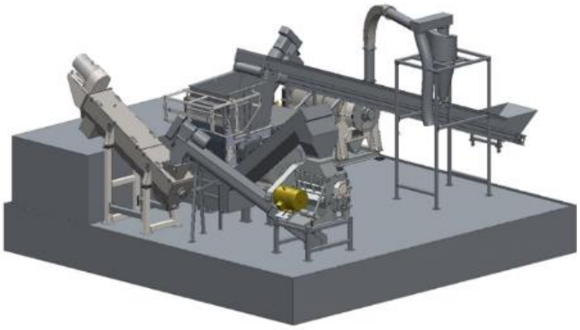
Circular Economy Solutions for Aotearoa New Zealand’s Soft Plastic Packaging

The Packaging Forum, Soft Plastics Scheme



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Executive Summary

The Packaging Forum is a New Zealand member-based organisation that has made a commitment to a voluntary "Soft Plastics Recycling Scheme" as part of the Waste minimisation Act 2008. Different to most Extended Producer Responsibility (EPR) programs, this Scheme is 100% funded by industry and has as an objective, to improve recycling outcomes for packaging. The Scheme has recommended the inclusion of soft plastics in the kerbside collection system to help meet the recycling target objectives. The Packaging Forum members have collated significant data on soft plastic sales and forecast post-consumer recycling (PCR) collection volumes, which they have provided to Nextek for use in this report.

Based on Nextek's global experience and knowledge of current and developing recycling technologies, a framework for a future strategy is suggested for the collection and recycling of post-consumer (PCR) soft plastic (film) products in New Zealand. Consistent with the Packaging Forum, Nextek's recommendation is to utilise existing kerbside collection infrastructure and allow soft plastics to be added to the recyclables bin which will maximise PCR film collection volumes. This will require defining a New Zealand wide system such as "bag in bag", to enable easier identification and separation from other recyclables. Upgrades at many Material Recovery Facilities (MRF's) will be required to separate and handle both the "bag in bag" material but also the presence of loose film material that should be expected to also increase in this kerbside collection scenario. Trials could be run at a number of council areas and MRF's to evaluate the sorting and baling of the soft plastics fraction. Flexcollect in the UK are currently conducting similar trials to assess materials volumes and processing. Support might be required to provide additional "pickers" and install additional materials handling equipment to deal with the increase in volume of the soft plastics stream; however, such support could also be provided through the purchase of already sorted soft plastic material. The opportunity may also be taken at this time to audit the soft plastic fraction that is collected to obtain data on composition and contamination.

Options for "take back" at transfer centres and other locations should remain open as an alternative collection system; however, quantification of the additional volumes is not easy to predict.

The next stage of the system may vary, dependent on volumes and existing local process capability, as to what materials are separated. Ideally, at all local MRF's PCR film is separated to its own stream and baled at this early stage. This material might be sold directly for durable products (Future Post, saveBOARD or other) but otherwise PCR film bales can then be transported to a larger regional facility (Hub) for direct sale or mechanical pre-treatment prior to sale, or for pyrolysis, either by shipping film overseas or to a domestic pyrolysis centre. There may be examples where PCR film pre-treatment is not required to remove contamination and separate polymers such as PVC, PVdC, PET, etc., however, Nextek consider that mechanical pre-treatment should be included as a process step at this feasibility design stage.

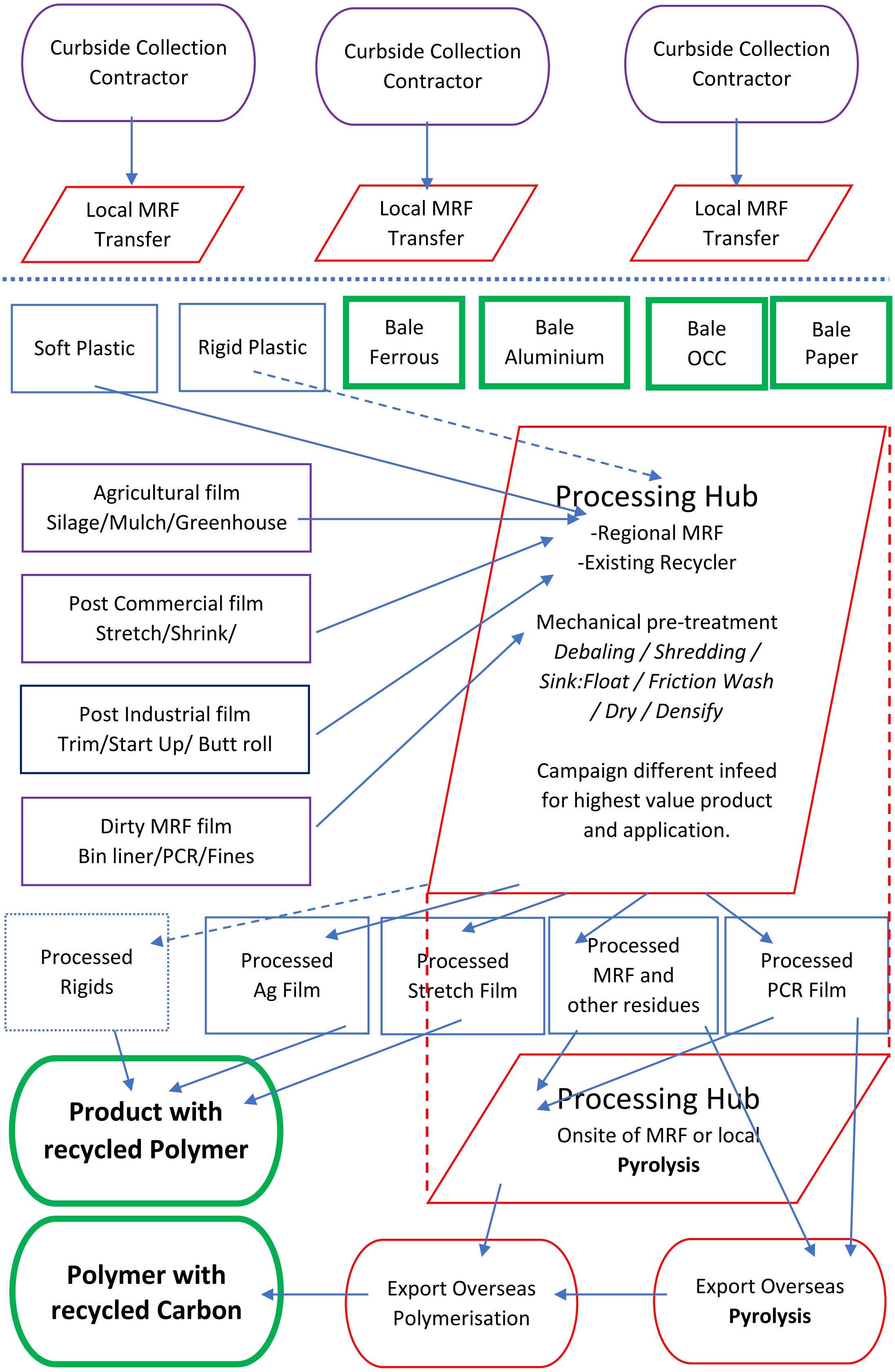
The presence of compostable and biodegradable film materials is a further complication as even in relatively small amounts these degradable materials can contaminate the recycled stream. Without NIR sorting the degradable films are difficult to identify visually for separation by manual pickers. Should degradable films become a large enough fraction of the PCR soft plastic stream to cause quality issues for mechanical or chemical recycling, the MRF's process would not change, but it may be necessary to also utilise NIR sorting at the Hubs, which could assist with reducing the levels of compostable films along with other contamination such as e.g. PVC, PVdC and PET.

A key aspect of this "Hub and Spoke" approach is Nextek' s recommendation for Hubs to include a wide range of plastic material infeed, not just PCR film. Hub processing capability should be designed to include post-industrial, post-commercial and agricultural plastics as well as MRF rejects. While the proposed broader collection of infeed materials does present some increased complexity, there is significant synergy in the pre-treatment for PCR film and these other infeeds. For a wide range of infeed materials, the same cold wash and water-based sink/float separation process can be used for recycling as suggested for pre-treatment of PCR film. By campaigning these different infeed materials, through the same process, recycled plastic products can be produced for a wide range of applications and assist in making the overall operations more viable.

The detailed economics for this expanded soft plastics collection and processing system requires further consideration, however, it is likely that the system will need to be financially supported, at least initially, to get it operational. Capital investment costs at MRF's may need to be reviewed on a case-by-case basis regarding additional materials handling and sorting capacity. The recovery of additional and ongoing operational costs, for the sorting, baling, pre-treatment and transport, pending the value of the sorted bale and/or the pre-treated and finished durable product, also need to be taken in to account. These further costs, need be considered or offset against the cost of landfill, if that is the alternative end of life scenario for these materials. Should the overall cost / benefit be negative for the MRF's or Hubs, some form of subsidy could be considered to sustain the development going forward.

These economic considerations need to be extended to the chemical recycling opportunity. The additional capital requirements could be justified as the resulting high-quality pyrolysis hydrocarbon products are currently in demand and are understood to have a favourable market value, as well as the polymers made with recycled carbon. In this way for a Hub processing arrangement, where many different sources of materials could be processed within a single operation, subsidies on the infeed may be able to be reduced.

It is difficult to forecast an ideal balance of infeed volumes, process capacity and the requirement of materials between mechanical and potentially chemical recycling. As discussed, a specific investigation, including trials on collection and sorting, mechanical pre-treatment and recycling to durable products, should be conducted. From that, the demand and requirements for chemical recycling should be more transparent, and a separate business case for that additional capability could then be developed.

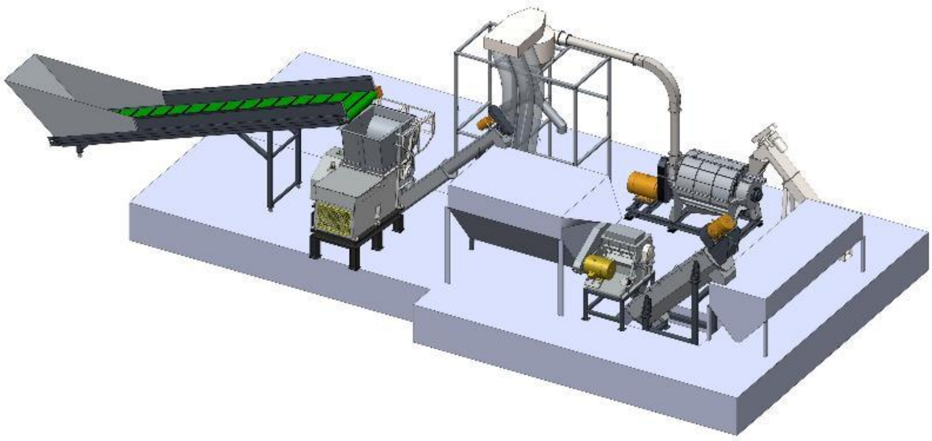


Schematic of proposed material process flow for PCR film and other materials

The mechanical pre-treatment consists of commonly available plastic recycling equipment that could be purchased from a number of suppliers; one equipment supplier has recently proposed a business model for a joint venture with material suppliers and product off-takers which is new to the industry. With some options, the pre-treatment would include;

- Wet-shredding to size-reduce film and begin cleaning off any dirt/contamination.
- Water based sink/float separation to remove non-polymers, PVC, PET, etc.
- Friction-wash to further remove contamination such as paper and food residues.
- Drying to remove excess water.
- Densification (baling / agglomeration / extrusion) for recycling or shipping.

[Resulting sink-residues from PCR film may be suitable for use in durable product or may require landfill. Energy from waste is also a potential process option.]



Indicative layout for a mechanical pre-treatment system for plastic film (densification not shown)

Automatic NIR polymer sorting may not be required; for PCR film the sink/float density step should provide adequate separation of contamination for pyrolysis applications, however, a number of film audits and trials would be able to confirm this. With other single source materials from commercial and agricultural applications, NIR sorting is not required and would be ineffective because of the carbon black content in many of these applications.

With the additional sources of infeed, the mechanical pre-treatment design capacity is suggested to target 1-2 tph, which capacity can operate with high productivity and producing a range of recycled products. Ideally, the mechanical pre-treatment would be co-located with a large regional MRF to form the basis of a Hub, receiving sorted infeed from a number of smaller MRF's, transfer stations and collection systems. It may be possible to export pre-treated PCR film to overseas pyrolysis plants as alternative markets or while domestic pyrolysis capacity is being developed. To minimise transport, when possible, the Hub should also be the site for co-locating the chemical recycling pyrolysis process. Capacity of the pyrolysis unit(s) should be designed to enable processing of additional plastic residues from other sources to be included as part of the infeed. A separate study to finalise the preferred pyrolysis technology supply is recommended and estimates of additional volumes and composition from these other infeeds should be included in the scope of the study. In this report the three pyrolysis technologies proposed for use in Australia have been reviewed. Theoretically, the Licella technology appears to have the best yields of liquid hydrocarbons and tolerance for impurities, but this may come at higher capital and operating costs. The Plastic Energy technology is the most developed with small commercial plants having been in operation for a number of years. The Biofabrik system offers a very small modular, perhaps even relocatable, option but is the least technically developed technology. Other pyrolysis systems suppliers are also available, including business models for joint ventures, and these should be included within the scope of the review of future chemical recycling pyrolysis technology.

KEY POINTS:

1. Maximise the collection of PCR films utilising the kerbside collection infrastructure.
   - Develop a "bag in bag" or other system and educate consumers on its use so film materials can be more easily separated in the comingled recycling bin.
   - Upgrade local MRF's to separate film bags and loose film to a separate stream.
     - Learnings from "Flexcollect" trials in the UK.
   - Facilitate the continued market development of using PCR film in a wider range of durable products this is currently the lowest carbon footprint process option.
2. Develop Hubs at large regional centres to collate materials and provide a mechanical pre-treatment prior to pyrolysis and other recycling applications.
   - Design to enable processing additional materials from post commercial, agricultural, post-industrial MRF's, etc., to supplement the PCR film volumes.
   - Hubs can process materials for direct use back into products and also material for pyrolysis by using essentially the same process equipment.
   - Pre-treated plastic materials for pyrolysis may be able to be exported, while a domestic capability is developed, or where internal freight is not a viable option.
3. Develop Hubs to co-locate chemical recycling pyrolysis processing to produce liquid hydrocarbons for re-polymerisation.
   - Recycling of carbon via pyrolysis back to polymers and film is currently the only technology option for PCR film to food grade applications.
     - Although pyrolysis has a higher carbon footprint than mechanical recycling, it delivers circularity for these complex compositions.
     - Technologies to mechanical recycling PCR films to food grade, such as COtooCLEAN™, are currently being investigated but are a number of years from potential commercialisation.
   - A specific study of the business case and technology selection is required; a range of small-scale process options are commercially available including Licella, Plastic Energy and BioFabrik.
   - Liquid hydrocarbons can also be used as fuel substitutes where export for polymer making feedstock is not viable.

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1. Introduction

The Report objectives are outlined in the brief provided by The Packaging Forum of May 2022 and further specified in subsequent discussions with the Packaging Forum team, in particular, Lyn Mayes of Mad World in May 2022.

The Packaging Forum in New Zealand is a member-based organisation representing the packaging industry who have committed to having all packaging in New Zealand reusable, recyclable or compostable by 2025. They operate voluntary product stewardship schemes for soft plastics and glass; The Soft Plastic Recycling Scheme (the Scheme) is 100% funded by industry and was accredited in March 2018 and is one of 12 voluntary schemes accredited under the Waste Minimisation Act 2008.

Based on the success of some Australian trials and systems introduced internationally, the Scheme members have recommended consideration of the inclusion of soft plastic collection in the New Zealand kerbside system to improve recovery rates and improve collection logistics. Data has been provided by Mad World and The Packaging Forum for current and projected collection volumes of PCR film materials available for recycling. On their own these volumes are modest and, even with current thresholds (APCO & ARL) and a global move to new packaging standards (CEFLEX) that will further improve recycling, the PCR film composition will remain complex past 2025 timeline targets.

The report will seek to provide the following recommendations:

- A potential network of processing plants for New Zealand.
  - Regional capacity to reduce transport costs.
  - To maximise onshore recycling for up to 30,000 tonnes of post-consumer soft plastic over next 3-10 years.
  - To increase New Zealand's ability to deliver on recycled content goals for packaging.
- Mechanical recycling options.
  - Benefits of mechanical recycling of soft plastics.
  - Building on existing manufacturing.
  - Optimised process capability and technology locations.
- Advanced recycling options.
  - Review of Chemical Recycling technologies.
  - Comment on projects regionally and globally.
  - Export of pyrolysis product to Australia/Asia for remanufacture.
- Economic considerations for New Zealand.
  - Modest collection volumes of PCR films.

    - Manufacturing infrastructure.
    - Optimisation of carbon footprint.
- Support for members to meet sustainability goals and requirements.

The report will explore these objectives with expert comment and recommendation from Nextek regarding potential systems, technologies, markets and economics. It is not the intention to prescribe specific solutions as these will require additional investigation beyond the scope of this report. However, the recommendations are intended to be practical and provide actionable aspects for further investigation.

2. Collection systems for PCR films

New Zealand has an active and successful "take back" culture where consumers bring a significant quantity of recyclables to transfer stations where these recyclables are accumulated and sent on for further processing. To maximise collection volumes, it is recommended that PCR films be included in the kerbside collection system. This provides a high level of convenience and simplicity for consumers which, if well-promoted with consumer education, should provide a significant increase in collection volumes.

New Zealand kerbside collection systems could be capable of providing a separate film collection fraction, so that film is not co-mingled with paper and rigid plastics. It would be ideal if segregation is able to be maintained at the point of pickup from kerbside. Having film simply combined with other dry recyclables, significantly increases the complexity of sorting, with impact on yields, purity and costs at Material Recovery Facilities (MRF's). Kerbside collection volumes could be increased by making use of a system such as the Curby™ trials for soft plastics recycling in New South Wales in Australia, or otherwise a "Bag in Bag" system. Any of these changes would need high levels of promotion and education with residents. Based on these experiences, trials could be replicated in New Zealand seeking to maximise collection and minimise the difficulty of sorting at MRF's. Such an approach would also allow the phased introduction in the number of facility locations, suggesting Auckland / Hamilton as a first location for the North Island.

In either case, it will be necessary for MRF's to increase their capability to sort and separate PCR films from other recyclables, in particular paper which is also a 2-dimensional (2D) shape. This might be done manually in small MRF's or with NIR automatic sorting in larger MRF's. Such changes are significant upgrades and may require Government support to deliver this level of infrastructure change. This report suggests a broader consideration of plastic material recovery, in addition to PCR film, to optimise recovery and generate larger process volumes. This wider scope should also be included in the proposed capability improvement at MRF's and collection centres.

3. Recycling process and market network opportunities

The projected available volumes of PCR film for the next 3 to 10 years present a challenge in regard to supporting a bespoke development of New Zealand's recycling capacity. Based on the New Zealand Soft Plastic Recycling Scheme 2021 Annual Report, the volume of PCR soft plastic going into the New Zealand market in 2021 was 7,877 tonnes, with a forecast of 470 tonnes being collected of which 246 tonnes is being processed domestically. While the objective is to grow the collection volumes to 5,550 tonnes by 2025[1] and up to 30,000[2] tonnes per year by 2035, currently PCR soft plastics volumes are relatively modest from the perspective of a dedicated recycling process. The Heat Map below using data provided, highlights the concentration in the North Island around the major population centres of Auckland and Hamilton, with small volumes at other centres on the North Island, potentially Wellington and on the South Island potentially Christchurch.

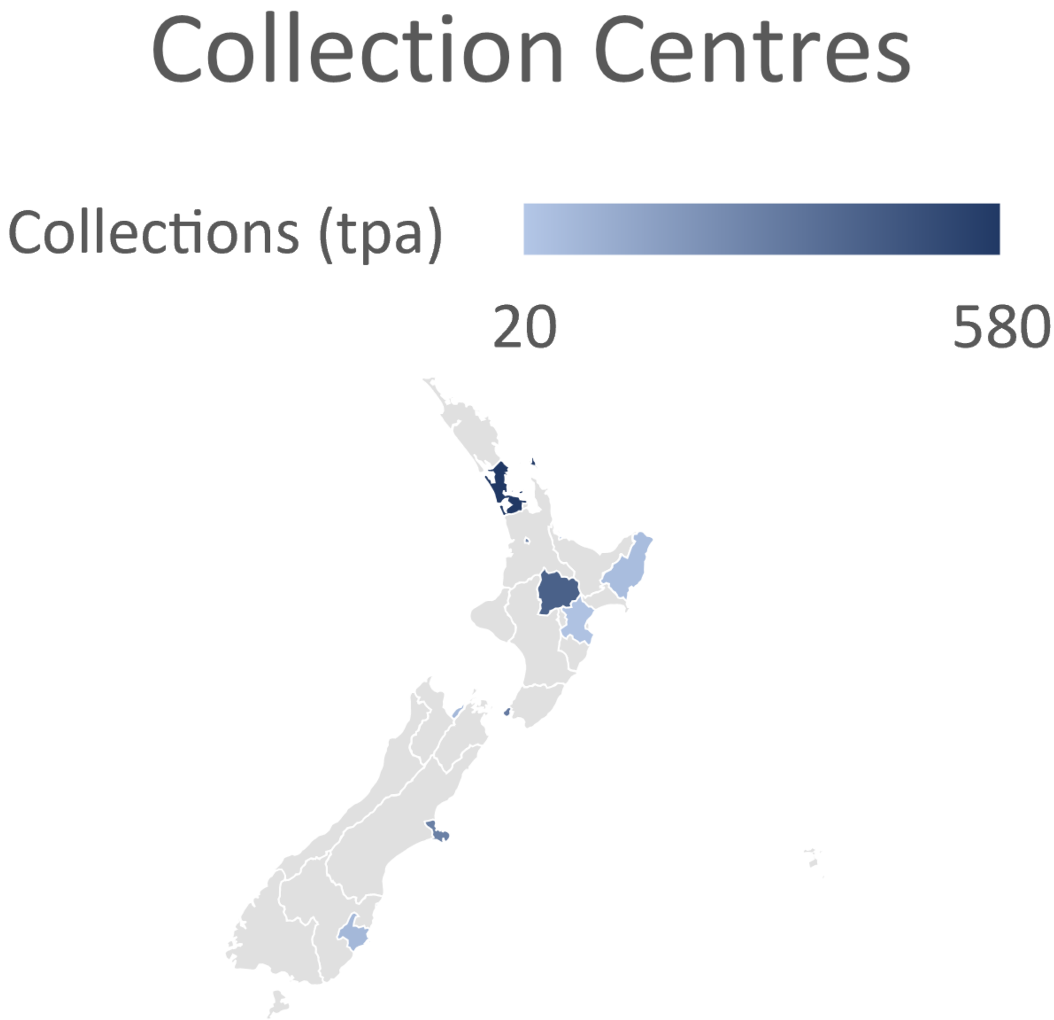


Figure 1: Heat map of current collection centres for PCR film

[1] Packaging Forum - Heat Map and forecast
[2] Circular economy solutions for Aotearoa New Zealand's soft plastic packaging - Brief

Given the geographical spread of major centres in New Zealand, collating the current volume of materials to a single dedicated recycling facility would be expensive from both an emission and an economic perspective. It is considered that, moving forward in New Zealand, the most suitable system for collection, processing and conversion would be to create centres with a "Hub and Spoke" collection system, which would serve to collate regional volumes of PCR film. Logically, the Hub would be in a major city, but the potential exists to also position a Hub in a smaller regional area that could service a number of larger towns or centres. The Hub might also be located nearby to, or as part of an existing MRF or a recycling facility such as Future Post, SaveBOARD, or other operation. In this scenario, recycling centres, transfer stations and MRF's will separate and bale the kerbside collected post-consumer, soft plastic fraction. These bales can be economically transported to a hub where there is the capability to recycle the film either mechanically or chemically.

By aggregating these materials limited to a relatively few Hubs, the volume required for a viable network of recycling facilities distributed across New Zealand could be accomplished. Each Hub does not need to have the same capacity and capability, but it is suggested each Hub does process a range of infeeds not just PCR film and target both mechanical and chemical recycling products for either domestic or international markets. Possible locations for a Hub based on volumes are, as might be expected, and illustrated in Figure 1 above.

- Auckland – Including Northland;
- Hamilton – Including Bay of Plenty, Gisborne, northern parts of Wanganui;
- Palmerston North – Including Taranaki, Hawkes Bay, Wellington;
- Christchurch – As much as possible of South Island.

This approach for a network of collection and processing facilities seems plausible when based on recycling facilities with the capability to process at 1-5 tonne/day of PCR film based on projected volumes. Hub facilities would benefit from also processing other sources of film, and possibly rigid plastics, in such a way that "rejects" from one stream might be utilised in another stream. In this format the smaller volumes and mixed composition of PCR film does not inhibit the economic viability of the Hub, as it is only one of a number of infeeds for the recycling process. Receiving, sorting and processing of PCR film as a separated fraction, will only occur in Hubs that have a market for these products. The market could be to converters such as Future Post and SaveBOARD, other markets may also be developed locally or internationally as a feedstock for chemical recycling. Depending on demand in their region, Hubs may favour one technology or market over the other.

3.1. Post-Consumer film volumes

As discussed, there are a number of factors, some of which are conflicting, that need to be considered when identifying potential locations for Hubs. While the markets for the separated PCR film products are a factor, principally the Hub location is related to the sources of infeed of PCR film and other materials. A Hub could be located principally for sources of post-industrial or agricultural film, but also be capable of collating/processing PCR film from that region.

An initial selection of locations for local processing facilities should be based on:

- Being able to collate an adequate infeed volume, which includes, but is not exclusive to, PCR film.
- Co-location with an existing MRF operation as process centre for the Hub to reduce transportation and handling costs:
    - Upgrading of MRF's to sort and bale or further process PCR film as a separate fraction.
- Co-location with and existing converter using PCR film as an infeed such as:
    - Future Post in Auckland, SaveBOARD in Hamilton.

As discussed in previous meetings, it is suggested to commence with considering a first processing facility for the Auckland / Hamilton area as this area is currently collecting the highest volumes with the following forecasted collection volumes and greatest potential to grow to include a second facility.

Table 1: Current and forecast collection volumes from Abilities + Courier bag service, Countdown and Foodstuffs in Upper North Island, Auckland and Hamilton areas.

Year	**2022**	**2023**	**2024**	**2025**
Tonnes	244	500	750	1,000

This could be followed by a phased introduction of another plant for the Wellington area, such as Lower Hutt, or in the Manawatu region such as Palmerston North. In the latter case, while PCR material would need to be transported from Wellington, increased volumes would also be collected from Hawkes Bay and Taranaki. The following collection volumes of PCR film have been forecast:

Table 2: Current and forecast collection volumes from Earthlink, Hawkes bay, Bay of Plenty, Thames Coromandel and Manawatu in Wellington, Tauranga, Hastings, Napier and Palmerston North areas.

Year	**2022**	**2023**	**2024**	**2025**
Tonnes	111	260	390	520

A third location to complete a first Phase would be located in Christchurch, possibly as south as Timaru, to enable collections mainly from the east coast of the South Island. Wider collection options could be considered if suitable logistics could be found to collect from Queenstown and the West coast. Based on forecast volumes, at this stage there does not appear to be justification for additional Hubs on the South Island.

Table 3: Current and forecast collection volumes from Kilmarnock (Christchurch), Waitaki, Cargill (Dunedin), and Nelson in the Canterbury, Otago and Marlborough areas.

Year	**2022**	**2023**	**2024**	**2025**
Tonnes	115	240	360	480

While such an approach would incur some logistical penalties in terms of cost and emissions, it is necessary to optimise the volumes for economic processing at larger facilities to lower processing costs. As collection volumes grow, additional facilities can then be considered.

3.2. Market demand for mechanically recycled PCR films

Based on the forecast figures provided[1] there is a significant demand for recycled materials by the existing converters. Volumes for Future Post and SaveBOARD, are indicated to grow to 5,500 tonne per year by 2025. Both of these facilities are in the Auckland and Hamilton areas, based on forecast collection volumes these annual quantities can be supplied from the Auckland area. Both businesses intend to expand to other regions of New Zealand, the locations of which are aligned with the Hub locations that are suggested.

Year	**2022**	**2023**	**2024**	**2025**
Future Post	1,000	1,600	2,200	2,500
SaveBOARD	500	800	2,200	3,000

The recent Australian situation with REDcycle, although creating a successful take back scheme, has demonstrated (once again) that promoting just collection is not recycling and on its own it is not a sustainable business model. Frameworks, specifications, support, and perhaps regulations, are required to develop and promote strong end-markets, which are the corner stone of a sustainable recycling industry.

In addition to collection and processing capacity, significant resources and focus should also be directed to the market development of products with recycled PCR film content to grow demand domestically. As the market transitions, the increased demand for products with recycled PCR film content, capacity processing by Future Post and SaveBOARD and potentially other new operators, will ensure that these organisations and markets for PCR film remain viable.

From the data provided, it is not clear if the forecast demand by Future Post and SaveBOARD (5,500 tpa) is for PCR film only or included other recycled materials that are used in the products. However, it is in excess of collection volumes through to 2025 (2,000 tpa) and should this demand materialise, it would seem unnecessary to require other process requirements in the short term, particularly if the expansion of these businesses to other regions of New Zealand would reduce the transport logistics.

Process technology options are described in further detail in later sections, however, mechanical recycling to durable products is the lowest carbon footprint recycling option, and this is recommended as a sustainable market option, but will likely require focussed support to expand the applications to other durable products such as road and public space furniture. Replacement of virgin polymer in bitumen road formulations is an example that has also proven to be successful. The road application example represents the other side of the supply demand equation, as it would consistently require significant volumes to support ongoing demand.

3.3. Market demand for chemically recycled PCR films

Domestically, New Zealand does not have a market for pyrolysis hydrocarbon products as feedstock for repolymerisation. Export to Australia or Asia are the most likely destinations, where products of suitable quality are in high demand, and this is expected to grow in the medium term. To provide circularity, it would be necessary for New Zealand to export pre-treated film or the pyrolysis hydrocarbon products, then import the polymers which would contain a percentage of the recycled carbon. This is the only technology option currently available to produce rLDPE for food-contact film. Second only to mechanical recycling, chemical recycling is the lowest carbon footprint option for PCR films, because most of the carbon remains captured as a polymer. While exporting, chemical processing and importing are required, it provides the highest level of circularity enabling most of the carbon to be reused back to its original application of food grade film.

While not providing the same level of circularity or carbon emission reduction, it is also possible to utilise the pyrolysis liquid hydrocarbons as substitutes and/or for blends with petrol and diesel. The economics of this liquid fuels market would need to be investigated further to establish its viability, but in some geographical or market situations such as Christchurch, it may provide a suitable alternative to transporting PCR film or pyrolysis liquids over significant distances. Some further processing/distillation of the raw pyrolysis liquid would be required to obtain the suitable quality specification for liquid fuels.

3.4. Recycling-Post-Commercial, Industrial and Agricultural volumes

It is suggested that in order to be of viable capacity and to minimise landfill waste, the Hubs should be designed to process a number of infeeds, not just PCR film. The situation for the Auckland area provides an example as including post-commercial, industrial and agricultural volumes will create the potential for a larger manufacturing plant assuming that the indicated and forecasted volumes will be reached.

Table 4: Pre consumer and post-industrial volumes currently processes by PACT and Polyprint in Auckland

Year	2022	2023	2024	2025

Tonnes	2,224	2,820	3,110	3,400

Further volumes are envisaged for a facility in Christchurch, which would assist to scale-up the total plastic film processing capacity to a viable process.

Table 5: Pre consumer and post-industrial volumes currently processed by TC in Christchurch.

Year	2022	2023	2024	2025
Tonnes	765	890	1,010	1,130

The suggestion is that, due to New Zealand's size and geographical spread, the strategy for recycling processing should not focus on specific sources of infeed. By scoping infeed more broadly, to include other plastic materials that are going to landfill or are not being recycled, significant increases in volume can be achieved to provide operational and market viability.

Developments in regard to Extended Producer Responsibility (EPR), recycled content mandates and other schemes that would add value to the PCR film and other feedstock, could otherwise provide financial incentives to recycling. These regulatory systems may provide the required investments and developments in recycling materials, in what has historically been a difficult market to establish and ensure growth.

4. Recycling technology opportunities

Each recycling technology has strengths and weaknesses that are discussed in further detail below, and these need to be considered specifically for PCR film in regard to costs and benefits. Each of these technologies also have a number of process options, in regard to sorting, cleaning and converting, all requiring consideration of the market demand and value for the products that are produced from the selected recycling technology. The technology options that are considered are:

- Mechanical recycling. While some sophisticated mechanical processes are technically capable of delivering higher value products including non-food film, the economic costs may be challenging based on PCR film composition. Unlike rigid PCR food packaging infeed, based on PET and/or HDPE bottles, current sorting and mechanical recycling technologies cannot convert PCR film back to food grade applications. For PCR film using less complex, lower cost mechanical recycling processes, to make durable products such as for road furniture and construction applications, has proven to be technically and commercially viable, as long as the products are price competitive and there is adequate market take-up.

- Chemical recycling (pyrolysis). In New Zealand currently, any liquid hydrocarbon products from chemical recycling would need to be exported for further processing back to polymers or used domestically as fuel substitutes. It is considered unlikely that New Zealand would develop an onshore polymerisation capacity because pyrolysis products were available. However, it is via chemical recycling and offshore processing of the hydrocarbons that will provide the highest level of circularity (film to film); this process option currently has high value and good market demand internationally.
    - Mechanical recycling pre-treatment to enable the export of the PCR film to an offshore chemical recycling facility is a fast and low-cost option to commence this option.
- *Energy recovery (combustion), is a further technology, and has merit as an option for the recycling of materials that cannot be processed otherwise. (Energy recovery is not considered further in the scope of this report.)*

Historically, recycling film from most applications has been challenging both technically and economically, but in recent years process and supply chain improvements have been developed in both areas. Businesses in many parts of the world are installing significant capacity for mechanical recycling of film to a high-quality product suitable for reuse into non-food contact film applications. These developments primarily target infeed from post-commercial applications (i.e., back of store and agriculture) for mechanical recycling. Chemical recycling technologies have improved with the commercialization of more efficient, continuous, modular and in some cases small scale pyrolysis systems, which would appear to be more amenable to the New Zealand market.

It will be necessary to consider both the volume and composition of the infeed from PCR film and other sources, as well as the process and market potential of the different resulting materials. The collection, sorting and mechanical recycling aspects can be trialed and evaluated to determine quality and operational costs. The building of a chemical recycling facility is largely a commercial exercise based on the development of a business case and an estimate of the cost/benefit of such an operation, in comparison with mechanical recycling.

4.1. Life Cycle Analysis (LCA) comparisons

The carbon footprint of the different technologies and the carbon savings compared to using virgin materials are important considerations in promoting specific recycling technologies. Carbon savings and other environmental factors are estimated by completing a Life Cycle Analysis (LCA) which calculates the carbon impact of each stage of the process. Depending on selected boundary conditions for the LCA and other assumptions, the sustainability benefits estimated by LCA studies can vary; however, it is widely accepted that recycled plastic materials have a lower carbon footprint compared to virgin plastics made from fossil sources. An article from the

German Chemical Society[3] (Gesellschaft Deutscher Chemiker) reviewing chemical recycling technologies provides a comparative chart of carbon emissions for different technologies. While not specific for New Zealand or PCR film, the graphic does provide a relative representation for different recycling technologies. [Some technologies such as Dissolution and Solvolysis are not suitable for Polyethylene polymers which is the major component of PCR films.] There is also a significant dependence on the specifications of the products that are being targeted from the technologies, and the different carbon emissions from the processes used.

However, it is apparent that mechanical recycling has lower emissions than pyrolysis, and both are preferred to combustion for energy recovery. The hierarchy still needs to be considered as part of the overall framework of the economics and the markets. A mechanical recycling process to produce high-quality material for remaking film may have a lower carbon footprint and a favourable market, but the process is likely to have a high economic cost. Also, a mechanical recycling process to produce durable products will have a lower carbon footprint and good economics, however, stable markets for high volumes of these products may need to be developed.

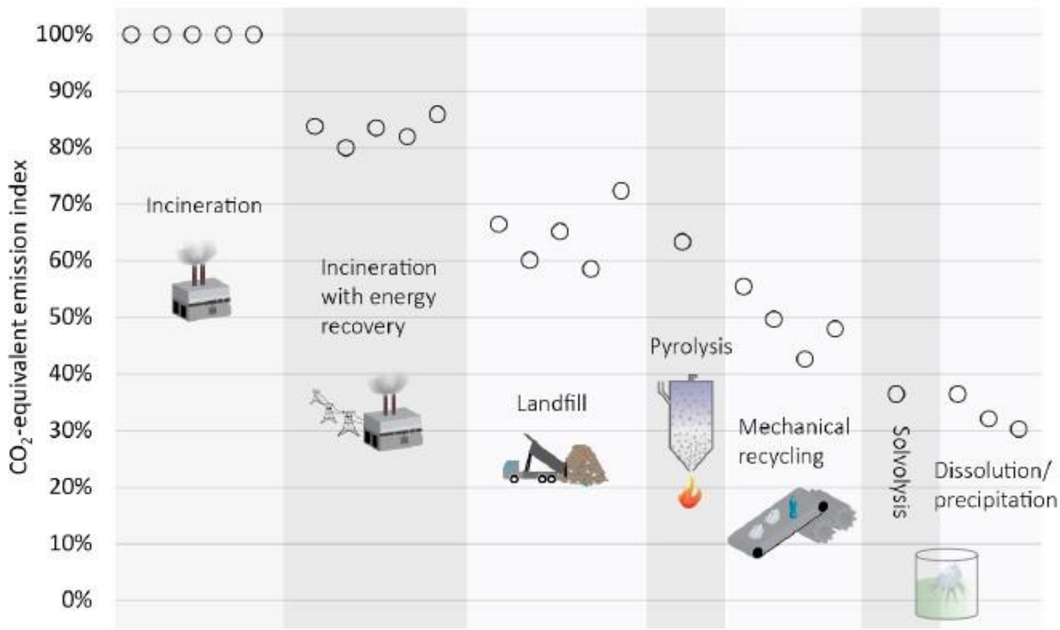


Figure 2: Graphic comparison of relative carbon emission from different recycling technologies. [4]

Nextek consider that, although the circularity is reduced, which may not meet member requirements, when possible, mechanical recycling of PCR film to durable products would be preferred compared to chemical recycling, because these are lower carbon emission processes, and in addition the conversions lead to high-quality durable products like Future Post, SaveBOARD and other materials that are ready for reuse in the New Zealand market.

[4] *Angew. Chem. Int. Ed.* 10.1002/anie.201915651

It is suggested that there is improved circularity by combining different sources of film and the different recycling technologies. Where mono-material film is sourced, from post commercial and agricultural sources, mechanical recycling can produce materials for reuse back into film, however, there will be rejects and residues that are suitable for durable products or chemical recycling. By integrating these different infeeds and recycling processes, (mechanical with and without washing/separation and chemical recycling), additional volumes would be available from rejects minimizing waste and landfill or destined for energy recovery. These sources of waste can also contribute to circularity and provide recycled carbon for use in food-grade film packaging, although that may not have been their most recent application.

5. Mechanical Recycling

Mechanical recycling encompasses a wide range of processes, from size reduction only, waterless cleaning, basic cold-wash systems and more complex automated sorting, hot-chemical washing processes. Size reduction processes with or without additional cold-wash processing are in wide use to produce products for durable thick section products such as street furniture, plastic wood replacement applications and posts. This is suggested as the preferred basis for mechanically recycling PCR film in New Zealand. Neither Future Post nor SaveBOARD use any washing; they simply size-reduce the collected plastic materials prior to conversion. A key aspect of this strategy is the development of markets and demand for these products. *See also comments on pre-processing for chemical recycling under point 6 below.*

For PCR film, recycling back into film applications, extensive sorting and hot chemical washing is required to remove contamination to very low levels, to meet the tighter product specification requirements, but this is not often utilized for PCR film and is not recommended.

5.1. Minimal processing for durable products

Minimal processing into durable products are operations that have been commercial for many years globally and in New Zealand such as demonstrated by Future Post[5], and, more recently, SaveBOARD[6], where post-consumer materials are minimally processed by size reduction (granulation) and typically blended with other materials for conversion into durable thick section products. Other examples of this section of the market in Australia are Plastic Forests[7], Integrated Recycling[8] and Replas[9], which produce a wide range of high-quality durable products using various types of soft

[5] Future Post
[6] Home | saveBOARD - Sustainable Building Materials | New Zealand
[7] Recycled plastic products, Made in Australia by Plastic Forests
[8] HOME | Integrated Recycling
[9] Home Replas - Australia's Leading Recycled Plastic Manufacturer

plastic and applying minimal processing. More technically demanding durable products such as railway sleepers are now also available with similar infeed materials and processing.

These systems have the very significant advantage of having relatively low conversion costs. Although they often result in higher cost per item, compared to wood and metal, the recycled plastic products are often more durable and require lower maintenance offering a longer-term cost-benefit, which offsets the initially higher purchase cost. Because of these circumstances, these simpler conversion systems enable the recycled plastic products to compete, most often with timber products with increasing degrees of success. These products may require further development into new products and support to expand the markets to increase the use of PCR film.

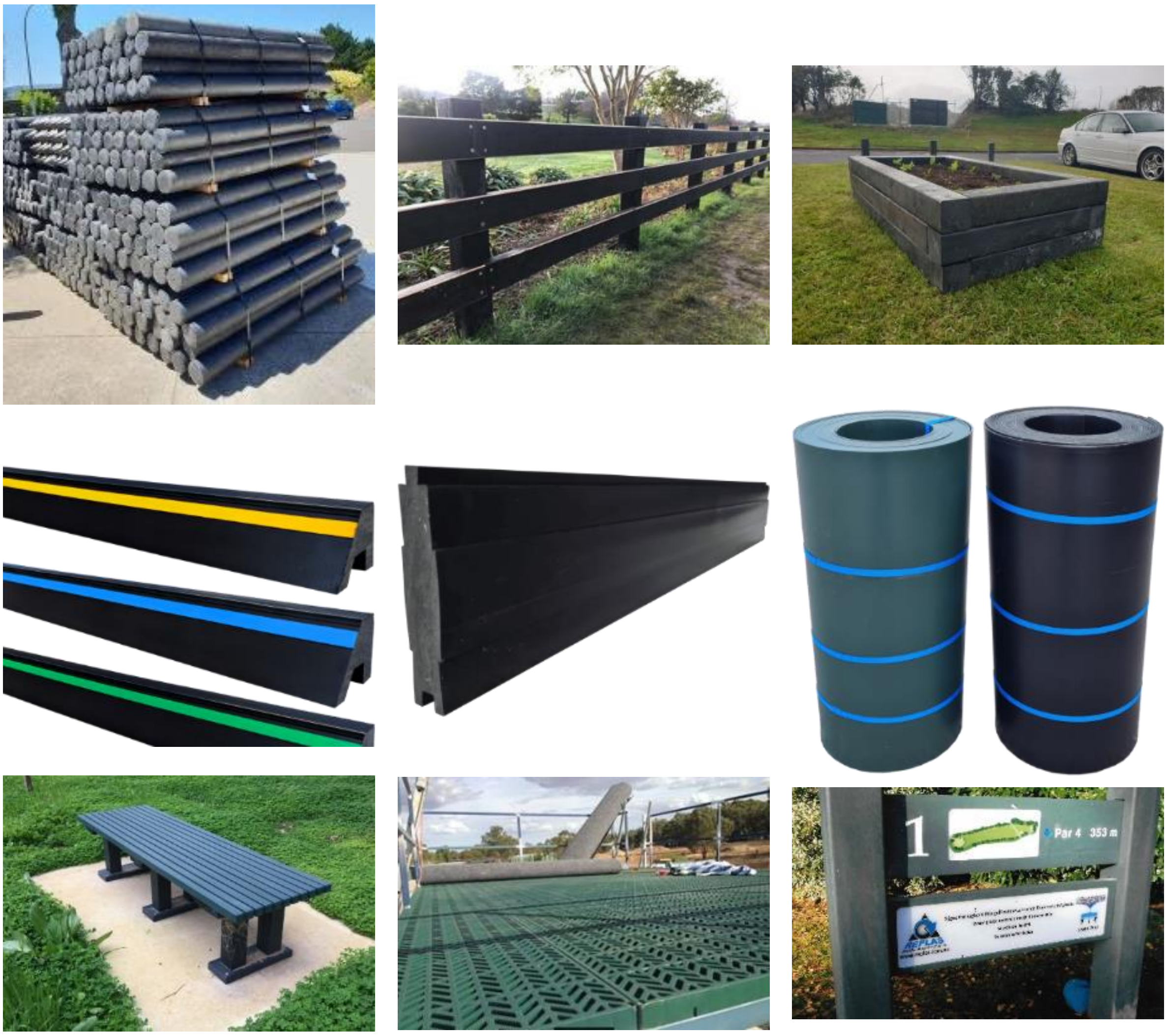


Figure 3: Durable thick section products. Top-Future Post. Middle-Plastic Forest. Bottom-Replas.

5.2. Cold-wash and density separation processing

Although a common process in Asia and Europe, there has not been a significant level of film washing conducted in New Zealand (or Australia) as often the added cost was not justified by the final product value and export of baled film was a preferred business model. Much of the PCR and post-industrial film exported to Asia (from many countries) was manually sorted, cold-washed and pelletized before conversion into thick films and other products. Many of the supermarkets in New Zealand (and Australia) that have re-usable plastic shopping bags, are produced in Asia and contain up to 80% recycled content from this process. Product quality can vary depending on both the infeed and sorting / washing processes. When the infeed is single-sourced, usually from commercial or agricultural applications, and a multistage cold-washing process is used with clean water, some high-quality products can be produced.

Contamination from multilayer applications with labels, adhesive tapes and inks which are not able to be removed by the cold wash, will remain in PCR film and will reduce material quality, so consequently the percentage addition rate, that can be used, and the type of products, that can be made, are reduced. Production of thicker dark-coloured bin liners may be possible based on thicker films for non-critical applications, or the thick section durable products can be made from cold-washed PCR film.

A relevant aspect to be considered for this level of processing, when designing Hubs and several infeed sources, is that this same process is also suitable for pre-treating PCR film, to improve quality and yields prior to chemical recycling. PCR film can be processed to remove extrinsic surface contamination like food-residues and in the next step sink/float separated to reduce many plastics contaminants such as PVC and PET to low levels. Material is then densified for transport to, or export to offshore, chemical recycling to new plastic products.

5.3. Automated sorting and hot-washing

Developments in automated sorting, hot-washing and extrusion based on decontamination technologies, have significantly improved the quality and productivity of recycled film material to a very high standard. Using these three process steps, multilayer and non-target polymers can be separated and virtually all the surface contamination can be removed including inks, adhesives and metallization materials resulting in recycled material which can be blended with virgin polymer at high addition rates to make high quality thin films.

Productivity is impacted by the low bulk density and high surface area of the films which result into throughputs rates which are reduced to a maximum of 7,000-10,000 tpa (1.0-1.5 tph) for most lines. As a consequence of the additional complexity, CAPEX and OPEX are also increased; historically, these cost-increases are resulting into product costs which are exceeding market value for the end product materials which has prevented the growth in this approach for PCR and other recycled films.

Some new sorting and washing technologies are being developed, which may provide new options for mechanical recycling PCR film back to film applications, perhaps including food grade, in the medium term of 3-5 years.

5.4. Mechanical recycling equipment options.

There are a number of supplier options for mechanical recycling as lower cost equipment can be sourced from Asia, particularly China and Taiwan, and, more recently, also from Eastern Europe. A level of investigation is required because not all suppliers provide equipment of good quality and performance. A few suppliers have local agents in Australia or New Zealand, and it is recommended to utilize these agents to provide technical and other support. European equipment suppliers offer the highest levels of performance; these suppliers typically come at a higher cost which is justified for complex automated sorting and hot-wash lines that operate non-stop. However, for basic systems, such as that being recommended for PCR film, the more cost-effective equipment from a good quality supplier in Asia or elsewhere is suitable.

Recently, a new business model for film materials has been proposed by a new company "PreOne" and a German equipment supplier. Rather than selling equipment, they propose to form joint ventures with partners to process film to meet product applications. It is expected that such partners would often be infeed suppliers and/or offtake customers. Further details of such alternative joint venture arrangement should be reviewed as this maybe a suitable business model for some operations to consider.

6. Chemical recycling (pyrolysis)

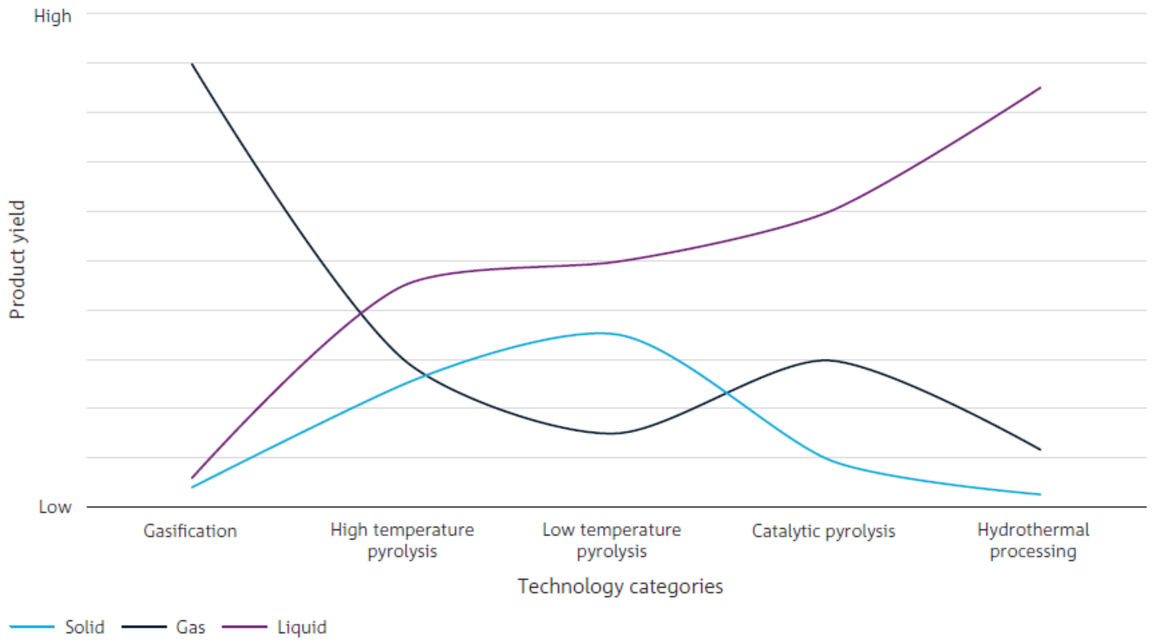
Chemical Recycling is mostly based on pyrolysis technology from which liquid hydrocarbon products can be further distilled based on boiling point into different fractions. Historically, light and heavy fractions suitable as fuel alternatives for Petrol and Diesel have been the target markets. More recently these products have been developed in such a way that hydrocarbon products can be used as feedstock for manufacturing of "virgin like" polymers with recycled carbon content delivering both circularity and reduced carbon emissions. This is the only technology option currently commercially available to recycle PCR film materials back to food grade applications.

Combustible gas products also produced in the pyrolysis process are typically used back into the process for heating / energy; in some cases this can become a closed loop system, once operational. Markets for solid char residues are still problematic, and these materials sometimes go to landfill or combustion energy recovery; however, new applications such as use in roads are being trialed and, as quantities increase, other markets are likely to develop.

Previously, chemical recycling has only been considered on a relatively larger scale, primarily for reasons of economics; smaller batch systems have been available but were mostly unsuitable for NZ markets due to labour and operating costs. Recently, a number of small semi-automated pyrolysis plants have become commercially available, that are perhaps even re-locatable, and could be a suitable business model for New Zealand.

Unlike mechanical recycling, chemical recycling involves high temperatures and pressures, with flammable and potential explosive intermediates and final products. The training and skills required to operate a chemical recycling plant are very different to those typically found in MRF's or mechanical recycling facilities. In large scale facilities, a number of chemical engineers, chemists and qualified trades would be engaged, as with a petrochemical operation. But for the newer, small-scale modules, although the same safety and risk factors apply, that range of skills for operation and service are not affordable. Although often marketed as "plug and play", caution and consideration to the location and safe operation of these smaller modules is required to ensure adequate safety measures are in place.

CSIRO of Australia recently published a report "Advanced recycling technologies to address Australia's plastic waste"[10]. This report makes some comparisons of different process technologies and provides performance data including product yield from different pyrolysis technologies; however, it should be realized that infeed composition and process conditions can alter the ratio of liquids, gases and residue solids (char).



While there is significant dependence on the infeed composition, these results would indicate that the hydrothermal technologies such as those developed by Licella, provide the highest yield of liquid hydrocarbon and conversely lower yields of gas and solid char although this would be at a higher cost and potentially other factors like water treatment need to be considered.

It is suggested that for most PCR film some pre-processing is required prior to the chemical recycling stage *[See section 5.2].* It is necessary to remove contamination to low levels to optimize yield and quality of the liquid hydrocarbon products; precisely

[10] Advanced recycling turning plastic waste into resources - CSIRO

what steps are required is dependent on composition and contamination of the infeed. Polymers like PVC, PS, PET, and PA which are common in multilayer film applications will reduce yield and increase char residues. Other contaminants such as paper, food and packaged-product residual organics, also have a negative impact on quality and yield. Pre-processing steps similar to a cold-wash process used in mechanical recycling are usually suitable to reduce these contaminants to low levels. Film flake (fluff) then needs to be densified if export or transport is also required.

There are a number of technology providers for chemical recycling, with process variations of the same principle of thermally breaking down the polymers, producing liquid and gaseous hydrocarbons with a range of boiling points. These hydrocarbons can then be used as fuel substitutes or as feedstock for chemical processing such as the manufacture of polymers. Only technologies that offer a fully continuous process should be considered to optimize productivity. Also, as with mechanical recycling equipment, preference should be with suppliers that have a record of providing adequate support for maintenance and operation parameters.

6.1. BioFabrik -PlastOil

The BioFabrik[11] module is an example of small-scale pyrolysis units which are being promoted in Australia and New Zealand by PlastOil[12]. The system is based on a continuous process which has 1 tpd and 5 tpd models available. While these smaller scale modules have a number of automated and programable features, which enable a good level of flexibility, they employ the same principles of pyrolysis as larger systems, but in some regards are more sensitive to changes in feedstock and process conditions. While promoted as "automated" it will be necessary to have trained and skilled staff in attendance to manage the system performance and operation, as well as quality control of products ensuring that safety and health considerations are taken into account.

[11] Impressum - Biofabrik

[12] Plastoil Australia

Figure 4: Image of the BioFabrik 1,000kg/day module with pre-processing on the left and pyrolysis on the right

Australian Paper Recovery (APR) in Melbourne has purchased a 1 tpd demonstration unit with the intention of scaling up and developing a chemical recycling operation for film and some other plastic products sorted from their MRF facilities.

6.2. Licella

The Licella platform uses its Cat HTR technology in superheated water and under high pressure to break down polymeric materials into shorter chain hydrocarbons and monomers resulting into a combination of liquid oil and gaseous products. They appear to have a number of licensees, in particularly with Mura (UK), a company that has projects with Dow in Europe, and there is also project development in Australia with Viva Energy and Amcor. Viva Energy target the higher boiling point, heavy fraction for their process, for which, in theory, the Licella technology is better suited. They have recently been granted a development license by EPA Victoria for a plant in Altona, Victoria.

The process has high-conversion efficiency, is scalable technology, and, due to consistent heat transfer in the water media, reactions are well controlled. They claim that this gives the process flexibility and minimal toxic by-products are being generated. As sophisticated engineering is required for the high-pressure process, it results in relatively higher CAPEX, and may also have a higher OPEX than other processes. Licella utilized a pilot scale plant for development, but what scale is available and viable commercially is not confirmed. The current Licella project with Viva Energy at Altona is designed for 20 ktpa as a Stage 1, which would be large for the proposed Hubs in the New Zealand market, perhaps only suited to Auckland.

The process can take waste from several sources such as MRF, EFW, etc., without segregation. It claims to be able to tolerate higher contamination levels from multi-layered materials, laminates and composite polymers and other contaminants such as organics, paper, cardboard, etc., as these convert to gases in the reaction process. Being a water-based process, there is no requirement to dry feedstock for any pre-processing steps.

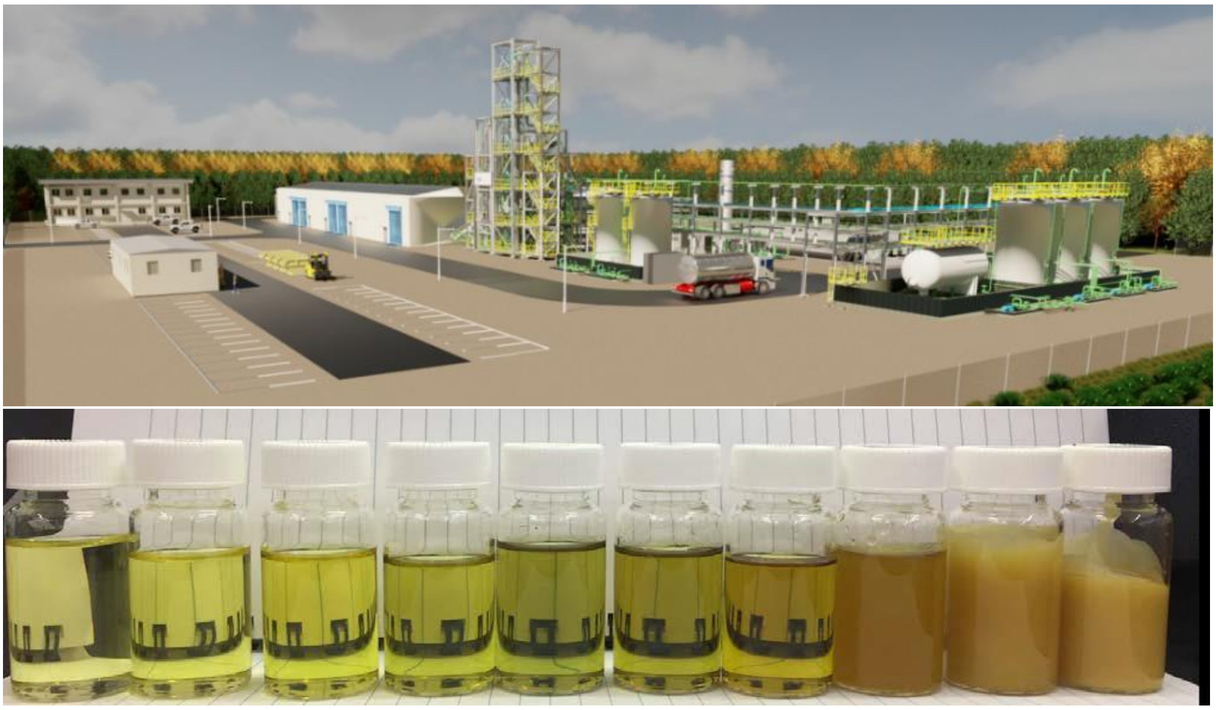


Figure 5: Render of proposed Licella Altona plant in Australia and Licella pyrolysis products.

6.3. Plastics Energy

Plastic Energy is an industry leader in chemical recycling that converts end-of-life plastic waste into hydrocarbon oils. They use patented Thermal Anaerobic Conversion (TAC) technology which converts polyolefins into TACOIL, a pyrolytic oil which is a mixture of hydrocarbon fractions. Currently the company owns and operates two recycling plants in Spain.

Tolerance for other materials is about 10% of the total input which can include metals, and non-targeted polymer materials (PET, PVC, EPS, nylon, textiles), etc. They claim that the input feed does not need to be washed or separated by polymer type in many situations, but this depends on composition.

For every ton of plastic waste that is processed through the plant, 850 liters of TACOIL is produced and the non-condensable gases and syngas are collected and combusted as process energy. Diesel and naphtha constitute 72-75% of the product yield, syngas and non-condensable gases represent 18%, the remaining 8-10% is char which they claim can be used for construction products.

At present, two 5 ktpa plants are operational in Spain and future capacity is planned for additional plants of minimum 20-25 ktpa capacity each by 2025 resulting in a total capacity of at least 300 ktpa. Partnerships with Sabic, Repsol and ExxonMobil are reportedly in place to use the pyrolysis oil feedstock to their crackers and to produce polymer materials. Qenos and Cleanaway have selected Plastic Energy as their technology provider for their chemical recycling project in Altona, Australia. For Qenos the lighter lower boiling point fraction is preferred, and process conditions can be adjusted to promote the yield of this fraction.

Figure 6: Plastic Energy plants in Spain

AMI magazine[13] recently published a brief overview of the global market, which provides a good insight into the level of activity in this market. A large number of other technologies and projects are being progressed globally, mostly with offtake partners, such as Dow, Eastman, LyondellBasell, Sabic and other partners from the petrochemical sector. The article explores challenges, technologies, industry projects, feedstocks, and carbon mass balance systems, which provide a positive context to these initiatives.

In addition to the 3 technologies detailed above, any consideration of chemical recycling should include a wider review of supply options. Nextek is aware of other process technologies and providers seeking joint venture arrangements to operate their chemical recycling pyrolysis systems, which may be attractive to some commercial operators.

7. Scale, market and economic considerations

Market demand is the key element to having a long-term sustainable recycling industry. Historically, and more recently, a significant number of mechanical recycling businesses have failed due to the inability to develop a consistent and competitive market for their products. Chemical recycling markets have historically been associated with crude oil and fuel pricing which has also been problematic. The market for chemical feedstock and polymers is very new, currently with high demand and high value, which is expected to persist in the medium term. Regulation in some countries and consumer engagement generally has pushed retail brand owners to develop sustainability policies and demonstrate participation in the circular economy. To a large extent this is the reason for the current demand for recycled plastic materials,

[13] Chemical Recycling Global Insight 2023

from mechanical or chemical processes. Given New Zealand has a relatively small population and collected volumes of PCR films, it is suggested to consider a staged introduction to better assess both material and process requirements to optimize mechanical recycling to durable products and then assess requirements for chemical recycling for a more circular economy outcome.

7.1. Mechanical recycling

For PCR film mechanical recycling to durable products, the production scale-up to increase volumes is relatively simple and modular and has comparatively low capital cost. In addition to a building and utilities, it requires only size-reduction, optional cold-washing, material handling and the converting equipment, to manufacture finished goods. Nextek does not have detailed knowledge of the business models for operations such as Future Post or SaveBOARD, (in Australia Replas, Plastic Forest, Integrated, etc.), but currently economics appear to be positive based on the current commercial activities of these businesses. However, these businesses and any new entrants are dependent on ongoing product demand, and expansion in the marketplace to reach the infeed volume forecasts and sustain a viable operation in the long term. Typically, sourcing infeed and production capacity have not been a limitation for these processes and products, the limitation has been sales of the products.

National and local government purchase and use of these products using recycled content is important, not only to create volume but also to build confidence in the products used and is often critical to achieving growth goals. Some existing application standards may prevent or otherwise restrict the use of recycled materials, the development of industry standards and specifications that enable the use of recycled materials and testing of these durable products to these standards to provide confidence in their use, is an area that government can support the manufacturers.

7.2. Chemical recycling

The production and market of pyrolysis products from recycled plastics is still novel, although there is a significant and growing global demand. As an infeed to polymer manufacture global standards and specifications on pyrolysis products are being developed by customers according to their process and often related to their petrochemical-based feedstock. These customers are typically large-scale petrochemical-based businesses, who work with a number of mostly smaller suppliers to develop and provide specifications suited to their process. Typically, these standards require low acidity, sulphur and chlorides, and high or non-boiling residues, which can be present in products due to PCR film contamination.

Pyrolysis capacity is growing globally as indicated in the AMI article, and feedstocks for pyrolysis are generally available in most geographies. However, in the short term and with small volumes, export of a suitably washed and densified PCR film product may be possible, perhaps with a reciprocal agreement for buying back plastic product. This situation would provide the opportunity for New Zealand to develop its national programs and meet member requirements while developing its own pyrolysis and energy from waste facilities. While engaging in the exporting for chemical recycling, significant learning on infeed quality, process technology and product specification could be attained to further develop and de-risk the New Zealand domestic program.

7.3. Technology economics

The specific costs and profitability of different recycling processes are as varied as the infeed, process options and market conditions. Most recently, the viability of recycling operations has improved because of increased demand for high quality rigid materials, food and non-food grades, both for use back into packaging, and also for minimally processed materials used for durable products.

Compared to mechanical recycling, Nextek estimates pyrolysis plants are at least twice the cost for process equipment, NZD$5 million and NZD$10-15 million respectively for about a 1 tonne/hour process. These cost ratios shift significantly based on scale, with smaller capacity units (1-5 tonne per day) being higher cost and larger modules (2 tonne per hour and greater) being lower cost on a per tonne basis. There are additional civil costs for building and utilities in both cases.

8. Discussion

Although the focus of this report is on the recycling of PCR film materials, it is suggested that moving forward, this source of infeed should be considered as just one part of the plastic's circular economy. Other difficult to mechanically recycle plastic infeeds, including MRF rejects and other plastic films fractions, should also be included as part of the overall strategy. With some variation, these other recyclable waste fractions can utilize similar process facilities and the suggested plan for creating processing Hubs would enable a significant level of integration to optimize material recovery volumes from a number of sources including PCR soft plastics.

Collected via kerbside will provide an increased level of convenience for consumers, who might not otherwise participate in take-back schemes, which will increase collection volumes. The soft plastics will require separation from other comingled recyclables at existing MRF's, and both the collection and sorting activities should be widely trialed, as is being done by Flexcollect in the UK, to establish performance and operational details. Sorted and baled films can be sold to converters, cold wash/separation for shipping to, or direct feeding into a pyrolysis module. Highly contaminated material (PCR film or other) will usually require cleaning and separation to remove contamination before pyrolysis. Rejects from MRF's which include small items (caps / tubes / fragments, etc.) and losses from automatic sorting and other sources of infeed could also be washed and density separated to produce a suitable infeed for pyrolysis.

Existing recyclers such as Future Post and SaveBOARD also utilize other plastic recyclable materials as part of the mix to manufacture their products, and these might be obtained from the same Hub as the PCR film. The Hubs should receive a wide range of plastics (and other materials?) and utilize a number of sorting, cleaning and separation technologies to minimize plastics going to landfill and maximize quality and value.

Nextek considers that a holistic approach to include this wider range of plastic waste infeeds, including PCR film, using the same processing equipment located at Hubs, would optimize quality and yield and would provide larger volumes. This would justify commercially viable size mechanical and/or chemical recycling plants of 1-2 tph operating at the major Hubs, in conjunction with the output of well-sorted fractions and cleaned /flake or pellet for sale to commodity markets.

For PCR film, the lowest cost and lowest carbon footprint recycling process currently available is basic mechanical recycling with size reduction and material blending to make durable products. Businesses such as Future Post and SaveBOARD are currently active in this market with their forecast volumes of 5,500 tpa, exceeding the forecast PCR film collection volume of 2,000 tpa by 2025. These products use a mixture of recycled materials, not just PCR film, and it is assumed that these forecast production volumes are inclusive of these other materials. The ability of these businesses to achieve this level of growth, and sustain a market of this size, may depend on support to establish standards and specifications that enable future development of new products. Ultimately, these businesses should have the ability to recover and recycle their own product, improving circularity by creating their own source of feedstock. In the short term, recycling PCR film and other plastics in this way is a rapid, environmentally sustainable business option that should be further supported and developed to include other durable products and applications, as part of the future pathway for PCR film in New Zealand.

Conversely, chemical recycling via pyrolysis is still a relatively novel commercial process with nascent but significant markets as either a liquid fuel alternative or as feedstock for repolymerisation. Currently, for PCR film, pyrolysis is the only technology option to produce virgin quality film material with recycled content that is suitable for food-grade applications. It is suggested that this capability be developed in parallel with the mechanical recycling pathway, Nextek suggest that to optimise pyrolysis yield and quality most PCR will need pre-treatment through this same mechanical process.

Technology selection and the business case for pyrolysis technology requires a specifically focused study; the three technologies referred to in this report being Licella, BioFabrik and Plastic Energy, all appear to have suitably scaled equipment between 350 tpa and 20,000 tpa. Based on current reports, Australian businesses have selected these three technologies for their own processing purposes, which may provide some insight, but other technology options should also be reviewed to suit the New Zealand volumes and market situation including mechanical recycling to durable products.

By considering a holistic plastics recycling strategy for feedstock coming not just from PCR film, but also a range of other film and polymer reject materials, from dirty MRF's (garbage bin), dry recyclable MRF rejects, industrial, agricultural, medical, commercial and construction/demolition waste streams. The circularity economy and the economic viability of the system can be optimised to minimise carbon emissions, and landfill. Plastic from packaging formats other than PCR film and other applications that are difficult to mechanically recycle, can contribute to the circular economy and recycling of carbon back to film applications. This broader plan for multiple inputs is inherently more complex, but could be developed in stages with different infeeds, most likely in Auckland / Hamilton, but possibly Manawatu Council (Palmerston North) or Christchurch, if there was suitable interest from the operators in those areas.

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Appendix: Modified Plastics Chain diagram