Plastics and Polymer Composites in Light Vehicles

Economics & Statistics Department
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Executive Summary

The $426 billion North American (NAFTA) light vehicle industry represents an important sector of economy of both nations and a large end-use customer market for chemistry. In 2017, the 16.88 million light vehicles assembled in the United States, Canada and Mexico required some 5.8 billion pounds of plastics and polymer composites valued at $7.0 billion, or $416 in every vehicle.

The latest data indicate that the average weight of North American light vehicles rose in 2017. At an average of 342 pounds per vehicle, the use of plastic and composites gained nearly 20 pounds per vehicle from 2016. Polypropylene, however, is also used in thermoplastics polyolefin elastomers (TPO) and its use in that area is reported separately under rubber. In addition, carbon fiber is utilized to manufacture carbon fiber reinforced plastics (CFRP) for automotive applications. Average TPO and carbon fiber use is about 34 pounds per vehicle and if they were included in plastics and polymer composites the total would be equivalent to about 376 pounds per vehicle. A change in consumer preferences for larger trucks and SUVs played a role. But because of low gas prices and the increased weight of the average vehicle, the percentage of total vehicle weight rose to 8.6% in 2017. Plastics and polymer composites are still essential to a wide range of safety and performance breakthroughs in today's cars, minivans, pickups and SUVs. In fact, the use of plastic and polymer composites in light vehicles has increased from less than 20 pounds per vehicle in 1960 to 342 pounds per car in 2017.

The role of plastics is actually much larger as these materials are compounded with colorant and other additives that impart functionality and other positive attributes. The value of these additives and compounding services along with value-added among producers of plastic automotive parts and components bring the market for finished automotive plastics and polymer composite products up to $20.6 billion in the United States. These automotive plastic products are produced at 1,622 plants located in 45 states. These plants directly employ about 63,080 people and feature a payroll of $3.2 billion.

Michigan is the leading state in terms of direct employment (over 15,275) and is followed by Ohio (about 8,900), Indiana (8,280), Tennessee (nearly 4,120), Minnesota (nearly 3,155), Pennsylvania (over 2,865), Wisconsin (2,320), Illinois (over 2,160), North Carolina (nearly 1,720), and New York (nearly 1,515).

Producers of automotive plastics and polymer composites purchase plastic resins, additives, other materials, components and services. As a result, the contributions of plastics and polymer composites go well beyond its direct economic footprint. The automotive plastics and polymer composites industry fosters economic activity indirectly through supply-chain purchases and through the payrolls paid both by the industry itself and its suppliers. This, in turn, leads to induced economic output as well. As a result, every job in the automotive plastics and polymer composites industry generates an additional job elsewhere in the US economy, for a total of over 119,000 jobs.

Introduction

This report presents the latest results of an assessment of the chemistry and other materials make-up of light vehicles, a major end-use customer for American chemistry. It marks the first time we have examined the market for all of North America. That is, the North American Free Trade Agreement (NAFTA) comprised of the United States, Canada and Mexico.

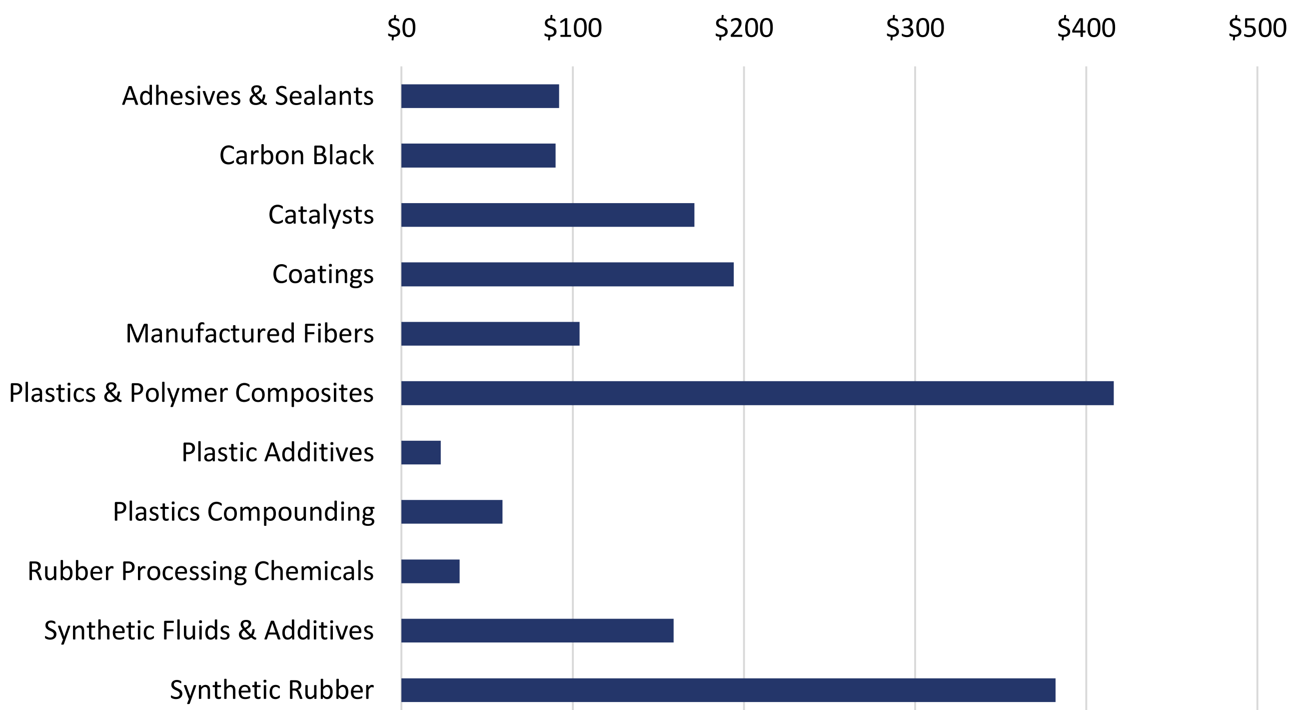
With 16.88 million light vehicles assembled in the NAFTA nations during 2017 this important market represents the equivalent of some $53.7 billion in chemistry. This chemistry value is up from $52.8 billion in 2016 when 18.02 million units were assembled. This 2017 value has increased significantly from the depths of the recession in 2009, when 8.45 million units were assembled and the associated chemistry value was $24.6 billion.

Chemistry and Light Vehicles

The light vehicle industry represents a large share of the North American economy, totaling more than $426 billion in shipments (at the manufacturer's level) in 2017 and employing 1.7 million workers. The light vehicle industry continues to be an important customer for most manufacturing industries, including the chemical industry. This relationship is particularly strong in basic and specialty chemicals because every light vehicle produced in the NAFTA nations contains $3,179 of chemistry (chemical products and chemical processing). The chemistry value per vehicle has grown considerably over the past 10 years, having grown 34% since 2007 when it was $2,371 per vehicle. With improving oil prices and prices for most chemistry combined with larger vehicles and higher chemistry content, average chemistry value rose 8.5% from 2016. Included in the chemistry value, for example, are antifreeze and other fluids, catalysts, plastic instrument panels and other components, rubber tires and hoses, upholstery fibers, coatings and adhesives. Virtually every component of a light vehicle, from the front bumper to the rear tail-lights features some chemistry.

Figure 1

Average Value of Direct Chemistry Content of North American Light Vehicles in 2017 ($/vehicle)



Note: Polypropylene is also used in thermoplastics polyolefin elastomers (TPO) as well and its use in that area is reported separately under rubber. The values of the carbon fibers are included under fibers. The resins are under plastics. Carbon fibers value is over $10 per vehicle.

The average values of direct chemistry content in North American light vehicles in 2017 for a variety of segments of the business of chemistry are presented in Figure 1 (measured in dollars per vehicle). Only details on the direct chemistry value of materials are presented (the chemistry value from processing and other indirect chemistry is not displayed). The values of the carbon fibers are included under fibers. Carbon fibers value is over $10 per vehicle.

Table 1
Average Value of Chemistry Content of North American (NAFTA) Light Vehicles ($/vehicle)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Adhesives & Sealants	$73	$76	$80	$82	$88	$90	$91	$92	$91	$91	$92
Carbon Black	52	73	95	101	107	107	104	102	83	79	90
Catalysts	130	135	137	144	161	159	165	172	170	168	171
Coatings	138	140	159	164	173	171	175	193	195	192	194
Manufactured Fibers	102	106	128	115	113	106	109	107	99	96	104
Plastics/Polymer Composites	345	381	375	391	436	412	411	414	396	380	416
Plastic Additives	19	21	21	21	24	23	23	23	21	21	23
Plastics Compounding	47	51	51	52	59	56	57	58	55	53	59
Rubber Processing Chemicals	22	28	28	31	42	33	29	28	26	29	34
Synthetic Fluids & Additives	106	133	132	136	163	169	165	166	161	157	159
Synthetic Rubber	274	350	350	400	528	409	351	327	301	329	382
Materials	**$1,308**	**$1,495**	**$1,555**	**$1,636**	**$1,893**	**$1,733**	**$1,680**	**$1,682**	**$1,598**	**$1,595**	**$1,723**
Processing/Other Chemistry	1,063	1,406	1,351	1,451	1,643	1,707	1,707	1,707	1,370	1,334	1,456
Total Chemistry Content	**$2,371**	**$2,901**	**$2,906**	**$3,087**	**$3,536**	**$3,440**	**$3,386**	**$3,389**	**$2,968**	**$2,929**	**$3,179**

Note: Polypropylene is also used in thermoplastics polyolefin elastomers (TPO) as well and its use in that area is reported separately under rubber. The values of the carbon fibers are included under fibers. The resins are under plastics. Carbon fibers value is over $10 per vehicle.

The direct chemistry value during 2017 averaged $1,723 per vehicle, 54% of the total chemistry value. Details on chemistry used are presented in Table 1. The remaining 46% (or $1,456 per vehicle) was from processing and other indirect chemistry (for example, glass manufacture uses soda ash and other processing chemicals).

Materials and Light Vehicles

The light vehicle industry is an important customer for a number of metal and other materials manufacturing industries. For plastics and polymer composites in particular there is significant competition with other materials, especially aluminum and steel.

In 2017, average weight of a light vehicle produced in North America increased by 0.7% (29 pounds) to 3,954 pounds. In 1990, average vehicle weight was 3,409 pounds. In 2000, the average vehicle weight was 3,873 pounds. The rising popularity of SUVs was a contributing factor in rising vehicle weight during the 1990s and for most of the last decade, peaking at 4,037 pounds in 2007. Higher gasoline prices in 2008, however, prompted a reversal of this trend and a shift to smaller, more fuel-efficient vehicles. As a result, average vehicle weight slipped during 2008 and 2009. An economic recovery and renewed popularity of larger vehicles in combination with lower gasoline prices then fostered increases in weight. Offsetting this to a limited extent is further penetration by plastics and composites and other lightweight materials which reduce average vehicle weight.

The performance of vehicles has improved significantly over the years. According to EPA data on light vehicles sold in the United States, for example, the average horsepower (HP) of model 2017 vehicles was 232 HP, compared to 214 HP In 2010, 181 HP in 2000 and 135 HP in 1990. Average fuel efficiency now averages 25.2 miles per gallon (MPG) compared to 22.6 MPG in 2010, 19.8 MPG in 2000 and 21.2 MPG in 1990. Although vastly improved engine technologies have played a role, so have chemistry and lightweight materials.

Regular steel and high- and medium-strength steel are the dominant materials in light vehicles. Combined, this steel accounts for 50% of vehicle weight. High- and medium-strength steel have been gaining share away from regular steel. In addition, hot-stamping offers many advantages and has supported steel use. Other steel and iron castings have generally lost share. Combined, all iron and steel (including castings) accounted for slightly over 59% of average vehicle weight, down from 60% in 2010, 66% in 2000 and 71% in 1990. Light vehicles are still very much iron-based in content.

Table 2
Average Materials Content of North American (NAFTA) Light Vehicles (pound/vehicle)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Average Weight	**4,037**	**3,964**	**3,855**	**3,862**	**3,910**	**3,801**	**3,808**	**3,830**	**3,886**	**3,925**	**3,954**
Regular Steel	1,619	1,596	1,462	1,422	1,405	1,335	1,322	1,308	1,293	1,295	1,222
High- & Medium-Strength	510	513	510	541	594	604	612	632	681	720	765
Stainless Steel	74	74	67	70	71	66	72	71	73	72	72
Other Steels	33	32	30	31	31	29	31	31	31	31	31
Iron Castings	317	248	201	236	255	263	264	271	260	242	243
Aluminum	314	310	319	332	337	342	348	361	387	404	416
Magnesium	10	11	11	11	11	10	10	9	9	8	8
Copper and Brass	65	69	70	72	71	70	69	67	65	67	69
Lead	41	43	41	40	38	35	34	35	35	35	37
Zinc Castings	9	9	9	9	9	8	8	8	8	8	9
Powder Metal	42	42	40	40	41	43	44	45	44	43	44
Other Metals	5	5	5	5	5	5	5	4	5	5	5
Plastics/Polymer Composites	328	334	368	343	336	318	314	315	321	322	342
Rubber	190	202	242	225	219	201	195	193	194	197	206
Coatings	30	31	35	35	32	27	27	28	28	28	29
Textiles	45	47	57	54	49	48	49	48	44	44	46
Fluids and Lubricants	213	211	214	215	217	215	218	220	221	222	222
Glass	102	97	87	90	96	93	94	94	93	92	95
Other	91	89	88	90	91	89	90	91	93	91	92
As a Percent of Total Weight	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Regular Steel	40.1%	40.3%	37.9%	36.8%	35.9%	35.1%	34.7%	34.1%	33.3%	33.0%	30.9%
High- & Medium-Strength	12.6%	12.9%	13.2%	14.0%	15.2%	15.9%	16.1%	16.5%	17.5%	18.3%	19.3%
Stainless Steel	1.8%	1.9%	1.7%	1.8%	1.8%	1.7%	1.9%	1.9%	1.9%	1.8%	1.8%
Other Steels	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
Iron Castings	7.9%	6.3%	5.2%	6.1%	6.5%	6.9%	6.9%	7.1%	6.7%	6.2%	6.1%
Aluminum	7.8%	7.8%	8.3%	8.6%	8.6%	9.0%	9.2%	9.4%	10.0%	10.3%	10.5%
Magnesium	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%
Copper and Brass	1.6%	1.8%	1.8%	1.9%	1.8%	1.8%	1.8%	1.7%	1.7%	1.7%	1.8%
Lead	1.0%	1.1%	1.1%	1.0%	1.0%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%
Zinc Castings	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Powder Metal	1.0%	1.1%	1.0%	1.0%	1.1%	1.1%	1.2%	1.2%	1.1%	1.1%	1.1%
Other Metals	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Plastics/Polymer Composites	8.1%	8.4%	9.5%	8.9%	8.6%	8.4%	8.3%	8.2%	8.3%	8.2%	8.6%
Rubber	4.7%	5.1%	6.3%	5.8%	5.6%	5.3%	5.1%	5.0%	5.0%	5.0%	5.2%
Coatings	0.7%	0.8%	0.9%	0.9%	0.8%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%
Textiles	1.1%	1.2%	1.5%	1.4%	1.3%	1.3%	1.3%	1.2%	1.1%	1.1%	1.2%
Fluids and Lubricants	5.3%	5.3%	5.5%	5.6%	5.6%	5.7%	5.7%	5.7%	5.7%	5.7%	5.6%
Glass	2.5%	2.5%	2.2%	2.3%	2.5%	2.5%	2.5%	2.5%	2.4%	2.3%	2.4%

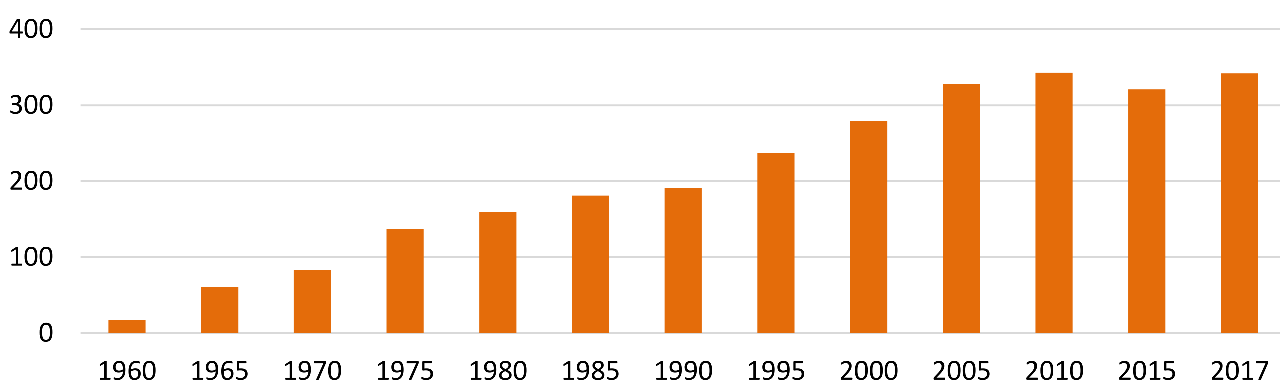
Note: Polypropylene is also used in thermoplastics polyolefin elastomers (TPO) as well and its use in that area is reported separately under rubber. Average TPO use is about 34 pounds per vehicle. The values of the carbon fibers are included under fibers. The resins are under plastics. Carbon fibers value is over $10 per vehicle.

Over the last several decades, lightweight materials have gained share away from iron and steel. For example, aluminum gained share in 2017, rising 3.0% (or 12 pounds) to an average of 416 pounds per vehicle. This is largely the result of the popular F-150 truck. Aluminum use represented 10.5% of average vehicle weight, up from 8.6% in 2010, 6.9% in 2000 and 4.7% in 1990. During this period, other lightweight materials such as magnesium and plastics and composites have also gained market share away from iron castings, steel, lead, and other heavier materials. Details on materials used are presented in Table 2. Additional metals include copper and brass, lead, and zinc, and others in both powder and solid form. Light vehicles are still very much metallic in content. All metals accounted for 74% of a typical light vehicle assembled in North America, up slightly from 2010, but down from 77% in 2000, and 79% in 1990. Glass, rubber, coatings, textiles, fluids and lubricants, and other materials round out the composition of a typical light vehicle.

Plastics and Polymer Composites in Light Vehicles

Light vehicles represent an important market for plastics and polymer composites in North America, one that has grown significantly during the last five decades. The average light vehicle now contains 342 pounds of plastics and polymer composites, 8.6% of the total weight. This is down slightly from 343 pounds in 2010, but up from 279 pounds in 2000 and 191 pounds in 1990. In 1960, less than 20 pounds were used. The typical light vehicle may contain over than 1,000 plastic parts.

Figure 2
Long-Term Trends in NAFTA Light Vehicle Plastics & Polymer Composites Use (pounds/vehicle)



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Composites are any combination of polymer matrix and fibrous reinforcement. Glass, carbon, aramid, and other fibers provide strength and stiffness while the polymer matrix (or resin) of polyester, polyurethane, epoxy, polypropylene, nylon, or other resin protects and transfers loads between fibers. This creates a material with attributes superior to polymer or fiber alone. In recent years, carbon fiber-reinforced composites have made inroads into light vehicle applications.

Plastics and polymer composites have been essential to a wide range of safety and performance breakthroughs in today's cars, minivans, pickups and SUVs. Today's plastics typically make up 50% of the volume of a new light vehicle but less than 10% of its weight, which helps make cars lighter and more fuel efficient, resulting in lower greenhouse gas emissions. Tough, modern plastics and polymer composites also help improve passenger safety and automotive designers rely on the versatility of plastics and polymer composites and the aesthetic possibilities when designing today's vehicles. In addition, many plastic resins are recyclable.

- **Automotive Body Exterior -** Plastics and polymer composites have revolutionized the design of body exteriors. From bumpers to door panels, light weight plastic provides vehicles with better gas mileage and allows designers and engineers the freedom to create innovative concepts that otherwise would be impossible. In the past, metals were synonymous with auto body exterior design and manufacturing. However, they are susceptible to dents, dings, stone chips and corrosion. They are also heavier and more expensive than plastics. Specifying plastics and composites for automotive body exterior panels and parts allows manufacturers to adopt modular assembly practices, lower production costs, improve energy management, achieve better dent resistance, and use advanced styling techniques for sleeker, more aerodynamic exteriors.

- **Automotive Interior -** The elements of automotive interior design -- comfort, noise level, aesthetic appeal, ergonomic layout, and durability -- have a great effect on a consumer's purchasing decision. Plastic automotive interior parts address all of these aspects, and more, in a remarkably effective and efficient manner.

- **Automotive Safety -** The versatility of plastics allows design options that reduce vehicle weight while producing safer vehicles. Included are plastic composite structures in the front end of a vehicle that reduce vehicle weight without compromising safety and plastic components in crumple zones that help absorb energy while lowering vehicle weight. Plastics are also used in door modules to maintain or improve side impact safety, plastic layers in automotive safety glass prevent passenger injuries, and plastic foams can add strength to automotive body cavities and increase occupant safety in vehicles.

- **Automotive Electrical Systems –** Over the last 20 years, the electrical systems of light vehicles have undergone a major revolution. Automotive electrical and electronic system components are now more numerous and important with computer chips regulating and monitoring ABS brakes, fuel injection, and oxygen sensors, GPS navigation equipment, obstacle sensors, state-of-the-art audio systems, and other systems. Plastics make possible the inclusion, operation, interconnection and housing of sockets, switches, connectors, circuit boards, wiring and cable, and other electrical and electronic devices.

- **Automotive Chassis -** A chassis is the supporting frame of a light vehicle. It gives the vehicle strength and rigidity, and helps increase crash-resistance through energy absorption. The chassis is especially important in ensuring low levels of noise, vibration and harshness (NVH) throughout the vehicle. Not only does a reduction in NVH allow for a more pleasant driving experience, but by putting less stress on connecting components it can help increase the life span of these components. The key determinant permitting reduced levels of NVH is energy absorption. As a result, passenger protection can be enhanced in the event of a collision. Plastics are making inroads into the chassis market. Innovations in plastic technology have brought about the development of successful chassis applications and structure, support and suspension performance.

- **Automotive Powertrains -** The powertrain is one of a light vehicle's most complicated parts. The term "powertrain" refers to the system of bearings, shafts, and gears that transmit the engine's power to the axle. Included are composite drive shafts that increase torque. Plastics help reduce the number of parts needed to assemble these complex components. Plastics also help reduce vehicle weight, which helps lower assembly costs while increasing fuel efficiency. For example, the utilization of lightweight plastics in a vehicle can allow manufacturers to utilize smaller, lighter weight engines.

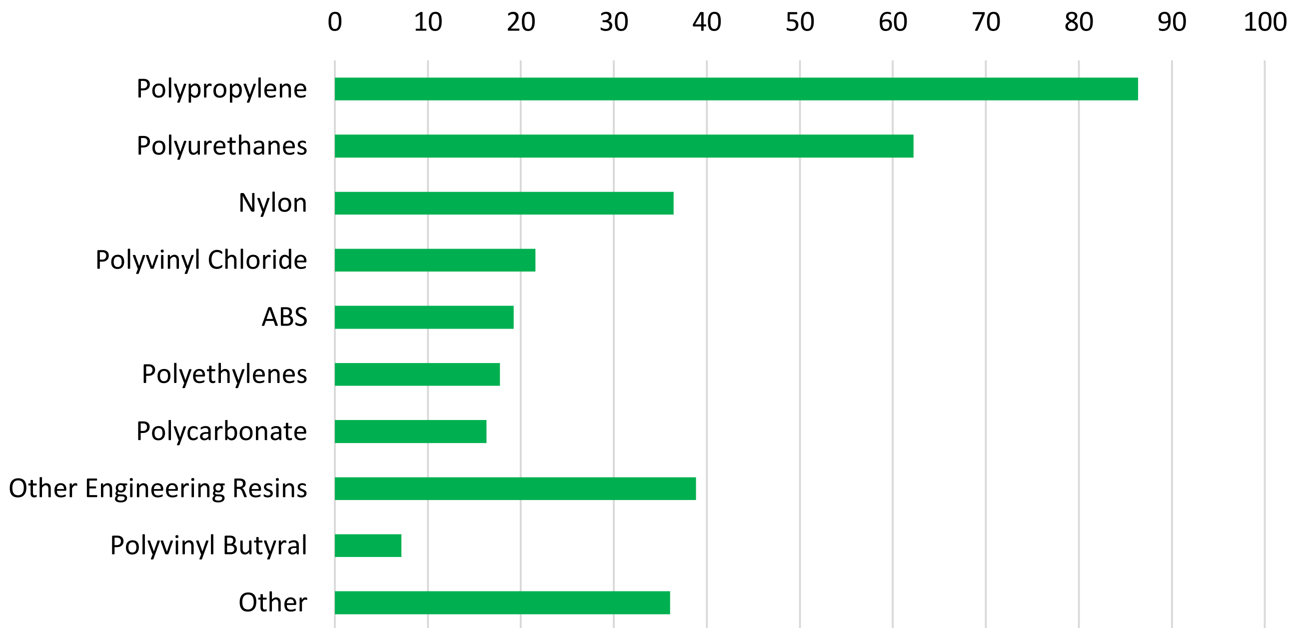
- **Automotive Fuel Systems -** For automotive fuel system components, plastics have several advantages that enable it to outperform metals. Plastic frees engineers from the design constraints that metal imposes. Plastic's light weight makes vehicles more fuel-efficient and from a safety standpoint, rupture-resistant plastics with high impact strength are helping keep automotive fuel tanks and related delivery systems leak-proof, corrosion-resistant, and reliable.

- **Automotive Engine Components -** Many of today's automotive engine components are plastic. From air-intake manifolds and systems to cooling systems to valve covers and other engine parts, plastic helps make engine systems easier to design, easier to assemble, and lighter in weight. Plastics' versatility has revolutionized automotive engine component design.

The automotive market is an important market for plastic resins such as polypropylene, polyurethane, nylon (polyamides), other engineering polymers, and thermoplastic polyesters. Light vehicle applications account for over 30% of the demand for each resin. Other resins include ABS and polyvinyl butyral. For the latter resin which is used in safety glass, the automotive market accounts for over 85% of total demand. Engineering polymers such as nylon, polycarbonate (and polycarbonate blends) and others are supplanting metals in many applications. Typical plastics and composite applications include exterior panels, trim, and bumper fascia, as well as interior trim panels, window encapsulation, headlamp housings, manifolds and valve covers, electronic/electric parts and components, wiring harnesses, steering wheels, insulation, dampening and deadeners, upholstery, mechanical parts and components, safety glass, and myriad other uses.

Average plastics and composites per North American light vehicle rose 20 pounds (6.2%) to 342 pounds in 2017, and plastics and composites lost some share of the overall weight of a typical vehicle. Over 15 major resins find significant use in light vehicles. Details on resin use are presented in Tables 3 and 4. Major polymers used in light vehicles include on average 86 pounds of polypropylene (PP), 62 pounds of polyurethanes, 36 pounds of nylon, 22 pounds of polyvinyl chloride (PVC), 19 pounds of acrylonitrile-butadiene-styrene (ABS), 18 pounds of polyethylene resins, and 16 pounds of polycarbonate resins.

Figure 3
Average Plastics & Polymer Composites Use in North American (NAFTA) Light Vehicles in 2017 (pounds/vehicle)



Note: Polypropylene is also used in thermoplastics polyolefin elastomers (TPO) as well and its use in that area is reported separately under rubber. Average TPO use is about 34 pounds per vehicle and if it were included in plastics and polymer composites the total would be the equivalent of over 375 pounds per vehicle.

Table 3
Average Large Volume Plastics Content of North American (NAFTA) Light Vehicles (pounds per vehicle)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total Plastic/Composites	**328**	**334**	**368**	**343**	**336**	**318**	**314**	**315**	**321**	**322**	**342**
Polypropylene	78	76	79	84	84	82	81	81	82	81	86
Polyurethanes	55	55	57	56	56	53	53	57	58	58	62
Nylon	41	41	42	37	38	36	35	35	35	34	36
Polyvinyl Chloride	27	28	38	30	25	22	21	20	19	20	22
ABS	21	23	27	23	21	18	17	17	17	19	19
Polyethylenes	15	16	18	17	17	17	17	16	17	18	18
Polycarbonate	15	17	21	18	17	16	16	15	15	15	16
Other Engineering Resins	40	40	45	38	37	34	35	36	36	37	39
Polyvinyl Butyral	7	7	7	7	7	7	7	7	7	7	7
Other	31	33	34	34	34	33	33	33	34	34	36
Total Plastic/Composites	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Polypropylene	23.6%	22.7%	21.5%	24.6%	25.0%	25.8%	25.7%	25.8%	25.5%	25.3%	25.3%
Polyurethanes	16.7%	16.3%	15.4%	16.3%	16.7%	16.8%	16.9%	18.0%	18.1%	17.9%	18.2%
Nylon	12.4%	12.1%	11.4%	10.8%	11.2%	11.2%	11.0%	11.0%	10.9%	10.6%	10.7%
Polyvinyl Chloride	8.1%	8.3%	10.3%	8.6%	7.5%	6.9%	6.7%	6.3%	6.0%	6.2%	6.3%
ABS	6.5%	6.8%	7.3%	6.6%	6.2%	5.6%	5.5%	5.3%	5.4%	5.8%	5.6%
Polyethylenes	4.4%	4.8%	4.8%	4.9%	5.0%	5.3%	5.3%	5.1%	5.3%	5.4%	5.2%
Polycarbonate	4.5%	5.1%	5.6%	5.2%	5.1%	5.1%	5.0%	4.8%	4.8%	4.7%	4.8%
Other Engineering Resins	12.3%	11.9%	12.2%	11.1%	11.0%	10.8%	11.2%	11.3%	11.4%	11.4%	11.4%
Polyvinyl Butyral	2.2%	2.2%	2.0%	2.0%	2.0%	2.1%	2.1%	2.1%	2.1%	2.2%	2.1%
Other	9.3%	9.8%	9.4%	9.8%	10.2%	10.4%	10.6%	10.3%	10.5%	10.6%	10.5%

Note: Polypropylene is also used in thermoplastics polyolefin elastomers (TPO) as well but its use in that area is reported separately under rubber in Table 2. TPO use averages about 34 pounds per vehicle. Polypropylene resin applications include Interior trim, under-the-hood components, HVAC components, battery cases, and other OEM uses.

Over the last few decades, other engineering resins such as polyacetal, polyphenylene ether (PPE), and thermoplastic polyester engineering resins have supplanted metals in a number of applications. Average use of these resins was 39 pounds in 2017, up from 38 pounds in 2010, 30 pounds in 2000 and 18 pounds in 1990. Polycarbonate and nylon are also classified as engineering resins (as are some ABS grades) and if polycarbonate and nylon resins were included, total engineering resin consumption would be 91 pounds. An average of seven pounds are polyvinyl butyral are used. Additional resins such as acrylics, phenolics, unsaturated polyester, and others account for the remaining 36 pounds.

Table 4
Average Engineering & Other Plastics Content of North American (NAFTA) Light Vehicles (pounds per vehicle)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Other Engineering Resins	**40**	**40**	**45**	**38**	**37**	**34**	**35**	**36**	**36**	**37**	**39**
Polyacetal	6	6	8	6	5	4	5	4	4	4	4
Polyphenylene Ether (PPE)	13	13	12	13	13	13	12	13	13	13	14
Thermoplastic Polyester Engineering Resins	20	18	23	17	16	15	15	15	16	16	17
All Other Engineering Resins	2	2	3	2	3	3	3	3	3	3	3
Other Plastic/Composites	**31**	**33**	**34**	**34**	**34**	**33**	**33**	**33**	**34**	**34**	**36**
Acrylics	5	5	5	4	4	4	4	4	5	5	5
Phenolics	9	11	10	12	12	12	12	12	12	12	12
Unsaturated Polyester	12	12	14	12	12	12	12	11	12	12	13
All Other Resins	4	5	6	5	6	5	5	5	5	5	6

Additional opportunities to reduce weight with plastics and polymer composites are possible. These include: 1) reducing the weight of existing plastic and composite parts with the use of low density additives, nanoparticles, and alternate fibers; and 2) converting more metal parts to plastics and composites. Furthermore, industry mega trends for future mobility, including self-driving vehicles and ride-sharing platforms will create numerous unique opportunities for plastics and composites due to increased safety requirements and new vehicle architectures. As a result, the light vehicle market presents significant opportunities for further diffusion of plastics and composites in the future.

Other Chemical Products and Light Vehicles

A variety of other products of chemistry are used in the manufacture of light vehicles. Most chemistry is used in processing and other indirect chemistry (e.g., soda ash in glass manufacture) but also over 280 pounds of rubber, textiles and coatings are used as well.

The typical North American (NAFTA) light vehicle utilizes, on average, 206 pounds of rubber, mainly in tires but also in non-tire applications such as belts and hoses, and other components. Natural rubber is used but by far the most widely used rubber is styrene-butadiene rubber (SBR) which is used in tire and a variety of non-tire applications. Common uses include radiator and heater hoses, various body and chassis parts, bumpers, weather-stripping, door and window seals, mats, grommets, tubes, fan belts and various molded and extruded goods. Thermoplastic polyolefin elastomers (TPO) are another widely used elastomer. Applications include a wide variety of exterior, interior and under-the-hood and chassis applications. Combined, natural rubber, SBR and TPO elastomers account for three-fourths of overall rubber consumption. Other elastomers include butyl rubber, chlorinated polyethylene, chlorosulfonated polyethylene, copolyester-ether, ethylene-propylene, nitrile, polybutadiene, polychloroprene (neoprene), polyisoprene, polyurethane, silicone, styrenic thermoplastics and other elastomers. Changes in tire design since the 1970s have resulted in less vehicle weight devoted to tires, resulting in some fuel savings since then. In recent years, longer-lasting, low- rolling-resistance tires and new materials have been developed and as these products penetrate markets, fuel performance should be enhanced.

The typical North American light vehicle utilizes 46 pounds of manufactured fibers, primarily synthetic fibers. Very few natural fibers are used and rayon and melamine fiber use has largely disappeared. Most notable synthetic fibers are traditional woven fibers of nylon and polyester but also non-woven fabrics of polypropylene and polyester used in various facings, backings, liners, acoustic panels, reinforcements and panels, and automotive filters. These fibers are derived from hydrocarbons. In recent years, traditional textiles are being supplanted by polyurethanes. Carbon fiber is typically blended with plastics to create carbon fiber reinforced plastics (CFRP) for automotive applications. Carbon fiber's high-strength but very low weight properties can play a major role in automakers' efforts to reduce vehicle weight. This is becoming increasingly important as manufacturers strive to meet fuel economy targets. The values of the carbon fibers are included under fibers. Carbon fibers value is over $10 per vehicle.

The typical North American light vehicle also featured 26 pounds of coatings (dry weight) in 2016. In automotive applications, coatings enhance value by making the vehicle attractive and protecting it. Without coatings, vehicles would quickly rust, be dull in appearance, and have a very short service life. Light vehicle applications include topcoats, primers and coatings for underbody components and include solvent-borne, water-borne and powder coatings. Powder coatings are based mainly on epoxy and polyester resins, which upon heating react with curing agents to form very durable coatings that emit virtually zero VOCs (volatile organic compounds). These have gained in use relative to traditional solvent-borne coatings in recent decades. Coatings use has declined in recent years because of reduced waste generation during application, thinner coatings, and the switch to higher solids coatings as well as greater plastics and polymer composite use.

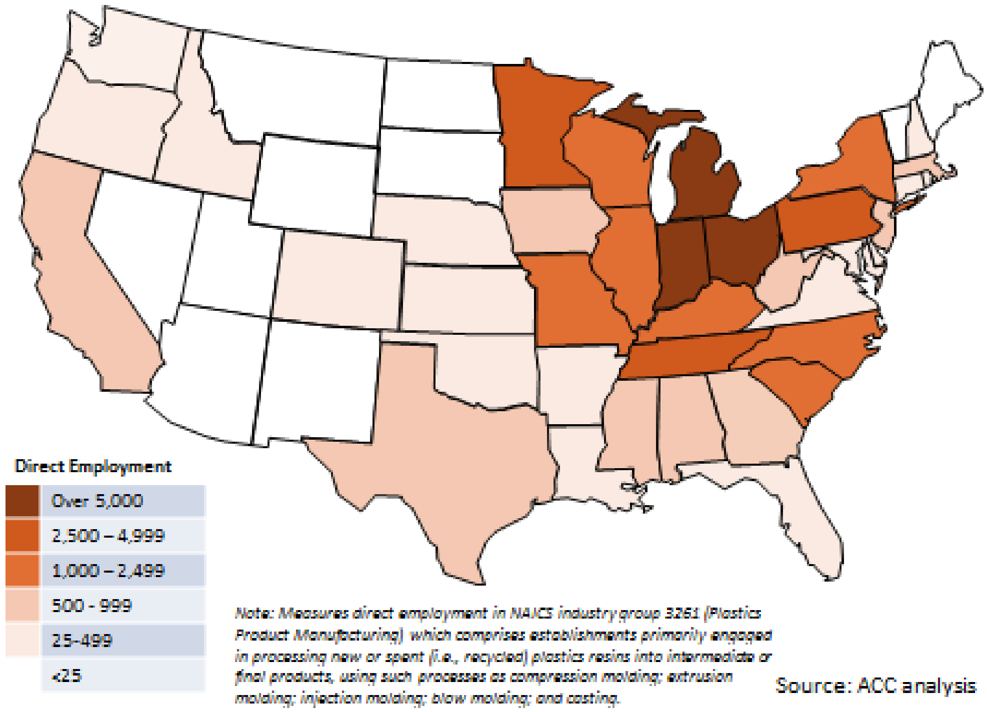
In addition to these materials, chemistry also plays a role in the 222 pounds of fluids and lubricants that a typical North American light vehicle contains. These include engine oil lubricants, transmissions fluids, windshield wiper fluids, refrigerants for air conditioners, and other products. All of these contain chemical additives to enhance performance while others such as fluorocarbon refrigerants are products of chemistry. In engine oil lubricants, synthetic lubricants are gaining market share away from traditional petroleum products.

Economic Footprint of Automotive Plastics and Polymer Composites in the USA

Light vehicles represent an important market for plastics and polymer composites, one that has grown significantly during the last five decades. The following analysis assesses the jobs (by state) associated with plastic products used in automotive applications in the United States. It measures jobs (and shipment value and the value of wages and salaries) by state at the level of plastic product manufacturing. That is, at the level of North American Industry Classification System (NAICS) industry group 3261 (Plastics Product Manufacturing) which comprises establishments primarily engaged in processing new or spent (i.e., recycled) plastics resins into intermediate or final products, using such processes as compression molding; extrusion molding; injection molding; blow molding; and casting.

Table 5 contains data on 2017 jobs by state as well as shipment and wages and salaries values for automotive plastic products. Shipments measure the value of these finished or fabricated products used in these automotive applications by establishments in NAICS industry group 3261 and produced within that state. In addition to direct employment, the analysis also measures indirect employment supported by the automotive plastic products sector via purchases from its supply chain and induced employment from the spending of those employed directly or indirectly by the automotive plastic products sector.

Figure 4
Automotive Plastics & Polymer Composites Direct Employment by State (2017)



The analysis is based on plastic processing volume data compiled by Townsend Solutions and data from the Bureau of Labor Statistics and the Census Bureau. The state data are for 2017:

- The value of automotive plastic products produced in the United States was $20.6 billion.
- These automotive plastic products are produced at 1,622 plants located in 45 states.
- These plants directly employ over 63,080 people and feature a payroll of $3.2 billion.
- Michigan is the leading state in terms of direct employment (over 15,275) and is followed by Ohio (about 8,900), Indiana (8,280), Tennessee (nearly 4,120), Minnesota (nearly 3,155), Pennsylvania (over 2,865), Wisconsin (2,320), Illinois (over 2,160), North Carolina (nearly 1,720), and New York (nearly 1,515).

The economic contributions of the US automotive plastics industry are numerous, though often overlooked in traditional analyses that consider only the direct jobs and output of the industry. Not only are jobs created directly by the industry, additional jobs are supported by the US automotive plastics industry and by subsequent expenditure-induced activity. The US automotive plastics industry pays its employees' wages and salaries and purchased supplies and services (including transportation, contract workers, warehousing, maintenance, accounting, etc.). These supplier businesses, in turn, made purchases and paid their employees, thus the US automotive plastics industry generates several rounds of economic spending and re-spending.

In addition to the direct effects of the US automotive plastics industry, the indirect and induced effects on other sectors of the economy can also be quantified. The economic impact of an industry is generally manifested through four channels:

- Direct impacts - Such as the employment, output and fiscal contributions generated by the sector itself
- Indirect impacts - Employment and output supported by the sector via purchases from its supply chain
- Induced impacts - Employment and output supported by the spending of those employed directly or indirectly by the sector
- Spillover (or catalytic) impacts - The extent to which the activities of the relevant sector contribute to improved productivity and performance in other sectors of the economy

This report presents the jobs created that are related to the first three channels. Spillover (or catalytic) effects do occur from, but these positive externalities are difficult to accurately quantify and were not examined in the analysis.

To estimate the economic impacts from the US automotive plastics industry, the IMPLAN model was used. The IMPLAN model is an input-output model based on a social accounting matrix that incorporates all flows within an economy. The IMPLAN model includes detailed flow information for 440 industries. As a result, it is possible to estimate the economic impact of a change in final demand for an industry at a relatively fine level of granularity. For a single change in final demand (i.e., change in industry spending), IMPLAN can generate estimates of the direct, indirect and induced economic impacts. Direct impacts refer to the response of the economy to the change in the final demand of a given industry to those directly involved in the activity. Indirect impacts (or supplier impacts) refer to the response of the economy to the change in the final demand of the industries that are dependent on the direct spending industries for their input. Induced impacts refer to the response of the economy to changes in household expenditure as a result of labor income generated by the direct and indirect effects.

An input-output model such as IMPLAN is a quantitative economic technique that quantifies the interdependencies between different industries (or sectors) of a national economy. Although complex, the input-output model is fundamentally linear in nature and as a result, facilitates rapid computation as well as flexibility in computing the effects of changes in demand. In addition to studying the structure of national economies, input-output analysis has been used to study regional economies within a nation, and as a tool for national and regional economic planning. A primary use of input-output analysis is for measuring the economic impacts of events, public investments or programs such as base closures, infrastructure development, or the economic footprint of a university or government program. The IMPLAN model is used by the Army Corp of Engineers, Department of Defense, Environmental Protection Agency, and over 20 other agencies, numerous government agencies in over 40 states, over 250 colleges and universities, local government, non-profits, consulting companies, and other private sector companies.

As shown in Table 5, the direct output and employment generated by the US automotive plastics industry is significant. The $20.6 billion industry directly generated over 63,080 jobs and $3.2 billion in payroll. But the full economic impact of the industry goes well beyond the direct jobs and output. Businesses in the automotive plastics and polymer composites industry purchase plastic resins, plastic additives, other raw materials, compounding and other services, and other products throughout the supply chain. Thus, nearly 21,185 indirect jobs are supported by US automotive plastics and polymer composites operations. Finally, the wages earned by workers in the automotive plastics and polymer composites industry and throughout the supply chain are spent on household purchases and taxes generating nearly 34,845 payroll-induced jobs. All told, the $20.6 billion in automotive plastics output generates a total of over 119,000 jobs. As a result, each job in the automotive plastics industry generates an additional job elsewhere in the US economy. These data are shown in Table 6.

Table 5
US Automotive Plastics & Polymer Composites Direct Jobs, Output and Wages & Salaries by State (2017)

State	Shipments ($ million)	Shipments/ Person	Payroll ($ million)	Wages/ Person	Direct Employment
AL	$349	$363,264	$43	$44,534	961
AR	$46	$313,480	$7	$44,632	148
CA	$280	$351,812	$43	$53,954	797
CO	$20	$251,843	$5	$57,944	80
CT	$49	$280,899	$11	$62,488	176
FL	$47	$305,982	$7	$48,256	154
GA	$245	$427,891	$29	$49,860	573
IL	$706	$326,474	$134	$61,815	2,163
IN	$2,131	$257,316	$414	$50,017	8,280
IA	$220	$268,393	$41	$49,559	820
KS	$93	$344,140	$12	$44,912	271
KY	$539	$382,724	$70	$49,464	1,409
MD	$29	$324,680	$6	$72,029	90
MA	$277	$366,332	$49	$64,893	757
MI	$5,317	$348,029	$803	$52,572	15,277
MN	$771	$244,417	$175	$55,590	3,154
MS	$274	$300,292	$37	$41,110	912
MO	$278	$233,403	$58	$48,635	1,190
NE	$13	$246,623	$2	$42,950	54
NH	$51	$177,845	$17	$60,130	286
NJ	$162	$280,985	$36	$63,021	578
NY	$635	$418,629	$81	$53,369	1,518
NC	$536	$312,490	$88	$51,210	1,716
OH	$3,199	$359,528	$425	$47,798	8,899
OK	$14	$379,318	$2	$48,231	38
OR	$17	$250,305	$3	$50,468	68
PA	$841	$293,212	$148	$51,487	2,867
SC	$456	$455,171	$55	$54,775	1,001
TN	$1,565	$362,408	$208	$48,219	4,319
TX	$388	$425,844	$48	$52,290	911
VA	$110	$406,730	$15	$55,946	271
WA	$21	$296,094	$4	$50,576	72
WV	$139	$229,964	$26	$42,525	603
WI	$625	$269,582	$118	$50,735	2,320
Other	$190	$543,672	$17	$47,325	349
Total	**$20,637**	**$327,146**	**$3,236**	**$51,303**	**63,082**

Sources: ACC analysis based on data from the Bureau of Labor Statistics, the Census Bureau, and Townsend Solutions.

Table 6
US Automotive Plastics & Polymer Composites Direct, Indirect and Induced Jobs by State (2017)

State	Direct Employment	Indirect Employment	Induced Employment	Total Employment	Jobs Multiplier
AL	961	294	425	1,680	1.7
AR	148	39	49	236	1.6
CA	797	333	447	1,576	2.0
CO	80	21	35	136	1.7
CT	176	50	74	300	1.7
FL	154	61	88	304	2.0
GA	573	187	309	1,069	1.9
IL	2,163	764	1,464	4,391	2.0
IN	8,280	2,277	4,208	14,765	1.8
IA	820	206	325	1,351	1.6
KS	271	69	110	450	1.7
KY	1,409	429	596	2,434	1.7
MD	90	26	53	169	1.9
MA	757	244	419	1,419	1.9
MI	15,277	5,921	10,249	31,448	2.1
MN	3,154	1,119	1,898	6,171	2.0
MS	912	213	327	1,452	1.6
MO	1,190	386	601	2,177	1.8
NE	54	15	22	91	1.7
NH	286	86	186	558	2.0
NJ	578	207	278	1,064	1.8
NY	1,518	349	385	2,252	1.5
NC	1,716	537	871	3,123	1.8
OH	8,899	3,103	4,775	16,777	1.9
OK	38	10	15	63	1.7
OR	68	26	37	131	1.9
PA	2,867	953	1,614	5,434	1.9
SC	1,001	303	506	1,810	1.8
TN	4,319	1,354	2,070	7,743	1.8
TX	911	444	578	1,933	2.1
VA	271	78	123	472	1.7
WA	72	27	35	134	1.9
WV	603	150	189	942	1.6
WI	2,320	788	1,325	4,433	1.9
Other	349	114	156	620	1.8
Total	**63,082**	**21,183**	**34,844**	**119,109**	**1.9**

Sources: ACC analysis based on data from the Bureau of Labor Statistics, the Census Bureau, and Townsend Solutions.

ACC Plastics Division

ACC's Plastics Division advocates unlimited opportunities for plastics and promotes their economic, environmental and societal benefits. Representing resin producers and distributors, the Plastics Division creates value for its members by promoting a positive issues climate and advantaging plastics in strategic markets. ACC's Plastics Division applies a three-pronged approach to strategic plastics issues management: (1) aggressive advocacy and grassroots action; (2) pre-emptive and targeted communications; and (3) highly focused technical and scientific programs. These integrated efforts enable the Plastics Division to effectively manage emerging and high-profile issues in the environmental and health arenas. Examples include product sustainability, recycling, and other end-of-life issues as well as chemical migration concerns specific to plastic products. In addition, the Plastics Division's four Market Issues Teams – Automotive, Building and Construction, Electrical and Electronics, and Packaging and Consumer Products – work with key customers and the plastics value chain to advantage plastics in strategic markets. Their activities include pre-competitive marketing, leveraging federal research dollars, advocating code and policy changes, and resolving potential obstacles to growth.

The Automotive Market/Issue Team (AMIT) operates in a political and technical environment managing key issues affecting the automotive plastics market such as energy policy, emissions control, substance disclosure, recycling, environmental sustainability, competitive material challenges, and specific Federal/State technology development programs. The AMIT is a proactive group dedicated to expanding the automotive market for plastics, and the team is focused on those pre-competitive initiatives that will help overcome key barriers and identifying and creating new opportunities to achieving a vision of "unlimited opportunities for plastics." The foundation of the automotive strategy is the implementation of the 2014 Plastics and Polymer Composites Technology Roadmap for Automotive Markets. The Roadmap is designed to maximize the value of polymers throughout the supply chain, provide a strategic technology agenda for plastics, align automotive and plastics industry needs, and engage science, technology, business, academic, and government leaders in support of the Roadmap's New Vision that "By 2030, the automotive industry and society will recognize plastics and polymer composites as preferred material solutions that meet, and in many cases set, automotive performance and sustainability requirements."

The Automotive Center in Troy, Michigan provides a forum to showcase the best in today's automotive plastics applications, encourages innovative thinking, and promotes broader applications for plastics in the industry.

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Economics and Statistics Department

The Economics & Statistics Department provides a full range of statistical and economic advice and services for ACC and its members and other partners. The group works to improve overall ACC advocacy impact by providing statistics on American Chemistry as well as preparing information about the economic value and contributions of American Chemistry to our economy and society. They function as an in-house consultant, providing survey, economic analysis and other statistical expertise, as well as monitoring business conditions and changing industry dynamics. The group also offers extensive industry knowledge, a network of leading academic organizations and think tanks, and a dedication to making analysis relevant and comprehensible to a wide audience.

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Appendix: Data Sources and Methodology

The information presented in this report is an update building on ACC's earlier assessments of materials use per vehicle. Those previous assessments depended upon the materials use per vehicle data supplied by American Metal Market with some adjustments for non-automobile light vehicles (SUVs, light-duty trucks, mini-vans, etc.) The reporter who tabulated this data, however, retired and the data are no longer available. The assessment presented here reflects an attempt to resurrect and re-estimate the data for materials use per vehicle. While the original data reflected typical domestic automobile use of materials, the present assessment reflects the average for all light vehicles on an OEM (original equipment manufacturer) basis. The analysis also builds upon research on automotive high-tech materials initiated during the 1980s (and since maintained) by Dr. TK Swift, the primary author of this analysis.

A "bottoms-up" approach was taken by examining light vehicle use by type of material. We examined over 70 distinct materials. The data for the materials use were provided by trade associations and government statistical agencies. Data sources include The Aluminum Association, American Composite Manufacturers Association, American Fiber Manufacturers Association, American Iron & Steel Institute, Copper Development Association, International Magnesium Association, and the Rubber Manufacturers Association. The provision of data and advice from these associations are gratefully acknowledged. Data from the Bureau of the Census and the US Geological Survey were also used.

The plastics and composite data are derived from the American Chemistry Council's Plastics Industry Producers' Statistics (PIPS) service, which provides relevant, timely, comprehensive and accurate business statistics on the plastic resins industry. This was supplemented by an exhaustive search of the trade literature. The averages are calculated using an assessment of the material consumed with adjustments made to take into account replacement demand. The sum of the individual materials data are close to the comparable average vehicle data provided by the Environmental Protection Agency (EPA) and the Office of Energy Efficiency and Renewable Energy (EERE) of the US Department of Energy (DOE).

The data represent the average use of materials for light vehicles assembled in North America. That is, the NAFTA region, which includes the United States, Canada, and Mexico.