Electric and Hybrid Vehicles: An Overview

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***Abstract*—The rise of electric vehicles (EVs) promises a new era of clean, efficient transportation, gradually phasing out tra- ditional gas-powered engines. Driven by environmental concerns and the desire to ditch expensive oil, EVs surpassed two million on the road worldwide by 2016. Several factors fuel their growth: advancements in battery technology and affordability, expanding public charging infrastructure, and government support. Battery electric vehicles (BEVs) and plug-in hybrids (PHEVs) are the leading contenders, each offering unique advantages and chal- lenges. To truly understand their potential, a deeper dive is needed. Quantify the environmental and economic benefits, delve into cutting-edge technologies, and analyze battery performance and affordability. Explore the details of government incentives and compare BEVs and PHEVs head-to-head. Don’t forget to address roadblocks like charging limitations, range anxiety, and recycling concerns. Finally, offer your own perspective: what does the future hold for EVs, and what can accelerate their widespread adoption? By painting a more detailed picture, you’ll illuminate the true potential of EVs to revolutionize transportation.**

***Index Terms*—hybrid electric vehicle (HEV; classification ; energy management; vehicle type**

1. Introduction

As traditional gas-guzzlers choke our planet with pollution and deplete precious resources, HEVs emerge as a beacon of hope. Their unique blend of an internal combustion engine and electric motor slashes emissions and fuel consumption through a suite of innovative technologies. Regenerative braking cap- tures lost energy during deceleration, turning it into electricity. Multi-talented motor generators both power the wheels and recharge the battery, while start-stop systems ensure the engine doesn’t waste fuel idling. Compared to their gasoline counter- parts, HEVs boast cleaner exhaust, impressive fuel economy, and even improved performance. However, challenges like cost, battery limitations, and charging infrastructure remain. Ultimately, HEVs represent a significant step towards sustain- able transportation, offering a practical bridge between the present and a greener future. While other alternatives like EVs and fuel cell vehicles hold promise, HEVs’ current efficiency and infrastructure compatibility make them a crucial player in the ongoing clean mobility revolution.

1. CLASSIFICATION OF HYBRID ELECTRIC VEHICLES
2. *Types by derivization structure*
   1. Series Hybrid

Ditch the complex gears and embrace electric simplicity! That’s the motto of series hybrid vehicles, where a combustion engine acts as a dedicated power station, generating electric- ity for an electric motor that propels the car. This clever setup keeps the engine operating at its most efficient point, minimizing emissions and fuel consumption. Even braking becomes a bonus, as captured energy recharges the battery, reducing reliance on the generator. To further optimize per- formance, tiny energy reservoirs called ultracapacitors act like mini-batteries, absorbing braking energy and providing power bursts, all while extending battery life and reducing stress. The result? A smooth, efficient ride with a simplified drivetrain that ditches the need for complex transmissions. Of course, energy conversion has its trade-offs with slight losses, and longer trips rely on the fuel tank’s capacity. But for city driving with frequent stops and starts, series hybrids offer a compelling combination of clean operation and electric-like simplicity, making them a strong contender in the race towards a greener future.

* 1. Paralel Hybrid

Parallel hybrids are all about teamwork! Combining an electric motor and an internal combustion engine (ICE), they share the driving duties through a clever single unit. Imagine the motor zipping you around town silently, while the ICE steps in for highway muscle. This dynamic duo delivers impressive benefits: the electric motor recovers braking energy, boosting your electric range, and seamlessly swaps with the ICE for optimal efficiency. Plus, the simplified design means less maintenance and weight. However, keep in mind the smaller battery – it’s more like an assistant to the engine, limiting pure electric range. Think of it as a practical choice for everyday driving, offering a taste of electric benefits without sacrificing long-distance capability. As batteries evolve, expect parallel hybrids to shine even brighter, becoming key players in the hybrid game.

* 1. Combined Hybrid

Combined hybrids are the chameleons of the hybrid world, blending the best of both series and parallel systems. Imagine a car that seamlessly switches between silent electric city commutes and powerful highway sprints, all thanks to its split personality. Confused? Don’t be! This system lets the engine act as a power generator for electric driving, or combine directly with the motor for highway muscle. Need maximum fuel economy? Go electric. Craving a power boost? Let both

engine and motor unleash their fury. But like any chameleon, complexity is the trade-off. Delicate power-splitting devices and intricate control systems add cost and potential main- tenance concerns. However, for drivers seeking the ultimate in flexibility and efficiency, combined hybrids offer a unique advantage. Think of them as adaptable athletes, ready to conquer any driving terrain. As technology progresses, expect these chameleons to become even more refined and efficient, potentially leading the charge in the future of hybrid trans- portation.

1. *Types by degree of hybridization*
   1. Strong Hybrid

Full hybrids are the ultimate switch-hitters of the EV world. Picture this: gliding silently through city streets on electric power, then effortlessly merging onto the highway with a burst of combined engine and motor muscle. No need to fumble with charging cords, a large battery pack lets these chameleons act like electric cars for short stretches, offering a taste of emission-free freedom. But don’t underestimate their practicality. A smart computer brain decides whether the electric motor’s whisper-quiet efficiency, the engine’s power, or both are needed for the job. And when the motor takes the lead, the engine takes a well-deserved break, saving fuel and keeping the air cleaner. Sure, they might not boast the extended electric range of pure EVs, but their self-charging abilities through regenerative braking and unmatched versatility make full hybrids a compelling choice for eco-conscious drivers who value both practicality and a touch of electric adventure.

* 1. Medium Hybrid

Motor assist hybrids are like the supportive gym buddy of the EV world. They might not be personal trainers leading the whole workout, but they’re there to lend a helping hand for better performance and efficiency. While gasoline remains their main source of power, a hidden electric motor acts like a secret weapon, providing an extra burst of torque when you need it, whether it’s for passing or tackling hills. Imagine smoother starts and stops thanks to the motor seamlessly restarting the engine, and bonus points for capturing braking energy to top up the battery and improve fuel economy. Plus, the smarter battery powers your entertainment system and other accessories efficiently. However, don’t expect extended electric drives like full hybrids – these guys are more about gas with a touch of electric assistance. But their smaller batteries and lower cost make them perfect for budget-conscious drivers who want to experience the benefits of electrification without breaking the bank. Think of them as a stepping stone, offering a taste of the electric future without going all-in.

* 1. Mild hybrid / micro hybrid

The world of hybrids isn’t one size fits all. There’s the tin- kering micro hybrid, focusing on small changes like stopping the engine at lights and using the alternator as a tiny motor for smooth restarts. Think fuel-saving efficiency with a focus on budget-friendliness. Then there’s the mild hybrid, packing a stronger electric punch thanks to a dedicated motor. Imagine smoother acceleration, better fuel economy, and even hybrid

pioneers like the Honda Civic or mighty Silverado enjoying a 10 percentage fuel boost. While both save fuel, micro hybrids keep it light on the wallet and electricity, while mild hybrids offer a more noticeable electric experience and bigger fuel savings. So, which one’s for you? It depends on your priorities. Think city driving and affordability? Micro might be your match. Crave a more noticeable electric feel and fuel efficiency gains? Mild could be your mild-mannered hero. Remember, even small steps matter on the road to electrification, and these hybrids prove that every spark counts.

* 1. Plug-in hybrid

PHEVs are like the ultimate hybrid superheroes, combining the electric might of silent commutes with the backup brawn of a gas engine. Think zero-emission city glides saving you money and the environment, then seamlessly switching to gas power for worry-free road trips. No more ”range anxiety” here! This dynamic duo offers unparalleled flexibility: zip around town on electric power for errands, then unleash the gas engine for extended adventures. It’s the best of both worlds, ready to adapt to any driving scenario. Sure, they might cost a bit more upfront and have slightly less cargo space due to their larger batteries, but the trade-off is worth it. PHEVs represent a giant leap towards sustainable transportation, and as battery technology improves and charging stations become more widespread, expect these eco-warriors to become even more powerful players in the future of mobility. So, buckle up for an electrifying ride with a touch of gas-powered backup – the PHEV awaits!

1. *Types by nature of the power source*
   1. Electric-internal combustion engine hybrid

Hybrid vehicles aren’t just one-size-fits-all! Under the hood, there’s a fascinating world of different designs, each with its own way of combining electric and gasoline power. Think of it like a buffet of options:

Series hybrids are like electric trains, with the engine acting as a power generator for the wheels. Parallel hybrids work like tag teams, with both engine and motor directly driving the car. Combined hybrids are the chameleons, switching between series and parallel modes for ultimate flexibility. But it’s not just about how they’re connected. Some hybrids are fuel- saving ninjas, shutting down the engine at stops to conserve energy. And the power balance? It’s not always 50/50 - each component contributes differently depending on the design and your driving needs.

The beauty of this diversity is that there’s a perfect hybrid out there for everyone. Whether you prioritize efficiency, flexibility, or pure electric power, there’s a technology waiting to take you on a greener ride. So buckle up and explore the exciting world of hybrid vehicles – the future of transportation is a delicious mix of innovation and efficiency!

* 1. Fuel cell hybrid

The hybrid party gets even more exciting with the arrival of fuel cell vehicles (FCVs)! Think series hybrid setup, but instead of a gasoline engine, they use futuristic fuel cells that combine hydrogen and oxygen to power the electric

motor, emitting only clean water vapor. Sounds cool, right? But there’s more! To give them bursts of power and keep costs manageable, FCVs often team up with trusty batteries or supercapacitors, acting like energy buffers. Imagine it as a high-tech tag team working for efficiency. And speaking of cost, researchers are constantly innovating to shrink fuel cells and make them more affordable, opening the door for wider adoption. By exploring these diverse technologies, we unlock a deeper understanding of electric, hybrid, and FCV worlds. Each with their unique connection styles and supporting tech- nologies, they paint a vibrant picture of the many roads leading to a more sustainable transportation future. So, buckle up and get ready for an electrifying ride with a touch of hydrogen magic – the future of mobility is full of exciting possibilities!

1. ADVANTAGES AND DISADVANTAGES OF A HYBRID ELECTRIC VEHICLE
2. *Advantages of a hybrid electric vehicle*
   1. Lower Carbon Emissions: HEVs produce lower carbon emissions compared to conventional vehicles, making them more eco-friendly.
   2. Improved Fuel Efficiency: With the electric motor assist- ing the Internal Combustion (IC) engine, the fuel consumption reduces, leading to improved fuel efficiency.
   3. Performance Enhancement: The electric motor assists the engine during initial acceleration to improve performance.
   4. Cost-Effective: HEVs are less expensive than full hybrid vehicles and have less complex components, making them cheaper to repair.
   5. No Need for Charging Infrastructure: HEVs do not need to be plugged into a power source to charge the battery. The battery pack gets charged via regenerative braking or through a generator run by the internal combustion engine.
   6. Fuel Efficiency at Slow Speeds: Plug-in hybrid cars are fuel-efficient at slow speeds, with the electric powertrain assisting the engine.
3. *Disadvantages of a hybrid electric vehicle*
   1. While you’re correct that hybrids aren’t powerhouses compared to their gas-guzzling counterparts, there’s more to the story than meets the eye. Sure, the individual gasoline engine in a hybrid is typically smaller, but don’t underestimate the punch of the electric motor! Its instant torque can deliver surprising power, sometimes even matching or exceeding traditional engines, especially during those city sprints. But remember, hybrids are all about efficiency, not drag racing. They shine in stop-and-go city traffic, where they cleverly recapture braking energy and glide on electric power, saving you fuel and keeping the air cleaner.

Now, it’s true that different hybrid types pack different punches. Plug-in hybrids, for instance, boast beefier electric motors and batteries, offering more muscle and extended electric range. And let’s not forget, power isn’t everything! Hybrids might not win speed battles, but they often pro- vide smooth, responsive driving experiences, something many drivers value more than raw power. Plus, factors like fuel

economy, environmental impact, and lower maintenance costs are often deal-breakers for many, areas where hybrids truly excel.

Technology is constantly evolving, and hybrid limitations are shrinking. Future generations promise even more power without sacrificing efficiency. So, while raw power might be your jam, if you prioritize a greener, smoother, and more economical ride, a hybrid could be your perfect match, even with its unique power delivery style. Remember, it’s about finding the car that best suits your needs and priorities, and hybrids offer a compelling package for many drivers!

* 1. Can be Expensive: The biggest drawback of having a hybrid electric vehicle is that it can burn a hole in your pocket. Hybrid electric cars are comparatively expensive than a regular petrol car and can cost 5000 to 10000 more than a standard version. However, that extra amount can be offset with lower running cost and tax exemptions.
  2. Poorer Handling: A hybrid electric car houses a lighter electric engine and a pack of powerful batteries. This adds weight and eats up the extra space in the car. Extra weight results in fuel inefficiency and manufacturers cut down weight which has resulted in motor and battery downsizing and less support in the suspension and body.
  3. While technology keeps evolving, mechanics have better tools and training to handle hybrids now. Finding a qualified mechanic might be slightly trickier, but major shops are catching up.

Cost-wise, studies suggest hybrids may even be cheaper to maintain in the long run. Electric power reduces wear on the engine and brakes, while regenerative braking saves on brake pads. Plus, some hybrid parts last longer.

Remember, regular maintenance is key for any car, hybrid or not. If you prioritize fuel efficiency, eco-friendliness, and lower running costs, potential maintenance concerns might be a fair trade-off. But if affordability and easy repairs are your main concerns, a traditional car might be the better choice.

* 1. High voltage batteries in hybrids sound scary, but don’t let the headlines fool you. These batteries are built tough! In an accident, automatic shut-offs isolate the power, strong casings protect them from damage, and bright orange cables warn everyone involved. Plus, emergency responders get special training to handle these situations safely. Studies show the risk of electrocution is super low, and hybrids often score well in safety tests thanks to their reinforced structures. So, while no car is 100

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