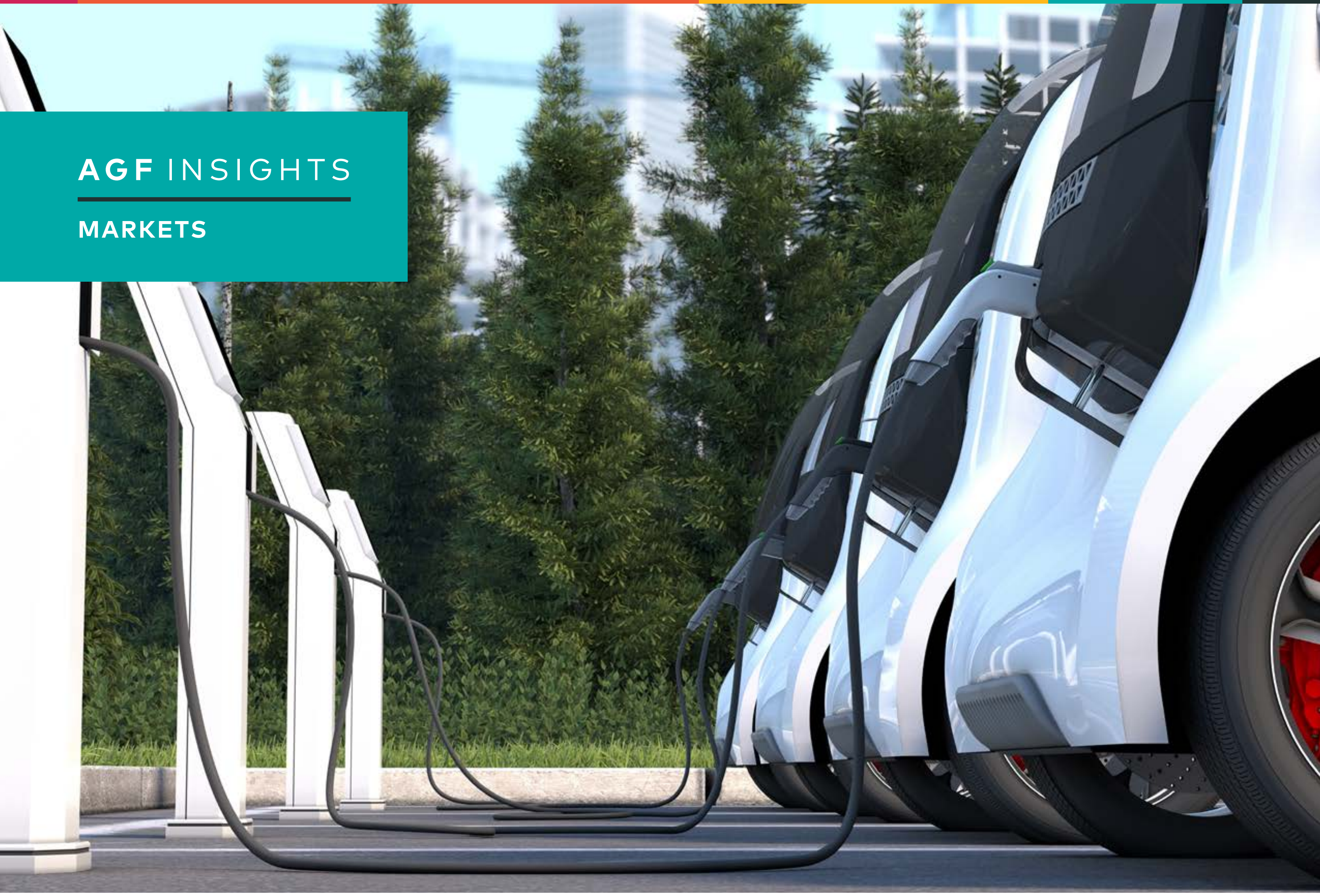
AGF INSIGHTS

MARKETS



Electric Vehicles and Autonomous Transportation

A unique confluence of factors, including regulatory pressure, technological innovation and consumer interest, is helping disrupt the global automaking industry and create new sustainable investment opportunities across its value chain.

The Opportunity

It's been five years since the Paris Climate Conference resulted in nearly 200 countries agreeing to limit the rise in global warming to at least 2 degrees Celsius from pre-industrial temperature levels, but it's only now that investors are beginning to fully appreciate the sheer ambition of the goal and what it will take to achieve by the 2050 target date. In fact, successfully curbing Earth's average temperature continues to hang in the balance, according to the United Nations[1]. By its estimates, greenhouse gas emissions still need to be cut by approximately 11 gigatonnes of equivalent carbon dioxide (GtCO2e) by 2030 to have a 66% probability of reaching the 2 degrees Celsius target. In other words, the world's current total carbon footprint needs to be reduced by about 21% in the next 10 years just to have a fighting chance at hitting the ultimate mark set for 29 years from today.

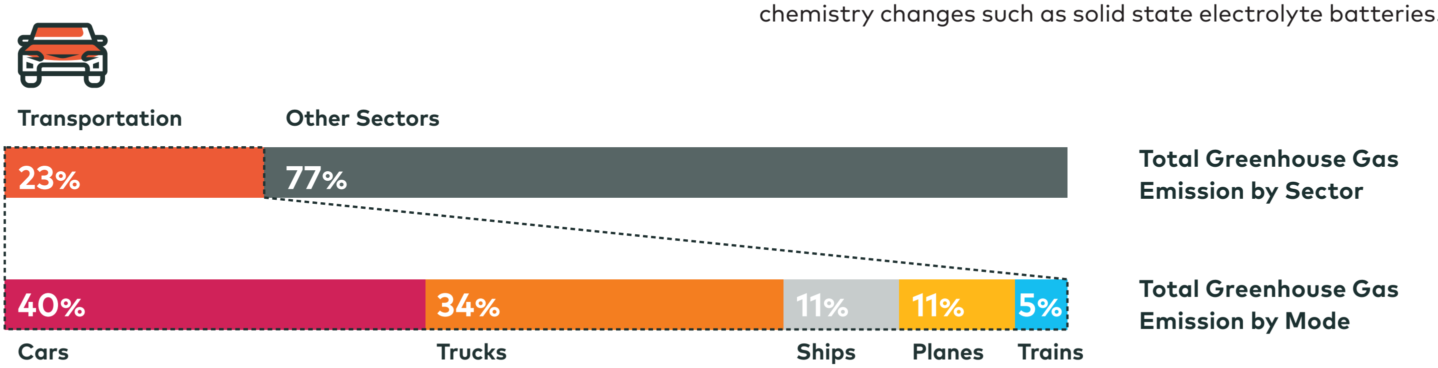
Given the backdrop, mitigating the risk of climate change is now a crucial imperative of almost all industries that make up the global economy and one that should help define investment opportunities going forward. This is particularly true of the transportation sector, which is responsible for roughly 23% of all anthropogenic emissions (i.e. pollutants from human activity) globally[2], but is still only in the early stages of transitioning its energy use away from fossil fuel combustion towards electricity. In 2019, for example, 83 million new passenger vehicles were sold globally but only 2.1 million were pure and/or plug-in hybrid electric vehicles (xEV), representing a penetration rate of roughly 2.5%[3].

While that figure has steadily increased in recent years, the overall share of xEVs will need to increase dramatically if global auto manufacturers are expected to do their part in reducing global emissions in line with the 2050 Paris Agreement commitments. More specifically, the International Energy Agency (IEA) estimates that between 25 and 46 million xEVs (or a penetration rate of close to 30% or more based on 2019 sales) would have to be sold globally by 2030 to help hit the sustainable development target. And slightly short of that, AGF research based on country specific targets and original equipment manufacturers (OEMs) expectations, suggests xEV sales should total ~22 million by 2030 and contribute roughly 25% of global passenger sales.

Whatever the case may end up being, the key to increasing penetration rates to these levels will likely come down to three factors: cost, convenience (i.e. fast and ubiquitous charging), and continued government support:

Cost

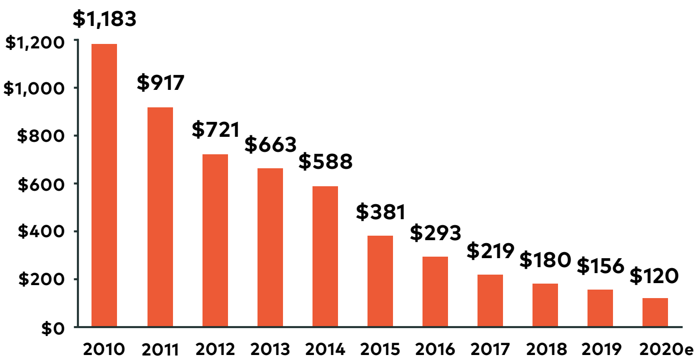
The largest cost component in an EV is the battery pack (predominantly lithium chemistry), which has seen material declines over the last decade from an average of US$1,200 per kilowatt hour (kwh) in 2010 to US$120/kwh in 2020. This reduction of almost 90% has been derived from better economies of scale and improved energy density and industry experts estimate further declines to the range of US$100/kwh will lead to cost parity with the internal combustion engine (ICE) over the next three to five years. In part, this will be achieved through continued scale advantages, but also because of greater deployment of nanotechnology for anode materials, improved battery management systems and, eventually, revolutionary chemistry changes such as solid state electrolyte batteries.



Source: Bloomberg New Energy Finance, as of December 2019[4]

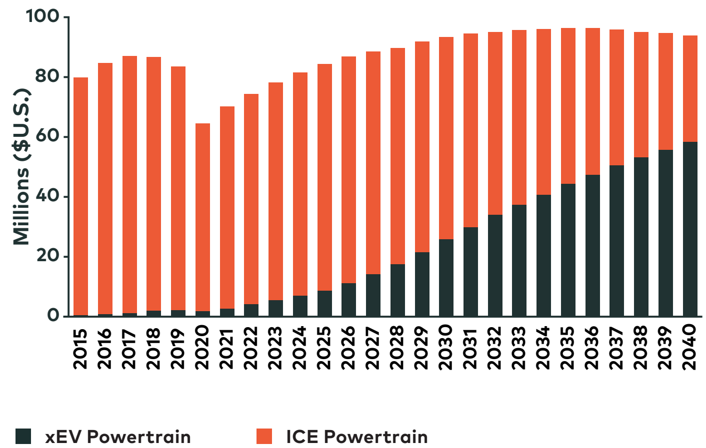
[1] United Nations Environment Programme (UNEP), 2020.
[2,4] Bloomberg New Energy Finance (BNEF), 2019.
[3] Bloomberg New Energy Finance (BNEF), 2020.

Historical EV Battery Pack Price ($US/kWh)



Source: BNEF, as of December 2020

Electrified Passenger Vehicle Sales Forecast



Source: BNEF, as of December 2020

Convenience

Advances in technology remain critical to manufacturing faster-charging EVs, but continued public/private investment in charging stations and other related infrastructure is equally important. Silicon carbide materials, for instance, are viewed as crucial in facilitating fast charging (the gold standard being an 80% charge in 20 minutes) as is the migration to 800 volts architecture that is already available on the Porsche Taycan. The current stock of fast-charging stations, meanwhile, typically work with approximately 400 volts and charging powers maximizing at 100 kilowatts. As a result, it typically takes 40 minutes to charge for 400 kilometers of EV driving, however the shift to 800 volts promises to reduce that by about 15 minutes.

Government Support

Government commitments to net-zero carbon emissions targets are reliant in large part on broad adoption of xEVs. To date, policies range from limits on the number of ICE powertrain vehicles that OEMs can sell to outright future bans in jurisdictions including the United Kingdom, California and Quebec. In addition, some governments have instituted significant financial penalties on auto OEMs for fleets that exceed CO2 targets and can be expected to continue offering purchase incentives, direct subsidies or tax rebates to consumers who choose to purchase electric vehicles. These incentives often range from US$4,500 to US$7,500 and are aimed at reducing the upfront cost burden on the purchase of xEVs.

Analyzing the Value Chain

Materials

To meet the anticipated demand, global xEV battery manufacturing capacity will need to grow at least 8 times from 77 gigawatt hours (GWh) to more than 440 GWh over the next half decade. Significant capacity growth in speciality materials (i.e. lithium, cobalt, graphite) and traditional metals (i.e. copper, nickel, aluminum) will be required to meet this demand. Many companies in the mining sector have some exposure to these materials, however, the most concentrated exposure can be found in major lithium producers such as Albemarle Corporation., Livent Corp., and Sociedad Quimica y Minera de Chile SA.

In addition, new materials are required to facilitate some of the technological innovation required for xEV penetration. For instance, one of the best potential opportunities is related to the use of silicon carbide (SiC) wafers instead of silicon for xEV power electronics. This can improve voltage handling by 10 times[5] and SiC Metal Oxide Semiconductor Field Effect Transistors (MOSFET) can operate at junction temperatures of up to 150 degrees Celsius[6], allowing for faster charging and improved miles per charge through raw efficiency savings and reduced weight.

[5,6] Wolfspeed, 2019.

Suppliers

Global xEV demand is expected to drive tremendous growth in the battery industry and increase capacity by as much as eight times over the next decade, according to even the most conservative estimates. This will result in significant growth opportunities for both specialty chemicals and battery manufacturers.

Of the former, there will likely be an uptick in demand for cathode, anode, electrolyte and separator manufacturing companies. In particular, there is currently high demand for three types of cathode chemistries: Lithium Nickel Manganese Cobalt (NCM); Lithium Nickel Cobalt Aluminum (NCA); and Lithium Iron Phosphate (LFP). While these variants already come with existing trade offs in terms of energy density, safety, longevity and material costs, changes in battery chemistry are more than likely over the coming decades and will continue to impact the investment case of specialty chemicals going forward.

There are a number of innovative companies across the spectrum of global battery makers. Companies like Samsung SDI Co Ltd., LG Chem Ltd., Contemporary Amperex Technology Co Ltd and Panasonic Corp., which are responsible for the assembly of battery components and work with automakers on battery cell design, including the cylindrical, prismatic and pouch constructions that are dominant today. Battery supply contracts can often range from battery cells only to full battery packs that typically contain cells arranged into modules, as well as a cooling system and battery management system. Cell makers have scaled up in recent years with giga factories located closer to their EV-OEMs and remain actively involved in research & development of new chemistries, innovative packaging, and cooling techniques.

Other non-battery components of electrified powertrains will also be impacted by the demand for xEVs. These components include current inverters, electric motors, battery management systems, reducers, on-board chargers and DC/DC converters. While some xEV auto OEMs have chosen to make these components in-house, others have completely outsourced to component suppliers and it's expected that more OEMs will gradually follow suit as outsourced manufacturing increases scale. In addition, many of these non-battery components should increase demand for semiconductor components like silicon carbide MOSFETs and insulated-gate bipolar transistor (IGBT) devices, sensors, and microcontrollers.

ESG and the EV Supply Chain

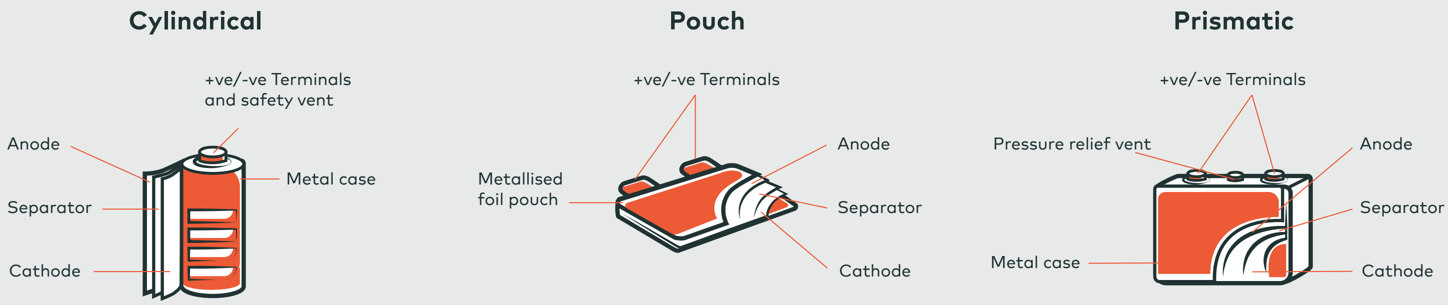
In terms of environmental, social and governance (ESG) factors, one of the biggest challenges is the highly extractive and energy intensive nature of mining specialty materials and traditional metals and the potential negative impact that can have on the environment and on local communities. For instance, more than 60-70% of the world's cobalt supply originates in the Democratic Republic of the Congo with an estimated 18-30% of this production coming from non-industrial suppliers (i.e. artisanal miners), which are synonymous with family operations[7]. The lack of government oversight in this segment of the supply chain is a significant risk for the entire battery supply chain.

Another key ESG concern surrounds the issue of battery materials recycling. When xEVs reach end-of-life after roughly 10 to 12 years, the most sustainable option is to close the loop by recycling the main components, especially battery materials. With very few xEVs currently reaching end-of-life coupled with low battery metal prices, the economics of recycling battery materials is poor. Most of the recycling currently done within the ecosystem is done to recycle manufacturing waste. To promote battery recycling, the European Commission recently announced its Sustainable Battery Regulation which aims to ensure that batteries placed in the market have some recycled content in them and a suggestion for the creation of battery databases for end-of-life management.

Lastly, governance remains a key ESG issue. The auto industry, in particular, is only now emerging from the 'diesel-gate' scandal and the well documented but perhaps overlooked governance concerns at Tesla. In addition, labour challenges are ubiquitous in the industry.

[7] OECD, 2019.

Battery Cell Construction and Design



Source: Johnson Matthey & Alliance Bernstein.

Producers

We have seen the emergence of pure-play electric vehicle OEM's, but traditional auto manufacturers are also pivoting from ICE programs to partial and full EVs. OEM's around the world have announced cessation of ICE investment and made various commitments to becoming full electric manufacturers over time. In turn, greater competition among OEMs should be expected going forward as technology leadership becomes more fleeting and performance expectations standardize over time.

Autonomous Transportation

Future growth of the xEV market will largely depend on the transition away from vehicles powered by internal combustion engines, but will also likely hinge on the further development of autonomous transportation. While electrification and driverless vehicles are not necessarily synonymous by definition, the link between the two will become increasingly inevitable as the latter innovation continues to advance and reaches its full potential. In turn, this relationship is poised to provide its own set of unique investment opportunities above and beyond those already discussed.

Six Levels of Vehicle Autonomy

Driverless vehicles can be classified into six different levels starting from zero (i.e. no automation) and ending at five (full automation).

0	**No automation.** The driver completely always controls the vehicle.
1	**Driver assistance.** The vehicle may control steering or speed under some conditions, with the driver doing everything else, and continually monitoring the car.
2	**Partial automation.** The vehicle may control steering and speed under some conditions, with the driver doing everything else, and continually monitoring the car.
3	**Conditional automation.** The driver can fully cede control of all safety-critical functions in certain conditions, but the driver must continually monitor operations and the car must sense when conditions require the driver to retake control.
4	**High automation.** The vehicle performs all safety-critical functions for the entire trip, with the driver not expected to control the vehicle at any time. Only certain conditions are allowed (e.g. highway-only, gated community-only; clear weather only, etc.) Not legal.
5	**Full automation.** Level 4, but with constraints on driving conditions removed. In theory, door to door completely human-unattended operations.

Source: Sanford C. Bernstein & Co., 2016.

As of now, only vehicles with level one and two capabilities are available to consumers. In both cases, human drivers are still required to operate the vehicle, however, advanced driver assistance systems (ADAS) that incorporate radar sensors and cameras help augment certain functions such as steering, braking and/or acceleration. In advanced level two systems, for instance, drivers can take their hands off the steering wheel for extended periods of time as long as certain conditions are met.

From this point, the next big leap will be the introduction of vehicles to the market that have level three and/or four autonomy. This, of course, still requires regulatory approval from various jurisdictions around the world, but short of that, some auto OEMs have already started testing out systems that will allow human drivers to cede control of all safety-critical functions in certain conditions. In doing so, vehicles of the near future will be equipped with an increasingly complex set of sensors and computer processors that will allow them to sense their environment, process the information gathered and then make intelligent driving decisions that are independent of human intervention.

Importantly for investors, this ongoing evolution of autonomous driving is helping establish incremental opportunities along the xEV value chain, including those related to a vehicle's electrical & electronics architecture and sensor suite technology.

On that front, the electrical architecture system effectively encompasses the data storage, compute stacks and other software needed to enable autonomous capabilities, while also encapsulating the vehicle connectivity technology that may be required via cellular, 5G, or dedicated short-range communication. An autonomous vehicle's hardware sensor suite, meanwhile, typically consists of vision (cameras), RADAR (Radio Detection & Ranging), LIDAR (Light Detection & Ranging), ultrasonic, infrared, and GPS units.

Notably, suppliers of these two value chain components largely include traditional major auto OEM suppliers such as Denso Corp., Continental AG, and Magna International Inc., some of whom are currently in the test and pre-production phases of development. Moreover, tech software companies will play an important role in supplying the software and algorithms required for autonomous systems. While a few auto OEMs see benefits in developing software and operating systems in-house, others have outsourced to focus on core functions.

Lastly, the sensing and computing requirements of autonomous driving requires chips and semiconductors, including components made by companies such as Amphenol Corp., and NXP Semiconductors NV.

Conclusion

We believe Electric Vehicle and Autonomous Transportation companies represent a remarkable opportunity to invest in a multi-decade transition in one of the broadest and most well represented supply chains in the global economy. A confluence of factors including regulatory pressure, technological innovation and consumer interest are all driving this opportunity, however, in our view broad market indexes have yet to reflect the dramatic changes to come.

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