HEARTLAND

White Paper

Engineering New Carbon Negative Materials (Polypropylene)

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Engineering New Carbon-Negative Plastic Additive Materials for the Automotive Industry (Polypropylene)

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Background and Context

Heartland is a material science company that engineers natural fibers as additives for plastics. The company was founded in 2020 and since that time has been dedicated to finding more sustainable, alternative materials to be used as plastics additives.

The material that Heartland has been focusing on is industrial hemp. We've chosen it for a number of reasons, mainly because when processed correctly, it's the most consistent natural fiber we have come across. Also, we have perfected blending in polyolefins and the dispersion and encapsulation of the natural fiber compares favorably to the typical mined additive in wide use today.

In the past three years, Heartland has partnered with many polymer scientists, automotive market experts, LCA analysts, and agricultural professionals to develop bio-based, natural fiber hemp additives for plastics used in today's and tomorrow's transportation industry. Our various partners bring specific expertise (sometimes polymer-specific) to the table, and our work has included various polymers beyond polyolefins that are common in the automotive industry like PE, PVC, and PA.

The combined research power of the participants in Heartland's research spans the supply chain for automotive including chemical, compounding, recycling, tier-one, and OEMs. We've also partnered with agricultural experts and carbon lifecycle professionals.

Heartland's research partners include:

- Interfacial
- Magna International
- Presidio Graduate School
- Lifecycle Associates
- USDA

Purpose of the White Paper

The purpose of this white paper is to outline Heartland's three years of research in the areas of:

- Polymer additive research for Polyolefins, most specifically, Polypropylene.
- Automotive industry uses (vehicle components, packaging).
- Raw materials test data (industrial hemp fillers, fibers, and Heartland's proprietary masterbatch product).
- Life Cycle Analysis (cradle-to-gate carbon emissions analysis, including sequestration, all farm inputs, logistics, and biomass evaluation).
- Agricultural processing (USDA soil health, crop rotation - industrial hemp using Heartland's SOPs).
- Operational and functional research in parallel with the automotive industry.
- Future polymer research to include Polyamides, Polyvinyl Chloride, Polyethylene, and others.

We know that plastics use in automotive is gaining momentum and the benefits of using polymers have been evident since the 1950s. Weight reduction, fuel efficiency, ease of design, and manufacturing are all important elements in the decision to use plastics in the transportation industry, not to mention the safety improvements made over the last several decades due to polymer advances (airbags, seat belts, higher-impact bumpers).

Heartland's research results point towards the rapid adoption of these new carbon-negative materials in automotive plastics that are lighter, stronger, and carry a much lower carbon footprint, all at cost parity or cost improvement over traditional materials.

There are many R&D efforts underway within the auto industry to become more sustainable as manufacturers, and lower carbon plastics will be paramount as they will directly lower Scope 3 emissions. Scope 3 emissions are by far the most difficult factor when reporting, as they are directly tied to supply chain activities, purchased materials, and production methods. Polymers are some of the highest carbon materials used in vehicles and offer a great opportunity to offset emissions directly.

This paper outlines the materials and technologies used to manufacture lower-carbon plastics, as well as the many use cases for decarbonized materials. The data show that carbon footprints in polypropylene are reduced by 40% or more, by using natural carbon-negative additives. The data also shows that the functional characteristics of the polymers are relatively unchanged, or even improved with the addition of the natural additives.

Overview of Traditional Plastics Additives in Automotive Manufacturing

Traditional additives in plastics are used to engineer the functional characteristics of polymers, making them useful in a variety of applications.

The functions include:

- Colorization (dyes, pigments)
- Flame Retardance
- Stabilization (UV, chemical, heat)
- Antioxidants
- Lubrication
- Tensile Strength
- Flexural Strength
- Elasticity
- Volumizing (fillers)
- Electrical Conductance
- Heat Conductance
- Dielectric Properties
- Insulation/Isolation
- Antistatic Properties

The materials used range from mined materials like talc, calcium carbonate, and glass fiber to various elastomers and plasticizers, which are mostly petrochemical based. Many of these materials have been in use for decades, and due to the nature of the product and/or the recovery methods, they carry a high carbon footprint.

Our research aims to improve the additives for plastics by utilizing natural, carbon-negative materials, and in turn, decarbonize the polymer materials used in the automotive industry.

Benefits of Using Lower Carbon Plastics in the Automotive Industry

The team is seeing a push for more sustainable products and methods in the auto industry. The main drivers include:

- **Environmental Sustainability:**
  Lower carbon materials contribute to reducing greenhouse gas emissions and environmental impact. By using materials with lower carbon footprints, automakers can play a role in mitigating climate change and promoting sustainability, all while reducing their Scope 3 emissions.
- **Regulatory Compliance:**
  Many countries and regions have implemented or are considering stricter regulations and standards to curb carbon emissions from vehicles. Using lower carbon materials can help automakers meet these regulations and ensure compliance, avoiding penalties and legal issues. These regulations can be seen mostly in Europe, but evidence points to the adoption of like regulations in other countries such as the United States.
- **Improved Fuel Efficiency:**
  Lower carbon materials can be lighter in weight compared to traditional materials. Lighter vehicles require less energy to propel, resulting in improved fuel efficiency and reduced emissions during operation. This can also translate into cost savings for consumers through lower fuel consumption. Efficiency can translate into better performance out of EVs also. A lighter weight means more range per charge.
- **Enhanced Performance:**
  Lower carbon materials can offer improved performance characteristics such as strength, durability, and safety. For example, advanced composites or high-strength steel can provide the same or better structural integrity while reducing weight, leading to better handling and overall vehicle performance.
- **Brand Reputation and Consumer Appeal:**
  Consumers are increasingly conscious of environmental issues and are actively seeking greener products such as EVs. By using lower carbon materials, auto makers can enhance their brand reputation as environmentally responsible companies, attracting environmentally conscious consumers and gaining a competitive edge in the market.
- **Innovation and Technological Leadership:**
  Embracing lower carbon materials requires research and development, encouraging auto makers to invest in innovative technologies and manufacturing processes. This will lead to technological advancements, fostering innovation within the industry and positioning companies as leaders in sustainable transportation solutions.
- **Supply Chain Resilience:**
  As the demand for lower carbon materials grows, auto makers can diversify their supply chains and reduce reliance on materials with higher carbon footprints. Biomaterials contribute to more localized, circular economies. This enhances supply chain resilience, reduces dependence on scarce resources, and helps manage potential supply disruptions in the future.

Advancements in Automotive Plastics

Plastics and polymers have risen to comprise over 10% of a vehicle's weight, and since they have lower specific gravity than steel (the most prevalent material in vehicles), the percentage by volume and parts count can be much higher.

We find a variety of plastics in the automotive industry (both in components and their packaging) such as polyethylene, polypropylene, polyamides, and PVCs. There are other specialty polymers used in the industry, however, these represent most of the weight and volume in vehicles, and in turn offer the most opportunity for carbon reduction.

Lightweighting

Lightweighting in the auto industry refers to the strategic process of reducing the weight of vehicles without compromising their performance, safety, or functionality, and plastic's first use in the mid-20th century was to replace higher-weight metal components.

The primary goal of lightweighting is to improve fuel efficiency, reduce greenhouse gas emissions, and enhance overall vehicle performance. Lighter vehicles accelerate faster, get better mileage (gas, electric, or hybrid), and offer improved handling and braking performance.

A few areas that are focused on lightweighting include:

Advanced Polymer Composites: The use of advanced polymer composites, such as carbon fiber-reinforced polymers (CFRP) and glass fiber-reinforced polymers (GFRP), is increasing in automotive applications. These composites offer high strength-to-weight ratios, allowing for substantial weight reduction compared to traditional materials like steel or aluminum. They are used in components such as body panels, structural parts, and interior components.

Thermoplastic Materials: Automakers are increasingly adopting thermoplastic materials, which offer advantages like lightweighting, improved design flexibility, recyclability, and cost-effectiveness. Thermoplastics, including reinforced grades such as polypropylene (PP) and polyamide (PA), are used in various automotive components such as bumpers, interior trims, and under-the-hood parts. Thermoplastics are also easier, and more cost-effective to recycle.

Bio-Based and Recycled Plastics: There is growing interest in using bio-based and recycled plastics in automotive applications. Bio-based plastics, derived from renewable sources, offer a lower carbon footprint and reduced dependency on fossil fuels. Recycled plastics contribute to the circular economy by reusing materials and reducing waste. These materials can be found in components like interior panels, carpets, and packaging.

Multi-Material Approaches: Automotive manufacturers are adopting multi-material approaches, combining different lightweight materials to optimize performance and achieve weight reduction goals. This approach involves using a combination of plastics, metals, and composites in various parts of the vehicle, considering factors such as structural integrity, crashworthiness, and cost efficiency.

Structural Foam Injection Molding: Structural foam injection molding is gaining popularity as a manufacturing technique for lightweight plastic components. It involves injecting a gas or chemical blowing agent into the polymer melt, resulting in a foam structure with reduced density while maintaining strength and stiffness. This technique is used in applications like instrument panels, door panels, and seats.

Thermoforming: Thermoforming involves heating a plastic sheet to a pliable temperature, then forming it into a specific shape using a mold, and finally cooling it to retain the desired shape. New applications see biomaterials as the interior of the mold, using spray-on polymers to encapsulate the part, then thermoforming as normal. Parts include inner door panels, body liners, even bumpers, and cargo management components.

Innovative Design and Simulation Tools: Automakers are utilizing advanced design and simulation tools to optimize lightweight plastic components. Computer-aided engineering (CAE) software allows for virtual testing and analysis of materials and structures, enabling efficient design iterations and ensuring performance requirements are met while reducing weight. New biomaterials are being added to the engineering libraries of many CAE software systems.

Electrification and Battery Housing: As electric vehicles (EVs) gain prominence, lightweight plastics are being used in battery housings and other EV components. Plastics offer electrical insulation, corrosion resistance, and design flexibility, contributing to weight reduction in EVs and extending driving range. New biomaterials are under development to provide not only the casing for batteries but also conductive and dielectric materials as well.

Lower Carbon Footprint

Lowering the carbon footprint is an industry-wide effort today in automotive, from manufacturing plants that run more energy efficiently to logistics and even employees working from home (lessening their commuting costs), automotive manufacturers are taking the lead on sustainability.

Lowering the carbon footprint in the automotive plastics industry is beneficial for several reasons:

Recyclability and Circular Economy:
Lower-carbon plastics often possess improved recyclability properties compared to traditional plastics, leading to a more circular approach in automobile production. By designing vehicles with recyclable plastics, the automotive industry can reduce waste and energy consumption during the manufacturing process.

Heartland's contracted farms and commercial facilities are located in Michigan, and all within 150 miles of the tier-two plastics compounders, tier one suppliers and final assembly plants located near Detroit. This centralized supply chain maintains a carbon negative footprint of 2.85:1 from cradle to gate. The data has been confirmed by third-party assessors (Lifecycle Associates) to ISO 14040 standards, and public data is available on request.

Biodegradability and Bio-based Plastics:
Some lower-carbon plastics are derived from renewable resources, such as bio-based plastics such as PLAs. These materials offer the potential to reduce reliance on fossil fuels and have a more favorable environmental impact. Additionally, biodegradable plastics can help reduce long-term pollution and waste in the automotive sector.

The team at Heartland is conducting testing on PLAs that utilize the same carbon-negative additives outlined in the polypropylene data in this report.

Government Regulations and Incentives:
Many countries and regions are implementing stringent environmental regulations and providing incentives for automakers to adopt lower-carbon materials. These policies can accelerate the adoption of sustainable plastics in the automotive industry. Many automakers are already imposing internal carbon costs in an effort to prioritize new products and projects.

Research and Investment:
The automotive sector and material science industries are actively investing in research and development to create innovative, lower-carbon plastics. Presenting the growth of R&D investments and emerging technologies can highlight the industry's commitment to sustainability.

Our team is currently involved in dozens of polymer trials all over the globe. As the results become available, we are committed to publishing the data, as well as continued partnerships in lower-carbon plastics research, development, and investment.

Safety

Safety concerns have been around in the automotive industry for nearly a century. We think of the early seat belt era (1950 and '60s) as the beginning of the focus on safety, but features like brakes, headlights, and rearview mirrors were very early in development. Today features like ABS and Driver Assistance systems are becoming commonplace.

Biomaterials and lighter plastics also lend to safer vehicles in a few ways:

Crashworthiness: Lower-carbon plastics can be engineered to have excellent impact-absorbing properties, making them suitable for various safety components in cars. For instance, they can be used in bumpers and crash structures to absorb and distribute impact forces during collisions.

Weight Reduction: As mentioned earlier, lower-carbon plastics are lighter than traditional materials like metals. By reducing the overall weight of the vehicle, these plastics can positively impact vehicle handling, braking, and stability, which are essential factors for driving safety.

Pedestrian Safety: Lower-carbon plastics can contribute to improved pedestrian safety by being used in the design of external components like bumpers, hoods, and fenders. These plastics can be engineered to provide better energy absorption during pedestrian impacts, potentially reducing the severity of injuries.

Seat Components: Eco-friendly plastics can be used in seat components, such as headrests and seatbacks, providing enhanced comfort and safety features.

Interior Components: Lower-carbon plastics can also be used for various interior components, such as airbag housings, door panels, and dashboard elements. Properly engineered, these plastics can meet safety requirements and offer comparable protection to traditional materials.

The Role of Biomaterials and Natural Fibers as Plastics Additives

Biomaterials and natural fibers are gaining increasing attention as potential additives in the development of new plastics due to their unique properties and environmentally friendly nature. Our research has uncovered a variety of benefits of natural fibers, and more specifically industrial hemp.

Sustainability:
One of the primary reasons for using biomaterials and hemp fibers as additives is their sustainability and biodegradability. Many conventional plastics are derived from fossil fuels and contribute to environmental pollution and GHG emissions.

By incorporating renewable biomaterials and natural fibers, the overall environmental impact of plastic products can be reduced, as these additives can be sourced from renewable resources and often break down more easily in the environment.

For this study, we've incorporated engineered natural fibers and fillers derived from industrial hemp. The team chose hemp for both the physical properties and its ability to sequester carbon. These new additive materials have been third-party verified for cradle to gate emissions by the research teams at Lifecycle Associates and Presidio University.

The testing was subject to ISO 14040 standards and the results showed that for every 1 pound of engineered hemp, we sequestered 2.85 pounds of CO_2. Meaning the product is carbon negative by nearly a factor of 3. This is solely the carbon impact of the biomass processed and does not include the CO_2 sequestered during the growing process. The team is working with the USDA on a three-year soil health program to understand the total carbon impact, which by some estimates increases by a factor of 10 or greater.

All calculations on carbon impact in this study are rooted in the published LCA results.

Improved Mechanical Properties:
Natural fibers can enhance the mechanical properties of plastics. For instance, incorporating natural fibers like hemp, jute, or flax into plastic matrices can improve the composite's strength, stiffness, and impact resistance. These natural fibers act as reinforcements, making the resulting composite materials stronger and more durable.

Reduced Weight and Enhanced Fuel Efficiency:
In automotive and transportation industries, adding natural fibers to plastic components can lead to weight reduction. Lighter materials, as outlined above, contribute to improved fuel efficiency and lower carbon emissions during the vehicle's lifetime.

Renewable Resource Management:
The use of biomaterials and hemp fibers as additives in plastics promotes sustainable resource management. As these materials are derived from renewable sources, they can be cultivated and harvested in an eco-friendly manner, reducing the dependency on non-renewable resources.

They also contribute to more circular, local economies as the business model focuses on providing the natural fibers from farms within 200 miles of the manufacturing centers. For example, Heartland's agricultural and operations centers for this study are located in Michigan, providing materials for the auto industry and its suppliers in and around Detroit.

Cost-Effectiveness:
In many cases, hemp fibers can be more cost-effective than traditional additives or reinforcements. As their volume to weight ratio is much higher than mined materials, a much lower amount (by weight) is needed to achieve the desired characteristics in polymers. As the availability of these resources is increasing, due to more farmers adopting crops like industrial hemp, they can be an economically viable option that is sourced locally.

Properties and Performance of Natural Additives in Automotive Plastics

Regardless of the application or the type of polymers compounded, the physical characteristics of bio-based additives will need to perform at parity or exceed the performance of traditional materials. Heartland has taken a polymer-agnostic approach to new product development. Meaning that the same base additive materials should perform in a variety of polymers, with minimal chemical processing.

Industrial hemp application data shows that with minor adjustments to the inputs and processes for additive manufacturing, and we span the majority of polymers used in the automotive industry; most specifically, polypropylene, polyethylene, polyvinyl chloride, and polyamides. The focus of this study however is confined to polypropylene.

Testing in parallel with current specifications for auto use, we focus on:

- Mechanical Properties (weight, tensile strength, flex, etc.)
- Thermal Properties (process temperature, heat dissipation, etc.)
- Impact on Weight Reduction
- Sustainability and Carbon Reduction Aspects

Results in Polypropylene

Our polypropylene test includes two basic versions of the additives, one additive for normal impact resistance, one for higher impact resistance. In both cases there were various load rates of the hemp additives introduced to the resins.

- 100% Virgin PP (control)
- 80%/20% 800-micron hemp
- 70%/30% 800-micron hemp
- 60%/40% 800-micron hemp

The characteristics of the polymers were tested to ASTM standards and focused on areas of concern for the automotive industry, such as strength, flex, and impact resistance. For comparison, the tests were also compared to traditional additives - talc and glass fiber as well as virgin PP material.

For the automotive industry testing, the team focused on two formulations of polypropylene that are consistent with much of the PP use in automotive. Those formulations are:

- 20% filled PP (talc, glass, and industrial hemp)
- 20% filled high-impact PP (talc, glass, and industrial hemp)

For future reference, the team chose to also load industrial hemp at higher rates beyond the typical rates, to gain an understanding of the upper limits to bio-additives. Tested were:

- 30% hemp-filled PP
- 40% hemp-filled PP

Along with the higher load rates, testing on recycled PP (rPP) was completed and showed a significant increase in carbon impact, in fact, the final material was rated carbon negative.

20% hemp PP results:

Conditions for testing include proper handling of the natural fiber additives. Storage in a closed container, kept out of direct sunlight exposure. Additives were dried at 176° F for 3-4 hours prior to processing. Compounding was performed in 27mm, twin-screw extruders. Molder conditions for all materials are suggested at 370-390° F barrel temperature, and mold temperatures between 115-135° F.

Testing standards were adhered to as follows:

- Tensile – ASTM D638
- Flex – ASTM D790
- Impact – ASTM D256, D4812
- Specific Gravity – ASTM D792
- Moisture Absorption – ASTM D5229

Carbon impact was calculated using Heartland Industries' proprietary "Engage" software platform.

Results in the 20% trials were positive. Compared to talc-filled applications, the hemp faired favorably in tensile strength and modulus, which is expected at hemp is one of the strongest natural fibers available. Compared to both glass and talc there is a significant weight saving as well as a major reduction in the carbon footprint, measured at carbon impact (lbs. per ton). The moisture content was measured at less than 1%.

	Specific Gravity	Tensile Strength PSI	Tensile Modulus PSI	Elongation %	Notched Izod ft.lb/in	Izod ft.lb/in	Carbon Impact lb./t
Polypropylene 20% Hemp Filled	0.98	5.7k	482k	2.6	0.41	2.83	2800
Polypropylene 20% Talc Filled	1.04	3.9k	328k	48.1	1.31	10.04	4040
Polypropylene 20% Glass Filled	1.06	9.2k	631k	5.4	1.83	8	4680
Polypropylene Virgin Resin	0.91	10.8k	213k	265	1.51	7.57	5000

Figure 1 - 20% Additive Load Rate Characteristics Comparison

During the research, it was noted that impact resistance and elongation was lower than expected. New formulations including impact modifiers were engineered with positive results. Notched Izod increased by 456%, with Izod increased by 227%. Elongation increased by 334%. These efforts proved that the materials could be engineered to accommodate various necessary characteristics. The team is currently testing a variety of agents to balance needed specifications in the auto industry.

High Impact 20% hemp PP results:

	Elongation %	Notched Izod ft.lb/in	Izod ft.lb/in
Polypropylene 20% Hemp	2.6	0.41	2.83
Polypropylene 20% Hemp 10% Impact Modified	8.69	2.28	7.46

Figure 2 - 20% Filled Impact Comparison

Increasing load rates is the planned progression to the bio-additives research plans. As engineered additives increase in performance, compatibility, market acceptance, it's natural that the amount of material compounded with polymer would increase with development of the additive science.

The team experimented with increased load rates well beyond the widely accepted 20% level (up to 40%). As expected, the carbon performance increased dramatically, by over a factor of four between 20-40% loading. However, the anticipated negative changes in other characteristics did not appear. In fact, strength, flex and Izod remained mostly unchanged, and elongation changed by less than one percentage point.

	Specific Gravity	Tensile Strength PSI	Tensile Modulus PSI	Elongation %	Notched Izod ft.lb/in	Izod ft.lb/in	Carbon Impact lb./t
Polypropylene 20% Hemp Filled	0.98	5.7k	482k	2.6	0.41	2.83	2800
Polypropylene 30% Hemp Filled	1	5.2k	598k	1.9	0.47	2.69	1700
Polypropylene 40% Hemp Filled	1.03	5.4k	700k	1.7	0.49	2.39	600
Polypropylene Virgin Resin	0.91	10.8k	213k	265	1.51	7.57	5000

Figure 3 - Varying Load Rate Characteristic Comparison

Carbon Reduction in Polypropylene

Tests on the materials at higher load rates (up to 40%) have been conducted. Since the natural filler material is carbon-negative, we see accelerating rates of carbon impact on PP. For example, the carbon impact of virgin PP resin is about 5000 lbs./ton. Meaning it is approximately 2.5:1 carbon positive. Every pound of resin produced 2.5 lbs. of carbon emissions.

The traditional additives typically have a lower carbon footprint than the virgin resin, as we would expect. So, adding them will decrease the carbon impact, and in essence if you loaded the additive at 99%, you end up virtually at the carbon footprint of that additive material, somewhere below the level of pure PP resin.

The natural additives have a negative carbon footprint, in this case 1:2.85. Meaning every pound of material *removes* 2.85 pounds of carbon emissions. In other words, it performs carbon sequestration. Following the same theoretical model above, increasing the load rate sufficiently, you end up with a carbon-negative product.

Obviously, we never load at 99%, that is essentially the base additive material, but the theory works out to show we can decarbonize PP at a higher rate using these materials. The charts below show the impact of varying the load rates in virgin PP material from 20-40%

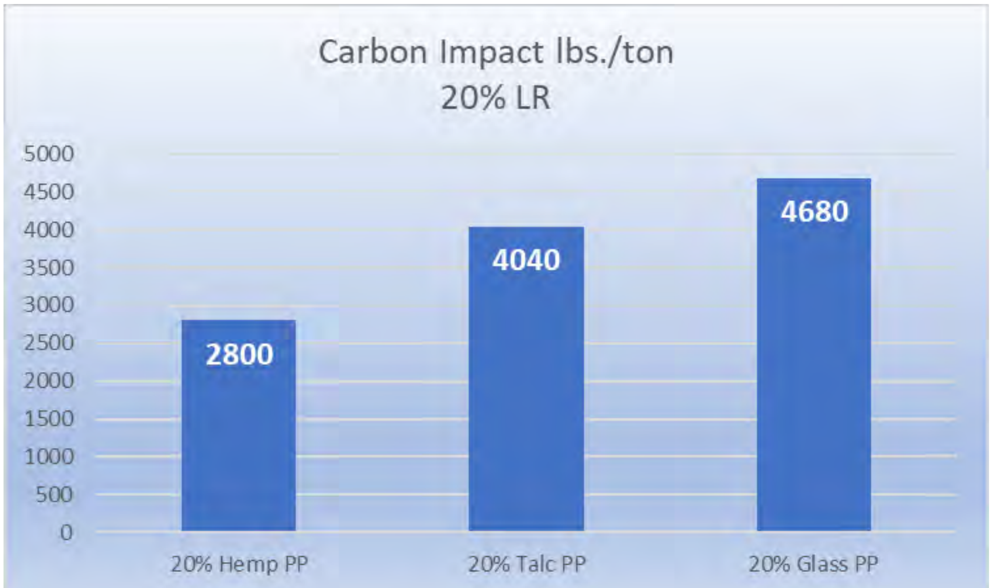


Figure 4 - Carbon Impact at 20% Load Rate Comparison

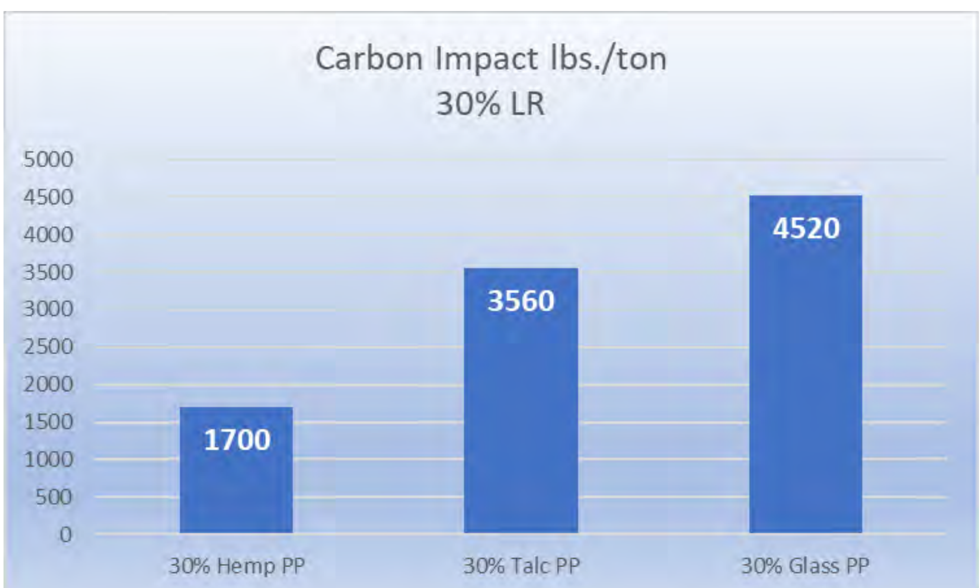


Figure 5 - Carbon Impact at 30% Load Rate Comparison

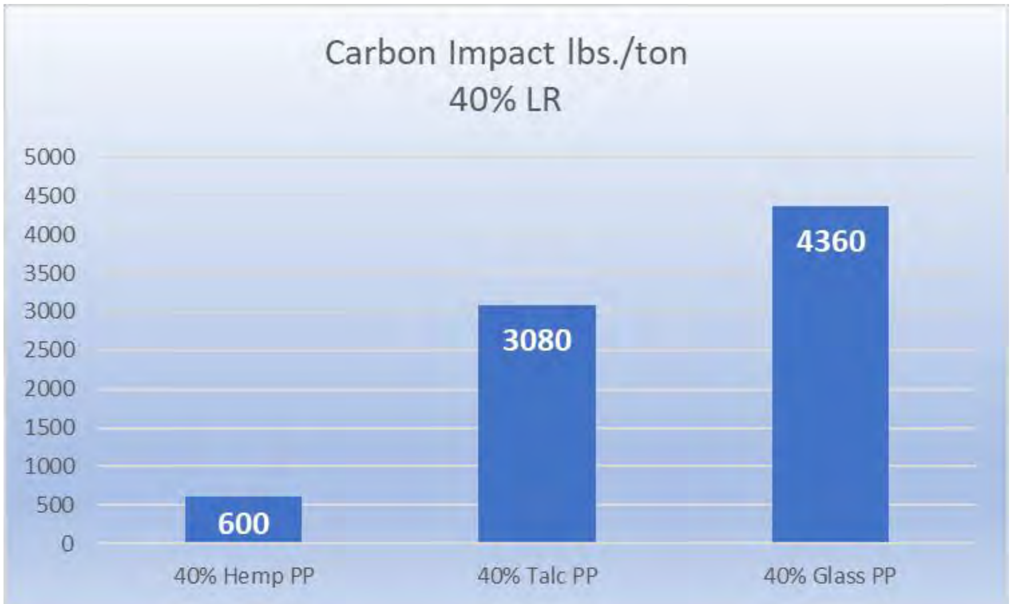


Figure 6 - Carbon Impact at 30% Load Rate Comparison

A final test for lowering the total carbon impact was performed by changing the polymer feedstock from virgin material to recycled PP. The results were dramatic. The carbon impact actually moved below zero, meaning the total carbon measured by adding only 20% of the engineered fiber additive was negative - by 200 lbs. per ton. The results prove the concept of a true, carbon-negative plastic that has favorable characteristics needed for the automotive industry, is achievable.

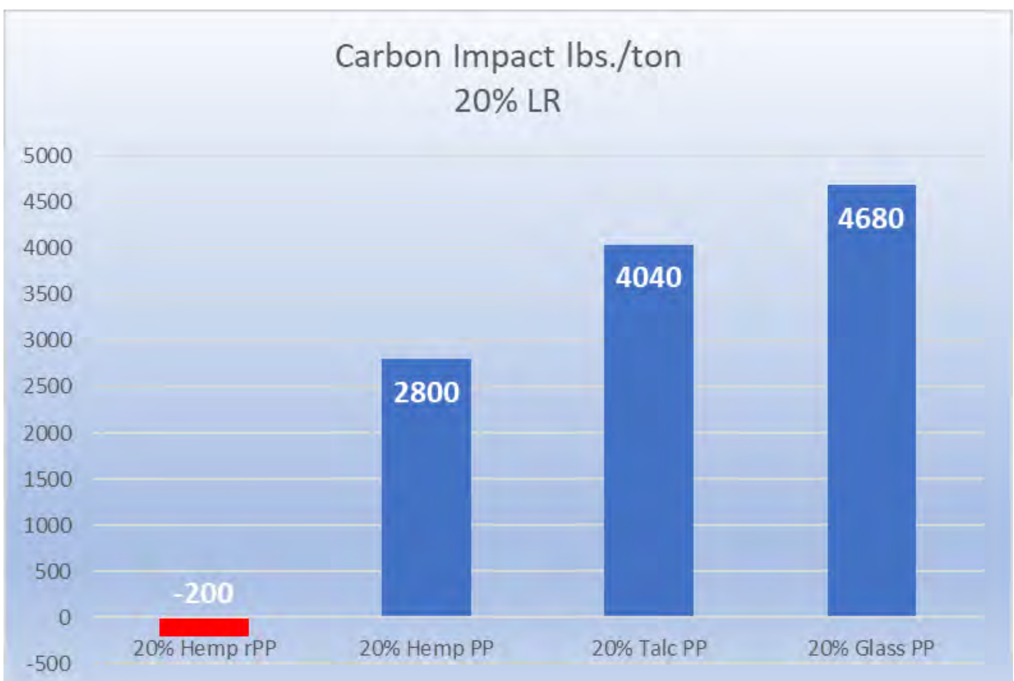


Figure 7 - Carbon Impact @20% Using rPP vs. Virgin Comparison

Future Perspectives and Opportunities

Applications of Lower Carbon Materials in Automotive Plastics

The partnership between Magna International and Heartland has uncovered many opportunities to advance polymers in the automotive industry. In both vehicle and process applications. Along with the vehicle applications, the team working with Magna International has uncovered opportunities in the wide range of packaging materials used in the industry.

The goal of Magna Packaging using the natural fiber material as an additive to our traditional plastic returnable packaging is to reduce the total carbon footprint of the part manufacturing process. The team is working on the LCA of the containers, and we anticipate lower emissions to offset any carbon credit purchases for the parts that are shipped in the containers.

The packaging manufacturers will use their current container LCA and compare that to the new LCA after adding the natural fiber additives to the packaging materials that already contain plastics (pallets, totes, and containers). The team will also test the key characteristics like tensile strength, tensile modulus, and impact resistance to ensure the strength of the container is comparable with the containers made from traditional materials. We are confident that using these new additives should be a non-intrusive way to reduce carbon emissions.

Notable examples of potential applications include:

Interior Components

- Dashboards
- Instrument Panels
- Seats
- Door panels
- Trim
- Door carriers
- Steering Wheels/Handles/Knobs
- Vents
- Storage Compartments
- Seat Belts
- Pedals

Exterior Components

- Bumpers
- Fenders
- Body panels
- Grills
- Trim
- Mirror Housings
- Roof Racks, Spoilers, Wings
- Wheel Covers

Electrical and Electronic Systems

- Circuit Boards
- Wire insulation
- Connectors
- Switches
- Fuses, Fuse Boxes, and Fuse Covers
- Relays and Relay Housing
- Cable Ties
- Wire Looms
- Battery Cases
- Sensor Housing
- Fans and Housings
- Motor Housings
- Speaker Housings

Engine and Under Hood Components

- Hoses and Lines
- Battery Trays
- Valve, Timing Chain, Throttle Body Covers
- Coolant Reservoirs
- Engine, Radiator Shrouds
- Air Filter Housings
- AGS

Packaging

- Bags
- Totes
- Pallets
- Tapes and Strapping
- Collapsible Boxes/Crates
- Dunnage and Spacer Blocks
- Tubes and Tubs

Potential for Further Advancements and Breakthroughs

The team chose to begin studies in 2020 with polypropylene, as that is the most common plastic used in the manufacturing of automobiles.

The initial results with polypropylene are encouraging as the partnerships led to breakthroughs in compounding bio-additives into polymers. In the past, the challenges have been consistency in additives (as natural products tend to be less consistent than synthetic ones), however, the team was successful in developing proprietary methods to ensure absolute consistency in the additives, from pound one to pound 100,000.

These results led the team to be confident that the biomaterials could be successfully blended with other polymers as well. To date, the team is working with major polymer manufacturers to test biomaterial additives in polyamides, polyvinyl chlorides, polyethylene, acrylonitrile butadiene styrene, polystyrenes, and polyurethanes. These polymers make up the majority of automotive plastics used in industry today.

Integration with Emerging Technologies

As EVs and autonomous vehicles are introduced into the market, the need to integrate new technologies will become vital to their acceptance and positioning. Some areas we see material advancements are:

Weight Reduction:
The research shows that these types of advanced plastics are often lighter than traditional materials like steel and aluminum. By replacing some structural and non-structural components with lightweight plastics, manufacturers can reduce the overall weight of EVs. This weight reduction contributes to improved energy efficiency, longer battery range, and enhanced performance.

Improved Aerodynamics:
Plastics can be molded into aerodynamic shapes that reduce air resistance. Streamlined designs, especially in the context of EVs, help enhance efficiency by requiring less energy to overcome air drag. This leads to improved range and reduced energy consumption.

Battery Thermal Management:
Plastics are used in the design of thermal management systems for EV batteries. Heat exchangers and coolant lines made from advanced plastics can efficiently regulate the temperature of lithium-ion batteries, ensuring their optimal performance and safety.

Safety:
Plastics with high impact resistance and energy-absorbing properties can be utilized in the design of vehicle components, including bumpers and crash structures. Improved safety features are crucial in both EVs and autonomous vehicles to protect occupants and pedestrians.

Sensor Integration:
Autonomous vehicles rely on numerous sensors and cameras for perception and navigation. Plastics can be used to house and protect these sensors while allowing for optimal sensor positioning.

Customization and Rapid Prototyping:
These new additives have been designed for drop-in replacements for traditional materials and processes, making them suitable for rapid prototyping and customized components. This flexibility allows manufacturers to adapt quickly to changing design requirements and produce vehicle parts efficiently.

Reduced Costs:
These natural fiber additives are proven cost-effective compared to other materials, contributing to cost savings in vehicle manufacturing, which will be paramount for the widespread adoption of EVs and autonomous vehicles.

Market Growth Potential

Knowing that most vehicles contain over 400 lbs. of plastic (and that number is up by 16% since 2012), it's easy to see the massive market potential for any innovation that can reduce the carbon footprints of those polymers by 40% or more.

As sustainability is gaining momentum, especially in transportation, the need for lower-carbon materials will be paramount for all manufacturers to meet their lofty carbon-reduction goals. Estimates are that Scope 1 and Scope 2 emissions (power and power purchase) only make up about 15-20% of a company's totals. Scope 3 emissions make up the remaining 80-85%, and that category is comprised of the emissions in our supply chains. This means that raw materials, and the processes to manufacture them represent the lion's share of emissions reduction opportunities.

In the U.S. the Securities Exchange Commission has floated the idea of carbon reporting mandates for all publicly traded companies. Their Carbon-Related Disclosures Proposal gives companies until 2024 to disclose Scopes 1 & 2, with an extra year to disclose Scope 3. In the EU the mandates will be even more stringent, as they are considering targets of zero emissions industry-wide by 2035!

According to Statista (www.statista.com) today's plastics market for automotive is over $40B. The estimates for 2027 are over $80B! With plastics in automotive manufacturing to grow by 100% by 2027, and the inconvenient truth that plastics carry a very high carbon footprint, our team is confident that that biomaterials in polymers will be the most significant effort we can take to decarbonize our industry.

Challenges and Limitations

Cost Considerations and Economic Viability

Cost, in any manufacturing environment, will always be a consideration. We have technology today that significantly lowers weight and increases strength, for example: titanium and carbon-fiber. However, the average family looking for a new vehicle is not going to pay a Formula-1 race car price tag for those advantages. We need to keep our costs in line with expectations.

Pricing at scale for these natural fiber additives are at parity, or less than today's options. Pound for pound, it's a fraction of the cost of glass fiber. Compared to mined materials, it is a higher pound for pound cost, however, when examining the cost in use, the price levels, because we need to add much less to achieve volume and strength. The use of these materials also lowers the amount of polypropylene needed to add to the mix.

Reliable Supply Chain

As with any raw material, if it's not available, it's not viable. Today, we see industrial hemp rates increasing at over 45% annually, and Heartland's acreage/biomass output is increasing nearly 500%, year over year.

Industrial hemp grows in nearly every agricultural region globally, and when rotated properly, does not compete with food crops. The acceptance of natural fibers has been gaining ground for some time, however, many of those materials pose challenges for creating a reliable supply chain.

Whether it is regional growth restrictions, logistics concerns (shipping lightweight materials), or geo-political concerns, Industrial Hemp has many advantages, due to the agricultural community's acceptance, ability to grow in most any region, and lastly the Farm Bill of 2018 which legalized its growth and transport in the U.S.

Manufacturing Processes and Scalability

Manufacturing processes for natural fiber separation typically involve complex and expensive equipment and custom facilities, and in turn, scaling up can be a costly and time-consuming endeavor. The processing for this study was performed using an advanced method that doesn't require the typical, complex separation equipment.

Hence, the process is much less expensive and can be performed in a lower physical footprint. The commercial facility used can process over 30 thousand pounds of material per 8-hour working day, and there are no restrictions on the uptime of the equipment, meaning a theoretical 24-hour process time is viable. This facility was brought online in less than two months, and scaling is a relatively easy process.

Formulations and Compounds

The research team has dozens of R&D projects running concurrently with various commercial partners as well as research institutions. Formulations include what polymers are selected for testing, but also the base agents added to the natural fibers to start with.

Natural fibers do not blend, or compound well with synthetic materials without some type of pre-intervention. These intervention methods (in polypropylene and other polymers) were the primary focus of the team’s research during the first year. Once the proper agents and processing controls were determined, the team set out to create polymer formulations using a wide variety of feedstock materials.

Since that time, the team has focused on agents to engineer the necessary characteristics of the blended materials. Examples include:

- Thermal Resistance
- Odor Elimination
- Dispersion
- Tensile Strength and Modulus
- Durability
- Opacity
- Impact Resistance
- Surface Finish and Appearance
- Melt Flow
- Drop-in Replacement Formatting
- Costs and Techno-economic Analysis

Regulatory and Standardization Efforts

Many State agricultural departments in the U.S. are actively promoting Industrial Hemp to their farming communities. Conversely to hemp grown for cannabis or CBD, industrial hemp has no cannabinoids, nor does it produce any THC (the psychotropic chemical in the cannabis plant), so acceptance in the agricultural community is growing, at the same time that regulatory efforts are steering towards more lenient handling of the materials.

A bi-partisan bill was introduced in Congress (March 2023) to remove background checks for hemp growing licenses, as well as removing the rigorous testing for non-extraction hemp. This points to more adoption of hemp both in agricultural circles and manufacturing environments.

Conclusion

The Heartland team and their partners have been conducting successful research on decarbonizing plastics in the automotive industry. The initial results focused on polypropylene, as that is one of the highest-use plastics in vehicles. Further testing is underway to include a variety of polymers including PA6, PE, PET, PVC, PCA, ABS, Polyurethane, etc.

The research focused on the additives to plastics, and the use of natural fibers to augment or replace traditional, high-carbon materials. The team centralized the fiber studies and chose a single material to utilize - industrial hemp.

Heartland and its partners have engineered the industrial hemp fibers to consistently blend with polymers, while increasing functional characteristics such as strength, modulus and impact resistance. The additives significantly reduce the carbon footprint of plastics, in some cases resulting in a polymer material that is carbon negative.

The team has been able to balance the materials breakthroughs with commercialization and supply chain readiness. At scale, the new material represents cost parity to traditional materials, and in many cases a cost advantage. The first natural fiber additive commercial facility is online, and a “copy and paste” replication model ensures future availability and a reliable supply chain.

Applications for this material are vast in the automotive industry. Categories include almost every application for plastics in the industry:

- Interior Components
- Exterior Components
- Electrical and Electronic Systems
- Engine and Under Hood Components
- Packaging
- Safety Systems

As sustainability gains awareness across the automotive industry, the need for solutions becomes imperative. Most OEMs, Tier Ones, and Tier Two suppliers have some sort of emissions standards, mandates, or goals in place. The major opportunity for improvement is in the category of Scope 3 emissions, however those are by far the most challenging and elusive to achieve. Raw materials can be 75-90% of a company’s emissions, and the material breakthroughs in this study will help brands and their suppliers reduce, measure, and report progress as it relates to lowering carbon emissions.

Products

Imperium Filler

Imperium Powder is a commodity natural fiber additive for brands, converters, and suppliers that are looking for bio-based powders to replace or augment talc, calcium, and fiberglass.

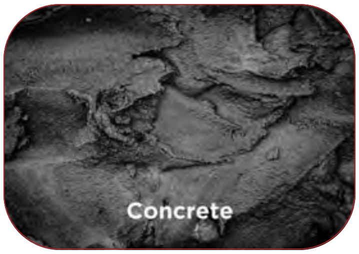
Imperium Materbatch

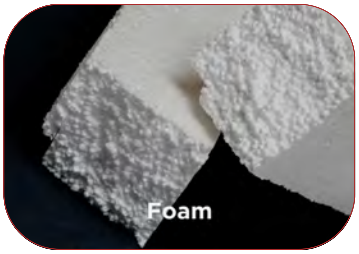
Imperium Masterbatch is for brands, converters, and suppliers that are looking for a drop-in high-performance carbon-negative plastic additive to help them use natural fibers inside of plastics at 40%+ load rates.

Imperium Filled Resin

Imperium-Filled Resin is a natural fiber-filled plastic that allows brands and suppliers to accomplish years of R&D on natural fiber additives in weeks. With Imperium-Filled Resin, brands and suppliers can test samples in 30 days.

Materials We Strengthen





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