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Making Carbon Fiber Composites Circular: CRTC Approach to Composites Recycling

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Composites Recycling Technology Center

Background

- In North America: estimated 29 M lbs. (~13,200 MT) of carbon fiber landfilled per year
- In Washington: estimated 2 M lbs. (~900 MT) of carbon fiber landfilled per year
- Majority (in WA) is pre-preg, primarily aerospace production scrap
  - Secondary amount is cured production trim
  - Some pre-preg scrap has to be oven cured prior to landfill
  - Regulations vary based on constituents in resin system
  - Adds cost/time burden on composite manufacturers

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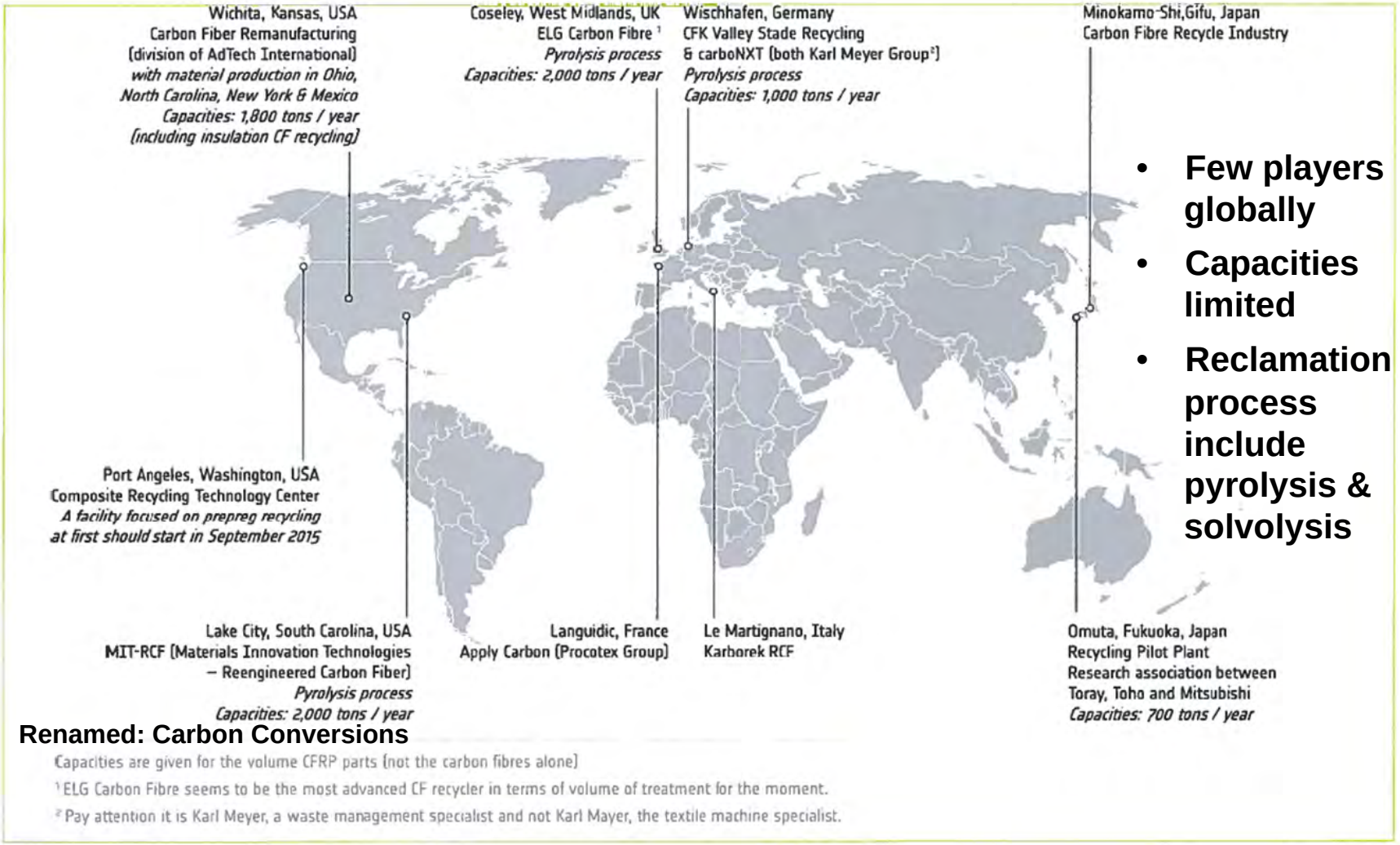
Carbon Fiber Recycling Landscape



- **Few players globally**
- **Capacities limited**
- **Reclamation process include pyrolysis & solvolysis**

Renamed: Carbon Conversions

Carbon Fibers: History Players and Forecast to 2020, JEC Group Strategic Study, 1st Edition 2015

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CRTC's Vision, Mission, Principles

Vision:

- Pioneering product development to realize the full potential of composite recycling

Mission:

- To lead and grow a composite recycling industry that fully diverts Washington State's carbon fiber scrap into value-added products

The following **Guiding Principles** shape CRTC's decisions:

- **Economic**: Enable the expansion of the advanced manufacturing industry through research and development for conversion of carbon fiber scrap into value-added products.
- **Environment**: Reduce the amount of composite scrap being landfilled through re-use in new applications with reduced energy and environmental footprints
- **Education**: Support the training of a workforce prepared for and accomplished in the skills required by the composite recycling industry

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Location – Space to Start-up and Room to Grow

PENINSULA COLLEGE

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PORT of PORT ANGELES

Composite Manufacturing Campus

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Status/Scale of Effort

- Interim R&D facility: moved in presses and tooling/prototyping equipment to start development in January 2106
- New 25,000 s.f. facility under construction
  - Built-in ovens, freezers, finishing booths, etc.
  - 75,000 pound pre-preg freezer capacity
  - High temperature ovens (800°F capable)
  - High-speed compression molding presses
  - Complete steel 4-axis CNC tooling capability in-house
  - Design/analysis capabilities, collaborative testing with WSU
  - Pursuing UW collaboration for expanding capabilities; offering research & training opportunities at CRTC
- Co-location with Peninsula College's Advanced Manufacturing - Composites Technology Program
- Separate production space and multiple laboratory spaces

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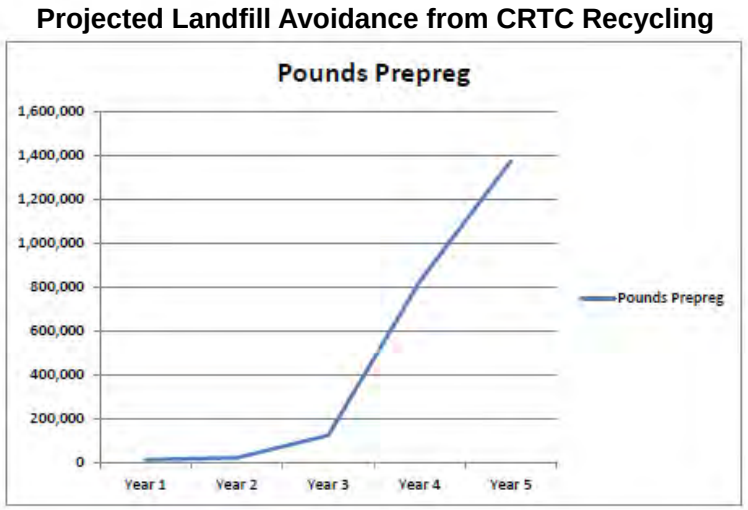
CRTC Approach

- Create demand for reclaimed materials via market pull from high-value products
- Select products to match availability of scrap, achievable properties, and quantity of materials
- Develop process science for converting autoclave cure cycles to press-based rapid cure cycles
- Explore additive manufacturing
  - Chopping to the format planned and building net preforms for compression molding as a form of "bulk" additive manufacturing
- Develop design property data to reflect “combined” materials properties and new cure cycles
- Work with companies to advance market-based applications and support these with product demonstration, materials, and process technologies



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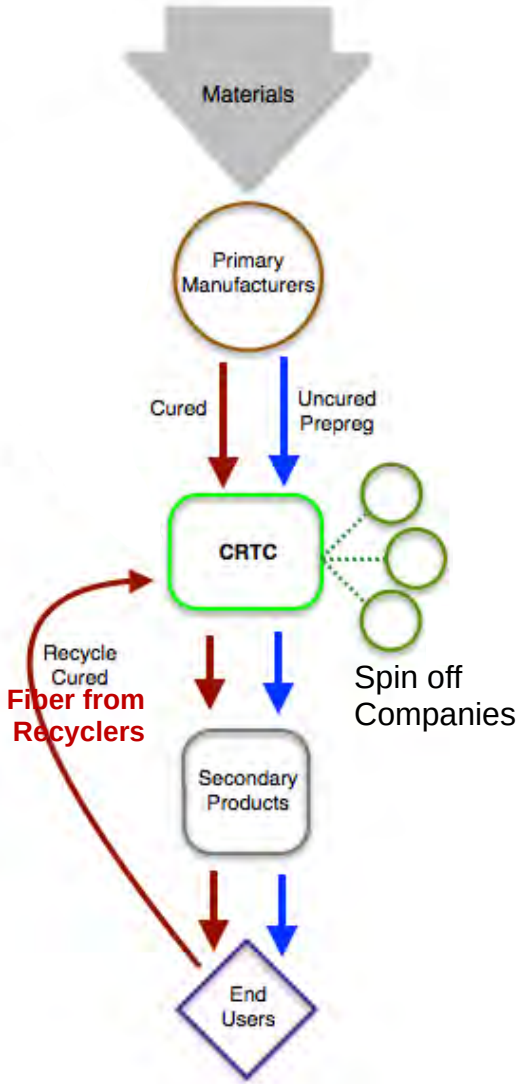
Value Proposition for Recycled Carbon Fiber (rCF)

- CRTC will develop manufacturing and product sales and create confidence in using recycled pre-preg
- CRTC's early rCF manufacturing and development efforts will generate property databases and process knowledge that feeds new applications
- CRTC success will attract increased R&D for new materials and processing technologies, such as Materials Genome Initiative
- Composite recycling needs "market pull" to improve reclamation business case
- CRTC will initiate with uncured carbon pre-preg Phase II will incorporate "recovered" dry fiber from Recyclers



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Transforming "*Waste*" Streams into Value Streams

- **Examining the Manufacturing Opportunity with Pre-preg Scrap**
  - Selected applications in Paddlesports, Snow-sports, Fishing, and Cycling
    - Only considered applications that can use the recovered form of materials
  - Range of as-manufactured costing examined on a unit weight basis
  - Looked at cost within manufacturing operations
    - Backed out all mark-ups and distribution costs plus SG&A and profit
- **Range is $75/pound to $192/pound. Average across the selected applications was $139/pound**
  - This figure represents labor, materials, consumables, amortization & production management expenses
- **2M lbs. total carbon fiber scrap currently in WA:**
  - Estimate 60% useful materials from landfilled scrap or ~1.2 M lbs/year
  - **$166.8 M** in direct manufacturing opportunity (converted to consumer goods)
  - Or approximately 1,100 direct jobs; plus 1,400 indirect jobs = **Total 2,500 jobs**
  - Equal to **$670 M** retail sales volume

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Recycled Carbon Fiber Case Study (Actual Project)

Large Radio Telescope Mount Support Components

- Is virgin, continuous fiber required?
  - What are the design drivers?
- What process should be used?
  - What are the molding requirements?
  - What are the masses/sizes?
  - Can process/tooling accommodate cure induced dimension changes?

Decision:

- Dish rim connectors utilize hybrid of recycled discontinuous carbon fiber (spool ends), and virgin BimaX™ surface braid (for hole drilling stability)
  - Fabric construction would have been 168 plies and ~84 ply drops – on 4 faces
- Metered infusion epoxy (low-exotherm), compression molded at ~300 psi, 160°F

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Carbon Fiber: Applications and Innovation

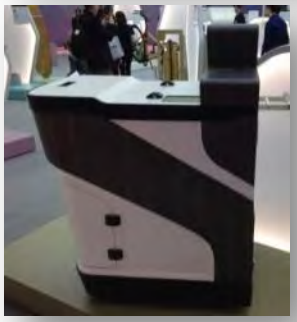
Automotive

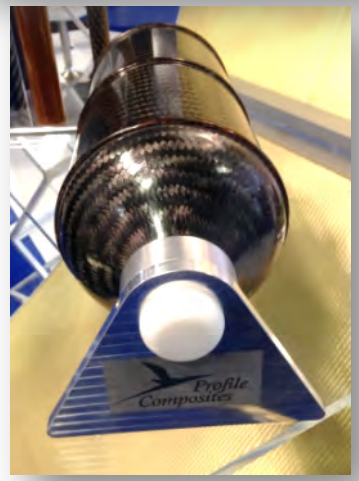
Recreational

Clean Energy

Non-structural

Aerospace





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Seeking Partners to Realize CRTC Vision

- **Industry Partnerships: Product design, development and sales**
  - Direct sales transitioning into private label products for established market players
  - Enter supply chain:
    - Partnerships enable continued growth in CF industries into mainstream, high-volume manufacturing applications
  - Bridging the gap between lab scale and large production
- **R&D/D Partnerships**
  - Innovation tech center for cutting edge research
  - Interested in teaming with partners that have complementary needs and goals
    - Explore potential of low cost rCF feedstocks for new materials
    - Process improvements for scale up
  - Engineer in Residence Program
- **Educational Partnerships**
  - Peninsula College space for classes, offices and laboratories
    - Recycling certification program first in state
  - Collaboration with WSU and other universities
  - Hands on research and production training for Graduate Students

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Conclusions

- Carbon fiber is a small business segment relative to other structural materials, and recycling is one barrier to achieving commodity scale
- Addressing recycling as part of high-volume production development will lower overall costs, and increase demand for CF materials
- CRTC is leading the way in closing the circle for composite recycling
- High performance characteristics of CF can be applied in new applications through use of low cost rCF
- CRTC focus on product development optimizes value of rCF material stream
- CRTC wants to partner and collaborate to grow the recycled carbon fiber industry
- rCF is part of the paradigm shift called for in the Materials Genome Initiative

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