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Fair carpet

Potential methods of extending the life cycle

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<p>Fair carpets play an important role in business events and exhibition showrooms to perform a formal but elegant experience for attendants. They help to make an event successful and yet their value is underestimated. After the show, they get removed and their life ends at that point. Every year, there are millions of tons of fair carpets that are dumped to the landfill or incinerated. It is still a traditional linear economy in the fair carpet sector, where reuse or recycling rarely occurs. With the spotlight of circular economy in the recent years, the old method does not work anymore. People are looking for ways to minimize the input of the process as much as possible and nothing is considered as waste in order to save natural resources. Therefore, this study was conducted to assess potential methods of extending the lifecycle of fair carpets. The main focus was on characteristics of polypropylene and its recyclable probability, as it is the key material of fair carpet. Different alternatives were re-searched and evaluated both on socio and economical aspects.</p>	
Keywords	Fair carpet, recycle, reuse, polypropylene

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1 Introduction

'Closing the loop – An EU action plan for the Circular Economy' was introduced on December 2015, when the European Commission kick-started its Circular Economy Package. With the ambition to boost the recycling level and, as a consequence, to reduce the amount of waste, recycling carpet was also taken into account.

When talking about carpets, most of the time people think about household carpets that are used to make the house cozy. Thus, studies about these carpets have been conducted, and they have been proposed to have a high possibility of being recycled. However, recycling fair carpets is still a new concept. Unlike household carpets, fair carpets have a much shorter life as they are only used once. Therefore, it is necessary to deal with fair carpet recycling matters.

2 Theoretical Background

2.1 Fair carpet

2.1.1 Usage

Fair carpet is commonly used in business events. It appears in exhibition stands, showrooms and office interior projects or corporate events (congress, company anniversary, and product launching) (Fair Partner Oy, n.d.). Companies in this sector usually choose to provide either full process (planning idea and concept, implementing and follow-up evaluation) or selling/renting carpet only. To name some companies in Finland, they are:

- Fair Partner Oy
- Roudaamo
- WS-Expo Group Oy
- Expomatto
- Näyttelymainonta Oy and so on.

Table 1 describes the fair carpet's main characteristics which make it the first choice of event planners through the UK and Europe.

Table 1. Fair carpet characteristics

Characteristic	Description
Mobility	It can be attached and removed easily without leaving any mark using special tape or glue

Variety in colours	One type of fair carpet is always available in approximately 20 colours and more (Roudaamo, n.d.)
Fireproof material	Fire certificate is a compulsory requirement (Bfi-s1/Cfi-s1) (WS-Expo Group Oy, 2015)
Affordable price	Fair carpet is sold in m ² ; thus, a user can purchase according to the need. In addition, the price is reasonable (€7.00 + VAT per 1 m ²) (Roudaamo, n.d.)
Lightweight	With a weight from 300-600g/m ² depending on surface texture, it is convenient for transportation (WS-Expo Group Oy, 2015)
Shape modification	It is feasible to cut/add pieces of a fair carpet to fit with the event's design

In Finland, the most three common fair carpet types are Expoline, Exposhow and Expoglitter. (Expomatto, 2018). Despite using the same material (polypropylene), the difference is the surface texture as shown in Figure 1.



Figure 1. Expoline, Exposhow and Expoglitter samples (from left to right)

Overall, the fair carpet is used widely because it brings elegant appearance at a reasonable price.

2.1.2 Material

Polypropylene (PP) is the main material of the fair carpet. It acts as a thermoplastic which means it melts at a certain temperature and turns into a liquid phase. The melting point depends on tacticity and crystallinity. For example, perfectly isotactic PP melts at 171°C and commercial isotactic PP melting range is [160°C, 166°C]. (Wikipedia, n.d.) After cooling down, it becomes solid again without significant change in its properties. It is considered as a huge advantage when it comes to recycling polypropylene. In addition, PP is hydrophobic, so it does not absorb liquid. Due to this property, stains in the fair carpet are reduced drastically. Besides, PP is attracted to oil because of its oleophilic property. However, this does not affect fair carpet usage because it is mainly used in an formal and non-industrial event. As PP having low density (0.895 and 0.92 g/cm³), it brings great economic benefit in massive production. There are several types of PP as shown in Figure 2.

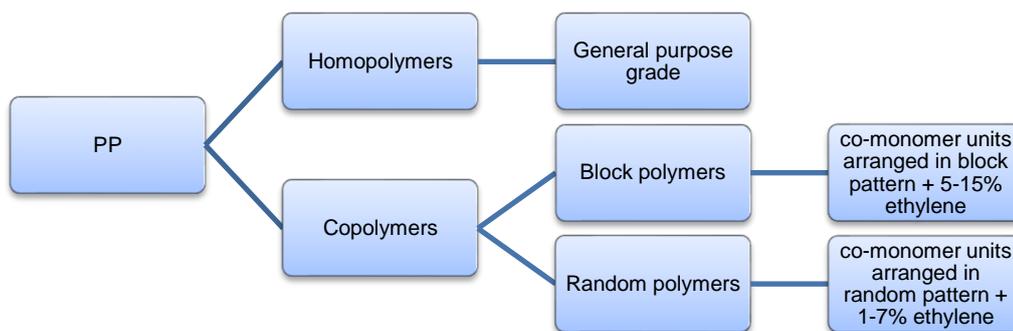


Figure 2. Different types of PP (Creative Mechanisms Staff, 2016)

While homopolymers (PP HOMO) hold poor impact resistance and film clarity, its tensile strength is the strongest among the three types. On the contrary, block copolymers (heterophasic copolymers – PP HECO) get good impact resistance and random copolymers (RACO) are the best at film clarity (Malpass & Band, 2012).

Polypropylene is a product of the polymerization process of propylene. In strict condition with certain catalyst, the reaction happens as shown in Figure 3.

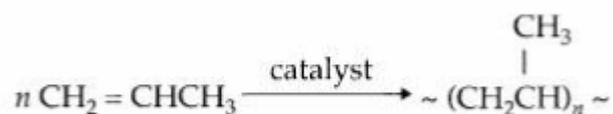


Figure 3. PP polymerization equation (Malpass & Band, 2012)

At an industrial scale, the most commonly used transition metal catalysts are Ziegler-Natta catalysts, and titanium is often used as a transition metal.

The tacticity of a polymer is defined depending on its stereoisomeric structure.

- Isotactic: if the methyl groups are placed in the same direction. It contains substantial crystalline content and is so called PP HOMO as described above.
- Syndiotactic: if the methyl groups are placed 1 by 1 evenly on both sides of the carbon chain. When mixed with 5-15% ethylene, it turns to block copolymer and similar to isotactic, it also contains substantial crystalline content.
- Atactic: if the methyl groups are placed randomly. Its main properties are rubbery, amorphous and tacky. With the contribution of 1-7% ethylene, it will become random copolymer and one of the applications is to manufacture adhesive.

In fair carpet manufacturing, PP HOMO is mostly used. Table 2 displays a comparison between two products of two well-known companies that provide raw chemical materials in Europe. More details of these products are shown in the Technical Data Sheet in Appendix 1 and 2.

Table 2. Products of PP that are suitable for manufacturing fair carpet

	150-GA03 from INEOS	Adflex Z 108 S from LyondellBasell
Application	Carpet backing, geotextiles, bags, twines and ropes	Carpet backing, filament yarn, hygiene nonwoven,...
Feature	High tenacity, melt flow rate consistency, good processability	High melt flow rate, high softness, very low flexural modulus
Melt flow rate (230°C/2.16 kg)	3 g/10 min	27 g/10 min

There are three typical processes in the factories: injection molding, fiber extrusion and film extrusion. Among them, injection molding is considered the most popular. There are many machine models with different configurations, Figure 4 and 5 show illustrations of a thermoplastic injection molding machine.

Exterior view of a typical thermoplastic injection molding machine

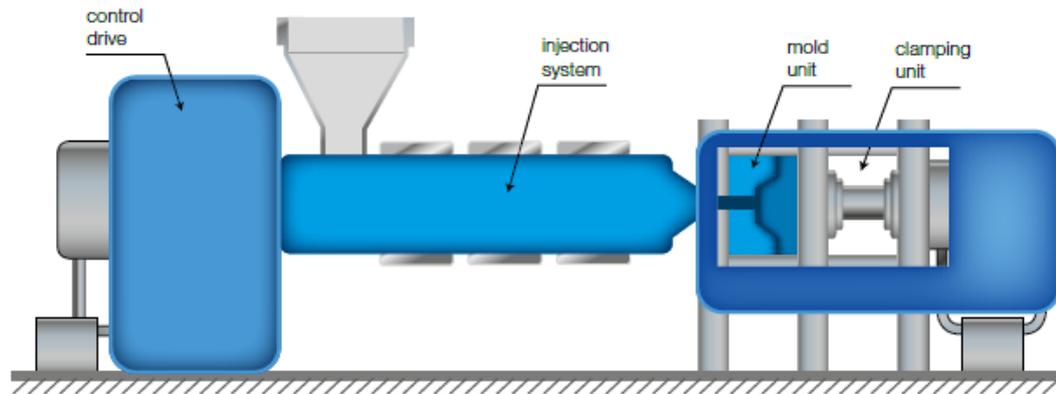


Figure 4. Thermoplastic injection molding machine 1 (Exxon Mobil, 2017)

Cross section of a typical thermoplastic injection molding machine

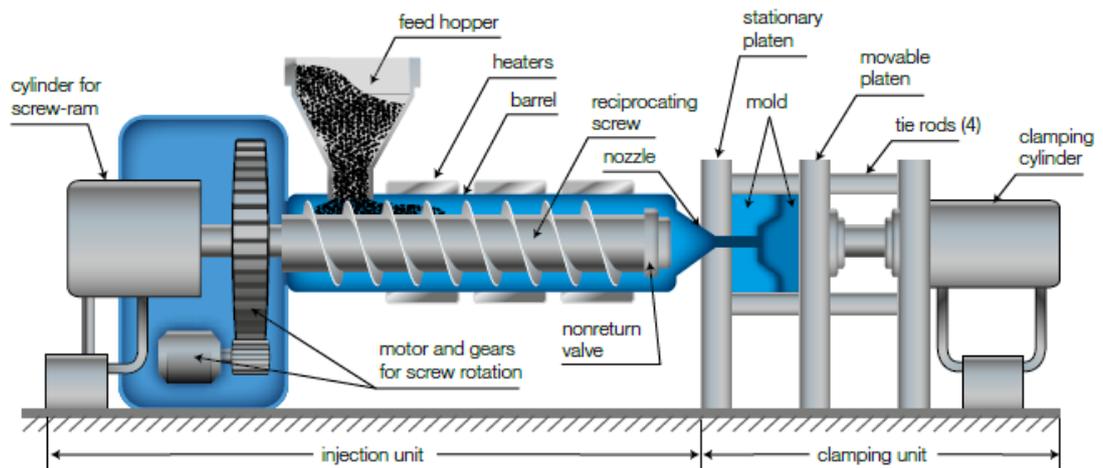


Figure 5. Thermoplastic injection molding machine 2 (Exxon Mobil, 2017)

For this type of injection molding machine, processing basically contains 5 steps:

- Mold filling, packing and screw rotation: after a mold is being filled almost completely (95-99%), mold packing takes action. It happens in order to compensate the lost volume that will occur when the material goes back to solidify phase after melting. Screw rotation is advised to be high and back pressure can be used as an extra. Actual injection pressure depends on the material melt temperature, mold temperature, flow length and other variables of the equipment.
- Drying of the material: Moisture control is crucial to prevent material degradation and maintain the best quality. It is suggested to reduce moisture level to 0.08% or less before any further processing.

- Coloring: There are three available sources to precolor the pellets into almost any colors or hue desired. They are solid color concentrates, colorant carriers and carrier-less color concentrates.
- Regrinding: to get rid of runner, sprues and scrap parts without damaging the material itself.
- Shrinkage: every process has its own shrinkage level, data can be obtained by contacting manufacturing companies.

2.2 Pyrolysis

Pyrolysis is defined as 'a thermalchemical decomposition of biomass into a range of useful products, either in the total absence of oxidizing agents or with a limited supply that does not permit gasification to an appreciable extent' according to (Basu, 2010). Basically, the process treats biomass in big molecules and turn them to smaller and simpler molecules (gas, liquid and char).

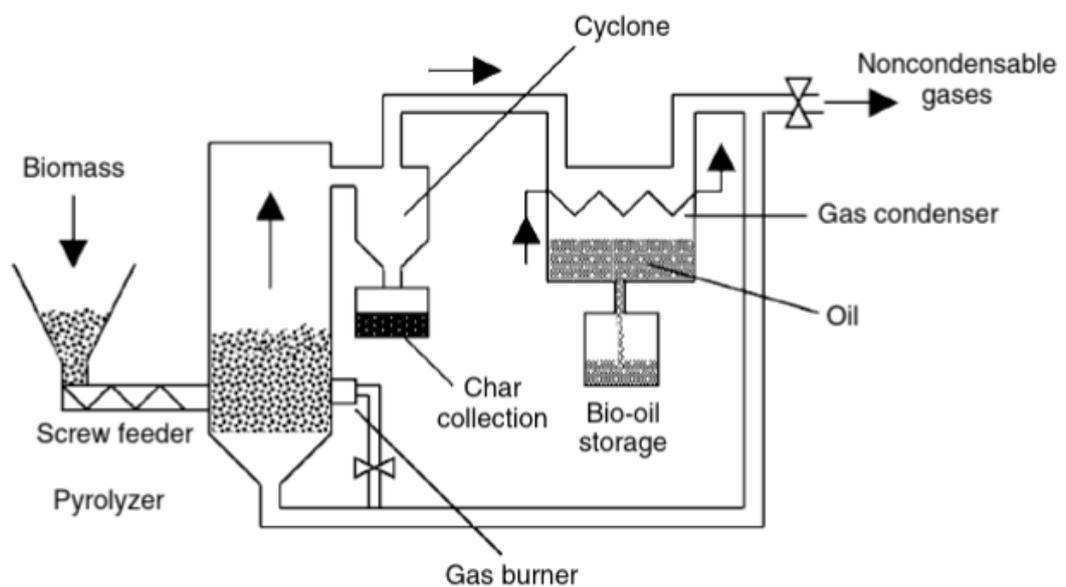


Figure 6. An ordinary pyrolysis process (Basu, 2010)

Figure 6 shows the simplest layout of a pyrolysis process. The first step is pyrolyzer which is the pretreatment of biomass. Biomass is put through a screw feeder and the efficiency depends on the particle sizes and moisture levels of the feedstock. After being dried and cut into a certain size, the biomass goes to pyrolysis reactor. In there, the combustion occurs, and the produced raw gases are evaporated through the top outlet. The leftover solid residues are richer in carbon contents. Raw gases are moved to a cyclone separator to remove char, which will settle down in a char collector. The new purified gases are introduced to a gas condenser to form oil and later deposited in the

bio-oil storage. On the other hand, the non-condensable gases are released. The non-desirable gases often return to the combustor and act as input energy source.

Temperature and catalyst are two factors that are utilized to boost efficiency of the pyrolysis process. Almeida and de Fátima Marques (2016) reported in their article on using pyrolysis for plastic waste that thermal pyrolysis' products were of low quality due to the required temperature. To tackle this problem, catalysts were added and the results were improved. Catalysts reduced the temperature and reaction time to create a more feasible products, hydrocarbons such as fuel oils or petrochemical feedstocks.

2.3 Circular economy business models

In September 2018, Sitra published a Circular Economy Playbook for Finnish SMEs (Sitra, 2018). It acts as a support material for companies in manufacturing industry that are planning to transform their business models to a more sustainable way. This playbook focusses on four sectors which hold strong positions in Finnish economy: machinery and equipment, marine, energy and transportation.

In the playbook, potential benefits from circular economy are explained and then suitable business models for each sector are shown. Evaluation of re-organization and operational changes is taken into discussion. On the basis of the assessment, a transformation roadmap is created to help companies achieve their goal.

Due to the objective of this study, the machinery and equipment sector is the closest sector to get inspiration from. There are five main core business models (Figure 7):

- Circular supply chain: to reform the use of resources
- Sharing platform: to optimize capacity use
- Product as a service: to offer outcome-oriented solutions
- Product life extension: to extend life cycles
- Recovery and recycling: to recover value in waste

Circular supply chain helps to gain value in manufacturing processes. By designing long-lasting products or using recyclable materials, input material quantity reduces significantly. While logistic is the main target of sharing platform business model. Increasing using times of a product leads to decreasing production of that type of product. Production as a service comes up from end-users' point of view. Leasing instead of owning is

the key to minimize unused products purchase. This can be operated by offering a borrow-service or exchange service with subscription fee to users. The product's life cycle is extended efficiently by offering services such as repair/maintain, upgrade or resell. Finally, recover and recycle is needed to avoid waste. It can be either recycled/upcycled (create new usage to a product) or return (bring waste to the source).

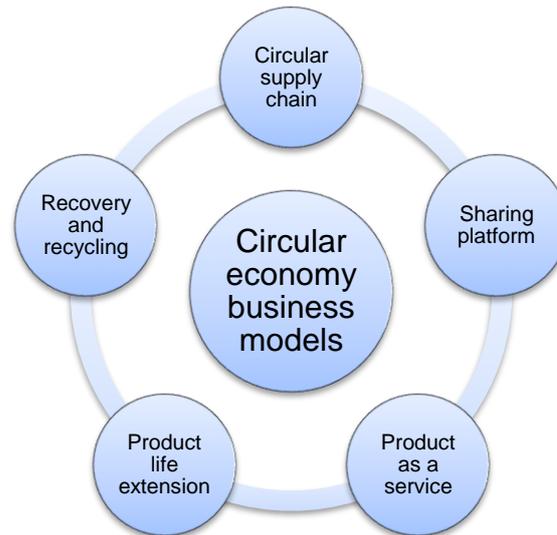


Figure 7. Circular economy business models

3 Current Situation

3.1 Fair carpet life cycle

At the moment, the full life cycle of a fair carpet is rather short. From olefin, it goes to polymerization process and becomes PP. After that, a raw material of the fair carpet is obtained. It is brought to fair carpet processing with special conditions and turns into many types of fair carpets. At this point, it is ready to be contributed to retailers and shops. However, after serving in a successful exhibition, its life continues as unknown. Most of the time, it is discarded into a landfill and people just continue their lives.

There are three main reasons to keep the recycling level of fair carpets very low. Firstly, event planners do not want to take risk of using second-hand fair carpets in their important days. It is understandable that a stain or mark on the carpet could make the whole organizing look unprofessional and could bring bad image. Secondly, there is rarely service for recycling. Often fair carpet providers remove the used carpet but do not have any further action. That happens due to the lack of need to clean used carpets as already explained. In addition, there are only a few companies that consider used fair

carpet as its raw material. In consequence, a huge amount of fair carpet is under-used. The high demand from market and low recycling efficiency lead to the third reason which is massive production. Manufacturing fair carpet becomes easier with all new technologies and methods. Nowadays, it is considered cheap and convenient.

3.2 Treatment method

According to Greenpeace pyramid of plastics, PP is considered to have less environmental and health problems in comparison with other popular industrial plastics (Figure 8). The pyramid is based on the evaluation of all processes, from production to product emissions in use, disposal and recycling.

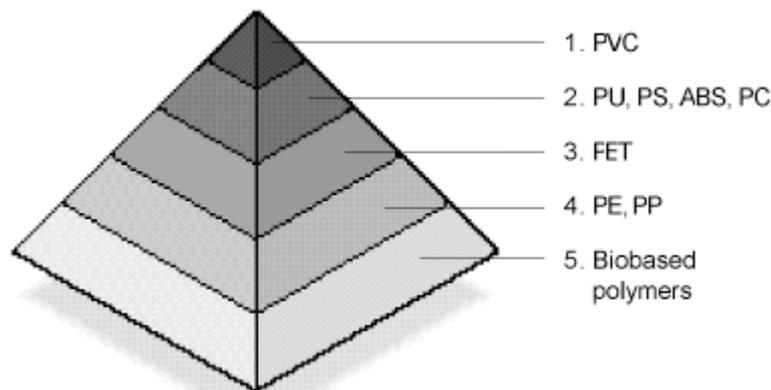


Figure 8. Greenpeace pyramid of plastics (Safe To Make, n.d.)

Theoretically, polypropylene, as a thermoplastic, is eminently recyclable. However, its reprocessing is still very limited. The most common disposal methods are throwing to landfill or incinerating (Malpass & Band, 2012)

- Landfilling: PP goes back to the soil where it has been extracted as petroleum and create carbon again. Therefore, it goes to full life cycle despite the fact that it will stay the same for many years before starting degradation. Carbon footprint is conserved in this case.
- Incinerating: this process reclaims energy and generates electricity. However, the side product is a massive greenhouse gas. According to measurement, three pounds of carbon dioxide are released when combusting one pound of polymer.

4 Suggested Solutions

4.1 Cleaning service

One of the fastest ways to extend fair carpet life cycle is recycling used carpets. The recommended model is adding a chain in fair carpet business, which is called cleaning service (Figure 9). The service will be in partnership with retailers. After the event, fair

carpets are collected by the retailer and passed to the cleaning service, where the carpets are treated, for example, dry cleaned or given special care if needed. Clean, like-new carpets are brought back to retailers and they are ready to re-use. The offer for cleaned used carpets will be economical, and the target group is small businesses/local communities which need a cost-saving solution. If the event organizers want to keep the carpet and reuse it themselves, the retailer can recommend experienced and trusted companies that they have been partnered with. Thus, it is a gain for every parties.



Figure 9. Proposed business model

Before creating cleaning services specially for fair carpets, normal carpet cleaning companies can be used as the substitutes. There are several nominated companies that have high potential to be part of the business model:

- Matto Palvelut offers washing different types of carpet plus a collecting service. They are experienced with interior carpets, but according to the company's size, they might be interested in a new business area (Matto Palvelut, n.d.).
- SOL Palvelut is publicly known for their laundry services and they have opened carpet cleaning in many locations in Uusimaa region (SOL Palvelut, n.d.)
- City Clean offers carpet washing as one of their key services. They are located in Helsinki so it would be near to many exhibition showrooms (City Clean, n.d.).
- Another choice for small scale is 24 Pesula where people can bring their carpet to be washed at service points (24 Pesula, n.d.).

4.2 Materials for daily use products

Besides reusing fair carpet for its own purpose, another approach is seeing it as a material for other products. With the contribution of textile designers, there are already products that are made of PP being sold in the market. Most of the time, they are bags and wallets due to PP durance quality (Figure 10). In Finland, there are online shops where you can purchase such items. For example, Messukeskus

(<https://messukeskus.com/joulu/messumattotuotteet/>) or Globe Hope (<https://www.globehope.com/>).



Figure 10. Card-holder box made from fair carpet (Globe Hope, n.d.)

This process transforms the fair carpet to a new product, serving a new purpose. Hence, its life cycle is extended as illustrated in Figure 11. Instead of being discarded immediately after the exhibition ends, fair carpet turns into new products and will be use again. Then that second product has the possibility to be placed in a second-hand shop or flea market and then recycled to something else later before being treated as waste.



Figure 11. New life cycle of fair carpet

4.3 Feedstock of other processes

Pyrolysis is considered a promising solution when dealing with plastic waste. All gas, liquid and solid products after the process can be utilized as a raw material to produce energy or a new plastic material (Figure 12). A study on the yield of thermal and catalytic pyrolysis of plastic waste (Almeida & de Fátima Marques, 2016) shows the potential to recycle PP. In addition, there are many other studies reported by Francis (2016) to prove this point.

- A study by Achilias about pyrolysis of PP using a laboratory fixed-bed reactor: the products (oil and gas) were found to be potential feedstocks to produce plastics and refine oils.
- Hayashi's study of PP pyrolysis with oxygen in 200-300°C. The result was 90% of PP transforms to volatiles with average carbon chain of 10.

In addition, co-pyrolysis is also applied. With the help of Brazilian crude oil, yield was up to 80% oil with 50% of that is diesel oil.

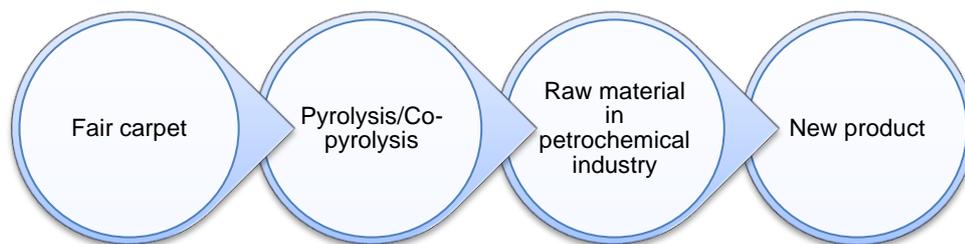


Figure 12. Fair carpet recycling at industrial scale

5 Discussion and Recommendation

Adding cleaning services in the business circle is a win-win situation for everyone involved. End-users such as companies or event planner organisations can re-use the fair carpet and thus save in the cost of the event. It is not necessary to use used fair carpet in all the area, but covering the less important, hidden parts is also great.

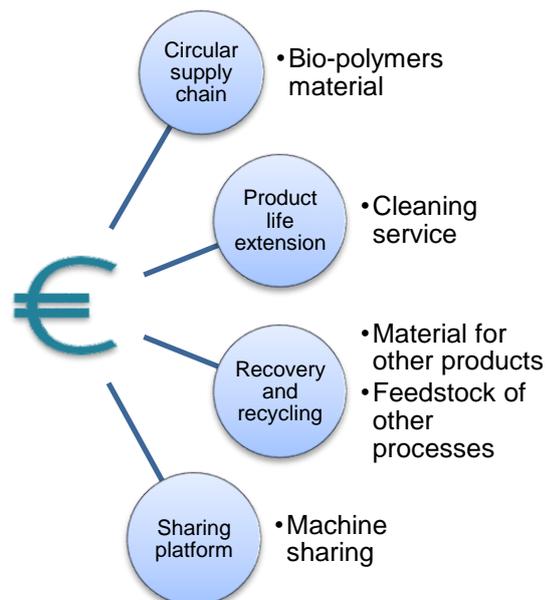


Figure 13. Solutions by business models

Obviously, cleaning services themselves will expand their business target and earn some benefits from this. By cooperating with fair carpet retailers, they can connect to potential customers easier. From retailers' side, they will provide cheaper products that attract new customer group: small businesses, local communities or family events.

However, cleaning or washing the fair carpet can be challenging. As the fair carpet is made of plastics, it will release small unseen particles through the process and these micro/nano plastics will drain to the sewage system. Eventually, eliminating these micro/nanoplastics will be a problem in wastewater treatment. Filters can be used as one of the solutions for this situation. But further studies about particle size is needed before making any decisions.

Seeing used fair carpets as a raw material for making other products is also an alternative. The advantage of this solution is that it is a straight forward method: it takes a short time to make these products and to get them back to end user directly. Unfortunately, it depends much on design companies and usually it is difficult to develop these products in a larger scale. In addition, the style is limited and it costs more than the average price due to the handmade design and performance (Figure 10). Instead of producing profit, the value of these products lies in raising society awareness about the possibilities of recycling the fair carpets. In addition, the effect of transformation from fair carpet to new products can be visualized through hand-on sessions, DIY teaching videos and blog posts. Because the products are familiar to human daily life, their impact is stronger.

Pyrolysis/co-pyrolysis processes provide a solution to recycle fair carpet in industrial scale. It will break down PP into monomers, serving as a recycled feedstock to manufacture other products. However, despite the great opportunity, a more detailed study needs to be conducted in order to know more about the relation of fair carpet and pyrolysis. After this research, laboratory experiments are recommended to test the theory.

While cleaning service represents a product life extension business model, a recovery and recycling model is illustrated by other methods: material for other products and feedstock of other processes (Figure 13). Even though there are manufacturing processes and logistics that have not been studied. In production processes, a more environmental-friendly material should be used instead of PP. Bio-polymers are nominated due to its popularity recently. However, PP's application and its low-cost production is difficult to

compete with. In addition, PP is also considered a recyclable material due to its thermo-plastic characteristic. Molding method can be applied to melting PP to form a new product but homo-colour is restricted due to broad colour spectrum of fair carpets. From the logistics aspect, sharing the platform, i.e. machines in the manufacturing factory is another opportunity. Instead of fair carpet production only, adjusting the settings of the machines to produce other products in spare time can be a good solution. It increases capacity use of machines and brings new source of income to the factories. The last business model is 'product as a service' is not suitable with fair carpet business, because of the existence of retailers which offer similar service.

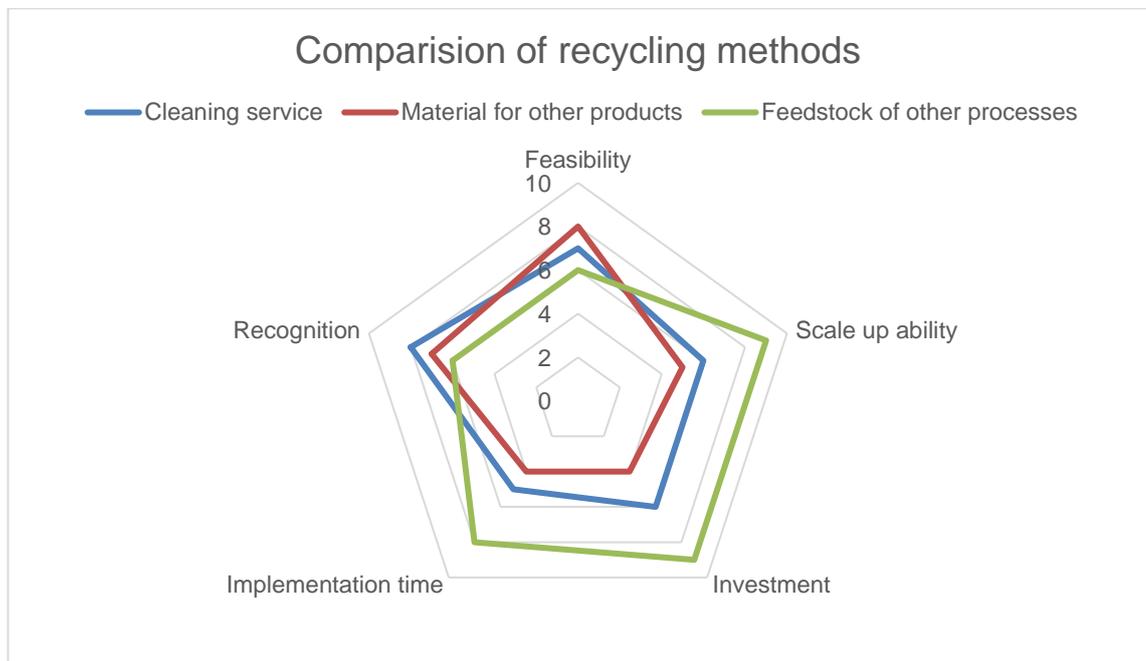


Figure 14. Comparison of recycling methods

To evaluate all solutions in different perspectives, a radar chart with scale from 1-10 is made (Figure 14). It includes socio aspect (recognition) and economical aspects (feasibility, investment, scale up ability and implementation time). Overall, seeing fair carpet as a feedstock for other processes gains the largest area. This indicates its potential role on the fight of plastic waste. However, large investments and long-term studies are its weak points. In comparison, establishing a cleaning service or making more recycled daily use products are easier to apply. In conclusion, the first two solution should be used to raise awareness about potential reuse of fair carpet while further research is being conducted.

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Appendix 1. 150-GA03 Technical Data Sheet



Product Technical Information

Polypropylene - Homopolymer

150-GA03 is a general purpose grade intended for extrusion and thermoforming applications requiring medium melt flow and good parison strength.

Applications

- General purpose thermoforming
- Carpet backing, geotextiles, bags, twines and ropes
- Injection Moulding

Benefits and Features

- Good processability and MFR consistency
- High tenacity

Properties		Test Methods	Values	Units
Physical				
Melt Flow Rate	230°C/2.16kg	ISO 1133	3	g/10min
Mechanical				
Flexural Modulus	@23°C	ISO 178	1450	MPa
Tensile Strength	@Yield	ISO 527-1,-2	35	MPa
Izod Impact Strength, notched	@+23°C	ISO 180/1A	4	kJ/m ²
Thermal				
Melting Point		ASTM D 3417	163	°C
Vicat Softening Temperature	@10 N	ISO 306/A	156	°C
HDT	@0.45 MPa	ISO 75/B	92	°C

December, 2008

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150-GA03

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Appendix 2. Adflex Z 108 S Technical Data Sheet



Product Description

Adflex Z 108 S is a reactor TPO (thermoplastic polyolefin) manufactured using the proprietary Catalloy process technology from LyondellBasell. Adflex Z 108 S features a very high softness, a very low flexural modulus and a high melt flow rate. It is used by customers for injection molding, impact modification, extrusion coating, soft compounding, film and fiber applications. It is also selected by customers for the modification of polypropylene homopolymer and random copolymer without altering the transparency. The grade is available in natural pellet form.

Regulatory Status

For regulatory compliance information, see Adflex Z 108 S [Product Stewardship Bulletin \(PSB\)](#) and [Safety Data Sheet \(SDS\)](#).

Physical

Melt Flow Rate, (230 °C/2.16 kg)	27 g/10 min	ISO 1133-1
Density, (23 °C, Method A)	0.88 g/cm ³	ISO 1183-1

Mechanical

Flexural Modulus	80 MPa	ISO 178
Tear Strength	62 kN/m	ASTM D624
Tensile Stress at Break	6 MPa	ISO 527-1, -2
Tensile Stress at Yield	5 MPa	ISO 527-1, -2
Tensile Strain at Break	800 %	ISO 527-1, -2
Tensile Strain at Yield	20 %	ISO 527-1, -2

Impact

Status	Commercial: Active
Availability	Europe; North America; South & Central America

Application	Carpet Backing; Filament Yarn; Hygiene Nonwoven; Impact Modification; Pipe
Market	Coating; Roofing Underlayment; TPO Foils and Skins Flexible Packaging; Industrial, Building & Construction; Textile
Processing Method	Cast Film; Compounding; Continuous Filament/Spinning; Extrusion Coating; Injection Molding; Spunbond
Attribute	High Elongation; High Flow; Low Hardness; Low Temperature Impact Resistance; Narrow Molecular Weight Distribution

Typical Properties	Nominal Value	Units	Test Method
Charpy Impact Strength - Notched			
(23 °C)	33	kJ/m ²	ISO 179
Note: Failure Mode - Partial Break			
(-20 °C)	2.8	kJ/m ²	ISO 179
Note: Failure Mode - Partial Break			
(-40 °C)	1.3	kJ/m ²	ISO 179
Note: Failure Mode - Complete Break			
Multi-axial Impact Strength			
(23° C, 2.2 m/s, 3.2 mm plaque)	10	J	ASTM D3763
Note: Failure Mode - Ductile			
(-40°C, 2.2 m/s, 3.2 mm plaque)	18	J	ASTM D3763
Note: Failure Mode - Ductile			
Hardness			
Shore Hardness, (Shore D, 15 sec)	30		ISO 868
Thermal			
Vicat Softening Temperature, (A50)	53	°C	ISO 306
Heat Deflection Temperature B, (0.45 MPa, Unannealed)	37	°C	ISO 75B-1, -2
DSC Melting Point	142	°C	ISO 11357-3
Optical			
Haze, (45 mil)	49	%	ASTM D1003
Gloss, (60°, 45 mil)	62		ASTM D2457
Additional Information			
Mold Shrinkage			ISO 294-4

Please contact LyondellBasell for shrinkage information.

Notes

These are typical property values not to be construed as specification limits.

Processing Techniques

Specific recommendations for resin type and processing conditions can only be made when the end use, required properties and fabrication equipment are known.

Company Information

For further information regarding the LyondellBasell company, please visit <http://www.lyb.com/>.

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