The PFAS Challenge
Recycling
Post-Consumer Carpet

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Disclaimer

All Information, Comments and Opinions are provided:

- As a representative of XT Green, and -
- NOT as a member/officer of the California Carpet Stewardship Advisory Committee, and --
- Not as a member of CARE, and --
- Not as part of Carpet Recycling Community
Presentation Outline

- Background on XT Green
- Short History of PFAS & Carpet Recycling
- XT Green’s commitment to resolve its PFAS issue
- Unique challenges/opportunities to remove/treat PFAS due to patented aqueous-based carpet recycling technology
- PFAS Study Results: Support for UC Berkeley Green Team
- PFAS and the Future of XT Green
Background on XT Green

- XT Green created to develop and commercialize an advanced manufacturing technology to recover resources from post-consumer carpet (PCC)
- Funded by XT Green private investors + California incentives
- Focused on aqueous-based technology to meet these goals:
  - Produce highest-quality recycled output
  - Minimize/eliminate need to augment recovered product with virgin petroleum-based material
  - Maximize greenhouse gas emission reduction benefits and recycling rates
  - Protect employee health and the environment by eliminating particulate emissions
  - Create high-quality California green manufacturing jobs
- Developed process and tested equipment in two pilot plants
More Background on XT Green

- Awarded two U.S. and one Canadian patents
- Recognized as an “advanced manufacturing technology” by the State of California.
- Overcame major obstacles including switching power companies and a world-wide pandemic. Last obstacle –

**PFAS contamination in post-consumer carpet**
Short History of PFAS & Carpet Recycling

- 1986: PFAS first used as stain repellant in carpet
- 2002: Carpet America Recovery Effort (CARE) created through MOU between Carpet Industry & EPA
- 2008: Under pressure from EPA, Carpet Industry committed to replacing long-chained PFAS with short-chain PFAS
- 2011: First carpet stewardship act in U.S. passed in California. CARE appointed as Stewardship Organization
- 2017: Healthy Building Network publishes “Eliminating Toxics in Carpet” lists 44 chemical types including PFAS
- 2018: DTSC publishes discussion draft of Product Profile for PFAS in Carpet and Rugs, includes “end-of-life” concerns
2018: California Carpet Stewardship Advisory Committee

CARE submits 2018-2022 Carpet Stewardship Plan to CalRecycle, no mention of PFAS

CARE issues guidelines for “In/on ground application of PCC” requires PFAS testing but no guidance regarding results

2019: Advisory Committee requests CARE to address PFAS concerns. CARE declines as there are “no specific guidelines or requirements for the use of post-consumer carpet”

2019: XT Green requests $10K grant for analytical work to determine levels of PFAS in PCC. CARE denies request.
California Carpet Stewardship Program run by Georgia Carpet Industry:

- **2016 - Present**: Lawsuit against Georgia Carpet Industry for Drinking Water Contamination in Alabama
  - 90% of all carpet in the world manufactured in Dalton GA
  - Carpet Industry negotiated with EPA to allow short-chain PFAS
  - Industrial discharge sent to Dalton WWTP. PFAS passes through to Conasauga River - One of the most bio-diverse rivers in the world, more species than all rivers in Europe combined. PFAS present.
  - Drinking water source for many cities in Georgia and Alabama

**Lawsuit Timeline**

- **2016**: Gadsen AL sues 30 carpet companies including Shaw & Mohawk for contaminating drinking water supply with PFAS
- **2017**: Centre AL joins because of PFAS drinking water contamination
- **2019**: Carpet Industry tries to change venue to Georgia. Blames Dalton WWTP for not treating “forever chemical.” Alabama denies venue change.
- **2020**: Carpet Industry petitions U.S. Supreme Court to change venue
- **January 2021**: Supreme Court refuses to take case. Stays in Alabama

While carpet industry spends $$$ to fight lawsuits, Alabama cities have installed PFAS treatment for $5 million to provide safe drinking water for citizens.

But it’s all not all PFAS “heads in the sand… denial” …
Companies & Organizations Requiring PFAS-Free Carpet
XT Green’s commitment to resolve its PFAS issue

Personal Background with “Legacy Chemicals” --
*Liability & Moral Responsibility Doesn’t Require Regulations*

- Hired by California Aerospace company named #1 Superfund site to address extensive chlorinated solvent groundwater contamination.

- Grew an environmental engineering company from 10 to 450 employees to investigate and remediate contaminated industrial sites across the U.S.

  Left company when focus changed to expert testimony defense of toxic chemical polluters

- Extensive knowledge of the “forever chemical” DDT and the life of Rachel Carson whose book “Silent Spring” resulted in the banning of DDT in 1972 --

  DDT legacy continues with 2021 discovery of 65,000 + DDT drums off California coast and health problems in grand-daughters of women exposed to DDT in the 60’s

- Plus ... Fiduciary responsibility to XT Green Investor
Unique challenges/opportunities to remove/treat PFAS due to XT Green aqueous-based technology

- **Challenge #1: Carpet is Designed to Stay Together**

- **Components of Carpet, e.g. Nylon Residential**
  - Face Fiber 40%
  - Polypropylene from Backing 15%
  - Rest of Backing: Latex & Calcium Carbonate* 45%

  “Post-Consumer Carpet Calcium Carbonate (PC4)”

PFAS added to carpet either in the production of fiber or applied to the entire carpet during manufacturing.
Where does PFAS go? First need to understand process* (It will be quick, promise)

“Advanced Manufacturing System to Recycle Carpet”
(patents in U.S. and Canada)

Sorte Whole Carpet, N6 or N6,6 Residential and/or Commercial Broadloom

Captured Airborne Particulates

Gross Size Reduction (only “dry” step)

Carpet Pieces @ 8” x 8”

Pulleers (Wet Process Begins)

Mixed Nylon & Poly Fiber Liberated Filler (PC4)

Cut to uniform size

Mixed Nylon & Poly Cut Fiber/Lesser PC4

Centrifuges

Nylon Fiber

Polypropylene Fiber

Water Treatment & Recycling System

Post-Consumer Carpet Calcium Carbonate + (PC4) Recovery

Water & Some Ash

Mixed Nylon & Poly Fiber/ Less PC4

Washer #1

Recovered “PC4”

Recovered Nylon

Recovered Polypropylene

Washer # 2

Mixed Nylon & Poly Cut Fiber

Water & Last PC4

RF Driers

Water Removal/ RF Diers

But what about the PFAS?!
How much PFAS is in Post-Consumer Carpet (PCC)?

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<tr>
<th>PF Type</th>
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</table>

- **PCC collection facility:** Multiple samples randomly pulled from multiple bales with Residential & Commercial PCC
- Researched literature for most likely PFAS in PCC
- Analyses done by PFAS-certified Weck Laboratories
  - PFAS removed through leaching protocol
  - LCMS analyses done by Triple-Quadrupole Mass Spectrometers
- **CA Water Board levels (RLs) requiring water systems to be removed from service:** 10 ppt for PFOA and 40 ppt for PFOS
- How does that relate to PCC? TBD but, of concern in landfills & in recycled content returning to circular economy
What will happen to the PFAS in the XT Green facility?

- Simulated XT Green aquatic-based process using fiber produced from XT Green pilot plant
- Hoping XT Green’s carpet recycling technology would result in PFAS going into process water for removal but ...
- Round 1 of testing: It stays in the fiber
- Considered abandoning project due to PFAS until --

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<th>Sample ID</th>
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</table>
Support from UC Berkeley Greener Solutions Team

- DTSC Simone Balan referral to UCB Thomas McKeag and “Greener Solutions” students investigating PFAS in carpet
- Work conducted by Ned Antell, Ph.D student
- Round #2 of testing:
  - Determine if strong base in aqueous solution can release the PFAS from the XT Green carpet fiber
- Strong base inadequate to remove PFAS from Fiber:
  - Result likely due to shielding of the ester bond by the PFAS hydrophobic tail due to inadequate distance between the 2+ non-fluorinated carbons separating ester bond from the hydrophobic tail

<table>
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<tr>
<th>PFAS</th>
<th># of Carbons</th>
<th>Extracted from Fiber (ppt)</th>
<th>2M NaOH/water</th>
<th>1 M NaOH/water</th>
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Round #3 of testing:

- Determine if strong base in aqueous solution plus organic solvents can release the PFAS from the XT Green fiber
- Five organic solvent candidates reduced to four after consultation with nylon fiber manufacturer

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<tr>
<th>PFAS</th>
<th># of Carbons</th>
<th>PFAS in fiber (ppt)</th>
<th>2 M NaOH + 50% Solvent #1 (ppt)</th>
<th>2 M NaOH + 50% Solvent #2 (ppt)</th>
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- Organic solvents improve removal of PFAS from carpet fiber, especially long chain PFAS
- Removal efficiencies different depending on organic solvent
- Precursors make up a large fraction of PFAS mass in carpet
- Need to expand measurement of PFAS beyond PFAAs for complete understanding of PFAS in carpet
Support from UC Berkeley Green Solutions Team (cont’d)

- Round #4 of testing:
  - Determine the residual PFAS in fiber and removal %
  - Determine the concentration of PFAS in the PC4

<table>
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<th>PFAS</th>
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<th>PFAS in fiber (ppt)</th>
<th>2 M NaOH + 50% Solvent #4 (ppt)</th>
<th>Residual PFAS in Treated Fiber (ppt)</th>
<th>% Removal</th>
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- Strong base in aqueous solution plus organic solvent #4 removes 99 to >99% of PFAS from carpet fiber
- Concentration of PFAS in PC4 similar to carpet fiber
Next Steps

**Technology Development:**
- Determine if strong base in aqueous solution plus organic solvents can remove PFAS from PC4
- Determine the residual PFAS in PC4 and removal
- Perform total oxidizable precursor assay on sample to quantify precursors without analytical standards
- Repeat experiments and compare results

**Operational Data to support XT Green process system design:**
- Determine reaction kinetics/optimal incubation times

**Additional Action Items:**
- Conduct preliminary economic impact to XT Green
- Secure guidance from regulatory agencies regarding acceptability of residual PFAS in fiber and PC4
- Discuss “level PFAS playing field” w/ CalRecycle & CARE
- Discuss preliminary results with recycled output buyers
- Continue discussions with PFAS removal/destruction vendors (including impact of organic solvents)
Conclusions: The PFAS Challenge & Future of XT Green

- Major Technical Challenges in Removing PFAS from PCC
- XT Green patented technology has potential to remove 99% of the PFAS from recovered carpet fiber (possibly PC4 too) for subsequent adsorption/destruction
- Role of CARE, CalRecycle and the California Carpet Stewardship Program in addressing PFAS in PCC?
- Must address acceptable PFAS residual in carpet recycled output vs. drinking water standards
Conclusions continued

- Need to compare risk of maintaining PFAS in circular economy vs. the risk of landfilling PCC. Does the risk change dependent on the use of the PCC recycled output?

- Do benefits of carpet recycling help outweigh these risks?
  - Between 3 - 4 billion pounds of PCC disposed annually
  - California has a recycling rate of 20+%  
  - Rest of US sends +95% of PCC to landfills or burned
  - PFAS released through air emissions & landfill leachate pass-through at wastewater treatment plants
  - Major GHG emission reduction benefits from carpet recycling as recovered products replace virgin materials*

*XT Green’s annual GHG emission reduction benefits would be equivalent to the carbon sequestered over 10 years by planting 2.5 million trees.

FINALLY ... SHOULD XT GREEN CONTINUE THIS QUEST OR --
Should We Recycle Cardboard Boxes?

Questions? Concerns? ... Solutions?

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Reclaiming Resources for a Greener Planet