Dept. of Architecture, University of Strathclyde

PPE Material Flows

Potential for Open Loop Remanufacturing of PPE waste to construction products

March 2021

University of Strathclyde Engineering
DEPARTMENT OF ARCHITECTURE

Dress for the Weather

Introduction

The ambition of our study is to identify the material flows that could connect PPE waste with products for use in the building and interiors industry. We have aimed to diagram the material flows of a range of PPE equipment by charting source, potential for re-use, process, regulatory considerations and future uses.

Our ambition for the benefits of this study is to create opportunities for local material flows that result in visually attractive, innovative products for the building industry.

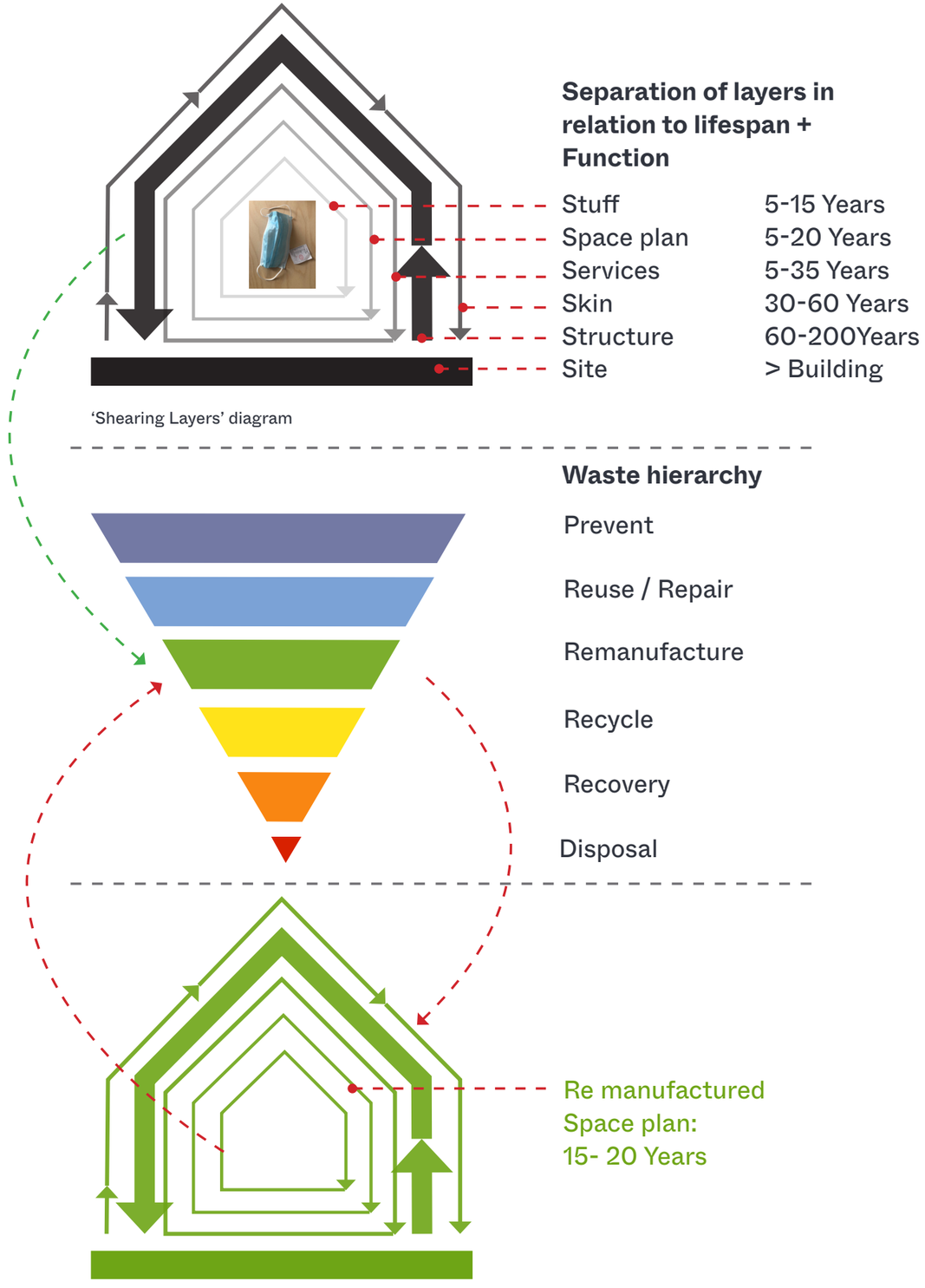
In focussing on the building industry we aim to find proposals that 'lock-in' this waste for an extended period before being reintroduced to the waste or recycling stream again.

Key Outcomes were initially stated as:

- Matrix showing prevalent areas of PPE waste generation
- Research of methods for material re-use of specific PPE equipment
- Material flow diagram showing source, processes and regulatory aspects of re-use process
- Practical examples / products etc of how PPE waste can be re-used with focus on architecture / interiors / building industry.

Our objective now is to design a prototype healthcare interior using products with 100% recycled material derived from PPE items.

This report has been prepared by Andy Campbell and Romain Charlet, Dept. of Architecture, University of Strathclyde. Andy and Romain also practice architecture together at Dress for the Weather, a Glasgow based architecture studio. The report has been funded by and made on behalf of the University however there are overlaps with architectural practice with opportunities for further development in practice and academia.



Methodology

The research first sought to define the PPE that we should focus on for the purposes of the report. By constraining our study to focus on NHS Scotland PPE provision we researched the various grades and recommendations for PPE under different clinical circumstances.

We limited our study to PPE items used on the NHS Scotland 'Low Risk' pathway because this presents the biggest possibility for recovery including similar items used by general public (Type IIR masks) and health care workers in care homes and other settings. For the purposes of this report, we are therefore constraining our definition of PPE to the following items:

- Apron (LDPE)
- Fluid Resistant Surgical Mask (Type xxx / PP)
- Gloves (nitrile)
- Eye Protection (polycarbonate goggles)
- Full Faceshield (PET)

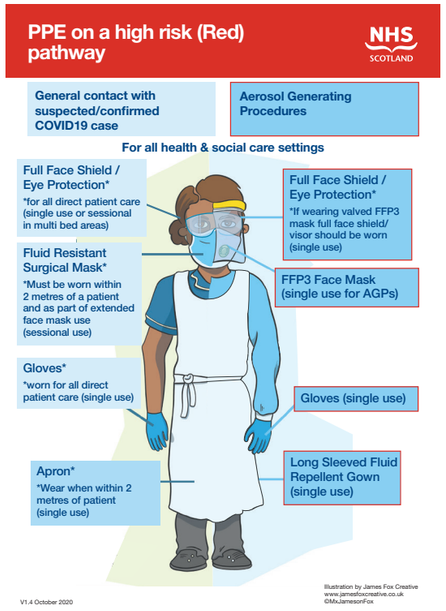
We ordered a sample selection of these materials and categorised their material composition through product labelling and web-based research.

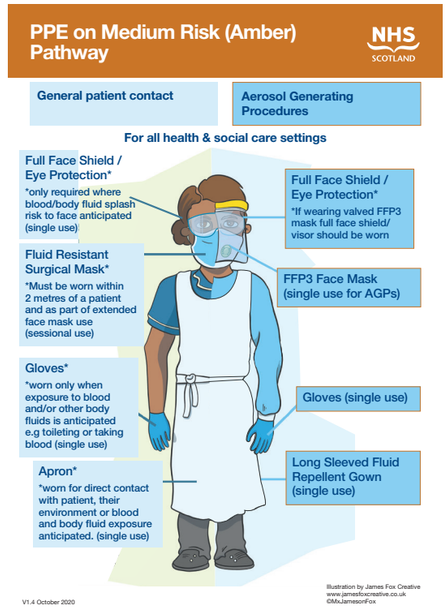
Once defined, we established the quantities of items issued to NHS Scotland in the last year through open source Scottish Government data. We also approximated the mass of these items through crude methods of weighing small numbers of items on domestic scales and multiplying by total quantities issued to NHS Scotland. This would allow us to make projections about waste and energy reduction etc.

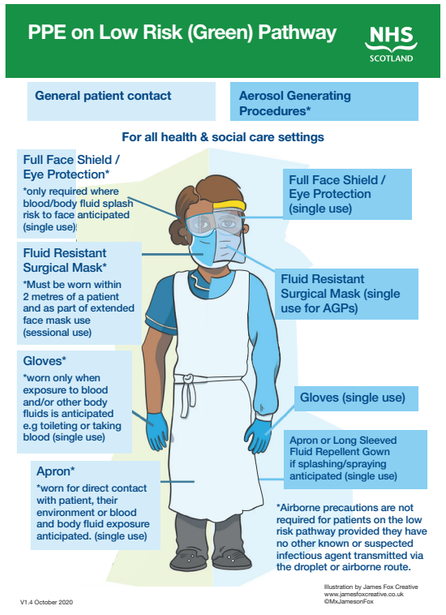
The Waste Streams with the NHS were researched and the focus of the study was then constrained to focus on Domestic (Black) and Low Risk (Orange) streams. While the Orange waste stream would still present significant barriers for re-use or recycling of material it was highlighted in the NHS Scotland Waste Prevention and Re-Use Guide that much of this clinical waste currently gets misclassified and could be redirected.

Further to the categorising of PPE base materials we carried out research into the opportunities for remanufacturing of these materials into a range of uses. The study focussed on the concept of 'Open Loop' recycling or remanufacturing, meaning to look at different uses for the material rather than 'Closed Loop' where the material would be re-made for the same use. The intent to focus on remanufacturing to building materials is central to the report and plays to our own interests, as architects, but also because it 'locks in' the waste material for much longer timeframe before re-entering the waste stream. By identifying opportunities for remanufacture as building materials we were able to focus on specific uses that give at least a 15-20 lifespan.

The barriers to remanufacture were also explored through internal workshops inspired by Ellen MacArthur Foundation resources. These barriers have been shown graphically on the proposed remanufacturing loop and furthered through research across a number of resources such as NHS Waste Management documentation, Zero Waste Scotland reports and conversations with recycling experts among others. It is acknowledged that we have not undertaken any direct conversation or consultation with NHS staff or departments relating to current waste flows and that this would be high on the agenda for further phases of the project should they arise.







Health + Safety Executive.
https://www.hse.gov.uk/toolbox/ppe.htm

Personal Protective Equipment (PPE) is a general term used for many items of protective clothing "that will protect the user against health or safety risks at work".[1] The NHS document 'Infection Prevention and Control' section 7.3.1, Safe Management of Waste states that "Waste must be segregated in line with the respective countries' national regulation and there is no requirement to dispose of all waste as infectious waste in the low risk pathway".

By focussing on this Low Risk Pathway PPE there is the greatest chance to implement practices to recover and recycle waste. With Medium and High Risk pathways where Aerosol Generating Procedures are involved there is a higher risk of contamination and likely need for incineration of waste.

We conducted web-based research on a number of case studies that remanufacture plastics into building materials. Also included in our case study research are projects that remanufacture from other sources for the purposes of collecting or building with waste materials. The aim here was to find solutions to the barriers identified and find innovative methods to re-use ‘hard to re-use’ items.

These case studies led to a number of conversations which we have recorded in our report. The conversations were not audio recorded however notes of important points have been included. These conversations led to further case studies as well as refinement of proposals and recommendations. The conversations ranged from material production to recycling practices and to expert virologists on decontamination of material.

Parallel with this activity we have also been making our own material tests with virgin PPE material. This included tests with aprons and masks and ranges from DIY testing in our own studio (using a table-top heat press) to commissioning Still Life Studio to prototype a stool top made from remanufactured aprons. These tests act as proof of concept with our intention to further this study with both larger scale products and involving used PPE which has been treated and decontaminated.

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PPE Material Categorisation

Apron

Material:
Plastic category 4, Low Density Polyethylene (LDPE)

Composition:
Single material type forming the structure and ties of the item.

Fluid Resistant Surgical Mask

Material:
Plastic category 5, Polypropylene (PP)

Composition:
- 2no layers of non woven PP
- 1no layer internal melt blown PP filter
- PP elastic cord
- PE nose strip

Gloves

Material:
Nitrile Butadiene Rubber (NBR). NBR is a synthetic rubber polymer

Composition:
Single material

Eye Protection

Material:
Plastic category: 7 (other) Polycarbonate

Composition:
- Polycarbonate lens
- Polycarbonate frame
- Stainless steel screw

Full Faceshield

Material:
Plastic category 1, Poly Polyethylene Terephthalate (PET)

Composition:
- PET visor (changeable)
- Foam Headband (reusable)

PPE Material Volume

The Scottish Government publish regular data [1] on the number of PPE items issued to NHS Scotland. In the table opposite we have highlighted the PPE items used on the Low Risk pathway with the numbers issued from 1st March 2020 - 31st March 2021.

We will use these numbers going forward as a baseline for estimating volume of potential material suitable for recycling. While we realise that a proportion of this equipment would need to enter higher risk waste streams destined for incineration we also acknowledge that this study does not take into account numbers for private health care, personal or commercial use and therefore should still be read as a conservative estimate on volume of equipment with potential for re-use.

On the following page these item numbers have been converted to approximate total mass which will be useful in quantifying the impact of re-using / recycling the PPE items.

Table 1: Number of PPE items issued

Item	Since 1 March 2020	In the seven days to 31 March 2021
Aprons	174,960,163	2,444,400
Goggles	2,840,164	0
Type IIR masks	179,884,805	2,040,865
FFP3 masks	6,704,044	175,635
Face visors	12,594,991	100,000
Gloves (singles)	619,694,370	8,370,510
Gowns (non sterile fluid-resistant)	2,589,605	99,252
Gowns (sterile)	1,151,278	26,404
Hand sanitiser	769,990	4,861
Total	1,001,189,410	13,261,927

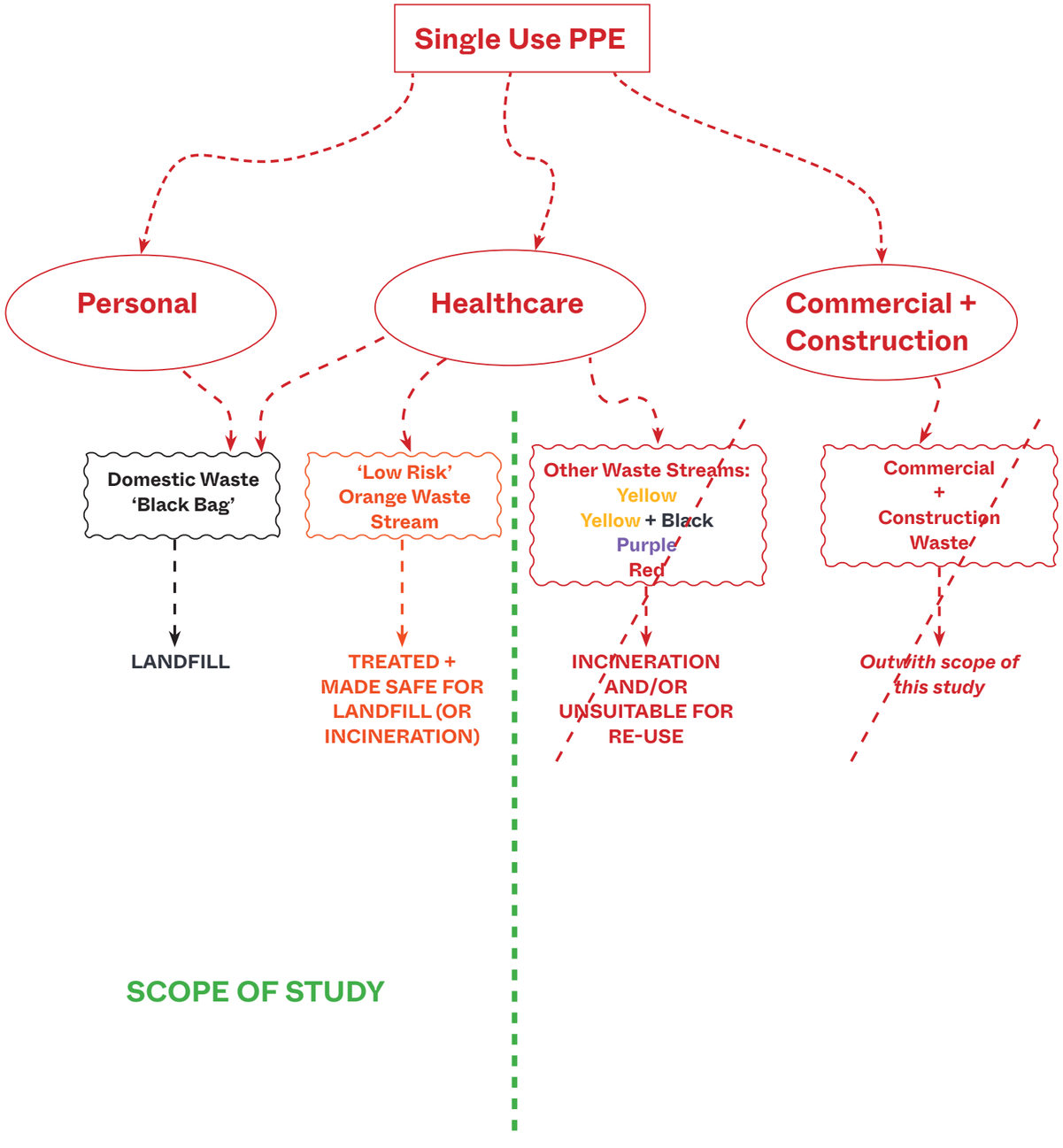
https://www.gov.scot/publications/coronavirus-cov-id-19-ppe-distribution-statistics/

PPE Material Volume

Item	Number Issued Mar'20-Mar'21 *	Individual Mass (kg) (approx) **	Total mass kg / tonnes (approx)
Apron	174,960,163	0.008kg	1,399,681kg / 1,400 tonnes
Goggles	2,840,164	0.021kg	59,643kg / 60 tonnes
Type IIR mask	179,884,805	0.0025kg	449,712kg / 450 tonnes
Face visor	12,594,991	0.027kg	340,064kg / 340 tonnes
Gloves (singles)	619,694,370	0.005kg	3,098,471.85kg / 3,100 tonnes
		Total	**5350 tonnes**

*** Figures taken from www.gov.scot / Coronavirus (Covid-19): PPE distribution statistics**
**** Single items measured with domestic digital scales.**

PPE Waste Stream

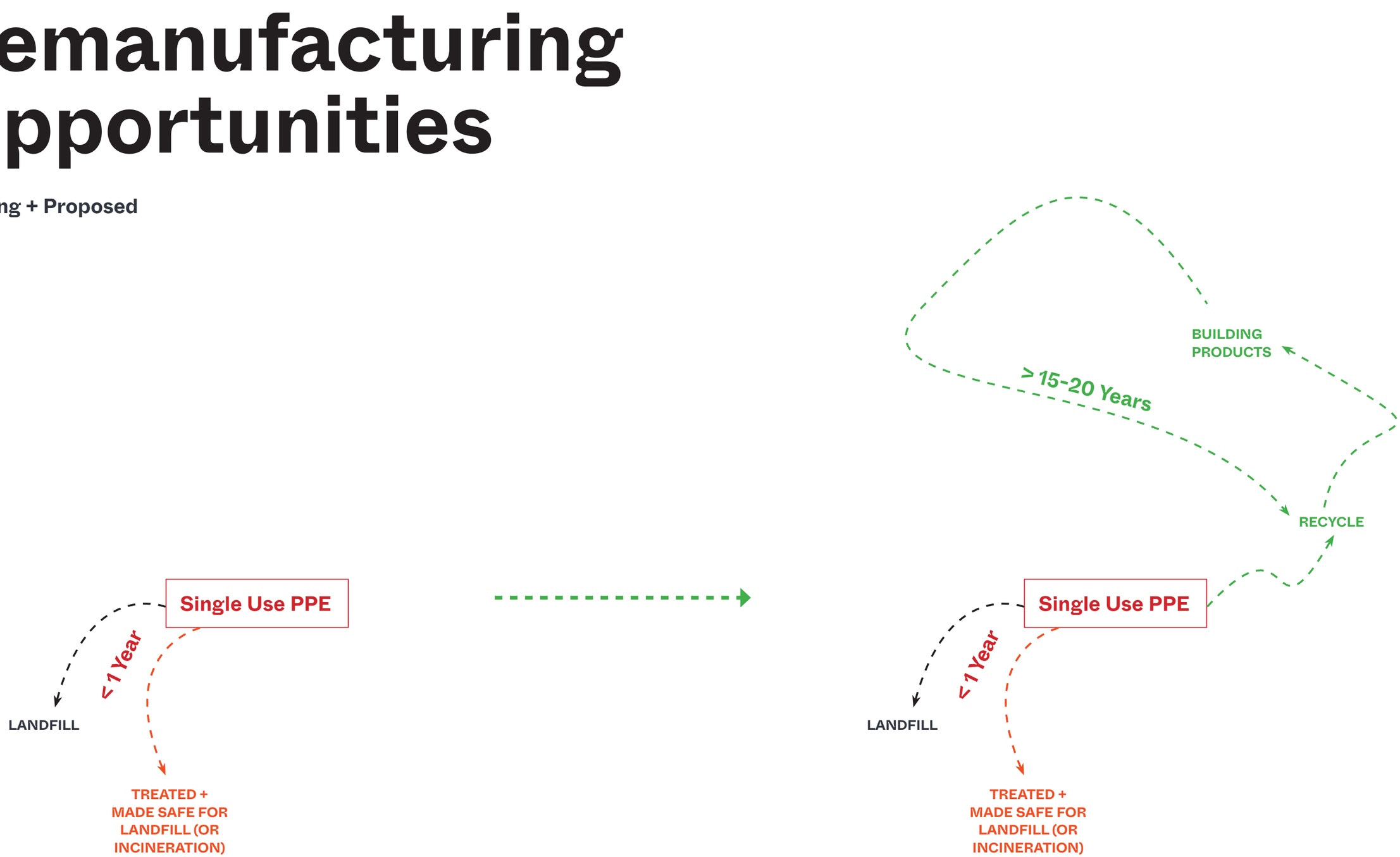


https://www.hps.scot.nhs.uk/web-resources-container/covid-19-the-correct-order-for-donning-doffing-and-disposal-of-personal-protective-equipment-ppe-for-healthcare-workers-hcws-in-a-primary-care-setting/

NHS Guidance differs between, for example, the Waste Prevention and Re-use Guide that states that "gowns and gloves not contaminated with blood and body fluids" are generally suitable for domestic waste streams and specific Covid-19 guidance such as this video showing instructions for donning, doffing and disposal of PPE which recommends the Orange Waste Stream.

Remanufacturing Opportunities

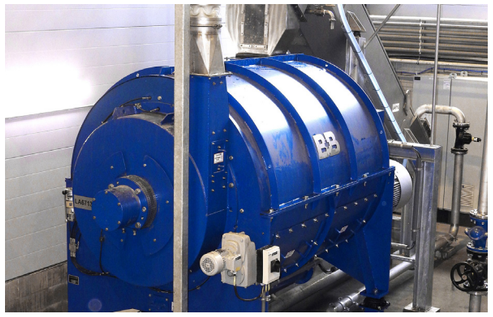
Existing + Proposed



Remanufacturing Opportunities

PPE Product	Material	Applications*	Lifespan
	4 LDPE **Low Density Polyethylene (LDPE)**	• Shipping envelopes • Rubbish bin liners	< 1 Year
		• Rubbish bins • Furniture	5-15 years
		• Plastic lumber • Panelling	5-20 Years
	5 PP **Polypropylene (PP)**	• Broom / Brushes • Houseware	5-15 years
		• Carpet fibre • Plastic lumber	5-20 Years
	**Nitrile Butadiene Rubber (NBR).**	• Toys	1-5 Years
		• Houseware • Furniture	5-15 Years
		• Rubber Flooring • Carpet underlay • Athletic tracks	5-20 Years
	7 OTHER **Polycarbonate**	• Interior Cladding • Plexiglass panelling	5-20 Years
		• Roofing sheets • Polycarbonate Sheet	30-60 Years
	1 PETE **Polyethylene Terephthalate (PET)**	• Plastic bottles	< 1 Year
		• Decorative fabrics • Clothing	1-15 Years
		• Insulation • Furniture Panel • Interior Lining	30-60 Years

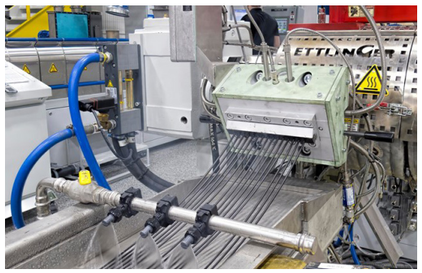
Remanufacturing Opportunities



De- Watering and Drying
The process reduces traces of moisture on the material to nominal figures.

Plastic separation by flotation
Allows heavier contaminant to sink to the bottom to be discarded or to separate the heavier PET from the lighter PP/PE

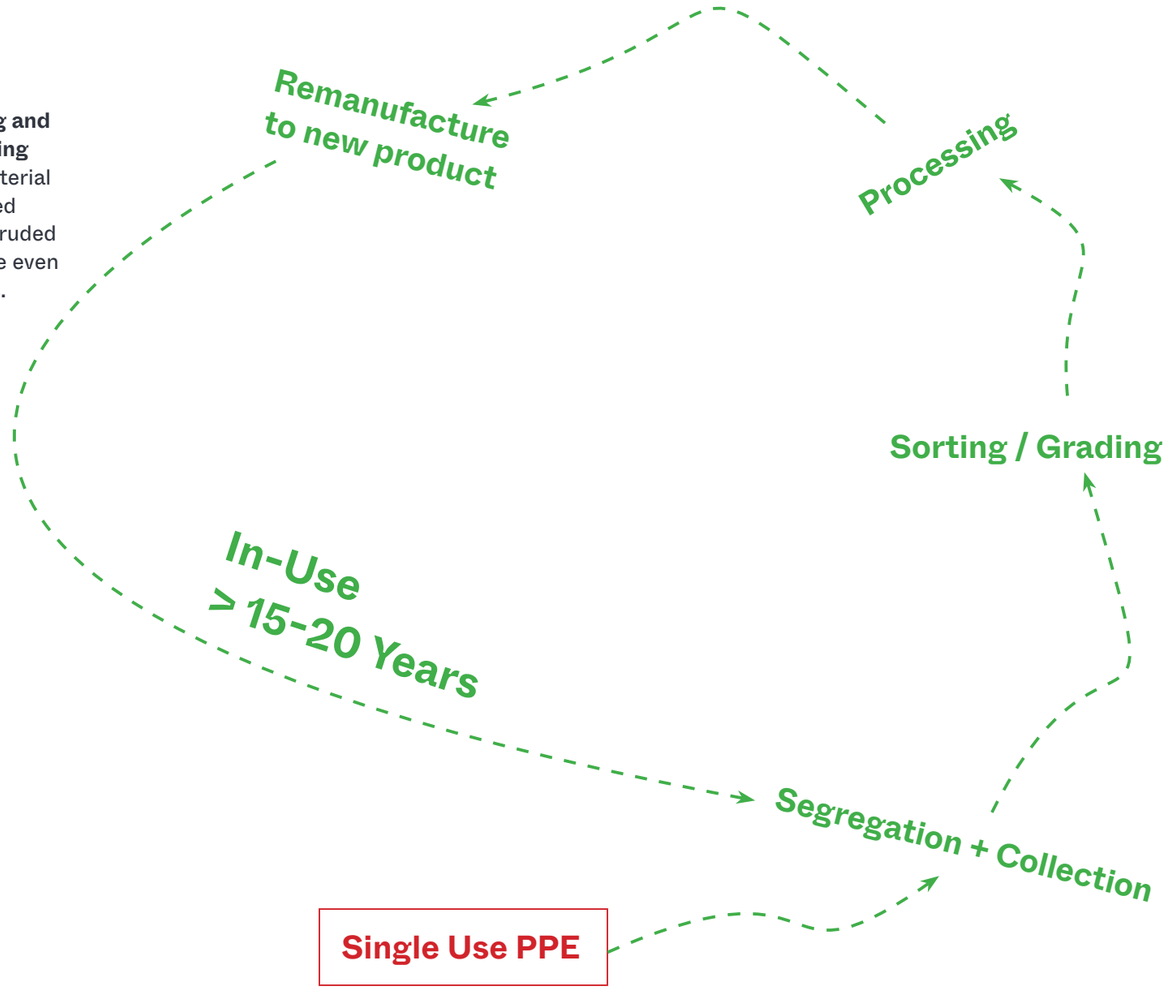
Washing and shredding
Materials are decontaminated by washing (type of washing depending on plastic and contamination) then split in smaller fibres / particles for use in production lines or melting.



Melting and Extruding
The material is melted and extruded into fine even strands.

Baling:
72 hour quarentine for material upon arrival. Materials are sorted by categories and amalgamated before being sent to processors.

Palletising
Strands are then cut into pellets. the pellets are weighted and bagged to be sold for re-manufacturing.



Collecting:
Materials are collected either through direct initiatives (eg, zero waste boxes or new recycling bins).

Remanufacturing Barriers

Barrier 1, Organisational and personnal changes:
For the private user this means the difficulty to access simple recycling streams for items that are not currently wildly recycled. Companies like Terracycle propose 'adopted' recycling programmes for a variety of items. However, such programmes are product centred and organised locally.

KIMTECH™ Recycling programmes are more adapted to corporate users. Terracycle offers partnerships with companies like Kimberley Clark to organise the distribution and collection of PPE. This, as pointed by Dr. Agnieszka Szemiel, while being a very good system, generates more space taken in a facility and more process to set up. The current examples do not work with medical waste streams and contaminated (blood, fluids etc) item of PPE.

Barrier 2, Decontamination:
Relates to the virology or bacterial contamination of the PPE. No recycling can take place if the product cannot be safely handled first. This has been discussed with CVR, the lifespan of an infection on the material of the PPE can be tested to see how to lift this barrier. Within PPE recycling schemes currently undertaken by Reworked and Terracycle this is managed through organised quarantine of the containers for a minimum period of 72H.

Barrier 3, Separation of equipment:
The separation of equipment has an important economic impact and highlights the necessity of setting up appropriate working relationships with companies providing collection and recycling services. At the moment items are either collected separately which multiplies waste streams and can significantly increase the costs and/or sorted on arrival at the recycling facility.

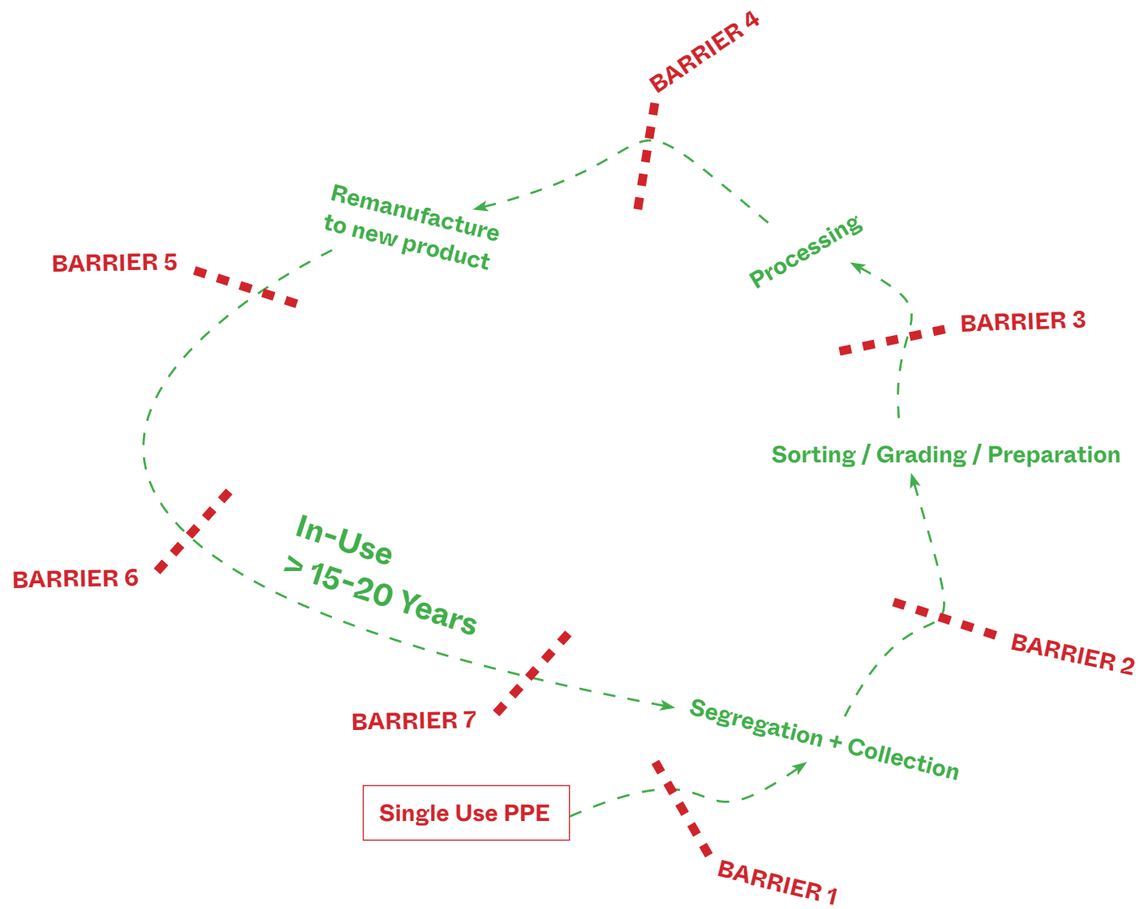
Barrier 4, Quality of recycled material
The resulting product of a recycled item increases in value when the items have been sorted properly to avoid mixing with other types of plastics for example.
It can be important to retain a single type of plastic within the process. Some manufactures, such as Smile Plastics, do use a mixed blend of plastic types in their recycled products however in general the economic value and quality control can be better maintained with single plastic (or other material) types.

Barrier 5, Testing, Certification and Manufacture
When considering the transformation of the recycled product in construction, it is important to acknowledge the weight of certification and performances required of a product to be installed within the fabric of a building. As discussed with Sam Patterson from the CS-IC, the insulation market is saturated by quantities of highly technological and efficient products and considering a recycled approach can reveal challenging. Other elements of the envelope however, as shown in the case studies, may demand lesser performances and have therefore higher circular value.

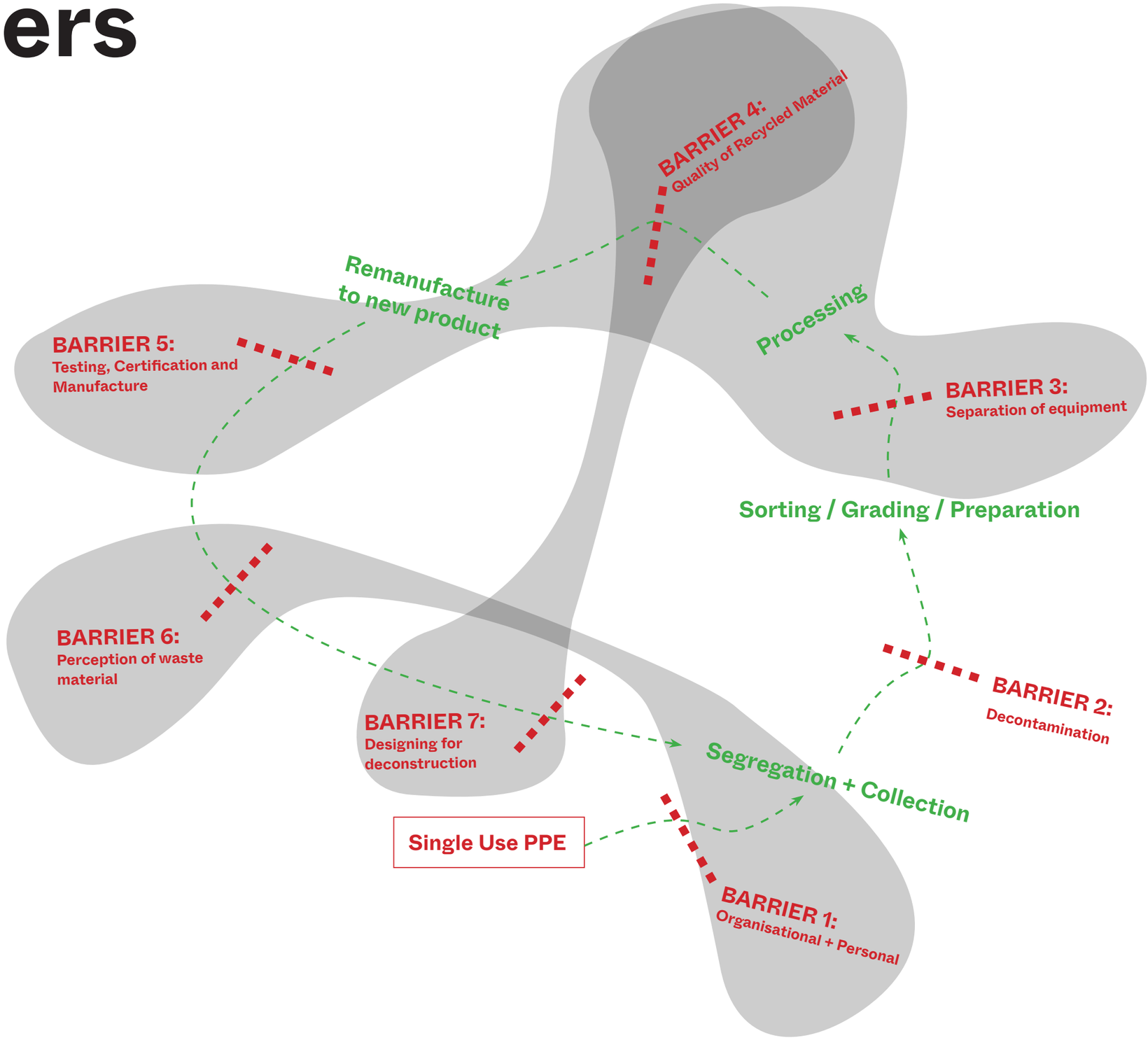
Barrier 6, Perception of waste material
Engaging people to recycle is an important challenge. The opacity, or lack of communication on the recycling process in regard to PPE items and its tangible impact need to be overcome to encourage the wider public as well as health boards to be more aware of the potential issues caused.

Overcoming the negative perception of a 'waste' or 'virus' material being used to construct a new building is another barrier to overcome.

Barrier 7, Designing for deconstruction
To complete the circular loop, any material specified and installed within a building should be detailed in a manner that allows simple deconstruction and re-use. This aspect is particularly problematic with plastic products where the standard solutions are to use strong glues and adhesives for fixing.



Remanufacturing Barriers



Conversations

Having identified barriers to more circularity in the remanufacturing of PPE, we engaged in a series of conversations and exchanges with various professionals and specialist to evaluate and find possible solutions to these.

Collection and Recycling

- Interview with Claire Lot, Terracycle

Decontamination

- Interview with Dr. Agnieszka Szemiel and Professor Arvind Patel, University of Glasgow, Centre for Virology Research (CVR)

Transformation / Manufacturing

- Interview with Sam Patterson, Construction Scotland Innovation Centre (CS-IC)
- Interview with Delphine Dallison, Rag to riches
- Interview with Aaron and WIII, Still Life Studio
- Interview with Alex Laurenson, Architecture + Design Scotland (Materials Library)

Terracycle

07.04.2021
Discussion with Claire Lot and Emma Bevan

Terracycle has been present in the U.S for 20 years and 10 years in Europe.

When taking individually each waste streams, everything can be recycled. The question is, does the cost outweigh the benefit ?

The reality is that recycling, generally is a market and not a public service. In order to compensate the low economic value of most plastics, Terracycle sets up partnerships with companies and large users to help bridging the financial gap.

Large body such as retail and schools form a network of collectors while manufacturers can join the programme by subsidising the waste collection and recycling of a product or a type of product. They become sponsors. The system allows terracycle to expand its recycling services and improve the sponsor's sustainability credentials.

From an operations point of view Terracycle acts locally. The waste collected in the UK is sorted and processed in the UK.

Goal: working with people and outlets that are offering durable solutions for the waste (no landfill or incineration)

Terracycle provides the logistic, delivers the recycling containers, collect and aggregate at the company's warehouse. When a bulk size is reached the plastics to be recycled are sent to third party processors. Along this journey, Terracycle helps the sponsors on communication, marketing and sale.

PPE Items:
The main issue with the PPE is the limited material value (small parts with smaller value) and the clinical hazard. Terra cycle cannot collect contaminated items.

Currently Terracycle has partnerships with companies such as O2 and Carrefour group (in France) to collect the PPE, including masks, used in stores.

Kimberly Clark Example:
The manufacturer gloves for health and hygiene solution offers their client to participate to the recycling programme at no extra cost. The gloves are disposed in a terracycle zero waste box by the user. the box supplied by Kimberly Clark with the products is then collected and send to Terracycle for processing. (See case studies for application)

The gloves are then recycled, turned into a powder that can then be manufactured into flooring, furniture and even insulation.

University of Glasgow, Centre for Virology Research (CVR)

18.03.2021
Discussion with Dr. Agnieszka Szemiel and Prof. Arvind Patel at CVR / CRUSH

CVR, CRUSH is designed to support the following activities:
- Screening the antiviral activity of drugs and therapeutics (e.g. monoclonal antibodies) against SARS-CoV-2, the virus responsible for COVID-19.
- identifying and characterising the emergence of potential drug-resistant viral mutations following treatment with antiviral drugs
- Monitoring the global incidence of SARS-CoV-2 strains with potential drug-resistant mutations and making this information openly available.

Crush provides services to companies to test virus inactivation methods.

Testing decontamination of PPE:
Parters can provide the material to be tested (layer of a mask, gloves,...) and CRUSH can set a timeline based testing for decontamination whether mechanical or natural (at room temperature time for virus to die.

We can discuss a programme and budget for testing, work out which materials are to be tested and devise a cost for the testing.

Current ways of disposal of PPE within the lab:
Bearing in mind that this is different from healthcare as we handle viruses directly, we have a 3 steps decontamination before removal:
- IMS wash
- Chlorine wash
- Autoclave (High pressure / high temperature decontamination)

Need to find when and where to jump in the recycling loop, after autoclave? Before incineration? Proposing change in disposable and recycling on facilities can be another barrier as using additional or more varied disposable containers means more space taken in the room.

To pursue, contact can be made with the HSE (health Safety Executive) for studies and research on the contamination factor of worn PPE.

Construction Scotland, Innovation Centre (CS-IC)

25.02.2021
Discussion with Sam Patterson in preparation of virtual tour of CS-IC non woven pilot line:

The discussion primarily focused on talking about face masks made from Polypropylene (PP) for use within insulation products. The Immediate barriers flagged were cleaning, biohazard as well as the mix of elastic bands within the product.

Quantity and quality of base material needing to be provided for launching tests on the non woven pilot line:
When considering testing the shredding and binding of Polypropylene or any fibres, the volume is an important factor. To provide a sufficient length of finish product we need approximately 1tonne of base material. The collection / study of these materials needs to be designed as it is a barrier at the moment.

While we can consider new PP fabric to implement tests, it is important to acknowledge the decontaminating and cleaning methodology for used PPE. UV light exposure has a proven effect in removing contamination from the fabric but this has a draw back of needing an even exposure to the material (ie, would be hard to treat in bulk). A quarantine period of the material before processing could also be proposed further to relevant guidance (See conversation with CVR)

Trying in-House test:
Best starting with an office shredder to try and get strands of approximately 50/60mm length, hand mix with a binder then fluff to aerate. The good ratio of PP fibres / binder is obtained through a repetition of tests. The binder used at CS-IC is a Bico (bicomponent polyesther) Binder. The mix can then be heated in a simple tin in a domestic oven at 180/200deg.

In theory a product from the line could work with a % of PP from masks with addition of other materials such as cotton but this as well depend on the desired outcomes

04/03/2021
Virtual tour by Sam Patterson of the non woven pilot line at the CS-IC:

Calculate / approach the best ratio binder/base material:
No definite recipe, the point is to understand and find the right size of mix and appropriate temperature, this requires testing with different mixes. This is a test and check approach as the variety of product and application dictates a variety of combination.

Insulation products:
The insulation market is highly competitive. It is difficult to compete with existing earth or green wools. When taking a recycling approach we need to proof the supply and quality of the base material which can prove a serious barrier to overcome.

On another point of view, Post Grenfell standards can prove prohibitive with insurance and performance certificates. There is a very high level of scrutiny on viability and application sectors, processes that can take a lot of time and money to set up

Other applications:
The range that can come out of this system is pretty varied, we can test and produce Acoustic insulation, bedding materials, felt for sofas and furniture, other high performance sport materials,...

Estimate testing rate at CSIC:
£1000.00 / day for running the machine (with staff support included)

^ CS-IC Pilot Line

^ CS-IC product samples

Architecture + Design Scotland

11.03.2021
Discussion with Alex Laurenson, Senior Design Officer, Materials Library (A+DS)

The Materials Library is based at The Lighthouse in Glasgow as a material store of sample materials. It is also an online resource at: https://materials.ads.org.uk

Discussion with Alex covered existing materials in the library that are made from recycled plastics, for example Smile Plastic panels - https://materials.ads.org.uk/recycled-plastic-panel/

The Materials Library is a free resource for anyone to use but is also targeted at architects and designers. Each product is given an overview template, like the image below, and a listing on the database.

PLS PRC UNK SMP 01 Marmax Products Ltd www.marmaxproducts.co.uk

RECYCLED PLASTIC DECKING

GROUND TREATMENT

Origin – location of manufacturing processing plant: UK

Description of product:
Recycled plastic decking board.

Embodied energy (processing plant emissions) – how much energy was used to make the product? (kWh per annum or $kgCO_2$):

data not supplied

Lifespan of materials if maintained correctly(years):

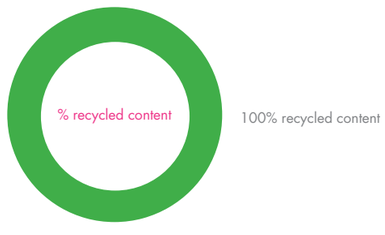
20-50

Thermal Conductivity (k) W/m °K:

data not supplied

Breakdown of product materials (% of each component part):

100% hdpe recycled plastic



100% recycled content

Scan for further information

Oban Joinery Services

25.02.2021
Discussion with Joe MacIntyre, Oban Joinery Services

Discussion revolved around OJS's prototype insulation made from recycled consumer plastic. This is inserted into the outer leaf of a 'double panel' timber frame.

The inner leaf timber frame has standard insulation and fire lining which allows a more experimental approach on the outer leaf.

OJS are currently developing the system further and the appeal of the idea is that the plastic is used in a very 'raw' form without extensive remanufacturing. It is cleaned shredded and packed into the frame.

Delphine Dallison, Rags to Riches

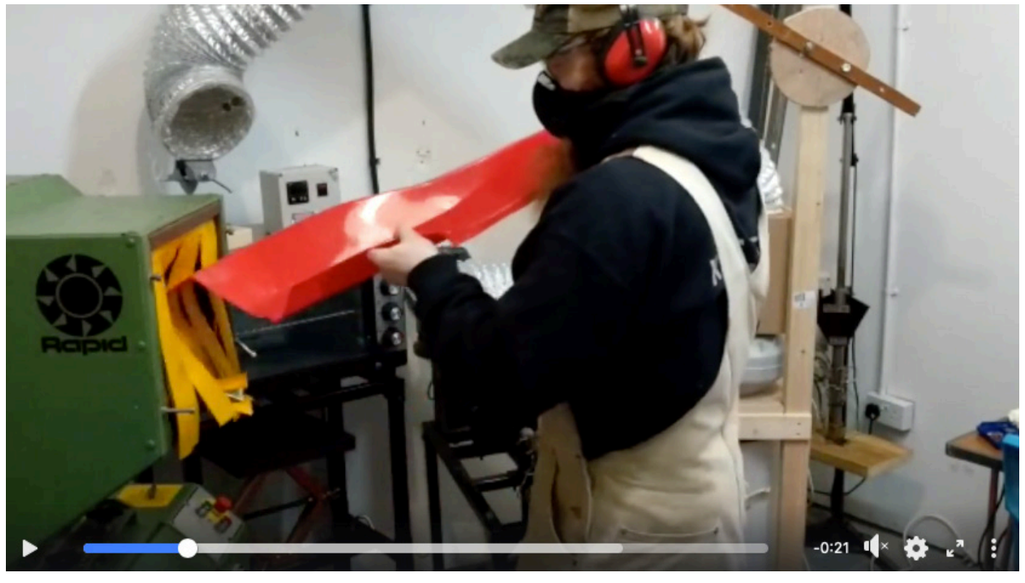
24.03.2021
Discussion with Delphine Dallison, Plastic Workshop Faciltator at Rags to Riches

We discussed the current community outreach projects and other initiatives that Rags to Riches are involved with as part of the Govanhill Baths Community Trust.

The project that had encouraged me to get in touch was from sseing a video of the project recycling broken sledges that they had collected from Queens Park after a weekend of snow.

Delphine explained that the project is in its infancy and is very much centred on community benefit and outreach. They have access to a plastic shredder and basic workshop facilties.

They have been experimenting with different ways of repairing, recycling, remanufacturing and capturing plastic. One idea discussed was to ‘capture’ shredded plastic from PPE items in cast materials such as jesmonite to create a terrazzo effect.



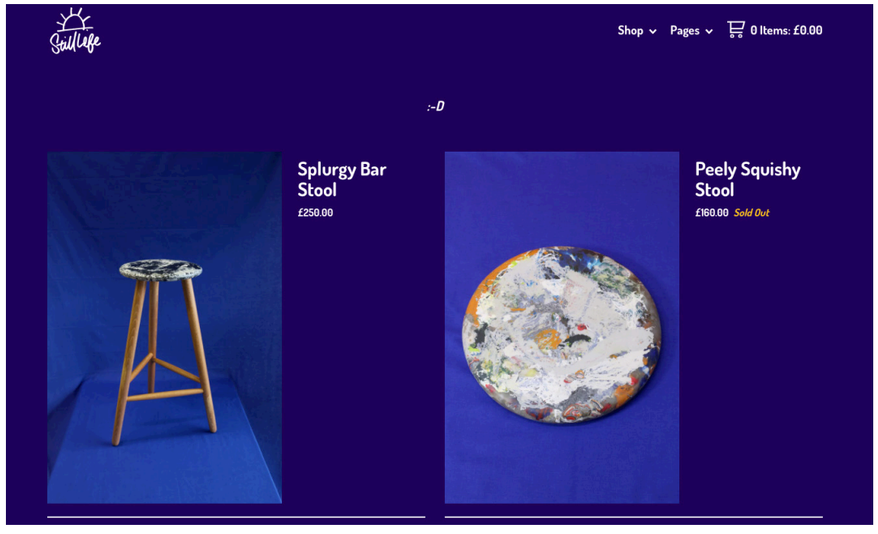
Still Life Workshop

26.02.2021
Discussion with Aaron + Will, makers at Still Life Workshop

Discussion focussed on possible collaboration to remanufacture healthcare aprons made from LDPE plastic into a stool top for which the workshop mould currently.

The workshop currently uses collections of bottle tops, HDPE plastic, to remanufacture into stool tops but the same process applies for them. We agreed to test the material and ordered a batch of white, blue and red aprons from experimentation.

The process involves heating the plastic within a domestic scale oven and then pouring into the mould and leaving to cool. We are continuing with the testing process and aim to complete tests by the end of April 2021.



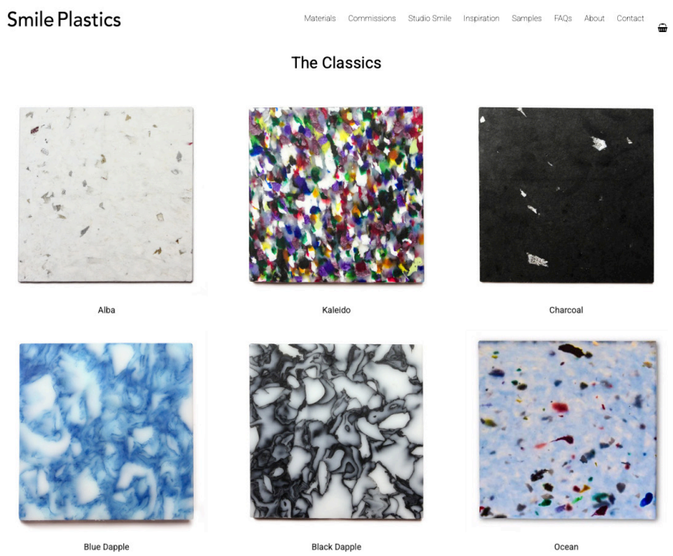
Case Studies

We conducted web-based research on a number of case studies that remanufacture plastics into building materials. Also included in our case study research are projects that remanufacture from other sources for the purposes of collecting or building with waste materials. The aim here was to find solutions to the barriers identified and find innovative methods to re-use ‘hard to re-use’ items.

The following case studies are expanded on in the following pages:

- **Smile Plastics**
- **The One Movement + Plastics for Change**
- **The Good Plastic Company**
- **Gumdrop**
- **Still Life Workshop**
- **Re-beauty: Nordic Built Component Re-Use**
- **Brighton Waste House**
- **Supasoft Insulation**
- **Terracycle**
- **Reworked**
- **RecoMed, PVC Take-Back Scheme**

Case Studies



Project:
Smile Plastics

Overview:
“Smile Plastics is a materials design and manufacturing house making exquisite hand-crafted panels from waste materials.”

Details:

Material type:	Collection / Disposal:	Manufacturing:	Usage / Life Span:
PET	General recycling streams	Furniture and	15-25 Years

INDEMAND

The One Bottle by The One Movement

The only reusable water bottle that transforms ocean plastic into homes for those in need.

Petrice Jones
1 Campaign | Los Angeles, United States

£20,558 GBP by 321 backers
£18,390 GBP by 286 backers on Nov 26, 2020

FOLLOW

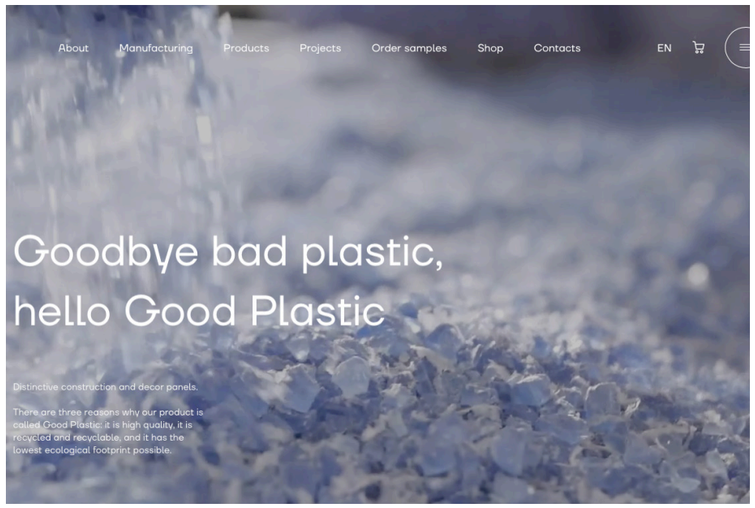
Project:
The One Movement + Plastics for Change

Overview:
Turning ocean plastics into compressed plastic bricks and sheets for house construction. Working with the ‘informal waste collectors’ in poorer areas, Plastic for changes aims to ameliorate their living conditions using the product of the recycling.

Details:

Material type:	Collection / Disposal:	Manufacturing:	Usage / Life Span:
LDPE	informal Waste Collectors	Compressed LDPE bricks & panels	Unknown

Case Studies



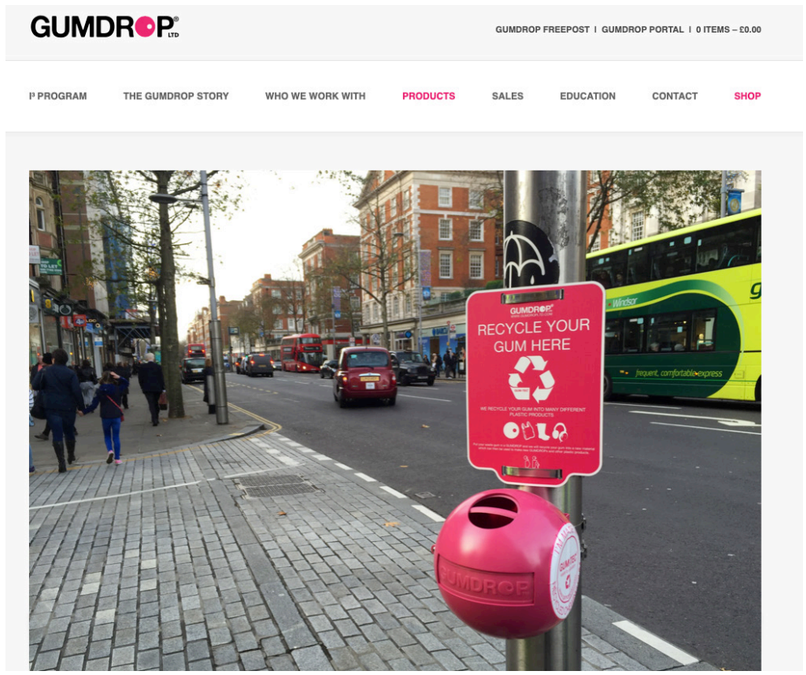
Project:
The Good Plastic Company

Overview:
“The Good Plastic Company is a mission-driven organisation that is determined to contribute to solving the problem of the 400 million tonnes of plastic waste that are generated annually. Plastic waste pollutes our oceans and affects our food chain and more; we want to address one of humanity’s greatest challenges

We produce environmentally friendly recycled plastic sheets. They are high quality and have the lowest ecological footprint possible. Each panel is made from a single type of plastic so it can be easily recycled, extending its use indefinitely.”

Details:

Material type:	Collection / Disposal:	Manufacturing:	Usage / Life Span:
PS, PP, PE, & more	General recycling streams	Furniture and panels	15-25 Years



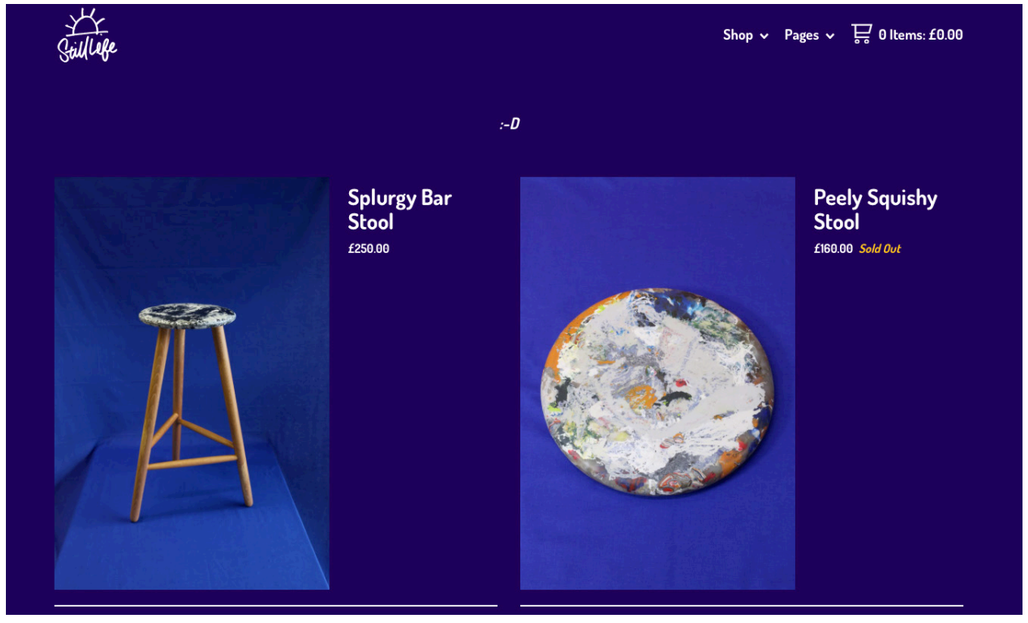
Project:
Gumdrop

Overview:
Turning waste chewing gum into bins for waste chewing gum, Gumdrop has developed a virtuous cycle. While the waste collected can produce more collection point, Gum-tec®, developed by Gumdrop can be used for various manufacturing process.

Details:

Material type:	Collection / Disposal:	Manufacturing:	Usage / Life Span:
Chewing gum	Gumdrop Bin	Gum-tec® Gumdrop Bin	5-15 Years

Case Studies



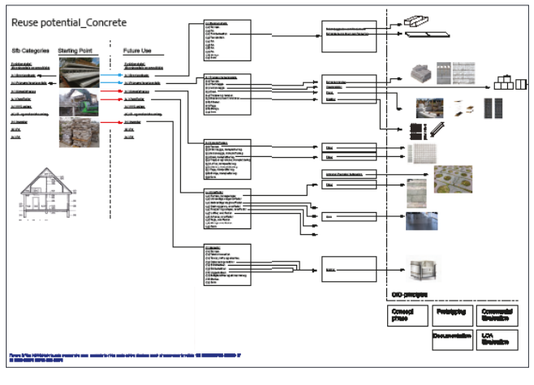
Project:
Still Life Workshop

Overview:
“Still Life is a recycling workshop based in Glasgow. We create furniture & objects using recycled plastic and sustainably sourced Scottish hardwood. We aim to make waste plastic more desirable and encourage it’s use as a resource.

We currently recycle HDPE (type 2) plastic with machines built using plans from preciousplastic”

Details:

Material type:	Collection / Disposal:	Manufacturing:	Usage / Life Span:
HDPE / LDPE	Local Collection	Furnitures & panels	5-20 Years



Project:
Vandkunsten architects
Re-beauty: Nordic Built Component Re-Use.

Overview:
Study by Danish architects Vandkunsten that explores the waste in de-construction and the ways to facilitate more circular economy through manufacturing and critiquing a series of prototype made from collected materials.

Details:

Material type:	Collection / Disposal:	Manufacturing:	Usage / Life Span:
Various	De-construction	Prototypes	25-60 Years

Case Studies

Project:
University of Brighton, Duncan Baker-Brown
Brighton Waste House

Overview:
The Brighton Waste House: a building constructed using over 85% ‘waste’ material and a living laboratory for eco-logical architectural design.

Notable waste materials : vinyl banners forming vapour control layers and carpet tiles used for external cladding

Details:

Material type:	Collection / Disposal:	Manufacturing:	Usage / Life Span:
Various	Community Engagement	85% of a House	25-60 Years

Project:
Supasoft insulation

Overview:
“It takes an average of 12,000 waste plastic bottles to produce enough SupaSoft to insulate a typical loft. That’s 12,000 plastic bottles that would otherwise have been buried in landfill, incinerated or left to litter the environment..”

Details:

Material type:	Collection / Disposal:	Manufacturing:	Usage / Life Span:
PET	General recycling streams	Loft Insulation	25-60 Years

Case Studies

Project:

Terracycle
Terracycle brigades, Zero waste boxes

Overview:

Terra cycle creates networks of collector and sets up partnership with manufacturers. They become sponsors and help bridging the financial gap of recycling low value materials such as PPE

Details:

Material type:	Collection / Disposal:	Manufacturing:	Usage / Life Span:
Various	Zero waste boxes	Producing raw Nitrile	only sponsors durable solutions

Project:

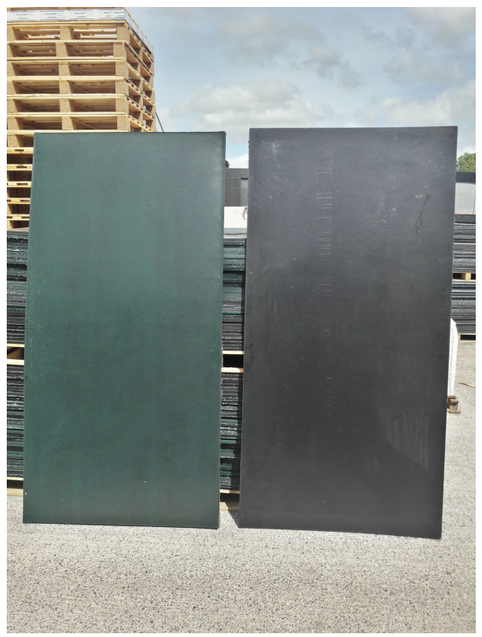
Terracycle
Terracycle - KIMTECH™

Overview:

TerraCycle® and KCP™ have partnered to create The KIMTECH™ Nitrile Glove Recycling Programme - the first recycling programme for disposable gloves.

Details:

Material type:	Collection / Disposal:	Manufacturing:	Usage / Life Span:
NBR	Zero Waste Boxes	Producing raw Nitrile	25-60 Years



Project:
Reworked Storm board

Overview:
Our standard boards are made from 100% mixed waste plastic. This is usually classed as “unrecyclable” plastic and includes bottle tops, crisp packet, cosmetic packaging, food packaging, garden toys etc and means that there could be particles of wood and paper mixed in. Don’t worry, the plastic is cleaned and cooked at over 200˚C during processing.

Details:

Material type:	Collection / Disposal:	Manufacturing:	Usage / Life Span:
Various	Zero waste boxes	Storm Board Panels	10-25 Years

Project:
RecoMed, British Plastics Federation, Axion Consulting
PVC Take-Back Scheme

Overview:
PVC take-back scheme currently being implemented at 36 different NHS hospitals across Britain (as of November 2019). The scheme involves the collection of used PVC medical devices including nasal cannulas; oxygen tubes; anaesthetic masks and oxygen masks. With around 1500 hospitals in the UK, estimates put the total tonnage of PVC waste at over 2,000 tonnes per annum - a potential avenue for significant cost savings for the NHS and a potential driver for the circular economy.

Details:

Material type:	Collection / Disposal:	Manufacturing:	Usage / Life Span:
PVC	Bespoke collection	Collection only	Unknown

Testing

We have collaborated with Still Life Workshop to re-manufacture the LDPE plastic from standard health-care aprons into rigid plastic panelling. In these experiments the result is a stool top as this is the mould that is available.

Further tests will experiment with different colour combinations and document each stage of the process.

400 aprons
(200 blue / 200 white)

=

1 stool top
(310 d x 31mm)

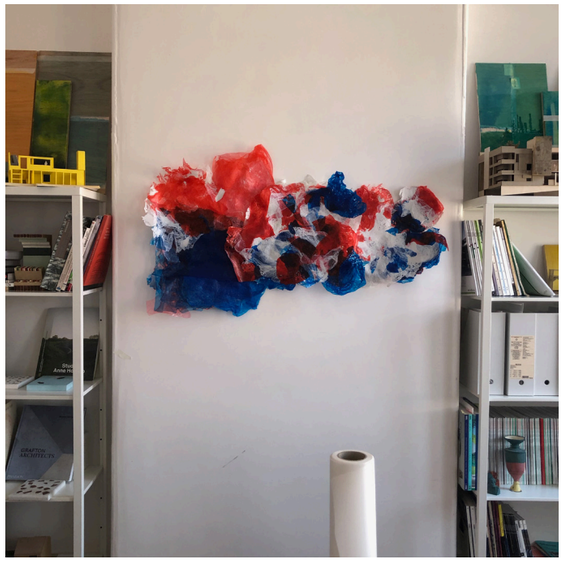
Tested for this project and made by Still Life Workshop

Further prototypes + tests to follow
+
1no. Stool like this to be manufactuered

Testing

Within our own studio we have experimented with using a simple, table-top heat press to reform standard medical aprons.

The result is a wall hanging that can be seen in the bottom right corner made from 72no. aprons of varying colours and ‘ply’.



Proposals / Recommendations

The principal solution proposed in this report is to create an Open Loop process that takes waste PPE items and remanufactures these into materials for the building of new healthcare environments. This would involve partnerships on various levels between NHS Scotland (including it's regional and special boards), recycling specialists, designers, manufacturers and contractors.

We have identified a number of products including internal cladding and panelling, furniture, floor tiles, partitions and technical textiles that would all be suitable for healthcare environments which can be created from waste PPE and lock-in that waste for a minimum of 15 years (although likely longer).

The key recommendations to achieve these solutions are as follows:

Segregation + Collection of Waste
The NHS Scotland Waste Prevention and Re-Use Guide outlines a number of recommendations for segregation of waste in healthcare environments in order to reduce the volume of clinical waste. This guide suggests that up to 50% of clinical waste gets misclassified and could be suitable for treatment / recovery as domestic waste. It goes on to state that healthcare facilities could decrease clinical waste by 15% through improved segregation practices.

Recycling firms such as Terracycle and Reworked have shown that it is currently possible to recover PPE items used during the Covid-19 pandemic, including fluid resistant surgical masks. They have various collection points with commercial organisations which involve a 72hour quarantine period for materials prior to sorting, processing and cleaning. RecoMed PVC Take-back Scheme also evidence recovery of medical equipment from clinical environments.

Our studies have found that the main barriers to better segregation of waste is the space taken within wards for extra bins and the 'just in case' factor of staff choosing the clinical waste stream. These barriers will have increased with Covid-19 at the same time as the volume of PPE being used.

NHS Guidance differs between, for example, the Waste Prevention and Re-use Guide that states that "gowns and gloves not contaminated with blood and body fluids" are generally suitable for domestic waste steams and specific Covid-19 guidance such as this video showing instructions for donning, doffing and disposal of PPE which recommends the Orange Waste Stream.

Clearly Covid-19 has meant that greater precaution is being taken and that risks of infection spreading need to be minimised but given the volumes of PPE now generated we recommend that further conversations between NHS Scotland and recycling partners such as Terracycle (or others) be explored for introducing better segregation of used PPE items which have not been contaminated with blood or body fluids.

Ideally this collection would segregate by items or material type. For example, a separate bin / container for used masks (PP) than for aprons (LDPE).

We understand that further consultation with NHS Scotland and Zero Waste Scotland will be happening concurrently with this report and that we are only scratching the surface of the issues at hand however we hope that these recommendations can support an argument for greater segregation, collection and recovery of PPE Waste.

Decontamination, Separation and Aggregation of PPE Waste
As outlined above there are commercial recycling providers that are currently handling the same PPE items as advised for use on the NHS Scotland Low Risk pathway. We recommend further consultation with these organisations with a view to better understanding the quarantine, cleansing and processing undertaken. This report does not focus extensively on this stage however through our Case Study research we are able to identify potential solutions.

The separation and aggregation of material has an important economic and quality impact and highlights the necessity of setting up appropriate working relationships with companies providing collection and recycling services. The base material of a recycled item increases in value when it has been sorted properly to avoid contamination of other types of plastics for example. If not recycled properly or from a mix of materials the remanufactured product can be of a lesser quality than the alternative virgin material.

The material categories we have identified within the NHS Scotland Low Risk Pathway are:

- Faceshields > Polyethylene Terephtalate (Cat.1 PETE)
- Aprons > Low Density Polyethylene (Cat. 4 LDPE)
- Fluid resistant masks > Polypropylene (Cat. 5 PP)
- Eye protection (goggles) > Polycarbonate (Cat. 7 Other)
- Gloves > Nitrile (NBR)

Remanufacture to new product
The aim of this report was to present possibilities for remanufacturing PPE items into building materials. We have selected 5no. materials and building products that align with the plastic categories listed above that can achieve close to, if not full, 100% recycled content as follow:

- Faceshields > PETE > Technical Textiles (for use in room dividers and curtains)
- Aprons > LDPE > Interior cladding and panelling (for use on walls and reception desks etc)
- Fluid resistant masks > PP > Furniture and recycling bins
- Eye protection (goggles) > PC > Plaxiglass partitions and screens
- Gloves > NBR Nitrile > Rubber floor tiles

All of these materials can be expected to have a lifespan of 15+ years and therefore would present solutions for 'locking-in' PPE waste for an extended time before re-entering the waste stream.

The main barriers that we have identified for working with these products are:
- Testing, Certification and Manufacturing
- Perception of Waste Material
- Designing for deconstruction

Our recommendations for overcoming these barriers are where our own skills can be best deployed (with recommendations for Segregation + Collection and Decontamination, Separation and Aggregation of PPE waste best furthered by others).

Currently we have identified the materials that are able to be remanufactured from the PPE Waste and we are working to visualise these products within a healthcare environment through computer modelling and rendering. These should be available for discussion by May 2021.

We hope that this may be the first step for further conversations and to extend the ‘proof of concept’. We recommend that a prototype 1:1 interior is constructed that would showcase a selection of these products. By going through the necessary processes for design, manufacturing and installation it is possible to test solutions to the barriers directly while also attempting to instil a positive perception of waste as a material.

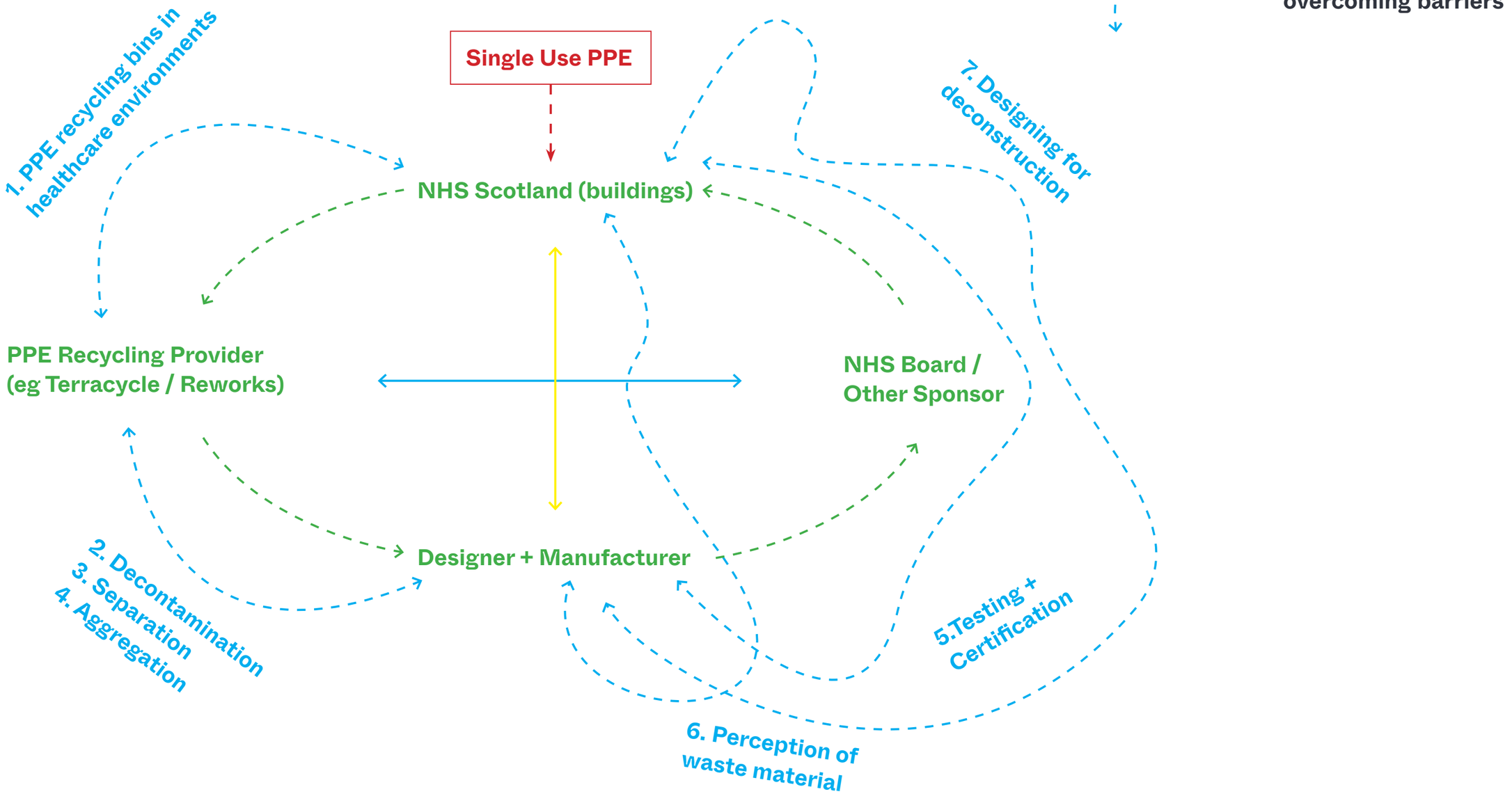
This will undoubtably require strong partnerships as discussed in the previous recommendation. We have produced a number of info graphics which illustrate aspects of waste, cost, raw material and energy reduction as well as the scale of potential. We hope that these can strengthen the argument for greater recovery, recycling and remanufacturing practices of PPE items.

KEY RECOMMENDATIONS:

Strategic:
- Create recycling + remanufacturing partnership between NHS Scotland, commercial recycling firm and sponsors to target recovery of PPE waste.
- Engage with designers to develop new PPE disposal bins in healthcare environments
- Review potential for Open Loop remanufacturing process with PPE items to products and materials for healthcare buildings.

Next steps for this project:
- Develop visualisation and specification for exemplar healthcare interior using products remanufactured from PPE items.
- Build 1:1 prototype interior from products remanufactured from PPE items.
- Consult with NHS Scotland, Zero Waste Scotland and Scottish Institute for Remanufacturing on report findings.

Local + Open Loop Remanufacturing

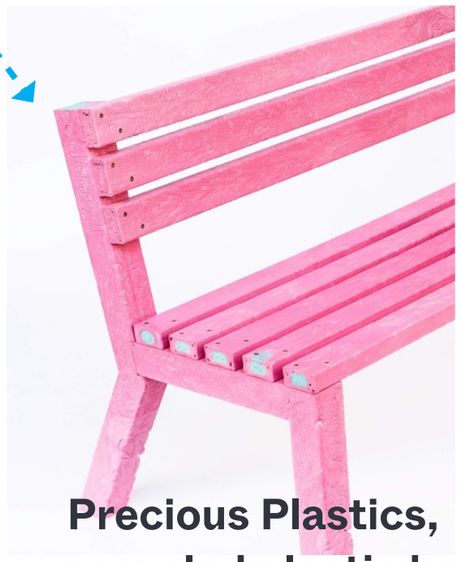


Remanufacturing Flow

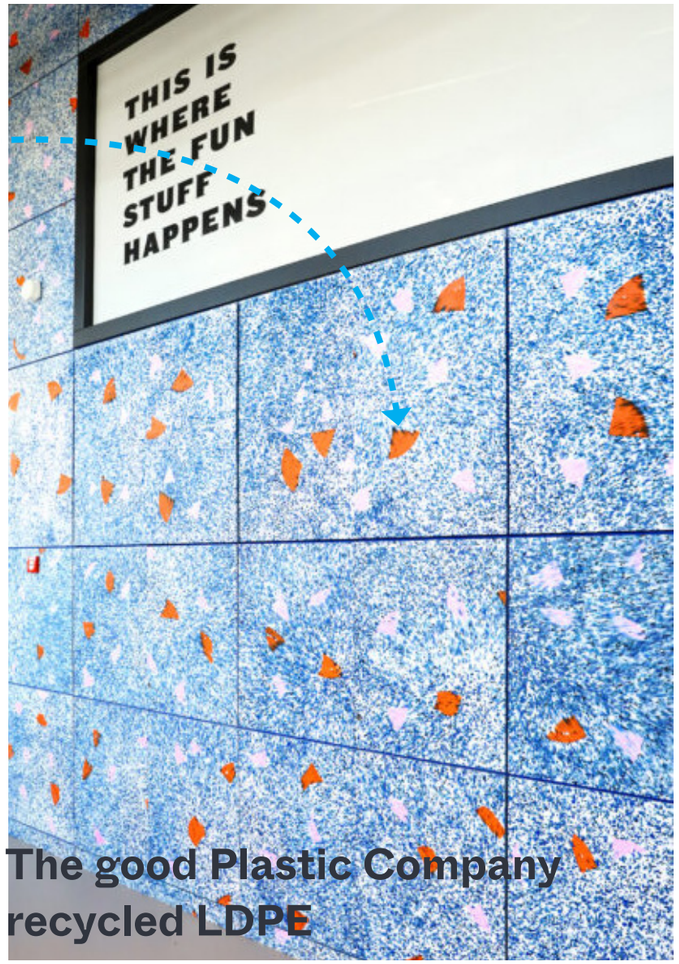
PPE Waste	Segregation + Collection	Sorting / Grading / Aggregation	Processing		Remanufacture to new product	Lifespan
 LDPE Low Density Polyethylene	Orange + Black waste: Better education + signage (ZWS) Partnering with recycling company Space within ward: New bins designed	Partnering with recycling com-pany	Ensure material types are kept separated for highest value	LDPE	**Cladding + Panelling:** • Reception desks • Protective wall surfaces	5-20 Years
 PP Polypropylene (PP)				PP	**Furniture:** • Waiting area seating • Recycling Bins	5-15 years
 Nitrile				Nitrile	**Rubber Floor Tiles:** • Flooring throughout	5-20 Years
 OTHER Polycarbonate				PC	**Plexiglass Partitions + Screens:** • Safety screens • Partition walls	5-20 Years
 PETE Polyethylene Terephthalate				PETE	**Technical Textiles:** • Room dividers • Curtains	1-5 Years

Applications

Reworked, mixed waste plastic sanitising station +



Precious Plastics, recycled plastic bench



The good Plastic Company recycled LDPE

PET waste

Ecore, recycled rubber floor

Impact + Reductions

NHS Scotland Waste Prevention and Re-Use Guide sets a target for “10% of new build and refurbishment project materials (by value) should originate from recycled content, aiming to exceed 15%”. By creating an Open Loop cycle using waste generated by NHS Scotland itself there seems to be a perfect opportunity to capture, remanufacture and lock-in this waste within a local and/or national level.

The same report also states that NHS Scotland could decrease clinical waste by 15% through better segregation practices. While this is a somewhat arbitrary figure within the current context we propose to use this as a baseline to measure the impact that recycling and remanufacturing PPE items could make in reductions for the purposes of this report.

Given that the impact is measured on 15% of all NHS Scotland Low Risk pathway PPE there is clearly potential for a much greater impact when considering other care, public and commercial environments.

The volume increase in PPE items since Covid-19 has heightened an existing issue with NHS Waste Streams and plastic waste in general.

This report provides examples of the scale of impact that could be made by recovering and remanufacturing 15% of certain PPE items issued by NHS Scotland. In the following sections this is done by providing examples of remanufacturing specific PPE items and the resulting reductions to waste, raw material, energy and cost.

Waste Reduction:
The total mass of aprons, masks and gloves issued between Mar ’20 – Mar ’21, as defined under NHS Scotland Low Risk pathway is approximated at 5800 tonnes.
If 15% of this waste could be recovered and remanufactured then it would result in a waste reduction of 870 tonnes that is sent to landfill or incinerated.

Raw Material Reduction:
For this section we have focussed on the apron (disposable LDPE type) to quantify the possible reduction of raw material needed to create new panelling for interior cladding.

In the last year NHS Scotland have issued approx. 175 million aprons.

If 15% of these could be diverted to recycling streams then 26 million aprons with an approx. weight of 200 tonnes could be remanufactured to interior cladding for healthcare environments.

By shredding, heating and re-pressing this material there is the opportunity to create 7,500 plastic cladding panels (2000×1000×12mm) which could be installed in areas where wipe-able, durable surfaces are required.

This would present an opportunity to reduce approx. 180,000m3 of virgin, raw materials within new build and refurbishment projects.

These figures have been calculated through material testing with Still Life Studio and the transformation of 400no. LDPE aprons into a stool top measuring 310mm diameter x 31mm thick.

Energy Reduction:
For this section we have focussed on the surgical facemask (Polypropylene) to quantify the embodied carbon emissions of making a product, a bench for example, with virgin polypropylene as well as other alternative materials.

In the last year NHS Scotland have issued approx. 178 million Type IIR masks.

If 15% of these could be diverted to recycling streams then 26.7 million masks with an approx. weight of 66 tonnes could be remanufactured to furniture and recycling bins.

The industry leading ICE (Inventory of Carbon + Ecology) lists the embodied carbon (kgCO2e/kg) as 4.49 kgCO2e/kg for virgin Polypropylene products.

While the database does not give figures for recycled PP it does give examples of recycled ABS plastic having a 88% decrease in embodied carbon in comparison with virgin ABS and recycled HDPE having a 76% decrease.

British Plastics Federation and their members Axion Polymers claim there is a 73% decrease in embodied carbon when working with recycled PP in comparison with virgin PP.

This would therefore suggest an embodied carbon value of around 1.21 kgCO2e/kg which is much closer to a material such as plywood (0.5 kgCO2e/kg) which is generally perceived as more sustainable but harder to use in healthcare settings.

To give another example, aluminium products have embodied carbon emissions of 9.22 kgCO2e/kg.

Cost Savings:
The cost savings outlined this report are in relation to NHS Waste Management. NHS Scotland Waste Prevention and Re-Use Guide gives this average yearly waste disposal cost:
Clinical Waste = £420/tonne
Domestic Waste = £122/tonne
Recyclable Waste = £75/tonne

If 15% of all PPE items currently placed into a clinical waste stream could be diverted to recycling and remanufacturing streams then it could result in an approx. 12% cost saving on waste management of those PPE items.

For the PPE items included in this study the cost saving of diverting 15% of them to recycling would amount to £300k/year.

This report has not included revenue analysis however information given in previous sections can give an indication of scale.

To use an example of nitrile gloves which produced approx. 3000 tonnes of waste in the last year then the cost saving on disposing of gloves alone could equate to approx. £160k/year.

These gloves could then be remanufactured into rubber flooring for healthcare environments.

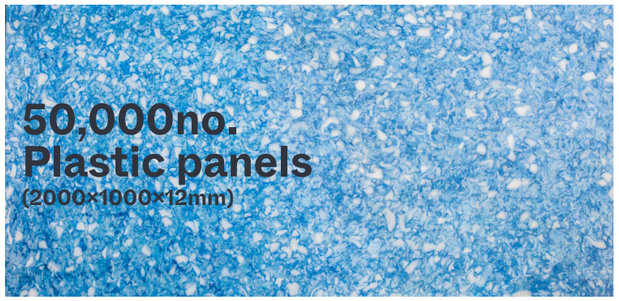
.....

This report has not included revenue or job creation analysis however information given in previous sections can give an indication of scale.

Raw Material Reduction

=

Example of ‘Blue Dapple’ panel made from chopping boards and plastic packaging by Smile Plastics

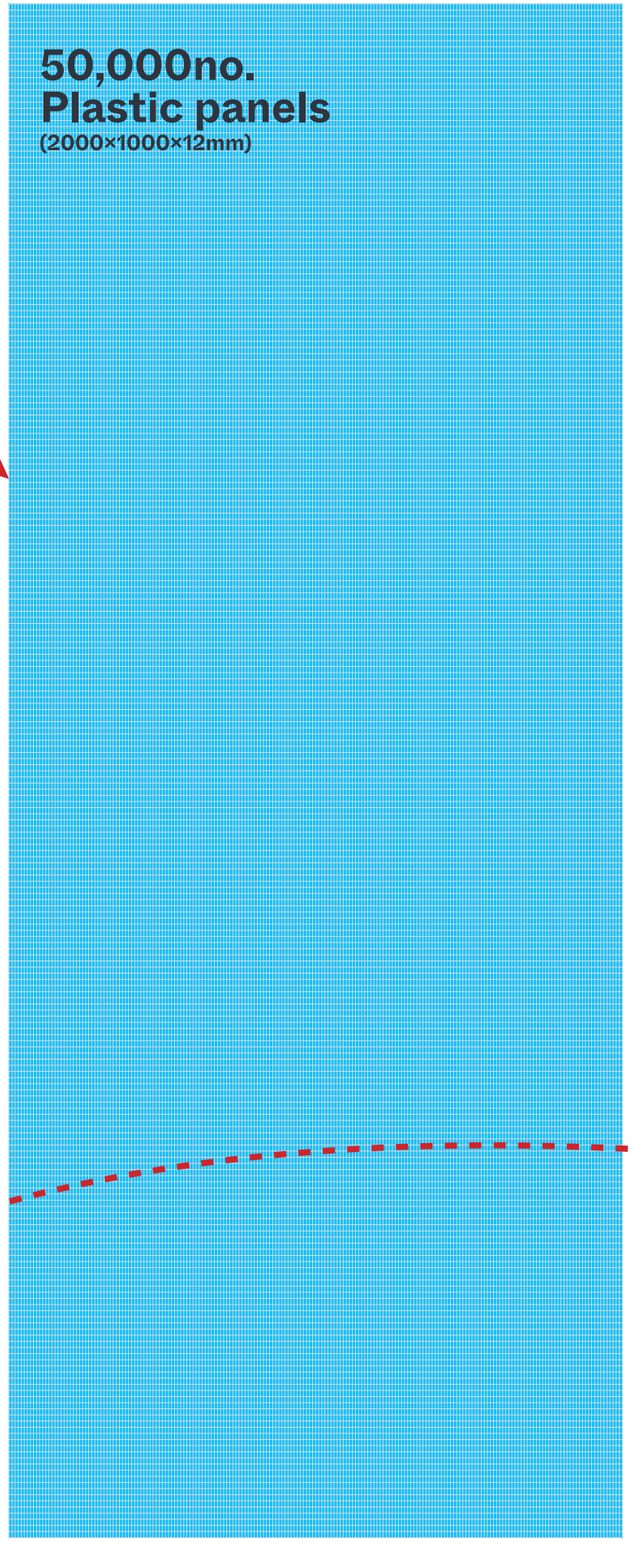


175 million aprons
issued by NHS Scotland in 2020-21

If 15% of all aprons issued by NHS Scotland in the last year could be diverted to recycling streams rather than medical waste then they could be used to create plastic panelling for interiors.

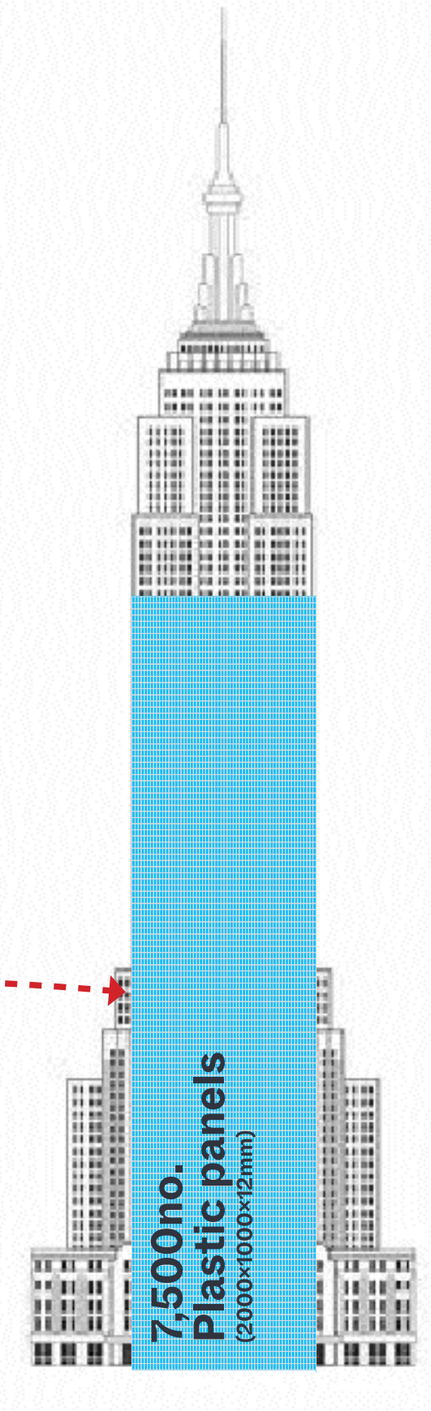
=

26 million aprons
15% of total aprons issued by NHS Scotland



If 100% of aprons could be recovered for remanufacture into 12mm plastic panelling then you could clad the Empire State Building.

With 15% of aprons recovered you could still cover the area highlighted below!

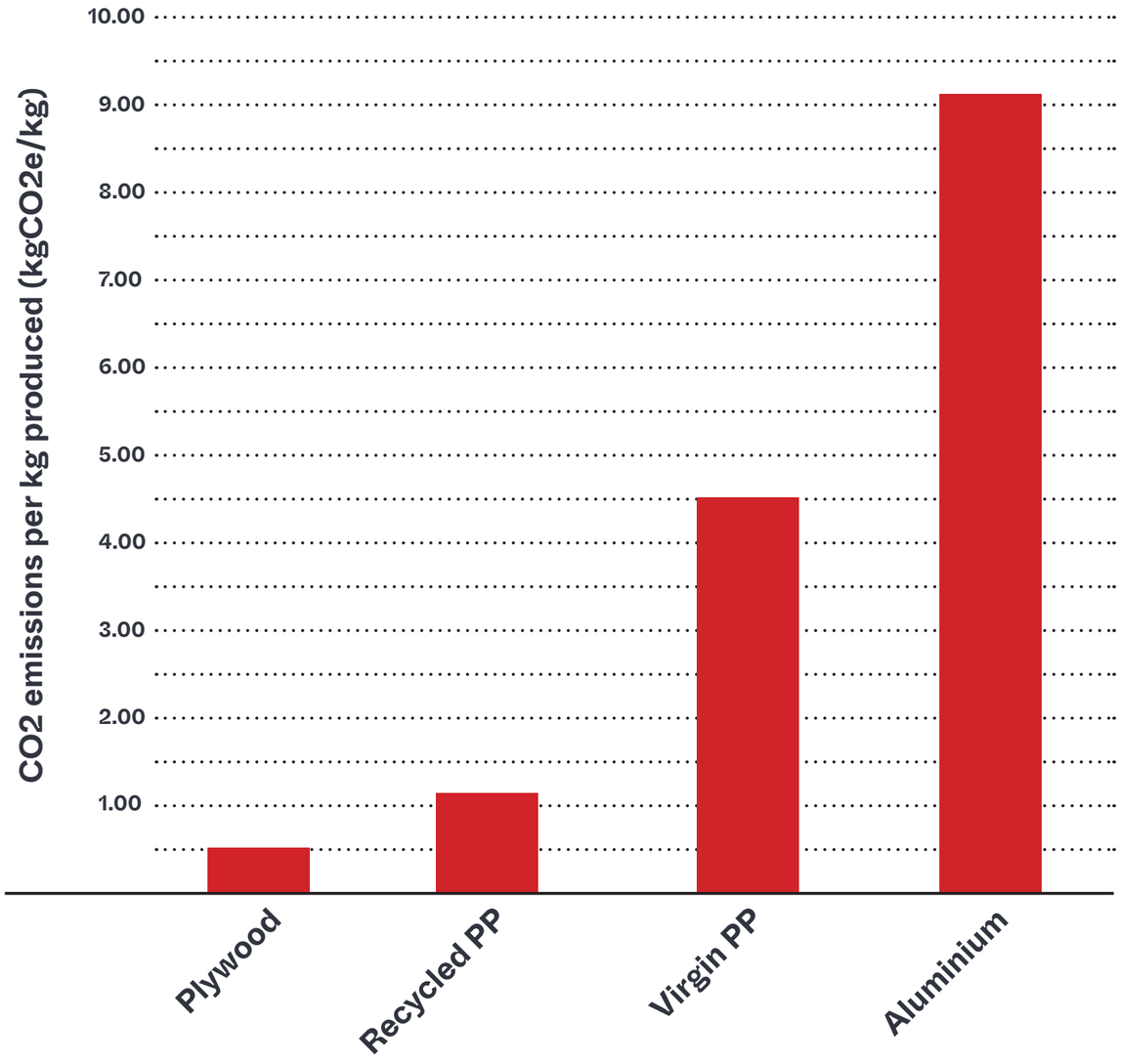


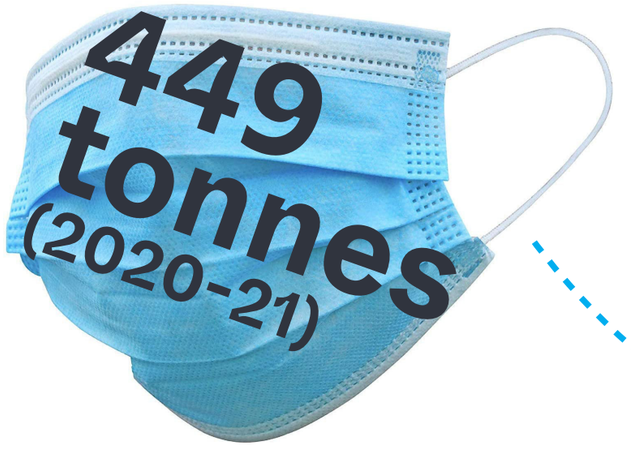
Energy Reduction

^ Recycled plastic bench from Precious Plastics

73% reduction

for embodied carbon emissions of recycled PP in comparison with Virgin PP plastic





^ Approx mass of Type IIR masks issued by NHS Scotland last year

If 15% of all Type IIR masks issued by NHS Scotland in the last year could be diverted to recycling streams rather than medical waste then they could be used to replace virgin polypropylene for creating products such as furniture and plastic lumber.

Cost Savings

5000 tonnes (2020-21) ^ Approx mass of PPE items issued by NHS Scotland last year

-15% / 750 tonnes

Average yearly waste disposal cost (£/t)*

Clinical Waste 420

Domestic Waste 122

Recyclable Waste 75

< Figures obtained from NHS Waste Prevention and Re-use Guide

If 15% of all PPE items currently placed into a clinical waste stream could be diverted to recycling and remanufacturing streams then it could result in an approx. saving of - £250k/year on waste management of those PPE items.

- £250K / year saving

University of Strathclyde Engineering

DEPARTMENT OF ARCHITECTURE

Dress for the Weather