Licensing Executive Society International
Automotive Industry Advisory Board
Vehicle Electrification
Summary of Session Held December 9, 2020

Background:

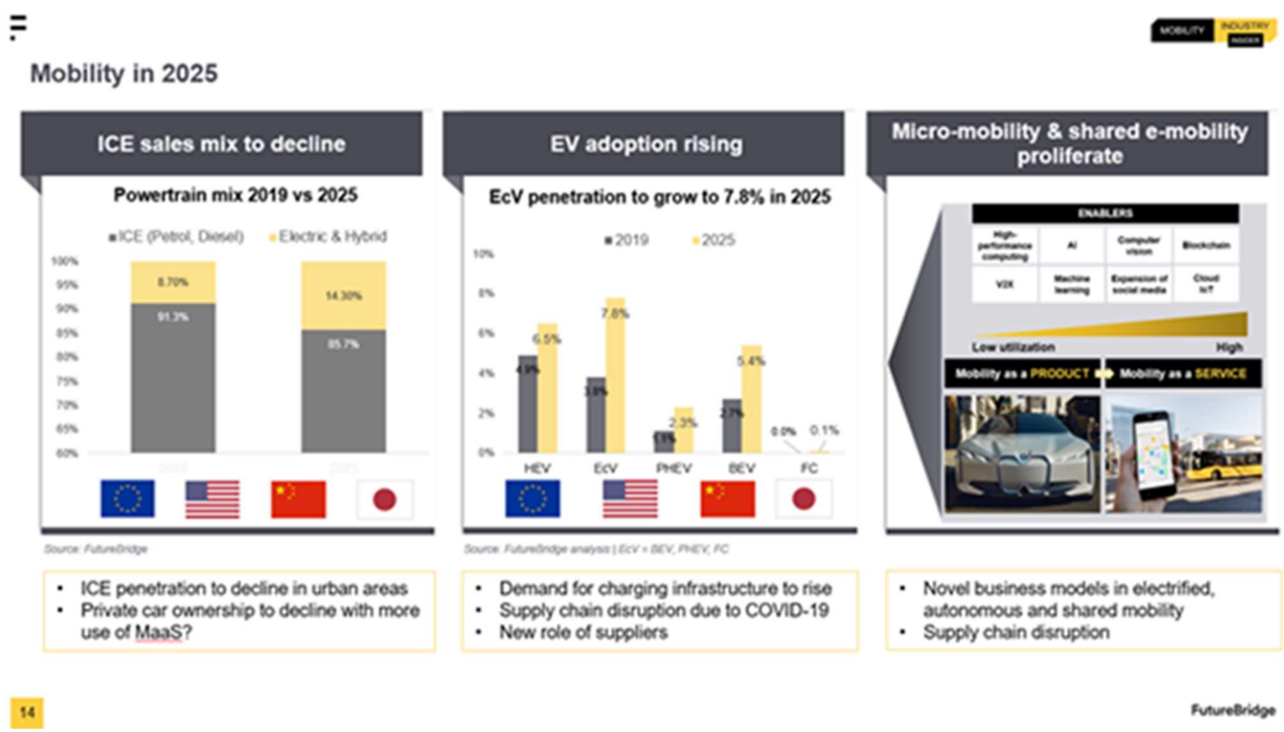
Since the early days of the automobile, electric vehicles have existed as a niche product. Off-road vehicles for applications such as golf carts and low speed vehicles that move materials have long relied on the safety and convenience of electric powered drive systems. The conversion to electric power for passenger vehicles has been a slow process. Battery powered electric vehicles (BEV) entered world car markets in the late 1990s, with GM's (EV1) and the Nissan Leaf vehicles. These vehicles demonstrated commercial viability of battery power for passenger cars and new vehicles using both fully electric and hybrid systems (using both electric drive and small traditional gasoline engines) gained a small, but growing foothold in world car markets. Toyota's Prius vehicle, equipped with a hybrid electric/internal combustion powertrain, became the global market leader for "green transportation". The Prius was introduced by Toyota in 1997 and remains the top model for hybrid vehicle sales worldwide, with over 4 million vehicles sold in 90 markets, during the 20 + year life.

Battery EV vehicles were slower to take significant share in major automotive markets. Early battery EV models struggled with limited range, safety issues and high prices, as the technology and cost of battery packs. Several major events changed the outlook for the BEV in the automotive world. The first was an interesting Chinese start up named BYD that with improvements to basic battery pack and an extended operating range. While GM stopped production of the EV1 in 1999, Nissan continued refinements to the Leaf model which remains in production today. The real breakthrough for many consumers for BEV awareness came with the introduction of the Tesla Model S in the US market. The Model S packaged improvements to battery and electric powertrain technology in a sleek design, that captured the attention of both investors and the vehicle buying public. Tesla, through the Model S, achieved market notoriety and offered consumers a sporty vehicle, with attractive styling that could be sold to environmentally conscious consumers or other early adopters of new technologies. Traditional vehicle OEMs viewed Tesla with scorn, as it grew and repeatedly predicted its demise. Tesla continued invest and growth the number and range of available models, market share as it captured and retained the attention of the investing community.

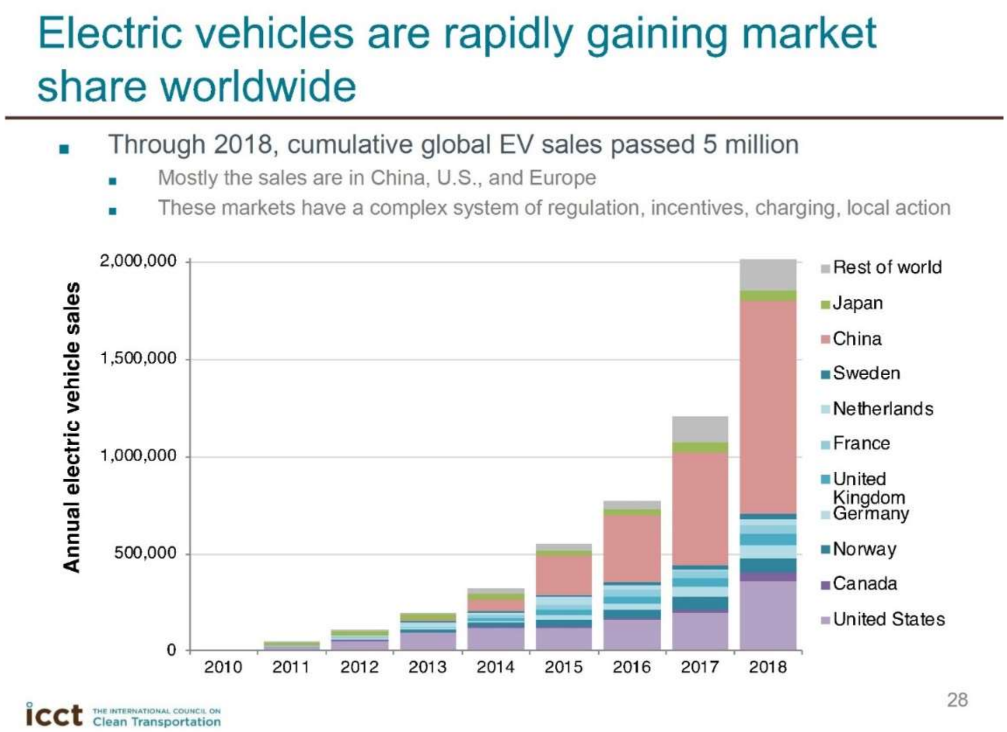
In China, government efforts to control some of the world's worst air pollution in major metropolitan areas, sought a solution through electric vehicles. China's plans for cleaner air came through replacing conventional gas vehicles with BEVs. A coordinated Chinese government effort resulted in increased BEV investment by existing and new vehicle OEMs and stimulated market demand for electric vehicles. Chinese poor air quality was compounded by the fact that China imports over 70% of its oil needs from sources outside China. The imported oil issue was aggravated for China by the fact that oil imports require payments “hard currency” (US Dollars). As China grew to become the world’s largest market for cars and trucks, paying for imported oil placed an ever-increasing demand on foreign currency reserves held by China. Chinese government pressure on vehicle OEMs in China included increasing vehicle fleet fuel economy standards for vehicle producers selling products in China. To achieve fuel efficiency standards, the Chinese vehicle producers responded by engineering and manufacturing dozens of new of BEV models, necessary to achieve fleet fuel economy standards and still allowing a profitable vehicle mix including gas powered SUVs and luxury vehicles. Fleet fuel standards set for the Chinese authorities increased to 47 mpg in 2020 and increase again to 56 mpg in 2025. The Chinese authorities also encouraged consumers to select BEV models through tax incentives, easy access to license plates essential for new vehicle registration and wide availability of charging stations in major metropolitan areas. Europe with a focus on green lifestyles also provide to be an active market for new BEV models from a growing number of local vehicle producers.

<u>LESI Focus BEV Growth and Innovation Remaining</u>.

At present, while gaining increasing share in major vehicle markets, BEV models remain more expensive than their internal combustion equivalents. LESI Auto IAB vehicle electrification discussions focused on the issues that remain in the BEV “lifetime use and cost equation” to allow for widespread adoption, what remains to be invented and how IP plays a role in this market transition.



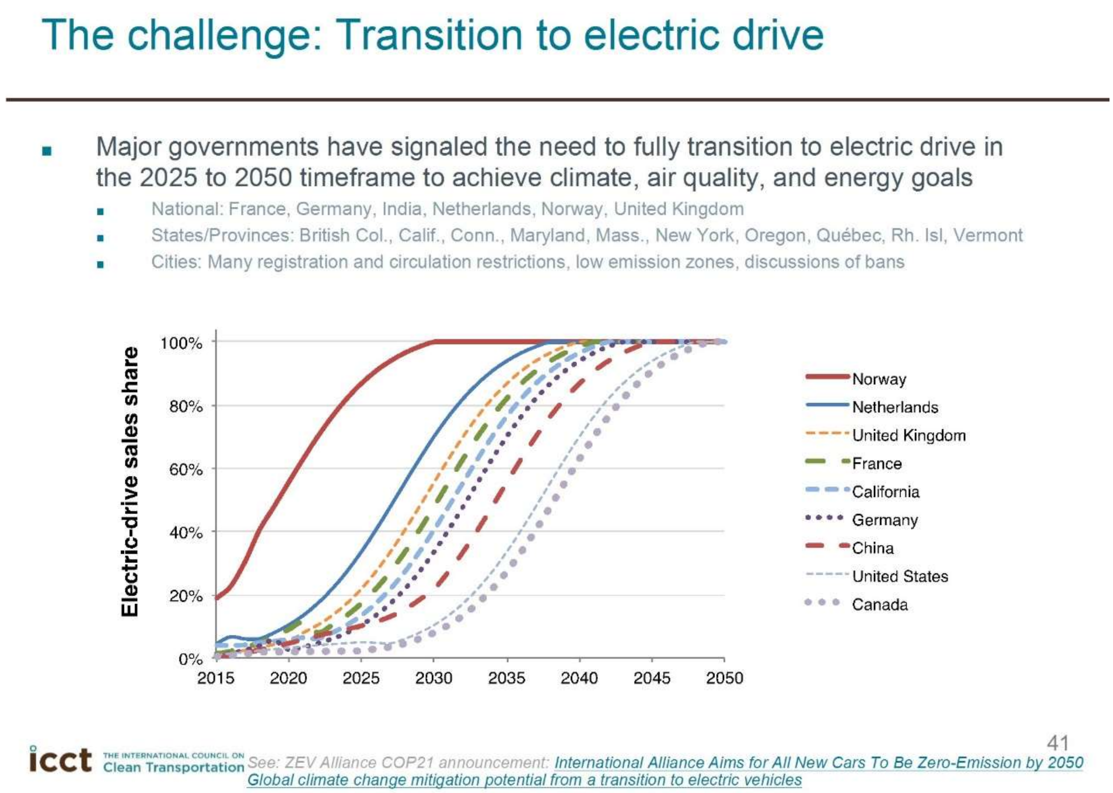
Given the growth of the use of electric vehicles in most major automotive markets, the question for the future of electric vehicles is what key enablers remain to make BEVs competitive in all market segments with their internal combustion counterparts. The opportunity for providers of vehicle and charging infrastructure will be largely focused on these new elements of the BEV ecosystem. The IP profession can support the process by understanding the BEV market changes under way and supporting new and existing suppliers in creating market solutions.



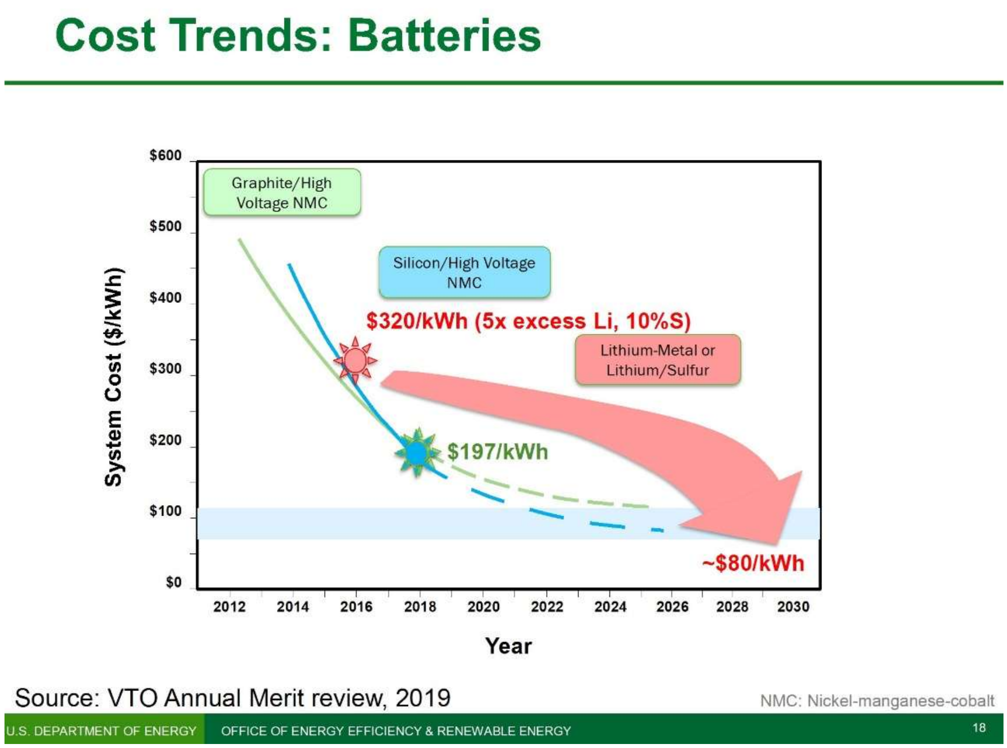
Key enablers for Widespread Adoption of BEV products in Key markets:

1. **Governments Policy and Incentives** - The major market for BEV sales today is the Peoples Republic of China. In China, the rapid development and adoption of the BEV by consumers was aided by an orchestrated effort on the part of the Chinese Central and local governments. Promoting BEVs became a Chinese government policy and vehicle producers also received strong financial incentives to develop and market BEV products ranging from electric busses, large trucks and consumer vehicles. Incentives for vehicle producers took the form of direct cash incentives for OEMS and avoiding penalties from missed fleet fuel economy performance. Consumers benefited directly from tax credits from the Chinese government. Consumers were also encouraged by more subtle persuasion in the form of easy, low-cost access to vehicle license plates for new BEV purchases in congested metropolitan areas in China. In large Chinese cities, access to license plates for new vehicle registration involves literally “winning the lottery” for access to a costly new plate. Vehicle buyers in China also benefited from local governments and employers to install charge stations where vehicle buyers work, shop and live. To encourage rapid BEV adoption outside China, national and local governments create incentives

for investment in BEV models by carmakers and also consumer to buy BEV products. The role of increasing fleet fuel economy standards is key to the long-term BEV planning, product design and investment required by vehicle producers.

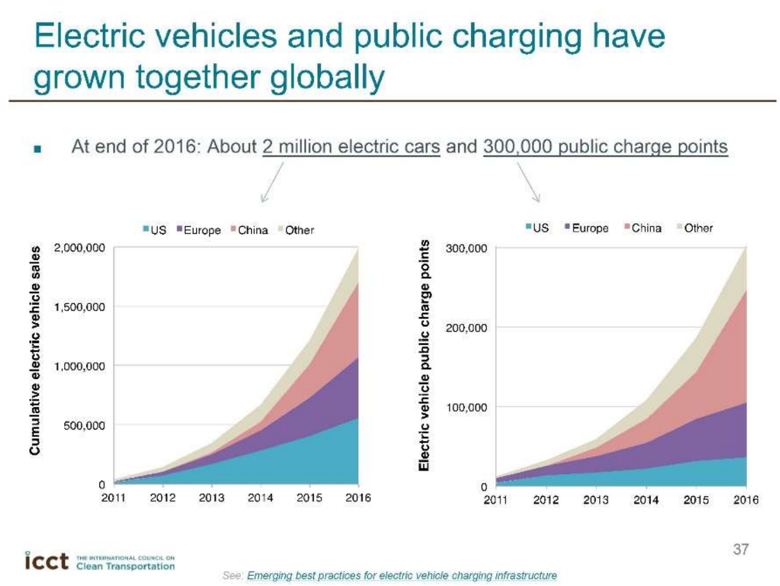


2. **Reducing the Cost of the Battery Pack** – Lithium-Ion battery systems are the overwhelming favorite technology of choice for BEV systems. Earlier hybrid vehicle leaders, like the Toyota Prius relied on a "tried and true" nickel metal hydride-based battery packs that were known for stability and long life, but lack the energy density required for competitive BEV models. Lithium polymer battery systems offered superior energy density allowing BEV models to offer operating ranges competitive with gas-powered vehicles. The cost of Lithium-ion battery packs has been reduced significantly since first introduced on Nissan Leaf in 2010. The power of the pack is measured in kWh and when the Leaf debuted in 2010, cost of the lithium packs exceeded of $300/kWh. Current reports from VW, who has announced a major commitment to EV technology, indicates Lithium-ion battery pack costs approaching $100 per kWh for next generation models. VW has made a major investment in Netscape, a Stanford University based startup featuring a solid-state Lithium Ion based battery. Below $100 per kWh, advanced battery packs begin to approach the cost of comparably powered ICE engines.



3. BEV Car Ownership – Reducing Consumer Anxieties

- **Range anxiety – A** 300 mile +/-, operating range on a single tank of gas, is the general benchmark for traditional ICE vehicles. A number of BEVs are approaching and surpassing this 300 mile range expectation. Tesla Model 3 was the 2020 world BEV market leader with 365,000 units sold worldwide. The current Tesla Model 3, 2020's market sales leader, advertises a 353 mile range. Other key BEV models from various makes worldwide are approaching this target as well.



- **Need for faster charging –** The time required to recharge an EV battery pack under normal use remains a consideration for EV purchasers. Time required to recharge depends on the overall capability of the charge system employed. Charging systems are commonly grouped into 3 levels based on input power and charging capability, including:

  - Level 1 – Residential charging systems utilizing input voltage around 120 volts (typical household plug) and charging at levels of 1.3 kW to 2.4 kW, requiring as much as 24 hours to full charge a heavily discharged BEV pack.
  - Level 2 **–** Residential and Commercial Charging – 208-240 volts input energy and charging at levels of 2.4 kW – 19 kW. Most level 2 charging systems can fully recharge deeply discharged battery packs for BEVs in 8 hours. Level 2 home charging systems are available in the US at prices in the mid - $300 range and up.
  - Level 3 **-** Direct Current Fast Charging (DCFC)– Input energy of 200 – 600 volts and up to 350 kW charge levels. These systems can recharge deeply discharged battery packs 80 charge in as little 20-40 minutes, with full charge capability in 60-90 minutes. The BEV industry is sponsoring development in fast charging systems and while no single standard for these systems prevails, CHeDMO, a global fast charging standards group based in Japan has promoted a series of standards for safe charging, standard charge plug interfaces and vehicle to charger communication protocols. Other similar fast charge systems from vehicle OEMs like Tesla and Porsche, as examples, are helping to make rapid charging a reality for major markets. Fast charging systems are limited by the ability of the vehicle to accept the incoming charge, in the higher output ranges. BEV models today are often restricted to a maximum incoming charge level of 50 kW, but new models from Tesla and Porsche are engineered to accept charging power levels exceeding 200 kW. One source indicates 15,000 DCFC stations are installed in the US today and that total continues to grow. Early indications are that battery pack capacity and operating lives may be reduced by frequent use of fast charge systems when compared to Level 2 systems as a primary charge method. (See appendix for further discussion)

- **Battery Pack "Swapping"** - China is introducing a novel solution for BEV quick power through battery pack "swapping" supported by several leading Chinese BEV producers. It is too early to tell in the market fight between fast charging vs. fast changing (battery pack "swapping") technology, who will win the popularity contest, but the competition has begun in the Chinese market. In China, super-fast charging stations available through Tesla (quick charge) and fast changing (battery pack swapping) stations available by through and BAIC are both available to BEV owners. The results, so far, are as follows:

  1. **For the user, "quick change" is generally preferred over "quick charge"**

In China domestic BEVs can use fast charging systems to achieve an 80% charge level, in about 30 minutes.   The Tesla V3 fast charge system is slightly faster, but the charging time is still slow, compared with fueling times for gas powered vehicles. Through October 5, 2020, Nio users had swapped battery packs more than 1 million times in China. This level of market activity proved that battery swapping can work in the Chinese BEV market. It also demonstrates that vehicle owners are willing to accept battery swapping, as a fast charge solution. The actual China experience, of about 3 minutes to change a battery pack, is about the same time as is required for gasoline refueling. This 3 minute “time to power” creates a very real advantage for battery swapping for Chinese BEV owners, over event the best fast charging systems.

2. When it comes to the cost, fast charging is better than fast changing

In June 2013, Elon Musk shared a video of Tesla's fully automatic battery swapping system. At that point, to many observers it appeared that Tesla might pursue a commercial battery swapping as a solution for fast charging needs. The Tesla plan appeared plagued by difficulties in the supply chain, high investment costs for changing station construction, and low margins on the actual service. Tesla eventually gave abandoned plans for battery swapping for its clients.

Nio’s offer of free battery pack swapping to their vehicle owners came after an extensive assessment of the program features and costs. Nio’s experience of the actual operation data statistics of free electricity exchange at present, on average, there will be 1000 users making use of the free battery pack exchange every day.   Many of the costs related to the Nio battery exchange program already were part of their cost structure. Actual experience of running the battery exchange program showed an increase to operating costs by $7000 per day.   Likely as the result of these additional costs, Nio decided to end the free electricity exchange service for new car owners, in October of 2020.

3. The China national standards for “fast swap” came later than “fast charge”.

Both technical solutions of fast charging and fast battery pack swapping have been supported by China government policies and standards. China Electric Power Enterprise Federation and CHAdeMO Association (Japan electric vehicle fast charger Association) jointly released the new fast charging standard CHAdeMo 3.0. Fast “swapping” remains behind fast charge from standard setting point of view.

- **Easy Access to Charge Stations –** Recharging vehicles away from home base remains a concern for many consumers. That anxiety has been reduced for many BEV owners in China and western markets by aggressive local governments and public utility investment in a network of level 2 charging stations. Smart phone-based charging applications make finding available charging locations relatively easy, aided by improved level 2 charging at home, helping to ensure that vehicles leave home with fully charged systems.

<u>Other Considerations:</u>

<u>How Truly Green are Electrified Vehicles?</u> – Total Impact of BEV Ownership on the Environment – A recent study by Argonne National Labs published in 2018 (The Impacts of Electrification of Light Duty Vehicles in the United States 2010 – 2017 – See Appendix), reached some interesting conclusions regarding the reduction in gasoline usage and related carbon reduction based on growing use of PEV/BEV vehicles in the US. The study developed estimates based on the cumulative PEV (plug in hybrid) and BEV usage in the US for the period of 2010 - 2017. This study also used relatively conservative assumptions, arguably some favorable to internal combustion vehicles and their carbon emissions in the vehicles replaced. The study concluded use of electrified vehicles (both PHEV/BEV) in the US in that in that 8 year period (2010 – 2017), reduced US gasoline consumption by 600 million gallons and net carbon emissions by 2.6 million metric tons. As with all estimates, the assumptions are subject to challenge, but as the grid becomes more reliant on more carbon efficient forms of power generation, coal usage converting to natural gas for a fuel source and wind and solar energy production continuing to increase, the favorable impact of electrified vehicle use continues to grow.

<u>Ongoing Technical Development</u>

Battery EV systems have made important progress towards as a market competitor for consumers. Work remains and ongoing technology development is required for wide adoption. In comparison to other internal combustion-based vehicle powertrains, BEV systems are still expensive and take too long to charge. Creating optimal BEV range will require that the added weight from battery packs and electric motors must be offset by weight reductions elsewhere in the vehicle. This creates significant opportunities for huge volumes of new light weight components based on aluminum, carbon fiber or anything else that be made to provide reliable functionality over life of the vehicle.

End of Life Recycling & Reuse – Battery Packs - The industry currently does not have a robust plan to recycle BEV battery packs at the end of vehicle life. The current designs from Tesla large numbers of individual cells that are individually encapsulated in metal cylinders that are “potted” or held in position in the battery pack with epoxy. The Tesla battery packs are designed for long life and durability, not recycling at the end of their service. Improving BEV cell and battery pack designs for recycling at the end of their service, requires additional effort and creates opportunities for new entrants with capable technology.

A potential bonus involving reuse of the automotive battery pack following its “on vehicle life” comes from work under way with the CHAdeMO group. Automotive battery packs are normally replaced when the recharge capacity reaches 80% of the original factory level charge capacity. At 80% capacity, the battery pack still has significant value as an energy storage device. Many applications, like home solar and wind power generation systems, could benefit from local storage of power generated, but not used immediately or sent to the power grid. Under the program now being evaluated by CHAdeMO, packs returned after on-vehicle use, could be repurposed as the original 62 kW battery pack reaches a maximum recharge capacity of about 50 kW (80%). 50 kW of stored energy could power most homes for several days, creating significant value to homeowners, when the sun does not shine, or the wind blow. The CHAdeMO plan considers working with solar and wind systems providers to “re-purpose” these battery systems for a secondary life as residential power storage system. This re-use creates new economic value that potentially offsets the cost of the battery pack in automotive use. This use scenario might offer the opportunity for the vehicle OEM to retain ownership of the battery pack at the point of consumer sale and benefit from proceeds from reuse. This would effectively reduce to cost recovered from the vehicle owner by recognizing the economic value of the “second life” for the battery pack in home storage or other applications.

Creating a Smart Grid Sufficient to Handle Increasing BEV Fleets - The electrical grid and charging infrastructure will require significant improvements as the fleet becomes more electrified. The improvements for efficient smart grid, aimed at supporting electric vehicles will create opportunities for firms in most western markets.

“Greening the Grid” - For BEVs to be truly green, the grid itself must change and rely less and less on fossil fuel electrical energy generation. The challenge remaining is creating a smart grid that offers power when required, 24 hours a day, 365 days a year, that is not reliant on fossil fuels. Wind, solar, nuclear, geothermal, hydroelectric, fuel cells, all are sources of electric power and do not generate carbon through combustion of fossil fuels. Significant work remains in developing smart electrical grids capable taking power from various sources, including the new energy variety and flawlessly delivering power on demand to billions of users worldwide. The hardware and software controls required for this seamless execution remain to be developed and implemented including storage systems enabling power on demand even when wind and sunshine are absent.

IP Protection

Vehicle OEMs have made certain IP available at low or no charge to facilitate adoption of electrified powertrains in cars and light trucks. Toyota offer for free use of hybrid car patents through 2030 and Tesla, “applying our open-source philosophy to patents” are examples of these activities:

[Toyota opens up 24,000 hybrid car patents to other automakers - The Verge]

[https://www.tesla.com/blog/all-our-patent-are-belong-you]

CHAdeMO

Fast Charging Consortiums life CHAdeMO encourage members to provide patented features providing safety and interoperability to key charge systems. The philosophy from CHAdeMO is that safety and interoperability and the building blocks for a global system that can aid in this essential BEV need. As a supplier of equipment, grid side chargers and on vehicle systems, sharing IP relating to safety and interoperability is fundamental to creating this market and therefore in the mutual best interest of the industry. CHAdeMO believes that other features not related to safety and interoperability, that are protected by proprietary IP, are more than sufficient to create sufficient competitive advantage for hardware suppliers. As of November 2020, CHAdeMo reports over 1 million BEV, PHEV vehicles are equipped to receive fast charging services from CHAdeMO compatible chargers. Their website is clear that CHAdeMo will not require licenses or royalty payments for access to their standards (https://www.chademo.com/beware-there-is-no-licensing-fee-or-royalty-payment-for-chademo/)

SAE INTERNATIONAL

The Society of Automotive Engineers (SAE) operates in the US and other countries, under a similar philosophy for access to IP relating to safety and vehicle interoperability. Patent holders for technologies are expected to abide by SAE policy relating to proprietary technology contained in the Technical Standards Board Governance Policy 15th Revision – October 2017. The relevant section reads as follows:

1.13.3 Patents

It has been traditionally the position of SAE to avoid the use of patented technology in Technical Reports where the principal objective is conformance to the Technical Report as defined by the SAE Technical Standards Board. However, with the advent of more complex technologies, it is not always possible to provide Technical Reports that meet today's needs without incorporating technologies that are patented. It has become difficult, if not impossible, to develop standards that do not take advantage of or otherwise incorporate the use of products, systems or process that implementation would necessarily infringe a claim of such a patent. Accordingly, SAE Technical Reports may include the known use of patent(s), including patent applications, if there is in the opinion of the committee developing the Technical Report technical justification and provided that SAE receive assurance from the patent holder that it will license applicants under reasonable terms and conditions for the purpose of implementing the standard. This assurance shall be provided without coercion and prior to the approval of the standard or reaffirmation when a patent becomes known after the initial approval of the standard. This assurance shall be a letter that is in the form of either:

A general disclaimer to the effect that the patentee will not enforce any of its present or future patent(s) whose claims would be necessarily infringed by implementation of the proposed SAE Technical Report against any person or entity implementing the mandatory provisions of the Technical Report to effect compliance or;

A statement that a license will be made available to all applicants without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination.

Concluding Thoughts

Large global vehicle producers, like GM and VW have made a huge commitment to BEV powertrains as the future technology of choice for cars, SUVs and light trucks. GM's chair Mary Barra committed to an "all-electric" vehicle line up by 2035. In related statements, GM announced that "We're committed to putting every driver in an electric vehicle on a scale previously unseen and bringing the world to an all-electric future". VW made a similar commitment. Thomas Ulbrich, VW's head of electric vehicles, summarized the VW situation in the FT Future of the Car Summit in London in 2019. "Our decisions are done. Our planning is in progress. We will have the ID.3 here in the middle of next year. There will be 70 new fully electric VWs by 2028; an investment of €30 billion in e-mobility by 2023; 22 million EV sales for the VW Group by 2028".

These decisions by key makers of traditional vehicle makers, will obsolete considerable investment in traditional gasoline engine manufacturing facilities worldwide. This represents a major direction change with huge investments required to develop and tool dozens of new vehicle platforms. It is not a decision not made lightly, by these conservative producers.

Given the growth of the use of electric vehicles sales worldwide and program now underway, BEVs are positioned to be a strong player in the future of automotive transportation. Making BEVs competitive in all market segments with their internal combustion counterparts will take time, new technology and investment. Significant opportunity for providers of vehicle, automotive systems and charging infrastructure will come from these new elements of the BEV ecosystem. The IP profession can support the process by understanding the change in motion and supporting new and existing suppliers in creating market solutions. New and potentially disruptive technologies will continue to come from universities, start-ups and as we have seen with new players like Tesla, Nio and other, coming from competitors that were in most cases, completely unknown, a decade ago. This should provide ample opportunity for market-based deals involving the IP generated and licensed by our profession.

Additional Materials and Reference Reading

1. **Charging Configurations and Suppliers**

SAE International — **SAE Charging Configurations and Ratings Terminology**

AC level 1 (SAE J1772™)	PEV includes on-board charger	*DC Level 1	EVSE includes an off-board charger
	120V, 1.4 kW @ 12 amp 120V, 1.9 kW @ 16 amp		200-450 V DC, up to 36 kW (80 A)
	Est. charge time:		Est. charge time (20 kW off-board charger):
	PHEV: 7hrs (SOC* - 0% to full)		PHEV: 22 min. (SOC* - 0% to 80%)
	BEV: 17hrs (SOC – 20% to full)		BEV: 1.2 hrs. (SOC – 20% to 100%)
AC level 2 (SAE J1772™)	PEV includes on-board charger (see below for different types)	*DC Level 2	EVSE includes an off-board charger
	240 V, up to 19.2 kW (80 A)		200-450 V DC, up to 90 kW (200 A)
	Est. charge time for 3.3 kW on-board charger		Est. charge time (45 kW off-board charger):
	PEV: 3 hrs (SOC* - 0% to full)		PHEV: 10 min. (SOC* - 0% to 80%)
	BEV: 7 hrs (SOC – 20% to full)		BEV: 20 min. (SOC – 20% to 80%)
	Est. charge time for 7 kW on-board charger		
	PEV: 1.5 hrs (SOC* - 0% to full)	*DC Level 3 (TBD)	EVSE includes an off-board charger
	BEV: 3.5 hrs (SOC – 20% to full)		200-600V DC (proposed) up to 240 kW (400 A)
	Est. charge time for 20 kW on-board charger		Est. charge time (45 kW off-board charger):
	PEV: 22 min. (SOC* - 0% to full)		BEV (only): <10 min. (SOC* - 0% to 80%)
	BEV: 1.2 hrs (SOC – 20% to full)		
*AC Level 3 (TBD)	> 20 kW, single phase and 3 phase		

*Not finalized
Voltages are nominal configuration voltages, not coupler ratings
Rated Power is at nominal configuration operating voltage and coupler rated current
Ideal charge times assume 90% efficient chargers, 150W to 12V loads and no balancing of Traction Battery Pack

Notes:
1) BEV (25 kWh usable pack size) charging always starts at 20% SOC, faster than a 1C rate (total capacity charged in one hour) will also stop at 80% SOC instead of 100%
2) PHEV can start from 0% SOC since the hybrid mode is available.

Developed by the SAE Hybrid Committee *ver. 031611*

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2. **One view of available vehicle charging systems - https://procarreviews.com/best-ev-charger/**
3. **Charge Locations – finding an open charge location - Typical Consumer Applicationhttps://chargehub.com/en/charging-stations-map.html**
4. **CHAdeMo (Example of Fast Charging Technical Consortium) - . https://www.chademo.com/**
5. **Argonne National Laboratory – "The Impacts of Electrification of Light Duty Vehicles in the United States 2010 – 2017" – Published January 2018 - https://publications.anl.gov/anlpubs/2018/01/141595.pdf**
6. **Charge times for major EV producers -**- https://www.carexpert.com.au/car-news/how-fast-can-my-electric-car-charge
7. **Impact of Rapid Charing on Battery Life**
   - DC Fast Charge Effects on Battery Life and Performance Study - 50,000 Mile Update (energy.gov)
   - Scientists find fast charging destroys electric vehicle batteries (thenextweb.com)