

University of Wales Trinity Saint David

Welsh Institute of Science & Art



The uses of Hybrid and Electric Technologies in Motorsport applications.

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Steffan Selwood

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¹ **Introduction**

Motorsport has long been the proving ground for manufacturers and engineers to innovate to be the best.

In recent years there has been a big push in motorsport to become more sustainable and more ecological.

This has therefore pushed engineers and manufacturers to make significant developments in electric and hybrid technology to keep motorsport ecologically viable for the future.

This paper explores the ways manufacturers have driven innovation in the industry, how this innovation has changed vehicle performance, and the advantages and disadvantages of integrating hybrid and electric technologies into motorsport applications.

² **Background of Hybrid and Electric Technology**

Hybrid and electric technology has been present for decades, with the first mass-produced electric vehicle being the General Motors EV1, built between 1996 and 1999 with around 1,100 units produced (Ehsani, Gao, and Emadi, 2018). The EV1 used lead–acid batteries and became the first purpose-built electric road vehicle, inspiring later models such as the Tesla Roadster and Nissan Leaf (Ehsani, Gao, and Emadi, 2018). Electric propulsion has, however, existed in motorsport since 1899, when Belgian driver Camille Jenatzy achieved over 100 km/h in La Jamais Contente (Ehsani, Gao, and Emadi, 2018). After a long absence, hybrid technology returned to racing through Toyota’s endurance projects in the 1990s (Toyota Gazoo Racing, 1997). This innovation led to hybrid victories such as the Audi R18 e-tron quattro at Le Mans (FIA, 2012), while systems like KERS in Formula 1 (FIA, 2009) and the creation of Formula E in 2014 (Formula E, 2014) cemented electrification in modern motorsport.

³ **Applications in Motorsport**

While hybrid technology was first developed and tested in endurance racing by Toyota, the first major motorsport championship to adopt the technology was Formula 1 in 2009. The Fédération Internationale de l'Automobile (FIA) introduced the Kinetic Energy Recovery System (KERS) to improve energy efficiency, reduce fuel consumption, and increase overtaking opportunities. KERS worked by harvesting kinetic energy that would otherwise be lost as heat under braking and converting it into electrical energy, which was then stored in a battery for later use. This stored energy could be deployed by the driver to provide a brief power boost of approximately 80 bhp for several seconds per lap, in accordance with the FIA's 2009 technical regulations (FIA, 2009).

Later in 2014, the (FIA) introduced the Motor Generator Unit–Heat (MGU-H), which worked alongside the Motor Generator Unit–Kinetic (MGU-K). The MGU-H harvested energy from the exhaust gases and converted this otherwise wasted heat into electrical energy, which could be stored in the battery or transferred directly to the MGU-K. This provided the driver with an additional power boost while further improving overall efficiency and reducing fuel consumption (FIA, 2014). The implementation of the MGU-H and MGU-K increased the total recoverable energy by approximately 20 % over a full race distance. Together, these two components became collectively known as the Energy Recovery System (ERS), a hybrid technology that remains integral to Formula 1 power units today (Scarborough, 2020).

⁴ **Applications in Motorsport**

Due to the success of KERS in Formula 1, the FIA introduced hybrid technology to the World Endurance Championship (WEC) in 2012, creating a new category: Le Mans Prototype 1 – Hybrid (LMP1-H), which ran from 2012 to 2020 (FIA WEC, 2012). Endurance racing provided the ideal platform for developing hybrid systems, as its long races demand exceptional energy efficiency, fuel economy, and reliability. A particularly notable car from this period was the Audi R18 e-tron quattro, the first hybrid to win the 24 Hours of Le Mans. Its success demonstrated that hybrids could combine both performance and efficiency when compared with traditional Internal Combustion Engine (ICE) vehicles. The R18 used a turbo-diesel V6 engine driving the rear wheels, paired with a front-axle flywheel-based KERS. This system recovered energy under braking and redeployed it through the front wheels to improve corner exits (Audi Sport, 2012). The R18's engine produced approximately 510–520 bhp, with the hybrid system contributing an additional 150–170 bhp in short bursts (FIA WEC, 2012).

⁵ **Applications in Motorsport**

After the success of hybrid systems in Formula 1 and the World Endurance Championship (WEC), the Fédération Internationale de l'Automobile (FIA) introduced an entirely new racing series in 2014 Formula E, the world's first fully electric, single-seater championship. Formula E was designed to promote sustainable technologies, urban innovation, and the development of electric-vehicle (EV) systems (FIA, 2014). The first generation of Formula E cars (Gen 1, 2014–2018) produced approximately 268 bhp, achieved a top speed of around 140 mph, and used a 28-kWh battery supplied by Williams Advanced Engineering. Energy recovery was achieved through regenerative braking systems similar in principle to Formula 1's KERS, though less efficient. As a result, drivers were required to swap cars mid-race to complete the full race distance (Williams Advanced Engineering, 2014). In 2018, the FIA introduced the second generation (Gen 2) of Formula E cars, which incorporated lessons from the championship's first four years. Power output increased to 335 bhp, range improved significantly, and car swaps were eliminated. The FIA also introduced Attack Mode, which, like Formula 1's Drag Reduction System (DRS), allows drivers to unlock a temporary power boost by driving through designated activation zones (Spark Racing Technology, 2018). The third generation (Gen 3, 2023–present) represents the most advanced Formula E car to date. These vehicles produce around 470 bhp, reach top speeds of 200 mph, and are both the lightest and most efficient cars the series has seen. Gen 3 cars also feature dual motors, with the front unit dedicated solely to energy recovery rather than propulsion, enabling combined regenerative braking of up to 600 kW (Formula E Holdings, 2023). Formula E has become a key platform for manufacturers to develop and refine EV technologies that directly influence modern road-car systems, contributing to global efforts to reduce carbon emissions and promote sustainable transport.

6 Challenges of Implementing Hybrid and Electric Systems in Motorsport

While hybrid and electric drivetrains have revolutionised the landscape of motorsport, there are significant advantages and challenges associated with implementing these complex and potentially hazardous systems within a competitive environment.

These hybrid and electric systems including the batteries, electric motors, and associated cooling components add a considerable amount of weight to the vehicle. This creates not only engineering challenges in chassis design and weight distribution but also logistical difficulties during development and race operations.

Due to the extensive research, high costs, and rigorous maintenance required, hybrid and electric systems can significantly limit smaller teams. For example, Racing Point, a smaller independent outfit, was rebranded as Aston Martin in 2021 following major manufacturer investment a pattern echoed by Sauber's transition to Audi for the 2026 season. This trend highlights how smaller teams increasingly struggle to remain competitive without backing from large automotive corporations. The sheer expense of designing, testing, and developing these advanced technologies is far greater than that of traditional Internal Combustion Engine (ICE) systems, which in turn restricts participation from teams with limited financial resources.

Overall, these challenges can often outweigh the advantages of hybrid and electric technology. Although such systems offer substantial performance and sustainability benefits, overcoming the associated engineering, financial, and logistical barriers will be essential to ensure the continued growth of hybrid and electric technology within motorsport applications.

⁷ **Future Development and Sustainability**

Although there are many challenges surrounding hybrid and electric systems, such as high cost, complexity, and limited accessibility for smaller teams, the future of these technologies appears almost set in stone. Continuous development in hybrid and electric powertrains is driving improvements in efficiency, reducing environmental impact, and making these systems more attainable across all levels of motorsport. Advancements in battery technology and regenerative braking are expected to deliver greater power output, faster energy recovery, and reduced overall weight (Zurschmeide, 2023).

With major regulation changes coming to Formula 1 in the coming years, the FIA aims to introduce sustainable fuel sources such as biofuels and a revised hybrid system featuring a 50:50 power split between the electric motor and internal combustion engine. This represents a significant step toward a more sustainable future for Formula 1 and the wider motorsport industry (FIA, 2024). These regulation changes also demonstrate the FIA's commitment to advancing environmentally responsible technologies and supporting global efforts to reduce carbon emissions.

These technological advancements not only enhance competition within motorsport but also encourage innovation in road-car development. As hybrid and electric systems continue to evolve, the lessons learned on the track will directly influence the commercial automotive sector, helping to drive the global transition toward a cleaner, more sustainable future (Scarborough, 2023).

⁸ **Conclusion**

Hybrid and electric technologies have significantly reshaped the landscape of motorsport, driving engineers and manufacturers to innovate and develop modern solutions that enhance efficiency, performance, and sustainability. While these advanced systems may appear complex and costly in the present, their long-term benefits far outweigh the drawbacks. Motorsport will continue to serve as a vital proving ground for manufacturers and engineers to refine and demonstrate these technologies under extreme conditions. The ongoing development and competition in this field will not only improve racing performance but also accelerate the transition toward a cleaner and more sustainable future for the automotive industry as a whole.

Ultimately, this continued cycle of innovation ensures that motorsport remains at the forefront of sustainable technological progress, influencing not only the performance of race cars but also the evolution of road vehicles and the global effort toward decarbonisation.

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