

Automotive

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Foreword

Welcome to the latest edition of our Industry Focus eBook, where we explore the dynamic and rapidly evolving world of automotive innovation. The automotive sector is undergoing a profound transformation, shaped by sustainability goals, regulatory shifts, and relentless technological advancement. From the development of smarter materials to the expansion of electric mobility, this eBook offers a curated view of the latest research and industry trends that are reshaping how vehicles are made, powered, and operated.

Materials science continues to play a pivotal role, as **New Smart Plastic to Revolutionize Aerospace and Automotive Industries** highlights the emergence of advanced polymers poised to enhance both performance and sustainability. Meanwhile, battery technology is accelerating into a new era, as detailed in **The Future of Graphene Batteries in Electric Vehicles**, where we examine how graphene could be the key to faster charging and longer-lasting EVs.

Global direction is equally important, and Industry Outlook: **How Global Policy Is Steering the Automotive Industry** provides insight into how legislation and international cooperation are guiding innovation across borders. On the technical frontier, **Metal-Organic Frameworks Improve Lithium-Ion Battery Cathodes Across All Key Material Types** explores how MOFs could unlock improvements in battery efficiency and longevity.

Infrastructure and safety are addressed in **Challenges of Electric Vehicle Charging**

Stations and The Role of Leak Detection Sensors in Electric Car Safety and Design, offering solutions to real-world concerns. Data-driven safety and performance enhancements take center stage in **How Tire Sensors Enhance Safety, Performance, and Efficiency in Modern Vehicles**, while **How Manufacturers Can Optimize EV Performance With Thermal and Sensor Technologies** shows how integrated systems can fine-tune electric vehicle output.

Finally, **How to Build a More Resilient Automotive Supply Chain Post-Chip Shortage** delivers strategic insight for navigating continued supply chain uncertainty.

This collection reflects the intersection of cutting-edge research and practical implementation. We hope it inspires new ideas and fuels your continued exploration of the innovations shaping the future of mobility.

How to Build a More Resilient Automotive Supply Chain Post-Chip Shortage

Moving raw materials, components, or finished products from the factory to the consumer has become a complex and uncertain process. Issues such as labor shortages, shipping bottlenecks, and public health restrictions have pushed many manufacturers to their limits.



Image Credit: Amphenol Advanced Sensors

Supply chain shortcomings have had a particularly severe impact on the automotive manufacturing industry. Once-streamlined production lines slowed sharply as securing third-party vehicle components became increasingly difficult.

In the case of electric vehicle (EV) production, it was one of the smallest vehicle components, microprocessors, that proved to be one of the most significant obstacles to efficient manufacturing.

Microprocessors control and regulate many of an EV's functions, but the undersupply of microprocessors has only served to highlight the fragility of the supply chain. This shortage

has also required manufacturers to become more agile and adaptable in order to keep production as close to normal as possible without too many compromises.

How the Automotive Chip Shortage Exposed Supply Chain Vulnerabilities

Whilst in part due to the COVID-19 pandemic, the [automotive](#) chip shortage was notably affected by other factors. The global health crisis played a role, but increasing consumer demand, pre-existing shortages in raw materials and components, competition for resources, and a lack of diversity in the production supply chain all contributed to the supply chain crisis.

These factors prompted the US Commerce Department to describe the situation as alarming and regard this as a major threat to factory production and the ongoing need to minimize modern transportation's reliance on fossil fuels.

Supply chain vulnerabilities arising from chip shortages in the automotive industry have also led to delayed production and increased prices in a range of items, including TV sets, washing machines, and car microprocessors.

The chip supply chain has been further impacted by more recent events. For example, Russia's attack on Ukraine has worsened the silicon shortage. Ukraine supplies roughly half of the world's semiconductor-grade neon, essential for the lasers used in chipmaking. This has led to increased chip shortage-related automotive vulnerabilities and further added to supply chain shortages since 2022.

The electrification revolution in transportation continues to be slowed by the lack of availability of these chips. In some instances, parking lots full of new cars cannot be completed until new chips arrive.

An executive order referred to as the CHIPS and Science Act of 2022 aims to address the automotive chip shortage and related supply chain vulnerabilities. However, this is a long-term solution that will require a considerable amount of time before providing relief.

As chip shortages continue, manufacturers are forced to employ aggressive automotive supply chain management, creativity, and patience.

Addressing the Car Microprocessor Shortage with Sensors

Different automotive sensor manufacturers have implemented a number of creative solutions to help mitigate the impact of the silicon shortage. For instance, Ford began shipping its Explorer SUVs without all the chips installed.

One of the most effective responses has been the use of 'swap-outs'. In this context, a swap-out means designing and manufacturing products able to accept parts made by other manufacturers. However, swap-outs involve more than simply replacing a part; each substitution requires rigorous testing and approval.

For example, a substituted sensor component requires additional testing and verification to confirm that it works as intended and performs under different environmental conditions. A different circuit board may require a different type of soldering, potentially impacting its function if completed incorrectly.

Sensor parts must still meet the Production Part Approval Process (PPAP) required to ensure consistent quality despite supply chain problems. In the case of the automotive industry, it may be necessary to verify that items meet as many as 18 requirements, including:

- Design records
- Design Failure Mode and Effects Analysis (DFMEA)
- Engineering change documents
- Customer engineering approval
- Process flow diagrams
- Process Failure Mode and Effects Analysis (PFMEA)
- Control plans
- Measurement System Analysis (MSA) studies
- Dimensional results
- Material performance test results
- Initial process studies
- Statistical Process Control (SPC)
- Qualified laboratory documentation
- Appearance Approval Reports (AAR)
- Master samples
- Sample products
- Checking aids
- Records of compliance with customer-specific requirements

- Part Submission Warrant (PSW)

Ensuring Streamlined Swap-outs by Working with an OEM Sensor Manufacturer

Manufacturers looking to leverage swap-outs to better manage supply chain issues are advised to work with an experienced EV sensor manufacturer. A good sensor manufacturer should have the expertise to ensure any swap-out meets design specifications, allowing manufacturers to complete all required testing to ensure compliance.

When engaging with an EV sensor manufacturer, it is prudent to check:

- How sensors are manufactured, for example, whether sensors are made from scratch, or whether they are assembled using sourced components.
- Where resources come from, including raw materials and prefabricated components. For example, are materials and parts sourced domestically or from an international source?
- What raw materials or components stocks are kept on hand or available via the sensor manufacturer's supplier, or how much inventory is it willing to purchase.
- Whether or not the sensor manufacturer has robust long-term agreements for sourcing raw materials or components.
- The type of allocation for components, what buffer is in place, and how much volume can be provided to customers.

Above all, carmakers need partners who offer complete transparency over design changes and sourcing. It is also important that manufacturers be made aware of any changes and provided with appropriate documentation so that they have an accurate record of a final product's makeup.

Documentation should also include appropriate testing and validation to ensure that products meet the necessary manufacturer's standards and regulatory requirements.

Mitigating Supply Chain Vulnerabilities

The global supply chain shows signs of recovery, but a return to pre-2020 conditions remains distant.

Manufacturers must continue to mitigate supply chain vulnerabilities from chip shortages in the automotive industry in the meantime, and this will continue to require a mix of ingenuity and patience.

For EV sensors and their microprocessors, experienced suppliers are essential in keeping production schedules on course.

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New Smart Plastic to Revolutionize Aerospace and Automotive Industries

Texas A&M researchers have developed an ultra-durable, recyclable smart plastic that heals and reshapes itself, offering major potential for aerospace, defense, and automotive applications.



Dr. Mohammad Naraghi showcasing ATSP, the carbon-fiber smart plastic. Image Credit: Dr. Mohammad Naraghi/Texas A&M University College of Engineering

Published in *Macromolecules* and the *Journal of Composite Materials*, Dr. Mohammad Naraghi, director of the Nanostructured Materials Lab and professor of aerospace engineering at Texas A&M, led the breakthrough.

The study investigated the mechanical integrity, shape recovery, and self-healing capabilities of an innovative carbon-fiber plastic composite known as Aromatic Thermosetting Copolyester (ATSP).

“ What’s really exciting is that this material isn’t just ultra-durable, it’s also adaptive. From on-demand healing in damaged aircraft to enhancing passenger safety in vehicles, these properties make it incredibly valuable for future materials and design innovations.

Dr. Mohammad Naraghi, Professor, Aerospace Engineering, College of Engineering, Texas A&M University

Healing Damage on Demand

ATSP gives up new possibilities in companies where performance and reliability are crucial, and failure is not an option. In aerospace, it could recover from high-temperature stress damage mid-service. In automotive applications, its bond-exchange chemistry can restore vehicle structure after a collision while protecting passengers.

Belonging to a class of materials called vitrimers, ATSP combines the flexibility of thermoplastics with the chemical and structural stability of thermosets. When reinforced with carbon fibers, it becomes several times stronger than steel yet lighter than aluminum. Unlike conventional plastics, ATSP can be recycled repeatedly without losing its chemical integrity.

“ These vitrimers, when reinforced with discontinuous fibers, can undergo level cycling – you can easily crush and mold it into a new shape, and this can happen across many, many cycles, and the chemistry of the material basically doesn’t degrade.

Dr. Mohammad Naraghi, Professor, Aerospace Engineering, College of Engineering, Texas A&M University

ATSP differs from typical plastics in that it can self-heal and restore its shape.

“ *Shape recovery and self-healing are two facets of the same mechanism. With shape recovery, it refers to the bond exchange within a continuous piece of material – a kind of built-in ‘intelligence.’ And, in self-healing, there’s discontinuity in the material like a crack.*

Dr. Mohammad Naraghi, Professor, Aerospace Engineering, College of Engineering, Texas A&M University

The researchers performed a unique stress test known as cyclical creep testing to investigate these material properties. Repeatedly stretching the material, while measuring how it absorbed, stored, and released strain energy, identified two key temperature thresholds.

“ *The first is the glass transition temperature, or the temperature at which the polymer chains can move around easily, and the second is the vitrification temperature. That’s the temperature at which these bonds are thermally activated enough that you can see massive bond exchanges to cause healing, reshaping and recovery.*

Dr. Mohammad Naraghi, Professor, Aerospace Engineering, College of Engineering, Texas A&M University

The researchers next performed deep-cycle bending fatigue experiments, occasionally heating the material to roughly 160 °C to initiate self-healing.

Their findings revealed that the ATSP samples not only withstood hundreds of stress and heating cycles without failure but also became stronger during the healing process. In the same way skin heals, the material deformed, healed, and "remembered" its original shape, becoming more durable than its original form.

In another series of tests, the team pushed ATSP through five extreme damage-healing cycles at 280 °C. The material regained nearly full strength after two cycles and maintained about 80 % efficiency by the fifth, with only minor wear from manufacturing defects. Its chemical stability remained unchanged throughout.

The breakthrough achieved by the research team symbolizes more than just an emergent class

of materials; it is a template for how daring science and smart collaborations might reimagine a future in which plastics change and adapt rather than just survive.

“ My students and post-docs do the heavy lifting, I cannot thank them enough. It's through trial and error, collaborations and partnerships that we turn exciting curiosity into impactful applications.

Dr. Mohammad Naraghi, Professor, Aerospace Engineering, College of Engineering, Texas A&M University

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Source:

[Texas A&M University](#)

The Future of Graphene Batteries in Electric Vehicles

The rapid growth of electric vehicles (EVs) is pushing the demand for more efficient, durable, and sustainable battery technologies. While lithium-ion (Li-ion) batteries have dominated the EV landscape, they have several limitations, including long charging times, degradation over multiple cycles, and safety concerns.

Graphene, a groundbreaking material known for its exceptional electrical and thermal properties, is emerging as a game-changer in battery technology. By integrating graphene into **energy storage** solutions, researchers and companies aim to significantly improve battery performance. This article examines graphene batteries' advantages, research progress, commercialization challenges, and impact on EVs.

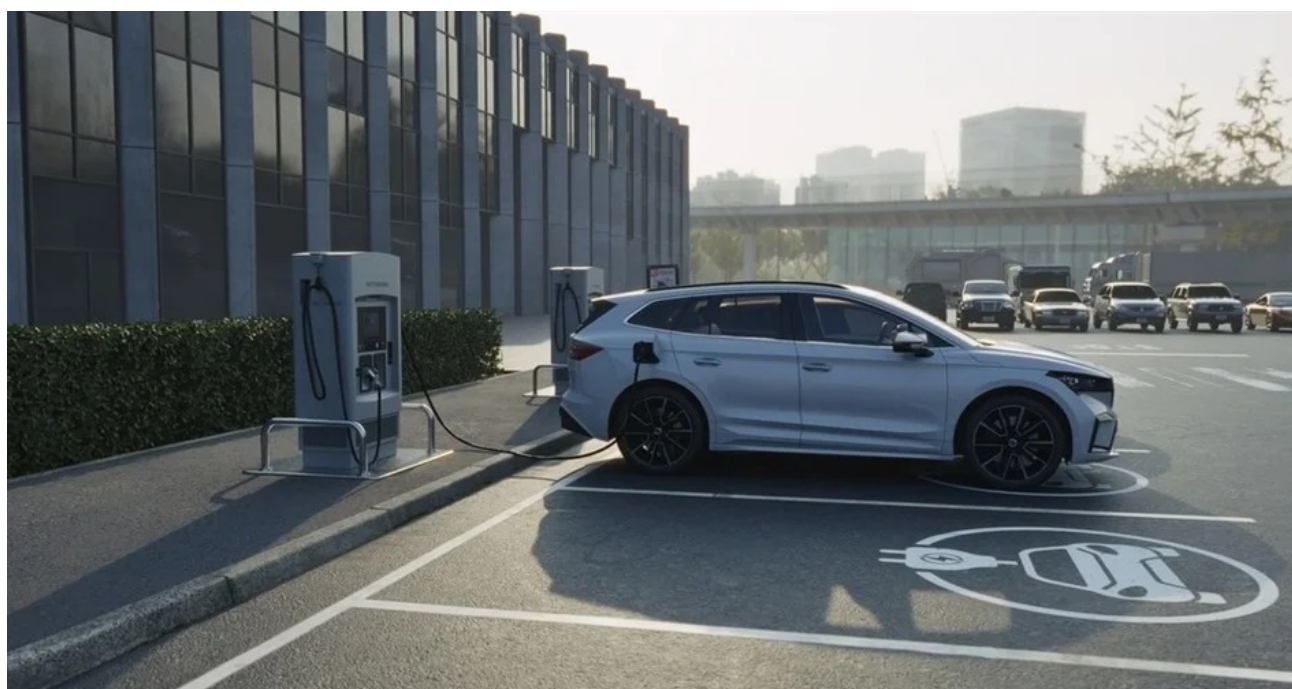


Image Credit: Aliaksei Kaponia/Shutterstock.com

What is Graphene?

Graphene is a single layer of carbon atoms arranged in a hexagonal lattice, making it the thinnest yet one of the strongest materials known to science. Its remarkable properties include exceptional electrical conductivity, superior mechanical strength, and high thermal conductivity.

Graphene is 200 times stronger than steel while being incredibly lightweight, enabling

innovative applications in various industries, from electronics to aerospace.¹

Due to its high electron mobility, graphene enables faster charge and discharge rates in batteries, enhancing efficiency and performance beyond traditional Li-ion technology.

Since its discovery, extensive research has focused on unlocking its potential for improving energy storage—especially in EV batteries, where it could enhance range, charging speed, and lifespan.¹

Advantages of Graphene Batteries Over Li-Ion Batteries

Graphene-based batteries offer several advantages over conventional Li-ion batteries, making them highly promising for the EV industry.

- **Faster Charging:** Graphene enables rapid electron movement, significantly reducing charging times. While Li-ion batteries take 30–60 minutes for a full charge, graphene batteries could potentially charge within a few minutes.^{1,2}
- **Higher Energy Density:** Li-ion batteries have a limited energy storage capacity. With their high surface area and superior conductivity, graphene batteries can store more energy in the same volume, extending the EV range.^{1,2}
- **Longer Lifespan:** Traditional batteries degrade with repeated charge cycles. Graphene batteries exhibit less wear and tear, resulting in a longer operational life and reducing the need for frequent replacements.^{1,2}
- **Improved Efficiency:** Graphene enhances ion transport, reducing energy losses during charging and discharging. This leads to better overall battery performance and improved vehicle efficiency.^{1,2}
- **Enhanced Safety:** Overheating and thermal runaway are common issues with Li-ion batteries. Graphene's superior thermal conductivity dissipates heat efficiently, minimizing the risk of fires and explosions.^{1,2}



Video Credit: Enkoretech/YouTube.com

Current Research and Development of Graphene Batteries

Several companies are actively developing graphene-based battery technology to bring it to commercial viability. For example, Nanotech Energy is working on commercializing graphene batteries with high energy density.

Samsung Advanced Institute of Technology (SAIT) is enhancing Li-ion batteries with graphene for faster charging, while Huawei focuses on graphene for improved heat management, boosting battery efficiency and longevity in EVs.¹

Similarly, research institutions and universities are also leading efforts in optimizing graphene battery applications for EVs.

A recent study published in [Applied Surface Science](#) investigated copper-doped graphene as a high-performance anode material for Li-ion batteries using first-principles computational methods.

Copper doping enhanced active sites, significantly increasing theoretical capacities to 1651.8 mAh/g for Li-ion. This material also exhibited low diffusion barriers, minimal lattice changes (<1%), and excellent conductivity, making it a promising anode material for next-generation energy storage solutions.³

Another notable study published in the [Journal of Power Sources](#) introduced a high-energy-density graphene-based anode using a polyethersulfone (PES) sheet and laser-induced graphene (LIG) techniques for Li-ion batteries.

The hexagonal porous structure enhanced lithiation, improving battery lifespan. This binder-free, non-hazardous anode retained 80.7% capacity from 710 mAh/g at 0.1C and achieved 99% coulombic efficiency over 200 cycles, offering a scalable solution for next-generation Li-ion batteries in portable devices and EVs.⁴

The Benefits of Graphene Batteries

Graphene batteries have the potential to significantly enhance EV performance across several key aspects.

Vehicle performance

In the near future, the higher energy density of graphene batteries is expected to enable EVs to achieve significantly longer driving ranges on a single charge, making them more viable for extended journeys. As graphene technology advances, improved power output will likely enhance acceleration and overall efficiency, pushing EVs closer to the capabilities of high-performance sports cars.^{1,5}

Furthermore, graphene's superior conductivity is anticipated to ensure consistent energy delivery, reduce performance fluctuations, and optimize power management for a smoother and more reliable driving experience.

Charging times

The ultra-fast charging capability of graphene batteries is one of their most significant advantages. With the ability to charge in minutes rather than hours, EV owners could experience a level of convenience comparable to refueling a traditional gasoline vehicle. This rapid charging would also reduce demand on charging infrastructure, improving accessibility and efficiency in EV networks.^{1,5}

Sustainability

Graphene-based batteries could contribute to a more sustainable EV ecosystem. Their longer lifespan reduces battery waste, and they contain fewer environmentally harmful materials than Li-ion batteries. Graphene can also be derived from abundant carbon sources, potentially reducing reliance on rare earth metals and minimizing the environmental impact of battery

production.^{1,5}

Challenges and Limitations of Graphene Batteries

Despite its potential, several challenges hinder the widespread adoption of graphene batteries in EVs.

- **Manufacturing Costs:** Producing high-quality graphene remains costly, making large-scale manufacturing a significant challenge.¹
- **Scalability Issues:** Scaling up graphene battery production to meet the demands of the EV industry requires major improvements in fabrication techniques.¹
- **Integration into Existing Systems:** Most current EVs are built around lithium-ion batteries. Shifting to graphene-based systems would require battery management systems and charging infrastructure updates.¹
- **Supply Chain Constraints:** Graphene production relies on specialized materials and processes. A sudden spike in demand could strain the supply chain.¹
- **Commercialization Timeline:** Although research is advancing, it may still take several years before graphene batteries are ready for mass-market adoption, primarily due to the need for further testing and cost reduction.¹

The Future Outlook of Graphene for Battery Production

The path to commercializing graphene batteries in EVs centers on overcoming technical and economic hurdles. Analysts suggest that over the next decade, graphene-enhanced batteries may begin to appear in high-end EV models, with wider adoption expected as production becomes more cost-effective.¹

Looking further ahead, graphene technology could play a key role in accelerating EV adoption by addressing key concerns such as range anxiety and charging limitations. As manufacturing processes mature, graphene-based batteries may also support sustainability efforts by reducing dependence on rare earth materials and extending battery life—helping to lower the overall environmental footprint.¹

Conclusion

Graphene batteries offer strong potential to reshape the EV landscape with faster charging, better performance, and greater durability. While there are still hurdles to clear, ongoing research and investment point to a promising trajectory. As technological progress reduces costs, graphene-based batteries could become a crucial driver of more efficient and

sustainable electric mobility.

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Water Detection Sensor



According to sharp growth of Electrical Vehicles (EV), many OEMs are using cooling systems for their battery pack systems. However, if an instance of water leakage were to occur in Li-ion battery packs, it would create dangerous conditions.

Thermometrics Water Detection Sensor detects moisture leakage via a change in resistance value of the sensor and feeds a signal to the Battery Management System (BMS) to warn the driver.

Features:

- $510k\Omega \pm 3\%$
- Operating Temperature Range: -40°C to 85°C
- Easy to install
- RoHS Compliance (Directive 2011/65/EU)

Applications

- Battery pack water detection
- Overflow of water/fluid
- Leak Detection from a burst pipe
- Level detection on take fill applications
- Condensate overflow sensor for HVAC Applications
- Sump Pumps



The Role of Leak Detection Sensors in Electric Car Safety and Design

Electric vehicles (EVs) rely on electrons rather than petrol or diesel and typically require less maintenance than their internal combustion engine (ICE) counterparts.



Image Credit: Amphenol Advanced Sensors

Even so, designing a vehicle to run on an electric car battery pack does not make it immune, and few drivers welcome the sight of unexplained fluid beneath their vehicle.

It's tempting to neglect regular inspections, as EVs do not require the routine oil changes associated with ICE vehicles. But it is important to check for unusual stains or fluids on the driveway or garage floor to prevent potentially severe and expensive issues.

Many EVs feature a suite of sensors that can check the vehicle's fluids. Coolant remains central to EV thermal management, keeping batteries, motors, and inverters within safe limits.

Contemporary EVs feature more sophisticated coolant control systems than their ICE predecessors. They use both coolant and refrigerant to manage temperatures via heat pumps, heat exchangers, valves, and sensors.

Fitting precise, dependable sensors is the most effective way to stop minor leaks from

becoming major faults. The most advanced electric car battery pack designs can detect coolant leaking into the spaces near battery cells or other areas where this could damage the vehicle.

Potential Leak Sources and the Sensors Required to Monitor These

Leak detection is key to monitoring an electric vehicle's battery health, whether the vehicle is on the road or charging. Leaks affecting an EV's battery pack are the most important to monitor because these leaks can affect its thermal management system. These include:

- Coolant
- Refrigerant
- Dielectric oil
- Electrolytes

This article looks at potential sources of these leaks and the sensor technology used to monitor these.

Monitoring for Liquid Coolant Leaks

In EVs, coolant circulates in a sealed loop around the battery, inverter, cabin, and sometimes the motors to maintain a suitable temperature range of 15-45 °C.

The thermal management system ensures that the EV's battery, inverter, and motors function without overheating, reducing the risk of the system triggering power-limiting mode or complete shutdown.

Sensor(s) Needed for Coolant Leak Detection

Electric vehicles require several sensors to detect liquid coolant leaks.

Coolant Level Sensors

An EV battery's thermal management system requires a specific level of liquid coolant to function properly, much like an ICE vehicle's cooling system. Coolant level sensors monitor the amount of liquid coolant present within the battery's thermal management system, ensuring this is kept at an optimal level.

Coolant Breach Sensors

Coolant breach sensors provide a secondary means of monitoring liquid coolant levels. A coolant breach sensor detects liquid near the battery cells, highlighting a potential coolant

leak within the coolant lines inside the battery pack.

They also monitor the presence of water and other liquids in the battery enclosure, which can potentially cause corrosion and short circuits.

Coolant Temperature Sensors

A coolant temperature sensor provides intelligent information on whether or not the coolant is efficiently transferring heat, for example, where the coolant may be unable to circulate properly, or where there may be insufficient cooling or aeration.

Many battery systems feature temperature sensors at both the inlet and outlet of heat-generating devices, such as the battery, inverters, motors, and heat exchangers. These sensors provide key information on heat exchange efficiency.

Monitoring for Refrigerant Leaks

Any EV with an air conditioning system will use refrigerants to keep the passenger space cool, but some manufacturers will also employ this system to maintain optimal battery pack temperatures. Refrigerant-based battery cooling via heat pump systems takes two forms:

- Direct, where refrigerant from the EV's air conditioning system flows through a series of cooling plates within the battery pack to maintain low temperatures.
- Indirect, whereby the EV's coolant fluids flow through plates cooled by refrigerant. This more complex cooling system also requires other components, such as a chiller, to keep coolant within an optimal range.

Sensor(s) Needed for Refrigerant Leak Detection

Two types of sensors are required to detect refrigerant leaks in electric vehicle battery packs.

Pressure Sensors

A loss of pressure within a refrigerant system will cause this to stop working. Pressure sensors usually give the first warning of a refrigerant leak, because the compressor, evaporator, and expansion valves all have an expected pressure at different points in the system. The inability to achieve target pressures likely means that some of the refrigerant has leaked from the system.

Temperature Sensors

The ideal gas law also applies to refrigerant, with the combination of temperature and pressure sensing in the gas and liquid phases within the system generally functioning as a reliable indicator of whether sufficient refrigerant is available.

Carbon Dioxide (R744) Sensors

R744 is a carbon dioxide-based refrigerant used in some of the most advanced EV refrigerant systems. This refrigerant leaking into the passenger compartment can result in unsafe levels of carbon dioxide in a breathable air space.

Non-dispersive spectroscopy can pinpoint CO₂ levels from a refrigerant leak with precision.

Monitoring for Dielectric Oil Leaks

Dielectric oil cooling boasts superior battery pack temperature control, making it extremely promising for battery pack thermal management applications.

Inside the battery pack, battery cells are immersed in dielectric oil, which circulates in a closed system to keep them cool. The oil, an engineered thermal conductive fluid, not only keeps battery cells cool but also suppresses thermal events.

Sensor(s) Needed for Dielectric Oil Leak Detection

Oil Level, Quality, and Dielectric Sensor

Battery pack thermal management using dielectric oil requires a specific level of fluid to work effectively, must like a coolant system. Monitoring the fluid's quality and dielectric will also offer insight into the life expectancy of the fluid, providing excellent prognostic tools.

Oil Temperature Sensor

This sensor monitors for spikes in dielectric oil temperature. An oil temperature sensor is a useful indicator of the system's functionality, highlighting issues with dielectric coolant flow that may signify damaged or kinked lines.

Monitoring for Electrolyte Leaks

Measuring the presence of electrolyte leakage is useful in ascertaining whether cells within an electric vehicle's battery pack are failing due to stress conditions or age. These leaks would generally be found within the battery enclosure, and it is impossible to observe them from outside the vehicle, so it is imperative that sensors inside the battery pack be used.

Sensor(s) Needed for Detection

Electrolyte Leakage Detection Sensors

A hydrocarbon sensor is ideally suited to detecting electrolyte leakage from damaged cells,

because this leakage typically contains volatile hydrocarbons.

Key Considerations for EV Battery Pack Design

Other Signs or Symptoms of an EV Coolant or Refrigerant Leak

Outside of sensor alerts, EV owners might notice physical signs indicating a coolant or refrigerant leak.

One of the most common of these signs is the presence of stains or puddles under the vehicle, which could potentially indicate leaking fluids.

There may also be a sudden drop in vehicle performance, such as the EV's battery overheating frequently or a notable drop in the air conditioning system's cooling ability. A strange odor may be another sign of coolant or refrigerant escaping.

These signs are not as precise or reliable as sensor alerts, but they may indicate that something is wrong.

Preventive Maintenance Steps to Reduce the Likelihood of Leaks

EV owners can take a number of preventive maintenance steps in order to minimize the likelihood of leaks. For instance, it is prudent to regularly inspect the vehicle for any signs of fluid leakage, including unusual smells or stains on the ground near the vehicle.

Coolant levels should be kept within the recommended range, and hoses and seals should be maintained to ensure they are in good condition. Checking the vehicle's cooling and refrigerant systems during routine maintenance can help detect potential issues before they develop into major problems.

Overall, keeping the vehicle in good condition and promptly addressing any minor issues is key to helping prevent leaks.

Risks and Consequences of Continued Operation with a Detected Leak

A detected leak in an EV should be dealt with immediately to avoid serious risks.

A vehicle's thermal management system may fail if the coolant or refrigerant levels drop too low, leading to the overheating of its battery, inverter, or motors. This overheating could lead to a reduction in performance, triggering power-limiting modes, or causing the vehicle to shut down entirely in more severe cases.

A leak involving dielectric oil or electrolytes can lead to corrosion, electrical shorts, or even fires, while refrigerant leaks in the passenger compartment can pose health risks due to unsafe levels of CO₂.

These potential consequences mean that it is important to immediately address any detected leaks, ensuring the vehicle's safety and longevity.

Electric Car Battery Pack Thermal Management Performance and Safety

Proper coolant system function is one of the most essential factors in ensuring an EV's peak performance and safety.

Just as an engine will quickly fail without coolant, an EV without it risks serious battery and electronics damage.

However, most modern electric vehicles have the 'sense' to alert their owners when fluid is required. They can alert their owners via alarms, visual alerts, and even text messages thanks to the presence of sensors within the vehicle.

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Industry Outlook: How Global Policy Is Steering the Automotive Industry

The global automotive sector is navigating a shifting policy landscape, with new regulations influencing supply chains, production models, and market strategies. Key changes include tariffs on imported goods, emissions targets, electric vehicle (EV) subsidies, and local production requirements.

Governments use these policy tools to support economic development, advance decarbonization goals, and strengthen domestic manufacturing.

This article explores how such measures are shaping the strategic decisions of automakers, suppliers, and consumers, highlighting differences across major markets and regions.



Image Credit: IM Imagery/Shutterstock.com

Trade Policies: Tariffs Reshape Supply Chains and Pricing

Trade tensions and protectionist measures are prompting automakers to reassess their global supply chains. In the United States, proposed tariffs include a 25 % tax on imports from Mexico and up to 60 % on goods from China. These measures could raise production costs and reduce vehicle affordability.

Analysts estimate that consumer prices may rise by 5–10 % for models that rely heavily on imported components such as semiconductors and battery materials.^{1,2}

The European Union and China are also adjusting to shifting market conditions. The EU has revised its Corporate Average Fuel Economy (CAFE) rules, which allow for increased production of traditional vehicles to help manufacturers meet compliance targets. This update has led to a 63,000-unit increase in Europe's 2025 production forecast.

China is leading in electric vehicle battery production, making more than 75 % of global components. This cost advantage enables Chinese automakers to sell EVs at prices up to 25 % lower than their Western competitors. As a result, Chinese automakers are quickly expanding into Europe and Southeast Asia.^{2,3}

These trends are driving a renewed focus on local manufacturing. [Ford](#) and [General Motors](#), for example, plan to assemble hybrid models in North America to avoid tariffs. At the same time, German automakers like [Volkswagen](#) are building battery gigafactories in Eastern Europe to reduce reliance on Asian suppliers.^{3,4}

Emissions Targets and EV Subsidies: Diverging Regional Strategies

Environmental regulations are shaping distinct market trajectories across regions.

The EU has committed to reducing carbon dioxide emissions by 55 % by 2030 and plans to ban new internal combustion engine (ICE) vehicles by 2035. This has prompted automakers to accelerate EV production.

However, adoption remains inconsistent. In 2024, EVs made up 12 % of the market in Europe, while hybrid sales rose by 23 %, reflecting consumer concerns about charging infrastructure.^{4,5}

In the U.S., federal EV incentives under the [Inflation Reduction Act](#) (IRA) clash with state-level initiatives. The IRA's \$7,500 tax credit for domestically assembled EVs has triggered \$40 billion in battery plant investments across the Midwest and South.

However, recent proposals to repeal or revise these credits have introduced policy uncertainty. Analysts expect EV sales growth to slow to 6.7 % in 2025, down from 48 % in 2023.^{4,6}

Meanwhile, China is doubling down on its first-mover advantage. Supported by state subsidies and a vertically integrated supply chain, the country is targeting 50 % EV sales by 2025, ten years ahead of its initial timeline.

Chinese brands like [BYD](#) now hold 12 % of Europe's EV market, up from 9 % in 2024. Their competitive advantage lies in cost-efficient production and advanced battery technologies.³

EU to propose three years CO2 targets to automakers | REUTERS



Localization and Industrial Policies: Redrawing Production Maps

Governments are ramping up domestic manufacturing incentives to reduce geopolitical risk and create local jobs.

In the U.S., the CHIPS and Science Act allocates \$52 billion to support semiconductor production, addressing shortages that have impacted advanced driver-assistance systems (ADAS) and electric vehicle components. Similarly, Canada's Critical Minerals Strategy is positioning the country as a key supplier of lithium and nickel for the North American battery supply chain.^{1,2}

These policies are fragmenting global production. Asia-Pacific remains the epicenter, accounting for 60 % of light vehicle sales in 2025, driven by China's 26 million-unit market and India's expanding middle class.

Meanwhile, North American output is projected to decline by 155,000 units this year, influenced by trade uncertainties and tighter [United States-Mexico-Canada Agreement](#) (USMCA) content requirements.

In response, automakers such as [Toyota](#) and [Hyundai](#) are scaling up hybrid production across multiple regions. This helps them comply with local content rules while aligning with regional demand trends.^{2,3,7}

Technological Investments: Software and Autonomy Take Center Stage

Policy developments are accelerating progress in software-defined vehicles (SDVs) and autonomous driving technologies. In the EU, the Digital Vehicle Data regulation, which mandates standardized access to connected car data, has prompted new collaborations between automakers and tech firms such as [Qualcomm](#) and [NVIDIA](#).

SDVs support over-the-air updates for features like safety systems and infotainment. By 2025, an estimated 7.6 million SDVs will be in operation, with North America accounting for 43 % of global adoption.^{4,7}

Autonomous vehicles continue to face regulatory hurdles. While companies like [Mercedes-Benz](#) and [BMW](#) have introduced Level 3 systems in Germany, U.S. regulators remain cautious. Legal issues, such as liability for AI-driven accidents, are major concerns. In fact, 78 % of industry leaders say this is a critical challenge.

China's proactive approach, which includes creating testing zones for autonomous vehicles in 20 cities, has helped companies like [Baidu](#) to advance Level 4 trials. However, widespread commercialization remains several years away.^{4,5,7}

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Labor and Market Adaptations: Unions and Dealerships Under Pressure

Policy-driven shifts in the automotive industry are placing new demands on labor and after-sales infrastructure.

[The United Auto Workers](#) (UAW) and European unions are asking for job guarantees as automakers transition to EVs, which requires 30 % fewer assembly workers. In response, the government has launched a \$2 billion EV workforce initiative to fund retraining programs in Michigan and Ohio, but progress is slow.^{1,6}

At the retail level, dealerships are adjusting to changing consumer habits. According to [Cox Automotive](#), 75 % of U.S. car buyers now prefer a mix of online and in-person purchasing. This shift is pushing dealers to invest in digital sales platforms. However, declining sales of traditional ICE vehicles, which are projected to fall to 75 % of the U.S. market by 2025, could reduce revenue from traditional maintenance services.^{5,6}

Conclusion: A Sector at a Crossroads

Global policy developments are steering the automotive industry toward a more fragmented landscape, where regional strategies increasingly shape production, innovation, and market access. While tariffs and localization efforts may benefit domestic sectors in the short term, they also introduce cost pressures and reduce cross-border cooperation.

At the same time, emissions targets and technology investments are advancing long-term sustainability goals, but progress is slow due to infrastructure issues and consumer acceptance. For automakers, adaptability will be critical. This includes supply chain diversification, workforce retraining, and strategic alliances such as the proposed Honda–Nissan–Mitsubishi merger.

As the industry moves forward, its trajectory will depend not only on consumer demand but also on how effectively economic policy aligns with environmental ambition.^{3,4}

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Metal-Organic Frameworks Improve Lithium-Ion Battery Cathodes Across All Key Material Types

Researchers have used metal-organic frameworks to engineer higher-performing lithium-ion battery cathodes. Their findings offer improved stability, conductivity, and energy density across several key materials.



Image Credit: Troggt/Shutterstock.com

A recent study published in [Materials Features](#) explores how metal-organic frameworks (MOFs) can serve as both templates and precursors in the synthesis of cathode materials for lithium-ion batteries. The research team systematically classified traditional cathode types, introduced MOF-based synthesis strategies, and evaluated the electrochemical performance of the resulting materials.

The findings demonstrate that MOFs offer precise control over morphology and structural characteristics, addressing longstanding limitations in conventional cathode synthesis. This molecular-level engineering could impact the development of more durable and energy-efficient batteries.

Cathode Materials

Lithium-ion batteries are central to modern portable electronics and electric vehicles, largely due to their high energy density and long operational life. As global energy is beginning to transition towards more renewable sources, there is growing pressure on battery technology to meet the rising demands for efficient, high-capacity storage.

Cathode materials play a critical role in determining battery performance, influencing energy density, cycle life, voltage range, and safety. Most lithium-ion battery cathodes fall into one of three structural categories: layered oxides such as lithium cobalt oxide (LiCoO_2), spinel materials like lithium manganese oxide (LiMn_2O_4), and polyanion olivine compounds including lithium iron phosphate (LiFePO_4).

There are reasons to choose each of these options, and reasons to avoid them. Layered oxides often suffer from phase instability, spinel materials struggle with electronic conductivity, and olivine compounds can exhibit sluggish lithium-ion transport. These challenges have prompted researchers to look for new approaches to cathode fabrication.

MOFs as Cathode Synthesis Templates

MOFs are crystalline materials composed of metal ions coordinated with organic ligands. They're renowned for their tunable porosity and structural flexibility. Here, the researchers used MOFs as scaffolds to create advanced cathode materials in a two-step process.

First, they synthesized MOF templates via hydrothermal or solvothermal reactions. These templates were then thermally converted in the presence of lithium sources to form the final cathode compositions.

This method allowed precise control over particle size, surface morphology, and chemical composition. Carbon coatings produced from the MOF ligands frequently incorporated nitrogen, which enhanced electrical conductivity and stabilized the interface between the electrode and the electrolyte. At the same time, doping with transition metals such as nickel, manganese, or aluminium helped to mitigate structural degradation during cycling and improved long-term stability.

Thermal treatment also generated oxygen vacancies, facilitated partly by mechanisms like the Kirkendall effect, which promoted ionic and electronic transport within the cathode material. However, these vacancies need to be finely tuned, as their excessive formation can lead to

performance degradation.

Overall, the compositional and structural flexibility offered by MOFs enabled tailored enhancements to layered, spinel, and polyanion cathode materials, improving their durability and electrochemical efficiency.

Performance Gains Across Cathode Types

The study found that MOF-mediated synthesis led to performance improvements across all three main cathode categories when compared to conventional methods. In layered cathodes, MOF-derived LiCoO_2 and ternary layered oxides demonstrated higher cycling stability, improved rate capabilities, and elevated operating voltages. One example involved a nitrogen-doped carbon-coated LiCoO_2 cathode that maintained a reversible capacity of 171.1 mAh g^{-1} after 200 cycles at 1°C , indicating strong performance retention.

For spinel cathodes, introducing oxygen vacancies and heteroatom-doped carbon coatings significantly improved conductivity and extended cycle life. An oxygen-deficient LiMn_2O_4 sample retained over 90 % of its capacity after 1000 cycles at 10°C , showcasing high durability and efficient ion transport.

Olivine cathodes also experienced substantial improvements. MOF-derived LiFePO_4 **composites** achieved high rate performance and maintained capacities above 160 mAh g^{-1} over several hundred cycles, reflecting enhanced structural integrity and long-term reliability. The results of the study indicate the potential of MOF-derived cathodes to deliver superior energy density, stability, and rate performance compared to traditionally synthesized materials.

This could be extended beyond lithium-ion batteries. The principles of this MOF-mediated synthesis may be applicable to other battery technologies, such as sodium-ion and potassium-ion systems. The ability to customise structure and composition at the nanoscale provides a powerful toolkit for designing next-generation electrode materials across a wide range of chemistries.

Even better, by improving both energy density and cycling stability, MOF-enhanced cathodes could significantly strengthen the performance of batteries used in electric vehicles and grid-scale storage systems. These materials could help support the wider integration of intermittent renewable energy sources into modern power infrastructures.

What's Next?

Despite their promise, MOF-derived cathode materials must overcome some obstacles before they can be scaled for commercial applications. Manufacturing processes must become more cost-effective and environmentally sustainable. Simplifying syntheses while maintaining performance will be essential for industrial adoption.

Further research is also needed to better understand lithium storage mechanisms and the structural evolution of these materials during cycling. Advanced characterization tools could help clarify these processes, guiding the rational design of future MOF-based electrodes.

Turning lab-scale breakthroughs into practical technologies will depend on stronger collaboration between researchers and industry. As research into MOF chemistry advances, it could offer an interesting way to improve cathode design and enhance overall battery performance.

Journal Reference

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How Manufacturers Can Optimize EV Performance With Thermal and Sensor Technologies

Thermal management has been a concern for as long as engines have propelled vehicles. Vehicle temperature has always been central to performance and safety, with poor thermal control risking anything from overheating to fire.

A shift from fossil fuels to electricity is transforming transport, with EVs already becoming a common sight on the roads. It will be some time before all modes of transportation are electrified, but fully electric vehicles (EVs) are already starting to dominate roadways.

Experts predict EVs could overtake petrol and diesel vehicles within a few years, with battery-powered aircraft, boats, and trains following close behind. Like their fossil fuel-powered counterparts, thermal management for EVs is essential, arguably more so.

Thermal management for EVs, primarily their batteries, has been a major barrier to making an alternative vehicle type viable. Mass charging infrastructure and range have also been ongoing issues.

Advances in thermal systems have allowed EVs to perform reliably, whether on short errands or long-distance journeys. They continue to ensure the next generation of transportation remains safe and dependable.

Despite their growing capability, EVs still need carefully controlled operating temperatures to ensure long life and peak performance.

Thermal runaway in a battery pack presents new hazards for drivers, passengers, and emergency crews. Rapid, accurate, and responsive thermal management systems are essential for vehicle design, from the engine block to the battery pack.

Six Places for Electric Car Temperature Sensors in Vehicle Design

Like an internal combustion engine (ICE) vehicle, excessive heat can severely affect an EV's safety, functionality, and useful life. In an EV, temperature sensors serve more roles than in conventional cars, as more components are sensitive to heat extremes.

Outside of their obvious role in the EV battery pack, six places can significantly benefit from temperature sensor placement.

The Motor

EV motors feature many components working seamlessly together, much like the engines of ICE vehicles. Most importantly, EV motors get hot when in use.

To run efficiently, an EV motor must be kept between 90 °C and 95 °C. Temperatures outside of this range can cause reduced efficiency or forced safe-mode operation due to overheating.

Electric vehicle temperature sensors should be installed in the motor to monitor:

- Electric motor oil temperature
- Electric motor winding temperature
- Electric motor coolant temperature

However, electric motor temperature control is not always concerned with keeping temperatures down. In colder climates, motor temperatures must be brought up to around 15 °C before driving to ensure efficient operation.

The Inverter

Inverters control the lifeblood of an electric vehicle, acting as the channel through which DC energy is converted to AC to power the motor. Although inverters convert DC to AC power for the motor, unchecked heat can quickly push them beyond safe 150 °C limits and cause component failure.

Interior components start to fail when exposed to excessive heat for too long, resulting in the device failing to function properly. Typical effects of overheating on inverters include:

- Insulation degradation
- Solder cracking
- Metal warping

The Charger Handle and Port

The EV charger's handle and charging port can also overheat due to their role as the source of an EV's power. High temperatures may be indicative of:

- Poor connection

- Charger malfunction

As fast-charging becomes standard, monitoring heat at the charging port is vital to avoid faults and maintain efficiency. Fast-charge technology has already decreased re-energizing times to just 30 minutes for 80 % power, but consumers continue to look for a refueling experience similar to filling a traditional gas tank.

Fast charging requires the conversion of a large amount of power, generating a significant amount of heat. As the technology improves and delivers ever-more-rapid recharging times, it will be important to monitor temperatures to ensure the process remains safe and efficient.

The Thermal Management System

A thermal management system's base function is to regulate an EV's battery and mechanical components, but the system itself also needs monitoring.

The temperature of the thermal management system directly affects the EV components it is designed to cool. For example, temperatures spiking beyond normal ranges may trigger a domino effect, causing issues with other components.

Temperature sensors monitoring critical points in both coolant and refrigerant systems pass critical sensor information to system controllers to optimize performance and minimize power consumption while maintaining appropriate system temperatures.

High temperatures within the thermal management system can indicate leaks, faults, or overloaded cooling components.

The Passenger Cabin

A vehicle that is too cold or too hot will be uncomfortable for drivers and passengers. Outside the EV's motor, the HVAC system is the next-most noticeable thing running while an electric vehicle is on.

Efficiency is the cornerstone of an electric vehicle's functionality, and it is vital that an EV uses no more power than is absolutely necessary. Electric vehicle sensors tell the car and computer precisely how hard the vehicle's systems must work to maintain this efficiency.

In-cabin EV HVAC system temperature sensors ensure drivers and passengers remain comfortable without draining the battery too fast and reducing the EV's range.

Under the Hood

The role of exterior temperature sensors extends beyond informing drivers and passengers of the climate outside the vehicle.

Like an in-cabin HVAC temperature sensor, an external sensor lets the vehicle know how hard some of its other systems have to work to respond to environmental temperatures, for example, the thermal management system. Outside temperature sensors are generally installed under the hood of a truck or car.

Fast Charging and Electric Vehicle Sensors

The ability to safely get from point A to point B is widely regarded as the primary function of any vehicle, so a vehicle must be ready to be driven when its owner wants to use it. Like an empty tank of gas, a depleted EV battery is the last thing an owner wants to see.



Image Credit: Amphenol Advanced Sensors

Electric vehicles leverage a different fuel source than their conventional combustion engine counterparts, but that does not change an owner's expectation that their vehicle, or fleet of vehicles, is always available for immediate, on-demand transportation.

Despite advances in battery technology, there remains a misconception that electric vehicles run out of power at the most inconvenient time or when the driver is far away from a charging station. Gas-powered vehicle owners are used to the refueling process taking just a few

minutes. Still, questions remain around how charging an electric vehicle can approach that level of speed and convenience.

Combining longer-lasting power banks and fast-charging EV technology addresses these concerns, allowing EVs to keep pace with trucks and cars running on fossil fuels.

Despite fast-charging technology and charging station infrastructure, EV consumers must still overcome worries about time lost re-energizing. Results matter to those looking for a seamless transition to driving an electric vehicle, meaning that electric vehicle sensors are key to making charging almost as fast as refueling at a gas station.

Fast Charging's Potential Impact on EV Battery Health

Fast-charging systems are making the conversion to electric vehicles more practical, but it is essential that these are used with proper monitoring because the primary by-product of fast charging is heat, particularly when converting electrical current from AC to DC.

Using Electric Vehicle Sensors to Monitor Fast Charging

Sensor technology is key to ensuring that high-speed EV charging is safe and efficient. Fast charging requires rapid-response sensors, most notably vehicle temperature sensors.

The risk of heat damage to an EV's components increases significantly without real-time monitoring that triggers systems designed to maintain ideal temperatures. There are three places in an electric vehicle where temperature sensors are essential for fast charging.

The Point of Connection

Temperature sensors are essential at the charging port and the charging handle.

Many electrons must pass rapidly from the EV service equipment to the vehicle battery to charge it quickly. This high current generates heat, meaning that high temperatures within the charging port can potentially indicate a poor connection between the EV's contacts and the charging handle.

In terms of efficiency, a poor connection means the vehicle is not charging as fast as it should be. High temperatures from an EV fast charger's connector are also indicative of a malfunction, or the charger being overtaxed by the power demand.

The Thermal Management System

Overheating within an EV's thermal management system represents a clear sign that the system's components are running hot and it is not working as intended. These include:

- Heat exchangers
- Cooling plates
- Coolant fluids
- Refrigerants
- Dielectric oils

Excessive temperatures are also a signal that the EV cooling system may be overwhelmed by excessive heat from the parts the system should be cooling.

The Battery

Lithium-ion batteries charge most efficiently between 45 °C and 60 °C, and risk overheating, shutdown, or thermal runaway if temperatures rise above this limit. In-pack temperatures extending beyond this range can cause the vehicle to go into safe mode and shut down, or worse, begin the thermal runaway process.

An overheating battery is one of the final indicators that something is wrong with the vehicle's charging or thermal management systems, or that the battery itself is not functioning correctly. Under these circumstances, immediate cooling is essential to maintain the battery's long-term functionality and safety.

The Future of EV Fast Charging

Fast-charging technology continues to evolve. Existing fast-charging technology takes approximately 30 minutes to re-energize an EV's battery to 80 %, but engineers are continually working to make fully charging an EV as quick and easy as filling up an ICE vehicle's empty gas tank, a process that generally takes under 10 minutes.



Image Credit: Amphenol Advanced Sensors

Demand for ultra-fast electric vehicle charging is not wholly driven by the need for convenience, however. Ultra-fast charging is being driven not only by convenience, but by the needs of heavy-duty fleets to minimise downtime.

This is because larger vehicles have battery packs several times bigger than those installed in electric cars. These larger battery packs take longer to charge, but this increased time spent charging represents lost income and productivity.

Rapid-response sensors designed to monitor heat throughout an EV are key to:

- Putting vehicles back in service faster
- Preventing battery degradation or damage

Electrification represents one of the most significant transitions in the history of transportation, but vehicle owners and operators still expect functionality and efficiency. Fast-charging technology is enabling this shift by directly addressing a major concern.

EV Thermal Management

Electric vehicle sensors are fundamental to making EV charging as uneventful as filling up a gas tank.

The literal power behind vehicles is now changing the way that people travel, and robust, reliable, and responsive sensor technology is at the forefront of keeping vehicles running

efficiently and safely.

As the natural by-product of using an EV, an incident of uncontrolled excessive heat in an electric car, truck, or any other vehicle has the potential to effectively derail the electrification revolution. Consumer protection agencies and consumers themselves have long memories when it comes to mischaracterized performance or safety failures.

An electric vehicle's performance is hardly distinguishable from their soon-to-be phased out fossil fuel-powered predecessors. Effective sensor integration enables EVs to match the safety and dependability expected from the vehicles they are replacing.

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Challenges of Electric Vehicle Charging Stations

As more electric vehicles (EVs) hit the roads globally, their growing presence and the shift toward sustainable transportation have become major talking points. A robust charging infrastructure is crucial to supporting the growing demand for EVs as the transportation sector moves toward decarbonization. However, several challenges in EV infrastructure affect the expansion of renewable energy and electric vehicles. This article will examine the key obstacles faced by EV charging stations.



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Technical Challenges of Electric Vehicle Charging Stations

Some primary challenges with electric vehicle charging stations center around technical issues whilst charging and charging station technology.

Firstly, there are issues with charger compatibility and a lack of standardization. Drivers need to know reliably whether the correct charger is available at an EV charging station for their vehicle. This is not a problem with ICE vehicles as gas and diesel pumps are standard designs worldwide.^{1,2}

Fast charging is a key consumer demand, presenting a bottleneck for EV adoption and electric vehicle charging stations. Despite the rapid evolution in charging station technology, many electric vehicle charging stations do not meet this demand: over half of all charger types in the UK, for instance, are slow charger types. These have a power rating of under 8KwH.³

These technical issues can slow consumers' adoption of [electric vehicles](#). Range anxiety is a top concern for many consumers, particularly in rural areas without proper charging infrastructure. If chargers are slow and incompatible, consumers may be less likely to replace polluting ICE vehicles.

Furthermore, battery limitations can present further technical challenges for the sustainable transportation sector. These can affect charging efficiency and longevity, hindering fast charging capabilities and potentially leading to increased costs and maintenance needs.

Infrastructure and Accessibility

Accessibility and infrastructure are also key challenges with electric vehicle charging stations. Whilst urban areas such as London in the UK have an impressive charging network, with London alone having a charging density of 221 chargers per 100,000 residents, this is not the case in rural areas. Expanded infrastructure is urgently needed to meet current and future demand.³

At-home charging points have done a lot of work in reducing the lack of EV charging infrastructure, but on-road solutions are distinctly lacking. Companies like Shell Recharge, which has installed nearly 9,000 public charging stations in the UK, are helping to overcome this bottleneck. Tesla's Supercharger network is also a noteworthy electric vehicle charging network.

Another accessibility issue and technical challenge is the non-standardization of apps. This aspect of charging station technology is another key bottleneck with electric vehicle charging stations. Multiple companies offer on-road EV charging, each with its own app that allows drivers to access charging and pay for its use.

Aside from the relative lack of charging infrastructure, there are concerns about adding so much capacity to energy grids. Grids must be able to cope with the current and future spike in demand for EV charging to avoid potential power cuts. By 2024, there were 1.1 million full EVs on the UK's roads alone, a remarkable 13% increase from 2023, leading to a marked increase in demand and capacity.

Electric vehicle charging station accessibility can also be an issue for disabled drivers. Parking spaces may be too small for adapted vehicles, charging points may not be visible, and payment systems can be too high for wheelchair users. Furthermore, the height of the curbs may make access difficult, and even heavy cables may be difficult for disabled drivers to use without help.

Environmental and Societal Impact of Sustainable Transport

While [renewable energy](#) and EVs are a significant element of the green energy transition, the rise of sustainable transportation does not come without some environmental cost.

The manufacturing cycle and end-of-life disposal of charging station technology such as batteries can present environmental and pollution issues and have potential societal impacts on local communities, for example, in developing nations. These issues must be addressed for charging station technology to be classed as truly sustainable.⁴

While renewable energy and EVs reduce greenhouse gas emissions overall, non-renewables in the energy grid mix may be used to power electric vehicle charging stations. However, this problem should be reduced over the coming years as the global renewables mix increases.



Video Credit: Incredible Ride/YouTube.com

Economic and Regulatory Hurdles of EV Charging

Aside from technical, infrastructure, and environmental issues around electric vehicle charging stations and sustainable transportation, there are also economic and regulatory hurdles proving challenging for the sector.

EV charging infrastructure is expensive to install and maintain. Batteries need to be replaced over time, and initial capital costs may be high. Charging infrastructure and technologies must be constantly updated, presenting additional lifecycle costs for operators. Costs could be passed onto consumers, but those same consumers may be reluctant to pay higher charging costs on top of the expense of new EVs.

Regulatory hurdles such as land use regulations, utility approvals, and permits can also be hard and costly to navigate. These regulatory frameworks are essential in shaping the development of electric vehicle charging stations and differ in each nation. The need for standardized policies across regions and nations is crucial.⁵

What is the Future of Electric Vehicle Charging?

The remarkable rise of sustainable transportation, renewable energy, and EVs has led to a growing recognition of the technical, infrastructural, accessibility, environmental, economic, and regulatory challenges faced by electric vehicle charging stations. Overcoming these challenges will require continued innovation and collaboration across private and public sectors.

While persistent EV infrastructure challenges present complex bottlenecks, some solutions will aid the uptake of sustainable transportation in the coming years. Improving rural charging stations, installing faster charge capability, standardizing chargers and apps, and streamlining regulatory processes are examples of how these critical issues could be addressed in the future.

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How Tire Sensors Enhance Safety, Performance, and Efficiency in Modern Vehicles

Tire Pressure Monitoring Systems (TPMS) are a game-changer for modern vehicles, helping drivers stay safe while improving performance and efficiency. By keeping tabs on things like tire pressure, temperature, and wear, these systems provide real-time insights that prevent accidents, enhance handling, and even boost fuel economy.^{1,2}



Image Credit: Tetrisme/Shutterstock.com

TPMS are more than just a safety feature—they're a key component in optimizing vehicle performance and efficiency. In this article, we'll cover:

- **Why Tire Sensors Matter** – The impact of tire pressure and wear on vehicle safety and handling.
- **How TPMS Works** – The technology behind tire sensors and their role in monitoring tire health.
- **Different Types of Tire Sensors** – A breakdown of optical, strain, accelerometer, and PVDF sensors.
- **Applications of TPMS** – How these systems enhance vehicle stability, predictive maintenance, and autonomous driving.
- **The Future of Smart TPMS** – Innovations that go beyond pressure monitoring, integrating temperature and wheel alignment tracking.
- **Key Industry Players** – The companies leading the charge in tire [sensor technology](#).

Why Tire Sensors are Important?

Tire problems like low pressure and blowouts are a leading cause of accidents worldwide. If your tires aren't performing properly, you're at a higher risk of losing control, especially in tricky driving conditions. Since tires are the only point of contact between your car and the road, they directly impact braking, cornering, and acceleration.^{1,2}

Modern TPMS go beyond just monitoring pressure—they improve safety systems like anti-lock braking systems (ABS), electronic stability control, collision mitigation, and adaptive cruise control. In self-driving cars, they're even more critical, providing data on road conditions and tire-road interactions to refine vehicle responses.¹

These systems also enable communication between vehicles and infrastructure, helping drivers and traffic systems anticipate and respond to potential hazards. On top of that, they provide valuable data for researchers working to design better, more durable tires.^{1,2}

How Tire Pressure Sensors Work

So, how do these systems actually work? Most tire sensor systems consist of a power unit, sensing unit, signal processing unit, auxiliary unit, and transmission unit. They directly measure tire states like acceleration, deformation, temperature, strain, and inflation pressure. This data helps estimators assess vehicle states for control systems.¹

Friction potential, tire forces, contact patch characteristics, and contact patch dynamics could be estimated by measuring the operational states.¹

Key types of tire pressure sensors include:

- [Optical sensors](#)
- Accelerometers
- Strain sensors
- Polyvinylidene fluoride (PVDF) sensors

Each type of sensor has unique advantages and challenges, making them better suited for different applications. Which type is best? That depends on the vehicle and the specific driving conditions.

Types of Tire Pressure Monitoring Systems

PVDF Sensor

PVDF sensors are widely used due to their flexibility, high sensitivity, and affordability. They generate voltage when pressure is applied, allowing for accurate measurement of tire strain

and deformation.

By integrating PVDF sensors with friction force models, engineers can estimate slip angles and lateral forces, helping improve traction control. However, they have some limitations—distinguishing between different directional strain signals and compensating for temperature variations remain challenges.¹

Strain Sensor

Strain sensors, typically made with high-elongation foil strain gauges, are attached inside the tire to measure lateral and circumferential strain. Newer versions use ultra-flexible materials to enable wireless monitoring.

However, strain sensors come with their own set of challenges. Stress concentration at the sensor-tire interface can impact longevity, and temperature fluctuations can introduce inaccuracies. Researchers are continuously working on making them more flexible and resistant to environmental factors.¹

Optical Sensor

Curious about how optical sensors work? They use lasers, cameras, and position-sensitive detectors to provide highly accurate, real-time data about tire deformation and structural integrity. Since they are mounted on the wheel rim and not in direct contact with the tire, they don't interfere with tire mechanics.

The enclosed environment of the tire cavity protects optical sensors from dust and debris, but they require additional light sources for precise measurement. While they offer exceptional accuracy, their high cost, power consumption, and complex calibration processes limit widespread use.¹

Accelerometer

Accelerometers are a well-established technology in TPMS. They are small, lightweight, and affordable, making them ideal for mass production. By detecting rapid changes in tire deformation, they help estimate the contact patch length (where the tire touches the road).

Most TPMS use triaxial accelerometers mounted inside the tire. These sensors track vibrations in great detail, but they can be sensitive to outside disturbances, leading to noise in the data. Additionally, alignment errors between the sensor and wheel frame can introduce measurement inaccuracies.¹

Where Tire Pressure Sensors Are Used

Tire Pressure Monitoring Systems (TPMS) play a crucial role in multiple aspects of vehicle performance, safety, and maintenance. But where do they have the biggest impact? Let's

break it down:

1. **Vehicle Stability Control** – TPMS contribute significantly to vehicle stability by working alongside ABS, traction control, and electronic stability management systems. By continuously monitoring tire pressure and temperature, these sensors help prevent issues like underinflation, which can compromise grip and handling. Maintaining optimal tire pressure ensures that braking, acceleration, and cornering remain predictable and stable.
2. **Performance Tracking** – Racing teams and performance car manufacturers rely on TPMS to gain real-time feedback on handling, braking efficiency, and fuel consumption. By analyzing pressure fluctuations during high-speed maneuvers, drivers and engineers can fine-tune tire performance for optimal results. In commercial vehicles, TPMS help fleet managers optimize tire longevity and fuel efficiency, reducing operational costs.
3. **Predictive Maintenance** – TPMS aren't just about immediate alerts; they also play a key role in long-term vehicle maintenance. By detecting early signs of uneven tire wear, gradual pressure loss, or heat buildup, these sensors allow for proactive tire servicing before problems escalate. This reduces the risk of tire blowouts, which can lead to costly repairs and accidents. For fleet vehicles, predictive TPMS data helps companies schedule maintenance efficiently, reducing downtime and extending tire lifespan.
4. **Autonomous Driving** – In self-driving and highly automated vehicles, TPMS are essential for ensuring that the vehicle can safely interact with the road. These systems provide real-time tire-road interaction data, allowing autonomous driving algorithms to adjust braking and steering dynamically. Without accurate tire data, autonomous vehicles may struggle to adapt to sudden road changes, such as wet or icy conditions. As autonomous technology advances, TPMS will become even more integrated into AI-driven vehicle control systems.

In short, TPMS are more than just a simple safety feature—they're an essential component in modern vehicle intelligence, offering benefits across performance, safety, and cost efficiency.^{1,2}

Smarter Tire Pressure Monitoring Systems

Most current TPMS only alert drivers when tire pressure drops below a safe level. But a study published in the IOP Conference Series: Materials Science and Engineering suggests an upgraded TPMS that does much more. This enhanced system not only monitors tire pressure but also tracks temperature and wheel alignment, giving drivers a more complete picture of their tire health and overall safety.^{2,3,4}

The system uses an electronic unit attached to each tire, which sends real-time data to an in-vehicle display. It's equipped with sensors, microcontrollers, a radio frequency transmitter,

and a battery, all working together to alert the driver when tire conditions go beyond safe limits.

Here's how it works:

- Sensors collect data on tire pressure, temperature, and alignment.
- A microcontroller processes this information.
- An accelerometer checks if the car is properly aligned.
- A temperature sensor monitors heat buildup from friction.
- The system uses amplitude shift keying to transmit data wirelessly.
- The receiving unit inside the vehicle, powered by an Arduino UNO, processes the incoming data and displays it on an LCD screen. A potentiometer allows the driver to adjust the screen's brightness for better visibility.

Successful experiments have shown that this smarter TPMS effectively helps drivers maintain their tires, improving both safety and driving comfort. With more comprehensive monitoring, drivers can catch potential issues early—before they turn into major problems.^{2,4}

Key Players

Leading companies in the tire sensor market include [Continental AG](#), [Sensata Technologies](#), [Denso Corporation](#), [NXP Semiconductors](#), and [Sumitomo Rubber](#). These industry leaders are actively pursuing strategic collaborations to strengthen their market presence and drive profitability.

Continental AG is at the forefront of tire sensor innovation, developing advanced solutions such as ContiSense™ and ContiPressureCheck™. These systems go beyond traditional tire pressure monitoring by providing real-time data on tread depth,

temperature, and road conditions. In India, the company is introducing cost-effective intelligent technologies, including the ContiPressureCheck system for CombineMaster tires, which continuously monitors both tire pressure and temperature.

Sensata Technologies and Denso Corporation are also major players, focusing on cutting-edge sensor technologies that enhance vehicle safety and performance. Meanwhile, NXP Semiconductors N.V. plays a crucial role as a leading provider of automotive semiconductors, including those used in tire pressure monitoring systems.

Sumitomo Rubber has launched proof-of-concept testing for a new Tire Pressure Monitoring System (TPMS) service designed to enable remote tire condition monitoring. This innovation has the potential to transform fleet management and vehicle maintenance by providing real-time insights.

Collectively, these key players are shaping the future of the tire sensor market, prioritizing safety, fuel efficiency, and comprehensive tire health data for vehicle operators and fleet managers.

Want to Learn More?

As tire sensor technology continues to evolve, its impact on vehicle safety, efficiency, and maintenance is becoming more significant. Whether you're an industry professional, fleet manager, or automotive enthusiast, staying informed about the latest advancements can help you make better decisions.

For further insights, explore topics such as:

- [How Pressure Mapping Advancements Will Change the Face of the Tire Industry](#)
- [What Are Automotive Sensors and How Do They Work?](#)
- [The Tire Industry Project: Addressing the Environmental Impacts of Tires](#)

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