# Building Capacity and Capability in the Bio-based Materials Manufacturing Sector

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## About the Center for Automotive Research

CAR is a leader in researching the significant issues that affect the global automotive industry's future. CAR, a nonprofit organization, is focused on a wide variety of important trends and changes related to the automobile industry and society at the international, federal, state and local levels. CAR's automotive industry research is performed by distinct groups and programs.

To fulfill its mission as an impartial voice of the industry, CAR maintains strong relationships with industry, government agencies, universities, research institutes, labor organizations, media, and other major participants in the international automotive community.

www.cargroup.org

# Executive Summary

Michigan is both a hub for automotive research and development activity as well as agricultural production: automakers and suppliers conduct over 75 percent of all privately-funded U.S. automotive R&D in Michigan annually, and the state ranks second nationally in bio-diversity of its agricultural products.[1] Manufacturing and agriculture come together through innovation in developing and manufacturing plant-based advanced materials for automotive uses—activities that have a long history in Michigan that goes back to the earliest days of the automotive industry. The Center for Automotive Research (CAR), with support from the U.S. Department of Commerce's Economic Development Administration, produced this research to explore pathways toward building capacity and capability in automotive use of manufactured biomaterials in Michigan.[2]

Bio-based materials are those that use renewable agricultural materials instead of conventional ones. These materials can be sourced from plant, animal, or marine origins, and are used to replace fabrics, adhesives, reinforcement fibers, polymers, and other conventional materials. Traditional uses of bio-based materials include wood trim, cotton textiles, and leather seats; biomaterials are also used in the auto industry as polymers as well as reinforcements and fillers. Bio-materials may be mixed with conventional materials, such as a petroleum-based polymer with natural reinforcement fibers. Bio-materials may or may not be biodegradable (able to be decomposed by living organisms).

Wooden frames and components were used in the very first automobiles manufactured in Michigan, and Henry Ford was a pioneer in using bio-based materials in composites, paints, enamels, and foam. Other manufacturers followed suit, using biomaterials in seats, cushions, and mainly non-structural interior parts. Since then, bio-based materials have been used in a number of automotive applications: natural fibers such as flax, sisal, hemp, coconut fiber, abaca (banana) fiber, bio-based foams, cotton, and natural latex have been incorporated in sound proofing, linings, insulation, seats, and cushions. Different types of fiber have different properties, and lend themselves to different applications throughout the vehicle. Bast fibers (from the stems of plants grown for fiber such as hemp, kenaf, flax, and jute) are strong and stiff and can be used as reinforcement; leaf fibers are tough and can be used in structural applications; seed and fruit fibers (such as cotton, kapok, and coir) are elastomerically tough,

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[1] California ranks first.

[2] This work was conducted through the Make it in America Challenge Grant program, and CAR's partners include the National Center for Manufacturing Sciences (NCMS), the Michigan Manufacturing Technology Center (MMTC)—with support from the U.S. Department of Commerce—National Institute for Standards and Technology, and the Macomb/St. Clair Workforce Development Board—with support from the U.S. Department of Labor—Employment and Training Administration.

but not structural. Natural fibers can offer equivalent (or superior) performance, often at a significant reduction in product weight.

Lightweighting is a significant trend in the auto industry, as manufacturers seek to reduce mass in order to meet stricter fuel economy and emissions standards. Biomaterials may play a role in mass reduction, but the bio-based products must meet or exceed current standards for conventional materials in quality, performance, and price. With suppliers facing increasing price pressures, bio-based materials must be cost-neutral compared to conventional products. It is not currently feasible or cost-effective to make large portions of passenger cars and trucks using bio-based materials, but these materials do make sense in certain applications. Many automakers are interested in utilizing more bio-based materials, but most have not made public announcements of their specific targets. European and Asian countries have been more aggressive in requiring use of bio-based materials than has the United States, but the concurrent move toward more global vehicle platforms and vehicle may increase U.S. usage since biomaterials are required in other markets.

The automotive industry's interest in environmentally-friendly materials and technologies goes beyond lightweighting and regulation compliance. Other factors driving the increased use of biomaterials include economic, sustainability, business, and product-specific concerns.

In many cases, biomaterials cost more than conventional materials. An increase in price of conventional materials sources—specifically, oil and natural gas prices—may make use of bio-based materials more cost competitive. Availability and scale are other economic factors limiting wider-spread usage of bio-based materials, at least in the short-term. Broader commercialization and supply chain development will be needed, as some of the newer biomaterials are not yet produced at a scale sufficiently large to supply mass-produced automotive parts and components. The lack of scale may also increase the risks of supply chain disruptions and price variability.

Certain bio-based feedstocks are either also consumed as food (e.g. soybeans and corn), or the land used to grow them could conceivably be used to grow edible crops. These issues can create political concerns about the switch to more industrial use of bio-based materials.

Consumer preferences have shifted toward more environmentally-conscious purchasing decisions, which is reflected in many automakers' and suppliers' company-wide sustainability policies. These polices often include targets for the increased use of bio-based materials, which leads companies to consider greater bio-content for its marketing and public relations value in addition to cost, quality, and performance.

Some bio-based plastics have advantages over conventional materials that make them preferable for certain applications. For instance, bio-based fibers are typically safer to handle and manufacture than glass, which can cause health concerns for employees who work with glass fiber reinforced plastics in the manufacturing environment. However, seasonal and geographic differences can cause unwanted variation in bio-based products—which limit the use in parts of the vehicle the customer can see and touch.

Technical factors can limit wider adoption of biomaterials. Manufacturing processes may need to be adapted to accommodate bio-based materials—for example, the flash point of fiber reinforcements might be lower than that of conventional reinforcements, which may require a change in the temperature required to manufacture plastics with natural fiber reinforcements. Also, due to the natural variability in bio-based materials, it is difficult to simulate and model product durability or manufacturing processes.

There are a number of opportunities Michigan could pursue to take advantage of increased prevalence of bio-based materials. Public sector agencies can help promote biomaterials through their strategic plans, focused attraction and job creation efforts, regulatory changes that support the use of bio-based materials, or through public funding or financing for bio-based material R&D and commercialization.

The private sector can also promote increased bio-based material usage. Automakers and suppliers might collaborate with other companies or even other industries to help achieve scale in production, or to address shared challenges that limit greater use of these materials. Bio-materials suppliers might also take on a greater share of the manufacturing process to demonstrate product functionality and manufacturability, or to standardize product inputs or develop new technologies such as additive manufacturing with bio-based materials.

*Roadmap for Bio-based Material Development*

*Companies:*

- Decide pursuing bio-based materials is a company focus.
- Create partnerships among traditional and non-conventional organizations.

*State:*

- Coordinate state-wide efforts.
- Provide shared test lab space.

*Federal:*

- Increase public awareness of bio-based materials and their benefits.
- Encourage exploration of bio-based products that can be made from currently unused or under-utilized parts of the raw and food material production process.
- Increase financing offerings for smaller, bio-based companies.

Bio-based materials are not likely to achieve widespread adoption in the automotive industry as long as petrochemical prices remain low, policymakers do not incentivize or mandate their usage, and consumer demand is low. However, the companies and organizations that are currently working to develop bio-based materials do so to ensure they are ready with a diverse portfolio of products if and when conditions become more favorable.

# Introduction

Michigan is the hub of U.S. automotive production and innovation. The state is home to automotive research and development (R&D), engineering, and production facilities for eleven major automakers and hundreds of automotive suppliers—including 61 of the top 100 auto suppliers in North America.[3] Automakers and suppliers conduct over 75 percent all of all privately-funded annual U.S. automotive Research and Development (R&D) in Michigan.[4] Biomaterials are an opportunity to capitalize on two of Michigan's strengths: manufacturing accounts for 20 percent of Michigan's GDP and the state ranks second nationally in bio-diversity of agricultural products.[5] While manufacturing and agriculture thrive throughout Michigan, there is a concentration of both in Southeast Michigan, which is home to agricultural production, value-added processing, logistics and distribution, and innovation around plant-based advanced materials manufacturing.

Given Michigan's abundance of manufacturing, R&D, and agriculture, the Center for Automotive Research (CAR) sought out and received a Make It in America Challenge grant, funded by the U.S. Department of Commerce's Economic Development Administration, to explore pathways toward Building Capacity and Capability in the Bio-based Materials Manufacturing Sector. Bio-based materials are those which use renewable feedstocks instead of conventional ones. This research builds and expands on Michigan's distinctive combination of manufacturing and agricultural assets. The primary goals are to support job creation and attract investment in the bio-based materials sector, as well as inform and prepare companies in the automotive supply chain about bio-material products.

Project partners include CAR, the National Center for Manufacturing Sciences (NCMS), the Michigan Manufacturing Technology Center (MMTC)[6], and the Macomb/St. Clair Workforce Development Board (M/SC WDB).[7] Experts from these organizations provided specific and specialized technical assistance to firms within the sector, and skills training for unemployed, incumbent, and new entrants in bio-based materials development with automotive industry applications. Partners also offered technical assistance to Michigan companies through access to high performance computing tools for modeling and simulating bio-based materials. The technical assistance was especially targeted at small- and medium-sized manufacturers in the

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[3] Automotive News. (2015). 2014 Top Suppliers Supplement.

[4] NSF. (2014). "TABLE 15. Domestic R&D paid for and performed by the company, by industry and company size, by state: 2011." Business R&D and Innovation Survey. Accessed December 8, 2014. <http://www.nsf.gov/>.

[5] *Michigan's Food and Agriculture Industry*. Michigan Department of Agriculture & Rural Development. 2012. Pg 2. Accessed 7 January, 2015. http://www.michigan.gov/documents/mdard/1262-AgReport-2012_2_404589_7.pdf

[6] MMTC's portion of the grant is funded by the National Institute of Standards and Technology.

[7] M/SC WDB's portion of the grand is funded by the Employment and Training Administration.

automotive supply chain, as they often lack the capital to invest in new equipment and/or R&D to explore and utilize new materials and methods. More detailed information on partner activities can be found in Appendices A-C.

## Methods

To support the development of a bio-based manufacturing sector, CAR researchers began by identifying which companies and organizations are working with bio-based manufacturing materials and where they are located. CAR utilized a previous report written on the landscape of bio-based materials,[8] and researchers used further literature searches and discussions with companies to identify other companies and organizations working with bio-based materials.

The organizations selected for inclusion in this study encompass all parts of the vehicle supply chain: automakers, automotive suppliers, compounders, and chemical companies. They also included academic, governmental, and other organizations that do research on the potential for bio-based materials. CAR interviewed close to sixty companies and organizations as part of this project. A full list is located in Appendix A: National Center for Manufacturing Sciences Project Summary.

CAR researchers developed a questionnaire, located in Appendix E: Bio-based Materials Questionnaire, to use as a basis to start a discussion with project participants. The primary goals of the interviews were to learn the following:

1. What the companies/organizations were doing with bio-based materials;
2. Why they were working with these materials;
3. What challenges did they either overcome or were continuing to experience with respect to bringing bio-material products to market.

The breadth of organizations interviewed allowed researchers to gain unique insight into the above questions for a variety of products and materials, and informed a holistic understanding of the bio-based materials market in the automotive industry.[9] In particular, the interviews helped guide creation of a list of opportunities to advance the bio-based sector, and the roadmap for how to take advantage of these opportunities. In the interviews, researchers also took the opportunity to introduce the project's partner organizations to ascertain whether the company/organization would like to engage with them.

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[8] Hill, Kim, Bernard Swiecki and Joshua Cregger. *The Bio-based Materials Automotive Value Chain*. Center for Automotive Research. April 2012.

[9] A list of production and concept vehicles that incorporate bio-based materials is located in Appendix F.

## Bio-based Materials Basics

Bio-based materials have many automotive applications. This section includes information on bio-material properties and costs, common feedstock materials, and an overview of standards and labeling programs for bio-based materials.

### Definition

The U.S. Department of Agriculture (USDA) defines a bio-based product as a "commercial or industrial product (other than feed, food, or fuel) that is composed in whole or in significant part of biological products—renewable agricultural materials (including plant, animal, and marine materials) or forestry materials."[10] The emerging concept of the "bio-economy" includes biofuels (ethanol and biodiesel), bioenergy (landfill gas and biomass), and biomaterials (organic solvents and biopolymers).[11] Bio-based materials are industrial products made from renewable agricultural and forestry feedstocks, which. These feedstocks can include wood, grasses, and crops, as well as wastes and residues. Bio-based materials are also used to replace fabrics, adhesives, reinforcement fibers, polymers, and other conventional materials.[12]

There are several ways to use bio-based materials in automotive components. Beyond traditional uses like wood trim, cotton textiles, and leather seats, there are two primary ways in which these materials are typically used: as polymers and reinforcements/fillers. Renewable and conventional materials can be combined to produce components; for instance, a bio-based composite could be composed of a petroleum-based polymer but use renewable natural fibers as reinforcement. Alternately, a renewable polymer can also use conventional reinforcement fibers. In addition, conventional and renewable polymers can be mixed, as can conventional and renewable reinforcement fibers.

#### *Controlled Decomposition*

Many people consider bio-based materials to be synonymous with biodegradable materials. For this study, we distinguish between the two: bio-based materials come from renewable agricultural or forestry feedstocks while biodegradable materials can be broken down and decomposed by living organisms. A bio-based product may or may not be biodegradable, depending on the processes required to turn the renewable feedstock into a new product. Similarly, a biodegradable material may be made of either bio-based or petrochemical

[10] USDA. (2013). "BioPreferred Program Overview." United States Department of Agriculture. May, 2013. <http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3806163.pdf>.
[11] Mid-Michigan Bio-Alliance. (2011). "Autobiography: The Story of Moving Michigan's Workforce and Talent to the New Bio-Economy." Mid-Michigan Bio-Alliance. September 9, 2011.
[12] Mohanty, Amar K., Manjusri Misra, and Lawrence T. Drzal. (2002). "Sustainable Bio-Composites from Renewable Resources: Opportunities and Challenges in the Green Materials World." Journal of Polymers and the Environment 10.1-2 (April 2002): 19-26.

feedstocks, thus may be bio-based or not. Because vehicles are designed to operate for many years before they reach their end of life, biodegradable materials are typically not used in automotive manufacturing. There is, however, some interest in the industry in developing biodegradable materials that can undergo controlled decomposition—remaining stable while the vehicle is still in use, but with the ability to be processed and biodegraded under controlled conditions at the end of the vehicle's lifecycle.

## Common Materials

Natural fibers are commonly divided into bast, leaf, and fruit/seed fibers.[13] Bast and leaf fibers are the most commonly used natural fibers for composite reinforcement in automotive components. Bast fibers come from the stem of plants that are specifically grown for fiber (such as hemp, kenaf, flax, and jute). Leaf fibers are commonly sourced from plants such as sisal, abaca (banana), and pineapple. Natural fibers can also come from a variety of wood sources or crop residues.

Bio-based polymers can be made from a variety of sources including soybean, castor bean, corn, and sugar cane. These feedstocks are usually fermented and go through a series of conversions to produce polymers for plastic composites. Just like their conventional counterparts, bio-based polymers can be extruded, blown, molded, injection-molded, foamed, and thermoformed.

## Vehicle Applications

Natural fiber fillers and reinforcements are the fastest growing polymer additive.[14] Over the past two decades, natural-fiber composites have increasingly been used by the European automotive industry,[15] such as sisal, kenaf and flax for several interior parts. More recently, these materials have gained traction in the United States as well, with use of natural fiber fillers and reinforcements and castor- and soy-based polyols for interiors (e.g., textiles, carpeting, and foams) becoming more widespread.

Bio-based materials have been tested and deployed in a number of automotive components. Flax, sisal, and hemp are used in door interiors, seatback linings, package shelves, and floor panels. Coconut fiber and bio-based foams have been used to make seat bottoms, back cushions, and head restraints. Cotton and other natural fibers have been shown to offer

[13] Njuguna, James, Paul Wambua, Krzysztof Pielichowski, and Kambiz Kayvantash. (2011). "Chapter 23: Natural Fibre-Reinforced Polymer Composites and Nano Composites for Automotive Applications." Cellulose Fibers: Bio- and Nano- Polymer Composites. S. Kalia, B.S. Kaith, and I. Kaur Eds. Springer 2011.
[14] Ashori, Alireza. (2008) "Wood–Plastic Composites as Promising Green-Composites for Automotive Industries!" Bioresource Technology 99.11 (July 2008): 4661-4667.
[15] Holbery, James and Dan Houston. (2006). "Natural-Fiber-Reinforced Polymer Composites in Automotive Applications." JOM Journal of the Minerals, Metals and Materials Society 58.11(November 2006): 80-86.

superior sound proofing properties and are used in interior components. Natural latex is used to enhance the safety of interior components by making the surfaces softer. Abaca fiber has been used to create under-floor body panels.[16]

## Material Properties

Bast fibers are strong and stiff, giving them the ability to support great loads before failing, while leaf fibers are tough, giving them the ability to absorb large amounts of energy before failing. Seed or fruit fibers (e.g. cotton, kapok, and coir) have elastomeric toughness, but are not structural.[17] Because different applications will require different properties, different types of fiber will be appropriate depending on the use, and in many situations, a blend of various types of fibers may be appropriate to achieve desired properties. The most common natural fibers used in automotive components are flax, kenaf, and hemp, which are all bast fibers that can be used to displace fiberglass reinforcement fibers in composites. Many natural fibers can provide equivalent (or even superior) performance compared to conventional reinforcement fibers, while reducing product weight due to their lower densities.

Several different fibers and polymers are listed in Table 1, along with associated physical properties—including density, elongation, and tensile strength. Density, the ratio of mass to volume, is an important characteristic for materials used in automotive components due to the recent emphasis placed on vehicle lightweighting. Lower density materials can potentially replace higher density materials to reduce weight and improve fuel economy or vehicle performance. Elongation is a measure of the strain (relative change in shape or size) on a sample when it breaks due to stress (force). It is measured as a percentage (i.e. extended length of sample after test divided by the original sample length). Typically, fibers have a low elongation and polymers have a high elongation. Tensile strength is a measure of the tension (stretching) required to break a sample. Fibers (especially bast fibers) often have a high tensile strength, while polymers have a low tensile strength. Young's modulus is a measure of elasticity and is expressed as the ratio of stress to strain.[18] A material with a high Young's Modulus is described as rigid. Fibers will typically have a higher Young's Modulus, while polymers will have lower values.

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[16] Ibid. Holbery and Houston. (2006).

[17] Brosius, Dale. (2006). "Natural Fiber Composites Slowly Take Root." Composites Technology. February 1, 2006. <http://www.compositesworld.com/articles/natural-fiber-composites-slowly-take-root>.

[18] Nave, R. HyperPhysics. Georgia State University. Accessed March 16, 2016. < http://hyperphysics.phy-astr.gsu.edu/hbase/permot3.html>

**Table 1: Mechanical Properties of Selected Fibers and Polymers**

| | Material | | Density (g/cm3) | | Elongation at Break (%) | | Tensile Strength (MPa) | | Young's Modulus (GPa) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fibers (Reinforcements) | Fiber Type | Low | Hig | Low | High | Low | High | Low | High |
| Bio-based | Bagasse | Bast | 1.3 | 1.3 | 1.1 | 1.1 | 222.0 | 290.0 | 17.0 | 27.1 |
| | Bamboo | Bast | 0.6 | 1.1 | 2.5 | 3.7 | 140.0 | 800.0 | 11.0 | 32.0 |
| | Flax | Bast | 1.4 | 1.6 | 1.2 | 4.0 | 300.0 | 2,000 | 24.0 | 103. |
| | Hemp | Bast | 1.4 | 1.5 | 1.0 | 6.0 | 270.0 | 900.0 | 23.5 | 90.0 |
| | Jute | Bast | 1.3 | 1.5 | 0.8 | 2.0 | 200.0 | 800.0 | 8.0 | 78.0 |
| | Kenaf | Bast | 1.4 | 1.4 | 1.5 | 2.7 | 223.0 | 1,191 | 14.5 | 53.0 |
| | Ramie | Bast | 1.0 | 1.6 | 1.2 | 8.0 | 348.0 | 1,000 | 24.5 | 128. |
| | Abaca (Banana) | Leaf | 1.5 | 1.5 | 1.0 | 10.0 | 400.0 | 980.0 | 6.2 | 33.7 |
| | Pineapple | Leaf | – | – | 2.4 | 2.4 | 170.0 | 1,627 | 60.0 | 82.0 |
| | Sisal | Leaf | 1.2 | 1.5 | 2.0 | 7.0 | 80.0 | 840.0 | 9.0 | 38.0 |
| | Coir | Seed/Fruit | 1.2 | 1.5 | 14.2 | 51.4 | 95.0 | 230.0 | 2.8 | 6.0 |
| | Cotton | Seed/Fruit | 1.5 | 1.6 | 3.0 | 10.0 | 264.0 | 850.0 | 5.0 | 12.6 |
| | Wool | Animal Fiber | 1.3 | 1.3 | 20.0 | 40.0 | 120.0 | 200.0 | 2.3 | 3.4 |
| | Viscose (cord) | Wood Fiber | 1.5 | 1.5 | 11.4 | 11.4 | 180.0 | 593.0 | 11.0 | 11.0 |
| | Soft Wood (kraft) | Wood Fiber | 1.5 | 1.5 | – | – | 1,000 | 1,000 | 40.0 | 40.0 |
| Conventional | E-glass | Glass Fiber | 2.5 | 2.6 | 2.5 | 3.0 | 1,800 | 3,500 | 70.0 | 73.0 |
| | S-glass | Glass Fiber | 2.5 | 2.5 | 2.8 | 2.8 | 4,570 | 4,570 | 86.0 | 86.0 |
| | Aramide (Normal) | Synthetic | 1.4 | 1.4 | 3.3 | 3.7 | 3,000 | 3,150 | 63.0 | 67.0 |
| | Carbon (Standard) | Carbon Fiber | 1.4 | 1.4 | 1.4 | 1.8 | 4,000 | 4,000 | 230. | 240. |

| | Polymers (Resins/Matrices) | Polymer Type | Low | Hig | Low | High | Low | High | Low | High |
|---|---|---|---|---|---|---|---|---|---|---|
| Bio-based | Nylon (PA 11) | Thermoplastic | 1.0 | 1.1 | 280.0 | 280.0 | 47.0 | 47.0 | 1.1 | 1.4 |
| | Polylactic Acid (PLA) | Thermoplastic | 1.2 | 1.4 | 1.5 | 380.0 | 10.0 | 60.0 | 0.4 | 2.8 |
| | Thermoplastic Starch (TPS) | Thermoplastic | 1.2 | 1.4 | 1.0 | 500.0 | – | – | 0.1 | 2.9 |
| | Polyethylene (HDPE)* | Thermoplastic | 0.9 | 1.0 | 30.0 | 1,000 | 20.0 | 32.0 | 0.6 | 1.4 |
| Conventional | Acrylonitrile Butadiene Styrene | Thermoplastic | 1.1 | 1.1 | 10.0 | 10.0 | 55.0 | 55.0 | 2.8 | 2.8 |
| | High Impact Polystyrene (HIPS) | Thermoplastic | 1.0 | 1.1 | 15.0 | 60.0 | 26.0 | 48.0 | 1.8 | 2.5 |
| | Nylon (e.g., PA 6, PA 12, PA 46, | Thermoplastic | 1.0 | 1.2 | 12.0 | 320.0 | 35.0 | 100.0 | 1.0 | 3.5 |
| | Polycarbonate (PC) | Thermoplastic | 1.2 | 1.2 | 100.0 | 100.0 | 62.0 | 62.0 | 2.3 | 2.3 |
| | Polyetherimide (PEI) | Thermoplastic | 0.0 | 0.0 | – | – | 105.0 | 105.0 | 2.8 | 2.8 |
| | Polypropylene (PP) | Thermoplastic | 0.9 | 0.9 | 200.0 | 200.0 | 35.0 | 35.0 | 0.8 | 0.8 |
| | Epoxy Resin | Thermoset | – | – | 6.2 | 6.2 | 32.0 | 32.0 | 0.5 | 0.5 |

**Biobased or conventional*

*Sources: Ashori 2008, Abilash and Sivapragash 2013, Dubey and Agnihotri 2013, Furtado et al. 2014, Misnon et al. 2014, Namvar et al. 2014, and Matbase 2014*

## Material Cost

There is intense price competition in the automotive industry, and automakers and suppliers are generally unwilling to pay a premium on materials, parts, or components. Suppliers therefore must address any shortcomings of bio-based materials, and bio-based components must be price-neutral compared with their conventional counterparts—which is a significant challenge for a new product to overcome. Many of the natural fibers used in composites are less expensive per unit mass than glass fibers, but more expensive than talc, another filler material commonly used in automotive composite materials (see Table 2 for price comparisons). Because most of these fibers have material properties that are superior to talc and sometimes even equivalent to glass fibers, these bio-based materials may be cost competitive for certain applications.

**Table 2: Average Prices for Selected Fillers**

| **Filler Material** | Filler | Price per Kilogram |
|---|---|---|
| Bio-based | Soft & Hard Wood | $0.20 – 0.55 |
| | Coir | $0.31 – 0.55 |
| | Jute | $0.33 – 0.55 |
| | Flax | $0.40 – 0.75 |
| | Hemp | $0.40 – 0.75 |
| | Kenaf | $0.40 – 0.55 |
| | Pineapple Leaf | $0.40 – 0.55 |
| | Sisal | $0.40 – 0.83 |
| | Cotton | $0.44 – 0.55 |
| | Ramie | $0.44 – 0.55 |
| | Abaca | $1.16 |
| Conventional | Talc | $0.30 |
| | Polypropylene | $1.50 |
| | E-glass | $2.00 |

*Sources: Furtado et al. 2014, Akil et al. 2011, and Stoeffler 2014*

## Standards

While Standards Developing Organizations (SDOs) have created standards related to bio-based materials, there are no U.S. regulations limiting what can and what cannot be called a bio-based material, nor what is an appropriate lower-bound to make claims of using bio-based materials. To the first point, SDOs such as the American Society for Testing and Materials (ASTM)[19] and the International Organization for Standardization (ISO),[20] have developed standards for

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[19] ASTM. (2014). American Society for Testing and Materials. Website. Accessed December 16, 2014. <http://www.astm.org>.
[20] ISO. (2014). International Organization for Standardization. Website. Accessed December 16, 2014. <http://www.iso.org>.

measuring bio-based content and conducting life cycle assessments (LCAs).[21] The automotive industry uses these standards to demonstrate the benefits of using bio-based materials and to verify the materials' renewable content. In February 2014, the Kia Soul EV was the first vehicle to be validated by Underwriters Laboratories for containing 10 percent bio-based content in its interior materials. The company saw bio-based materials a way to expand sustainability issues beyond the common fuel-efficiency/carbon emission conversation to considering the life-cycle perspective of a vehicle.[22] The vehicle contains 52.8 pounds of bio-based plastics.[23]

But companies wishing to include the bio-based content of a product in their marketing materials need an objective way to determine both the environmental impacts of using various materials in their products, as well as a sound method for quantifying the portion of their product that is bio-based in a way that will give legitimacy to the figures used. Food labeling programs such as "Non-GMO Project Verified" or "USDA Organic" are examples of other standards have come to signify specific product characteristics to the general population, and both are increasingly used by consumers in purchasing decisions.[24] Until formal industry standards are developed and agreed upon, certifications and validations such as the UL/Kia example remain less impactful in terms of a marketing/customer recognition point of view than they otherwise could be.

## Labeling and Procurement Programs

The U.S. Department of Agriculture (USDA) Biopreferred Program is comprised of two major initiatives: the voluntary product labeling initiative and the preferred federal procurement initiative.[25] The USDA would like to eventually include automobiles under these programs, but first must solve the difficult issue of creating a labeling system for complex assemblies (such as automobiles) that integrate numerous components. The 2014 Farm Bill establishes procedures for designating complex assemblies as eligible for the USDA programs.[26]

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[21] These standards provide frameworks for determining bio-based content in a product (ASTM D6866 and ASTM D7026) and for evaluating the environmental implications of bio-based materials (ASTM D7075, ISO 14040, and ISO 14044). For more information on these standards, visit the ASTM (www.astm.org) and ISO (www.iso.org) websites.
[22] Kia. (2014). "Kia Soul EV earns world automotive industry's first UL Environment Validation for Bio-based Organic Carbon Content." Kia Media. February 3, 2014. < http://www.kiamedia.com/us/en/media/pressreleases/8072/kia-soul-ev-earns-world-automotive-industrys-first-ul-environment-validation-for-bio-based-organic-carbon-content1>
[23] Kia. (2014). "2015 Soul EV Overview: Fun-and-Funky Goes Green: Soul EV Arrives as Kia's First All-Electric Vehicle in the U.S." Kia Media. September 11, 2014. <http://www.kiamedia.com/us/en/media/pressreleases/9382/2015-soul-ev-overview>.
[24] Consumer Reports. "GMO Foods: What you need to know." *Consumer Reports.* February 26, 2015. <http://www.consumerreports.org/cro/magazine/2015/02/gmo-foods-what-you-need-to-know/index.htm>.
[25] Ibid. USDA. (2013).
[26] USDA. (2014). "USDA Announces Inclusion of Wood Products and Other Materials in BioPreferred Program." United States Department of Agriculture. August 6, 2013. <http://www.usda.gov/wps/portal/usda/usdahome?contentidonly=true&contentid=2014/08/0169.xml>.

It is not currently feasible or cost-effective to make a significant portion of an automobile out of bio-based materials, but some components within existing vehicles are routinely composed of more than 25 percent bio-based content (e.g., parts made from bio-based foam or natural fiber-reinforced composites). The minimum bio-based content requirement for the USDA programs is set at 25 percent, and if these component suppliers were to be considered on their own, they would be eligible for those programs. However, the vehicle as a whole would not meet the USDA 25 percent minimum content requirements.

Similar to the federal program, many state and local governments have passed legislation establishing preferential procurement for bio-based products.[27] In 2007, the Midwestern Governors Association set the foundation for creating a bio-based product procurement initiative as part of its Energy Security and Climate Stewardship Platform for the Midwest.[28]

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[27] States with bio-based procurement programs include including Arkansas, Illinois, Indiana, Iowa, North Dakota, Ohio, and South Dakota.
USB. (2015). "State and Local Activities" United Soybean Board. Website. Accessed January 30, 2015. <http://www.soybiobased.org/resources/state-and-local-activities>.

[28] MGA. (2008). "Guidelines for Implementing a Regional Bioproduct Procurement System." The Midwestern Bioproduct Procurement System Task Force Report, Midwestern Governors Association. 2008. <http://www.midwesterngovernors.org/Publications/Bioproduct%20Report.pdf>.

# Automotive Usage

The use of agricultural materials in vehicles has a rich history, starting with some of the earliest models in the early part of the 20th century. This section discusses this history of bio-based material use in auto, how these materials are being developed and commercialized in today's automotive industry, and the current market for bio-based materials.

## History

The earliest automobiles contained bio-based materials in the form of wooden carriage bodies. In the 1920s, Henry Ford developed Fordite, a composite of wheat straw, rubber, and other materials that was used in steering wheels.[29] By the 1930s, Ford was using bio-based materials in paints, enamels, and molded plastic parts. Ford also used soybeans, hemp, wood pulp, cotton, flax, and ramie in various components.[30] In 1941, Ford unveiled a car that had soy-based plastic body panels,[31] which is shown in Figure 1. The "soybean car's" body integrated wheat straw, hemp, flax, ramie, and soybeans. In Figure 1, the image on the left shows Ford and Robert Boyer, one of the company's top soybean researchers, with the soybean car. The image on the right shows Ford demonstrating the strength and resilience of bio-based plastics by swinging an axe and having it bounce off the trunk of his personal car, which had been modified with a bio-based plastic rear deck lid.[32]

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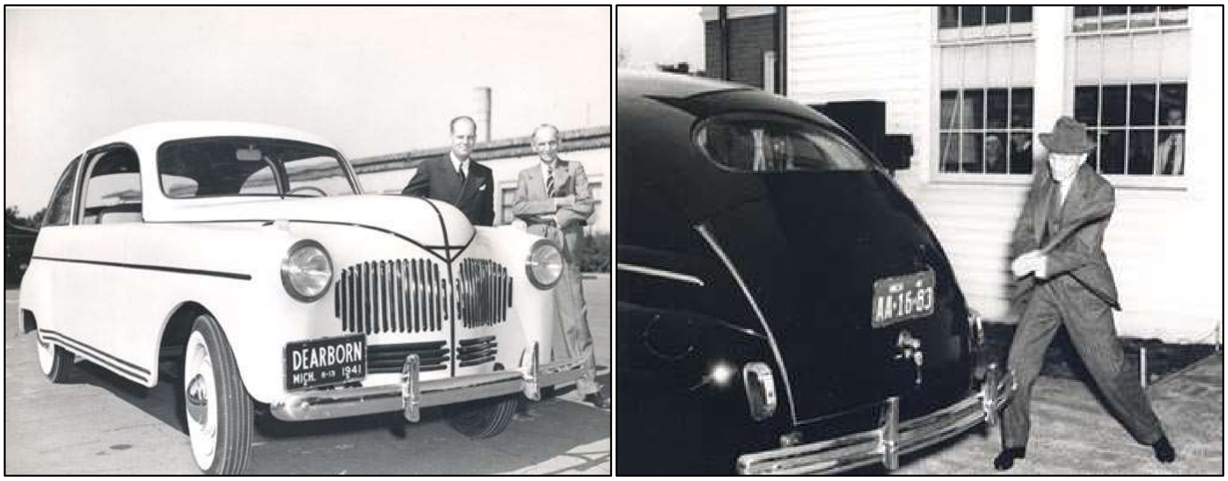
[29] Ford. (2009). "Ford Teams Up to Develop Wheat Straw-Reinforced Plastic; New Biomaterial Debuts in 2010 Ford Flex ." Ford Motor Company. PR Newswire Press Release. November 11, 2009. <http://www.prnewswire.com/news-releases/ford-teams-up-to-develop-wheat-straw-reinforced-plastic-new-biomaterial-debuts-in-2010-ford-flex-69750107.html>.

[30] Crawford, Craig. (2009). "Automotive Bioplastics: Back to the Future." Canadian Chemical News 6.6(June 2009):28-30. <http://www.cheminst.ca/sites/default/files/pdfs/ACCN/BackIssues/2009%20-%2006%20June.pdf>.

[31] Davis, Rusty. (1988). "Henry's Plastic Car: An Interview with Mr. Lowell E. Overly." V-8 Times, 25.2 (March/April 1988):46-51.

[32] Henry Ford Museum. (2015). "The Henry Ford Image Source." The Henry Ford Museum. Website. Accessed January 30, 2015. <http://www.thehenryford.org/research/soybeancar.aspx#>.

**Figure 1: Ford's 1941 Soybean Car and Ford Demonstrating the Strength of Bio-based Plastics**




*Source: Henry Ford Museum 2015*

Other automakers followed Ford's lead, and by the 1960s, coconut fibers were used by many car makers in car seats and wood flour fillers were used in polypropylene composites for interior parts.[33] The use of bio-based materials in components gained more traction in the early 1990s, including replacing glass fibers with plant fibers in composites for automotive parts and components.[34] During this period, advances in bio-based material technology involved mostly non-structural interior applications. Bio-based materials were introduced in several vehicles, first in Europe and later in North America, and were used to manufacture components such as door panels, package trays, seat backs, and trunk liners.[35]

## Commercialization

Commercialization is the process used to describe a product's path, starting as an idea in R&D, and moving through validating performance prototypes, getting customer approvals, persuading the customer's engineering, design, and purchasing departments to include the new material, and developing the manufacturing processes to include it in a vehicle. While new materials are constantly being developed at universities and private research centers, not all are destined for commercialization. Bringing the material from the idea phase to a commercial product can be a very long process, and many new ideas do not make it from start to finish. In order to be successfully implemented, a new material must pass through each step in the process and production must scale up rapidly to meet the high volume demands of the

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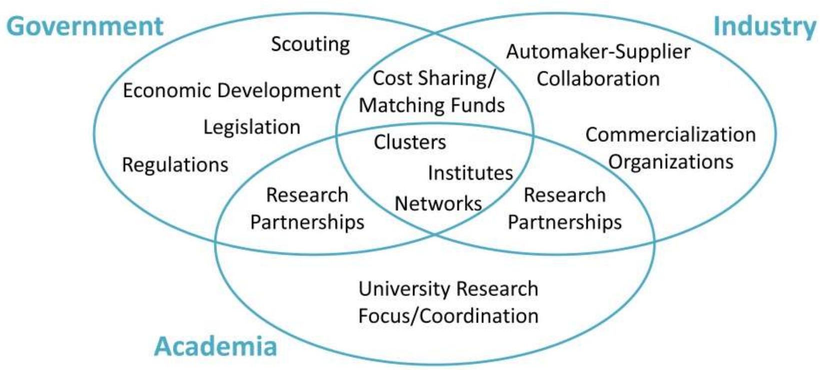
[33] Aparecido dos Santos, Paulo; Joao Carlos Giriolli, Jay Amarasekera; and Glauco Moraes. (2008). "Natural Fibers Plastic Composites for Automotive Applications." SABIC Innovative Plastics. 8th Annual Automotive Composites Conference & Exhibition, Society of Plastics Engineers. September 16-18, 2008. <http://www.speautomotive.com/SPEA_CD/SPEA2008/pdf/c/BNF-04.pdf>.
[34] Ibid. Ashori. (2008).
[35] Ibid. Brosius. (2006).

automotive industry. Technologies are particularly vulnerable in the "valley of death" when the technology is developed enough that it is no longer basic research appropriate for university labs, but is not sufficiently developed enough for the private sector to invest in bringing it to market.

There are numerous approaches to increase the commercialization of bio-based materials in automotive components. In general, the commercialization process could benefit from strong stakeholder involvement and the creation of partnerships and institutions to promote the research and institutional support necessary to enhance the state-of-the-art in bio-based parts and components and overcome current barriers to implementation. Advancing commercialization can be done in a number of ways. Figure 2 outlines various methods which have been used to promote the penetration of bio-based materials in automobiles.

**Figure 2: Methods to Promote Bio-based Material Commercialization**




*Source: CAR 2016*

The methods listed above do not represent independent pathways to commercialization. Instead, these initiatives demonstrate collaborative ways to enhance the commercialization environment for bio-based automotive components.

Many automakers and suppliers are already working on bringing bio-based components to market. For instance, Ford has established a department specifically to conduct work on bio-based materials and has committed to purchasing certain bio-based components for its vehicles. Companies supplying components or materials have dedicated significant resources to developing and testing their products. Strong automaker initiatives and commitments to use bio-based materials can provide the certainty suppliers need to make investments in large-scale bio-based material and component production.

Universities play a large role in basic research in bio-based materials, and regional industries can benefit from coordinated university programs that leverage the academic resources of a region to address specific issues. In addition to coordinating universities with each other, encouraging universities and industry to work together can provide academic researchers greater understanding of business, while directing research towards practical applications that are valuable to industry partners. This strategy has been employed in Canada (e.g., Ontario BioCar Initiative and AUTO21) and is the basis for the National Network for Manufacturing Innovation (NNMI) institutes and the Center for Bioplastics and Biocomposites ($CB^2$) in Iowa.[36]

Commercialization organizations play a vital role in bridging the gap between university research and bringing products to market. These organizations can be quite diverse, ranging from government programs and non-profit groups to for-profit businesses that take university research and move it through the pilot stage. A prominent example of this type of organization is MBI (formerly Michigan Biotechnology Institute) in East Lansing, Michigan. MBI helps organizations ascertain the most promising technologies for commercialization, and assists them in developing their products. MBI specifically focuses on bio-based products. Other types of organizations can include incubators that offer small start-ups space and equipment to test and market their products or establish commercialization funds (e.g., Ontario BioAuto Council).

Networking among the various stakeholder organizations—such as automakers, suppliers, economic development organizations, universities, and government agencies—is instrumental to creating an environment conducive to bio-based product commercialization. By connecting the various stakeholders, knowledge and industry clusters can be created, supply chains can be developed, partnerships explored, and advocacy networks can be strengthened. With greater understanding of the bio-based materials landscape, stakeholders can work together to make these products commercially viable.

### *Supply Chain*

The supply chain for automotive bio-based materials is representative of one for any newly introduced technology. In many cases, a supply chain is created for a specific need of a single customer (often an automaker). Suppliers develop new capacities to meet that specific need, and if the material is successful, they may continue to develop their capabilities as new orders are placed. Some suppliers, especially chemical companies but also compounders, are more proactive and develop bio-based products that can readily replace conventional materials. For example, large chemical companies, such as BASF, Braskem, and DuPont, are currently

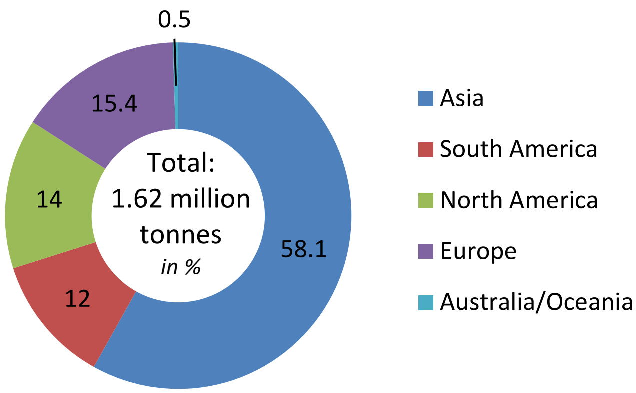
[36] $CB^2$ is an NSF-funded collaboration between university researchers and industry representatives. Industry partners support university research into bio-based materials through membership fees and together decide on precompetitive research projects at participating universities (Iowa State University and Washington State University). Current members include several automakers and automotive suppliers, as well as representatives from other industries.

marketing bio-based polymers. There are also several companies engaged in compounding natural fibers; A. Schulman and RheTech are two high-profile examples.

## Bio-based Materials Market

Growing demand for lightweight material in automobiles is expected to encourage demand for bio-based materials.[37] Global production capacity for bio-based polymers rose by 800,000 tons from 2013 to 2014, to 1.7 million tons, and is expected to increase to 7.85 million tons by 2019.[38] Figure 3 displays capacity by region.

**Figure 3: Global Production Capacities of Bioplastics by Region, 2014**




*Source: Aeschelmann and Carus 2015*

Packaging applications are the main driver for growth in bio-based polymers, but there is strong growth in textile and automotive applications.[39] As of 2014, the automotive sector used 18 percent of global bio-based polymer production, tying consumer goods as the second largest user after packaging (rigid and flexible), which used 21 percent of bio-based polymer production.[40]

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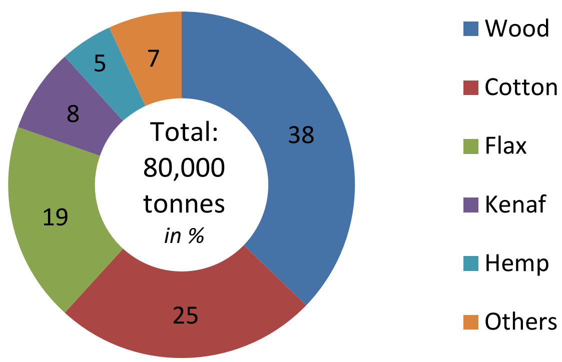
[37] Grand View Research. (2014). "Bio-Based Polyethylene Terephthalate (PET) Market By Application (Packaging (Bottles), Technical, Consumer Goods) And Segment Forecasts To 2020 Expected To Reach 5,800 kilo tons By 2020." Grand View Research – Market Research & Consulting. December 2014. <http://www.grandviewresearch.com/press-release/global-bio-based-polyethylene-terephthalate-pet>.
[38] EBB. (2014). "Bioplastics Production Capacities to Grow by More than 400% by 2018." European Bioplastics Bulletin 2014.6 (December 2014): 2-3. December 11, 2014. <http://en.european-bioplastics.org/wp-content/uploads/2014/newsletter/Issue6_14.pdf>. and Aeschelmann, Florence and Michael Carus. (2015). "Bio-based Building Blocks and Polymers in the World." Nova-Institute. December 2015. <<http://www.bio-based.eu/markets>.
[39] Ibid. EBB. (2014).
[40] Ibid Aeschelmann and Carus. (2015).

The automotive industry is also a large user of natural fiber-reinforced composites, including wood. In 2012, automotive sector accounted for nearly 43 percent of all wood-plastic and natural fiber-reinforced composites produced in Europe.[41] These composites average more than 50 percent natural fiber by weight. In 2011, the average vehicle contained 3.8 kg of natural fibers and wood fibers, a number that increased to approximately 4.9 kg in 2012.[42] Figure 4 displays bio-based feedstocks for composites used by the automotive industry in Europe.

**Figure 4: Wood and Natural Fiber used for Automotive Composites in Europe, 2012**




*Note: "Others" category consists mainly of jute, coir, sisal, and abaca.*
*Source: Carus et al. 2015*

## Current Usage

Automotive components that incorporate bio-based materials have been used by many automobile manufacturers around the world, including Audi, BMW, Daimler (Mercedes Benz), Fiat Chrysler (FCA), Ford, General Motors, Honda, Hyundai-Kia, Mazda, Nissan, Peugeot, Renault, Toyota, Volkswagen, and Volvo.[43] The materials used in these vehicles are frequently sourced where the manufacturing plant is located. North American producers of bio-based materials are already supplying automotive manufacturers with bio-based materials for use in a variety of components.

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[41] Carus, Michael, Asta Eder, Lara Dammer, Hans Korte, Lena Scholz, Roland Essel, Elke Breitmayer, and Martha Barth. (2015). "WPC/NFC Market Study 2014-10 (Update 2015-06) Wood-Plastic Composites (WPC) and Natural Fibre Composites (NFC): European and Global Markets 2012 and Future Trends in Automotive and Construction." Nova-Institute. June 2015. <http://www.bio-based.eu/markets>.
[42] Ibid. Carus et al. (2015). and ACEA. (2013). "The Automobile Industry Pocket Guide 2013." European Automobile Manufacturers Association (ACEA). 2013. <https://www.acea.be/uploads/publications/POCKET_GUIDE_13.pdf>.
[43] Hill, Kim, Bernard Swiecki, and Joshua Cregger. (2012). "The Bio-based Materials Automotive Value Chain." Center for Automotive Research. February 2012. <http://www.cargroup.org/?module=Publications&event=View&pubID=29>.

Of all the automakers using bio-based materials, again, Ford is the most active. Across its lineup, the company uses nearly 300 parts made of bio-based materials, and the average Ford vehicle contains 20 to 40 pounds of renewable materials.[44] Ford currently uses eight different bio-based feedstocks in its vehicles: castor beans, cellulose, coconut, jute, kenaf, rice hulls, soybeans, and wheat straw.[45]

Across all automakers, the most common components that have been made with bio-based materials include door panels, seat backs, package trays, dashboards, headliners, trunk liners, and other interior trim parts. There have been fewer exterior or under-the-hood applications, though bio-based plastics have been used in Toyota's radiator end tanks and FCA's fuel lines. Flax fibers have been used in car disk brakes to replace asbestos fiber, and underbody panels for Mercedes vehicles have been created using abaca fibers in place of conventional glass fiber reinforcement.[46] Currently, automotive companies are using natural fiber-reinforced composites more so than bio-based polymers.

In recent years, there have also been attempts to use natural fiber composites in structural applications—an area which has previously been the reserve of synthetic fibers like glass and aramid.[47] Some researchers are interested in combining natural fibers with nanomaterials to develop structural components that could potentially be used in automotive components. Though exterior, under-the-hood, and structural applications are more limited and frequently still in various stages of research and commercialization, these uses represent some of the more high-technology and high-value applications of bio-based materials and could potentially become an important part of the market.

During the 2008-2009 recession, there was an uptick in bio-based materials in the automotive aftermarket sector. However, most aftermarket providers are relatively small and do not have the research and development budgets of larger companies. Thus much of the bio-based work has decreased as the economy has improved and petroleum prices remain low.[48]

## Announced Usage/Goals

Though many automakers have expressed interest in using more bio-based materials in their products, most have not publically stated specific targets for use of bio-based materials in their

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44 IHS. (2014). "Editorial - Ford's Love for Bio-Based Materials." IHS Supplier Business. June 30, 2014. <http://www.supplierbusiness.com/news/26645/editorial-fords-love-for-bio-based-materials-?rf=weeklyinsight>.
45 Mielewski, Deborah. (2014). "Building the Bio-based Automobile." Presentation. Mid-Tech Biobased Materials Commercialization Symposium, Midland, Michigan. October 21, 2014.
46 Ibid. Hill, Swiecki, and Cregger. (2012).
47 Ibid. Njuguna et al. (2011).
48 Waraniak, John (2016). Interview with John Waraniak, Vice-President Vehicle Technology, Specialty Equipment Manufacturers Association. April 19, 2016.

vehicles. In 2008, Toyota set a goal of replacing 20 percent of the plastics it used with bio-based plastics by 2015.[49] Though recent sustainability reports do not reference this goal, they do indicate that Toyota is continuing to evaluate bio-based materials and is using them when appropriate.[50]

Ford has internal goals for renewable materials usage by department, but these goals are not numeric, because it is difficult to predict when the materials will be available at competitive cost, quality, and volume. Ford has modified specifications to require suppliers to include a minimum amount of bio-based content in seat foams. Ford's modification has ensured the automaker will continue to use these materials in its products into the future. Ford has developed a Sustainable Materials Strategy to enable sustainable materials leadership without compromising quality, durability, performance, or economics. Under this strategy, Ford has committed to selecting renewable materials whenever technically and economically feasible and set the goal of increasing recycled and renewable content each year, model by model where possible.[51]

As with Toyota and Ford, General Motors has affirmed its commitment to use recycled and bio-based materials, but has not set a specific numerical target. The 2014 GM sustainability report indicates that the company will use these materials "when economically and technically feasible."[52]

One way automakers initiate the use of new materials is by including them in concept vehicles. Over the years, several automakers have unveiled concept vehicles incorporating bio-based materials (see Appendix F for a list of concept and production vehicles with bio-based materials). More recent concepts that integrate bio-based materials include a concept Fusion Energi that Ford unveiled in 2013, integrated interior fabrics made from bio-based PET fibers using PlantBottle Technology from Coca-Cola.[53] The Biofore Concept Car from UPM, which uses natural fiber composites and wood-based materials in its body panels, also premiered in 2013.[54]

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[49] Otani, Takuya. (2008). "Toyota Plans to Replace 20% of Plastics with Bioplastics." Tech On! October 21, 2008. <http://techon.nikkeibp.co.jp/english/NEWS_EN/20081021/159844/>.
[50] Toyota. (2015). "NorthWar American Environmental Report 2015." Toyota Motor Corporation. November 2015. <http://www.toyota.com/usa/environmentreport2015/materials.html>.
[51] Ibid. Mielewski. (2014).
[52] GM. (2015). "GM: A Driving Force, 2014 Sustainability Report." General Motors. May 2015. <http://www.gmsustainability.com/>.
[53] Ford. (2013). "Driving Innovation: The Coca-Cola Company and Ford Unveil Ford Fusion Energi with PlantBottle Technology Interior." Ford Motor Company Media Center. November 15, 2013. <https://media.ford.com/content/fordmedia/fna/us/en/news/2013/11/15/driving-innovation--the-coca-cola-company-and-ford-unveil-ford-f.html>.
[54] UPM. (2014). "The Biofore Concept Car." UPM. November 13, 2013. <http://www.upm.com/upmcc-en/Pages/default.aspx>.

The material choices in these concept vehicles reflect potential consideration of bio-based components for actual production models in the future. Many of the bio-based material technologies demonstrated in these vehicles have slowly made their way into production vehicles.

## Why Michigan?

Many other agricultural states, such as Iowa and Minnesota, have already developed plans to guide their own strategies for strengthening production and use of bio-based materials.[55] Does it make sense for Michigan to develop and implement a bio-based materials strategy of its own? What attributes does Michigan have that would allow it to become a leader in this area? In addition to having a vibrant and diverse agriculture sector, Michigan is the top automotive manufacturing state with well-developed supply chains both within the state and among its neighbors in the Great Lakes region. Furthermore, Michigan hosts the bulk of automotive research and development (R&D) in North America. These strengths translate to advantages in feedstock resource production; material production, forming, and application; and new material and product development and commercialization.

### Agriculture

With 54,900 farms and 10 million acres of farmland,[56] Michigan is a large agricultural state. Michigan produces more than 300 commercially produced agricultural commodities,[57] which places the state second only to California in terms of crop diversity. Furthermore, Michigan is the top producer of 18 commodities and ranks in top 10 states for 56 other commodities. In addition to growing crops, Michigan also has a diversified food processing portfolio. Michigan's top three agricultural exports are soybeans, corn, and wheat,[58] all three of which have been used to produce bio-based materials for automotive components. According to the Michigan State University Product Center, agriculture has annual economic contribution to the state's economy of more than $100 billion.[59]

### Manufacturing

Along with agriculture, manufacturing is one of Michigan's priority industry clusters, meaning it remains vital to the Michigan economy and remains a major source of employment in the

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[55] Iowa State University. (2002). "Biobased Products and Bioenergy Vision and Roadmap For Iowa." Center for Industrial Research and Service (CIRAS), Iowa State University. October 2002. <http://www.ciras.iastate.edu/publications/IABioVisionRoadmap.pdf>.
LifeScience Alley and the BioBusiness Alliance of Minnesota. (2012). "Minnesota Roadmap: Recommendations for BioIndustrial Processing." LifeScience Alley and the BioBusiness Alliance of Minnesota. March 2012. <http://www.ascension-publishing.com/BIZ/MN-Roadmap.pdf>.

[56] MDARD. (2012). "Michigan's Food & Agriculture Industry." Michigan Department of Agriculture and Rural Development. <https://www.michigan.gov/documents/mdard/1262-AgReport-2012_2_404589_7.pdf>.

[57] MI Ag Council. (2014). "Michigan Agriculture Facts." Michigan Ag Council. November 2014. <http://www.michiganagriculture.com/farming-in-michigan/michigan-agriculture-facts/>.

[58] Ibid. MDARD. (2012).

[59] Michigan. (2014). "Gov. Rick Snyder says economic impact of food, agriculture industry surpasses $100 billion goal" State of Michigan. October 29, 2014. <http://www.michigan.gov/snyder/0,4668,7-277-57577_57657-340323--,00.html>.

state.[60] In 2014, manufacturing was responsible for $88.6 billion of economic activity in Michigan, which represents more than 20 percent of the state's GDP.[61] Though battered by the 2008-2009 recession, manufacturing employment in Michigan has recovered to approximately 600,000 employees—about 16 percent of all private employment in the state.[62] Michigan is home to 12 automotive assembly plants and thousands of supplier facilities, and is the top producer of both motor vehicles and engines in North America.

## Research and Development

Michigan is the hub for North American automotive R&D. As of 2012, it accounted for nearly 77 percent of all automotive R&D conducted in the United States.[63] While automakers Fiat Chrysler, Ford, and General Motors constitute a substantial portion of this R&D, they are not the only companies that have established Michigan as the leader in automotive R&D. Michigan hosts facilities for eleven of the largest automakers,[64] and hosts the headquarters for 61 of the 100 top North American automotive suppliers.[65] In total, there are more than 400 automotive R&D facilities located in Michigan.[66]

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[60] WDA. (2013). "Manufacturing Cluster Workforce Analysis." Michigan Workforce Development Agency. January 2013. <http://www.michigan.gov/documents/mdcd/WDA_ManufacturingFINAL_opt_410543_7.pdf>.

[61] BEA. (2015). "Regional Data: GDP & Personal Income" Bureau of Economic Analysis. Accessed December 9, 2015. <www.bea.gov>.

[62] BLS. (2015). "Databases, Tables & Calculators by Subject: State and Area Employment, Hours, and Earnings." Bureau of Labor Statistics, U.S. Department of Labor. Accessed December 9, 2015. <www.bls.gov>

[63] Wolfe, Raymond. (2015). "Business Research and Development and Innovation: 2012." National Science Foundation. October 29, 2015. <http://www.nsf.gov/statistics/2016/nsf16301/#chp2>.

[64] These include Ford, General Motors, Fiat Chrysler, Toyota, Honda, Volkswagen, Mitsubishi, Subaru, Hyundai-Kia, Nissan, and Daimler.

[65] Automotive News. (2015). "2014 Top Suppliers Supplement." Automotive News. June 15, 2015. <http://www.autonews.com/section/datalist42>.

[66] CAR. (2015). Internal Research. Center for Automotive Research; MEDC. (2007). "Michigan Automotive Research & Development Facilities Directory." <http://www.michiganbusiness.org/cm/files/directories/medc_autord_directory_2007.pdf>; and ELM. (2014). ELM Supplier Database. Accessed October 2014.

# Market Factors for Bio-based Materials

Through the many interviews conducted as part of this project as well as a thorough literature review, researchers identified key market factors that affect commercialization of bio-based materials in the automotive industry. This section first discusses the drivers and benefits to using these materials, followed by gaps and challenges.

## Drivers and Benefits

The industry's emphasis on environmentally-friendly materials and technologies has been spurred by government regulations, consumer preferences, and, in some cases, financial savings that can be realized from the adoption of bio-based materials and associated technologies. Environmentally-friendly materials and technologies hold the promise of accelerated adoption, as costs drop due to economies of scale made possible by high volume production. The drivers and benefits of bio-based materials adoption in the automotive industry can be roughly categorized as political, economic, company policy, product-specific, and sustainability. In some cases, the benefits of bio-based material usage cut across multiple categories.

### *Political Factors*

The United States has not been as aggressive as some countries in Europe and Asia in requiring automakers to use bio-based materials, promoting recyclability of vehicle components, or requiring automakers to take responsibility for vehicle disposal at the end of a vehicle's service life. Despite the lack of a regulatory push domestically, automakers operating in the United States also function in global markets, and automakers are increasingly reliant on global vehicle platforms as well as global supplier contracts for parts and components. If using bio-based materials in their products will help automakers meet government mandates in other countries, those automakers may also choose to use bio-based materials in their North American models to simplify design and sourcing, and to save on costs.

In the United States, federal fuel economy standards that mandate light-duty vehicles to achieve an average of 54.5 mile per gallon (mpg) by 2025[67] are driving greater adoption of vehicle lightweighting technologies. Vehicle weight is a considerable factor in vehicle fuel economy: a 10 percent reduction in vehicle mass can result in a fuel economy improvement of

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[67] White House. (2012). "Obama Administration Finalizes Historic 54.5 MPG Fuel Efficiency Standards." The White House Office of the Press Secretary. August 28, 2012. <http://www.whitehouse.gov/the-press-office/2012/08/28/obama-administration-finalizes-historic-545-mpg-fuel-efficiency-standard>.

up to 5-7 percent.[68] Natural fibers can replace fillers and reinforcement fibers, such as glass or talc, resulting in bio-based composites that are lighter than their conventional counterparts. Several companies interviewed for this project noted they are considering the use of bio-based materials to decrease vehicle weight.

### *Economic Factors*

High oil and natural gas petroleum price increases have been cited as a key to making bio-based plastics cost competitive with conventional materials. In recent years, however, both oil and natural gas prices have fallen substantially. While low cost for petroleum products may not bode well for bio-based plastic adoption,[69] large price fluctuations can make it difficult for automakers and suppliers to price their products. In an industry where product lifecycles and supply contracts last for many years, short-term price fluctuations can impact long-term profitability.

In many cases, bio-based materials cost more than their conventional counterparts. This is especially true for lower cost polymers, such as packaging materials. Automakers require bio-based materials to be on par with—or better than—conventional counterparts in terms of price, performance, and availability. Engineering polymers like bio-based nylons and polyesters, however, often can compete well with conventional counterparts because these higher-valued materials have more complicated supply chains and more intricate manufacturing procedures.[70] One example is Toyota's 2009 use of a bio-based nylon radiator end tank for the 2010 Camry because it resulted in financial savings compared to the incumbent component.[71]

A major economic issue that bio-based materials must overcome is the high unit cost of materials combined with low production levels. In many cases, conventional materials have a well-developed infrastructure and high production levels, resulting in lower unit costs. As demand for bio-based materials increases, some of these materials may become less expensive due to increasing economies of scale. While crop production and manufacturing of parts and components have arguably already attained economies of scale, certain portions of the value chain must scale up in order to reduce prices. For instance, processing (retting) and

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[68] NHTSA. (2012). "Corporate Average Fuel Economy for MY 2017-MY 2025 Passenger Cars and Light Trucks." National Highway Transportation Safety Administration, U.S. Department of Transportation. Pages 435-436. August 2012. <http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/FRIA_2017-2025.pdf>.

[69] Crawford, Craig. (2014). "Ontario BioAuto Council Closes Its Doors." Canadian Chemical News. 11.1(January-February 2014): 13. <http://www.cheminst.ca/sites/default/files/pdfs/ACCN/2014PDFs/2014JanuaryFebruary.pdf>.

[70] Bell, Richard. (2016). Interview with Richard L. Bell, Development Manager, DuPont. March 31, 2016.

[71] Bell, Richard L. and Pete Szanto. (2010) "DuPont Renewably Sourced (RS) Engineering Polymers." Presentation. November 9, 2010. <http://www2.dupont.com/Automotive/en_US/assets/downloads/knowledge%20center/webcasts/Bell_Szanto_FINALSLIDES.pdf>.

compounding of natural fibers, if done at a larger scale, could result in lower unit costs. Likewise, increased volumes could drive vertical integration in the automotive bio-based materials supply chain, further reducing cost.

### *Company Policy-Related Factors*

Many automakers have adopted company-wide sustainability policies that highlight the firm's environmental responsibilities to both its employees and the public. Companies adopting sustainability policies, which may include the increased use of bio-based materials, may do so for a variety of reasons, such as reducing waste, increasing efficiency, improving public perceptions, improving employee pride and morale, differentiating their products, receiving marketing and publicity, and demonstrating leadership.[72] A number of prominent corporations, including automakers and their suppliers, have embraced the business value of sustainability measures.

Consumers have shown increased awareness of environmental issues, and a study from the Boston Consulting Group indicated that 73 percent of consumers consider it important that companies have a good environmental track record.[73] In recent years, automakers have highlighted their use of bio-based materials to customers; in the case of the BMW i3, designers made the natural fibers used in the dashboard and door panels visible to occupants.[74]

In cases where a company-wide sustainability policy addresses bio-based materials adoption, bio-based materials may potentially receive greater consideration for new applications. For example, corporate goals can favor increased use of recycled materials (as with Toyota's and Ford's initiatives) or specifications can favor bio-based materials (as with the case of soy-based foam in Ford's seating systems).

### *Product-specific Factors*

In many cases, bio-based plastic products are adopted not only for their environmentally-friendly image, but also because they have specific advantages over their conventional counterparts that make them preferable for a given application. As technology advances, suppliers expect these benefits—along with cost reductions made possible by increasing economies of scale, to drive increased adoption of bio-based components—as opposed to "soft" drivers such as projecting an environmentally-friendly corporate image.

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[72] EPA. (2009). "Smart Steps to Sustainability: A Guide to Greening Your Small Business." Environmental Protection Agency. September 2009. <http://www.epa.gov/osbp/pdfs/smart_steps_greening_guide_042101.pdf>.
[73] Manget, Joe, Catherine Roche, and Felix Münnich. (2009). "Capturing the Green Advantage for Consumer Companies." Boston Consulting Group. January 2009. <http://www.bcg.com/documents/file15407.pdf>.
[74] BMW. (2013). "BMW i3: Design." BMW AG. Website. November 16, 2013. <http://www.bmw.com/com/en/newvehicles/i/i3/2013/showroom/design.html>.

Bio-based components have several inherent qualities that may make them a superior choice, as compared to their conventional counterparts for specific applications. Because natural fibers (such as hemp, kenaf, and jute) tend to be less dense than traditional fillers (such as fiberglass or talc), components that use these materials are lighter than their conventional counterparts.[75] As mentioned previously, lower densities may make some natural fiber-reinforced composites attractive to automakers interested in lightweighting their vehicles.

Bio-based fibers have characteristics which could make them easier to work with in the manufacturing environment. They are typically safer to handle than conventional materials, such as glass, and are less likely to cause skin and respiratory irritation or other health concerns among employees who handle them.[76] Because equipment used in the manufacturing of bio-based plastic components typically runs at a lower temperature than in the manufacture of petroleum-based plastic components, companies can save time and energy use.[77] Natural fibers also tend to be less abrasive than conventional reinforcement fibers, and therefore cause less wear to manufacturing equipment. Usually, bio-based materials can use the same equipment for both bio-based and conventional materials in the production process, negating the need for new capital expenditures to process bio-based materials.

### *Sustainability Factors*

In the United States, sustainability factors play less of a role in decision-making than they do in Europe. Part of this difference is policy—end-of-life recyclability targets in Europe favor natural fibers over glass fibers—and part of the difference is consumer awareness and desire for "green" materials. While drivers of bio-based material use in the United States may be more pragmatic (e.g., material cost, lightweighting, improved material properties, and rural economic development), decision-makers in Europe value the outcome of lifecycle analyses (LCAs), which calculate the total environmental and energy impacts of using a particular material.

An LCA for a bio-based material may show that it uses less "fossil" carbon and instead cycles carbon from atmosphere. In that case, the material would not lead to higher concentrations of carbon in the atmosphere. If, however, a bio-based material requires more energy to process, form, or transport, its use may result in more greenhouse gas emissions (GHGs) or other environmental costs (e.g., air pollution, water pollution, or landfill use). Depending on sourcing

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[75] Ghassemieh, Elaheh. (2011). "Chapter 20: Materials in Automotive Application, State of the Art and Prospects." New Trends and Developments in Automotive Industry. Prof. Marcello Chiaberge (Ed.). InTech. Pages 365-394. January 8, 2011. <http://cdn.intechopen.com/pdfs-wm/13343.pdf>.
[76] Kim, Hyun-Joong and Byoung-Ho Lee. (2009). "Sustainable Bio-based Green-Composites for Automotive Interior Parts." American Institute of Chemical Engineers. Fall Conference. Fall 2009. <http://www.aicheproceedings.org/2009/Fall/data/papers/Paper169922.pdf>.
[77] Ibid. Brosius. (2006), Njuguna et al. (2011), and Ghassemieh. (2011).

and manufacturing processes, a bio-based material may perform well on an LCA, but there is no guarantee that it will. Automakers may choose to market their vehicles using bio-based materials with positive LCA results, noting the GHG or petroleum use reductions that result from using a bio-based material.

## Gaps and Challenges

After years of research and commercialization efforts, more and more bio-based materials are close to meeting or exceeding performance and cost parameters of conventional plastics. Despite these advancements, some drawbacks exist which prevent wider application in the automotive industry. Bio-based materials must overcome these performance or manufacturing shortcomings, while achieving price-parity (or superiority) with their conventional counterparts—a significant challenge for any new product to overcome. In addition, due to an industry-wide focus on vehicle optimization, specifically around cost, performance, and weight reduction – there is an explosion of material input options, of which bio-based products are just one option.

### *Political Factors*

Certain bio-based feedstocks, such as soybeans and sugarcane, are also consumed as food, resulting in political challenges to using these feedstocks to produce industrial materials. In many cases, companies focus on using feedstocks from an existing waste stream, such as wheat straw, which is often burned or tilled back into the soil. The issue can be resolved if the edible portion of a plant is consumed as food, while the inedible portions are used in bio-based materials applications.

Even when a bio-based plastic application uses a crop that is not edible, concerns can still arise, as the land used to grow the crop could conceivably have been used to grow an edible crop for human consumption. Many suppliers of bio-based feedstocks have been careful to avoid these issues. Recent objections related to the use of corn in ethanol production, which was said to drive up the cost of corn used in food and other applications, has made many bio-based materials companies careful in how they approach their raw materials sourcing strategy. While soybeans are used to produce polyurethane foams for vehicle interiors in North America, where there is surplus soybean production, they are not used in many other parts of the world that suffer from food insecurity.

### *Economic Factors*

Even though activity is increasing, relatively few firms have released products using bio-based materials, and most of the existing products have not been standardized or commoditized. As a result, customers are often unable to source from multiple suppliers. Automakers typically structure their specifications to have multiple sources of given components and raw materials to minimize the risk of supply chain disruptions and price variability. These policies have slowed the adoption of bio-based materials in the industry, since it is often difficult to locate multiple suppliers of the same material in the emerging bio-based materials industry.

Furthermore, because volumes are still relatively low for most bio-based materials, companies have not engaged in a high degree of vertical integration, which has made them more reliant on outside providers—another driver of high prices. For example, the hammer mills and compounding facilities necessary for processing natural fibers could be acquired and run by the same supplier if higher volumes justified the investment. Without vertical integration, each individual process may be performed by a contracted firm, which adds its own margin, resulting in a costlier product.

### *Product-specific Factors*

Bio-based materials have different properties than their conventional counterparts. In many cases, a particular material may have some attractive properties, but it may be less competitive with respect to other properties. For instance, some natural fiber-reinforced composites are marginally less strong and rigid than their conventional counterparts, which could limit their use in certain structural components. Natural fibers may also be more susceptible to water and heat damage, limiting their use in exterior applications.[78] Many bio-based materials, in particular natural fibers and soy, also present odor challenges.

Because bio-based material properties may differ substantially from those of conventional materials, automakers must test bio-based components for additional failure modes beyond those typically tested. While these extra steps protect consumers from quality issues in their vehicles, they also increase the performance challenges that bio-based materials must overcome in order to be used in vehicles. The time and cost required for additional testing may be a barrier to greater use of bio-based materials.

Seasonal and geographic differences can cause variation in natural fiber properties. Weather and climatic conditions, soil properties, and other factors can alter material quality, making it potentially necessary for suppliers to monitor these materials and adapt manufacturing processes.[79] Natural variation can cause inconsistent material appearance and texture. “Precision agriculture,” an effort to improve and standardize agriculture by making it the process smarter using advanced technologies, has been gaining attention and venture capital

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[78] Panthapulakkal, Suhara and Mohini Sain. (2007). “Studies on the Water Absorption Properties of Short Hemp–Glass Fiber Hybrid Polypropylene Composites.” Journal of Composite Materials 41.15(August 2007): 1871-1883.
[79] Ibid. Njuguna et al. (2011).

investment,[80] but this process is not yet widespread. This lack of consistency has resulted in reluctance on the part of some automakers to adopt bio-based materials in the visible and touchable interior parts of the vehicle (e.g., “Class-A” surfaces). Class-A surfaces incorporating bio-based materials, therefore, are more likely to be covered with more consistent, conventional materials. One recent counterexample is the BMW i3 which uses an uncovered natural fiber-reinforced composite in its dashboard and door panels.[81] As consumers learn to associate the variations in bio-based materials with uniqueness and exclusivity, these materials may be more extensively applied to bio-based door inserts, headliners, and other Class-A surfaces.

### *Manufacturing Factors*

The previously-mentioned differences between conventional and bio-based materials may make it necessary for suppliers to adapt their manufacturing processes to accommodate bio-based materials. For instance, natural fibers have a lower point of ignition or charring compared to conventional materials.[82] Because many plastics are processed at temperatures that are at or above the burning temperature of the fibers, this heat sensitivity limits the use of bio-based materials in applications that require high-temperature manufacturing processes. Some bio-based materials require chemical coupling or compatibilizing agents to modify properties, which adds cost to the manufacturing process.[83]

In many cases, even when a bio-based material achieves cost parity with its conventional counterpart, a supplier electing to use the material may have to incur changeover costs that affect both manufacturing and economic factors. If the supplier does not have enough demand to dedicate an entire machine to the bio-based material, it may need to stop running its processes, completely purge its equipment of the old materials, and change equipment settings each time it switches between producing one material to the next. This procedure adds costs in the form of both labor to perform the changeover and equipment downtime. Such costs are lower for “drop in” bio-based materials that can replace conventional materials with no modification to manufacturing equipment.

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[80] Clancy, Heather. (2014). “Is Precision Agriculture Finally Taking Route?” *Forbes*. May 9, 2014. <http://www.forbes.com/sites/heatherclancy/2014/05/09/is-precision-agriculture-finally-taking-root>.
[81] Ibid. BMW. (2013).
[82] Brouwer, W.D. *Natural Fibre Composites in Structural Components: Alternative Applications for Sisal?* Food and Agriculture Organization of the United Nations. 2.5 Disadvantages of Natural Fibres. (Accessed April 29, 2016) <http://www.fao.org/docrep/004/y1873e/y1873e0a.htm>
[83] Ibid. Ashori. (2008).

### *Workforce Factors*

Most companies interviewed for this study suggested they are adequately staffed with workers who have the knowledge and skills necessary to manage current bio-based materials efforts. While some workforce needs may be felt at the R&D portion of product development, at the manufacturing level, there does not appear to be major needs. Since bio-based products are ideally drop-in replacements for conventional counterparts, at this point there is minimal training necessary to put the product into production. As one compounder stated, "Since our process is basically extrusion/compounding, there are lots of people with that experience that just need to learn the nuances of extruding bio-material."

Thus if anything, workforce needs are more strongly felt in the R&D portion of product development, where there is demand for highly-skilled, college-educated workers, though not on the manufacturing side.

### *Technical Factors*

Bio-based materials suffer from a lack of standardization and limited tools for simulation and modeling. In addition to lacking modeling software for bio-based materials, information on specific materials is often limited and properties may vary even with the same feedstock materials. For instance, inconsistency in natural fiber preparation (fiber retting, mat formation) can substantially change material properties. One interviewee noted that the strength of a part can double depending on the retting process and supplier providing the fiber. This potentially high variation can be an impediment to adopting new materials, and even once new materials are commercialized, it can be difficult for customers to source from multiple, competing material providers.

Many of the molders trying to use new materials learn how to do so through trial and error, using different settings on machines and comparing results from various attempts. This process consumes time and resources, but may not achieve desirable results and may slow the adoption of new materials. Materials providers need to provide assistance to their potential customers to help them understand the nuances of working with new materials.

### *Sustainability Factors*

Just as the use of corn-based ethanol prompted "food vs. fuel" debates, the use of agricultural products in materials could raise potential ethical concerns. As mentioned in the Political Factors section above, some companies – particularly in Europe – have sidestepped this issue by vowing to not use edible feedstocks in their bio-based materials. Many companies are using soy-based foams in North American vehicles—Ford regularly touts its soy-based seating—but do not use these materials in parts of the world where there are food shortages. In the United

States, surplus soybeans are often tilled back into the soil rather than harvested, and bio-based foam is an opportunity to add value to crops that would otherwise go uneaten.

As previously mentioned, bio-based does not necessarily mean sustainable, as these materials do not always have positive LCA results. Bio-based materials are also not necessarily more recyclable. While some natural fiber composite applications may be more recyclable than glass fiber composite applications, not all bio-based composites can successfully be ground up, melted, and remolded into new parts. Furthermore, automotive plastics and composites have low levels of recyclability and often end up as shredder residue during the vehicle’s end-of-life stage. A bio-based composite may result in more landfill or incinerator waste than a conventional metal component it replaces.

# Opportunities and Best Practices

Through the many discussions with companies, academic institutions and other organizations during the course of this project, several opportunities emerged that could help Michigan prosper in the bio-based materials space. Different but related opportunities exist for the public sector, private sector, and partnerships between the two.

## Government

Public sector agencies can help promote bio-based materials in a variety of ways. These agencies can develop strategic plans, focus attraction and job creation resources towards supporting firms in bio-based materials supply chain, change regulations to support use of bio-based materials, and provide funding or financing sources for R&D and commercialization activities.

### *Michigan-specific Plan for Supporting Bio-based Materials Development*

To encourage and support a bio-based materials sector, the State of Michigan can develop a plan similar to what other states have done that outlines steps and goals toward growing this sector. Iowa and Minnesota have each drafted plans on this topic. The Michigan Economic Development Corporation (MEDC) and State of Michigan could work together to coordinate policy and economic development efforts, with particular focus on exploring broader users for bio-based polymers, given Michigan's agricultural strengths in this regard.

### *Scouting*

Especially if bio-based materials become a focus—but even if they do not—the state can devote resources to scouting commercialization opportunities from universities in Michigan and other states that may wish to expand and take advantage of manufacturing assets in Michigan. Take, for example, a Sacramento-based start-up, Micromidas. Micromidas began as a business idea two college friends had just prior to graduation. The chemical and research company developed ways to produce intermediaries and plastics using bio-based and other low-value products as inputs. The company was looking to expand and increase its manufacturing capabilities, and explored the possibility of locating in Michigan to take advantage of sugar beet processing residue streams from the Michigan Sugar Company.[84] The company is no longer pursuing a Michigan production facility, but it provides an example of how internal employees or external consultants with solid networks, particularly with universities, could offer this important information on growing companies for organizations like the MEDC to pursue. If the MEDC were to target research universities in states with limited manufacturing capabilities, the state

[84] Smith, Patrick. (2014). "Carbohydrates to p-Xylene." Mid-Tech Biobased Materials Commercialization Symposium, Midland, Michigan. 21 October 2014

could potentially land growing companies that wish to take advantage of Michigan's manufacturing and/or agricultural assets. This could benefit bio-based market as well as other emerging fields.

### *Government Regulation*

Governmental regulations draw opposing viewpoints as to their usefulness and effectiveness. Opinions on regulations aside, there are several ways in which governmental regulations could encourage growth in the bio-based sector. Beyond the regulatory push for fuel economy, which stimulates lightweighting and use of composites, government regulation could require a certain amount of bio-based content at a vehicle or component level.

Instead of passing regulation specifically requiring bio-based materials use, automakers could be given flexibility in achieving CAFE standards. For example, in lieu of achieving an MPG target, a bio-based program could allow credits based on sustainable materials content. This would ease the burden on automakers to achieve high MPG requirements by allowing them the option of sourcing inputs more sustainably and receiving credits for doing so. Additionally, governmental regulation of toxic chemicals, such as phthalates and formaldehyde, could encourage companies to seek alternatives that would possibly be bio-based.

From a USDA perspective, the administration could expand bio-based labeling and production program to include forestry products, and appropriate additional funds to USDA to certify more projects. Additionally, the administration could expand the USDA loan program for companies producing bio-based materials to reduce their capital cost expenditures. There is also a proposed bill in the Senate, "Qualifying Renewable Chemical Production Tax Credit Act of 2013" (S.1267), which would provide a tax credit for renewable chemical production. However, this bill has been sitting in a senate committee for over two years, which does not bode well for its passage.

### *Industrial Hemp in Michigan*

Industrial hemp is used by several companies as the plant's properties are very beneficial in making bio-plastic composites. Hemp fibers tend to have a preferred strength to elongation at failure ratio[85], and the plant itself is relatively easy to grow, requiring few pesticides, and often can produce two crop cycles per year. Several European automakers already use hemp in their composite materials, including Daimler, General Motors (Opel), PSA Peugeot Citroën, and Volkswagen.

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[85] Brouwer, Rik. *Natural Fibre Composites in Structural Components: Alternative Applications for Sisal?* Food and Agriculture Organization of the United Nations. <http://www.fao.org/docrep/004/y1873e/y1873e0a.htm>

It is legal to grow industrial hemp in Europe and in Canada, but not yet fully legal in the United States. While heavily regulated, Canada has allowed industrial hemp to be grown with permits since 1998, and generates revenues in the tens of millions of dollars.[86] A 2014 provision to the U.S. farm bill removed hemp grown for research purposes from being a controlled substance, but each state also needs to approve its use for research independent of the national law. Even if a state approves growing industrial hemp, it is still not yet able to be legally grown for general agriculture production. Should this change, Michigan would be a prime spot to grow industrial hemp, and auto companies could potentially source the product in-state and develop local processing facilities as well.

### *Sources of Funding and Financing*

Funding is a significant issue for any start-up or established company hoping to develop a new product line. Some of the discussion in the governmental regulation section has to do with ways the government can ease the burden on this front. But from a market point of view, the biggest question is will the industry get to a point where bio-based materials are in demand fast enough before a start-up (or company trying a new product line) burns through its allotment of funding?

Venture capital funding is often seen as a viable way to get the necessary cash influx to produce. However, start-up companies can be reluctant to pursue this funding for fear of losing control over the important decisions of the company. Thus, this option is not always ideal.

From the raw production side, according to farm credit services bank GreenStone, the farm credit infrastructure in place is solid and dependable. Farmers often look for a higher value per acre crop, and if the automotive industry has commercially-feasible products, the raw material infrastructure is there to produce the crops.

## Private Sector

The private sector can also promote bio-based materials. Firms can collaborate within a single industry or across industries; partner with government agencies, universities, nonprofits, and other organizations; join networks of organizations with similar interest. There are many different avenues for commercialization as well as opportunities to use bio-based materials in new ways, such as in additive manufacturing applications.

[86] Agriculture and AGri-Food Canada. Industrial Hemp Profile. <http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/crops/pulses-and-special-crops-canadian-industry/industrial-hemp/>

## *Collaboration with Other Industries*

Ford has been collaborating with companies outside the automotive industry for new ideas. One example of this is the Plant PET Collaborative, which also includes Coca-Cola, Heinz, Nike, and P&G. The goal of the group is to find new opportunities to use bio-based polyethylene terephthalate (PET) in consumer products.[87] Coca-Cola is using PlantBottle™ packaging technology in its plastic beverage bottles and Heinz is using the material in some of its ketchup bottles. Ford is looking into using bio-based PET in fabrics for vehicle interiors, and has collaborated with Heinz to explore using tomato peels in automotive composites.[88] Ford is also involved with the Bioplastic Feedstock Alliance, a multi-stakeholder forum convened by the World Wildlife Federation focused on the environmental and social performance of feedstocks used in bio-based materials. Ford is a founding member of the group, along with Coca-Cola, Danone, Heinz, Nestle, Nike, P&G, and Unilever.[89] The $CB^2$ program at Iowa State University is an example of non-competing industries working together to better understand bio-based materials and collaboratively support basic research at universities. Ford and Hyundai are both members of $CB^2$, and supplier companies, such as 3M and RheTech, are also members.

## *Network*

Several of the companies interviewed expressed interest in some sort of network of bio-based companies and organizations. Such a network could meet periodically and discuss challenges and emerging opportunities with respect to commercializing these products. Some interviewees saw a need for greater communication between agriculture industry and automotive, even suggesting the creation of a bio-based products promotion committee, akin to the present Soybean Promotion Committee. Michigan's Soybean Promotion Committee pools funding from soybean farmers across the state to promote the industry and create a sustainable future for its farmers. This includes identifying innovative new uses for the crop.

Universities, particularly with an agriculture or forestry school, can play a unique role within this network. They can bridge the gap between raw material production and engineering those materials into commercialization-ready products. Relevant universities can also participate in joint ventures between farmers and automotive companies.

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[87] Ibid. Ford. (2013).
[88] Ford. (2014). "You Say Tomato; We Say Tom-Auto: Ford and Heinz Collaborate on Sustainable Materials for Vehicles." Ford Motor Company Media Center. June 10, 2014. <https://media.ford.com/content/fordmedia/fna/us/en/news/2014/06/10/ford-and-heinz-collaborate-on-sustainable-materials-for-vehicles.html>.
[89] BFA. (2015). Bioplastic Feedstock Alliance. Website. February 23, 2015. <http://www.bioplasticfeedstockalliance.org>.

Michigan Tech University has created a program called the Michigan Forest Bio-materials Initiative (MiFBI). MiFBI is a parent organization concerned with the entire life cycle of forest based products, including growth, manufacturing, marketing and recycling/reuse. MiFBI has identified strategies to address each part of the life cycle, such as necessary research, supply chain, social attitudes, and working toward a green economy. They partner with a variety of public and private organizations along the wood supply chain.

### *Commercialization*

Unlike some industries with higher margins, the automotive industry does not, in general, pay a premium for bio-based materials which, at a minimum, must meet or exceed cost and performance of the incumbent material. Yet, even when a product achieves these two stringent goals, it takes significant steps to convince potential clients these requirements are met.

One tactic used to promote bio-based product commercialization is offering customers a real-life demonstration of how products are developed and how they function. A small pilot plant can show potential clients how the product works and the manufacturing steps necessary to produce it. Taking this tactic a step farther, some larger companies create a temporary supply chain within themselves. One chemical company gets fiber mats, coats them in resin, dries, cuts and compression forms the mats all under one roof. Ideally, the company would just provide the resin, but in the short term, they can introduce customers to these parts and supply them until a more robust supply chain is created. It clearly takes significant capital investment to make this happen, thus this option would likely prove impossible for small/medium manufacturers.

### *Develop Manufacturing Practices to Help Standardize Bio-based Material Inputs*

Lack of predictable characteristics could hinder use of bio-based materials and vehicle optimization, and this is especially true of natural fibers. While precision agriculture could be part of the solution, standardized manufacturing processes could be a quicker, more attainable answer.

For the polymer compounding industry, an opportunity exists to process natural fibers into consistent lengths, fiber bundle size, and with chemical sizings that will improve the bond to the polymer and thereby increase strength of the final composite compound. Currently, polymer compounders receive fibers in bags or bales, and these fibers have received the minimum processing at the source producer. The compounder must then develop processes to further mill, separate, and treat the fibers. In some cases, this requires investing in new equipment to efficiently process the natural fibers. If natural fiber development centers or labs were to invest in these processes, the adoption of natural fibers as fillers or reinforcements would be easier.

### *Additive Manufacturing with Bio-based Materials*

Over the past few years, additive manufacturing—also known as three-dimensional (3D) printing—has been a hot topic in the automotive industry.[90] Automakers, automotive suppliers, tool & die companies, and other automotive firms are using 3D printing to perform R&D activities, make tools, and customize vehicles. Companies using 3D printing methods can reduce material waste while producing superior products with complex internal structures. Parts formed with 3D printing can be designed to be stronger, lighter, or more functional than parts made with conventional manufacturing processes. Though the materials currently available for 3D printing are somewhat limited, many companies are working to offer new materials. Bio-based materials can be used in 3D printing,[91] and there are a variety of bio-based 3D printing filament materials currently available, including those made from natural fibers,[92] sugars,[93] algae,[94] and even waste byproducts from coffee and beer production.[95] Currently these bio-based, 3D-printed materials are not found in mass-produced vehicles, but several automotive companies are looking for new ways to use 3D printed components,[96] so some of these materials may eventually find their way into vehicles.

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[90] Cregger, Joshua. (2015). "Implications of Additive Manufacturing for the Automotive Industry." Area Development Magazine, Automotive Supplement 2015. August 12, 2015. <http://www.areadevelopment.com/Automotive/q3-2015-auto-aero-site-guide/Implications-Additive-Manufacturing-Auto-Industry-672233.shtml>.

[91] Ad van Wijk, Ad and Iris van Wijk. (2015). "3D Printing with Biomaterials: Towards a Sustainable and Circular Economy." Delft University Press. January 2015. <http://ulib.iupui.edu/static/pdfs/3DPrintingBiomaterials.pdf>.

[92] Plastics Technology. (2015). "Additive Manufacturing: 3D Print PLA with Natural Fibers." Plastics Technology. January 2015. <http://www.ptonline.com/products/additive-manufacturing-3d-pla-filaments-are-reinforced-with-natural-fibers>.

[93] Romanik, Ron. (2015). "Floreon: Bio-based 3D Printing Filament." Packaging World. September 14, 2015. <http://www.packworld.com/sustainability/renewable-resources/floreon-bio-based-3d-printing-filament>.

[94] Molitch-Hou, Michael. "ALGIX and 3D Fuel Partner for Sustainable Algae 3D Printing Filament." 3D Printing Industry. April 22, 2015. <http://3dprintingindustry.com/2015/04/22/algix-and-3d-fuel-partner-for-sustainable-algae-3d-printing-filament/>.

[95] Scott, Clare. (2015). "3Dom Introduces Buzzed, the 3D Printing Filament Made From Beer." 3DPrint.com. October 21, 2015. <http://3dprint.com/101856/3dom-buzzed-beer-filament/>.

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## Roadmap for Bio-based Material Development

Given the various gaps and opportunities for bio-based materials in the automotive market, there are some clear steps companies, the State of Michigan, and even the federal government can take to promote the growth of this industry.

### Company

Decide pursuing bio-based materials is a company focus. This decision is clearly easier when a directive for bio-based materials comes from a client. But whether client-based or not, supplier companies can still make bio-based materials an R&D focus, understanding that in this global market, bio-based materials present significant opportunities to diversity their product lines.

Create partnerships among traditional and non-conventional organizations. The Bioplastic Feedstock Alliance is a prime example of this, as it joins non-competing organizations together around a shared goal of utilizing bio-based materials. Because bio-based materials at their core level can have applications both in automotive and elsewhere, partnerships like this can help companies develop technologies that can perhaps be first introduced in less-stringent industries than auto, while they begin to make inroads into the automotive industry.

### State

Coordinate state-wide efforts. Any efforts in the bio-based space should be coordinated via a single point of contact, either within the state government or via a state-determined third-party. In this way, efforts such as monitoring present activities, scouting future opportunities, and state-specific bio-based materials plan development can be achieved in an organized way.

Provide shared test lab space—an incubator of sorts—for researchers and small companies to explore new bio-based materials but who lack the capital to fund full-on research themselves. The state could document current test facility capacities in Michigan, and potentially partner with organizations or academic institutions to make existing facilities more available to early-stage research.

### Federal

Increase public awareness of bio-based materials and their benefits. Products marketed as "natural" are increasingly popular in the United States, but those typically extend to consumer products and food. Promoting benefits of bio-based materials in the auto manufacturing process, such as potential sustainability improvements, diversifying a supply chain, and diminishing reliance on fossil fuels, hold the potential to increase consumer demand for these products. A federal level campaign could be most effective in this effort.

Encourage exploration of bio-based products that can be made from currently unused or under-utilized parts of the raw and food material production process. Wheat straw and rice hulls are two examples of by-products that come from food production that can also be used as reinforcements in bio-based polymer products. Creating co-products maximizes production efficiencies and provide raw material suppliers with extra revenue sources for products.

Increase financing offerings for smaller, bio-based companies. Small companies often have difficulties accessing sufficient capital to pursue technology and product development. Given additional constraints on bio-based material development for the auto industry, providing targeted forms of assistance could help carry companies beyond the “valley of death.”

# Conclusions

At this point, bio-based materials are not poised to take over the auto industry on a large scale in the near future. Petroleum prices remain low, policymakers have not regulated bio-based materials, and most North American consumers are not demanding these materials in the products they buy. Despite these facts, over one hundred companies, academic institutions, and other organizations are not only researching pathways to bring bio-based materials to commercialization but are bringing these products to market even with prevailing conditions. They are identifying creative ways to not only substitute these renewable resources into products, but also develop new compounds, materials and other products which may solve emerging market or societal needs. These companies and organizations are wisely using resources to ensure they are ready with a diversified product offering when market conditions change.

## Petrochemical Prices

The world is currently experiencing depressed oil and natural gas prices, and forecasts show low prices continuing into the future.[97,98] But as history proves, prices fluctuate, and prior to the current dip, both oil and natural gas prices had shown an upward trend since January 1998.[99,100] It is clearly possible that petrochemical prices will rise again, and companies that are prepared with alternatives to these products will fare better once that happens. The U.S. Energy Information Administration, for example, predicts a slow but steady rise in crude oil prices over the next decade.[101]

## Regulations

There are no U.S. regulations that require companies, automotive or otherwise, to use bio-based materials, but that does not mean there never will be. Regulations often arise in response to an external shock, either natural or man-made. Consider Congress' Corporate Average Fuel Economy (CAFE) requirements, which began in response to the Arab oil embargo in 1975. Auto companies are now required to meet annually-increasing fuel economy targets. Clorofluorocarbons (CFCs) are another example. In 1974, two scientists proposed the theory that CFCs were contributing to depletion of the earth's ozone layer. Public awareness of and concern about the issue grew, and companies voluntary transitioned from CFCs to alternatives.

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[97] Lynch, Michael. "Long-term Oil Prices: Goldman Sachs vs. OPEC." *Forbes*. 25 September 2015.
[98] Moody's. "Moody's: Low oil and natural gas prices furthers negative outlook for global oilfield services and drilling industry." *Moody's Investor Services.* 6 May 2016.
[99] Gongloff, Mark. "Oil Prices Actually Aren't That Low, Historically Speaking." *The Huffington Post.* 13 January 2015.
[100] U.S. Energy Information Administration. Henry Hub Natural Gas Spot Price. Accessed 28 September 2016. <https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm>
[101] U.S. Energy Information Administration. *Annual Energy Outlook 2015.* DOE/EIA - 0383(2015). April 2015.

When the EPA prohibited use of CFCs in 1978, most companies had already stopped use.[102] In each of the two situations, either a perceived or real crisis urged lawmakers to step in and regulate the market.

The U.S. Department of Agriculture manages an initiative called the BioPreferred® Program, whose purpose is to "increase the purchase and use of biobased products."[103] Created in 2002 and expanded in 2014, it outlines mandatory purchasing requirements for federal agencies and contractors and voluntary labeling initiative for bio-based products. The federal government is clearly aware of bio-based products and the promise they represent. It is feasible to think this initiative will be expanded over time to include more complex products, such as automobiles.

## Consumer Demand

Consumer demand is the primary market driver for any and all products, and in the United States and elsewhere, products with 'natural' or otherwise healthy ingredients and components have made significant inroads into the market. This trend is clear in food products, as organic and non-genetically modified foods take up more and more market share.[104,105] It is also increasingly common and popular among personal care, cleaning and even packaging products. Consumers are more aware of (and concerned about) harmful chemicals with which they could come in contact.

Progressive regulations, such as what requiring bio-based content would be considered, often originate on the east or west coasts of the United States, and then migrate toward the center. No-smoking laws are one example. In 2002, Delaware was the first state to enact comprehensive smoke-free laws. New York soon enacted a similar law, and then Massachusetts, Rhode Island, Washington, and New Jersey followed suit by 2006. Colorado was the first inland state to adopt a law in July of 2006, and between then and 2010, nineteen more states enacted smoking bans.[106] Another example is the zero-emission vehicles (ZEV) regulation California initially passed in 1990 that required two percent of vehicles sold in California are

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[102] Consumer Aerosol Products Council. "CFCS History." Consumer Aerosol Products Council website. Accessed 29 December 2015. <http://www.aerosolproducts.org/environment/chloroflurocarbons-cfc-history/>
[103] USDA. (2015). "BioPreferred Overview." United States Department of Agriculture. Accessed December, 2015. <https://www.biopreferred.gov/BioPreferred/faces/pages/AboutBioPreferred.xhtml>
[104] USDA Economic Research Service. "Organic Market Overview." Accessed 5 Jan 2016. <http://www.ers.usda.gov/topics/natural-resources-environment/organic-agriculture/organic-market-overview.aspx>
[105] Nunes, Keith. "Continued Growth Ahead for non-GMO Products." *Food Business News.* 13 August 2015.
[106] Centers for Disease Control and Prevention. "State Smoke-Free Laws for Worksites, Restaurants, and Bars --- United States, 2000—2010." *Morbidity and Mortality Weekly Report*. 22 April 2011.

ZEV.[107] The percentage required has increased over time, and to-date, nine states, all on the east or west coasts, have adopted similar programs.[108] Time will tell whether these laws migrate inward, but as concerns grow over emissions—especially after the current Volkswagen emissions scandal—it is feasible to think more states will create similar laws.

Companies that take a proactive approach to utilizing bio-based materials in their products will likely fare better than those who do not explore the use of these materials. Doing so better positions a company for unexpected changes in demand or other market conditions, and given the hundreds of companies engaged in this space—many of whom have automotive business—it is a wise, strategic move to continue developing products that use bio-based materials.

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[107] California Environmental Protection Agency Air Resource Board. Accessed 4 January 2016. <http://www.arb.ca.gov/msprog/zevprog/background.htm>

[108] Center for Energy and Climate Solutions. "ZEV Program." Accessed 4 January 2016. <http://www.c2es.org/us-states-regions/policy-maps/zev-program>

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# Appendix A: National Center for Manufacturing Sciences Project Summary

The National Center for Manufacturing Sciences (NCMS) is a membership-based non-profit committed to manufacturing. Working with collaborative project teams, the NCMS focus is to bring new technologies and capabilities to the manufacturing community in order to improve competitiveness and produce robust systems quickly, economically, and with higher quality.

**Goals**

Our primary goal for this effort was to support both the identification and bridging of gaps between the current capabilities, necessary materials, workforce skills and other resources of the bio-based materials sector. To accomplish this NCMS:

- Identified and served bio-based materials companies that could benefit from free or greatly subsidized high performance computing (HPC) tools including expertise, hardware, software and training.
- Offer customized technical assistance to at least four manufacturers within the bio-based materials cluster for the purposes of utilizing HPC tools.
- Identify and meet with cluster firms to gauge their need for HPC tools in the integration of bio-materials into their products, match those firms to specific technical assistance, and provide that assistance.

**Approach**

To accomplish these goals, the following steps were incorporated into our approach:

- Work with CAR to establish a database of SMMs that support the bio-based manufacturing industry. Cross-referenced NCMS current list over 5,000 SMMs in Michigan to help develop bio-based database.
- Co-develop a web presence (miia.doitindigital.com/) for MIIA to use as a resource for bio-based companies, a place to refer for more information, to host questionnaires and request site visits.
- Plan manufacturing focused events for technology providers and SMMs, including those in the bio-based industry.
- Perform site visits to provide an overview of the grant initiatives and the available resources.
- Develop relationships with other organizations in Michigan's bio-based industry to look for new opportunities for Michigan SMMs.
- Promoted MIIA activities to broader NCMS membership.

In broad support of all these activities NCMS successfully leveraged three resources to reach and engage the bio-based material companies in Michigan. These three resources outlined below:

Digital Manufacturing (DM) Initiative

The Digital Manufacturing Grid Initiative is a national effort by NCMS to put manufacturing innovation on fast forward—a unique fusion of physical innovation centers and virtual collaborative space. A place where manufacturers are empowered with advanced tools and technology. Collaboration makes everything less risky and less costly, even adopting new manufacturing solutions.

Michigan Digital Manufacturing Grid Cell

The Michigan Digital Manufacturing Grid Cell™ is an innovation center providing manufacturers with a place for technology demonstrations, training, and collaborative events. Staffed by NCMS outreach and collaboration experts, university students and other partners, the centers ease the growing pains of technology introduction and commercialization. The Grid Cell™ educates, engages and elevates the manufacturer.

Voice of the Customer (VOC)

In late 2013, the National Center for Manufacturing Sciences (NCMS) developed a plan to engage *backbone* manufacturers in a new conversation about Digital Manufacturing tools. The objective was to engage manufacturers in a conversation about the tools they use and the challenges they face. The Voice of the Customer outreach program was limited to the State of Michigan at first, to control project scope and establish best practices for a larger national intelligence rollout. While NCMS has a stated interest in advancing Digital Manufacturing tools through its Grid InitiativeTM, the survey effort was not meant to promote one solution or strategy over any other. Instead, our objective was simply to learn: to reach out to backbone manufacturers and listen to what they had to say about themselves.

**Successes / Challenges:**

As with any program there were many successes, but also our fair share of challenges. To summarize some the successes included:

- Executed a web presence for MIIA to use as a resource for bio-based companies, a place to refer for more information, to host questionnaires and request site visits.
- Created collateral for bio-based manufacturers to use both as an online and a print communication tool on website and site visits.
- Made numerous site visits to potential MIIA bio-based industry SMMs.
- Planned, promoted and hosted two events at the NCMS Grid Cell promoted in several SMM networks including those that MIIA is helping to develop.
- Hosted the Digital Manufacturing Revolution event focused on Grid Cell engagement for SMMs and potential partners and software providers. Invited bio-based manufacturers from database as well as MIIA partners.
- Partnered with NCMS member, Simafore (www.simafore.com) and organized an analytics lunch and learn event for at NCMS headquarters.

- Partnered with UberCloud (www.theubercloud.com/) to offer the *HPC Experiment* subsidized case studies to bio-based SMMs in Michigan.
- Partnered with NCMS member, Altair Engineering (www.altair.com), to promote web-based tools and resources for SMMs.

We also had some significant challenges. Through phone calls, site visits and engagements it was clear that a vast majority of SMMs were not considering bio-based materials. Most of the SMMs were plastics companies, and they were not interested in using bio-based materials. The consistent feedback was that unless their customer is requesting it which they are not considering bio based materials. They added that without a customer forcing function it was not worth the money or the time to research. Most of these SMMs see it as a 5-10 year need and that doesn't affect them yet. In summary, we are not sure SMMs were ready for an effort focused on bio-based materials.

**Outcomes / Deliverables:**

There were some great outcomes in the forms of deliverables.

1. Bio-based material company database: This database are companies that NCMS researched and with whom we communicated (introductory emails introducing the initiative and NCMS partnerships with Simafore, Altair, and UberCloud. All of these companies were added on all future invite lists.
2. Potential Bio-based company list: This larger list of 2nd and 3rd tier companies represent the larger ecosystem of potential SMMs. However, for this effort no engagements were made, but are considered future prospects.
3. Engaged SMM database: This list includes both the companies engaged and the assistance offered. It includes additional offerings beyond those mentioned above.

# Appendix B: Michigan Manufacturing Technology Center Project Summary

1. **Conduct Research on SMM Needs and Challenges in Transitioning to New Materials – Acted on knowledge gained to develop our program**
    a. Our Materials Survey coupled with face to face interviews and meetings with SMM's as well as materials suppliers, major Tier One suppliers, and OEM's have provided us with a strong indication of trends away from conventional steel and toward advanced high strength steel, aluminum, other light metals, polymer composites, biomaterials and thermoplastics. There is a limited bio-materials industry in Michigan and demand is driven by a small number of OEM's who have well developed specifications and applications. Need for MMTC type services in this segment is very limited.
    b. Shifted program focus to lightweight material to include biomaterials, polymers, composites, and lightweight metals.
    c. Our studies have found that capabilities and gaps vary from company to company. Our initiative to create strong alliances with the National Manufacturing Innovation Centers in Michigan, LIFT (ALMMII) and IACMI will bring us closer to deeply committed SMM's and we expect these companies to become strong clients for MMTC.
    d. MMTC is providing services to LIFT including, member surveys, SME member meetings, market research, help desk service, program management.
    e. Recruited a tech team of 6 sub-contractors and one temporary employee to provide services and create broad network of industry resources. We network with a number of trade associations, technical societies and industry marketing groups. Through LIFT and IACMI we extend our reach to major universities.

2. **Develop and Present Events for SMMs on Transitioning to New Materials**
    a. Lightweight Seminar in Detroit in June, 2014; Lightweighting Summit at MMTC Nov, 2014.
    b. Focus group at LIFT-Detroit June, 2015; SMM Member meeting at LIFT July, 2015 with over 40 present.
    c. Lightweight materials seminar at Saginaw Valley State University- May, 2015; over 40 attendees, Positive survey results, one prospective client engagement. Speakers from Nexteer, Dow Chemical, Dow Corning, Ducker Worldwide, MMTC.
    d. Trends and Applications in Lightweight Materials seminar at Automation Alley, March 24, 2016 featuring speakers from Ducker, Steel Marketing Institute, Nexteer. Over 50 attendees.

3. **Develop MMTC Technical Assistance Products for SMMs Transitioning to New Materials**
    a. Drawing on our market research we utilized an entrepreneurial Business Model Canvas to create a business plan for our Materials focused program.
    b. New products involve providing technical consulting across a variety of materials and processes that will impact the use of lightweight materials. These are in conjunction with traditional MMTC products such as Lean Manufacturing and Quality Programs.
    c. We have built a Tech Team of highly qualified consultants as sub-contractors to be able respond to all clients materials and process issues including stamping, casting, metallurgy, welding and joining, and composites.
    d. Potential clients segmented with rollout January 2016. We will deliver technical assistance through two channels: the LIFT help desk and our own MMTC Tech Team. Both will utilize the same team of experts. Our experts will first communicate by telephone with the company in need to determine the nature and depth of the problem, then schedule a half-day visit to analyze the problem and develop an appropriate course of action. MMTC will then write a contract with the client company to deliver the services required.

4. **Monitor and Provide Feedback on Work of MIIA Partners Concerning Bio-Based Materials**
    a. Attended and presented at the quarterly partners meetings. Sharing all relevant client and industry meeting reports to MIIA Dropbox. All partners were invited to the Saginaw event and one attended. We have provided Macomb Community College with mailing list of SMM's for their multi-day course in biomaterials and helped introduce them to LIFT in their workforce development program. We recruited a member of the CAR staff to speak to SME's at the LIFT event in July.
    b. Attended the IACMI National Conferences and SPE ACCE Conference in September making contact with composite and biomaterials suppliers, key people in the DOE and at Michigan State/IACMI Vehicle Technology Center.
    c. Provided business plan and grant writing assistance to a client companies. Met with cellulose fiber producer to offer services, but too early in start-up cycle to value our assistance. Met with polymer compounder specializing in bio-materials used as reinforcements to replace heavier inorganic minerals.

5. **Deliver Technical Assistance Projects to SMMs**
    a. Provided technical and strategic consulting services to 3 companies facing materials challenges. One, metals, two were composites, one of which was a biomaterial start-up company.
    b. Biomaterial company developing process to separate bamboo fibers and sell them to composites manufacturers. Wrote business plan and advised go to market strategy.

**6. Future Plans**

a. Present seminars addressing changes to lightweight materials to group of client companies involved in manufacture of components for the automotive and other industries. Present in partnership with MIIA partners when feasible.
b. Support MIIA and other partner organizations in their efforts to provide services to companies involved in lightweight materials and bio-materials.
c. Provide technical assistance to SMMs challenged with transitioning to new and/or unfamiliar materials; depending on referrals from project partners, some of these are likely to include helping companies to use biomaterials.
d. As referrals are made by project partners, provide technical assistance to SMMs that are direct participants in the biomaterials supply chain—e.g., materials suppliers, capital equipment providers.
e. Write Blog reports in support of lightweight materials development, use and manufacturing that will be informative to our client companies.

# Appendix C: Macomb Community College Project Summary

Macomb Community College is at the forefront of providing career pathways to ensure adults can find sustainable wage employment while working towards ever advancing certificates, credentials and degrees. Utilizing funds from the Make It in America grant opportunity, unemployed participants were trained for and receive certificates in the areas of unigraphics, CNC, and multi-skilled technician worker credentials. With a focus on bio-based materials manufacturing, these technology-specific training opportunities fit along a career pathway toward an Associate of Applied Science degree, and further toward engineering, a position currently held frequently by H-1B visa holders.

Training incumbent workers in Southeast Michigan created opportunities for skilled employees to obtain new skills and remain competitive in the job market, preventing layoffs and protecting Michiganders from having their potential job opportunities filled by H1-B visa holders. The unemployment rate in Metropolitan Detroit hovered at 11.9% in December 2012; employment in the manufacturing sector has shown an increase in the three years. Continuing to train incumbent workers to meet the evolving skill needs in automotive manufacturing will prevent increases in unemployment and encourage growth.

Every course offered through this project provided classroom instruction which combined theory, hands on learning and demonstrations. Successful completion of the course is dependent on skill demonstration. This training model was proven successful in an ARRA and Jobs Accelerator funded training grant.

Utilizing existing relationships with employers and Michigan Works, the target population for this training opportunity was unemployed adults and employed / incumbent workers. The target population for the unemployed trainees will be those individuals that are long term (27 weeks or longer) unemployed and underrepresented populations with previous work experience in manufacturing. These individuals were identified through a screening at the local Michigan Works Service Centers (America Job Centers), as well as recruitment through the community college. The training is geared to increase their employability in fields of study related to advanced manufacturing technology.

Individuals enrolled in this program received a series of assessments to ensure they were the right fit for the program. These assessments which identified aptitude in basic skills, provided Macomb with the information necessary to appropriately place the individual. Once assessment was complete, participants received technical instruction in a classroom setting as well as in advanced manufacturing simulation labs. This combination ensured that participants have both the working knowledge and direct skills necessary to complete jobs once they transition into an employment setting. In addition, all participants were required to build their workplace competencies by taking soft skills classes, attending seminars, and taking part in other programs available through student services.

Once a participant satisfactorily completed both the soft skills and technical training, they begin working with a job coach. This position plays a critical role in the success of Macomb's grant programs. Participants had opportunities to meet with employers at small-scale, on-site job fair where 3 to 5 employers directly interacted with each cohort of students.

CAR and MMTC worked with employers to identify their needs with regard to upgrading the skills of current employees as well as finding new qualified employees. CAR and MMTC communicated those needs to the training partners, Macomb/St. Clair Workforce Development Board (MSCWDB) and Macomb Community College (MCC). MSCWDB ensured that all training participants were eligible to participate in grant funded training. MSCWDB used the Michigan Works system to recruit interested individuals who are appropriate for this training.

Over the three-year period the ETA grant amount of $1,071,800 planned to train a total of 54 unemployed individuals and 24 employed/incumbent participants. Macomb Community College served as the training provider and received $943,400 of the ETA funds.

It was discovered early on in the grant that many regional employers were not utilizing bio-based products, but there was an interest in using unfamiliar materials. Expanding the training scope from bio-based materials to unfamiliar materials allowed the college to provide training related to aluminum and its alloys, and metallurgy for the non-metallurgist, which was of interest to regional employers for their incumbent workers. This shift in material focus did not affect the training geared toward unemployed participants. They still received an overview of bio-based materials in order to provide some background in this field.

It was also discovered that placement of long term unemployed individuals was more difficult than MCC had originally thought. Services available through the MCC's student services department did not always address the barriers faced by unemployed students participating in grant training. To increase the placement rate of the unemployed students Macomb/St. Clair Michigan Works was hired to provide training in workplace competencies. This training was integrated into the regular classroom sessions and case managers came to the college to work with students. There was co-enrollment into WIA / WIOA in order to provide work based through On-the Job Training if the student needed this extra support. The last three training cohorts received this enhanced service model.

*The chart on the following page indicates the final grant goals and outcomes.*

| Deliverable Snapshot | | | | |
|---|---|---|---|---|
| | **Goal** | **Actual** | **Percent** | **Difference** |
| Beginners | 78 | 277 | 355% | **199** |
| Unemployed | 54 | 93 | 172% | **39** |
| Incumbent | 24 | 184 | 767% | **162** |
| Completers | 70 | 265 | 379% | **195** |
| Unemployed | 48 | 82 | 171% | **34** |
| Incumbent | 22 | 183 | 832% | **161** |
| Placed | 39 | 64 | 164% | **25** |
| Retained | 32 | 33 | 103% | **1** |

# Appendix D: List of Organizations Interviewed

**Automaker Interviews**

1. BMW
2. Chrysler (now FCA)
3. Ford Motor Company
4. General Motors
5. Hyundai-Kia
6. Mitsubishi Motors
7. Toyota (questionnaire response)
8. Volkswagen

**Automotive Supplier Interviews**

1. Addcomp
2. Ashland Performance Materials
3. BASF
4. Bayer Material Science
5. Blue Water Bioproducts
6. Braskem
7. Citadel Plastics
8. Diversified Tooling Group
9. Dow Chemical
10. Dräxlmaier
11. DuPont
12. Eastman Chemical (questionnaire response)
13. Eco Bio Plastics Midland
14. Faurecia
15. FlexForm
16. Flint Hills Resources
17. GreenCore Composites
18. Henkel
19. IAC – International Automotive Components
20. Innovative Plastics and Molding
21. Innovative Polymers, Inc.
22. Johnson Controls
23. KTM Industries/Landaal
24. Lyondellbasell
25. Noble Polymers
26. Omtech
27. RheTech

**Other Company Interviews**

1. Algal Scientific
2. EcoBridge
3. GreenStone Farm Credit Services
4. Guiding Green, LLC
5. Nova Institute
6. The Andersons, Inc.

**Other Organization Interviews**

1. American Chemistry Council
2. Great Lakes Ag-Tech Incubator
3. MBI
4. MichBio
5. Michigan Agri-Business Association
6. Michigan State University
7. Michigan Technological University
8. National Renewable Energy Laboratory
9. National Research Council of Canada
10. Senator Stabenow's Office
11. State of Michigan – Michigan Department of Agriculture
12. State of Michigan – Michigan Department of Environmental Quality
13. United Soybean Board
14. University of Michigan
15. World Wildlife Fund
16. Specialty Equipment Manufacturers Association

# Appendix E: Bio-based Materials Questionnaire

The Center for Automotive Research (CAR) is performing a study on the use of bio-based materials in the automotive industry. This effort is sponsored by the Economic Development Administration, and seeks to increase understanding of the degree to which bio-based materials have been adopted in the automotive industry, opportunities they present, and the challenges that exist to commercialization.

**Usage**

- Please describe the bio-based materials your company is using and their applications
- Which bio-based materials are the foci of major research and commercialization efforts?
- What applications could feasibly incorporate bio-based materials in the future? Which materials, and in which vehicles?
- What are the challenges you currently face or have faced with respect to bio-based materials (e.g., issues related to technology or manufacturing)?

**Drivers**

- Does your company have a particular goal for bio-based content in your products?
- What is the main impetus behind the growth of automotive bio-based materials usage for your company: consumer demand, cost savings, green marketing, government regulation, or something else?

**Suppliers**

- What are the important capacity considerations for developing this industry?
- How have you partnered with your suppliers to incorporate bio-based materials into your products?
- How much do you know about your bio-based materials supply chain?
- Which of your suppliers are leaders in the field of bio-based materials or components?
- What are your greatest concerns with respect to bio-based materials supplier capacity?

**Overall Industry Growth**

- What will catalyze overall growth in this field?
    - Is there anything government – state or federal – can do to enable growth?
- What are the broader challenges to industry growth?

**Current and Future Workforce Needs**

- Does your company need training now to develop your current employee's skills to expand in this area? What kind of training would that be?
- In terms of expansion and future workforce needs, what skill sets will you be looking for?

## Appendix F: Bio-based Materials in Production and Concept Vehicles

| Company | Brand | Model(s) | Feedstock | Application |
|---|---|---|---|---|
| BMW | BMW | 7 Series | Sisal | Interior door panel |
| BMW | BMW | i3 | Kenaf | Interior door panels, instrument panel |
| Daimler | Mercedes-Benz | A-Class | Abaca/banana fiber | Underbody panels |
| Daimler | Mercedes-Benz | A-Class | Flax | Seatbacks |
| Daimler | Mercedes-Benz | A-Class | Natural fiber | Spare tire cover |
| Daimler | Mercedes-Benz | A-Class | Castor | Engine cover |
| Daimler | Mercedes-Benz | BIOME Concept | Renewable raw materials | Body panels, wheels |
| Daimler | Mercedes-Benz | C and A-Class | Flax | Engine cover, transmission cover, underbody panels |
| Daimler | Mercedes-Benz | C-Class | Sisal, cotton | Rear panel shelf |
| Daimler | Mercedes-Benz | E-Class | Jute | Interior door panel |
| Daimler | Mercedes-Benz | E-Class | Renewable raw materials | Interior door panel |
| Daimler | Mercedes-Benz | S-Class | Wood chips, kenaf fibers | Interior door panel |
| Daimler | Mercedes-Benz | S-Class | Hemp, flax, sisal, coconut fibers | Interior door panel, door cladding, seatbacks, package shelves, foam seating |
| Fiat Chrysler | Alfa Romeo | Giulietta | Castor | Fuel line |
| Fiat Chrysler | Alfa Romeo | MiTo | Castor | Fuel line |

| Company | Brand | Model(s) | Feedstock | Application |
|---|---|---|---|---|
| Fiat Chrysler | Chrysler | Sebring | Kenaf, hemp | Interior door panel |
| Fiat Chrysler | Fiat | 500 | Castor | Fuel line |
| Fiat Chrysler | Fiat | Panda | Castor | Fuel line |
| Fiat Chrysler | Fiat | Punto | Castor | Fuel line |
| Fiat Chrysler | Jeep | Grand Cherokee | Natural fibers | Door panels |
| Fiat Chrysler | Lancia | Delta | Castor | Fuel line |
| Fiat Chrysler | Lancia | Ypsilon | Castor | Fuel line |
| Ford | Ford | Econoline | Soy | Foam seating |
| Ford | Ford | Edge | Soy | Headliner |
| Ford | Ford | Escape | Soy | Foam seating |
| Ford | Ford | Escape | Kenaf | Door bolster |
| Ford | Ford | Expedition | Soy | Foam seating |
| Ford | Ford | F-150 | Soy | Foam seating |
| Ford | Ford | F-150 | Rice hulls | Wire harness bracket |
| Ford | Ford | Fiesta | Corn | Tires |
| Ford | Ford | Fiesta | Kenaf | Interior door panel |
| Ford | Ford | Flex | Soy | Foam seating |
| Ford | Ford | Flex | Wheat straw | Interior storage bins |
| Ford | Ford | Focus | Soy | Foam seating |
| Ford | Ford | Focus | Castor | Instrument panel |
| Ford | Ford | Focus | Kenaf | Interior door panel |
| Ford | Ford | Focus BEV | Coconut fiber | Loadfloor |
| Ford | Ford | Freestar | Wood fiber | Sliding door inserts |
| Ford | Ford | Fusion | Soy | Seating headrests |
| Ford | Ford | Fusion | Engineered ebony wood | Trim |

| Company | Brand | Model(s) | Feedstock | Application |
|---|---|---|---|---|
| Ford | Ford | Fusion Energi Concept | Sugar cane | Interior fabric (seat cushions, seat backs, head restraints, door panel inserts and headliners) |
| Ford | Ford | Model U Concept Vehicle | Soy | Foam seating, rigid polyurethane tailgate |
| Ford | Ford | Mondeo | Kenaf | Interior door panel |
| Ford | Ford | Mustang | Soy | Foam seating |
| Ford | Ford | Mustang GT RTD | Flax, linseed | Body |
| Ford | Ford | Taurus | Soy | Foam seating |
| Ford | Ford | Taurus SHO | Engineered ebony wood | Trim |
| Ford | Lincoln | Mark LT | Engineered ebony wood | Trim |
| Ford | Lincoln | MKS | Soy | Foam seating |
| Ford | Lincoln | MKS | Engineered ebony wood | Trim |
| Ford | Lincoln | MKX | Soy | Headliner |
| Ford | Lincoln | MKX | Engineered ebony wood | Trim |
| Ford | Lincoln | MKZ | Soy | Seating headrests |
| Ford | Lincoln | MKZ | Renewably sourced | Console door |
| Ford | Lincoln | MKZ | Engineered ebony wood | Trim |
| Ford | Lincoln | Navigator | Soy | Foam seating |
| Ford | Lincoln | Navigator | Engineered ebony wood | Trim |
| Ford | Mercury | Mariner | Soy | Headliner, foam seating |
| General Motors | Cadillac | DeVille | Wood fiber | Seatbacks |
| General Motors | Chevrolet | Impala | Flax | Trim, rear shelf |

| Company | Brand | Model(s) | Feedstock | Application |
|---|---|---|---|---|
| General Motors | Chevrolet | TrailBlazer | Wood fiber | Cargo area floor |
| General Motors | Chevrolet | Volt | Soy | Foam seating and internal plastic parts |
| General Motors | GMC | Envoy | Wood fiber | Cargo area floor |
| General Motors | GMC | Terrain | Kenaf fiber | Ceiling liner |
| General Motors | GMC | Terrain | Cotton | Acoustic insulator |
| General Motors | Opel | Astra/Vectra | Hemp, kenaf, flax | Interior door panel, seatbacks |
| General Motors | Saturn | L300 | Kenaf, flax | Interior door panel, package trays |
| Honda | Honda | FCX Fuel Cell Concept Vehicle | Corn | Interior fabric (seat covers, door coverings, headliners, floor mats, and other fabric-covered surfaces) |
| Honda | Honda | Pilot | Wood fiber | Floor area parts |
| Hyundai-Kia | Hyundai | "i-flow" Concept Vehicle | Castor | Seat frames |
| Hyundai-Kia | Kia | Soul EV | Cellulose | Interior components (cellulose-based plastic) |
| Hyundai-Kia | Kia | Soul EV | Renewable raw materials | Interior components (bio-foam) |
| Hyundai-Kia | Kia | Soul EV | Sugar cane | Interior components (thermoplastic elastomer fabric) |
| Mazda | Mazda | Mazda 5 Hydrogen RE Hybrid | Corn | Console, seat fabric |

| Company | Brand | Model(s) | Feedstock | Application |
|---|---|---|---|---|
| Mitsubishi | Mitsubishi | Galant Fortis (Lancer) Sportback | Wood fiber | Rear shelf |
| Mitsubishi | Mitsubishi | i-MiEV | Cotton | Seat fabric |
| Mitsubishi | Mitsubishi | i-MiEV | Corn | Floor mats |
| Mitsubishi | Mitsubishi | miniCAB | Cashew nut shell | Oil filler cap |
| Mitsubishi | Mitsubishi | Mirage | Sugar cane | Floor mats |
| Mitsubishi | Mitsubishi | Outlander P-HEV | Cashew nut shell | Plastic parts |
| Mitsubishi | Mitsubishi | Outlander P-HEV | Sugar cane | Floor mats |
| Nissan | Nissan | Leaf | Corn | Floor mats |
| PSA Peugeot Citroën | Peugeot | 208 | Hemp | Interior door panel |
| Renault | Renault | Mégane Trophy BioConcept | Renewable raw materials | Doors, fenders, engine hood, bumpers, spoilers, & trunk lids |
| Toyota | Lexus | CT 200h | Sugar cane | Luggage compartment liner, carpeting |
| Toyota | Lexus | CT 200h | Corn | Floor mats |
| Toyota | Lexus | CT 200h | Bamboo | Speaker diaphragms and interior trim |
| Toyota | Lexus | CT 200h | Soy | Seat cushions |
| Toyota | Lexus | ES300 | Kenaf | Package shelves |

| Company | Brand | Model(s) | Feedstock | Application |
|---|---|---|---|---|
| Toyota | Lexus | HS250h | Renewable raw materials | Interior components (luggage-trim upholstery, cowl-side trim, door scuff plate, tool box area, floor finish plate, seat cushions, and package tray behind the rear seats) |
| Toyota | Lexus | RX 350 | Soy | Seat cushions |
| Toyota | Toyota | "i-unit" and "i-foot" Concept | Kenaf | Body structure |
| Toyota | Toyota | 1/X Plug-in Hybrid Concept | Seaweed (kelp) | Body panels |
| Toyota | Toyota | Brevis | Kenaf | Interior door panel |
| Toyota | Toyota | Camry | Castor | Radiator end tank |
| Toyota | Toyota | Celsior (Lexus LS) | Kenaf | Interior door panel |
| Toyota | Toyota | Corolla | Soy | Seat cushions |
| Toyota | Toyota | ES3 Concept Vehicle | Sweet potatoes, sugar cane | Interior components |
| Toyota | Toyota | Harrier (Lexus RX) | Kenaf | Interior door panel, seatbacks |
| Toyota | Toyota | Matrix | Soy | Seat cushions |
| Toyota | Toyota | Prius | Corn | Instrument-panel, air-conditioning system outlet |
| Toyota | Toyota | Prius | Soy | Seat cushions, scuff plate, cowl side trim |
| Toyota | Toyota | Raum | Starch, kenaf | Spare tire cover, floor mats |

| Company | Brand | Model(s) | Feedstock | Application |
|---|---|---|---|---|
| Toyota | Toyota | RAV4 | Soy | Seat cushions |
| Toyota | Toyota | SAI | Corn | Ceiling surface skin, sun visor, and pillar garnish |
| UPM | Biofore | Biofore Concept | Natural fibers and cellulose | Body panels |
| Volkswagen | Audi | A2 | Flax, sissal | Interior door panel |
| Volkswagen | Audi | A3 | Cotton, cellulose, paper | Floor insulation, headliner, load compartment floor, filter |
| Volkswagen | Audi | Various models | Castor | Crankshaft cover |
| Volkswagen | Seat | | Castor | Crankshaft cover |
| Volkswagen | Škoda | Octavia Estate | Cellulose, wood, paper | Floor insulation, trunk floor trim, load compartment floor |
| Volkswagen | Škoda | Various models | Castor | Crankshaft cover |
| Volkswagen | Volkswagen | Amarok | Renewable raw materials | Parts not indicated |
| Volkswagen | Volkswagen | Caddy | Renewable raw materials | Parts not indicated |
| Volkswagen | Volkswagen | Golf | Flax, kenaf | Interior door panel, seating, and front-end module |
| Volkswagen | Volkswagen | Golf | Cotton, hemp, flax, paper | Floor insulation, door and side panel trim, load compartment floor |

| Company | Brand | Model(s) | Feedstock | Application |
|---|---|---|---|---|
| Volkswagen | Volkswagen | Passat | Renewable raw materials | Parts not indicated |
| Volkswagen | Volkswagen | Polo | Renewable raw materials | Parts not indicated |
| Volkswagen | Volkswagen | Sharan | Renewable raw materials | Parts not indicated |
| Volkswagen | Volkswagen | T5 | Renewable raw materials | Parts not indicated |
| Volkswagen | Volkswagen | Touran | Renewable raw materials | Parts not indicated |
| Volkswagen | Volkswagen | up! | Renewable raw materials | Parts not indicated |
| Volkswagen | Volkswagen | Various models | Castor | Crankshaft cover |