The Demands, Lubricant Challenges and Future Impact of Electric Vehicles (EV)

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How far have we come in a century? And how far will we come in the next 20 years?

https://blog.qad.com/2017/01/henry-ford/

https://finance.yahoo.com/news/elon-musk-telling-customers-unusual-235150180.html

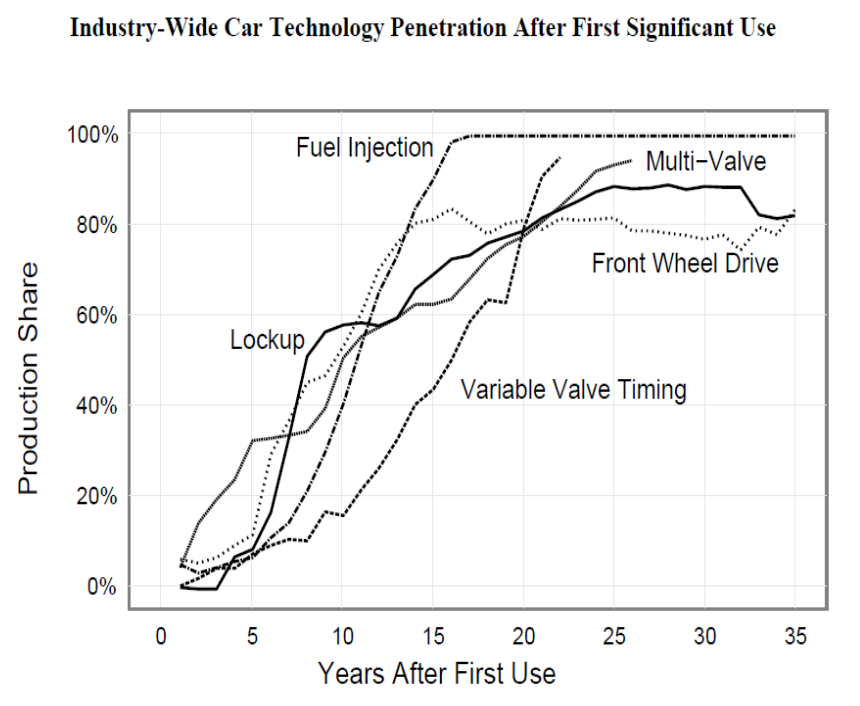
https://giphy.com/gifs/telephone-zhG2sDdPpXgDS

https://giphy.com/gifs/thevoice-selfie-blonde-hair-dont-care-life-41t8ooqOaK1eE/

Today's Discussion

- The EV Race
- Factors affecting EV inception rates
- Current and projected EV inventory & Sales
- New lubricant challenges
  - Noise reduction & friction reduction
  - Thermal transfer
  - Copper and electrical influences
  - Elastomer and new material compatibility
  - Fill for life capability
- Future Impact on lubricants and base oils

The Next 20 years

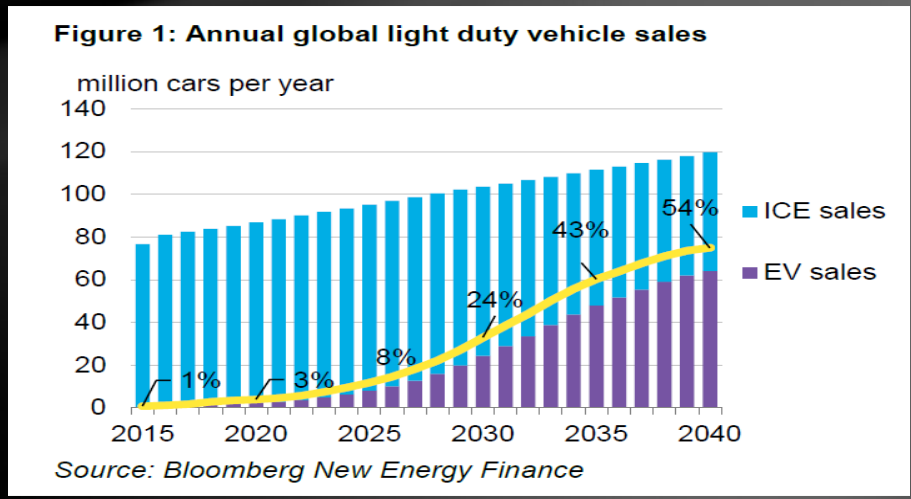


Edward P. Becker, P.E., Ph.D. Friction & Wear Solutions, LLC

- By 2040, >50% of new car sales will be electric, and 33% of the global fleet will be electric

-Hybrid technology will serve as bridge to full BEV

Battery electric vehicles (BEV) will reach cost parity with ICE vehicles by 2025, and PHEV/HEV will likely start to phase out



https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF_EVO_2017_ExecutiveSummary.pdf

The EV Race

Top 25 Automakers by Market Cap

Rank	Company	Mkt Cap (USD $B)	Change (USD $B)	Chg %	Symbol	Price/Share	Country
1	Tesla	400.52	4.22	1.07%	TSLA	429.83 USD	USA
2	Toyota	185.96	0.62	0.33%	TM	132.87 USD	Japan
3	Volkswagen	84.17	-0.97	-1.14%	VOW.DE	147.00 EUR	Germany
4	Daimler	61.41	-0.34	-0.55%	DAI.DE	48.82 EUR	Germany
5	BMW	49.89	-0.02	-0.03%	BMW.DE	65.72 EUR	Germany
6	BYD	47.98	2.69	5.94%	1211.HK	128.40 HKD	China
7	General Motors	46.31	1.04	2.31%	GM	32.36 USD	USA
8	Ferrari	45.10	-0.55	-1.20%	RACE	181.20 USD	Italy
9	Honda	42.62	-0.19	-0.44%	HMC	24.71 USD	Japan
10	Hyundai	35.93	-0.50	-1.37%	005380.KS	180,500 KRW	South Korea
11	SAIC*	32.92	-	-	600104.SS	19.13 CNY	China
12	Maruti Suzuki	29.12	0.09	0.30%	MARUTI.NS	7,068.15 INR	India
13	Ford	29.08	0.28	0.97%	F	7.31 USD	USA
14	NIO	26.24	-0.11	-0.42%	NIO	21.46 USD	China
15	Fiat Chrysler	25.54	0.04	0.16%	FCAU	12.62 USD	Italy/USA
16	Suzuki	22.10	-	-	SZKMF	45.29 USD	Japan
17	Geely	19.75	0.13	0.65%	0175.HK	15.60 HKD	China
18	Groupe PSA	16.52	0.06	0.38%	UG.PA	15.84 EUR	France
19	Subaru	15.15	-0.31	-1.98%	FUJHY	9.89 USD	Japan
20	Xpeng	14.97	-0.33	-2.18%	XPEV	19.76 USD	China
21	Nissan	14.33	-0.18	-1.22%	NSANY	7.27 USD	Japan
22	Mahindra	10.77	0.06	0.54%	M&M.NS	635.00 INR	India
23	Nikola	9.38	-0.36	-3.73%	NKLA	24.76 USD	USA
24	Changan	8.23	0.02	0.30%	000625.SZ	13.43 CNY	China
25	FAW	8.20	-0.09	-1.06%	000800.SZ	12.08 CNY	China

Googledocs.com as of 10/8/2020

Nikola Badger Truck

- Hybrid battery-electric/hydrogen fuel-cell powertrain
- 600 mile range
- Production starting 2022

Rivian R1T, off-road pickup

- R1T scheduled release date in 2021
- Highest end model will have 400 mile range, mid-range goes 0-60 in 3.0 seconds
- First OEM to offer 4 electric motors (1 for each wheel), for true torque vectoring

NIO – ES6

- Chinese-based
- In it's Chinese form, the name NIO translates to "Blue Skies Coming"
- Part of sales plan includes installing home charging station with purchase of vehicle
- Currently there are no plans to sell NIO vehicles in the USA

XPENG Motors

- Headquartered in Guangzhou, China
- Base price $33,391 for the long range model - up to 349 miles
- No intentions of selling in US at this time

Lordstown Endurance

- Purchased the former GM Lordstown plant
- Recently merged with acquisition company and plans to go public
- Target production date January 2021

Lucid Air

- Long-range luxury vehicle
- Produced in California beginning late 2020
- The Lucid Air will offer the capability to charge at rates of up to 20 miles per minute when connected to a DC Fast Charging network
- To date will be the only electric vehicle able to achieve ¼ mile in under 10 seconds
- Price range $80,000 - $160,000

Fisker Ocean Crossover SUV

- Ocean SUV starting price $37,500, with 250-300 mile range.
- Debuting 2022
- 3 additional Fisker vehicles to be rolled out by 2025

Faraday Future FF 91

- FF91 Sedan designed for the luxury market, priced in $250,000 range

Filed bankruptcy December 2019

Byton mid-sized SUV

- Chinese-based startup
- Starting price of $45,000 and at least 224 mile range. Release date 2021
- Includes curved 48-inch dash screen

Nissan Leaf

- 100% electric up to 226 mile range
- Starting price around $32,000

Jaguar I-Pace

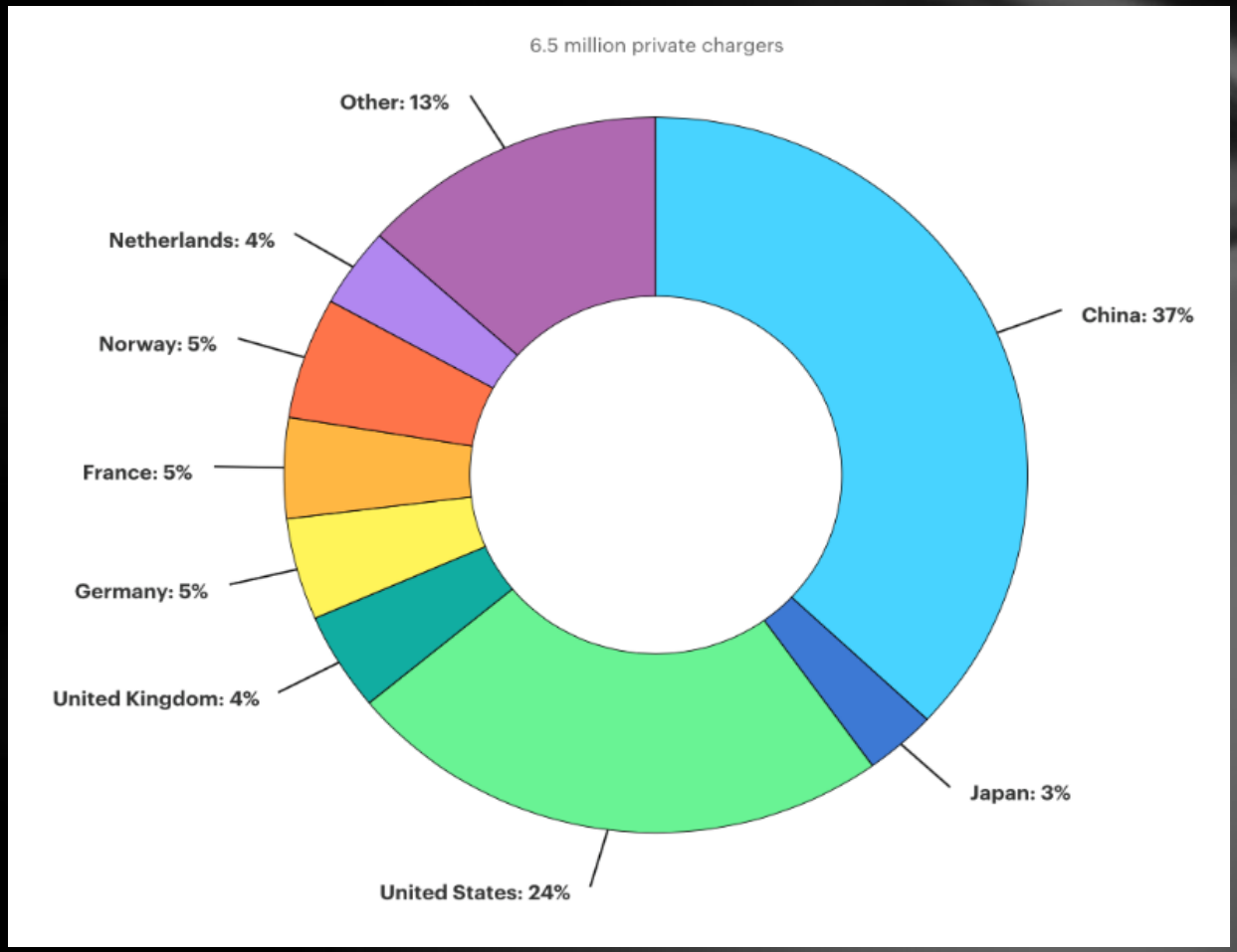
- Starting price $70,000, released 2019
- 234 mile range

Volvo XC40 Recharge

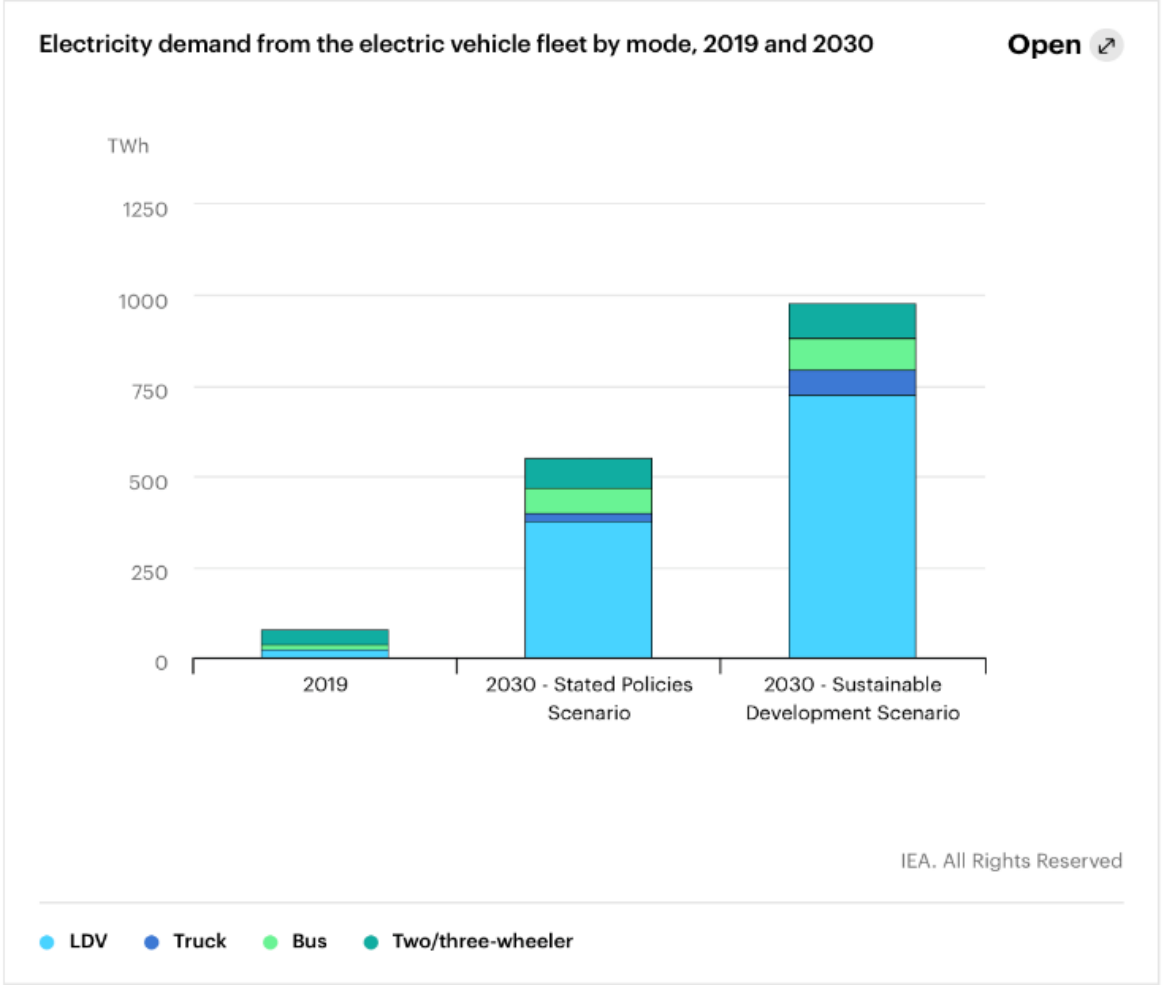
- 200 mile range
- $50,000 est starting price
- Release date late 2020

Factors affecting EV Inception rates – Range Anxiety

- Overcoming Range Anxiety (fear of not having access to high-speed charging stations)
- Improvements to Battery technology
  - charging rates, charging infrastructure, storage capacity,
- There has been a 60% increase in public charging stations worldwide. > 80% of public fast charging stations are in China as of 2019. U.S. is 2nd at 5%

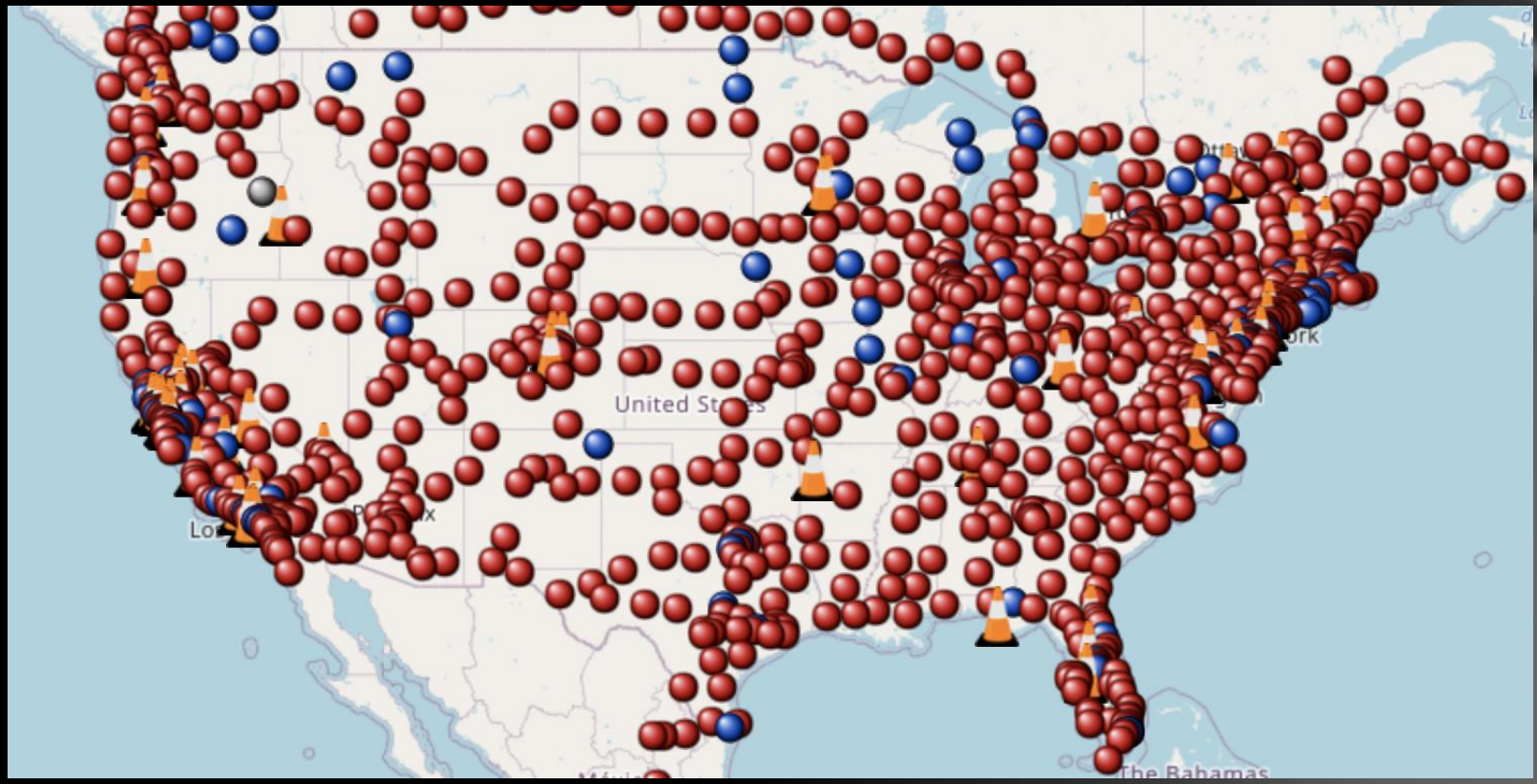


Factors affecting EV Inception rates – Electricity demand



- Electrical grid development is underway
- Under the currently stated policies Scenario, global EV battery capacity increases from ≈ 170 GWh per year today to 1.5 TWh per year in 2030, and 1,800 TWh by 2040
- In the Sustainable Development Scenario, demand of 3TWh is projected by 2030.
- Ambitious wind energy projects to reduce overall carbon footprint of converting to EVs.

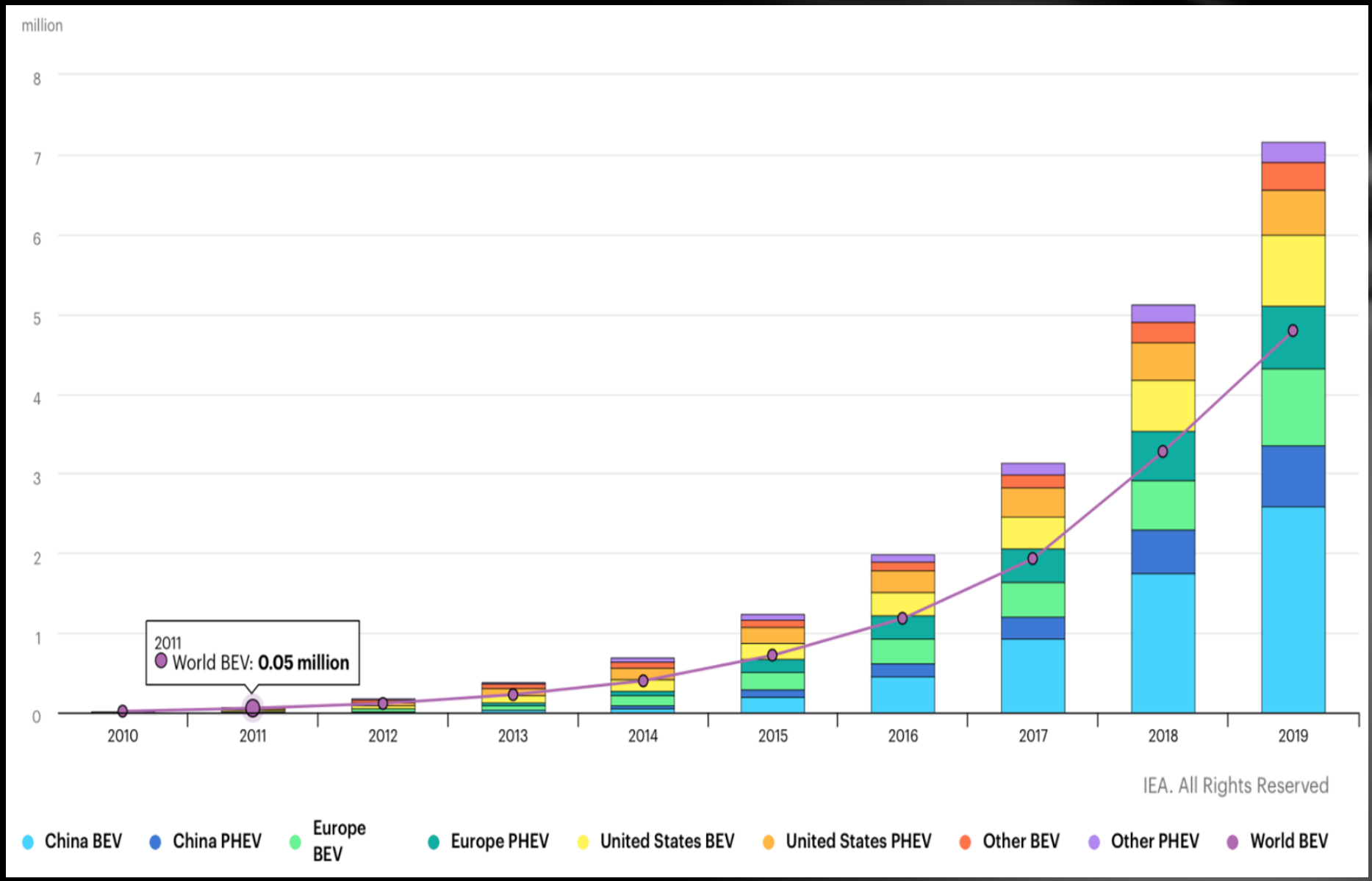
Tesla's Supercharger Network

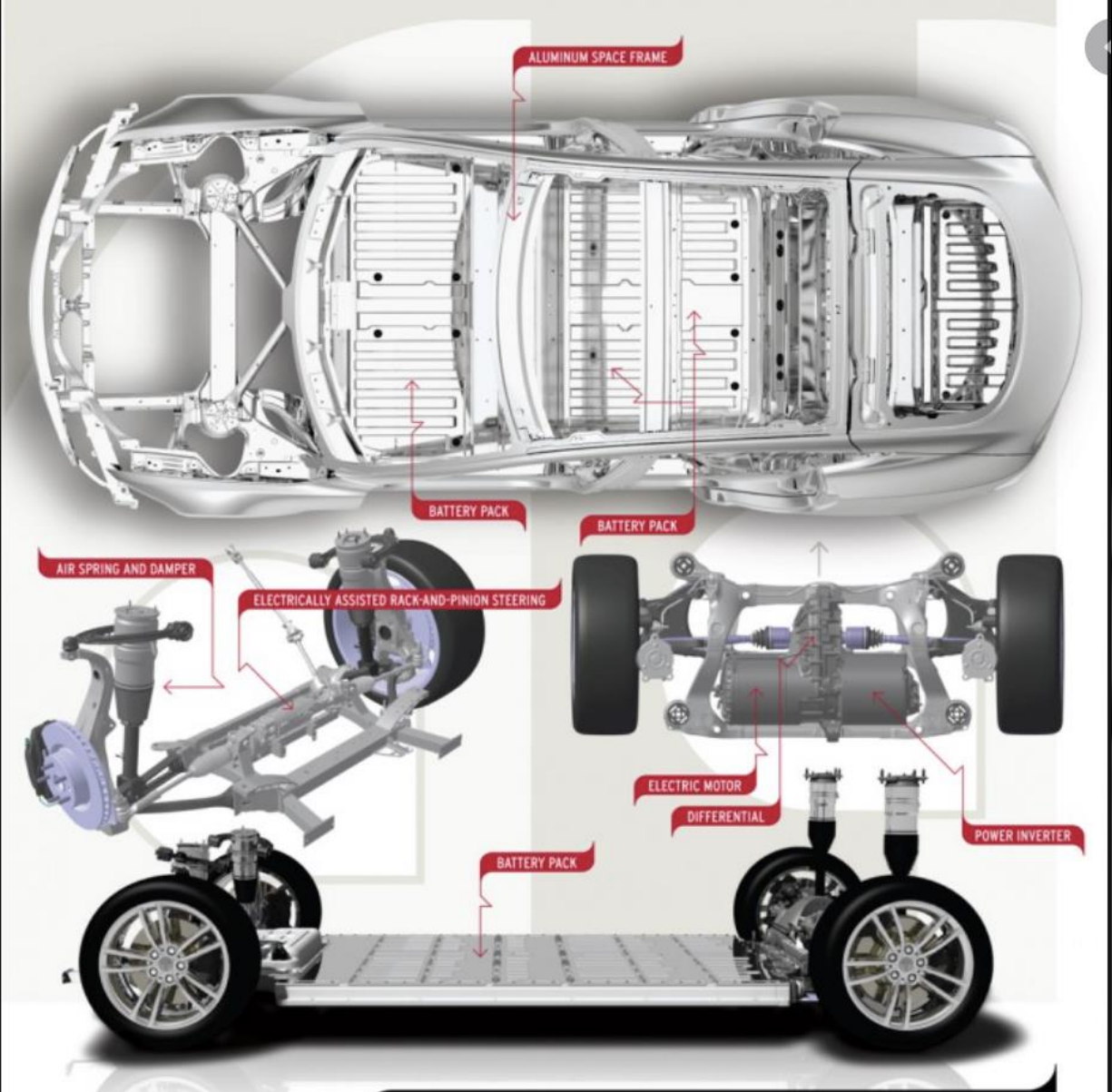


Factors affecting EV Inception rates – Cost & Government Incentives/Mandates

- Cost
  - Overall improvements to battery value chain
    - Battery pack costs are down 80% from 2010 to 2019 (from $1100 to $156 per kWh)
  - Next generation batteries will be released within 5-10 years
- Government initiatives, mandates, incentives
  - Norway 17,000 EUR subsidies for consumers who opt for EVs
  - China – bans on 2-wheeled ICE in some cities, today 60% of global EV sales are covered by China's New Energy vehicle mandate.
  - Canada, Chile, Costa Rica, India, and New Zealand are adding policies to support EV transition
  - Governor Newsom's newest mandate – California to ban new ICE vehicle sales beginning 2035
  - Governments are reviewing lost fuel tax revenues and looking at taxing based on vehicle activity
- Paris 30@30 Treaty

Worldwide EV Stock 2010-2019





UNDER THE TESLA'S SKIN

The Model S's spacious five-plus-two-passenger cabin is enabled by its compact propulsion system and clever component layout. The AC drive motor, power-inverter circuits, and final-drive differential are contained within compact housings supported by a rubber-isolated rear subframe. More than 7000 cylindrical battery cells are vertically oriented inside a large aluminum box that also serves as the body structure's floor. Liquid cooling circuits keep the driveline and battery pack within desired temperature limits during strenuous driving. A rigidly attached front crossmember supports the suspension system's lower control arms and the power rack-and-pinion steering gear. An aluminum space frame–augmented by high-strength steel B-pillars and bumper beams–supports the above components as well as the formed-aluminum body panels.

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Fluids in an Electric Vehicle

- Gearbox fluid (ATF)- 12 years or 150,000 miles
- Brake fluid, replace every 2 years or 24,000 miles
- Shock absorber hydraulic fluids
- Chassis, bearing, door lock greases
- Battery coolant - mixture of G-48 ethylene-glycol coolant (HOAT)
- A/C system oils
- Windshield washer fluid

E-Fluid Technology Trends

- Friction Requirements, with increasing focus on NVH (Noise, Vibration, and Harshness)
- Thermal management of high-speed gears
- Increased voltage around the fluid, and presence of copper and power electronics
- New elastomer technology
- High Speeds
- Low viscosity fluids
- Fill for life

Noise Reduction

- No humming motor to hide vibration noises
  - EV motors turn at speeds up to 25,000 rpm
  - There will continue to be a drive to higher speed motors to improve efficiency
- Noise, Vibration, and Harshness (NVH) as well as Buzz, Squeak, and Rattle (BSR)
  - → both become annoyances
- Noises in the cabin create perception of low quality and can affect driver comfort
- Noise can also affect increasingly used safety sensors
  - → Proper lubricant choices can make the vehicle safer
- Specifications for noise performance of lubricants in EVs are not yet standardized

Friction Reduction

- Low viscosity lubricants and greases will be used to improve vehicle range
  - Film strength and film thickness are reduced by lower viscosity fluids
  - → Reduced film thickness increases operating temp and thereby reduces the calculated fatigue life of bearings
- Bearings become a key focus for EVs
  - Power dense, fuel-efficient bearing solutions being developed for
    - weight reduction, lower bearing operating temperatures, improved powertrain efficiency
  - New bearing solutions can also reduce NVH by eliminating the clearance in the bearings and preventing the backlash motion when going from drive to coast conditions encountered during regeneration
  - High precision bearings and surface coatings on bearings are also being developed to reduce bearing fatigue, temperature, noise and friction

(*Chris Marks, Senior Engineering Specialist, Timken*)

Figure 1. Bearings for electric vehicles. (*Figure courtesy of Schaeffler.*)

Figure 2. Needle bearing for electric vehicles. (*Figure courtesy of Schaeffler.*)

Increased focus on Fluid Thermal Properties

4 factors in fluid heat transfer

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LUBRIZOL 360 WEBINAR

Fluid Heat Transfer Basics

Factors in Order of Importance

1. Dynamic viscosity (μ) *cP*

- *How easily a substance can flow*
- *Can be lowered as long as hardware protected*

2. Density (ρ) *g/ml*

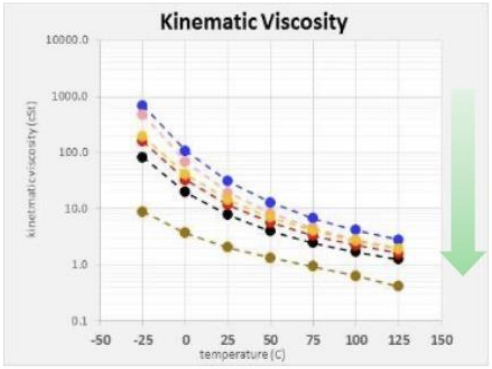
- *How much substance in a given volume*
- *Some ability to increase*

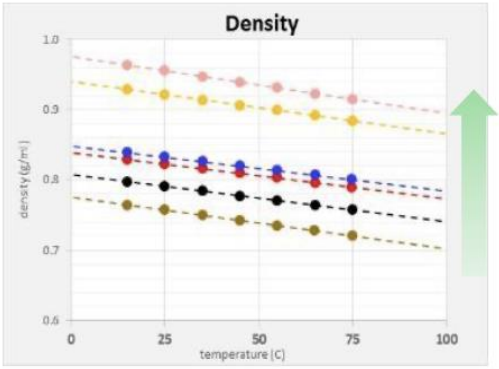
3. Specific Heat Capacity (C) *J/(g*K)*

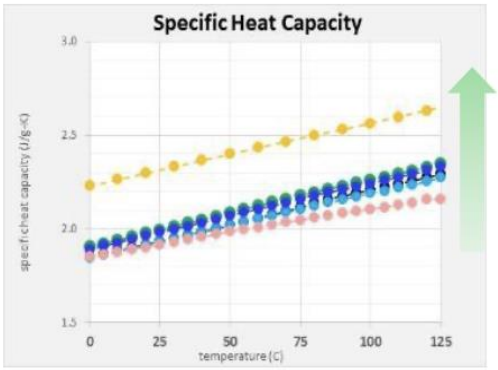
- *How much heat a substance can store*
- *Similar for hydrocarbon oils*

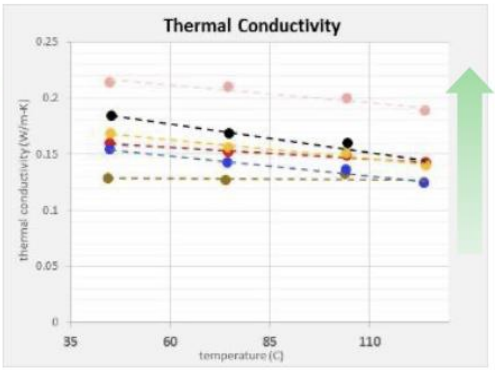
4. Thermal Conductivity (K) *W/(m*K)*

- *How easily heat travels through a substance*
- *Similar for hydrocarbon oils*

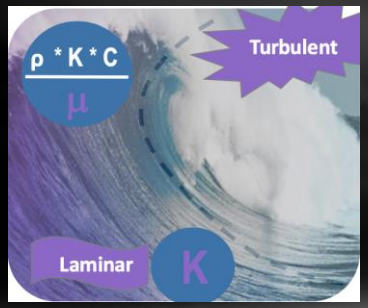








Affects of lubricating fluid on heat transfer



- Heat dissipation from electric motors, heat transfer capacity becomes more important - specific heat comparisons gain relevance
- Fluid Prandtl number (fluid thermal capacity) is studied
- Lowering lubricant viscosity has the biggest impact
- Static vs Dynamic heat transfer
  - → push for engineering hardware improvements

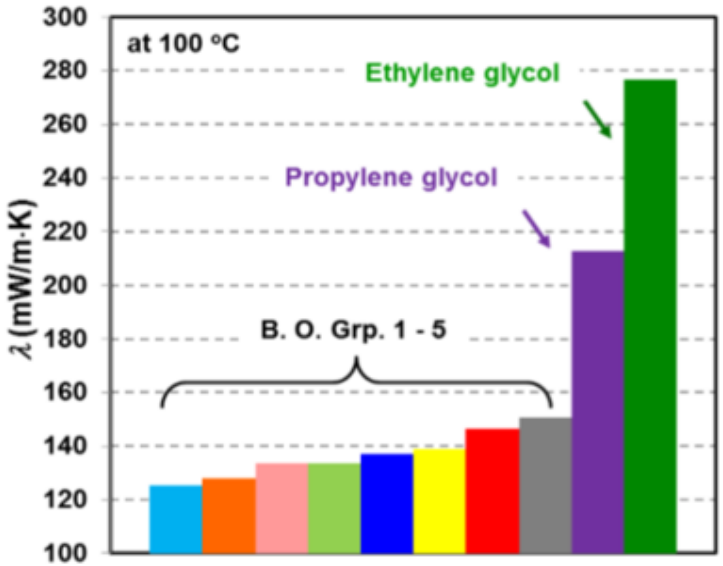


Figure 1. Thermal conductivity (λ) of a few representative BOs with ethylene glycol and propylene glycol. All BOs here, other than EG and PG, have KV100 within 4 ± 0.4 cSt.

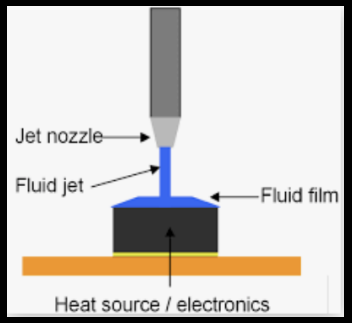
Affects of lubricating fluid on heat transfer

Very limited data available in the literature

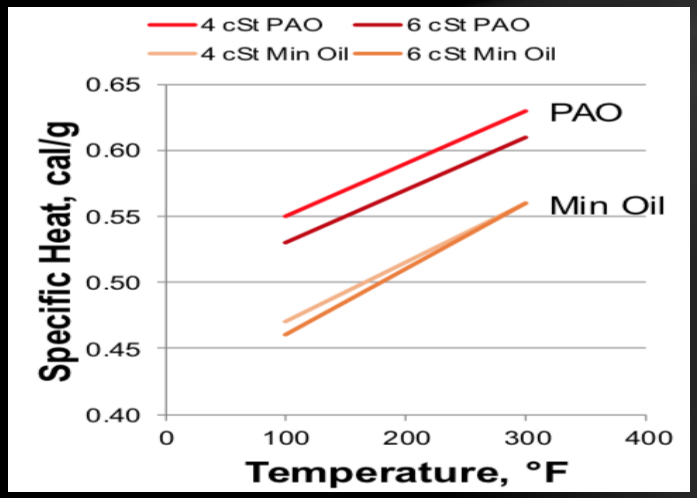
Oils	Thermal Conductivity, W/m°K	Specific Heat, Cal/g°C
Group I		
Group II	0.130	0.506
Group III		
Group IV (PAO 6cSt)	0.132	0.548
Group V		
Diester	0.149	0.513
PAG	0.156	0.508
Phosphate Esters	0.128	0.509
Silicone (Dimethyl)	0.150	
Ethylene Glycol	0.258	

Tribology Data Handbook, Ed. E.R. Booser, STLE

- Use of nanoparticles to improve thermal transfer
- Solution will be a combination of the lubricant along with the hardware.
  - Increasing volumetric flow rate through
    - Engineered Turbulence
    - Forced Convection
    - Liquid jet impingement
- ***Lubricant formulators and hardware engineers will need to work in tandem with each other***



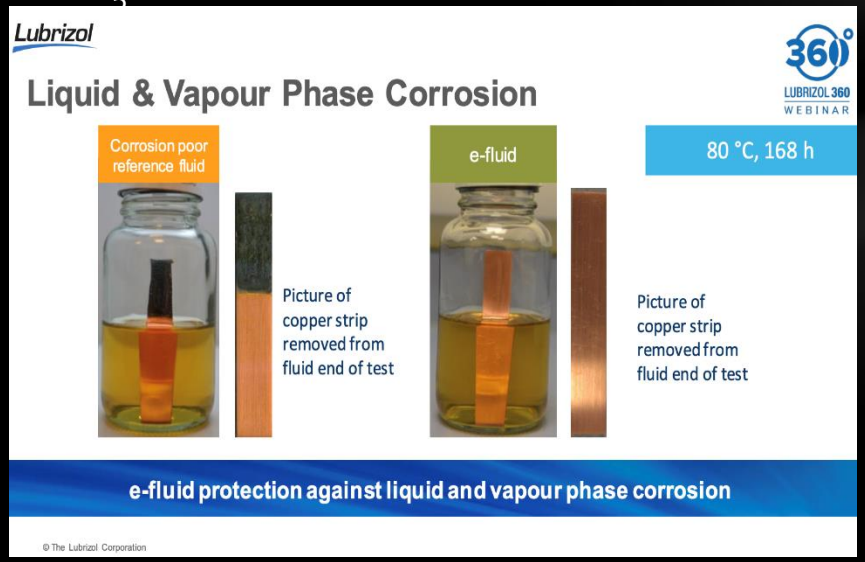
Liquid jet impingement

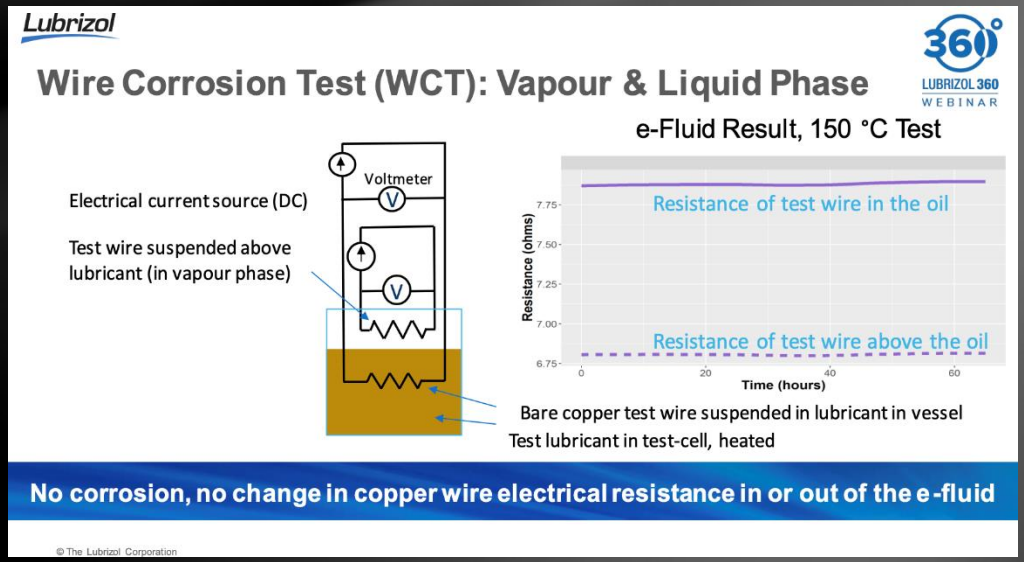


Dr. Arup Gangopadhyay – Ford Motor

Electrical and Copper Influences

- Copper corrosion tests become more critical in EV applications
  - The impact of additives and base fluids on corrosion are still being studied
- Coatings developed to prevent electrical discharge through the bearing
- Ensure that EV lubricant do not corrode copper components
  - → existing powertrain lubricants are corrosive on copper and will need reformulation
- Examples of copper corrosion tests
  - Copper strip test
  - WCT – measure changes to resistance in both liquid and vapor phase under heated conditions
  - Long-term influence of magnetic fields with lubrication



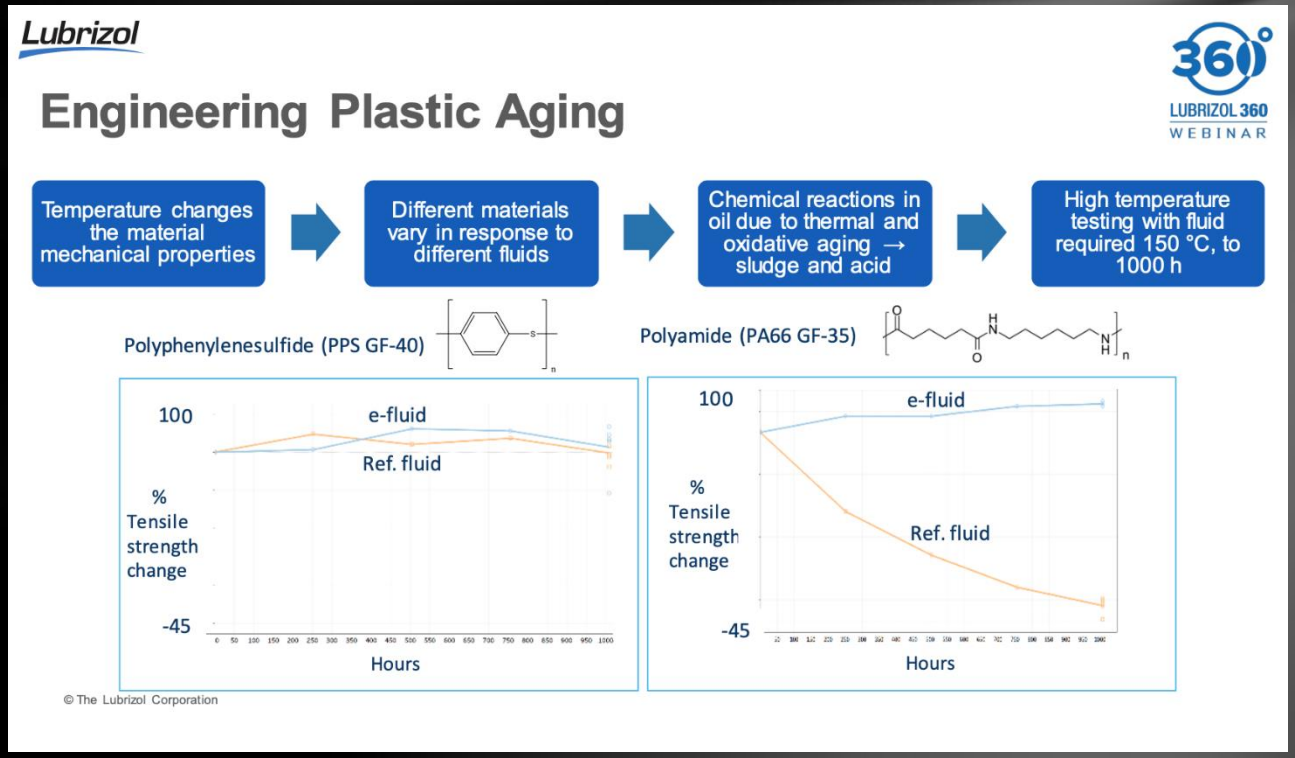


Dr. Michael P. Gahagan (Lubrizol)

Elastomer and engineering plastic compatibility

- Driving range is improved with lower vehicle weight
- Compatibility with new materials
  - High-performance thermoplastic-polyetheretherketone (PEEK) replaces metal bearing parts with thrust bearings to save weight
  - Polyphenylenesulfides & polyamides increasingly used to save weight

- Lightweight material must deliver mechanical and electrical performance for the life of the vehicle
- E-Lubricants should not alter tensile strength of the material over the life of the vehicle
- Compatibility with noise and friction reduction coatings needs consideration



Dr. Michael P. Gahagan (Lubrizol)

Fill for life

- Electric motor bearing greases 3 primary functions –
  - minimize friction and wear
  - seal the motor from contaminants
  - protect bearings against corrosion

- High dropping point needed for greases due to high temps in electric motor bearing operations
  - --> push for higher speeds and higher efficiency
  - Shear stability of urea greases gives them an advantage, likely will see more urea greases used in e-lubricants
  - Synthetics and PAOs used for longer life

Challenges for Lubricating EV's - Summary

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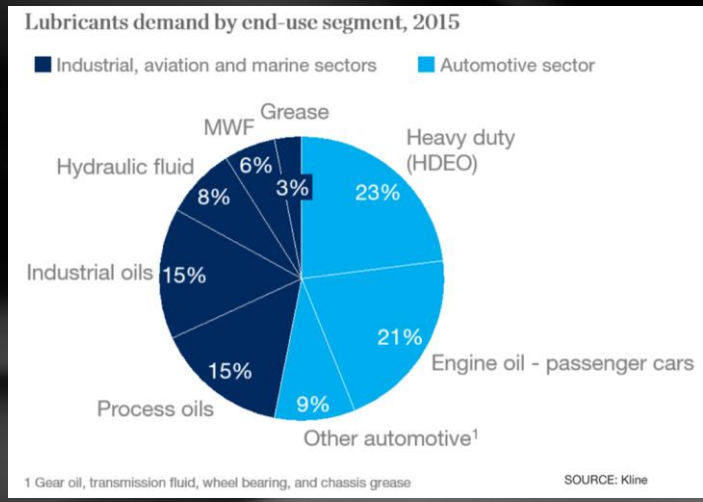
- Friction and noise , improvements to NVH
- Thermal capacity of the fluid and opportunities for hardware engineering advances
- Compatibility with copper influences
- Elastomer and new engineering plastics compatibility
- Fill for life capability
- Max gearbox torque at low speed

Effect on Base Oils, Lubricants and Lubricant Type

- 2030 is the tipping point
- Engine lubricant demand expected to plateau/decline beyond 2030, PCMO blenders may be in search of alternate ways to fill capacities
- Basic wheel bearing and chassis grease requirements remain unchanged with push for lower friction
- Electric motor grease demand will rise, and there will be more opportunities for longer-life synthetic greases designed for EV's. Grease manufacturers are fairly well-positioned for inception of EVs.



- Lubricant diet will change, requiring less use of Solvent Refined GP I Technology, more use of GP III's, PAOs and synthetic base stocks in EV gearbox applications
- Challenge will be to balance tomorrow's base oil demands with today's capacities → additional rationalization or upgrades of lower quality base stock refiners will eventually occur.
- Process oil and electrical transformer oil demands will continue to increase, boding well for naphthenic refiners
- DIY market will continue to deteriorate → consumer can only add windshield washer fluid a full BEV

Other Industry Challenges / Food for Thought

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- Changing consumer behavior due to autonomous vehicles / ride sharing / Waymo / car summoning and ownership sharing. 80% of autonomous vehicles in shared applications will be electric by 2040 due to lower operating costs
- Does Covid-19 have a long-term impact of accelerating autonomous driving?
- Infrastructure to support adequate charging & fast charging stations for growth of EVs
- Lithium replacements such as graphene that will revolutionize recharging time
- Disruption of oil supply
- Electrical grid developments to support increased demands from EVs
- disposal/recycling of lithium
- alternate technologies - fuels cell technology and fuel recycling
- What vehicle will today's teenagers want to purchase when they graduate from college? Do they even want a vehicle?
- The "Sheep Herding Effect"

https://www.google.com/search?biw=944&bih=932&tbm=isch&sa=1&ei=ZDZIXbufG4WAsQXIm7ClAQ&q=GIF+of+jetsons+in+a+car&oq=GIF+of+jetsons+in+a+car&gs_l=img.3...11014.11935..12047...0.0..0.67.418.7.....0....1..gws-wiz-img.sE8gb55pelA&ved=0ahUKEwi74diJmqPkAhUFQKwKHcgNDBEQ4dUDCAY&uact=5#imgrc=aTe_JZRjNeN2kM:&spf=1566914159948

QUESTIONS?

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  - Student
  - Individual
  - Corporate

How to Play….and win a Prize!!!

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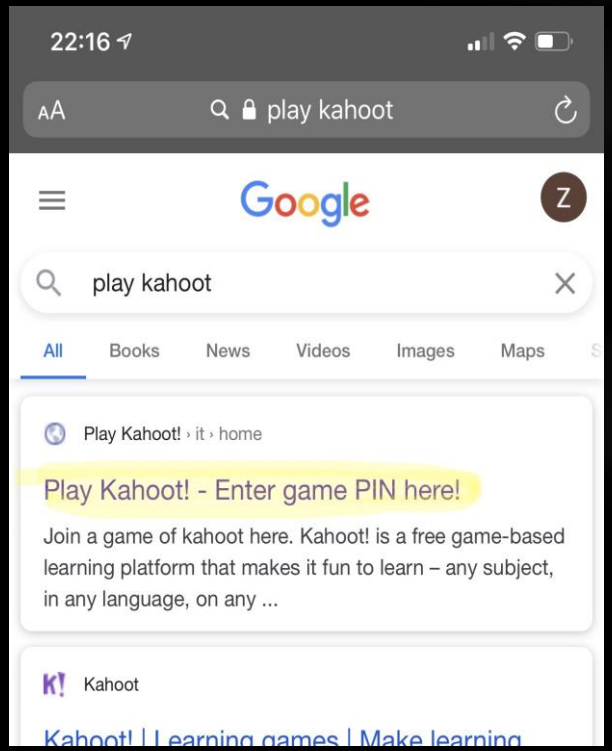
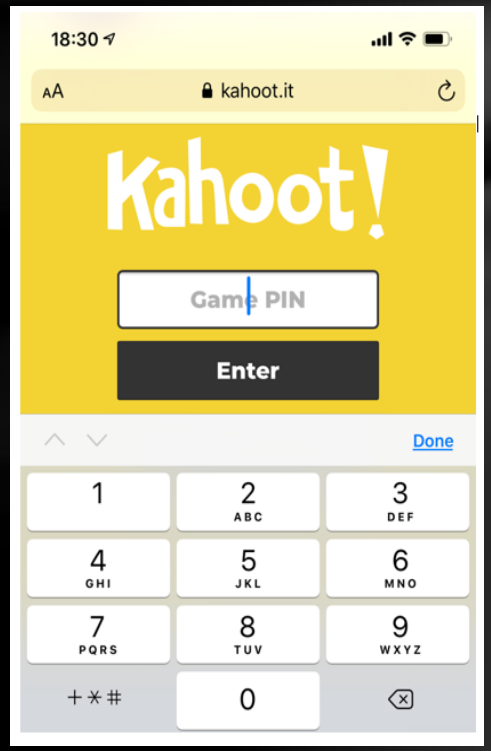
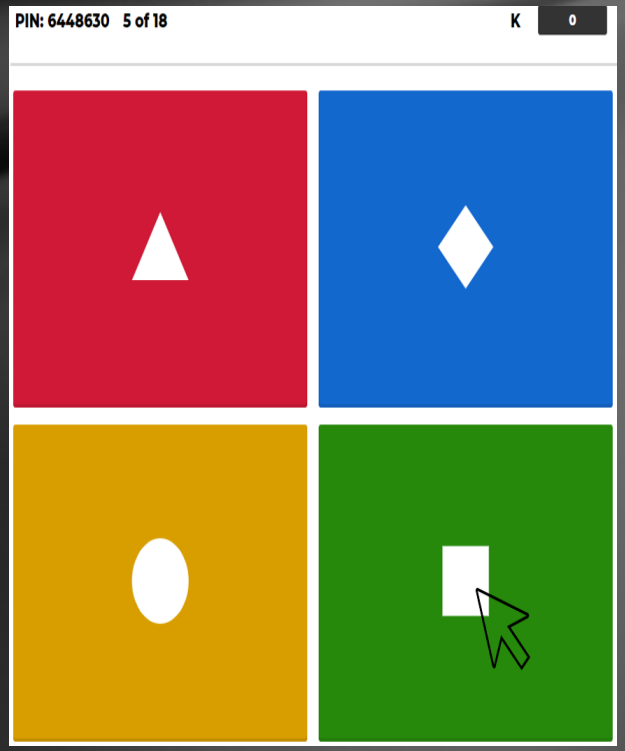
- From your device, search play Kahoot
- Enter the PIN provided, and your first and last name
- **You'll have 20 seconds, but enter your answer FIRST to win more points**







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- *Tulstar provides raw materials to manufacturers within the petrochemical, industrial and automotive lubricant industries, transformers and other niche chemical markets*

- *Privately held, established in 1986*

- *Custom-tailored solutions to meet our client's evolving demands*

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