

# Key Battery Trends Driving Successful Electrification



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The battery landscape is exceptionally diverse, driven by the needs of a wide variety of applications across automotive, industrial, and consumer markets<sup>1</sup>. From the compact cylindrical cells used in power tools and smaller vehicles like e-bikes, to larger prismatic and pouch cells found in passenger electric vehicles (EVs)<sup>2</sup>, industrial vehicles<sup>3</sup>, and stationary battery energy storage systems (BESS)<sup>4</sup>. Each electrified application today has highly specific requirements for power, reliability, safety, operational environments, and preferred supply-chains for cells and battery hardware, and yet there's still many more untapped industries that can benefit from electrification<sup>5</sup>.



*Examples of Dukosi DKCMS installed with different cell types: top left: 4680, top right: secure prismatic (inside the cell housing), bottom left: prismatic cell module, bottom right: pouch cells in plastic cassettes.*

## What cell type should you choose?

Broadly speaking, cylindrical cells are often used in batteries for their ease of manufacturing, cost, and mechanical robustness, while pouch cells can offer superior energy density for applications with strict weight and size constraints, and prismatic offer a blend of both in a strong, space-efficient package<sup>6</sup>.

However, the application influences not only the preferred cell type but also the performance priorities of the battery designer. Automotive batteries for consumer xEVs generally need to balance range, safety, and cost. Some applications, such as newer xEV variants used in agricultural and mining operations, must instead prioritize robustness due to demanding usage patterns and harsh environments. Alternatively, battery energy storage systems supporting renewable energy production tend to prioritize long cycle life, cost efficiency, and ease of maintenance over compactness or weight.

## Major cell chemistries used today

Different lithium-ion chemistries, such as variations of nickel-manganese-cobalt (NMC) and lithium-iron-phosphate (LFP), the two most popular, offer trade-offs between capacity, performance and cost.

After years of development, solid-state batteries are nearing commercial production<sup>7</sup>. They promise higher energy density, faster charging, improved safety, and longer life compared with conventional lithium-ion cells. Significant challenges are being overcome, including scaling the manufacture of solid electrolytes, ensuring long-term reliability under fast-charging and extreme temperature conditions, and achieving the yield and cost targets needed for commercial competitiveness.

The Dukosi Cell Monitoring System (DKCMS™) supports a wide operating voltage range that covers all major cell chemistries, including the latest solid-state batteries. This gives battery designers cell-agnostic flexibility, allowing a single architecture to be used across multiple designs or even enabling specification changes during battery development, reducing costs.

## Cell type performance, safety, and cost advantages

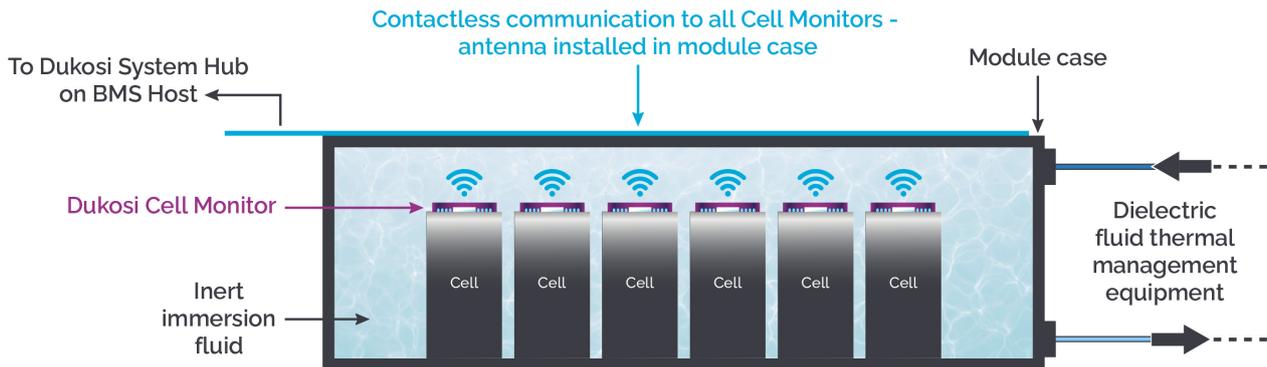
NMC cells can offer higher energy density and performance, making them well suited for applications like passenger xEVs. However, they are more expensive and less stable than LFP cells. LFP offers slightly lower energy density and are more challenging to track State of Charge, but deliver improved safety and cost-effectiveness, making them ideal for more affordable xEVs, plus larger commercial or industrial vehicles applications like buses, as well as BESS.

The range of battery chemistries on the market reflects the scale and diversity of electrification required for global sustainability<sup>8</sup>. It also highlights the real need for flexible battery monitoring that can seamlessly adapt to the specific requirements of each chemistry, ensuring performance and safety are maintained across a wide range of applications.

## What's new in battery design?

New battery designs are also transforming the vehicle-cell relationship. These include innovative architectures such as cell-to-pack (CTP), which removes the need for intermediate modules, and cell-to-chassis (CTC), which integrates cells directly into the vehicle's structural chassis for further gains in space and weight efficiency. In both cases, the aim is to increase design flexibility and energy density while simplifying production<sup>9</sup>. DKCMS is ideal for the latest C2P and C2C architectures, but ultimately supports all types of battery layouts.

Typical batteries use thermal plates or liquid channels as heat exchangers, circulating a liquid to ensure the cells operate within their correct temperature range. Thermal transfer efficiency can be improved through immersion cooling, which submerges the cells entirely in a non-conductive liquid and maximizes heat transfer potential. Continuing to demonstrate its readiness for transformative technologies, DKCMS is also well suited for immersion systems. Because these systems require sealed enclosures, traditional battery architectures with extensive wireline cabling make this approach impractical. In contrast, the simplicity of Dukosi technology provides a viable pathway to achieving immersion-based systems.

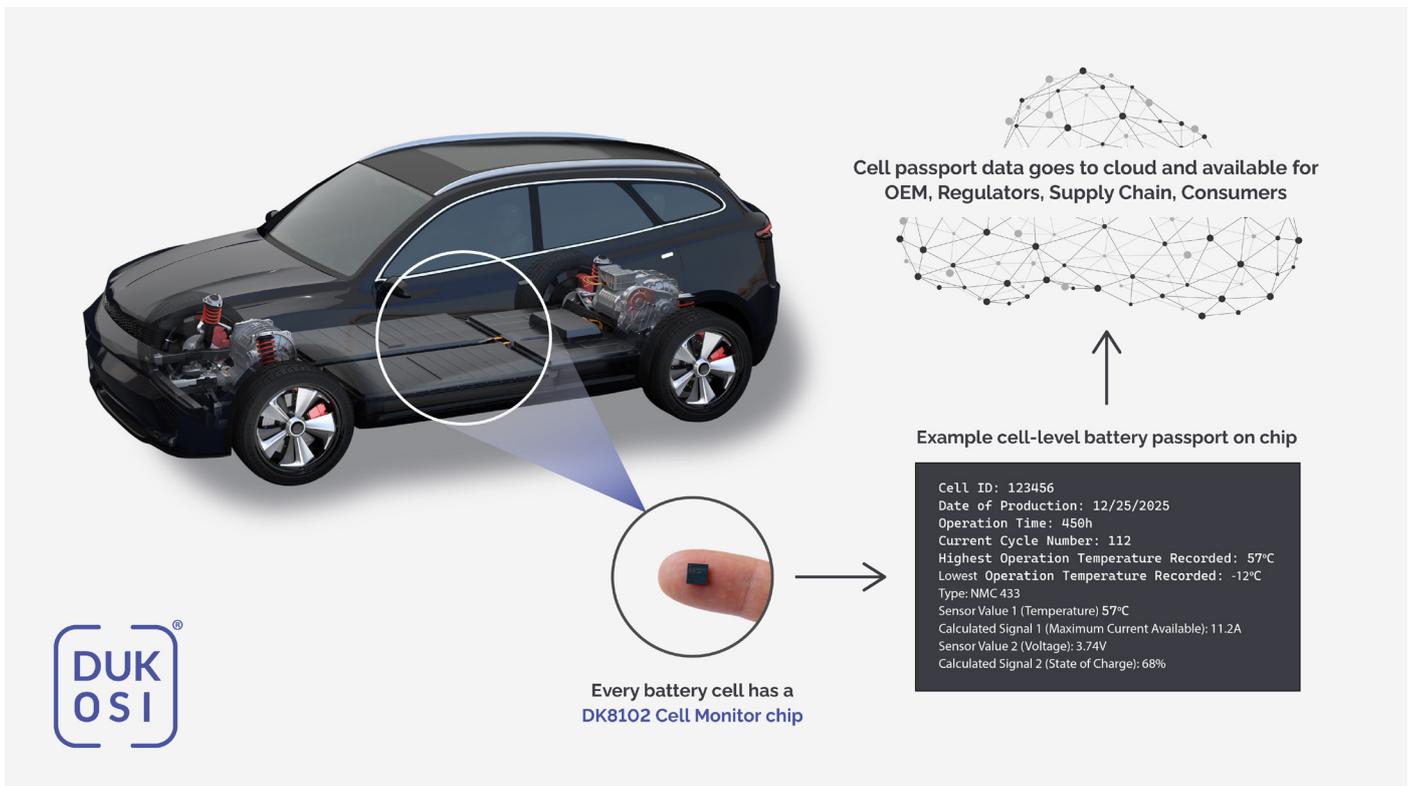


*An example of an immersion regulated battery using DKCMS with bus antenna built direct into the casing, eliminating all communication wiring from inside the immersion area without affecting data integrity.*

## Global Regulations

The European Union's Battery Passport<sup>10</sup> requirement, part of the new EU Battery Regulation (Regulation 2023/1542)<sup>11</sup>, will become mandatory on 18 February 2027. From that date, batteries with a capacity over 2 kWh placed on the EU market must include a digital battery passport. This passport is a digital record that provides detailed lifecycle information about the battery, including its material composition, carbon footprint, origin of raw materials, performance data, and information to support recycling and reuse. The goal of this requirement is to improve transparency, support sustainability and circularity in battery supply chains, and give regulators, manufacturers, and consumers access to critical data throughout a battery's life.

In preparation for this upcoming regulation, Dukosi participated as a technology partner in a Europe-wide public trial of a cell-level battery passport project featuring a Kia EV3 equipped with the Dukosi Cell Monitoring System (DKCMS™)<sup>12</sup>. The purpose was to better understand the actions required to successfully implement the EU Battery Passport, and to explore the opportunities it presents for data sharing among multiple stakeholders in the world's first real-world, cell-level battery passport test. Each Dukosi Cell Monitor operates with a unique identifier and provides cell-level data storage that holds both static and dynamic information, including state of health data. Dukosi's per-cell monitoring and on-cell data storage represent a technological breakthrough that enables a new level of transparency in electric vehicle batteries.



A KIA EV3 test vehicle was fitted with Dukosi DK8102 Cell Monitors during the public trial.

## Improving on existing battery communication systems

Battery designers are seeking to improve reliability, robustness, and safety across applications ranging from stationary energy storage to transportation in land, marine, and aerospace sectors. Raising standards for quality and safety places traditional battery architecture under scrutiny, as wireless alternatives avoid many of the limitations associated with complex wired designs. However, far field wireless solutions (wBMS) still face challenges due to signal reliability issues in enclosed high-voltage environments and the lengthy validation processes required.

## From a battery management system, to a cell management system

A battery management system (BMS) processes information from all cells, potentially hundreds, into a single state estimation. This requires input from every cell to calculate state of health<sup>13</sup>, state of charge, and available power in real time. However, because every cell is unique, this estimation ultimately represents an average of all cells combined.

When analytics are brought down to the cell level, allowing each cell to independently monitor and track its own behavior, batteries can become significantly safer and smarter.



These "Smart Cells"<sup>14</sup> can enhance battery lifetime performance by enabling more fine-grained data collection and improved cell-level control. They also strengthen safety through mechanisms such as alerting when a cell's performance or environment falls outside specifications, as well as through outlier detection.

Adopting a feature-rich cell monitoring solution creates platform intelligence that extends beyond the battery itself. This enables next-generation designs such as virtualized or zero BMS batteries in software-defined vehicles, supports more effective digital twins<sup>15</sup>, and improves sustainability. Cells can be extracted, evaluated, and reused multiple times before recycling, helping to minimize their overall carbon footprint.

## Application influences in battery design

High-voltage, high-power batteries are central to electrification in both automotive and industrial settings, but their design and management do differ due to the unique requirements of each sector.

As mentioned above, automotive applications balance efficiency, safety, and range, necessitating batteries that can support long-distance travel and fast charging, with battery weight being a key consideration. To streamline production and manage costs, passenger xEVs require modular battery platforms capable of capacities ranging typically from around 40 kWh to 100 kWh. However, the ongoing trend of upgrading battery system voltage from 400V to 800V to enhance charging speeds and reduce energy losses is introducing new design complexities. In automotive battery management, safety is of utmost importance, but factors like streamlined integration and enhanced operation efficiency are also critical.



Larger industrial and commercial EV applications, however, must manage higher peak loads and more sustained operation, while frequently operating in challenging environments with high temperatures<sup>16</sup> or continuous vibrations. Therefore, battery robustness and overall capacity are key<sup>17</sup>. This second element is especially crucial and affects the applications that can currently be addressed by industrial EVs.

For example, while the world's biggest electric construction excavators weigh around 26 tons and use batteries of around 300 kWh, large mining vehicles can easily reach up to 1000 tons – far beyond the limits of today's batteries. In order to meet the demands of vehicles working in harsh environments as well as larger vehicle types, the manufacturing of larger batteries needs to be simplified, while energy density and efficiency optimized.

In BESS applications, like those supporting renewable energy deployments, high-power batteries prioritize energy density, longevity, and thermal stability. Unlike automotive or industrial systems, BESS designs are less constrained by weight or size, enabling the use of larger-format prismatic cells, which can help to reduce design complexity and enhance durability. Nevertheless, challenges persist in guaranteeing the safety and maintainability of the system, mandating comprehensive sensing<sup>18</sup> and battery monitoring to identify issues such as cell-level imbalances and to optimize energy distribution across battery packs for enhanced longevity and reliability<sup>19</sup>.

Despite their differences, all three markets will benefit from any technology that can enhance key performance metrics while improving production flexibility and scalability, especially as the total demand for high-voltage batteries continues to grow.

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Dukosi Ltd develops revolutionary technologies that dramatically improve the performance, safety, and efficiency of battery systems, and enable a more sustainable battery value chain. The company provides a unique cell monitoring solution based on chip-on-cell technology and C-SynQ® communication protocol for electric vehicles (EV), industrial transportation and stationary battery energy storage markets.

For more information, email [info@dukosi.com](mailto:info@dukosi.com) or visit [www.dukosi.com](http://www.dukosi.com).