



Plastics and Polymer Composites
TECHNOLOGY ROADMAP
for Automotive Markets

March 2014

About this Roadmap

For decades, advanced plastics and polymer composites have helped improve the appearance, functionality, and safety of automobiles while also reducing vehicle weight and delivering superior value to customers. New regulations, shifts in consumer preferences, and recent technology innovations are encouraging automakers to continue increasing their use of advanced plastics and polymer composites to meet tomorrow's challenges and opportunities.

To address these trends and help enable the increased use of plastics and polymer composites, the American Plastics Council (now the Plastics Division of the American Chemistry Council [ACC]) published the *Plastics in Automotive Markets Vision and Technology Roadmap* in 2001. The roadmap outlined a vision of the application of plastics and polymer composites in automobiles and the business and technology strategies needed to provide solutions for the automotive industry. In 2009, ACC updated this roadmap in response to changing industry trends. While many of the same issues discussed in the 2009 roadmap remain relevant, the automotive marketplace and regulatory drivers are significantly different from what they were only a few years ago, led by many factors including the new U.S. Corporate Average Fuel Economy (CAFE) standards.

ACC's Plastics Division recognized the need to update the roadmap in response to these changes to develop an effective industry-wide strategy that will extend to 2030 and beyond. During the roadmap update process, Nexight Group conducted telephone interviews, reviewed recent literature publications, facilitated a two-day expert workshop, and engaged with three relevant professional societies. The roadmapping process engaged technical experts and leaders from the automotive and plastics and polymer composites industries, including perspectives from original equipment manufacturers, tier suppliers, material developers, researchers, federal agencies, and consultants, to discuss the current limitations to the increased use of plastics and polymer composites and to identify industry-wide actions that can accelerate the

increased widespread use of these materials in future vehicles.

This roadmap synthesizes the findings from this effort and sets a path forward for the plastics and polymer composites and automotive industries through 2030. This roadmap is designed to help the automotive and plastics and polymer composites industries maintain a strong foundation upon which to build partnerships and initiate collaborative programs that address changing market needs. Although this roadmap is focused primarily on the North American automotive market, it addresses globally significant issues. Implementing this roadmap will require significant resources to accomplish both shorter-term priorities and the long-term vision for 2030 and beyond.

This roadmap was developed under the guidance of Gina Oliver, Senior Director, ACC Plastics Division Automotive Team; George Racine, ExxonMobil Chemical and ACC Auto Team Chairman; and member company representatives participating on the Auto Team (member companies and member company representatives noted in Appendix B). ACC wishes to thank Ross Brindle, Lindsay Pack, and Sarah Lichtner, all with Nexight Group, for their leadership in designing and executing the Roadmap update, as well as their expert facilitation of the stakeholder workshop and support preparing this document. ACC also thanks Jared Kusters and Warren H. Hunt, Jr., PhD, also with Nexight Group, for their outstanding technical guidance.

The automotive industry experts who made vital contributions through phone interviews, workshop attendance, and roadmap reviews, are also identified in Appendix B of this report. ACC's Plastics Division would also like to thank the American Composites Manufacturers Association (ACMA), the Society of Plastics Engineers (SPE), the Society for the Advancement of Material and Process Engineering (SAMPE), and the Society for Automotive Engineers (SAE) for their support and contributions to this effort.

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Executive Summary



The 2014 Chevrolet Corvette Stingray features carbon-fiber-reinforced hood and roof assemblies, resulting in a roof that is approximately seven pounds lighter than the previous version. In addition, panel gap consistency was improved by 30% and part costs/unit area were reduced roughly 40% compared to the previous model.

Now more than ever, the automotive industry is under increasing pressure to meet higher fuel efficiency, environmental, and performance demands at competitive costs.

Arguably the most influential force in the North American automotive market is the joint Corporate Average Fuel Economy (CAFE) standards set by the National Highway Traffic Safety Administration and the U.S. Environmental Protection Agency, which set emissions and miles per gallon (mpg) requirements for model year 2025 vehicles to more than 50 mpg. This rapid mpg increase, combined with ever-present consumer demand for better performance and appealing styling at an affordable price, has the automotive industry searching for ways they can cost-effectively drop more and more weight from vehicles while maintaining quality and safety.

All materials industries—plastics and polymer composites as well as steel, aluminum, and magnesium—are working to respond to the automotive industry's changing needs. For example, the steel industry claims that advanced high-strength steel (AHSS) will provide weight-saving improvements at an incremental cost of \$0.30 per pound of weight saved, an estimate by steel producer ArcelorMittal that has yet to be validated by the automotive value chain.¹ Combined with the ability to be produced with existing high-volume manufacturing infrastructure, AHSS is gaining use in the automotive world, albeit largely as a replacement material for conventional steel.

Most auto industry forecasts also predict significant growth in the use of aluminum as a lightweight material. Clearly, the metals industries are pursuing innovation targeting the automotive market.

The plastics and polymer composites industry has a long track record of delivering strong performance and continues to pursue transformative innovations. One material class that promises such opportunity is high-performance polymer composites. In addition to potential innovative aerodynamic design and styling aesthetics, polymer composites' high strength-to-weight and stiffness-to-weight ratios have made them the material of choice in industries like motor sports and aerospace for years. Many polymer composites offer an unmatched energy-absorbing capability per unit mass, making them a strong, lightweight choice.

One type of polymer composite in particular—carbon-fiber-reinforced composites—presents major lightweighting opportunities for structural vehicle components. At a weight 50% lighter than conventional steel and 30% lighter than aluminum,² more automakers are taking notice: for example, BMW is using the material as the body structure of its electric city car, the i3, which goes on sale in the United States in 2014.

¹ Dr. Blake K. Zuldema, ArcelorMittal Global Research and Development, "On the Role of Body-in-White Weight Reduction in the Attainment of the 2012–2025 US EPA/NHTSA Fuel Economy Mandate," presentation.

² David Sedgwick, "New techniques cut cost of carbon fiber," Autoweek (July 2011), <http://www.autoweek.com/article/20110711/CARNEWS/110719991>.

With advantages that align directly with the automotive industry's needs, plastics and polymer composites can be a major part of the solution for automakers. To fully realize this opportunity, several barriers should be addressed. For example, carbon-fiber-reinforced composites are still costly, discouraging many automakers from using them extensively in vehicle fleets, and recycling some plastic and polymer composite components can be challenging. The automotive infrastructure and workforce have evolved over the past 100 years to accommodate metals, creating barriers to plastics and polymer composites. And, the vast number of specialized, proprietary material compositions and processing techniques within the plastics and polymer composites industry—a strength that allows materials to be tailored to specific needs—also creates barriers to addressing major challenges collaboratively. The combination of opportunities and challenges that are driving the automotive plastics and polymer composites market today make it an ideal time to develop and implement a plan that capitalizes

on these drivers by guiding cooperative action and supporting needed innovation.

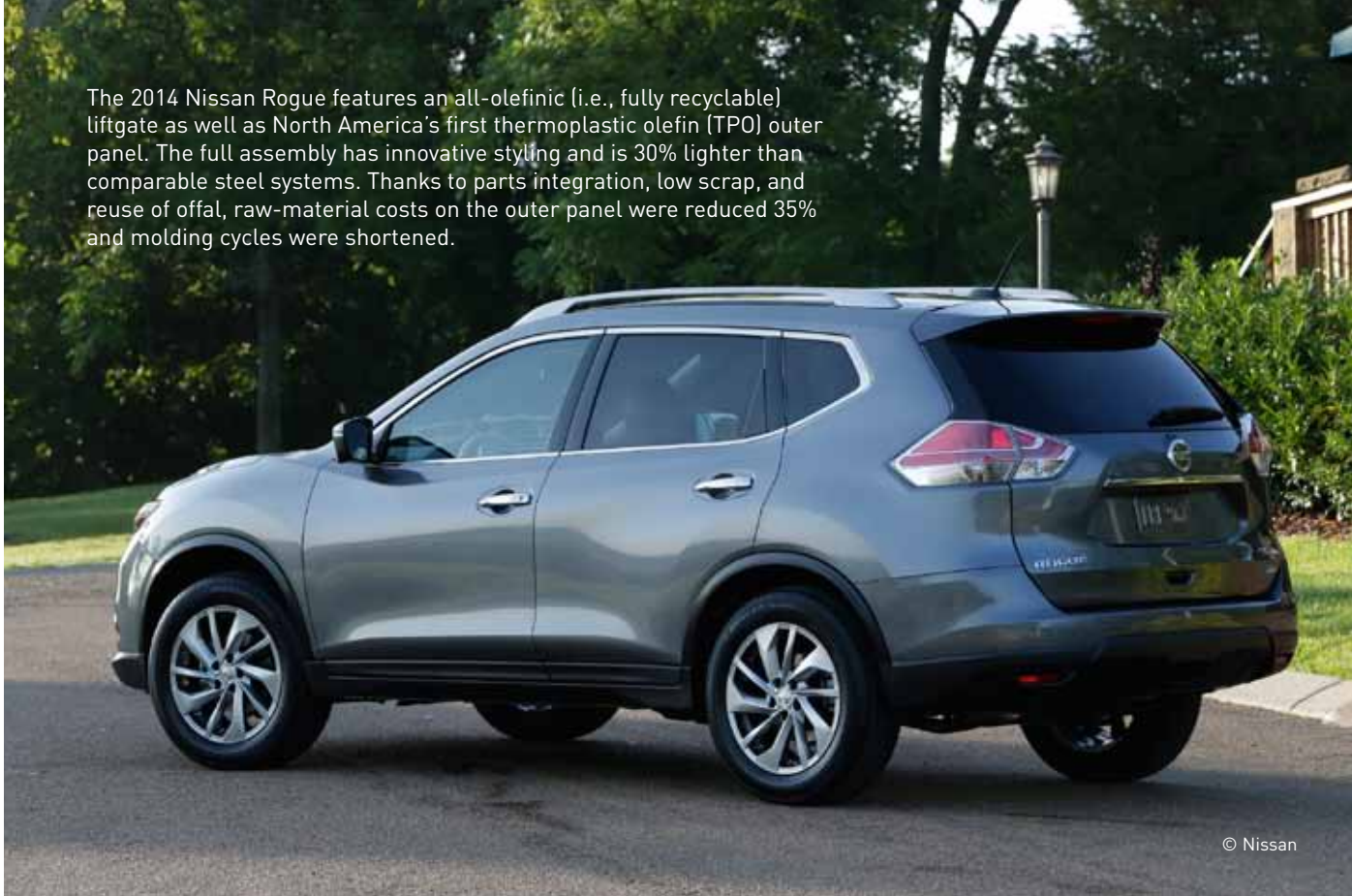
Recognizing this pressing need, the automotive and plastics and polymer composites industries worked together with the guidance of the American Chemistry Council (ACC) Plastics Division to create this roadmap—a new strategic framework for collaborative progress. The roadmap sets a path to realizing the previously established vision for the automotive plastics and polymer composites industry: by 2030, the automotive industry and society will recognize plastics and polymer composites as preferred material solutions that meet, and in many cases set, automotive performance and sustainability requirements.

A New Strategy

The strategy outlined in this roadmap leverages the lightweighting drivers the automotive industry is facing as well as the significant opportunities presented by plastics and polymer composites.

By 2030, the automotive industry and society will recognize plastics and polymer composites as preferred material solutions that meet, and in many cases set, automotive performance and sustainability requirements.

The 2014 Nissan Rogue features an all-olefinic (i.e., fully recyclable) liftgate as well as North America's first thermoplastic olefin (TPO) outer panel. The full assembly has innovative styling and is 30% lighter than comparable steel systems. Thanks to parts integration, low scrap, and reuse of offal, raw-material costs on the outer panel were reduced 35% and molding cycles were shortened.



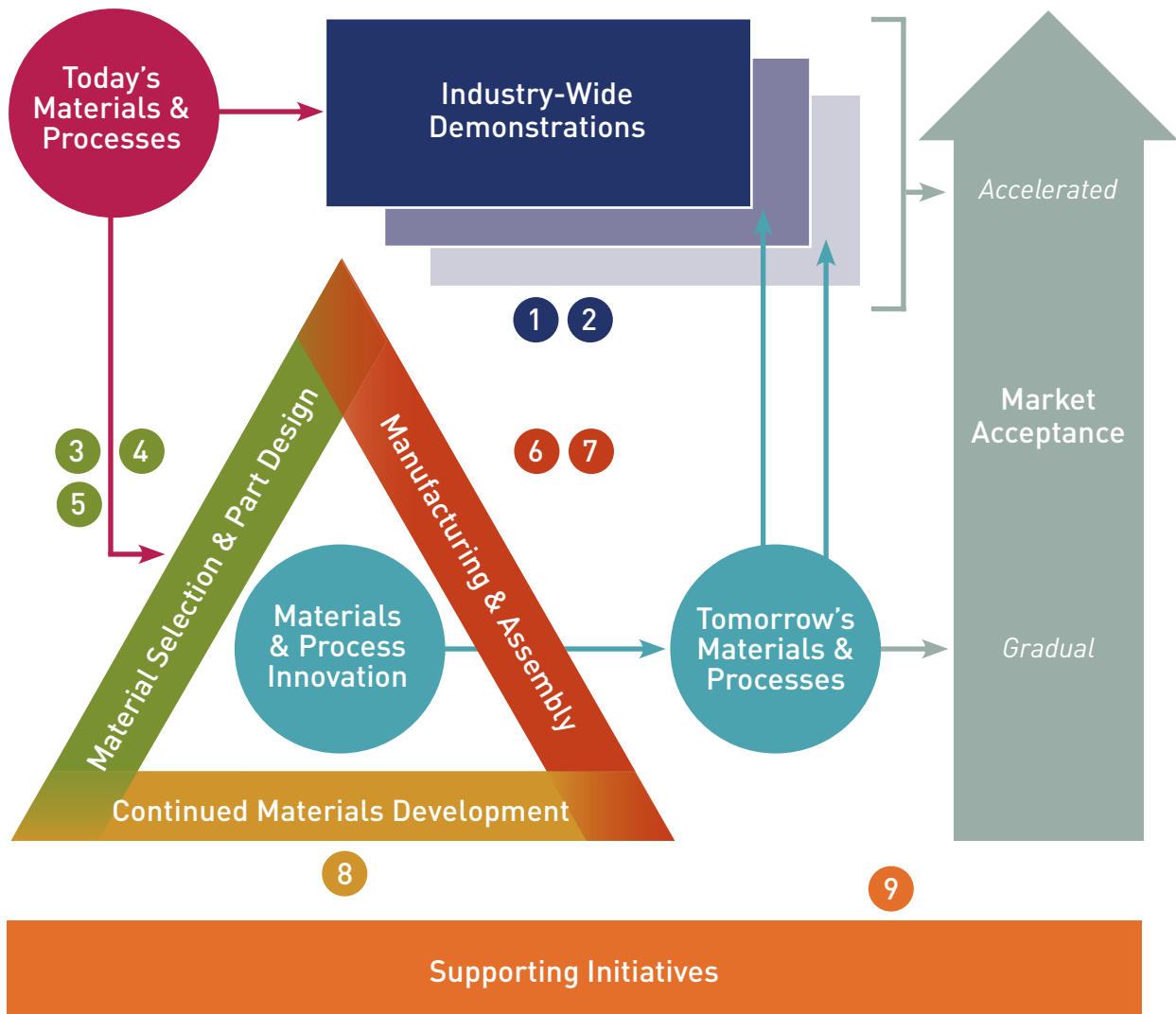
To accomplish this, the roadmap outlines key initiatives and actions that should occur within each aspect of the materials development and implementation process, as well as across it:

- **Industry-Wide Demonstrations** – Conduct high-profile demonstrations of plastics and polymer composites in increasingly challenging automotive applications to help accelerate innovation and market acceptance.
- **Material Selection and Part Design** – Enable tier suppliers and original equipment manufacturers (OEMs) to more easily select the best plastic and polymer composites for automotive applications and to model part designs to ensure that a material has the necessary performance capabilities.
- **Manufacturing and Assembly** – Improve the way materials, components, and systems are manufactured and assembled into vehicles, as well as the final appearance and functionality of the vehicle throughout its lifecycle.

- **Continued Materials Development** – Improve the properties and cost-effectiveness of existing and newly discovered materials to better address the future needs of automotive applications.
- **Supporting Initiatives** – Improve coordination across the supply chain and strengthen the workforce to help accelerate innovation in plastics and polymer composites and increase industry support for these technologies.

Critical to the success of this strategy is the ability of the plastics and polymer composites industry to work together with the automotive industry and its supply chain to implement the actions it contains in an appropriate, pre-competitive environment. The *Plastics and Polymer Composites Technology Roadmap for Automotive Markets* will foster a culture of collaboration that will revolutionize not only plastics and polymer composites and how they are used, but also the way that the plastics and polymer composites industry works together and with automakers to achieve greater efficiency, performance, and value.

Figure 1. Plastics and Polymer Composites Technology Roadmap for Automotive Markets Strategy



Industry-Wide Demonstrations

- 1 Establish an independent, pre-competitive technology development center where OEMs and suppliers can conduct laboratory work and test concepts at small volumes while collecting standardized data
- 2 Develop generic cost models to demonstrate the cost and benefit of plastics and polymer composites compared to alternative materials as examples to provide mass reduction possibilities

Material Selection & Part Design

- 3 Define a standard package of material properties desired for automotive applications, and then test the data through simulation for a specific automotive system (e.g., engine mounts, instrument panel, cross-car beams)
- 4 Establish design guidelines (e.g., for wall thickness, radii) and tools for typical plastic and polymer composite structures that are intended to be used by design engineers
- 5 Develop models that can simulate the behavior of plastic and polymer composite materials and components during and after impact events

Manufacturing & Assembly

- 6 Develop a manufacturing center or consortium to advance high-speed polymer composites processing
- 7 Develop technically and economically viable techniques to join plastics and polymer composites to similar or dissimilar materials and study service, repair, and disassembly

Continued Materials Development

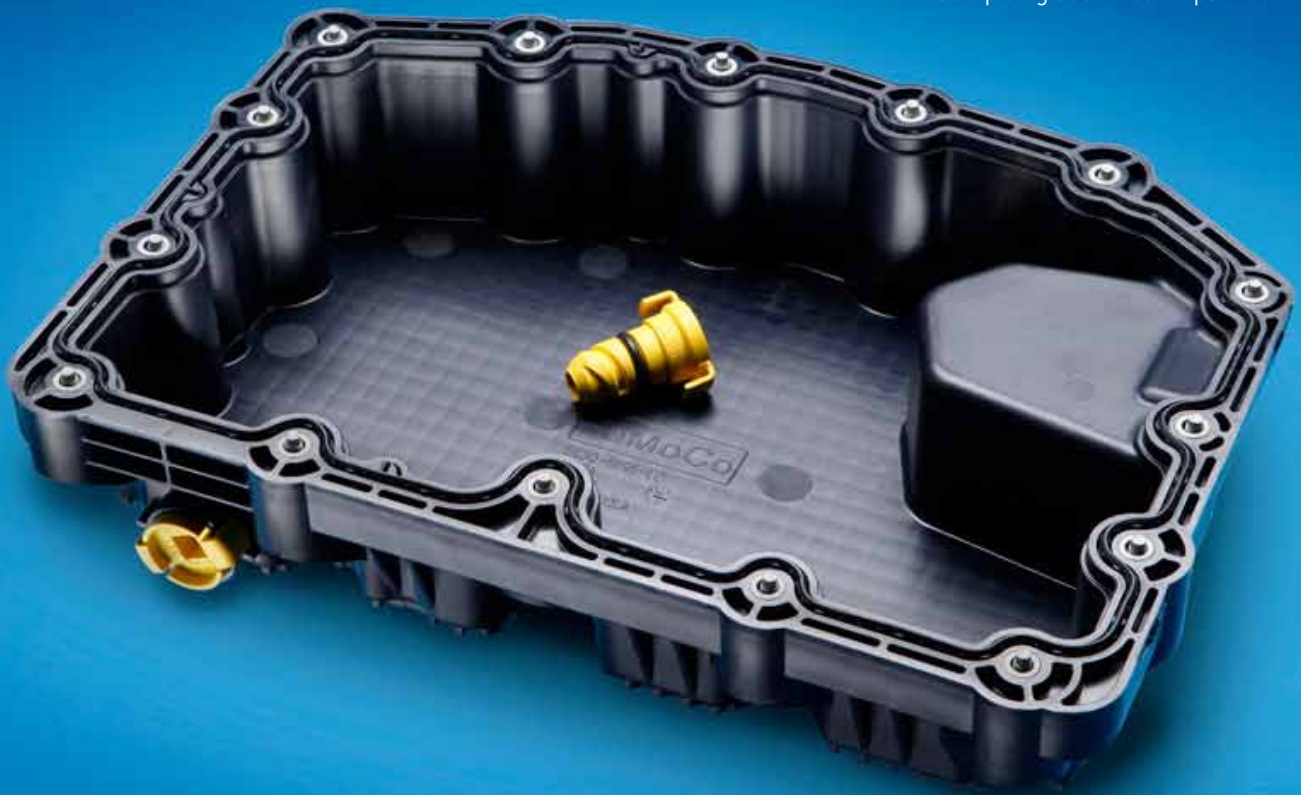
- 8 Support development of engineered plastics and polymer composites with improved properties (e.g., stiffness, strength, fatigue, environmental resistance, creep, energy management, temperature capability), and develop performance standards to characterize the properties for designers

Supporting Initiatives

- 9 Advocate for plastics and polymer composites training classes and degree programs at all major universities

The Case for Plastics & Polymer Composites in Vehicles

Scorpion glass-filled oil pan. *Courtesy of BASF*



Plastics and polymer composites provide the weight savings, strength, and versatility the automotive industry needs to meet new standards without sacrificing quality.

The global economic recession that began in 2008 seriously challenged the North American automotive industry. Several automakers plunged into debt, closing plants and laying off workers nationwide. More than 50 U.S. automotive parts suppliers filed for Chapter 11 protection and up to 200 U.S. automotive parts suppliers were liquidated.³ However, since 2010, the automotive industry has experienced a strong rebound, with the pace of motor vehicle assemblies jumping to a six-year high in 2013.⁴ This recovery has reaffirmed the automotive industry's status as a major economic and employment force. But as it continues to rebuild, the industry faces a new challenge: meeting tougher environmental regulations and efficiency standards while continuing to satisfy customers' constant demand for increased performance and value.

Increasing efficiency and decreasing emissions levels are putting pressure on the automotive industry to take as much weight out of their vehicles as possible. The U.S. Environmental Protection Agency (EPA) has established a set of standards aimed at reducing emissions levels that are projected to require, on an average industry fleet-wide basis, less than 163 grams of CO₂ per mile in model year 2025—the equivalent

to 54.5 miles per gallon (mpg) if this reduction were achieved solely through improvements in fuel efficiency.⁵ These regulations were developed jointly with the National Highway Traffic Safety Administration (NHTSA)'s new Corporate Average Fuel Economy (CAFE) standards and are essentially equivalent in terms of stringency and the required level of efficiency improvements.

NHTSA coordinated with the EPA to determine a graduated path toward improved fuel efficiency and lower emissions levels by 2025. Ultimately, these standards will increase fuel economy requirements for model year 2025 vehicles to close to 50 mpg for passenger cars and light trucks. This rapid mpg increase combined with the economic challenges of a still rebuilding industry has automakers and parts suppliers searching for ways they can cost-effectively drop more and more weight from their vehicles while maintaining or improving performance, quality, or safety.

Plastics and polymer composites, which already dominate vehicle interiors, exteriors, trim, and lighting, are gaining use in other vehicle systems as lightweight, value-producing materials that can meet increasingly challenging

³ Office of Transportation and Machinery, U.S. Department of Commerce, *On the Road: U.S. Automotive Parts Industry Annual Assessment* (2011).

⁴ Lucia Mutikani, "Manufacturing sector regaining some momentum," Reuters, September 16, 2013, <http://www.reuters.com/article/2013/09/16/us-usa-economy-output-idUSBRE98F0DV20130916>.

⁵ Environmental Protection Agency and Department of Transportation, 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule, 77 Fed. Reg. 62623 (Oct. 15, 2012).

Definitions: Plastics and Polymer Composites

This roadmap uses the term “**plastics and polymer composites**” to refer to a wide range of polymeric materials.

The term “**plastics**” refers to two-dimensional chains or three-dimensional networks of repeating chemical units formed into a material. Polymers occur in nature and can be manufactured to serve specific needs. The majority of manufactured plastics are thermoplastics, two-dimensional chains that, once formed, can be heated and reformed over and over again. The other group of plastics, called thermosets, is formed by creating three-dimensional networks that do not melt once formed. Both types of plastics are used in automotive applications today.

“**Polymer composites**” refers to material systems that combine a plastic resin (the raw material used in plastics and polymer composites) with a filler material to produce improved properties. Filler materials can be talc, short glass or carbon fibers, long glass or carbon fibers, or long continuous glass or carbon supports. Resins in such composites can be thermosets or thermoplastics. The term “composites” can also refer to plastic-metal hybrid structures, cored sandwich structures, and other arrangements that combine polymeric materials with other material classes.

automotive requirements. These materials’ many advantages have enabled them to grow to become a significant part of the materials mix in the automotive industry over the past 40 years. As the push to lightweight vehicles intensifies, projections indicate that plastics and polymer composites can and should play an even more substantial role in the automotive industry through 2025 and beyond.

Offer unparalleled weight savings

In order to meet the progressively increasing efficiency and emissions standards by 2025 (see Figure 2), it is critical that automakers continue to find new ways to lightweight their vehicles. Ducker Worldwide estimates that 400 pounds—about 10 percent—needs to be removed from the average car to meet the proposed EPA emissions standards that are equivalent to 54.5 mpg.⁶ The industries producing metals like aluminum and

advanced high-strength steel (AHSS) are working to attain lightweighting gains to help meet these needs. Aluminum weighs about one-third as much as conventional steel, while AHSS provides weight-saving improvements at a modest incremental cost.

Plastics and polymer composites continue to deliver significant weight savings to automakers. In addition to their current role as an excellent choice for lightweighting, aesthetics, aerodynamic design, and value in many interior and exterior applications, plastics and polymer composites—particularly fiber-reinforced composites—are also fast becoming a contender in structural applications like body-in-white and chassis components due to their ability to drastically reduce overall vehicle weight while maintaining or improving safety and performance. Carbon-fiber-reinforced composites are 50% lighter than conventional steel and 30% lighter than aluminum,⁷ which is encouraging more and more parts suppliers and

⁶ Len Boselovic, “Aluminum and steel slug it out to become the lighter, stronger metal for cars,” Pittsburgh Post-Gazette, October 9, 2011, <http://www.post-gazette.com/business/businessnews/2011/10/09/Aluminum-and-steel-slug-it-out-to-become-the-lighter-stronger-metal-for-cars.html>.

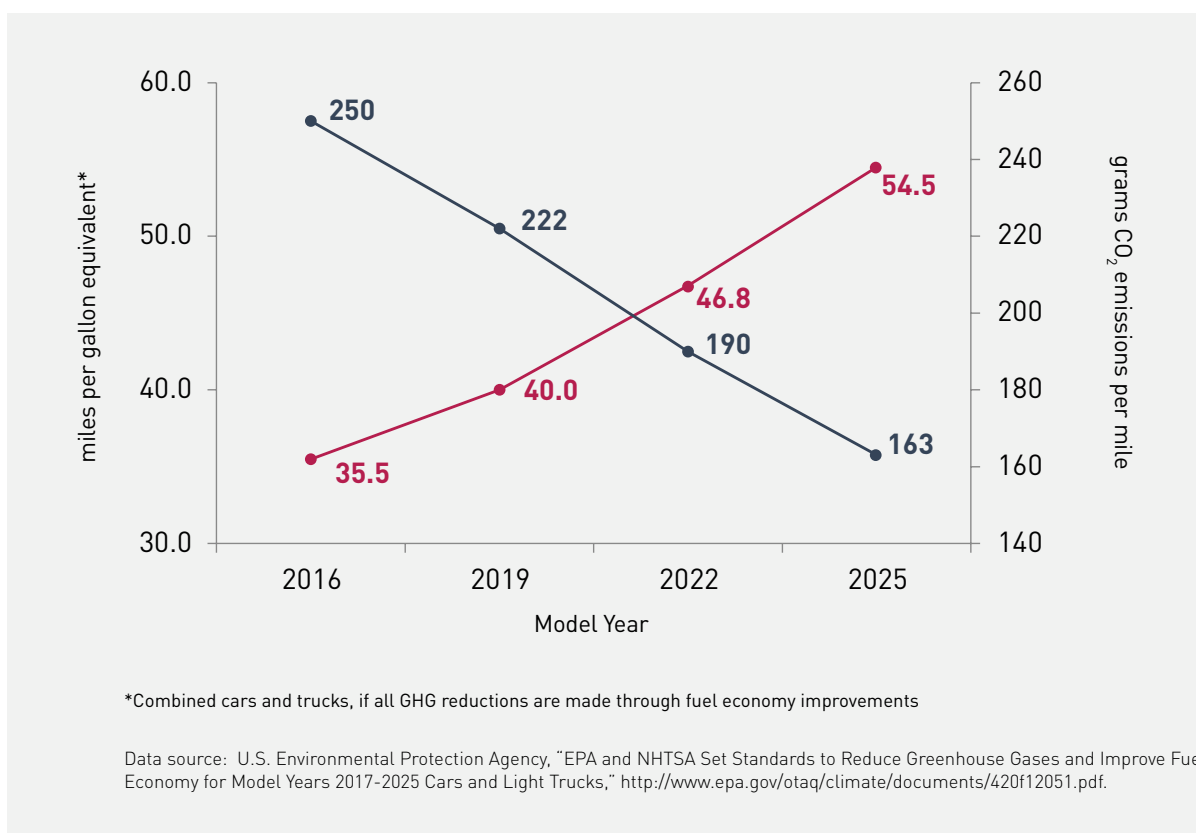
⁷ David Sedgwick, “New techniques cut cost of carbon fiber,” Autoweek (July 2011), <http://www.autoweek.com/article/20110711/CARNEWS/110719991>.

automakers to take notice. For example, BMW is using the material as the body structure of its electric city car, the i3, which goes on sale in the United States in 2014.⁸ DuPont has also run computer simulations that have shown that polymer composite driveshafts can be produced at half the weight and at half the cost of aluminum options.⁹ With even more innovation under way, the plastics and polymer composites industry is committed and well poised to meet and exceed the lightweighting needs of the automotive industry.

Provide high energy absorption for improved strength and safety

As automakers strive to make cars lighter, they will also face the challenge of maintaining and improving strength and safety standards. Both NHTSA and the Insurance Institute for Highway Safety (IIHS) are currently pursuing stricter crash-test rating systems to improve both pedestrian and passenger safety through increased crash avoidance technologies and better crashworthiness.¹⁰

Figure 2. National Program to reduce greenhouse gas emissions and improve fuel economy drive lightweighting



⁸ Tim Stevens, "2014 BMW i3 EV drive review," Autoweek (October 2013), <http://www.autoweek.com/article/20131015/carreviews/131019872#>.

⁹ "DuPont-Leading the metals-to-plastics revolution in transmissions and driveline," Autofocus, Vol 18, 2012, http://www2.dupont.com/Plastics/en_US/Knowledge_Center/autofocus/issue18/autofocus_issue18_02.html.

¹⁰ Department of Transportation, National Highway Traffic Safety Administration, Federal Register Volume 78, Number 66, 49 CFR Part 575, <http://www.gpo.gov/fdsys/pkg/FR-2013-04-05/html/2013-07766.htm>; "What's New at the Show In PUR/RIM," Plastics Technology, September 2007; "Shop Smart for a Safer Car, SUV, Mini-Van or Light Truck," [safercar.gov](http://www.safercar.gov/Safety+Ratings), <http://www.safercar.gov/Safety+Ratings>.

Plastics and polymer composites not only provide a weight savings to vehicles, but their high energy-absorption qualities means that they can be developed to meet strict safety standards that simulate collisions and other accidents. In industries like motor sports and aerospace, polymer composites have been the material of choice for years, thanks to their high strength-to-weight and stiffness-to-weight ratios. Polymer composites offer an unmatched energy-absorbing capability per mass, making them a strong, lightweight choice. The high strength and energy absorption of structural polymer composites can also improve crash safety by strengthening vehicle compartments to help protect passengers during crashes.¹¹ On the other end of the materials spectrum, energy-absorbing, injection-moldable materials such as polypropylene or polycarbonate blended with polybutylene terephthalate (PC+PBT) as well as low-density foam polymer materials are already being incorporated into vehicle bumpers in Europe to meet new pedestrian protection guidelines set forth by the European Commission.¹²

Realize alternative powertrain vehicles

Alternative powertrain vehicles—such as electric, hybrid, plug-in hybrid, compressed natural gas, liquefied petroleum gas, and flex-fuel vehicles that can operate on E85—are becoming a larger part of the vehicle mix thanks to drivers like the new CAFE standards. Some experts estimate that more than one-third (36%) of new passenger vehicles will be equipped with alternative powertrains by 2025.¹³ Because these new vehicles are using different fuels with varying chemical compositions and combustion

temperatures, they require powertrains composed of materials that can withstand these different conditions.

Plastics and polymer composites can not only help reduce the weight of powertrains, they can also withstand many of the alternative fuel environments that metals cannot. Thanks to this advantage and other material properties, over 200 tons of plastics and polymer composites were used in electric vehicle applications in 2010 for powertrains, battery casings, thermal management systems, and wire and cables, a figure that is projected to increase to 26,000 tons by 2017.¹⁴ By providing vehicles with lighter powertrains that can better withstand the conditions of alternative vehicles, plastics and polymer composites are and will continue to significantly aid in the market realization of these new vehicle technologies.

Create value through parts consolidation

Traditionally, vehicles are constructed by manufacturing a large number of individual components, combining them into systems, and assembling these systems together using joining techniques like spot welding, adhesives, and fasteners. While necessary, this process can add both cost and weight to vehicle production, as well as create weaknesses at joining points.

Through parts integration, plastics and polymer composites provide automakers with the ability to manufacture one complex part instead of joining multiple parts together. This advantage results in faster processing times and the elimination of expensive joining and assembly tooling. For example, the 2013 Ford Escape

¹¹ Aviva Brecher and John Brewer, Volpe National Transportation Systems Center, and Stephen Summers and Sanjay Patel, National Highway Traffic Safety Administration, Characterizing and Enhancing the Safety of Future Plastic and Composite Intensive Vehicles (PCIVs), <http://www-nrd.nhtsa.dot.gov/pdf/esv/esv21/09-0316.pdf>.

¹² Euro NCAP, "Guidelines," <http://www.euroncap.com/guidelines.aspx>.

¹³ Tim Dunne, "One-Third of Vehicle Mix to Feature Alternative Powertrains in 2025," J.D. Power Global Auto Blog (April 29, 2013), <http://www.jdpowercontent.com/globalauto/one-third-of-vehicle-mix-to-feature-alternative-powertrains-in-2025/2013/04/29/>.

¹⁴ Shree Vidhya Karunanidhi, Frost & Sullivan, Strategic Analysis of Plastics in the Electric Vehicles Market in Europe and North America (December 2011).



Panorama roof on Smart Car featuring Bayer polycarbonate and polycarbonate blended material.

features a two-shot window lift carrier plate that replaces a metal-intensive assembly comprising 21 components produced with 16+ processing and assembly steps with a plastics-intensive, 10-component unit produced in 10 assembly steps.¹⁵ The result delivers design flexibility, weight and cost savings, simplified assembly, and a reduction of process steps.¹⁶

May benefit from natural gas supply boom

Some of the biggest barriers cited by the automotive industry to the use of advanced plastics and polymer composites involve cost.

Recognizing this issue, the plastics and polymer composites industry is working to find more cost-effective ways to produce these materials that are so critical to the future of vehicle lightweighting. The recent boom in U.S. shale gas production has the potential to aid the industry in making these gains.

Natural gas is currently used to make plastic and polymer composite materials. In 2010, about 412 billion cubic feet (Bcf) of natural gas were used to make plastic materials and resins (about 1.7% of total U.S. natural gas consumption); however, only 13 Bcf were used as feedstock while 399 Bcf were burned as fuel.¹⁷ Chevron Phillips Chemical Company has suggested that the development

¹⁵ "Two-Shot Window Lift Carrier Plate," [Plasticscar.blogspot.com](http://www.plasticscar.blogspot.com/2012/11/two-shot-window-lift-carrier-plate.html), November 21, 2012, <http://www.plasticscar.blogspot.com/2012/11/two-shot-window-lift-carrier-plate.html>.

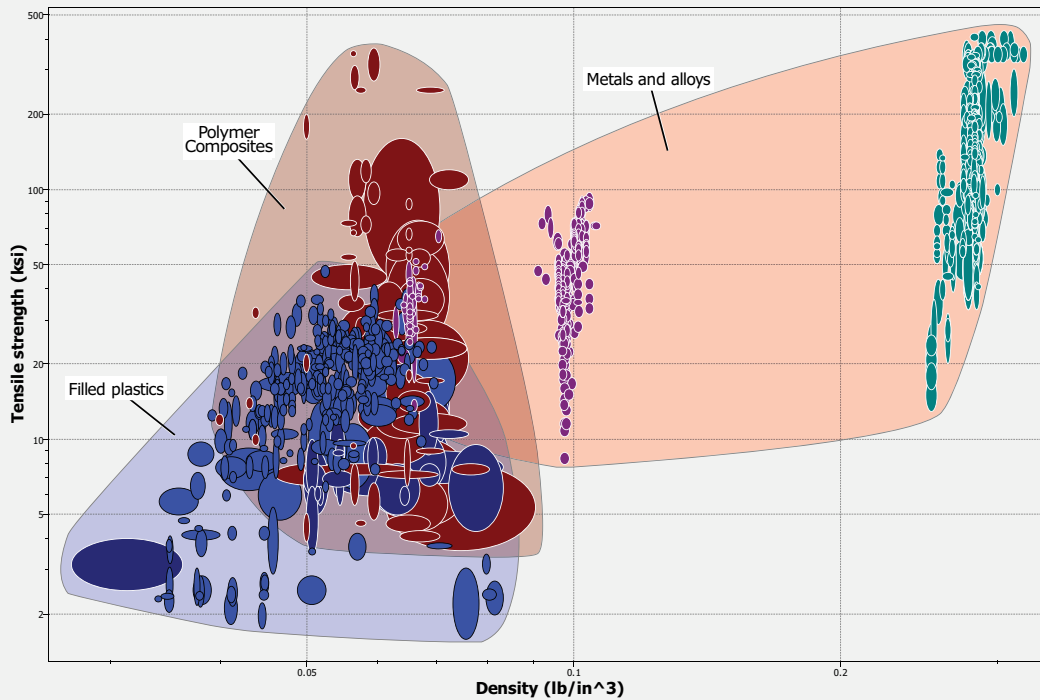
¹⁶ *Ibid.*

¹⁷ U.S. Energy Information Administration, "How much oil is used to make plastic," Frequently Asked Questions, <http://www.eia.gov/tools/faqs/faq.cfm?id=34&t=6>.

of shale gas may encourage the plastics and polymer composites industry to invest \$30 billion to construct new petrochemical units that convert natural gas into plastics.¹⁸ As a result,

the plastic and rubber products industry could experience a 17.9% boost (equivalent to \$33.28 billion) in industry output above the 2010 baseline in the 2015–2020 period.¹⁹

Figure 3. Tensile strength versus density for filled plastics, polymer composites, and metals and metal alloys

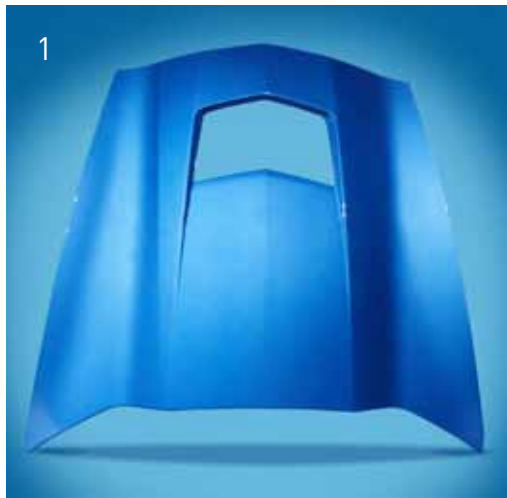


Courtesy of Granta Design

The chart above provides data on the tensile strength and density of filled plastics, polymer composites, metals, and alloys. As shown in the chart, there are many plastics and polymer composites that are significantly less dense than most metals and alloys while offering similar tensile strengths. These data illustrate the fundamental physical advantage that many plastics and polymer composites offer over metallic automotive materials: higher strength-to-weight ratios that can enable automakers to lightweight vehicles while maintaining safety and performance.

¹⁸ Charles Kennedy, "US Plastic Industry Set to Grow with \$30 Billion Investment in New Factories," Oilprice.com, March 7, 2012.

¹⁹ American Chemistry Council, Economics & Statistics Department, Shale Gas, Competitiveness and New U.S. Investment: A Case Study of Eight Manufacturing Industries (May 2012).



1. Carbon-fiber-reinforced composite hood that takes 17 minutes to produce.
2. Valve covers. *Courtesy of BASF*
3. Nissan liftgate, featuring LyondellBasell material.
4. Audi A8 front end structure. *Courtesy of LANXESS*
5. Roof assembly.
6. Nissan Leaf battery cover. *Courtesy of SABIC*
7. Door trim panel. *Courtesy of Bayer*
8. In mold coloring in front grill.
9. Ford Bosch diesel exhaust treatment. *Courtesy of BASF*
10. Lightweight seat pan.
11. Foam-filled door frame. *Courtesy of Dow*

Industry-Wide Demonstrations



The VW XL1 diesel plug-in hybrid uses carbon-fiber-reinforced composites for the frame and body and polycarbonate and SABIC polycarbonate glazing material for the side windows for weight savings that help it achieve an estimated 261 mpg.

Industry-wide demonstrations of today's and tomorrow's plastics and polymer composites in real-world automotive applications can highlight performance gains and accelerate market acceptance.

Demonstration programs that highlight the unique capabilities of plastics and polymer composites—and that overcome the challenges that using these materials presents—can convince automakers of the value of these materials and accelerate adoption. While advances in material selection and part design, manufacturing and assembly, and materials development will be made through the work of individual companies, this proprietary work will be most beneficial if informed by and supported through collaborative, pre-competitive

initiatives among plastic and polymer composite providers, original equipment manufacturers (OEMs), tier suppliers (Tiers), government agencies, and research communities. Such industry-wide activities can significantly expand the reach and accelerate progress in enabling lighter weight, more fuel-efficient, and more cost-effective vehicles. Increased coordination is essential to help accelerate innovation in plastics and polymer composites and enable their increased integration into vehicles through 2030.

Current Barriers

While the plastics and polymer composites industry has been working collaboratively with the automotive industry for many years, barriers remain that limit the use of plastics and polymer composites in vehicles. Coordination within the automotive supply chain and with other industries and cost modeling of certain plastic and polymer composite components can be strengthened to stimulate growth in the use of these materials.

Insufficient pre-competitive collaboration with other industries

The plastics and polymer composites industry collaborates with other industries involved in advancing vehicles or plastics and polymer composites technology, but this collaboration could be expanded to achieve maximum benefit. Without increased collaboration, advanced hybrid material systems that combine plastics and polymer composites with metals will be slower

to develop. Further, increased collaboration with other industry sectors, including motor sports, aerospace, athletic equipment, wind turbines, and military applications, can accelerate the use of carbon-fiber-reinforced composites in vehicles.

Limited collaboration across the automotive supply chain

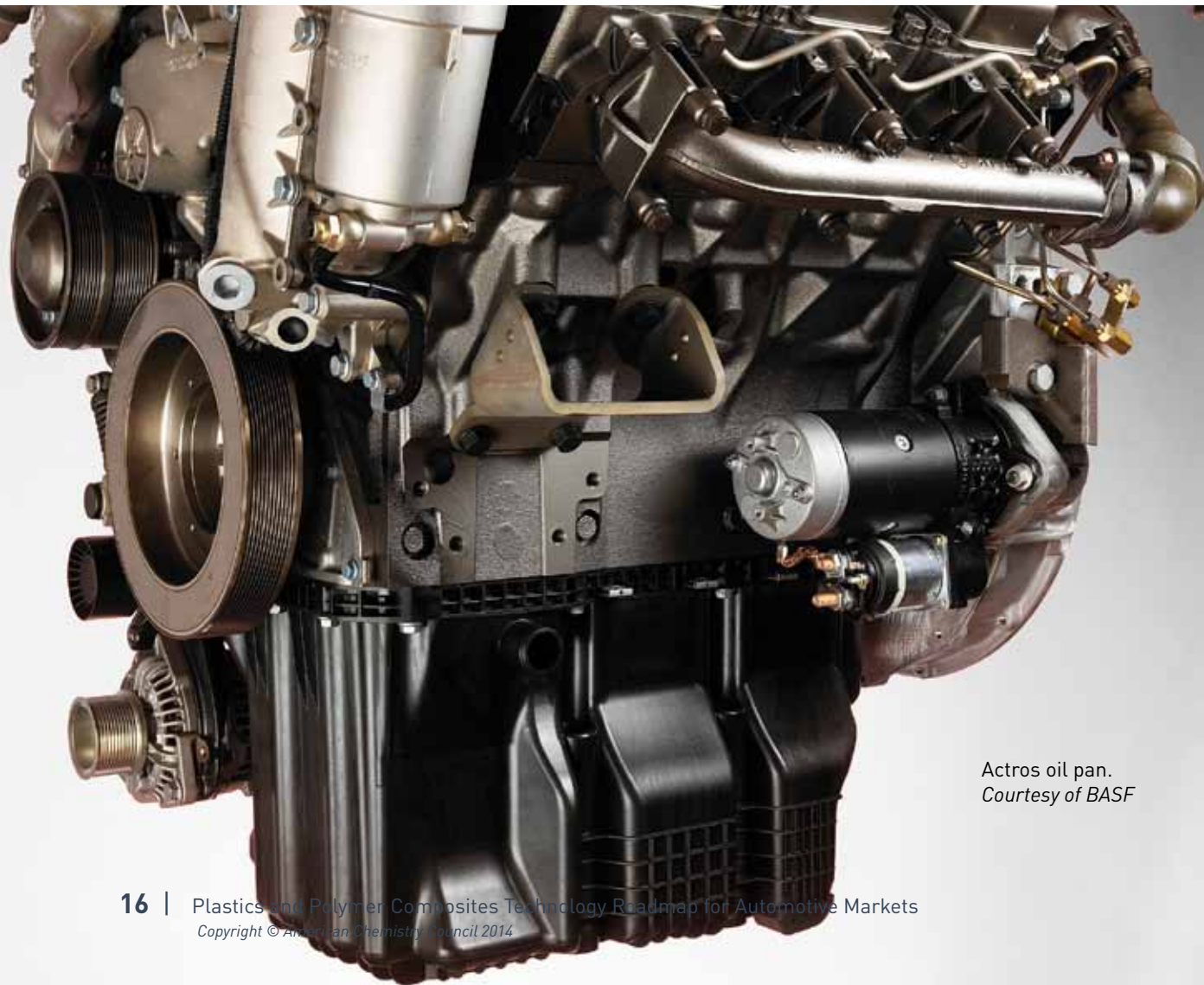
To develop new automotive materials, components, and systems in the most effective way, the whole automotive supply chain needs

to work together. However, currently the supply chain is not sufficiently integrated among OEMs, Tiers, and material developers on materials development, part design, and manufacturing and assembly, often because of intellectual property or other legal or business issues. Material suppliers often are not fully aware of the needs of OEMs, while material suppliers and Tiers do not always present OEMs with the data they need to increase their confidence in plastic and polymer composite automotive parts. As a result, instead of adopting new materials, OEMs tend to select existing components with which they are familiar.

High initial cost of certain plastic and polymer composite materials

Some plastics and especially polymer composite

materials are more costly on a mass or part basis compared to materials such as steel, aluminum, and glass when purchased at medium and even high volumes. Lightweight fillers (e.g., glass beads) and alternative glazing materials also face cost-related challenges that limit their use in vehicles today. While these materials may offer greater value than alternative materials throughout the vehicle lifecycle, OEMs typically focus on material and component pricing instead of considering whole system cost, which includes the cost of materials, part fabrication, vehicle assembly, warranty maintenance and reparability, and the cost of energy throughout the lifecycle of the material. The plastics and polymer composites industry currently lacks verified cost models for many plastic and polymer composite applications that include all of these factors and that are accepted by the automotive industry, hindering its ability to demonstrate lifecycle cost savings in a way that is accepted by automakers.



Actros oil pan.
Courtesy of BASF

Key Initiatives

Although many advances in materials development, materials design and selection, and manufacturing and assembly will occur throughout the automotive plastics and polymer composites industry, there is a significant need for increased industry-wide demonstrations and coordination both within the automotive supply chain and with other industries. More defined partnerships would better link the capabilities of developers and designers with the needs of OEMs and leverage existing knowledge, ultimately helping to streamline and accelerate innovation efforts. The following key initiatives, which are divided into near-term (2014–2016), mid-term (2017–2025), and long-term (2026–2030+) actions, are needed.

Conduct high-profile demonstration programs for plastic and polymer composite components and systems

No amount of research and development is as convincing as a real-world, integrated demonstration of an innovation in action. In order to convince automakers and their suppliers that plastic and polymer composite materials are reliable, valuable options in automotive systems, the plastics and polymer composites industry should work with automotive value chains to conduct well-communicated and publicized demonstrations that convincingly display the unique benefits of plastics and polymer composites and can overcome inherent familiarity with and resulting default selection of metals within the automotive industry. Demonstrations should include not only material and component research and development, but also show pathways to cost-effective, high-volume production capability; address multi-materials joining and assembly issues; and consider how plastics and polymer composites should be managed at the end of vehicle life.

Critical Actions (Priority actions in bold)

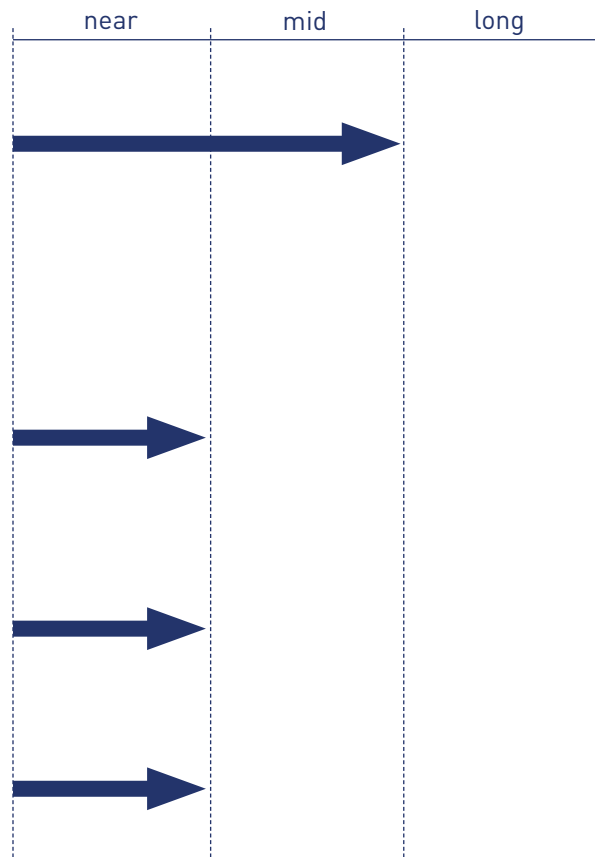
Establish an independent, pre-competitive technology development center where OEMs and suppliers can conduct laboratory work and test concepts at small volumes while collecting standardized data (see Appendix A, Priority Action 1)

- **Leverage centers like Fraunhofer, RWTH Aachen, and the National Composite Center**

Fund a manufacturing development center to conduct a demonstration of high-performance plastic and polymer composite parts through a holistic, collaborative effort that engages material suppliers, OEMs, Tiers, and machine developers

Conduct a demonstration project for intrusion-resistant polymer composite structures, including setting targets, producing parts, and testing component performance

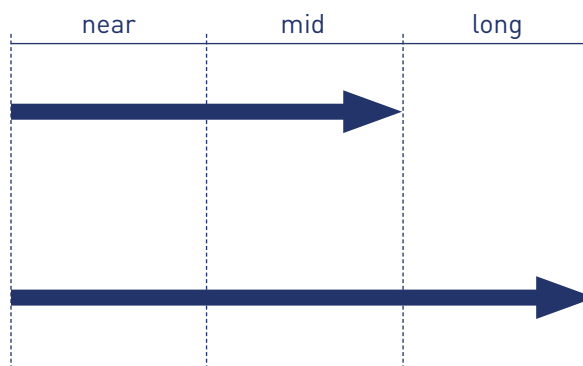
Conduct a demonstration project for energy-absorbing polymer composite structures, including setting targets, producing parts, and testing performance



Critical Actions (Priority actions in bold)

Conduct systems demonstrations that design and drive full systems development (i.e., taking a part all the way to production) as a way to validate work on material properties data gathering and design tools development

Create a recycling and energy recovery demonstration program to develop and prove the effectiveness of innovative recycling techniques for automotive plastics and polymer composites



Improve collaboration across the supply chain to align efforts

The automotive plastics and polymer composites industry should develop cooperative R&D partnerships among industry, government, and academia that effectively leverage funding and align specialized resources and expertise. Collaborative, multifunctional, multidisciplinary organizations would help material suppliers and Tiers better understand the needs of OEMs and accelerate innovation in developing prototype parts and manufacturing processes that meet OEM needs. Earlier collaboration (e.g., via increased communications, technology exchanges, early design reviews, manufacturing process validation) between OEMs and material suppliers could ultimately reduce cost and increase the number of applications for plastics and polymer composites.

Critical Actions (Priority actions in bold)

Identify areas of vehicles with the greatest opportunities for part consolidation and integration with high-performance plastics and polymer composites

Encourage OEMs to work together by establishing common goals (e.g., weight reduction)

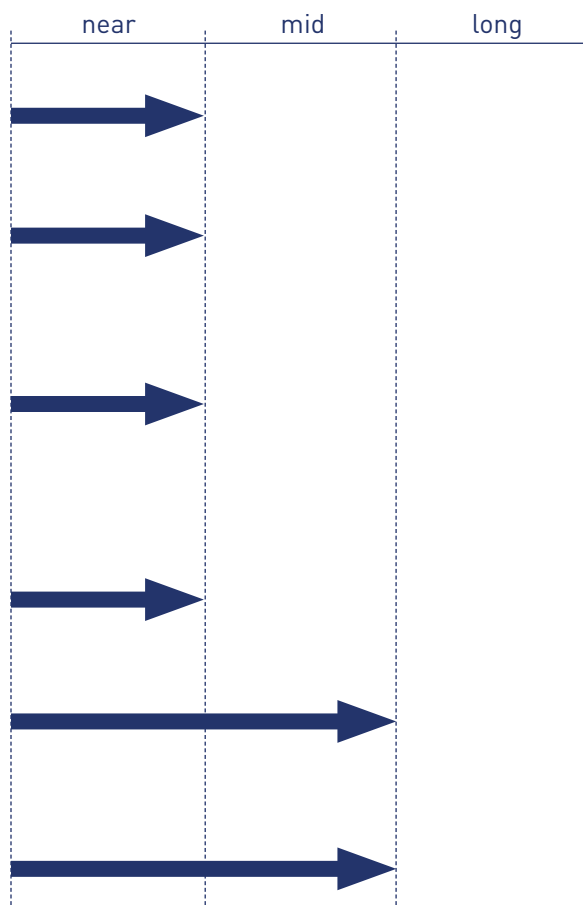
Establish an integrated supply chain working group that includes material suppliers, Tiers, OEMs, accredited testing organizations, and standards organizations to share information and identify tactics for improving supply chain coordination

- Engage small- and medium-sized companies that can contribute innovations

Develop a supply chain roadmap that outlines a plan to 2030 for achieving U.S. Department of Energy projections for automotive materials

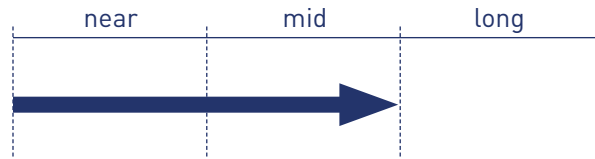
Launch a collaborative project to develop a simple system for determining materials and process predictions (e.g., start-to-end prediction for fiber injection molding)

Increase collaborative efforts in legislative, regulatory, and voluntary consensus standard development



Critical Actions (Priority actions in bold)

Establish a cross-industry (aerospace/aviation/automotive) consortium to develop the needed technology and supply chain



Conduct cost modeling to demonstrate system-level benefits

Traditionally, automotive OEMs have used component-based approaches for evaluating alternative material choices and estimating value-added contributions. However, design flexibility, parts consolidation, vehicle lightweighting, and many other benefits frequently result in lower system and lifecycle costs that are missed when only examining component cost. Initiatives to produce cost-benefit analyses that model system-level benefits of plastics and polymer composites will help automakers and their value chain realize greater performance and aesthetics advances by fully exploiting the performance capabilities of plastics and polymer composites. While there are some specific near-term actions related to cost modeling of plastic and polymer composite parts, a key benefit of many of the key initiatives in this roadmap is that they may directly or indirectly reduce the cost of the integration of plastics and polymer composites in vehicles.

Critical Actions (Priority actions in bold)

Develop generic cost models to demonstrate the cost and benefit of plastics and polymer composites compared to alternative materials as examples to provide mass reduction possibilities (see Appendix A, Priority Action 2)

Conduct industry-wide cost modeling of key automotive systems using plastics and polymer composites and compare to traditional systems

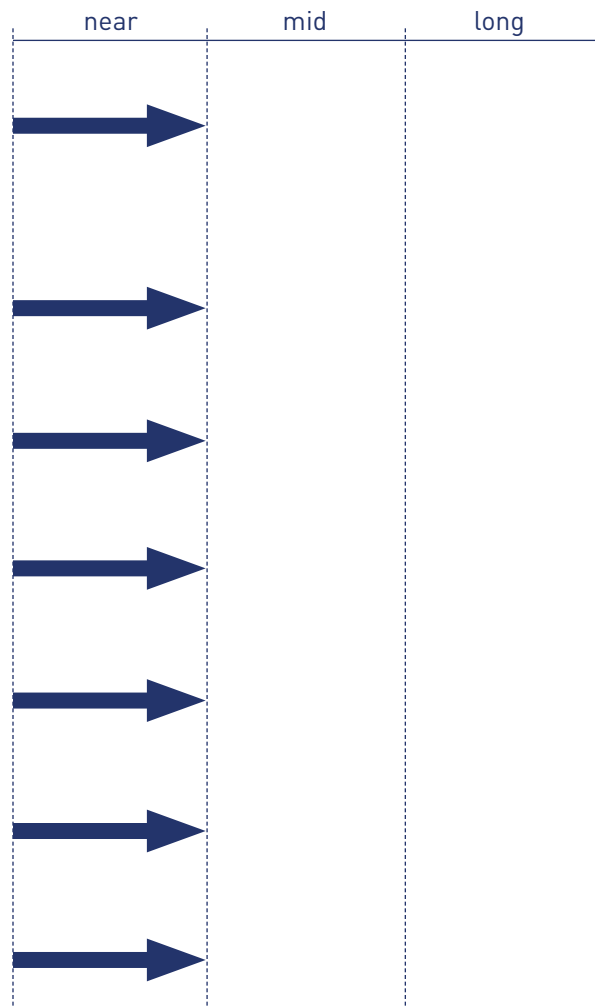
Fund research and development to identify more cost-effective solutions for carbon-fiber-reinforced composites

Form public/private partnerships to support ongoing efforts to develop technologies that reduce processing time and carbon fiber cost

Evaluate the cost effectiveness of material solutions based on vehicle unit build (i.e., capital investment vs. piece price)

Create database with a business-case analysis of best practices, including a cost-benefit analysis on component weight

Collaborate with OEMs to better understand the relationship between cost to achieve weight reduction and fuel efficiency improvement



Material Selection & Part Design



Cross-section of polyurethane roof module. *Courtesy of Bayer*

Designing vehicle systems requires careful selection of the right material that can get the job done.

During material selection, Tiers and OEMs must match the properties (e.g., rigidity, tolerance to high temperatures, corrosion resistance) of many materials to the performance needed in the target application and choose the material or materials that can most cost-effectively fulfill the need. While selecting the materials with the necessary properties, designers must also

develop and model part designs that optimize the materials' performance capabilities and can be cost-effectively integrated into the rest of a vehicle. To get the most out of material properties, material selection and part design should be closely integrated, a process that poses certain challenges for plastics and polymer composites for reasons discussed below.

Current Barriers

The current developmental infrastructure for plastics and polymer composites used in automobiles is limited by the lack of readily accessible data and design tools developed specifically for these materials. Insufficient material properties databases and design tools that do not effectively model many plastics and polymer composites limit the ability for designers to cost-effectively develop component solutions that take full advantage of the benefits of these materials. The plastics and polymer composites industry should work with automotive OEMs and Tiers to overcome the following barriers to efficient material selection and part design to encourage further integration of plastics and polymer composites in automotive markets.

Lack of standardized material properties databases

There are many different plastic and polymer composite material options, enabling new, customized properties that can improve automotive components. However, designers and engineers lack access to standardized material properties and performance data for many classes of plastics and polymer composites. To complicate matters, the properties of plastics and polymer composites can also vary depending on environmental factors such as temperature and humidity. Without a materials characterization database with verified property and performance data, it is difficult for engineers and designers to select the best plastic or polymer composite for an application. Developing such databases, however, will be costly and will

therefore require significant investment from material developers, Tiers, and OEMs.

Limited tools to model plastic and polymer composite designs

While predictive modeling tools are currently used for some types of plastics and polymer composites in applications such as instrument panels, door modules, and front-end modules, some automotive parts containing these materials are currently being modeled using tools designed for use with metals. These tools do not account for the unique performance characteristics of plastics and polymer composites. Without robust and reliable predictive engineering tools optimized specifically for

plastics and polymer composites that can also be used by non-experts, it is difficult for Tiers to test designs. Such tools are critical for proving

the reliability and quality of plastic and polymer composite parts during the design phase and ultimately for encouraging OEM adoption.

Key Initiatives

As material scientists improve existing plastic and polymer composite materials and develop new ones, the industry should also develop the tools and processes necessary to better prove and capitalize on the vast array of properties and performance capabilities offered by these materials. More complete, reliable, and standardized data about the material properties of plastics and polymer composites under different conditions will enable designers to explore more novel applications and maximize the benefits these materials can bring to automotive part designs. The successful development of new design tools that incorporate more varieties of plastics and polymer composites will improve performance predictions, minimize the cost of testing and prototype development, and ultimately help to update an infrastructure that has evolved primarily with metals in mind. A strong developmental infrastructure can also lead to improved manufacturing capabilities and a stronger manufacturing infrastructure. The following key initiatives, which are divided into near-term (2014–2016), mid-term (2017–2025), and long-term (2026–2030+) actions, are needed.

Generate standardized material properties data

To expand the adoption of plastics and polymer composites in automotive applications, material suppliers, Tiers, and OEMs need to work together to define and generate a standardized set of materials data. Having a centralized source for material properties and performance data could improve communication among material developers, Tiers, and OEMs and optimize material selection. The availability of such data could also facilitate the creation of performance-based materials standards, ultimately enabling improved design specifications.

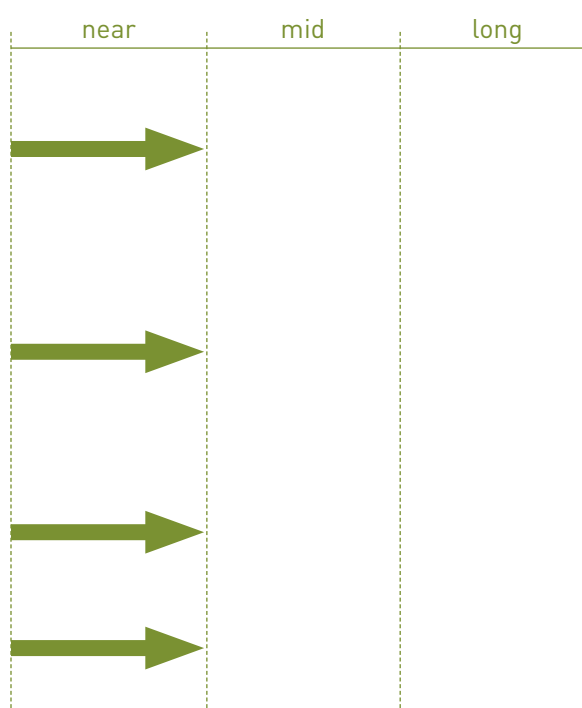
Critical Actions (Priority actions in bold)

Define a standard package of material properties desired for automotive applications, and then test the data through simulation for a specific automotive system (e.g., engine mounts, instrument panel, cross-car beams) (see Appendix A, Priority Action 3)

Generate categories of material properties useful to automotive applications, and then categorize plastics and polymer composites based on important parameters (e.g., fiber type and length, performance ranges) to facilitate more effective material selection

Develop a roadmap that outlines the necessary steps for developing performance-based materials standards for plastics and polymer composites

Create a testing library that includes a large database of material properties, including environmental variability of materials



Critical Actions (Priority actions in bold)

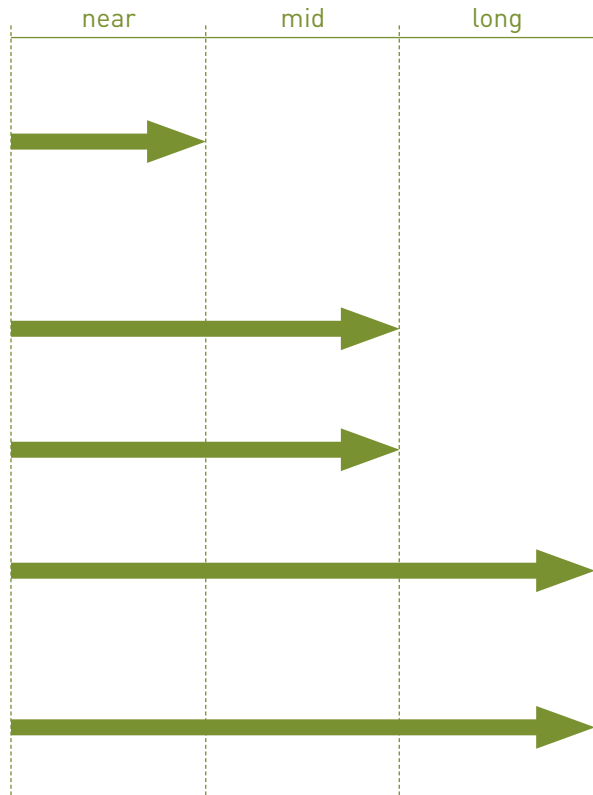
Initiate a U.S. government-sponsored plastics and polymer composites modeling effort to define a common information architecture, using the United States Council for Automotive Research (USCAR) and the Composites Materials Handbook (MIL 17) as examples

Standardize plastic and polymer composite specifications for vehicle performance across OEMs and Tiers

Generate data to determine how fiber orientation in injection molding affects the properties of fiber-reinforced composites

Develop a best practice handbook for the automotive industry similar to the Composite Materials Handbook 17 (MIL 17) used by the aerospace industry

Continue the effort to standardize plastic and polymer composite performance specifications across OEMs to adjust for changing automotive and fuel requirements



Develop design and modeling tools specific to plastics and polymer composites that use standardized data

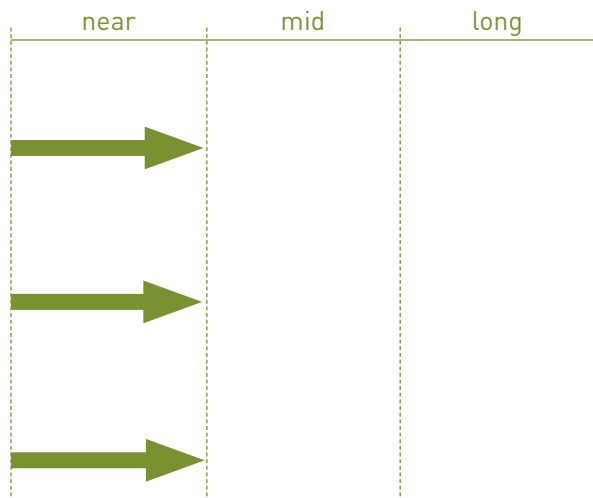
The plastics and polymer composites industry also needs to work with Tiers and OEMs to improve existing and develop new predictive modeling tools that are customized to the unique requirements and capabilities of these materials, instead of relying on models that have been designed for metals. The development and use of models and standard testing procedures specific to plastics and polymer composites (e.g., for fatigue and strain) will help better predict materials performance and increase OEM confidence in model results.

Critical Actions (Priority actions in bold)

Establish design guidelines (e.g., for wall thickness, radii) and tools for typical plastic and polymer composite structures that are intended to be used by design engineers (see Appendix A, Priority Action 4)

Develop models that can simulate the behavior of plastic and polymer composite materials and components during and after impact events (see Appendix A, Priority Action 5)

Define application specifications and requirements that are not materials-specific and disseminate them across the industry



Critical Actions (Priority actions in bold)

Compile and document best practices for simple plastic and polymer composite systems: shear panel structure, crush can (compression), bumper (tension), and multi-material molding processes

Create a consortium involving OEMs, material suppliers, and tool developers to develop computer-aided engineering (CAE) tools and test methods for plastics and polymer composites

Develop integrated computational materials engineering tools for plastics and polymer composites

Convene an OEM collaborative group to identify the reasons that past plastic and polymer composite innovations are no longer being implemented (e.g., cross-car beam, door panels)

Gain auto industry acceptance of a standard data package and models specifically developed to predict plastics and polymer composites

Develop tools and practices that allow design engineers to design to the strengths of polymer-based materials from the beginning, rather than finding a material to fit the pre-determined design

Homologate data between validated and verified CAE tools and testing standards at the materials and structural level

Develop a fundamental knowledge of critical properties for design success (e.g., failure analysis) for uncomplicated applications

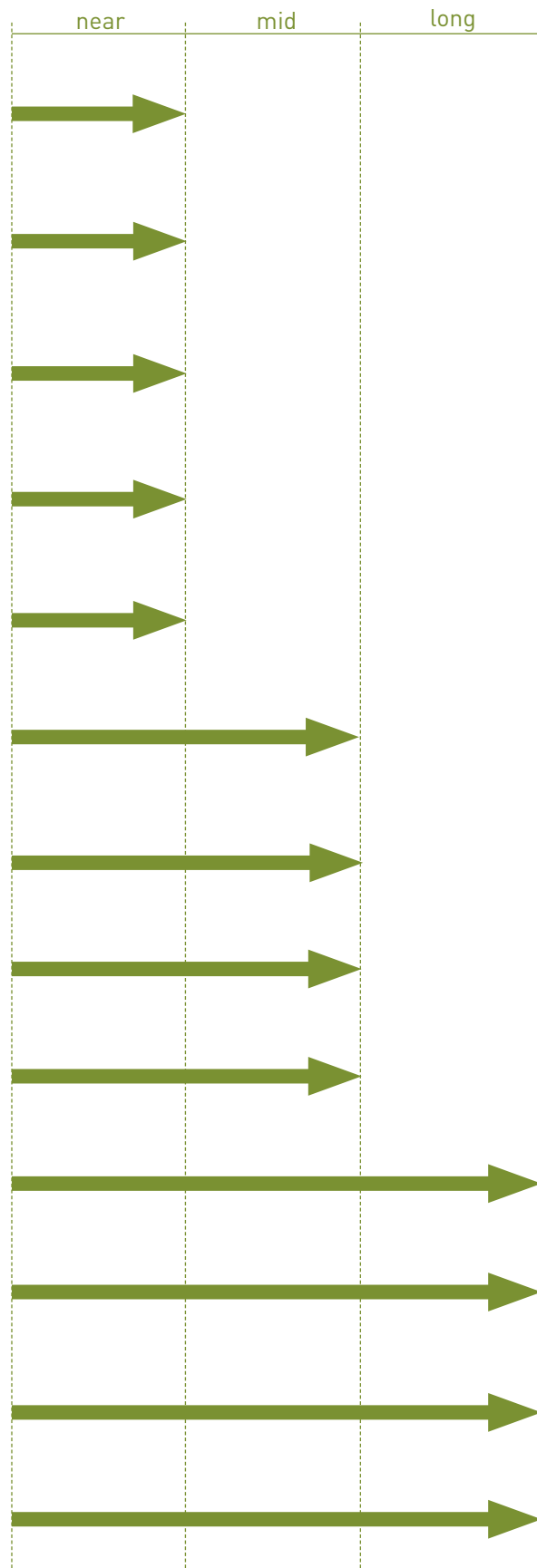
Standardize testing methods for parts and materials at the vehicle level, application and systems level, and material level

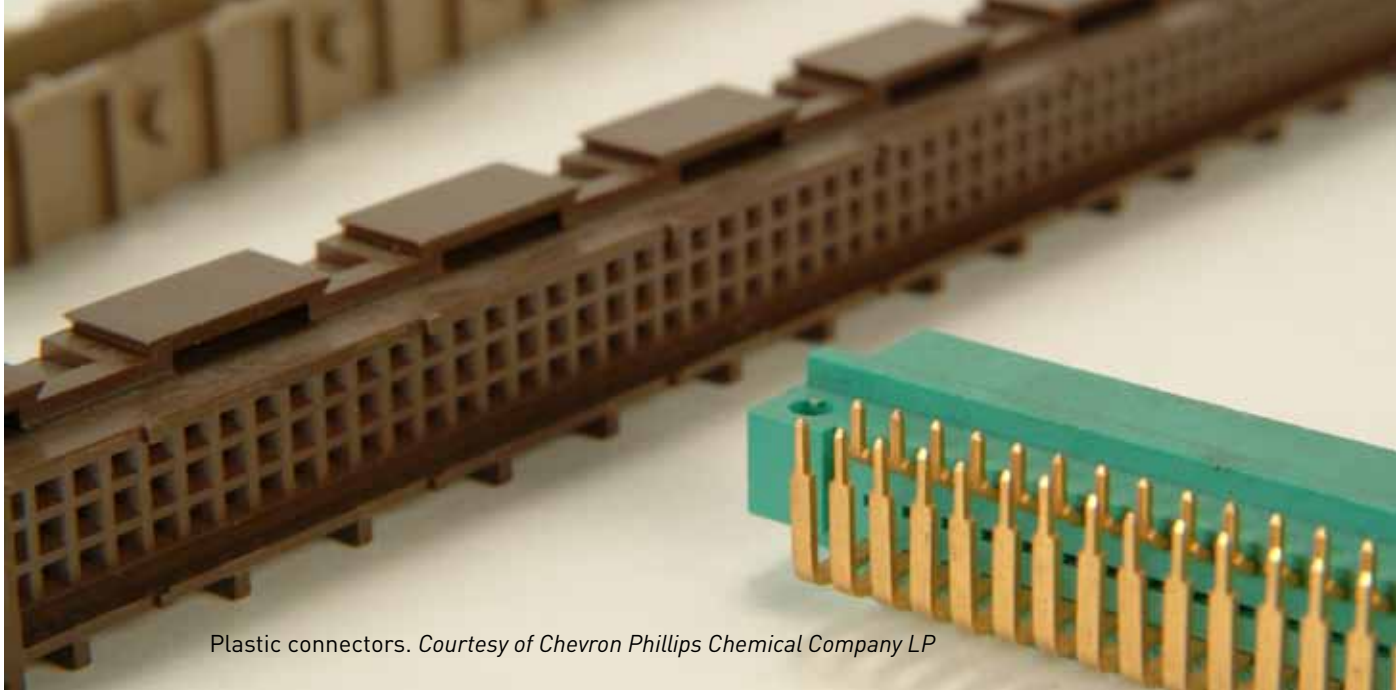
Develop a fundamental knowledge of critical properties for design success (e.g., failure analysis) for demanding structural applications

Extend the data and tool development processes completed in the mid term to other materials and processes

Develop new CAE, predictive technology, and materials characterization methods for plastics and polymer composites that fully exploit the standardized OEM data developed in the near term

Establish industry-wide tools for linking process simulation results to part finite element analysis input





Plastic connectors. *Courtesy of Chevron Phillips Chemical Company LP*

Increase data sharing and accessibility

Many material developers currently maintain their own material properties and performance databases. Increased data sharing of nonproprietary data will help reduce redundancy of effort and accelerate the improvement of existing plastics and polymer composites and the development of new materials. As importantly, by making reliable data available to the automotive industry, the plastics and polymer composites industry can empower Tiers and OEMs to more accurately model these materials, thereby facilitating consideration of plastics and polymer composites as a material option.

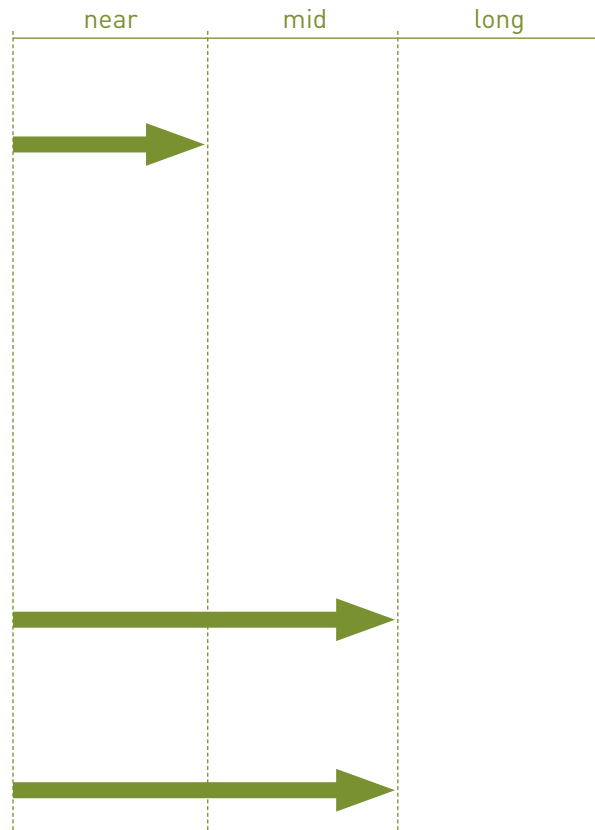
Critical Actions (Priority actions in bold)

Design an open access database for nonproprietary data, determining where the data will be stored, who will be responsible for data management, and how the data will be accessed and encrypted

- Gather existing nonproprietary material properties data
- Begin with data for existing material processes and use these processes as a demonstration and template for new material processes
- Leverage existing data-sharing platforms (e.g., the Composites Design and Manufacturing HUB at Purdue and Matweb)

Examine data for plastics and polymer composites used in other industries (e.g., smart phones, films, high-speed processors) to identify critical data and data standardization and sharing methods

Identify 20–30 pieces of data that OEMs need as a starting point for creating the material properties database



Manufacturing & Assembly



Automotive glazing
injection molding machine.
Courtesy of Bayer

Making parts is only half the battle. Assembling multi-material vehicles requires speed, precision, and reliability.

During the automotive manufacturing and assembly process, individual vehicle components are produced, then joined with other parts to develop vehicle systems, and ultimately assembled into a fully functional vehicle. The assembly process also includes surface finishing processes such as electrocoating, painting, and polishing that help protect vehicles from environmental conditions and improve

vehicle aesthetics. The current automotive manufacturing infrastructure is optimized for metals, which can create challenges when automakers seek to adopt plastics and polymer composites for new automotive applications. Developing manufacturing and assembly processes that can accommodate plastics and polymer composites is critical to increase the use of these materials in automotive markets through 2030.

Current Barriers

The current automotive manufacturing infrastructure that can fully capitalize on the unique capabilities of plastics and polymer composites is limited because many automotive production and assembly processes have been optimized for historically traditional materials like steel and glass. This entrenched infrastructure—representing billions of dollars in capital investments by Tiers and automakers that will remain in place for years or decades—means automakers seeking to use plastics and polymer composites in new automotive applications should find ways to accommodate these materials in metals-oriented systems, often with sub-optimal results. The plastics and polymer composites industry should work to overcome the following barriers to manufacturing and assembly to encourage further integration of plastics and polymer composites in automotive markets.

Current infrastructure is not designed for plastics and polymer composites

Decades of capital have been invested in the current automotive manufacturing and assembly infrastructure, making it difficult for plastics and polymer composites to displace more established materials despite their potential performance benefits. Assembly plants operate at high temperatures (i.e., as high as 200°C or higher) for electrocoating, which are difficult temperatures for plastics and polymer

composites to withstand because of differences in heat resistance and coefficients of linear thermal expansion between these materials and metals. Additionally, because the infrastructure is in place for producing metal components (e.g., fenders, brake calipers, knuckles, control arms, and suspension cradles), the path from prototype to manufactured part is more established for metals than for plastics and polymer composites. Similarly, a lack of an established infrastructure for polycarbonate glazing and the inherent challenge of switching materials in a highly complex and well-established value chain make it difficult for plastic windows to displace



Plastic impellers. Courtesy of Chevron Phillips Chemical Company LP

glass windows. Because replacing the existing manufacturing and assembly infrastructure would require large new investments, the automotive industry often cannot capture the valuable systems integration potential of plastic and polymer composite components.

Long cycle times for certain polymer composites limit high-volume production

While the composition of metals is typically homogenous, polymer composites have a heterogeneous composition consisting of fibers overlaid with resins. The increased complexity of these polymer composites, particularly continuous fiber composites and composites using thermoset resins, increases their curing time and makes them more difficult to mold than metals. As a result, thermoset composites currently have long cycle times, which hinders high-volume production of polymer composite parts. To produce high-quality parts at large volumes of 100,000 parts per year or more, highly parallel parts processes may be needed, which could require additional investment.

Inadequate techniques for multi-materials joining

Though future vehicle designs will be composed of multiple materials to optimize vehicle performance, joining plastics and polymer composites to metal components remains challenging. Joining techniques such as spot welding, rivets, and fasteners designed for metals cannot be used to join plastic and polymer composite parts to each other or to metals; joining of plastic and polymer composite

walls presents a particular challenge. There is currently insufficient data available to determine how these existing joining technologies alter material properties, as well as insufficient collaboration between the plastics and polymer composites, metals, and automotive industries to optimize multi-material structural designs.

Limited capability to detect and repair damage

Damage detection and repair techniques are less established for plastics and polymer composites than they are for metals because plastics and polymer composites have different failure modes. As a result, common metal damage detection techniques, such as magnetic particle testing and eddy current testing, cannot be used with plastic and polymer composite materials. Modeling failure mechanisms and damage tolerances in plastics and polymer composites is challenging because the methods and tools to do so are still emerging. As a result, low-cost, robust, easy-to-use, and non-destructive damage detection techniques applicable to these materials are not readily available. Additionally, the infrastructure (e.g., body and paint shops) able to repair plastic and polymer composite components after a crash and ensure component performance and durability after the repair is limited.

These limitations create potential concerns that can discourage automakers from increasing the use of plastics and polymer composites for load-bearing automotive structural applications (e.g., seats, frames, steering column supports, instrument panels, cross-car beams). Damage detection and repair limitations also currently constrain design by forcing designers to debate producing systems with more parts that require additional joining versus designing systems

with fewer parts that may require wholesale replacement if damaged during an impact event.

Difficulty achieving surface quality requirements

Because the current automotive manufacturing and assembly structure is designed primarily for metals, it can be difficult for some plastics and polymer composites to achieve surface

quality requirements. Some styling options used for metals (e.g., painting) are not easy to apply to certain plastics and polymer composites because of their performance properties, including their high coefficient of thermal expansion. Dramatic styling changes (e.g., packaging changes because of lower material rigidity) might be needed to fully take advantage of plastic and polymer composite properties and enable these materials to achieve a Class A surface finish.

Key Initiatives

As the plastics and polymer composites industry further demonstrates the potential benefits of plastics and polymer composites in vehicle designs, they should also work with the automotive industry to improve the manufacturing and assembly processes that will enable their widespread use. Novel processes are needed that reduce manufacturing cycle times, increase cost effectiveness, and improve process automation while yielding high-quality and reliable products. Improved processing techniques and increased manufacturing efficiency will decrease the amount of time required for a vehicle to enter the market and enable plastics and polymer composites to be used in higher-volume vehicle models. The following key initiatives, which are divided into near-term (2014–2016), mid-term (2017–2025), and long-term (2026–2030+) actions, are needed.

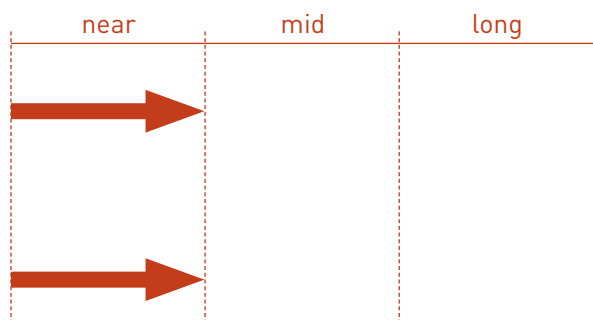
Advance high-speed plastics and polymer composites processing

To enable greater use of plastic and polymer composite materials in vehicles manufactured at high volumes, it is critical for the plastics and polymer composites industry to reduce manufacturing cycle times. Without this advancement, the use of polymer composites, particularly thermoset-based composites, in new applications will be limited to niche vehicles. The plastics and polymer composites industry should work with the automotive industry to develop manufacturing processes in the short term that enable the integration of plastic and polymer composite parts through the existing manufacturing infrastructure. In the long term, the industries should develop processes that maximize the benefits of integrating plastics and polymer composites into vehicle designs and enable high-volume vehicle production.

Critical Actions (Priority actions in bold)

Establish a manufacturing center or consortium to advance high-speed polymer composites processing (see Appendix A, Priority Action 6)

Create plastics or polymer composites designed specifically for existing automotive manufacturing processes and equipment (e.g., stamping)



Critical Actions (Priority actions in bold)

Conduct new manufacturing development work to produce chassis/powertrain parts at the demonstration level, starting with the design of a manufacturing process that is already in place

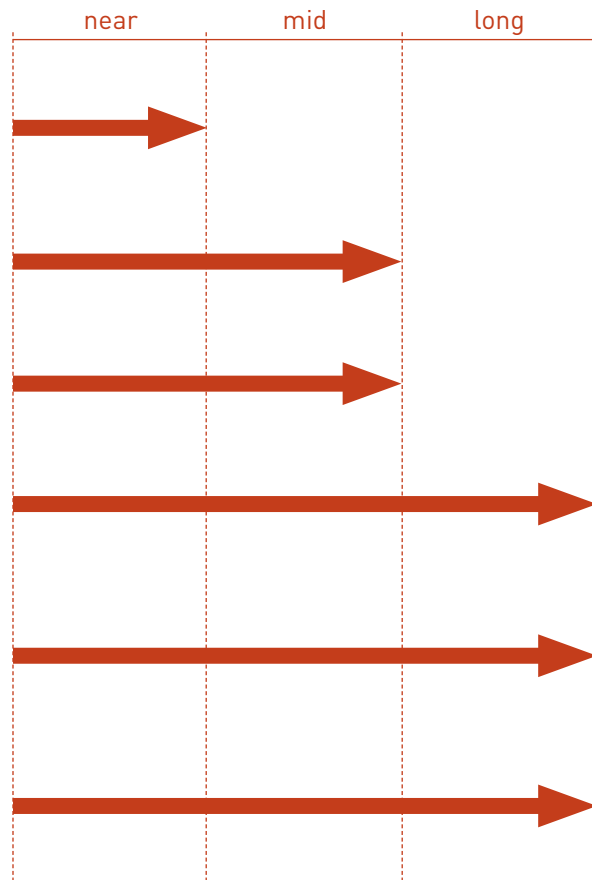
Pursue innovative methods to optimize the orientation of filler during polymer composite processing

Pursue higher-speed manufacturing approaches to increase processing speed and decrease the cost of production in traditional assembly plants

Use additive manufacturing technologies to develop prototypes that are representative of production parts and evaluate these technologies for full-scale production

Incorporate digital/additive manufacturing approaches to reach volumes adequate for the automotive industry

Work with automotive OEMs to lower steel hardening and coating temperatures, thereby lowering electrocoating temperatures and enabling plastics and polymer composites to undergo e-coat processes



Identify solutions to multi-materials joining

Future vehicles will most likely use multi-materials designs that use the right material in the right way for the optimal result. Providing automotive designers with this flexibility requires cost-effective techniques to join dissimilar materials to enable improved vehicle assembly while also addressing end-of-life disassembly and recycling requirements. Identifying best practices and demonstrating such joining techniques will enable the production of lighter, stronger, more reliable vehicles that are more easily recycled and recovered at the end of their useful lives.

Critical Actions (Priority actions in bold)

Develop technically and economically viable techniques to join plastics and polymer composites to similar or dissimilar materials and study service, repair, and disassembly (see Appendix A, Action 7)

Work with fastening companies to develop fasteners that can join metal parts to plastic and polymer composite parts

Translate R&D and proprietary work on adhesives from the metals industry to assess their applicability in vehicles to multi-materials joining

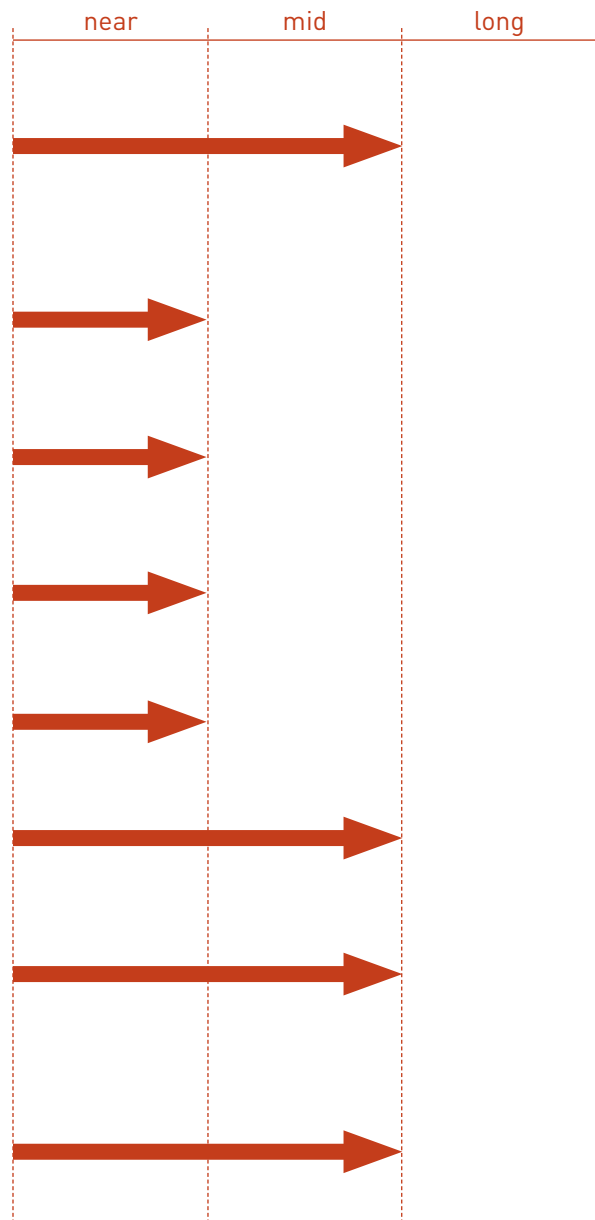
Develop case studies on the use of adhesives with plastics and polymer composites in the automotive and other industries

Conduct demonstration projects for off-site body manufacturing and multi-material bodies

Compile and document best practices for multi-materials joining in the automotive and other industries

Standardize testing for plastic and polymer composite materials and joints, working with appropriate Federal agencies

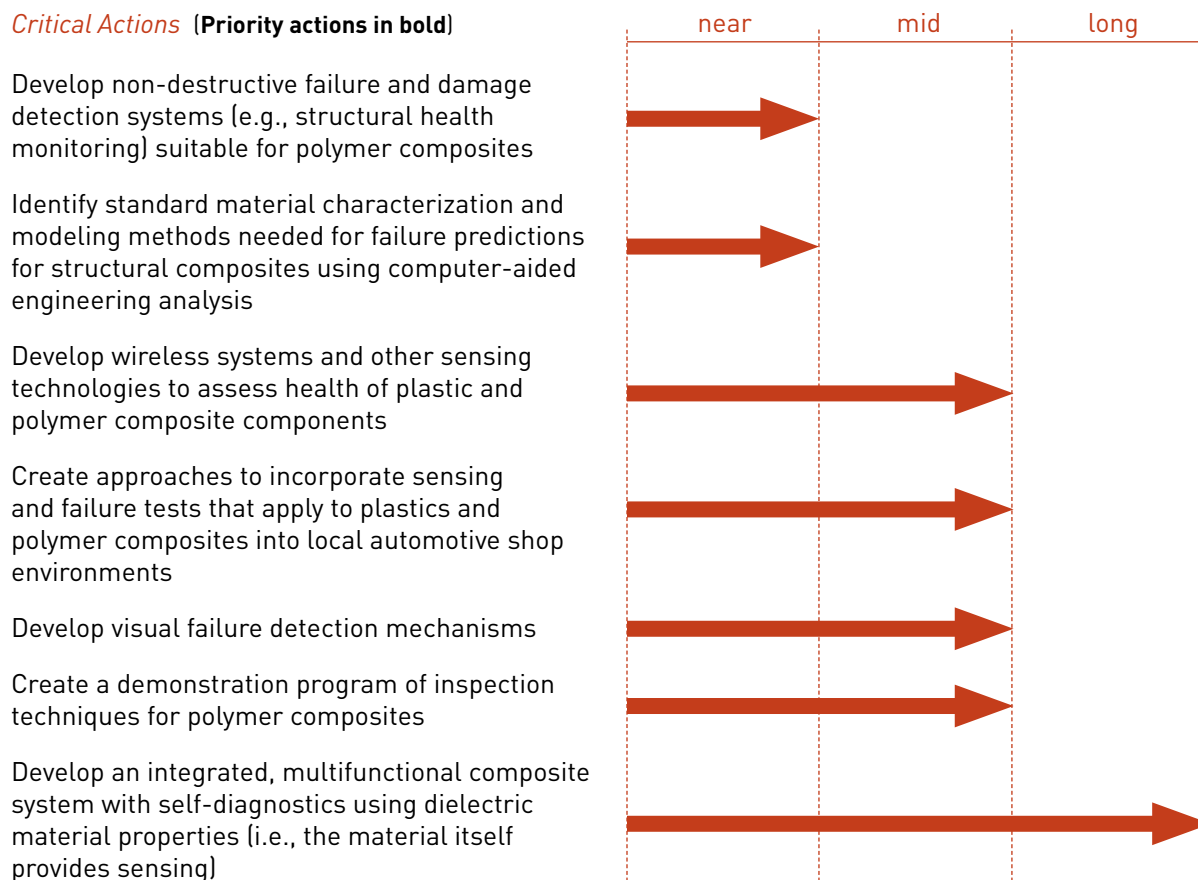
Conduct a demonstration project for metal-to-polymer composite joining to produce a lifecycle cost assessment that includes joint design, manufacturing and assembly processes, vehicle usage, and end-of-life recycling



Develop methods and tools for damage detection and repair

To maximize vehicle safety, the plastics and polymer composites industry needs techniques that can quickly, easily, and cost effectively detect whether the structural integrity of the vehicle has been compromised following impact. They should also strengthen and grow the repair infrastructure so any damage that occurs to plastic and polymer composite parts can be quickly and reliably repaired. Advanced damage detection and repair is critical to improve the automotive industry's confidence in the capabilities of plastic and polymer composite materials during and after a crash sequence.

Critical Actions (Priority actions in bold)






Processing Baydur STR with long fibers.
Courtesy of Bayer

Continued Materials Development

Carbon fiber laminate plate. *Courtesy of BASF*



Sustaining advances in plastics and polymer composites will expand and accelerate the benefits these materials deliver to automakers.

By manipulating the composition of materials and the processing techniques with which the materials are created and formed into parts, scientists can alter the strength, ductility, durability, density, and other material properties until they achieve a set of properties that offers promising advantages for targeted automotive application.

While opportunities for industry collaboration on new materials development do exist, much of the research and development work in this area is considered proprietary and is conducted by individual companies looking to develop the next game-changing material. Plastics and polymer composites are built up from fundamental chemical building blocks, providing material providers great flexibility to experiment with and create customized materials that offer unique properties. This ability to create customized, proprietary material formulations

and processing approaches means automakers can get precisely the material they need for the target application. It also creates challenges for automotive engineers and designers who must understand and accurately predict material performance for many variants of plastic and polymer composite materials.

The breadth and scope of both materials options and applications for plastics and polymer composites is large and can be complex. This complexity increases dramatically for polymer composites, which rely on reinforcements that create far more variables, such as reinforcement type, geometry, alignment, and volume fraction. Despite the challenges, the benefits that plastics and polymer composites promise to deliver to automakers and the car-buying public are significant enough that sustained innovation to create future generations of materials is a key component of this roadmap to 2030 and beyond.

Current Barriers

One of the biggest barriers to advancing plastics and polymer composites is for material developers to gain a complete understanding of the material properties desired by OEMs for specific automotive applications. Different OEMs, and even different automotive engineers at the same OEM, want different material properties—usually combinations of temperature, strength, stability, ductility, and other requirements that are challenging to achieve at an acceptable cost. The plastics and polymer composites industry should work to overcome the following barriers to materials development to encourage further integration of these materials in automotive markets.

Difficulty withstanding challenging operational conditions in certain automotive applications

As automotive designs continue to evolve in response to drivers for efficiency, value, and style, operating conditions are often pushed to more challenging regimes in certain applications. While today's plastics and polymer composites offer exceptional performance that can withstand the rigors of many demanding applications, some operating conditions, such as high temperatures, corrosive chemicals in fluids and lubricants, electric currents, weather variations, or minerals from roadways, are too harsh for some plastics and polymer composites to withstand over a vehicle's life. These conditions can have long-term effects on the durability, performance, and aesthetics of the materials in automotive components. Similarly, during the production of automotive components, systems, and vehicles, existing automotive tooling capabilities may struggle to adjust for shrinkage, flow, and other

subtle material changes that certain plastics and polymer composites may experience. This challenge is managed successfully for current automotive components made from plastics and polymer composites and should be kept in mind as the plastics and polymer composites industry develops new materials.

Difficulty balancing materials performance, aesthetics, and cost

The automotive industry is constantly seeking to improve aesthetics and reduce the weight of vehicles while simultaneously increasing their strength and improving crash performance. However, balancing the feel and appearance of a material with its strength, stiffness, ability to withstand dimensional tolerances, and cost is a critical challenge. Most plastic and polymer composite materials, particularly injection-molded materials, do not have the modulus capability required for structural applications, such as interior cross-car beams and engine



In-mold coloring.

cradles. With an increased emphasis on thinner materials to improve aesthetics and continuously reduce vehicle weight, plastics and polymer composites are faced with processing, flow, and stiffness challenges that they must meet cost-effectively.

Limited polymer composite materials supply base

The current North American materials supply base for polymer composites may not be large enough to accommodate high-volume

production, particularly when the use of polymer composites is increasing in other industries that may offer more attractive investment opportunities because of the cost and liability issues that come with automobiles. Today's current polymer composites supply chain not only features a limited number of material producers, but also a small molding supply base and a limited number of North American Tiers which can make Class A exterior composite parts. Major investments will be needed to strengthen the supply chain for polymer composite materials if they are to achieve widespread, mass-market use in vehicles.

Key Initiatives

To improve materials performance in automotive applications, material developers need to work closely with Tiers and OEMs to better understand their needs and then engineer materials with the desired properties for current and future automotive applications. The following key initiatives, which are divided into near-term (2014–2016), mid-term (2017–2025), and long-term (2026–2030+) actions, are needed.

Develop materials with improved properties and performance

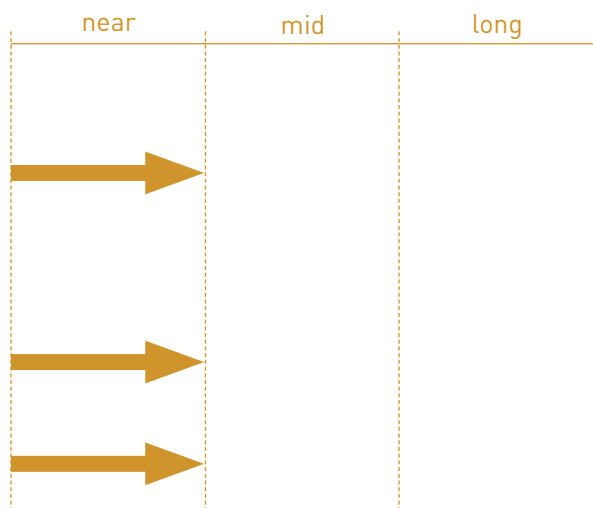
Innovative materials development is needed to create cost-effective materials that can better withstand the challenging operational conditions of vehicles and the processes used to produce the materials and components at high speeds and volumes. Advancing the material properties (e.g., stiffness, strength, fatigue, environmental resistance, creep, energy management, temperature capability) of plastics and polymer composites while maintaining cost effectiveness can help them to deliver superior value to automakers. Polymer composites in particular offer much promise for improvements in not only the base and reinforcement materials themselves, but also in the processing techniques used to produce them.

Critical Actions (Priority actions in bold)

Support development of engineered plastics and polymer composites with improved properties (e.g., stiffness, strength, fatigue, environmental resistance, creep, energy management, temperature capability), and develop performance standards to characterize the properties for designers (see Appendix A, Priority Action 8)

Work with OEMs to identify the most desired material properties for automotive applications

Continue working with national laboratories to develop low-cost carbon fibers and higher-speed processing technologies



Critical Actions (Priority actions in bold)

Conduct benchmark studies of polymer composites used in body-in-white construction with emphasis on applications with demanding operating conditions (e.g., exhaust collectors, mufflers)

Gather existing information and begin development efforts for using short-fiber glass as a model

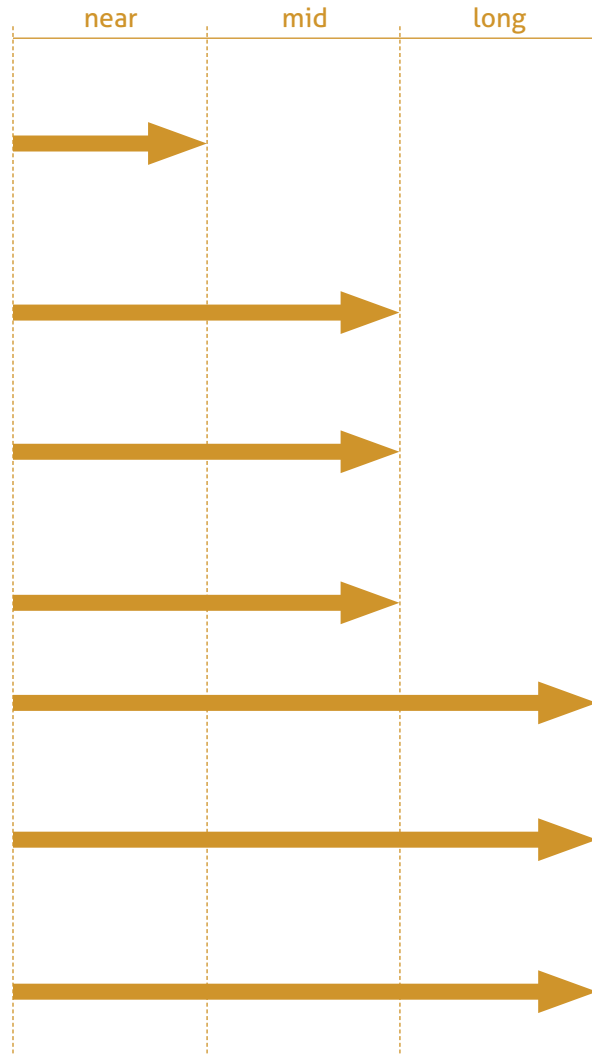
Increase collaboration among OEMs, suppliers, and universities to develop materials models and standards that accurately estimate performance and system cost and provide guidelines for conversion from metal parts

Develop innovative materials and processes to maximize polymer and filler compatibility

Partner with academia to conduct fundamental research on advancing material properties at the molecular level

Develop advanced plastic and polymer composite systems with higher modulus for applications that would benefit from this type of enhanced performance

Develop recycling and innovative recovery solutions for existing polymer composite materials and/or new polymer composite materials that can be reprocessed



Polymer composite wheels.
Courtesy of BASF



Supporting Initiatives

Lightweight seating foam. *Courtesy of BASF*

Cost and environmental modeling, supply chain integration, and continued workforce development can support the use of current and future plastics and polymer composites in automobiles.

Material development and selection, design, manufacturing, and vehicle assembly are all important aspects of creating and using new materials in vehicles. To be most effective, they should be pursued in an integrated way, as described in earlier sections of this report. However, materials and processing innovation

alone are unlikely to lead to widespread and timely adoption of new plastic and polymer-composite-based components and systems. Also needed are supporting initiatives to develop the methodologies, tools, and workforce necessary for automakers to fully capitalize on the capabilities of plastics and polymer composites.

Current Barriers

Technological progress alone will not encourage automakers to fully exploit plastic and polymer composite materials to their maximum potential. Inadequate education and training to develop an automotive workforce knowledgeable about plastics and polymer composites, insufficient data necessary to encourage OEMs to adopt plastics and polymer composites, and concerns regarding consumer perception of plastics and polymer composites could all constrain growth in the use of these materials.

Inadequate lifecycle analysis data and recycling options

The plastics and polymer composites industry currently lacks the data needed to accurately assess the cradle-to-grave energy use and CO₂ emissions of these materials using established lifecycle analysis tools and to allow OEMs to compare to that of metals. Also, automotive plastics and polymer composites recycling is at an earlier stage in development, with varying levels of recyclability of different types of plastics and polymer composites.

Insufficient plastics and polymer composites education in engineering programs

Most engineers are trained to work with metals and receive little, if any, education regarding plastics and polymer composites in high schools, colleges, graduate schools, and in continuing education programs. As a result, today's engineering workforce largely lacks the knowledge to confidently make automotive design changes that integrate plastics and

polymer composites and maximize their performance capabilities. Additionally, in contrast to engineers in automotive industries in Europe and other world regions, engineers in the North American automotive industry do not typically have an automotive system specialization (e.g., doors). As a result, lessons learned by attempting to incorporate alternative materials into an automotive system are not continuously built upon to optimize future designs.

Consumer perception of plastics and polymer composites as inferior materials

Some consumers do not perceive plastics and polymer composites as a premium material and have misperceptions about the health, safety,

and environmental impact of automotive plastics and polymer composites. These consumers may be wary of plastic and polymer composites used in structural applications and are concerned about the ability for these materials to serve the same functions as metals. Conversely, some plastics and polymer composites, such as carbon-fiber-reinforced composites, are viewed by some consumers as high-tech, high-value materials, and are given high visibility by automakers. Consumers are also accustomed to the look, feel, and response of metals in many automotive applications, so the varying look, feel, and even sound of plastics and polymer composites may make some consumers hesitant to purchase vehicles featuring these materials. OEMs, in turn, may not be willing to take the risk of investing in plastic and polymer composite technologies for fear of this consumer reaction.

Key Initiatives

A workforce with sufficient plastics and polymer composites education, regulations appropriate for plastics and polymer composites, and improved consumer perception will support the faster transition of these materials into automotive applications where they can deliver superior value. The following key initiatives, which are divided into near-term (2014–2016), mid-term (2017–2025), and long-term (2026–2030+) actions, are needed.

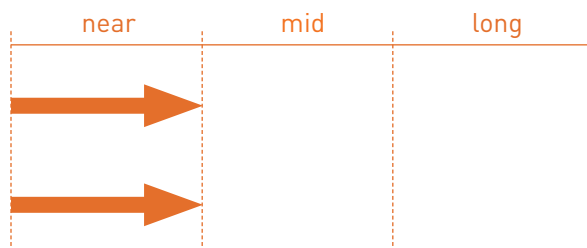
Produce a thorough lifecycle assessment on the environmental impact of plastics and polymer composites

The plastics and polymer composites industry should work with automotive partners to develop thorough lifecycle assessments (LCA) that demonstrate the cradle-to-grave energy use and environmental impact of plastics and polymer composites throughout the entire value chain and vehicle life cycle, from materials manufacturing and processing to end-of-life disposition, including recycling and recovery. They should also continue to improve end-of-life vehicle recovery and recycling of plastic and polymer composite parts, with the ultimate goal of full recoverability and recycling back to original or other high-end uses.

Critical Actions (Priority actions in bold)

Collaborate on recycling strategies to create a unified voice and strategy for implementation

Prepare bottom-up analysis of sustainability benefits for plastics and polymer composites in automobiles

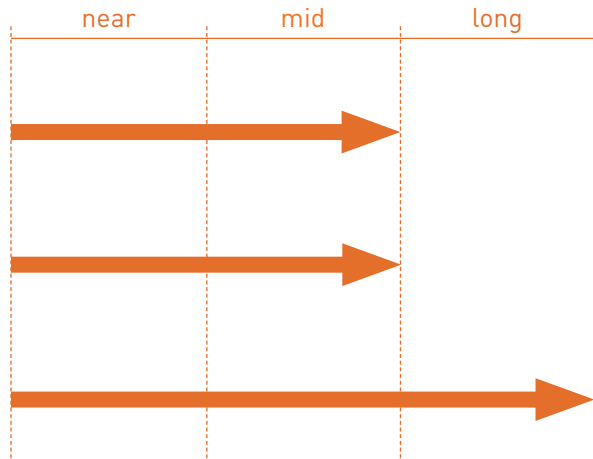


Critical Actions (*Priority actions in bold)

Determine if the lack of accepted LCAs that properly treat plastics and polymer composites is a true barrier or just a perceived barrier by soliciting feedback from OEMs on existing LCAs

Develop a production-scale recycling facility for polymer composites funded by a government-industry-academia partnership

Leverage plastics-to-energy LCA work being done in Europe (including standards and trials) to help improve and promote the LCA of plastics and polymer composites in North America



Improve plastics and polymer composites education and training to build a more highly skilled workforce

The plastics and polymer composites industry should work with educators, particularly in university and continuing education programs, to increase the ability, willingness, and confidence with which automotive engineers make automotive design changes that integrate plastics and polymer composites. Courses in polymer science and related engineering disciplines specific to automotive applications, coupled with industry partnerships with colleges and universities, will increase interest and bolster the automotive industry through the addition of skilled workers and researchers who can deliver value and innovation. Training courses that deliver similar information to the existing engineering workforce can greatly accelerate the workforce transition and are needed to complement the education of new engineers.

Critical Actions (Priority actions in bold)

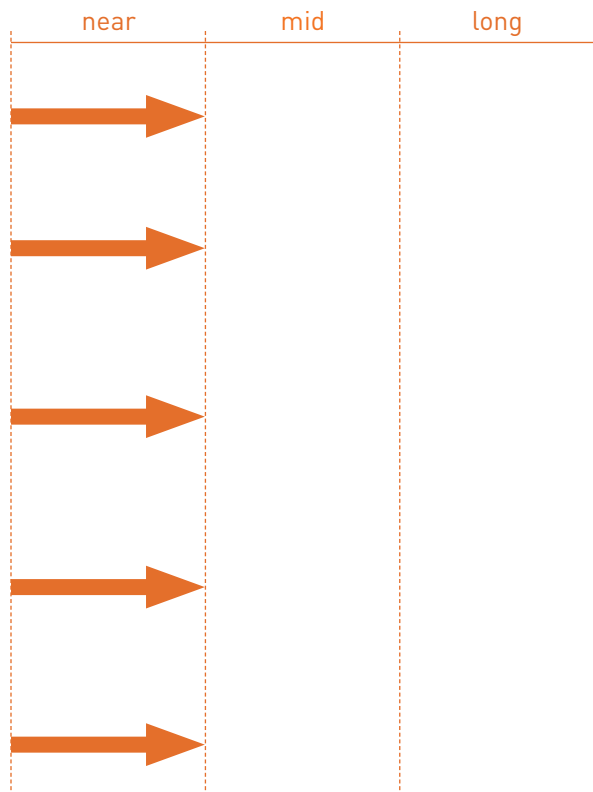
Advocate for plastics and polymer composites training classes and degree programs at all major universities (see Appendix A, Priority Action 9)

Enhance the workforce knowledge base by promoting and increasing the visibility of new designs that use plastics and polymer composites, with a particular emphasis on younger students

Develop plastics and polymer composites training seminars for automotive engineers in the existing workforce, leveraging existing programs within companies to showcase design opportunities for plastics and polymer composites

Create a module for classroom instruction for tomorrow's engineers (e.g., ACC Center for Automotive Engineering Design focused on plastics and polymer composites)

Develop a grassroots education effort to change the automotive industry's metal/steel mindset toward being open to all material options, including plastics and polymer composites



Critical Actions (Priority actions in bold)

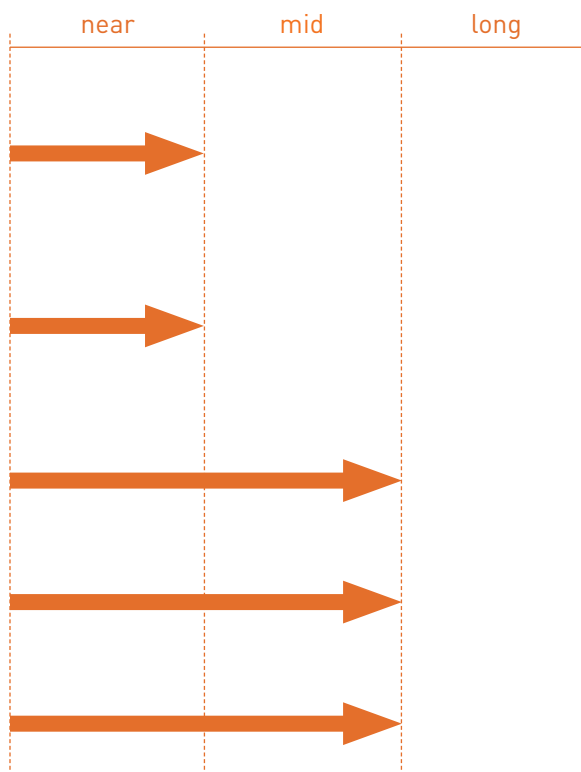
Sponsor a mobile demonstration and training capability, similar to SAE International's "Wheels of Motion" program, for industry experts to teach classes on essential topics at OEMs, Tiers, and universities

Strengthen plastics and polymer composites education by improving collaboration among OEMs, material developers, supply chain partners, and academics

Offer training from community college to the university level in plastics and polymer composites engineering

Advocate for educational programs to focus on design/functionality engineering rather than only process engineering

Create an X prize-style competition or student design competition for a demanding plastic or polymer composite application (e.g., a knuckle)



Educate consumers on the benefits of plastics and polymer composites

Many vehicle features, such as air bags, video devices, radios, and global positioning systems, could not exist without the use of plastics and polymer composites. Even the sleek, aerodynamic shape of most modern vehicles is dependent on plastics and polymer composites. Communicating the value plastics and polymer composites bring to vehicles through improvements in safety, fuel economy, performance, and comfort can help to correct consumer misconceptions of these materials as inferior and drive consumer acceptance.

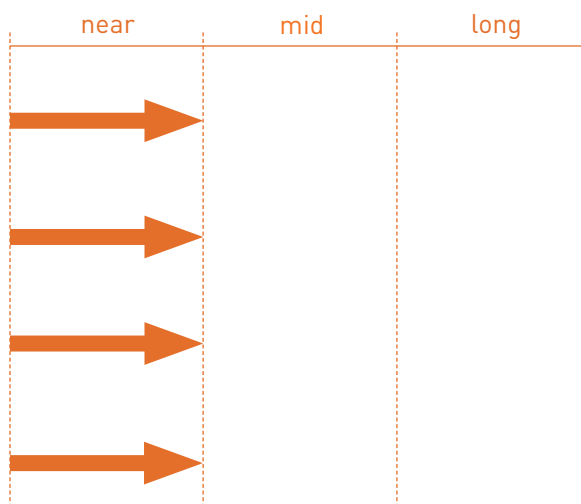
Critical Actions (Priority actions in bold)

Increase consumer education to build public perception of plastics and polymer composites as lightweight, strong and stylish materials

Develop branding and specific definitions for high-performance polymer composites (e.g., chopped or woven, thermoset or thermoplastics)

Leverage the positive view the public has of carbon-fiber-reinforced composites (e.g., in racecars)

Leverage the positive view the government has of carbon-fiber-reinforced composites

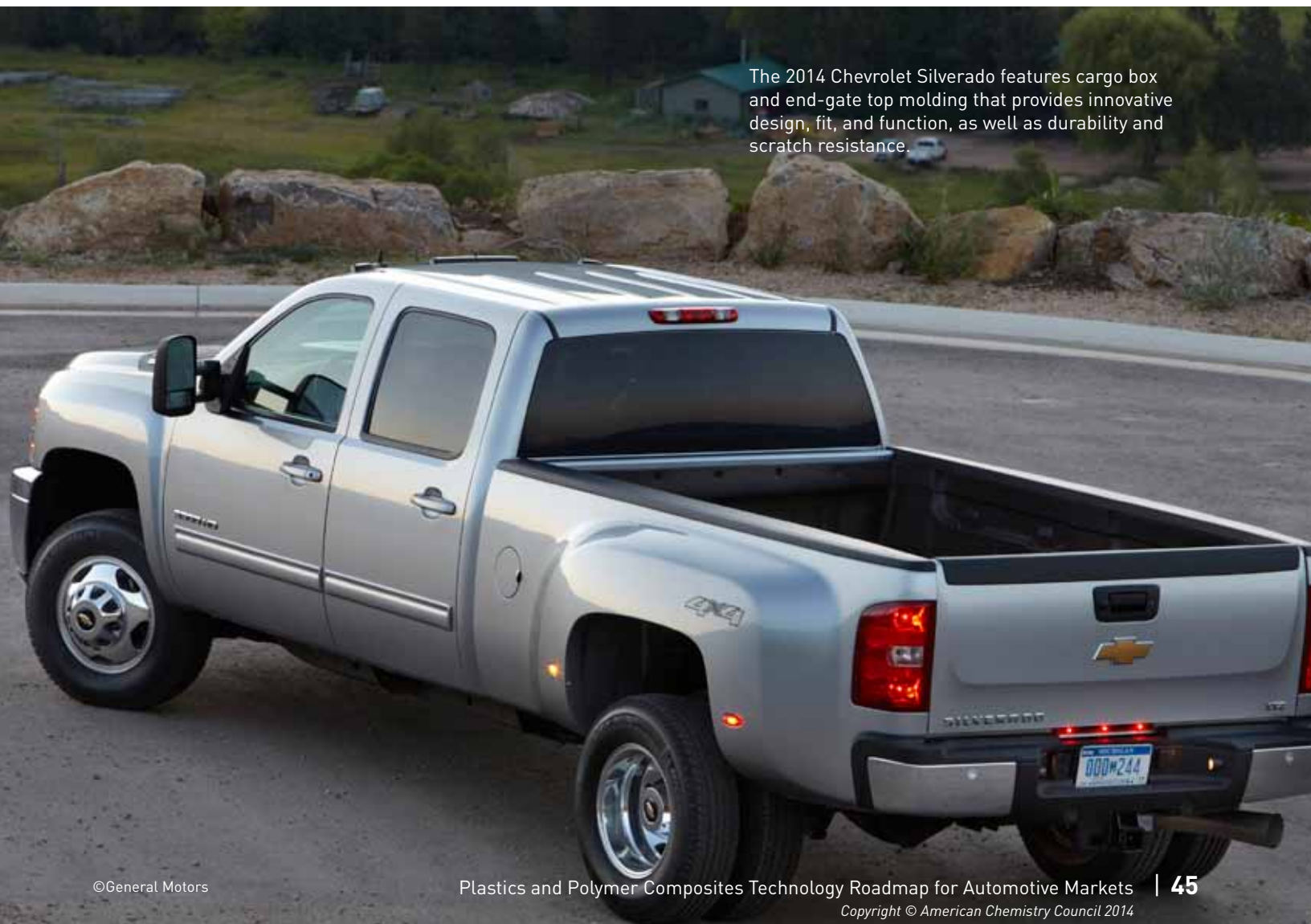


The 2014 Chevrolet Corvette Stingray features innovative door-trim technology that eliminates the need for adhesive and secondary process steps to help reduce direct costs by 7% and weight by 5%.



©General Motors

The 2014 Chevrolet Silverado features cargo box and end-gate top molding that provides innovative design, fit, and function, as well as durability and scratch resistance.



©General Motors

The Path Forward



The Hyundai QarmaQ interior features SABIC polycarbonate and polycarbonate film material.

The future competitiveness and prosperity of the North American automotive industry depends on its ability to pursue market position by effectively leveraging the full potential of plastics and polymer composites.

This roadmap provides important insight and guidance for the automotive industry as a whole. At the same time, it also sounds an important call to action for the plastics and polymer composites industry that is nested within the supply chain of the greater automotive industry. Given the critical role of plastics and polymer composites in the vehicles of today and tomorrow, it is important for the automotive and plastics and polymer composites industries to work together to accelerate progress by leading efforts to develop innovative materials and processing approaches, create shared databases and tools that allow designers to select and fully leverage these materials, and create the assembly techniques that automakers need to produce tomorrow's multi-materials vehicles. By showcasing these advances in real-world demonstrations, the plastics and polymer composites industry can convince automakers that adopting plastics and polymer composites is viable and can deliver real value.

Appendix A contains brief action plans for the most critical initiatives identified in this roadmap. They are intended as starting points for catalyzing industry-level action to implement this roadmap.

Each action plan provides a detailed description of the initiative; its associated tasks; the benefits that its implementation may achieve; and the roles of ACC, industry, government, and academia in executing the plan. While not a complete action plan, these outlines are

intended to provide a quick-start guide for an implementation initiative focused on the identified action item.

The presentation of these action plans entails three assumptions:

1. The oversight, coordination, and leadership for implementation efforts may come initially from ACC. However, the implementation of an industry roadmap is necessarily a cooperative process because the issues discussed are beyond the scope and resources of any single organization or agency. Implementation initiatives need to leverage the resources and capabilities of OEMs, Tiers, materials developers, universities, national laboratories, government, and other stakeholders.
2. Given limited resources, only a subset of these action items is likely to be implemented at any one time. It is not likely to be possible to maintain a focused, energized, and adequately funded implementation effort across all of these areas at once. These actions are all presented to help engage increased stakeholder interest and support.
3. This is a North American authored and focused effort, but it has global implications. It is assumed that member companies will use their global presence to implement the roadmap priorities.

Appendices

Brake pedal prototype with
Tepex® composite sheet.
Courtesy of LANXESS



Appendix A. Action Plans

Priority
Action

1

Technology Development Center

Establish an independent, pre-competitive technology development center where OEMs and suppliers can conduct laboratory work and test concepts at small volumes while collecting standardized data

Key Tasks

- Identify processes that would most benefit from this approach
- Identify/acquire membership
- Establish business model
- Determine funding method

Roles

- **Industry:** Material/part suppliers jointly describe need for concept and lead effort
- **ACC:** Leads solicitation of other industry associations and university/knowledge centers toward goals
- **Other Stakeholders:** Government provides funding; academia sets education and technology development goals

Immediate Next Steps

- ACC to take lead on soliciting other industry associations toward this goal
- ACC to solicit input from universities and knowledge centers

Key Milestones

- Develop business model
- Acquire funding
- Obtain location and equipment

Outcomes/Benefits

- Demonstration of complete solutions in support of industry
- Confidential technology development for individual companies
- Collaboration on research toward shared industry goals

Specialized Resources

- Review existing models (e.g., Fraunhofer, Canadian National Research Council, National Composite Center, RWTH Aachen)

Priority
Action
2

Generic Cost Models

Develop generic cost models to demonstrate the cost and benefit of plastics and polymer composites compared to alternative materials as examples to provide mass reduction possibilities

Key Tasks

- Identify how metals industries provide cost-benefit estimates via case studies
- Identify how other organizations and regions (e.g., Europe) develop cost models
- Use National Highway Traffic Safety Administration Silverado economic cost model to validate results
- Understand Corporate Average Fuel Economy (CAFE) standards for vehicle segments and targets to identify final targets
- Select target segment (e.g., interior, exterior, powertrain, body-in-white) to evaluate cost model, comparing plastics and polymer composites to current alternative material for a particular application (e.g., glazing)
- Conduct sensitivity analysis and validate the models' accuracy for providing cost-benefit estimates

Roles

- **Industry:** Validate cost models and provide key inputs, drive gap identification to fix potential supply chain issues
- **ACC:** Coordinate activity, publish results, collect cost models used today
- **Government agencies:** Compile existing economic data (e.g., U.S. Environmental Protection Agency); help understand the boundaries specific to CAFE standards

Immediate Next Steps

- Publish cost value for weight reduction in United States
- Validate model
- Make model available to industry

Key Milestones

- Identify how metal industries provide cost-benefit via case studies
- Identify how other organizations in Europe do cost models
- Understand CAFE standards for vehicle segments and targets to identify final application targets

Outcomes/Benefits

- Understand how the world has developed its cost model for metal and if credits are involved
- Understand how the United States values plastics and polymer composites
- Understand how the rest of the world values plastics and polymer composites used in automobiles

Specialized Resources

- Identify expertise for regional information (e.g., Europe, China)
- Hire company to develop the model



Material Properties Database

Define a standard package of material properties desired for automotive applications, and then test the data through simulation for a specific automotive system (e.g., engine mounts, instrument panel, cross-car beams)

Key Tasks

- Identify data needed for accurate modeling
- Ensure database definition is developed and agreed upon by end users in industry, government, and academia
- Organize data/materials by fiber type and length
- Drive toward standardized test methods (e.g., fatigue, strain rates, etc.)
- Determine whether the database is informal/formal (e.g., Digimat)
- Collect materials model and solver-independent data
- Evaluate the applicability of existing materials models to spur university research into the establishment of new models
- Identify how to handle the data (e.g., encryption, management)
- Determine who should own the database
- Develop/populate the database with raw data; material suppliers will determine what information is proprietary
- Populate first with lower-cost data and then move forward into more complex, cost-intensive data

Roles

- **ACC:** Advocate to OEMs to encourage data sharing; engage member companies to develop the data
- **Industry:** Lead collaborative effort; provide their data needs; prioritize the materials to be included in the database
- **National laboratories/universities:** Conduct research into the applicability of existing models and the development of new models
- **Tier suppliers:** Participate in the demonstration and correlation study efforts

Immediate Next Steps

- Query OEMs and Tiers for standards (e.g., what models they are using, what data they have)
- Decide what should be included in the database
- Determine where the database will be housed

Key Milestones

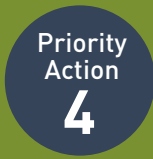
- A set of standardized data organized by fiber length class
- A populated database

Outcomes/Benefits

- An available database of usable information organized by fiber length class that can be used for part simulation
- Correlation studies that show the validity of the simulation model
- A designed part that can be used for demonstration

Specialized Resources

- New models
- New tools
- Molding capabilities



Design Guidelines

Establish design guidelines (e.g., for wall thickness, radii) and tools for typical plastic and polymer composite structures that are intended to be used by design engineers

Key Tasks

- Collect and assess available knowledge base and technology readiness level of design methodologies and tools
- Prioritize high-impact elements of methodologies and analysis tools that will need to be developed for short term
- Develop basic fundamental part design
- Develop basic computer-aided engineering (CAE) method integrating full part design
- Develop characterization methods for harmonizing tests and CAE tools
- Propose standardized test for testing procedures that are currently unavailable
- Create a materials database
- Fund example projects to support design development and prove out process
- Capture inputs from damage and testing and repair

Roles

- **ACC:** Facilitate open communication and joint cooperation; provide umbrella initiatives
- **Industry:** Active participation and supply: needs, abilities, tools, best practices
- **Other Stakeholders:** Study variation tolerance, fund activities, align regulations with standards

Immediate Next Steps

- Initiate collection and assessment task

Key Milestones

- Publish design guidelines and testing standards
- Validate methodology for simple structures
- Apply process methodology to full body-in-white

Outcomes/Benefits

- Improved agreement of tests and analytical processes
- More confidence in the use of polymer composites for structural applications
- Faster and less costly development cycle

Specialized Resources

- CAE tool development
- Input from testing organizations

Priority
Action
5

Material and Component Models

Develop models that can simulate the behavior of plastic and polymer composite materials and components during and after impact events

Key Tasks

- Establish a task force with representatives from plastics and polymer composites organizations that can co-fund the effort
- Identify existing models used by the automotive industry for plastics and polymer composites
- Identify existing models used by the aerospace industry for polymer composites
- Identify 2–4 OEM priority material systems (polymer + filler) that need models
- Identify potential co-funding opportunities with government organizations, OEMs, and Tiers
- Issue joint RFPs to research organizations and universities for each OEM priority
- Disseminate information about models to promote implementation

Roles

- **ACC:** Spearhead development of task force; use composite modeling expertise to contribute to and influence the process
- **Plastics and Polymer Composites Industry:** Contribute to task force via industry organizations, in-kind support, co-funding
- **Automotive Industry:** Provide technical expertise, modeling requirements, and co-funding
- **Universities/Research Organizations:** Develop models and/or test data
- **Government:** Provide co-funding

Immediate Next Steps

- Use polymer composites model that is currently being developed for carbon-fiber nylon as an example
- Begin establishing task force based on feedback

Key Milestones

- Establish task force with representatives from plastic and polymer composite organizations to co-fund and drive the effort
- Identify 2–4 OEM priority material systems (polymer + filler) that need models
- Obtain co-funding (government, OEMs, Tiers) and issue RFPs to develop models for each system
- Obtain test data and generate models (universities/researchers)
- Actively disseminate models to OEMs, academia, and researchers

Outcomes/Benefits

- Models become a standard used throughout academia, research, and industry
- Facilitate use of plastics and polymer components in design

Specialized Resources

- Highly rated test facilities

High-Speed Manufacturing Center

Develop a manufacturing center or consortium to advance high-speed polymer composites processing

Key Tasks

- Develop a charter
- Identify and recruit stakeholders, including machine developers, Tiers, OEMs, and material suppliers
- Prepare proposal and secure funding
- Identify and develop processes needed to make high-performance thermoplastic composite engineering components
- Integrate technology scouting into process
- Select demonstration parts and specimens for development; initiate demonstration projects
- Design parts for high-volume manufacturing; should ultimately know costs of each process step for the demonstration (integration)
- Develop marketing technology center that publishes and communicates data

Roles

- **ACC:** Convene consortium and provide pre-competitive environment; help to secure government funding
- **Materials company:** Develop competitive environment projects within consortium
- **OEMs:** Define application requirements
- **Tiers:** Manufacture parts, provide process capability
- **Equipment manufacturers:** Develop optimized equipment

Immediate Next Steps

- Prepare charter
- Establish advisory committee
- Identify current initiatives
- Create business case for funding

Key Milestones

- Establish committed stakeholders
- Secure funding
- Identify specific design requirements and application
- Develop concepts and downselect to demonstration part
- Design and develop material processes for application
- Invest in tooling and facilities and computer-aided engineering needed to conduct demonstration

Outcomes/Benefits

- Integrate supply chain improvement
- Drive innovation for plastic and polymer composite materials and processing
- Demonstrate to OEMs what is possible with plastics and polymer composites and high-speed processing
- High-volume capable processes

Specialized Resources

- Expertise in developing funding proposals
- High-speed testing facilities

Priority
Action
7

Joining Techniques

Develop technically and economically viable techniques to join plastics and polymer composites to similar or dissimilar materials and study service, repair, and disassembly

Key Tasks

- Create a consortium of adhesive, materials, and Tier suppliers and automotive OEMs
- Key elements to address include:
 - Loading and alignment
 - Joining equipment
 - Address noise, vibration, and harshness galvanic corrosion
 - Transmission/management of heat/exotherm
- Summarize the state of the problem and what currently exists in the industry; as part of this process, catalogue the OEMs' existing standards for joints
- Focus on repeatable, fast, simple, and robust processes
- Identify best combinations of mechanical and chemical joining
- Determine where/when to use adhesives (e.g., access difficulty)
- Conduct research in assembly techniques able to withstand continuous 150°C exposure
 - Design compression limiters at temperatures that achieve dimension tolerance and do not add significant mass or cost
 - Reduce the complexity, weight, and cost of joining solutions
 - Develop adhesives modeling capabilities (e.g., modeling bonded vibration joints)

Roles

- **ACC:** Convene consortium; seek funding; draft executive summary of benefits; consult with other trade associations (e.g., Adhesives and Sealants Council)
- **Industry:** Define target opportunities; define objectives and performance requirements; share existing data related to materials joining of plastics and polymer composites to other plastics and polymer composites and to metals; contribute funding
- **Other Stakeholders:** Universities to conduct research in kind

Immediate Next Steps

- Define scope
- Define necessary participants
- Determine funding requirements and mechanism

Key Milestones

- Establish a consortium
- Establish best practices
- Identify structural parts that are best for demonstrating key joining technology

Outcomes/Benefits

- Standards and process selection
- Validated testing of joined systems
- Proven materials systems of choice for use in multiple joining combination applications
- Cost-effective joining methods
- Commonality of joining technology

Specialized Resources

- Knowledge of specific regulatory information related to performance of automotive assemblies (e.g., joints)
- Fastener and adhesives experts
- OEM experience (critical)
- Testing of part and vehicle

Priority
Action

8

Engineered Materials with Improved Properties

Support development of engineered plastics and polymer composites with improved properties (e.g., stiffness, strength, fatigue, environmental resistance, creep, energy management, temperature capability), and develop performance standards to characterize the properties for designers

Key Tasks

- Develop demonstration programs to establish key property requirements, including variation tolerance as defined by a team of OEM and supply chain representatives
- Define requirements used to set key property roadmap (near-, mid-, long-term)
- Fund both private and public projects to develop materials and processes to deliver the required properties
- Develop standardized methods to quantify product by process variability
- Implement industry standards based on performance

Roles

- **ACC:** Facilitate formation of working group
- **Industry:** Define agenda and roadmaps, own the working group, establish working group relationship through supply chain, advocacy
- **Academia:** Discover next-generation materials and processes, testing methods, and statistical models
- **Government:** Facilitate standard homologation globally, fund the R&D, align regulations with standards, integrate with Integrated Computational Materials Engineering efforts, and expand plastic and polymer composite effort

Immediate Next Steps

- Establish integrated supply chain working group (material suppliers to OEMs, accredited testing organizations, and standards organizations)
- Complete initial property goal setting and gap assessment

Key Milestones

- Establish integrated supply chain working group (material supplier to OEM, accredited testing organizations, and standards organizations)
- Complete initial property goal setting and gap assessment
- Define demonstration programs
- Fund initial demonstration programs
- Develop assessment of existing standard methods
- Develop roadmap for standards based on performance
- Launch plastic and polymer composite materials/processing improvement projects
- Fund initial standards projects

Outcomes/Benefits

- Reliable property data including variability available to designers
- Guidance for prioritizing supply chain/government R&D
- Performance-based standards enable supply base to develop new materials and processes that can be certified for body-in-white applications

Specialized Resources

- Co-development testing facilities, including environmental tests
- Availability to obtain parts from processing groups



Education and Training

Advocate for plastics and polymer composites training classes and degree programs at all major universities

Key Tasks

- Build education task force by visiting key universities near auto centers
- Develop training classes that can be taken as electives or integrated into a degree program; classes can include webinars by suppliers and visits to key development centers
- Develop degree curriculum
- Utilize curriculum to train engineers
- Advocate government to support education need
- Integrate training courses into demonstration centers

Roles

- **ACC:** Advocate for task force, become voice for government advocacy
- **Industry:** Involve Society of Plastics Engineers to utilize already-developed curriculum; identify knowledge base and resources for syllabus/ classes; conduct the gap analysis; OEMs, Tiers can help to identify key topics and help develop local industry consortia that collaborate and avoid duplication of efforts
- **Other Stakeholders:** Institutes and universities host the new plastics and polymer composites degree programs and training efforts

Immediate Next Steps

- Identify potential members of task force and formalize
- Define baseline metric for comparing graduates who enter the auto industry now to future trends
- Develop webinars with material suppliers

Key Milestones

- Identify the task force lead
- Develop gap analysis of existing programs
- Define locations for universities and government laboratories

Outcomes/Benefits

- More plastics and polymer composites engineers participating in the automotive industry
- Increased acceptance of plastics and polymer composites
- Penetration of plastics and polymer composites in educational institutions

Specialized Resources

- Industry experts

Appendix B. Roadmap Contributors

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