Plastics and Polymer Composites in Light Vehicles

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Executive Summary

The $361 billion North American light vehicle industry represents an important sector of economy of both nations and a large end-use customer market for chemistry. In 2015, the 14.38 million light vehicles assembled in the United States and Canada required some 4.8 billion pounds of plastics and polymer composites valued at $5.9 billion, or $408 in every vehicle.

The latest data indicate that the average weight of North American light vehicles rose. In 2015, the use of plastics in light vehicles increased by over 160 million pounds. At an average of 334 pounds per vehicle, the use of plastic and composites rose five pounds per vehicle from 2014 reflecting increased plastic use. But because of lower gas prices and the increased weight of the average vehicle, the percentage of total vehicle weight stabilized (at 8.4%) in 2015. Plastics and polymer composites are 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 334 pounds per car in 2015.

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 $18.10 billion. These automotive plastic products are produced at 1,572 plants located in 45 states. These plants directly employ about 57,425 people and feature a payroll of $2.8 billion.

Michigan is the leading state in terms of direct employment (over 14,400) and is followed by Ohio (over 8,400), Indiana (over 6,200), Tennessee (about 3,910), Minnesota (nearly 3,050), Pennsylvania (about 2,775), Illinois (over 2,400), Wisconsin (nearly 2,200), New York (about 1,570), and North Carolina (about 1,520).

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 108,000 jobs, representing 11.7% of the light vehicle industry workforce.

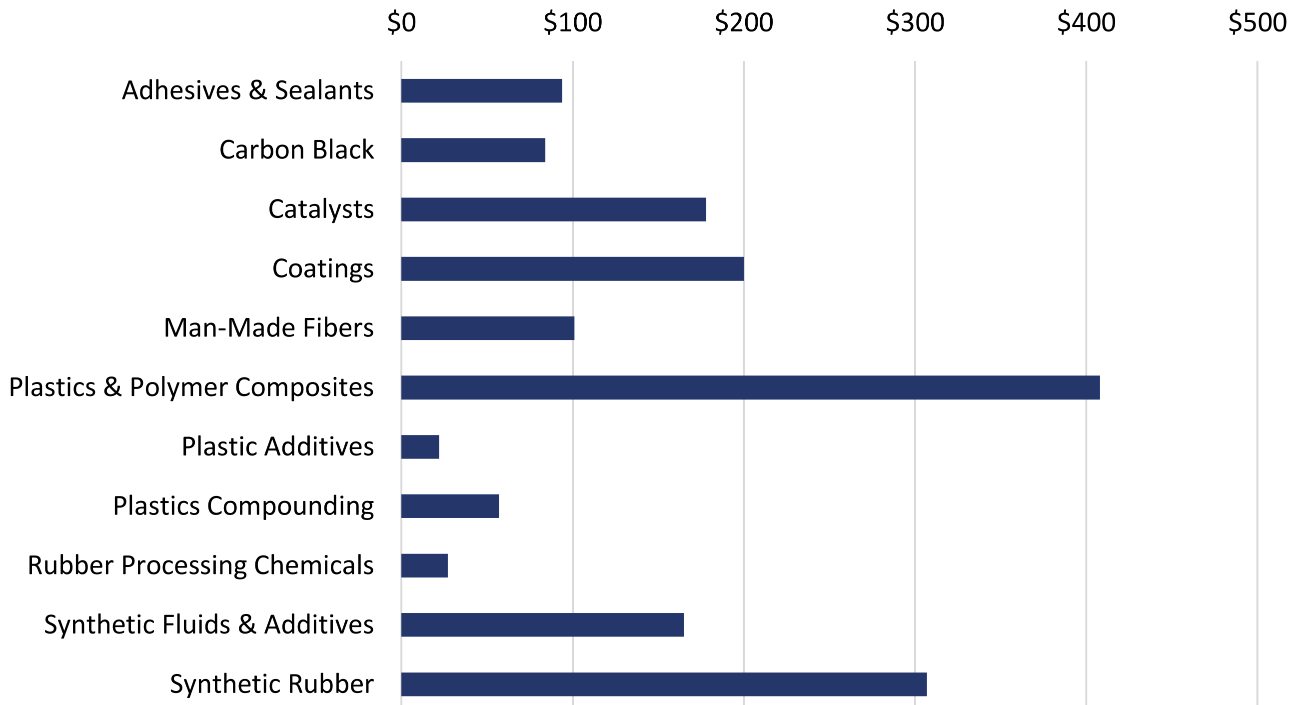
Introduction

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. With 14.38 million light vehicles assembled in the United States and Canada during 2015 this important market represents the equivalent of some $43.9 billion in chemistry. With the slump in oil prices and prices for most chemistry, chemistry value is off from $49.2 billion in 2014 when 14.08 million units were assembled. This moderated 2015 value, however, is still up from the depths of the recession in 2009, when 6.94 million units were assembled and the associated chemistry value was $20.7 billion.

Chemistry and Light Vehicles

The light vehicle industry represents a large share of the North American economy, totaling more than $361 billion in shipments (at the manufacturer's level) in 2015 and employing 916,000 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 United States and Canada contains $3,053 of chemistry (chemical products and chemical processing). The chemistry value per vehicle has grown considerably over the past 10 years, having grown 38% since 2005 when it was $2,219 per vehicle. With the slump in oil prices and prices for most chemistry, average chemistry value fell 12.5% from 2014. 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 2015 ($/vehicle)



The average value of direct chemistry content in North American light vehicles in 2015 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).

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

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Adhesives & Sealants	$65	$71	$74	$78	$82	$84	$90	$92	$93	$94	$94
Carbon Black	41	55	53	74	96	102	108	109	106	103	84
Catalysts	100	128	132	138	140	148	165	163	169	177	178
Coatings	130	131	140	143	163	168	177	175	179	198	200
Manufactured Fibers	103	108	103	108	131	118	116	109	111	109	101
*Plastics/Polymer Composites	313	337	356	396	392	409	457	430	428	430	408
Plastic Additives	17	19	20	22	22	22	25	24	24	24	22
Plastics Compounding	39	43	48	53	53	54	62	58	59	60	57
Rubber Processing Chemicals	18	22	22	28	28	32	43	33	30	28	27
Synthetic Fluids & Additives	79	99	108	136	135	139	167	173	169	170	165
Synthetic Rubber	236	269	277	355	355	406	536	416	357	333	307
Materials	**$1,141**	**$1,282**	**$1,334**	**$1,532**	**$1,596**	**$1,682**	**$1,946**	**$1,781**	**$1,726**	**$1,728**	**$1,643**
Processing/Other Chemistry	1,078	1,162	1,084	1,441	1,388	1,492	1,690	1,757	1,755	1,763	1,410
Total Chemistry Content	**$2,219**	**$2,444**	**$2,418**	**$2,973**	**$2,984**	**$3,174**	**$3,636**	**$3,538**	**$3,481**	**$3,491**	**$3,053**

*Note: Polypropylene is also used in thermoplastics polyolefin elastomers (TPO) as well and its use in that area is reported separately under rubber. Average value for TPO is $54 per vehicle and if it were included in plastics and polymer composites the total average value per vehicle would be $462 for 2015.

The direct chemistry value during 2015 averaged $1,643 per vehicle, slightly more than 50% of the total chemistry value. Details on chemistry used are presented in Table 1. The remaining 50% (or $1,410 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 2015, average vehicle weight increased by 1.6% (63 pounds) to 3,991 pounds. In 1990, average vehicle weight was 3,426 pounds. In 2000, the average vehicle weight was 3,922 pounds. The rising popularity of SUVs was a contributing factor in rising vehicle weight during the 1990s and for most of the last decade. 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. An economic recovery and renewed popularity of larger vehicles in combination with lower gasoline prices then fostered increases in weight. Offsetting this is further penetration by plastics and composites and other lightweight materials which reduces average vehicle weight.

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

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Average Weight	**4,047**	**4,081**	**4,103**	**4,046**	**3,953**	**3,960**	**4,007**	**3,896**	**3,900**	**3,928**	**3,991**
Regular Steel	1,634	1,622	1,644	1,627	1,501	1,458	1,439	1,368	1,354	1,342	1,330
High- & Medium-Strength Steel	491	502	518	523	524	555	608	619	627	649	701
Stainless Steel	71	73	75	75	69	72	73	68	74	73	75
Other Steels	35	34	34	33	31	32	32	30	32	32	32
Iron Castings	328	331	322	253	206	242	261	270	271	278	268
Aluminum	316	323	319	316	324	338	344	349	355	368	395
Magnesium	10	10	10	11	11	11	12	10	10	10	10
Copper and Brass	71	67	66	71	71	74	73	71	70	68	66
Lead	38	39	41	44	42	41	39	35	35	36	35
Zinc Castings	10	10	9	9	9	9	9	8	8	8	8
Powder Metal	42	42	43	43	41	41	42	44	45	46	45
Other Metals	4	5	5	5	5	5	5	5	5	4	5
*Plastics/Polymer Composites	336	342	339	348	384	359	353	332	328	329	334
Rubber	182	198	192	204	245	228	223	205	198	196	198
Coatings	30	30	30	31	36	36	33	28	28	28	29
Textiles	49	47	46	48	58	56	50	49	50	49	45
Fluids and Lubricants	210	211	215	214	217	219	221	219	222	224	225
Glass	104	105	103	99	88	92	98	95	96	96	95
Other	87	89	92	91	90	92	93	91	92	93	95
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	40.4%	39.7%	40.1%	40.2%	38.0%	36.8%	35.9%	35.1%	34.7%	34.2%	33.3%
High- & Medium-Strength Steel	12.1%	12.3%	12.6%	12.9%	13.3%	14.0%	15.2%	15.9%	16.1%	16.5%	17.6%
Stainless Steel	1.8%	1.8%	1.8%	1.9%	1.7%	1.8%	1.8%	1.7%	1.9%	1.9%	1.9%
Other Steels	0.9%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
Iron Castings	8.1%	8.1%	7.8%	6.3%	5.2%	6.1%	6.5%	6.9%	6.9%	7.1%	6.7%
Aluminum	7.8%	7.9%	7.8%	7.8%	8.2%	8.5%	8.6%	9.0%	9.1%	9.4%	9.9%
Magnesium	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%
Copper and Brass	1.7%	1.6%	1.6%	1.7%	1.8%	1.9%	1.8%	1.8%	1.8%	1.7%	1.7%
Lead	0.9%	1.0%	1.0%	1.1%	1.1%	1.0%	1.0%	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%	1.0%	1.0%	1.1%	1.0%	1.0%	1.0%	1.1%	1.2%	1.2%	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	8.3%	8.4%	8.3%	8.6%	9.7%	9.1%	8.8%	8.5%	8.4%	8.4%	8.4%
Rubber	4.5%	4.8%	4.7%	5.1%	6.2%	5.8%	5.6%	5.3%	5.1%	5.0%	5.0%
Coatings	0.7%	0.7%	0.7%	0.8%	0.9%	0.9%	0.8%	0.7%	0.7%	0.7%	0.7%
Textiles	1.2%	1.2%	1.1%	1.2%	1.5%	1.4%	1.3%	1.3%	1.3%	1.2%	1.1%
Fluids and Lubricants	5.2%	5.2%	5.2%	5.3%	5.5%	5.5%	5.5%	5.6%	5.7%	5.7%	5.6%
Glass	2.6%	2.6%	2.5%	2.4%	2.2%	2.3%	2.4%	2.4%	2.5%	2.4%	2.4%
Other	2.1%	2.2%	2.2%	2.2%	2.3%	2.3%	2.3%	2.3%	2.4%	2.4%	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 over 35 pounds per vehicle and if it were included in plastics and polymer composites the total would be about 370 pounds per vehicle for 2015.

The performance of vehicles has improved significantly over the years. According to EPA data, for example, the average horsepower (HP) of model 2015 vehicles was 233 HP, compared to 214 HP In 2010, 181 HP in 2000 and 135 HP in 1990. Average fuel efficiency now averages 24.7 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 51% of vehicle weight. High- and medium-strength steel have been gaining share away from regular steel. Other steel and iron castings have generally lost share. Combined, all iron and steel (including castings) accounted for slightly over 60% of average vehicle weight, up from less than 60% in 2010, but down from 65% in 2000 and 70% in 1990.

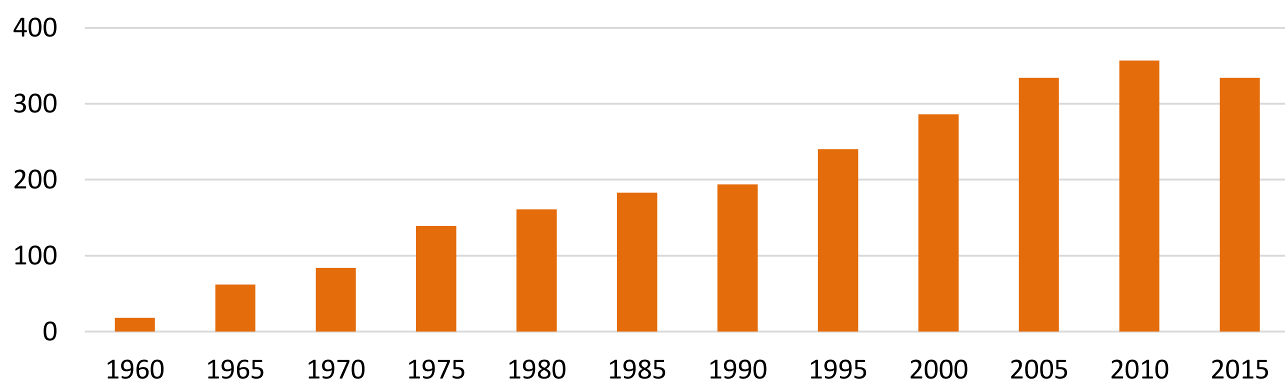
Over the last several decades, lightweight materials have gained share away from iron and steel. For example, aluminum gained share in 2015, rising 7.3% (or 27 pounds) to 395 pounds per vehicle. This is largely the result of the newly redesigned F-150 truck. Aluminum use represented 9.9% of average vehicle weight, up from 8.5% 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. 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, one that has grown significantly during the last five decades. The average light vehicle now contains 334 pounds of plastics and polymer composites, 8.4% of the total weight but approximately 50% of total vehicle volume. This is down from 359 pounds in 2010, but up from 286 pounds in 2000 and 194 pounds in 1990. In 1960, less than 20 pounds were used. The typical light vehicle may contain over than 1,000 plastic parts. 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 now over 35 pounds per vehicle and if it were included in plastics and polymer composites the total would be about 370 pounds per vehicle for 2015.

Figure 2

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



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.

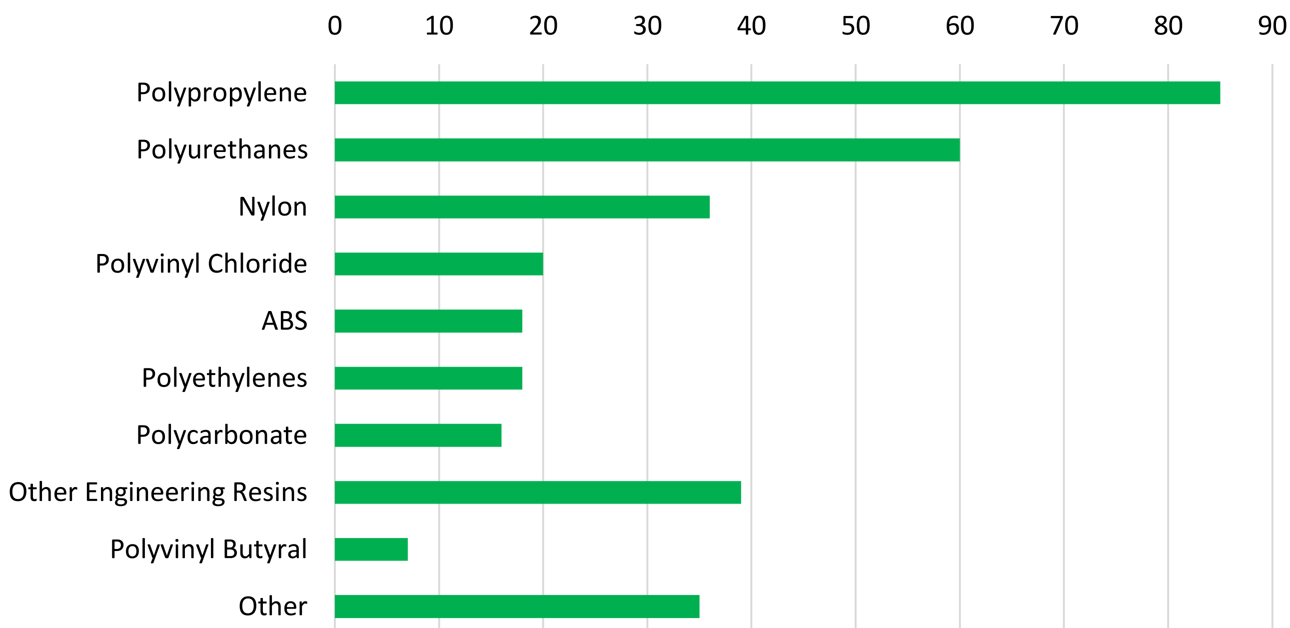
- **Automotive Fuel Systems -** For automotive fuel system components, plastics have several advantages that enable it to outperform metals. Plastic frees engineers from the design constraints that metal imposes. Plastic's light weight makes vehicles more fuel-efficient and from a safety standpoint, 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 vehicle use rose five pounds (1.5%) to 334 pounds in 2015, 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 85 pounds of polypropylene (PP), 60 pounds of polyurethanes, 36 pounds of nylon, 20 pounds of polyvinyl chloride (PVC), 18 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 Light Vehicles in 2015 (pounds/vehicle)



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 over 35 pounds per vehicle and if it were included in plastics and polymer composites the total would be about 370 pounds per vehicle.

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

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total Plastic/Composites	**336**	**342**	**339**	**348**	**384**	**359**	**353**	**332**	**328**	**329**	**334**
Polypropylene	77	81	80	79	83	88	88	86	84	85	85
Polyurethanes	64	59	56	57	59	58	59	56	55	59	60
Nylon	42	41	42	42	44	39	39	37	36	36	36
Polyvinyl Chloride	23	27	28	29	40	31	26	23	22	21	20
ABS	25	23	22	24	28	24	22	19	18	17	18
Polyethylenes	13	14	15	17	19	18	18	18	17	17	18
Polycarbonate	14	15	15	18	22	19	18	17	16	16	16
Other Engineering Resins	38	42	42	42	47	40	39	36	37	38	39
Polyvinyl Butyral	7	7	7	7	7	7	7	7	7	7	7
Other	32	33	32	34	36	35	36	35	35	34	35
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	23.0%	23.8%	23.6%	22.7%	21.5%	24.6%	25.1%	25.9%	25.8%	25.8%	25.5%
Polyurethanes	19.0%	17.2%	16.6%	16.3%	15.4%	16.3%	16.6%	16.8%	16.9%	17.9%	18.0%
Nylon	12.7%	12.0%	12.4%	12.1%	11.4%	10.8%	11.2%	11.2%	11.0%	10.9%	10.9%
Polyvinyl Chloride	6.9%	8.0%	8.1%	8.3%	10.3%	8.6%	7.5%	6.9%	6.7%	6.3%	6.0%
ABS	7.5%	6.8%	6.5%	6.8%	7.3%	6.6%	6.2%	5.6%	5.5%	5.3%	5.3%
Polyethylenes	3.8%	4.0%	4.4%	4.8%	4.8%	4.9%	5.0%	5.3%	5.3%	5.1%	5.3%
Polycarbonate	4.3%	4.2%	4.5%	5.1%	5.7%	5.2%	5.1%	5.1%	5.0%	4.8%	4.8%
Other Engineering Resins	11.3%	12.2%	12.3%	11.9%	12.3%	11.1%	11.1%	10.8%	11.2%	11.5%	11.6%
Polyvinyl Butyral	2.0%	2.1%	2.2%	2.2%	1.9%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Other	9.5%	9.6%	9.3%	9.8%	9.4%	9.8%	10.2%	10.4%	10.6%	10.3%	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 is averages over 35 pounds per vehicle. Polypropylene resin applications include Interior trim, under-the-hood components, HVAC components, battery cases, and other OEM uses.

Over the last two 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 reached 39 pounds in 2015, off from 40 pounds in 2010, but up from 31 pounds in 2000 and 19 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 35 pounds.

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

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Other Engineering Resins	**38**	**42**	**42**	**42**	**47**	**40**	**39**	**36**	**37**	**38**	**39**
Polyacetal	6	6	6	6	8	6	5	4	5	5	5
Polyphenylene Ether (PPE)	11	13	13	14	12	13	13	13	13	13	14
Thermoplastic Polyester Engineering Resins	19	20	20	19	24	18	17	16	16	16	17
All Other Engineering Resins	2	2	2	3	3	3	3	3	3	3	3
Other Plastic/Composites	**32**	**33**	**32**	**34**	**36**	**35**	**36**	**35**	**35**	**34**	**35**
Acrylics	5	5	5	5	5	4	4	4	5	5	5
Phenolics	9	10	10	11	11	13	13	12	12	12	12
Unsaturated Polyester	14	14	13	13	15	13	13	13	13	12	13
All Other Resins	4	4	4	5	6	6	6	5	5	5	6

Carbon fiber is expected to hit a 9.9 percent compound annual growth rate between 2014 and 2020 to $3.7 billion (market research report). Increased demand from the automotive industry is contributing to carbon fiber market growth. 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 of 54.5 mpg by 2025. In 2015, the average value of carbon fiber per vehicle was $6.97 per vehicle, up from $6.24 in 2010 and $1.56 in 2000.

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. 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 nearly 275 pounds of rubber, textiles and coatings are used as well.

The typical light vehicle utilizes 198 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 light vehicle utilizes 45 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.

The typical North American light vehicle also featured 29 pounds of coatings (dry weight) in 2015. 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 225 pounds of fluids and lubricants that a typical 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.

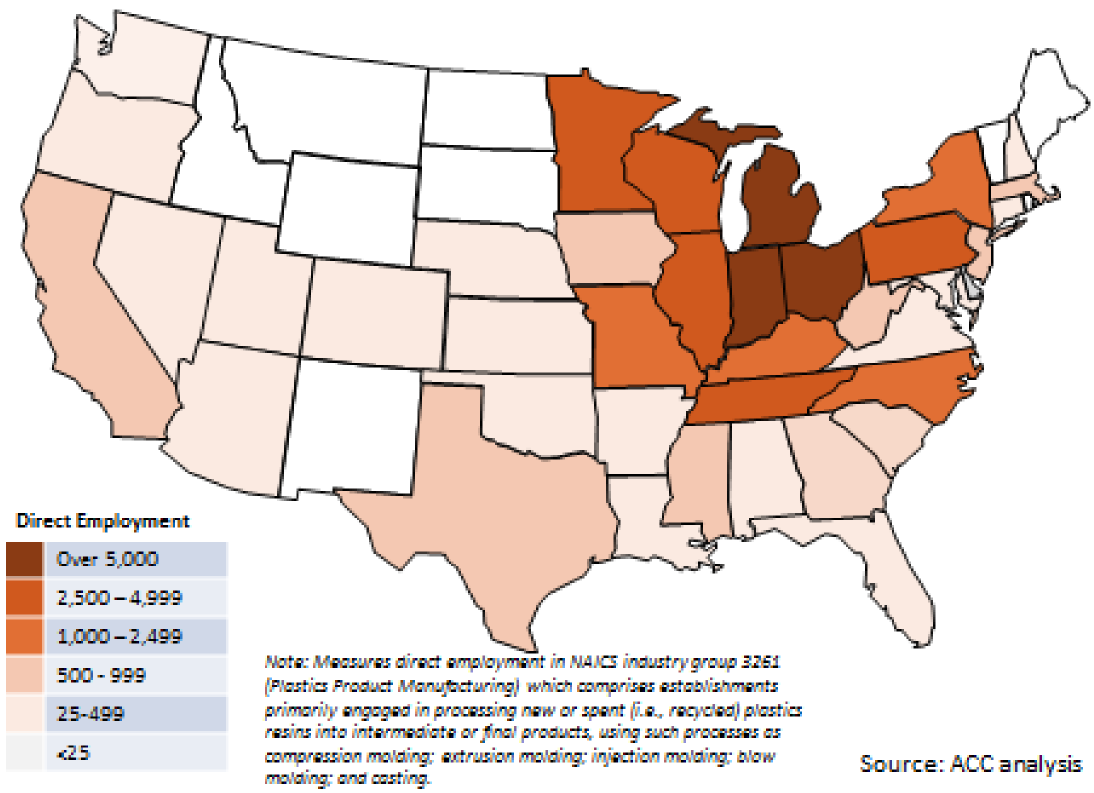
Economic Footprint of Automotive Plastics and Polymer Composites

Light vehicles represent an important market for plastics and polymer composites, one that has grown significantly during the last five decades. The average light vehicle in 2015 contained 334 pounds of plastics and composites, 8.4% of the total weight and 50% of total vehicle volume. This is up from 286 pounds in 2000 and 194 pounds in 1990. In 1960, less than 20 pounds were used.

The following analysis assesses the jobs (by state) associated with plastic products used in automotive applications. 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 2015 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 (2015)



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 2015:

- The value of automotive plastic products produced in the United States was $18.0 billion.

- These automotive plastic products are produced at 1,572 plants located in 45 states. These plants directly employ 57,425 people and feature a payroll of $2.8 billion.

- Michigan is the leading state in terms of direct employment (over 14,400) and is followed by Ohio (over 8,400), Indiana (over 6,200), Tennessee (about 3,910), Minnesota (nearly 3,050), Pennsylvania (about 2,775), Illinois (over 2,400), Wisconsin (nearly 2,200), New York (about 1,570), and North Carolina (about 1,520).

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 $18.0 billion industry directly generated over 57,400 jobs and $2.8 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, an additional 19,400 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 an additional 31,900 payroll-induced jobs. All told, the $18.1 billion in automotive plastics output generates a total of over 108,000 jobs. As a result, each job in the automotive plastics industry generates an additional 0.9 jobs 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 (2015)

State	Shipments ($ million)	Shipments/ Person	Payroll ($ million)	Wages/ Person	Direct Employment
AL	$157	$331,938	$20	$43,381	472
AR	$45	$275,602	$7	$43,130	162
CA	$340	$408,188	$42	$50,721	832
CO	$20	$261,627	$4	$55,844	77
CT	$25	$219,092	$7	$59,321	112
FL	$47	$282,054	$8	$46,394	165
GA	$278	$536,810	$25	$48,000	517
IL	$837	$344,488	$135	$55,544	2,431
IN	$2,507	$403,983	$283	$45,530	6,206
IA	$225	$320,350	$33	$46,388	703
KS	$64	$380,769	$7	$42,657	169
KY	$607	$464,938	$61	$46,485	1,306
MD	$18	$251,328	$5	$65,571	70
MA	$273	$357,673	$47	$61,628	764
MI	$4,021	$278,655	$734	$50,868	14,429
MN	$670	$220,495	$159	$52,327	3,037
MS	$242	$281,963	$35	$40,604	859
MO	$270	$265,297	$48	$47,380	1,019
NE	$21	$497,887	$2	$43,357	42
NH	$11	$204,747	$3	$55,582	55
NJ	$176	$328,017	$30	$56,384	537
NY	$607	$386,890	$80	$51,135	1,568
NC	$515	$339,142	$70	$46,014	1,519
OH	$2,162	$256,736	$407	$48,309	8,422
OK	$22	$506,597	$2	$46,091	44
OR	$26	$240,508	$6	$50,582	110
PA	$795	$286,829	$136	$48,918	2,772
SC	$417	$507,213	$46	$55,529	823
TN	$1,032	$264,126	$172	$43,930	3,907
TX	$519	$586,060	$44	$49,950	886
VA	$165	$630,505	$14	$54,477	262
WA	$16	$273,063	$3	$49,167	60
WV	$198	$343,208	$23	$40,547	576
WI	$623	$284,473	$108	$49,443	2,189
Other	$85	$262,558	$15	$44,975	325
Total	**$18,037**	**$314,084**	**$2,819**	**$49,092**	**57,427**

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 (2015)

State	Direct Employment	Indirect Employment	Induced Employment	Total Employment	Jobs Multiplier
AL	472	144	209	825	1.7
AR	162	42	54	258	1.6
CA	832	347	466	928	1.1
CO	77	21	33	131	1.7
CT	112	32	47	191	1.7
FL	165	65	95	325	2.0
GA	517	168	279	965	1.9
IL	2,431	859	1,646	4,935	2.0
IN	6,206	1,707	3,154	11,067	1.8
IA	703	177	279	1,159	1.6
KS	169	43	69	281	1.7
KY	1,306	398	553	2,256	1.7
MD	70	20	41	131	1.9
MA	764	246	422	1,432	1.9
MI	14,429	5,593	9,680	29,702	2.1
MN	3,037	1,078	1,828	5,942	2.0
MS	859	200	308	1,367	1.6
MO	1,019	331	514	1,864	1.8
NE	42	12	17	71	1.7
NH	55	16	36	107	2.0
NJ	537	193	259	988	1.8
NY	1,568	360	398	2,326	1.5
NC	1,519	475	771	2,765	1.8
OH	8,422	2,937	4,519	15,878	1.9
OK	44	12	17	73	1.7
OR	110	42	60	212	1.9
PA	2,772	922	1,560	5,254	1.9
SC	823	249	416	1,488	1.8
TN	3,907	1,224	1,873	7,004	1.8
TX	886	432	562	1,880	2.1
VA	262	76	119	457	1.7
WA	60	23	29	112	1.9
WV	576	143	181	899	1.6
WI	2,189	744	1,250	4,183	1.9
Other	325	107	146	577	1.8
Total	**57,427**	**19,436**	**31,889**	**108,035**	**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, climate change, 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 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).