

Whitepaper

Hybrid powertrains in transition: global pathways, concepts, and architectures

A Bosch perspective on global market dynamics and hybrid system design

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01
Market context: the global transition of powertrain technologies

For passenger cars, the global shift in powertrain technologies is accelerating, but the rate of this acceleration differs from region to region. According to the IEA Global EV Outlook 2026, global electric car sales surpassed 20 million units in 2025 and are expected to grow to 23 million units in 2026, corresponding to 28% of new passenger cars sold worldwide. BloombergNEF similarly projects continued double-digit growth, with electrified vehicles approaching 25% of global light-vehicle sales. However, this global average masks significant regional divergence in technology pathways.

China remains the clear frontrunner, accounting for approximately 60–65% of global eletric vehicles sales. In 2025, new energy vehicles – including battery-electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) – already exceeded 50% of new car sales in China. According to Bosch market research and internal powertrain scenario modeling, electrification will continue to accelerate up to 2035, with battery-electric vehicles becoming the dominant architecture in new light-vehicle sales. At the same time, hybrid technologies – including full hybrids, plug-in hybrids, and range-extended electric vehicles (REEVs)– remain a structural element of the transition, reflecting the continued role of electrified vehicle pathways in the Chinese regulatory and industrial framework.

Europe is progressing along a similar trajectory, though under stronger regulatory pressure. Electrified vehicles currently account for roughly 20–25% of new registrations across the region. Bosch powertrain scenario modeling indicates that the European market will gradually move toward a BEV-dominant structure by 2035, while hybrid architectures continue to co-exist as a compliance-relevant technology during the transition period.

In the United States, electrification is progressing more gradually. EVs (BEV, PHEV, REEV) account for roughly 10% of new vehicle sales, with BEVs leading but having their growth constrained by infrastructure rollout and regional policy differences. At the same time, full hybrids have gained significant market relevance, driven by their ability to deliver efficiency improvements without compromising range, towing capability, or refueling convenience. Bosch market research indicates that a mix of electrified powertrain architectures will remain in the long term, with hybrids playing a key role in meeting customer requirements in a geographically expansive market.

The transition to new powertrain technologies is far from uniform and remains highly heterogeneous worldwide. Even as electrified options become more common, different regions follow their own unique pathways, shaped by local regulations, infrastructure, and market demands. This means that a mix of traditional engines, hybrids, and electric vehicles will continue to coexist for the foreseeable future, rather than converging on a single solution.

These findings underline a central reality: global electrification is advancing rapidly, but the transition is not uniform. Regional policy frameworks, infrastructure maturity, industrial structures, and end-customer purchasing decisions continue to shape distinct technology pathways. Within this context, hybrid powertrain technologies – including HEVs, PHEVs, and REEVs – remain in a critical transitional architecture. They enable scalable CO_2 reduction, provide flexibility in markets with uneven charging infrastructure, and maintain affordability across mass-market vehicle segments. As a result, the medium-term global powertrain landscape is best understood as a heterogeneous system centered on gradual electrification rather than a single universal technology pathway.

02
Driving the choice: how regional use cases and regulation define powertrain concepts

The selection of vehicle powertrain concepts is increasingly determined by two fundamental factors: regional vehicle use cases and the prevailing regulatory environment. While technological capability defines what is possible, it is these two external parameters that ultimately determine which propulsion concepts are deployed at scale. As a result, the global transition toward electrified mobility does not follow a single technological pathway. Instead, different markets converge with distinct combinations of internal combustion engines, hybrid systems, and battery-electric drivetrains.

Regional vehicle use cases strongly influence powertrain concept selection. Vehicle duty cycles – such as daily driving distance, highway utilization, towing requirements, or urban congestion – determine the relative value of electric driving capability, fuel efficiency, thermal robustness, and refueling flexibility. In parallel, regulatory frameworks define the economics and compliance of boundaries within which manufacturers must operate. CO_2 fleet limits, zero-emission mandates, incentive schemes, and taxation structures therefore directly influence the competitiveness of different propulsion technologies.

In **North America,** vehicle use cases are characterized by long-distance travel, high highway speeds, and significant towing requirements, including towing load and speed during towing. Crossover utility vehicle (CUV) and Sport Utility Vehicle (SUV) segments – including small and midsize SUVs – represent the majority of most of the passenger vehicle market, accounting for well over 50% of new vehicle sales in the US, while pickup trucks dominate specific high-value segments with particularly demanding use cases (e.g., towing and payload). Full-size pickups and large SUVs dominate important segments of the market, requiring propulsion systems capable of sustained high loads and long operational ranges. Within this context, powertrain concepts that combine combustion engines with hybridization offer an attractive balance between efficiency improvements and operational capability. Mild hybrids (mHEV) and strong hybrids (sHEV) can deliver measurable efficiency gains while preserving towing capacity and refueling convenience. At the same time, HEV penetration is increasing in these high-volume SUV segments, driven by demand for improved fuel efficiency without changes in usage behavior. Battery-electric vehicles are expanding into this segment, but the combination of high energy demand and towing requirements continues to favor hybridized combustion architectures for many use cases.

In **Europe,** the regulatory environment is a primary driver of powertrain strategy. Strict fleet-average CO_2 targets, low-emission zones in urban centers, and high fuel prices strongly incentivize electrified propulsion systems. At the same time, European driving patterns combine dense urban commuting with high-speed highway travel. As a result, manufacturers increasingly deploy powertrain concepts that enable significant electric driving capability while maintaining flexibility for long-distance travel. Plug-in hybrid electric vehicles therefore play a strategic role, allowing daily electric operation while supporting longer journeys without reliance on charging infrastructure. Battery-electric vehicles (BEV) are rapidly gaining importance, but hybridized combustion concepts remain a critical component of the transition – especially in countries where charging infrastructure is still not sufficient to cover users' needs.

China represents a regulatory and market environment that strongly favors electrified propulsion concepts. National and regional policies promoting new energy vehicles, combined with urban driving conditions in large metropolitan areas, create a strong incentive for high electric driving shares. Within this framework, manufacturers deploy a broad mix of electrified concepts, including battery-electric vehicles, range-extended electric vehicles, and advanced hybrid systems. These architectures allow electric-dominant driving in congested urban environments while maintaining range flexibility for intercity travel. Government policy instruments – such as purchase incentives, license plate restrictions, and industrial policy supporting domestic supply chains – have still accelerated the adoption of these electrified concepts.

In **Japan** and several other Asian markets, powertrain concept selection is strongly influenced by customer priorities of efficiency, reliability, and smooth drivability. Urban density and shorter daily driving distances favor propulsion systems that deliver consistent fuel economy improvements without requiring external charging infrastructure. Consequently, strong hybrid systems have achieved particularly high market penetration, offering substantial efficiency benefits compared to internal combustion engines (ICE) while maintaining the operational simplicity of conventional vehicles.

In **South America,** the roadmap towards carbon neutrality follows a distinct pathway shaped by local conditions, with Brazil representing around 80% of vehicle production in the region. Rather than rapid BEV adoption, the market is characterized by a multi-energy approach, supported by a well-established biofuel ecosystem: approximately 85% of light vehicle sales in Brazil are flex-fuel vehicles capable of operating on ethanol. Overall, the Brazilian vehicle market is growing, and powertrains including internal combustion engines follow this overall market expansion. Within this framework, flex-fuel hybrid concepts (mHEV, sHEV, and PHEV) are gaining relevance as a scalable solution to reduce CO_2 emissions while maintaining affordability and compatibility with existing infrastructure. At the same time, mHEV, sHEV, and PHEV are increasing their market share, while REEV adoption is not yet visible; it remains to be seen whether Chinese OEMs will establish corresponding models in the Brazilian market. As a result, the region is expected to remain predominantly ICE- and hybrid-based in the medium to long term, reflecting a region-specific approach to decarbonization.

In **India,** powertrain development is shaped by high cost sensitivity, diverse usage patterns, and evolving regulatory frameworks. Similarly to Brazil, the overall vehicle market in India is growing, and powertrains, including ICE, continue to follow this trajectory. Electrification is progressing selectively, with hybrids (mainly mHEV, and HEV), compressed natural gas, and emerging flex-fuel concepts complementing conventional ICE powertrains rather than replacing them. Within electrification, HEV and BEV vehicles are gaining market share, although from a relatively low base. Regulation (e.g., India's vehicle emission standards Bharat Stage 6 emission norms (BS6) and its goal of blending 20% ethanol with petrol (E20) targets) supports a gradual shift toward lower-emission solutions while maintaining affordability, while charging infrastructure limitations continue to constrain large-scale BEV adoption. As a result, the market is expected to follow a diversified pathway, with ICE-based powertrains – combined with hybridization and alternative fuels – remaining dominant in the medium term.

These regional examples show that powertrain concepts are not selected in isolation based on technological potential alone. What becomes viable in the market is defined by the interplay of vehicle use cases, regulatory requirements, infrastructure maturity, and customer economics. As a result, multi-energy platforms – combining ICE, hybrids, and battery-electric solutions – are becoming a structural requirement rather than an option. They enable manufacturers to address diverging regional needs with greater flexibility while leveraging scale across technologies and markets. Instead of committing to a single pathway, OEMs must manage a broad portfolio of propulsion concepts – ICE, mHEV, sHEV, PHEV, REEV, and BEV – each optimized for specific conditions. Powertrain strategy has therefore moved beyond one topology for all markets; the competitive advantage lies in deploying the right technology mix on scalable platforms that can adapt to shifting demand and regulatory uncertainty.

This increasing regional differentiation of powertrain concepts also has significant implications for industrialization and sourcing strategies. Developing and manufacturing multiple region-specific powertrain solutions across all major architectures – ranging from mHEV to REEV and BEV – requires substantial engineering resources, platform adaptations, and supply chain complexity. For individual OEMs, maintaining this breadth of in-house capabilities is increasingly difficult to justify from both a cost and scale perspective. In this context, Tier 1 suppliers with a global footprint and cross-architecture expertise can leverage significant economies of scale by developing modular, reusable solutions across multiple customers and markets. This not only reduces development effort and complexity for OEMs but also enables faster deployment of market-specific powertrain concepts. As a result, a buy strategy supported by a capable system supplier with system competence becomes structurally more competitive than a fragmented make approach, particularly in a world of diverging regional requirements and accelerating technology cycles.

The following chapter examines how these powertrain concepts are technically realized through different hybrid system topologies and architectures.

03
Engineering hybridization: key powertrain architectures in modern vehicles

While the previous chapter examined how regional use cases and regulatory environments influence the selection of powertrain concepts, the next step in the engineering process concerns the technical realization of hybrid propulsion systems. Once a vehicle program has determined that hybridization represents the appropriate concept – whether as a full hybrid, plug-in hybrid, or range-extended architecture – the specific hybrid topology defines how electric machines, combustion engines, transmissions, and energy storage systems interact within the drivetrain.

Hybrid topologies differ primarily in the mechanical and electrical coupling between the combustion engine and the electric drive system. This coupling determines how power flows are managed between the engine, electric motor(s), battery, and wheels. As a result, topology selection has a direct impact on key vehicle attributes, including fuel efficiency, electric driving capability, system cost, packaging complexity, driving performance, and scalability across vehicle platforms.

Over the past two decades, several hybrid architectures have emerged as dominant solutions in the global automotive industry. Each topology reflects a different engineering philosophy regarding the balance between mechanical simplicity, electrification capability, and system efficiency. Some architectures prioritize incremental electrification of conventional drivetrains, while others are designed to enable electric-dominant driving with the combustion engine acting primarily as a supporting energy source.

For vehicle manufacturers, the selection of a hybrid topology therefore represents a critical strategic and engineering decision. It must align not only with the vehicle's intended use case and market requirements, but also with broader considerations such as platform integration, manufacturing scalability, supplier ecosystem maturity, and long-term electrification strategies. In addition, legacy decisions – including existing intellectual property, prior investments, and established technology roadmaps – play a significant role, as they influence both the feasibility and economic viability of adopting new architectures.



This chapter reviews four major hybrid topology families that have achieved broad relevance across global markets and will remain relevant for the future:

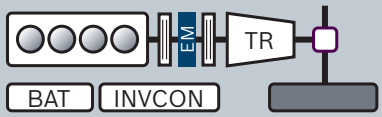
- **P2, P3,** and **dedicated hybrid transmission (DHT)** architectures, which build upon conventional drivetrain layouts by integrating electric machines at strategic locations within the powertrain.
- **Power-split** architectures, which utilize planetary gearsets to combine mechanical and electrical power paths for highly flexible operating strategies.
- **Series / parallel hybrid** systems, which enable multiple operating modes allowing the combustion engine to either directly drive the wheels or generate electricity.
- **Range-extended electric vehicle** architectures, where electric propulsion is primary and the combustion engine functions mainly as an onboard energy generator.

For each topology family, the following sections evaluate the key technical characteristics, advantages, and potential limitations, considering factors such as efficiency potential, system complexity, cost implications, and suitability for different vehicle segments and regional markets. Through this comparison, the chapter aims to clarify how different hybrid architectures support the diverse electrification pathways outlined in the previous chapter.

Bosch Mobility's experience across all major hybrid architectures provides a unique system-level perspective on these trade-offs, grounded in decades of development and production series.

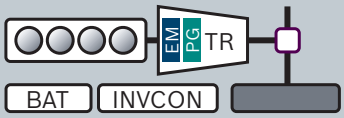
P2

6–9 speed transmission



DHT (for example, with an EM)

3–6 speed DHT with eCVT-mode
w/o clutch element, w/o reverse gear



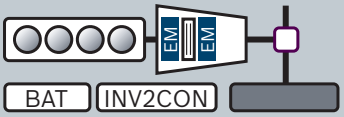
Power-split

Power-split
w/o clutch element, w/o reverse gear



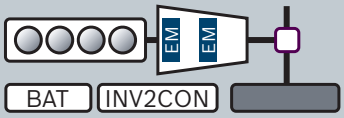
Series / parallel

Series / parallel hybrid
dog clutch, w/o reverse gear

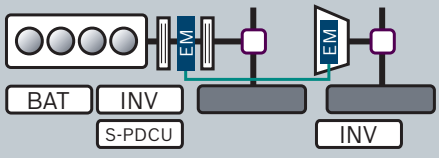


REEV

Series hybrid
w/o reverse gear



P1.5 + P4



Conventional automatic transmission

Dedicated hybrid transmission (DHT)

Pure electrical powertrain

List of abbreviations:

AWD:	All-wheel drive
BAT:	Battery
BEV:	Battery electric vehicles
CNG:	Compressed natural gas
DOF:	Degrees of freedom
eCVT:	Electronically-controlled continuously variable transmission
EM:	Electric motors
EV:	Electric vehicle
FWD:	Front-wheel drive
HEV:	Hybrid electric vehicles
ICE:	Internal combustion engine
INVCON:	Inverter control
INV2CON:	Dual inverter with DC/DC converter
NEV:	New energy vehicles
PG:	Planetary gear
PHEV:	Plug-in hybrid electric vehicles
REEV:	Range extender electric vehicles
s-PDCU:	Super Powertrain Domain Control Unit
TR:	Transmission

Figure 1: Overview of topologies and transmission technologies

3.1
P2, P3, and further DHT topologies

P2, P3, and further developed dedicated hybrid transmission (DHT) architectures represent a class of hybrid systems that build on conventional drivetrain layouts, integrating one or more electric machines at defined positions within the transmission or driveline. In P2 configurations, the electric machine is typically placed between the engine and transmission, often replacing or complementing the torque converter or clutch. P3 architectures shift the electric machine downstream of the transmission, while further DHT concepts with reduced numbers of gears extend this approach into multi-mode hybrid transmissions with increased functional integration.

These architectures are characterized by a high degree of compatibility with existing vehicle platforms, enabling incremental electrification with relatively limited disruption to established powertrain designs.

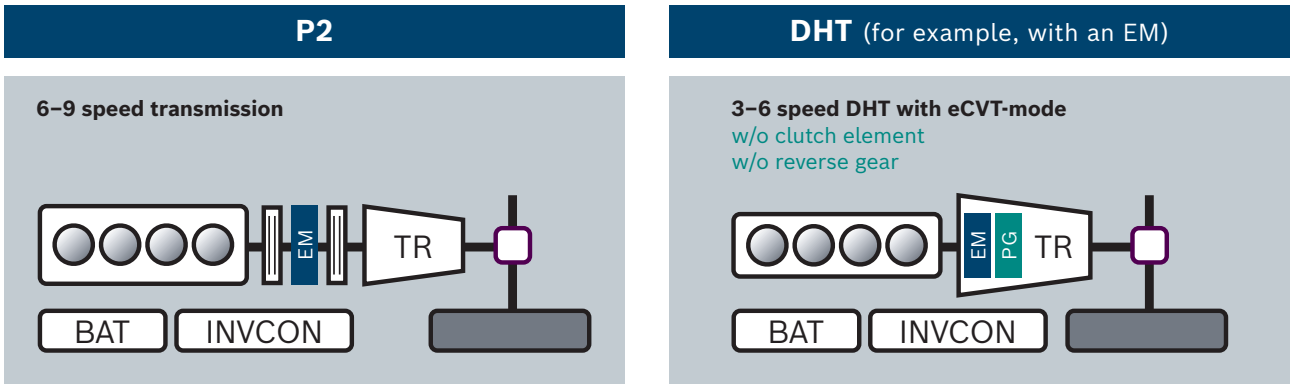


Figure 2: P2 and DHT reference topology

Benefits and use cases

A key advantage of P2, P3, and DHT architectures lies in their scalability and integration efficiency. By leveraging existing transmission concepts, hybridization can be implemented through relatively straightforward integration of an electric machine, in some cases replacing conventional drivetrain components such as clutches or torque converters. This allows for cost-effective electrification – but only when existing technology investments can be reused.

The architectures provide instantaneous torque response, improving drivability and supporting both efficiency- and performance-oriented (“fun-to-drive”) vehicle characteristics. Depending on electric motor power and battery size, they can deliver significant efficiency gains and CO_2 emissions reduction, extending from mild hybrid applications (even possible with 48 V) up to plug-in hybrid capability in certain configurations.

From a use-case perspective, these systems are particularly well suited for:

- Legacy-based vehicle platforms where high carry-over of existing architectures is required
- Vehicles with high-load demands, including towing and sustained highway driving
- Applications where refueling flexibility and long-range capability remain critical

Their robustness under high load conditions and compatibility with mechanical all-wheel-drive solutions (and optionally electrified rear axles) further reinforce their suitability for large vehicles and demanding duty cycles.

Drawbacks and technical limitations

Despite their advantages, P2, P3 and DHT architectures exhibit certain structural limitations. Due to their parallel modes, where the ICE is directly coupled to the wheel, potential for ICE complexity reduction is limited.

Transmission-related benefits are also bounded, as simplification potential compared to conventional drivetrains is limited, especially in architectures that retain multiple mechanical components. In addition, packaging complexity can become a challenge due to the integration of electric machines within existing transmission envelopes.

Operational aspects such as engine start behavior require careful calibration to ensure seamless transitions between operating modes, particularly in customer-relevant driving situations.

OEM adoption and market relevance

P2-based architectures are widely adopted across the industry and represent one of the highest-volume hybrid solutions in Europe. Typical applications can be found across European and global OEM portfolios, including BMW, Ford (EU), Mercedes-Benz, and Audi.

Further DHT and multi-mode hybrid systems are gaining traction, particularly in markets with strong hybrid demand. OEM implementations include Renault, Geely, BYD, and General Motors, reflecting the scalability of these architectures across different regions and vehicle segments.

Bosch Mobility perspective

From a system perspective, further development of P2, P3, and DHT architectures benefits from end-to-end integration across the full Bosch Mobility technology stack, spanning powertrain, electrification, transmission, and braking systems. This enables a holistic optimization of vehicle functions, including diagnostics, emission strategies, thermal management, and energy-flow control within a unified system architecture.

At the same time, these architectures place particularly high demands on system integration and calibration quality, as overall performance is strongly influenced by the interaction between combustion engines, electric machines, and transmission. Bosch Mobility combines best-in-class components with deep system competence, built on decades of experience in combustion-engine and hybrid-system development. A key strength in this context is the development of dedicated features for hybrid engines, specifically tailored to the operating profile of P2, P3, and DHT systems. This includes optimized engine starts as well as holistic operating strategy optimization for efficiency, emissions, noise, vibration, harshness, and reliability. This is particularly relevant in areas typically considered as limitations of these topologies. Through advanced control strategies and calibration expertise, Bosch Mobility improves engine start behavior, mode transitions, and overall drivability under mixed propulsion conditions. Leveraging its long-standing internal combustion engine and electrification competence, Bosch Mobility ensures smooth, robust, and customer-relevant system behavior, with stable operating point management and consistent response across real-world driving situations.

In addition, the close coupling of propulsion and braking functions allows for optimized energy recuperation and refined control strategies, improving both efficiency and driver-perceived comfort – e.g., through seamless transitions between regenerative and mechanical braking.

Overall, Bosch Mobility's ability to combine component excellence with cross-domain system integration enables scalable and application-specific solutions for P2, P3, and DHT architectures, supporting OEMs in balancing performance, cost, and complexity across global vehicle platforms.

3.2
Power-split topologies

Power-split architectures represent a distinct hybrid topology that combines mechanical and electrical power paths through a planetary gearset. In this configuration, the internal combustion engine is not directly coupled to the wheels via fixed gear ratios, but instead interacts with two or more electric machines, which manage power distribution between propulsion and energy generation.

This architecture enables a high degree of operational flexibility, allowing the system to continuously optimize engine operating points and energy flow depending on driving conditions.

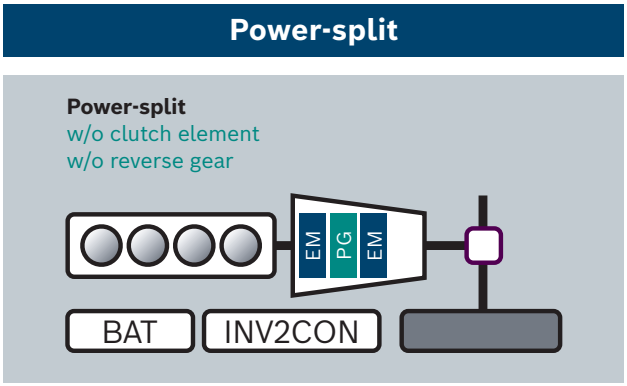


Figure 3: Power-split reference topology

Benefits and use cases

A key advantage of power-split topologies is the ability to divide power between mechanical and electrical paths, allowing the internal combustion engine to operate largely independently of vehicle speed. This enables the engine to be maintained at speed-load operating points that deliver high efficiency, while the electrical drive path compensates for differences between engine output and wheel torque demand. As a result, the system can continuously optimize both the engine operating point and the distribution of power between the mechanical and electrical paths to achieve the desired vehicle performance with improved overall efficiency.

The architecture allows for a simplified combustion engine design, as the absence of a fixed mechanical coupling to the wheels enables more flexible engine operation. In addition, the system offers compact packaging due to its high level of functional integration.

Power-split systems are widely recognized for their smooth and continuous driving behavior, often perceived as a continuously variable transmission-like driving experience. This characteristic, combined with decades of field experience, has contributed to their strong acceptance in the market.

Typical use cases include:

- Passenger vehicles with a focus on comfort and smooth drivability
- Applications where proven, highly reliable hybrid technology is a key requirement
- Markets prioritizing fuel efficiency and low operating costs over high load capability

Depending on electric motor power and battery size, the concept can be scaled from conventional hybrids up to plug-in hybrid applications. When equipped with an additional eAxle, four-wheel drive applications are also available.

Drawbacks and technical limitations

A potential drawback of power-split architectures is that engine speed does not necessarily correlate with vehicle speed or acceleration. Depending on the system design and calibration, this may result in a driving feel that differs from that of conventional powertrains, as engine sound and vehicle response can appear temporarily decoupled during certain operating conditions.

In general, for architectures with a significant series power flow share, achieving high towing capability requires increased system effort. This is because traction power is routed through electrical conversion paths rather than a direct mechanical connection. This leads to higher requirements in component sizing, thermal management, and overall system design when targeting towing performance comparable to conventional or parallel hybrid architectures.

OEM adoption and market relevance

Power-split systems represent one of the most established hybrid architectures globally, with more than three decades of proven use in production vehicles. They are widely deployed across multiple OEMs, including Toyota and Lexus as primary adopters, as well as Mazda and Ford in selected applications.

This long-standing market presence underscores the maturity and robustness of the architecture, particularly in segments focused on efficiency and comfort.

Bosch Mobility perspective

As outlined in the previous section, power-split architectures particularly benefit from co-optimization of electric machines, inverters, and braking energy recuperation within the Bosch Mobility technology stack, combining competencies in powertrain, electrification, and braking.

The performance of these systems is largely defined by the interaction of multiple electric machines, inverters, and the combustion engine, requiring precise coordination of energy flows and operating strategies. Bosch Mobility leverages its system-level expertise and component portfolio to optimize this interaction holistically, ensuring efficient operation across all driving conditions while maintaining a high level of drivability.

At the same time, typical trade-offs of the architecture can be effectively addressed through intelligent system design and integration concepts. The requirement for multiple electric machines and power electronics can be mitigated through modular and scalable component solutions, enabling cost-efficient implementations without compromising performance.

In addition, advanced control strategies and calibration approaches allow for improved drivability, reducing perceptible eCVT effects and aligning vehicle behavior more closely with customer expectations.

Furthermore, thermal system design and advanced thermal management play a key role in extending the operational envelope of power-split architectures. By optimizing thermal behavior across powertrain and electrified components, Bosch Mobility enables improved performance under higher load conditions, including applications with increased towing or sustained power demand.

In combination with integrated braking system capabilities, supporting efficient energy recuperation and smooth transitions, this cross-domain approach ensures a balanced system performance in terms of efficiency, comfort, and robustness.

Bosch Mobility combines best-in-class components with deep system integration expertise to deliver power-split architectures that are optimized for efficiency at scale, without sacrificing drivability in real-world use.

3.3
Series / parallel topologies

Series / parallel hybrid architectures combine characteristics of both series and parallel hybrid systems, enabling flexible operation depending on driving conditions. In this topology, the vehicle can be propelled either purely electrically, with the combustion engine acting as a generator, or through a direct mechanical connection between the engine and the wheels with the dog clutch engaged. This dual-mode capability allows the system to adapt dynamically between electric-dominant and engine-supported driving.

In many implementations, the architecture is closely aligned with battery-electric vehicle design principles, including the use of underfloor battery integration, while retaining the combustion engine as a range-extending or performance-supporting element.

Series / parallel

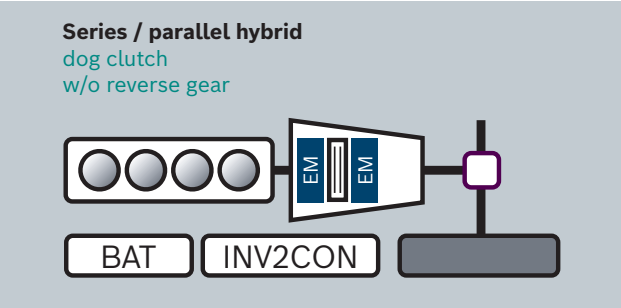


Figure 4: Series / parallel reference topology

Benefits and use cases

A key strength of series / parallel architectures is their ability to deliver high efficiency across both low-speed and high-speed driving conditions. In low-speed city driving, the efficiency benefit is mainly caused by the free operating point shift of the internal combustion engine in the series operation mode. However, in long-distance highway driving, the parallel mode generates a benefit for high-load internal combustion engine driving with its high mechanical efficiency. Additionally, at low speeds and in urban environments, the system can operate in pure electric mode, enabling a driving experience comparable to BEVs, including smooth and responsive acceleration.

The architecture benefits from a high level of system integration, allowing for compact packaging and simplified drivetrain layouts. In many cases, the transmission may be reduced to a relatively simple gearbox with a single dog clutch, eliminating the need for components such as torque converters and reverse gears.

These characteristics make the concept particularly suitable for:

- Electric-first driving use cases, where a BEV-like experience is desired
- Applications requiring extended driving range with fast refueling with fuel
- Vehicles with higher towing requirements, especially in multi-gear DHT-based implementations

The ability to combine electric driving with engine-based energy generation also provides flexibility in markets where charging infrastructure remains uneven. Equipped with an additional eAxle also four-wheel drive applications are available.

Drawbacks and technical limitations

The primary trade-off of series / parallel architectures lies in their system complexity, particularly due to the requirement for two high-power electric machines and corresponding inverter systems. This increases both system cost and integration effort compared to simpler hybrid configurations.

In addition, the need to manage multiple operating modes – electric, series, and parallel – places higher demands on control strategies and system calibration, particularly in ensuring smooth transitions between modes.

OEM adoption and market relevance

Series / parallel hybrid systems are increasingly adopted across global markets, particularly in applications that aim to combine electric driving characteristics with extended range capability. Key implementations can be found among OEMs such as BYD, Honda, and Mitsubishi, reflecting the growing relevance of this architecture in both passenger vehicles and electrification-focused platforms.

Bosch Mobility perspective

Building on the cross-domain system integration capabilities outlined in the previous sections, series / parallel architectures particularly benefit from coordinated control of multiple propulsion modes and energy flows, as well as from precise interaction between combustion engine, electric drive, and transmission.

The key challenge of these systems lies in the management of modes of transition between electric, series, and parallel operation, which directly impacts both efficiency and customer-perceived drivability. Bosch Mobility addresses this through advanced operating strategies and calibration expertise, enabling smooth and robust transitions across all driving conditions while ensuring optimal utilization of each operating mode.

In addition, the inherent system complexity – driven by multiple high-power electric components – can be effectively managed through integrated system design and modularization approaches, supporting scalable and cost-efficient implementations across vehicle segments.

As in other hybrid architectures, braking system integration plays a central role in maximizing recuperation potential and stabilizing vehicle behavior during mode changes. This contributes to a consistent and predictable driving experience, particularly in electric-dominant operation.

In summary, Bosch Mobility's system-level approach enables series / parallel architectures to fully realize their potential – combining BEV-like driving characteristics with high efficiency and extended range, while mitigating the complexity typically associated with multi-mode hybrid systems.

3.4
REEV topologies

Range-extended electric vehicle architectures represent a hybrid topology in which electric propulsion is the primary mode of driving, while the internal combustion engine serves exclusively as an onboard energy generator. In this configuration, there is no direct mechanical connection between the engine and the wheels; instead, the vehicle operates as a series hybrid, with electric drive determining vehicle dynamics.

Typically based on BEV-derived platforms, REEV systems integrate underfloor battery layouts and electric drivetrains, complemented by a compact combustion engine unit designed for energy generation rather than propulsion. In addition to pure series REEV concepts, emerging variants such as the so-called P1.5 topology in combination with a separate eAxle provide limited all-wheel drive functionality.

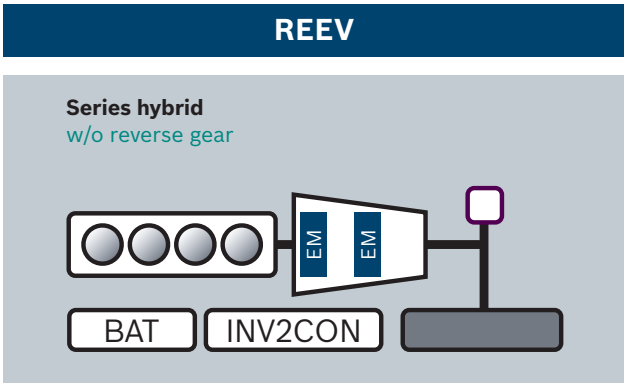


Figure 5: REEV reference topology

Benefits and use cases

A defining advantage of REEV architectures is their ability to deliver a fully electric driving experience, including smooth acceleration and low-speed efficiency, while eliminating range limitations through onboard energy generation. This results in high efficiency in urban and low-speed driving conditions, where electric operation dominates.

The architecture benefits from strong design synergies with BEV platforms, including the use of standardized electric drive components and battery integration. This enables compact packaging and reduces mechanical complexity, as key drivetrain elements such as multi-speed gearboxes, clutches, torque converters, and reverse gears are no longer required.

In addition, the combustion engine can be significantly simplified, as it operates in a more controlled and limited set of operating conditions, primarily for energy generation.

Typical use cases include:

- Electric-first vehicles with extended range capability, combining BEV driving characteristics with refueling flexibility
- Markets or customer segments where charging infrastructure is still developing, but demand for electric driving remains high
- Applications prioritizing low development complexity through BEV platform carry-over
- Large, heavy vehicles with high range requirements (e.g., large SUVs or vans)

This makes REEV architectures particularly attractive in regions where customers value electric driving experience without full dependence on charging infrastructure.

Drawbacks and technical limitations

REEV systems require two high-power electric machines and corresponding inverter systems, contributing to increased system cost and complexity.

At higher speeds and under sustained load conditions, the architecture can exhibit reduced efficiency, as energy must be converted from fuel to electricity and then back to mechanical propulsion. This results in higher fuel consumption during highway driving compared to parallel hybrid architectures.

In addition, towing capability and efficiency under heavy load are typically lower, reflecting the absence of a direct mechanical connection between engine and wheels.

As the performance of the system can dramatically reduce in case the battery is empty, the compromise between installed ICE and generator power and battery size has to be chosen carefully.

OEM adoption and market relevance

REEV architectures are increasingly gaining relevance, particularly in markets with strong demand for electric driving combined with range flexibility. Key OEM implementations include Li Auto, Leapmotor, XPeng, Mazda, VW Group, and RAM, highlighting the growing adoption of this concept across both passenger car and light commercial vehicle segments.

The architecture is especially prominent in regions where customer demand for electric driving experience intersects with infrastructure constraints, supporting its role as a transitional solution toward full electrification.



Bosch Mobility perspective

Building on the cross-domain system integration capabilities described in the previous sections, REEV architectures particularly benefit from holistic coordination of electric propulsion, energy generation, and battery management, as overall system performance is strongly driven by energy conversion efficiency and operating strategy.

A key challenge of REEV systems lies in reduced efficiency at higher speeds and sustained load conditions, where multiple energy conversion steps occur. Bosch Mobility addresses this through best-in-class efficiency in electrified powertrain components, including double inverter and advanced inverter technologies such as in-house silicon carbide-based solutions, enabling highly efficient energy conversion across a wide operating range. This directly contributes to improved system efficiency, particularly in highway driving scenarios. In addition, dedicated measures to increase engine thermal efficiency – such as optimized operating points and combustion system design – further improve overall system efficiency, especially during sustained generator operation.

Moreover, system-level dimensioning and operating strategy optimization are critical for balancing battery capacity, generator power, and overall vehicle performance. Bosch Mobility leverages its system expertise to define optimal sizing and control strategies, ensuring robust and consistent vehicle behavior even under demanding conditions, such as low battery states or high power demand.

Furthermore, the interaction between combustion engine and electric drivetrain requires careful management to ensure refined noise, vibration, and harshness behavior and overall driving comfort. Through coordinated control of generator operation and electric propulsion, Bosch Mobility enables smooth and well-balanced system behavior, maintaining the expected electric driving characteristics while minimizing disturbances from the range extender.

As in other hybrid architectures, integrated braking system capabilities support efficient energy recuperation and stable vehicle behavior, reinforcing overall system efficiency and consistency.

All in all, Bosch Mobility's combination of high-efficiency components, system-level design competence, and advanced control strategies enables REEV architectures to deliver a compelling balance between electric driving experience, efficiency, and robustness across real-world operating conditions.

04
Conclusion / summary

The global transition toward electrified powertrains is progressing rapidly, yet remains fundamentally heterogeneous across regions, use cases, and regulatory environments. As this paper has outlined, hybrid technologies will continue to play a structural role in the medium term, bridging the gap between conventional powertrains and fully electric mobility, and will remain relevant in some markets in the long term. The diversity of hybrid concepts and topologies reflects the need for tailored solutions rather than a single dominant architecture.

At the same time, increasing regional differentiation significantly raises the complexity of powertrain development and industrialization. Managing a broad portfolio of architectures across multiple markets requires substantial engineering effort, platform adaptations, and supply chain coordination. In this context, scalable and modular solutions developed across OEMs and regions become a key lever for efficiency, making collaboration with globally positioned system suppliers an increasingly attractive alternative to fully in-house approaches.

In this environment, Bosch Mobility is uniquely positioned to support OEMs with a comprehensive and scalable technology portfolio across all major hybrid architectures – from P2, P3, and DHT systems to power-split, series / parallel, and REEV concepts. As illustrated, Bosch Mobility provides relevant components and system solutions across the full hybrid landscape, including electric machines, inverters, eAxles, power electronics, combustion engine systems, and vehicle motion-control components. This enables a consistent and modular approach to hybrid system development, independent of the selected topology.

Bosch Mobility has built a particularly strong position in the lead market of China, both as a local partner for Chinese OEMs and as a global development hub. To date, Bosch has produced more than 25 million components for electrified driving and will deliver over 7 million electrification components and systems in 2026 alone, supplying more than 30 OEMs in China. This scale is complemented by continuous improvements at component level: electric motor designs have achieved around 50% higher power density (up to ~16 kW/kg) and efficiency gains of up to 30% (e.g., <1 kWh/100 km contribution), while optimized material usage and integration concepts significantly reduce weight and system cost. These capabilities enable Bosch to develop solutions “in China for China” and at the same time support OEMs going global with their portfolio.

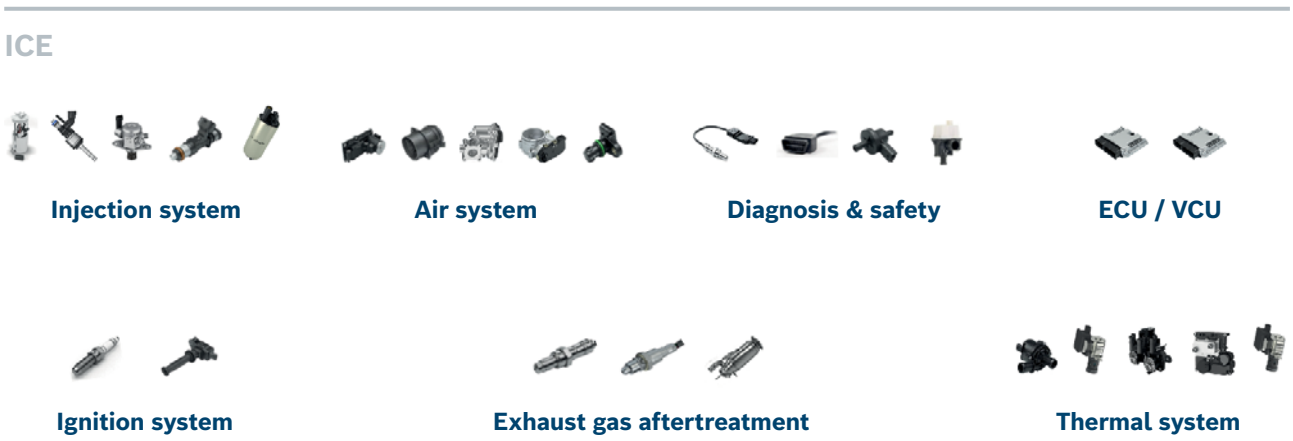


Figure 6: Bosch Mobility component overview

ECUs (Electronic Control Units) / VCUs (Vehicle Control Units)

What ultimately differentiates solutions across all topologies is the ability to handle real-world system trade-offs consistently – from drivability and mode transitions to efficiency under load and cost of electrification. This becomes visible in concrete applications: refined engine start and torque blending in P2 and P3 systems, stable mode switching in series / parallel architectures, cost-efficient system layouts in power-split concepts, and maintaining high efficiency in REEVs even in sustained highway operation. Delivering this level of performance requires not only strong components, but also a deep understanding of how powertrain, electrification, and vehicle systems interact under real-world driving conditions.

This system-level understanding is directly reflected in how Bosch supports OEMs in developing and industrializing hybrid powertrains.

Bosch Mobility acts as a development partner across the full life cycle of hybrid systems, leveraging a broad knowledge base built on statistical fleet data from vehicles across all global regions. This data is combined with real-world parameters such as local climate conditions and customer usage patterns (e.g., charging and parking behavior), enabling the creation of highly realistic use cases that guide early powertrain architecture decisions.

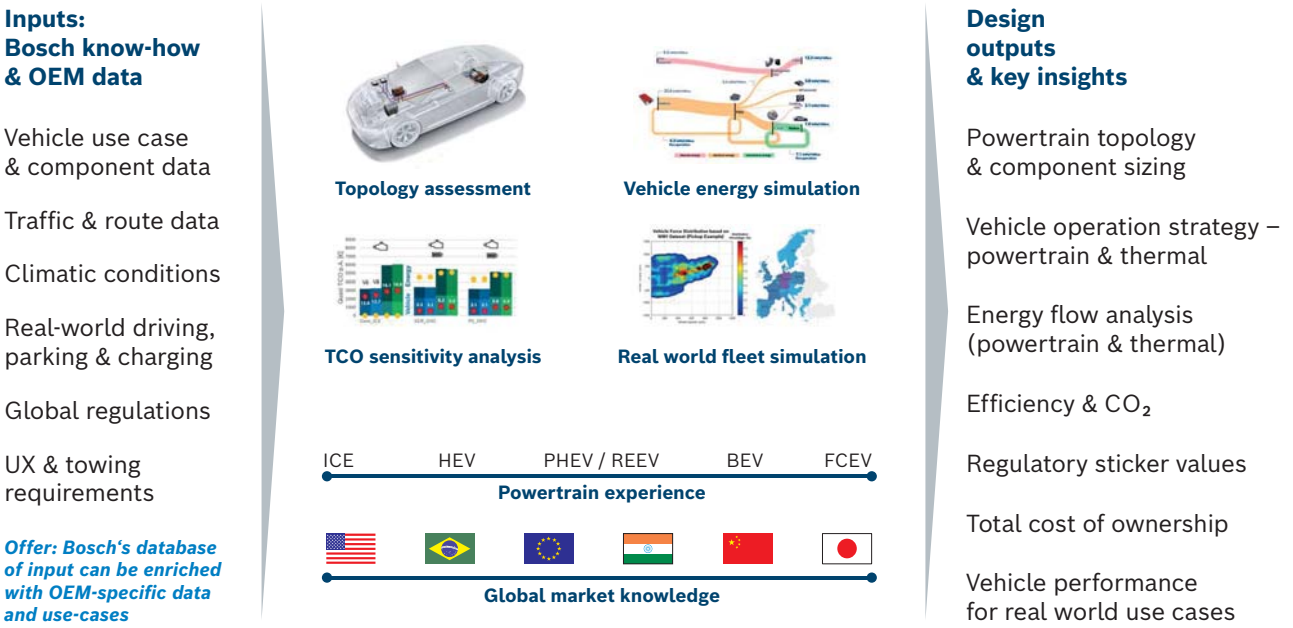


Figure 7: Powertrain system analysis solutions

TCO (Total cost of ownership) / UX (User experience) / FCEV (Fuel cell ev)

Building on this foundation, Bosch applies its expertise in vehicle, energy, and powertrain simulation to identify optimal hybrid concepts. This includes precise component dimensioning for specific vehicle segments, customer groups, and regional requirements. Furthermore, Bosch develops advanced control and operating strategies to balance efficiency, emissions, noise, vibration, harshness, and component durability. In parallel, system-level trade-offs – such as cost, packaging, and overall efficiency – are evaluated holistically, ensuring a consistent and application-specific system design.

This end-to-end approach extends from concept definition to detailed component specification, calibration, and full system integration, enabling faster development cycles and reducing overall integration complexity.

A practical example of this system approach can be seen in compliance with future emission requirements. By leveraging intelligent hybrid system control – e.g., in combination with solutions such as the Rapid Catalyst Heater (RCH) – Bosch enables active thermal management of the aftertreatment system, keeping it within its most efficient operating window. This allows OEMs to meet stringent emission targets with optimized system design, including the use of lower-cost catalyst materials.

In this way, Bosch translates system understanding into tangible vehicle-level benefits, supporting OEMs in developing the next generation of efficient, robust, and cost-competitive hybrid vehicles.

Bosch Mobility brings this together as a technology partner for OEMs, with vertical integration from semiconductor to system level, and a global engineering and manufacturing footprint. This allows Bosch to translate regional requirements into scalable solutions while supporting all major OEMs across segments and markets. At the same time, Bosch's scale and cross-domain expertise contribute to the establishment of industry standards and the enablement of flexible multi-energy platforms, helping OEMs adapt to shifting demand across ICE, hybrid, and electrified powertrains. This also helps to de-risk product strategies, as scalable solutions across multiple energy paths reduce exposure to market volatility and uncertain technology ramp-ups.

In this environment, Bosch Mobility supports OEMs in bringing hybrid systems to market faster, with lower complexity and competitive cost, while maintaining performance and robustness across applications.

Looking ahead, hybrid powertrains are only one part of a broader vehicle-level transformation. Further gains will come from cross-domain innovations – ranging from integrated vehicle motion control and predictive energy management to software-defined functions that optimize the interaction between powertrain, braking, and chassis systems in real time. Bosch Mobility is already working across these domains, building on its system understanding to unlock additional efficiency, performance, and customer value beyond the powertrain itself.

Ultimately, the winners in this transition will be decided not by a single technology, but by the ability to integrate the right technologies into a coherent, scalable system for each market.



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Get in touch with our expert team. We are looking forward to support you with our expertise to find out more about the future of mobility.

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