

+LISTengineered

Polymer Recycling

Jakob Müller Company



PLASTIC RECYCLING WITH LIST

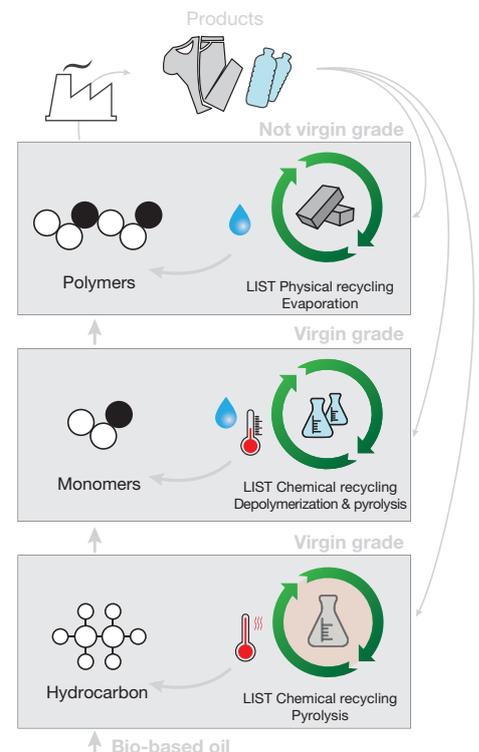
To reduce the consumption of resources, material cycles must be closed. With the LIST Kneader, sophisticated processes for recycling plastics can be realized. Depending on the product and technology, material recovery can be carried out by different processes.

For processes with LIST Kneaders, a distinction is made between physical and chemical recovery, as well as pyrolysis.

Physical recycling characterizes the recovery of polyolefins from polymer solutions. The purity of the recyclete is very high.

In **chemical recycling**, suitable plastics are depolymerized and the resulting monomers are separated from the residue and discharged.

With the **pyrolysis**, mixed plastics are depolymerized at temperatures up to 600°C back to hydrocarbon.



The European Green Deal, the Circular Economy Action Plan (CEAP) and the Industrial Strategy identified plastics as a priority sector in which the EU can pave the way towards a carbon neutral, circular economy, and announced an EU Strategy on plastics.

Different recycling loops are necessary for a successful transition to a circular economy.

The technology portfolio from LIST offers technology for the physical and chemical recycling step of plastics.



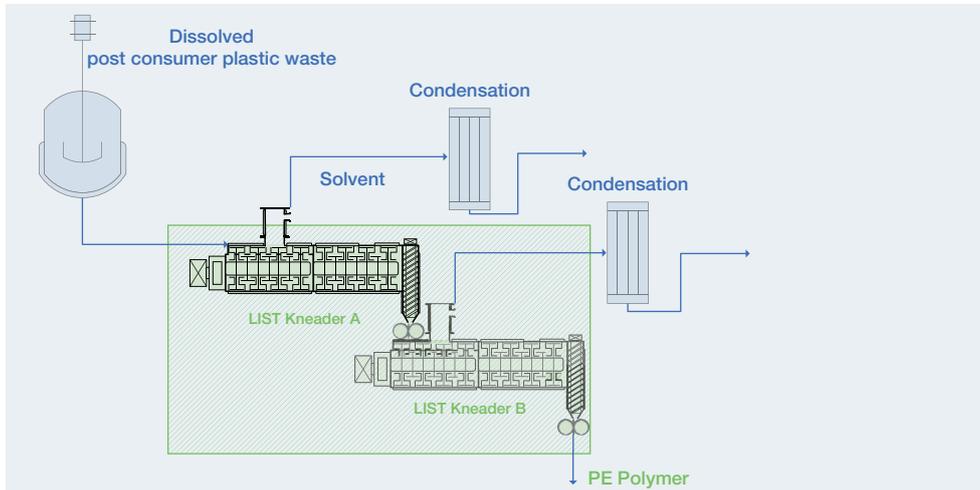
Roland Kunkel
LIST Technology AG

Benefits of the LIST process

- Continuous operation 24/7
- High product quality
- Max temperature control
- Flexible residence time
- Single train up to 10 t/h
- Processing in the concentrated phase
- No fouling
- Low environmental impact

LIST Physical Recycling

Solvent-based processes, with plastics dissolved in solvents, enable the recycling of currently non-recyclable plastic compounds. With the LIST process, polyolefins can be recovered after selective dissolution of a polymer. The solvent is gently separated from a polymer solution, the polymer is recovered, and the solvent is condensed. A residual solvent content of less than 300 ppm is able to be achieved.



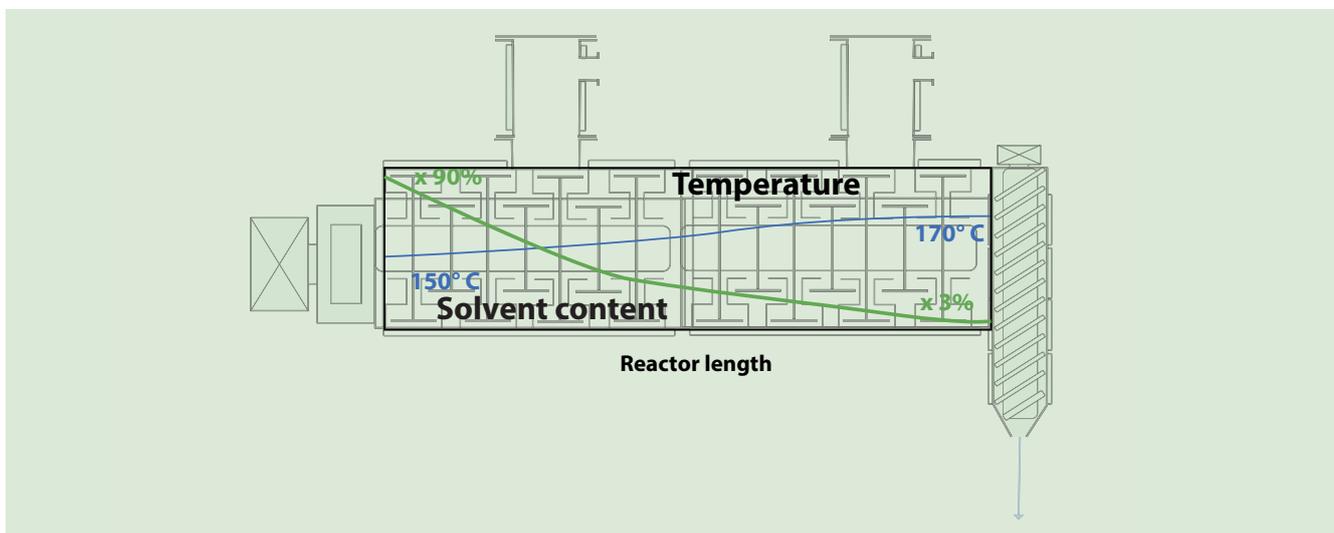
Process for Physical Recycling with LIST

! Your idea

- LDPE-Recycling
- HDPE-Recycling

✓ Our offer

- Proven technology for the separation of solvents from solutions and viscous polymer melts
- High product purity due to optimal interfacial renewal for phase change
- Optimized shear for efficient and gentle separation of the solvent to protect the product
- Safe cleaning and continuous discharge of the polymer and thus recovery of a high-quality raw material
- Safe discharge of the vapors without product entrainment resulting in simple and stable process control
- Extensive testing facilities in our test centers in Switzerland and Korea, for targeted process development
- Industrialization experience for scale-up, up to 10 t/h polymer solution



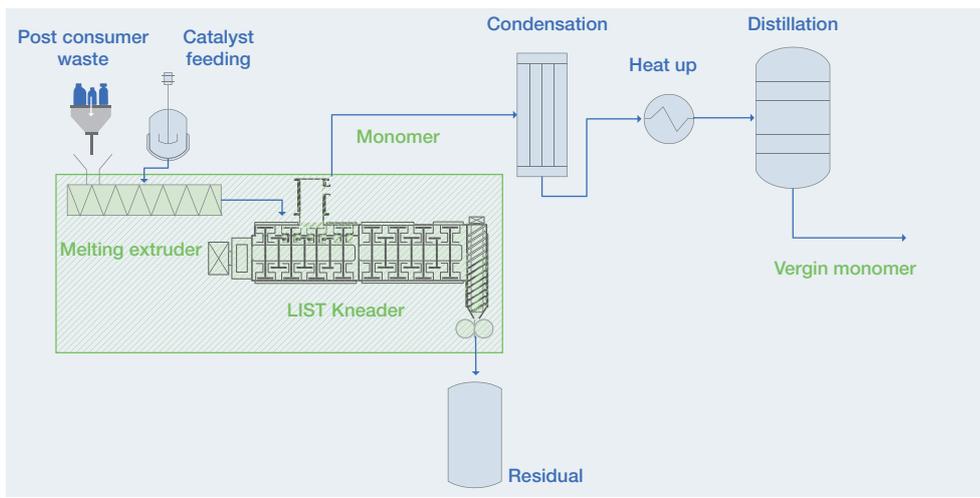
Solvent content and temperature during the physical recycling

LIST Chemical Recycling

Depolymerisation in a

➤ SINGLE STEP

The use of virgin grade raw materials is essential for the production of polymers with clearly defined properties. **Suitable polymers** can be converted into monomers by **depolymerization**. For this purpose, the polymer is disintegrated with catalysts in the kneader under suitable process conditions. The recovery rate is up to 96%. The monomer is evaporated in the kneader and condensed outside the reactor. The monomer is evaporated in the kneader and condensed outside the reactor.



Process for the depolymerisation in a **single step**

! Your idea

- PET-Recycling
- PVC-Recycling
- PMMA-Recycling
- PS-Recycling
- PU-Recycling

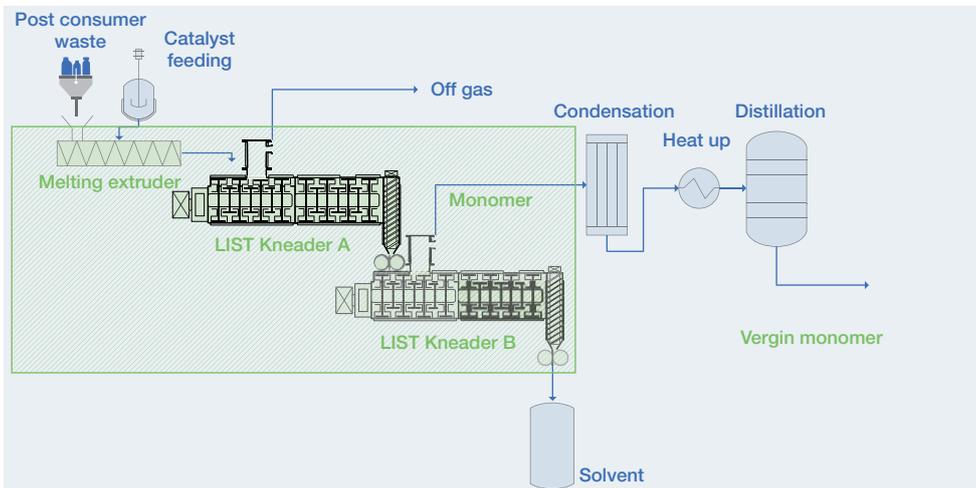
✓ Our offer

- Process intensification: Efficient depolymerization of polymers without addition of solvent
- Dosing and heating of the polymer; stoichiometric mixing of the catalysts
- High product purity due to optimal interfacial renewal for phase change
- Safe cleaning and trouble-free continuous discharge of the residue
- Safe handling of the vapors without product entrainment resulting in simple and stable process control
- Extensive testing facilities in our test centers in Switzerland and Korea, for targeted process development
- Industrialization experience for scale-up, up to 10 t/h polymer

Chemical Recycling in

➤ TWO STEPS

Solvent-based processes allow plastics to be recycled back to the monomer. Polymers from Polycondensation can be depolymerized by adding an excess of condensate and mixing in catalysts. In a 2nd downstream process step, the product is purified with high selectivity. A residual solvent content of less than 300 ppm is able to be achieved



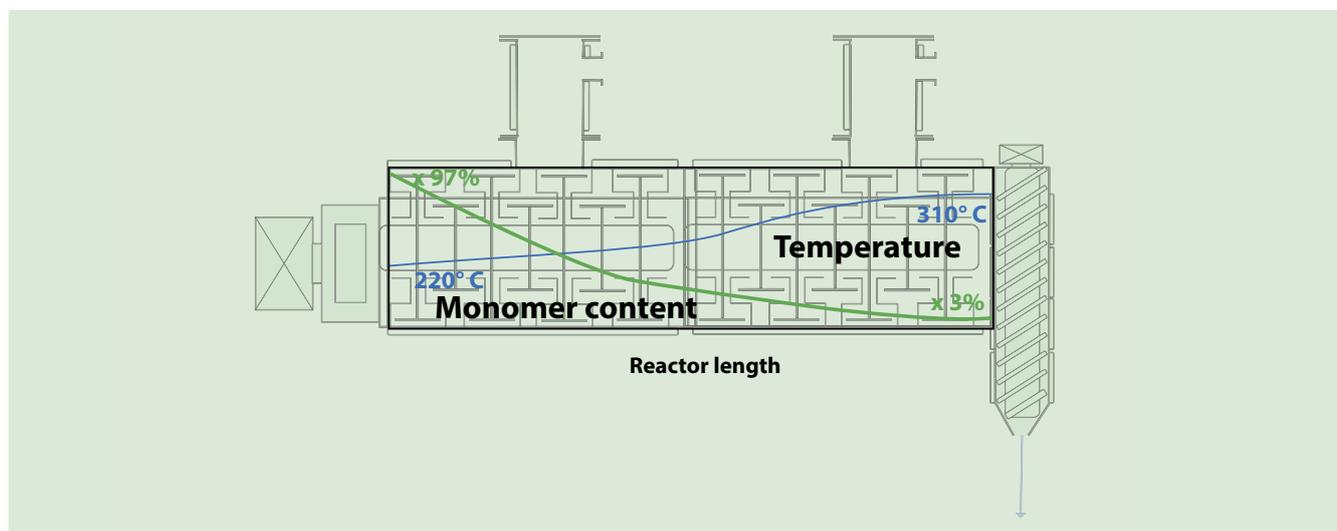
Process for Chemical Recycling in **two steps**

🚫 Your idea

- PET-Recycling
- PVC-Recycling

✅ Our offer

- Efficient depolymerization of polymers with minimal use of liquid reactants
- Dosing and heating of the polymer and stoichiometric mixing of the catalysts
- High product purity due to optimal interfacial renewal for phase change
- Optimized shear for efficient and gentle separation of the solvent to protect the product
- Safe cleaning and continuous discharge of the polymer and thus recovery of a high-quality raw material
- Safe discharge of the vapors without product entrainment resulting in simple and stable process control
- Extensive testing facilities in our test centers in Switzerland and Korea, for targeted process development
- Industrialization experience for scale-up, up to 10 t/h polymer

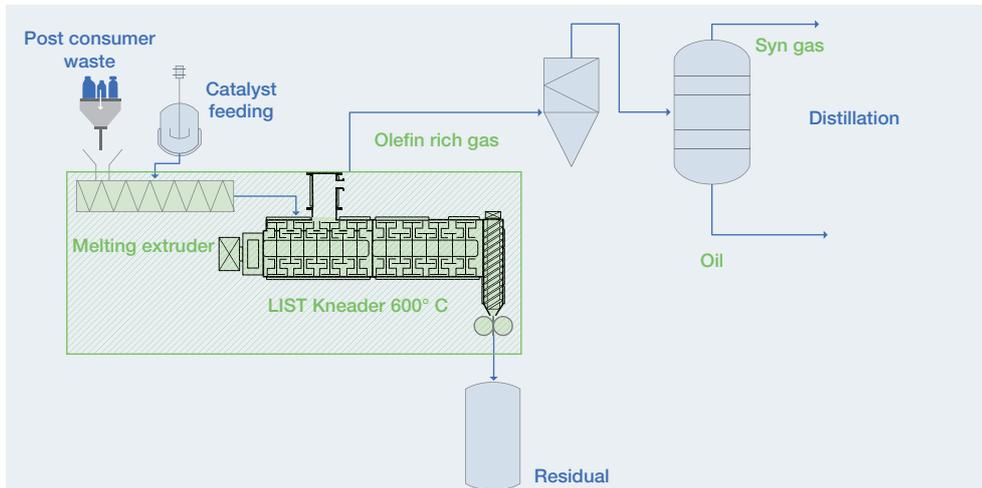


Monomer content and temperature during depolymerization

LIST Pyrolysis

Pyrolysis up to 600°C

Chemical recycling in the form of pyrolysis is a way of obtaining oil, heavy oil or waxes from mixed plastic waste. The use of virgin grade raw materials is essential for the production of high quality polymers with well-defined properties. The advantages of pyrolysis for the treatment of plastic waste are, that a wide rather unspecific waste mixture can be converted. The processed molecular pyrolysis products can be used as feedstock in existing refineries.



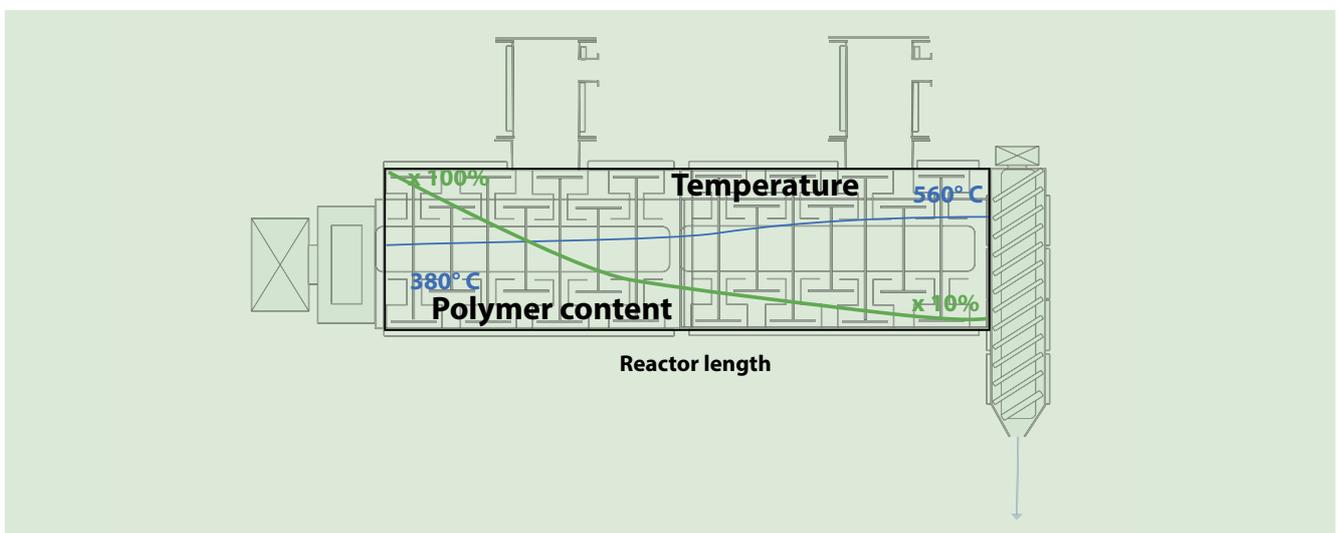
Process for Pyrolysis with a LIST kneader

! Your idea

- Carbohydrates from plastic waste

✓ Our offer

- Modular approach for the recovery of naphtha, diesel, aromatics or other hydrocarbons from pyrolysis oils
- Dosing and heating of the polymer and stoichiometric mixing of the catalysts
- High separation efficiency due to optimal interfacial renewal for phase change
- Recovery of a high-quality molecular raw material
- Safe cleaning and continuous discharge of the residue
- Safe discharge of the vapors without product entrainment resulting in simple and stable process control
- Extensive testing facilities in our test centers in Switzerland and Korea, for targeted process development
- Industrialization experience for scale-up, up to 10 t/h polymer



Polymer content and temperature during the pyrolysis

LIST Technology AG

LIST KneaderReactor Technology is a key technology for optimizing processes in high viscosity processing technology. We focus on industrial processes that work without the use of solvents and that run-in the concentrated phase. This allows us to reduce the energy and material costs, thereby also lowering production costs. LIST KneaderReactor Technology brings significant advantages when carrying out processes such as bulk polymerization, crystallization, process

intensification, polycondensation, drying, main evaporation, devolatilization, chemical reactions, dissolving, mixing and reactive compounding, sublimation and torrefaction. These advantages include high process reliability, low energy consumption, pioneering sustainability, high product consistency, maximum plant availability and the largest production scales in the world.

