Plastics and Polymer Composites in Light Vehicles

Economics & Statistics Department
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Executive Summary

The $334 billion North American light vehicle industry represents an important sector of economy of both nations and a large end-use customer market for plastics and polymer composites. In 2014, the 14.08 million light vehicles assembled in the United States and Canada required some 4.6 billion pounds of plastics and polymer composites valued at $6.1 billion, or $430 in every vehicle. At 329 pounds per vehicle, the use of plastic and composites as a percentage of total vehicle weight slipped in 2013 (due to larger gains by other materials) but are still essential to a wide range of safety and performance breakthroughs in today's cars, minivans, pickups and SUVs.

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 $18.1 billion. These automotive plastic products are produced at 1,572 plants located in 45 states. These plants directly employ 55,500 people and feature a payroll of $2.7 billion.

Michigan is the leading state in terms of direct employment (15,300) and is followed by Indiana (nearly 7,900), Ohio (5,800), Minnesota (nearly 2,900), Illinois (2,600), Wisconsin (over 2,500), Tennessee (about 2,280), New York (over 2,250), Pennsylvania (about 2,150), and Kentucky (over 1,450).

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 105,000 jobs.

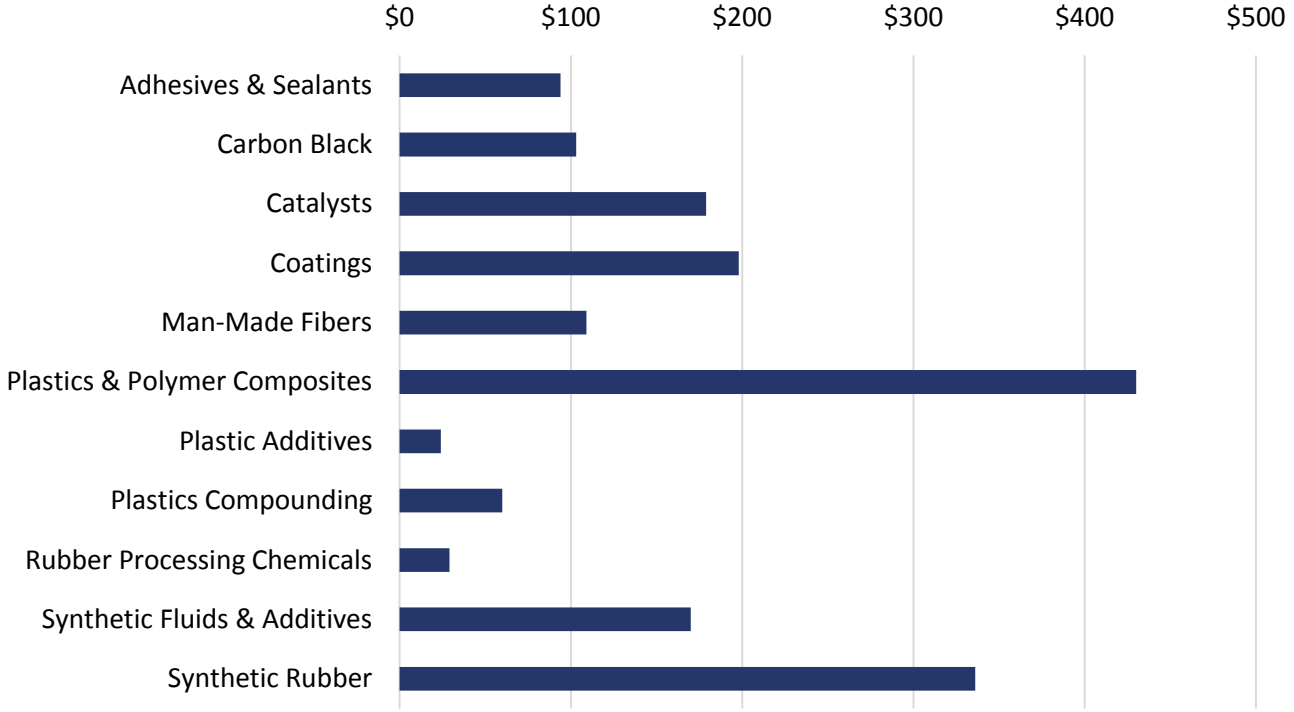
Introduction

This report presents the latest results of an assessment of plastics and polymer composites and other materials make-up of light vehicles, a major end-use customer for American chemistry. With 14.08 million light vehicles assembled in the United States and Canada during 2014 this important market represents the equivalent of some $49.2 billion in chemistry, a new record. This chemistry value is up from $46.8 billion in 2013 when 13.43 million units were assembled and 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 value last peaked at $32.7 billion in 2007 (when 13.08 million units were assembled).

Chemistry and Light Vehicles

The light vehicle industry represents a large share of the North American economy, totaling more than $334 billion in shipments (at the manufacturer's level) in 2014 and employing over 910,000 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 $3,490 of chemistry (chemical products and chemical processing). The chemistry value per vehicle has grown considerably over the past 10 years, having grown 74% since 2004 when it was $2,001 per vehicle. In 2014, average chemistry value rose 0.3% from 2013. 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 2014 ($/vehicle)



The average values of direct chemistry content in North American light vehicles in 2014 for a variety of segments of the business of chemistry are presented in Figure 1 (measured in dollars per vehicle). Only the direct chemistry value of materials is 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)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Adhesives & Sealants	$62	$65	$71	$74	$78	$82	$84	$90	$92	$93	$94
Carbon Black	34	41	55	53	74	96	102	108	109	106	103
Catalysts	111	100	128	132	138	140	148	165	163	170	179
Coatings	123	130	131	140	143	163	168	177	175	179	198
Manufactured Fibers	98	103	108	103	108	131	118	116	109	111	109
Plastics/Polymer Composites	287	312	335	355	394	390	407	456	428	425	430
Plastic Additives	18	17	18	20	22	21	22	25	24	24	24
Plastics Compounding	40	39	43	48	53	53	54	61	58	59	60
Rubber Processing Chemicals	16	18	22	22	28	28	32	43	34	30	29
Synthetic Fluids & Additives	69	79	99	108	136	135	139	167	173	169	170
Synthetic Rubber	204	236	269	277	355	355	406	536	420	361	336
Materials	$1,062	$1,140	$1,279	$1,332	$1,529	$1,594	$1,680	$1,944	$1,785	$1,727	$1,732
Processing/Other Chemistry	939	1,080	1,164	1,091	1,443	1,390	1,494	1,692	1,755	1,754	1,758
Total Chemistry Content	**$2,001**	**$2,220**	**$2,443**	**$2,423**	**$2,972**	**$2,984**	**$3,174**	**$3,636**	**$3,540**	**$3,481**	**$3,490**

The direct chemistry value during 2014 averaged $1,732 per vehicle, slightly less than 50% of the total chemistry value. Details on chemistry used are presented in Table 1. The remaining 50% (or $1,758 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 2014, average vehicle weight increased by 1.7% (66 pounds) to 3,988 pounds. In 1990, average vehicle weight was 3,426 pounds. In 2000, the average vehicle weight was 3,921 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 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)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Average Weight	**4,043**	**4,046**	**4,079**	**4,102**	**4,044**	**3,951**	**3,958**	**4,015**	**3,914**	**3,928**	**3,994**
Regular Steel	1,650	1,634	1,622	1,644	1,627	1,501	1,458	1,439	1,375	1,361	1,379
High- & Medium-Strength	479	491	502	518	523	524	555	608	619	627	649
Stainless Steel	70	71	73	75	75	69	72	73	68	74	73
Other Steels	34	35	34	34	33	31	32	32	30	32	32
Iron Castings	331	328	331	322	253	206	242	261	270	271	271
Aluminum	311	316	323	319	316	324	338	353	359	375	398
Magnesium	10	10	10	10	11	11	11	12	10	10	11
Copper and Brass	71	71	67	66	71	71	74	73	71	70	71
Lead	37	38	39	41	44	42	41	39	36	37	36
Zinc Castings	10	10	10	9	9	9	9	9	8	8	8
Powder Metal	43	42	42	43	43	41	41	42	44	45	46
Other Metals	5	4	5	5	5	5	5	5	5	5	4
Plastics/Polymer Composites	338	334	341	338	347	383	357	351	331	326	329
Rubber	175	182	198	192	204	245	228	223	206	199	197
Coatings	27	30	30	30	31	36	36	33	28	28	28
Textiles	51	49	47	46	48	58	56	50	49	50	49
Fluids and Lubricants	210	210	211	215	214	217	219	221	219	222	224
Glass	105	104	105	103	99	88	92	98	95	96	96
Other	86	87	89	92	91	90	92	93	91	92	93
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	40.8%	40.4%	39.8%	40.1%	40.2%	38.0%	36.8%	35.8%	35.1%	34.6%	34.5%
High- & Medium-Strength	11.8%	12.1%	12.3%	12.6%	12.9%	13.3%	14.0%	15.1%	15.8%	16.0%	16.2%
Stainless Steel	1.7%	1.8%	1.8%	1.8%	1.9%	1.7%	1.8%	1.8%	1.7%	1.9%	1.8%
Other Steels	0.8%	0.9%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
Iron Castings	8.2%	8.1%	8.1%	7.8%	6.3%	5.2%	6.1%	6.5%	6.9%	6.9%	6.8%
Aluminum	7.7%	7.8%	7.9%	7.8%	7.8%	8.2%	8.5%	8.8%	9.2%	9.5%	10.0%
Magnesium	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Copper and Brass	1.8%	1.8%	1.6%	1.6%	1.8%	1.8%	1.9%	1.8%	1.8%	1.8%	1.8%
Lead	0.9%	0.9%	1.0%	1.0%	1.1%	1.1%	1.0%	1.0%	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	1.1%	1.0%	1.0%	1.0%	1.1%	1.0%	1.0%	1.0%	1.1%	1.1%	1.2%
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	8.4%	8.3%	8.4%	8.2%	8.6%	9.7%	9.0%	8.7%	8.5%	8.3%	8.2%
Rubber	4.3%	4.5%	4.9%	4.7%	5.0%	6.2%	5.8%	5.6%	5.3%	5.1%	4.9%
Coatings	0.7%	0.7%	0.7%	0.7%	0.8%	0.9%	0.9%	0.8%	0.7%	0.7%	0.7%
Textiles	1.3%	1.2%	1.2%	1.1%	1.2%	1.5%	1.4%	1.2%	1.3%	1.3%	1.2%
Fluids and Lubricants	5.2%	5.2%	5.2%	5.2%	5.3%	5.5%	5.5%	5.5%	5.6%	5.7%	5.6%
Glass	2.6%	2.6%	2.6%	2.5%	2.4%	2.2%	2.3%	2.4%	2.4%	2.4%	2.4%
Other	2.1%	2.2%	2.2%	2.2%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%

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 30 pounds per vehicle.

The performance of vehicles has improved significantly over the years. According to EPA data, for example, the average horsepower (HP) of model 2014 vehicles was 233 HP, compared to 214 HP In 2010, 181 HP in 2000 and 135 HP in 1990. Average fuel efficiency now averages 24.3 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.

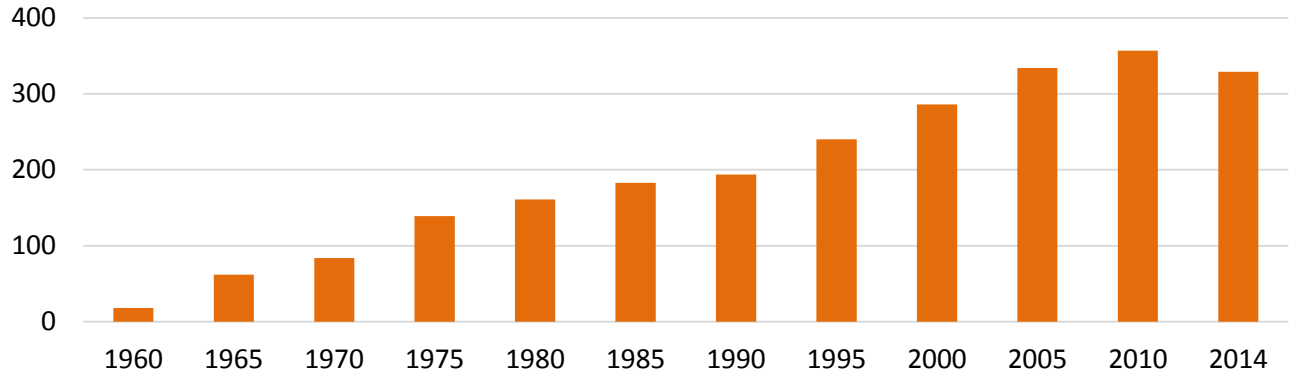
Regular steel and high- and medium-strength steel are the dominant materials in light vehicles. Combined, this steel accounts for 51% of vehicle weight. High- and medium-strength steel have been gaining share away from regular steel. Other steel and iron castings have generally lost share. Combined, 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 2014, rising 6.1% (or 23 pounds) to 398 pounds per vehicle. This is largely the result of the newly redesigned F-150 truck. Aluminum use represented 10.0% 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 329 pounds of plastics and polymer composites, 8.2% of the total weight. This is down from 357 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.

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.

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 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.

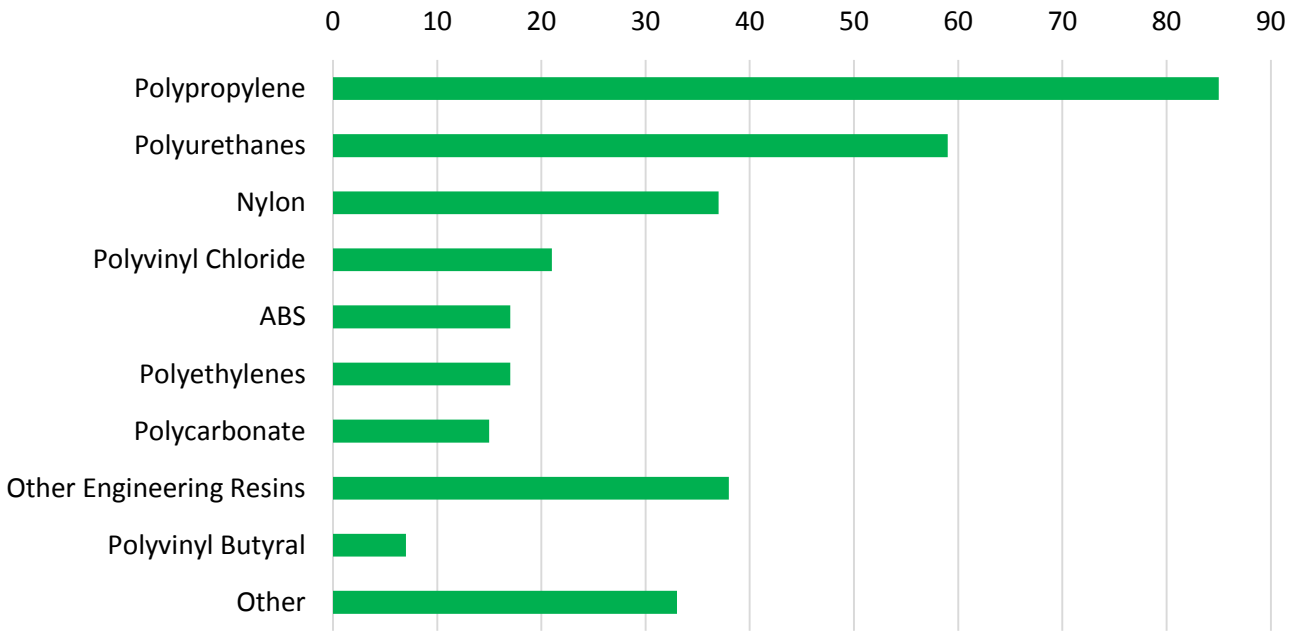
- **Automotive Engine Components -** Many of today's automotive engine components are plastic. From air-intake manifolds and systems to cooling systems to valve covers and other engine parts, plastic helps make engine systems easier to design, easier to assemble, and lighter in weight. Plastics' versatility 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 four pounds (1.2%) to 329 pounds in 2014, 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), 59 pounds of polyurethanes,

37 pounds of nylon, 21 pounds of polyvinyl chloride (PVC), 17 pounds of acrylonitrile-butadiene-styrene (ABS), 17 pounds of polyethylene resins, and 15 pounds of polycarbonate resins.

Figure 3
Average Plastics & Polymer Composites Use in Light Vehicles in 2014 (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 30 pounds per vehicle and if it were included in plastics and polymer composites the total would be about 363 pounds per vehicle.

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

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total Plastic/Composites	**340**	**334**	**340**	**337**	**348**	**383**	**358**	**350**	**332**	**325**	**329**
Polypropylene	79	77	81	80	79	83	88	88	86	84	85
Polyurethanes	64	64	59	56	57	59	58	59	56	55	59
Nylon	43	42	41	42	42	44	39	39	37	36	37
Polyvinyl Chloride	25	23	27	28	29	40	31	26	23	22	21
ABS	26	25	23	22	24	28	24	22	19	18	17
Polyethylenes	14	13	14	15	17	19	18	18	18	17	17
Polycarbonate	14	14	15	15	18	22	19	18	17	16	15
Other Engineering Resins	38	38	42	42	42	47	40	39	36	37	38
Polyvinyl Butyral	7	7	7	7	7	7	7	7	7	7	7
Other	30	31	31	30	33	34	34	34	33	33	33
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	23.2%	23.1%	23.8%	23.7%	22.7%	21.7%	24.6%	25.1%	25.9%	25.8%	25.8%
Polyurethanes	18.8%	19.2%	17.4%	16.6%	16.4%	15.4%	16.2%	16.9%	16.9%	16.9%	17.9%
Nylon	12.6%	12.6%	12.1%	12.5%	12.1%	11.5%	10.9%	11.1%	11.1%	11.1%	11.2%
Polyvinyl Chloride	7.4%	6.9%	7.9%	8.3%	8.3%	10.4%	8.7%	7.4%	6.9%	6.8%	6.4%
ABS	7.6%	7.5%	6.8%	6.5%	6.9%	7.3%	6.7%	6.3%	5.7%	5.5%	5.2%
Polyethylenes	4.1%	3.9%	4.1%	4.5%	4.9%	5.0%	5.0%	5.1%	5.4%	5.2%	5.2%
Polycarbonate	4.1%	4.2%	4.4%	4.5%	5.2%	5.7%	5.3%	5.1%	5.1%	4.9%	4.6%
Other Engineering Resins	11.2%	11.4%	12.4%	12.5%	12.1%	12.3%	11.2%	11.1%	10.8%	11.4%	11.6%
Polyvinyl Butyral	2.1%	2.1%	2.1%	2.1%	2.0%	1.8%	2.0%	2.0%	2.1%	2.2%	2.1%
Other	8.8%	9.3%	9.1%	8.9%	9.5%	8.9%	9.5%	9.7%	9.9%	10.2%	10.0%

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 30 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 38 pounds in 2014, 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 90 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 33 pounds.

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

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Other Engineering Resins	**38**	**38**	**42**	**42**	**42**	**47**	**40**	**39**	**36**	**37**	**38**
Polyacetal	6	6	6	6	6	8	6	5	4	5	5
Polyphenylene Ether (PPE)	10	11	13	13	14	12	13	13	13	13	13
Thermoplastic Polyester Engineering Resins	20	19	20	20	19	24	18	17	16	16	16
All Other Engineering Resins	2	2	2	2	3	3	3	3	3	3	3
Other Plastic/Composites	**30**	**31**	**31**	**30**	**33**	**34**	**34**	**34**	**33**	**33**	**33**
Acrylics	5	5	5	5	5	5	4	4	4	5	5
Phenolics	9	9	10	10	11	11	13	13	12	12	12
Unsaturated Polyester	13	14	14	13	13	15	13	13	13	13	12
All Other Resins	3	3	3	3	4	5	4	4	4	4	4

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 197 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 49 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 28 pounds of coatings (dry weight) in 2014. 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 224 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

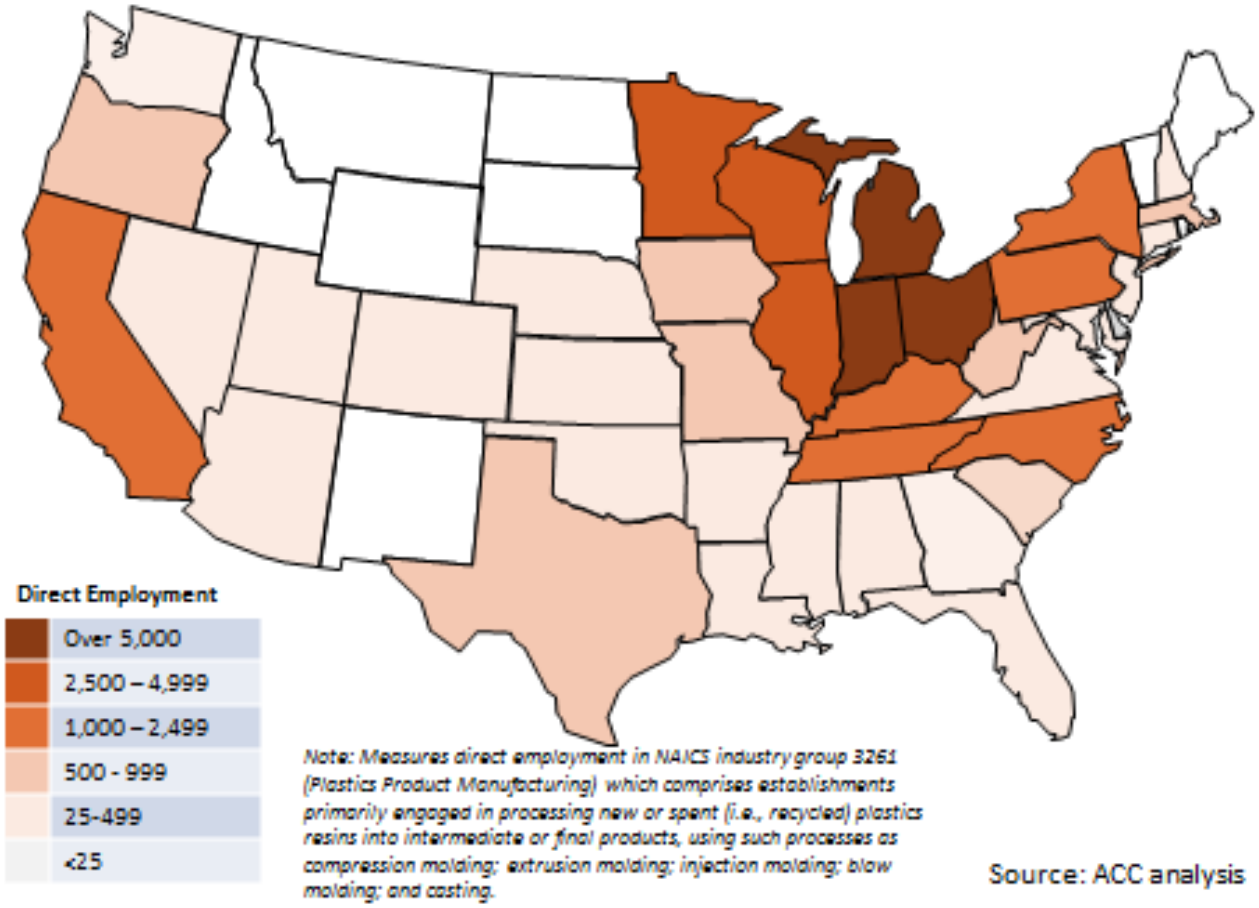
Light vehicles represent an important market for plastics and polymer composites, one that has grown significantly during the last five decades. The average light vehicle in 2014 contained 329 pounds of plastics and composites, 8.2% of the total weight. This is up from 286 pounds in 2000 and 194 pounds 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 2014 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 (2014)



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 2014:

- The value of automotive plastic products produced in the United States was $18.1 billion.
- These automotive plastic products are produced at 1,572 plants located in 45 states. These plants directly employ 55,550 people and feature a payroll of $2.7 billion
- Michigan is the leading state in terms of direct employment (15,300) and is followed by Indiana (nearly 7,900), Ohio (5,800), Minnesota (nearly 2,900), Illinois (2,600), Wisconsin (over 2,500), Tennessee (about 2,280), New York (over 2,250), Pennsylvania (about 2,150), and Kentucky (over 1,450).

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 $18.1 billion industry directly generated over 55,500 jobs and $2.7 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 18,800 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 30,975 payroll-induced jobs. All told, the $18.1 billion in automotive plastics output generates a total of over 105,000 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 (2014)

State	Shipments ($ million)	Shipments/ Person	Payroll ($ million)	Wages/ Person	Direct Employment
AL	$157	$421,273	$16	$43,652	372
AZ	$14	$526,287	$1	$44,106	27
AR	$45	$352,349	$6	$43,952	127
CA	$340	$327,762	$51	$49,610	1,036
CO	$20	$182,818	$6	$51,942	110
CT	$25	$260,794	$5	$56,402	94
FL	$47	$351,236	$6	$44,801	133
GA	$278	$609,361	$21	$47,008	455
IL	$837	$322,106	$143	$55,116	2,600
IN	$2,507	$319,142	$352	$44,766	7,856
IA	$225	$335,697	$31	$46,784	671
KS	$64	$418,574	$6	$41,903	154
KY	$607	$417,380	$67	$46,142	1,455
MD	$18	$307,088	$4	$63,977	57
MA	$273	$331,260	$52	$62,747	825
MI	$4,021	$262,707	$773	$50,484	15,305
MN	$670	$234,182	$149	$52,106	2,859
MS	$242	$655,085	$15	$40,123	370
MO	$270	$284,952	$44	$46,432	949
NE	$21	$363,155	$2	$41,760	58
NH	$11	$214,577	$3	$54,612	52
NJ	$176	$366,244	$27	$56,118	481
NY	$607	$269,427	$113	$50,206	2,252
NC	$515	$408,371	$58	$45,892	1,261
OH	$2,162	$372,716	$265	$45,661	5,801
OK	$22	$443,746	$2	$46,130	50
OR	$26	$207,379	$6	$49,904	128
PA	$795	$371,017	$105	$48,904	2,143
SC	$417	$484,057	$47	$54,037	862
TN	$1,032	$453,071	$103	$45,070	2,278
TX	$519	$521,076	$50	$49,968	996
VA	$165	$463,919	$20	$55,395	356
WA	$16	$298,668	$3	$47,743	55
WV	$198	$356,610	$22	$40,395	554
WI	$623	$246,930	$121	$48,099	2,522
Other	$85	$352,334	$13	$37,272	242
Total	**$18,051**	**$324,974**	**$2,709**	**$48,765**	**55,546**

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 (2014)

State	Direct Employment	Indirect Employment	Induced Employment	Total Employment	Jobs Multiplier
AL	372	114	165	650	1.7
AZ	27	8	12	48	1.8
AR	127	33	42	202	1.6
CA	1,036	432	581	2,049	2.0
CO	110	29	48	188	1.7
CT	94	27	40	161	1.7
FL	133	53	76	261	2.0
GA	455	148	246	850	1.9
IL	2,600	919	1,760	5,278	2.0
IN	7,856	2,160	3,992	14,009	1.8
IA	671	169	266	1,106	1.6
KS	154	39	63	255	1.7
KY	1,455	443	616	2,513	1.7
MD	57	16	34	107	1.9
MA	825	266	456	1,547	1.9
MI	15,305	5,932	10,268	31,505	2.1
MN	2,859	1,015	1,721	5,595	2.0
MS	370	86	132	589	1.6
MO	949	308	479	1,735	1.8
NE	58	16	23	97	1.7
NH	52	16	34	102	2.0
NJ	481	173	232	885	1.8
NY	2,252	517	571	3,340	1.5
NC	1,261	395	640	2,296	1.8
OH	5,801	2,023	3,113	10,937	1.9
OK	50	14	19	83	1.7
OR	128	49	70	246	1.9
PA	2,143	713	1,206	4,062	1.9
SC	862	261	436	1,559	1.8
TN	2,278	714	1,092	4,083	1.8
TX	996	486	632	2,115	2.1
VA	356	103	162	621	1.7
WA	55	21	26	102	1.9
WV	554	137	174	866	1.6
WI	2,522	857	1,440	4,819	1.9
Other	242	79	109	430	1.8
Total	**55,546**	**18,770**	**30,975**	**105,291**	**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).

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