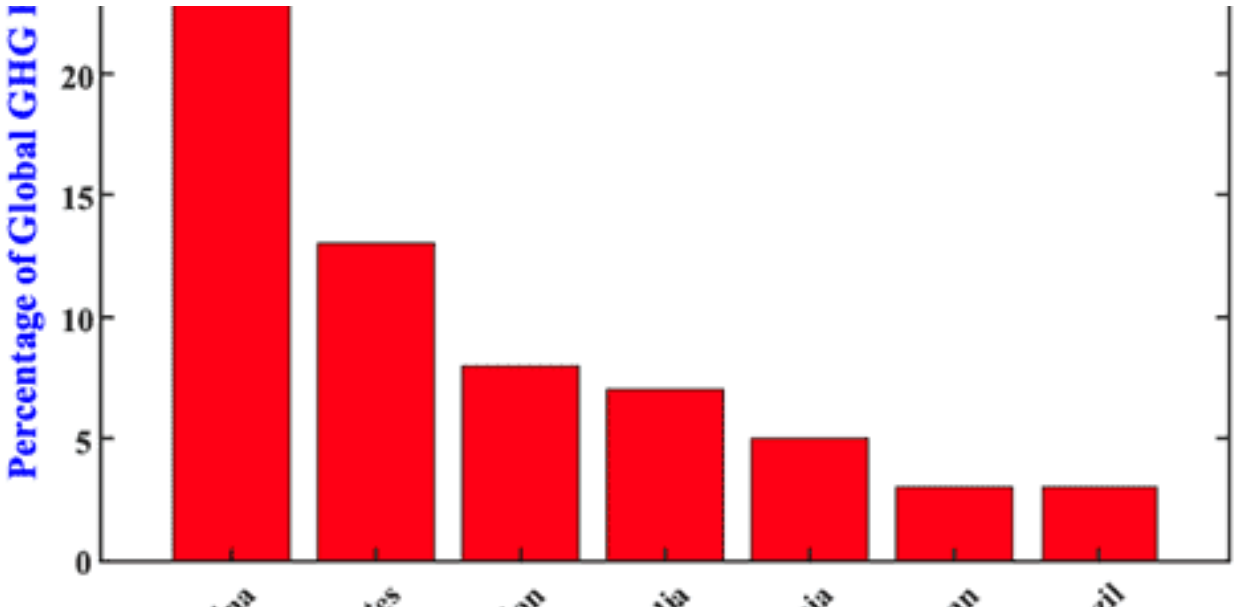

Our Last Post: Beyond the Powertrain: Why Charging, Standards, and Smart Optimisation Will Define the Transition

Posted on 26.Jan 2026

Image: Report on: Advancement of electric vehicle technologies, classification of charging methodologies, and optimization strategies for sustainable development – A comprehensive review

Electrification is accelerating — but scaling it is not just a question of building better vehicles. It is equally a question of **charging systems, interoperability, grid integration, and optimisation**. A 2024 open-access review in *Heliyon*provides a structured overview of electric-vehicle technologies, charging methodologies, and optimisation strategies that can accelerate sustainable deployment.

The transition is multi-technology — and hybrids still matter where infrastructure lags

The review compares conventional vehicles, battery-electric vehicles (BEVs), hybrid electric vehicles (HEVs), and fuel-cell vehicles, outlining how each technology trades off emissions, efficiency, cost, and infrastructure dependency. Notably, it highlights a pragmatic point: **hybrids remain advantageous in regions where charging infrastructure is limited**, because they can continue operation seamlessly once the battery is depleted and still benefit from regenerative braking.

For a transition that must work across geographies and duty cycles, this reinforces a core Hybrid Alliance principle: progress depends on **deployable solutions under real-world constraints**, not on one-size-fits-all narratives.

Charging is not one method — it is an ecosystem of options

The paper organises EV charging into three major approaches: **conductive charging**, **wireless power transfer (WPT)**, and **battery exchange/swapping**.

- **Conductive charging** remains the dominant approach due to simplicity and cost, but scaling fast charging introduces grid constraints, infrastructure complexity, and power-quality considerations.
- **Wireless charging** improves convenience and can enable charging without cables — even potentially while the vehicle is in motion — yet the review notes constraints around efficiency versus coil distance/alignment and electromagnetic interference considerations.
- **Battery swapping** can cut “charging time” to minutes and may enable controlled, slower off-board charging; however, it faces adoption hurdles such as standardisation, inventory management of spare batteries, space requirements, and higher capital costs.

The takeaway for industry and policymakers is clear: charging infrastructure planning should be technology-inclusive and context-driven — especially for commercial operations where uptime is the key KPI.

Standards and interoperability: the silent bottleneck

A recurring barrier is interoperability. The review highlights how **regional charging standards differ** (e.g., connector types, voltage ranges, communications protocols), making global harmonisation difficult and multi-standard infrastructure more expensive. It also points to ongoing work on interoperability and the emergence of wireless charging standards such as SAE J2954 and IEC 61980.

In practice, this means the transition is constrained not only by vehicle supply, but by the pace of **standards convergence**and the ability to deploy **compatible charging networks** at scale.

V2G: attractive in theory — challenging in deployment

Vehicle-to-grid capabilities can support grid balancing via bidirectional energy flow, but the review is explicit about challenges: accelerated battery degradation through frequent cycling, higher costs and lower availability of bidirectional chargers, the need for grid upgrades, and unresolved interoperability issues despite the role of protocols such as ISO 15118.

V2G will likely be most impactful where use cases, incentives, and technology readiness align — rather than as a universal assumption for all EV deployment.

Optimisation: turning constraints into scalable performance

The most actionable part of the review is its framing of optimisation objectives:

- **Maximise grid stability**
- **Minimise power loss**
- **Minimise waiting time**
- **Minimise charging cost**

It discusses a toolbox of methods — from Mixed Integer Linear Programming and metaheuristics (GA/PSO/ACO) to machine-learning approaches such as deep reinforcement learning and fuzzy logic for uncertainty.

This matters because the “winning” charging system is rarely the most advanced hardware alone. It is the system that is **optimised for local grids, local pricing, local user behaviour, and real operational constraints**.

Hybrid Alliance takeaway

Decarbonisation is a systems problem. Vehicles, charging, standards, grid readiness, and optimisation must be engineered as a coherent whole. The review underlines why the transition will be **multi-solution and context-specific** — and why pragmatic hybrid pathways remain relevant where infrastructure maturity is uneven.

Read more – source: Advancement of electric vehicle technologies, classification of charging methodologies, and optimization strategies for sustainable development – A comprehensive review – ScienceDirect