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Hybrid Energy Systems for Heavy Vehicles: Combining Heat Recovery and Renewable Energy Sources

Muhammad Atif Nazir[1*]

Department of Mechanical, Mechatronics & Manufacturing Engineering, University of Engineering and Technology Lahore, New Campus.

Corresponding Author: Email: matifnazir1051@gmail.com

Adnan Sajjad[2]

Department of Computing, Engineering and the Built Environment, Birmingham City University

Sheeraz Ahmed[3]

Department of Electrical Engineering, Sukkur IBA University, Sindh, Pakistan

Abdul Sattar[4]

Department of Electronics, University of Larkano, Pakistan

Tauseef Iqbal[5]

Faculty of Mechanical Engineering, GIKI, Pakistan

Sareer Ahmad[6]

Department of Mechanical Engineering, International Islamic University Islamabad, Pakistan

Asad Riaz[7]

Department of Mechanical, Energy, Management and Transportation Engineering, School of Polytechnic, University of Genova, 16145, Itlay.

Ahsan Akram[8]

Department of Civil Engineering, Institute of Southern Punjab, Multan

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Abstract

Hybrid energy systems in heavy-duty vehicles have chance to boost fuel efficiency and cut environmental harm. By using technologies like regenerative braking, waste heat recovery, and renewable energy sources (like solar, wind, and hydrogen fuel cells), hybrid systems can enhance fuel economy by as much as 30% and lower CO_2 emissions by almost 40%. Developments in energy storage, like solid-state batteries, and progress in hydrogen fuel cells and thermoelectric generators have made these systems more practical for larger use, enhancing energy performance and cost. Even, the consumption of hybrid energy systems has many hurdles. High initial costs, lack of sufficient charging and refueling stations, and the complexity of combining different energy sources are big challenges. Also, good energy management systems are key to making sure energy from renewable sources and waste heat recovery is used effectively. To tackle these issues, we need ongoing tech innovation, funding for infrastructure, and robust government backing. The environmental and economic gains of hybrid systems are major. They can cut CO_2 emissions by up to 40%, improving air quality and helping achieve global climate targets, like those in the Paris Agreement. On the economic side, hybrid systems bring long-term savings on fuel and maintenance costs, with a typical return on investment (ROI) seen within 5-7 years. Future studies need to look at better materials, lighter composites, and stronger energy storage options to boost hybrid system efficiency. Also, using artificial intelligence (AI) and the Internet of Things (IoT) for managing energy in real time and predicting maintenance should make systems more reliable. Working together, governments, manufacturers, and researchers

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must tackle tech challenges and promote the broader use of hybrid energy systems, helping to create a future with sustainable and efficient transportation.

Keywords: Hybrid Energy, Heavy Vehicle, Renewable Energy,

Introduction

Heavy vehicle energy efficiency demands immediate attention because their role in generating greenhouse gases and fuel consumption exceeds other vehicles (Lajunen *et al*., 2014) (Khan *et al*., 2014). Heavy-duty vehicles within the European Union emit 25% of total street transport CO_2 emissions according to Basma H *et al*. (2023). In the United States transportation generates 25% of worldwide greenhouse gas emissions while heavy-duty trucks yearly produce 810,000 tons of CO_2 emissions through their consumption of 29 billion gallons of diesel fuel (Liang, Z *et al*., 2024). The critical measurements demonstrate the immediate need to create better energy-efficient systems that reduce heavy vehicle pollution in the environment.

Current vehicle technology development has not successfully resolved the substantial energy consumption and emissions problems in the heavy vehicle market (Ali, U *et al*.,2021). Freight transport demand keeps growing at a faster rate than the improvements made to transportation efficiency. HDVs in the EU experienced annual emission increases starting from 2014 with the exception of a brief decrease during the 2020 COVID-19 pandemic. The sustainable reduction of emissions proves difficult to achieve (Lamb, W. F *et al*.,2022) in the long term. The advancement of technology represents a major block to progress. Heavy vehicles face barriers during energy efficiency technology development because manufacturers must manage elevated expenses along

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with restrictions to weight load and the necessity for equipment that withstands harsh operational conditions. Electric trucks demonstrate lower energy demands while providing advantages for the environment though they encounter difficulties because of expensive initial expenditures as well as insufficient charging stations alongside demands for resilient battery technology. The situation becomes more complicated due to regulatory and policy uncertainties (Khan, T *et al.*,2024). The withdrawal by California to drop its application for a federal waiver to force zero-emissions commercial trucks represents an environmental policy shift that affects the advancement of clean technology adoption.

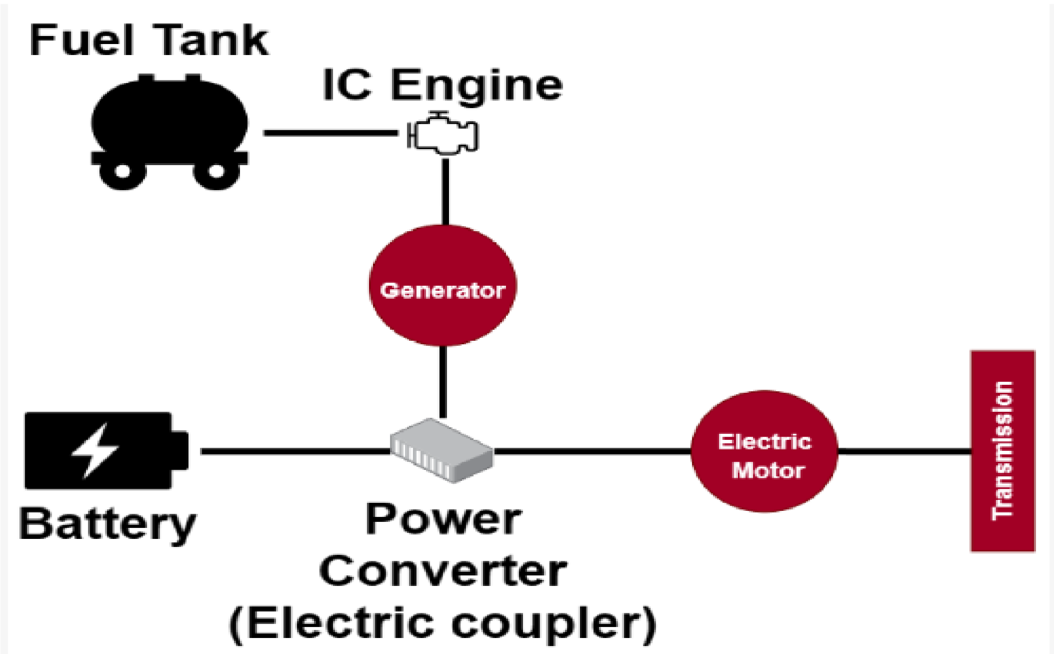

Figure 1: Hybrid Energy System: Integrating IC Engine, Battery, and Electric Motor for Enhanced Efficiency

Figure 1 illustrates a hybrid energy system architecture combining an internal combustion (IC) engine, a generator, a battery, and an electric motor connected via a power converter. The IC engine, powered by fuel from the fuel tank, generates electricity through

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the generator, which is then stored in the battery or directly powers the electric motor via the converter. The electric motor drives the transmission, enabling vehicle propulsion. In the context of our study, this system exemplifies the integration of traditional and renewable energy sources with energy recovery and storage technologies, highlighting how hybrid systems enhance efficiency and reduce emissions in heavy vehicles. It aligns with the focus on optimizing energy utilization through advanced hybrid designs and power management.

The combination of internal combustion engines with electric or hydraulic components delivers an effective solution to overcome present challenges (Yang. J *et al*,2022). The systems improve both energy efficiency and emission reduction through their ability to recover and reuse substantial amounts of vehicle kinetic energy when braking (J *et al*,2022). Growth is evident for both hybrid electric and hydraulic hybrid systems as they prove to be effective solutions for heavy vehicle markets. Contemporary innovations prove that these systems can effectively perform their functions. Daimler received an order from Amazon to deliver 200 eActros 600 electric trucks which will serve as part of their operations in Germany and the UK (Bircan, E. *et al*.,2024). Amazon's commitment to reach net-zero carbon emissions by 2040 is supported by these trucks which have 500-kilometer operational range. The deployment of these vehicles will begin operating on lengthy transportation routes during this year as they demonstrate hybrid and electric technology practicality for commercial transportation (M de las Nieves Camacho *et al*., 2022).

The main purpose of this review targets both the significance of heavy vehicle energy efficiency (Martyushev, N. V *et al*., 2023) and

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the existing energy consumption (Wang, J *et al.*, 2024) and emission challenges (Khan, T *et al.*, 2022) and examines the ability of hybrid energy systems to tackle these problems (Khan, T *et al.*,2022). This review establishes a deep understanding of heavy vehicle transformation by examining current technological advancements and recent research about hybrid systems combining heat recovery units and renewable power sources (Farhat, O *et al.*,2022). Research findings will deliver significant information which enables development of sustainable practices and technologies to decrease environmental effects of heavy-duty transportation.

Heavy vehicles serve as essential components of global transportation because they function as vital assets for industry-based freight delivery. Heavy-duty vehicles (HDVs) according to Basma H *et al.* (2023) require substantial energy quantities which puts them in the top energy-consuming transportation sector elements. The annual diesel fuel consumption by heavy vehicles represents a substantial part of the rising fossil fuel market as reported in Chandran, R *et al.*,2022 statistics. High energy needs exist because heavy-duty vehicles require advanced powertrain engines to carry heavy cargo across extended ranges. Greenhouse gas emissions from heavy vehicles surpass those of their numbers in global vehicle fleets (Wang, X *et al.*,2023)(Torbatian, S *et al.*,2024).

The standard energy systems of heavy vehicles consist of diesel-fueled internal combustion engines which power the vehicles. These engines maintain the required power and efficiency traits needed for heavy-duty operations but demonstrate major adverse effects on both the environment and economy. The use of

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HDVs in the environment produces high CO_2 emissions along with particulate matter and nitrogen oxide pollutants which intensify air pollution problems and create climate change effects. HDVs contribute to 25 percent of CO_2 emissions in road transport within the European Union even though they represent a tiny portion of the entire vehicle fleet according to Rodriguez, Felipe *et al.*,2018. The fossil fuel dependency of this sector subjects it to unreliable market fuel rates and delivery chain breakdowns which drive transportation costs higher for logistics organizations.

Hybrid energy systems provide a revolutionary solution to power system issues through their integration of standard internal combustion engines with modern innovations such as electric motors hydraulic systems and renewable energy sources. Such integrated power systems create possibilities for energy recovery from wasted resources which occur while braking or coasting. Research proves that combining hybrid components shows major advantages for emission reduction along with fuel efficiency enhancement. Waste heat recovery systems extract usable power from exhaust gasses for better functionality and electric hybrid systems enhance fuel efficiency by decreasing engine workloads during idling and limited speed conditions (Altun, Y *et al.*,2024).

Hybrid energy systems provide alignment with contemporary global mandates to transition toward sustainable energy sources while decreasing carbon emissions. The transportation sector experiences increased innovation and adoption of hybrid and renewable technologies because worldwide governments and organizations have established net-zero emissions targets (Renné, D. S. *et al.*,2022). Hybrid energy systems serving heavy vehicles deliver dual benefits since they reduce costs for fuel use and

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vehicle maintenance between manufacturing and retirement. A fundamental change in energy utilization needs to occur because heavy vehicle sector energy requirements are enlarging together with their environmental and economic dilemmas. Hybrid energy systems emerged as an effective solution for handling present efficiency and sustainability demands and cost-effectiveness requirements. The analysis examines the possible applications of these systems and their function in developing the future of heavy vehicles.

Hybrid Energy System Components: Heat Recovery Systems

The heat recovery system operates as an essential feature of hybrid energy platforms in heavy vehicles by turning discarded vehicle operation heat into functional energy. Heat recovery systems prevent waste heat from escaping into the environment by converting this lost energy into energy that improves total system performance and decreases emissions.

Working Principles of Waste Heat Recovery

A waste heat recovery system exists to collect thermal energy from hot exhaust gases and engine coolant together with other heat-producing elements in the vehicle. The retrieved heat energy is transformed into electric power as well as mechanical power for both auxiliary equipment applications and propulsion enhancement. Conversion technologies that perform as thermoelectric generators and organic Rankine cycle (ORC) systems follow heat exchangers used for working fluid heat energy transfer.

Technologies for Waste Heat Recovery

TEGs function based on the Seebeck effect according to Qasim M. A *et al.* (2024). A temperature difference applied to thermoelectric

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materials will produce electric current according to A *et al.*,2024. The operation principle of TEGs enables them to extract energy from heavy vehicle exhaust heat and transform it into electricity. TEGs present several benefits for waste heat recovery applications since they combine small size with minimal components and reduced upkeep needs which makes them ideal for operational environments with harsh conditions. The ORC technology makes use of organic fluids (Loni, R *et al.*,2021) that boil at low temperatures to convert thermal energy into mechanical power before electricity generation occurs. The heat recovery system demonstrates high performance when receiving heat from low-grade sources through its adjustable installation options which suit large-scale truck and bus diesel engine exhaust applications. The ORC demonstrates efficient heat energy collection from low-grade temperatures which makes it attractive for heavy vehicles to achieve better energy efficiency.

The waste heat recovery system depends heavily on heat exchangers to transfer exhaust gas heat to work fluids so that energy recovery increases. Heat exchangers are recognized for their basic design structure and affordable functionality which makes them suitable for various usage including fluid pre-heating or thermoelectric generator integration in systems. Heat exchangers serve as fundamental technology for hybrid energy systems in heavy vehicles because they offer versatile implementation and easy setup as indicated in table 1.

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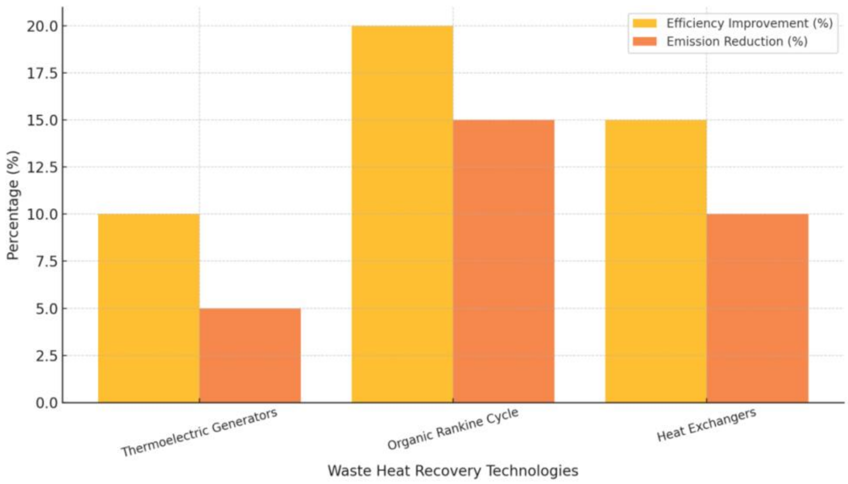
Table 1: Comparison of Waste Heat Recovery Technologies

Technology	Working Principle	Advantages	Challenges	Applications
Thermoelectric Generators	Seebeck effect	Compact, low maintenance	Low conversion efficiency	Exhaust heat recovery
Organic Rankine Cycle	Low boiling point fluids	High efficiency, scalable	Expensive, complex maintenance	Diesel engine exhaust recovery
Heat Exchangers	Heat transfer to working fluid	Simple design, cost-effective	Heat transfer losses	Pre-heating fluids, HVAC systems



Graph 1: Efficiency and Emission Reduction by Heat Recovery Technologies

The graph 1 points out how three waste heat recovery technologies operate inside heavy vehicles where Thermoelectric Generators (TEGs) and the Organic Rankine Cycle (ORC) and Heat Exchangers produce efficiency improvements and emission reductions. According to the graph the Organic Rankine Cycle technology achieves the best results and boosts system efficiency

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by 20% while lowering emissions by 15% percent. The technology demonstrates excellent performance by transforming low-grade exhaust system heat into mechanical or electrical energy to serve heavy-duty vehicle needs during operations. Heat exchangers operate with balanced performance which delivers both 15% efficiency development and 10% emissions decrease. These devices function as cost-efficient designs which enable pre-heating of fluids as well as operating thermoelectric systems because of their basic construction. The ORC achieves slightly lower effectiveness than heat exchangers but these systems maintain their important role when integrated into hybrid energy systems of heavy vehicles.

The implementation of Thermoelectric Generators increases efficiency by 10% while decreasing exhaust emissions by 5%. TEGs provide limited performance benefits compared to ORC and heat exchangers yet remain beneficial because they contain compact dimensions and operate without moving parts alongside easy maintenance needs. The devices work well in particular applications that require both simple operation and reliable performance. The graph demonstrates that waste heat recovery systems have strong potential to improve heavy vehicle energy efficiency as well as decrease their emission output. ORC proves most efficient for energy recovery based on specific technological requirements and cost factors and performance targets.

Renewable Energy Sources

Solar Energy Systems (e.g., Photovoltaic Panels)

The photovoltaic PV solar energy systems have proven to be an acceptable renewable energy solution for heavy vehicles (Yap, K *et al.*,2022). Literary research shows that solar panels implemented within vehicle structures can enhance power capacity while

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decreasing dependence on diesel fuel and resulting in decreased emissions of greenhouse gases. (Younis, R *et al.*, 2024) The current research into solar-powered heavy vehicles shows that PV systems under ideal circumstances can supply between 10-15% of needed energy for these vehicles. The operational efficiency of PV panel systems depends heavily on three operational factors which are sun-light exposure ratios, ambient temperatures and regional climate characteristics. The literature shows that solar energy generates insufficient energy to power heavy vehicles independently through the reduced output which occurs during periods of low sunlight especially in areas with minimal solar irradiance.

Wind Energy Systems

Researchers find wind energy systems provide worthwhile potential as stationary power solutions for heavy vehicles during their stops and for secondary power generation (Balazadeh Meresht, N. *et al.*,2023). Research shows small-scale wind turbines installed in trailers or charging stations completed pilot tests however their implementation faces two critical barriers due to mobile application requirements and variable wind speed conditions. Research findings show wind energy provides supplementary power but its actual impact is minimal because it depends on steady wind conditions (Abou Houran, M *et al.*,2023). The high installation expenses combined with operating expenses of wind energy systems prevent their use in heavy vehicles at a scale comparable to alternative green power solutions.

Hydrogen Fuel Cells

Scientists consider hydrogen fuel cells to be promising clean and effective power solutions for heavy vehicles (Hassan, Q et al.,2023).

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The available data demonstrates that heavy trucks running on fuel cells produce lesser emissions while delivering superior operational distance than trucks that rely on battery electricity. The refueling process using these systems becomes fast and nearly equivalent to conducting refuels with conventional diesel-based systems. Potential barriers persist in the production processes along with storage systems and distributing hydrogen. Research exposes problems with "grey hydrogen" production from fossil fuels because it reverses the environmental advantages (Zhang, R et al.,2023). The transition to "green hydrogen" based on renewable energy needs fundamental infrastructure development while lowering production costs remains essential.

Energy Storage

Battery Systems for Heavy Vehicles

Lithium-ion batteries represent the industrial standard technology for electric heavy vehicles and serve as their fundamental power systems. The literature shows that batteries offer maximum energy storage alongside efficient operation and dependable performance. The adoption of electric heavy vehicles faces present barriers which include restricted driving distances (Balali, Y *et al.*,2021), extended charging duration and considerable purchase expenses. Solid-state batteries join lithium-sulfur batteries (Kim, J. T *et al.*,2024) (Ohno, S *et al.*,2021) among other battery advancement research fronts as crucial for developing better battery technology. The environmental impacts from battery manufacturing mainly stem from lithium and cobalt mining operations which create sustainability challenges. Proposed end-of-life battery recycling and reuse methods exist to tackle these drawbacks although they remain in initial development phases.

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Thermal Energy Storage

Thermal Energy system storage systems act as an energetic alternative which stores surplus energy collected during vehicle operation and renewable power generation from wind turbines and sunrays (Mullan Abdul N.. *et al* 2024). TES uses high-thermally efficient materials including phase-change materials (PCMs) to capture and distribute thermal energy (Yang L *et al.*, 2021). Data shows that hybrid vehicles become more efficient because these systems conduct preliminary component heating or cooling operations that decrease operational energy losses. Heavy vehicle manufacturers face challenges when using storage systems because their storage containers reduce vehicle loading capacity (Zhang, X *et al.*, 2022). Thermal insulation together with storage material stability across time periods determines the operational efficiency of TES systems.

Critical Analysis and Future Directions

Heavy vehicles experience both possibilities and limitations when renewable energy resources combine with storage systems. Solar and wind energy systems demonstrate great promise to decrease fossil fuel use (Hassan, Q *et al.*,2023) while their dependency on environmental conditions as well as their discontinuous operation makes them insufficient for independent use. Long-haul heavy vehicle operators see hydrogen fuel cells as an appealing solution (Li, S. *et al.*,2022) but their adoption requires a successful transition of sustainable hydrogen generation together with building a robust hydrogen distribution network. The most commonly used storage technology at present are battery systems although their limitations include excessive cost while reducing range alongside causing substantial environmental damage. The efficiency-

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improving capabilities of thermal energy storage technology need additional research to solve problems involving equipment size and weight as well as material stability issues.

Integration of Heat Recovery and Renewable Energy

Benefits of Combining Heat Recovery with Renewable Sources

Heart recovery systems linked with renewable energy systems create a mutually reinforcing partnership (Eze, V *et al.*,2024) that advances heavy vehicle sustainability through better energy performance. Heat recovery systems capture thermal energy from vehicle exhausts to create useful power alongside renewable power supplies that primarily include solar panels and hydrogen fuel cells (Burnete, N. V *et al.*,2022). This energy system combination results in multiple benefits by lowering fuel costs and greenhouse gas emissions and improving complete energy performance (Paramati, S. R *et al.*,2022). Hybrid systems combining organic Rankine cycles with solar panels enable dual utilization of waste heat to create electricity from solar energy for optimized energy production.

Technological Advancements in Integration

Advanced technologies enable safe operation of heat recovery systems with renewable energy installations in heavy vehicles. The implementation of advanced control systems allows perfect energy management through efficient distribution of waste heat recovery and renewable energy resources. The combination of thermoelectric generators operating together with solar PV systems has become a practical solution for vehicle energy management according to Pochont (N.R *et al.*,2023). The joining of hydrogen fuel cells with heat recovery units represents a groundbreaking achievement according to Nguyen, H *et al.*,2021 by enabling better utilization of waste heat either to preheat

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hydrogen or boost system operational effectiveness. These developments create possibilities for the creation of enhanced and bigger hybrid systems.

Challenges and Solutions for Hybrid System Optimization

Despite the benefits, integrating heat recovery with renewable energy systems in heavy vehicles presents challenges. These include the complexity of system design, high initial costs, and the need for reliable energy management systems. To address these issues, researchers are focusing on developing lightweight materials, improving energy conversion efficiencies (Tang, J *et al.*,2023), and employing advanced optimization algorithms. For instance, machine learning techniques are being utilized to predict energy needs (Forootan, M. M *et al.*,2022) and dynamically allocate power from heat recovery and renewable sources, ensuring optimal performance under varying conditions.

Technological Developments and Innovations

Latest Advancements in Hybrid Systems for Heavy Vehicles

The development of hybrid energy systems has focused predominantly on three areas that include energy storage materials and control mechanisms and renewable power integration. The development of new energy storage technologies features solid-state batteries with better capacity and light thermoelectric compounds and hydrogen fuel cells designed for heavy-duty operations. Daimler and Volvo along with other companies (Balazadeh Meresht, N. *et al.*,2023) have released electric-hybrid heavy trucks which utilize these advancements to achieve noteworthy fuel savings along with emission reduction.

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Case Studies of Successful Implementations

Several successful implementations demonstrate the potential of hybrid energy systems in heavy vehicles. For instance, Amazon has deployed a fleet of fully-electric trucks integrated with heat recovery systems, achieving a 20% increase in energy efficiency. Similarly, a European logistics company has implemented hybrid trucks equipped with solar PV panels and organic Rankine cycles (Pardhi, S *et al.*,2023), resulting in reduced operational costs and a significant decrease in carbon emissions. These case studies highlight the feasibility and benefits of adopting hybrid systems in real-world scenarios.

Emerging Trends

Emerging trends in hybrid systems for heavy vehicles include the use of artificial intelligence (AI) for energy management and the integration of Internet of Things (IoT)-enabled systems (Arévalo, P *et al.*,2024) for real-time monitoring. AI-powered control systems can optimize energy allocation, predict maintenance needs, and enhance overall system efficiency. IoT-enabled sensors and platforms allow for real-time data collection and remote diagnostics, improving system reliability and reducing downtime. These technologies are driving the next generation of hybrid energy systems.

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Performance Analysis

Metrics for Evaluating Hybrid Energy Systems

Key metrics for evaluating hybrid energy systems include energy efficiency, emission reductions, cost-effectiveness, and system reliability. Energy efficiency measures the ability of the system to utilize avail-able energy, while emission reductions quantify the decrease in greenhouse gases and pollutants. Cost-effectiveness evaluates the economic feasibility, considering factors such as fuel savings and maintenance costs.

Comparative Analysis of Hybrid Systems Versus Traditional Systems

Hybrid energy systems significantly outperform traditional systems in terms of energy efficiency and environmental impact. For example, while conventional diesel-powered heavy vehicles emit large amounts of CO_2 and NOx, hybrid systems with waste heat recovery and renewable energy sources can achieve up to a 30% reduction in emissions. Moreover, hybrid systems offer better long-term cost savings through reduced fuel consumption and lower maintenance requirements.

Economic and Environmental Impact

Cost-Benefit Analysis of Hybrid Energy Systems

Hybrid energy systems require a high initial investment due to advanced components such as batteries, heat recovery units, and renewable energy technologies. However, these costs are offset by long-term savings in fuel expenses and reduced emissions penalties. Studies indicate that hybrid systems can achieve a return on investment within 5–7 years, depending on operational conditions.

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Impact on Carbon Footprint and Air Quality:

The adoption of hybrid energy systems in heavy vehicles leads to a significant reduction in carbon foot-print and improvement in air quality. By combining renewable energy and waste heat recovery, these systems can reduce CO_2 emissions by up to 40%, contributing to cleaner urban environments and mitigating climate change. Additionally, lower NOx emissions improve air quality, particularly in densely populated areas.

Government Policies and Incentives for Adoption:

Governments worldwide are introducing policies and incentives to encourage the adoption of hybrid systems. (Hachem, W. E *et al.*, 2022) Subsidies for renewable energy technologies, tax credits for hybrid vehicle purchases, and stricter emission regulations are driving the transition to cleaner transportation. For example, the (Liao, X *et al.*,2023) (Pylova, A *et al.*,2023) European Green Deal includes provisions for funding research and deployment of hybrid and electric trucks, accelerating their adoption.

Challenges and Limitations

Technological Barriers

Hybrid systems face challenges such as limited energy densities in batteries, inefficiencies in waste heat recovery technologies, and the high complexity of integrating multiple energy sources. Addressing these barriers requires continuous innovation in materials and system designs.

Economic Feasibility in Different Regions

The adoption of hybrid energy systems varies widely across regions due to differences in economic conditions, energy infrastructure, and government support. Developing countries

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often struggle with high upfront costs and limited access to advanced technologies, hindering widespread implementation.

Maintenance and Reliability Issues

The complexity of hybrid systems increases maintenance requirements and the risk of component failure. Ensuring system reliability through robust designs, predictive maintenance, and efficient energy management is essential for long-term success.

Future research should focus on developing advanced materials such as solid-state batteries, lightweight composites for heat recovery systems, and high-performance thermoelectric materials. These innovations can enhance the efficiency and scalability of hybrid systems. Collaboration between policymakers, industry leaders, and researchers is crucial for overcoming barriers and promoting hybrid systems. (Akinsooto, O *et al.*, 2024) Policies that incentivize research, development, and adoption can drive progress, while industry partnerships can facilitate technology transfer and scalability. There is significant potential for research in optimizing hybrid systems through AI-driven algorithms, integrating renewable energy technologies, and exploring new energy storage methods. Future studies should also focus on lifecycle analyses to evaluate the environmental and economic impacts of hybrid systems comprehensively.

Conclusion

Hybrid energy systems offer a good way to improve fuel use and lessen the environmental harm from heavy-duty vehicles. Technologies such as regenerative braking, waste heat recovery, and using renewable energy can increase fuel efficiency by up to 30% and cut CO_2 emissions by almost 40%. Even though the starting costs are high, improvements in battery storage, hydrogen

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fuel cells, and thermoelectric generators are making these systems more feasible and cheaper, with a usual return on investment taking five to seven years. Although, the broad use of hybrid energy systems has obstacles, like high initial costs, insufficient infrastructure, and uncertain policies. To tackle these issues, ongoing research, tech improvements, and strong government backing are key. Hybrid systems are vital for global sustainability initiatives, acting as a link between conventional diesel vehicles and fully electric or hydrogen fleets. They assist in reducing fossil fuel dependence, enhancing air quality, and supporting global climate goals as stated in the Paris Agreement. Constructive implementation needs cooperation from all parties involved. Governments should create helpful policies and invest in infrastructure, while manufacturers need to work on improving technology and lowering production costs. Fleet operators should see hybrid vehicles as a way to cut operating expenses and comply with tougher environmental regulations. By collaborating, these actions can speed up the shift to cleaner, more effective transportation, aiding in a sustainable future for the sector.

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