THANK YOU TO OUR 2018 RPET ROUND TABLE PARTNER:

NSF®
rPET Meeting Goals

• Provide a market update
• Identify mechanical rPET intervention points
• Updates on chemical rPET innovations
• New goals for 2030
rPET Meeting Agenda

- 2 minute Introduction by our Sponsor - NSF
- 13 minute opening
  - Goals
    - rPET Commitment status
    - Market updates
    - rPET mechanical supply chain intervention points
    - future of rPET chemical developments
    - New goals for 2030
- 50 minute presentations
  - 20 minute market update ICIS
  - 20 minute rPET Outside of Textiles
  - 10 minute microfiber report out EOG – Katy remote
- 10 minute break
- 125 minute working session
  - 75 minutes Mechanical – Bill - Where can we intervene and make progress
  - 15 minutes Chemical – Karla update on the chemical recycling landscape
  - 15 minutes new goals 2030 based on today’s work
- 10 minutes Wrap-up
rPET Commitment Status

• Collective usage of rPET among the signatories grew by 36% and did so two years before the challenge’s projected end-date.

• Textile Exchange’s 2018 Preferred Fiber & Materials Market Report also showed that, among participating companies, the top three rPET users are all signatories of the challenge.

• Overall, companies that participated in the Preferred Fiber & Materials Benchmark program, reported a 28% increase in rPET usage.
A review of rPET market

Matt Tudball
Head of European Markets, ICIS

Susan Mair
Analytics & Consulting, ICIS
Virgin Polyester Chain

- Global production

- para-xylene: 41 million tonnes
- MEG (mono ethylene glycol): 24 million tonnes
- PTA (purified terephthalic acid): 61 million tonnes
- PET melt: 70 million tonnes
  - PET resin: 27%
  - polyester fibre: 68%
  - polyester film: 5%

Source: ICIS Supply & Demand Database
www.icis.com
Recycle Polyester Chain

- Global production

- PET bottles → PET flake / pellets
  - 41 million tonnes

- PTA (purified terephthalic acid)
  - 61 million tonnes

- MEG (mono ethylene glycol)
  - 24 million tonnes

- PET melt
  - 70 million tonnes
  - 15 million tonnes

- PET resin
  - 23 million tonnes

- Polyester fibre
  - 57 million tonnes

- Polyester film
  - 4 million tonnes

Source: ICIS Supply & Demand Database
PET Melt Phase Capacity

- PET melt phase CAGR 6.5% from 2000-2017
- Growth is set to slow going forward
- By 2030 recycled PET melt from mechanical recycling is forecast to account for 20% of global capacity
- Chemical recycling becoming a more feasible option

Source: ICIS Supply & Demand Database
Recycled capacity – China dominates

- rPET Melt Phase Capacity 2017
  - CHINA: 69%
  - ASIA EXC CHINA: 11%
  - EUROPE: 8%
  - NORTH AMERICA: 8%
  - OTHER: 4%
  - 20 million tonnes

- rPET Melt Phase Capacity 2030
  - CHINA: 65%
  - ASIA EXC CHINA: 15%
  - EUROPE: 8%
  - NORTH AMERICA: 6%
  - OTHER: 6%
  - 32 million tonnes

Source: ICIS Supply & Demand Database
China R-PET Import Ban

• 2018 ban on plastics imported into China

• Already seeing production shifting to other countries in Asia

• Virgin operating rates increasing as a result

Source: China customs
European feedstock price drivers

• Crude oil movements drive feedstocks

• Drops in crude, naphtha drove down prices in March

• September PX/PTA spikes result of tightness in Europe and rise in Asia PX
European PET price drivers

- Crude oil drops narrowed gap between PET and rPET in 2015
- Preference for virgin impacted recycling capacity
- 2018 – market tightness impacted prices
- US ADD could increase imports

Source: ICIS
Sustainability is rapidly becoming top focus for petrochemical industry
European petchem producers buying up recycling companies
Lack of recycling capacity could impact sustainability goal implementation
Opaque market in terms of rPET availability and quality
Questions and contact

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Matt Tudball
Head of European Markets
Matt.tudball@icis.com
Cross Industry Collaboration

Maurizio Crippa
CEO at gr3n SAGL
What’s Going on RPET Sector Outside of Textile?

The project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement no 768573.

Call identifier: H2020 – SPIRE-09-2017
Only 12.5% of global PET/polyester production is recycled...

Recycling itself has an impact
Incineration is still the most common way of «recycling»...

Energy “recovery” is not circular
Every year 8M tons of plastic waste leak into the oceans...

Unpredictable effects on environment
On a global basis 83% of tap water and 93% of bottled water is contaminated by plastic microfibers, which entered into the food chain...

Unpredictable effects on environment
PET/Polyester Life Cycle in figures: textile value chain absorbs all the material

Source: ICIS 2015 data

- Virgin PET production: 72Mt
- PET packaging: 24Mt, Avg life = 0.5yrs, σ = 0.1yrs
- Textile: 48Mt, Avg life = 5yrs, σ = 1.5yrs
- Textile waste: 33Mt
- Recycled textile: <0.1Mt
- Packaging 33%
- Packaging waste: 23Mt
- Recycled packaging: ~9Mt
- 53Mt(2)
- 37Mt
- Landfill and dispersed
- 16Mt Incinerated

(1) 1.8Mt loss in the recycling process
(2) Including secondary production
PET/Polyester current market structure: numerous players and high waste
PET/Polyester new market segment: taking unwanted waste to close the loop
Beverage industry: the brands commitment

How does Coca-Cola’s 100% recycling commitment stack up?

Coca-Cola says it is ‘fundamentally reshaping its approach to packaging’ by pledging to collect and recycle the equivalent of 100% of its packaging globally by 2030. But what does this mean in practice?

‘A vision for zero plastic packaging waste’: Danone, Nestlé and others set out industry challenge to rethink plastic

Danone, Nestlé, Suntory and other bottled water and soft drinks companies have set out their vision for a future where no plastic packaging is sent to landfill or ends up as litter. How can this be achieved?
Achievability: not enough material to get the targets

Despite the high collection rate in some areas and the optimized value chain for sorting and recycling, the current technology is unable to provide enough material.

PET = 82m tons

- Polyester fibers: 54 tons
- Polyester film: 4m tons
- Pet resin: 24 tons
- Mixed colors: 14m tons
- Light blue: 6m tons
- Light blue: 4m tons

Mechanical recyclability:
- 66% not recyclable
- 5% only 5% recyclable
- 17% recyclable
- 7% recyclable
- 7% recyclable

Source: ICIS 2016 data
Current technology: linear process to non-useful material

Virgin PET + Additives: • plasticizers • UV protectors • Pigments • radical scavengers • etc.

Bottle PET → R-PET → Unusable polymer
Innovative technology: circular process to infinite useful material
Innovative technologies: different methods for the same purpose

- Several depolymerization reactions can be chosen
- The main driving forces of the choice are:
  - The economical benefits in terms of reaction energy/time and product purification efforts
  - The purity of the products according to the feedstock contamination

References:
Actions: PEPSICO -> LOOP

Montreal, Quebec and Purchase, New York (October 9, 2018) – Loop Industries, Inc. (Nasdaq: LOOP), a leading technology innovator in sustainable plastic and PepsiCo, Inc. (NASDAQ: PEP) today announced that they have entered into a multi-year supply agreement that will enable PepsiCo to purchase production capacity from Loop’s joint venture facility in the United States and incorporate Loop™ PET plastic, which is 100% recycled material, into its product packaging by early 2020.
Unilever to pioneer breakthrough food packaging technology together with Ioniq & Indorama Ventures

04/04/2018

London/Rotterdam – Unilever has announced a partnership with start-up company Ioniq & the largest global producer of PET resin Indorama Ventures to pioneer a new technology which converts PET waste back into virgin grade material for use in food packaging.

Ioniq has developed a proprietary technology that is able to convert any PET waste - including coloured packs - back into transparent virgin grade material. The technology has successfully passed its pilot stage and is now moving towards testing on an industrial scale.

PET (Polyethylene Terephthalate) is widely used to produce plastic packaging, yet worldwide only around 20% of this material makes its way to recycling plants with the rest either incinerated, disposed of in landfills or leaking into the environment.
Actions: L’ORÈAL -> CARBIOS

L’Oréal and Carbios to develop plastic bio-recycling technology

Cosmetics firm L’Oréal has signed a partnership agreement with French biotech Carbios to develop new bio-recycling technology to address plastic pollution.

As part of the collaboration, which is open to companies from any other sectors looking to develop new plastic bio-recycling solutions, a new five-year consortium that will work on Carbios’ enzymatic bio-recycling process for plastics will be formed.

The consortium aims to bring the bio-recycling technology to market on an industrial scale.

“This consortium will enable Carbios’ bio-recycling technology is capable of breaking down plastic waste in a sustainable way.”

The collaboration is part of a broader effort by L’Oréal to reduce its impact on the environment and align with the UN Sustainable Development Goals.
Actions: COCA COLA -> gr3n/DEMETO

What is ‘chemical recycling’ and why is it exciting?

It is a chemical process that can turn previously un-recyclable plastic (PET) into new bottles, clothes and other everyday products. Currently, PET is mechanically recycled, involving expensive machinery to sort, shred and wash the plastic. This works well, but to recycle PET to make new food and drink packaging — so-called “food-grade” PET — you can only use existing food-grade plastic. One of the main problems with recycling PET is the limited supply of good quality, food-grade PET on the market. This makes it more expensive than new PET, and also means there’s a lot of plastic out there that can’t be recycled, and too often ends up in landfill, incinerated or as waste in our streets and oceans.

In fact, only 20 percent of all PET is currently recycled, which shows how much never makes it back into the value chain. The really exciting thing about chemical recycling is that any waste plastic (PET) can be used to make food-grade PET, not just used plastic bottles, but also waste recovered from oceans and plastic from other sources, like polyester textiles. Ultimately, if all plastic can be recycled, then waste plastic could potentially become a thing of the past.
Thanks for your attention!

Maurizio Crippa
CEO @ gr3n sagl
maurizio.crippa@gr3n-recycling.com
Outdoor Microfiber Consortium: Progress and next steps

Dr. Katy Stevens, European Outdoor Group
Outdoor Microfibre Consortium

• An industry response to actively understand the problem of microfibre shedding and develop industry based solutions.

• This collaborative, brand driven approach encourages more in depth research projects, and facilitates greater levels of understanding and solution building than would be achievable alone.
Microfibre Consortium – why?

- Lack of consistent and in some cases contradictory data – including variations in methodology
- Uncertainty over scale and severity of the problem based on data
- Need for industrial alignment to reduce replication and encourage alignment

<table>
<thead>
<tr>
<th>Sample</th>
<th>No of washes</th>
<th>No of shed fibres</th>
<th>Mass shed (w%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Browne 2011 blanket</td>
<td>1</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Browne 2011 fleec</td>
<td>1</td>
<td>290</td>
<td></td>
</tr>
<tr>
<td>Browne 2011 shirt</td>
<td>1</td>
<td>160</td>
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<tr>
<td>Bruce Patagonia A Technical</td>
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<td>0.493</td>
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<tr>
<td>non-fleece synthetic jacket</td>
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<tr>
<td>Bruce Patagonia B Synthetic</td>
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<td>0.282</td>
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<tr>
<td>fleece pullover</td>
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<td></td>
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<tr>
<td>Bruce Patagonia C Synthetic</td>
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<tr>
<td>fleece midlayer jacket</td>
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<tr>
<td>Bruce Patagonia D Synthetic</td>
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<tr>
<td>sweater fleece jacket</td>
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<tr>
<td>Bruce Budget Budget synthetic</td>
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<td></td>
<td>0.404</td>
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<tr>
<td>sweater fleece jacket</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Napper 2016 PET-cotton jumper</td>
<td>5</td>
<td>137931</td>
<td>7.5E-06</td>
</tr>
<tr>
<td>Napper 2016 polyester jumper</td>
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<td>4.65E-05</td>
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<td>Napper 2016 acrylic jumper</td>
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<tr>
<td>Pire 2016 fleece blanket</td>
<td>10</td>
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<td>0.0012</td>
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</table>

Outdoor Industry Microfibre Consortium - Outputs

**Strategy**
- Roadmap – complete
- Infographic - complete

**Integrity**
- Test method development – draft method available Oct 2018 for validation process

**Research**
- Don’t feed the fish – complete
- Virgin v’s recycled – in progress
- Understanding colour – in progress

**Product development**
- Tools for product development teams
- Product based solutions
Microfibre Infographic: Why?
Microfibre release from garments, is a cross industry challenge affecting all fabric types, through in-process manufacturing and consumer use (through fibre pull out and fragmentation). Solutions to this challenge will be found in cross-industry process modifications and fabric reengineering.
The Outdoor Industry Microfibre Consortium: Work-Streams

The Microfibre Infographic will be used as a framework to guide the work of the consortium.
Test method development

- Method due for public release Q4 2018
- Extensive in house repeatability and validity testing complete
- Multi lab reproducibility testing to carried out over coming weeks
- Inclusion in global discussion to develop single harmonised test method
Manufacturer projects

Virgin v’s recycled

This work will answer the questions

1. Does recycled raw material effect microfibre loss at the product level?

2. Which recycling processes are less impactful than others, and what understanding can we apply to engineering new solutions?

Understanding colour

This work will answer the questions

1. What effects do different colouration methods?

2. Which processes / routes to product are less impactful than others and what understanding can we apply to engineering new solutions?

Project progress

• Samples prepared and ready for testing (dependent on release of test method)
• Expected completion – Q4 2018
# Microfibre Consortium: Roadmap 2.0

## 1. Structure & Strategy
Ensuring the consortium is positioned to deliver product development support to its consortium members.

<table>
<thead>
<tr>
<th>Earlier</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consortium Forms</td>
<td>Consortia Evolves</td>
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</table>

## 2. Integrity
Embedding Microfibre management, within global and national policy.

One standard apparel & textile certification to assess fibre loss.

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<th>2018</th>
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<td>AATCC</td>
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## 3. Research
Environmental research to identify the scale of the issue and industry research at the polymer, fibre, yarn, fabric, garment and laundering level.

Used for the creation of understanding, development, industry guidance and product solutions.

<table>
<thead>
<tr>
<th>Patagonia, More</th>
<th>Mistra, Sandra Ross</th>
<th>Noveltion, Leeds University</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>P&amp;G</td>
<td>BINTFEP</td>
<td>Mermaids</td>
<td>Ebi Clean (Arutex Spain)</td>
<td>Hohenstein</td>
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<td>EMFA</td>
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<td></td>
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<td></td>
<td>Seehals</td>
<td>BSI Germany, Textile Mission</td>
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</tbody>
</table>

## 4. Tools & Communication
Development of tools for the acceleration of best practice. A singular consumer facing communication to be used globally to align on understanding and best practice.

<table>
<thead>
<tr>
<th>Mermaids</th>
<th>The Story of Stuff</th>
<th>The Women’s Institute</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>OAI Consumer Communication</td>
<td>Entry Level Product Development Tool</td>
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</table>

## 5. Product Solutions
The creation of product solutions at the polymer, fibre, yarn, fabric and garment level that can demonstrate improvements and be communicated at the consumer level.

<table>
<thead>
<tr>
<th>Tierra</th>
<th>Everball &amp; Guppy Friend</th>
<th>Pontetorto BioPile</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tool supports product development at brand, retail and supplier level</td>
<td></td>
</tr>
</tbody>
</table>

**Key**
- Completed
- In Development
- Proposed

**DISCLAIMER:**
This roadmap is intended to be used in conjunction to the infographic and represents the depth of work currently being undertaken as well as opportunities for new work-streams. Inclusion in this roadmap does not indicate the endorsement of the quality of the work included within it, which varies greatly.

**Fillers:**
- Facilities measurement
- Process measurement
- Filament v’s spun
- Understanding manufactured cellulosics
- Fabric structure and fabric finishing
- Entry level product development tool
- Facilities best practice document
- Textile measurement / process measurement tool update
- Tool supports product development at brand, retail, and supplier level
Thank you

katy.stevens@europeanoutdoorgroup.com
Recycled Polyester Working Group

Bill Jasper
Two Eleven Associated
Recycled Polyester Working Group

How do we increase polyester recycling into yarn and fiber?
Recycled Polyester Working Group

• Is polyester bottle and waste recycling to fiber really green?
• Status today
  • Less than 15% of polyester fiber and yarn is produced from recycled materials
  • Both mechanical and chemical recycling available, but mechanical dominates
  • Economics are a challenge for either
  • Let’s focus on mechanical

• Mechanical economics
  • Some observations based on a project I prepared for a green field installation.
Recycled Polyester Working Group

• What are the factors inhibiting growth in polyester mechanical recycling?
  • Economic model does not work if competing with virgin commodity yarns
  • Local availability of clear waste bottles
  • Consumer demand?
  • Many producers recycled products have consistency issues
  • Others?
Recycled Polyester Working Group

• Lets break into groups, each focused on one factor
• Develop a plan:
  • Brainstorm ways to overcome the factor
  • Identify the most feasible and promising
  • Develop a plan to overcome that factor
• Plan should include:
  • What has to be done?
  • Who has the ability to do it?
  • Government
  • Brands and retailers
  • Suppliers
  • Associations
• How would you execute it?
Recycled Polyester Working Group

- A few groups report out
- We will collect and communicate all results to all in the groups
- We will distill the results into a potential plan
Chemical Innovators

• Carbio
• Gr3n
• HKRITA
• Jeplan
• PerPETual
• Worn Again
CARBIOS has created the biological recycling of PET waste

PET PLASTICS OR POLYESTER FIBERS WASTE

Selection of microorganisms degrading plastics

PET

PURIFICATION

PTA

MEG

NEW VIRGIN PET PLASTICS OR POLYESTER FIBERS

97% DEGRADATION IN 16 HOURS

CARBIOS ENZYMATIC BIORECYCLING

Close the Loop

2014
LAB. /PRE-PILOT STAGE (100 L)
✓ Done

2017

2018
PILOT (1 - 5 m³)
✓ In progress
✓ First bottles at the end of 2018

2020

2019

2021
DEMO. PLANT
✓ First productions in 2021 (hundreds tons)

2023
INDUSTRIAL ROLL-OUT
✓ Full size units
✓ International licensing

www.carbios.fr
gr3n, Making Polyester Circular
Post-consumer Blended Textile Separation and Recycling by Hydrothermal Treatment

The hydrothermal process uses only heat, water and less than 5% of a green biodegradable catalyst, with an 85% recycle rate of the used water and catalyst. Within 0.5-2 hours, the cotton decomposes selectively into cellulose powders, which enables the remaining polyester fibres to separate from the blend.

- Over 98% of separated polyester fibres can be recovered
- Remains good quality of the separated polyester fibres which is ideal for re-spinning and manufacture of new fabric
- Cotton is decomposed as cellulose powders, which could be applied to functional cellulose products (e.g. super-absorbency materials) or regenerate cellulose fibre
- Reduces the demand for virgin fibres in the textile industry
- At pre-industrial scale 100kg daily

Hydrothermal Treatment

Material sorting
Cutting
Color sorting

Cellulose Powder
Polyester Fiber

Collected for Re-spinning
Direct Spinning

Hydrothermal Treatment (selected conditions of temperature, time and green chemical usage)
Technology Development – Genuine solution for textile waste and sustainable products

1. Depolymerization
2. Purification / Decolorization
3. Polymerization
4. Manufacture

PET pelleting (polyester fluff)
Crude BHET
BHET (Bi-chlorohydrin) monomer
Recycled products

PET included in clothing is degraded into its monomer (BHET)
BHET is purified and decolorized
Purified BHET is polymerized and turned into recycled PET resin
PerPETual’s Chemical (PET) Recycling—Patented and Proprietary {Process, Engineering, Product}

THE PerPETual (ReNEW) RECYCLING PROCESS
1) glycol-based de-polymerization; gradual; **low temperature**; glycol re-covered/re-used
2) Proprietary filtration and colour removal [no catalysts, foreign reactants]
3) Proven: Commercial scale operations for years

TWO PRODUCTION ALTERNATIVES TIED TO CUSTOMER NEED

**Continuous (Standard)** > (comparable to virgin) Direct 24x7 continuous feed of low molecular weight molten ester to standard polymerisation unit, then spinning and texturising lines
   - Primary operating mode; technical limits of filament yarn same as virgin

**Bespoke (Future/scale based on market development/demand)** > (Low-melting temp., low-molec. weight *ester flake stored*; then used when desired, e.g. paired with commercial-scale batch- or continuous-polymerisation, depending on volume, etc.)
   - No drawbacks of higher temp textile polymer chip re-melt for be-spoke products;
   - Well-suited for gradual development/scale up of specialty products **Examples:**
     - Textiles: special sustainable yarns, e.g. cationic, flame retardant; Non-Textiles: Sustainable thermoplastics; PETG for 3D printing; unsaturated poly resins; etc.

SELECTED PROCESS ENHANCEMENT OPPORTUNITIES

- **Scale-up Potential (High)** > Analogous to virgin poly unit cost reductions over time
- **Feedstock Diversification** > Broad - Decontamination and de-colouration inherent to the PerPETual process, e.g. sustainable textile feedstocks
- **Catalyst substitution** > Possible [Example: Replacing antimony absorbed during decontamination with preferred catalysts (s.t. evaluating feasibility + cost hurdles)]
- **Polyester polymer improvements** > Virgin polyester innovations applicable
worn again technologies: October '18 update

**Inputs**
- End-of-use, post industrial textiles
- *Pure and blended* poly and cotton - tolerance up to 20% 'other'
- PET bottles/packaging

**Process**
- Closed loop solvent-based approach
- PET recaptured as polymer rather than depolymerisation to monomers (less energy, lower costs)
- Grant received from Cradle to Cradle to become C2C certified.

**Output**
- Virgin equivalent quality polyester and cellulose outputs
- Target of below-virgin pricing.

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**Dec-2017**
- worn again hits US$7 million investment target

**Jul-2018**
- announces successes on developing its polymer recycling technology and new investor and strategic partners
Goals 2030

• TBD
Wrap Up

• 2018
• 2019 projects
Next Steps for 2019