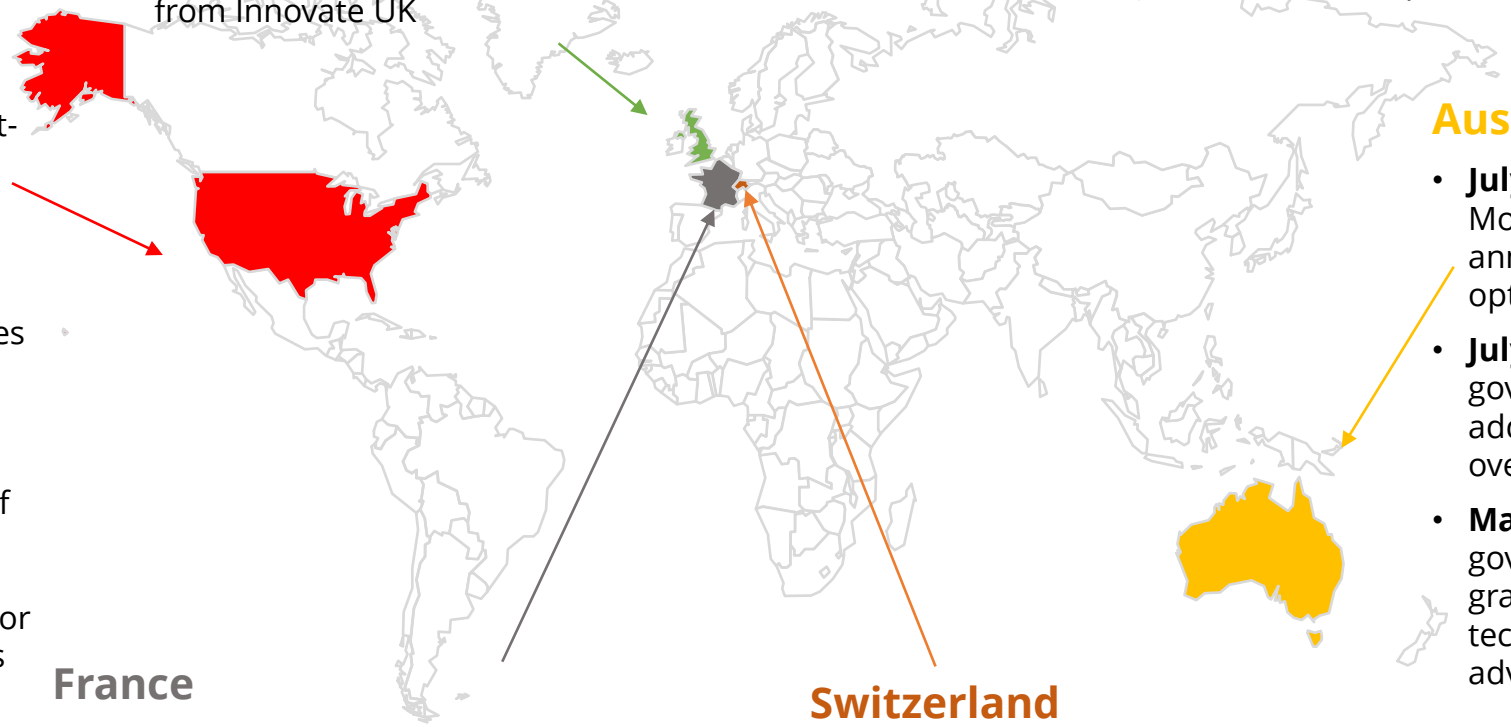
- **November 2023:** EPA announces $93M investment for plastic recycling systems in tribal communities
- **October 2023:** REMADE Institute announces $9.8M in grants for university and start-up research on chemical recycling and sorting technology
- **August 2022:** Inflation Reduction Act signed, allocates $275M in annual grants for recycling supply chain improvements
- **January 2022:** Department of Energy announces research grants totaling $110M for pyrolysis plastic fuels, $27M for plastic upcycling technologies

United Kingdom

- **January 2024:** Innovate UK announces $35M grant spread over 10 projects researching plastics circularity and recycling
- **November 2023**: Mura Technology opens ReNew ELP, their first hydrothermal depolymerization plastic recycling site in Teesside, England and is awarded $5.5M from Innovate UK

Global

- **January 2024:** World Bank announces 14 year, $100M bonds for plastic recycling infrastructure with partners Citi Bank and Verra Registry
- **March 2022:** Braskem and FCC S.A. announce Brazilian-sponsored catalyst research to improve South American plastic recycling



Australia

- **July 2023:** Recycling Modernization Fund (RMF) announces $40M for robotics, optical sorting, and pyrolysis
- **July 2023:** Federal governments announce additional $24.3M invested over 21 recycling projects
- **March 2023:** Federal government announces $60M grant targeting recycling technology innovation and advanced recycling techniques

France

- **December 2023:** Government announces $54M grant to Carbios to expedite several PET recycling facilities

Switzerland

- **July 2023:** gr3n announces microwave PET depolymerization plant in Spain alongside Intecsa Industrial after successful pilot in Italy

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Plastic Recycling: Innovator Examples

Innovation is coming from every corner in advanced recycling with varying maturity levels, end consumers

MACROCYCLE

Positioning: Chemical upcycler producing rPET products from recycled polyester waste

Market insight

- Mechanical recycling loses too much of PET's value
- Pyrolysis can produce valuable fuels but is a poor return on investment for PET
- Polymers can be upcycled or horizontally recycled to improve or retain value

Company insight

- Use selective depolymerization to recycle polyester waste into several products; initial focus is textiles and food plastics
- Maintains key polymer structures, reducing waste and energy consumption, increasing value
- Utilize solvents to treat plastics and catalysts to build new chemical structures

Milestones:

- Working to secure initial offtake partnerships in packaging space
- IP on processing technology, considering various production models and licensing

Capital: $1M

Contact: Stewart Peña Felix, CEO

PLASTIC ENERGY

Positioning: Pyrolysis plastic recycling company specializing in mixed waste to plastics (PE and PP), chemicals, and fuels

Market insight

- European pyrolysis market is very saturated with producers, low technological differentiation
- High competition for feedstocks in Europe due to higher purity and rate of recycling
- Asia and U.S. high priority targets for chemical recycling facilities

Company insight

- Broke into microwave pyrolysis market early and established robust feedstock, offtake partnerships
- Process produces gas, wax, and oil for fuel
- Expanding operations in U.S. and Asia, finishing construction on several European facilities

Milestones:

- Pyrolysis oil provider for TotalEnergies, Axens, constructed French facility with ExxonMobil
- Plastic monomer producer for SABIC, INEOS

Capital: $171M

Contact: Marc-Antoine Belthé, Feedstock Director

JEPLAN

Positioning: Provider of PET depolymerization technology using glycolysis for bottles and clothes

Market insight

- Removing textile waste from PET fiber is an expensive process most companies disregard
- Industry standard is to extract just BHET from PET or dispose of non-polyester blends

Company insight

- Jeplan's BHET extraction process extracts valuable monomers while preserving monetary value of waste textiles like cotton
- Weighing licensing and constructing more facilities equally, looking at Asia and U.S. for next facility
- Achieved horizontal bottle and textile recycling

Milestones:

- Highest recorded commercial depolymerization yield (98%)
- Two commercial-scale facilities in Japan, partnerships with Nippon Sumitomo, Sojitz
- Licensing PET to BHET technology to Axens, Toray Films for European expansion

Capital: $32M

Contact: Masaki Takao, CEO

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Plastic Recycling: Oil & Gas Incumbents Engaging Pyrolysis Innovation

	Positioning	Engaging Innovation
TotalEnergies	▪ International energy company diversifying from crude oil and natural gas exploration ▪ Expanding chemical offerings across aviation fuel, packaging, and food plastics ▪ Uniquely equal attention toward sorting technologies and plant expansion	▪ Collaboration with Plastic Energy, Freepoint Eco-Systems to develop pyrolysis, cracking plants in France, Spain, and Texas for monomer and fuel production ▪ Investment into mechanical recycling by acquiring Iber Resinas and improving French facility with mechanical recycling unit to maximize profits ▪ Developed OMNI, an AI optical sorter for household post-consumer PP waste, alongside Recycleye and Valorplast
Shell	▪ International oil, natural gas, and chemical company investing in pyrolysis oil access ▪ Particularly interested in diversifying energy feedstocks and improving processing at regional research hubs called Shell Chemical Parks	▪ Shell partnered with Braskem to build PP pyrolysis plant producing virgin replacement plastics for the automotive and packaging industries ▪ Several pyrolysis oil offtake agreements with Pryme and BlueAlp in the Netherlands, Corsair in Singapore ▪ Established largest Asian and European pyrolysis upgrading plants with BlueAlp technologies, PreZero research partnerships
ExxonMobil	▪ International oil and gas company producing fuels and chemical products ▪ Building chemical recycling infrastructure next to plants to create naphtha feedstocks ▪ Investing in feedstock sorting technologies in developing countries, pyrolysis focused	▪ Collaboration with Plastic Energy to supply pyrolysis oil for new French facility ▪ Extended partnership with Plastic Energy and IPE to improve sorting ability and roll out chemical recycling pilots in Indonesia ▪ Partnered with Agilyx, and LyondellBasell to create Cyclyx consortium, improving feedstock sorting capabilities and upcycling technology sharing at hub facility in Houston

Plastic Recycling: Commercial Waste Incumbents Engaging Innovation

	Positioning	Engaging Innovation
REPUBLIC SERVICES	▪ Second largest American waste collection company expanding into recycling, energy ▪ Actively creating vertical integration at Polymer Centers to recycle plastic waste using exclusive residential waste collection contracts ▪ Lack refining and end-market access	▪ Launched 50,000-ton Las Vegas PET Polymer Center facility that is fully supplied by its own waste streams and future refining centers ▪ Invested $294M to construct a second Polymer Center; plan for two additional centers ▪ Pursuing select corporate offtake partners such as Coca-Cola for their rPET resins ▪ Launching four PE and PP pelletization plants in the U.S. with partner Ravago ▪ Announced robotics, data partnership with EverestLabs to improve sorting capabilities
WM WASTE MANAGEMENT	▪ Largest American waste collection company improving sorting to supply high purity plastic waste/resin ▪ Aiming for 200,000 tons of annual recycled resin production from their 500,000 tons of plastic waste by 2025	▪ Invested $1B in modernizing 35 facilities for plastic sorting; building eight new facilities ▪ Acquired 13 recycling companies in 2022, including $372M for Avangard Innovative ▪ Announced partnership with Dow Chemicals to produce PE plastic films with WM's waste, further $125M investment to build out faculties ▪ Expanding sorting technologies to include optical sorters, robotics, ballistic separators
LRS	▪ LRS is the fifth largest independent American recycling and waste management company with services across the Midwest and southcentral U.S. ▪ Actively looking to expand output through aggressive acquisition strategy ▪ Recycling currently secondary to expansion	▪ Launched $50M flagship Chicago facility to process 300,000 tons of waste per year ▪ Expanding recycling services in Illinois, Wisconsin, Iowa, Indiana, Michigan, Minnesota, Kansas, Arkansas, Tennessee and Mississippi to form untapped middle American hub ▪ Acquired over three dozen regional recycling companies in the last three years to expand feedstock access in preparation for new Chicago facility ▪ Multi-million dollar loan from Closed Loop Partners to install AI sorting technologies

Plastic Recycling: Chemical Manufacturing Incumbents Engaging Innovation

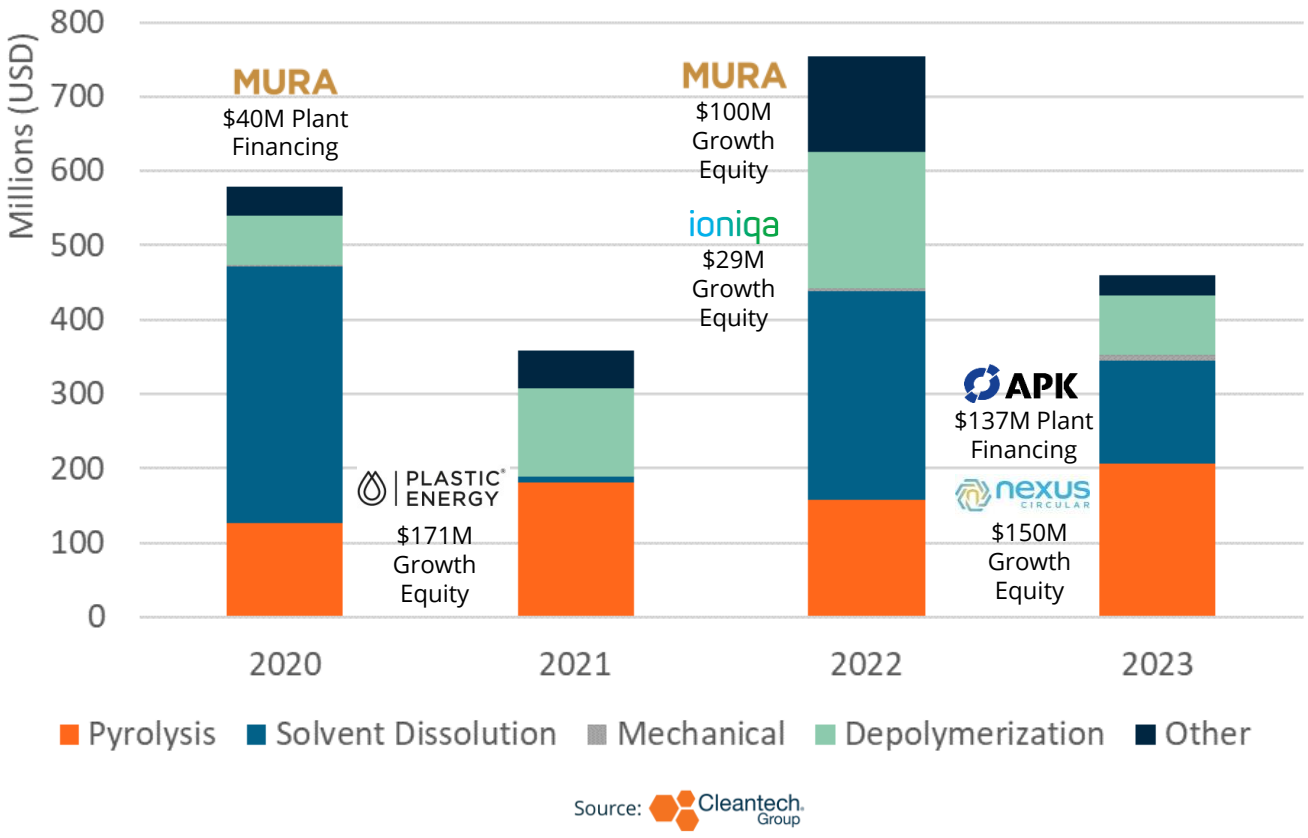
	Positioning	Engaging Innovation
LYB	▪ Global chemical manufacturer specializing in PE, PP plastics and pyrolysis ▪ Focused on incorporating recycled resin into their medical and food packaging brands ▪ European focus, expansion to U.S. ongoing to broaden feedstock access	▪ Launched Source One Plastics with 23 Oaks Investments to improve German sorting infrastructure for new German pyrolysis facility ▪ Pyrolysis technology sharing hub with ExxonMobil and Agilyx in Texas ▪ Secured feedstock partnerships with leading processers including Nexus Circular for LYB's Texas facility, ownership of Quality Circular Polymers for European facilities ▪ Acquired California mechanical recycling facilities from PreZero
EASTMAN Eastman Chemical Company	▪ Eastman is a chemical manufacturer providing industrial acids, adhesives, solvents, and other chemical solutions ▪ Set to own three of the world's largest chemical recycling facilities ▪ Looking to expand feedstock acquisitions	▪ Invested $2.5B to build three PET Methanolysis Depolymerization recycling facilities across France and the U.S. to process 400,000 tons PET/year ▪ Acquired feedstock partnerships with Interzero, Rumpke, and Citeo to fully supply the new facilities ▪ Began researching PET Methanolysis in 1990; own several patents relating to processing technologies
SK	▪ SK Chemicals is the leading manufacturer of chemical products in Korea with a specific focus on plastic engineering ▪ Sourcing cheap depolymerized PET for refining into food and medical packaging ▪ Engagement across recycling types to hedge bets on technology development	▪ Signed a $100M offtake agreement with Shuye, a leading PET recycler, to challenge Jeplan's emerging dominance in the Asian rPET for food-grade plastic and textiles ▪ Invested across advanced recycling technologies: partnership with PureCycle Technologies to build 55kt/year Korean solvent dissolution facility, signed on as Brightmark's refining partner for a Korean pyrolysis facility, and own 10% of Loop Industries with agreement to build five Asian depolymerization facilities to achieve a 300kt/year output of rPET

Plastic Recycling: FMCG Incumbents Engaging Innovation

	Positioning	Engaging Innovation
Coca-Cola	▪ International beverage and bottling corporate seeking to create PET recycling supply chain ▪ Set goals for 100% packaging recyclability by 2025, using at least 50% recycled material in packaging by 2030	▪ Founded the Greycroft Coca-Cola System Sustainability Fund, a $138M venture capital fund to expedite packaging sustainability and facility decarbonization ▪ Invested $20M to expand PET collection in Mexico, opening 15 new facilities ▪ Signed rPET offtake agreement with Republic Services ▪ Investments in Planeta, PETValue, Ioniqa, CuRe Technology to expand Asian PET recycling
Nestlé	▪ Nestle is a global food and beverage company with goals to reduce virgin plastic use by 33% and produce only recyclable plastic by 2025 ▪ Developing several advanced recycling technologies concurrently and supporting them with sorting investments	▪ Investments in depolymerization startups Gr3n, Carbios and solvent dissolution start-up PureCycle Technologies ▪ Also invested in thermal treatments including UK pyrolysis plants with Plastic Energy, Mexican pyrolysis plant with Greenback, and Australian cracking plant with Licella ▪ $9M investment to supply UK plants with sorting technologies from Impact Recycling ▪ Established Alliance to End Plastic Waste to organize private resource sharing, plants
P&G	▪ Proctor and Gamble is a cosmetics and hygiene products company with goals of waste reduction ▪ Set 50% virgin plastic use reduction, 100% recyclability targets for 2030 ▪ Encountered difficulty in securing adequate feedstocks for recycling facilities	▪ Signed multiyear offtake agreement for rPET produced at Eastman's Tennessee facility ▪ Leased PureCycle Technologies' solvent dissolution technology to develop several American recycling facilities for horizontal packaging recycling ▪ Developed HolyGrail 2.0, a digital sortation code embedded on all products to expedite sorting processes in Europe

Key Trends: Investments in Innovators

Figure 9: Investment in Recycling by Technology



Source: Cleantech Group

Investment Highlights

- Venture investment focused on pre-seed to Series A with $100M+ growth equity rounds for highly successful pilots
- 33% of all investment is project financing and structured debt, $236M for pyrolysis and $892M for solvent dissolution
- Corporate engagement minimal without proven pilot
- Established chemical recyclers are launching large commercial facilities with a variety of investors:
  - Mura signed construction agreements for 10 cracking facilities across Australia, Asia, Europe, and the U.S.
  - Ioniqa is commercializing glycolysis in Europe with investment support from Coca-Cola and Koch
  - Purecycle raised several hundred million Post-IPO dollars
- Development partnerships, offtake agreements enable rapid scaling:
  - Mura leads joint development agreements Dow Chemical, Mitsubishi, KBR for facility construction
  - APK constructing several solvent dissolution plants, offtake agreements with Kirkbi, LyondellBasell
  - Loop Industries launching plants in Asia, Europe, U.S. with L'Oréal, L'Occitane, CocaCola, and PepsiCo
- Dominance in one type of recycling (Jeplan's glycolysis) does not guarantee successful expansion; licensing is more successful due to **highly competitive regional, monopolistic national feedstock markets**
- Multi-company recycling facilities are very common amongst chemical, oil & gas, and food companies to encourage resource sharing and infrastructure development
- Partnership much more uncommon in refineries where all oil & gas companies seek total control of process

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Waste & Recycling Sector Research

Recent Published Research

Spotlights

- Grid Flexibility (Q1 2024)
- Residential Heat Pumps (Q4 2023)
- Cultivated Protein (Q4 2024)
- Plant Protein (Q3 2023)
- eJet (Q2 2023)
- Cathode Manufacturing (Q2 2023)
- Flood Resilient Infrastructure (Q1 2023)

Upcoming Topics

Insights

- Battery Recycling

Spotlight

- Chemical Plastic Recycling

Upcoming Events

- **Cleantech Forum Asia** – Singapore - May 7-8, 2024
- **Cleantech Forum Europe** -- Chantilly, France – November 5-7, 2024
- **Cleantech Forum N. America** – San Diego, CA – January 27-29, 2025

Research Analyst – Parker J. Bovée

- Focused on emerging innovation & trends across cleantech sectors, including water management systems and recycling technology.
- Prior to joining Cleantech Group, Parker developed wildfire prevention technologies with VegaMX and researched wildfire management at Duke University and the University of California, Berkeley.
- Parker earned a Bachelor's degree in History and Public Policy from the University of California, Berkeley where he specialized in the history of American environmental entrepreneurship.

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