Q4 2021

rho motion magazine

The pathway to a sustainable energy transition

In this issue:

- EV market update
- Battery technology development
- Localisation of battery supply chains
- Charging infrastructure

Introduction to the magazine

Adam Panayi
Managing Director, Rho Motion

Hello and welcome to the Q4 2021 edition of the Rho Motion Magazine. The purpose of the magazine is to draw attention to issues that we feel are important to the progress of the energy transition, with a focus on EV, ESS, charging and battery technology developments. This draws on our ongoing research and analysis from our regular data and publications, as well as our bespoke consulting work. A focus for this issue is around how the energy transition can be sustainable as it continues to pick up pace; and can new technologies, and supply chain development meet the challenges of rapid growth and change? I would also like to thank Nano One, ePropelled, OneD and Electra Battery Materials Corporation for their fantastic contributions to this issue of the magazine.

I hope you enjoy the magazine,
Adam

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After exponential growth in 2021, can the EV market continue at this pace in 2022?

Adam Panayi
Managing Director, Rho Motion

As we approach the end of 2021 it seems reasonable to take account of what has passed in this year, and what is on the horizon for 2022. In this article, we'll examine the drivers of the rapid growth in EV sales in 2021 and ask whether they are likely to remain in place next year. We will also examine the key risk factors for the market in 2022 and beyond.

For all vehicle classes, year-to-date BEV and PHEV sales Q3 2021 have surpassed 4 million units, which already far exceeds the full-year number for 2020, at roughly 3.2 million units. We now expect final year sales to exceed 6 million units across all vehicle classes. In terms of where this growth has come from and why, over half of this sales growth has been in China, while a third has been seen in the EU & EFTA & UK, so we will focus our attention on these two markets.

Starting with China, the market has grown by 177% on a ytd basis until the end of the third quarter, despite the fact the subsidies were cut by 20% going into 2021. This is because the EV market in the country already functions largely like a mature sector, with significant consumer choice at multiple price levels. This year consumers have had a choice of over 220 BEV and PHEV models, starting at roughly USD5,000 for the bestselling GM-Wuling Mini.

In Europe, legislation has been the key factor behind market growth in one way or another. The increased number of models on the market, 177 BEV and PHEV in 2021, has largely been driven by OEMs need to get as close as possible to fleet average emissions of 95 grams per KM CO_2 (which we will deal with in more detail shortly). This increased choice has boosted public perception and acceptance of BEVs and PHEVs. Pandemic subsidies have still been a factor this year as well, although not at the levels seen in 2020, as we discussed in the last issue of the magazine.

In both China and Europe it is also important to remember that lockdowns supressed sales in the first half of 2020, which inflated the perception of growth in 2021, and the absolute of vehicle sales for this year has not been completely unforeseeable. For instance, in our pre-pandemic forecast in Q1 2020, we forecasted 6 million BEV and PHEV sales.

Looking at 2022, we forecast sales of 8.5 million vehicles globally for BEV and PHEV, while this shows a declining growth rate, this is from a higher base, and of course represents nearly 2.5 million extra vehicle sales in unit terms, which is significant. We remain bullish on China, despite a further 30% decrease in the subsidy going into the new year, which we believe will have minimal impact over the year despite an assumption of pre-buying in December, as the market continues to mature in terms of both the variety and quality of vehicles available.

In Europe, there is still work for OEMs to do in terms of the detail of the CO_2 emissions standards with super credits being further eroded in 2022. In 2020, only the 95% least emitting vehicles sold by OEMs were counted, with low emitting vehicles (under 50 grams CO_2 per Km) counting for 2 within an OEM fleet average. In 2021 and for all subsequent years, all vehicles are counted, and the rate of credit for lower-emitting vehicles is being scaled back in 2022 and 2023. The other important point here is that while significant improvements have been made by OEMs in reducing their fleet average emissions, and therefore fines, most OEMs will not meet their targets. As a result, many choose to pool their emissions with other, low-emitting OEMs, as seen by the recent announcement from JLR, Honda and Tesla. How long OEMs will be prepared to pay their competitors for use of their credits remains to

Chart: Global PC & LDV EV sales by quarter

Source: Rho Motion

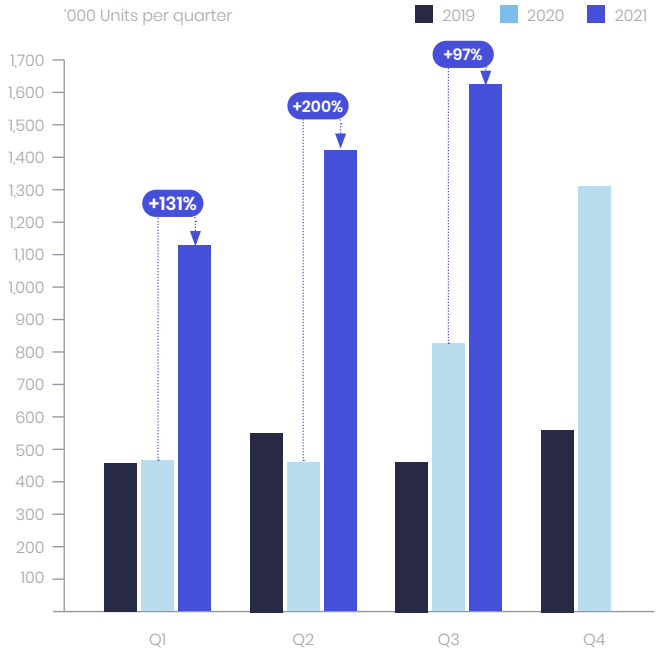


Chart: Global PC & LDV EV sales YTD, Q3 21

Source: Rho Motion

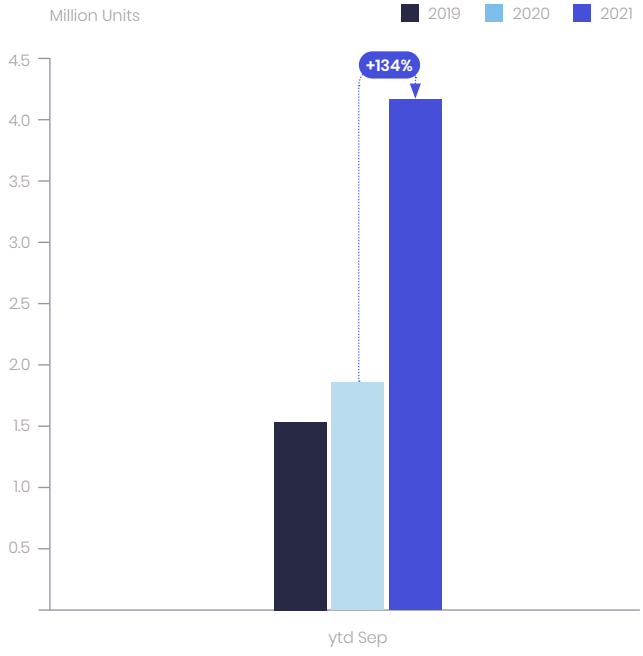
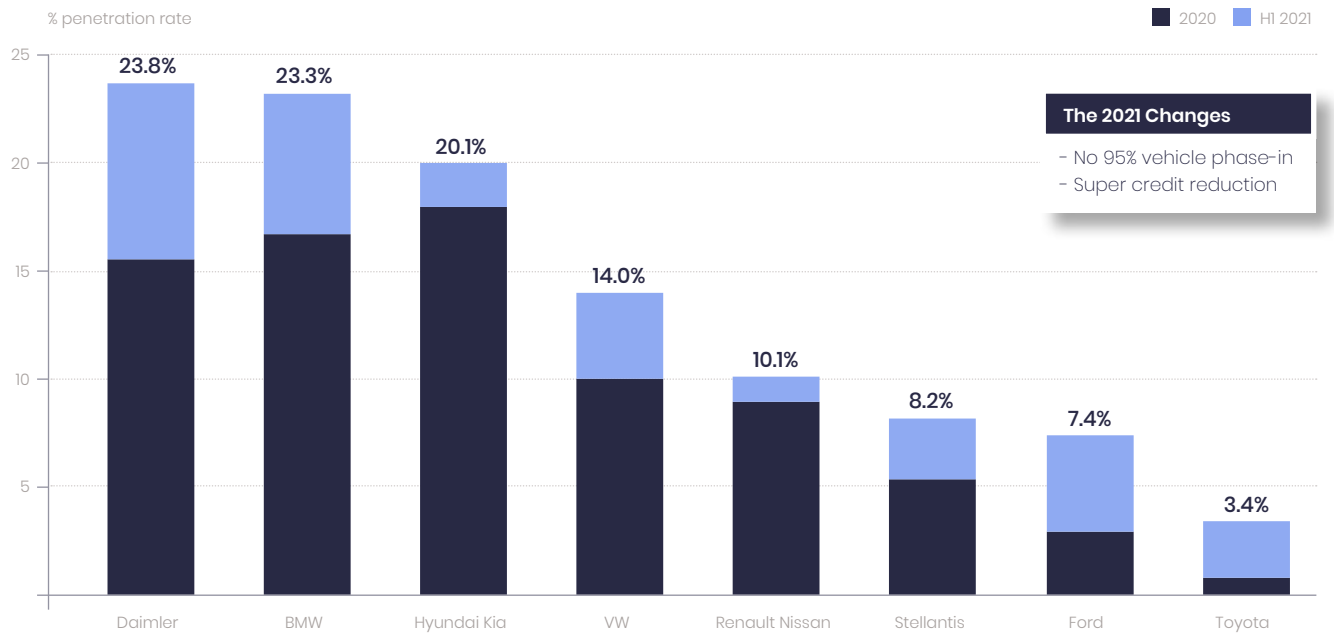


Chart: EU & EFTA & UK PC & LDV OEM BEV & PHEV Penetration Rate H1 2021 vs 2020

Source: Rho Motion



be seen but must be a motivating factor to reduce overall emissions, by virtue of selling more HEVs, PHEVs and BEVs. In 2022, the US market will start to pick up pace in terms of units sold. This comes in part from the increased support that the Biden administration will be providing once its proposals pass through the legislature. As we mentioned after the election, removing the cap on volumes for tax credits would be an obvious measure to take, and this seems to be one that will have a big impact on the market next year and beyond. Perhaps more importantly traditional OEMs in the region are already taking concrete action to electrify their model offering and ensure battery capacity build out with key partners. As a result, there are key model launches next year, not least the Ford F150 Lightning, the BEV version of the bestselling pickup truck. GM, Stellantis and of course Tesla and Rivian are all increasing EV capacity in the coming years and we expect that the North American consumer will respond positively to the increased variety of choice, improved quality, and relatively competitive pricing.

So, what about the downside? Well, as ever, the risks remain on the supply side. This is not just limited to battery raw materials and cell supply, where rising prices are being felt at the cell level and the burden of which will likely be shared to some extent by both the OEM and the consumer. The semiconductor shortage continues to cause production outages worldwide, and while EVs have largely been insulated from this, it remains a threat if the situation persists.

There is also the rather prosaic, but still important, potential for a significant magnesium shortage. The alloy is a key material for use in aluminium frames, which are used in EVs to lightweight the vehicle and offset increased battery weight versus ICE vehicles. This is largely a function of electricity shortages in China, which could be exacerbated by the Beijing Winter Olympics.

Finally, when scaling a new product line there is always the potential for issues to arise, and anything that extends already long order times for EVs can be potentially harmful to market development. These issues are, of course, all potential symptoms of a rapidly growing market, for a technology that consumers have come to desire.

Super Credit Incentive System	2020	2021	2022	2023
Vehicles with emissions less than 50g/km are counted multiple times for the calculation of the average specific emissions of a manufacturer	2 vehicles	1.67 vehicles	1.33 vehicles	1 vehicles

Source: Rho Motion

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EV & Battery

Our EV & Battery market analysis is based on bottom-up model-by-model analysis, combined with industry leading insights into the future direction of the sector

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EV & Battery Quarterly Outlook

Rho Motion is an industry leader in EV market analysis. Our forecast provides long-term outlooks for EV penetration, battery pack size and chemistry by vehicle class, based on robust and informed methodologies.

EV Battery Chemistry Monthly Assessment

The assessment provides monthly sales weighted average of battery pack sizes and battery demand by chemistry market share for the EV industry across vehicle classes.

EV & Battery Monthly Database

Our core EV & Battery database, tracking sales, vehicle and battery development on a by-model basis

EV Motors Monthly Assessment

The assessment provides monthly weighted averages of motor technology demand across vehicle classes, detailing the power and quantity deployed regionally and by vehicle segment.

Hybrid EV & Battery Quarterly Outlook

Our Global HEV forecast provides a long-term outlook for HEV penetration, battery pack size and chemistry by vehicle class. Alongside our EV & Battery Quarterly Outlook it sits as an essential tool for tracking the total vehicle markets battery demand.

Our EV and Battery market analysis is delivered in flexible, dynamic formats that can be customised for the user.

Find out more, contact us +44 (0) 203 960 9986, info@ rhomotion.com

Battery hype: Pressure is mounting for new technologies

Photo: Manuel Chinchilla

Ulderico Ulissi
Battery Research Lead, Rho Motion

The IEA estimates that clean energy and efficiency investments will exceed $700 billion in 2021, with China leading in spending. This figure is set to increase dramatically during the next couple of years. Most countries are setting ambitious targets to reach net-zero carbon dioxide emissions by 2050-2070.

At the same time, we emerge from a pandemic showing the fragility of supply chains, as chip shortages and raw materials price hikes are set to cause multi-billion losses. These facts lead to increased pressure for all actors involved in the field of clean energy. Onshoring of production is becoming increasingly relevant. With environmental, social and corporate governance risks being concrete, investors are seeing an opportunity with green innovation and are looking for new ventures. Moreover, we might have net-zero targets today, but we still do not have a clear path towards achieving them. We know that, as a society, we need to

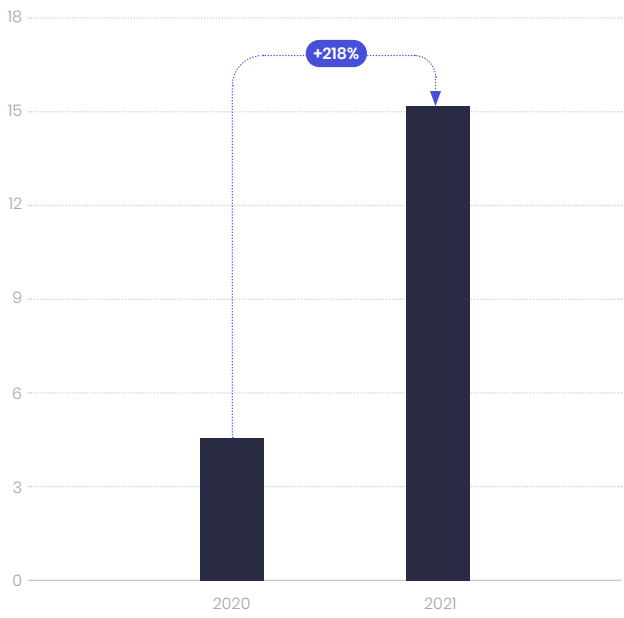
focus on energy efficiency. Undoubtedly, electrochemical energy storage will keep playing a pivotal role in enabling the electrification of several sectors. Therefore, investors are betting large sums of money, with companies in this field raising capital via, e.g., Special Purpose Acquisition Companies (SPAC) mergers – a shortcut to more traditional Initial Public Offerings (IPOs). Between 2020 and 2021, we saw a year-on-year increase of over 218%, with companies in the field of EVs and electrochemical energy storage raising over 15 billion USD in 2021. Companies and start-ups have been promising to deliver next-generation technologies in five years, setting themselves with very challenging technical targets considering the complexity of manufacturing EVs and energy storage devices. This is bringing a lot of attention to the field, an industry that is not new to hype.

Battery Hype is not new to the market

Safe to say, back at the end of the 18th century, little could Alessandro Volta imagine how ubiquitous and hyped his invention would be while sandwiching wet cardboard between Zinc and Silver to assemble the first electrochemical battery. However, fast-forward by ninety years, and Thomas Edison publicly denounces the problems caused by overselling in a famous interview to the New York Sunday Herald (The Electrician, February 1883). Talking about energy storage, Edison thought there would be no hope of doing legitimate work in that field. He stated, "Just as soon as a man gets working on the secondary battery, it brings out his latent capacity for lying". This statement was fuelled by his rightful concern that an increasing number of people, swindled by illegitimate actors, were losing confidence in electric lighting. Despite Edison having most probably changed his mind about batteries (as evidenced by his works on the nickel-iron batteries and electric vehicles), many in our community still share a similar feeling – and are still concerned that people might lose confidence in electrification. Fast-forward to 2020, and Prof. Stan Whittingham, Noble Laureate for the invention of lithium-ion batteries, reminds us to "stop the hype" (Chem. Rev. 2020, 120, 14, 6328–6330). Edison identified one of the root causes behind this hype – this is a field that appeals to the imagination of individuals, the ideal playing field for stock swindlers.

Commercialising technologies such as batteries or electric vehicles is complex and expensive, which plays in favour of those with short-term financial goals in mind.

Chart: EV, Battery and ESS SPAC Mergers, USD Billions



Source: Rho Motion

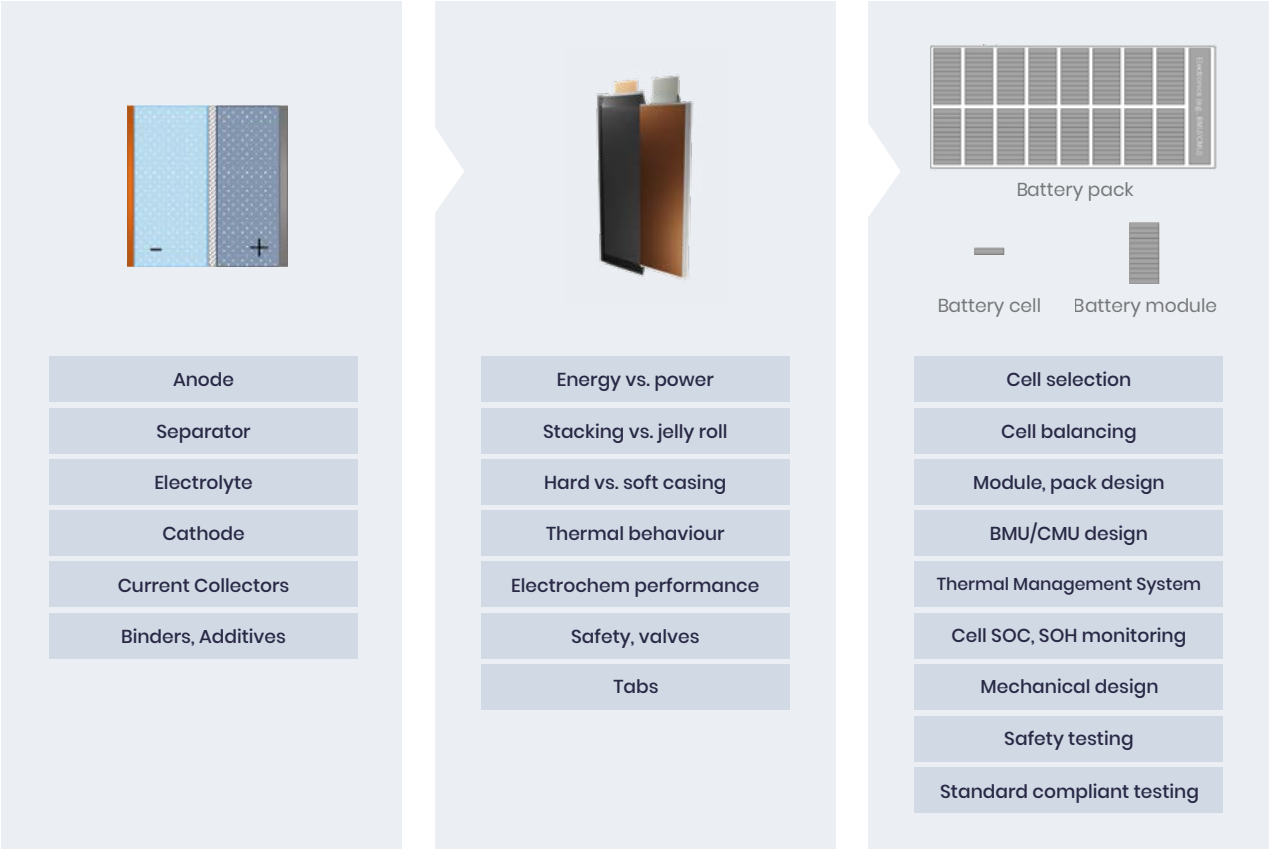
Battery manufacturing requires professionals with a varied skill set, including several branches of chemistry (e.g., electrochemistry, inorganic, organic, polymer, computational), engineering (e.g., software, electrochemical, electrical, mechanical, chemical), knowledge of precision, and high-quality manufacturing. Companies like CATL state that a battery R&D centre looking at the development of next-generation cell/pack technologies (i.e., 21C Lab) can have an initial cost of over 450 million USD and, in time, will require thousands of experts. Setting up a Gigafactory is even more expensive and involves capital expenditures in the 1-5 billion USD range. Considering these figures, it shouldn't be a surprise why this field is plagued by overhyping and overselling. It is not uncommon to read presumptuous press releases stating that the next battery breakthrough will be commercialised within five years. Unfortunately, designing an energy storage system for application in a car is a complex endeavour, which usually takes longer than that.

Avoiding costly mistakes

It is probably fools' gold if these promises are based on testing a battery cell that is the size of a coin (µAh or mAh), very far from commercial standard, or if only headlines are presented when an idea is pitched. Innovation in battery science often starts in academia, which usually lacks the resources and knowledge to scale up the new findings. In the West, technology is often transferred to

Chart: Considerations when designing a battery cell, module, pack

Source: Rho Motion



the market through a spin-out/start-up company. Capital on these ventures is spent assuming that only a few will succeed, and most will fail. One of the problems is that while there are some notable exceptions (e.g., Tesla, Inc.), many of these small ventures have been raising capital for over ten years without a product. Others lead to disastrous failures, with resources (monetary and nonmonetary) being wasted. Nikola Corp. could be the latest to join the club, with the company founder currently charged with securities fraud. Some of the more discussed include Envia system (GM), SEEO (Bosch), Sakti3 (Dyson). These might have one thing in common: technical experts' opinion was most probably ignored by management and stakeholders who authorised these deals (ATZ worldwide, 120, 122-125). What we should recognise is that a "miracle battery" is unlikely to exist, considering that it took more than 30 years for the lithium-ion technology to get where it is today in terms of cost and performance. Fundamental knowledge is still in the hands of a few players, primarily located in Asian countries. These companies are not only investing a considerable amount of resources in R&D but also have effectively developed manufacturing to a very high standard, which is notably the most expensive and complex part of getting technology to the market.

Possible solutions

Possible solutions have been proposed to avoid these costly mistakes:

- Get more technical people into management or have them act as advisors whose opinion is taken seriously.
- Scrutinise results more carefully and introduce either internal or independent third-party technical validation for new technologies.
- Develop standardised testing and data reporting (e.g., USABC, ISO 12405).
- Assess technologies critically, considering resources needed to successfully get to market and be wary of those who do not release any data.

From our side, we will be contributing by reporting the latest technologies and hot topics in energy storage, critically dissecting public results using knowledge matured from years of experience in the value chain, knowing criticalities of the academic, start-up and corporate world. Our bespoke consulting work has helped would-be investors look at next-gen technologies and learn more about due diligence and market lending. Watch this space.

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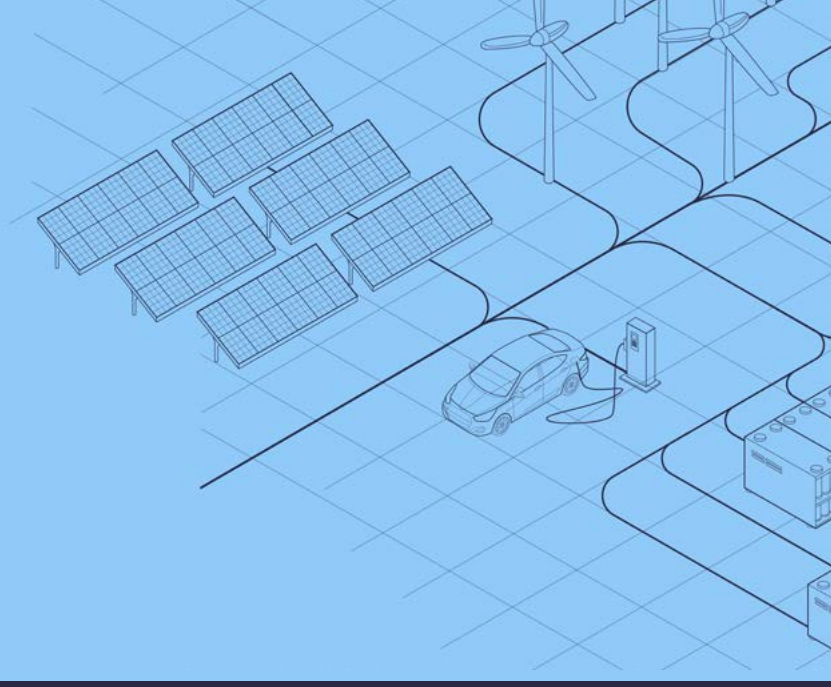
Battery Demand Service



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The Battery Demand Service combines all our battery outlooks and assessments in one place.

	Pro	Plus	Premium
Battery Demand Service: Outlook Excel file • Updated in line with outlook report releases	✓	✓	✓
EV & Battery Quarterly Outlook PDF and Excel File • Quarterly releases	✓	✓	✓
HEV Outlook PDF and Excel File • Quarterly releases	✓	✓	✓
Battery Energy Stationary Storage Outlook PDF and Excel File • Quarterly releases	✓	✓	✓
Fuel Cell Electric Vehicle Outlook PDF and Excel File • Annual releases	✓	✓	✓
Electric 2&3 Wheeler Outlook PDF and Excel File • Annual releases	✓	✓	✓
Electric Micro Mobility Outlook PDF and Excel File • Annual releases	✓	✓	✓
Monthly EV Battery Chemistry Assessment PDF and Excel File • Monthly releases		✓	✓
Monthly Battery ESS Assessment PDF and Excel File • Monthly releases		✓	✓
Monthly EV & Battery Database Excel File • Monthly releases			✓

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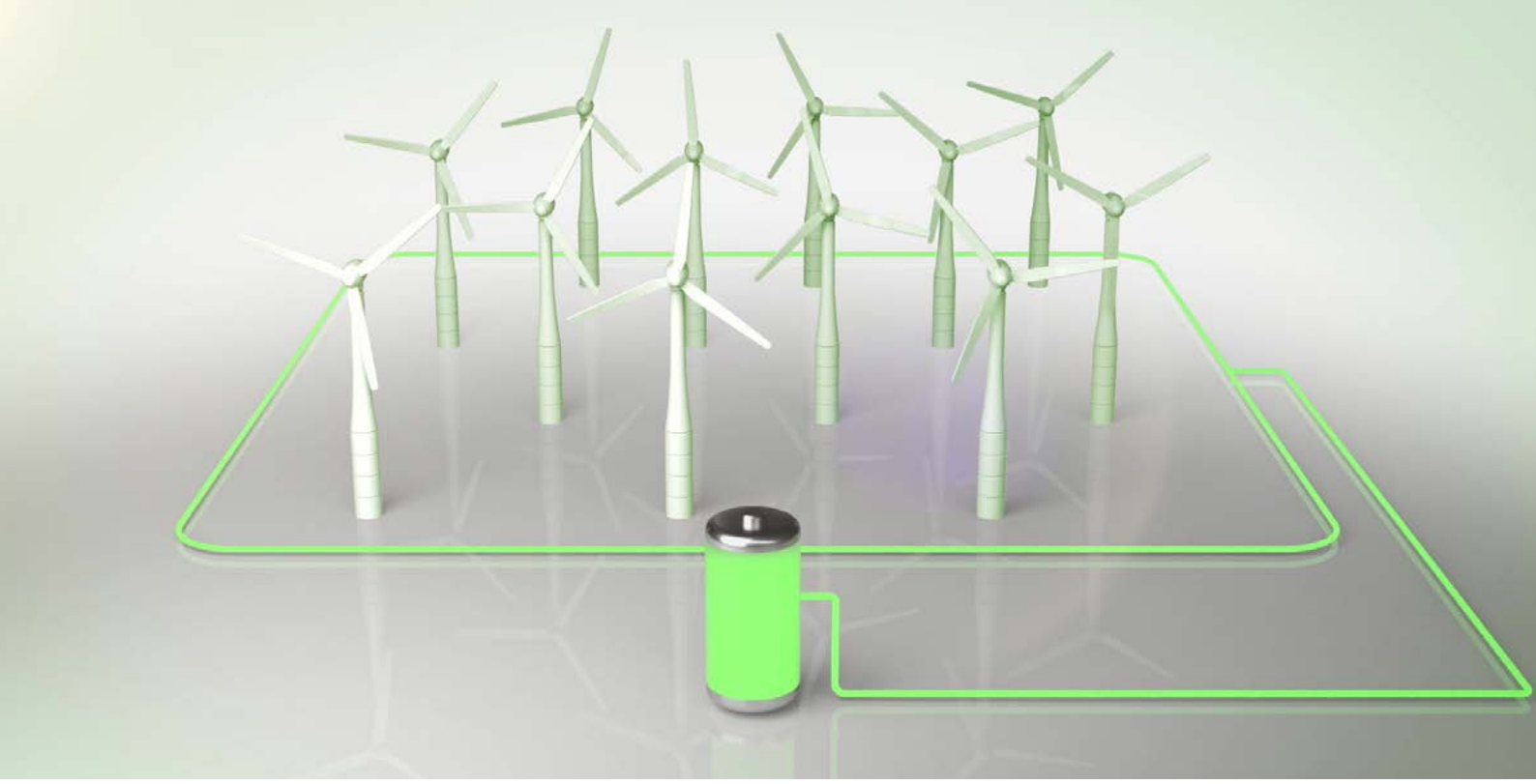


We must leapfrog the battery supply chain

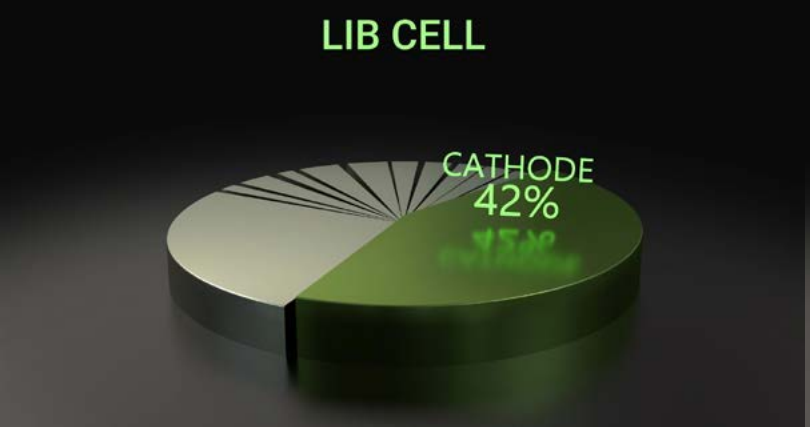
Dan Blondal
CEO, Nano One

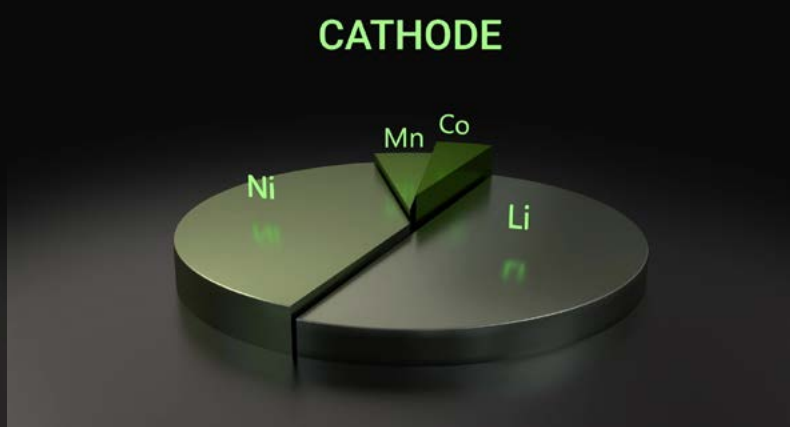
The net-zero transition is underway and accelerating at a rapid pace. The world's largest companies are retooling and re-inventing to electrify their products. Governments and financiers are fueling the transformation with legislation and support, including unprecedented levels of funding.

At the core of this revolution are lithium-ion batteries, commercialized 30 years ago to power cameras, a veritable cornucopia of consumer electronic devices, and an extraordinary shift to electric vehicles (EVs) and renewable energy storage.

As EVs and the energy transition gain momentum, battery metals markets are booming and straining a supply chain that is dominated by Asia and one that is deeply entrenched and burdened with cost, complexity, and environmental waste. Automotive scale production will amplify the demand and the vulnerabilities; and regrettably, the waste and costs will continue to pile up. In short, we must change how battery materials are made.

The lithium-ion battery supply chain is ripe for disruption, particularly in North America and Europe, where late adoption offers a once-in-a-generation chance to





innovate and leapfrog the early pioneers who are invested in older technology and beholden to the very infrastructure that gave them their initial lead.

In the 1990's, mobile phone technology catalysed developing nations, to leapfrog antiquated telecom infrastructure, bypass traditional banking, and revolutionize point of sale transactions. In the same way, the opportunity in the battery space is to leapfrog a complacent supply chain using western ingenuity and political will to herald in low carbon, low waste, and low-cost technologies for a sustainably differentiated future.

Western nations are leaders in innovation and mutually aligned on responsible mining, but today we export the ideas and the raw materials overseas only to buy them back as value-added goods. It would be easy to just emulate existing methods, however, this would make it impossible to differentiate, compete, and break the reliance on overseas markets, wasteful and costly as it is.

Governments, as seen recently in Canada and the US, are putting critical mineral policies in place, sometimes between nations, to secure responsibly near-sourced raw materials. Trade associations, such as Battery Metals Association of Canada and Clean Energy Canada are also taking up the cause. But the flow of raw materials to established overseas refiners and converters can only be diverted back to local companies if governments and automotive industry embrace technological change to create an economically and environmentally differentiated supply chain.

We must play to core strengths in continuous innovation, optimization, and collaboration. However, technology adoption is risky, and will require the support of governments, capital markets and automotive industry to fuel and build resilience into localized supply chains in mining, refining, materials, batteries and EVs.

The opportunity to differentiate lies in simplifying today's long and complex supply chain.

In the existing supply chain, nickel, cobalt, and manganese are mined, smelted, and refined to form finished metallic powders and briquettes, or mixed hydroxide products (MHP), or mixed metal sulfides known as matte. These materials are converted to battery grade metal sulfates. Meanwhile lithium is mined, refined, and converted to battery grade lithium hydroxide, often worked up from lithium carbonate.

The battery metals refining steps add considerable cost, energy, water usage and up to 5x the shipping weight, burdening the supply chain with substantial logistics and serious carbon footprint issues. All this waste is further compounded during cathode production where the battery metals are combined in a series of chemical and mechanical operations, more water is used and all the sulfate is diverted to landfill or costly recycling, having been introduced upstream only to be discarded downstream.

Nano One, based in Canada, has developed a One-Pot processing technology that is applicable to a range of

Chart: Illustration explaining complexity, cost, and waste in the lithium-ion battery cathode supply chain. *Source: nanoOne*

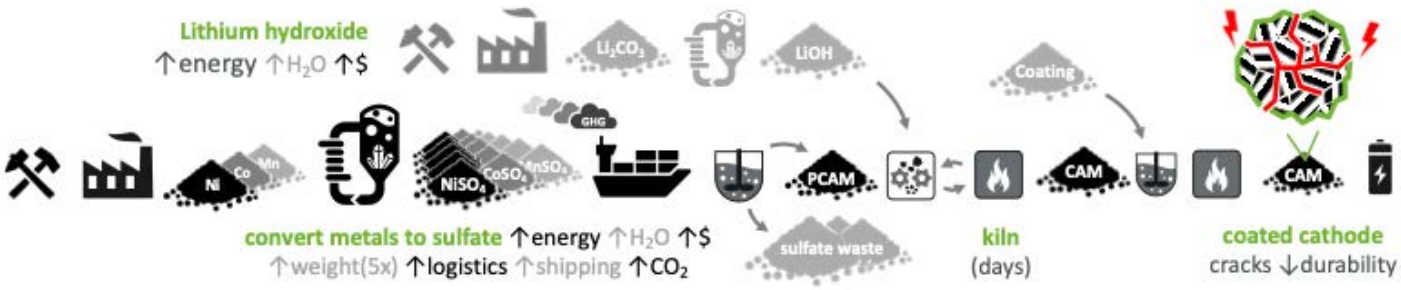
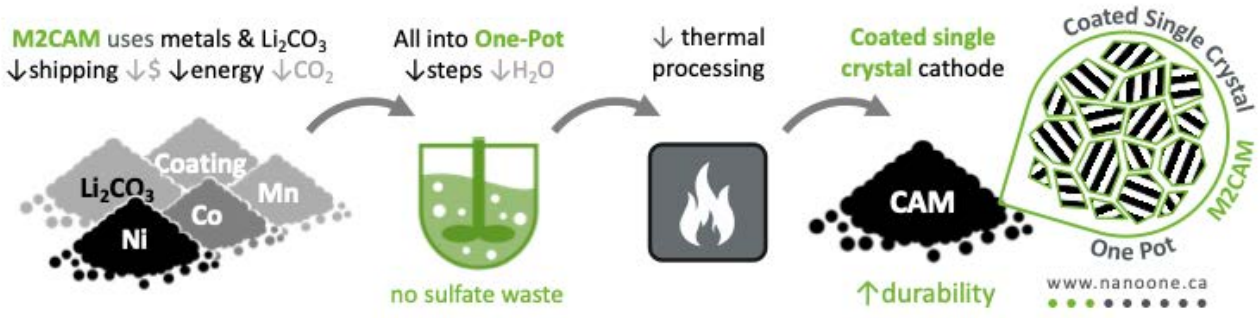
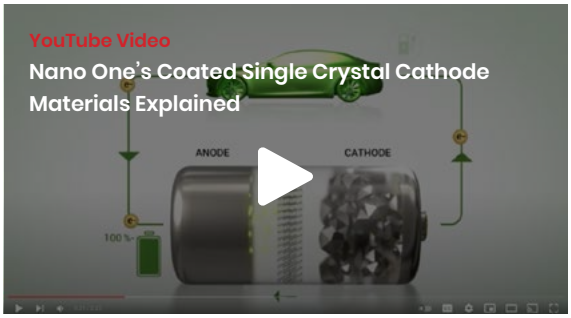


Chart: Illustration explaining Nano One technology and potential for reduced complexity, cost, and environmental footprint in the lithium-ion battery cathode supply chain.

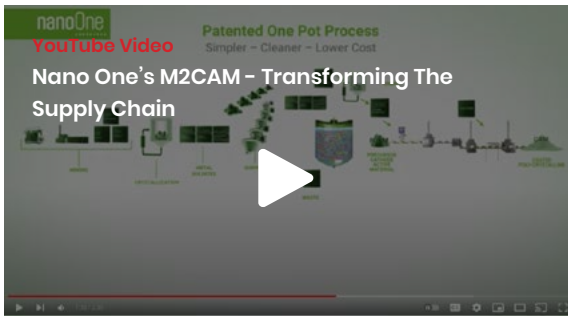
Source: nanoOne



battery cathode materials including NMC, LNMO and LFP. Nano One's technology forms durable single crystal cathode powders and protective coatings simultaneously.



It also enables cathode materials to be made directly from metals and lithium carbonate to eliminate the wasteful and costly conversion to metal sulfates and lithium hydroxide (see Nano One M2CAM video).



Nano One's innovations are intended to drive down cost, waste, energy, and carbon footprint in the battery supply chain and thereby align with the objectives of automotive companies, cathode producers, miners, investors, and global net-zero initiatives. Metals cost thousands of dollars per tonne less than metal sulfates, ship with 4-5x fewer emissions and eliminate the environmentally costly disposal of sulfates during cathode production.

The key to breaking global reliance on offshore battery supply chains is to redefine and leapfrog them through innovation. Despite conventional practices and wisdom, metal sulfates and lithium hydroxide are not required for nickel rich cathode materials. With class 1 metals and lithium carbonate, it is possible to build a sustainably differentiated supply chain while eliminating the waste streams, complexities, costs, and carbon footprint associated with the incumbent systems.

These innovations are applicable to the full suite of cathode materials in demand today and in the future, regardless of battery form. By differentiating in this way, the supply chain can be collapsed, simplified, and fully integrated for robust North American and European solutions.

Sustainable differentiation will have collateral benefits for generations, spawning innovation, carbon reduction, responsible mineral exploration, and competitive onshore manufacturing. Battery metal miners and recyclers can by-pass the margin erosion and heavy footprint of metal sulfate, MHP and matte production. With that will come job growth and economic multipliers, security and resiliency of supply, and a fundamental shift from technology export to full cycle ecosystems. Further, it will help reduce the growing CO2 footprint of shipping materials around the world and back.

We cannot sustain the electrification of everything without this level of re-invention and it would be short-sighted to only tweak and optimize the entrenched systems. We must leapfrog the supply chain with innovation, from mining to materials to batteries, if we are to break our reliance on wasteful legacy systems and unlock critical mineral supply chains.

Chip shortages, production delays and shipping bottlenecks are already plaguing supply chains globally, and it is only through the collaborative adoption of technological change that governments, capital markets and industrial leaders can nurture innovation, de-risk technology and secure a pathway to an economically and environmentally differentiated lithium-ion battery supply chain.

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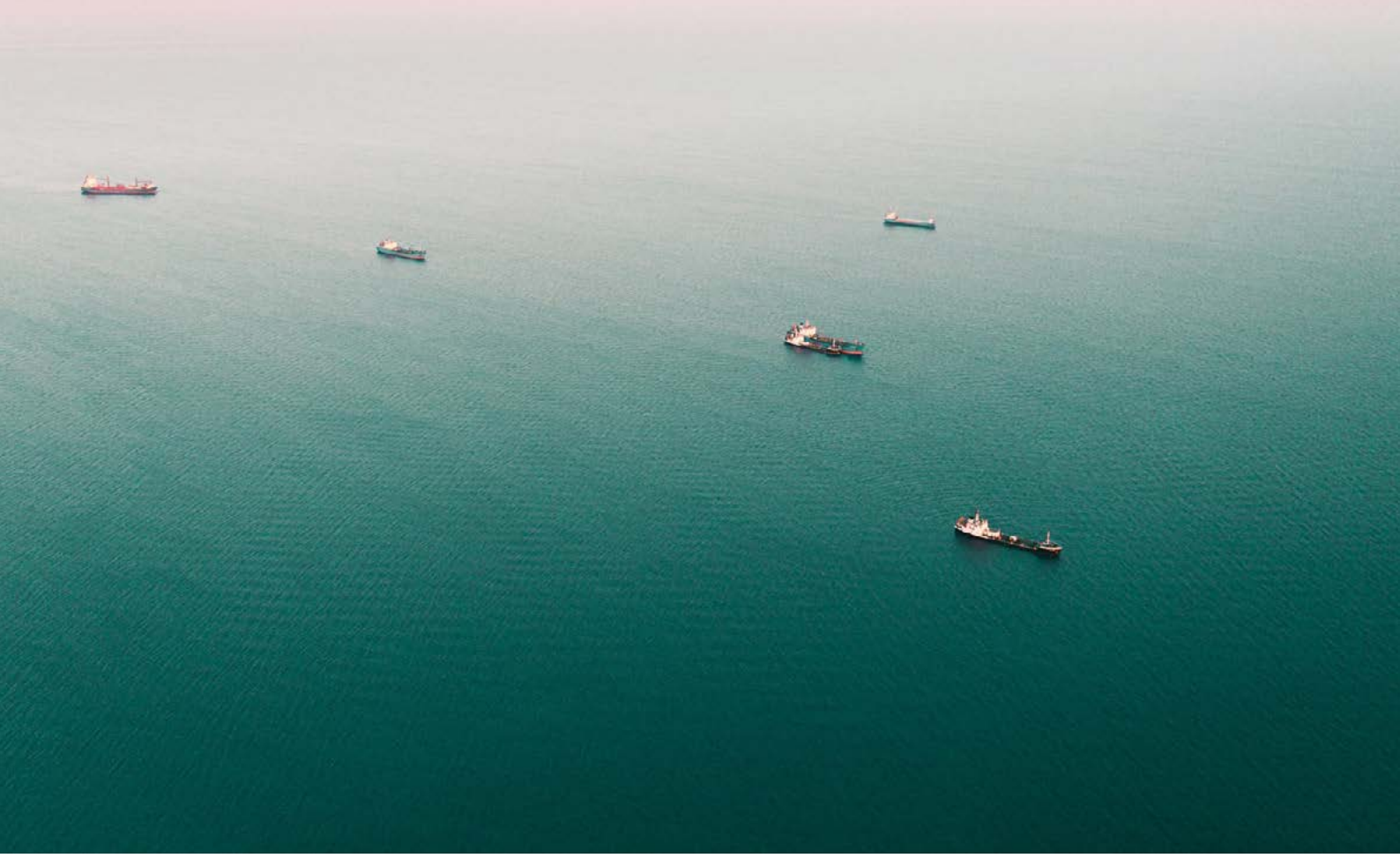


Photo: Jaanus Jagomagi

Onshoring the EV and Battery Industry in Europe and North America: At what cost?

Terry Scarrott
Principal Consultant, Rho Motion

The stage was recently set for the automotive industry at the COP26 climate summit as policy makers sought to achieve a global deal to eliminate new car emissions by 2040. Some of the world's largest carmakers, such as BMW, Volkswagen and Toyota have already expressed their doubts or opposition to the global deal because they're not seeing their ambitions being matched by governments.

For the EV and Battery industry, legislation is a key driver of widespread EV adoption, and we expect both the European and North American markets to continue with further tightening of regulation to achieve their climate goals. However, this raises an important point: does the current or planned legislation go far enough to support the EV & Battery supply chains and its key stakeholders?

What is the problem?

The onus is on the European and North American markets to aggressively build cell capacity in their respective markets to reduce their over-reliance on China, who hold nearly all the world's current cell capacity. Meanwhile, legislation and policy indicate support for the localisation, known as "onshoring", of EV and battery supply chains; the European Commission's new Sustainable Batteries Regulation, which is expected to repeal the Batteries Directive 2006/66/EC from 2030, and the United States' $1.2tn Infrastructure Plan which was recently passed Congress. In Europe, the new regulatory framework fits within the narrative of the European Green Deal; comprising a more introspective spotlight on different stages in the product life cycle and references to "sustainability", "circularity" and "safety". However, the overwhelming focus still appears to be on the downstream part of the value chain, with priorities such as end-of-life management, recycling, labeling, and carbon footprint life cycle.

For the upstream and midstream, which includes raw material extraction, refining and conversion to battery-grade material, this very much seems like an "out of sight, out of mind" approach. The environmental and social impacts across the lithium-ion battery value chain are already well documented, but what does this legislation mean in practical terms for the EV value chain and how might this impact the transition to a global lithium-ion economy in the next decade?

The automakers consider themselves to hold all the risk when it comes to end-use, as evidenced by an agreement in October 2020 between GM and LG Chem to reimburse the car maker $1.9bn over faulty batteries that caused a series of fires in the Chevrolet Bolt.

At present, the EV industry is stuck in a chicken and egg scenario. The OEMs are looking to the policy makers for further support mechanisms to transition from ICEs to EVs and support growth of the entire lithium-ion value chain; the policy makers are making pledges to meet climate goals, with strategies running the full gamut of commitment; from enacting legislation, to making pledges, to doing nothing. As legislation inevitably tightens, this will place increasing pressure on the automakers to manage their own supply chains, including onshoring, but they are unlikely to comprehensively solve all the challenges on their own and not before the end of the decade at the earliest. What happens if the automakers cannot meet these legislative targets? Are the policy makers willing to impose penalties for not adhering to regulatory guidelines? This could result in a potential own goal for governments as automakers lobby for change or seek alternative ways to preserve their bottom line and maintain competitive advantage, such as diverging from the onshoring model.

Challenges on the horizon

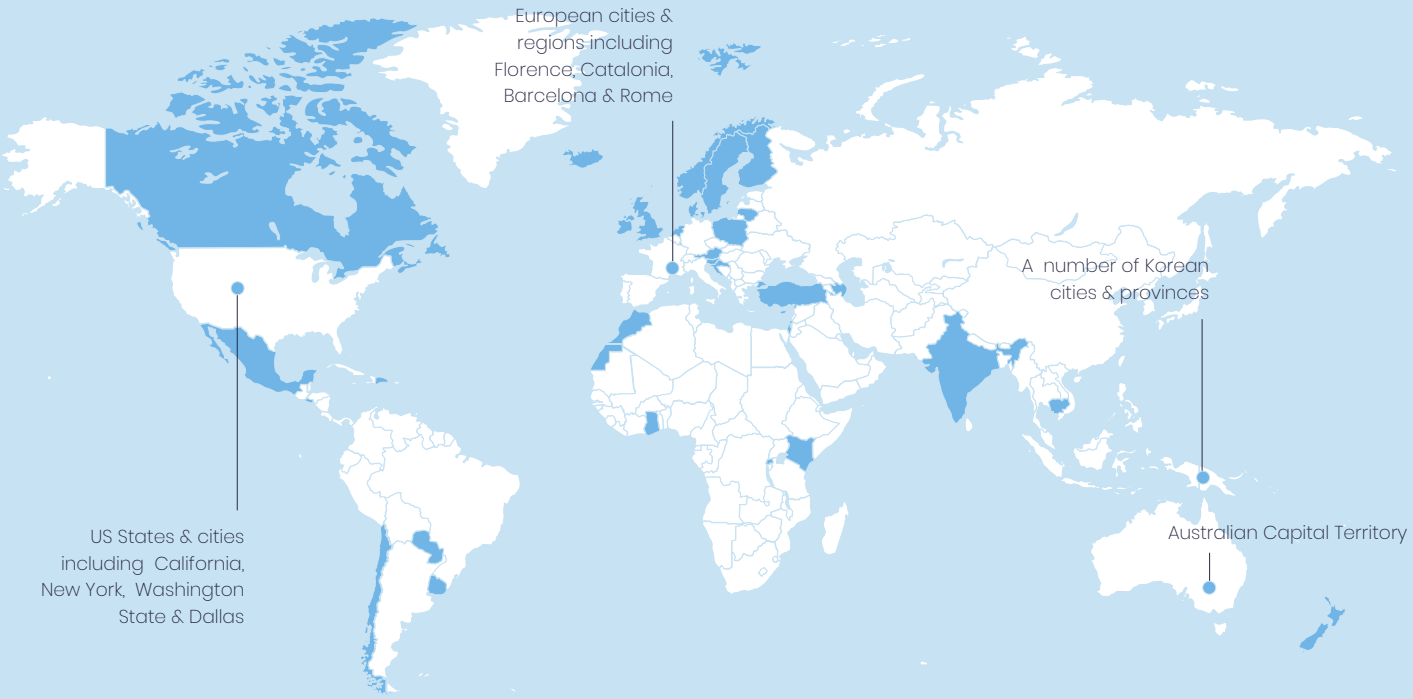
COP26 has undoubtedly raised awareness and brought many of the leading economic powerhouses together in the pursuit of global climate targets, but significant inconsistencies remain, like the failure of major economies such as the US, Australia, India, and China to phase-out coal by 2030. For the EV sector, it is difficult to know exactly how far legislation will go to support growth. For the European and North American OEMs, however, waiting is simply not an option.

Automakers and cell manufacturers are currently in a race to electrify their fleets and build cell manufacturing capacity, thus most of the major OEMs are making significant investments in the value chain as they seek ways to improve their bottom line and maintain competitive advantages. This includes securing access to high-quality feedstocks for battery-grade materials, either through direct investments in next-generation battery technology, vertical integration, joint ventures, or other alliances, such as GM's investment in geothermal energy to extract lithium from brine in California.

One of the greatest challenges facing the European and North American EV value chain is that projects take several years to bear fruit and it will be difficult to serve rising demand for EVs towards the end of the decade. Examples of capacity ramp up are not only limited to cell manufacturing. They may also include co-location of a gigafactory that produces NCM batteries near to a CAM or pre-CAM producer, commercialising the next-generation cell innovation, optimising manufacturing processes such as dry electrode manufacturing, or all the above; to improve cell performance, optimise manufacturing

Chart: The Glasgow Declaration on Zero Emission Cars and Vans

Source: Rho Motion



OEM signatories	Ford	gm	Mercedes-Benz	BYD	VOLVO	JAGUAR / LAND ROVER
Previous targets	40% BEV/PHEV by 2030	100% BEV/PHEV by 2035	100% BEV/PHEV by 2030	None	100% BEV by 2030	60% EV by 2030

processes or secure access to high-quality and cost competitive materials. These projects require significant investment and carry considerable risk.

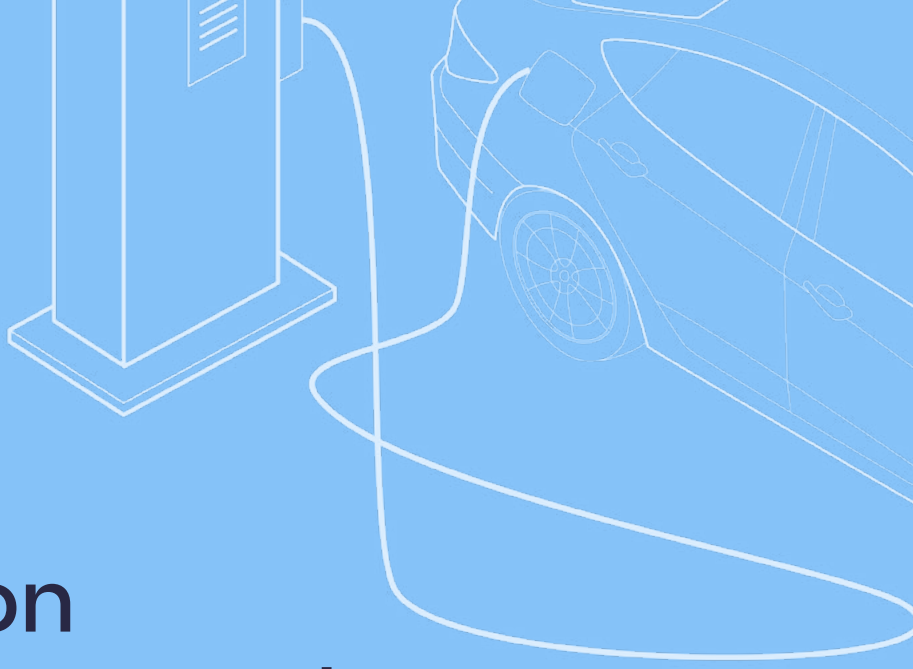
How prepared are the OEMs?

At present, apart from Tesla, Chinese OEMs are well placed to leverage their position as established EV producers to scale-up manufacturing capacity in response to market needs. Other OEMs, such as VW, GM, Stellantis, Hyundai and Renault-Nissan, are catching-up, as they announce ambitious plans for electrification, however, still have some way to go to match the Chinese OEMs in terms of cell manufacturing capacity. Other legacy OEMs are currently lagging but are not expected to catch up until the end of the decade. This presents us with fundamental questions: which OEMs are best positioned to win? How can the tailenders succeed? What does the future look like for these companies?

So, what next?

The burgeoning lithium-ion industry is expected to experience unprecedented growth in the next two decades. However, those involved in the industry – from the policy makers to private organisations and institutional investors, need only look at the rapid rise of online retailing, advertising, and social media sectors, to see the existence of significant divergences and trade-offs between governments and powerful private institutions, such as Amazon, Facebook, and Google.

For the automakers and cell manufacturers, who are destined to become powerhouses as the industry consolidates, there is a clear opportunity to build the narrative with the policy makers, not only close to home but across the value chain. Onshoring might be one solution against price rises for lithium-ion battery and electric vehicle raw materials, especially as demand is expected to outstrip supply for many of the critical materials throughout the next decade without significant supply increases. Further, it gives governments an opportunity to create jobs and boost GDP, which are economic indicators of success. However, this can only apply to those markets with access to raw materials and refining capability. For many markets, however, this simply will not be possible, which is why it is too simplistic for policy makers to focus on onshoring the entire value chain. No one organisation or government can comprehensively address the future challenges in the lithium-ion value chain, but partnerships and alliances are expected to become an increasing part of the landscape as all the major actors look for ways to benefit from comparative advantages.



Rho Motion Consultancy and Advisory Services

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Rho Motion provides bespoke consultancy and advisory services, based on our clients' needs covering the EV and battery supply chains in the following areas:

- Competitor analysis
- Market entry strategy
- Business appraisal and strategy
- Battery chemistry and technology evaluation
- Techno-economic modelling
- Technology strategy
- ESG circular economy
- PFS/DFS

Our clients are diverse, global players and our research is relied upon in bankable feasibility studies, preliminary economic assessments and public finance raising including IPOs and debt issues.

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Made in America: Building the region's first Battery Materials Park

Trent Mell - CEO, Electra Battery Materials Corporation
Michael Insulan - VP Commercial, Electra Battery Materials Corporation

North America, the home of technological innovation, is on the cusp of engaging in the electric vehicle revolution in earnest. It is the home of Tesla, which arguably enabled, and certainly accelerated, the adoption of electric vehicles worldwide, and it is the launch site for some of the world's largest auto makers to go all in on electric mobility.

Readers of this magazine are already aware that the future of electric vehicles relies on batteries, and batteries in turn rely on the efficient, secure, and environmentally friendly extraction and conversion of minerals. Nickel, cobalt, manganese, lithium and graphite are the key components of active cell materials. All are found in abundance in North America.

Yet, 80-90% of all conversion of battery minerals to relevant raw materials for the lithium-ion battery industry takes place in China.

This is not sustainable. In addition to emissions generated by excess ocean freight, a reliance on China for the conversion of minerals to battery materials lends itself to numerous risks: freight cost fluctuations, container and vessel shortages, tariff amendments, geopolitics, quality assurance, intellectual property, and much more.

In early November 2021, Electra Battery Materials Corporation (Electra) announced its intention to help solve the region's supply shortage with the development of North America's first Battery Materials Park.

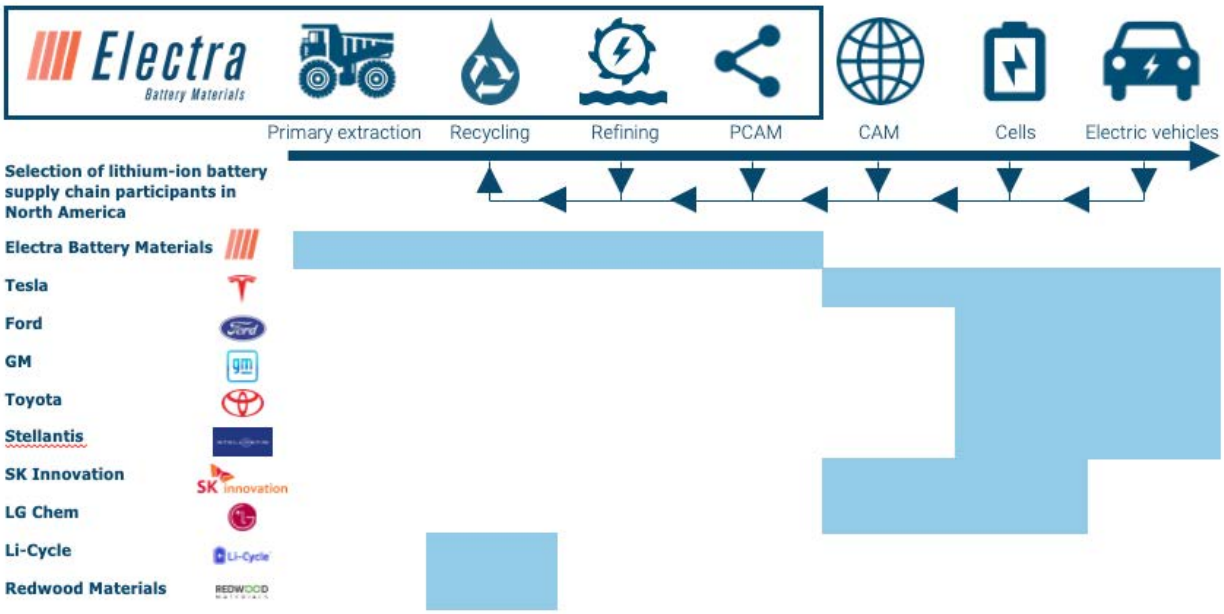
North America needs a local battery materials solution

In the past 18 months, all big US auto makers have joined forces with international battery makers, announcing major build-outs of battery cell manufacturing capacity in North America. Some of these initiatives include cathode active materials plants.

These facilities, then, are forced to import either battery precursor materials or cathode active materials; most of which is expected to come from operations in East Asia.

Chart: Electra's ambition is to operate in the first four stages of the battery supply chain

Source: Electra Battery Materials



1. Lithium-ion battery precursor material 2. Lithium-ion battery cathode active materials

Chart: North American battery cell pipeline exceeding 600 GWh

Source: Electra Battery Materials, CIC energiGUNE

1. Assuming average vehicle pack size of 67kWh (2021 YTD average in North American market)
Source: Electra Battery Materials, CIC energiGUNE

We have a situation, then, where the mineral wealth of North America is shipped to Asia before it returns as an enhanced battery raw material.

Electra's Battery Materials Park – located in Ontario, Canada – intends to change this.

Upon completion of this project, Electra will cover three fundamental stages of the lithium-ion battery supply chain: primary extraction, refining, and precursor making.

By virtue of operating on a brownfield site, the Company will also be able to capitalize on existing infrastructure and equipment to process lithium-ion battery waste.

Lithium-Ion Battery Recycling

Electra is expected to announce the conclusion of an engineering study to process black mass, as well as off-spec precursors, cathodes, and primary battery cell scrap at the Company's existing facility in Canada. The decision to proceed in this direction comes after the Company announced in July 2021, that it successfully extracted nickel, cobalt, copper, manganese, lithium and graphite from a "black mass" product recovered from recycled batteries.

Full commercial production from the recycling line is expected to commence in 2023.

The facility will be perhaps the largest commercial hydrometallurgical recycling facility of black mass in North America.

A four phased modular approach

Electra's Phase I battery grade cobalt sulfate refinery will be commissioned in Q4 2022, followed by commercial recycling of lithium-ion batteries in Phase II in 2023. Nickel sulfate will come in 2024-2025 in Phase III, and will be based on North American raw material feed. Phase IV entails a precursor materials plant which is expected to be commissioned in 2025 with a joint-venture partner.

Electra can deliver this project fast. The Company has an existing permitted hydrometallurgical site, with an already established refinery. It has proximity to raw material feed, and reputable black mass sources. The infrastructure is in place and Ontario's abundance of clean hydroelectric energy will power the site.

The initial capacity of the Battery Materials Park will be sufficient to supply raw materials for more than 1.5 million battery electric vehicles per year. But the facilities will be built in a modular fashion, allowing Electra's Battery Materials Park to expand capacity in coming years as the lithium-ion industry grows.

Low environmental footprint

Based on independent peer comparisons conducted by Minviro Ltd., Electra's facility will have 51% lower carbon-dioxide emissions, 73% lower water consumption, and 30% lower eutrophication potential than comparable plants in China.

Electra will remain true to its purpose and help make the world a better place.

Storage & safety: Market growth and the issue of safety in battery energy stationary storage

Photo: Appolinary Kalashnikova

Iola Hughes
Senior Research Analyst, Rho Motion

As we consider the fast-evolving battery energy stationary storage (BESS) market in recent months, two key stories have caught the market's attention. Firstly, the increasingly strong legislative support from China, the US, and Europe is beginning to provide an ever more appealing market for BESS deployment. Secondly, the issue of safety. The recent fire at Tesla's Victorian Big Battery Project has raised many questions on accountability and cell chemistry choice.

Globally, legislative support for BESS is increasing

In recent months we have witnessed announcements from China, the US and Europe that will all provide direct support and remove some of the current barriers for BESS. These barriers have created an insecure environment for businesses and consequently hindered investment in storage technologies in recent years.

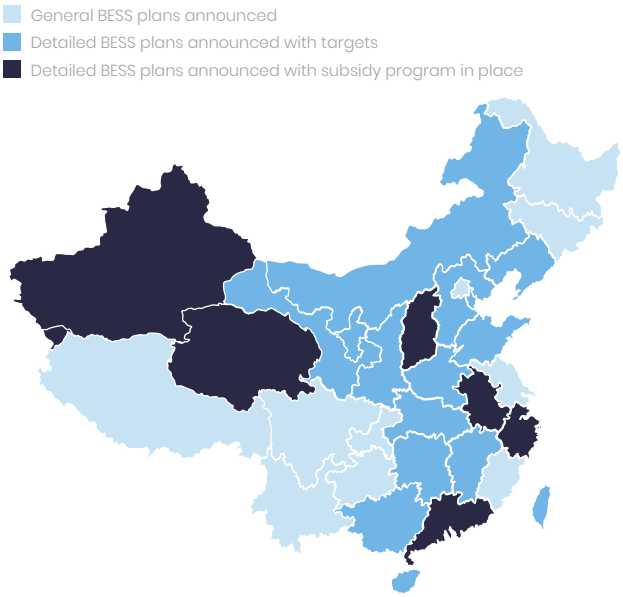
China

In July, China released its first national energy storage target of installing 30GW of new energy storage by 2025. Similarly, most provinces now require storage, with policies requiring one to two hours storage capacity at 5% - 20% of the maximum power of the renewable project. The real impact of this will be seen from 2022, with a growing list of projects announced. This includes a number of large-scale projects over 1GWh required to support China's renewable energy bases due to come online from 2023.

North America

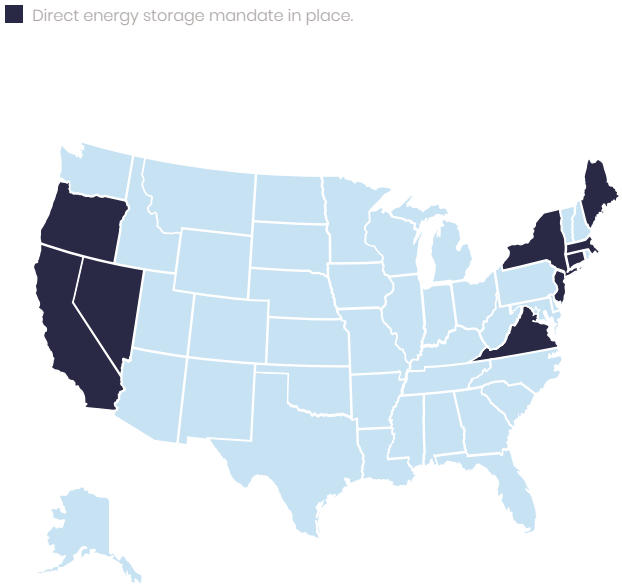
In North America, the grid scale market has seen strong growth this year, driven by several large-scale projects and good legislative support. Nine states have direct energy storage legislation in place, these vary in scale

Chart: Chinese Provinces with direct energy storage legislation



Source: Rho Motion

Chart: US States with direct energy storage legislation



Source: Rho Motion

from Maine's recently announced 400MW by 2030 to New York's 3GW by 2030. Over half of the installed capacity is in California, supporting a number of solar farms and frequency control projects. The grid market is set to continue its strong growth with five projects with a capacity greater than 1GWh, and a further six at 0.8GWh already announced for 2023. In August it was announced that the standalone Investment Tax Credit (ITC) will be included in the Federal Budget Reconciliation Proposal. The bill will cover both commercial and residential energy storage installations. Purchasers will be eligible for a base credit rate of 6% or a bonus credit rate of 30%.

Europe

Growth in the European grid market is limited compared to the North American and Chinese markets, a result of the relatively small-scale projects in Europe. YTD eight large-scale projects have been installed at a combined capacity of 0.21GWh, compared to 1.5GWh in the US for the same number of projects. This is set to change in 2022, a result of the UK's change in planning laws that now allow projects over 50MW, and the proposed revision of the European Energy Tax Directive (ETD) that will remove the double taxation issue. The 2003 European ETD classifies storage as both a consumer and distributor, resulting in taxation for both drawing and supplying power. The proposal will reclassify storage as a redistributor allowing for drawing and supplying with a single tax applied. Double charging regimes have previously been the major barrier to market entry in many European countries, including Germany. In 2022 the European grid market is set to see strong growth with over ten projects announced with greater than 50MWh capacity.

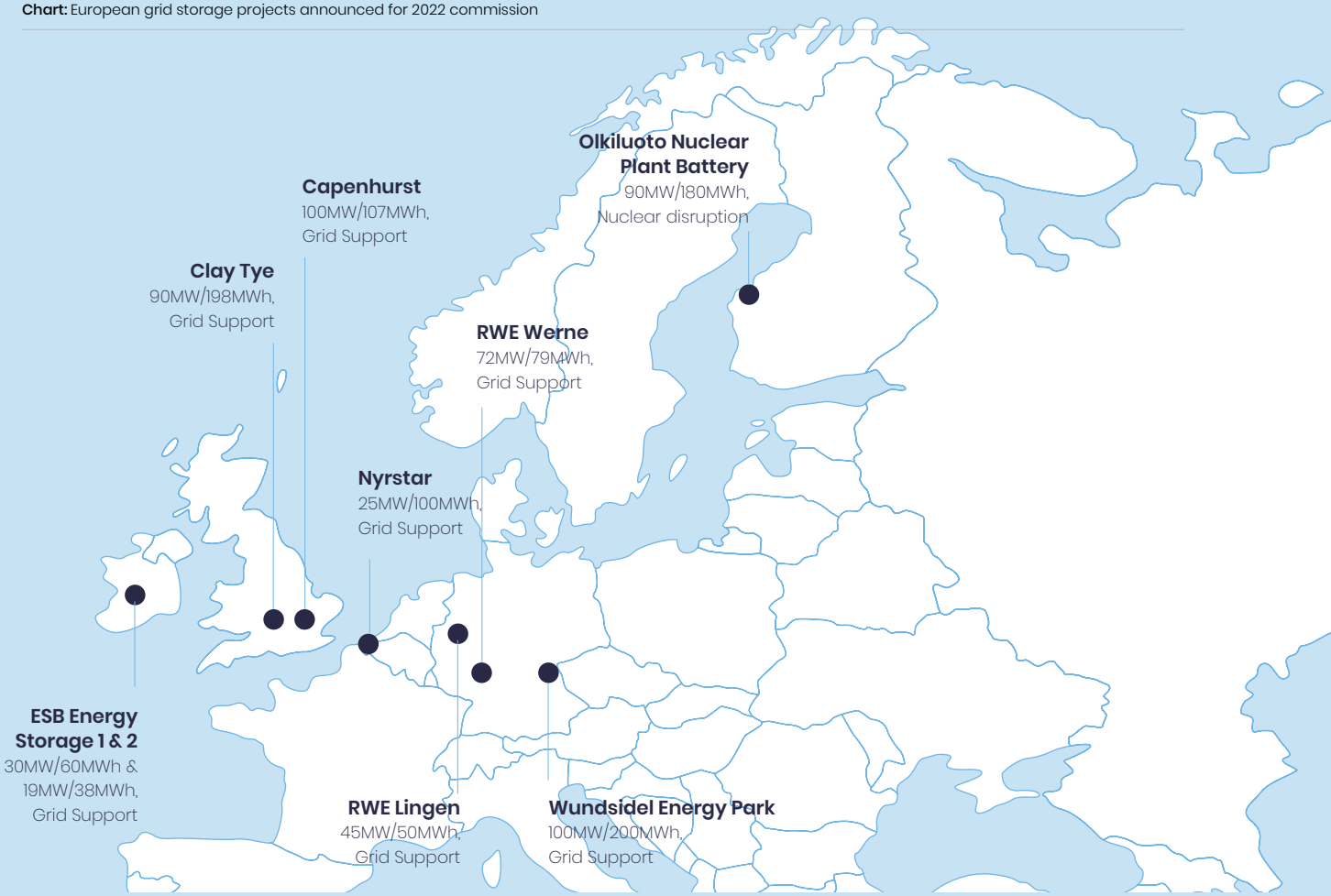
> *In 2022 the European grid market is set to see strong growth with over ten projects announced with greater than 50MWh capacity.*

Safety in BESS

On 30 July, a fire broke out in a Tesla Megapack at the 300MW Neoen owned Victorian Big Battery Project, currently under construction in Australia. It took four days to be brought under control. Dealing with the fire was particularly difficult, due to both the nature of battery fires, which cannot be extinguished directly with water and the layout of the Megapacks that provided insufficient space for fire crews to easily manoeuvre between the batteries. Investigations have since found the cause of the battery to be an undetected coolant leak.

The fire is among 40 known fires within large-scale lithium-ion BESS in recent years, with the 2019 McMicken Battery Plant fire in Arizona leaving four seriously injured and the Beijing shopping mall battery fire leaving two dead and a third injured earlier this year. The majority of these 40 fires

Chart: European grid storage projects announced for 2022 commission

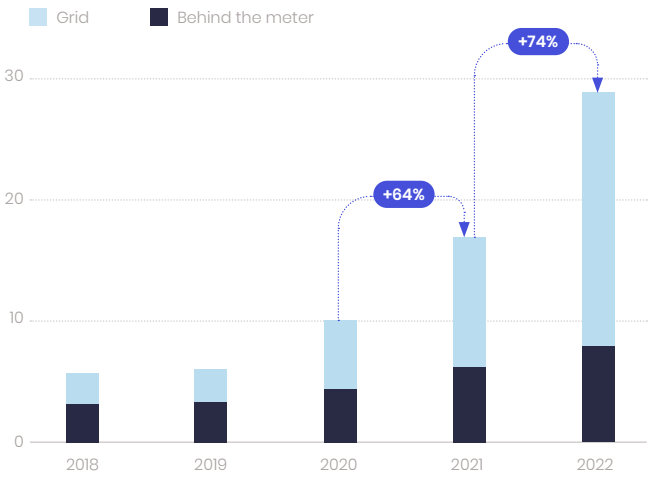


have happened in the last three years and the Victorian Big Battery fire has once again brought attention to the importance of safety at BESS sites. Cell chemistry has been central to this discussion with Maoneng, who is also building a battery in Victoria, subsequently announcing they will use LFP cells at the 480MWh Mornington BESS Project due to come online in late 2022.

This plays into the wider conversation of a shift to LFP in BESS. Earlier this year, Tesla announced it will use exclusively LFP cells in its Powerwall, Powerpack and Megapack products going forwards. They have since announced a new 40GWh Megapack factory that will significantly boost Tesla's BESS production from 3GWh over the last 12 months.

> *The fire is among 40 known fires within large-scale lithium-ion BESS in recent years.*

Chart: Annual installed BESS capacity by Type

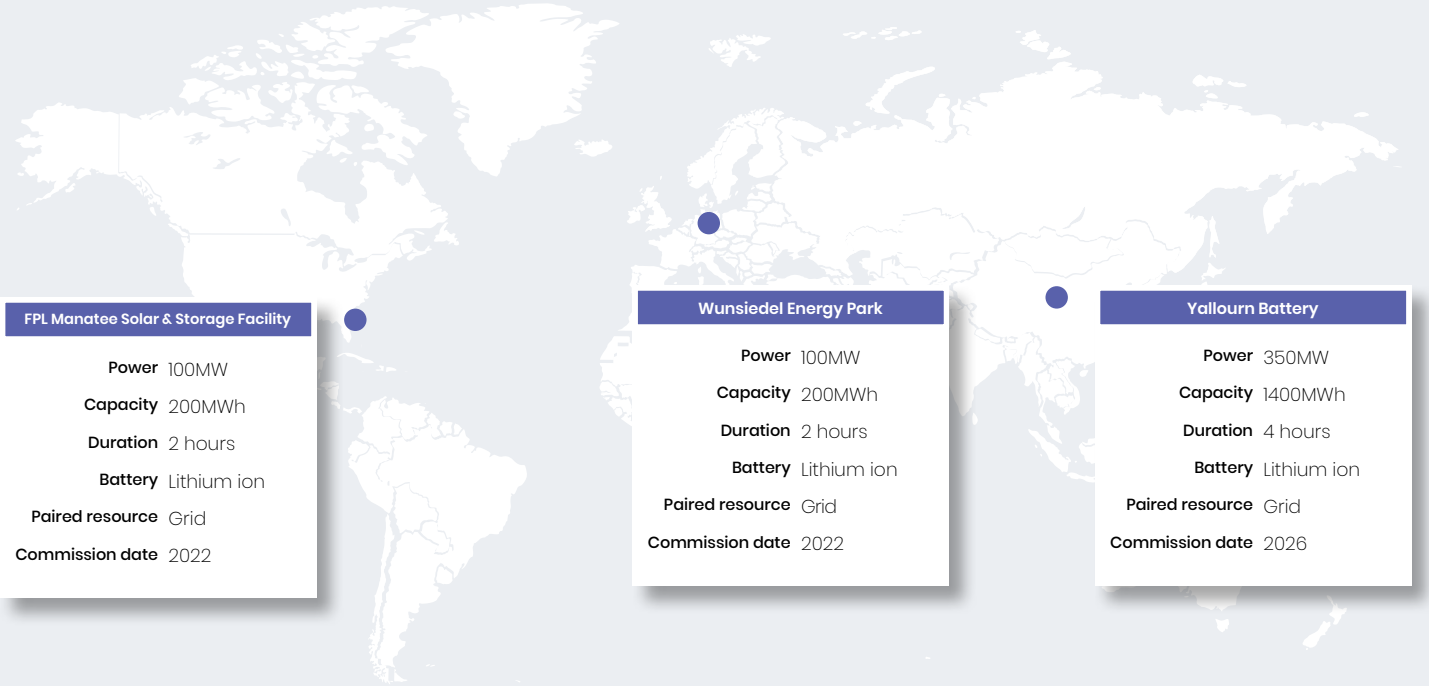


Source: Rho Motion

Next year we will continue to see strong growth in the BESS market, with a number of large-scale grid projects in the pipeline, as well as increasingly strong support for the behind the meter market. Safety will remain to be a central issue, expanding the use of LFP as developers look to a market that is not accommodated by surplus electric vehicle batteries but driven by BESS use case.

Projects set to come online 2021-2023

Here, we examine the dynamics of a few large scale BESS projects that have recently been or are in the pipeline and due to be commissioned from our Battery Energy Stationary Storage Monthly Assessment.



PROJECT SPOTLIGHT 1

FPL Manatee Solar & Storage Facility, Florida US

In August, the first of 132 battery storage containers were installed at the Florida Power & Light (FPL) Manatee Energy Storage Centre, a 409MW/900MWh BESS project due to begin operation in late 2021. The project announced in March 2019 will be the largest solar-battery storage project in the world, charged by the existing nearby 74.5MW FPL Manatee Solar Energy Centre. FPL's parent company NextEra Energy, through its renewable energy developer subsidiary NextEra Energy Resources, plans to build up to 14.4GW of new solar energy capacity and as much as 6.3GW of energy storage between now and 2024.

PROJECT SPOTLIGHT 2

Wunsiedel Energy Park, Germany

Siemens Smart Infrastructure and ZENOB have signed a letter of intent for the construction of a 100MW/200MWh battery in Wunsiedel, Germany. The battery is intended to use surplus renewable energy from the grid to cover demand peaks and will sit alongside Siemen's 8.75MW green hydrogen production plant. The battery will be provided by Siemens' JV Fluence and will be among the largest battery projects in Europe upon completion in 2022.

PROJECT SPOTLIGHT 3

Inner Mongolia Projects China

In September, two large-scale renewable energy and energy storage projects entered construction in Inner Mongolia, China. The first project is developed by CGDG in Wutumeiren, Geermu. Here, 3GW of solar power and 300MW of thermal power will be built along with 1.04MWh/0.52MW of battery energy storage. The second project is developed by Power China in Wulanchabu. 3GW solar power and 1.7GW wind power will be built along with a 1.1GWh/0.55GW energy storage system. These join a growing list of projects with a capacity over 1GWh required to support China's renewable energy bases, coming online from 2023.

*Rho Motion's **BESS Quarterly Outlook** and **BESS Monthly Assessment** provide up to date insight with all developments in this space. The assessment provides analysis of project announcements, updates, and commissions, tracking the development of key battery stationary storage metrics over time, as well as monthly news and market updates. Our outlook provides long-term outlooks for battery demand and battery chemistry, by application and region, based on robust and informed methodologies.*

The variation in EV charging demand

Photo: Vlad Tchompalov

Charles Lester
Senior Research Analyst, Rho Motion

Global EV sales are expected to double in 2021, requiring a significant increase in the number of public EV chargers to facilitate the rising demand. We expect the majority of EV charging to take place at home, but there are many circumstances where this will be problematic, not least for households that do not have access to private charging.

In 2021, we expect the global number of public EV charging points to rise by 52% y-o-y to 1.9 million, with most of the growth coming from China and Europe. By 2025, we forecast 4.3 million global public EV charging points will be required, and over 9 million by 2030.

The distribution of public EV chargers varies significantly by country as shown in the graph below. A key metric we use is the number of EVs to public chargers (the global average is 12), and the number of BEVs to fast chargers (the global average is 19). We can use this metric to draw a comparison of public EV charging coverage versus EV fleet by country.

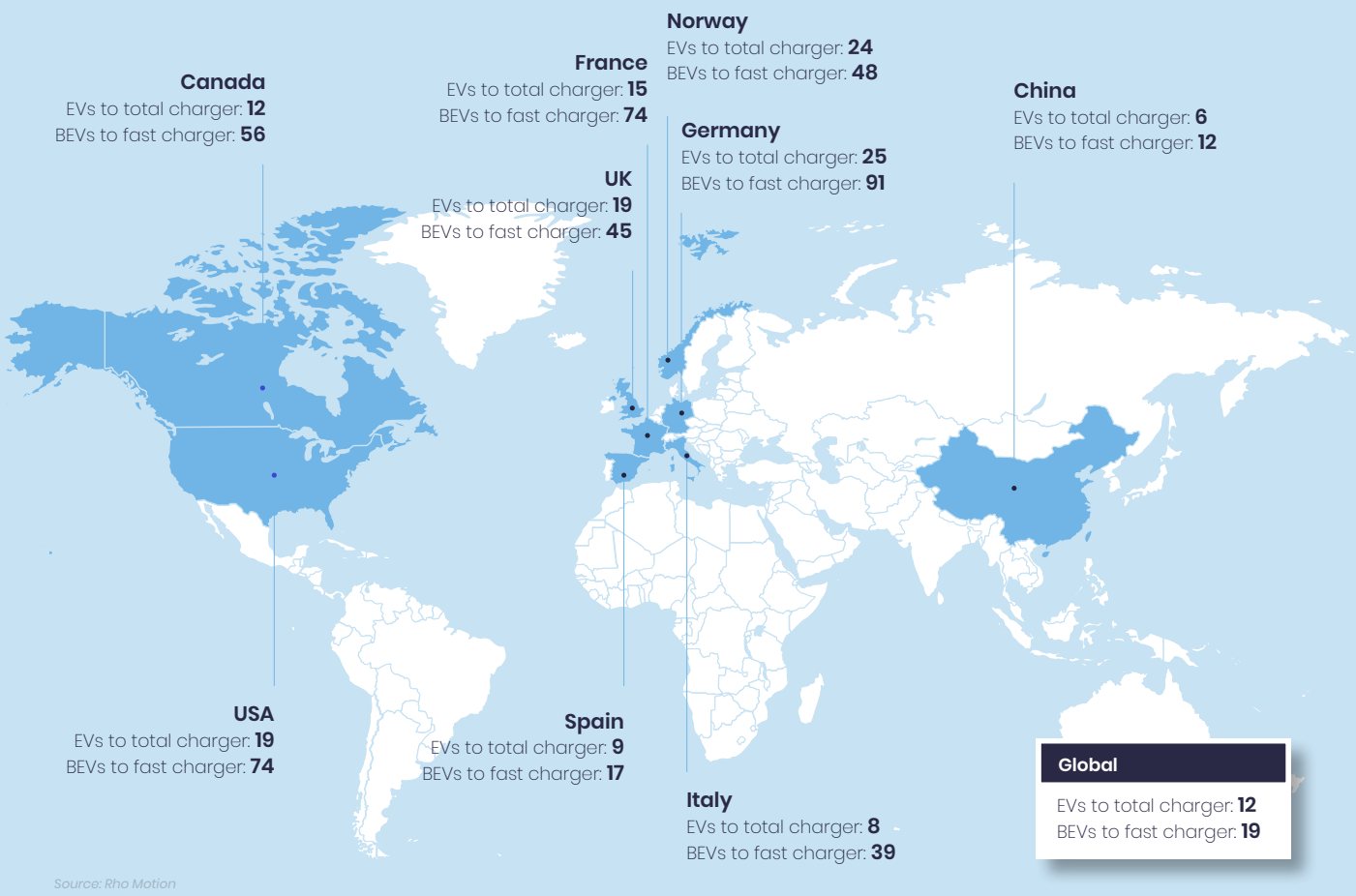
To draw a key comparison, China has the largest EV fleet and a very high number of public AC and DC chargers. As a result, it has 6 EVs for every AC charger and 12 BEVs for every DC charger. Opposingly, Norway has the most mature EV market with an expected EV sales penetration rate of ≈70% in 2021 but, has significantly more EVs to chargers. This is due to better access to private charging in Norway than there is in China. More EV owners will charge at home than in public, and therefore, there is less demand for public charging infrastructure.

How much public EV charging is required?

Looking forward, the coverage of public EV charging infrastructure will vary significantly, by country, city, and town. To assess how much will be required, we look at variables such as the share of those that live in apartments, the urban population, population density by region and city, among other factors to determine the overall regional access to private charging.

The chart illustrates at a high level the distribution of EVs to chargers and the share of fast charging, with the country's population density. EV charging speed is also an important factor when installing a charger. In China, around 80% of EVs sold are BEVs, whereas in Europe the split is around 50:50. As such, the current proportional demand for public EV chargers is more likely to be higher for DC fast charging

Chart: EV public charging ratios, EV Charging Major Markets, 2021



Source: Rho Motion

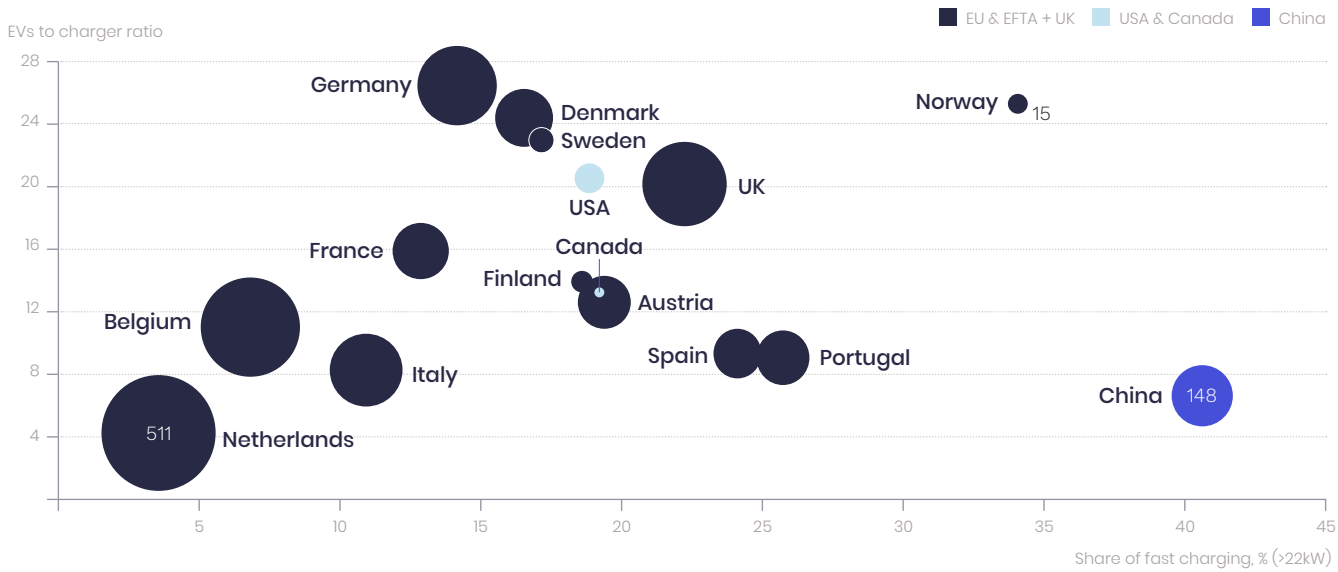
in China. Unlike in Europe, where half of EVs are PHEVs and mostly cannot fast charge. As EV penetration rates rise across the globe we will see the landscape of EV charging differ significantly across countries.

There are also blurred lines over who pays for charging infrastructure, especially for those that will need to publicly charge. Many regions provide support for charging infrastructure, such as in the UK, where the Electric Vehicle Homecharge Scheme provides a grant of up to 75% towards the cost of installing a charger. In the US, the Biden Administration has settled for half its desired EV infrastructure funding at $7.5 billion for a target of 500,000 public EV charging stations by 2030.

With such different use-cases for public EV chargers, it is difficult to assign a target for the number needed, and therefore targets vary significantly as well. Alongside

Chart: The number of EVs to charging points by region, % of fasting charging, 2021

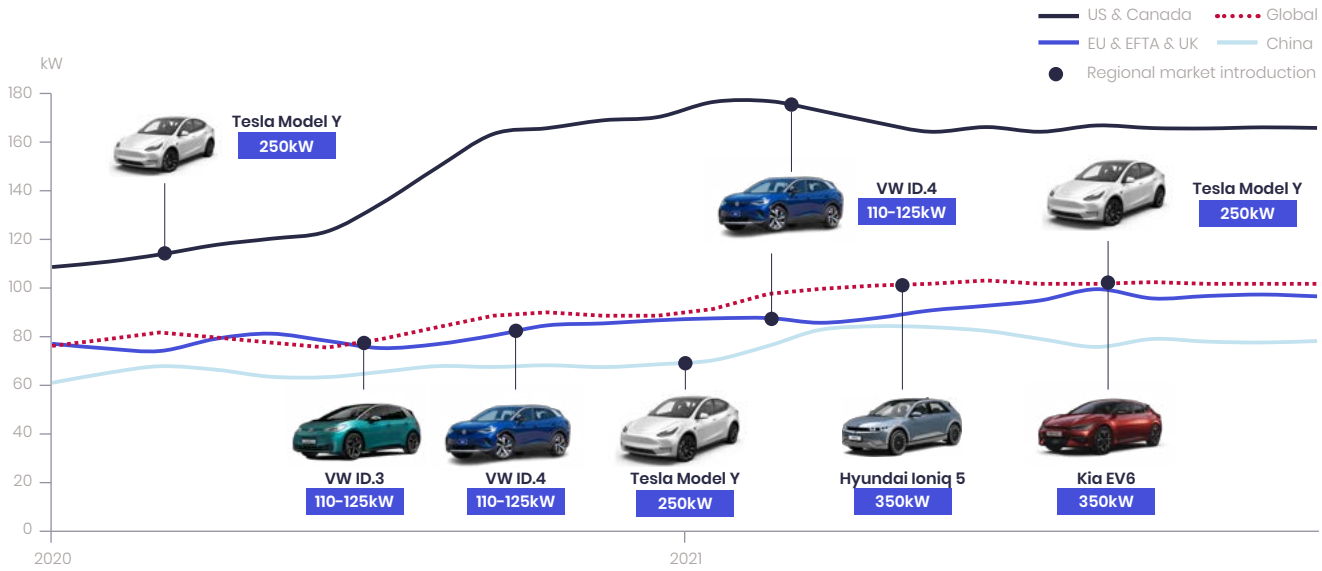
Size of bubble represents population density, population per KM2



Source: Rho Motion

Chart: 3-month sales weighted average maximum BEV charging speed

Source: Rho Motion



the USA's target, Germany targets one million public EV charging stations by 2030, and Korea targets around 500,000 public chargers by 2025. China does not have a national target, but instead many provinces have set their own targets, Shanghai is targeting 200,000 chargers and Sichuan 250,000 - both by 2025.

How much charge can an EV take?

From 2018 to early 2020, the global average maximum BEV charging speed had been around 80-90kW with little variation. Since then, the global average has been steadily rising which we put down to three core reasons alluded to in the chart below. Firstly, the introduction of the Tesla Model Y which has a maximum charging speed of 250kW. It was initially introduced in the US in early 2020, then in China in January 2021, and now exported from China to Europe from Q3 2021, it is the third best-selling EV in 2021. Model Y sales are expected to continue to be strong in Europe, especially as Giga Berlin will be up and running in 2022. Secondly, the introduction of volume segment BEVs on dedicated EV platforms, such as Volkswagen's ID range. Both the ID.3 and the ID.4 can charge up to 125kW and are in the top five sales in Europe in 2021. As more OEMs roll out EVs on dedicated platforms, there will be a rise in EV charging speed. Finally, more affordable EVs have entered the global market with an 800-volt system (compared to the Porsche Taycan and Audi e-tron GT); the Hyundai Ioniq 5 and Kia EV6, which can facilitate up to 350kW maximum charging. We track the average BEV maximum charging speed, amongst other metrics in our EV Charging Monthly Database.

However, the average charging speed for a Model Y will typically be between 100-150kW for a 20-80% charge. There are still significant technological steps required to improve average charging speed, primarily focused on the anode.

> *From 2018 to early 2020, the global average maximum BEV charging speed had been around 80-90kW with little variation. Since then, the global average has been steadily rising*

How and when can it be improved further?

Alongside Hyundai-Kia and Volkswagen, other OEMs have made further commitments to 800-volt platforms. Stellantis and Daimler are expected to have 800-volt systems on future EV platforms, Volkswagen will also expand its use of 800 volt systems, for Audi and Porsche, with models built on the PPE platform, beginning with the Audi A6 e-tron expected to be released in 2023.

The longer-term developments in battery cell chemistry, such as silicon dominant and solid-state, could also improve the charging speed. Claims on charging speed range from <20 minutes to <5 minutes for a full charge. To put this into perspective, the current charging time of a Hyundai Ioniq 5 (maximum charge of 350kW) is around 20 minutes for a 10-80% charge using a 350kW charger.

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EV Charging Monthly Assessment

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EV Charging Monthly Database

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The key to silicon anode solutions: Cost

Steven Addis
Chief Marketing Officer, OneD

Charging an EV battery is simply storing electrons and lithium ions in the appropriate electrode of the cells in the battery pack. Today, almost all the anode electrodes store electrical energy in natural or synthetic graphite particles coated onto the current collector in large EV cell factories. A few leading EV models (for example Tesla Y, Tesla 3, and Porsche Taycan) contain a small amount (a few percentage points) of silicon oxide additives mixed with the graphite, to increase the cells energy and power density, hence increasing EV range and charging speed for a better driving experience versus graphite-only EVs.

Industry experts recognize that consumer demand for even better EVs will drive the amount of silicon to increase progressively to 10-20% in most of the 2025 EV models, and to even higher levels by the end of the decade, accelerating the transition from ICE to EV.

But that's easier said than done. Adding more silicon oxide, for example, is not the answer for both technical and cost reasons. New ways to add more silicon in EV cells is key to the EV competitive race. The economic factors for any silicon solution must be considered across the supply chain: cost of the precursors, capital equipment & manufacturing costs, and impact on the total cell production cost.

We will compare three types of silicon solutions to replace current silicon oxide additives:

Type 1: Encapsulating nano-silicon particles into a new type of carbon or polymer matrix mixed with inactive additives and graphite powders (with the goal to replace graphite altogether).

Type 2: New proprietary anode electrodes with no graphite powders.

Type 3: Fusing silicon-nanowires directly onto existing commercial graphite without inactive additives and without requiring mixing with graphite powders.

Cost of precursors

Both Type 1 and 2 require a silicon precursor to form silicon particles and a carbon precursor to form a scaffolding and a shell. Metallurgical grade silicon ("MGS") can be purified and ground into a powder, then coated with amorphous carbon or conductive polymer. Alternatively, MGS is used to produce a pure silane gas (SiH_4) which must be converted into nano-silicon particles inside a new carbon matrix because of the very high surface area of these silicon particles. The costs of having to produce a carbon or polymer matrix and having an incomplete conversion of the precursor into silicon anode active material are significant, and the processes produce waste.

Type 3 requires only four abundant and inexpensive precursors already scaled-up in mature supply chains: commercial EV grade graphite (EV standard supply chain), silane gas (solar cells standard supply chain), nitrogen (inexpensively extracted from ambient air), and tiny amount (ppm level) of copper catalyst. No new materials are needed to be produced in large quantities and no inactive material is added to the silicon.

Capital equipment and manufacturing costs

The specialized equipment required to produce the additives for Type 1 and 2 is new and custom designed without a reasonable risk-mitigated path to scale-up. When producing small quantities (from one ton to hundreds of tons), the equipment CAPEX amortization costs per kg are high. When contemplating scaling-up to supply meaningful quantities required for millions of EVs,

new equipment must be designed, built, and tested. This increases risks, upfront investments, and maintenance costs. In addition, the manufacturing high energy consumption costs and the low yields of these solutions come with a significant carbon footprint impact (e.g., waste processing).

By contrast, Type 3 manufacturing equipment are standard CVD machines, already part of the very mature solar cell supply chain – designed, built, and sold for years in large quantities by multiple suppliers to the huge solar cell factories. The design costs have already been amortized and the safety, reliability, and the lower maintenance costs are well known. In addition, the use of the copper catalyst to decompose silane into nano-silicon is key to reducing manufacturing costs: more than 99% of the silane is converted into nano-silicon at a lower temperature and the hydrogen exhausted can be re-used. Type 3 relies on a faster, simpler process with no waste and lower electricity costs and smaller carbon footprint.

Based on actual measured process metrics, including end-to-end yield losses, the Type 3 variable costs to add silicon nanowires to commercial graphite totals only about $1.6 per kWh added to the energy storage capacity of the graphite. Since EV grade graphite typically cost about $6 per kWh, the cost of the resulting composite anode active materials is lower, and the cost savings increase as the amount of silicon nanowires fused onto the graphite increase.

Total cell production costs

Anode active materials are blended with conductive additives and binders to form a slurry, which is applied onto current collector foils in the large coating machines found in EV cell factories. The anodes are then paired with separators and cathodes and the cell formation cycles are completed before assembly into EV battery packs. The silicon solution choice has a largely underestimated impact on the costs associated with these steps.

Type 1 and 2 silicon solutions are responsible for a substantial cost increase of this EV cell manufacturing process. First, slurry mixing requires a departure from the recipes fine-tuned with commercial EV-grade graphite powders for years. This is because these silicon powders introduce multiple new materials and particle sizes, affecting the slurry rheology, the adhesion to the electrode foils, and require new slurry formulations. In addition, these silicon solutions introduce significant new challenges when moving from wet to dry electrode coating.

Finally, these silicon solutions lower first cycle efficiency, requiring extra costly cathode materials.

Type 2 solutions require new anode machines that are proprietary and not yet produced or used at large scale in EV factories, which increases risks and initial CAPEX costs.

By contrast, the Type 3 solution is based on fusing nano-silicon on the same graphite powders already used in preparing slurries and coating electrodes in large EV cell factories. The addition of tiny silicon nanowires onto the micron-sized graphite particles, surprisingly, slightly reduces the BET surface area of the pure graphite substrate. And the size distribution of the particles in the composite powder is identical to the distribution in the pure graphite. Thus, the mixing and slurry rheology are simple to fine-tune and the coating of graphite with fused nano-silicon achieves uniform distribution – whether in large electrode coating machines using wet coating or in the newer, significantly less expensive dry coating processes.

The first cycle efficiency of the Type 3 composite is about the same as that of the graphite used as a substrate. This avoids extra cathode costs. Furthermore, in dry electrode processes, the option exists to add a small amount of stabilized lithium powder, which can further increase first cycle efficiency by direct contact pre-lithiation. There is no need for special conductive polymers to ensure the proper electrical pathways for electrons to move in and out of the silicon during cycling. The contact points between the tens of thousands silicon nanowires on each graphite particles are permanent and act like the plug of an extension cord into an outlet (the graphite particle). SEI layers form onto both the silicon nanowires and the graphite particles, but not at the attachment points. Finally, simple formation protocols keep the formation costs to a minimum.

Conclusion

We believe that the 2025 EV models year will determine the winners of the ICE to EV conversion race. Highly disruptive manufacturing processes can't scale fast enough and are cost prohibitive. Silicon nanowire technology, however, offers the performance, scale, and cost effectiveness to win that race.

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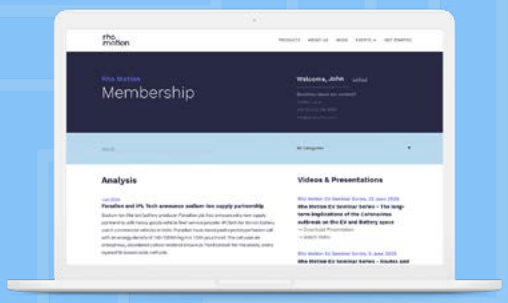

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Vehicle platforms and the importance of EV-dedicated architecture

William Roberts
Research Analyst, Rho Motion

Photo: Obi Onyeador

The use of multi-vehicle platform architectures by OEMs can be traced back to the 1960s at least. The Citroen Ami, released in 1961 was built on the same chassis as the famous 2CV, it was fundamentally a re-bodied 2CV with a slightly larger engine designed to respond to perceived customer demand. Platform sharing began in earnest in the 1960s in the US with General Motors manufacturing vehicles across the Buick, Pontiac, and Chevrolet brands using the same platform.

Common architectures and platforms have numerous advantages, not least the cost savings made in vehicle development as well as the reduction in parts variation allowing for more streamlined inventory and manufacturing. It can also lead to greater product differentiation as a new model lead time is dramatically reduced.

Those same driving factors that led to the first common architectures are still at play as the industry moves to electrification. Price parity of EVs and ICE is the new customer demand and OEMs now need modular, flexible, EV dedicated platforms to get them over the line.

Over the past 7 years, the cost of battery cells for automotive OEMs per cell has fallen from $290/kWh in 2014 to under $105/kWh today. This decrease has been vital, and the continued fall is often cited as the core factor for reaching price parity. However, the rate of decrease has leveled off and is even set to rise as demand increases and raw material supply is strained. Therefore, reducing costs and increasing efficiency through all other aspects of the design is essential if OEMs are to reach price parity for consumers, it cannot be done with battery developments alone.

For ICE vehicles, OEMs can afford to have a wide variety of platforms to meet the demands of every vehicle type available as the cost of development is much lower. For example, today General Motors produces vehicles on 19 different platforms with over 100 past platforms now discontinued.

Rho Motion's pricing analysis shows that although there are still savings to be made in battery cost, significant savings need to be made in vehicle platform costs to reach price parity and profitability this decade. Modular platforms that allow the cost of development to be spread over a higher volume of sales can help achieve this.

To reach the same level of profitability with electric vehicles OEMs need to streamline the baseline technology,

Chart: Lithium ion cell price, Large contract, Automotive, $/kWh (NCM)

Source: Benchmark Mineral Intelligence

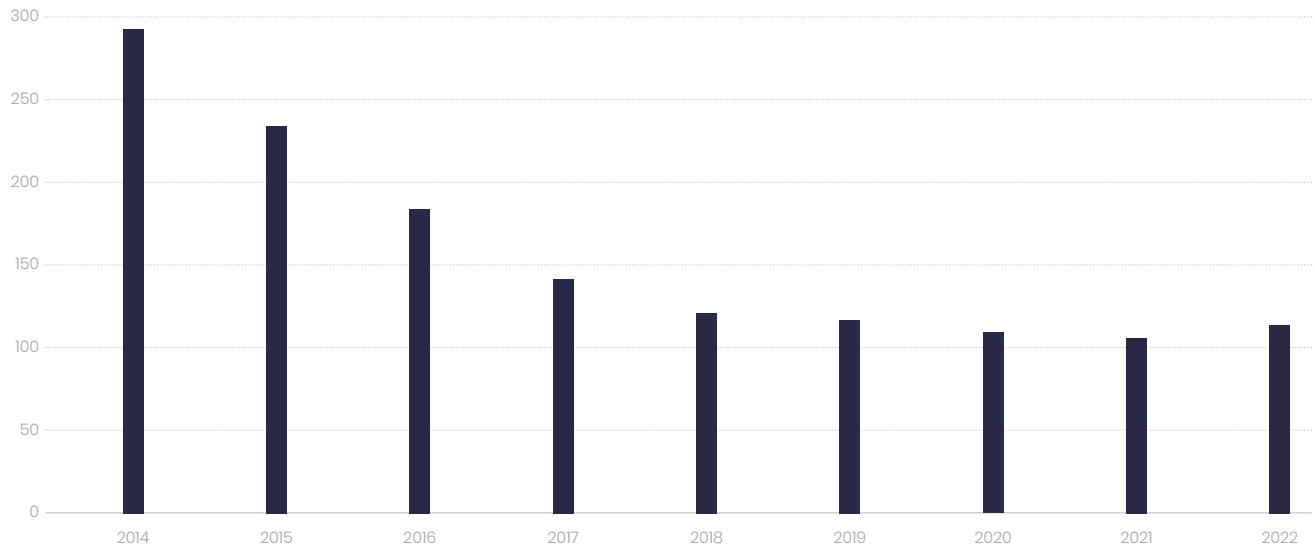
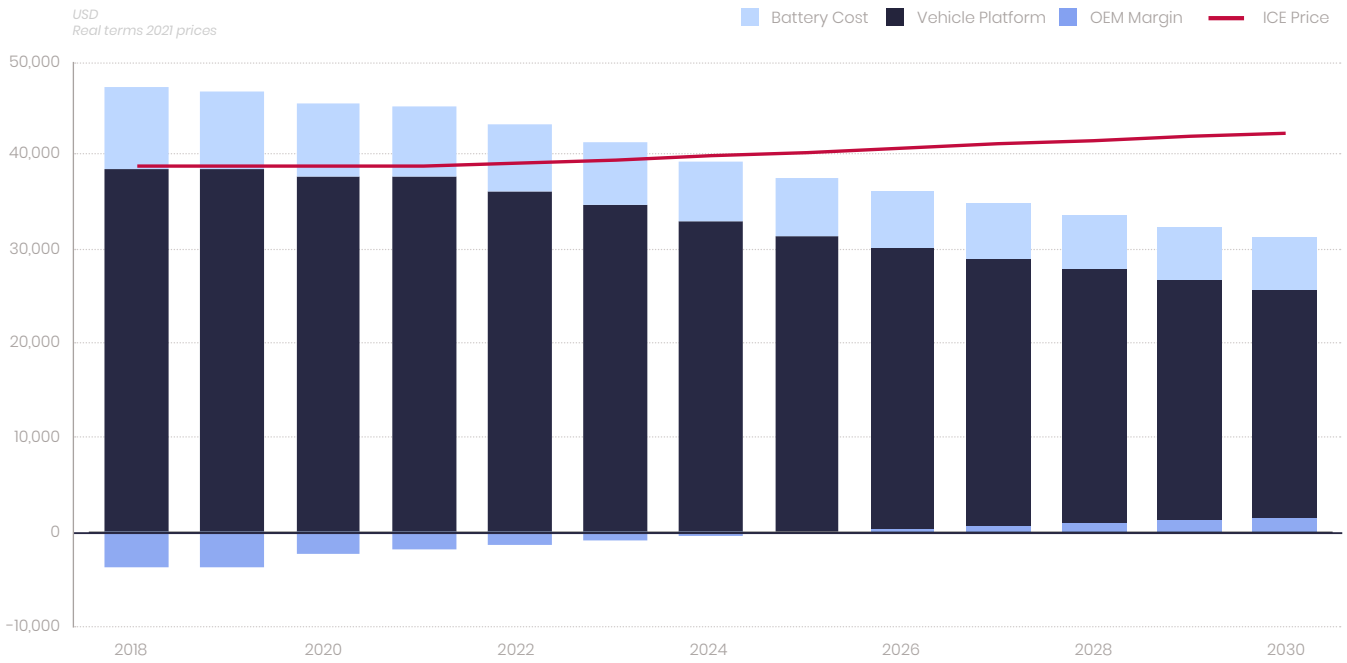


Chart: Rho Motion pricing analysis, medium segment BEV and ICE, new model releases, NCM622/712

Source: Rho Motion



with differentiation coming later. A more modular approach is required where small adaptations which fit in to a common framework allow for consistency of parts, manufacturing, and operation.

Modern Electric Vehicle Platforms

The ICE-adapted platform

Almost every legacy OEM's first modern electric vehicle falls into this category, VW fitted an ICE Golf with Li-ion batteries and an electric motor, Ford did the same thing to the Focus in 2011. A more refined version of this process still underpins most of EVs available today, more recently the Mercedes-Benz EQB has been released, like its sister the EQA this car is based on the MFA II platform developed for the A, B, CLA, and GLA-Class ICE vehicles and in production since 2017. The benefit of this approach is what has allowed the pace of EV adoption to become so rapid in the past few years, OEMs needed to be able to bring vehicles to market relatively quickly and using the tools already available is the best way to achieve this.

EV-dedicated platforms

EV-dedicated platforms are a ground up, blank page approach to the manufacture of an EV. It allows the OEM to integrate all components as effectively as possible without having to compensate for accommodating ICE components too.

The most obvious advantage of this is extra space in the cabin; wheel-base can be extended with less front and rear overhang due to the absence of radiators and engines. The floor can also be kept flat with only a battery beneath it. This then extends to the volume available in the boot and bonnet of the car – electric motors and power electronics can be more effectively packaged which has of course given rise to the 'frunk'. Additional features such as vehicle to load are also becoming common.

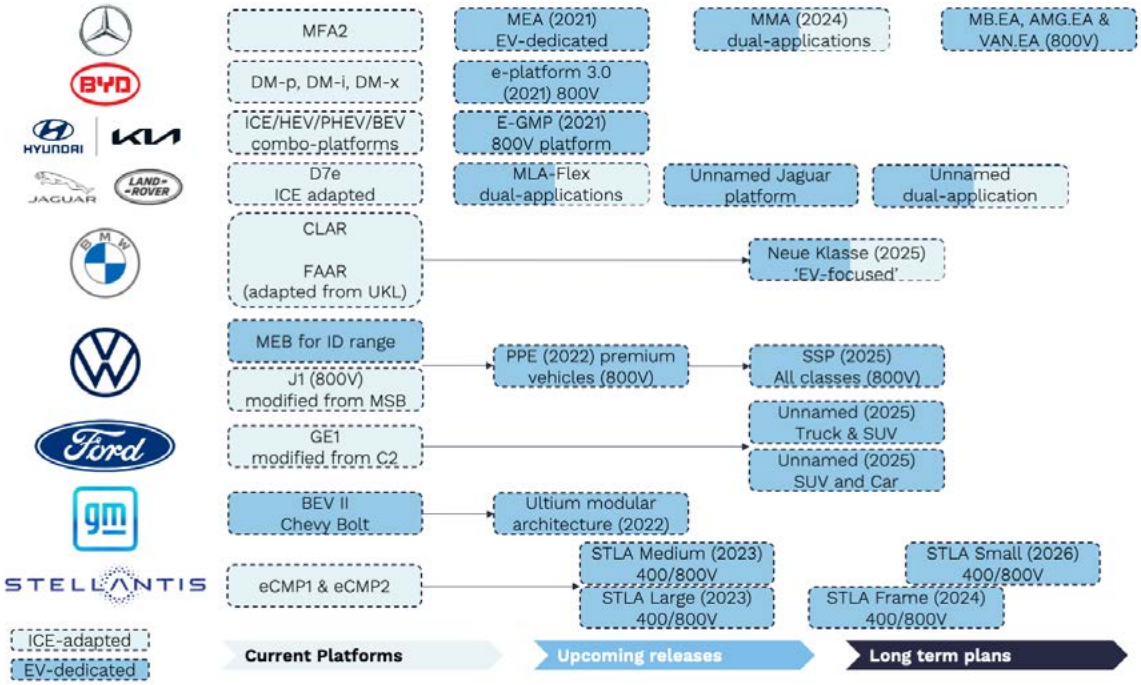
Beyond the spatial improvements, better efficiency can be targeted too, there are a lot of factors that can all be marginally improved to increase vehicle efficiency.

Aerodynamics may be easier to design around without having to make considerations for an ICE set-up, the more recent trend of additional air vents and ducts for aesthetics will likely disappear for some time as EVs strive to push down the coefficient of drag.

Ancillary systems are another major area for improvement, previously squeezing every drop of efficiency from the HVAC, powertrain cooling, infotainment and lights wasn't a priority as although it made a difference to overall fuel economy the cost-benefit didn't warrant extensive R&D. With EVs the potential savings of a 1% system efficiency improvement can be significant if it leads to a reduced battery cost. Designing an EV from the ground up allows more freedom to design integrated cooling systems – one of the most advanced of which is Tesla's 'Octovalve' in the Model Y, an eight-way valve central to the control of anything in the car which requires heating or cooling. Ditching any ICE integration allows innovation such as this to occur.

Chart: OEM electric vehicle platform roadmap

Source: Rho Motion



Hybrid application platform

This option lands somewhere in the middle, allowing OEMs to develop a platform designed to work for all powertrain configurations, but with full consideration from the start for electric vehicles. The EMP1 and EMP2 platforms co-developed by PSA and Dongfeng fulfill this role now for Stellantis. Hyundai-Kia has several models available with this full range of powertrains, these are based on hybrid application platforms developed on the back of ICE-only platforms the group already had. This has allowed maximum flexibility within those model's line-ups. The drawback of this approach is the limitations imposed on EV development as it must also accommodate an ICE set-up.

What are OEMs doing today?

OEM electric vehicle platform roadmap above illustrates the shift to EV-dedicated platforms, VW is already well underway with the transition through the MEB platform. Mercedes, Hyundai-Kia, and BYD have all launched their first EV-dedicated platforms this year with the EQS, Ioniq 5, and Dolphin respectively. Stellantis plan to adopt a family of common architectures under the STLA name with each variation defining the range of specifications available and STLA Frame providing a commercial vehicle body-on-frame architecture.

Jaguar Land Rover and BMW are still following a slightly different strategy, yet to commit to the full EV-dedicated platform. The new PHEV Range Rover is built on the MLA-Flex architecture, a development of the architecture built for the cancelled Jaguar XJ. In the future Land Rover will continue to use hybrid application platforms with the possibility of hydrogen powertrains as well. Jaguar is searching for an EV dedicated platform to fulfill the marque's 2025 goal to be 100% electric.

BMW plans to continue using the CLAR and FAAR platforms for now, developing an 'EV focused' platform by 2025 which can still be used for ICE applications.

Ford will move to two new flexible EV-only platforms later this decade and General Motors, who have been using an EV dedicated platform for the Chevrolet Bolt for some time, will begin using the Ultium platform from next year in the Cadillac Lyric.

What this means for adoption

EV dedicated platforms are beginning to join and will soon dominate the market, this is only going to be a good thing for EV adoption as vehicle's specifications improve while manufacturing complexity and cost falls for OEMs. This can also lead to new models of greater variation being developed as the modularity of these EV platforms is utilised to full effect. Going all-in on a modular EV dedicated platform allows the high cost of development to be shared over every BEV allowing the all-important price parity with ICE vehicles which consumers demand to be achieved.

What's keeping EVs from profitability?

David Hudson
Head of EV Strategy

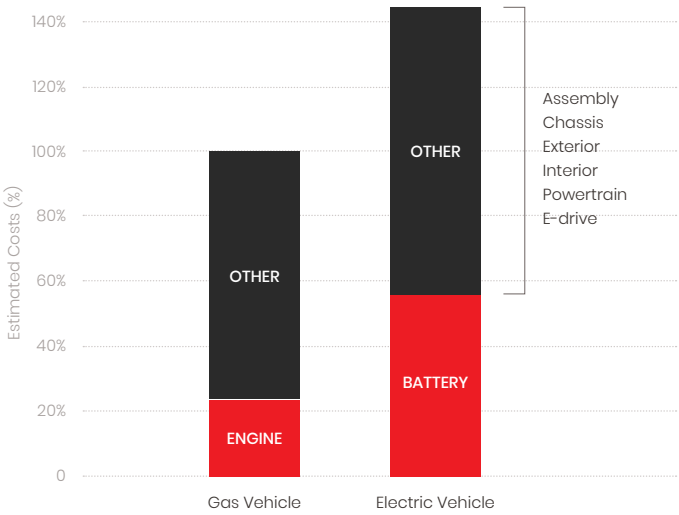
We know that the world is on the verge of a significant change, with a clear trend towards electric mobility. Governments are setting dates to end internal combustion engine sales and extend support for EV initiatives such as charging stations and consumer incentives.

But even without incentives, more consumers each year seem eager to embrace electric vehicles. Manufacturers follow their lead by investing billions of dollars in trying to fulfill these needs as well as government requirements.

According to Reuters, consumers spent approximately $120 billion on EVs in 2020, globally. But at the same time, governments provided subsidies of around $13 billion, which was "equivalent to around 10% of total spending, down from 20% of total spending in 2015." [1]

Chart: Estimated Vehicle Cost

Source: ePropelled



However, EVs cost more to manufacture than gas vehicles, which means that most OEMs do not make a profit from the sale of EVs[2] and, due to subsidies, producers only break even. The fact is that the cost-to-revenue ratio remains a serious challenge for manufacturers.

The battery pack

The most expensive component of the whole electric vehicle is its battery pack. In fact, BloombergNEF placed the average cost at $137/kWh at the end of 2020.[3] The average estimate of the battery pack cost when compared to the entire vehicle is 30%, which means that any cost to that component would be of enormous value to the manufacturers.

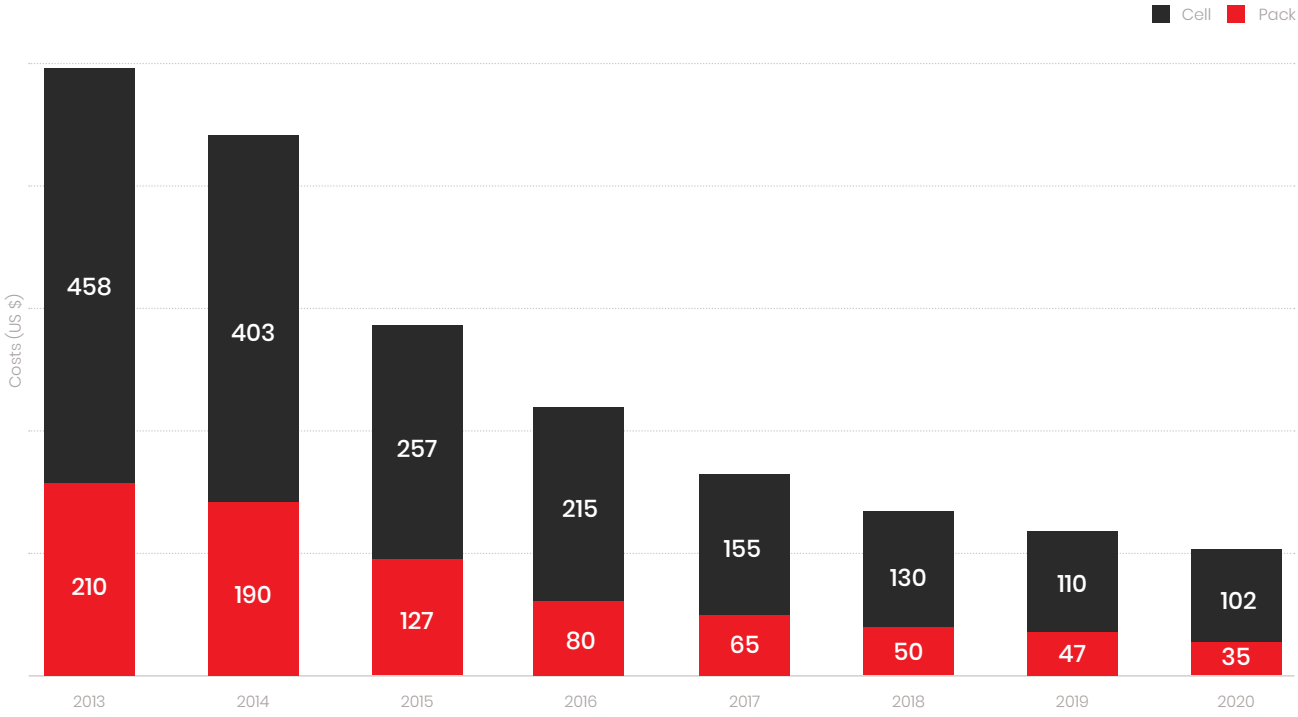
In general, high-tech goods tend to get cheaper as the manufacturing volumes increase, which is only partly true for batteries.[4] The dramatic early growth of the industry makes reaching earlier savings very difficult, if not impossible, because the law of diminishing returns seems to have well and truly set. The flattening curves provide clear proof of that.[5]

When it comes to the price per kWh of power, price reduction curves have flattened significantly, and

[1] Nick Carey, "(OFFICIAL) Global EV Sales Accelerating, but Government Help Needed–IEA", Reuters.com, last modified April 29
[2] "The Future of Mobility Is at Our Doorstep", McKinsey Center for Future Mobility, 2019
[3] "Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh", BloombergNEF, last modified December 2020
[4] Timoty B. Lee, "Battery Prices Have Fallen 88 Percent Over the Last Decade", arstechnica.com, last modified December 18, 2020
[5] Nic Lutsey and Michael Nicholas, "Update on Electric Vehicle Costs in the United States Through 2030", ICCT, 2019

Chart: Battery Cost Reductions are Flattening

Source: ePropelled



they will continue to do so. Battery costs are going to stop declining and it's no longer a question of if but of when. Even now the reductions continue by such small increments as to be almost insignificant. Ten years ago, they were dramatic, now they're barely visible.

Technological lag

The technology itself is also affecting this flattening curve. According to The Times, "A major technological breakthrough will be required to make electric cars much, much cheaper." Typically, when it comes to technology, any improvements contribute to a lower price. Unfortunately, such improvements take time and any improvements that make batteries more cost effective have not been serious enough to significantly affect the price curve.

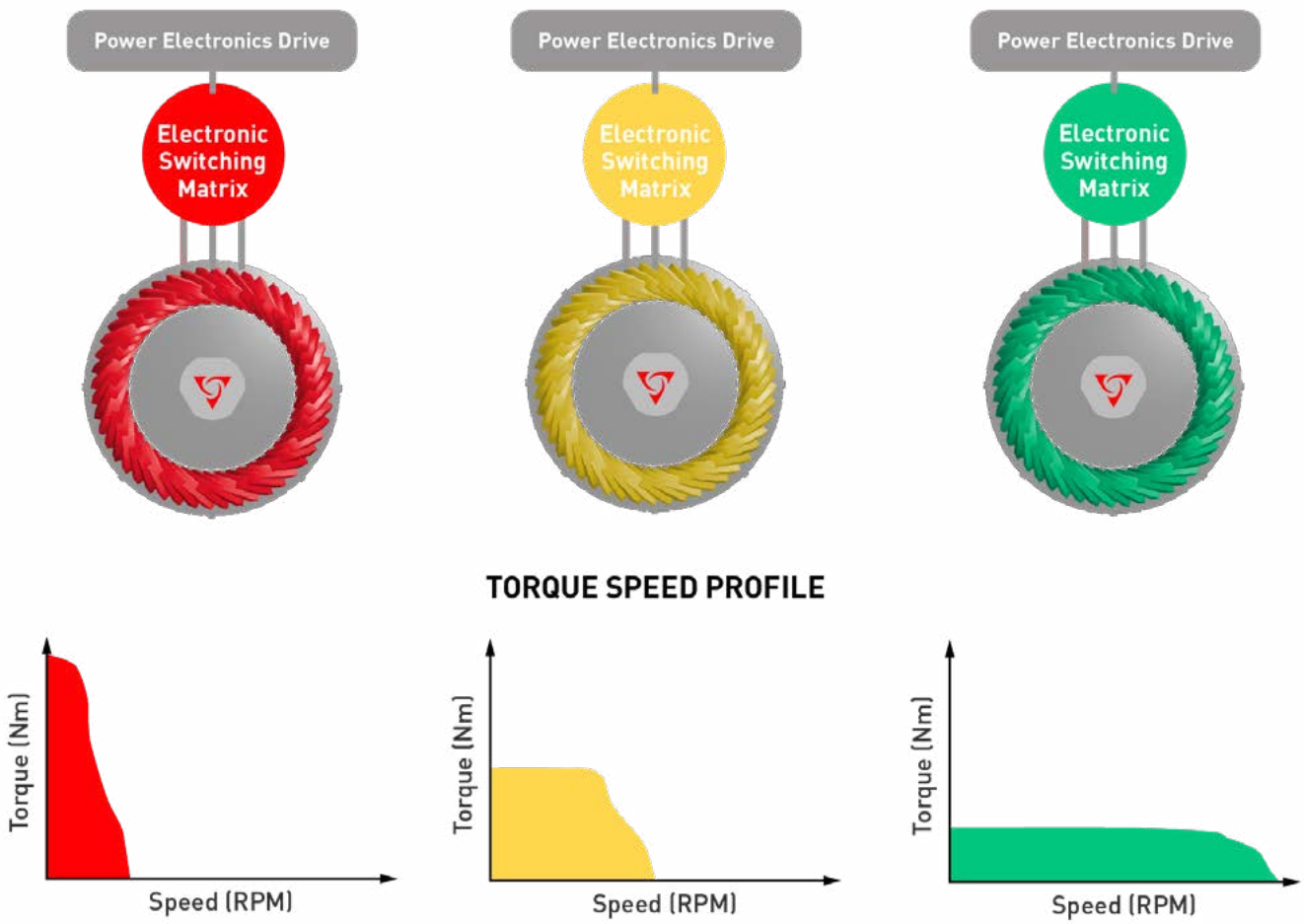
While looking for new technology, some manufacturers are reviving older battery types—more specifically, the LFP[6] (lithium-iron phosphate)—in vehicles that are very cost sensitive. Although these batteries display lower energy density, they do have the advantage of a good life cycle. They are also not negatively affected by higher temperatures, which makes a big difference in geographical locations such as India. From an end-user perspective, these batteries are also more socially acceptable as they contain fewer "conflict minerals."
But going back and searching through old battery types to find savings only highlights the fact that batteries are hard to improve upon. And even if it was possible to do so quickly, it would take time for these innovations to make it into viable product and then into vehicles.
While waiting for great technological breakthroughs in battery technology (that might not come for decades), it's important for manufacturers and independent innovators to keep redesigning engines, make them more efficient and, therefore, extend battery life and reduce its size.

Proposed solutions

Optimizing costs is always on manufacturers' minds and one of the main suggestions is decontenting. Among other choices, this could include removing some displays, wiring, buttons, switches, and some structural components. Another option is reducing design and feature complexity of the vehicle.

What is important to remember, however, is that simplifying the overall design can make the vehicle seem less impressive visually and, in the eyes of the potential buyers, could reduce the perceived value of the vehicle

[6] "The Latest Trends in Lithium-Ion Batteries", BNamericas, last modified June 28, 2019



by more than the actual price reduction brought by those changes. More importantly, such savings would not be as substantial as those achieved by improvements in battery prices and efficiencies.

Other suggestions for saving costs sometimes include reducing battery capacity to a level that would still offer the average optimal range needed by consumers—urban/suburban travel with occasional rural travel. However, offering consumers exactly the average optimal range means that any unexpected changes to their habits or needs would cause range anxiety and discourage them from purchasing such a vehicle.

Other ways of saving costs focus on how vehicles use energy to meet consumer needs and cut costs at the same time. Better aerodynamic designs, smaller tires, and lower overall weight can save energy and, therefore, battery life.

The battery pack is the main place for improvements. Battery size, its energy density, and life are the things to improve for cost reduction and profitability. Manufacturers need to look for new technologies that allow for reduced battery use because this would translate into either smaller battery packs for the same range or an extended driving range with the same battery size.

For example, systems like ePropelled's Dynamic Torque Switching (eDTS) technology—in which the speed and torque can be varied inside the motor in real time, delivering at least 15% in motor efficiency improvement—may not be widely used yet due to its very recent development, but they could be a huge step forward for the industry.[7]

There should be no need for manufacturers to choose between impressive interior and profit because the right motor technology can reduce the costs of the most expensive component in their vehicles—the battery. This will finally allow them to meet consumer preferences for size and range, stop relying on subsidies, and start making profits.

[7] "Product Overview: Dynamic Torque Switching", ePropelled, September 2021

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The electrification of heavy-duty trucks in China

Photo: Nigel Tadyanehondo

Yu (Frank) Du
Research Analyst, Rho Motion

According to the National Bureau of Statistics of China, 111.67 million tonnes of diesel and 60.68 million tonnes of petrol were consumed in the transportation and logistics sector whereas, only 35.04 million tonnes of petrol were consumed by residents. In other words, private vehicles only account for roughly 16.9% of total energy consumption. In order to achieve China's 2060 carbon neutrality pledge, actions have to be taken to accelerate the usage of clean energy in the transportation and logistics industry.

Over the years, several policies have been issued to support the electrification of commercial vehicles in China. A good example would be the Ten City Thousand EV act in 2009, where the government provided subsidies to ten selected cities to launch and operate one thousand NEV in each city in a three-year period. As a result, there has been some progress in electrification of buses. In 2018, Shenzhen became the first large city in the world that operates only electric buses. Currently, over 90% of global electric bus sales happen in China. However, the electrification progress of heavy-duty trucks is not as smooth as that of buses. The penetration rate of electric HD trucks is struggling to reach 1% and there are several bottlenecks that need to be resolved.

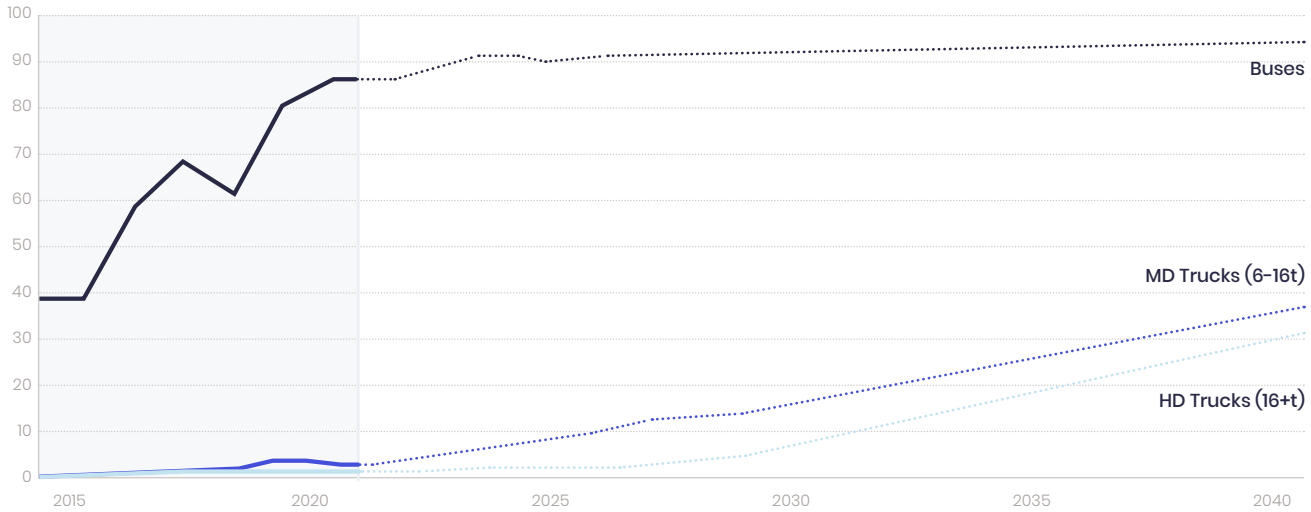
In general, there are three main reasons that stop companies switching to new energy trucks.

High Price

The current models are too expensive even with subsidies. While the total cost of ownership may be competitive,

Chart: Penetration Rate of Chinese Market by Vehicle Class

Source: Rho Motion



the large initial investment can cause significant concern to fleet operators and truck owners. For BEV models, the price difference is mainly caused by the large battery pack, which accounts for over 35% of the overall vehicle cost. For fuel cell models, the higher price comes from the less developed supply chain and the current technology limitation.

Heavy Unladen Weight

An average LFP battery pack for heavy duty trucks can weigh 2~3 tonnes. Given the maximum authorized mass is fixed, electric heavy-duty trucks carry less load than traditional ICE HD trucks. In addition, the large battery pack may cause design issues because the vehicle still needs to follow the length, width, and height restrictions. In short, for the same HD truck, the driver may deliver fewer products each trip if they choose a BEV over an ICE model.

Low Charging Speed

Except for some special applications, the power of most common DC chargers in China is 60kW at the moment. That means it takes over four hours to fully charge an electric HD truck with a 250kWh battery pack. Commercial fleets must make sure that all their trucks are on road as much as possible. Additionally, it is very common to have two drivers take turns to drive for long-haul trips. So, a four-hour break for charging every 350km is even harder to accept in the transportation and logistics industry.

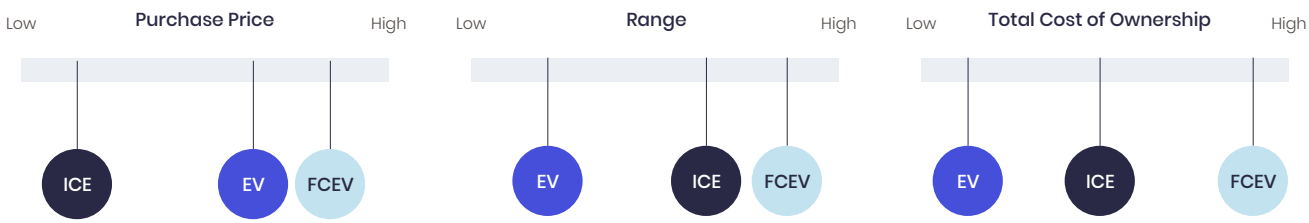
To tackle these issues, the Chinese government has started working with the industry to explore possible solutions. Although some seem more developed than the others, all solutions for accelerating HD truck electrification are in the early stages.

Battery Swapping

Battery swapping is one of the most popular topics in China. With the BaaS (Battery as a Service) business model, battery swapping technology can significantly reduce the initial purchase price of HD trucks and eliminate the waiting time for charging. Taking Geely as an example, it only takes 5~10 minutes to complete the battery swapping service. The average battery life

Chart: Vehicle comparison: Fuel cell, battery & ICE

Source: Rho Motion



increases by 10% because of the centralized slow charging. Geely is also working with GCL Energy Technology to build 60 truck battery swapping stations and sell more than 3,000 battery swapping HD trucks over the next three years. Other major OEMs, such as Dongfeng, SAIC, Foton, and FAW, also have plans for their own battery swapping HD truck models.

However, nothing is perfect. Battery swapping technology has its own drawbacks. The biggest road blocker is the heavy initial investment of the battery swapping network for HD trucks. If one station carries ten 250kWh battery packs, the cost of the packs alone is above RMB 2 million (~USD 310,000) and the overall cost can easily go above RMB 3 million (~USD 470,000). As the range goes up, the size of the battery packs will increase, driving up the initial cost of a battery swapping station. Another issue is the non-standardized battery packs. This means that the battery swapping network cannot be shared amongst different OEMs.

Fuel Cell Hydrogen Technology

Fuel Cell vehicles are another promising solution to the electrification problem of HD trucks. FCEVs have nearly the same range as a traditional ICE vehicle and the hydrogen refilling takes just about the same amount of time as refueling diesel. Furthermore, FC trucks can operate in low-temperature environments and the FC system is much lighter than a battery pack. Currently, all major HD Truck OEMs have launched at least one fuel cell model in China. However, the sales of FC HD trucks are very low.

The key issues with Fuel Cell vehicles are the hydrogen supply and the refilling network. As shown in the figure below, the hydrogen supply chain is long and very different from the current Li-ion battery supply chain. In other words, the industry must establish a new supply chain and a new hydrogen refilling network.

Supercharge Technology

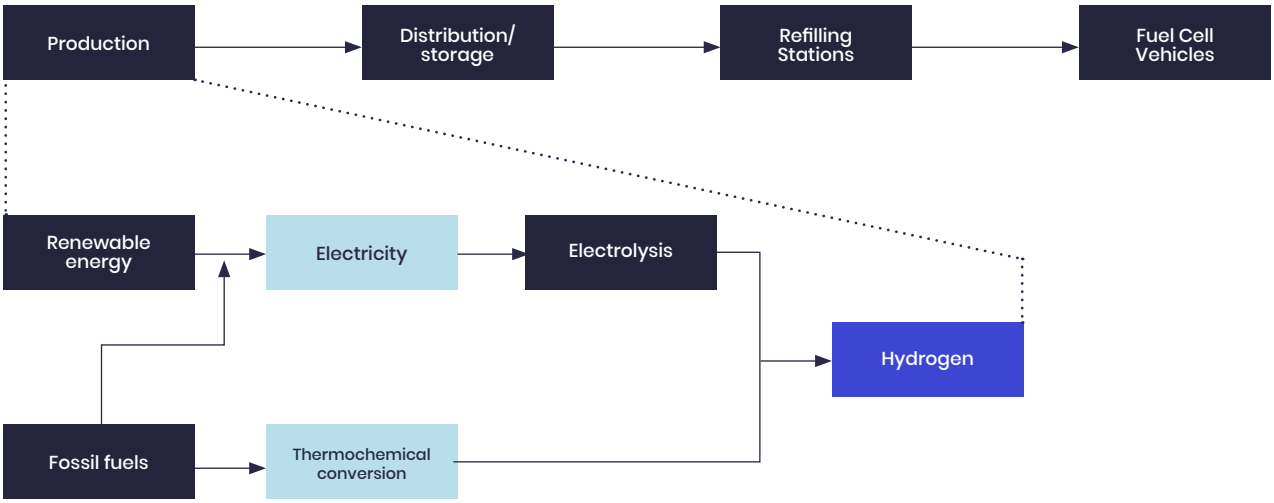
Lately, more and more OEMs have launched 800V charging technology for passenger vehicles. With a high voltage EV platform, the charging power has reached 480kW (GAC and XPeng). If supercharge technology can be used on electric trucks, the waiting time for charging will be reduced from around four hours to less than an hour. Although not as fast as refueling diesel, supercharging can bring the waiting time down to a more acceptable level.

At the moment, the technology is still under development, and it may not make sense economically when it comes to HD trucks. The extra cost from switching to a high voltage platform and upgrading the battery pack can drive up the already high price. Moreover, it will take a long time to build up the supercharging network.

In all, the electrification of heavy-duty trucks is an essential part of China's 2060 carbon neutrality plan. The government is betting on all possible technology solutions and providing support whenever possible. Because of the huge market in China, a winner-take-all situation is unlikely to happen. In the future it is possible we will see a range of solutions in operation, such as fuel cell trucks operating in the northern regions where the wintertime temperature falls well below zero. In the warmer, more densely populated parts of the country battery electric trucks and swapping stations may be more viable.

Chart: Fuel Cell / Hydrogen Supply Chain

Source: Rho Motion



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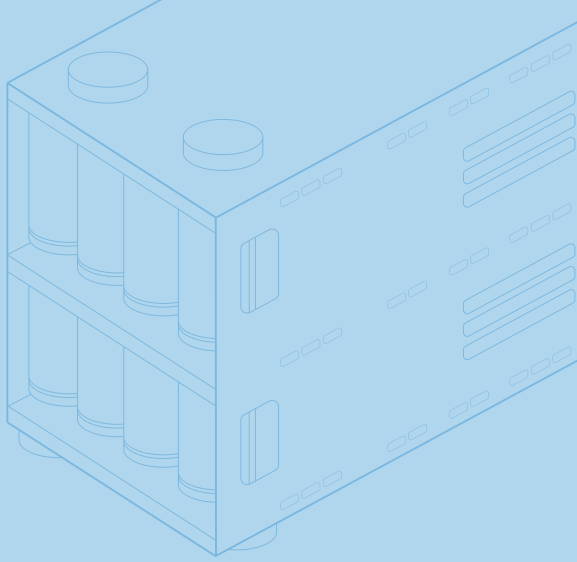

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Photo: Sid Verma

Fuel cell EV demand recovery and its long-term growth

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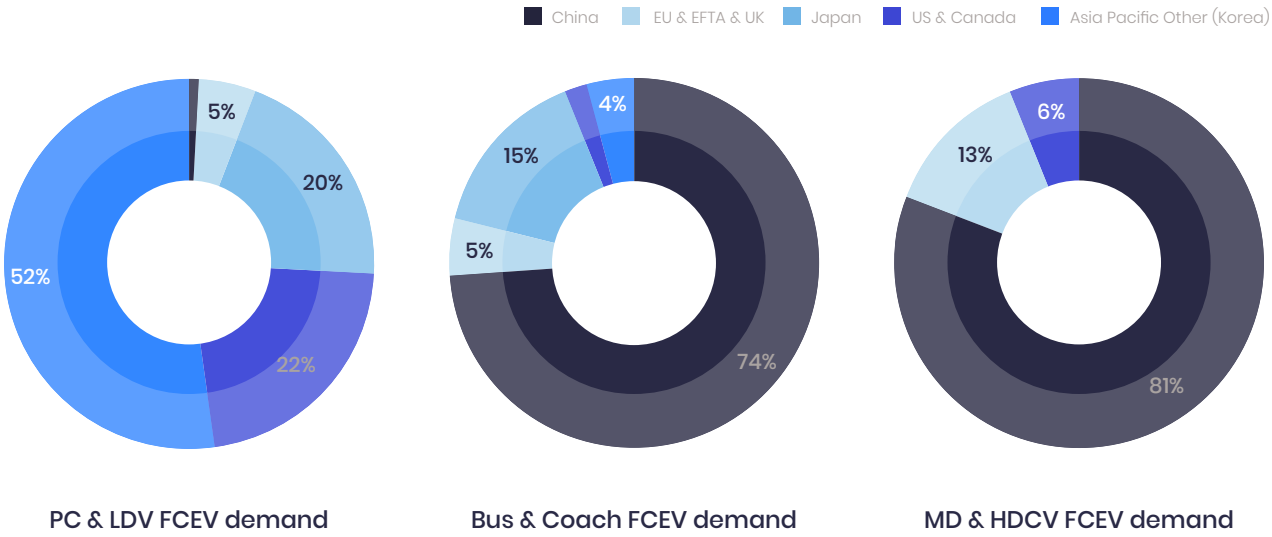
The fuel cell electric vehicle (FCEV) market is starting to rebound to the pre-pandemic growth level in 2021 largely owing to an increase in passenger car and light duty vehicle (PC & LDV) demand. The FCEV market is expected to continue to grow although at a limited speed in the long term, facing challenges including insufficient infrastructure, high costs and technology developments.

Chart: Fuel cell EV demand by region in 2021

Source: Rho Motion



The fuel cell electric vehicle (FCEV) market has begun to show signs of recovery this year after a slowdown caused by the pandemic. FCEV sales between January and July in 2021 reached over 11,000 units, surpassing the full-year sales in 2020. The largest year-on-year growth was seen in passenger car and light duty vehicle (PC & LDV) sales, which took 86% of total FCEV sales.

The PC & LDV FCEV demand is largely led by the South Korean market with significant support from the state and local governments and investments from Korean OEMs. In Korea, the overall FCEV budget of the state government rose by 62% year-on-year to 257.4 billion won ($220 million) in 2021, providing a subsidy of 22.5 million won ($19,300) per vehicle. In addition, the local governments offer subsidies between 9 million and 15 million won ($7,700-$13,000) per vehicle. However, further growth in the Korean market share is expected to be limited in the long term as the Chinese market, where FCEV PC & LDVs sales were witnessed for the first time this year, is expected to grow.

As for the heavier classes including medium and heavy-duty commercial vehicles (MD& HDCV) and bus & coaches, sales were largely driven by pilot schemes, such as the use of Toyota's new hydrogen fuel cell bus, the Toyota Sora, at the Tokyo Olympics. FCEV demand for

Chart: Advances in fuel cell technology within the Mirai

Source: Rho Motion

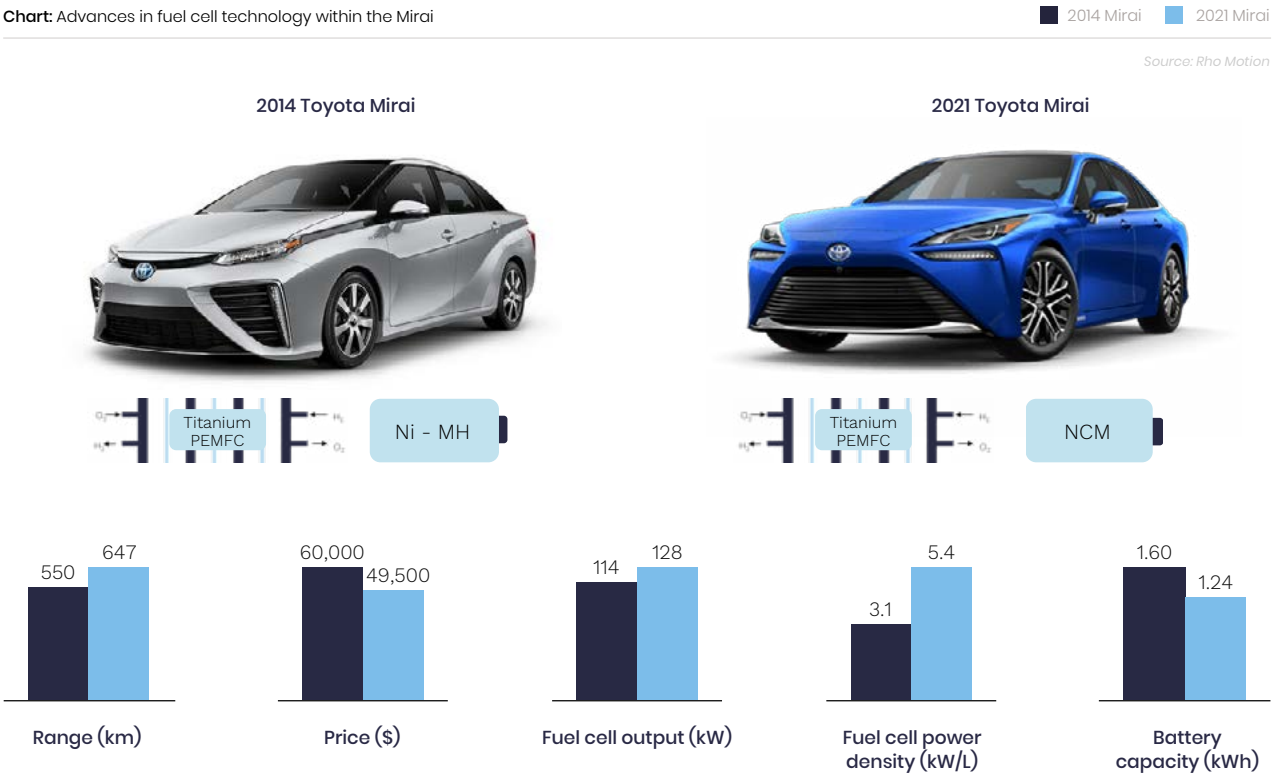
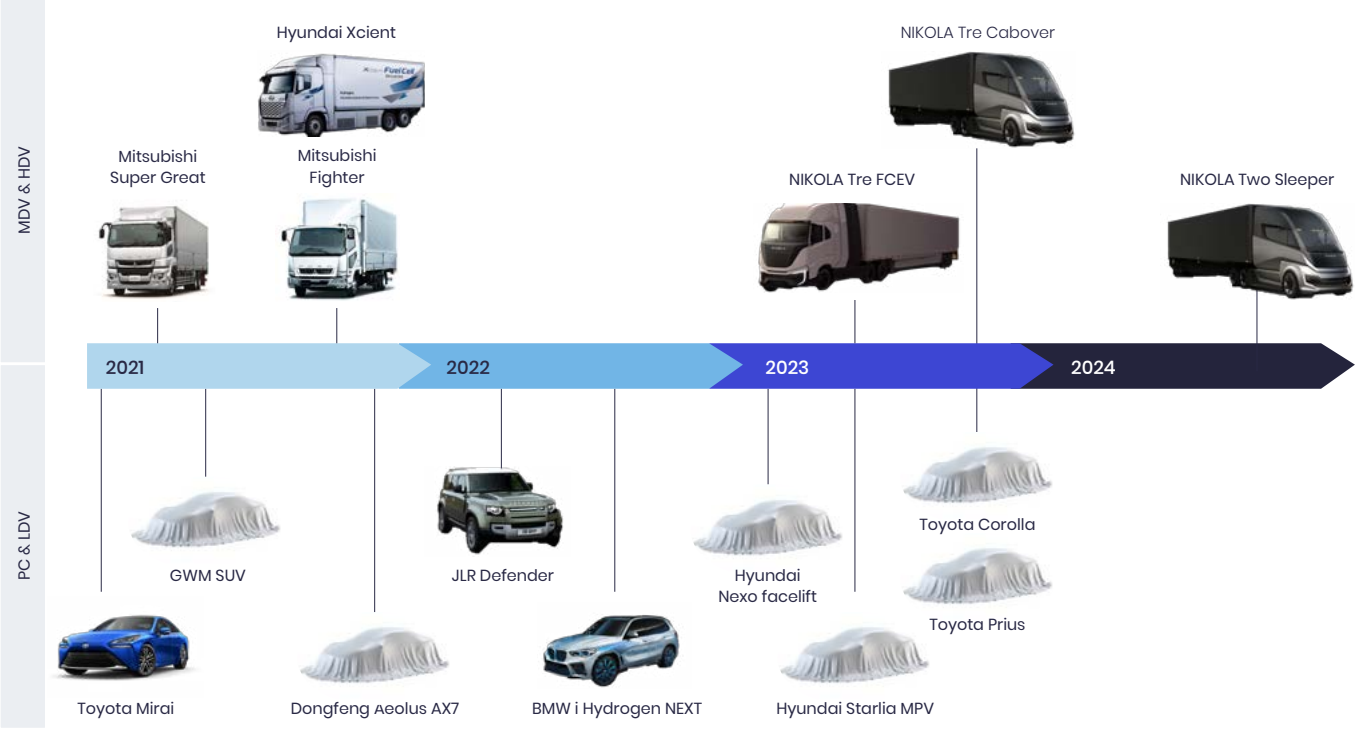


Chart: Upcoming Hydrogen Combustion and Fuel cell EV models, 2021 - 2024

Source: Rho Motion



those segments comes largely from China, taking up over 70-80% of the global demand. While China is expected to continue being the largest market for MD & HDCVs and bus & coaches, other markets are set to increase their market share in the long term as government supports and hydrogen refueling infrastructure increase.

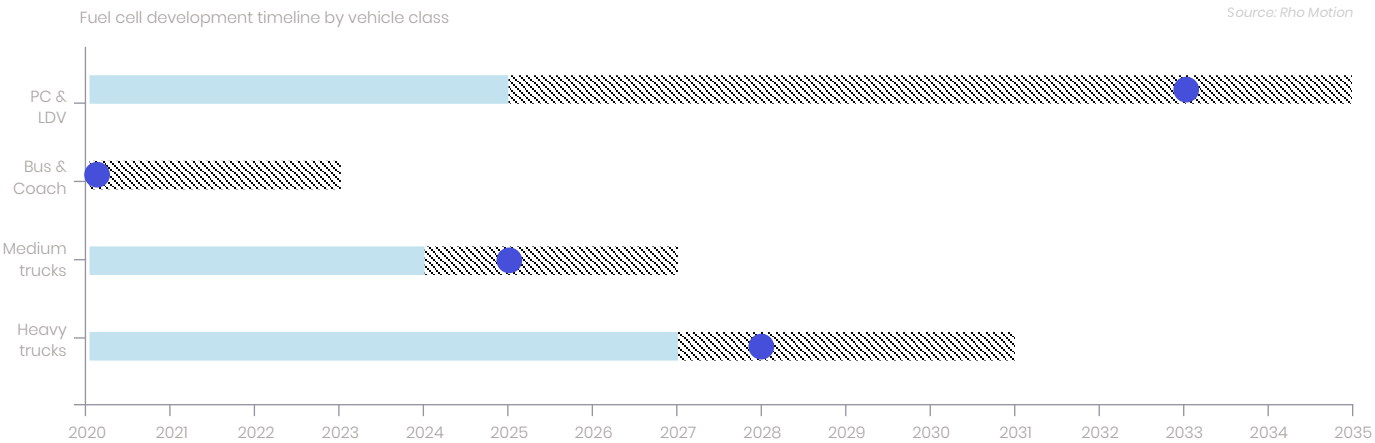
FCEV market competition rises with new entrants

The PC & LDV FCEV market has become more oligopolistic after Honda decided to discontinue the Honda Clarity this year due to weak demand. Hence, only two models, the Toyota Mirai and Hyundai Nexo, remain widely available in the current market. Toyota and Hyundai are continuing investments in their FCEV production and developments to remain dominant.

Toyota plans to increase its annual production capacity of FCEVs to 30,000 units, which is 10 times the current capacity. The Japanese OEM first launched Toyota Mirai in 2014, selling mainly in the US and Japan. In April 2021, Toyota

Chart: Fuel cell EV development timeline

Source: Rho Motion



Commercialisation process including FCEV development, testing & OEM qualification, and vehicle design and concept

Market acceptance: FCEV sales >1% of total sales when aggregating sales from EU & EFTA & UK, China, Japan, Korea, and North America

Downside including battery chemistry technology advances, refilling station scaling and ongoing challenges over FCEV efficiency and costs

Photo: Han Chenxu

launched its newly improved second-generation Toyota Mirai, offering a higher range and greater efficiency at a lower cost compared to its predecessor. Its fuel cell is claimed to be 50% lighter and smaller, yet 12% more powerful.

Hyundai announced its PC & LDV FCEV roadmap this September: its next-generation NEXO by the end of 2023 and a large SUV FCEV model after 2025. Its affiliate Kia also announced in the same month to enter the PC & LDV FCEV market by 2028. Likewise, Genesis models are expected to fully run on batteries and fuel cells by 2030.

Chinese OEMs including Great Wall Motors (GWM) and Dongfeng plan to continue investing in hydrogen R&D and launching new models: GWM is set to roll out its first C-class hydrogen FC SUV as well as 100 FC heavy-duty trucks this year. Further investment of 3 billion yuan ($464 million) in hydrogen R&D is planned over the next few years, following its investment of 2 billion yuan ($309 million) to date. Dongfeng also plans to launch a new model, Aeolus AX7 FCEV, equipped with an 80kW FC system, in China in 2022. Besides, Hyundai Group announced its strategy to launch 21 electrified models including FC vehicles in China by 2030. Its FC system plant in Guangzhou, China, which is coming online in 2022, is expected to support the strategy.

Toyota and Hyundai are also increasing MD & HD FCEV production capacity: Hyundai plans to offer hydrogen FC versions for all its trucks and buses by 2028 with an aim to cut the commercial vehicle prices to BEV levels by 2030 by lowering cost of FC systems by half from the current level. In August 2021, Toyota announced its plan to start assembling FC modules for its HD commercial vehicles at its Kentucky plant in 2023.

Nikola will be entering the HD FCEV market with its new models, Nikola Tre Cabover and Nikola Two FCEV Sleeper: The Two FCEVs with a 1,450km range are expected to be produced in Q3 2024 followed by the Tre Cabover FCEV with an 805km range in mid-2023.

Th limited growth of the FCEV market

In our Fuel Cell Electric Vehicle Outlook 2021 report, we estimate the FCEV development timeline covering the commercialisation process, market acceptance and downside. The heavier classes are expected to expand their market shares relatively faster than PC & LDV mainly owing to greater use cases. Relatively higher costs of PC & LDV FCEVs and advanced battery chemistry technology are expected to result in slow demand growth in major markets including Europe, China, and North America.

We forecast the FCEV penetration rate growth to remain stagnant in the long term, due to battery electric vehicles being dominant, and challenges associated with FCEV adoption. The PC & LDV FCEVs forecast to show the lowest penetration rate among other vehicle classes mainly due to the limited refueling infrastructure and fuel costs that are higher than fossil fuels and electricity used for battery electric vehicles. The higher penetration rate is expected to be seen in the heavier classes at 3% globally on the back of greater use cases by providing enough range for long haul trucking with ease.

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