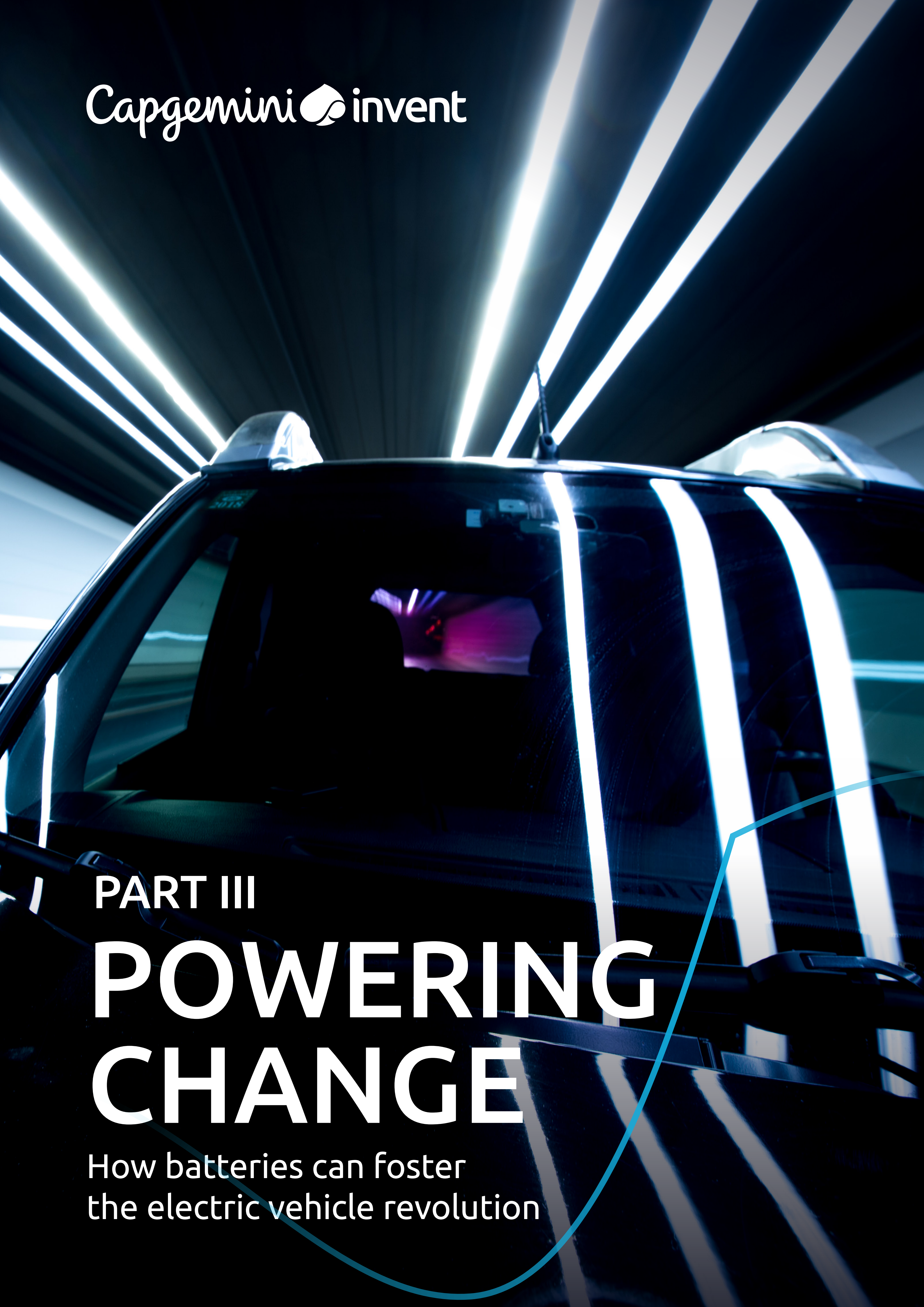
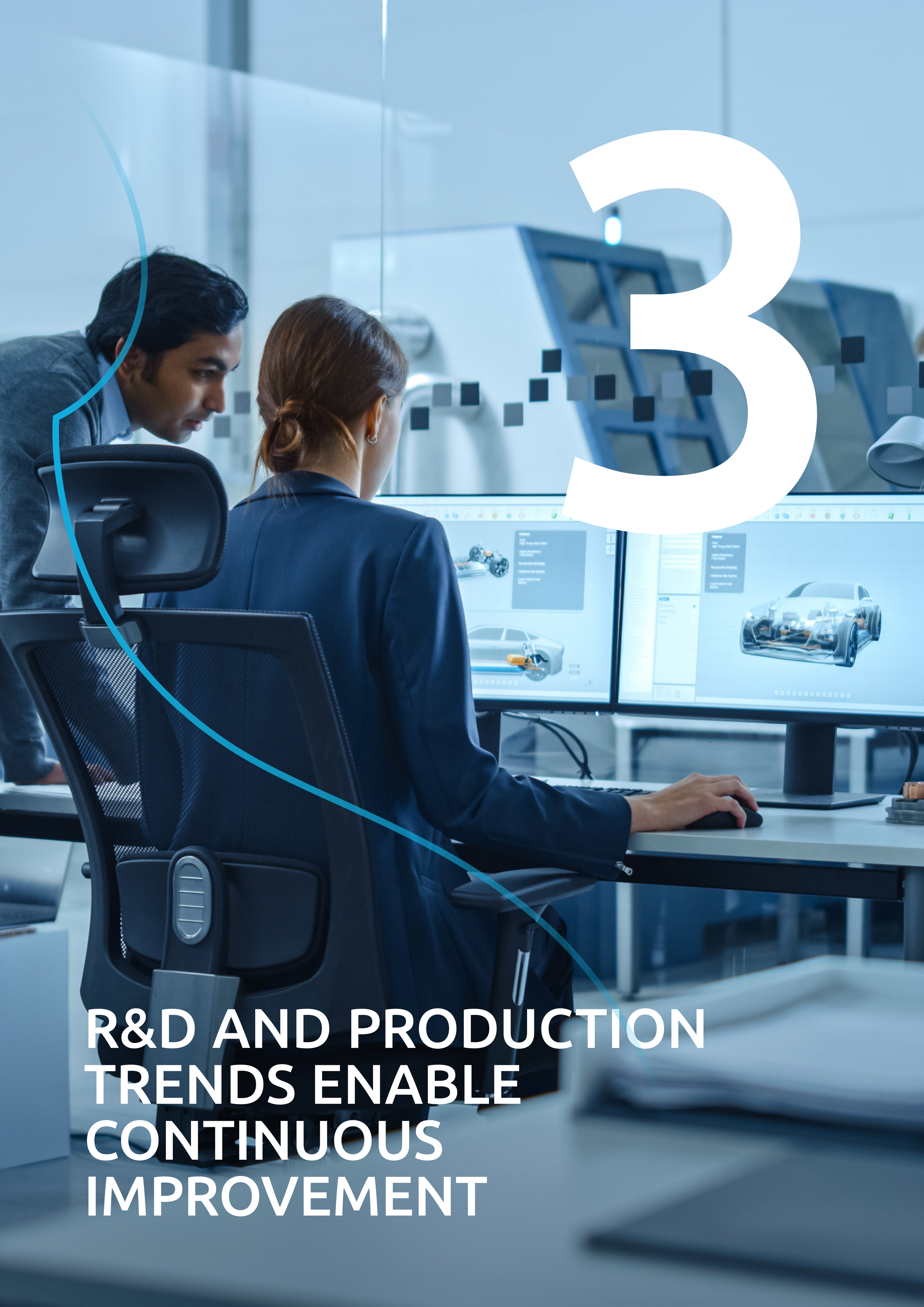
Capgemini invent



PART III

POWERING CHANGE

How batteries can foster the electric vehicle revolution



3

R&D AND PRODUCTION TRENDS ENABLE CONTINUOUS IMPROVEMENT

To fill the projected demand of automotive batteries, there is a need to meet the mass market requirements of affordability and high-volume market processes and standards. And as the trend of consumer awareness on sustainability grows (it's likely that a potential buyer of an EV is both sustainability minded) producers will be forced into designing batteries to fully align with the circular economy model.[39]

This means that future gigafactories, and those currently being built, need to be flexible and scalable to not only meet future demand but to be capable of shifting future battery technology requirements including a likely need to align with circularity.

The requirements of a circular economy mean that batteries need to gain further intelligence, for example, second life applications need to be fully aware of the battery health or meeting sustainability criteria. The need to assess their capacity at different charging rates, the internal resistance or impedance at different life stages, and lifespan and cycle life in different conditions becomes more important in a circular economy.

"Battery producers must now consider the circular economy during the design phase."

[39]IEA (2021)

3.1 R&D changes due to battery design

In a conventional battery manufacturing process, battery cells are first combined into modules and then the modules are combined to form a battery pack. Each battery module has its own independent battery management and diagnostic system. This allows more controllability and diagnostics at the module level, in addition to some structural support for the battery pack. The trade-off of this design is that the module's terminal plates, side plates, and internal connectors take up more space and weight.

In cell-to-pack technology (CTP), the cells are integrated directly into the battery pack, forgoing the intermediate module formation step, resulting in much higher volume and mass integration efficiencies compared to a conventional battery pack. Battery cell design is increasingly transitioning to a cell-to-pack design, therefore more widely streamlining the module structure, and saving on space and weight. This removes the need for aluminum housing, something that could soon be made viable with the resurgence of solid-state batteries.

"Cell-to-pack and cell-to-chassis designs will limit Second Life Use Cases"

- Klaus Feldmann, CTO for Automotive Sustainability & e-Mobility, Capgemini Engineering

R&D trend	Existing R&D initiatives and examples
Cell-to-pack (CTP) and cell-to-chassis (CTC)	Suppliers like BYD and CATL have worked on the development of cell-to-pack (CTP) and cell-to-chassis (CTC) technologies. These batteries have an optimized pack structure, reducing the battery volume by up to 70%. CTP designs may limit Second Life Applications to only use the whole battery pack, since no single BMS is attached to a battery module.
Virtual cell development and design	Cell design can be sped up and facilitated by simulation and digital tools. E.g. Siemens offers a tool to support engineers in the physical and performance cell design.
Security of supply	Several cell manufacturers further integrate into the raw materials value chain. E.g., LG Energy acquired a 4.8% stake in Greatpower Nickel & Cobalt Materials of China, to secure supply of battery materials. LG Energy will receive around 20,000 tons of nickel from 2022 to 2028. This amount is sufficient to power 370,000 EVs that can run at least 500km on a single charge.
High Nickel, Cobalt reduction to improve cost and performance	E.g., Panasonic has worked on reducing the cobalt in automotive cells, which it reduced to less than 5%. Also, LG Energy Solutions is developing next-generation battery products that contain a lower portion of cobalt but attain a higher nickel content.
LFP in entry level models	LG Energy Solutions plans on building a pilot line for the LFP batteries in 2022. Unlike other LFP batteries, these will be of pouch type.

R&D initiatives & targets by major battery manufacturers

3.2 Design for recycling

The pursuit of solutions that result in a circular economy is producing some promising recycling strategies, one of which is Design for Recycling (DfR). As you might expect, DfR makes recycling a priority from the outset of a product's lifecycle. By optimizing the consumption of energy and materials, this eco-design strategy ensures the extended viability of products by facilitating EOL applications.

Li-Ion batteries have a complex assembly structure, where individual cells are assembled in modules which are, in turn, organized together in a battery pack. An EV battery pack comprises up to thousands of battery cells, which not only have to be opened individually but also removed from the ensemble. Moreover, the intricate structure and the associated risks makes the dismantling slow and laborious – the recycling takes more time and is more expensive.

By incorporating the principles of DfR, lithium-ion batteries can increase the overall quantity and quality of materials recovered from EOL products. Naturally, the reusability of these materials results in the product's increased value. Overall standardization of product design and size can be one key to streamline and optimize operations for recycling companies; but at present, this is far from reality.[40]

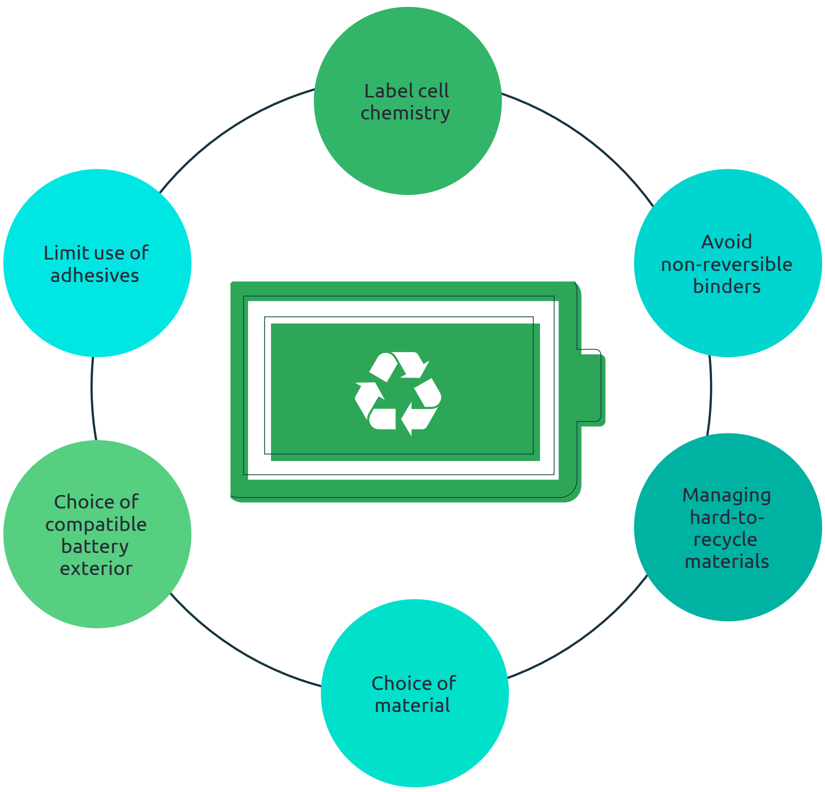
Battery cells are hermetically sealed, and adhesives are often used to join the modules and pack. This provides the pack with rigidity and safety, but these non-reversible and difficult-to-break bonds slow down the material recovery process and make recycling unfeasible. Limited use of adhesives or binders can drive efficiency and standardization in recycling.

Due to technological developments, even the same EV models with different versions may consist of different battery chemistries. When it comes to the recycling process, it is not advisable to mix battery chemistries. At best, it can lead to unwanted results. At worst, it can be a safety hazard. That is why, there are currently only a limited number of acceptable methods of recycling. Improved identification methods can mitigate this problem and help in the segregation of different batteries chemistries via identification methods such as color coding, RFID and ultraviolet, or infrared scanning or blockchain.[41]

The choice of exterior battery materials is important because some exterior materials may be affected by chemical or high-temperature recycling processes. Ensuring compatibility between exterior materials and the recycling process can help skip early physical separation.

The eco-strategy known as Design for Dissassembly (DfD) encourages to avoid rigid exteriors that are durable and cannot be easily removed.

Recycling metrics such as material recovery rate and purity are directly proportional to the choice and the distribution spread of materials in the battery. Use of incompatible materials can result in a comingling of recycling output streams. Also all solid state designs with ceramic electrolytes may limit the ability to recycle, thus making it more difficult to reach overall recycling quotas.



Design for recycling principles

[40]Norgren (2020) [41]Chen (2020)

It is important to remember that the majority of modern batteries are composed of chemistries that incorporate hazardous materials. The amount varies depending on the battery. But the amount is irrelevant. Whenever hazardous materials are used, proper safety and precautionary measures must be observed during the recycling process. Consequently, the cost of the operation increases and the efficiency decreases. Moreover, hazardous materials may lead to the contamination of other recycled materials.[42 43]

3.3 Production trends

As described in the introduction, EV demand is predicted to grow tremendously within the next years, especially in China and Europe, but also in the US.

Besides the current challenges of meeting automotive demand with a limited and volatile semiconductor supply and the issues caused by COVID-19 and wire harness supply issues arising from the conflict in Ukraine, future automotive production will face additional challenges due to battery availability – the industry has challenges with producing EVs in sufficient quantities, despite the growing demand.

For many traditional automotive companies EV production and battery assembly is still in the early stages and lacks standardization. Also, each manufacturer follows their unique battery pack design, resulting in many manual steps for EV battery assembly. Therefore, as they ramp up production, EV manufacturers are often encountering battery production bottlenecks. To meet future demand, battery manufacturers must automate their processes completely and improve process speeds. Automation is the key to improving assembly safety, ensuring quality and traceability, and managing battery costs.

The battery supply chain needs to be as efficient, agile, smart, and digitalized as the production floor to be able to evolve in-step with the overall existing EV supply chain. This will also bring a need for gigafactory technologies to be revamped to maximize speed, flexibility, and throughput.

As demand grows and EV production grows to meet the demand, it's essential that partnerships are forged and fostered in the battery production ecosystem, such as between Bosch and Volkswagen, who plan to supply integrated battery production systems and to support battery cell and system manufacturers with ramp-up and on-site maintenance.[44]

For battery manufacturers the meeting of ESG criteria becomes more important. For example, CATL managed to get rewarded as a Global Lighthouse project by the WEF for outstanding sustainability in production. They leveraged artificial intelligence, analytics, and cloud computing to achieve a reduction of energy consumption by 10% per year.[45]

[42] ACS (2021) [43] RSC (2020) [44] Volkswagen (2022) [45] WEF (2021)

Rankings	Automation and IoT platform to increase production flexibility[46]	Digital twin technology plays a major role in battery production[47]	End-to-end automation of gigafactories[48]
Overview	A high-volume production line for battery modules, using the latest technologies following Industry 4.0 principles, for the digitization and automation of the line.	Digitizing and automating production lines at a European battery gigafactory.	A 40+GWh lithium-ion battery manufacturing facility in Northern Europe.
Automated processes and technologies deployed	Deployment of a highly automated line combining industrial robots, vision systems, laser welding, and automated in-line validation of joints via artificial intelligence.	Digitization of an R&D pilot line and production plant, using a variety of solutions and products for the production lines including hardware, HMI screens, light stack, network topology, standardized machine interface, and energy monitoring.	—
Outcome	Production increase to six times its present capacity. Expected time savings and cost reduction by using the IoT and MES platform was 20% in this case, and the line was able to support 50 different product configurations.	The digital twin technology enables the production of premium customized batteries and reduces the time for batteries to go from laboratory to production.	End-to-end automation and digitization of its manufacturing processes at its upcoming facility from the arrival of materials to the output of battery cell products.

These short case studies show possible improvements by major production technologies:

[46]Automation (2021) [47]Siemens (2021) [48]Morrow Batteries (2021)

3.4 R&D and production needs to be flexible, recycling-ready, and fully digitalized

Even though we expect design to pivot around Li-Ion batteries for the next few years, accelerating technology, and the quest to find better and safer batteries, means that R&D and production needs to be flexible, to be able to quickly scale, and easily incorporate future technologies, such as all-solid-state-batteries. In short, it's imperative that research and production facilities are entirely digitalized.

It seems likely too that the sustainability concerns of end-consumers will continue to ramp up and that recycling standards, and regulations will rise in tandem. This will put pressure on a need for even greater flexibility in R&D and production. Such flexibility can be realized though full digitalization, which can be achieved by:

Further automating battery production and battery system integration

It's not only about serving volatile battery demand; it is also about needing to keep pace with the quick evolution of battery technology. As it evolves, battery producers need the ability to evolve along with it and shift in an agile way to produce multiple battery types. To do this you have to adjust production lines rapidly, while still hitting production targets and maintaining quality as well as reducing scrap rates. Automation is the key to achieving this.

Gigafactories leveraging IOT Technology to catch up with demand for data

The rising demand for EVs will require gigafactories for battery manufacturing, which use innovative production processes, ad a paradigm shift in thinking to maximize speed, flexibility, and throughput. Smart manufacturing is vital to scale battery production and feed entire lifecycle optimization. IoT increases the visibility of assets and enables the quick benchmarking of multiple plants, lines, and machines. It provides real-time shop-floor information, and other sources to give a 360-degree view.

"Digital twins will improve planning, testing, manufacturing and aging performance prediction."

- Christian Michalak, Executive Vice President, Head of Intelligent Industry Germany

Using digital twins to enable second-life and further use cases

A world awash with data provides an intricate interconnected network of sensors that enables real-time monitoring and measurement. This is the internet of things, and it brings significant potential for developing use cases to supercharge the second life applications and the recycling process.

Key considerations

In R&D, data can be used to construct virtual 'digital twins' digital versions of batteries that can be used in planning and testing as well as in the manufacturing process, and later when in use out there in the real world. Digital twins bring many capabilities such as establishing the validity of a use case and the allowing of fast ramp up of production. But R&D with digital twins need not end there – as batteries are manufactured, sold and used, data is fed in real-time via their battery management system (BMS) to measure performance and to iterate and optimize. This kind of continuous monitoring and measurement will be vital for battery safety, and optimization and the knowledge of the battery history will further enable and foster Second Life usage.

Where do batteries go when they die?
Learn about the fascinating end-of-life and second life uses for EV batteries in chapter IV of Powering Change, or download the full report now on our website.

AUTHORS

SEBASTIAN TSCHÖDRICH
HEAD OF AUTOMOTIVE GLOBAL
sebastian.tschoedrich@capgemini.com

DR. PHILIPP MARTIN HAAF
HEAD OF ELECTRIC MOBILITY
philipp.haaf@capgemini.com

SIMON SCHÄFER
MANAGER: AUTOMOTIVE
simon.schaefer@capgemini.com

PHILIPP KOLBECK
SENIOR CONSULTANT
philipp.kolbeck@capgemini.com

THANH THI VO
CONSULTANT
thanh-thi.vo@capgemini.com

DAVID MANDRYSCH
SENIOR CONSULTANT
david.mandrysch@capgemini.com

CHRISTIAN MICHALAK
HEAD OF INTELLIGENT INDUSTRY GERMANY
christian.michalak@capgemini.com

CONTACTS

SPAIN
LAURA FERRER
laura.ferrer-montiel@capgemini.com

GERMANY
CHRISTIAN HUMMEL
christian.hummel@capgemini.com

CHINA
HUU HOI TRANH
huu-hoi.tran@capgemini.com

ITALY
JORGE ALBERTO RUBALCAVA CARILLO
jorge.rubalcavacarrillo@capgemini.com

NORTH AMERICA
MICHAEL DARR
michael.darr@capgemini.com

SWEDEN
HAKAN ERANDER
hakan.erander@capgemini.com

UK
BRAD YOUNG
brad.young@capgemini.com

BENELUX
PHILIP CEULEMANS
philip.ceulemans@capgemini.com

FRANCE
ERIC GRUMBLATT
eric.grumblatt@capgemini.com

INDIA
ASHISH SHARMA
ashish.sharma@capgemini.com

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