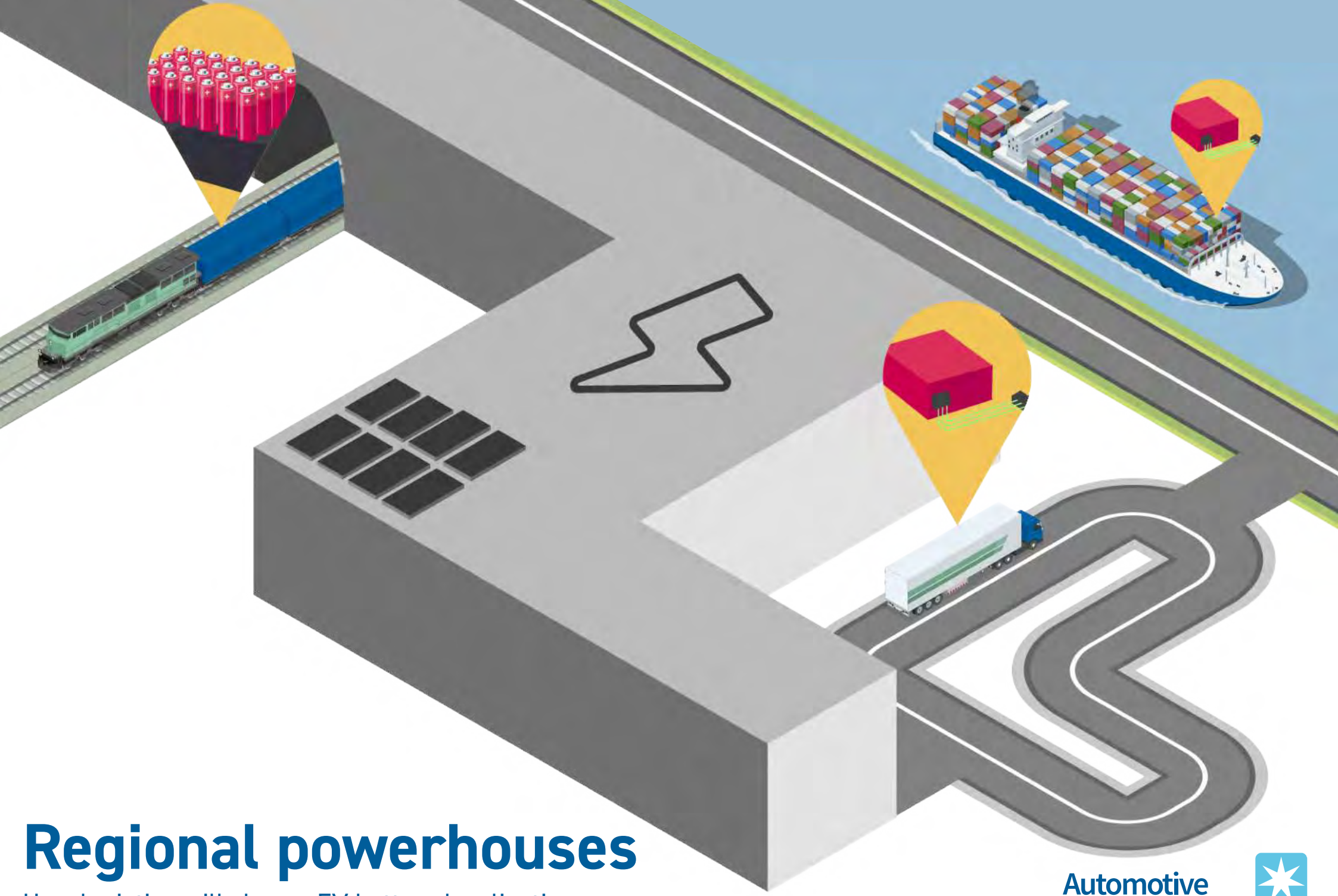

Regional powerhouses

How logistics will charge EV battery localisation

Automotive LOGISTICS

MAERSK

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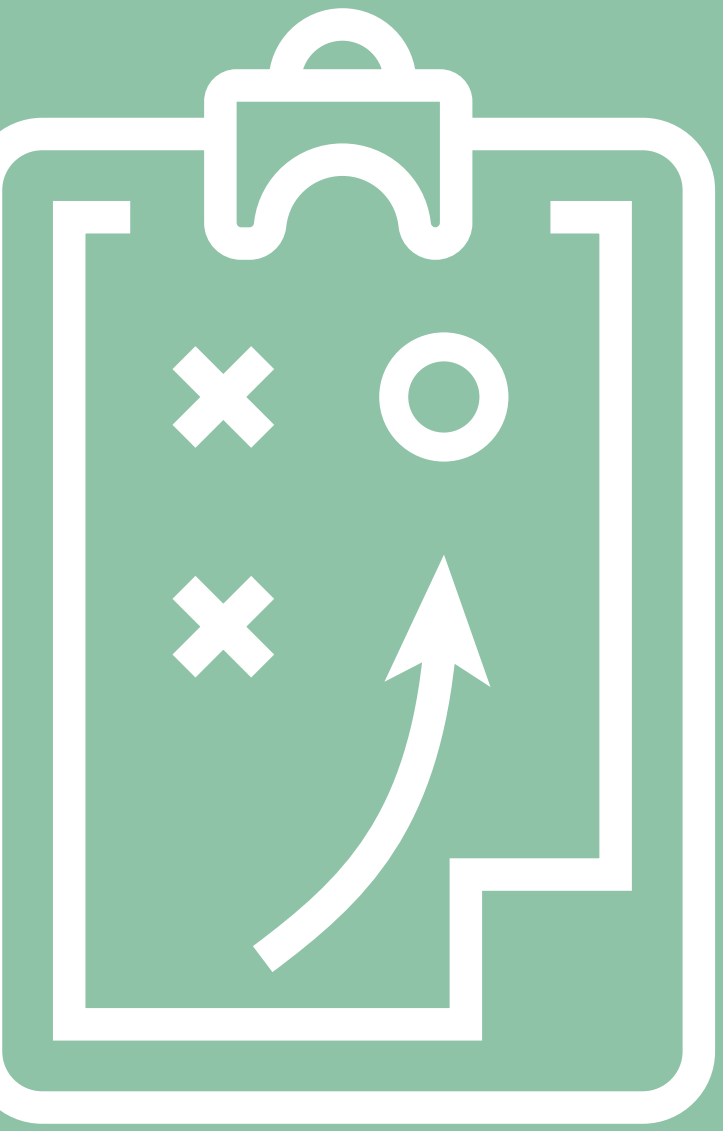


Introduction – The supply chain's greatest opportunity

Global climate change mitigation policies have been the overriding driver of electrification in the automotive industry, with emission regulations compelling automotive OEMs to produce and sell more low- and zero-emission vehicles. However, while regulations are pushing electrification, carmakers' ability to transition manufacturing at scale will depend on planning, efficiency and availability in the supply chain, especially for lithium-ion batteries.

A large share of new vehicles in major regions like China, Europe and North America are set to have more electrified powertrains over the next two decades – including hybrid, electric and hydrogen fuel cell vehicles. To achieve these plans, manufacturers will need to invest significantly in battery gigafactories across regions as well as to further ramp up the supply chain of upstream materials, minerals and energy sources.

With much of the current value chain for powertrains set to change, the risk is that critical parts and technologies won't keep pace with demand. Disruption in the wake of Covid-related lockdowns, including shortages of semiconductors, materials and labour, have shone a light on the critical role of supply planning across the automotive industry, and the importance of inventory visibility in storage, transit, production and the order pipeline. Shortages in the battery supply chain could eventually impact automotive production to an even greater degree than the semiconductor crisis, which led to lost production of more than 10m vehicles in 2021.

Meanwhile, the increase in EV and battery production will occur even as the internal combustion engine (ICE) represents a majority of new vehicle output for at least the next decade in most markets. OEMs and suppliers will need to manage a more complex powertrain mix, while also reacting quickly to engineering changes based on new and evolving regulations. That will in turn require more flexibility and agility in assembly processes, supply chains and logistics.

“When we define what our value chain will be, it will look nothing like the value chain that exists today.”

Shilpan Amin,
General Motors

Designing battery supply chains and logistics from the ground up

Meeting the growth opportunity of the battery supply chain while adapting to rising complexity will be an existential requirement for OEMs and automotive suppliers.

Existing OEMs will need to retool their ICE manufacturing facilities and supply chains for electrified powertrains to avoid widespread obsolescence, waste and job losses across global operations.

Startup manufacturers, too, will have to work together with the right partners to increase output and produce electric vehicles efficiently, even where they may lack the scale and established processes of existing OEMs.

Both established and startup OEMs, meanwhile, will need to work with suppliers and logistics partners to manage the battery supply chain sustainably, including by reducing emissions in production and transport and using more recycled materials.

As GM’s vice-president of global purchasing and supply chain, Shilpan Amin has said, as OEMs and suppliers make these changes across operations, products and suppliers, things simply won’t look the same. “When we define what our value chain will be, it will look nothing like the value chain that exists today,” he said.

An agile and resilient supply chain will be central to scaling up battery production. That is why OEMs are partnering with cell and component suppliers for their technology as well as for their production and delivery capabilities. They want to be sure that these companies will be able to meet their needs.

The expansion of regional battery manufacturing – especially beyond its current concentration in Asia – will be part of a strategy to secure and diversify supply, manage inventory levels and reduce emissions.

OEMs are increasingly considering total supply chain and logistics network design to make the most of this regionalisation, including proximity to clean energy sources, major port and transport hubs for global materials, local supplier proximity and specialised regulatory requirements in the handling of specific chemistries in the battery production and logistics process.

Strategic logistics design and partnerships

In scaling up battery production, manufacturers are also focused more on efficient integration of complete battery packs, including cell configurations, engineering processes for enclosures and final assembly. Logistics and handling are key to managing inventory levels, transport costs and line-feeding strategies. In response, OEMs are co-locating battery pack production with vehicle assembly, and sometimes even with cell manufacture, to reduce logistics cost and increase automation of supply.

In designing such complex supply chains from the ground up, OEMs and battery manufacturers have opportunities to work more closely and earlier in the process with logistics experts and lead logistics providers (LLP). Such partnerships can help to integrate global and regional transport services, consolidate materials and component consolidation, select warehousing locations and material handling equipment.

This joined-up approach can help improve visibility and ensure total cost considerations in manufacturing decisions. It can also benefit sustainable supply chain strategies, for example by choosing lower emission routes, and integrating closed-loop material cycles and recycling. In other words, such partnerships provide OEMs and suppliers with the chance to use this once-in-a-century transformation to redefine supply chains to be more resilient, responsible and ethical.

Battery supply chain developments

Supply chain regionalisation

Battery cell manufacturers are expanding in Asia, Europe and North America to diversify supply, reduce transport costs and lead times, and improve resiliency

Integrated battery pack production

Manufacturers are localising modules and packs near or within vehicle assembly plants to reduce logistics costs and increase flexibility

Logistics network design is key

Logistics engineering is helping battery manufacturers to consolidate freight, optimise transport modes and inventory, including buffer stock locations

LLPs for battery supply chains

Lead logistics providers have a unique chance to support integration of battery production from early phases, improving capacity management and transparency across the end-to-end supply chain

Smart and sustainable

OEMs are increasingly developing battery supply chains that are sustainable, reducing emissions and energy in production, and increasing recycling of key materials

Chapter 1

Ramping up regional battery supply chains

Forecasts for electric vehicle powertrains and battery gigafactory capacity point towards significant expansion of battery cell production and supply, but diverging across regions

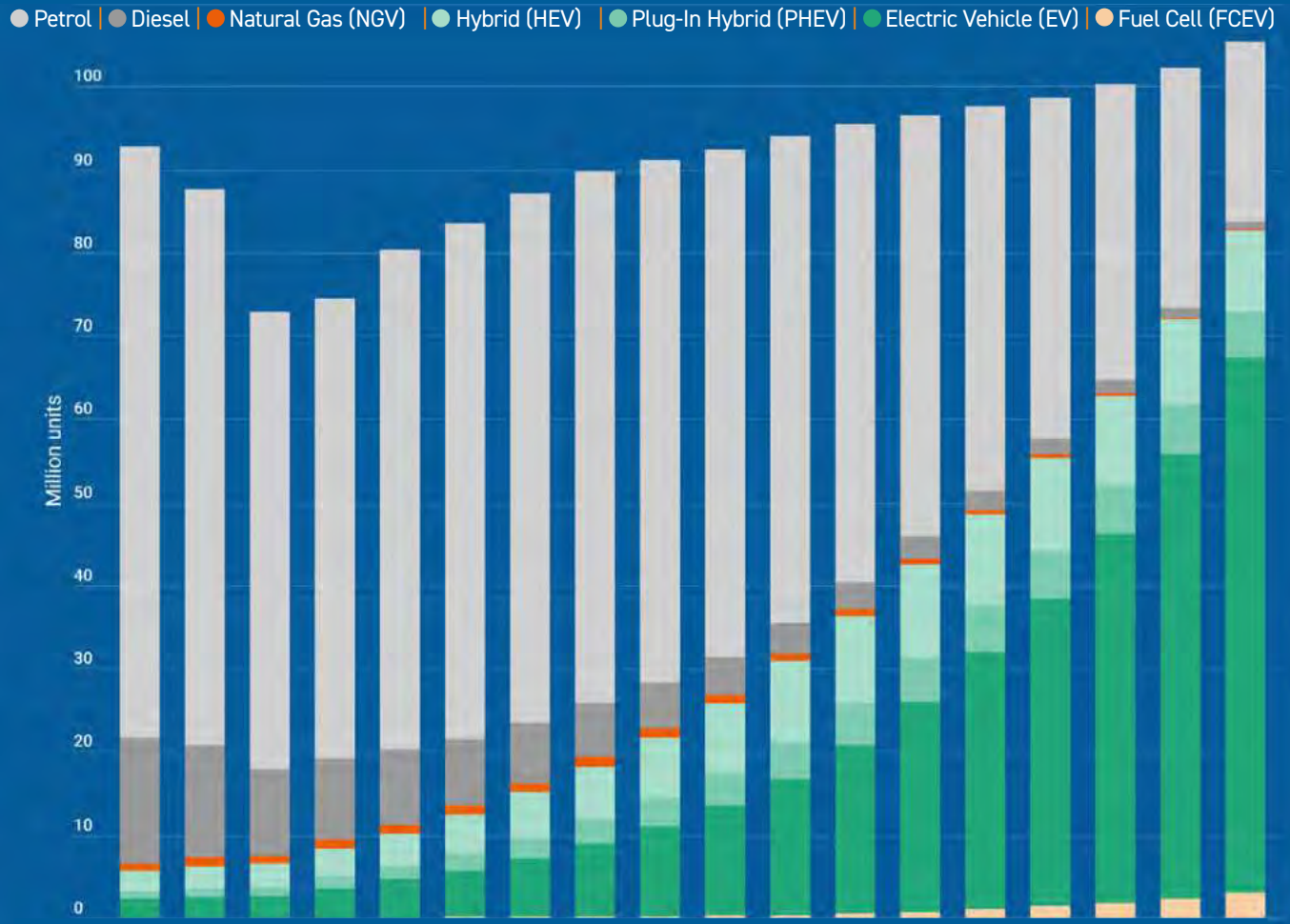
Electrified vehicle sales and production have accelerated over the past three years even as overall output declined following the pandemic and subsequent component shortages. Global pure EV sales volumes reached 3.6m units in 2021, a growth of more than 60% in the period, while in Europe they have more than trebled. Sales of hybrids and plug-in hybrids have also doubled over the past three years.

With emissions regulations tightening, and more countries setting EV targets and dates to phase out sales of new ICE vehicles, growth in electrification will move into another gear. Global volumes of pure electric vehicles are expected to increase by nearly nine times over the next decade to surpass 30m units by 2031. And although hybrid vehicles may serve as transitional technology, volume is also forecasted to treble in the same period to more than 16m units per year. At the same time, ICE-based volume will steadily decline.

This rise in electrification will reshape and redevelop the battery supply chain, including regional production locations and new OEM and supplier relationships. John Andrew Carmichael, head of automotive at shipping and logistics giant Maersk, noted that batteries will drive significant regionalisation through regulatory and logistical imperatives.

“The key regionalising component is the battery,” said Carmichael. “That is a trend accelerated through geopolitical tensions but also through supply chain challenges.”

Global Light Vehicle Production Forecast by Powertrain 2018-2035



	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Petrol	71.1	66.8	55.0	55.3	60.0	62.1	63.6	63.9	62.9	61.0	58.4	55.1	50.7	46.3	41.1	35.5	28.8	21.6
Diesel	15.1	13.6	10.4	9.7	9.0	8.0	7.2	6.4	5.5	4.6	3.8	3.2	2.6	2.2	1.8	1.5	1.2	1.0
NGV	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.1	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2
HEV	2.4	2.7	2.8	3.4	3.9	4.6	5.4	6.3	7.3	8.5	9.7	10.5	11.2	11.1	11.1	10.7	10.3	9.6
PHEV	1.0	1.1	1.1	1.4	1.7	2.1	2.5	3.0	3.4	3.8	4.4	5.0	5.4	5.5	5.8	5.9	5.9	5.6
EV	2.2	2.4	2.6	3.5	4.5	5.6	7.0	8.7	10.7	13.2	16.3	20.2	25.1	30.9	37.0	44.4	53.4	64.3
FCEV	0.03	0.04	0.04	0.06	0.08	0.11	0.14	0.19	0.25	0.33	0.44	0.59	0.79	1.03	1.35	1.77	2.32	3.06

Source: Automotive from Ultima Media, AAM, ACEA, ANFAC, ANFAVEA, ANFUA, CAAM, CCFA, EIA, JAMA, KAMA, OICA, SIAM, SMMT, VDA
*Light vehicles include passenger cars and commercial vehicles under 6 tonnes

Batteries beyond Asia

Today's lithium-ion battery industry is in many ways rooted in consumer electronics. Sony commercialised the first lithium batteries in 1991, technology which would be dominated by electronic giants including South Korea's LG and Samsung, and Japan's Panasonic. These companies have become prominent players in automotive lithium battery production, and by 2020 more than 77% of global lithium battery cell capacity was located in Asia.

During the last decade, as EV production volume remained low in the US and Europe, it made sense for OEMs to import batteries from existing production bases, often working in exclusive supply agreements with battery cell manufacturers. Even where OEMs localised cell production or battery pack assembly, a large share of parts were still imported from suppliers in Japan, South Korea and China.

Increasingly, with EV sales and production on the rise, these parameters are changing, with a strong need for regional production, and more diversity of supply agreements. Shipping lithium-ion batteries is further complicated by their designation as dangerous goods, requiring special certification and equipment.

Today, the pipeline of battery gigafactory capacity is growing, with new and established players expanding their presence in key markets.

Growth on a giga scale

To meet the growing demand for electric vehicles, gigafactory production capacity will need to rise annually by around 25% every year for the next two decades. EVs will drive the largest share of this demand, with further requirements from consumer and storage.

However, battery supply chain regionalisation will occur at different speeds, expanding fastest in China and Europe, more moderately in North America, and more slowly in emerging countries within Asia, Africa and South America.

What follows will be significant capacity growth and new gigafactories, but heavily weighted towards regions with faster EV penetration.

According to Automotive from Ultima Media, the business intelligence unit of *Automotive Logistics*, there are around 125 new factories in the pipeline, including more than 60 in Asia, 40 in Europe and around 25 in North America.

Capacity in gigawatt hours will increase substantially in each of these regions compared to 2020. Although the expansion ▸

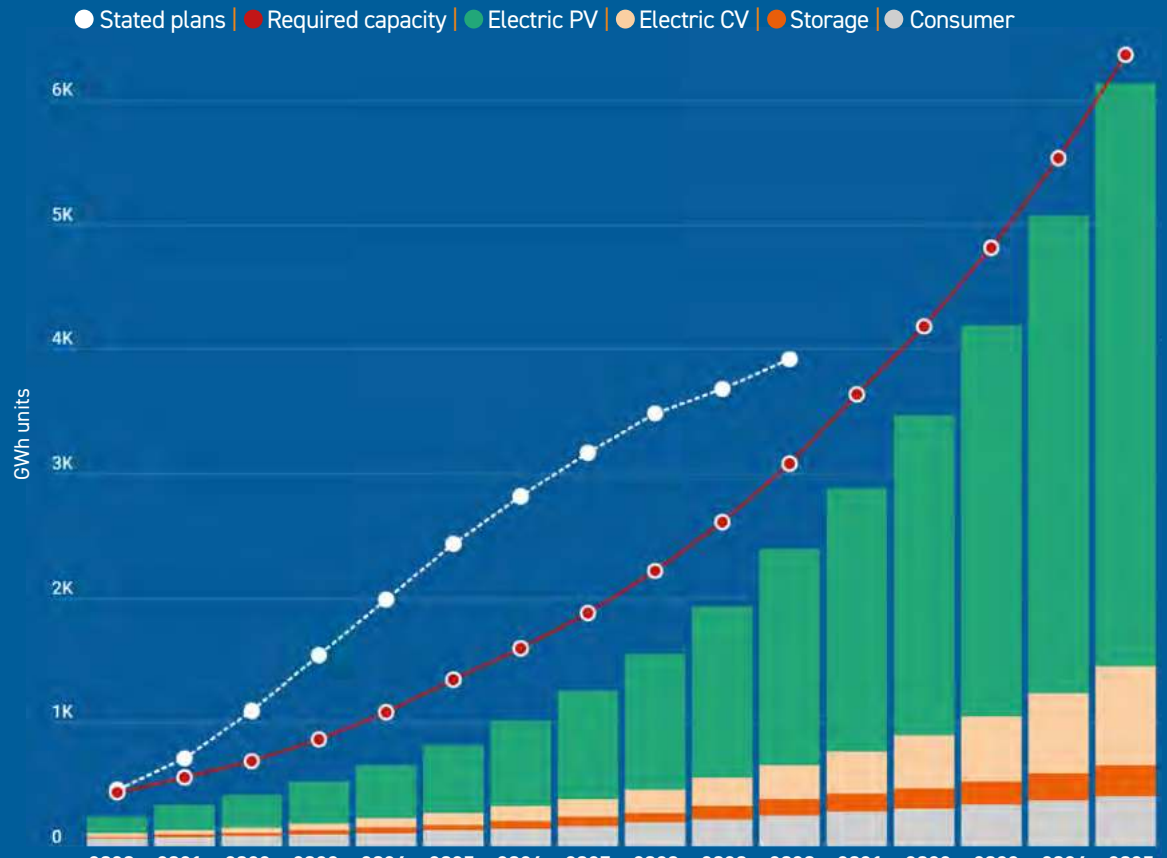
is dramatic, the roadmap is clear enough for manufacturers to plan and invest. Thus far, battery capacity has been sufficient to meet demand even with recent growth. Based on the current trajectory, including the level of gigafactory capacity that has thus far been announced, overall cell capacity should be sufficient to meet or exceed global demand through the next decade. According to data from Automotive from Ultima Media, planned gigafactory capacity will reach 3,900 GWh by 2030, about 20% higher than demand is forecast to reach by then.

That headline figure masks risks and disparity, however. The lack of gigafactory investment in some regions could lead to imbalances in battery supply and especially hold back production opportunities in regions where battery supply chains remain underdeveloped.

Even in regions where manufacturers are investing in gigafactories, investments could be delayed or deferred depending on EV penetration. Material price rises and shortages could slow or stop production. As battery cell production is a chemical process, there are further limiting factors that could prevent sites from reaching planned output.

After 2030, as more emission targets and ICE bans take effect, the shift to EVs is likely to accelerate, and battery supply chains and gigafactories will need to expand even further.

Global lithium battery demand and capacity forecast by sector 2020-2035



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Stated plans	459	704	1090	1536	1985	2431	2819	3161	3483	3675	3920	-	-	-	-	-
Required capacity	475	575	695	841	1018	1232	1466	1737	2050	2419	2891	3455	4128	4933	5895	7045
Electric PV	140	203	260	333	426	545	687	865	1090	1373	1731	2111	2576	3142	3834	4677
Electric CV	25	35	45	57	73	94	117	147	184	229	282	347	427	525	646	794
Storage	20	24	29	35	41	50	60	72	86	103	124	142	164	188	217	249
Consumer	60	72	83	95	110	126	145	167	192	220	253	279	306	337	371	408

Source: Automotive from Ultima Media

Batteries in the right place, at the right time

More gigafactory capacity will almost certainly be announced in the coming years. However, if OEMs and battery producers struggle to make margins during a tough period of transition and relatively low overall volume growth, then financing this expansion could become an issue. Carmakers, suppliers and logistics providers could struggle to keep up with demand, with prices and lead times rising as a result.

The coming growth in EV demand will also require that battery production capacity is in the right location as well as being the right size. Importing large volumes of heavy batteries is uneconomical at scale, especially when there are increasing pressures to reduce battery prices to make EVs more affordable. Shipping heavy batteries around the world hardly supports climate policies, either.

Regionalising the battery supply chain has become a political priority. Governments realise that OEMs would be at risk of losing a significant share of the value chain – batteries currently represent 30-40% of a vehicle's value – without reshoring production.

This in part explains why many OEMs have established joint ventures to develop and produce battery cell plants closer to vehicle assembly lines. Both Tesla and VW are also planning to produce their own cells in-house.

EV production forecast by region 2020-2035

Source: Automotive from Ultima Media

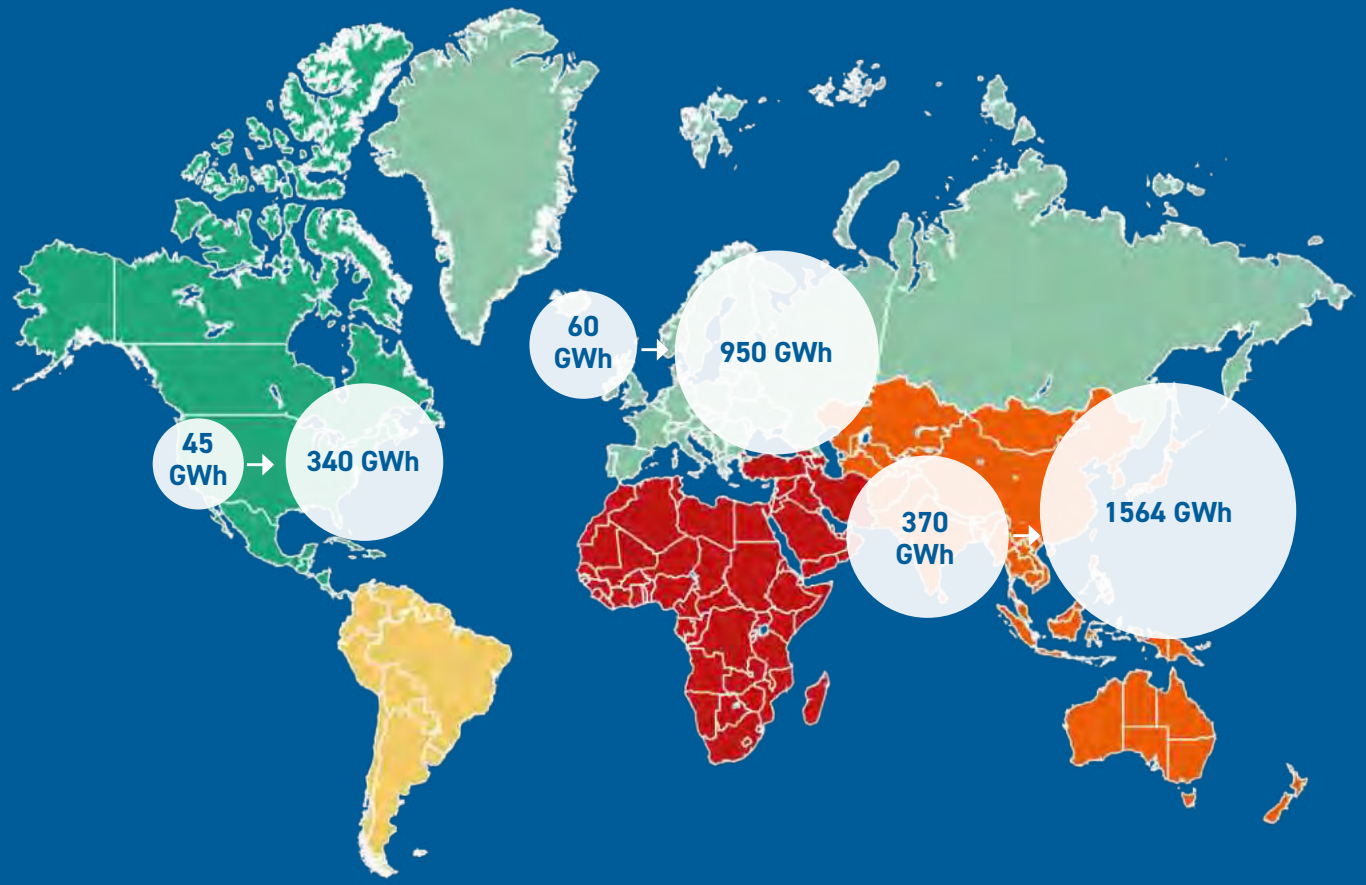
Recent disruption to supply chains has raised further concern over much OEMs rely on Asian sourced parts. In early 2021, US president Joe Biden signed an executive order to launch a **100 Day Battery Supply Chain Review** to evaluate and address the risks of the US being so dependent on other countries for battery supply.

The European Commission has also set out strict environmental requirements on batteries and their carbon footprint in its **New Regulatory Framework for Batteries**, which includes limits on the energy used in producing and transporting cells, targets for recycled materials and for handling batteries at end of life. Transparency and certification of battery origins would also emphasise regional sourcing and production.

While the framework has sustainability objectives, this regulation would also limit how many batteries would come from Asia, with the aim of further supporting localisation of production in Europe.

Ultimately, there is a strong push at both industry and government level to recapture and reshore the battery supply chain thanks to the economic, sustainability and efficiency benefits of regionalisation.

Lithium battery production capacity by region 2020 vs. 2030

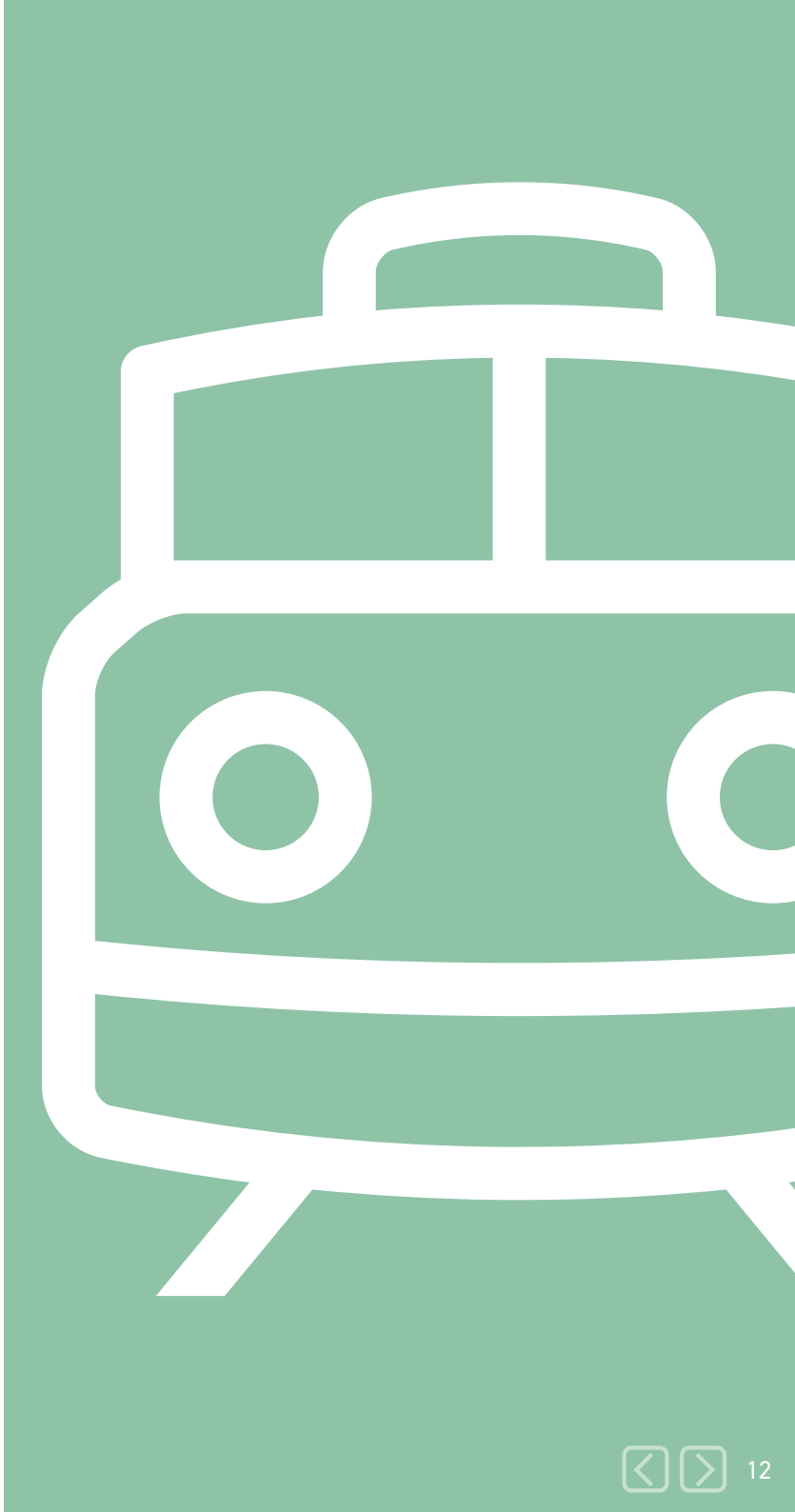


Source: Automotive from Ultima Media

Chapter 2

Optimising logistics for battery supply chains

Manufacturers have an opportunity to design battery logistics more strategically, including working with lead logistics providers to determine inventory levels, storage locations and battery pack integration



The growth of battery production will create new locations, volume and value across the automotive supply chain, which carries both great opportunities and risks in logistics. For manufacturers and suppliers, it is a chance to redefine the shape of the supply chain from the ground up compared to ICE powertrains, creating a more reliable and resilient operation, and technology that is sourced and shipped economically and sustainably.

Ramping up these complex supply chains will require close partnership between logistics providers, OEMs and battery cell manufacturers especially in transport, inventory, supplier and production considerations.

It's a collaboration that Maersk's head of automotive, John Andrew Carmichael, already sees as a gap across the industry. But the regionalisation of EV and battery supply chains will make it more important, especially for providers who can integrate logistics services across stakeholders and locations.

Even as manufacturers build batteries regionally, many components, materials and technologies will still be sourced and developed globally. OEMs will need to consider the capacities of upstream suppliers, ensuring there is a stable supply for fast-moving demand.

Manufacturers expanding in Europe and North America, such as South Korea's LG or China's CATL, are also drawing on scale and expertise in Asia. That will require ongoing consolidation and shipment of components and products, as well as sharing data across regions. Battery producers must be ready to shift suppliers or expedite parts following engineering changes or shifts in demand.

By working with specialist LLPs, OEMs and battery producers can better plan contingency supply and expedite freight flows. Maersk, for example, uses planning tools that engineer logistics based on dynamic flow control, helping to make lead times more reactive to changes as well as more predictable. "Logistics design will favour agility, as manufacturers must be able to react to demand changes as fast as possible," said Carmichael.

With supply chain volatility and disruption part of the new normal, OEMs and suppliers are turning to logistics providers to improve supply chain and tracking, while integrating

sales and capacity planning into logistics engineering. The better the visibility an LLP has of what is expected and what the production plans are, the better it can support operations.

For example, to pre-empt shortages, manufacturers and logistics providers might hold strategic buffer stocks in specially designed and certified warehouses. In Europe, there is already a significant lack of suitable storage facilities, and so identifying potential capacity early on is important, according to Carmichael. Furthermore, working with an LLP could also mean accessing shared storage platforms, where OEMs can use space on a per use basis, rather than finding dedicated warehousing.

"Shared logistics hubs to serve EV and battery parts are a way to design a supply chain with multiple levers to reduce cost, improve supply access and reduce carbon footprints, as well use space more optimally," said Carmichael.

Bringing battery packs home

As battery and EV production increase, there is also more focus on logistics for battery module assembly and pack integration. In dealing with heavy and expensive parts like battery packs – which can weigh up to 500kg – more OEMs are choosing to locate module and pack production close to or directly at manufacturing plants.

Localisation might also occur at facilities that integrate cell production. Tesla's upcoming factory near Berlin will eventually build battery cells and modules alongside vehicles. Ford's joint venture with SK Innovation will include an integrated battery and vehicle production hub in Tennessee. Nissan, Renault and GM have set out similar plans.

Lars Carlstrom, founder and CEO at Italvolt, which is planning the largest gigafactory in southern Europe at a site near Turin, Italy, also sees more opportunity for localising cells, pack and vehicle production.

"Localisation is key including super-localisation where you can actually create these gigasites to combine production, which will reduce logistics costs and emissions," he said.

This localisation reduces transport and handling costs but can also help mitigate against supply shocks. For OEMs, keeping safety stocks of batteries in storage is problematic both because it ties up working capital, but also because it creates regulatory and handling issues.

"Battery storage is one the key pain points in the industry," admitted John Andrew Carmichael from Maersk.

"How do you actually store batteries to keep the supply chain resilient without having to amass safety stock at some port or some intermediate location that is too far away from the assembly line?"

There are a number of different approaches emerging across the industry.

Examples of gigafactory and vehicle assembly localisation

OEM	Cell Manufacturer	Location	Capacity (GWh)	Start of Production
Tesla	Tesla	Berlin, Germany	Up to 100	2022
Nissan	Envision AESC	Sunderland, UK	9	2022
GM	LG Chem	Ohio, US	30	2022
GM	LG Chem	Tennessee, US	30-40	2023
Renault	Envision AESC	Douai, France	9-24	2024
Ford	SK Innovation	Tennessee, US	43	2025
Ford	SK Innovation	Tennessee, US	43	2025
Ford	SK Innovation	Tennessee, US	43	2025

Creating local supply control and flexibility

As many OEMs are contracting with multiple battery cell providers to secure supply, a complete integration of battery cell and final modules is not always practical, with the decision on where to "decouple" parts of the supply chain a key driver of strategic supply chain decisions, according to Carmichael.

Volvo Cars, for example, has signed contracts with LG and CATL for supply across production in China, Europe and the US, allowing for flexibility in sourcing, as well as scale with other brands within the Geely Group, such as Polestar, Lynk & Co and Zeekr in China.

In Europe, where the carmaker has launched production of its first EV models, Volvo Cars chose to insource the subassembly of the battery pack at its plant in Ghent, Belgium, to better control and plan inbound and in-plant logistics, according to Magnus Ödling, head of global inbound logistics engineering and car program management.

"Producing multiple derivatives of the XC40 in trim and final in Ghent – the internal combustion engine, plug-in hybrid and electric vehicle – adds a lot of parts, suppliers, fluctuations and complexity, which requires even more careful planning and forecasting," he told *Automotive Logistics*.

Localising such a module also helps OEMs to reduce internal logistics costs and handling. To avoid sequencing heavy, complex parts over long distances, carmakers like Volvo have installed conveyors to move the battery pack from the subassembly area directly to final assembly. Other OEMs and battery manufacturers are also exploring the use of autonomous mobile robots to move this equipment more flexibly across plants.

For electric vehicle manufacturers, reducing logistics cost, complexity and handling will be essential in scaling up battery cell and battery pack production.

Advantages of regional and local battery supply chains
Reduces logistics and inventory costs
Supports economies of scale to bring down battery costs
Mitigates against supply disruption
Helps manufacturers preserve lost value from ICE powertrains
Contributes towards regional energy independence
Reduces the carbon footprint of the battery supply chain
Increases supply and production flexibility

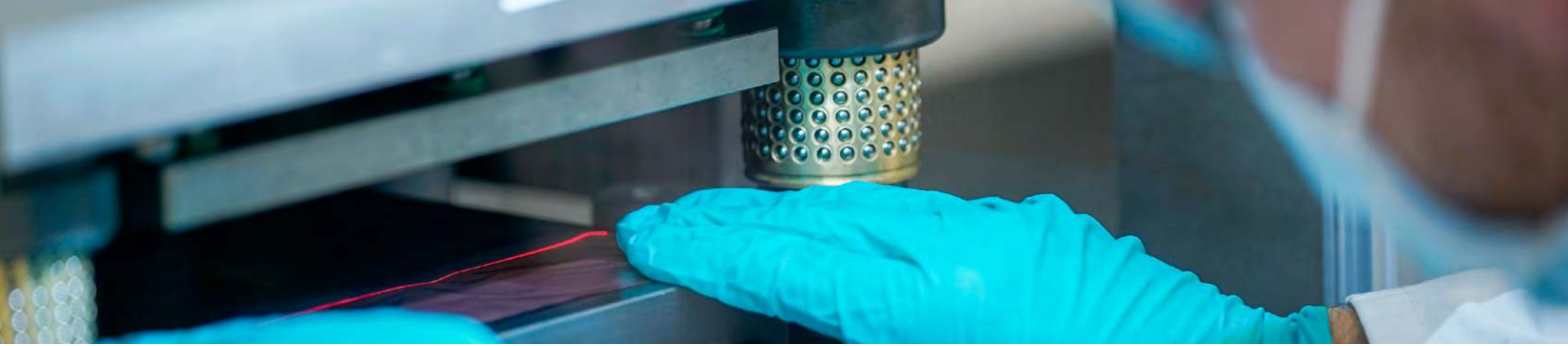
“Producing multiple derivatives of the XC40 in trim and final in Ghent – the ICE, plug-in hybrid and electric vehicle – adds a lot of parts, suppliers, fluctuations and complexity, which requires even more careful planning and forecasting”

Magnus Ödling, Volvo Cars

Chapter 3

Swimming upstream in the battery supply chain

The wider battery supply chain will remain global and complex, with logistics management and sustainability major factors in determining sourcing and localisation of key components



Although battery cell gigafactories are becoming more regionalised and battery pack production more localised, their parts and materials are not always able to follow production. Key components such as the anodes, cathodes, separators and electrolytes remain highly concentrated within the Asia region, specifically China and Japan, and are likely to remain so for the foreseeable future.

Further upstream, the raw materials are sourced from far-flung parts of the world with specific natural resources and mining capabilities, ranging from Australia and Chile for lithium, to the Democratic Republic of Congo (DRC) for cobalt.

What's most striking about current raw material production for lithium-ion batteries is that the output from Europe and North America is negligible. Even as manufacturers build gigafactories and battery plants in these regions, they will be reliant on suppliers and materials from across the world, with supply chains that often lack transparency on price and volume but also labour and environmental standards.

For many OEMs, the extended battery supply chain is new territory, as few would have had experience working directly with many of these companies. As Shilpan Amin, GM's vice-president of global purchasing and supply chain, has observed, there are "a whole different set of raw minerals" compared to production of ICE powertrains. The battery pack also contains significant amounts of electronics, software and other components, some of which could present supply constraints and production challenges as volumes ramp up.

In response, more OEMs are pursuing deeper vertical integration in the battery supply chain, including joint ventures with battery cell manufacturers, but also by establishing direct partnerships or even JVs with raw material and mining suppliers.

Tesla, for example, is exploring mining lithium and cobalt directly in North America. General Motors has announced a joint venture with the chemical division of steel producer Posco to build cathode materials in North America from 2024.

Several OEMs are also partnering in R&D to try to reduce the use of minerals in batteries like cobalt.

As with their response to the semiconductor shortage, carmakers and battery producers want to exert more control over the value chain, as much to influence chemistry and technology development as to lock in supply and mitigate against shortages. More control would also provide better visibility of materials, along with environmental and ethical practices.

This vertical integration offers more opportunities for manufacturers and LLPs to engineer logistics flows, with the potential to consolidate transport and storage across the supply chain as well as to certify shipping and handling processes.

Sustainability and rules of origin

Sustainability of the battery supply chain is increasingly a part of an OEM's brand image, as more carmakers realise that it is not enough just to offer a zero-emission vehicle to convince some consumers, especially when there are ethical questions around the provenance of key minerals and materials from countries like the DRC.

It is also a critical question of environmental credibility over a vehicle's lifecycle.

Volvo Cars revealed a study that showed its C40 electric sedan, which is built in Belgium, required almost twice as many emissions in its production, materials and lithium-ion battery module processes compared to the ICE version of its XC40 crossover, driven mainly by emissions during battery and steel production. Although the EV produces far fewer emissions during use, the carmaker estimated that it could take 50,000-110,000km of driving to offset this increase, depending on energy sources for electricity.

Solutions for improving this footprint include using more renewable energy sources across battery and steel production and logistics, as well as localising more elements of the supply chain closer to final assembly.

Regulators are also focusing on reducing emissions in the EV supply chain.

The **EU's proposed battery regulation** would phase in strict carbon footprint limits and rules of origin requirements by 2027. Some OEM executives and experts have questioned how feasible it will be for the wide European supply chain to reach these objectives in the timeframe. A particular challenge would be in raw materials, as it would likely take around a decade to establish local mining capacity in the region.

However, some manufacturers anticipate that such regulations will reinforce procurement and production decisions to regionalise more of the supply chain. Lars Carlstrom, founder and CEO at battery gigafactory startup Italvolt, suggested that such regulations should go even further.

"Batteries produced in Asia for use in Europe should be labelled as dirty batteries, as these batteries have been transported far and have an unclear supply chain in many cases," he said.

Carlstrom acknowledged that Europe and North America are far behind Asia in developing these supply chains, but still saw further localisation as a realistic long-term prospect.

Better supply visibility and validation

Despite rising regionalisation and localisation, it is likely that battery supplies will continue to come from across the world and will require a robust supply chain strategy.

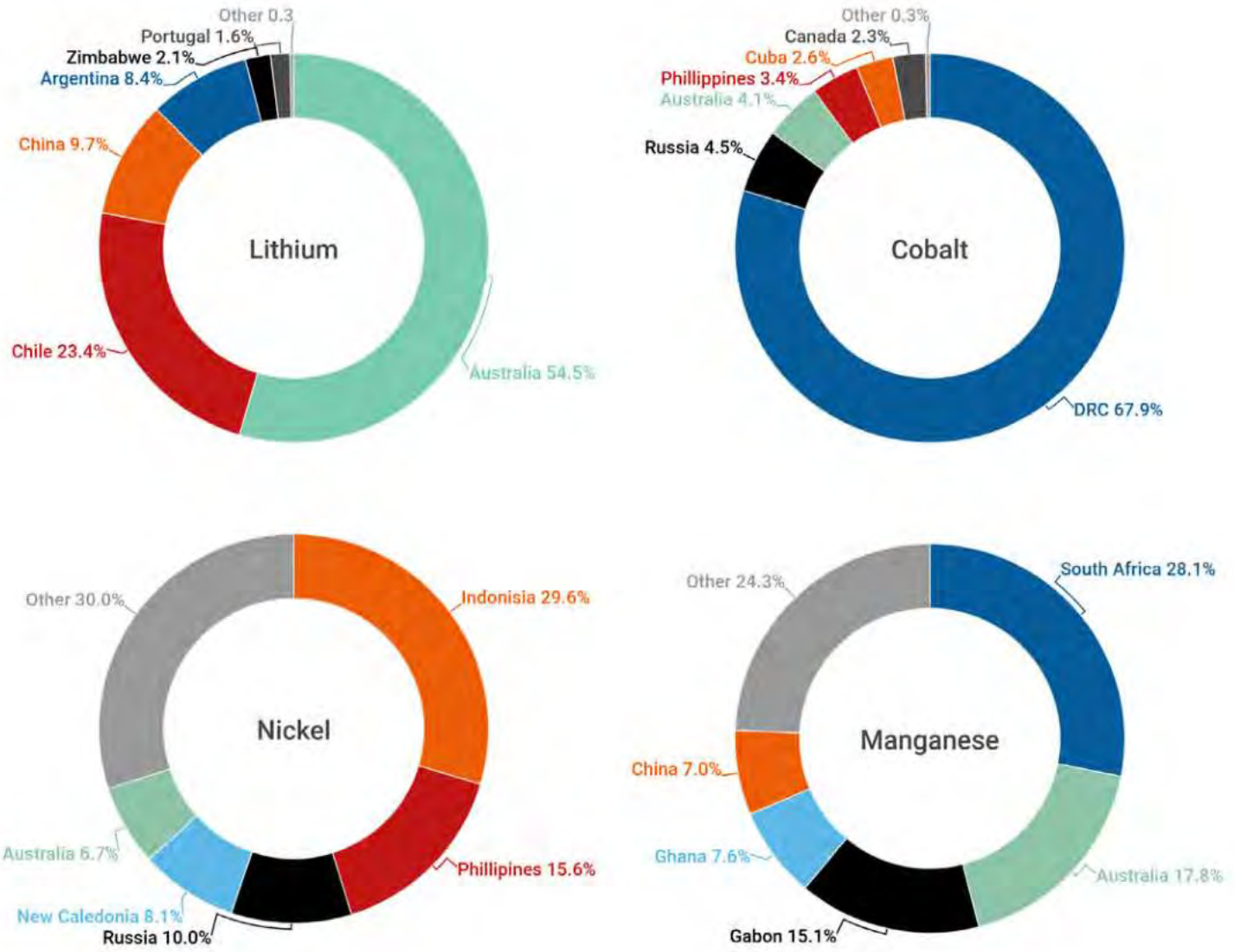
By partnering with a strong global logistics provider, manufacturers can better coordinate and control these critical material flows, which will be essential to ramping up production.

“Scalability is key as a solution, as logistics providers need to connect new tier one suppliers in the battery chain and integrate them seamlessly into new and growing production centres,” said John Andrew Carmichael at Maersk.

LLPs such as Maersk can provide real-time shipping visibility, including AI-driven tools that predict lead times. Technology can also play a key role in validating and tracing materials to ensure ethical sourcing.

“Traceability in the conflict mineral discussion is important, and companies have already invested in technologies such as blockchain to try and mitigate risks,” said Carmichael. “Such approaches will be important in determining how to source chemicals.”

EV battery raw material sourcing locations by market share



Source: US Geological Survey

Chapter 4

Specialised technology, specialised logistics

Lithium-ion batteries have special characteristics when it comes to supply chain and logistics, from dangerous and hazardous goods regulations to considering energy sources for gigafactories

As OEMs and suppliers build more electrified powertrains and vehicles, there are specific considerations and changes that will be important for logistics, including the location of new suppliers, the equipment and processes involved in handling and storage of batteries, and the infrastructure requirements for gigafactories.

Logistics expertise from ICE production will often translate to the EV era, which will be advantages for manufacturers that partner with the right companies.

Among the complexities in managing battery supply chains are transport and storage regulations. Lithium-ion batteries are classified as dangerous goods, and as a result fall under a myriad of international, national and regional rules around handling.

For example, there are specific requirements and limitations for air freight to avoid fire risk, notably around limits in passenger cargo holds. Batteries must be handled, packed and stored in specific ways, with specialist certification required for staff.

There are also rules and best practice around road, rail and shipping. Most batteries are shipped by sea in temperature-controlled reefer containers. They also must be stored in specific facilities certified for dangerous goods.

While the requirements can vary, adding extra cost and equipment, these challenges are not insurmountable. Logistics providers can attain certification and clearances that mean they can handle batteries more efficiently. Such partnerships will be key for manufacturers as they scale up battery production.

Overview of battery transport regulations
Lithium batteries are considered as **Class 9 miscellaneous dangerous substances and articles** under UN regulations, relating to the following main categories:
UN 3090 - lithium metal batteries shipped individually
UN 3091 - lithium metal batteries contained in equipment or packed with equipment
UN 3480 – lithium-ion batteries shipped individually (including lithium-ion polymer batteries)
UN 3481 – lithium-ion batteries contained in equipment, or lithium-ion batteries packed with equipment (including lithium-ion polymer batteries)
UN 3536 - lithium batteries installed in cargo transport unit (lithium-ion batteries or lithium metal batteries)
All batteries must be tested and meet the criteria as stated in the **UN Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria Part III subsection 38.3**
Batteries are also subject to international regulations according to transport mode, including:
Road – the Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR)
Rail – the International Carriage of Dangerous Goods by Rail (RID)
Air – the International Civil Aviation Organization (ICAO) Technical Instructions (TI) for the Safe Transport of Dangerous Goods by Air and the International Air Transport Association (IATA) Dangerous Goods Regulations
Sea – the International Maritime Dangerous Goods Code (IMDG Code)

Gigafactory planning

The large size and resource demands of gigafactories have specific logistics requirements that go beyond those of ICE powertrains. According to Lars Carlstrom at Italvolt, a gigafactory often needs space of 100-150 hectares to support production, supply and allow space for logistics handling.

"It also needs good access to highways, and be at least a reasonable distance to a port," he said.

The chemical processes involved in battery cell processing also require safety and fire precaution measures, according to Carlstrom.

Battery manufacturers must consider the carbon footprint of their production, including energy sources that would make plants carbon neutral, such as access to clean energy sources.

"When you get into gigafactory scale, using renewable or green energy sources is key, so we must plan that in," said Kevin Brundish, chief executive officer and founder of AMTE Power, a battery supplier with a factory in Scotland and plans to build a gigafactory in England.

"A core part of becoming part of an on-shore supply chain is to make sure you can access low carbon energy and have as sustainable operations as is possible," he said.

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Kevin Brundish, AMTE Power

Managing parrallel supply chains

While differences are clear, there are also considerable similarities in the logistics requirements for supporting battery production as for ICE powertrain. John Andrew Carmichael at Maersk pointed out that, much like for engine and vehicle production, there will likely be a mix of extended supply chain and regional production, with low volume products built centrally and then supplied globally, for example as knockdown kits.

However, there is considerable complexity that manufacturers must manage together with suppliers and providers. For example, EVs require fewer components than ICE vehicles, which in theory simplifies inbound supply chains and logistics flows. However, over the next decade powertrain varieties are set to increase, in many cases leading to production of multiple powertrains on the same line, including ICE, hybrid and electric. With demand and regulations in flux, volumes are likely to vary, too. The result will be multiple supply chains running in parallel over the next decade in production, and even longer in the aftermarket, which logistics providers will also need to manage in parallel.

"That will actually lead to a multiplication of part numbers and of complexity before it really dies down and becomes less parts per EV in the future," said Carmichael.

As EV and battery supply chains ramp up, there will be players new to the automotive industry, such as consumer electronics companies and new startups. Many of these companies will require support in managing the volume, cost pressure and variety of the automotive supply chain, whether in exports or in setting up regional supply chains.

"The existing battery cell players will evolve from intercontinental to regional players, while others will need to set up their logistics from scratch," said Carmichael.

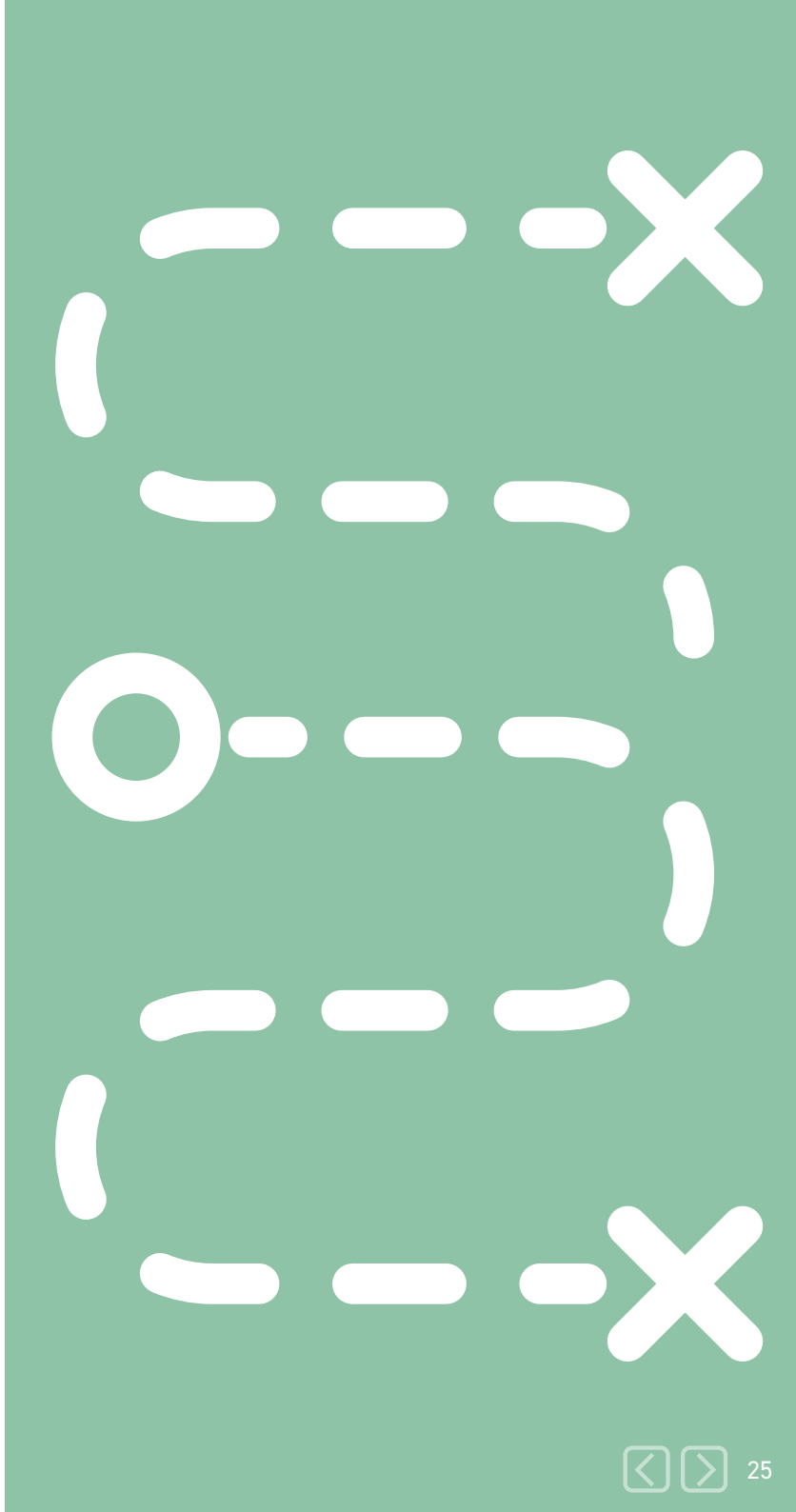
These new entrants would benefit from relationships with logistics operators to help them succeed in the automotive market, including setting up lean inventory and just-in-time supply strategies.

Challenges in battery supply chain	Opportunities in battery supply chain
Speed of ramping up the supply chain	Designing a new supply chain
High cost of intercontinental transport	Rapid battery supply chain growth
Limits to storage facilities	Coordinating upstream materials and global battery shipments
Dual supply chains for EV & ICE, multiplying complexity	Designing warehouses specifically for batteries
Complex regulation around transporting batteries	Aftermarket and service parts for EV
Working with suppliers new to the auto industry	Reverse logistics for batteries
Complexities in shipping used and damaged batteries	Recycling of batteries and materials

Chapter 5

Why battery suppliers are turning to logistics providers

Maersk's John Andrew Carmichael sees more need and a greater willingness from battery manufacturers to work collaboratively with logistics providers compared to many other automotive manufacturers



John Andrew Carmichael, director and global head of automotive, **Maersk**

John Andrew Carmichael has worked at Maersk for 15 years, with experience in operations in Central and South America, as well as in Europe. For the last three years he has been focused on the automotive vertical, including the development of EV and battery supply chains. He became director and global head of automotive at the beginning of 2019.

Q&A

The automotive sector has less involvement of lead logistics providers in some segments than other industry verticals. Is there a particular aspect of EVs and battery supply chains that would benefit from LLPs?

We're seeing a lot of battery suppliers which are actually quite interested in more integrated lead logistic solutions than many OEMs have been in the past. I think this comes from the fact that their focus is the battery technology and manufacturing, not necessarily supply chain and logistics. They need experts to manage logistics. Here we're working with quite a few battery manufacturers on managing their full supply chains, as we would with retail and lifestyle customers in other industry verticals. We are seeing this industry sector become more attractive.

Also, because of the high requirements that the OEMs demand of suppliers, outsourcing logistics to experts seems to be much more palatable for battery cell suppliers.

There are also opportunities in the integration between the inbound supplier flows and the OEM, including the visibility that they need in the upstream battery supply chain, with which OEMs tell us they sometimes struggle. That's where an LLP can provide both parties with value-add, firstly by helping to manage quite a complex supply chain with high requirements, as well as to provide visibility to the OEMs of what's going on in an upstream supply chain that another party controls.

How do you see logistics design evolving in response to growing battery supply chains? For example, you have spoken about multimodal tracking and visibility, software, predictive data analytics, and we're seeing a strong rise in integrated sales and operation and planning (S&OP). Do you see those factors coming into play for battery supply chains?

I do. In general, there is a movement in the automotive industry to think of logistics design a bit differently and modernise some of the processes. We have systems and processes that worked until 2019 – pre-pandemic – but which are now under a lot of pressure.

We're already seeing that because demand is high for battery movements and is growing so quickly that we're using all transport modes and means possible. That includes ocean freight, which is probably the most used, as well as intercontinental rail. We're even seeing some customers trucking batteries from China into Europe because there's such an urgent need for them. Logistics design will favour that agility to be able to react to demand changes as fast as possible.

The other thing is how you then react to disruption, which is where predictive analytics come in to help manage by exception. The key is not to react only when there is already a problem, but when you can anticipate problems coming and are able to react quicker.

I also see multimodal transport becoming more important. There is the opportunity, for example, of changing from one transport mode to the other earlier in the delivery stage to not have to duplicate inventory. If there's already a shortage of batteries, duplicating inventory won't really be a possibility.

Finally, integrated S&OP with LLPs will be important in the future. The better the visibility an LLP has into what's expected in demand and in production planning, the better it can

align to support those plans in the logistics. That's also an area that has not traditionally been too integrated between OEMs and logistics providers, but there is now a lot of interest, particularly from battery manufacturers.

Can you give examples of where you're already working more closely with battery and EV manufacturers on key projects?

There are quite a few, but a good example is with China's CATL, with which we're working to move batteries from Asia into Europe. The transportation in this case has not been a major concern, but rather the challenges are in scaling up volume. Moving from Asia to Europe is relatively controlled, but once in Europe the real risk is in getting the batteries to the assembly line in time.

We're providing the visibility and supply chain management from origin all the way into Europe, but then we're also using what we call 'virtual warehouses', which are essentially depots close to assembly facilities. Containers become virtual warehouses for the batteries, which can be called off in a much shorter time to the assembly line.

In doing so, we have moved the supply chain's decoupling point closer to the assembly line instead of having it at the port, where there could be many containers stored and other delays that limit delivery times. That is one of several interesting ways of moving around the complexity of setting up warehouses.

In eastern Europe, we're also working with several customers where battery supply is through a mix of local production and imports from Asia. In that case, we have created a staging point in the region with storage facilities, which then also serves other customers in continental Europe through these virtual warehouses.

A third example is a Norwegian start-up battery manufacturer Freyr, with which we are working on designing the supply chain basically from scratch. In this case, it's a completely different consideration, but presents many interesting opportunities to take a strategic approach to supply chain design.

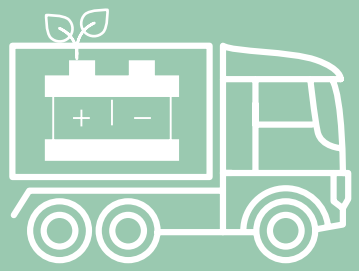
"Containers become virtual warehouses for the batteries, which can be called off in a much shorter time to the assembly line. We have moved the supply chain's decoupling point closer to the assembly line"

John Andrew Carmichael,
Maersk

A strategic approach to battery supply chains at Maersk

Logistics services for battery producers are growing strongly. At Maersk, which already works with many automotive clients, demand for integrated logistics services in the battery supply chain is also in strong demand. The logistics giant is now exploring ways to optimise the upstream battery supply chain to the benefit of OEMs, as well. For example, it already serves multiple OEMs that share battery suppliers, with opportunities to combine transport, storage and deliveries to reduce costs, space and emissions.

The company's strategic approach to supporting the regional growth of the battery supply chain includes:



- **Partnerships –** forming strong relationships with clients to meet their needs
- **Visibility –** using advanced technology and AI to track and predict lead times
- **Virtual warehousing –** moving the decoupling point for regional and intercontinental supply chains closer to the assembly line with local storage
- **Strategic supply chain design –** designing logistics networks with battery start-ups and growing players that prioritise lead time, resiliency and optimisation

Conclusion: Partnerships on a long charge

The automotive industry's electrified future will be a long journey of transformation. The rise of battery cell gigafactories and localised battery pack production will be an important and ongoing part of this development.

This supply chain regionalisation will itself spur even more complexity in global supply chains, especially as upstream components and materials continue to be sourced in far-flung locations.

Furthermore, ICE sales and production will not disappear overnight and will likely continue for decades. With multiple powertrain supply chains running in parallel – along with new technology including fuel cell and later solid state batteries coming online – the next decade or more will likely see even greater variety of part numbers and complexity in supply chains.

Much of the focus of the battery supply chain today is on new electric vehicle production. But as first generation EVs gradually come out of service, there will be considerable aftermarket and reverse logistics opportunities. Transporting new batteries is a complex business but moving used and potentially damaged batteries creates a whole new set of safety challenges. Battery recycling and return logistics is highly specialised and will require capable operators to manage the process safely and effectively.

These developments only reinforce how important it will be for manufacturers to pursue closer partnerships with logistics providers. In the short term, they will need these experts to ensure battery transport, packaging and storage follow the right regulations. But as regional supply chains develop, they will need fully integrated solutions that manage material and components across intercontinental shipments, regional supplier consolidation and just-in-time, sequenced flows. And with the importance of battery recycling, manufacturers will ultimately want to work with partners with a lifecycle perspective.

Logistics companies that embrace and navigate this transformation proactively will benefit. But it is OEM and battery manufacturers who stand to gain most, especially those pursuing logistics partnership that go further than is common for many ICE vehicles. For EV and battery producers, now is the time to design logistics networks and supply chains, and work together at the earliest stages in product, plant development and supply chain design. In this way, logistics will help charge the battery supply chain revolution.

Key takeaways: regional battery supply chain power

Redefining the supply chain

Designing the supply chain from new is a chance to integrate logistics and consider sourcing of materials more responsibly, sustainably and economically

Supply chain regionalisation

Battery cell manufacturing is expanding in new regions at a fast rate. As it grows, it will bring new opportunities and requirements across logistics and materials management

Battery pack localisation

Battery cell module and pack assembly will increasingly happen in OEM assembly plants, and even as part of wider campuses with cell production. This provides considerable on-site logistics opportunities for automation and cost reduction

Strategic LLP relationships

OEMs and battery suppliers can benefit from LLP network optimisation and integrated planning to ensure logistics capacity and lead times match the growth of battery supply chains

Logistics network design

Efficient battery supply chains will benefit from high visibility and tracking of suppliers and freight, with predictive analytics to anticipate issues, along with resiliency features such as localised storage hubs

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