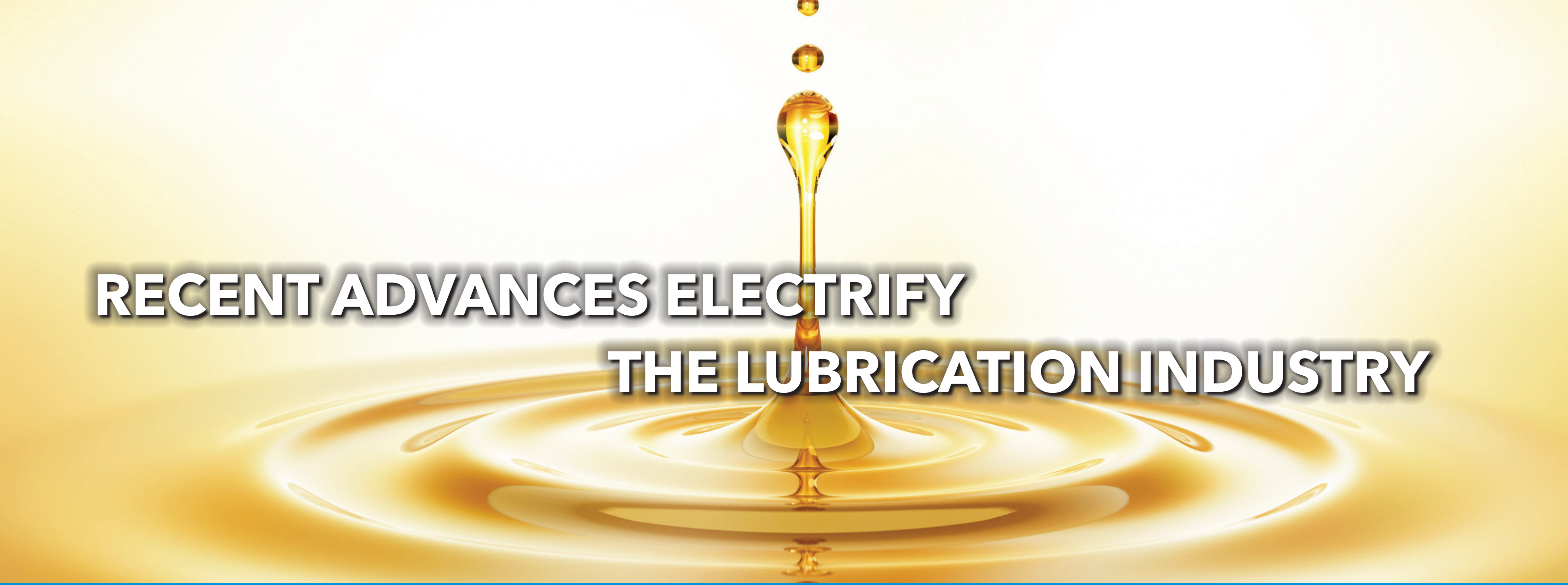
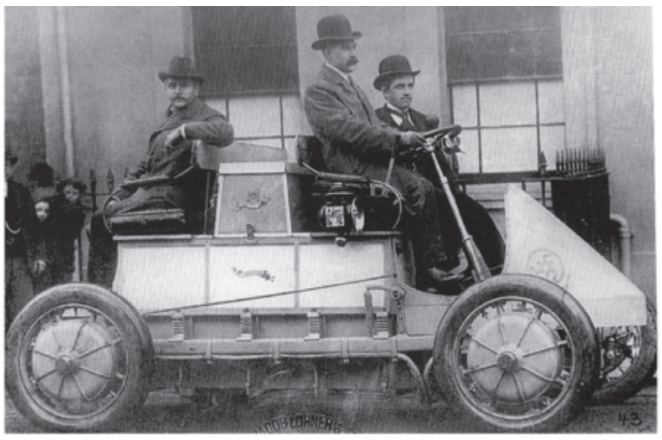


RECENT ADVANCES ELECTRIFY THE LUBRICATION INDUSTRY

One of the most sought after areas in the oil and gas industry has typically been lubricating and motor oils; however, with the rise of electrification in the transportation sector, a period involving the change to battery-powered vehicles is inevitable. In order to speculate on what may be in store for the industry, this article presents several outlooks and changes that have already began to occur in the market for automotive lubes and greases.

1896



Lohner-Porsche Four-Wheel Drive Electric Car (1901)

Images courtesy of Wikipedia

E-mobility is as old as the internal combustion engine and dates back to the late 1800s and early 1900s. In 1896, American Electric Vehicle Co. presented a fully electric vehicle. In 1901, the well-known Ferdinand Porsche developed the Lohner-Porsche, an electric vehicle in which the motors were integrated into the wheels of the car. Over the next 120 years, demand for electric vehicles declined as consumers opted for cheaper means of transportation, mainly in forms of the early internal combustion engine. What has changed in today's world that is responsible for this recent increased hype in e-mobility and electrified public discussion in regard to the automotive industry?

As the world's population continues to grow, the demand for automobiles will also grow. This upcoming growth in global mobility can only be realized on an affordable and efficient scale, where both gas- and battery-powered vehicles are considered. Continued debate over the environmental impacts of these types of vehicles has only proved to be detrimental to the further improvement and development of better means of transportation and even the Earth.

Facts and Figures: Market Share and Predicted Growth

McKinsey & Company conducted a comprehensive market study for automotive lubes and obtained detailed projections through 2035. Their primary discovery was that, "while volume growth may be flattening, there is still room for value-pool expansion." This will vary greatly contingent on region, market segment, and product type. In addition, this growth will also incur some considerable risks regarding areas in policy and technology.

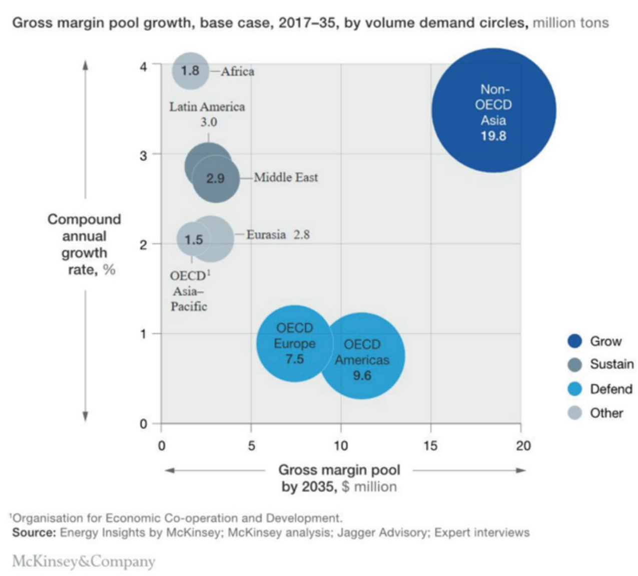


Figure 1. Gross margin pool growth by region (McKinsey & Company)

McKinsey & Company's expectations have been so far validated as the volume growth for lubes have yet to cease, but are projected to experience a slightly reduced rate in years to come. It has also been confirmed that road-transport demand, which currently accounts for 40 percent of the total volume growth, is projected to reach its apex within a span of the next five years. Thereafter, there will be a slow decline of transport demand as the share of electric vehicles (EV) and ride shares increase, and as there begin to be longer change intervals for the leftover internal-combustion-engine (ICE) vehicles.

While other transportation sectors according to margin reports (such as industry, marine, aviation, and rail) are less notable but still expanding, the greatest share of the demand for lubes is comprised of non-transport and industrial consumption, which will also continue to grow at a steady rate, compensating for diminishing transport demand. However, the road transport sector will continue to boom as higher-margin synthetic lubes expand significantly to take a 70 percent market share by 2035.

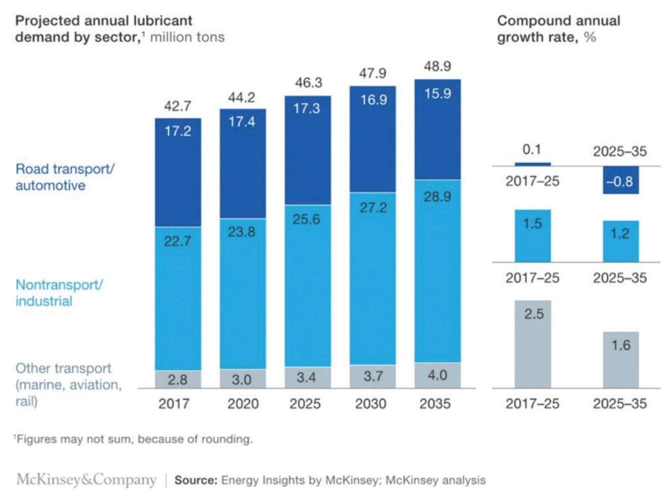


Figure 2. Lubricant demand by sector (McKinsey & Company)

As the move to electric vehicles steadily increases, light-vehicle lubricants will see demand begin to decline in Europe and North America by 2030. There were approximately 1.3 billion light (passenger) vehicles in 2018, and within the market share for newly sold vehicles in the 2017-18 year, electric vehicles accounted for 2.2%. In 2018, the global fleet of electric vehicles reached 50 million units. Among these shares, battery electric vehicles (BEV) made up for 0.1% of light vehicles; whereas, hybrid electric vehicles (HEV/PHEV) made up for 0.8%.

According to estimates by the International Energy Agency [1], the number of electric vehicles worldwide is expected to increase to 300 million by 2040, while the stock of vehicles with internal combustion engines will increase from 1.3 billion vehicles to approximately 2.1 billion vehicles in the same period. Thus, the internal combustion engine remains the main engine for the foreseeable future and has to be fed by suitable, environmentally-friendly energy sources, in which there is further CO_2 reduction driven by friction optimization and lubricant development. The lubricant demand will increase, but in which markets and specifications?

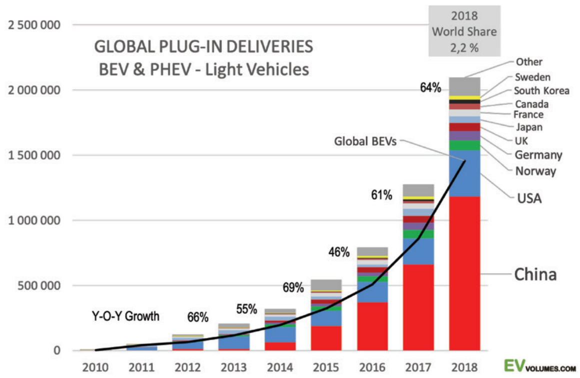


Figure 3. Electric vehicles in circulation by the millions and region [1]

Global motorization accounts for only ~14% of the total population, 65-85% of which comes from America and Europe. This is expected to grow ~23% by 2035. The majority of this growth will happen in Asia, Africa, and South America. Thus, these lubricants must be affordable and meet the economic requirements of these regions. Finally, there will be a net growth in finished lubricants, but who will benefit?

In 2015, even in light of the limited proliferation of electric vehicles, the tendency toward electrification of road passenger transport seemed likely to gain traction over the next decade as more countries and municipalities globally put into practice efforts for the reduction of emissions such as carbon and particulate matter. The recent inking of the Paris Agreement, in tandem with rising air quality concerns and the diesel emissions scandal, have all aided in the implementation of diesel and fossil fuel restrictions. By 2040, France will ban all gasoline and diesel vehicles, while Athens, Madrid, and Mexico City have announced that by 2025 they plan to outlaw all diesel cars and vans. In addition, China and India are also considering electric vehicle targets.

Concurrently, original equipment manufacturers (OEMs) are divesting from internal combustion engines (ICEs), adding fuel to this transitional flame. In this understanding, it is clear that car manufacturers are investing in e-mobility, as it will have a significant market share in the near future. With other alternative options such as e-fuels and hydrogen fuel cells on the horizon, it is unclear what the future of e-mobility will look like.

Facts and Figures: Resources

When considering the e-mobility of cars, resources are a prominent limiting factor. Lithium, nickel, and cobalt are mostly used in today's automotive battery concepts. Lithium is a product that is mined with high demand, where the customers who pay the most are the ones who will get it. The availability is limited, also in terms of growth, and the prospects are concentrated in South America. On the other hand, greater than 95% of cobalt production comes from by-pass production, and therefore the upscaling of volume is finite. Will an operator of a copper or nickel mine increase production in order to sell more cobalt? This is just one scenario in which these economic factors come into play. Additionally, cobalt compounds are labelled as carcinogenic, mutagenic, and toxic. In the case of lithium ion batteries, IATA regulations require that the batteries be fully discharged for commercial air transport. In some areas of the world, fire fighters recommend that when an e-vehicle is on fire to let it burn out on its own and evacuate the area in order to stay away from the harmful fumes.

Assume that an automotive top five producer wants to sell electric vehicles in 2025 and needs battery capacities of 300 GWh, ten times that of TESLA´s Gigafactory in Nevada. Even without considering the availability of resources, this project would be costly and require a significant amount of work. The range today for the battery size in vehicles varies from 35 kWh to 100 kWh. If the automotive producer wanted to sell electric vehicles with 100 kWh batteries, they could produce at most 3 million vehicles given the size of the plant. Keep in mind that the top five today sell around 10 million vehicles each year. In 2018, a total of 989 million light vehicles were produced globally. Thus, for electric vehicle producers to be able to effectively compete, then they would need a factory capable of handling 3,000 GWh. Depending of the battery type used (see Table 1), 300 GWh will consume from the following percentages from the total volume mined percentage in 2018:

a. 23-32% of lithium
b. 3-7% of nickel
c. 0.1-1.5% of manganese
d. 12-50% of cobalt.

Table 1. Full metal demand in thousands of tons for 300 GWh of battery capacity and different battery types

Battery type		LCO	NCA	LMO	LFP*	$LiNi_xMn_yCo_zO_2$ (NMC)				
						111	433	532	622	811
Metal demand **[thousands of tons]** for 300 GWh	Li	25,2	21,0	19,5	26,1	27,3	25,8	24,0	22,2	20,7
	Mn	-	-	310,2	-	63,3	61,8	57,3	35,1	16,2
	Ni	-	143,1	-	-	69,3	86,7	102,0	112,2	139,5
	Co	214,2	27,0	-	-	69,6	65,4	41,1	37,5	17,4

LFP= lithium-iron-phosphate; 111= Li(Ni0.33Mn0.33Co0.33)O_2; 532= Li(Ni0.5Mn0.3Co0.2)O_2; 622= Li(Ni0.6Mn0.2Co0.2)O_2; 811= Li(Ni0.8Mn0.1Co0.1) O_2; LFP= $LiFePO_4$; LMO= $LiMn_2O_4$; NCA= Li(Ni0.80Co0.15Al0.05)O_2; LCO= $LiCoO_2$

The 2018 mined production of metals [tons p.a.]:

Lithium: 85,000

Nickel: 2,200,000

Mangan: 21,000,000

Cobalt: 140,000

Copper: 23,600,000

On average, a vehicle with an internal combustion engine consumes 20-30 kg of copper, whereas full battery vehicles require 75-100 kg of copper.

Lithium ion batteries are composed of other metals in addition to lithium. For example, as shown in Table 1, five general types of lithium batteries are shown. LCO is lithium cobalt oxide, NCA - lithium nickel cobalt aluminum oxide, LMO - lithium manganese oxide, LFP - lithium iron phosphate, and NMC - lithium nickel manganese cobalt oxide. Lithium and cobalt are limited in mined volumes, and nickel and copper are predicted to face a scarcity following 2025, which is a limitation for electric vehicle manufacturers.

E-fuels

In the industry for e-fuels, greenhouse gas neutral e-fuels and feedstocks will be needed to meet the EU's climate change objectives in the transport sector. Synthetic fuels are of central importance to the transport sector, as approximately 98% of the transport energy consumed in the transport sector comes from liquid fuels. Currently, the expert discussion revolves around the dependability of the biogenic resource, in particular with regard to its life cycle assessments and target cost levels. Different approaches are used to generate biogenic base materials (fuels), like biomass, sugar, and algae. Also, power to liquid (PtL) processes are a possibility, where surplus electricity is used, preferably from renewable energy conversion, for the conversion of carbon dioxide into liquid hydrocarbons.

Carbon dioxide neutral e-fuels have the advantage of allowing for the continued use of existing gasoline, diesel, kerosene, and even natural gas infrastructures (pipelines, filling stations, and vehicles). The drivers for carbon neutral e-fuels are the automotive and aerospace industries. The following molecules are typically considered: triptane (octane rating of 112) from methanol and dimethylether, paraffine from the Fischer-Tropsch process using biomass, tri- and tetraoxymethylenglycoldimethylether from biomethane, biodimethylether (bio-DME) from biomethanol, bioolefine from algae (Botryococcane), and "farnesane" from sugar. The advantage of these ideally carbon-neutral alternatives lies in the fact that they are suitable as a direct substitute for conventional fuels due to their liquid state and high energy densities, which require only minor changes to existing engine concepts and infrastructures.

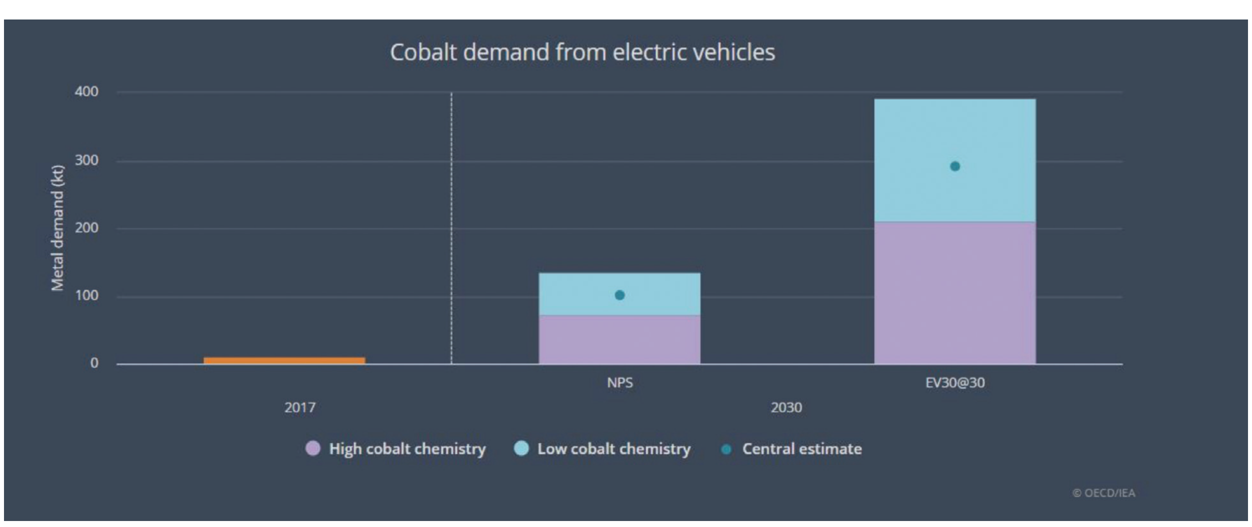


Figure 4. Cobalt demand for electric vehicle batteries [1]

Lubricant Demand

For example, Volvo has made a recent announcement that it will stop developing new diesel engines after 2019, and BMW to stop production of ICE by 30.06.2030. These decisions may be later revised or weakened. This is primarily due to the belief that conforming to carbon emission standards would be challenging to do at an efficient cost. Due to these benchmarks and other similar actions worldwide, combined with technology-driven cost and performance improvements, EVs are likely to gain market share from ICE vehicles in the forthcoming decade, faster than what has happened in the past. In 2015, more than half of the world's lubricant demand (>40 million tons) originated from the automotive industry; therefore, any change during the transition to EVs would be substantial to the entire lubricant market.

Lubricant demand in the light vehicle sector mainly consists of engine oil, which accounted for more than 50% of the automotive lubricant demand and 21% of the total lubricant demand in 2015. Besides engine oil, lubricant demand also consists of: wheel bearing and chassis grease, which is mostly sealed and changed every 130,000 km, if at all; transmission fluid, which is changed every 150,000 km, if at all; and gear oil, which is changed every 50,000-60,000 km, but can also last for the lifetime of the engine.

It is projected that by 2030 the number of light vehicles will reach 1.6 billion (an increase of 500 million from 2015), with an estimated 18% of the total 290 million cars being electric. In 2017, 98.9 million motor vehicles were produced (ACEA Pocket Guide), with 80.2 million being passenger cars. Approximately 1 million passenger cars were electric vehicles (IEA). In 2018, slightly more than 50 million of electric vehicles circulated globally. At this juncture, a mere 5% of these vehicles were hybrid electric vehicles (HEV). This is an increase from 0.1% in 2015 and signifies a predicted growth of 38% p.a. during the span of 2015 through 2030. This scenario would have a significant effect on the demand for light vehicle lubricants because the infiltration of BEVs, which do not use engine oil at all, would alter the needs of the industry. With Asia at the forefront of this movement, total lubricant demand in 2030 would still be on the upswing by approximately 1% p.a.

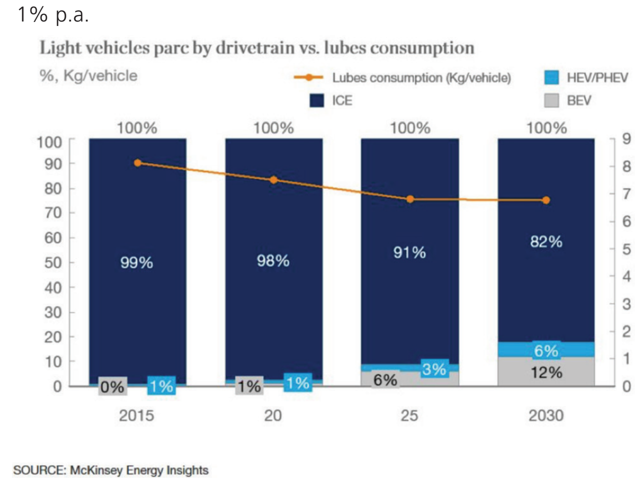


Figure 5. Lubricant consumption for ICE vehicles, hybrid/plug-in hybrid, and battery electric vehicles (McKinsey & Company)

This stalling of growth, and especially the decline in demand in Europe and North America, indicates dire consequences for lubrication companies. However, they can make efforts to maintain growth, so as to avoid shrinking in step with the market by expanding market share in Asia and other developing markets, in addition to zeroing in on higher margin products like synthetic lubes and high-grade lubes for the growing HEV/PHEV market. Alternately, these companies could consider growth through diversification into new or growing tangential sectors. For the foreseeable future, the primary question will be the proportion of the two types of EVs, as well as the general rate of uptake. Therefore, it is imperative that lube companies keep a close watch on proposed legislation and uptake rates through the next decade to stay up-to-date with the likely trajectory of industry trends.

One thing is certain with the influx of vehicle electrification looming on the horizon: lubricant and additive companies must take into consideration the challenges that will come with this innovative technology broached by the changing demand for the amounts and types of fluid. The currently favored e-configuration includes a reduction gear and differential, both lubricated with a fluid of about 3 to 4 liters. In addition, functionalized cooling liquids are often discussed, which can be in amounts around 20 liters. Considering the many complex components of a modern motor vehicle, such as steering, brakes, shock absorbers, and joints, no major changes are currently accepted for the lubrication of these parts. With that fact in mind, the demand for lubricating greases and dry lubricating coating will continue to grow, at least for the time being. Since the amount of hybrid electric and fully-electric vehicles on the road is steadily rising, most noticeably in the European Union, there will be an additional influence on the development of lubricant technology. For instance, in Germany, the continent's most prominent car market, registrations of hybrids and electric vehicles grew by 54.8 percent and 39 percent, respectively, in 2017. Across the EU block, 431,504 hybrids and 216,566 electric vehicles entered the fray. According to the EU, hybrid and electric vehicles will hold a market share of approximately 40 percent by 2028.

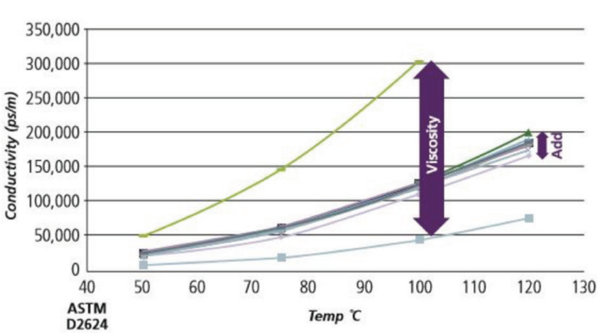
Changes in the Development of Lubricant Technology

The abovementioned impact on lubricant technology will translate to improved corrosion protection of metal parts in contact with the oil, especially at higher temperatures, and the oil's thermal stability. Lubrizol's global manager for transmission lubricants, Michael Gahagan, informed Lubes n' Greases of the following statement: "We are seeing more focus now on characterizing the electrical and heat transfer properties of lubricating oils. It is possible that a new range of lubricating fluids may be used in the drivetrain to enable these advancements in vehicle electrification," he said.

The manner in which OEMs seem to be currently specifying lubricants is for them to be "compatible across the board," said Gahagan at an industry conference in early 2018. He also indicated that a gearbox of a specific model will require a lubricant that will meet OEM standards and requirements, regardless of the type of engine used. While today's hybrids can and often do employ traditional driveline fluids, manufacturers would also do well if they adopted new, dedicated fluids that are better able to protect and ensure the smooth functioning of the electrified drivetrain parts.

The vehicle that comes to mind when most people think of a hybrid is the Toyota Prius. It had global sales of nearly 100,000 units of all variants in the first quarter of 2018. This automobile utilizes what is known as a power-split unit. This unit is a planetary-type gearbox which links the internal combustion engine, generator, oil pump, and electric motor together, allowing the ICE to function independently of the car's speed.

At this same conference, Gahagan mentioned another important consideration for developing novel EV fluids: the electrical conductivity of fluids and related safety considerations. EVs have higher system voltages of up to 48 volts in a basic hybrid EV, compared to 12 V in a conventional ICE car. Of major concern among OEMs regarding lubricants in hybrid EVs is electrical charge in the lubrication fluid. This is most prominent at the power split, where the oil is in contact with the electric motor. Therefore, fluids made to hybrid and EV specifications would need the proper conductive properties and be compatible with the surrounding insulation.



Source: Afton Chemical

Figure 6. Conductivity versus temperature for additives of different type and viscosity (Lubes'n'Greases)

According to Gahagan, there are two main factors that must be dealt with when it comes to the conductivity of fluids: one is if the conductivity is too high, there is a possibility of the current leaking, which could have deadly consequences for any passenger who comes into contact with charged parts; conversely, if conductivity is too low, electrostatic charge can start to build up. This results in degradation of the fluid, compromising its protective features. It can also lead to arcing, which can do damage to bearings and seals. It is fortunate that lubricants happen to be ineffective electrical conductors. However, lubricants are static dissipative, meaning they allow charge to leisurely pass through them Oxidation, which causes oil to deteriorate with time, is another factor which can increase conductivity.

[1, 2, 3]

Implementation of New Testing Methods and Legislation

The same applies to lubricant test methods as does lubricants, according to Lubrizol, when it comes to adapting needs for hybrid and electric vehicles. Due to the presence of electrical components and wires in the hybrid architecture, and in light of the possibility of fluctuations in the level of conductivity and a greater variation in temperatures, corrosion deposition tests must be made more advanced. New legislation has been enacted in the UK on July 19, 2018 to accomplish this. Although this legislation applies only to the UK, it is important worldwide because it is one of the first attempts to codify the requirements for autonomous vehicles and electric vehicle charging into law. The legislation is known as the "Automated and Electric Vehicles Act 2018," sponsored by the Secretary of State for Transport, Christopher Grayling. Although there has been discussion since 2013, this is the first definite step to be made. It started as a government bill in October 2017 and has been evaluated in both the House of Commons and the House of the Lords, before being given Royal Assent in its final form.

The Automated and Electric Vehicles Act 2018 is intended to enable and encourage the use of autonomous and ultra-low emission vehicles in the UK. The bill has two main components: make provisions in relation to automated vehicles and provisions in relation to the charging of electric vehicles. The measures in this bill are intended to help deliver the aim that almost every car and van or truck will be a zero-emission vehicle by 2050.

The bottom line is that automotive and lubricant blenders and marketers are keeping a close watch on government regulations for electric vehicles. The engine in electric vehicles is battery-powered, as opposed to the ICEs employed in automobiles since the era of Henry Ford and the Dodge brothers. The absence of an ICE translates to EVs having no requirements for engine oils, a market segment that accounted for more than three-quarters of all global automotive lubricant sales in 2016. There can be various consequences of this since electric vehicles require fewer mechanical parts. This can result in the loss of thousands of jobs. Furthermore, 60 to 70 percent of battery prices are linked to resource costs, which can result in an unpredictable transition of money and jobs to locations around the world.

Although EVs have been in existence for more than a century, only now are they starting to be a possible alternative to ICEs when it comes to power and cost. As such, several prominent car manufacturers, including Volkswagen and General Motors, have vowed recently to solely produce EVs in the future. In addition, an ever-increasing number of governing bodies around the globe are looking at EVs as a means to cut carbon emissions after the implementation of the Paris Agreement. Several European nations have set moratorium dates on sales of vehicles that burn gasoline or diesel fuel. However, in recent years an unexpected country - China - has taken precedence over the worldwide EV market.

Image courtesy of Volkswagen

In a ploy to improve traffic congestion and pollution, several cities in China have limited the number of license plates they approve per year, and those that are granted are done so by auction or sometimes lottery, where the odds of earning the right to own an automobile are around a meager 1%.

The challenge of procuring a plate has made for plenty competition and division, especially among the different socioeconomic classes. Consequently, illegal markets have surfaced in China, causing some to pay more for their license plate than the car itself. In 2015, a dispute broke out at a Chinese auction over a license plate number in the city of Huzhou. In Shanghai, a loophole in the rules preventing private plate sales allows the free transfer of plates between spouses. This has led to many sham marriages where plate owners offer their faux fidelity and license plates in a quid pro quo arrangement and in exchange for cash. The Chinese government now offers another path to obtaining legal license plates for EVs. Special plates are issued for owners of EVs through a program put forth in 2016, enabling consumers to bypass the stress of obtaining traditional plates.

This action by China is just one example of how world governments are using innovative tactics to incentivize EV purchases in the hopes of reducing pollution. For instance, Norway, which boasts the highest adoption rate of EVs in the world, has tried different EV incentives over the years, such as allowing EVs to be driven in bus lanes and providing free public parking. Other countries offer tax breaks, stimulus payments, or a combination of the two.

Relative Effects on Oil Supply and Demand

It is important to note that all is not grim for automotive lubricant suppliers. While the ICE is projected to be phased out of new vehicle production, it is unclear what will be the market share of e-vehicles because the transition will not be completed for decades to come, even according to the earliest predictions. Despite the effects EVs will have on engine oils, not all types of automobile lubricants are in jeopardy. EVs still require greases and most need gear oils, which currently account for a small percentage of automotive lubricant sales, to lubricate their differentials, chassis, and wheels. EVs also require coolants for the battery. Drivers will still need shock absorber fluids to aid in a smoother ride and brake fluids to stop. In addition, consumers haven't begun buying EVs without incentives from their governments. On the other hand, further developments are needed to ensure the cooperation between the electrical components and oils and greases.

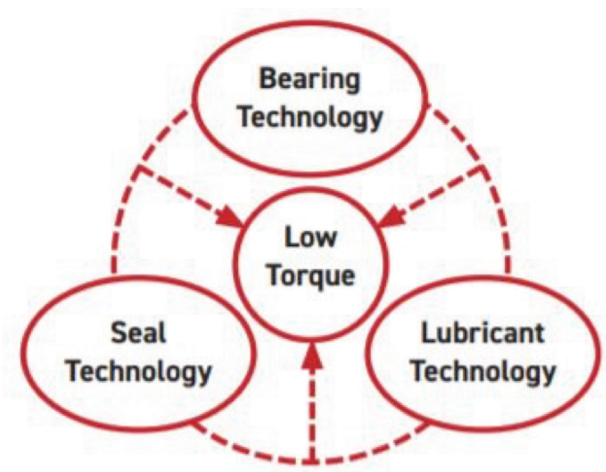


Figure 7. Methods to meet low-torque requirements for EVs (STLE)

While there is no way to refute that EVs will greatly change the transportation scene in forthcoming decades, the metamorphosis will be evolutionary and poses no imminent danger to global oil demand through the mid-21st century. The rise of EVs will not be the death of oil and grease products in the same vein that digital was to film. This is because EVs, conventional gasoline, and diesel-powered automobiles will exist simultaneously, with significant growth potential on both sides. Modeling by BP demonstrates that even a worldwide ban on new ICEs would create a 10 million barrels a day dent in oil demand by 2040. Since the oil market nearly reached 100 million barrels a day in 2018, this equates to only about a 10% loss to the oil industry.

Oil will remain a global powerhouse because demand growth for oil in sectors such as petrochemicals, heavy industry, aviation, and other heavy transport keeps growing significantly; moreover, these areas are by and large sheltered from fuel switching. So as not to think that it is just "Big Oil" touting this to be a fact, the International Energy Agency (IEA), the overseer for large, developed energy-consuming economies, agrees. According to the IEA, an estimated 50 million EVs will be in operation by 2025 and 300 million by 2040, in comparison to the approximately 5 million electric vehicles on the road today. That growth is projected to reduce global oil demand by 2.5 million barrels a day or about 2%. A ratio of 6-to-1 easily offsets that reduction with increased demand from petrochemicals, trucks, shipping, and aviation, all sectors the IEA says could lead to net demand growth of up to 14 million barrels a day. Overall, the IEA expects net oil demand to be 12 million barrels a day higher in 2040 compared to 2016. This prediction is contrary to the new "peak demand" movement that has sprung up among industry watchers and is as misguided as the "peak oil" supply predictions of a decade ago. America's transportation sector is evolving on the basis of the demands of the market, and ultimately, the market will be expansive enough to enable both electric vehicles and conventional internal combustion vehicles to flourish.

The Infrastructure Issue

In the 1890s, car owners had to purchase their gasoline in pharmacies; now it is available almost everywhere due to the construction of pipelines and shipping routes. Infrastructure cannot be a showstopper for a new technology, but shall be an investment case in the form of public-private partnerships. In Japan, for example, a hydrogen network for fuel cell applications is under installation. In Germany, 74 hydrogen stations are predicted to be operational by August 2019, which is still not enough to power either fuel cells or internal combustion engines.

The performance of existing electric grids is a limiting factor for e-mobility, and the fact that 83% of the electricity used globally emits CO_2 (with a prognostic until 2030 of still ~70%) from its generation, questioning the environmental benefit. However, investments can help alleviate this and also the proper allocation of energy to the best application by the following three primary axis:

a. E-mobility

Urban driving - short track profiles of 100 miles reduce the sizes of batteries and costs, as well as the loading of grids. For occasional longer trips, car sharing is an option, as most households have two or more cars, one being an ICE. RENAULT ZOE/NISSAN Leaf concept - the battery is owned by the car maker and a dead battery can be easily replaced at any Renault dealer along the trip with a charged one.

b. E-fuels

They fit with all distances above 100 miles and the existing infrastructure, including internal combustion engines. This not only saves jobs, but also creates new jobs associated with the synthesis of these e-fuels.

c. Hydrogen

Only for heavy loads and long distances in back-to-back relations. The infrastructure can be implemented in any industrial plant, where trucks travel from one point to the next. Liquefied hydrogen can be used over pressurized hydrogen (<800 bar), because once the truck is filled with fuel, the hydrogen is immediately distributed. Thermal losses of ~2% per day are no issue. In addition, the operators can be trained to handle liquefied (cryogenic) hydrogen. This includes trucks, trains, busses, internal navigation, high-sea ships, etc. Up to 20 volume percent of hydrogen can be blended with natural gas without having adverse effects.

How we fuel in future ground transportation CO_2-neutral?

Images courtesy of M. Woydt, except for synthetic fuels

A spiraling number of fuels do not cooperate with the current business models of petrochemical companies, suggesting that further action needs to be taken to integrate these alternative fuels at an affordable cost. For example, EN 16942 recognizes today 13 fuel grades including hydrogen (H2) and synthetic e-fuel (XTL).

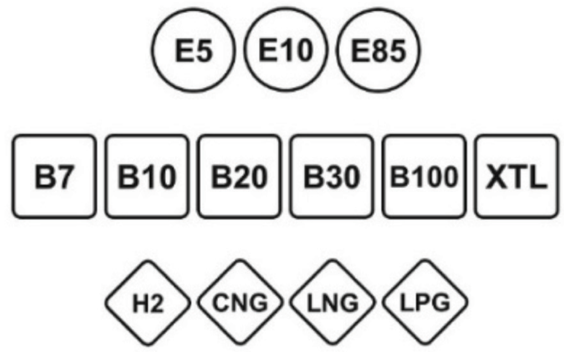


Figure 8. Thirteen fuel grades as listed in EN 16942 (DIN)

Hydrogen can be used in fuel cells or internal combustion engines. The hydrogen fueled ICE is very similar to the LPG engine as demonstrated by BMW, Toyota, and Honda.

Fuel cells do not use lithium and cobalt, but instead they use platinum. Their weak point is the cleanliness of the hydrogen, especially for elements in the ppb range. High purity hydrogen is required to achieve long lifetimes of the proton exchange membranes. See the following for further information:

a. Hydrogen fuel spec ISO 14687-2

b. CaFCP Hydrogen Quality Guideline

c. SAE J2719.

Life-Cycle Analysis

With respect to electric vehicles, NGOs, media, press, and politics only consider the emissions of an e-vehicle when it stands curbside. They neglect the amounts of energy and resources consumed to build it. Independent from the method of propulsion, all vehicles need a car body, drive train (air conditioners, transmissions, wheels, exteriors, fenders, load floors and suspension components, etc.), interiors, and other necessary parts.

Several full life-cycle analyses (LCAs) indicate no clear advantages of e-vehicles or other means of transportation, with all returning approximately the same values. The different propulsion technologies - hydrogen, battery, gases, or fuels - were similar in their CO_2 accounts. The ranking of the scenarios depended on the type of energy resource and were assigned values based on the CO_2 benefits provided.

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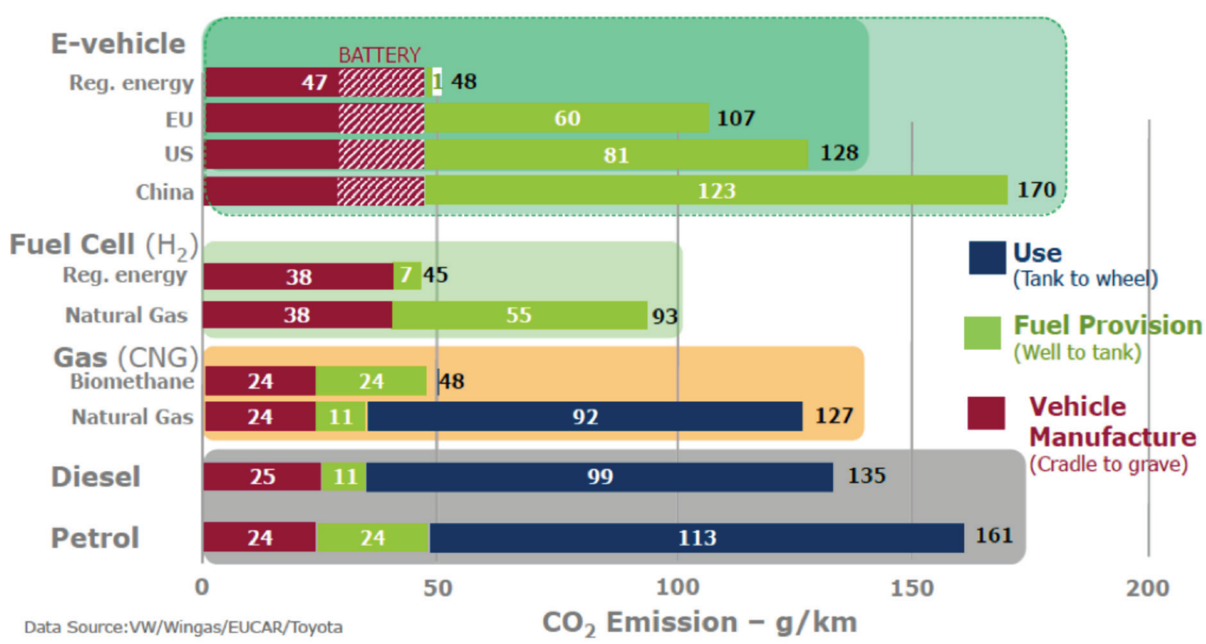

Figure 9. Lifecycle CO_2 emission comparisons [2]

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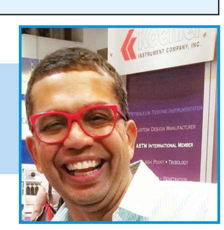

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