



Making the future of mobility

Chemicals and specialty materials in
electric, autonomous, and shared vehicles

The entire way we travel from point A to point B is changing. This transformation is creating a new ecosystem of personal mobility, with implications affecting more than just the automotive industry. Our Future of Mobility practice serves the entire ecosystem of companies working in and around mobility to actively shape its emergence.

In the competitive global chemicals & specialty materials sector, consolidation, globalization, increased competition, and economic uncertainty are generating both tremendous challenges and opportunities. At Deloitte, our range of services is focused on helping you improve performance.

CONTENTS

Introduction | 2

A new “oil shock”?

Chemicals and materials in transportation | 3

Future role of chemicals and materials in transportation | 7

Assessing the impact on chemicals and materials providers | 10

Approaching the future of mobility through an advanced materials system lens | 13

Endnotes | 14

Introduction

A new “oil shock”?

Four decades ago, the auto industry saw the role of chemicals and materials fundamentally reshaped, as the oil shock spurred the need for lighter-weight and lower-cost components.

TODAY, a new series of converging trends could even more profoundly affect how—and of what—vehicles are made. Electric vehicles, autonomous vehicles, and shared mobility will help define the future of mobility, likely creating winners and losers in the chemicals and specialty materials (C&SM) sector.

In the past, shifts in transportation have deepened many of the relationships between auto original equipment manufacturers (OEMs) and suppliers and chemicals companies. As advances in materials enabled new designs, the C&SM industry has expanded its footprint. In the United States, \$35 billion of annual chemical industry sales flow to motor vehicles, the industry’s largest single source of revenue.¹

The history of mobility has been mutually shaped and enabled by developments in chemicals and material science, and so too might its future. Shifting regulations and advances in battery technologies could signal a new phase of growth for electric vehicles, which would mean a radically simplified powertrain with fewer fluids and other chemicals needed. While much remains uncertain,² autonomous

vehicles could be in commercial use as early as this year,³ and the technology could ultimately enable reimagined vehicle interiors and new body materials for cars that hardly ever crash. And the ongoing shift toward shared mobility looks to place new demands on suppliers, with vehicles seeing higher utilization and specifications that are increasingly dictated by fleet operators rather than OEMs. The transformation is global, with important advances in China, Europe, and the United States in particular.

This article explores the challenges and opportunities that the new mobility ecosystem could create for chemicals and specialty materials companies. Although the pace and breadth of these shifts may follow well-known paths, there is also the very real possibility that the changes will be highly disruptive across the entire C&SM ecosystem. In the face of marketplace shifts in material requirements and demand, firms may need to create value—and they appear to have an opening to actively shape this demand and co-create the new mobility landscape. Those that simply react are likely to find themselves with a shrinking—and commoditized—share of the transportation materials market.

Chemicals and materials in transportation

INNOVATIONS in materials have long enabled breakthroughs in transportation technology, from sailors using pitch to waterproof wooden ships to metallurgical advances enabling safer boilers for steam engines.⁴ The modern automobile may represent the ultimate integration of materials and transportation technology—consider that roughly half of a car’s volume is various polymers, and it contains sophisticated metal alloys and tempered glass.⁵ Our analysis identified more than three dozen distinct material classes, behind which stand thousands of specific grades of materials and hundreds of thousands of individual products (see figure 1).

Exterior. Once the domain exclusively of steel, rubber, and glass, the exterior of most modern automobiles encompasses body panels from plastics and advanced composites, transparent engineering polymers in windows and LED lighting, and multi-layered paint systems as well as traditional materials like rubber, glass, and steel in tires, windshields, and frames.

Interior. Synthetic materials comprise nearly every part of most modern cars—they even typically coat leather seats. Molded instrument panel skins hide airbags, synthetic foam seating can ensure comfort, and touchscreens have largely replaced mechanical dials and gauges.

Under the hood. An internal combustion engine-powered car still typically contains forged metal parts alongside synthetic fluids, belts, hoses, cables, and tanks. The breadth of specific products from the C&SM sector is often impressive: compounded natural rubber, EPDM and other synthetic elastomers, mineral oil lubricants, synthetic lubricants such as polyalphaolefins, polyamide

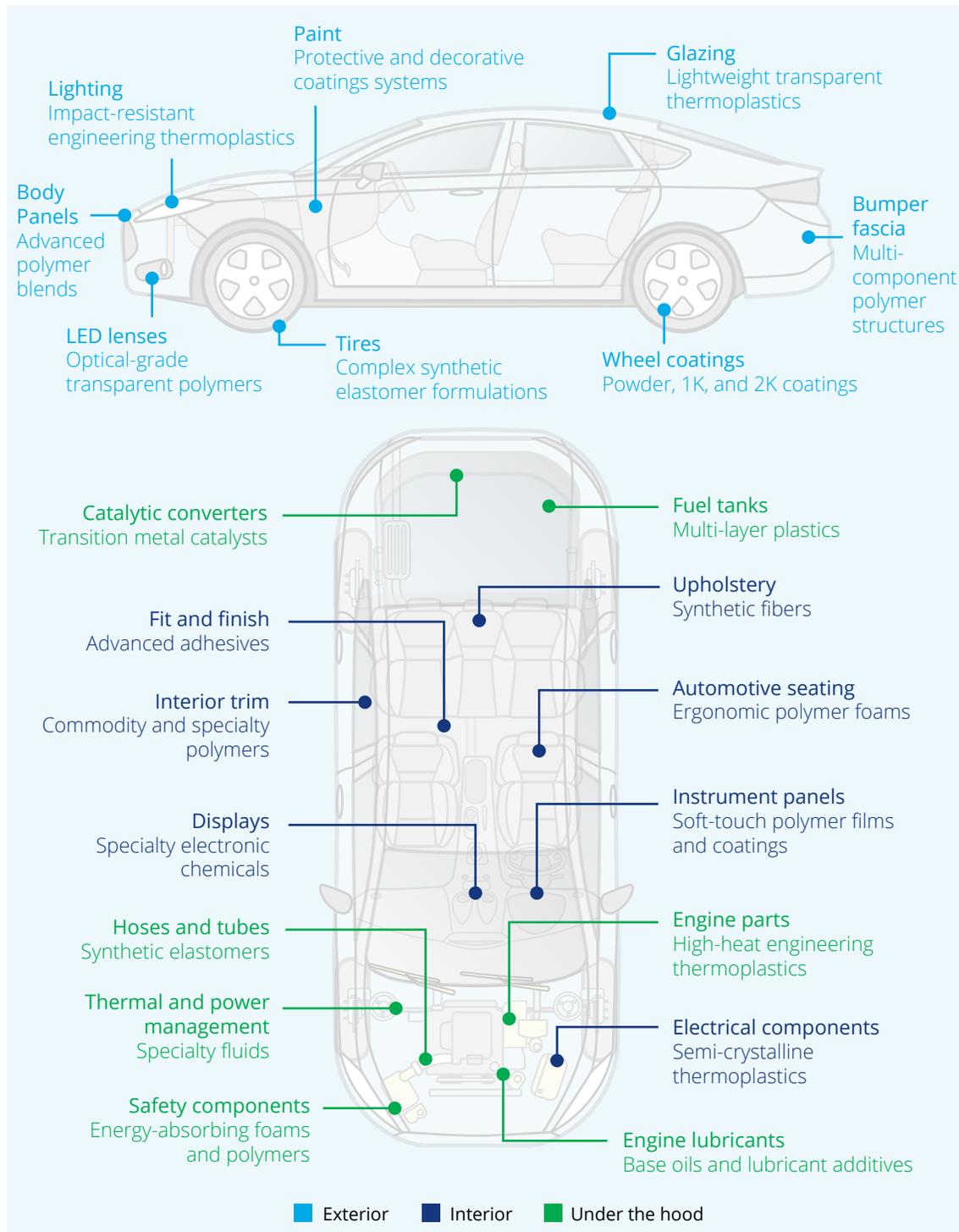
electrical connectors, polyolefin ducts and gasoline tanks, and many more.

The result of those diverse components is a typical automobile that contains more than \$3,000 worth of chemistry, including more than 330 pounds of plastics and polymer composites and over 270 pounds of rubber, textiles, and coatings.⁶ Across the nearly 100 million new cars and trucks that automakers build every year globally,⁷ the economic impact can be measured in the hundreds of billions of dollars.

But will that trend continue? The entire way people and goods move about is changing, and the new mobility ecosystem will likely affect the chemicals and materials sector just as deeply as automakers, insurers, and technology providers.

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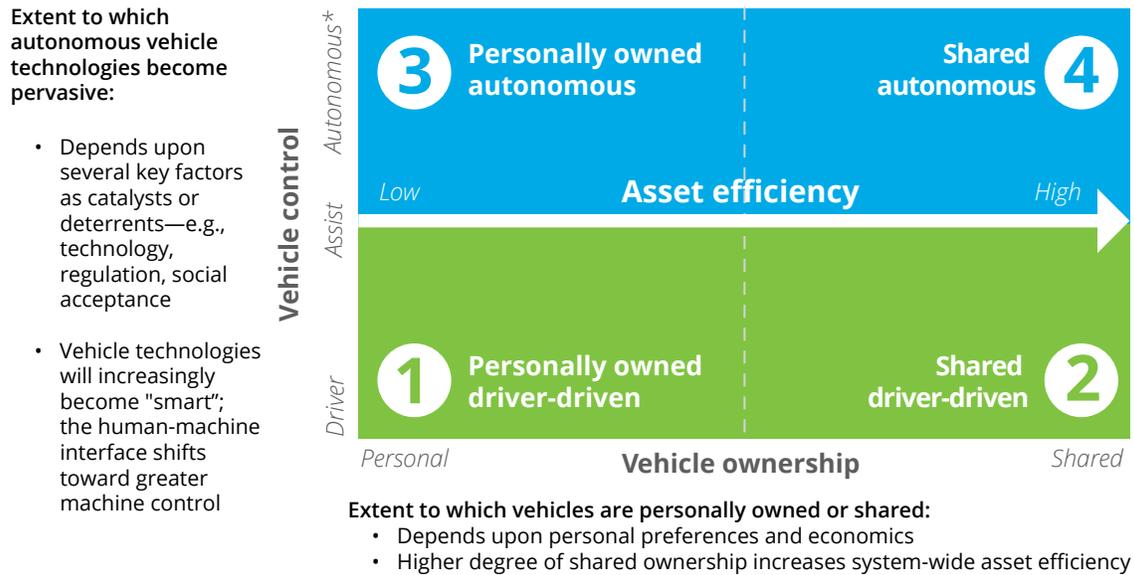
Figure 1. The diverse array of chemicals and materials in a modern car



Source: Deloitte analysis.

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Figure 2. The future states of mobility



*Fully autonomous drive means that the vehicle's central processing unit has full responsibility for controlling its operation and is inherently different from the most advanced form of driver assist. It is demarcated in the figure above with a clear dividing line (an "equator").

Source: Deloitte analysis.

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The future of mobility

A series of technological and social forces—including the emergence of connected, electric, and autonomous vehicles and shifting attitudes toward mobility—are beginning to profoundly change the way people and goods move about, affecting a host of industries. As these trends unfold, we anticipate four concurrent *future states* emerging within a new mobility ecosystem, emanating from the intersection of who owns the vehicle and who operates the vehicle (see figure 2).⁸

1. *Personally owned driver-driven*: This vision of the future sees private ownership remaining the norm as consumers opt for the forms of privacy, flexibility, security, and convenience that tend to come with owning a vehicle. While incorporating driver-assist technologies, this future state assumes that fully autonomous drive doesn't completely displace driver-controlled vehicles.
2. *Shared driver-driven*: The second future state anticipates continued growth of shared access to vehicles through ridesharing and carsharing.

Economic scale and increased competition would drive the expansion of shared vehicle services into new geographic territories and more specialized customer segments. As shared mobility could serve a greater proportion of local transportation needs, multivehicle households can begin reducing the number of cars they own, while others may eventually abandon ownership altogether.

3. *Personally owned autonomous*: The third state is one in which autonomous drive technology⁹ proves viable, safe, convenient, and economical, yet private ownership continues to prevail. Drivers still prefer owning their own vehicles but seek driverless functionality for its safety and convenience. This future sees a proliferation of highly customized, personalized vehicles catering to families or individuals with specific needs.
4. *Shared autonomous*: The fourth future state anticipates a convergence of both the autonomous and vehicle sharing trends. Mobility management companies and fleet operators would offer a range of passenger experiences to meet widely varied needs at differentiated price points. Tak-

ing off first in urban areas but spreading to the suburbs, this future state would provide seamless mobility across modes that is faster, cheaper, cleaner, safer, and more convenient than today.

Cutting across all of these future states is likely to be the growing prevalence of electric vehicles (EVs). Plug-in electric vehicles could reach 10 percent of total light-duty vehicle sales by 2025, with China likely to be the largest single market.¹⁰ Already, 56 percent of consumers in China say they want a hybrid or fully electric powertrain in their next vehicle.¹¹ As we move north and east toward shared autonomous mobility, in particular, EVs could become increasingly important. The higher utilization of rideshare vehicles could make the longevity and simplicity of electric powertrains relatively attractive and their higher initial cost less of a deterrent.

Similarly, EVs' low latency and inherent drive-by-wire capabilities could make them well suited to autonomous operation.¹²

All of these future states are likely to exist in parallel for some time, and geography and demography could affect when and how quickly new forms of mobility are adopted. Dense urban areas and younger consumers are likely to lead the way, with more rural and suburban areas trailing. The increasingly complex mobility landscape likely means that even as shared mobility and electric and autonomous vehicles become increasingly commonplace, companies should be prepared to continue serving their traditional, ICE-centered customers. Still, the overall trend is likely to be toward a mobility ecosystem that offers integrated multimodal travel enabled by (but not exclusively composed of) shared, electric, and autonomous vehicles.¹³

Future role of chemicals and materials in transportation

TO be clear: The future of mobility is unlikely to be about incremental change. The confluence of social and technological trends seems likely to fundamentally reshape mobility in a way not seen in a century. And for chemicals and materials companies, it could dramatically alter their relationship with the broader transportation industry. Each of the key dimensions of the future of mobility—shared transportation, self-driving cars, and electric vehicles—could significantly affect chemicals and materials companies’ business. We examine how those impacts could play out, and what companies can do to prepare for an uncertain future.

Shared mobility: New materials demands, new business models

While still a small fraction of the overall transportation market, ridesharing and carsharing have grown rapidly in many major markets, including China, the United States, and Europe. Forty-three percent of consumers in China and 23 percent of American consumers report using ridesharing at least once a week.¹⁴ While some taxis have specialized interiors, to date most shared vehicles have simply been repurposed personal vehicles, creating minimal impact on chemicals and materials suppliers.

That could change as shared mobility continues to grow and as fleets of autonomous “robotaxis” take to the streets in the next few years. Vehicle exteriors could evolve as branding becomes increasingly important and protection and corrosion requirements shift, but the larger implications are likely to be in car interiors. As this space shifts from being largely utilitarian (comfortable seats and no

sharp edges) to enabling an in-transit experience offering business and entertainment options, opportunities could emerge for organic light-emitting diode display materials, anti-bacterial coatings, and many more functional materials.¹⁵ Vehicles in shared fleets could be increasingly modular, with future designs focused on more easily (or more cheaply) replacing interior components that fail from increased wear and tear before the rest of the vehicle. (American drivers put just over 11,000 miles per year on their average vehicle, while a car transporting passengers full time might cover more like 70,000.¹⁶) Such modularity could also facilitate relatively rapid changes in vehicle functionality, allowing customization for particular types of trips. One could envision the same vehicle “platform” being used during the week as a shared commuting vehicle (outfitted with productivity software and office-style seating) and on weekends as a shared vehicle for entertainment and socializing (seats facing together, with screens that play music videos). The fleet owner would “swap out” the interior modules, including floor coverings, seats, and electronic devices embedded into the vehicle.

The confluence of social and technological trends seems likely to fundamentally reshape mobility in a way not seen in a century.

Shifts in how and to whom materials are sold are likely to be just as significant as the potential changes to the vehicles themselves. As large fleet operators begin to represent a greater share of the mobility market, chemicals and materials companies may find that their ultimate customer is no longer an end consumer or even an OEM. Already, Waymo, Uber, and Didi have ordered tens of thousands of vehicles from automakers for their planned autonomous ride-hailing fleets.¹⁷ Those fleet managers may bring different perspectives on material choice and specification relative to individual owners. The effects of shifting business models and materials requirements could be uneven as well, likely taking hold first in densely populated urban areas and with younger users. Chemicals and materials companies would need to be able to supply that new market while continuing to serve existing vehicle component needs.

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Autonomous vehicles: Rethinking a century-old design

The emergence of autonomous vehicles could disrupt what chemicals and materials go into the vehicle on the factory floor, and what are required over the course of the vehicle's life. Accident data already reflects the impact of advanced driver-assist technologies. Research suggests that innovations such as antilock brakes, stability control, and now autonomous braking and lane centering can decrease the number and severity of some types

of accidents.¹⁸ As more vehicles on the road are equipped with crash-avoidance technologies, aftermarket body shops will likely see an impact on the number of cars that need repairs and repainting. This segment is already in decline relative to the broader coatings space; in time, the \$7 billion market for coatings supply for automotive refinishing could dwindle markedly.¹⁹

The automotive refinish market, albeit significant, is fairly small compared to the total value of the materials used in an automotive interior. To date, safety concerns have largely driven those materials' form and composition, with a secondary emphasis on providing passengers (especially drivers) a comfortable and user-friendly ride. Consider a modern instrument panel that houses safety, climate control, and entertainment systems but must comply with the design constraints of serving a driver securely belted into a seat. One can imagine the implications of a shift away from a driver-driven vehicle: The interior could be completely reconfigured for entertainment and utility, creating new demands for the materials needed to enable that experience, such as high-definition touchscreens capable of augmented-reality features.

Electric vehicles: Dramatic changes under the hood

From a materials perspective, the most dramatic impact of the new mobility ecosystem could lie not in the emergence of shared autonomous vehicles but in the accelerating shift toward electric powertrains. Cars today are designed around the internal combustion engine (ICE). As a transportation power source, the modern ICE has been highly refined and has distinct advantages, such as leveraging an energy-dense fuel (47.6 MJ/Kg for gasoline, still around 100 times that of lithium ion batteries) and a ubiquitous supporting ecosystem (fuel stations and massive refinery capacity).²⁰

Despite all of these advantages, a modern ICE is a complicated machine composed of (depending on the model) hundreds of moving parts. The bill of material can be equally complex, with materials ranging from forged metal to rubber hoses and viscous fluids.

The need to manage the harmful side products of the conversion of chemical to mechanical energy has driven specialty materials-based technologies, such as the platinum, palladium, and rhodium in catalytic converters.

In contrast, a typical vehicle powered by a battery and electric motor has far fewer moving parts and a dramatically simplified bill of materials—and tends to require far less maintenance. The only fluids in an electric drivetrain are a small amount in the (much simpler) single-gear transmission, brake fluid, and some type of heat transfer fluid in the battery thermal-management system. As a further consequence, an EV system eliminates the need for much of the rubber tubing (often synthetic elastomers) common to vehicles for decades. Finally, EVs would render irrelevant the use of advanced engineering polymers

that have been specifically developed to handle the higher heats typical in ICE engines. Aftermarket suppliers would find themselves scrambling as well: Except for tire rotations and cabin air filters, an electric vehicle might well require no preventive maintenance for 150,000 miles (or five years)—which could represent the entire service life of a shared vehicle.²¹

There is a silver lining for chemicals and materials companies: Electric vehicles require the increased use of specific materials at levels that ICE vehicles would never need. Every 1 percent increase in EV market penetration is estimated to increase lithium demand, for example, by 70 kilotons per year—even as supply constraints could drive up prices and prompt sourcing from new markets.²² A fully electric car uses some 80 kilograms of copper in batteries, windings, and copper rotors.²³



Assessing the impact on chemicals and materials providers

TAKEN individually and collectively, shared mobility, autonomous vehicles, and electric powertrains could create significant shifts in materials usage and where value is created in the chemicals sector. Not all companies are expected to come out ahead. Of the more than 40 distinct classes of synthetic materials used in the construction of a modern automobile, the need for some will be completely eliminated, while others will likely grow in importance.

Of course, the transition will not happen overnight, and there are important countervailing forces, such as increased ICE car ownership in major markets such as China.²⁴ Nonetheless, the long-term trends seem clear: more EVs, more shared vehicles, and the arrival of fully autonomous cars. For chemicals and materials companies participating in the automotive supply chain, developing a comprehensive understanding of their exposure to these trends—and from there considering the possible strategic implications—is likely to be key.

Nonetheless, the long-term trends seem clear: more EVs, more shared vehicles, and the arrival of fully autonomous cars.

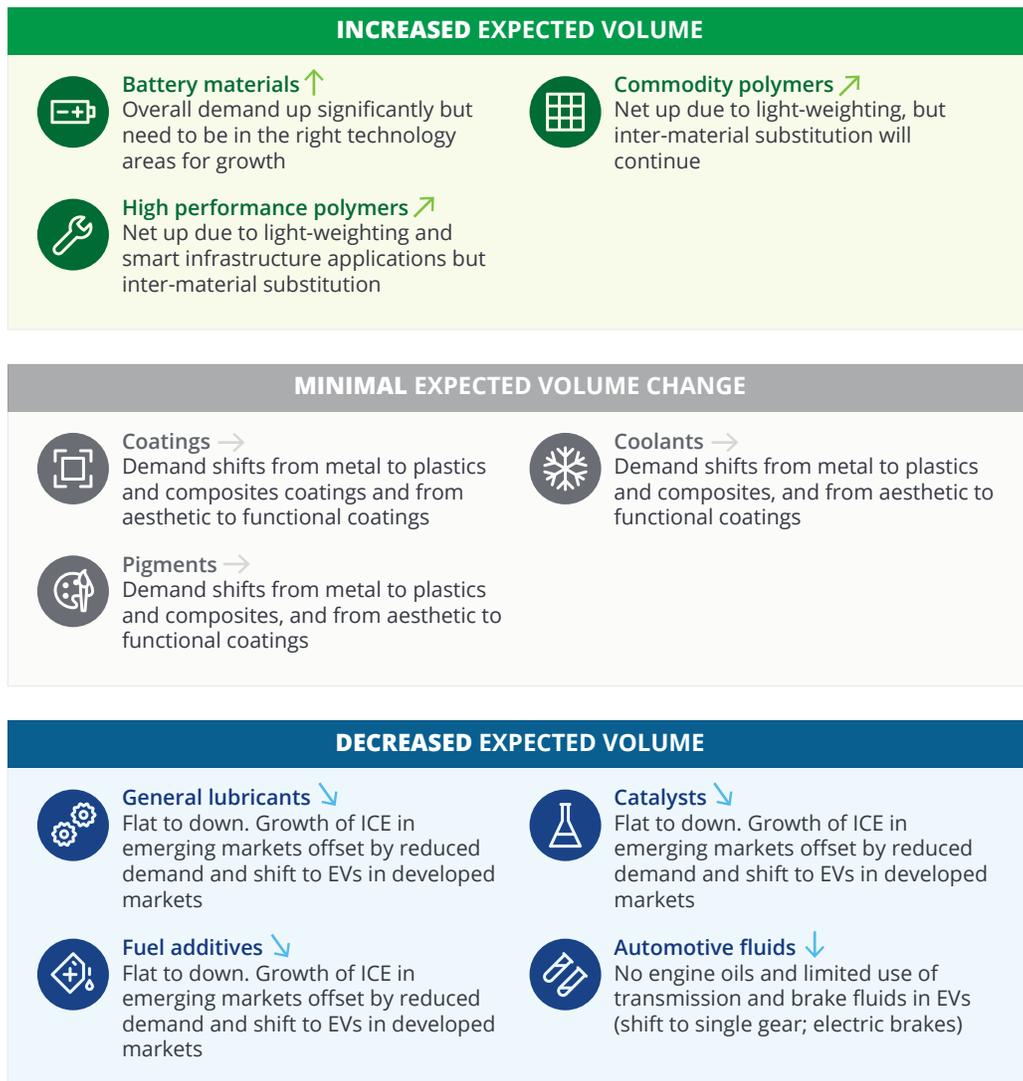
Figure 3 shows a high-level view of how the future of mobility could affect various materials' classes. In general, one can be optimistic about materials that play a role in reducing weight or enabling autonomy. In contrast, materials that are integral to the complexity of the internal combustion engine and its related gearing and powertrain systems will likely be under pressure. There are also materials systems that may remain important but undergo significant shifts—for example, fewer supplies to auto refinish shops but many more haptic coatings.

We also expect a general shift from materials that play a purely structural role to those that provide both structure and a specific function—often a digital function. Some characterize these as “smart materials” because of the amount of materials design (advanced composites) that goes into them or the fact that they respond to some stimuli:

- **Lightweight materials.** There will likely be a continued shift to lightweight materials, influenced by both electrification and autonomy. The desire to extend EVs' range means that automakers will scrutinize every source of weight beyond passengers and cargo. Autonomy may enable this shift toward lighter-weight materials, since fewer crashes could challenge perceptions that larger cars are inherently safer;²⁵ autonomous vehicles operating within geo-fenced urban areas may never travel faster than 25 miles per hour. Ultimately, regulatory changes could relax some of the strict crash-test requirements for vehicles. These trends could collectively drive the adoption of polymers, advanced composites, and aluminum and lightweight steel alloys.

- Coatings.** Future mobility trends may profoundly affect coatings manufacturers and their suppliers. While business from automotive re-finish shops could decline, there would be many opportunities for “functional” coatings in general infrastructure and haptic materials in the car. Autonomous vehicle technology may require that vehicles “see and are seen,” in turn necessitating surfaces that are reflective across a broad range of wavelengths and in difficult weather conditions (for example, whiteout snow).
- Battery materials.** The advances in battery technology have been astonishing, with costs falling roughly 80 percent between 2010 and 2017 to \$209 per kilowatt-hour.²⁶ Prices continue to fall due to technological improvements, manufacturing cost reductions—especially as production scales up—global manufacturing

Figure 3. The impact of the future of mobility on chemicals and materials usage



Source: Deloitte analysis.

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overcapacity, and competition.²⁷ The innovation will likely continue in every aspect of battery and EV-focused materials, ranging from cooling systems to lithium ion battery cathode binder materials such as PVDF and SBR.

- **Enabling the in-vehicle experience.** For in-vehicle entertainment and information systems, there will likely be a drive to lightweight, low-energy-usage, and flexible materials—hallmarks of organic light-emitting diode (OLED) displays. For example, Porsche’s Mission E electric car already will feature an OLED display.²⁸ Advanced display technologies themselves are almost completely built around advances in material science. The challenge for suppliers of these components is that the amount of material is typically measured in nanometers and milligrams, rather than square meters and kilograms. That requires a shift in mind-set for many chemicals and materials firms, as they place increased emphasis on value over volume.

There is also a more disruptive scenario that should be considered, one that moves beyond material substitutions to shifts in actual material production and supply chains—a world of shortages of key materials (for example, cobalt), new and unlikely competitors, vastly different purchasing behaviors, and dislocation to typical C&SM channels. Well-known operating models could come under pressure, requiring skills and talents that chemical companies do not typically possess or unanticipated technology and business model innovations that require chemical producers to operate and perform differently. The odds of such a disruptive future coming to pass are difficult to know, but it behooves market participants to consider and plan for all possible scenarios.

Approaching the future of mobility through an advanced materials system lens

MOST fundamentally, succeeding in the emerging mobility ecosystem will likely require chemicals and materials companies to dramatically reevaluate how they think about their business. Success likely requires approaching the change with an ecosystem perspective that cuts across traditional industry lines. That may pose a challenge to many in the chemical industry, which has historically focused on molecule-level discoveries or developing novel applications, all with a focus on selling a solid or liquid with next-level performance. Chemical companies looking to break the mold and move toward collaborative solutions should rethink traditional approaches to innovation—and aim to move beyond the lab.

To help companies deconstruct the challenge and approach the development of new solutions at an ecosystem level, Deloitte has developed a framework for thinking about advanced materials systems such as those likely necessary in the new mobility ecosystem.²⁹ It emphasizes targeting end-market and application challenges, and leading holistic and collaborative solution development across the ecosystem by:

- Clearly articulating the functional requirements that solve market needs—and breaking down those requirements into targeted engineering and business model-related problems. Figure 3, above, provides a starting point for thinking through the implications of shared mobility, autonomous vehicles, and electric powertrains.
- Understanding and defining an ecosystem of capabilities. All the required capabilities are unlikely to reside within the four walls of a single

enterprise. For chemicals and materials companies, that could mean partnering not only with automakers and suppliers but with technology and media companies, fleet operators, and, for smart infrastructure, city governments.

- Creating an effective collaborative model for each of the individual problems across the ecosystem, from design to full-scale production. Approaches could vary from formal partnerships to joint ventures to participation in cross-industry mobility-focused consortia.
- Owning the overall solution architecture and managing individual piece solutions to integrate into the whole.

In principle, these might sound practical and easy to do. But given the long culture of innovation in the chemical industry, this approach—managing change to utilize a series of capabilities from across the ecosystem—has been rare. And the time to act is now; companies are announcing new open innovation partnerships with increasing frequency, with the potential to disrupt the traditional chemical industry.

Chemicals and specialty materials companies will likely play a critical role in making the future of mobility a reality. Without their advances, the promise of a transportation system that is faster, cheaper, cleaner, and safer than today may never be realized. But the future won't wait. Chemicals and materials companies should start now, by revisiting their product portfolios in light of these trends and considering who are the partners that can help them innovate for tomorrow's mobility solutions.

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ABOUT THE AUTHORS

ROBERT J. KUMPF

Robert J. Kumpf is a specialist executive with Deloitte Consulting LLP, serving clients in the chemicals and specialty materials sector with a focus on strategy, innovation, and leading company transformations. He has 27 years of chemical industry experience at both large multinationals and start-ups.

SHAY ELIAZ

Shay Eliaz is a principal with Monitor Deloitte, Deloitte Consulting LLP's Strategy practice. He is the innovation leader for Deloitte's Manufacturing practice and serves as the project adviser for the World Economic Forum's New Vision for Agriculture initiative. He specializes primarily in chemicals and specialty materials companies but has experience across multiple industries.

TOM ALDRED

Tom Aldred is a principal with Deloitte Consulting LLP's Manufacturing practice, leading client projects in corporate and business unit strategy development, commercial excellence, market analysis, innovation, M&A due diligence, and operational performance improvement. His client base includes leading companies in chemicals and specialty materials, paper and packaging, and life science in North America, Europe, the Middle East, and Asia.

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CONTACTS

Robert J. Kumpf

Specialist executive
Strategy and Operations
Deloitte Consulting LLP
+1 412 452 8023
rkumpf@deloitte.com

Shay Eliaz

Principal
Monitor Deloitte
Deloitte Consulting LLP
+1 212 618 4296
seliaz@deloitte.com

Tom Aldred

Principal
Monitor Deloitte
Deloitte Consulting LLP
+1 845 537 6398
taldred@deloitte.com

Scott Corwin

Future of Mobility practice leader
Managing director
Deloitte Consulting LLP
+1 212 653 4075
scottcorwin@deloitte.com

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