5 Collection and Feedback

5.1 Collection

Collection is the first stage of a multistage procedure leading to the recycling, reuse, or disposal of flexible plastic packaging waste. Flexible plastic packaging is not widely collected for recycling around the world, and the collected volume remains considerably lower than is feasible. One key imitation is that the packaging waste is often difficult and costly to collect. Another key limitation is the awareness of the public. Collection is a prerequisite for higher recycling. The CEFLEX project makes a number of recommendations aiming at increasing collection [1]:

- proper collection at all levels is required for successful recycling;
- collection prevents packaging from leaking into the environment;
- to avoid cherry-picking of easy recyclables, mandatory separate collection of all packaging is needed;
- without mandatory collection, flexible packaging may not generate sufficient material volumes to make recycling commercially viable; and
- mandatory collection is the basis of more investment in infrastructure for sorting and recycling of flexible packaging.

The expansion of film collection is dependent on the creation of new end-use markets that will increase demand for recycled film [2].

5.2 Sources of Flexible Plastic Packaging Waste

There are generally three sources of flexible plastic packaging waste[1]: postconsumer (residential or household) derived from residences, post-commercial generated by businesses, and postindustrial generated during processing.

[1] Agricultural film is outside the scope of the book.

Recycling of Flexible Plastic Packaging
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5.2.1 Postconsumer Flexible Plastic Packaging

In terms of volumes, one of the largest sections in film recycling is postconsumer film waste. Postconsumer film quality can significantly vary according to the market conditions, and mainly depends on the type of collecting and presorting systems that are employed by the recyclers. The material collected may present different degrees of humidity and contamination. In addition, film waste is often in very different printing conditions and shapes. The main contaminations to be treated in postconsumer film are a high quantity of organics as well as different polymers, such as multilayers; multilayer films are composed of a variety of materials, and often, they even contain metallic components. For these films to be treated, a preliminary sorting section should be foreseen. Postconsumer flexible plastic packaging includes a mixture of low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE), high-density polyethylene (HDPE), and polypropylene films and a growing number of multilayer packaging films [3].

It has been estimated that some 1.1 million tons of packaging film arises in the UK waste stream every year. This is about 44% of all plastic packaging. Of this amount, about 560,000 t are postconsumer plastic film [4]. More than 50% of plastics in household in Norway and Sweden are packaging films, mainly LDPE films. A large part of these films consists of multiple layers [5]. Residential postconsumer flexible plastic packaging shows the lowest recycling rates mainly because of inefficient sorting technologies [6]. Postconsumer multilayer packaging is not a targeted material and is not currently recycled. It is estimated that 97% of postconsumer plastic films end up in landfills and oceans [7].

TerraCycle promotes the Zero Waste Bags to collect and recycle virtually any type of residential waste including flexible plastic packaging. The consumer must purchase Zero Waste Shipping boxes to send the Plastic Packaging Zero Waste Bags back to TerraCycle [8].

In the European Union, it is envisaged that by 2025, there will be an established collection, sorting, and reprocessing infrastructure developed for postconsumer flexible packaging, based on end-of-life technologies and processes that deliver the best economic, technical, and environmental outcome for a circular economy [9].

The two main routes for the collection of residential postconsumer films are through local authority curbside recycling schemes and front of store recycling points (generally located at larger supermarkets).

5.2.1.1 Curbside Collection

Flexible film and plastic bags from curbside collection are usually considered as contaminants and a source of problems for the machinery of Materials Recovery Facilities (MRFs) and are removed from the waste stream. At best, they are intended for energy recovery, but, often, they end up in landfills [6]. Very few MRFs accept curbside polyethylene film because of the cost to process it and lack of markets for curbside film, while there are no MRFs that accept majority polypropylene bags and multilayer pouches. The MRFs that handle curbside collected recyclables use complex machinery to sort a variety of recyclables; film clogs (jams) the machines wheels, and its removal is problematic and costly [10].

Of the total amount of collected film in the United States in 2016 (0.59 MMT), less than 2% was obtained from curbside recycling programs and processed through MRFs [2]. Bales of curbside polyethylene film are traded at a much lower price than mixed film that comes from retail collection programs due to the contamination of curbside film collected during collection and processing in MRFs [11] (see Chapter 11, Section 11.3).

The Hefty® EnergyBag™ program is an initiative that collects hard-to-recycle materials, including flexible plastic packaging and materials contaminated with food waste, at curbside and converts them into valuable resources [12]. The program is built on learnings from a 2014 pilot sponsored by Dow, the Flexible Packaging Association and Republic Services, along with the City of Citrus Heights. The first permanent Hefty® EnergyBag® program was launched in the U.S. in 2016 in Omaha, Nebraska and now there are a number of active, self-sustaining programs in the U.S., with plans to launch the first program in Canada in late 2019.

All materials collected have been diverted from the landfill and are helping to create end-of-life solutions for plastics and advancing the development of a plastics circular economy. The goal is to turn plastic waste resources into higher value applications that are in the Recycle and Recovery categories of the EPA's Waste Management Hierarchy such as supplying valuable raw materials to industry, remanufacturing the recycled raw materials into new products, conversion of non-recyclable waste materials into useable fuel (Reference [X]: United States Environmental Protection Agency (EPA). Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy. 10-08-2017. https://www.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy).

Consumers use an easily identifiable orange bag into which they place hard to recycle plastic packaging such as bags, pouches and wrapper (see

Figure 5.1 Orange bags filled with hard-to-recycle plastic packaging (The Hefty® EnergyBag® program) [12].

Fig. 5.1). The bag is then placed in the single stream recycling bin or next to the bin for collection and pulled off the sortation line at the MRF. Flexible packaging items that can be collected as part of the program include flexible drink pouches, candy bar wrappers, plastic pet food bags, and shredded cheese bags. Other plastic packaging that is not usually recycled but collected as part of the program may include plastic meat packaging, straws/stirrers, and plastic service ware (plates and cups) (see also Chapter 11, section 11.14).

The bag-in-bag system, where plastic bags and film are collected in a larger plastic bag before bringing to a local retailer, is gaining ground. However, the success of the system depends on the degree to which curbside recycling program participants place film inside of one film bag and tie it off. For example, one film bag containing 20 pieces of film has only 5% of the direct manual sorting cost of film set out for recycling as individual pieces. Even when film is bagged, collection truck compaction and metering equipment at the MRF can cause bags to break open and their contents to be scattered. MRF scrap film value is much lower than the cost to sort and bale it [7].

The following best practices for curbside collection of bagged film are recommended by Reclay StewardEdge [11]:

- extensive and continued education on what are acceptable packaging materials;
- collect films in specially assigned plastic bags to reduce contamination of other materials and sorting costs at the MRF;
- monitor/reduce truck compaction to reduce bag breakage;
- utilize carts to reduce moisture; and
- curbside-collecting loose film is not recommended.

There is emerging evidence that postconsumer multimaterial flexible packaging may eventually be collected and sorted through a curbside system. There are various scenarios for the collection of multilayer flexible packaging materials at curbside [13]:

- Multilayer packaging materials could be “bagged” and collected at curbside. Bagged multilayers would be easier to presort at the MRF. However, loose laminates would be easier for the consumer and potentially increase the collection rate.
- A separate pickup could go directly to the processor, removing the sorting challenge, but collection cost could be higher.
- Multilayers collected at a drop-off would bypass the MRF and sortation challenge but would require more effort on the part of the consumer. A multimaterial laminate collection pilot is currently being explored.

Materials Recovery for the Future (MRFF), a project of the American Chemistry Council Foundation for Chemistry Research and Initiatives, is a collaboration of brand owners and trade associations to undertake research to determine how flexible packaging of all types (i.e., not just polyethylene) can be collected in curbside recycling programs and sorted by MRFs. The increased convenience of curbside recycling collection offers the possibility for much higher recycling rates than is found in retail return programs [14] (see also Chapter 11, Section 11.14).

Return collection centers or drop-off sites are the principal means for collecting flexible plastic packaging. Collection sites that accept film for recycling include retail, municipal, nonprofit, and commercial program drop-off facilities. The most common drop-off flexible packaging material is polyethylene. It is relatively pure (75–90%) and includes LDPE, LLDPE, and HDPE. Common contaminants found in drop-offs include receipts, paper labels (metalized), bonus tickets, and the like, which are detrimental to recycling [3].

The majority of locations are retail drop-offs. There are more than 18,000 retail collection or drop-off centers throughout the United States. Examples of flexible plastic packaging films and bags that can be brought to drop-off locations include [15]:

- shopping bags: grocery, retail, carryout, produce, newspaper, bread, and dry cleaning bags (clean, dry, and free of receipts and clothes hangers);
- zip-top food storage bags and pouches (clean and dry);
- plastic shipping envelopes (free of labels), bubble wrap, and air shipping pillows (deflated);
- product wrap of water/soda bottles, toilet paper, paper towels, napkins, disposable cups, bathroom tissue, diapers, and female sanitary products;
- furniture and electronic wrap; and
- plastic cereal box liners (not containing paper).

Examples of flexible plastic packaging that cannot be brought to drop-off locations include:

- cling wrap (or cling film);
- candy bar wrappers (multilayer);
- flower and gift wrapping (cellophane, polypropylene);
- chip or cookie bags;
- salad and green bags;
- plastic squeeze tubes;
- paper-lined plastic;
- plastic straps;
- six-pack rings;
- biodegradable packaging;
- oxodegradable packaging; and
- PVC packaging (e.g., zipper bedsheet bags).

The consumer returned packaging material (e.g., bags, sacks, and wraps) is often combined with film generated through business operations (e.g., polyethylene stretch wrap) to make bales, which are sold to reprocessors or recyclers that make new products [10].

The main obstacles in the collection of flexible plastic packaging in retail shopping centers are [16]:

- the activity of recycling is disconnected from the activity of retail shopping;
- consumers rarely return small plastic bags to a source whereby they can be recycled;
- in areas that have banned plastic shopping bags, stores have removed bag and film recycling bins;
- discerning a multilayer film from a pure polyethylene film is impossible;
- odor and leakage from residual food packaging may be an issue when accumulating and storing materials for sale to recyclers;
- traditional polyethylene processors may reject mixed materials;
- retail recycling centers are inconsistent among different stores with regard to bin placement, signage, and materials accepted; and
- the volume of space that must be dedicated to store precompacted flexible plastic packaging waste is usually impractical for most businesses; for example, the amount of shrink wrapped film or garment bags necessary to fill a single bale of only plastic may take weeks or months to accumulate, requiring great expense to store a significant amount of uncompacted packaging film.

An important issue is that consumers do not always know which packaging can and cannot be recycled. Another problem is throwing items in the wrong recycling bins. Not only does this take time to separate at a recycling facility but it can also contaminate other items in the same bin.

CleanRobotics, a Pittsburgh-based start-up, developed the so-called TrashBot to address the aforementioned issue [17]. TrashBot is a robotic trash can system embedded with artificial intelligence. Once a consumer throws a packaging item into the bin, the system uses a set of sensors and machine learning to identify the type of packaging. It will also weigh it, drain any liquids, and place it into the right bin, while providing 90% accuracy. Because of the great capacity, TrashBot can be deployed at airports, shopping malls, stadiums, office buildings, and other businesses that handle large quantities of packaging waste. CleanRobotics plans to add LEDs to the system to let the user know whether the item they throw away is recyclable [18].

Bin-e, a Polish tech start-up, developed the "smart waste bin" designed to recognize and sort packaging waste according to its category [19]. The smart waste bin is equipped with a camera and sensors, and it relies on machine learning to detect and identify the waste that is thrown in it. After it recognizes the packaging item, it directs the item into the right chamber. When the chambers are full, it notifies the maintenance team to take the packaging waste to the recycling plant. Every time a consumer throws a packaging item into the bin, its computer system will collect information such as the brand and quantity of items, and the data will be automatically uploaded to the cloud [18].

5.2.2 Postcommercial Flexible Plastic Packaging

Postcommercial polyethylene film, also known as polyethylene clear film (see Chapter 11, Section 11.3), primarily comes from large commercial generators and includes mainly clear bags and stretch wrap film. This type of film contains lower amounts of contaminants compared with postconsumer waste film and in many cases does not require washing before recycling. Postcommercial polyethylene film represents the majority of film that is currently recycled, with an estimated 21% recycling rate. Much of this film is recycled into trash bags and thicker commercial films [7].

Postcommercial mixed color film, also known as polyethylene color film, also comes from commercial sources and includes stretch wrap.

A special type of postcommercial flexible plastic packaging that is recycled is woven polypropylene bags.

5.2.3 Postindustrial Flexible Plastic Packaging

A considerable amount of scrap is generated in the course of manufacture of flexible plastic packaging films, such scrap coming from trimming from roll ends (edge trims or offcuts), film breakages, filling custom orders involving less than the full width of rolls of the film, or rolls out of specification (1991, **WO9117886** A1; 1992, **US5128212** A, DUPONT). Experience shows that still in most of the cases, 2−10% of the production materials are lost due to process reasons [20].

It is estimated that 79% of postindustrial plastic films end up in landfills and oceans [7].

5.2.3.1 Feedback of Scrap Film

The feedback of plastic scrap generated during processing corresponds to the first out of three recognized types of plastic recycling.[2] In primary (or preconsumption) recycling, preconsumer industrial scrap and salvage is collected by the plastics producer at the site of manufacture and fed back into the processing apparatus to thereby effectively use the scrap material.

It is a general practice to recycle at least part of this type of flexible plastic packaging waste generated in a film-forming extrusion process back into the extruder to, thereby, effectively use the scrap film in the formation of extruded film from which the waste material was generated. The reutilization of scrap films, which exist in considerable quantities as rejects or cuttings, by direct processing in an extruder is possible only to a very limited extent because of their voluminous nature and poor flow property. Such plastic waste must first be pretreated appropriately by comminution, and the plastic particles, which have thereby become flake-like, are then agglomerated into highly compacted, free-flowing, and abrasion-resistant granules. The granules obtained in this way must have the same quality as the granules of virgin material, so that they can be proportionately admixed with the latter (see Chapter 8, Section 8.3).

In the case of monolayer plastic film, it is safe to recycle scrap film with virgin polymer because the composition of the scrap film and the virgin polymer is the same. Reprocessing of scrap film can take place either on the site of film production or at a remote location. For economic reasons, scrap film recycling most commonly takes place at the location of film production. In on-site recycle processing, the edge trim that is slit from the film is immediately conveyed to a cutter that cuts the trims into small pieces (chips) in preparation for further processing (1992, **US5170949** A, SPROUT BAUER INC ANDRITZ); see also Chapter 8, Section 8.2.2.

[2] The other two types of plastic recycling include secondary (or postconsumption) recycling, which involves sorting out postconsumer and postcommercial plastic waste and physically reprocessing the waste by shredding/grinding, melting, and/or reforming the plastic (see Chapters 6 and 8Chapter 6Chapter 8), and tertiary (chemical) recycling, which involves depolymerizing a polymer into repolymerizable monomers and oligomers (see Chapter 9). A fourth type of plastic recycling could be considered the quaternary (energy) recycling, where energy recovery of plastic waste occurs by controlled incineration (see Chapter 8, Section 8.4).

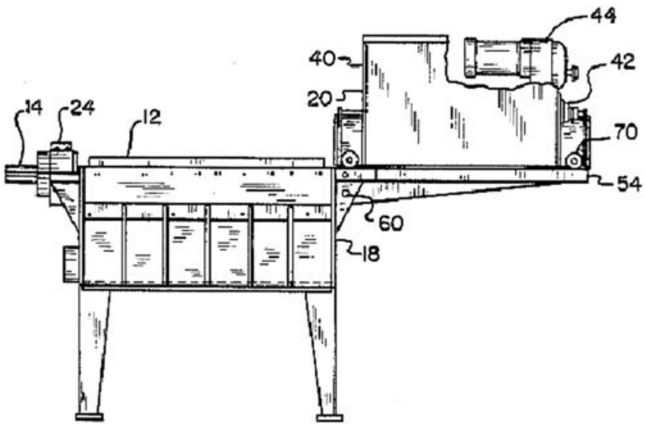

Figure 5.2 Schematic drawing of a rotary knife cutter with a roll-off cover (1988, **US4738404** A, SPROUT-BAUER, INC). 12, Cylindrical rotor; 14, Rotor shaft; 18, Base portion of the cutter housing; 20, Cover portion of the cutter housing; 24, Bearing bushing; 40, Feeder; 42, Feed rolls; 44, Variable speed motor; 54, Laterally spaced rails; 60, Hinge pin means; and 70, Laterally extending side flanges.

It is often necessary to open the rotary knife cutter and clean any film fragments that may have accumulated in cracks or crevices within the working chamber of the cutter housing before changing plastic composition or color to prevent contamination of the new batch when recycling the scrap material. However, such a process can be laborious and time-consuming in that it commonly takes two men from 1 to 6 hours, depending on the machine design and location, to open a prior art rotary knife cutter for cleaning or service (1988, **US4738404** A, SPROUT-BAUER, INC).

This problem has been addressed by **US4738404** A (1988, SPROUT-BAUER, INC), which discloses a rotary knife cutter provided with a roll-off cover, which can be readily translated to facilitate access to the cutter rotor for cleaning and maintenance (see Fig. 5.2).

US5170949 A (1992, SPROUT BAUER INC ANDRITZ) discloses a method and an apparatus, shown in Fig. 5.3, for reprocessing scrap film generated in the film-forming process. The apparatus (10) includes a film—air separation chamber (14) for separating air from incoming strips of scrap film, a cutter (20) for cutting the strips into small pieces, and a storage tank (26) or further reprocessing means to which the cut pieces of scrap film are conveyed. An air bypass line (36) having a computer-controlled valve (38) conveys air directly from the film—air separation

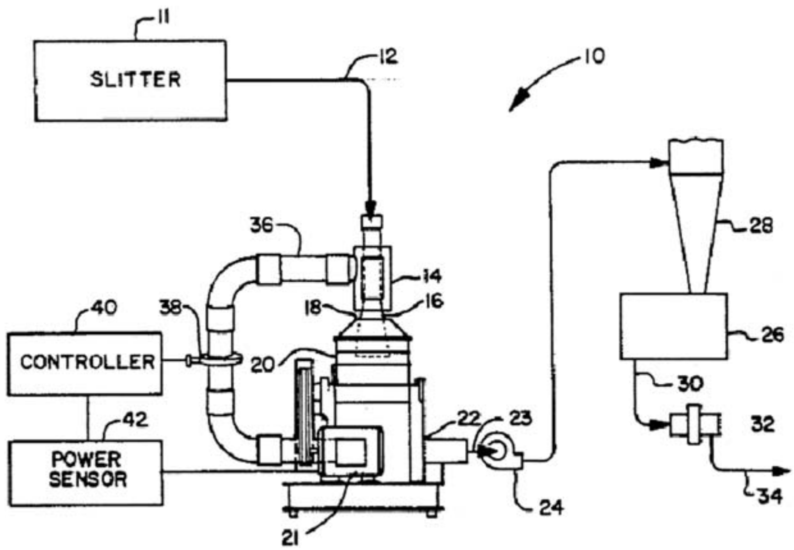

Figure 5.3 Schematic side view of an apparatus for reprocessing scrap film (1992, **US5170949** A, SPROUT BAUER INC ANDRITZ). 10, Scrap film reprocessing apparatus; 11, Edge slitter; 12, Scrap film inlet line; 14, Film–air separation chamber; 16, Film outlet opening; 18, Inlet opening of 20; 20, Scrap film cutter; 21, Motor; 22, Cutter outlet end; 23, Tubular cutter outlet line or discharge conduit; 24, Fan; 26, Fluff storage tank; 28, Cyclone; 30, Bin discharge line; 32, Pelletizer; 34, Pellet outlet line; 36, Air bypass line; 38, Control valve; 40, Valve controller; and 42, Solid-state motor power sensor.

chamber (14) to the cutter outlet (22) when the valve is in an open position and causes all of the air to flow into the cutter inlet when the valve is in a closed position. The open or closed position of the air bypass valve depends on the cutter motor power, which varies as the volume of scrap film in the cutter varies. Because of the inclusion of the accurately controlled air bypass valve (38), only a single fan (24) is needed to convey the film into and out of both the film–air separation chamber (14) and the cutter (20). The cost and energy consumption of the single fan were about half of the cost and energy consumption of two fans used in the conventional system.

Example: Narrow strips of polyethylene scrap film trimmed from a roll of film product by a conventional slitter were conveyed through a 5 inches pipe at a rate of 5000 ft/min (25.4 m/s) through a film–air separator and into a film cutter, model DSF 1512 from Andritz Sprout-Bauer, Inc.

having a 30 hp (22.4 kW) motor, and outward from the cutter to a fluff storage tank. The strips of scrap film were conveyed from the slitter to the fluff storage tank by a single fan located downstream from the cutter and upstream from the fluff bin. During start-up, when the power of the cutter exceeded about 18 hp (13.4 kW), the control valve on the air bypass line was closed, resulting in an air flow rate of about 800 ft^3/min (0.38 m^3/s) from the top of the separator to the cutter outlet. This air flow pulled the film out of the cutter through the cutter outlet and onward to the fluff bin. The motor power was sensed by monitoring each of the three power phases with a voltmeter, and the amperage of one leg was monitored in order to determine horsepower. The valve controller was a combination of commercially available components commonly used to monitor electrical power and energizes an air-operated valve.

The practice of refeeding the granules or chips to the process together with virgin material can lead to process difficulties including:

- inconsistent feeding performance of the production extruder;
- air inclusion in the melt that leads to defects of the finished products; and
- no way to remove process materials such as printing inks, coatings, and adhesives [20].

In the case of multilayer film of layers having different composition, the scrap film has a different composition from any individual layer of the film (1991, **WO9117886** A1; 1992, **US5128212** A, DUPONT). It is industry practice to take scrap trim and defect material generated in the multilayer film-forming process, such as coextrusion, and comminute the scrap trim into flakes pelletize the flakes through a secondary extrusion process, crystallize those pellets, so that they do not agglomerate during further processing, and use these pellets as part of the resin feed to form a layer, such as a core or skin of a multilayer film (2011, **WO2011140317** A1, TORAY PLASTICS AMERICA INC).

WO9117886 (1991, DUPONT) relates to the use of scrap heat shrinkable multilayer film along with virgin polymer to form new multilayer heat-shrinkable film. TThe scrap film is derived from a multilayer film comprising a core composed of 50-90 wt% on the weight of said core of LLDPE and 10-50 wt% based on the weight of said core of highly branched polyethylene. The scrap multilayer film is incorporated into the core layer of the new co-extruded film in an amount of about 25 to 40 wt% on the weight of the core layer. Various methods are available for incorporating the scrap film into the coextruded core of the heat shrinkable film. Most conveniently, the scrap film can be cut up into flakes no larger than about 4 mm. The flakes can be preblended with molding granules of virgin polymer to form the coextruded core and then added to the extruder, or the preblending can be carried out by simultaneously adding the desired proportions of scrap and virgin polymer to the extruder, which extrudes the core. It has been found that despite the different shapes of the recycle polymer film and the virgin polymer feeds to the extruder, and despite the fact that the recycled polymer is formed from multilayer film of different overall composition from the core layer, the coextruded blend portion of the core is provided as a homogeneous blend of recycled polymer and virgin polymer. Tie layer(s) of recycled film can be formed by using one or more extruders to melt process the recycled film and coextrude the tie layer(s) along with the coextrusion of the rest of the multilayer film.

EP0679487 A1 (1995, GRACE W R & CO) discloses a process for the manufacture of a multilayer crosslinked heat shrinkable film by recycling industrial scrap of the same film, generated at different stages of the production of the film, in an amount of up to 10 wt% in the core of the new crosslinked film. Particularly, the process is applied to an oriented, heat-sealable, multilayer crosslinked film comprising a core layer, consisting essentially of LLDPE and two outer layers each comprising a three component blend of LLDPE, medium-density polyethylene (MDPE), and EVA.

The process of making metalized plastic films also generates waste of scrap trim. Scrap trim results from slitting rolls to custom product widths or from recovered metalized plastic film, such as poly(ethylene terephthalate) (PET) film that has defects, which cause rejection (e.g., wrinkles, creases, or poor metallization). However, metalized plastic films have not been recycled. The metal particles can potentially cause web breaks during film formation processing if, for example, reclaimed metallized PET film is fed in a similar manner to reclaimed nonmetallized PET film. The tendency for web breaks to occur is attributed due to the difference in crystallinity. Accordingly, trim and defect-containing metalized PET waste has traditionally been discarded at cost of materials, processing cost, and disposal and environmental costs (2011, **WO2011140317** A1, TORAY PLASTICS AMERICA INC); see also Chapter 8, Section 8.8.

WO2011140317 A1 (2011, TORAY PLASTICS AMERICA INC) discloses the use of metalized film that has been shredded, pelletized or densified, and dried/crystallized as a component for either the core or skin layer in a PET film. By appropriate processing conditions in the pelletizing operation, sufficiently small particles of the aluminum layer can be formed and dispersed in the PET. It is contemplated that other metalized films such as oriented polypropylen (OPP), oriented HDPE, and oriented polyamide can also be reused. For example, shredded and pelletized metalized OPP film can then be used as a portion or the whole of the core and/or skin layer of a newly made OPP film. The reclaimed metalized OPP replaces at least a portion of the virgin polypropylene in such a film for cost reduction purposes.

Sources of such waste material include scrap product generated during deviations from normal operating conditions that occur at production line start-ups, shutdowns, and unexpected machine failures. Also in film production, it is typical to generate scrap product by trimming film product to specification sizes.

Example: Reclaimed metalized PET was obtained by trimming PET film on which had been deposited a layer of aluminum of about 3.0 nominal optical density. The PET of this film contained no metalized reclaim material, i.e., there was no aluminum in the PET. This metalized film was shredded into flakes and densified to form pellets. The densified reclaimed metalized PET contained 0.33 wt% aluminum. The reclaimed metalized PET pellets were melt blended with nonmetalized reclaimed PET film at a 1:9 weight ratio. The melt blend was cast and stretched to form PET film containing 10 wt% of metalized reclaimed PET. This oriented PET sheet was plasma treated on one side, and then aluminum was placed by vapor deposition on the treated side to a nominal thickness of about 3.0 optical density.

In the production of biaxially oriented polyamide film (BOPA), a large amount of edge trims is also produced. **CN203156973** U (2013) and **CN104070617** A (2014) of FANGCHENGGANG CITY GANGKOU DISTR HONGDA PLASTIC FACTORY disclose a recovery system of BOPA film edge trims, shown in Fig. 5.4, comprising a fan (5), a shredder (7), and an air direction converter (1), wherein an air pipe is connected between the fan (5) and the air direction converter (1); a material pipe (3) is connected between the air direction converter (1) and the shredder (7); one end of the material pipe (3) near to the air direction converter (1) is connected with an edge trim suction feeder (2); one section of the material pipe (3) near to the shredder (7) is at an elevating position; a connecting pipe (6) is between the elevating section and the shredder (7); and the upper part of the connecting pipe (6) is provided with an air outlet. In practical use, the high-pressure air flow generated by the fan (5) is sent from the air duct (4) to the air direction converter (1). After the air direction is converted, the edge material is sucked into the material pipe

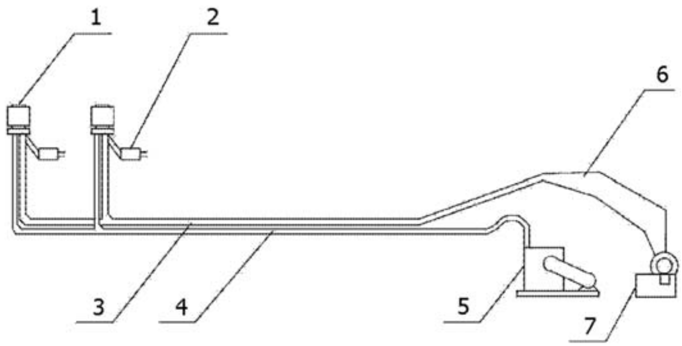

Figure 5.4 Schematic view of a recovery system of biaxially oriented polyamide film (BOPA) film edge trims (2013, **CN203156973** U; 2014, **CN104070617** A, ANGCHENGGANG CITY GANGKOU DISTR HONGDA PLASTIC FACTORY). 1, Air direction converter; 2, Suction material feeder; 3, Material pipe; 4, Air duct; 5, Fan; 6, Connecting pipe; and 7, Shredder.

(3) by the suction material feeder (2), and, then, the edge material is blown to the connecting pipe (6). The edge material is slid down by the connecting pipe (6) into the shredder (7), and the shredded edge material can be recycled. The system is claimed to be able to recover edge trims generated in a BOPA production process without the need of a granulator at a reduced production cost.

US3797702 A (1974), **US4014462** A (1977), and **US4340347** A (1982) of ROBERTSON J disclose various versions of a waste recovery and feed system, wherein plastic edge trims obtained during the manufacture of films or sheets are cut and fed back to the processing machine along with the base material, such as a virgin plastic and various additives. The plastic waste is fed with an auger from an upper hopper toward the outlet opening of a lower hopper containing the base material. The materials are mixed just before entry in the extruder or other processing machine. An inducer blower and forced air, preferably an adjustable vacuum-pressure air stream, are used to blow plastic edge trims along an open conduit into a grinder. After grinding, a separator separates the waste from the air stream, where the ground waste falls into a feed hopper. The feed hopper is continuously filled with base material and processes trim material to an extruder.

In plastic-blown film extrusion processes, it is known that the equipment cannot directly reutilize ground trim material and feed that trim directly back to the process material input section. Simple grinders do not produce the correct pelletized form required to begin the extrusion process,

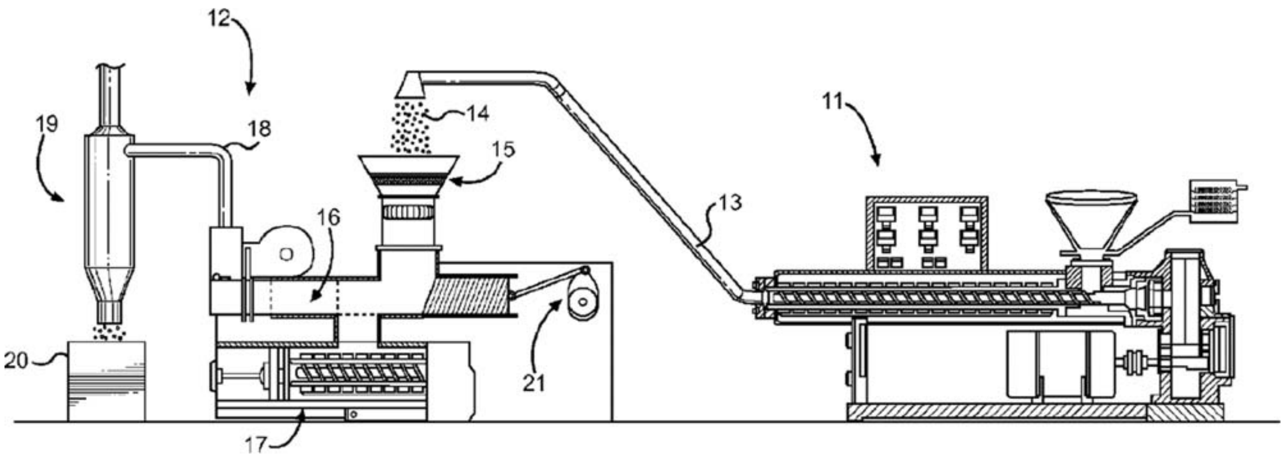

Figure 5.5 Schematic view of a plastic trim reclaim process in-line with an existing extrusion process (2012, **US2012258189** A1, WILHELM MICHAEL BRANDON). 12, Reclaim apparatus; 11, Thermoplastic extrusion process; 13, Feed line; 14, Edge trims; 15, Inlet section; 16, Bricker section; 17, Extruder/pelletizer section; 18, Forced air stand-pipe; 19, Upstanding separator; 20, Container; and 21, Driven ram.

therefore such trim is generally discarded or sold, creating a loss of material and a process by-product. Common practice is to ship out scrap to be repelitized with different types of plastics; consequently, when the repelitized material is blended back into extruders, problems such as gels, discoloration, carbon buildup, and esthetic errors occur in the extruded output (2012, **US2012258189** A1, WILHELM MICHAEL BRANDON).

To solve these issues, **US2012258189** A1 (2012, WILHELM MICHAEL BRANDON) disclosed a process for recycling waste trim from a typical blown film extrusion process that takes in-line trim and reprocesses it into either a pellet or elongated composite brick. The apparatus, shown in Fig. 5.5, combines four sections to process waste trims: an input and feed section, a grinding and presizing section, a compaction and sizing section, and a repelletizing and recovery section. The final product takes one of two forms: a compacted plastic brick or pellet-sized beads that can be directly reused in a new extrusion process. The compaction and sizing section utilizes a heating chamber and ram to force ground trim through an extruder, which is then cut into sections to form brick. The repelletizing and recovery section utilizes an extrusion process that feeds into a cutting plate, whereafter the sized pellets are cooled to solidify their structure before being vacuum transported into a container for reuse.

Figure 5.6 E:GRAN chopper–feeder–extruder combination. Sample stand-alone application: Feeding defective film via a roll feeder. *Courtesy of Next Generation Recyclingmachinen GmbH. NGR, Plastic recycling technologies. E:GRAN. https://www.ngr-world.com/product/egran/.*

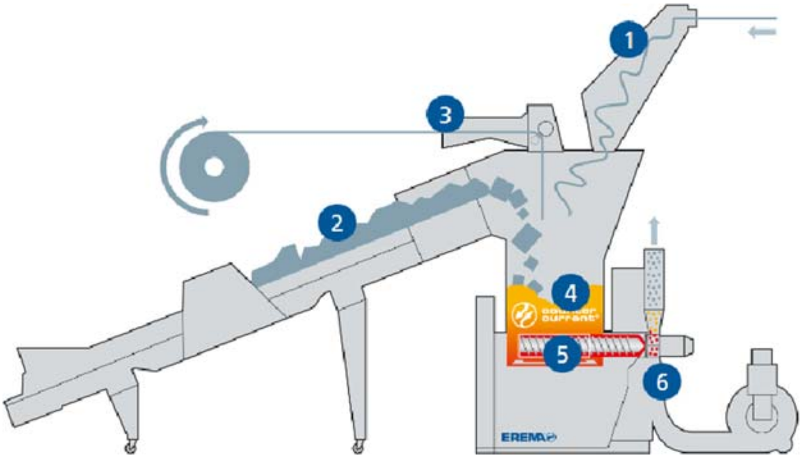

Figure 5.7 Schematic diagram of the Intarema® K system. *Courtesy of Erema Engineering Recycling - Machinen und Anlagen Ges.m.b.H.. INTAREMA® K. https://www.erema.com/en/intarema_k/) 1, Cyclones; 2, Conveyor belt; 3, Feed rollers; 4, Preconditioning Unit; 5, Extruder; and 6, Pelletizing system.*

Next Generation Recyclingmaschinen developed the E:GRAN series of recycling machines for the processing of defective films and film edge trims [21]. All models of the E:GRAN series feature a shredder/feeder/extruder combination (see Fig. 5.6). Plastic film and film edge trims are shredded directly in the extruder feed section. The conically shaped conveying area of the screw compresses the material as it enters the extruder. In the extruder, the material is brought to a uniform melt temperature and subsequently pelletized. The feed section (where the material is shredded), the conveying area, and the extruder all lie along a single shaft. The resulting design requires only one energy-efficient drive. All the components are positioned in close proximity to prevent oxidation of the material and to make optimal use of heat from the shredding process.

Erema developed the Intarema® K recycling system for transforming plastic film edge trim efficiently into high quality, clean pellets [22]. The Intarema® K recycling system, shown in Fig. 5.7, works as follows: Feeding with edge trim is automatic and direct via pipes and cyclone (1). Loose waste material can also be fed into the machine by conveyor belt (2) or feed rollers (3). In the patented Preconditioning Unit (4), the material is cut, mixed, heated, dried, precompacted, and buffered. Next, the tangentially connected extruder with its extremely short screw is filled continuously with hot, precompacted material. The innovative Counter Current technology enables optimized intake action across an extended temperature range. The Counter Current technology changes the direction of rotation inside the cutter/compactor: the plastic material thus moves in the opposite direction to that of the extruder screw. In this special, patented extruder (5), the material is melted at an extremely low temperature and turned into pellets in an air-cooled pelletizing system (6). Intarema® K can be used to recycle several types of clean plastic scrap, including polyethylene mono- or multilayer films; polyethylene films with polypropylene, polyamide, ethylene vinyl alcohol; and breathable films such as polyethylene with calcium carbonate.

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Patents

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CN203156973 U	20130828		CN20132141412U 20130326	ZHANG XUEYUN	FANGCHENGGANG CITY PORT DISTR HONGDA PLASTIC FACTORY	BOPA (biaxially oriented polyamide) production leftover recovery system.
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KR100361735 B1	20021107		KR20020009924 20020225	LEE YOUNG CHUL	KOREA IND TECH INST	Method for recycling multi-layered film waste for packing.
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US2009148629 A1	20090611		US20080333175 20081211; US20060482356 20060707; US20050299442 20051212; US20050166516 20050624	SASINE JOHN; JONGERT CHARLES ACEY MARVIN; ASHBY JEFFERY A	PAPER AND PLASTIC PARTNERSHIP, LLC	Systems, methods and devices for collecting, packaging, and processing recyclable waste.