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- **Natural Fiber Composites Market Overview**
- **Natural Fiber Composites Competitiveness and Market Opportunity**
- **Market Trends and Opportunity**
- **Growth Opportunities in 2011 and Beyond**
- **Conclusions**
- **About Lucintel**
Executive Summary

• Global natural fiber composites market reached $2.1B in 2010, with compound annual growth rate of 15% in last five years

• Automotive & Construction: largest segments among natural fiber composite applications
  • Bast fiber such as flax, Kenaf, hemp, etc. are materials of choice for automotive, while wood plastic composite are preferred by building and construction players

• North American natural fiber composites market was largest for wood plastic division whereas Europe is leader in automotive segments
  • Driven by Government support, environmental regulations, and customer acceptance

• By 2016, natural fiber composite market expected to reach $ 3.8B (10% CAGR)

• Strong market opportunities driven by (i) Rising prices of petroleum based products, (ii) strong government support for eco-friendly products, (iii) higher acceptance and (iv) lower price of natural fiber composites

• Major challenges for natural fibers composite industry is natural fiber quality, such as fiber degradation during processing, sensitive to humidity and fiber consistency/quality

• Performance improvement in materials will drive growth for natural fiber composites in new application areas
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## Evolution of Natural Fiber Composites: Henry Ford developed first car with hemp fiber but due to economic limitations did not enter the market

<table>
<thead>
<tr>
<th>Applications</th>
<th>Materials</th>
<th>Time Frame</th>
<th>Number of Automotive applications</th>
<th>E&amp;E: Cases of cellular phones</th>
<th>Sporting goods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw</td>
<td>Clay/mud reinforced composites</td>
<td>3000 year ago</td>
<td>In Egypt clay/mud reinforced by straw to build walls.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuselage skins of spitfires</td>
<td>Flax + Phenolic</td>
<td>1939</td>
<td>Shortage of Aluminum in England, led to use natural fiber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prototype composite car by Henry Ford</td>
<td>Hemp</td>
<td>1942</td>
<td>First production car built from Natural fiber composites</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body of “Trabant” car in Germany</td>
<td>Cotton + Polyester</td>
<td>1950-1990</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flax, Hemp, kenaf, Abaca</td>
<td>Kenaf + PLA</td>
<td>2000 onwards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flax, Hemp, kenaf</td>
<td></td>
<td>2004 onwards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sporting goods</td>
<td></td>
<td>2006 onwards</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Reinforced Natural Fiber Classification: Vegetable fibers are used as reinforced material with two segments wood and non wood fibers

- **Natural Fiber**
  - **Non-Wood Fiber**
    - **Seed/Fruit**
      - Cotton
      - Kapok
      - Milkweed
      - Coir
    - **Bast**
      - Flax
      - Hemp
      - Jute
      - Ramie
      - Kenaf
    - **Leaf**
      - Pineapple (PALF)
      - Abaca (Manila hemp
      - Henequen
      - Sisal
    - **Stalk**
      - Wheat
      - Maize
      - Barley
      - Rye
      - Oat
      - Rice
    - **Grass, Cane**
      - Bamboo
      - Bagasse
      - Esparto
      - Sabei
      - Phragmites Communis
  - **Wood Fiber**
    - **Hard Wood/Soft Wood**
    - **Recycled Wood**
Natural Fiber Composite Applications

Automotive
- Door panels
- Seat backs
- Headliners
- Dash boards
- Trunk liners

Compression Molding
Injection Molding

Electrical & Electronics
- Mobile cases
- Laptop cases

Injection Molding

Sporting Goods
- Tennis Racket
- Bicycle Frames
- Snowboards

Oven Cure

Construction
- Door panels
- Decking
- Railing
- Window Frames

Extrusion
Compression Molding
Injection Molding
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Competitive analysis: Natural fiber v/s synthetic Fibers

- Natural fiber composites excel in most parameters except strength
- Strength of glass fiber composites is higher compared to natural fibers

- Flax fibers offer highest reinforcing potential amongst natural fibers
- Flax offers higher tensile strength compared to others making it suitable for composite applications
### Competing Natural Fiber in Different Applications

<table>
<thead>
<tr>
<th>Key Fibers</th>
<th>Automotive</th>
<th>Construction</th>
<th>E &amp; E</th>
<th>Sporting Goods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flax</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Hemp</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>●</td>
</tr>
<tr>
<td>Jute/Kenaf</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Sisal</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Abaca</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Wood</td>
<td>○</td>
<td>●</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

- **Flax, hemp & kenaf** are widely used for automotive interior application, with usage of these fibers just begun in E & E and sporting goods applications.
- Wood fiber is material of choice for construction due to lower life cycle cost and ease of maintenance.
- Past shows European players have strong usage of flax, hemp and kenaf, whereas wood fiber has shown significant growth in North America region.
### Performance Price Comparison of Competing Materials for Automotive Applications

<table>
<thead>
<tr>
<th>Materials</th>
<th>Average amount per car (lbs)</th>
<th>Performance/Price ratio (Strength/$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>2000</td>
<td>1.1</td>
</tr>
<tr>
<td>Aluminum</td>
<td>600</td>
<td>0.2</td>
</tr>
<tr>
<td>FRP</td>
<td>77</td>
<td>0.7</td>
</tr>
<tr>
<td>Natural Fiber Comp.</td>
<td>35.2</td>
<td>1.5</td>
</tr>
</tbody>
</table>

When taking into consideration the density of steel, its relative performance compares well to composites . . . .
### Performance Price Comparison of Competing Materials for Automotive Applications

<table>
<thead>
<tr>
<th>Materials</th>
<th>Average amount per car (lbs)</th>
<th>Performance/Price ratio (Specific strength/$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>2000</td>
<td>0.15</td>
</tr>
<tr>
<td>Aluminum</td>
<td>600</td>
<td>0.08</td>
</tr>
<tr>
<td>FRP</td>
<td>77</td>
<td>0.36</td>
</tr>
<tr>
<td>Natural Fiber Comp.</td>
<td>35.2</td>
<td>1.15</td>
</tr>
</tbody>
</table>

For equal volumes, composites outperforms steel and aluminum. Natural fibers have additional strong penetration potential.
Composites (fiber reinforced plastics—glass and carbon fiber based)
Penetration in Various Market Segments: Natural fiber composites have significant potential in transportation and construction market

<table>
<thead>
<tr>
<th>Market Segment</th>
<th>Composite Materials Market</th>
<th>Structural Materials Market (Steel, Al &amp; Composites)</th>
<th>Composites Penetration</th>
<th>Performance Gap</th>
<th>Price Gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>$2.7 B</td>
<td>$75.7 B</td>
<td>3.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marine</td>
<td>$0.5 B</td>
<td>$0.7 B</td>
<td>68%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerospace</td>
<td>$2.0 B</td>
<td>$19.1 B</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe &amp; tank</td>
<td>$2.1 B</td>
<td>$29.6 B</td>
<td>7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>$3.1 B</td>
<td>$78 B</td>
<td>4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind Energy</td>
<td>$2.0 B</td>
<td>$5.4 B</td>
<td>38%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumer Goods</td>
<td>$1.1 B</td>
<td>$7.7</td>
<td>14%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Composites Penetration compared to Competing Materials (Steel & Al)

Source: Lucintel
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External Forces Shaping the Natural Fiber Composites Industry: Future higher market fragmentation expected due to emerging economies. Companies in Developed nations with innovation capability can thrive and gain share.
Natural Fiber Composites Trend and Forecast 2005 - 2016

Natural Fiber Composites Trend & Forecast 2005 – 2016 (US$M)

Key Insights

- Natural fiber composites has experienced healthy growth in last 5 years
- Market has two segments: wood fiber and non-wood fibers
  - Automotive is largest segment for non-wood fibers
  - Construction is for wood fibers
- Europe is largest region for Automotive applications
- North America is largest region for Building & Construction applications
- Natural fiber composites are new to E&E and Sporting goods applications
- Environmental concerns are making natural fiber composites suitable in various new applications

Notes: Market includes wood and non wood natural fiber composite markets
Trend in GDP in Various Regions: 2005 - 2010

- Natural fiber composites has observed positive growth in each region, and surpassed GDP growth.
- Natural Fiber Composites industry performed well relative to GDP during last 5 years, and is expected to continue to grow higher than GDP over next 5 years.

Notes:
- Others includes Asia and rest of the world
- Bubble size represents market size 2010 ($ M)

Source: Lucintel
Natural Fiber Composites Potential in Different Regions

Notes:
- Others includes Asia and rest of the world
- Bubble size represents market size 2010 ($ M)

Market Leader:
- North America is leader in natural fiber composites consumption followed by Europe

Potential Market:
- Europe shows potential due to increasing awareness and acceptance of natural fiber composites by automotive players
- Asia has significant growth potential as penetration per capita is significantly lower than developed nations

Source: Lucintel
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Growth Opportunities of Natural Fiber Composites in Various Applications

- Demand for natural fiber composites expected to be high in automotive and construction applications due to:
  - Awareness towards green products and increasing acceptability
  - Need for light weight and cost effective products
  - Reduce global warming impact
  - Governmental support
- Natural fiber composites are new in E& E and sporting segments, but has healthy potential to capture good market share in near future

Key Insights
### Drivers and Challenges

#### Major Drivers

<table>
<thead>
<tr>
<th>Raw material source</th>
<th>• Natural fiber composites made with easily available renewable sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties</td>
<td>• Lighter weight, low energy consumption and low cost product</td>
</tr>
<tr>
<td>Volatility in Oil prices</td>
<td>• Impacts substitute materials market and NFC costs less so</td>
</tr>
<tr>
<td></td>
<td>• Encourage world to use NFC</td>
</tr>
<tr>
<td>Environmental advantages</td>
<td>• Natural fiber composites are eco friendly and help to reduce global warming effect</td>
</tr>
<tr>
<td>Government Support</td>
<td>• Legislative/policy commitment to carbon reduction</td>
</tr>
</tbody>
</table>

#### Key Challenges

| Material quality | • Uniformity and consistency of raw material are major industry challenges |
|                 | • Lower impact strength, not suitable for applications requiring optimal strength |
|                 | • Low UV resistance limits market                                        |
| Processing      | • Natural Fiber variability and subsequent degradation while manufacturing composite products |
|                 | • Technological improvements needed                                       |
| Inventory of raw material | • Fibers are hydrophilic which drives potential degradation and biological attack by fungi |
|                     | • Subsequent difficulty to store for long periods of time made more acute by dependency on seasonal production |
Innovations in Natural Fiber Composites Market

Eco Mobile by NEC 2006:
- First time in world an environmentally sound material has been used for a mobile phone casing

Model Name:
- “FOMA(R) N701iECO”

Material used:
- Reinforcement: Kenaf
- Resin: Poly Lactic acid

Advantages
- Heat resistant
- Environment friendly

Innovations in Automotive:
1. OEM & Model Name:
   - Ford Motor Co., 2010 FordFlex CUV

Applications:
- Trim bin

Material & Process:
- Wheat-Straw-Reinforced PP, Injection molding

2. OEM & Model Name:
   - BMW 2008MY BMW 7 Series Luxury Sedan

Applications:
- Door Panel

Material & Process:
- Prepreg of Natural fiber with acrylic polymer, Compression molding

3. Process Innovation
   - Highly automated D-LFT process by Daimler Chrysler

Racing Bicycle with NFC:
- Museeuw Bikes has developed first racing bike with flax carbon epoxy prepreg

Model Name:
- MF1, MF3, MF5

Material used:
- Reinforcement: Flax, Hemp
- Resin: Epoxy

Advantages
- Good anti-vibration property
- Low cost
Natural fiber in automotive applications: Bast fiber such as flax, hemp & kenaf are most suitable natural fibers for various automotive applications and are focused on lower strength needs.

<table>
<thead>
<tr>
<th>Applications</th>
<th>Fiber</th>
<th>Size of Opportunity</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Door panel/inserts</td>
<td>Kenaf/ Hemp Wood fiber</td>
<td>Medium</td>
<td>• Lower weight</td>
<td>• Lower strength</td>
</tr>
<tr>
<td>Rear parcel shelves</td>
<td>Kenaf</td>
<td>Medium</td>
<td>• Lower cost</td>
<td>• High moisture absorption</td>
</tr>
<tr>
<td>Seatbacks</td>
<td>Flax</td>
<td>Medium</td>
<td>• Eco friendly</td>
<td>• Lower durability</td>
</tr>
<tr>
<td>Spare tire covers</td>
<td>Flax</td>
<td>Medium</td>
<td>• Friendly processing</td>
<td>• Poor fire resistance</td>
</tr>
<tr>
<td>Other interior trim</td>
<td>Kenaf</td>
<td>Small</td>
<td>• Thermal recycling is possible</td>
<td></td>
</tr>
<tr>
<td>Spare-wheel pan</td>
<td>Abaca</td>
<td>Medium</td>
<td>• Good thermal and acoustic insulation</td>
<td></td>
</tr>
</tbody>
</table>

DaimlerChrysler’s model with abaca + pp

Mercedes E class reduced 20% weight with NFC

Door, Panel, Door Inserts, Interior Door Panel
# Emerging Natural Fiber Composite Applications in Construction

<table>
<thead>
<tr>
<th>Applications</th>
<th>Fiber</th>
<th>Size of Opportunity</th>
<th>Key Drivers</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decking</td>
<td>• Wood flour/fiber: mainly natural wood alternatives construction applications</td>
<td>High</td>
<td>• Low life cycle cost</td>
<td>• Lower strength</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Low &amp; easy maintenance</td>
<td>• High moisture absorption</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Low moisture absorption</td>
<td>• Lower durability</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Lower variability than wood</td>
<td>• Poor fire resistance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Eco friendly</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Government regulation</td>
<td></td>
</tr>
<tr>
<td>Railing Systems</td>
<td>• Flax</td>
<td>High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Window frame</td>
<td>• Rice husk</td>
<td>High</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Bagasse</td>
<td>Medium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fencing</td>
<td></td>
<td>High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Natural fiber in other applications: Flax and kenaf fibers have strong penetration in sporting goods and electronics applications

<table>
<thead>
<tr>
<th>Applications</th>
<th>Fiber</th>
<th>Size of Opportunity</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tennis Racket</td>
<td>Flax</td>
<td>Medium</td>
<td>• Good anti vibration</td>
<td>• Lower strength</td>
</tr>
<tr>
<td>Bicycle Frame, Fork, Seat Post</td>
<td>Flax</td>
<td>Medium</td>
<td>• Lower cost</td>
<td>• High moisture absorption</td>
</tr>
<tr>
<td>Snowboarding</td>
<td>Hemp</td>
<td>Small</td>
<td>• Eco friendly</td>
<td>• Lower durability</td>
</tr>
<tr>
<td>Mobile Cases</td>
<td>Kenaf</td>
<td>Medium</td>
<td></td>
<td>• Poor fire resistance</td>
</tr>
<tr>
<td>Laptop Cases</td>
<td>Flax</td>
<td>Medium</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Applications:**
- Bicycle with NFC frame
- Tennis Racket
- Snowboard
Natural Fiber Composites Market Potential Analysis in Automotive in 2015

Applications

<table>
<thead>
<tr>
<th>Applications</th>
<th>NFC Potential in 2015</th>
<th>NFC Potential Strength Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Door Panels</td>
<td>145 M lbs</td>
<td>@ Current Strength</td>
</tr>
<tr>
<td>Door inserts</td>
<td>US$ 72 M</td>
<td></td>
</tr>
<tr>
<td>Shelves</td>
<td></td>
<td>@ 25% Improvement</td>
</tr>
<tr>
<td>Spare wheel</td>
<td>234 M lbs</td>
<td></td>
</tr>
<tr>
<td>pan cover</td>
<td>US$ 117 M</td>
<td>@ 50% Improvement</td>
</tr>
<tr>
<td>Headliners</td>
<td>324 M lbs</td>
<td></td>
</tr>
<tr>
<td>Bumpers</td>
<td>US$ 162 M</td>
<td></td>
</tr>
<tr>
<td>Protection trim</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Methodology: Sensitivity analysis between consumption volume & strength performance of natural fiber

Source: Lucintel
Conclusions

- New business models need to be re-invented to address the fast changing complex world
- Higher specific properties with lower prices of natural fiber composites are making it attractive for various applications
- Good anti-vibration properties & low cost are key drivers for higher adoption of natural fiber composites in sporting goods segment
- Due to lower life cycle cost & easy maintenance of wood plastic composites, it is gaining more acceptance in building & construction applications
- Eco-friendly measures taken by electronic companies are the major growth drivers for natural fiber composites in Electrical & Electronics applications
- Rising prices of petroleum based products, strong government support to eco-friendly products, higher acceptance and positive growth of end use industries will drive natural fiber composites growth to new horizon
- Performance improvement of natural fibers will help to cater more applications and industries in near future
Conclusions

- New business models need to be re-invented to address fast changing complex world
- Higher specific properties with lower prices of natural fiber composites are improving attractiveness for various applications
- Good anti-vibration properties & relative low cost are key drivers for higher adoption of natural fiber composites in sporting goods segment
- Due to lower life cycle cost & easy maintenance of wood plastic composites, gaining more acceptance in building & construction applications
- Eco-friendly measures taken by electronic companies are major growth drivers for natural fiber composites in Electrical & Electronics applications
- Rising prices of petroleum based products, strong government support to eco-friendly products, higher acceptance and positive growth of end use industries will drive natural fiber composites growth
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- Marine
- Construction
- Renewable Energy
- Recreational
- Composite Materials

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- Growth and Strategic Consulting
- Benchmarking
- Opportunity Screening
- Partner Search and Evaluation
- Due Diligence and M&A
- Market Entry Strategy
Lucintel has an extensive toolkit to address key strategic questions for increasing your company’s profitability and market presence.

**Key Questions**

- **Is market space / opportunity of current product offerings sufficiently robust?**
- **Markets are focus for many: how can my company profitably differentiate?**
- **Based on our core skills, where should we focus?**
- **Should we build or buy? Is build even an option?**
- **What game changer actions exist and/or is a more incremental approach best?**
- **What is the order sequence of market entry segments / products?**
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