

Carpet Recycling 101

Post Consumer Carpet Recycling in North America

Carpet Recycling 101

- ◎ **The Participant will gain knowledge in the following:**
 - › Drivers for Carpet Recycling
 - › General Categories of carpet recycling
 - › Differences in Various types of recycling
 - › Market Values of Various Recycled Products
 - › Demand for Recycled materials from Carpet
 - › Understanding Capital needs of Recycling
 - › Present & Anticipated recycling capacities
 - › Present & New Recycling technologies
 - › Challenges & Opportunities

Post Consumer Carpet Drivers

Factors driving Recycling of Post Consumer carpet

Post Consumer Carpet Recycling Drivers

◎ **Broad List of Drivers:**

> **Carpet Manufacturers**

- > **LEED building Standards – Need P. Consumer for high value/Specifications**
- > **NSF 140**
 - > High value of P.C. content
 - > Platinum Level highly prized: Requires Min. Post consumer content.
 - > Platinum Level requires P.C. Carpet recycling at CARE Goal levels – Escalate every year.
- > **Professional Specifying Commercial Community demands Sustainability**
 - > Reward most Sustainable companies with increased business: or NO business
 - > Recycling and P. Consumer recycled content is large factor
- > **Large National Accounts demanding sustainable initiatives:**
 - > Wal-Mart, Home Depot, etc.
- > **Good Old healthy competition.**

Post Consumer Carpet Recycling Drivers

◎ **Broad List of Drivers:**

> **Entrepreneurs:**

- > Willing to risk Capital for carpet recycling
- > They are beginning to see fairly good business model
- > Beginning to make money from carpet recycling
- > They are essential link in the value chain of processing

> **High Oil prices**

- > Keeps Virgin Nylon very expensive
- > Cost Spread between virgin and P. Consumer is wide
- > Makes P. Consumer very attractive for cost savings .

> **Post Industrial Feedstocks are rapidly diminishing**

- > P. I. Nylons have been standard product in plastics compounding for decades
- > Hundreds of millions of pounds have disappeared from the marketplace
- > Post Consumer Products are beginning to fill the large gap.
- > Nylon 6.6 in critically short supply

> **New Recycling technologies: Produce Higher value products**

Recycling Processes

Classification of Discrete recycling processes

General Categories of Carpet recycling & Diversion

◎ Broad Recycling Types/Classifications:

- › Chemical Recycling
- › Mechanical Recycling – Dry Systems
- › Mechanical Recycling – Wet/Dry Systems
- › Mechanical Recycling – Skiving Systems
- › Commercial Carpet Recycling – General Information
- › Hybrid System – Kela Synthetic Fuel Pellet
- › CAAF: Carpet as Alternate Fuel
- › WTE: Waste to Energy

Chemical Carpet Recycling

Available systems in North America

Systems in Operation

◎ Chemical Recycling Systems in Operation

> Nylon Depolymerization Plant: Augusta Ga.

- Capped at Approx. 100 million lb capacity
- Depolymerizes Face Fiber to Caprolactam: building block of Nylon 6.
- Processes Nylon 6 only.
- All output used for carpet fibers.
- Used as Post Consumer content in nylon 6 carpet fibers
- Non Carpet components recycled into beneficial applications

Systems in Operation

◎ Chemical Recycling Systems in Operation

> Nylon Depolymerization - Canada

- Approx. 5 million lb capacity - Can be expanded.
- Depolymerizes Carpet to Caprolactam: building block of Nylon 6.
- Process for Nylon 6 only.
- All output used internally and/or sold to outside Companies.
- Used as Post Consumer content in nylon 6 carpet fibers
- Leaves all non-nylon components as Sludge.

Systems in Operation

◎ Chemical Recycling Systems in Operation

> Formic Acid Dissolution - Delaware

- Operations begin July 2010.
- Formic Acid Process – Licensed from Auburn U. Patent.
- Raw material input : Baled nylon fibers: Various sources
- Dissolution of Nylon in formic acid.
- Precipitates almost pure nylon.
- Can process both Nylon 6 and Nylon 6.6.
- Presently 1 site – 5 million Lbs. Going to 15 million w/Expansion.
- Plans to expand regionally in various parts of the country.
- Leaves small amount of Non-Nylon components

Common Elements

◎ Common Elements of all Chemical Recycling

- All use some mechanical Pre-processing prior to Chemical process
 - Performed either on site or outside Pre-processor
 - Includes, but not limited to:
 - Size reduction – Shredding
 - Calcium Carbonate Reduction – Hammer mills or Textile Tearing.
 - Leaves Non-Nylon components to be recycled via some other method.
 - Extremely Expensive capital requirements w/exception of MCR

Advantages/Disadvantages

◎ Advantages De-Poly systems

- › Purest nylon output of any carpet recycling system.
- › Virtually no contaminants.
- › No degradation in properties.
- › Perfect for new nylon fiber (fiber to fiber).

◎ Disadvantages De-Poly systems

- › Extremely expensive capital outlay
- › Limited to Nylon 6
- › Single site exists in U.S. – Capacity limited to one site
- › High cost logistics – Carpet trucked all over U.S.
- › Costs are higher than virgin nylon .

Advantages/Disadvantages

◎ Advantages Formic Acid system

- › Nylon Purity 2nd only to Depoly. Processes.
- › Very little contaminants.
- › Suitable for Plastics Market & Fiber
- › Can process both nylon 6 & 6.6.
- › Multiple site can be built Economically
- › Cost effective nylon fiber source from Post Consumer carpet.

◎ Disadvantages Formic Acid system

- › Not all color is removed from nylon as with De-poly systems
- › Leaves non-nylon for other form of recycling

Mechanical Carpet Recycling

Dry Recycling Systems

Dry Systems

○ Dry Systems & Types

- › Very prevalent and broad based
- › Mechanically processes carpet
- › Two types of Mechanical Processing
 - **Process 1 – Beating process**
 - Size Reduction – Shredding
 - Sequential steps of step cleaning and Hammer mills to remove ash.
 - **Process 2 – Textile Process**
 - Size Reduction
 - Sequential opening and combing to remove ash.

System Outputs

◎ Dry Systems Outputs

- › Co-mingled carpet fibers (face/back)
- › No Separation of face & backing components
- › Desired Final product Ash content can vary dramatically
 - **Depends on no. of cleaning steps**
 - **Depends on needs of End markets**
 - **Ash content varies – 25% down to 5%.**

End Uses & Markets

◎ Dry System Uses and Markets

- › Input material for low value plastics:
 - **Typical market is China**
 - **Requires very low processing & Wage markets.**
- › Input material for further mechanically processed products
 - **Fiber carpet underlayment – Great for mixed polymers**
 - **Geo Hay type materials.**
 - **Plastic Lumber Composites – Decking, Sound Barriers, Rail Ties, etc.**
- › Input Materials for higher Value Output recycling systems
 - **Input for De-Poly operations – Lower Contaminants improve efficiencies of next process.**
 - **Input for Wet/Dry Recycling systems**

Advantages/Disadvantages

◎ **Dry System Advantages**

- **Low cost process**
- **High Volume, High Speed process**
 - **Multiple lines in single facility**
 - **Can produce various grades in one facility**
- **Liberates Calcium fillers (40% to 50% of carpet weight)**
 - **Allows calcium to be reclaimed into new products**
- **Low cost Input for Higher Value Recycling processes & Recycled products**
 - **Wet/Dry**
 - **Depoly**
 - **Underlayment**

Advantages/Disadvantages

○ Dry System Disadvantages

- Low Value product Output
- Very sensitive to costs
- High Yield losses – Typical losses of 50% to 60%.
- Process Cannot Separate carpet Polymers
- Large Volume operation requires millions of dollars Capital

Mechanical Carpet Recycling

Wet/Dry Recycling Systems

Wet/Dry Systems

○ Wet/Dry Systems & Types

- Only 3 Facilities Exist in U.S.
- Material Input comes from Dry System output – Mixed polymers
- Combines Several processes: **Described Below**
- Economically feasible only for Nylon Post consumer carpets.
 - **Process 1 – Very fine particle size reduction**
 - Mechanical systems
 - **Process 2 – Polymer Separation**
 - Wet Separation of Polymers
 - Separate backing from Face components
 - **Process 3 – Polymer Continuous Drying**
 - **Process 4 – Densification of Each polymer Stream**
 - Several densified physical forms

System Outputs

◎ **Wet/Dry System Outputs**

- **Separated Nylon Face & Backing components.**
 - **Nylon Face.**
 - **Polypropylene Back.**
- **Relatively Pure Nylon Pellets - 95% pure.**
 - **Some Residual P.P. in Nylon**
 - **Calcium constitutes most of contamination – Cannot be totally removed**

End Uses & Markets

○ **Wet/Dry System Uses and Markets**

> **What Industry**

- **Plastics Industry**
- **Engineered Resins: (Definition)**
- **Nylon 6 & Nylon 6.6 used extensively**

> **Who are the Plastics Industry Customers.**

- **Compounders: (Definition)**
- **End Users w/compounding capabilities**
- **End users who specify Post Consumer plastics**

> **What are some of the Plastics Industry sectors**

- **Automotive - Largest**
- **Small Appliances**
- **Lawn & Garden**
- **Commercial – Furniture Industry**

Advantages/Disadvantages

◎ **Wet/Dry System Advantages**

- **Achieve Relatively High purity levels:** Can be melt filtered to some degree thru extruder, but costs increase & loose polymer.
- **Good Costs vs. Performance for Plastics Industry**
 - **Lower costs vs. Post Industrial Nylons**
 - **Do not perform as well as P.I, but cost/Performance curve favorable.**
- **Product increasingly accepted in Plastics**
 - **Relatively new product Category**
 - **Experience, exposure needed for further acceptance**
- **High Value output goes directly to Plastics compounding**

Advantages/Disadvantages

◎ **Wet/Dry System Disadvantages**

> **Only 3 systems exist**

- **1 site -Tennessee**
- **1 site - S. Carolina**
- **1 site - Georgia**

> **Limited availability**

- **Not likely to expand in the short term**
 - **Relatively high capital requirements: Highly skilled workforce needed**
 - **Total Capacity : Approx. 50 MM to 60 MM pounds/Yr. output.**
 - **However: P.C. Carpet needed to produce output is: 160 MM to 200 MM Lbs/Yr.**
- ### > **Quality of input material is key for Purity levels.**

Mechanical Carpet Recycling

Skiving or Shearing

Shearing Systems

◎ **What are they? What do they do?**

- **Removal of face yarn from carpet via. Lateral Cutting action.**
- **Shaves carpet face from rest of carpet.**
- **Origination of Equipment**
 - **Converted “Leather Slitting” machines**
 - **New Machines being built specifically for Carpet Shearing.**
 - **They take into account the uniqueness of Post Consumer carpet**
 - **Metal contamination**
 - **Variations in pile heights**
 - **Density of carpet materials**

System Outputs

◎ Shearing System Outputs

- › Concentration on Nylon Post Consumer Carpets
- › Face fiber Output
 - Still in Yarn form
 - Nylon is preferred: Nylon 6 & Nylon 6.6
 - Fiber typically baled
- › Output is Very Pure Nylon
 - Typical 99% purity
 - Commands good value in Market.
 - Misc debris constitutes contamination: Approx. 1%
- › Carpet “Carcass”.
 - Left over carpet from Shearing:
 - Much is landfilled today: 60% to 75% of Carpet weight left.
 - Technology developing to harvest high Value from Carcass Recycling
 - Some Carcass will go to CAAF, but needs better answer.

End Uses & Markets

◎ Sheared Nylon End Uses and Markets

- › Same Industry as Wet/Dry nylon Output.
 - **Plastics Industry**
 - **Engineered Resins**
 - **Nylon 6 & Nylon 6.6 used extensively**
- › Who buys these products in the Plastics Industry.
 - **Compounders**
 - **End Users w/compounding capabilities**
 - **End users who specify Post Consumer plastics**
- › What are some of the Plastics Industry sectors
 - **Automotive - Largest**
 - **Small Appliances**
 - **Lawn & Garden**
 - **Commercial – Furniture Industry**

End Uses & Markets

- ◎ **Sheared Nylon End Uses and Markets Con't**
 - > **Carpet Industry**
 - > **Used for fiber extrusion, but:**
 - **Must be further purified prior to extrusion**
 - **Nylon 6 & Nylon 6.6 are Prime Candidates**
 - **Produces Post Consumer Content for new Nylon fibers**
 - > **New Applications for Fibers Developing**
 - **First application: nylon 6.6**
 - **Nylon 6 beginning to be developed**

Advantages/Disadvantages

◎ Shearing System Advantages

- › Very High Purity output
 - **99% Purity**
- › Relatively Small Capital outlay for business start up
 - **Shearing Equipment: From \$50K to \$340K per machine**
 - **More costs for Auxiliary equipment: ID guns, balers, Material handling, etc.**
- › Carpet Fiber back to Carpet Fiber (Closed Loop)
- › Local Processing Facilities Very easy
 - › **Install process where carpet is collected**
- › Very low footprint recycling
 - **Reduced Logistics: Haul from small local Radius**
 - **Low Energy recycling**

Advantages/Disadvantages

◎ **Shearing System Disadvantages**

- **Low yield from Original carpet**
 - **60% to 75% of carpet not Harvested**
- **Why:**
 - **Purity of output must be maintained**
 - **Cannot shear off entire face**
 - **Varying face fiber heights: continual adjustments**
- **Carcass Disposition**
 - **Much goes to landfills today**
 - **Out of 1MM lbs Post Consumer carpet sheared – 600K to 750K is Landfilled**
- **Technology Developing to harvest Value from Carcass**
 - **Includes Thermoplastic component**
 - **Calcium**

Mechanical Carpet Recycling

Calcium Carbonate fillers: Residential carpets

Calcium Carbonate Recycling

- **Filler represents large portion of carpet weight (40% to 50%)**
 - > **Process recycles filler into new carpet fillers**
 - **Combines recycled filler w/Virgin filler & other materials**
 - **Used as P. Consumer content in new carpet products**
 - **East cost Site and West Coast Site**
 - **Many carpet mills in trial phase. Some are already using.**
 - > **Benefits**
 - **Keeps millions of pounds out of landfills**
 - **Reduces mining for virgin fillers**
 - **Fairly low cost P. Consumer content for new carpets.**
 - **Low impact recycling.**

Commercial Carpet Recycling

Overview

Commercial Carpet Recycling

- Due to the extremely varied nature of Commercial carpets, a variety of processes must be employed for recycling.
- Many products, especially tiles, contain backing pre-coats of chemistries that differ from the main backing coat.
 - > Must be segregated by face fiber and backing types
 - > General backing chemistries - Broadloom
 - Latex
 - Polyurethane
 - PVC – 6 ft wide
 - > Tiles
 - PVC
 - Thermoplastic Extruded
 - Polyurethane
 - > Recycling uses one or several recycling processes already described. It is not in the scope of this presentation to describe commercial recycling in detail.

Hybrid Recycling Process

Kela Energy Promise

Kela Energy

◎ Synthetic Fuel System

- > Synthetic Coal Bricket
- > Constituents
 - Coal fines
 - Wood Dust
 - Post Consumer Carpet: Glue that holds it together
- > Technology
 - Licensed to Utilities by Kela Energy
 - Carpet added at Plant sites
 - Carpet is Dry processed (Shredded) prior to insertion
- > Sites
 - Several are planned in the next 5 years
- > Start up
 - > Projected for Late 2010

Advantages/Disadvantages

◎ Kela System Advantages

- › Outlet for Million of tons of Coal dust
- › Uses million of Lbs. carpet of all types
- › Beneficial use of Wood dust
- › Lower Emissions than cleanest Stocker Grade coal
- › Product manufactured at Coal fine locations
- › Takes polluting Coal fines out of environment
- › Reduces dependence on new coal mining

CAAF

Carpet as Alternate Fuel

CAAF

◎ Carpet Diversion Technology

- > Uses single source fuel
- > Carpet is only fuel source
 - Carpet must be collected
 - Shipped
 - Dry processed prior to Fuel generation
- > Technology
 - New Technology by Shaw
 - Start up in late 2010
 - Two phases are planned
- > Benefits
 - Uses carpet that otherwise cannot be easily recycled
 - Could be very beneficial for some types of commercial carpets

Recycling capacities

Present Post Consumer Carpet Recycling capacities

Carpet Recycling Capacities

2010 Estimated Utilization

- > Dry Recycling systems
 - 200 Million Lbs .
- > Chemical Recycling systems
 - 85 Million Lbs.
- > Wet/Dry Recycling systems
 - 30 Million Lbs.
- > Shearing Systems
 - 30 million Lbs.
- > Kela
 - 10 Million Lbs.
- > WTE
 - 50 million Lbs.
- > Misc:
 - 20 Million

> **Total: 425 Million**

2012 Estimated Utilization

- > Dry Recycling systems
 - 250 Million Lbs..
- > Chemical Recycling systems
 - 150 Million Lbs.
- > Wet/Dry Recycling systems
 - 40 Million Lbs.
- > Shearing Systems
 - 200 million Lbs.
- > Kela
 - 60 million Lbs.
- > CAAF
 - 100 million Lbs.
- > WTE
 - 60 Million Lbs.
- > Misc:
 - 20 Million Lbs.

> **Total: 860 Million**

Challenges & Opportunities

What does the future hold?

Challenges

◎ What are some of the hurdles that must be overcome

- › Sound Economic Recycling Models: Price/Performance Continuum
 - › **Discuss Values of P.C. Streams: vs. (Virg. P.I.) and vs. (various P.C. Streams)**
- › Carpets constructed for Recycling
- › Commercial Carpet Diversity
- › Patchwork of Regulatory rules
- › New Recycling Technology advances: How can it be incentivized.
- › Thermoplastic Purity
- › Full acceptance of Post Consumer products in all Markets
- › Purity of outputs
- › As we mature: Collecting & Mining Enough carpet
- › Polyester Value chain:
 - › **In 5 years, could be 1 Billion pounds of output**

Opportunities/Benefits

◎ What is the Future Potential

- › Great source of Material for Plastics
- › Will replace P. Industrial as the source to the Marketplace
- › Steady/Dependable pricing: Insulates marketplace from wild fluctuations
- › De-couples plastic materials from the Oil well: Multiple lives
- › Low Environmental impact vs. Virgin Plastic production
- › Relieves landfill burdens Nationally
- › Develops an entire new industry with jobs
- › Projects carpet as more Sustainable product
- › Purity of outputs
- › As we mature: Collecting & Mining Enough carpet
- › Polyester Value chain:
 - › In 5 years, could be 1 Billion pounds of output

Thank You

Questions