

PLASTICS MARKET WATCH

A SERIES ON ECONOMIC-DEMOGRAPHIC-CONSUMER &
TECHNOLOGY TRENDS IN SPECIFIC PLASTICS END MARKETS

WATCHING:

Automotive



**Automotive
Recycling**
Devalued is now
Revalued.

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Automotive Recycling: Devalued is now Revalued



Introduction

Closing the loop on auto plastics: Growing opportunities for use of recycled content and recovery

Last year, SPI initiated the Plastics Market Watch series to study the economic, demographic, consumer and technology trends in specific plastics end markets. SPI published four reports: Automotive & Transportation, Plastics in Healthcare & Medical Devices, Plastics in Packaging, and Plastics in Building & Construction.

The series provides our members—and the plastics industry at large—with forward-looking reports that blend economic and demographic data to paint the landscape plastics facing in key sectors.

For the first issue of 2016—Automotive Recycling—we provide an extension and further analysis of the Automotive & Transportation report, while drilling down on a specific area that many SPI members are involved in: recycling plastics, moving toward zero net waste manufacturing and developing new plastic components with recycled content for the automotive industry.

With this report, we are expanding our intended audience to reach not only SPI members, but also key partners and customers in the plastics life cycle, including auto manufacturers and designers, scrap recyclers, and policymakers. A look at automotive



It is critical that stakeholders outside the plastics industry recognize the value of the material not only in the automotive manufacturing process, but also in terms of post-industrial and post-consumer recycled material that can be used in products, both in auto applications as well as other industries.

recycling and the design of new parts using polymers and recycled plastics requires a broader analysis and audience. It is critical that stakeholders outside the plastics industry recognize the value of the material not only in the automotive manufacturing process, but also in terms of post-industrial and post-consumer recycled material that can be used in products, both in auto applications as well as other industries.

Plastics make
up about
50%
of a modern
automobile's volume,
but only
10%
of its weight.

Auto recyclers have been focusing on the recyclability of some car parts and components for decades, most notably steel parts. In contrast, automotive plastics recycling is still in its relative infancy, given the fact that recycling some plastic and polymer composite components can be challenging in terms of costs, technologies required and the very properties of plastics.

Significant strides are being made to recycle plastics, however, particularly post-industrial scrap, and use recycled plastic materials in car parts as automotive companies have made strong commitments to reduce waste and incorporate recycled materials in new vehicles. The quality of recycled bales and materials have dramatically improved over the past few decades, increasing the ability of engineers to use recycled plastic for new components.

As part of our mission of pursuing zero waste, SPI works to leverage the strength of our full supply chain membership—from resin suppliers and equipment manufacturers to processors, brand owners and recyclers—by identifying challenges to recycling across the variety of plastic packaging and products. In the transportation end markets, like automobiles, SPI is undertaking projects to help identify opportunities for both recycling useful plastic from automobiles that have reached the end of their practical life, as well as using recycled content to build new cars and components.

Plastics and recycled plastics are playing an innovative and growing role in automotive manufacturing around the world. The Plastics Division of the American Chemistry Council reports plastics make up about 50 percent of a modern automobile's volume, but only 10 percent of its weight. Engineers and designers looking for cost and weight savings are embracing technologically advanced plastics components for their unique properties and flexibility.

The paramount catalyst for embracing plastics in car designs is meeting or exceeding the Corporate Average Fuel Economy (CAFE) standards and helping boost

a vehicle's fuel mileage. The amount of plastics in automobiles is increasing, but with the auto industry's

focus on reducing costs, and the recent significant drop in oil and natural gas prices, the market dynamics of using virgin resins vs. recycled content materials is shifting. For this reason, it's important for auto manufacturers to recognize the value of recycled content, both in terms of material properties as well as environmental benefits. The value of recycled content extends far beyond the potential cost savings that can at times be realized.

Auto manufacturers recognize cultural trends and buying habits of consumers who want companies and products to be environmentally responsible. Some U.S. and foreign manufacturers have been at the forefront of the green movement, not only

CAFE



Corporate Average Fuel Economy (CAFE) standards



Around the world, 27 million cars reach the end of their useful lives each year—some are the average 11-year old vehicles driven until their last mile while others are current year models involved in crashes.

in terms of developing lighter, safer and alternatively fueled vehicles, but also in reducing waste and recycling materials including plastics.

Plastics can be found inside and outside of every vehicle on the road today. On average, plastics reduce the weight of automobiles by 500 to 750 pounds. But with about 39 different types of plastics being used in automobiles, recycling those vehicles at their practical end-of-life—about 27 million every year around the world—can be a challenge. However, with increased use of plastics in vehicles, increased attention should be given to what happens to those plastics when vehicles reach their end of life.

Increased awareness and understanding of plastics and recycled plastics in automotive manufacturing is also needed with the very engineers that are developing designs and specifications for new components. High-quality

recycled plastics, at scale, need to be provided to automotive engineers at a competitive price. Cross-industry collaborations are critical for the continued development and use of recycled plastics in automotive parts—and the recycling of plastics used during automotive manufacturing and end of life. The car-buying public, particularly younger consumers, are interested in the footprint of their vehicle and the companies that manufacture their products; plastics should be at the forefront of the conversation about future automobile production and recycling.

SPI is releasing this paper as part of its 2016 Refocus—Recycling Summit & Expo in Orlando, Florida. “Key Trends in Auto” will be one of the industry tracks during the summit. SPI will discuss this report and share it with other stakeholders including automotive manufacturers, materials suppliers, processors, recyclers, automotive recyclers and policymakers. We welcome your feedback on the report.

Plastics reduce auto weight on average by

500 lbs.



39

different types of plastic used in autos



27 million

ELV autos every year worldwide



Automotive
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Plastics
Growing
Role in Auto
Manufacturing



By 2020, IHS estimates the average car will incorporate about 770 pounds of plastic by weight compared to the 440 pounds averaged in 2014—an increase of 75 percent.

Plastics Growing Role in Auto Manufacturing

From SPI's Market Watch report published last year, "Automotive & Transportation," a number of factors, including economics, demographics and the need for lightweight, fuel-efficient vehicles, are boosting the plastics industry's contributions to car, truck and transportation design and manufacturing.

Automobiles are a growing market for plastics as car sales increase. A number of forces combined in 2015 to spur an all-time record of U.S. car sales topping a 15-year-old peak. Cheaper gas prices, improved employment numbers and continued low interest rates helped automakers sell 17.5 million cars and light trucks—a 5.7 percent increase from 2014. Global automotive sales for 2015 jumped 2.4 percent to hit 88.6 million vehicles, according to IHS Automotive—marking a fifth year of growth. IHS has indicated 90 million vehicle sales worldwide will be within reach for 2016.

With this growing number of vehicle sales, the embrace of plastics and new polymer technologies by automotive and transportation engineers will continue in passenger

cars, trucks and mass transit vehicles. By 2020, IHS estimates the average car will incorporate about 770 pounds of plastic by weight compared to the 440 pounds averaged in 2014—an increase of 75 percent.

More parts are being developed with plastics as technology has improved the tensile strength and other properties of plastics when compared to traditional metals like steel and aluminum. The development of thermoplastics was a watershed event in that it led to polyamide, polyacetal and polycarbonate that allowed engineers to blend different plastics to create new and useful engineering-grade materials.

Already the third largest sector of U.S. manufacturing in dollar value of shipments, plastics in the automotive industry

will continue to grow as new materials are utilized in designs. Carbon fiber reinforced plastic (CFRP) usage in vehicles will increase from 3,400 tonnes in 2013 to 9,800 tonnes in 2030. The expectation of increased use of 3D printing and its derivatives will pave the way for even more innovative applications of plastic in and outside of cars, particularly for specialty cars and specialization.



The quest for lightweighting vehicles has been ongoing for decades across every manufacturer whether the new material be plastic, aluminum or carbon fiber. While these initiatives may not have been the focus of advertising campaigns like Ford Motor Co.'s "military grade" aluminum featured in the 2015 F-150 truck, the company and others have been driving innovation in manufacturing for building trucks and cars for years.

Peter Frise, a mechanical engineer and the scientific director at AUTO21, an automotive research think-tank at the University of Windsor told CBC News that despite the steel vs. aluminum marketing battle between some companies, lightweighting will continue. "They can't just keep making the same stuff. They'll have to adopt new technologies, new design methods...there will be big changes." And these changes will likely mean increased material replacement opportunities for plastics.

The world's first 3D-printed car, the Strati EV, by Local Motors and Cincinnati Inc., on display in SABIC Innovative Plastics booth at NPE 2015.

It has been about 18 months since the Association for Manufacturing Technology teamed with Local Motor, Oak Ridge National Laboratory and Cincinnati, Inc. to 3D print, assemble, and drive a composite, acrylonitrile butadiene styrene (ABS), reinforced carbon fiber electric car at the International Manufacturing Technology Show.

Strati (which means "layers" in Italian), is a two-seater convertible that has become a global symbol of how direct digital manufacturing—or 3D printing—is poised to revolutionize manufacturing processes.

The Strati has 49 major 3D printed components (the body being the largest) in addition to a number of traditionally-designed and built parts like an electric motor, wheels, seats and windshield.

While visionaries foresee the day consumers may pick and print their vehicles in car showrooms, the reality is 3D printing has been used in automotive design for years and its usage is only growing.

The Strati vehicle is certainly not ready to be mass-produced today, but 3D printing has clearly transitioned from its prototyping beginnings to "additive manufacturing" where the technology can be utilized for design and low-volume productions at a reasonable cost model.



Frise predicts the truly groundbreaking innovations in automotive manufacturing will become routine within a matter of years as the entire automotive supply chain adapts and innovates.

Matthew Marks, chair of the American Chemistry Council (ACC) Plastics Auto Division team, participated on a panel about lightweighting at the 2015 CAR Management Briefing Seminars and called for "a little" risk in research and development of new components. "Let's do an aluminum-bodied truck. Let's do a composite passenger cell," Marks said. Advancements, according to Marks, will not come from one company or one material; rather he believes automakers and suppliers need to work together through consortiums and other collaborations to achieve advancements.

Steel, aluminum and plastic representatives at the CAR Management Briefing Seminar downplayed any competition between the materials and rather embraced the "multi-material" concept and what their material does best. Getting engineers to look beyond their traditional materials—and toward understanding other cutting-edge materials and technologies—will be crucial to lightweighting success.

In 2014, the ACC released its Plastics and Polymer Composites Technology Roadmap for Automotive Markets calling for identifying best practices and demonstrating multi-material and joining techniques to enable the production of lighter, stronger, more reliable vehicles that are more easily recycled and recovered at the end of their useful lives. ACC wants to collaborate on a project for metal-to-polymer composite joining to produce a lifecycle cost assessment that includes joint design, manufacturing and assembly processes, vehicle usage, and end-of-life recycling.

It would be hard to get into a 2016 model year vehicle and sit for a minute without touching several plastic parts and components



WEIGHT



COST



DESIGN FREEDOM



INNOVATION

Why Use Plastics?



FLEXIBILITY



CORROSION & RUST RESISTANCE



INCREASED SAFETY



COMFORT

It would be hard to get into a 2016 model year vehicle and sit for a minute without touching several plastic parts and components—even in high-end vehicles with leather and wood finishes. Plastic parts are found in and out of every vehicle on the road—dozens of parts are made with an array of plastics.

While weight and cost are most frequently identified as the reasons for using plastics, there are other benefits for designing and using plastic parts, including design freedom and innovation, flexibility in integrating different components, corrosion and rust resistance, increased safety and comfort.

Despite the growth of plastics usage in vehicles, some consumers may not perceive plastics and polymer composites as a premium material and have misperceptions about the health, safety, and environmental impact of automotive plastics and polymer composites. These consumers may be wary of plastic and polymer composites used in structural applications, and concerned about these material's ability to serve the same functions as metals.

Conversely, in recent years, carbon fiber reinforced plastic (CFRP) has been embraced by a wide range of automotive manufacturers—particularly the plug-in and battery-powered models coming to market. At a weight 50 percent lighter than conventional steel and 30 percent lighter than aluminum, more automakers are taking notice of the benefits and wide uses for carbon fiber inside and outside of a vehicle. CFRP is viewed by some consumers as a high-tech, high-value material, and therefore is given high visibility by automakers.

These plastic materials and parts can be recycled—either at the manufacturing facility as part of a post-industrial recycling program that many automobile companies and parts manufacturers have adopted, and as well as the recovery option that will eventually extend to end of life vehicles (ELVs) as well. The closed loop recycling of PIR scrap adopted by manufacturers is recognition of the value of the plastics and the byproducts in their manufacturing, and the opportunity to recycle plastic parts into new components.

ELV recycling of these plastics can come via the recycling of specific parts—like plastics used in bumpers—or in the auto shredder residue (ASR) that is ultimately produced in the crushing and shredding of end-of-life vehicles. Reusing these plastics from the ASR requires sorting and cleaning, but companies in the European Union are recycling plastics from ASR.

Automotive Exteriors

Today's plastics have revolutionized the design of auto body exteriors. From bumpers to door panels, light weight plastic gives cars better gas mileage and allows designers and engineers the freedom to create innovative concepts that otherwise would never be possible. Unlike traditional metal alloys that were used for decades, plastic components are not as susceptible to dents, dings, stone chips and corrosion. Choosing plastics for auto body exterior parts allows manufac-

Choosing plastics for auto body exterior parts allows manufacturers to adopt modular assembly practices, lower production costs, improve energy management, and use advanced styling techniques for sleeker, more aerodynamic exteriors.

Most Common Plastics in Cars Today (Craftech)

According to Craftech Industries, the most common plastics found in vehicles today are polypropylene, polyurethane and polyvinyl chloride; but a variety of plastics and polymers are used and combined for automotive parts. Craftech identified the leading plastics and their uses in cars:

POLYPROPYLENE (PP). Polypropylene is a thermoplastic polymer used in a wide variety of applications. A saturated addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids. The properties of PP can be further enhanced through additives, like long-glass fiber reinforcement.

Applications: Front / rear bumpers, chemical tanks, cable insulation, carpet fibers.

POLYURETHANE (PUR). Solid Polyurethane is an elastomeric material of exceptional physical properties including toughness, flexibility, and resistance to abrasion and temperature. Polyurethane has a broad hardness range, from eraser soft to bowling ball hard; other polyurethane characteristics include extremely high flex-life, high load-bearing capacity and outstanding resistance to weather, ozone, radiation, oil, gasoline and most solvents.

Applications: Flexible foam seating, foam insulation panels, elastomeric wheels and tires, automotive suspension bushings, cushions, electrical potting compounds, hard plastic parts.

POLYVINYL CHLORIDE (PVC). PVC has good flexibility, is flame retardant, and has good thermal stability, a high gloss, and low (to no) lead content. Polyvinyl chloride molding compounds can be extruded, injection molded, compression molded, and blow molded to form a huge variety of products, either rigid or flexible, depending on the amount and type of plasticizers used.

Applications: Instruments panels, sheathing of electrical cables, pipes, doors.

ACRYLONITRILE BUTADIENE STYRENE (ABS). ABS is a copolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene. The styrene gives the plastic a shiny, impervious surface. The butadiene, a rubbery substance, provides resilience even at low temperatures. A variety of modifications can be made to improve impact resistance, toughness and heat resistance.

Applications: Body parts, dashboards, wheel covers.

POLYAMIDE (PA, NYLON 6/6, NYLON 6). Nylon 6/6 is a general-purpose nylon that can be both molded and extruded. Nylon 6/6 has good mechanical properties and wear resistance. It is frequently used when a low cost, high mechanical strength, rigid and stable material is required.

Applications: Gears, bushes, cams, bearings, weatherproof coatings.

POLYSTYRENE (PS). PS is naturally clear and exhibits excellent chemical and electrical resistance. Special high gloss and high impact grades are widely available.

Applications: Equipment housings, buttons, fittings.

POLYETHYLENE (PE). Polyethylene has high impact resistant, low density, and exhibits good toughness. It can be used in a wide variety of thermoplastics processing methods and is particularly useful where moisture resistance and low cost are required.

Applications: Car bodies (glass reinforced), electrical insulation.

POLYOXYMETHYLENE (POM). POM has excellent stiffness, rigidity, and yield strength. These properties are stable in low temperatures. POM also is highly chemical and fuel resistant.

Applications: Interior and exterior trims, fuel systems, small gears.

POLYCARBONATE (PC). Amorphous polycarbonate polymer offers a unique combination of stiffness, hardness and toughness. It exhibits excellent weathering, creep, impact, optical, electrical and thermal properties.

Applications: Bumpers, headlamp lenses.

ACRYLIC (PMMA). A transparent thermoplastic, PMMA is often used as a lightweight or shatter-resistant alternative to glass.

Applications: Windows, displays, screens.

POLYBUTYLENE TEREPHTHALATE (PBT). The thermoplastic PBT is used as an insulator in the electrical and electronics industries. It is highly chemical and heat resistant. Flame-retardant grades are available.

Applications: Door handles, bumpers, carburetor components.

POLYETHYLENE TEREPHTHALATE (PET). PET is mostly used to create synthetic fibers and plastic bottles.

Applications: Wiper arm and gear housings, headlamp retainer, engine cover, connector housings.

ACRYLONITRILE STYRENE ACRYLATE (ASA). Similar to ABS, ASA has great toughness and rigidity, good chemical resistance and thermal stability, outstanding resistance to weather, aging and yellowing, and high gloss.

Applications: Housings, profiles, interior parts.

(Source: Craftech)

turers to adopt modular assembly practices, lower production costs, improve energy management, and use advanced styling techniques for sleeker, more aerodynamic exteriors. Carbon fiber has opened even more doors for exterior part designs given its structural integrity and performance. However, expanded use of carbon fiber does present challenges when it comes to recycling PIR scrap and ELVs, which will be further discussed later in the report.

Automotive Interiors

Plastic can be found everywhere in the interior of today's cars as well, proving to be the ideal material for creating comfortable, durable, and aesthetically pleasing interior components, while reducing noise, harshness and vibration levels in the interior of the car.

Plastic's design flexibility helps manufacturers create innovative, integral single-piece light weight components, while cutting costs, saving time and helping lessen the problems associated with vehicle redesign.

Under the Hood, In the Trunk, Out of Sight

Much of the plastic—and recycled plastics—in automobiles today are not in view of the driver, but play a vital role in the vehicle's powertrain, cushioning, soundproofing and undercarriage. Plastic resins are being used in a number of systems found in the car, including:

- Safety components, including airbags and restraints
- Electrical systems
- Chassis design & noise, vibration and harshness performance
- Powertrains
- Fuel systems
- Engine components

The extent of plastics' role in automobile design is evident by the components offered by International Automotive Components (IAC), a global manufacturer with 84 facilities and 28 design, technical and commercial centers, serving a wide variety of U.S. and foreign automotive companies. IAC has five major categories of interior and exterior components and systems that utilize plastic technologies:

Doors & Trim Systems	Instrument Panels, Consoles & Cockpits	Flooring & Acoustic Systems	Headliner & Overhead Systems	Other Interior & Exterior Components
Door panels	Instrument panels	Floor carpets	Overhead systems	Interior
Acoustic Insulators	Acoustic insulators	Acoustic insulators	Air distribution ducts	Cargo management
Armrests	Air duct systems	Engine insulators	Assist handles	Load floors
Decorative appliqués	Air registers	Expandable sealing	Coat hooks	Seat components
Garnish trim	Center consoles	Floor mats	Garnish trim	Exterior
Hard & soft panels	Cockpits	Heat shields	Headliner substrates	Fascias
Map pockets	Cupholders	Package trays	Interior lighting	Garnish trim
Safety components	Decorative appliqués	Trunk trim	Overhead consoles	Rec. vehicle trim
Speaker grills	Glove box assemblies	Utility flooring	Safety components	Reservoir systems
Switch bezels	Hard & soft panels	Wheel arch liners	Visors	Rocker panels

Solvay—Plastic Car Engine

Pushing the envelope in developing plastic-based car parts is not new—designers and engineers are on a constant search for innovations and new applications that will save weight, improve safety, offer savings, simplify manufacturing and increase flexibility. Few parts in a car have not been altered or improved with plastics technology—save the wood and leather found in some luxury vehicles.

Polimotor—a plastic-based motor engine—was developed by American Engineer Matti Holtzberg in the early 1980s and was then successfully raced around the world in a LolaT616 racecar. Solvay Specialty Polymers is currently developing Polimotor 2, a next generation plastic-based engine, with the objective of introducing new innovative polymers and

processing technologies, demonstrating light-weighting possibilities and showcasing CO2 reduction technologies.

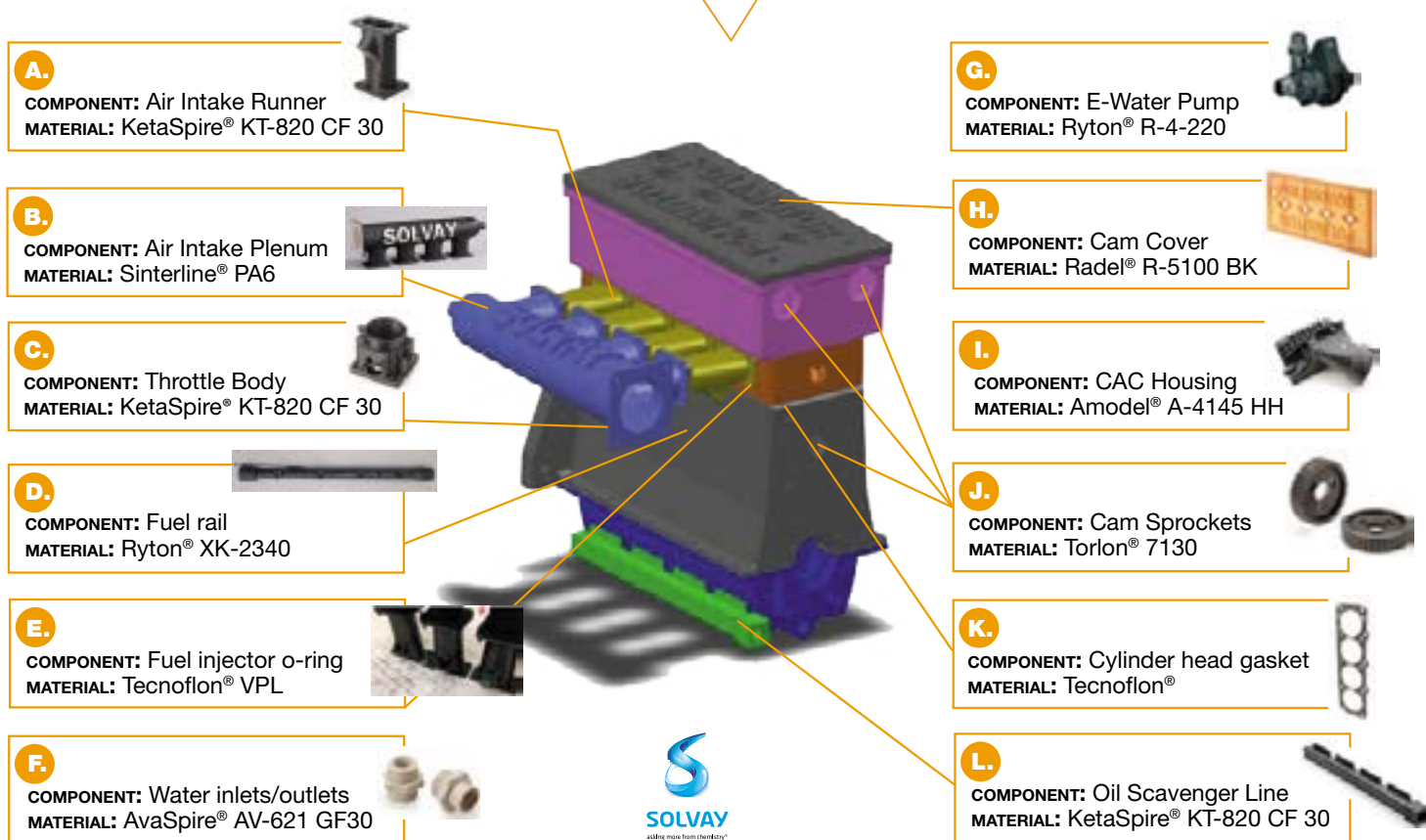
The Polimotor 2, announced in May 2015, will be based upon a 2-liter, 4-cylinder Ford engine with double-overhead CAMs—and it too will be destined for a racecar. The expected output of the engine is 375–400 horsepower and will also deliver a 40 percent reduction in weight.

Polymer components in Polimotor 2 will include:

- **Cylinder block**
- **Cylinder head**
- **Cam cover**
- **Intake manifold (plenum)**

- **Air duct (runner)**
- **Oil pan**
- **Cam sprocket**
- **Water inlet/outlet**
- **Throttle body**
- **Fuel rail**
- **Oil pump**
- **Others to come**

Solvay believes its polymer engine will be circling Europe and U.S. racing circuits, including Watkins Glen, Daytona and others in 2017.



To meet these new mileage standards, EPA and NHTSA expect automakers to use a range of efficient and advanced technologies to transform their vehicle fleets, including advanced gasoline engines and transmissions, vehicle weight reduction, lower tire rolling resistance, improvements in aerodynamics, diesel engines, more efficient accessories and improvements in air conditioning systems.

CAFE Standards

Federal Corporate Average Fuel Economy (CAFE) standards have guided the designs and engineering of vehicles for more than 40 years. The forward-looking standards set by the U.S. Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration (NHTSA) have set the course for lighter vehicles and more fuel conserving engines and drivetrains for all manufacturers.

The standards are intended to reduce petroleum consumption, increase and diversify alternatively fueled vehicles, lower greenhouse gas emissions and promote the advancement of innovative technologies.

In 2012, the Obama Administration updated the CAFE standards to 54.5 mpg for cars and light-duty trucks by Model Year 2025. When combined with previous standards set by the Administration, the move will nearly double the fuel efficiency of cars and trucks in nine years compared to vehicles currently on the roads. Today, manufacturers are under the CAFE standards for cars and light trucks for Model Years 2011–2016 which requires the equivalent of 35.5 mpg.

The new CAFE standards have broad support among manufacturers and environmental groups—13 major automakers that account for more than 90 percent of all vehicles sold in the

United States endorsed the standards. To meet these new mileage standards, EPA and NHTSA expect automakers to use a range of efficient and advanced technologies to transform their vehicle fleets, including advanced gasoline engines and transmissions, vehicle weight reduction, lower tire rolling resistance, improvements in aerodynamics, diesel engines, more efficient accessories and improvements in air conditioning systems.

The CAFE program also provides incentives for early introduction and adoption of new advanced technologies like electric vehicles, plug-in hybrid electric vehicles, fuel cell vehicles and natural gas vehicles. These next generation vehicles are employing plastics technology, including carbon fiber for interior and exterior components. BMW, which has invested hundreds of millions of dollars into developing carbon fiber components, is using CFRP in a wide range of vehicles, from its i3 electric city car and i8 hybrid models, to its flagship 7 Series sedan.

For new entrants into the automotive sector, like Tesla, identifying the best material for its undercarriage and body panels was a priority. Tesla tested its lightweight carbon fiber/epoxy composite for two years before finalizing its formula. Tesla weaves long, thin carbon fiber strands into a fabric that are molded with plastics or resins.





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Current
Automotive
Recycling



Current Automotive Recycling— Vehicles and Parts

End-of-Life Vehicles
are recycled in four
basic steps:

- 1** Dismantling
- 2** Crushing
- 3** Shredding
- 4** Material Recovery

The car crushing compactors—so popular in movies and advertising—actually tell a small part of the end-of-life vehicle story. While it offers great video and images, so much more goes on in the recycling of automotive parts, components, systems and fluids, for the estimated \$22 billion automotive recycling industry. To date, this industry has been largely built on metals recovery and recycling—but that is changing.

Around the world, 27 million cars reach the end of their useful lives each year—some are the average 11-year old vehicles driven until their last mile while others are current year models involved in crashes.

Regardless of a vehicle's age, very few go straight to the compactor and shredder—there are too many valuable parts and components, reusable resources, recyclable materials and hazardous fluids and chemicals that need to be sorted and collected. This is the role of automotive recyclers around the world that help optimize recovery of vehicles, save consumers money by offering parts for reuse, and protecting the environment by maximizing the resources contained in each car.

Automotive vehicles are some of the most recycled items in the U.S.; more than 95 percent of vehicles in the U.S. are being recycled at the end of their life. Automotive recycling is evolving into a mature marketplace and technology-driven industry that constantly changes to keep abreast of innovations in automotive technology and manufacturing techniques.

ELVs are recycled in four basic steps:

1. Dismantling
2. Crushing
3. Shredding
4. Material Recovery

In the dismantling stage, recyclers recover the fluids and remove the usable parts and components of the vehicle. These include lead-acid batteries, wheels and tires, steering columns, front and rear fenders, radios, engines, starters, transmissions, alternators, and select plastic parts and components in and out of the vehicle—based on parts condition and market demand.

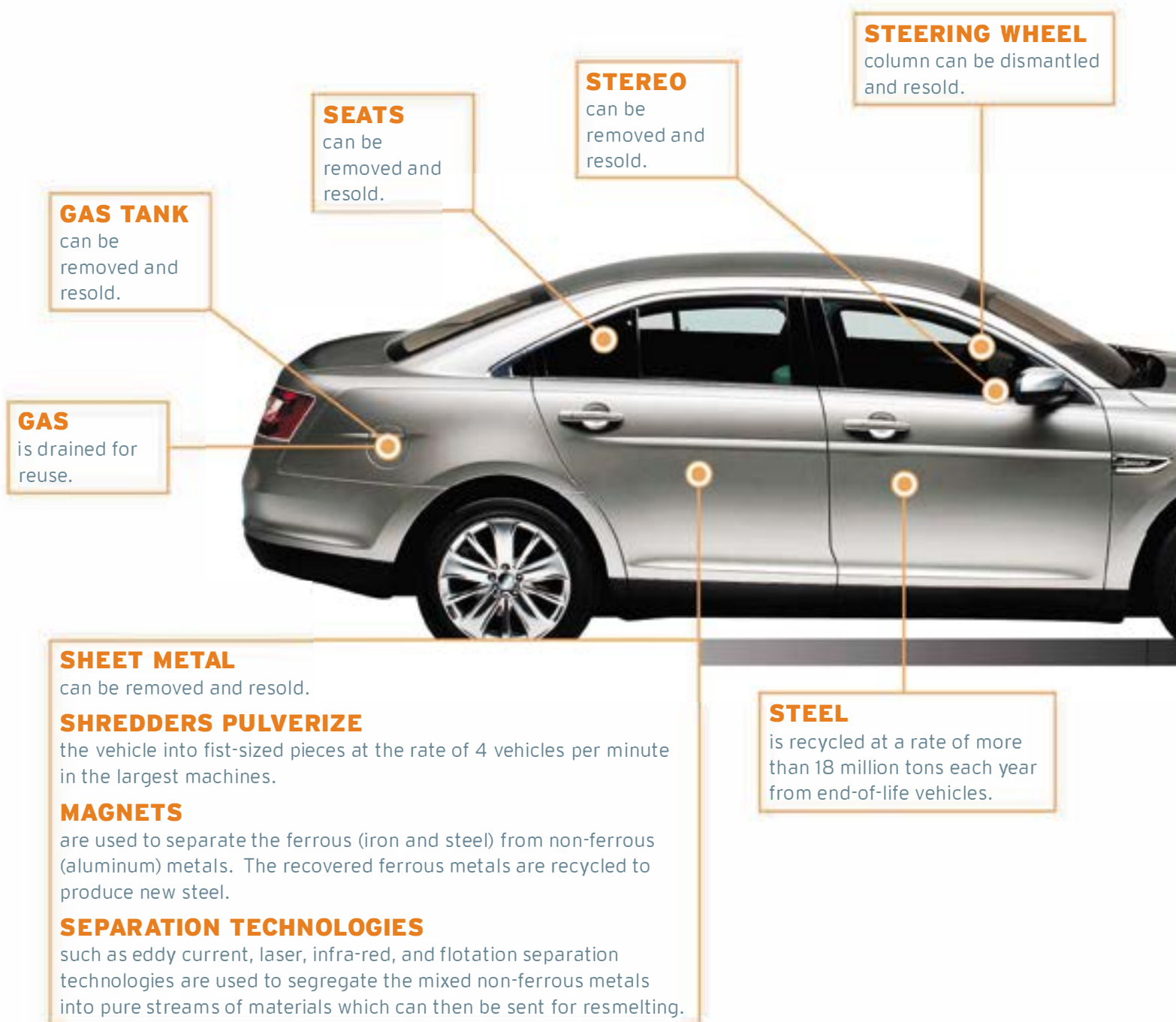
For instance, a current year Ford Focus or Chevy Malibu with extensive rear-end damage still has numerous, valuable front end and interior parts and components that can be provided to repair shops—these reused, OEM components save consumers millions of dollars each year in lower insurance premiums and repair costs regardless of whether the reused component is made of plastic, steel or aluminum.

The United States Council on Automotive Research (USCAR), a collaboration of domestic auto manufacturers, estimates that approximately 84 percent of a motor vehicle

by weight is currently recycled in the U.S., with metal being the largest target material for recovery.

Currently in North America, there is minimal recycling of plastic automotive parts during the dismantling stage of ELV vehicles due to the economics of collecting, sorting and processing old plastic parts, but that is changing. For example, the Institute of Scrap Recycling Industries (ISRI) has been working with recyclers and potential buyers to develop scraps specifications for plastic automotive bumper covers; final specs could be approved this summer. The ISRI process to develop specifications for ELV bumpers will help spur additional recycling and usage of the material.

Bumpers are the most aggressive target for recovery according to Virginia Whelan, executive director of the Automotive Recycling Association's Educational Foundation, but interior dashboards and car door panels are being researched. Whelan stated, "We are looking at larger parts that make up a vehicle that are made from plastics—more and more are



We are looking at larger parts that make up a vehicle that are made from plastics—more and more are appearing on the vehicles—so this is why we keep going back to manufacturers and others to determine what we can do with these parts and how we can do it efficiently in our processes with our labor.

STARTER & ALTERNATOR

can be removed and resold or sent for remanufacturing.

BATTERY

can be resold or recycled.

WINDSHIELD WASHER

fluid is drained for reuse.

COOLANT

is drained for reuse.

ENGINE & TRANSMISSION

can be dismantled, reconditioned, and resold.

TIRES

are reused depending on a visual inspection and tread depth evaluation. Worn tires can be recycled by shredding, cleaning, and processing into a variety of products including asphalt, playground surfaces and garden mulch. Additionally, worn tires can be used as a fuel for the beneficial recovery of energy.

appearing on the vehicles—so this is why we keep going back to manufacturers and others to determine what we can do with these parts and how we can do it efficiently in our processes with our labor.”

Once dismantled, the vehicles (along with whitegoods such as refrigerators, washing machines and dryers, and other household appliances collected by recyclers) are compacted for shredding; the compacting is perhaps the simplest step in the end of life recycling of vehicles. The shredder pulverizes the vehicle into fist-sized pieces of materials—plastics, rubber, wood, papers, fabric, glass, sand, dirt, and ferrous and nonferrous metal pieces—which are then sent by conveyors to sophisticated separation technologies, including magnetic separation, eddy current, laser and infra-red systems.

The metal recovered by these facilities becomes raw material feedstock for steel mills, electric arc furnaces, aluminum and other non-ferrous metal smelters to manufacture a variety of products, including new vehicles. Unfortunately, according to ARA's Whelan, prices for scrap metals are near all-time lows, primarily due to China's economic downturn; ISRI reported export sales of scrap metal last year had their worst year since 2006.

The remaining materials not separated—pieces of plastic, rubber, wood and paper, dirt and sand—are processed into fine, auto shredder residue (ASR) that is sent to landfills in the U.S. and often used as alternative daily cover (ADC) for the landfills. An estimated 5 million tons of ASR are diverted to landfills each year; automotive plastics represents about 0.5 percent by weight of a typical landfill. In Europe, however, due to mandates on recycling and use of recycled content, more ASR is separated using float/sink tanks, dryers and other technology to separate plastics and other fine ASR materials—diverting material from landfills.

In 2013, in a change from its previous position that ASR was only to be landfilled, the U.S. EPA announced a new interpretation of its regulations that would allow auto shredder plant operators to recycle the plastics in the ASR. The agency's longstanding concern was the ASR may be contaminated with polychlorinated biphenyl (PCB). This was unfounded and the U.S. EPA harmonized regulations for ASR treatments with Europe.

Given the growing role of plastics in automotive parts, the percentage of plastic particles in ASR will increase in the coming years. This change in the ASR content represents an additional opportunity for plastics recovery from ELV vehicles that may change the economics of ASR recycling and present a sizable opportunity for the recovery of new feedstreams of recycled plastics.

The EU's regulations have caused a shift in the thinking of some global auto manufacturers. "It has forced design engineers in the U.S. to think differently," said Carrie Majeske, associate director global sustainability integration at Ford Motor Company. "The challenge becomes there is not the same infrastructure all over the world...we have different recycling streams here in the U.S.." Majeske said global designs have localized contents and sourcing to allow flexibility in the recycled plastic components.

Glossary of Automotive Recycling Terms (ARA)

Automotive Recycling—The efficient, environmentally responsible processing of motor vehicles for reusable components and materials.

End-of-Life Vehicle—Any identifiable motor vehicle, with or without all component parts, in such condition that its highest or primary value is either in its sale for reusable components or recyclable materials.

Hard Parts—Any mechanical automotive parts or components (i.e. engine, transmission, suspension, etc.).

Parts Car—A vehicle that is purchased and dismantled for the recovery of reusable parts and recyclable materials.

Recycled/ Recyclable Parts—Parts removed from a vehicle and made available for resale/reuse.

Remanufactured Part—A used part that has been inspected, rebuilt, or reconditioned to restore functionality and performance.

Repairable Vehicle—A salvage or damaged vehicle that can be economically and safely repaired or restored to its prior condition for reuse or retitling.

Replacement Part—A part that replaces a damaged part on a vehicle. This part can be new, recycled, aftermarket, remanufactured or OEM.

Reused Parts—Parts removed from a vehicle and used as a replacement part for repair.

Scrap Metal Processor and Recycler—One who, from a fixed location, utilizes machinery and equipment for processing and manufacturing iron, steel or nonferrous metallic scrap into prepared grades and whose principal product is scrap iron, scrap steel or nonferrous metallic scrap for sale for remelting purposes.

Secondary Metals Recycler—Any person or entity who is engaged, from a fixed location or otherwise, in the act of paying compensation for ferrous or nonferrous metals that have served their original economic purpose, whether or not engaged in the business of performing the manufacturing process by which ferrous metals or nonferrous metals are converted into raw material products consisting of prepared grades and having an existing or potential economic value.

Source: ARA

Automotive
Recycling:
Devalued is now
Revalued

Recycled
Plastics in
Auto Parts and
Components



The technologies required at state-of-the-art recycling facilities cost millions of dollars and are significantly more advanced than the well-known car crushing compactors.

Recycled Plastics in Automobile Parts and Components

39

different types of basic plastics and polymers used to make an automobile today;

66%

of the plastic used in autos comes from these three polymers:

Polypropylene
32%

Polyurethane
17%

Poly-Vinyl-Chloride PVC
16%

Auto recyclers and automotive companies are turning their attention to plastics and polymers: 1.) automotive companies are recycling their plastic scraps, defective parts and other materials as part of their manufacturing processes as well as recycled post-consumer plastics; and 2.) recyclers and scrap companies are beginning to recycle ELV plastics.

There are currently about 39 different types of basic plastics and polymers used to make an automobile today; however, 66 percent of the plastic used in autos comes from these three polymers: Polypropylene (32 percent), Polyurethane (17 percent) and Poly-Vinyl-Chloride PVC (16 percent).

The wide variety of plastics used in automobiles presents a challenge for recyclers according to Robert Dishman, senior vice president of Geo-Tech, a recycling company that specializes in coated plastics used in automotive and consumer applications. In order to develop a consistent, high quality bale of recycled material, Geo-Tech must be selective in processing one stream of material at a time, like automotive bumpers made of PPO. "If we start mixing other polymers together, our quality standards are off," Dishman said. "We will either end up with a wide-spec plastic or something that cannot be used at all."

The technologies required at state-of-the-art recycling facilities cost millions of dollars and are significantly more

advanced than the well-known car crushing compactors. Separation technologies, such as float-sink tanks, magnetic separation, eddy current separators, and laser and infra-red systems used to distinguish and separate plastics based on color are available and being used by manufacturers for post-industrial recycling and recyclers in handling post-consumer materials. But, they can cost millions of dollars per facility and represent one part of the recycling process.

While all the thermoplastic polymers are technically capable of being recycled, it can cost more to separate, clean and collect each polymer than purchasing virgin plastic—particularly now with the recent low oil and natural gas prices. Given the priority of cost and weight that automotive manufacturers put on components, plastics are continuing

to win the weight test, but virgin plastics are winning the cost test given the current price of prime material.

The boom in domestic natural gas supplies followed by the recent dramatic decline in the price of oil was seen as a major opportunity for automotive plastics—but not necessarily recycled polymers due to the fixed processing costs of recycled plastics. Chevron Phillips Chemical Company suggested that the increased development of shale gas may encourage the plastics and polymer composites industry to invest \$30 billion to construct new petrochemical units that convert natural gas into plastics. As a result, the plastic and rubber products industry could experience a 17.9 percent boost (equivalent to \$33.28 billion) in industry output above the 2010 baseline in the 2015–2020 period according to the ACC.

Some bales of plastic bottles were selling for \$230 a year ago—today the bales are worth approximately \$112.



Clearly, the current economics of plastics is squeezing participants across the recycling landscape, including post-consumer and post-industrial recyclate consumers. As reported by *The New York Times* this year, some bales of plastic bottles were selling for \$230 a year ago—today the bales are worth approximately \$112.

Michael Taylor, vice president for international trade with SPI noted that corporate commitments and sustainability objectives were vital both short- and long-term to maintain recycling flows and the continued use of recycled plastics. “There are still customers for recycled materials, for reasons other than pure economics. The thinking is that demand will grow because of the greening of the mainstream American consumer,” he noted.

Toyota, for instance, has committed to increasing its plastic parts that contain plant-derived plastics (bioplastic) and recycled plastics. In its SAI vehicle, Toyota has used Ecological Plastic to cover 80 percent of the total interior surface area, the highest rate of any Toyota vehicle. With the new SAI, Toyota succeeded in replacing 20 percent of the total weight of plastic parts with Ecological Plastic and recycled materials.

Toyota is also working with Boles Parts Supply Co. in the U.S. to recycle all kinds of automotive plastic materials at its plants as part of its post-industrial recycling effort; sixty-seven tons of plastics between April 2014 and June 2015 were recycled through their partnership.

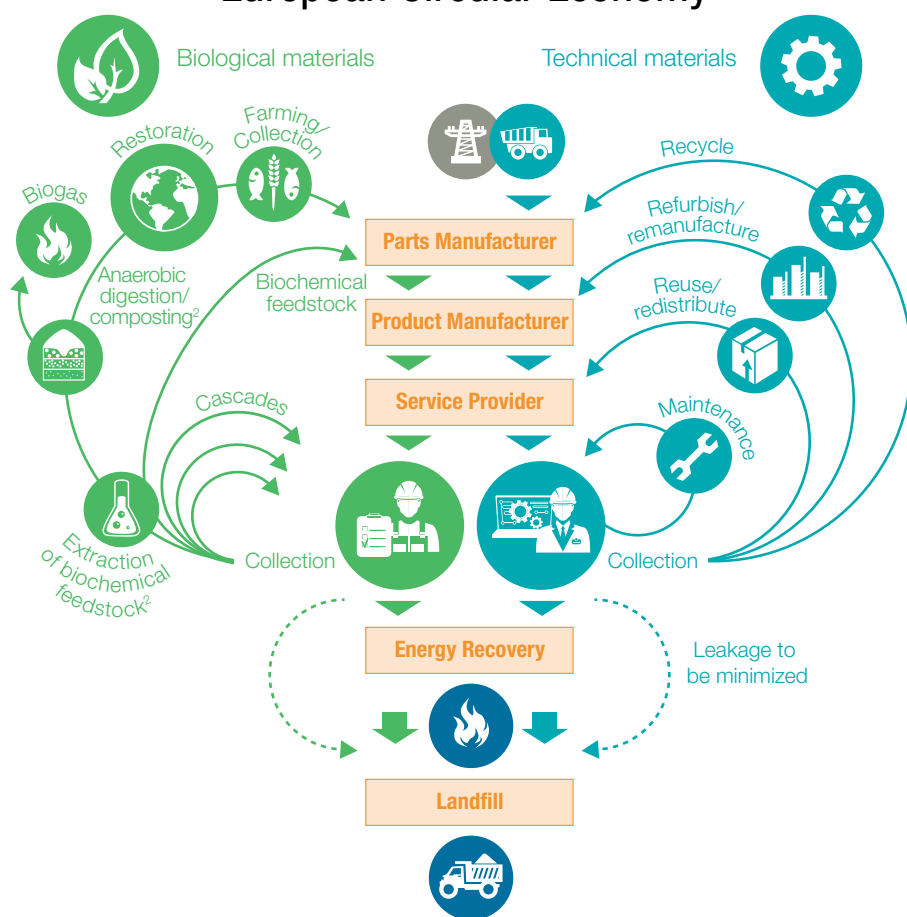
Likewise, Ford Motor Company has embraced environmental programs as part of its global sustainability strategy in addition to developing lightweight cars and trucks and

Toyota has committed to increasing its plastic parts that contain plant-derived plastics (bioplastic) and recycled plastics.

We try to get more recycled content or renewable content in every new major program we do,” said Majeske at Ford. “If we do an all new car or truck, or a major overhaul of an existing vehicle, with new powertrains and new parts, we try to estimate the recycled plastics content we had on the outgoing model and do better with the new vehicle. It is kind of a continuous improvement mentality.

Subaru’s plants are also focused on post-industrial recycling; for instance using its scrapped bumpers for trims and underfloor coverings.

European Circular Economy



advanced fuel-efficient technologies that meet CAFE standards. The company has put a priority on using non-metal recycled and bio-based materials for its components.

“We try to get more recycled content or renewable content in every new major program we do,” said Majeske at Ford. “If we do an all new car or truck, or a major overhaul of an existing vehicle, with new powertrains and new parts, we try to estimate the recycled plastics content we had on the outgoing model and do better with the new vehicle. It is kind of a continuous improvement mentality.”

The recycling of end-of-life vehicles and plastic parts needs to be matched by commitments to use recycled plastics in manufacturing from brand owners across all industries. The fundamentals of the sustainable materials management—similar concept to the European-based term “circular economy”—requires the active participation and engagement of several industries collaborating together to find solutions and new methods to work together.

Subaru last year marked its tenth year of building cars in the U.S. in zero landfill plants; it was a significant commitment made by the company and has become one of its marketing differentiators. Subaru tracks its waste using bar codes in near real-time, keeping tabs of waste throughout its plants; many items, like shipping packaging for engines are reused multiple times. Subaru’s plants are also focused on post-industrial recycling; for instance using its scrapped bumpers for trims and underfloor coverings.

But today, all auto makers—and large industrial manufacturers—recognize the need to reduce waste in processes and find opportunities to reduce, reuse and recycle materials and embrace full circle recycling.

Recyclers recognize the commitment automotive manufacturers have made regarding sustainability, particularly when it comes to closed loop recycling. Bob Houston of Industrial Resin Recycling Inc. (IRRI) works most closely with Ford plants in Michigan, Ohio and Indiana. An automotive approved recycler, IRRI provides closed loop recycling operations for the Ford plants by collecting post-industrial parts—like door panels—and then disassembles them, grinds the plastics and repelletizes the resins to process them through an extruder for reuse. IRRI will use a team of 40 to 50 employees to dismantle Ford parts—from doors and seats to trims—and reuse the plastic components.

IRRI is one of a few ISO 9001:2000 certified plastic recyclers, handling 40 million pounds of post-industrial plastics. Most of IRRI's plastics come directly from automotive manufacturers, although some come from Tier 1 suppliers and an estimated 5 percent comes from the secondary market.

Geo-Tech also works with automotive manufacturers to recycle post-industrial plastics—a service that not only reduces waste, but saves money. Geo-Tech worked with one automotive manufacturer in Michigan to recycle 100% of their painted TPO and PC/ABS plastics; the company's cleaning process produces recyclate materials that met the original prime material specifications.

Robert Render, commercial manager of Ravago Recycling Group characterized these closed loop recycling efforts as solutions that “help companies divert from landfills and help them get the maximum use of their byproducts.” Ravago processes and sells more than 200 million pounds of plastics annually. They also work with companies to assess and audit what post-industrial scrap a plant may have—and help them find the markets for the material and execute the compounding, recycling, tolling and micronization or pulverization to a small size so the resin can be used for certain finished product applications that require customized feedstocks (e.g. rotomolding). The solutions Render seeks are those that do nothing to change a company's manufacturing process—just the ultimate disposition of the material.

The corporate drive for sustainability and environmental stewardship is ultimately linked to the car-buying public. “It is all about the customer—everybody is a winner if customers want recycled materials,” said Render. There is a generational shift in recycling as well according to Render; while a Baby Boomer may look at a plastic water bottle being recycled into a car part as something of cheaper quality, Millennials and Generation X expect to see and want recycled products.

SPI's Kim Holmes, senior director recycling and diversion, underscored this point, and also linked corporate sustainability efforts to environmental organizations and non-government organizations that monitor corporate behavior. “Cost is not the only incentive for using recycled content. We have found that when there is a publicly stated corporate commitment to use recycled content, they can't back away from that. NGOs, like Greenpeace and others, are watching and paying attention to these commitments; and if you state a recycled content goal and do not meet it, you run the risk of an NGO shaming you,” Holmes said. “If you have that public commitment, you will use recycled content even if it comes with a cost premium.”

Holmes also linked the benefits of using recycled content to meeting consumer demand; because consumers want to see recycled content, environmentally conscious consumers will place a preference on purchasing those products from companies that use it. Companies are using recycled content as a market differentiator in their advertising and branding. “In addition to improving mileage, this may be an important way for

The corporate drive for sustainability and environmental stewardship is ultimately linked to the car-buying public.

automakers to connect with environmentally minded consumers. When Ford came out with using recycled PET in their carpet fibers, that became part of their ‘green story’ and a way to differentiate them from their competitors,” Holmes said.

Using Recycled Plastics in Car Parts

Using recycled plastics to manufacture new auto parts and components is an objective of participants across the automotive life cycle. Ford Motor Company initially started its recycling program in 1991 when it formed Recycling Action Teams (or “Rat Packs”) focused on developing new plastic components. These early efforts were frequently focused on single applications or parts where it could be challenging for companies and suppliers to get critical mass to make the parts.

Significant progress has been made over the years according to Majeske at Ford. “We look for every opportunity to put recycled content in where we can do it without any compromise. And we have found a large number of applications. Every time we do a new major vehicle upgrade, we look across the plastics and say ‘what parts are applicable, do we have a supplier that is anxious to do this and is capable?’ Then we specify that we want those materials to have as much recycled content as is feasible with feed streams and all the performance constraints.”

Recycled plastic from cars, bottles, caps, containers and other packaging are increasingly being utilized to make new car parts in vehicles. Some examples of post-industrial and post-consumer plastics being used, according to the American Chemistry Council, include:

- **CHRYSLER** uses recycled polyurethane foam plastic in the seat cushions of its Jeep Grand Cherokee, and the wheel liners on the Jeep Wrangler and Chrysler 200 are made with 64

percent recycled plastics. In 2013, nearly 40 percent of the thermoplastics in Chrysler’s European vehicles were recycled plastics.

- **FORD** uses recycled plastics to create upholstery for passenger seat cushions in numerous models. For example, the seat fabric for each Focus is made with approximately 22 plastic water bottles. The company used more than 50 million pounds of post-consumer recycled plastics on the exterior of Ford vehicles made in North America—that equals nearly 18 pounds per vehicle on average.
- **HONDA** recycles scrap bumpers generated during the manufacturing process; plastics from bumpers produced at five Honda plants in the U.S. and Canada are reformulated and reused in Honda’s supply chain to make mud and splash guards.
- **GM** uses air deflectors (used to direct air flow) for its Volt made from plastic caps, bottles and other recycled materials. The company also uses plastic caps and shipping aids from its Fort Wayne facility to make radiator shrouds (used to protect the radiator) for the Chevrolet Silverado and GMC Sierra pickups built at that facility.
- **NISSAN** uses plastic fibers made from used bottles as the main component in sound insulation layers in dashboards. The automaker also uses plastics recycled from bumpers to create new bumpers, as well as plastics recycled from bottle caps to make new auto parts.
- **TOYOTA** uses recycled plastics throughout its vehicles. The company recently announced that 20 percent of the plastics used in its vehicles are made with recycled plastics or plastics derived from plant materials.

Source: American Chemistry Council

Corporate sustainability commitments are vital when it comes to using recycled plastics—it helps balance the priority of cost and weight that every company places on components.

Like any industry, auto manufacturers want to know that if they choose to approve a resin, it will be available and consistent, according to Ravago’s Render. The challenge continues for the plastics and recycling industries to have consistent, quality streams that are scalable. “With time this is never a problem—they need to know that the supply of a recycled material can jump 20 percent in one year if necessary,” Render said.

Parts manufacturer IAC has global environmental and sustainable targets too, including optimization of using the best material for each application, utilizing renewable resources and recycled materials—both post-consumer recyclate and post-industrial recyclate.

IAC’s recycled resin objectives in its manufacturing process includes:

- Optimize materials for each application
- Improve product performance
- Improve product competitiveness/material cost stabilization
- Reduce shipments to landfill
- Utilize renewable resources
- Reduce part weight

Kozora believes this is an opportunity for plastics as the demand for lightweight solutions will be accelerating as companies drive to meet CAFE standards.

Turning Recycled Plastics into Cars

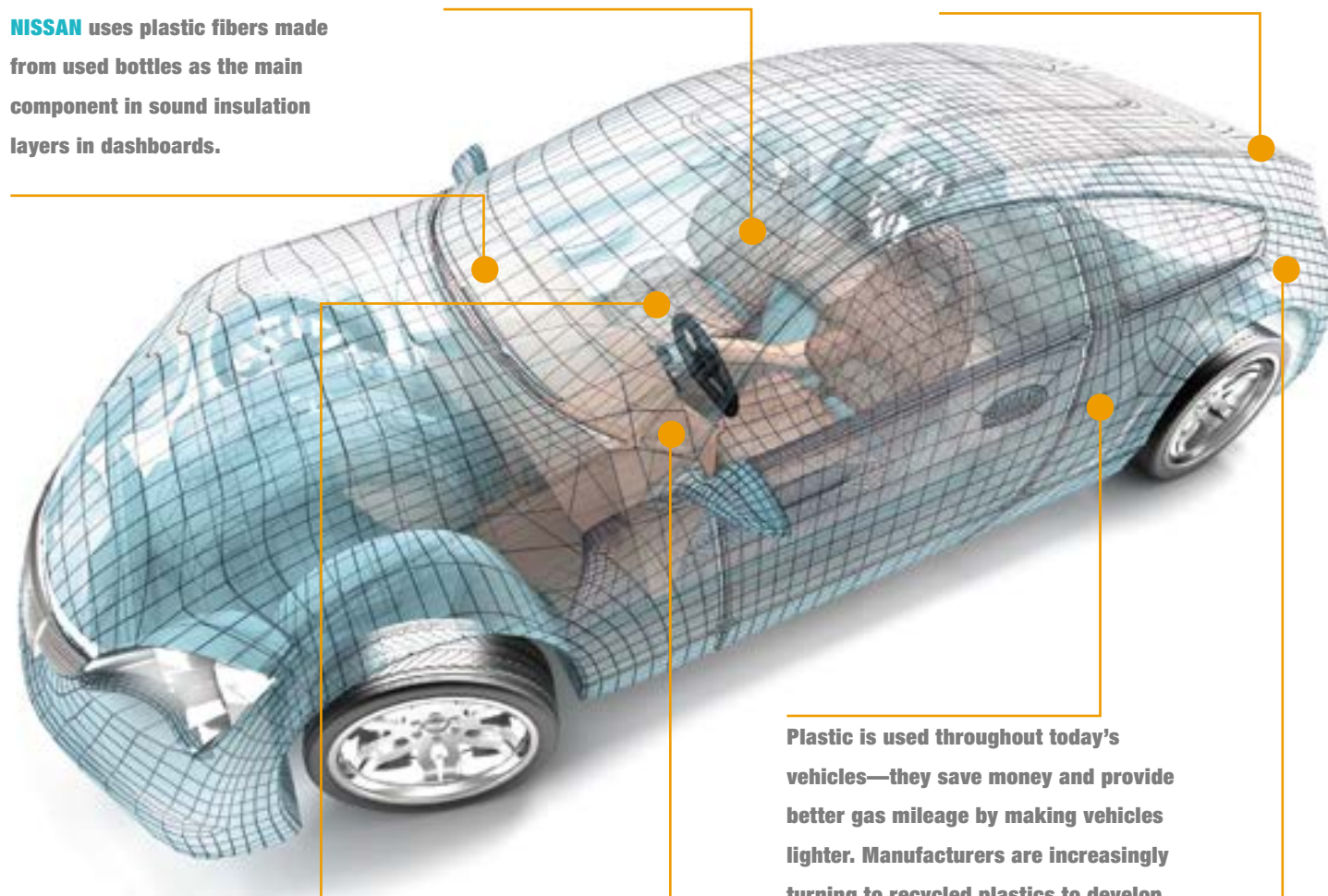
Recycled plastic from cars, bottles, caps, containers and other packaging are increasingly being utilized to make new car parts in vehicles. Many of the household and kitchen items you recycle can be turned into new, plastic car components.

Source: American Chemistry Council

CHRYSLER uses recycled polyurethane foam plastic in the seat cushions of its Jeep Grand Cherokee

GM uses air deflectors (used to direct air flow) for its Volt made from plastic caps, bottles and other recycled materials.

NISSAN uses plastic fibers made from used bottles as the main component in sound insulation layers in dashboards.



FORD uses recycled plastics to create upholstery for passenger seat cushions in numerous models. The seat fabric for each Ford Focus is made with approximately 22 plastic water bottles.

Plastic is used throughout today's vehicles—they save money and provide better gas mileage by making vehicles lighter. Manufacturers are increasingly turning to recycled plastics to develop their new components.

Vehicle air duct applications in vehicles are among the most widely used component containing post-consumer recycle; more than 50MM pounds of HDPE is used in air ducts systems of several manufacturers, including Toyota, Volkswagen, Nissan, Ford and others.

FORD used more than 50 million pounds of post-consumer recycled plastics on the exterior of Ford vehicles made in North America—that equals nearly 18 pounds per vehicle on average.

According to Sue Kozora, Manager—Materials Engineering at IAC Group, automotive manufacturers still put an emphasis on cost and weight, but other considerations are beginning to flow between departments at the companies and into the thinking of engineers. Kozora believes this is an opportunity for plastics as the demand for lightweight solutions will be accelerating as companies drive to meet CAFE standards.

A hurdle recycled plastics face is the bias or pre-conceived notions that some automotive engineers have about using recycled plastic materials.

According to Kozora, “Engineers still often see recycled plastics as a risk, despite the fact that virgin and recycled polymers are equal and can meet their specs.” The bias or reluctance of some engineers to use recycled plastics Kozora added, comes from 20 years ago when there were some lower performing recyclable plastics and bad recycling. That is no longer the case as plastic components using a variety of recycled plastic materials are meeting manufacturer specifications and are being used in vehicles around the world.

The ACC also recognizes that plastics and polymer composite materials face a challenge with engineers, noting there is “inadequate education and training to develop an automotive workforce knowledgeable about plastics and polymer composites, and insufficient data necessary to encourage OEMs to adopt plastics and polymer composites.”

Ravago Recycling Group’s Render attributed the engineer reluctance, in part, to the competitive automotive marketplace. “In the automotive world today, the culture of quality and the drive for quality is at a point where people are very proud of what they produce and very reluctant to want to do things that would impact their real sense of the quality of the product,”

Render said. “With non-cosmetic parts—hidden parts from the consumer—we have made great progress, like air ducts, wheel wells and parts you just don’t see, engineers are just more willing to use recycled, plastic materials. But this will change over time.”

Carrie Majeske at Ford Motor Company said there may be some reticence among engineers, but that it is likely tied to costs and scale. “It becomes a business challenge when you introduce recycled content into that supply chain; and at times, introducing recycled content can be a cost hurdle.”

Recycled plastics have made significant inroads in the vehicle’s power train, said Eric Parrell, automotive segment manager, Entec Polymers. “Anything with black plastic under the hood, that is where recycled material is playing.” But Parrell said OEMs are becoming more cautious recently about parts due to all the recent recalls, “On safety components, OEMs won’t touch recycled plastics in making those parts.”

Using recycled content for black plastics under the body was a significant challenge technically according to Ford’s Majeske. “We have progressed to some higher temperature applications under hood that did present some challenges, but we have used some post-consumer recycled material in a lot of our power train like cam covers that do have to survive the under hood environment.”

Recyclers have to step up their game to prove that they can meet the material specifications set by the industry according to SPI’s Holmes. “A material spec is a material spec—let’s not care about where the resin came from; what we need to care about is whether the resin qualifies. At the same time, we need to encourage recyclers to expand their capabilities in compounding and quality assurance testing so they can consistently meet the customer’s needs—which is consistently meeting their material spec,” she said.

Vehicle air duct applications are IAC’s most widely used component containing post-consumer recycle; more than 50MM pounds of HDPE is used in air duct systems of several manufacturers, including Toyota, Volkswagen, Nissan, Ford and others.

Original equipment manufacturer specifications, expectations and targets for components all vary. For example, BMW and Mercedes have very strict volatile organic compound (VOC) and odor requirements that virgin and recycled materials must meet. The extensive testing manufacturers conduct to satisfy OEM specifications cost between \$15,000 and \$20,000; no exceptions are given—or expected—for components using recycled materials.

Parrell indicated that OEMs can be very complicated in their specifications and willingness to work with recycled plastics,

In theory, end-of-life vehicles are nearly 100 percent recoverable. In practice, however, the cost in energy and labor to recover all vehicle material often exceeds the value of the materials and offers insignificant value to the environment.

and that it takes an enterprise buy-in to get recycled plastics to the forefront of parts development. “The problem we run into more than anything else with OEMs is that they always want the material to be the same as a prime, virgin material and it is just not going to happen,” Parrell explained. “So they want recycled, they want the price of recycled, but they want it to meet the specifications of a virgin material. That is what the challenge really is.”

Some specifications developed by OEMs are engineered for prime materials only and recycled materials cannot meet those specifications.

OEM's almost always expect lower costs from recycled products—from 10 to 50 percent. While using recycled polymers does not necessarily translate to reduced costs, it does offer pricing stability. Where virgin PET may fluctuate due to petroleum price spikes, recycled PET is predictable and offers manufacturers cost stabilization when worked into their long-term sourcing strategy.

Automotive Shredder Residue (ASR)

As noted earlier, nearly all automotive shredder residue (ASR) in the U.S. is directed toward landfills today. The Institute of Scrap Recycling Industries Inc. (ISRI) indicated the EPA's ruling three years ago resolved regulatory uncertainty about ASR handling and disposal—and that the ruling could lead to further investments and development in innovative methods to separate plastics from ASR aggregate that would produce broad environmental benefits and increase global competitiveness.

Unfortunately, the EPA's ruling in 2013 coincided with the dramatic increase in domestic oil and natural gas supplies; the economics of recycling the material have been challenging for the industry. U.S. recyclers have been researching the potential for recovering plastics in ASR; but to date no market has opened up for the material domestically. In the E.U., plastic is being extracted from ASR, due in part to a mandate that recycling and recovery rates for end-of-life vehicles were set at 95 percent—only 5 percent of a vehicle could be directed to landfills.

The challenge for ASR plastic recycling in the E.U. and U.S. is that shredded plastics are very dirty and resins frequently used in automotive and electronic goods are mutually incompatible—the mixture of high-density polyethylene (HDPE), acrylonitrile butadiene styrene (ABS), PP and polyvinyl chloride (PVC). The fixed price to segregate those resins currently exceeds the price of prime in today's market. GDE Recyclage in France has developed a complete granulating and washing line to process significant volumes of

plastics, focusing initially on polyethylene and polypropylene plastic fractions.

Olivier Pitavy, development project manager for ECORE B.V., the parent company of GDE Recyclage in France, told *Recycling Today* that his company worked with several manufacturers to test processed shredder residue with respect to consumers' specifications for various grades of material. GDE's ASR end products produced at its shredding plants include traditional ferrous and nonferrous grades, including zorba and zurik, insulated aluminum and copper wire suitable for upgrading, printed circuit boards, mixed aluminum, mixed stainless, polypropylene and polyethylene plastic fractions, and solid recovered fuels (SRFs).

The technology and economic challenges facing recyclers are well understood by car manufacturers. Valentina Cerato, Ford materials engineer in Europe, said, “In theory, end-of-life vehicles are nearly 100 percent recoverable. In practice, however, the cost in energy and labor to recover all vehicle material often exceeds the value of the materials and offers insignificant value to the environment. We remain focused on achieving the highest economically viable and environmentally sound recovery percentage possible.”

Automotive
Recycling:
Devalued is now
Revalued

Research
and Work
Underway



Automotive manufacturers around the world have made commitments to reduce their industrial footprints and have made plastics a cornerstone of their environmental sustainability efforts.

Research and Work Underway for Plastics Recycling in Automobiles

To date, weight and cost savings have been the trump card for plastics' increased usage in automobiles around the world. The design advantages and properties of plastics and polymers have given engineers a major lift in meeting CAFE standards while keeping automobiles affordable. Plastic parts and components that were originally hidden from the

consumer, and perceived as a potential symbol of "cheap" or "unsafe" parts, are now being showcased in vehicles as high-tech and advanced materials.

Recycled plastics—post-consumer and post-industrial—are used in dozens of car parts, primarily interior and drivetrain components. Vehicle air ducts today were detergent bottles yesterday. Automotive manufacturers around the world have made commitments to reduce their industrial footprints and have made plastics a

cornerstone of their environmental sustainability efforts.

The response by the recycling industry, plastics manufacturers and automotive companies will require collaboration and other experts like university researchers. Getting all players together in a collaborative environment is a priority for SPI and others; the 2016 Refocus Summit and Exposition is one of the forums and educational programs to identify challenges companies face in their supply chains and product design processes in using recycled content, designing for recycling, pursuing zero waste in manufacturing, and developing next-generation technologies and materials like bioplastics.

The ACC published its Plastics and Polymer Composites Technology Roadmap for Automotive Markets that outlined the need to "Create a recycling and energy recovery demonstration program to develop and prove the effectiveness of innovative recycling techniques for automotive plastics and polymer composites."

There continues to be a need to develop more lifecycle analysis data for recycling options and bolster arguments for programs like zero net waste in manufacturing. According to the ACC, the plastics and polymer composites industry currently lacks the data needed to accurately assess the cradle-to-grave energy use and CO₂ emissions of these materials using established lifecycle analysis tools and to allow OEMs to compare to that of metals.

Key research is underway with players taking leadership on specific areas, materials and processes; these kinds of collaborations were a highlight of the ACC's blueprint of the future for the automotive markets. The establishment of the Institute for Advanced Composite Manufacturing Innovation (IACMI), one of the newest National Network of



Vehicle air ducts
today were detergent
bottles yesterday.

Manufacturing Institutes championed by the Obama Administration, is the kind of public/private research initiatives that will bolster the development of new advanced and recyclable materials. With ACC's support, IACMI identified recycling of automotive composites as a main focus area for the institute.

Fiat Chrysler Group has been taking a holistic look at its materials—raw, recovered or recycled—in order to reduce the company's environmental footprint for products throughout all stages of their lifecycle.

In 2013, 41.9 percent of the weight of some Fiat Chrysler vehicles in Europe was made of recycled materials, including metals and plastics. The company's achievement came through a number of international research projects on innovations in the use of recycled materials and biomaterials. These initiatives evaluate the environmental benefits of using different formulas of polymers—post-consumer recycled plastic or biopolymers—reinforced with natural fibers. The company is closely monitoring the recyclability and recoverability of a number of its European vehicles. All vehicles that the Fiat Chrysler Group sells in Europe were 95 percent recoverable and 85 percent recyclable by weight, in compliance with European guidelines outlined in Directive 2005/64, Reusability, Recyclability, Recoverability—RRR which establishes the limits of recoverability and recyclability.

In North America, some of the group's leading research is underway to understand product recyclability through the entire product life-cycle from development, concept and use, to end-of-life disposal and recycling. The Vehicle Recycling Laboratory at the Fiat Chrysler Group's Automotive Research and Development Centre (ARDC) in Windsor, Canada is equipped with material identification equipment, vehicle fluid removal equipment, unique vehicle dismantling equipment, and advanced data analysis equipment.

Recycling Carbon Fiber Reinforced Polymers

New generation automobiles have embraced the use of carbon fiber reinforced polymers (CFRP)—particularly some European designs and alternatively fueled vehicles. Even though these vehicles help manufacturers comply with fuel economy and CO₂ regu-

All vehicles that the Fiat Chrysler Group sells in Europe were 95 percent recoverable and 85 percent recyclable by weight, in compliance with European guidelines outlined in Directive 2005/64, Reusability, Recyclability, Recoverability (RRR).

lations, they are still required to comply with the EU's ELV recycled content requirements: the newest advanced polymer is also the newest material to be analyzed for recycling and reuse by manufacturers and scientists.

With all EU vehicles needing to meet a requirement that 85 percent of the materials used in each car and light truck, by weight, be reusable or recyclable, recycling advances must be made to catch up with metals and other plastics. While challenging when compared to other plastics, there are strategies under development according to *CompositeWorld* to reclaim and repurpose CFRP, particularly the materials' waste stream from automotive and aerospace manufacturing.

BMW is reusing CFRP production scraps to manufacture the roofs for its i3 and i8 models as well as the rear seat structure in the i3.

Currently, all commercial recycling of carbon fiber involves pyrolysis in which the CFRP is shredded and then vaporized through pyrolyzation. Pilot projects from a



Carbon fiber is an expensive material to work with, but if you are using production waste, then it's a different cost structure from working up raw carbon fiber.

few years ago have developed into commercial production capabilities. Materials Innovation Technologies in Fletcher, N.C. started reclaiming carbon fiber in 2009 and today processes stream from multiple sources: dry scrap from fiber manufacturers, braiders and weavers; uncured prepreg from prepreggers, Tier 1s and OEMs; and fully cured parts. After its pyrolysis processing, Materials Innovation Technologies sells the chopped RCF (reclaimed carbon fiber) directly or

90%

GM's manufacturing waste is reused or recycled, generating an estimated

\$1 billion
per year;

104

of the manufacturer's facilities are landfill-free.

converts it into LFT (long-fiber reinforced thermoplastics) pellets or into rolls of chopped fiber mat.

All CFRP recyclers have been challenged in finding a dependable supply of raw materials, but aerospace manufacturers have become the leading source for recyclable material. Automobiles represent the greatest marketplace for recycled carbon fibers—as BMW has shown with its utilization of recycled production waste. SGL Automotive Carbon Fibers reports that 10 percent of the CFRP used in the BMW *i* vehicles is recycled, and BMW has already declared that it will apply its CFRP technology beyond the *i* and *M* models.

The hurdles facing CFRP recycling are similar to those facing other plastics: increased education and understanding of the material for engineers and designers, accepting changes to supply chains, continued development of pilot projects and demonstrations showing waste-to-reuse viability and performance of recycled carbon fiber products.

Costs could be a strong counterargument, as commercial recyclers note that recycled carbon fiber offers a 20 to 40 percent cost savings vs. virgin fiber. BMW's Lightweight Construction Manager Franz Storkenmaier has listed seat frames, instrument panel frames and spare wheels as RCF targets and recently told *Auto Express* magazine: "Carbon fiber is an expensive material to work with, but if you are using production waste, then it's a different cost structure from working up raw carbon fiber."

SPI Initiatives

Earlier this year, SPI launched its Zero Net Waste (ZNW) recognition program to assist the plastics industry in managing wastes in manufacturing by offering specific tools to evaluate waste reduction opportunities and maximize landfill diversion. SPI's program takes the view that the plastics manufacturers, more than anyone, should recognize that their product—and scrap products—are a valuable asset worth recycling and diverting from landfills. For auto makers and their supply chain, this means capturing all scrap and non-spec parts for recycling and turning post-industrial plastics waste into pellets and other recyclable material.



Zero Net Waste efforts have been embraced by participants in the automotive sector; GM has been on a decade-long effort to reduce its manufacturing waste stream—and generate revenue from its production byproducts, such as steel, plastics, rubber and even paint. Approximately 90 percent of GM's manufacturing waste is reused or recycled, generating an estimated \$1 billion per year; 104 of the manufacturer's facilities are landfill-free.

SPI's program provides a best-practices manual that offers real-world, step-by-step tools and resources for companies throughout the plastics value chain to ensure that plastic materials and other manufacturing byproducts are put to their highest and best use. From building the business case for pursuing zero net waste, to educating employees and offering practical guidance on finding the right service providers, the ZNW program manual is designed to enable companies of all sizes to take immediate steps to begin pursuing zero waste in their facilities.

SPI member companies who participate in the program, and meet requirements of the two-step qualification and verification process will be recognized for their efforts.

In a separate recovery effort, SPI members are looking for solutions and common ground among players in the automotive plastics life cycle supply chain. SPI has launched a collaborative research project with the Automotive Recyclers Association (ARA), the Canadian Plastics Industry Association (CPIA), and Scout Environmental to explore the viability of collecting and recycling auto plastics from ELVs and build a basic recovery model for whole parts before shredding, beginning with thermoplastic polyolefin (TPO) and polypropylene (PP).

More than a decade ago, ARA members conducted a similar review of plastics automotive recycling and concluded that the associated labor costs required to recover the

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plastics were greater than the resulting economic benefits. The current review, which will be broader in scope and industry participation, will help determine the feasibility of recovery today pared against material performance and demand for recycled TPO and PP. If successful, this project will serve as a launching point to further explore the opportunity to recover additional plastics, both through whole-parts recovery and eventually ASR.

Through increasing the knowledge about the value of plastics, and linking ARA members to markets for those scrap materials, we believe increased recovery can be achieved. With approximately 12–15 million vehicles being scrapped each year in the U.S., an increasing amount of those vehicles comprised of more and more plastic components and

parts, there is an opportunity—and steady supply—for recyclable plastics.

For the project, participants will identify the parts that could be included in a TPO/PP bale, based on accessibility and ease of recovery, quantity and consistency of plastics in the components to reduce contamination, and the market value of materials. Examples of the parts include: air filters, battery cases, bumper fascia, door panels, fender liners, floor mats and running boards.

SPI expects the recovery project and whitepaper report to be complete at the end of 2016 or early 2017, and will share the findings and best management practices across industry sectors.



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Bioplastics—in cars now and in the future

Bioplastics—plastics derived from renewable biomass sources—are also finding their way into the automotive manufacturing process. Ford is using soy to develop bio-based polyurethane foams on the seat cushions, seatbacks and headliners on 11 vehicle models. The company is also working with H.J. Heinz Company on research to use tomato fibers (skins, stems and seeds) for vehicle wiring brackets and storage bins such as coin and cup holders.

The challenge for Ford—and all manufacturers—is developing bioplastics that meet vehicle specifications and integrity standards.

Valentina Cerato, Ford materials engineer in Europe, said, “Sustainable materials need to meet the same high standards for quality, durability and performance as virgin material; there can be no compromise on product quality.”

Toyota has been working with its plant-derived Ecological Plastic in its cars for several years to develop scuff plates, headliners, seat cushions and other interior vehicle parts. The company’s commitment to bioplastic technologies is part of the company’s successful effort to replace 20 percent of a vehicle’s plastics with recycled or Ecological Plastic materials.

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Farm Grown Truck Parts Recycled Ford Parts

www.dieselpowermag.com



GM, SUBARU, FORD AND OTHER
MANUFACTURERS ARE EMBRACING ZERO
WASTE MANUFACTURING AND RECYCLING

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PLASTICS USAGE IN AUTOMOBILES IS INCREASING AS
MANUFACTURERS LOOK TO IMPROVE THE MPG OF THEIR
VEHICLES.

By 2020, the average car will have about 770 pounds
of plastics by weight compared to the 440 pounds
averaged in 2014—an increase of 75 percent.

AUTO MANUFACTURERS ARE TURNING
TO RECYCLED PLASTIC FROM
BOTTLES, CAPS, CONTAINERS AND
OTHER PACKAGING TO MAKE NEW CAR
PARTS IN VEHICLES.

Ford used more than 50 million
pounds of post-consumer
recycled plastics on the exterior
of Ford vehicles made in North
America—that equals nearly 18
pounds per vehicle on average.

CONTINUED COLLABORATION IS
NEEDED TO FURTHER INNOVATION
AND ADOPTION OF RECYCLED
PLASTICS FOR NEW AUTOMOTIVE
PARTS AND COMPONENTS

VALUE OF PLASTICS AS COMPONENTS—AND
MATERIAL—BEING RECOGNIZED AND APPLIED
TO NEW VEHICLES

Carbon fiber reinforced plastic (CFRP)
usage in vehicles will increase from
3,400 tonnes in 2013 to 9,800 tonnes
in 2030. Used inside and out of,
CFRP weighs 50 percent less than
conventional steel and 30 percent lighter
than aluminum. BMW is reusing CFRP
production scraps to manufacture the
roofs for its i3 and i8 models as well as
the rear seat structure in the i3.

Closing the loop on auto plastics:
Growing opportunities for use of
recycled content and recovery

Automotive
Recycling:
Devalued is now
Revalued



Conclusion

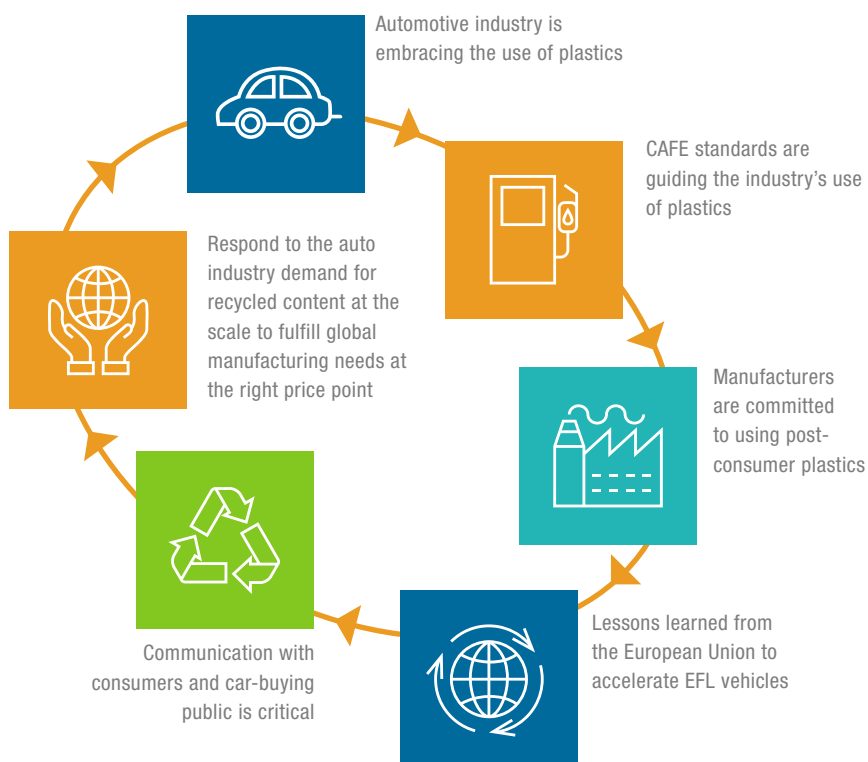
Conclusion

In 2012, SPI adopted a new mission statement for its members and industry: *SPI advances a pro-manufacturing agenda, strengthens global competitiveness, improves productivity and pursues zero waste strategies for the U.S. plastics industry.* The mission is being fulfilled across the country by a number of industry sectors, including the automobile industry.

The automotive industry is embracing plastics in its designs and manufacturing processes, and finding new ways to use polymers to produce efficient, safe and innovative vehicles. Plastics are valuable for car companies in making cars—they recognize the value of plastics—and therefore they are using zero waste to save that valuable plastic and recycle it.

The impetus for plastic's growing role in automotive designs—the Corporate Average Fuel Economy (CAFE) Standards—continue to increase and challenge engineers to develop lighter, affordable components while improving vehicle safety. Weight and cost have been the mantra for automotive designers, and will likely dominate engineering and design in the future. Plastic components, initially for parts that were out-of-sight and out of-mind, have grown with the development of new plastics and polymers to be featured as interior and exterior components.

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The CAFE standards are guiding the automobile industry's use of plastics, but their commitment to zero waste manufacturing, drive to save costs, and environmental stewardship are the roots to increased recycling of plastics and using recycled content for automobiles. Numerous manufacturers have successfully embraced closed loop philosophies at their facilities with the assistance of plastic recyclers and new technologies.

The plastics industry and recycling companies must respond to the automobile industry's demand for high-quality recycled content, at the necessary scale to fulfill global manufacturing needs, and at a price point that makes sense to designers and engineers.

The recycling of post-industrial plastic materials is being matched by the automobile industry's commitment to use post-consumer plastics in their designs and new models. For some drivetrain parts, recycled plastics are the norm and go-to material for manufacturers. Commitments by manufacturers to increase the use of recycled plastics (and bioplastics) in components is vital to the continued use of recycled materials—particularly with the current oil and natural gas price drop that has reduced the costs of prime materials.

There are other challenges to using recycled materials in automotive components beyond the short-term price drop of virgin plastics. Some are easily overcome, like an engineer's reluctance to turn to plastic design solutions for new components. Others are more complex, like the vast number of plastics used in auto-



mobile designs and the ability to consistently provide quality, recycled material, at scale, to meet manufacturer needs.

Market-based solutions are at hand and being embraced across all participants in the recycled automotive plastics supply chain. Some of these steps are particular to one player in the supply chain although most are the result of cross-collaboration and open communication between players. The development of specs for bumper bales is an example of progress—but clearly more can be done to develop standards on what kinds of automotive plastics can be collected, how it is processed and qualified to meet common industry standards, and how it gets to an end market. Some lessons can also be learned from the European Union where regulations have been established to accelerate the recycling of end-of-life vehicles and plastics.

Communication within the plastics supply chain and with automobile manufacturers will be crucial to addressing these challenges and finding solutions; but communication will also be critical to consumers and the car-buying public. The perception of plastics has dramatically changed over the past few decades, evolving from a material to be hidden under the hood to a material that is showcased on a vehicle's front grill, bumper and fascia. New plastic materials and components have cache with designers of the most expensive vehicles on the road as well as the generation of alternatively fueled vehicles—the carbon fiber look, feel and performance will likely expand to more vehicles.

Additionally, the use of plastics—and record of recycled plastics and closed loop manufacturing—need to be a pillar of marketing and communications efforts of the supply chain to consumers. Raising awareness of plastics recycling in automobile manufacturing is a story consumers need to hear consistently.

The role of plastics will continue to grow in automotive manufacturing; some will be new advanced polymer materials, but traditionally used plastics will continue to expand their footprint within a vehicle. The question for automotive manufacturers, the plastics industry, and the recycling sector is how much of this plastic content will be recycled. Continuing commitments to increase recycled plastic content in vehicle updates and redesigns are critical—but the plastics industry and recycling companies must respond to the automobile industry's demand for high-quality recycled content, at the necessary scale to fulfill global manufacturing needs, and at a price point that makes sense to designers and engineers.

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