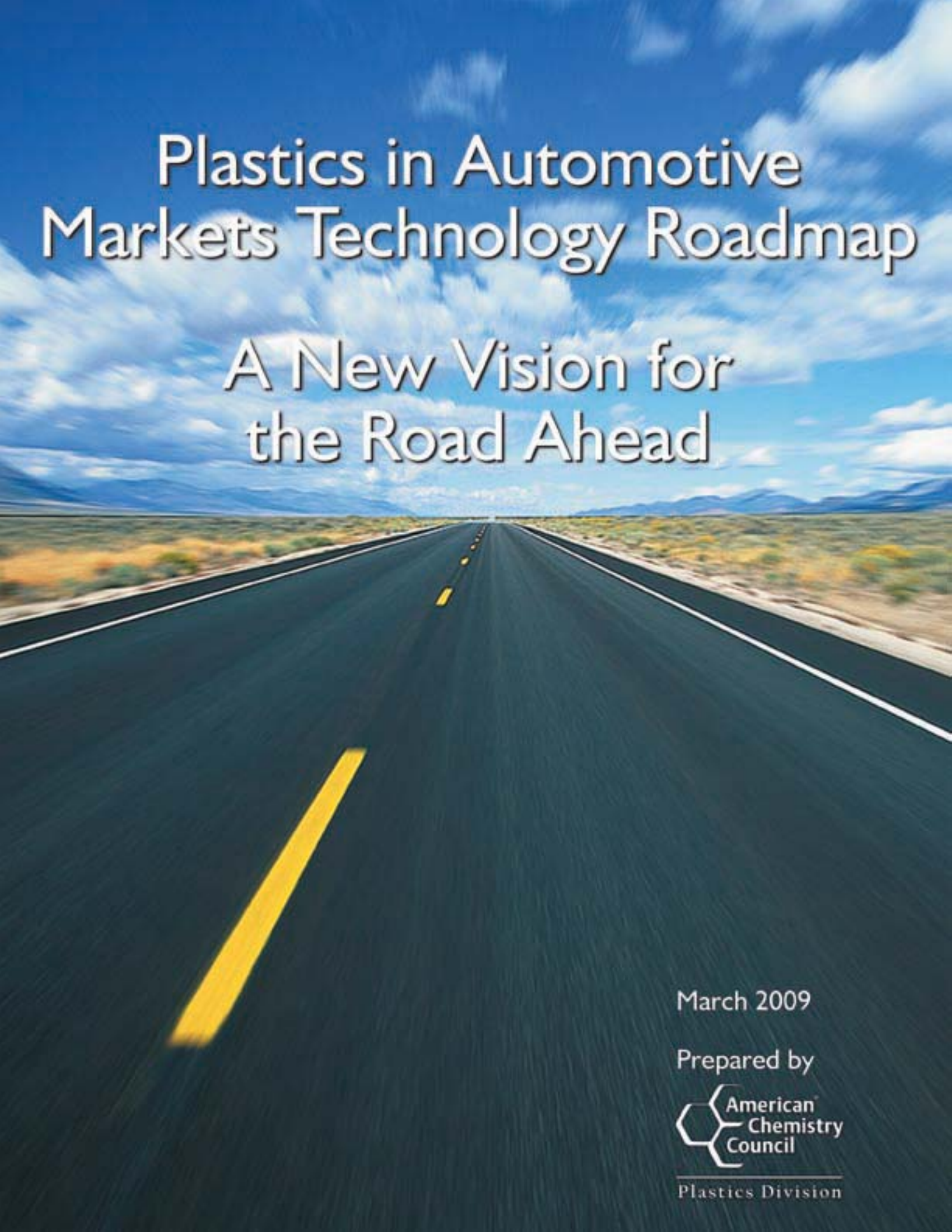

Plastics in Automotive Markets Technology Roadmap

A New Vision for the Road Ahead

March 2009

Prepared by

American Chemistry Council

Plastics Division

Preface

The Plastics Division (PD) of the American Chemistry Council (ACC), working with the automotive industry, is leading an effort to enhance future automotive performance and sustainability through the use of plastics and polymer composites. As part of its efforts, ACC PD has developed this seminal document, ***Plastics in Automotive Markets Technology Roadmap: A New Vision for the Road Ahead***. This document is an update of the *Plastics in Automotive Markets: Vision and Technology Roadmap*, published by ACC in 2001. The document is based in large part on a series of workshops held in 2008 in Detroit, Michigan, which were attended by representatives of plastic producers, original equipment manufacturers (OEMs), tier suppliers, academia, non-governmental organizations (NGOs), and government. During these workshops, participants identified many of the critical technology developments needed to meet, and sometimes set, future automotive requirements domestically and internationally. The document also draws on additional input from experts throughout the automotive value chain, on current publications and trade journals related to automotive plastics, and on technology roadmaps published in related areas of the chemical and automotive industries.

This technology roadmap provides guidance to the automotive and plastics industries and their stakeholders as they pursue the research and development that is needed to create innovative materials and design approaches that meet automotive performance criteria. By establishing a dialog among senior technical and business leaders, the roadmap will help to align the technical and business capabilities of the plastics industry with the needs and expectations of automotive producers and consumers.

This roadmap was developed by the ACC PD Automotive Group led by the Automotive Roadmap Steering Committee. The project benefited greatly from the leadership of Jim Kolb, Senior Director, Automotive, at ACC PD. This document was prepared by Energetics Incorporated. The principal writers were Ross Brindle, Jack Eisenhauer, Fred Hansen, and Mark Ellis. The document was designed by Julie Chappell. Many valuable contributions were provided by members of the plastics and automotive communities, who are listed in Appendix B.

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Executive Summary

Plastics and polymer composites encompass a wide variety of functional materials that exhibit a vast range of desirable properties. They are durable, strong, and lightweight; they are resistant to chemicals and harsh environments; and they are excellent thermal and electrical insulators. They can be transparent, translucent, or opaque; soft, flexible, or hard in almost any shape and size; heat- and corrosion-resistant; and recyclable. They can even be electrically and thermally conductive. These benefits, combined with their cost effectiveness, have established plastics as the preferred materials in a wide variety of commercial applications.

As a result, plastics and polymer composites have become some of the most widespread, value-added, engineering materials used in automobiles across the globe. In the last 40 years, the use of lightweight plastics in U.S. automobiles grew from an average of 60 pounds (27 kilograms) per vehicle to approximately 330 pounds (150 kilograms) per vehicle in 2007. More than 50% of a typical vehicle's volume is composed of plastics and polymer composites, but these materials only account for approximately 10% of total vehicle weight. These extraordinary facts have allowed automobile designers to reduce vehicle weight while also reducing cost and improving safety, vehicle performance, and fuel efficiency, ultimately delivering greater value to automotive customers.

The Challenges Ahead

The automotive industry is in the midst of one of the most challenging times in its history. Highly volatile, rising energy prices and the growing concern about global climate change are driving greater consumer demand for improved fuel efficiency in many parts of the world. Global market dynamics are shifting in response to the growth of massive markets in India, China, and other regions and in reaction to the emergence of new automotive manufacturers from these regions who promise to become major global players in the next decade and beyond. Consumers continue to demand better performance and functionality from their vehicles while expecting to pay less. Finally, societal demands for safety performance, environmental stewardship, and economic development are driving regulations that create additional challenges for automotive manufacturers.

Plastics offer critical solutions to these challenges. The automotive plastics industry is committed to leading a transformation in the application of innovative polymers in vehicles that will significantly increase the value of the automotive industry to the driving public. Under the leadership of the Plastics Division of the American Chemistry Council (ACC PD), plastics producers have worked with automotive original equipment manufacturers (OEMs), tier suppliers, universities, national laboratories, non-government organizations (NGOs), and government agencies to revise the vision and strategy for meeting the material and design challenges facing the automotive industry over the next 10 years.

A New Vision

The automotive plastics industry has revised its vision to reflect these challenges and the opportunities provided by ongoing technological advances. By 2020, the automotive industry and society will recognize plastics as a preferred material solution that meets, and in many cases sets, automotive performance and sustainability requirements.

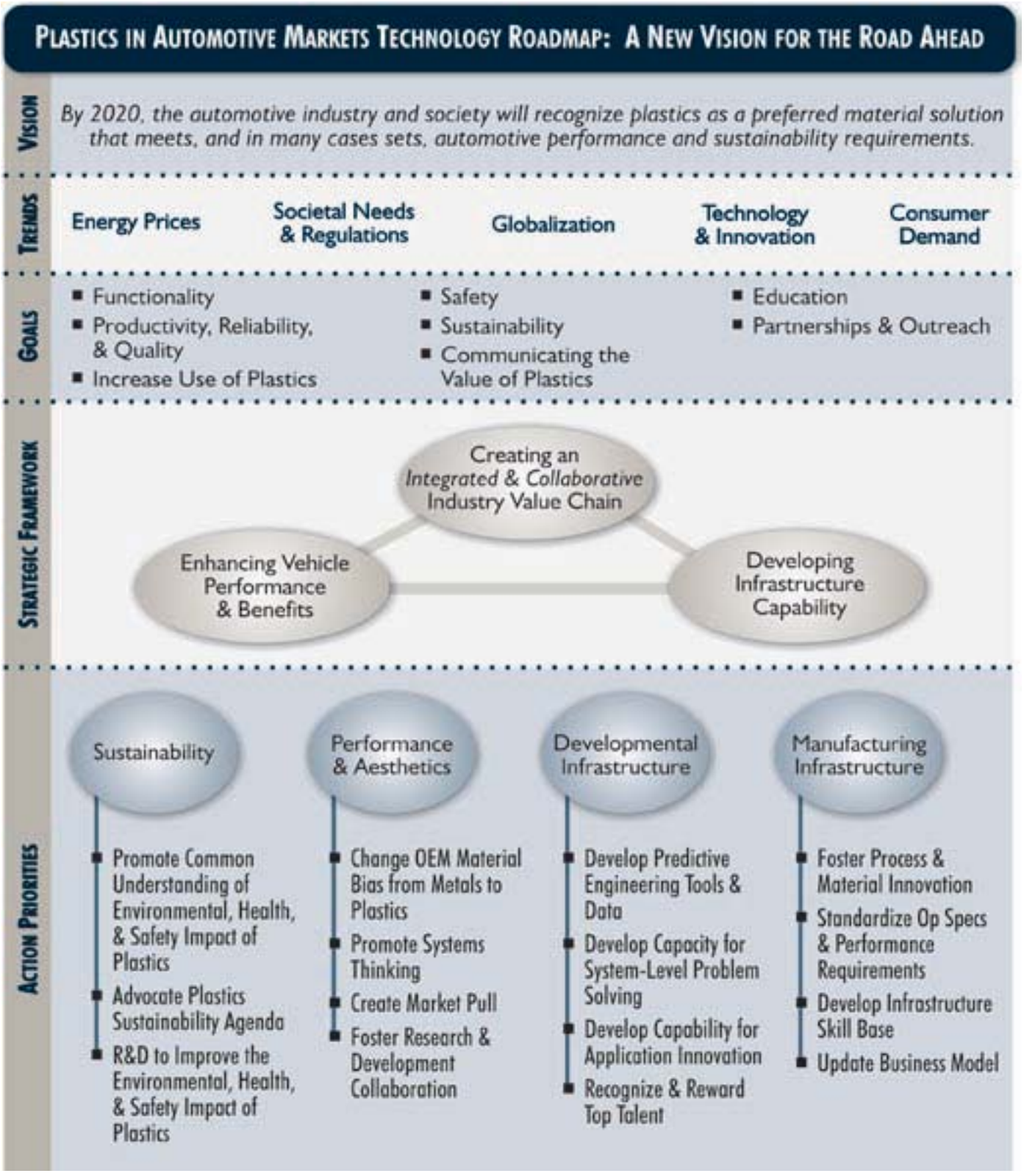
This vision is supported by strategic goals ranging from the improvement of vehicle safety to the development of industry-wide cooperative efforts. The accomplishment of the vision and goals will help to foster an era of renewed prosperity and innovation for the automobile industry by meeting and exceeding the consumer, environmental, and regulatory demands of today and tomorrow.

Three-Part Strategy

The automotive plastics industry has created a three-part strategy for achieving its vision. The focus of the strategic framework is on the development of an automotive industry that is more competitive and prosperous in the global marketplace. It is based on the understanding that future competitiveness and prosperity depends on the ability of the automotive industry to effectively leverage the full potential of plastics and polymer composites.

The first theme for effective industry development is the creation of a more integrated automotive value chain that stimulates greater cooperation among tier firms as well as between the tiers and the OEMs.

The second theme concerns the continual enhancement of the sustainability, performance, and aesthetic benefits of the vehicles produced by the industry. The full and effective utilization of plastics and polymer composites will empower the automotive industry to meet diverse customer and societal requirements.



The third theme concerns the development of industry capabilities that support the ongoing enhancement of vehicle sustainability, performance, and aesthetics. The industry's manufacturing infrastructure must become fully effective while working with plastics and combining multiple materials into a functional whole. Simultaneously, the industry's developmental infrastructure must become fully adept at designing with plastics and innovating new applications for plastics and polymer composites, especially in light of evolving safety performance criteria and energy efficiency goals.

The Road Ahead

The financial and technical resources needed to accomplish this vision and roadmap are beyond the practical reach of any individual company. The plastics industry has worked closely in partnership with automotive OEMs, tier suppliers, academia, national laboratories, and government agencies to address the priorities of the original roadmap. These public-private partnerships will continue to form a cornerstone of ACC PD's efforts to implement this new roadmap.

Future competitiveness and prosperity will depend on the ability of the automotive industry to be truly innovative and to effectively leverage the full potential of plastics and polymer composites. The plastics industry is committed to working with the automotive industry to use less energy and diversify energy sources, making both industries more efficient and more adaptable to fluctuating conditions. Through the combined efforts of all partners and under the leadership of the ACC PD, plastics will continue to play a vital role in the ongoing innovation that drives the automotive industry to higher performance, safety, and sustainability levels in 2020 and beyond.

1. Introduction

In 2001, the American Plastics Council (APC), now the Plastics Division of the American Chemistry Council (ACC PD), published the *Plastics in Automotive Markets Vision and Technology Roadmap*, outlining a vision of the application of plastics in automobiles and the business and technology strategies needed to provide solutions for the automotive industry. Since then, ACC PD has implemented several cooperative projects through its Automotive Group to address the challenges and priorities outlined in that roadmap. In 2007, ACC PD initiated a project to update the 2001 Roadmap in light of these advances and new market realities. This roadmap document is the product of that project.

Since the publication of the original 2001 Roadmap, the landscape of the automobile industry has been drastically altered. Demand for sport utility vehicles (SUVs) and light-duty trucks, which at one point were the staple of the American automobile market, has declined. Concern over climate change and volatile energy prices is driving an increased consumer demand for vehicle fuel efficiency and a renewed focus from Congress. Biofuels and hydrogen fuel cell vehicles continue to receive significant attention from the U.S. federal government, foreign governments, global original equipment manufacturers (OEMs), nongovernmental organizations (NGOs) and other entities. Similarly, hybrid-electric vehicles have gained a significant interest and a growing share of the market, and are available in an increasing number of makes and models. Amid such drastic domestic changes, global automobile markets and production capacities are developing and expanding at an accelerated rate. While the original roadmap remains generally valid and applicable to both the plastics and automotive industries, this updated roadmap responds to the new pressures faced by these industries.

This roadmap is designed to help the automotive and plastics industries maintain a strong foundation upon which to build relationships, establish priorities, and initiate programs to address changing market needs. Although this roadmap is authored by the North American automotive plastics industry, it addresses globally significant issues. The recommendations of this roadmap will require significant resources to accomplish both shorter term priorities and our 2020 vision.

Mission of Technology Roadmap:

To identify changes since the 2001 Roadmap, provide guidance regarding what areas industry should now be focusing their resources, function as a communication tool to gain a consensus perspective, and drive cooperation among multiple stakeholders.

The remainder of this roadmap is organized as follows:

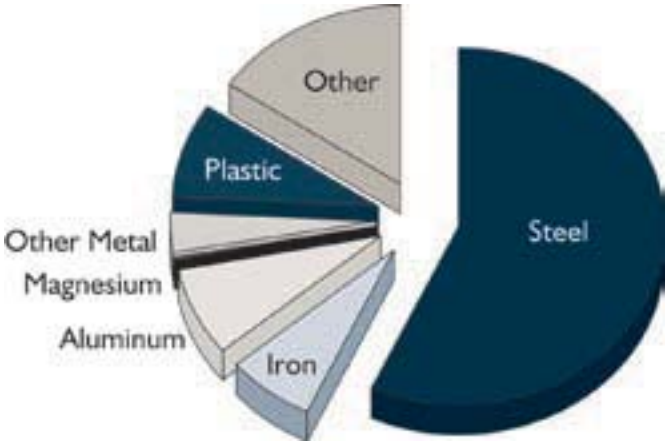
- ***Chapter 2*** describes the current state of the automotive industry and major changes that have occurred since 2001.
- ***Chapter 3*** presents the vision and strategic goals of the roadmap, offering a view of the future automotive industry and how plastics and polymer composites can help to enable that future.
- ***Chapter 4*** presents a strategic framework that characterizes the roadmap's overall approach to achieving the vision and goals.
- ***Chapters 5 through 8*** present an analysis of barriers, activities, and priorities in the four areas of sustainability, performance and aesthetics, developmental infrastructure, and manufacturing infrastructure.
- ***Chapter 9*** discusses the implementation of the roadmap and presents plans for top-priority action items.

2. Plastics in the Automotive Industry Today

Although plastics have been used in automobiles since the 1940s,[1] the use of plastics and polymer composites in automobiles is typically viewed as a modern innovation, as many of the materials that are considered "plastics" are a recent development. These advanced materials have benefited vehicle appearance, performance, and safety, and continue to offer the automotive industry new ways to improve its vehicles today. The creation of this growing range of new materials has even forced a shift in the label "plastics" to the more accurate "plastics and polymer composites." (In order to maintain a concise narrative, both labels are used in this roadmap [see sidebar]).

As the development of innovative plastics and polymer composites has impacted the automotive industry, so has the changing automotive market impacted the focus and priorities of the plastics industry. While many of the same forces, such as consumer demand and global competition, continue to shape the automotive market, the marketplace of today is very different from what it was only a few years ago. In order to remain competitive and prosperous, both the plastics and automotive industries need an integrated strategy for the future, one that aligns the interests of both industries and effectively leverages the full potential of plastics and polymer composites. These industries must also seek to work in partnership with state and federal governments and non-governmental organizations (NGOs) to further advance the shared goals of addressing global climate change, ensuring security of energy supplies, and reducing U.S. dependency on foreign oil.

Exhibit 2-1. Material Used in Automobiles by Weight[2]



This roadmap uses a variety of terms to refer to full range of materials that are most accurately referred to as plastics and polymer composites. Alternative labels include polymers, plastics, and composites.

Lightweighting

The development of high-performance plastics and polymer composites during the past 40 years has allowed automakers to lower the weight of many vehicle components by substituting steel with a lighter weight plastic material. Since 1965, the use of lightweight plastics in automobiles grew from an average of 60 pounds (27 kilograms) per vehicle to approximately 330 pounds (150 kilograms) in 2007.[3] At present, over 50% of a vehicle's volume is composed of plastics and plastic composites; yet, at 330 pounds (150 kilograms), plastics still only account for approximately 8–10% of the total weight of a vehicle (Exhibit 2-1). This remarkable achievement was made possible by the significantly lower density/weight and higher versatility of plastics compared to other materials.

Vehicle Characteristics

Major advances in material properties, design capabilities, and the processing of polymers led automakers to incorporate plastics and polymer composites into all major systems of the automobile, including the interior, exterior, chassis, powertrain, engine, electrical system, and fuel system (Exhibit 2-2). The automakers' reasons are clear: plastics often offer a better value than alternative materials, providing heightened performance for lower costs.

Increases in the use of plastics have made an indelible impact on the automotive industry that goes beyond the lightweighting of vehicles. Plastics have enabled designers to achieve new levels of vehicle performance, functionality, and aesthetic design. In many scenarios, plastics provide the only practical solution for achieving critical safety, weight, spatial, aesthetic, and fuel efficiency goals.

1. Henry Ford patented a plastic-bodied automobile in 1942.
2. Richard A Schultz, "Metallic Material Trends for North American Light Vehicles." (Troy, Michigan: Ducker Worldwide, 2007), http://www.autosteel.org/AM/Template.cfm?Section=PDFs&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTFILEID=9284 (accessed November, 2008)
3. T. Kevin Swift, "Changing Customer Dynamics: Chemistry and Light Vehicles" (American Chemistry Council, November, 2008).

Exhibit 2-2. Plastic Applications in Automobiles

Exterior—Plastic components resist dents, dings, stone chips, and corrosion. They allow modular assembly practices, lower production costs, and enable advanced exterior styling. Common applications include bumpers and fascia systems, body panels, grills, lighting systems, trim, and glazing.

Interior—Plastics are ideal for contributing to more comfortable, durable, and aesthetically pleasing interiors while reducing noise, harshness, and vibrations that disturb drivers and passengers. Plastic's design flexibility helps manufacturers create innovative, single-piece components that lower costs. Common applications include airbags, seating, instrument panels, steering wheels, air ducts, trim, door panels, consoles, sound abatement, and head liners.

Electrical—As the demand for electrical and computer-aided devices increases, plastics are enabling their inclusion by providing lightweight, non-conductive, and flexible housing, mounts, and insulation. Common applications include component housings, switches and sockets, connectors, sensors, lighting systems, circuit boards, and wiring harnesses, as well as foils for capacitors and displays.

Powertrain—Plastic's ability to withstand high temperatures and exposure to a variety of chemicals make it ideal for powertrain components. The use of additives, fillers, and reinforcements can vary the properties of plastics to meet specific needs. Plastics help minimize the number of parts needed to assemble complex components and reduce assembly costs. Applications include CV and U joint boots and internal transmission parts.

Chassis—Plastics are helping to make the chassis lighter, stronger, and more crash-sustainable, while reducing manufacturing costs. Plastics allow multiple components to be integrated into single units. They also help to reduce noise and vibration. Common applications include structure, support, suspension, load floors, front-end modules, fuel tanks, and brake components.

Engine—Plastics are making under-the-hood components easier to design and easier to assemble. Plastics such as nylon, polypropylene, polyethylene, and thermoset polyesters hold up well in the high-temperature, corrosive environment found in the engine compartment while reducing engine weight and noise, harshness, and vibration levels. Common engine applications include air-intake systems, fuel-intake systems, cooling systems, fluid containers, and valve covers.

Automotive Markets

Over the past 25 years, automotive markets have undergone tremendous changes shaped by the forces of globalization, technological innovation, government regulations, and changing customer expectations. While these forces continue to operate, they are transforming the marketplace at speeds never before experienced or predicted. In the last five years alone, these forces have led to profound changes in automotive markets.

- ***New Global Markets***—The opening of markets in developing countries has produced a tremendous increase in the global demand for automobiles. Over 70 million vehicles were produced worldwide in 2007 (a 5% increase over the previous year) and vehicle sales are expected to recover and continue to increase in the future. This increase will create new opportunities for both the automotive and plastics industries. China and India, in particular, present strong growth potential, each boasting large, increasingly affluent populations and rapidly developing vehicle markets.[3] General Motors, for example, saw sales in China rise 32% to nearly 880,000 vehicles and recently announced plans to build hybrids in China. Ford's China sales of all brands rose 87% to about 167,000 units.[4]
- ***New Global Competition***—Global competition has always been a factor in the automotive industry, and recent years have seen the emergence of powerful new competitors. China, already the third largest producer of vehicles (after Japan and the United States), increased its vehicle production by 22% in 2007 and is expected to maintain similar growth until at least 2015. India and other smaller producers such as Hungary, Indonesia, and Ukraine are growing even quicker; Slovakia nearly doubled its production capacity in 2007, producing over half a million vehicles.[5]
- ***New Regulations***—Concerns over global energy supplies, environmental impacts and climate change, health and safety, and global economic developments are driving increasing government regulation. Recent regulations include:
  - New standards on fuel economy (e.g., amended Corporate Average Fuel Economy [CAFE] standards)
  - New national and state emission standards
  - Pedestrian safety regulations in Europe
  - Interior air quality concerns
  - The European Commission's Registration, Evaluation, Authorisation, and restriction of CHemicals (REACH)
  - In addition, there are ongoing efforts toward the harmonization of vehicle regulations which are making progress in several venues, including the development of Global Technical Regulations (GTRs) under the United Nations.

4. Steve Stackhouse, *Automotive Industry Update 2007*. (Area Development Online, 2007), http://www.areadevelopment.com/industryReport/feb07/automotive.shtml.
5. "Slovakia—Largest Car Producer in the World." *Visit Slovakia*. http://visitslovakia.wordpress.com/2008/01/28/slovakia-largest-car-producer-in-the-world/ (accessed November, 2008)

- ***Electronic Innovation***—Technological innovation in automobile electronics is continuing to produce new devices and electronic accessories for automobiles, particularly in terms of driver-assistance features that involve wireless communication with other infrastructures. Such features—referred to as "telematics"—include navigation aids, global positioning, traffic information, emergency service, remote engine diagnostics, full internet service, television, and satellite radio. Future additions will include active safety and intelligent vehicle systems. These technologies move from futuristic luxuries to commonplace necessities in the eyes of consumers, who also expect these accessories to be offered without increasing vehicle size or decreasing internal comfort.
- ***Shifting Consumer Demand***—Consumer expectations often increase disproportionately to their willingness to sacrifice or pay. Consumers want more sophisticated technology, better mileage, and additional options for the lowest possible price, with no loss of performance, comfort, or safety. Energy prices, at a relative low point in 2001, recently reached unprecedented levels. As a result, the demand for sport utility vehicles (SUVs) and light-duty trucks, which at one point were the staple of the American automobile market, is declining, while hybrid-electric vehicles have gained a significant interest, a growing share of the market, and are available in an increasing number of makes and models.
- ***Continued Pursuit of Alternative-Fueled Vehicles***—Several major automotive manufacturers have announced plans to develop alternative-fueled vehicles, including plug-in hybrid electric vehicles (PHEVs) and all-electric vehicles. Similarly, interest in alternative-fueled vehicles running on compressed natural gas (CNG), propane, and E-85 ethanol continues to grow. Finally, the U.S. Department of Energy, in partnership with automotive OEMs and other partners, continues to pursue research and development targeting hydrogen-fueled vehicles.

3. Vision and Strategic Goals

The automotive industry is currently facing a host of new challenges that are likely to intensify in the years ahead. Recently, new market pressures such as ballooning fuel costs, a challenging business climate, and heightened global competition have caused drastic shifts throughout the automotive industry, limiting manufacturing capability, freedom of design, innovative capacity, and market success. However, while these challenges are immense and evolving at an unprecedented pace, they are not insurmountable and even offer significant opportunity. To address these challenges, the automotive and plastics industries have created a new vision and strategic framework to guide cooperative action and support needed innovation.

A Vision for 2020

By 2020, the automotive industry and society at large will recognize plastics as a preferred material solution that meets, and in many cases sets, automotive performance and sustainability requirements. Plastics and polymer composites will continue to offer substantial and increasing value to automakers as they develop and produce vehicles that meet consumer demands and societal requirements. Many of the outstanding characteristics of plastics, such as strength, durability, light weight, and recyclability, have already been recognized by automakers. Fully capitalizing on the broad range of properties and functionality of plastics and polymer composites will allow automakers to further enhance the safety, comfort, performance, and appearance of vehicles while reducing energy use and environmental impacts.

> *Roadmap Vision:*
>
> By 2020, the automotive industry and society at large recognize plastics as a preferred material solution that meets, and in many cases sets, automotive performance and sustainability requirements.

While plastics are used extensively in vehicles today, there is significant room for growth as automakers seek innovative material solutions to design challenges. There are several issues that have limited the use of plastics in vehicles; three factors have had the greatest impact:

- **Much of today's embedded manufacturing ability—both physical infrastructure and human capability—has evolved primarily to optimize the use of metals.** Design engineers often lack the proper tools to create and optimize plastic designs. Further, many automotive production and assembly processes have been optimized for metal components and may be less suitable for use with plastics. Often, plastics and polymer composites are not utilized to the full range of their unique capabilities because of infrastructure limitations.
- **Some automotive customers, as well as some members of industry, do not perceive plastics as a premium material.** They may also be wary of using plastics in structural applications, such as the vehicle frame. This view is at odds with reality. When properly formulated and applied in an optimized design, plastics and polymer composites can provide many times the strength of steel, and are used today in applications in vehicles, aircraft, and other functions in which safety is paramount.
- **Today, many desirable plastics and polymer composites are more costly on a per pound/kilogram or part basis than alternative materials.** While initial material costs may be higher, opportunities granted in design flexibility, parts consolidation, vehicle weight, and many other benefits frequently result in lower system and life-cycle costs.

To answer these challenges and respond to the trends shaping the automotive market, the automobile and plastics industries have identified strategic goals in eight areas critical to the achievement of their vision. These goals are not only intended for plastics manufacturers, but also to benefit the automotive industry.

Strategic Goals

Exhibit 3-1 presents 15 strategic goals that articulate the achievements necessary for the automotive and plastics industries to achieve their vision. These goals range from the improvement of vehicle safety to the development of industry-wide cooperative efforts. The accomplishment of these goals can help to foster an era of renewed prosperity and innovation for the automobile industry by meeting and exceeding the consumer, environmental, and regulatory demands of today and tomorrow.

Safety

Safety is a critical priority in the automotive industry; however, incorporating new safety features can increase the cost and weight of vehicles. Plastics and polymer composites address this challenge by providing safety features such as air bags, seatbelts, and trim.

Exhibit 3-1. Strategic Goals for Automotive Plastics

Safety

- Support improved safety in automobiles at weight-neutral and cost-neutral position, or better

Functionality

- Optimize vehicle functionality in a weight-neutral and cost-neutral position, or better

Sustainability

- Enable 95% content recovery and recyclability from end-of-life vehicles by 2015
- Benchmark and reduce life-cycle energy and environmental costs of petroleum-, natural gas- and bio-based plastics in vehicles relative to those of alternate materials

Productivity, Quality, and Reliability

- Improve predictive engineering capabilities to more accurately support the performance and durability of automotive plastics products and systems
- Develop new plastics and plastic-hybrid material design tools
- Improve processing techniques and manufacturing efficiency to speed time to market
- Work with American Society for Testing and Materials (ASTM International) to develop standards compliant with the International Organization for Standardization (ISO) by 2020, helping to establish a stronger U.S. seat at the ISO table

Market Position

- Increase average plastics content in vehicles over 2008 levels

Education

- Partner with colleges and universities to create attractive career value proposition for students
- Increase polymer science and engineering course offerings, including those specific to automotive applications

Partnerships & Outreach

- Accelerate pace of innovation through cooperative R&D partnerships between industry, government, and academia that effectively leverage funding and align specialized resources and expertise

Communicating the Value of Plastics

- Communicate life-cycle energy and environmental costs of plastics in vehicles relative to those of alternate materials
- Correlate improvements to vehicle fuel efficiency, safety, reliability, weight savings, and environmental impact to related increases in plastics content
- Communicate the unique benefits and significant value that plastics add to vehicles through dedicated awareness campaign to change perception of plastics as a less effective material option

Additional innovation can allow these materials to further reduce the dangers associated with driving, with minimal impact on vehicle cost and weight.

Functionality

Automobile customers are demanding value (more for less). Customer demand for increased performance and modern electronic devices is one of several trends that remains unchanged since 2001 and is likely to remain unchanged for the foreseeable future. However, customers increasingly expect many additional features to become available without adding cost or weight to the vehicle. The innovative use of plastics can enable automakers to meet this demand. Many vehicle features, such as air bags, video devices, radios, and global positioning systems (GPS) simply could not exist without the use of plastics. Even the sleek, aerodynamic shape of the modern vehicle is dependent on plastics. Increased use of plastics and polymer composites will give vehicle manufacturers more options and allow for better performing vehicles, without compromising cost or weight.

Sustainability

Tomorrow's vehicles must be produced in the most sustainable manner possible. The recovery and recycling of materials from end-of-life vehicles has seen extensive and reliable growth in recent years as corporations are increasingly being held accountable for their products at the end of their life cycle. To date, the primary focus in applying plastics and polymer composites in vehicles has been to enhance component and vehicle performance and/or to aid in lightweighting vehicles. In the coming years, automakers and plastics providers will need to combine such pursuits with even greater emphasis on end-of-life vehicle recovery and recycling, with the ultimate goal of full recoverability and recycling back to original or other high-end uses. Much of the necessary research to achieve this goal has been completed.

Another facet of sustainability is the sustainability of the materials used to produce a vehicle. Plastics consume only a small fraction—just 3%—of U.S. oil and natural

gas. In use, plastics reduce energy demand during the life of the fleet through lightweighting, saving 88 million barrels of oil equivalent (BOE) each year and avoiding 30 million tons of CO_2 emissions, which helps to forestall climate change.[6] The plastics industry must benchmark itself against alternate materials to assess and improve the sustainability of its materials. Finally, the innovative use of plastics can enable and facilitate the design of alternative drivetrain technologies that offer further fuel efficiency and related CO_2 emissions reductions.

Productivity, Quality, and Reliability

The successful development of new design tools that incorporate plastics, polymer composites, and hybrid material systems will help to update an infrastructure that has evolved primarily with metals in mind. Automotive designers, lacking sufficient tools to effectively design for plastics and hybrid materials, are often forced to apply plastics in suboptimal ways, underutilizing the major advantages offered by these materials. New design tools will allow engineers to achieve higher levels of performance and an aesthetic flexibility only available through the optimal use of plastics. An important step in increasing quality and reliability will be the consideration of internationally recognized voluntary standards. In several cases, these standards have become market requirements. Domestic companies can ease the difficulties of functioning in a global industry by participating in international standard-setting processes such as those conducted under the International Organization for Standardization (ISO).

Increased Use of Plastics

Throughout its evolution, the increasing plastics and polymer composite content in vehicles has not only offered weight savings and performance enhancements, but has also enabled the freedom of design which separates modern vehicles from older models. Without plastics, such advances simply would not have been possible. Further increasing the use of plastics in vehicles is a clear metric to measure the effectiveness with which plastics deliver value and innovation to the automotive industry.

Education

The plastics industry suffers from a shortage of collegiate specialization, leading potentially interested students to be left unaware of the exciting opportunities inherent in a career working with plastics in the automotive industry. Increased exposure to automotive plastics in an academic setting can increase interest and, subsequently, the number of specialists entering the industry. To do so, the industry must help to expand the number of courses offered in polymer science and related engineering disciplines. Courses specific to automotive applications, coupled with industry partnerships with colleges and universities, will increase interest and ultimately bolster all aspects of the automotive industry through the addition of skilled workers and researchers, bringing value, growth, and innovation.

Partnerships & Outreach

Conducting the type of advanced R&D needed to optimize current products and enable the next decade of vehicles is a massive undertaking. Current market pressures are increasing the need for innovative products at a time when demand for automobiles is changing and when human and financial resources within the automotive industry are stretched thin. Continued success will require greater industry outreach and cooperative efforts that engage additional stakeholders and partners to help bear the burden and realize the benefits of ongoing innovation in the use of plastics in vehicles.

Communicating the Value of Plastics

The utility and value of plastics and polymer composites have never been greater. However, the public can sometimes hold a negative view of plastics in vehicles. Many consumers fail to recognize the vast range of plastics and polymer composites that touch their lives every day. In reality, the unique characteristics of these materials have enabled advances that benefit society in thousands of applications in fields as diverse as modern medical care to the most sophisticated electronic devices. Communicating the value plastics bring to vehicles through improvements in safety, fuel economy, performance, and comfort can help to correct these misconceptions and drive consumer acceptance.

6. Association of Plastics Manufacturers in Europe. *Plastics—At work for a sustainable future*. (2004), http://www.plasticseurope.org

4. Strategy for Plastics in Automotive Markets

The previous chapter presented the long-term vision and strategic goals that constitute the destination of this roadmap. The following chapters present an analysis of activities and action priorities for moving forward. This chapter provides a strategic framework that helps bridge the gap between aspiration and action.

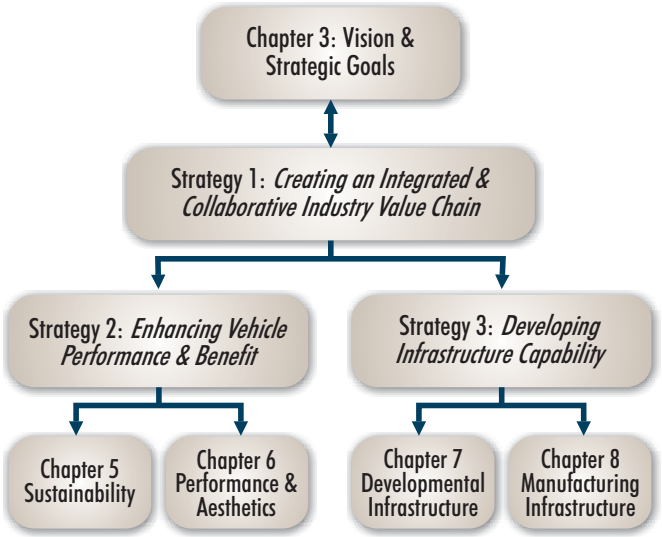
The strategic framework focuses on the development of an automotive industry that remains competitive and prosperous in the global marketplace. It is based on the understanding that future competitiveness and prosperity depends on the ability of the automotive industry to effectively leverage the full potential of plastics and polymer composites. In essence, the framework provides a way to think strategically about how the vision and goals may best be achieved. The strategy of the framework revolves around three themes for effective industry development.

The first theme for effective industry development is the creation of a more integrated and cooperative automotive value chain. In stepping up to the challenges of a global marketplace, the automotive industry must compete as an integrated whole. In many cases, the automotive industry has used competitive pressures to drive costs out of the supply chain to the extent that it has reduced resources for innovation and long-term technology development. From a strategic point of view, it is sensible to increase communication and common understanding within the value chain and to foster greater cooperation and collaboration among tier firms as well as between the tiers and the OEMs. This is a strategically critical theme that underlies the vision and goals of the industry (Chapter 3) and is an overarching imperative for the identification of activities and priorities in each of the next four chapters (see Exhibit 4-1).

The second theme concerns the continual enhancement of the sustainability, performance, and aesthetic benefits of the vehicles produced by the industry. To remain competitive and prosperous, the automotive industry must be able to offer vehicles that meet evolving customer needs and also comply with increasing government regulations. The full and effective utilization of plastics and polymer composites will empower the automotive industry to meet these diverse requirements. Plastics enable the continual enhancement of vehicle features and benefits. This theme runs through each of the next four chapters, but is particularly emphasized in Chapters 5 and 6 (see Exhibit 4-1).

The third theme concerns the development of industry capabilities that support the ongoing enhancement of vehicle sustainability, performance, and aesthetics. The industry's manufacturing infrastructure must become fully effective while working with plastics and combining multiple materials into a functional whole. Simultaneously, the industry's developmental infrastructure must become fully adept at designing with plastics and innovating new applications for plastics and polymer composites. Developing infrastructure capability applies to each of the next four chapters, although it is a particular focus of Chapters 7 and 8 (see Exhibit 4-1).

Exhibit 4-1. Roadmap Structure



5. Sustainability

The sustainability of the automotive industry can be considered a measure of its effectiveness in meeting the health, safety, and environmental requirements for its products and its processes while achieving acceptable financial performance for participating companies. These requirements are typically imposed by society through consumer choices, public policy, and enacted legislation. One major component of the sustainability performance of the industry is the total energy and environmental impact of its operations and outputs over the entire value chain and vehicle life cycle, from materials manufacturing and processing to end-of-life materials recycling, recovery, or disposal. Sustainability performance is also a function of the protection that vehicles provide against a range of injuries and threats that may occur in the case of an accident, including the protection of vehicle occupants and pedestrians alike. A final aspect of sustainability is the industry's impact on employment. The automotive industry strengthens and supports the U.S. economy by providing millions of jobs. Monitoring the industry's contribution to social sustainability through job creation is another measure of its sustainability performance.

Plastics and polymer composites have played a critical role in supporting automakers' pursuit of greater sustainability in recent years. Plastics have enabled vehicle lightweighting via materials substitution, thereby increasing fuel economy. Leveraging the unique properties of plastics in both interior applications (e.g., seatbelts, airbags, and instrument panels) and exterior applications (e.g., bumpers, energy absorbers, windshields, head lamps, and tail lights) has contributed significantly to the safety of vehicles. In these and many other ways, including helping to maintain employment levels by enabling a more globally competitive automotive industry, plastics create greater sustainability in the automotive market. The automotive and plastics industries can continue working together to enable even greater sustainability for vehicles in the years ahead. This chapter outlines the barriers, potential solutions, and priorities for doing so.

Barriers & Limitations

Several important barriers currently limit automakers' ability to enhance sustainability through the use of plastics and polymer composites.

- Misperceptions about the health, safety, and environmental impact of automotive plastics have led to a resistance to plastics that prevents the automotive industry from fully realizing the enabling benefits of plastics.
- Consumers, OEMs, and tier firms sometimes assess the costs of plastics-enabled enhancements to sustainability to exceed their benefits or consumers' willingness to pay for those enhancements.
- Biases, misperceptions, and lack of understanding among regulators and legislators can lead to sustainability requirements that overlook recycling/recovery options, life-cycle effects, or are too restrictive and thus limit the use of plastics and polymer composites.
- Certain material property issues (e.g., VOC emissions, flammability) and material processing issues (e.g., recyclability of mixed materials, handling and storage of liquid resins) still need to be considered in order to optimize the sustainability advantages of plastics.

Solutions

The automotive and plastics industries have generated a range of potential action items that offer solutions to the barriers described above. These action items identify three general action agendas for increasing both the sustainability-enabling potential of plastics and the industry's realization of that potential:

- ***Promote common understanding of the impact of plastics on automotive sustainability.*** This action agenda focuses on establishing an accurate and common understanding of the actual impacts/benefits of plastics on the cradle-to-grave environmental, health, and safety performance of the automotive industry. This effort involves conducting research and development efforts to produce accurate and complete data about the environmental, health, and safety impact/benefit of plastics. Communication efforts publicizing these results will help raise awareness and create a common, fact-based understanding throughout society that plastics are a sustainable material.
- ***Advocate plastics sustainability agenda.*** This action agenda focuses on educating and influencing the biases, misperceptions, and misunderstandings of policymakers, legislators, and regulators regarding the impact/benefit of plastics on the cradle-to-grave environmental, health, and safety performance of the automotive industry. By educating this audience and advocating initiatives designed to promote a more informed approach to end-of-life vehicle solutions, the industry will increase legislative acceptance of plastics as a sustainable material choice for use in vehicles.

Keeping regulators and legislators informed and up-to-date about the importance of plastics, the needs and limitations of plastics manufacturers, and the sustainability impact/benefit of plastics is important to the continued consideration of plastics' recycling/recovery options and life-cycle profile in future sustainability requirements.

- ***Foster R&D that allows plastics to enhance sustainability.*** The greatest benefit will be realized by establishing an action agenda focused on addressing specific material property and the material processing issues that continue to limit the full realization of sustainability benefits of plastics. This effort involves conducting R&D initiatives to improve the material properties of plastics in regard to volatile organic compound (VOC) emissions, flammability, resistance to impact damage, and recyclability. The sustainability benefit of plastics will also be improved by conducting R&D initiatives to improve the upstream footprint of operations and processes involving plastics (e.g., the development of manufacturing processes that use less energy; the development of advanced processes that manufacture plastics from fossil-based raw materials and renewable sources).

Top Priorities

Within the action agendas described above, there are specific action items that are identified as top priorities for improving automotive sustainability (both economically and environmentally) through the use of plastics and polymer composites. These items are considered top priorities because of their high potential for significant impact. Depending on how these items are implemented, this impact may be broad in nature and involve a longer term commitment of energy and resources, or it may be more near term and serve to strengthen interest, enthusiasm, and commitment. The top priority action items for sustainability are listed below.

- Produce a life-cycle analysis of the environmental impact of plastics versus other materials (including carbon footprint and other factors).
- Conduct research, design, and development (RD&D) to better understand the effect of vehicle weight and vehicle size on safety.
- Communicate the economic impact of the plastics industry to all levels of government and society.
- Demonstrate the safety of composite and plastic structures and widely communicate the results.
- Continue to improve the ability to recycle and recover automotive plastics in an economically sustainable manner.
- Communicate the advantages of plastics, particularly "green" properties, strength, and durability; highlight the benefits of plastics relative to other materials, particularly with regard to safety.

6. Performance and Aesthetics

Automotive performance and aesthetics requirements are a dynamic manifestation of changing consumer demands and technological advances expressed in a highly competitive marketplace. They reflect the diversity of individual preferences, needs, and desires regarding vehicle appearance, comfort, functionality, reliability, and longevity. To effectively meet consumers' performance and aesthetics requirements, automakers must continually innovate to meet expectations. This mission is further realized by offering a range of vehicles and vehicle options that are able to meet each consumer's individual combination of needs and desires. Plastics help to make this possible. By leveraging the unique properties of plastics in both interior and exterior applications, the automotive industry has significantly enhanced the performance and aesthetics of the vehicles it produces. Automakers have also been able to offer a wider range of options and features while improving their ability to customize vehicles to suit individual customers' unique preferences.

Demands for enhanced performance and aesthetics will only increase in the years to come. Expanding the potential of plastics to enable superior performance and aesthetics and ensuring that potential is realized is an important part of the path toward achieving the vision and strategic goals of the industry. This chapter identifies the particular barriers and limitations of using plastics to this end and presents the range of research, education, and other activities needed to overcome those barriers.

Barriers & Limitations

While plastics and polymer composites have been used for decades to enhance the performance and aesthetics of vehicles, several barriers currently constrain automakers' abilities to maximize the enabling benefit of plastics.

- Because of their widespread application in modern life, plastics are sometimes discounted and not perceived as a premium material solution. This results in market resistance, or at least a lack of market pull, that keeps the automotive industry from fully realizing the enabling benefits of high-performance plastics.
- Several barriers currently constrain OEMs, stemming from the material legacy of metal in the automotive industry. Metal has been the default material choice for some components for so long that designers fail to consider other material options or inadvertently create designs that are biased toward metal.
- The way value is assessed and compensated within the industry value chain also creates barriers. The value-added contribution of plastics often manifests at a systemic (total system cost) level. The common practice of assessing value using a piecemeal (vs. total system) approach underestimates the value-added contribution of plastics. The enabling benefit of plastics is therefore inhibited because the use of plastics may not be viewed as a cost-effective solution.
- The balance of properties and costs of some low- to medium-volume plastics and polymer composites that are currently produced limit the range of automotive applications for which those materials are used. This constraint, in turn, creates a ceiling on the performance enabling potential of plastics.

Solutions

The automotive and plastics industries have generated a range of action items that offer potential solutions to the barriers described above. These action items identify four general action agendas for increasing both the performance- and aesthetics-enabling potential of plastics and the industry's realization of that potential:

- ***OEMs recognize plastics as a preferred material choice.*** This action agenda focuses on creating an unbiased material selection process to replace the selection process that is a legacy of the OEM history of and comfort with metal as the material of choice. The industry's realization of the performance and aesthetics benefits of plastics will be enhanced by initiatives that promote or stimulate more widespread consideration of plastics and polymer composites by OEM and Tier 1 designers. Initiatives that induce designers to move the material consideration further upstream in the overall design process can also spur innovation by suppliers who may provide new ways of thinking.
- ***Create greater market pull for plastics and polymer composites and for the performance and aesthetic enhancements these materials can provide.*** The automotive industry's realization of enhanced performance and aesthetic benefits using plastics will be improved by initiatives to reform the image of plastics with consumers by creating a broad appreciation that plastics are a "high-tech" solution. This initiative will be

enhanced by promotional efforts to create market buzz around plastics by creating prototypes that showcase the performance and aesthetic benefits of plastics and by publicizing technological advances and future innovations.

- ***Promote systems thinking in OEMs to better reflect overall value of plastics.*** Traditionally, automotive OEMs have used component-based approaches to evaluating alternative material choices and estimating value-added contributions. This approach often fails to capture the full value and potential of plastics to enhance vehicle performance and aesthetics. Initiatives to produce cost/benefit analyses that model a systems-thinking approach and show the system-level benefits of plastics will help automakers and their value chain realize greater performance and aesthetics advances by fully exploiting plastics and polymer composites. These initiatives also should include models that enable systems thinking while creating and supplying individual components to OEMs.
- ***Foster R&D collaboration and funding mechanisms to address specific material property and technology issues around plastics.*** The enabling potential of plastics, while significant today, can be enhanced by R&D partnerships that lead to improved material properties for plastics, polymer composites, and hybrid materials. Such advances can open new areas of application for these materials while delivering innovation to automakers seeking to enhance performance and aesthetics. At the same time, R&D collaboration with automotive companies can further their realization of the enabling potential of plastics, particularly when specific R&D achievements are realized. To stimulate broad-based interest in plastics, such partnerships should engage a diverse range of R&D allies from both the public and private sectors and serve as a form of passive promotion that enhances the public attitude and overall disposition toward the use of plastics in vehicles.

Top Priorities

Within the action agendas described above, there are specific action items that are identified as top priorities for improving automotive performance and aesthetics through the use of plastics and polymer composites. These items are considered top priorities because of their high potential for significant impact. Depending on how these items are implemented, this impact may be broad in nature and involve a longer term commitment of energy and resources, or it may be more near term and serve to strengthen interest, enthusiasm, and commitment. The top priority action items for performance and aesthetics are listed below.

- Form partnerships between material suppliers, molders, and OEMs to focus development priorities & efforts.
- Demonstrate to OEMs how a systems approach in design can improve the bottom line.
- Initiate partnerships to improve mixed material (e.g., plastics, metal, etc.) manufacturing processes to protect vehicles from corrosion while maintaining or improving energy savings and/or vehicle appearance.
- Create plastic concept prototypes that showcase a "plastics" solution to key OEM problems.
- Embrace emerging change-oriented vehicle manufacturers.

7. Developmental Infrastructure

The developmental infrastructure embodies the plastics industry's capability for innovation and creative problem solving in addressing automotive challenges and opportunities. Because it comprises the technological, institutional, and educational components for developing new plastic and polymer composite material applications, this infrastructure can be leveraged to deploy plastics to meet automotive industry needs in the most value-added ways. The effectiveness of the developmental infrastructure can be measured by the enhancement to productivity, design cycle times, and vehicle performance that is enabled through these innovative material solutions.

For the automotive industry to remain effective and capture the most value possible in the global market, the industry must maximize this capability within the value chain. A strong developmental infrastructure also leads to improved manufacturing capabilities and a stronger manufacturing infrastructure (see Chapter 8). The continuous improvement of the developmental infrastructure is an important part of the path toward achieving the vision and strategic goals of the industry. This chapter informs and facilitates the continuous improvement of the developmental infrastructure by identifying the particular barriers and limitations to its effectiveness and determining the range of research, education, and other activities needed to overcome them.

Barriers & Limitations

A number of barriers and limitations in the developmental infrastructure prevent the automotive industry and its customers from realizing and expanding the full benefit of plastics in vehicles.

- The economic risk associated with innovation presents some limitations. Innovation typically requires significant upfront investment to cover the costs of research, testing, prototype development, and so on. The size of the investment and the uncertainty of the payoff make it difficult for single firms to bear and often exceed the risk threshold of senior management, particularly if the automotive industry is enduring financial challenges.
- The effectiveness of the developmental infrastructure is impaired by a lack of tools and data. Limited or incomplete material property data for some plastics and polymer composites and limited predictive engineering tools that incorporate those materials constrain the ability of automotive designers to model the performance of plastics. Such effective design tools are necessary for developing innovative material solutions in a cost-effective manner.
- The automotive value chain has historically had some difficulty in establishing collective problem-solving agendas, forming multidisciplinary partnerships, and maintaining cooperation and collaboration across tiers and firms. Without this type of integration and cooperation across the value chain, the industry's capacity for collective, system-level problem solving is significantly impaired.
- Recognition and rewards given to top talent "on the floor" and "at the bench" are limited, serving to de-motivate or undermine the creative energy and engagement of the individuals who, because of their high level of expertise and inventiveness, have the greatest capacity for innovation and creative problem solving.

Solutions

The automotive and plastics industries have generated a range of action items for public- and private-sector attention that offer potential solutions to the barriers described above and position this infrastructure as an asset on which to build toward the vision. These action items identify four general action agendas for maintaining and enhancing the innovation and creative problem-solving capabilities of the industry value chain in using and working with plastics and polymer composites.

- ***Develop enhanced predictive engineering tools and material property data for plastics and polymer composites.*** Improved tools and data enable more designers to explore more novel applications, reduce cycle time, and minimize costs of testing and prototype development. Thus, infrastructure effectiveness will be improved by research initiatives that produce more complete, reliable, and standardized data about the material properties of plastics under different conditions. Software and design tools with more complex computational mathematics that help designers more effectively apply material property data to predict the performance of plastics in specific applications will greatly enhance the effectiveness of the developmental infrastructure.
- ***Expand capacity for innovation in generating new automotive applications that leverage the properties and benefits of plastics.*** The developmental infrastructure can be strengthened

and become more effective by providing a capability to explore different approaches, techniques, or tools for using plastics in innovative ways, ultimately to stimulate creativity and inventiveness. Building more opportunities for collaboration into the innovation and problem-solving process and incorporating a more diverse set of skills, knowledge, and perspectives will improve the overall innovation capacity. Expanded capacity will also manifest itself through an increase in the scope of concerns, considerations, and issues that are the focus of the innovation and problem-solving efforts of the automotive and plastics industries. This focus includes material properties and processing R&D and engineering design.

- ***Increase motivation and engagement of top talent through appropriate recognition and rewards.*** By stimulating the inventiveness and creativity of the most talented individuals, especially design engineers with advanced knowledge and expertise in composite materials, the automotive and plastics industries can draw greater human resources to the pursuit of innovation. The human capital issues are focused less on education, training, and developing skills; rather, the focus is on revitalizing the people who already have the greatest capacity for innovation and creative problem solving through the use of plastics. Developmental infrastructure will be greatly enhanced by recognizing and appreciating individual mastery and creativity in regard to the use of plastics to solve pressing automotive challenges and to fairly reward success in such pursuits.
- ***Develop capacity for system-level problem solving.*** Creating an infrastructure that has the ability to bring diverse groups, skill sets, and industry stakeholders together to identify and address system problems within the automotive value chain can have powerful effects. Initiatives to establish a formalized process or coordinating entity that is responsible for industry-wide planning and cooperative problem solving is one approach to creating such a capability. The industry can measure success in this endeavor by monitoring initiatives to raise awareness, build common understanding, and stimulate interest and a sense of urgency around industry-wide issues.

Top Priorities

Within the action agendas described above, there are specific action items that are identified as top priorities for improving the developmental infrastructure and its realization of the enabling potential of plastics. These items are considered top priorities because of their high potential for significant impact. Depending on how these items are implemented, this impact may be broad in nature and involve a longer term commitment of energy and resources, or it may be more near term and serve to strengthen interest, enthusiasm, and commitment. The top priority action items for developmental infrastructure are listed below.

- Expand funding for public-private predictive engineering for plastics.
- Improve predictive software for composites through the use of more sophisticated computational mathematics.
- Conduct an industry gap analysis of the developmental infrastructure and implement a strategy and tactics to close the gaps.
- Improve academic and continuing education opportunities to develop and exercise systems thinking.
- Establish testing resources to determine and provide access to high-strain rate data and predictive engineering data.
- Partner with software companies to preload and continually update the physical property data of plastics into design software sold to OEMs.

8. Manufacturing Infrastructure

Manufacturing is a cornerstone of economies across the globe. For the United States, manufacturing has traditionally been a competitive strength. This is particularly true in the automotive industry as evidenced by the fact that many foreign automakers' leading U.S. models are being manufactured in the United States. An important component of the industry's strength in this regard is its operational capacity in using and working with plastics and polymer composites.

The manufacturing infrastructure is that part of the industry value chain that involves the processing of plastics and polymer composite materials and the manufacture and assembly of vehicle components, systems, modules, and finished vehicles that meet customer and societal requirements. The effectiveness of the manufacturing infrastructure is measured in a number of ways. At the most basic level, it is measured by the overall timeliness, cost effectiveness, and productivity of the manufacturing operations and the quality and reliability of its outputs. Effectiveness is also measured by the agility, robustness, and flexibility of the infrastructure and its ability to operate as an integrated whole.

For the automotive industry to realize the full potential of its manufacturing infrastructure, its capability in using and working with plastics must be maximized across the industry value chain. A strong manufacturing infrastructure also leads to a stronger developmental infrastructure (see Chapter 7). The continuous improvement of the manufacturing infrastructure is an important part of the path toward achieving the vision and strategic goals. This chapter informs and facilitates the continuous improvement of this infrastructure by identifying the particular barriers and limitations to its effectiveness and by determining the range of research, education, and other activities needed to overcome them.

A rebirth of state-of-the-art manufacturing in the United States is expected to be an important byproduct of ongoing investments in nanotechnology, biotechnology, and renewable energy. Transportation-related manufacturing will draw on these areas, but also contribute profoundly and directly to a revitalized manufacturing infrastructure.

Barriers & Limitations

Today's constraints within the manufacturing infrastructure create barriers that prevent the automotive industry from realizing the full benefit of plastics and polymer composites. These barriers provide a useful picture of the challenges involved in maintaining and enhancing the operational capability of the industry value chain in using and working with plastics.

- Several barriers and limitations are associated with the material properties and manufacturing processes. To a large extent, the infrastructure is inhibited by entrenched practices that do not maximize the value and benefits of plastics and polymer composites because those practices have evolved primarily with metals in mind.
- The infrastructure is inhibited by a lack of uniform standards, performance specifications, and quality criteria for the use of plastics in automobiles. The current inconsistencies make quality assurance more challenging than it needs to be.
- The limited skill base of the infrastructure pertaining to plastics and composites is also limited across the entire automotive value chain, particularly the availability of engineering knowledge and expertise. This limitation constrains the degree to which the automotive value chain can be fully integrated and optimized.
- The effectiveness of the manufacturing infrastructure is inhibited by business and market dynamics that impair cooperation and cause difficulties in supply chain integration, creating resistance to change and sometimes inhibiting capital investments in needed infrastructure.
- The plastics/automotive infrastructure is limited by the present capital in place centered around metals.

The identification and specification of these barriers and limitations are important because they provide a context for identifying action priorities and serve as targets, focuses, and purposes for action initiatives.

Solutions

The automotive and plastics industries have identified a range of potential solutions to the barriers described above and position this infrastructure as an asset on which to build to achieve the vision. Five general action agendas have emerged for maintaining and enhancing the operational capability of the industry value chain in using plastics and polymer composites to their fullest potential.

- ***Enhance the operational components of the manufacturing infrastructure through process and material innovation.*** These operational

components may be distributed throughout the value chain and include material processing technologies, tooling, manufacturing techniques, and assembly processes and operations. The effectiveness of the manufacturing infrastructure will be enhanced by research and development efforts that produce new innovations in both materials and operations. Creating new ways of manufacturing components, systems, and vehicles and learning lessons from other industries that have successfully innovated using plastics can also enhance the effectiveness of the infrastructure. Particular areas of focus include adhesives and joining techniques, painting processes, and mass customization.

- ***Standardize operational specifications and performance requirements for plastics performance in different applications under a variety of conditions.*** The characterization and standardization of operations and outputs of the manufacturing infrastructure are important both to maintaining quality control and to improving communication and integration across the supply chain. Thus, the effectiveness of the manufacturing infrastructure will be enhanced by generating cross-industry initiatives to establish uniform guidelines or standards, by creating materials and guides that disseminate these standards, and by developing methods to monitor and assess performance against the standards.
- ***Develop infrastructure skill base to expand expertise and capability to work with plastics and composite materials.*** While the first two agendas focus on methods improvement, this area addresses the management of human capital. For the manufacturing infrastructure, the human capital issue is primarily about the training and development of the current and future workforce. Improvements in the quality of science and technology education, starting at the high school level and continuing on into colleges and universities, can help expand a globally competitive manufacturing infrastructure skill base. Specific activities may include encouraging advocacy for curriculum improvements, creating mentoring programs and internships, and supporting initiatives that encourage interest in polymer composite material science (e.g., through scholarships). Additionally, a standardized personnel development program around plastics processes (e.g., injection molding), as well as standard courses with certificates for employees who want to stay with the industry and improve their capabilities/ marketability, could be established.
- ***Develop strategy to improve tooling design and manufacture expertise***. While much of the tooling design work continues to be done within the United States, tool manufacturing is moving overseas to low labor-cost regions. In the long term, however, this may cause tooling design to also be moved overseas which would hinder U.S. leadership in tooling innovation and eventually lead to more components being manufactured overseas. A focused strategy to improve tooling design and manufacturing expertise can reverse this trend and maintain the strength of the manufacturing infrastructure in this regard. This initiative could be considered a specific target within the larger agenda of developing the infrastructure skill base.
- W***ork with government to improve capital asset turnover.*** The development of operational and manufacturing capabilities with the automotive industry is impaired by entrenched capital assets that are expensive to replace. The effectiveness of the manufacturing infrastructure would be enhanced by initiatives to inform and work with governments to stimulate capital asset turnover in the industry value chain. This could be done with governmental incentives, such as accelerated depreciation. Key activities would include the development of a compelling argument about how this cooperative effort would serve the public good in terms of creating jobs, leveraging the environmental advantages of plastics, etc.

Top Priorities

Within the action agendas described above, there are specific action items that are identified as top priorities for improving the manufacturing infrastructure and its realization of the enabling potential of plastics. These items are considered top priorities because of their high potential for significant impact. Depending on how these items are implemented, this impact may be broad in nature and involve a longer term commitment of energy and resources, or it may be more near term and serve to strengthen interest, enthusiasm, and commitment. The top priority action items for manufacturing infrastructure are listed below.

- Conduct R&D on the assembly and joining of plastics and metals.
- Develop a high-volume manufacturing and assembly process that is friendly to mixed materials.
- Work with schools and engineering degree programs to restructure their programs to add more plastics-related curricula.
- Develop case studies focusing on part integration to clarify manufacturing advantage.

9. The Road Ahead

This document presents a strategic roadmap for the development of an automotive industry that remains competitive and prosperous in the global marketplace. The central theme and message of this roadmap is that future competitiveness and prosperity depends on the ability of the automotive industry to be truly innovative in the pursuit of market position and to effectively leverage 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 industry that is nested within the supply chain of the greater automotive industry. Given the critical role of plastics and polymer composites, it is important for the automotive and plastics industries to take the lead in creating a more integrated and cooperative automotive value chain and to spearhead efforts to develop the automotive industry's capacity and effectiveness in leveraging the full potential of plastics.

Implementation

Appendix A contains one-page "getting started" outlines for 12 of the top priority action items identified at the end of Chapters 5–8. There are outlines for one or more top priorities in each of the four areas discussed previously: sustainability, performance and aesthetics, developmental infrastructure, and manufacturing infrastructure. The purpose of these one-page outlines is to catalyze industry-level dialogue and planning around the implementation of this roadmap.

Each outline provides a more detailed description of the action item and the benefits that its implementation may achieve. The outlines also discuss opportunities for collaboration and identify roles for key stakeholders. Finally, each outline identifies steps for getting started. While not a complete action plan, the description of the initial steps is intended to provide a "jump-start" for an implementation initiative focused on the identified action item.

The presentation of these outlines entails three assumptions:

1. The oversight, coordination, and leadership for implementation efforts will come initially from the ACC PD. 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, supplier groups, universities, national laboratories, government, and other stakeholders. On the other hand, there needs to be a central entity that coordinates the participation of multiple partners and maintains the focus and energy of the implementation effort. ACC PD, recognized globally, is well positioned to take on this initial role.
2. Only a subset of these action items will be implemented at any one time. It is simply not possible to maintain a focused and energized implementation effort across 12 different fronts. The reason for presenting all 12 is to create a wide range of options for engaging stakeholder interest and support. Because the automotive industry is a cornerstone of the U.S. economy, a diverse collection of institutions, groups, and organizations have a stake in its continued success. It is therefore important to offer the broadest possible array of opportunities for participation.
3. This is a North American authored and focused effort, but it has global implications. It is assumed that the global inputs required to implement this roadmap will be provided by member companies and automotive contributors that operate at a global level. In other words, it is assumed that these companies will use their global presence to implement the roadmap priorities.

Appendix A: Brainstorm Sessions on Top-Priority Items

The following pages present one-page "getting started" outlines for 12 of the priority action items identified at the end of Chapters 5–8. Each outline provides a more detailed description of the action item and the benefits that its implementation may achieve. The outlines also discuss opportunities for collaboration and identify roles for key stakeholders. Finally, each outline identifies steps for getting started.

It is important to note that even though these outlines identify steps for getting started, they are not intended to be action plans. Rather, they are intended to catalyze industry-level dialogue and planning around the implementation of this roadmap and to provide a "jump-start" for implementation initiatives.

It should be noted as part of a focused effort on automobile plastics safety research, the National Highway Traffic Safety Administration (NHTSA) has under development a *Plastics and Composites Intensive Vehicles (PCIVs) Safety Roadmap* with support from ACC's Plastics Division. This specialized roadmap focuses on the potential safety benefits of PCIVs that will enable their deployment by 2020. Existing PCIV-related safety knowledge was reviewed and assessed to identify gaps, key research needs, and the challenges and opportunities for safety enhancements. The initial result identifies near-term, mid-term, and long-term research needs and priorities to facilitate the design, development, and future deployment of fuel efficient and safe PCIVs. The Safety Roadmap for Future PCIVs emphasizes the plastics industry's ongoing commitment to safety—an effort on which *ACC's Plastics in Automotive Markets Technology Roadmap: A New Vision for the Road Ahead* seeks to build.

The recommended action priorities for implementing *Plastics in Automotive Markets Technology Roadmap: A New Vision for the Road Ahead* are as follows:

- Conduct R&D on the assembly and joining of plastics and other materials
- Develop a high-volume corrosion prevention process, friendly to mixed materials, which prevents steel corrosion
- Translate plastics processing approaches from other industries to the auto industry
- Improve predictive software for composites through the use of more sophisticated computational mathematics
- Partner with software companies to preload plastics physical property data into design software for OEMs
- Conduct an industry gap analysis and establish a governing mechanism responsible for the development of a strategy and appropriate response
- Conduct R&D to better understand the effect of vehicle weight and vehicle size on safety
- Communicate the economic impact of the plastic industry to all levels of government and increase plastics industry education targeted to regulators, representatives and/or members of Congress
- Demonstrate the safety profiles of composite and plastic structures and publish the results
- Produce a life cycle analysis of the environmental advantages of plastics versus other materials (including carbon footprint)
- Create a plastic concept prototype that showcases a "plastics" solution to a key OEM problem
- Initiate a partnership between paint suppliers and plastic companies to develop low-temperature paints, providing OEMs with energy savings

Action Priority

Conduct R&D on the assembly and joining of plastics and other materials

Description

- Steel is likely to be a viable material for certain automotive components, so there is a need for a joining process that maintains durability and adequate structural integrity
- Joining can also be an issue between different types of plastics and polymer composites
- R&D could focus on adhesives, welding, mechanical joining, and/or advanced design techniques (e.g., over molding)

Potential Impacts

- Broader use of multi-materials in automotive components
- Increased styling options for vehicles over what is possible with metals
- Increased market growth/penetration for plastics applications (particularly re aesthetics)
- Creation of a standard for the melding of diverse materials to decrease anxiety and concern around melding and using melded parts
- Increased potential for modularization and decreased complexity through integration of parts
- Decreased manufacturing costs and carbon footprint
- Greater flexibility and options for repair and replacement when vehicle is damaged
- Improved ability to recover and recycle parts

Steps for Getting Started

- Study quality issues and assess infrastructure barriers
- Identify unmet needs, and specify components or applications of interest and determine materials involved
- Define requirements for these components or applications and collaborate with OEMs to create performance specifications
- Develop business model of impact, potential return, ownership, promotion, etc. for joining innovations
- Develop R&D strategy that deploys best innovators, engages partners, and is in line with the incentives, opportunities, and limitations identified in the business model
- Develop validation process for joining innovations that is aligned with performance specifications
- Identify strategy and partners to create and capitalize on promotional opportunities for new innovation

Opportunities for Cooperation

- Partnering with adhesives companies and plastics material suppliers around development of new processes and products
- Developing partnerships with automotive metal firms/associations (steel, aluminum, etc.)
- Cooperating with paint suppliers to develop compatible processes that are more integrated into the manufacturing process and result in a more seamless infrastructure

Roles

Auto OEMs

- Define environment and technical specifications
- Create pull for innovation
- Develop for future architects
- Perform validation at the end

Auto Tiers

- Identify which systems or subsystems would benefit
- Act as leaders for technique development
- Identify most promising and design-enhancing areas for joining

ACC PD and Resin Providers

- Discover formulation solutions
- Demonstrate willingness to adjust

Government

- Enable alternative technique R&D (through recycling stage)
- Share cost
- Provide durability prediction tools and testing

National Labs & Universities

- Provide durability prediction tools and testing
- Provide expertise
- Work on basic chemistry changes required

Action Priority

Develop a high-volume corrosion prevention process, friendly to mixed materials, which prevents steel corrosion

Description

- The present corrosion prevention process (phosphate/e-coat) requires temperatures and other conditions that are usually incompatible with the use of plastics/polymers, as well as other materials used in body-in-white applications.
- Steel will always be a viable material for certain automotive components so there is a need for increasing compatibility of steel and plastic composites
- This is an important innovation for the manufacturing infrastructure that will improve flexibility and productivity within the supply chain

Potential Impacts

- Use of plastics and other lightweight materials as main structural elements in a vehicle
- Significant changes that enable higher plastic content
- Lower energy use in manufacturing (through use of lower heat processes)
- Use of alternate materials that are more sustainable in vehicles
- Greater achievement of lightweighting goals that lower emissions and raise fuel economy

Steps for Getting Started

- Develop an understanding of what other steel corrosion prevention processes could be used
- Identify the parameters of the phosphate process (temperature, chemical interactions, etc.) compared to the other processes
- Compare potential process parameters with capabilities of present plastics
- Assess and identify potential improvements, to both the preferred process and the high-potential (promising) plastics, which could make the process more plastics friendly

Opportunities for Cooperation

- Cooperation between OEMs, steel manufacturers, and plastics manufacturers to develop a new body manufacturing process
- Strong participation from coatings companies, led by OEMs or an OEM research consortium

Roles

Auto OEMs

- Potentially lead efforts (or an OEM research consortium)
- Help fund

Auto Tiers

- Coatings firms supply the alternative technology and participate in scoping (since they perform product development)
- Steel companies provide feedback

ACC PD and Resin Providers

- Plastics providers provide input and/or feedback

Government

- Help fund, possibly in a joint effort with OEMs and other stakeholders

National Labs & Universities

- Develop alternative corrosion processes
- Identify fundamental polymers and polymer properties that could be enhanced for an alternate corrosion prevention process

Action Priority

Translate plastics processing approaches from other industries to the auto industry

Description

- This involves examining innovative plastic processing technologies used in other industries and determining whether and how they can be adapted for the auto industry and fit into the industry's production model-process needs to be consistent with the manufacturing platform, cost effective, and enable high volume
- The plastics processing approaches of industries such as aerospace, personal watercraft, etc. should be studied
- The plastics processing approaches to be studied should include low volume to high volume and intelligent databases
- This also requires the development/deployment of a validation process for approaches, technologies, and innovations that might be transferred

Potential Impacts

- Development of new plastics processing approaches, which enable new, clean-slate product design options, material substitution, and enhancement of existing products
- Decreased innovation cost and incidence of "reinventing the wheel"
- Faster innovation process

Steps for Getting Started

- Identify areas of plastics processing where there is a great need or potential for improvement, and specify key parameters, functional requirements, issues, barriers, etc.
- Develop a list of innovative, high-performing industries that are likely to have new and better approaches for plastics processing
- Develop a model or template for developing a business case and/or cost study to justify the testing and/or adoption of any new approaches
- Develop a case study approach and evaluation protocol to ensure that observation/study of other industries is consistent, comprehensive, effective, and efficient (e.g., is able to quickly identify barriers and determine whether or not they are prohibitive)
- Create a multi-disciplinary team to conduct case studies and evaluations

Opportunities for Cooperation

- Participation of ACC Plastics Division Members

Roles

Auto OEMs	Auto Tiers	ACC PD and Resin Providers	Government	National Labs & Universities
▪ Provide requirements ▪ Share development burden ▪ Facilitate or enable systems integration	▪ Serve as an enabler of new approaches ▪ Help with testing and validating	▪ Help with materials development and tuning ▪ Help determine feasibility and aid adoption of existing technique	▪ N/A	▪ N/A

Action Priority

Improve predictive software for composites through the use of more sophisticated computational mathematics

Description

- This involves optimizing/refining existing tools (methods and software) to enable computational prediction and modeling with plastics
- The challenge is that plastics are very complex-there are unknown variables and interactions of composites
- Understand scope and present state of knowledge-characterization of raw materials, manufacturing process, and ultimate performance
- Look at a range of materials and processing techniques, not just long-fiber orientation in injection molding
- Need to understand application-specific performance characteristics such as fatigue, creep, stiffness, strength, impact, and weatherability
- Structure-property-processing (SPP) drives computational process engineering (CPE); CPE provides an architectural assessment and fundamentally changes the architecture

Potential Impacts

- Increased acceptance of engineering with plastics
- Increased ability of OEMs to design with plastics
- New opportunities for market growth/penetration, such as more plastic-specific OEM designs and expanded use of plastics in vehicles
- Improved quality and reduced failure; lower risk and warranty costs
- Shortened design cycle, elimination of prototypes, and reduced testing costs, which all help increase speed to market
- Improved reputation for plastics, due to adequate characterization

Steps for Getting Started

- Define systems of interest (e.g., sealing system) and identify key problems to solve (should be done by working with collaborative partners)
- Define benefits and develop precompetitive proposal
- Understand performance requirements and develop test plan-figure out what work needs to be done to fully test (validation)
- Identify software suppliers who have the expertise to make software improvements and capability to produce, market, and distribute software (look at other industries)
- Identify universities, labs, etc. that have the expertise to conduct the materials research and develop predictive data for plastics

Opportunities for Cooperation

- Determining which methods work through use of university, national lab, and industry expertise (involving these groups could enhance modeling capability)
- Improved communication between government, OEMs, and academic institutions would benefit cooperative efforts
- OEMs/global automotive industry would benefit from participation

Roles

Auto OEMs

- Understand performance requirements
- Identify key problems
- Provide design guidance and market pull
- Develop future vehicle architectures

Auto Tiers

- Same role as OEMs, but a narrower view
- Utilize data and software in component design
- Provide precompetitive collaboration

ACC PD and Resin Providers

- Contribute to material properties database
- Provide raw data re materials and material science expertise
- Share cost (e.g., sweat equity)

Government

- Provide funding and share cost
- Encourage participation of national labs
- Includes NSF and other agencies

National Labs & Universities

- Provide technical expertise and serve as potential research partners
- Determine modeling fundaments and conduct fundamental research
- Provide computing and modeling (national labs)

Action Priority

Partner with software companies to preload plastics physical property data into design software for OEMs

Description

- Establish a non-compete partnership or contractual relationship with specific software vendors to integrate standardized material data re plastics into design software used by OEMs
- Key challenge is that software vendors are not likely to participate unless this upgrade is valued by the OEMs
- Other challenges include: determining the scope of information and materials to be included; locating the needed data (which may not exist in an easily accessible form); and achieving stakeholder consensus on physical data to be used

Potential Impacts

- Steel is no longer the default material choice in programs
- Inherent marketing of plastics (in software)
- Reduced cycle time with plastics
- Increase in designers making a more conscious material choice early on and beginning experimentation with different materials
- Increased innovation of OEM designs and more reliable and successful use of plastics
- For OEMs, reduction of run size due to not being restricted by huge steel setup costs
- Enhanced credibility of the plastics industry and development of industry capability through standardized material data

Steps for Getting Started

- Approach software firm(s) to open dialogue and build buy-in
- Form partnership between ACC and software vendor(s) and approach OEMs; goal is to convince/generate interest in at least one OEM
- Work with software vendor to begin to establish specs and identify standardization issues
- Solicit OEMs to provide requirements & specs that they need integrated into software
- Begin to build standardized material property data
- Establish within industry a process for selecting physical data

Opportunities for Cooperation

- Building a mutually beneficial alliance with software vendors
- Involving universities as third-party testers who lend credibility to data
- Creating greater cooperation and a more unified front as an industry as members give support and agreement to standardized material data
- Involving ISO and getting European firms to integrate their data and create global standardized material data
- Working with Tier 1 suppliers in building standardized data

Roles

Auto OEMs	Auto Tiers	ACC PD and Resin Providers	Government	National Labs & Universities
▪ Provide requirements and specs for software ▪ Encourage software vendors to upgrade software (i.e., provide market pull)	▪ Provide buy-in re standardized data and share models, expertise, and information (Tier 1s have a stake in this too)	▪ Be willing to seek standardization in favor of greater "pull" and competitiveness at an industry level	▪ N/A	▪ Provide third-party testing and some leg work and labor re developing standardized data

Action Priority

Conduct an industry gap analysis and establish a governing mechanism responsible for the development of a strategy and appropriate response

Description

- The gap analysis should identify where industry is today and where we want it to be re vehicle performance, aesthetics, and sustainability (consider global market)
- The gap analysis should then identify system level gaps, holes, and barriers to industry competitiveness and achievement of vehicle performance, aesthetics, and sustainability targets
- Conducting this analysis also involves establishing a governing body and charter of OEMs and tiers that has credibility and acceptance, and that has the capability and systemic vision to understand and address system-level gaps, holes, and barriers
- The charter is to study, prioritize, and develop a strategy to deal with the system level gaps, holes, and barriers

Potential Impacts

- Greater industry competitiveness
- Better cars, superior products
- More effectiveness with available resources
- Increased innovation-more focused R&D, less redundant R&D
- More lightweight plastic and composite intensive vehicles (PCIVs), resulting in lower fuel consumption and carbon emissions
- Better industry-wide understanding and use of plastics

Steps for Getting Started

- Agree on a gap analysis template/tool
- Agree on the elements of the analysis (which are essentially the output of this roadmap exercise)
- Invite marine, aerospace, construction, and energy decision makers to contribute
- Identify the makeup, charter, and operating requirements of the governing/orchestrating entity (develop website, communication channels, meeting logistics and schedule, etc.)
- Develop a marketing/lobbying effort to build and maintain energy and support
- Build on/explore synergy with NHTSA-led PCIV Safety Roadmap

Opportunities for Cooperation

- Participation in governing/orchestrating body provides an opportunity for industry-wide collaboration to improve future competitiveness
- Designing the makeup and charter of the governing body requires cooperation among industry leaders at all points along the supply chain
- Working/coordinating with marine, aerospace, and construction

Roles

Auto OEMs	Auto Tiers	ACC PD and Resin Providers	Government	National Labs & Universities
▪ Contribute/generate end-user requirements re maintaining competitiveness in global market (strategic)	▪ Generate tactical requirements	▪ Contribute input (they have the most at stake) ▪ Educate everyone else and initiate effort ▪ Orchestrate effort—need an organization to do this (e.g., "University of Plastics")	▪ Encourage carmakers to work together ▪ Orchestrate multiple industries and provide a 50-year plan for the nation	▪ Provide training and precompetitive knowledge creation

Action Priority

Conduct R&D to better understand the effect of vehicle weight and vehicle size on safety

Description

- Need to understand independent effect of weight on safety and independent effect of size on safety-can we make big vehicles lighter and lighter vehicles safer?
- Must consider all the different vehicle size/weight possibilities-1) light and small, 2) heavy and small, 3) light and large, 4) heavy and large-and body structures (e.g., unibody construction)
- Need to better understand compatibility issues in vehicle-to-vehicle crashes
- Need to explore how to minimize damage to vehicle and occupants (this is a key variable/parameter in the research)

Potential Impacts

- Better understanding of the tradeoffs of lightweight vs. safety
- Better understanding of the implications of lightweighting
- Identification of other passive safety improvements
- Improved ability to produce large cars that are lighter and more sustainable
- Improved ability to optimize performance, safety, and sustainability of auto industry
- Expanded use of plastics in vehicles-market growth/penetration

Steps for Getting Started

- Design experiment necessary to independently assess weight and safety
- Identify from the present fleet of light-duty vehicles the vehicles that represent the range of vehicle size/weight types and body structures, or build prototypes if necessary
- Carry out crash tests that involve collisions of all possible combinations of vehicle size/weight and report results

Opportunities for Cooperation

- Conducting crash tests and measuring results with government and the insurance industry

Roles

Auto OEMs
- Recipient of data

Auto Tiers
- N/A

ACC PD and Resin Providers
- Recipient of data

Government
- DOT/NHTSA lead and fund efforts

National Labs & Universities
- N/A

Other
- Insurance industry can help design experiments, set test parameters, supply data on insurance benefits/impacts

Action Priority

Communicate the economic impact of the plastic industry to all levels of government and increase plastics industry education targeted to regulators, representatives and/or members of Congress

Description

- Educate legislators and regulators to give them greater understanding and awareness of larger consequences of vehicle and material legislation
- Plastics industry should explore what is available and how to leverage existing programs/policies
- Work at state and local level, build to federal level
- Connect with legislators that have major plastics industry players within their constituencies
- Include all elements of plastics industry (resins, processors)

Potential Impacts

- Promotes smarter and more effective legislative/regulatory action
- Impact on entire plastics industry (broader than automotive applications)
- Development of new technology and a capability to expand economic growth/jobs
- Fewer barriers and reduced industry fragmentation
- Greater government funding for plastics research and development of tools and datasets as legislators recognize value of basic research and resources
- Increased confidence in engineering with plastics to the same degree as metals

Steps for Getting Started

- Hold cooperative meeting of all plastics associations (e.g., ACC PD, SPI, ACMA, SPE)
- Research what programs/policies are currently available and decide which agencies to approach (e.g., DOE, DOT, DOC, etc.)
- Aggregate information/data from all trade associations (e.g., what is impact of plastics on legislators' districts-from all areas impacted by plastics in any way [e.g., plastic producers, manufacturers, suppliers, users])
- Put together communication devices; coordinate package; identify members of congress
- Decide which associations should contact who; devise a plan; determine who takes lead

Opportunities for Cooperation

- With associations: SPE (Society of Plastics Engineers), SPI (The Society of the Plastics Industry), ACMA (American Composites Manufacturing Association, National Composites Center, SAMPE (Society for the Advancement of Material and Process Engineering)

Roles

Auto OEMs	Auto Tiers	ACC PD and Resin Providers	Government	National Labs & Universities
▪ Obtain supporting data to demonstrate need for plastics ▪ Reinforce importance of plastics	▪ Similar to OEMs	▪ Initiate communication with their trade associates (may be multi-pronged approach to contacting legislators-high-profile company lead and ACC)	▪ Recognize benefit that plastics bring to countries	▪ Obtain government funding

Action Priority

Demonstrate the safety profiles of composite and plastic structures and publish the results

Description

- There are conflicting opinions, misconceptions, and erroneous assumptions around the safety of plastic/polymer composite structures in vehicles
- There is also a lack of concrete data and study results that specifically consider thermoplastics as an enabler in body structure
- In designing the research, need to consider how consumer demand will drive the features and qualities of future vehicles as well as the increasing importance of the sustainability benefits of plastics
- It is important to not only produce the results, but also to publish and promote them to begin to correct people's assumptions and misconceptions

Potential Impacts

- Decrease in the misperceptions and erroneous assumptions about plastic's lack of safety
- Increased perception of the whole life-cycle benefit of plastics and increased market pull for lighter, more fuel-efficient plastic and composite intensive vehicles (PCIVs)
- Removal of a key barrier to the use of plastics in vehicles and elevation of the ceiling on the total plastic content of vehicles
- Expanded use of plastics in vehicles
- Greater sustainability for vehicle and market growth/penetration for plastics

Steps for Getting Started

- Identify and prioritize key audiences (where improved understanding and factual knowledge will have the most impact)
- Identify the research, data (e.g., high strain rate crash, temperature conditions), and/or other demonstration tools and content that will be most compelling to different audiences
- Design the research and data collection program (data collection enabled by computational process engineering [CPE])
- Develop a strategy to produce other demonstration tools and content as needed to effectively demonstrate component-level feasibility
- Develop a strategy to communicate results in a way that maximizes impact on audiences

Opportunities for Cooperation

- With the Automotive Composites Consortium Crash Energy Group (involved in similar activities)
- With DOT (cooperation is important and could be established through ACC PD)
- Research with the American Society of Body Engineers (ASBE) (could provide credibility)

Roles

Auto OEMs	Auto Tiers	ACC PD and Resin Providers	Government	National Labs & Universities
▪ Increase receptiveness to new data that may challenge assumptions ▪ Act on demonstration data in vehicle design ▪ Drive architectural changes	▪ Participate/work together on effort to build, test, and demonstrate	▪ Provide materials and materials development	▪ Provide funding ▪ Provide communication forums or venues ▪ Validate results	▪ Conduct fundamental research

Action Priority

Produce a life cycle analysis of the environmental advantages of plastics versus other materials (including carbon footprint)

Description

- Requires a cradle-to-grave analysis of plastics vs. metals (especially steel) in the automotive market
- It is important to produce comparable results that are credible and authoritative
- May need to limit scope to specific plastic or metal applications
- Define boundary conditions (e.g., renewable vs. nonrenewable; powertrain options)

Potential Impacts

- A common and clear understanding of the auto industry's potential re sustainability performance and outcomes
- Broadened public support for plastics
- Better targets for achieving sustainable performance
- Mitigation or elimination of the fragmented, non-optimized, piecemeal approaches to improving sustainability performance of the industry and vehicles it produces
- Maximized sustainability performance of industry processes and products
- Improved environment for future generations

Steps for Getting Started

- Define basis of life cycle (e.g., energy, CO_2 generation, etc.) and the boundary conditions and underlying assumptions
- Gather data on each cycle in the life of each material (raw materials gathering, manufacturing, use, recycling/recovery, and disposal)
- Conduct analysis
- Communicate results

Opportunities for Cooperation

- (none identified)

Roles

Auto OEMs	Auto Tiers	ACC PD and Resin Providers	Government	National Labs & Universities
▪ Supply data	▪ Supply data ▪ Includes, in particular, steel, aluminum and magnesium suppliers	▪ Supply data	▪ Lead ▪ Manage special interests of groups ▪ Serve as arbitrator	▪ Generate data ▪ Perform analysis

Action Priority

Create a plastic concept prototype that showcases a "plastics" solution to a key OEM problem

Description

- Prototype needs to be at a level of complexity that is more than a simple component and less than a complete plastic vehicle (fully plastic car may not be credible)
- Prototype needs to showcase/demonstrate a specific benefit, or set of benefits, derived from using plastics in this application
- Prototype should be targeted at specific perceptions (misperceptions) about plastics held by OEMs, tier suppliers, government, or general public
- Key challenge is consensus and buy-in of ACC members-prototype showcases industry capabilities and benefits
- Includes development of a multi-function educational and promotional tool that has a "wow" factor and can be used in multiple ways with multiple audiences

Potential Impacts

- Increased OEM acceptance of new possibilities and understanding of misconceptions about plastics
- Change in OEM paradigm that only considers material after the design is completed
- Increase in OEM designers questioning metal-biased assumptions and designing conventions
- Decreased resistance to plastics caused by lack of knowledge, misperceptions, and preconceptions

Steps for Getting Started

- Determine the primary audience, target perceptions, and primary properties/benefits to be demonstrated-must consider key "tip points" for OEMs and what will have the most "wow" factors
- Determine how, or in what venue/forum, the prototype will be best used and/or have the most impact (traveling display, permanent exhibit, etc.)
- Specify the component to be prototyped (window, seat structure, chassis component, etc.) and how it demonstrates the identified properties/benefits
- Identify molders and tier suppliers who have most/least to gain and enlist aid of those who stand to benefit the most to form a partnership to drive prototype development
- Identify who can create the prototype since the capability to do so may not be common

Opportunities for Cooperation

- The initial steps of determining the benefits to showcase, the primary audience, the nature of the prototype, etc.
- With national labs (they have a potential engineering role)
- With the insurance industry; if the prototype changes the repair scenario
- With tier suppliers; if they are involved in creating the prototype

Roles

Auto OEMs	Auto Tiers	ACC PD and Resin Providers	Government	National Labs & Universities
▪ Provide the forums/venues for demonstrating or displaying prototype (e.g., lobbies, management meetings, etc.)	▪ Help create the prototype or provide advice/input re the prototype (third-party engineers)	▪ Be willing to agree on a prototype	▪ Provide the forums/venues for displaying the prototype and demonstrating U.S. ingenuity	▪ Provide input to the development of the prototype and the forums/venues for displaying the prototype

Action Priority

Initiate a partnership between paint suppliers and plastic companies to develop low-temperature paints, providing OEMs with energy savings

Description

- High temperatures in the OEM paint process (e-coating) greatly restrict the range of plastics that may be used—need lower temperature curing paints for a lower-temperature e-coat and top coat
- The incentive or benefit of this for OEMs and tiers is in the energy savings that comes from a lower temperature process

Potential Impacts

- Reduced number of paint formulations required
- Elimination of a key obstacle to the introduction of new plastics—this is a showstopper to many plastics
- Increased opportunity for thermoplastics and thermosets (integrated impact shields, rear tubs, etc.)
- Expanded use of plastics in vehicles
- Greater functionality and aesthetic performance for the vehicle, market growth/penetration for plastics, and improved competitiveness for the automotive industry

Steps for Getting Started

- Identify the temperature ranges for various plastics and establish a target range that has the best cost/benefit result for all concerned (OEMs, paint suppliers, plastics industry)
- Develop a compelling case for paint suppliers and enlist OEMs to create pull for paint suppliers
- Get existing paint suppliers to the table along with OEMs and plastic representatives; describe individual benefits and mutual interest, and establish a consensus that this is an objective

Opportunities for Cooperation

- With the coatings industry
- With OEMs and tier suppliers to convince paint suppliers that this is in best interests of the auto industry as a whole
- With DOE to lower energy consumption in paint line and enable lightweighting of vehicles

Roles

Auto OEMs	Auto Tiers	ACC PD and Resin Providers	Government	National Labs & Universities
▪ Create the pull on painting firms ▪ Help establish this as an industry objective ▪ Help validate the solutions	▪ Help create pull for painting firms ▪ Help develop the lower temperature coatings system	▪ Identify which plastics can be used at which temperatures	▪ Underwrite this development for energy savings and lightweighting (DOE) ▪ Create pull on painting firms	▪ Conduct basic research re coating and painting

Appendix B: Roadmap Contributors

Plastics in Automotive Markets Technology Roadmap Steering Committee

Michael Day	DuPont
Mary Fraser	BASF Corporation
James Kolb	ACC Plastics Division
Martin Levine	ExxonMobil Chemical Company
Donald Little	The Dow Chemical Company
Paul Platte	Bayer MaterialScience
Josh McIlvaine	DuPont
Don Schomer	Bayer MaterialScience

Participants in Automotive Strategy Workshop

Bruce Benda	Bayer Material Science
Michael Brylawski	Rocky Mountain Institute, Inc.
Howard Cox	General Motors
Jay Dias	ExxonMobil Chemical Company
Cliff Eberle	Oak Ridge National Laboratory
Michael Fisher	ACC Plastics Division (retired)
Mary Fraser	BASF Corporation
William Hollowell	WTH Consulting, LLC
James Kolb	ACC Plastics Division
Martin Levine	ExxonMobil Chemical Company
Donald Little	The Dow Chemical Company
Christopher Murphy	DuPont
Mark Murphy	Dow Automotive
John Myers	Chrysler LLC
Paul Platte	Bayer MaterialScience
Tony Posawatz	General Motors
Dwight Rust	National Composite Center
Rose Ryntz	International Automotive Components Group
Karyn Schmidt	American Chemistry Council
Joe Venner	BASF Corporation

Participants in Automotive Roadmapping Workshop

Eduardo Alvarez	PolyOne
Jay Baron	Center for Automotive Research
John Brewer	US Department of Transportation, Volpe Center
Dale Brosius	Brosius Management Consulting
Paul Burke	ExxonMobil Chemical
Joseph Carpenter	US Department of Energy
Paul Chalmer	National Center for Manufacturing Sciences
Howard Cox	General Motors
Mike Day	Dupont
David Dyke	Meridian Auto Systems
James Economy	University of Illinois
Fran Elenbaas	Johnson Controls, Inc.
Darin Evans	NetShape
Mary Fraser	BASF Corporation
Norm Kakarala	Inteva Prodcuts
Nikolas Kaprinidis	Ciba
Max Kismarton	The Boeing Company
James Kolb	ACC Plastics Division
Donald Little	The Dow Chemical Company
Lou Luedtke	National Composite Center
Pankaj Mallick	University of Michigan, Dearborn
Peter Manders	ExxonMobil Chemical
Dave McLeod	Dow Automotive
Robert Mora	Battelle
Bob Norris	Oak Ridge National Laboratory
Doug Pickett	General Motors
Thomas Reiter	Bayer MatrialScience, LLC
Don Schomer	Bayer MaterialScience, LLC
Roger Shulze	University of Michigan, Dearborn
Ahmed Soliman	Ohio State University
Micheal Taylor	Ashland Distribution Company
Carrie Van Ess	Magna Internation, N.A.
Andreas Weller	Webasto Roof Systems, Inc.
Steve Willis	Krauss-Maffei Corporation
Phillip Wilson	BASF Corporation
Johanne Wilson	Ciba
Brian Winicki	Ashland Distribution Company
Matt Zaluzec	Ford Motor Company

American Chemistry Council

Plastics Division
Automotive Center
1800 Crooks Road
Troy, MI 48084
Phone: (248) 244-8920
www.americanchemistry.com/plastics-car