

Why EV's may not be the FUTURE: A Multidimensional Analysis of Physical, Economic, and Geopolitical Constraints

Aditya S. Patil¹, Chinmay S Gajmal², Sarvesh S. Sankpal³ and Shubham P. Dhurat⁴
^{1,2,3,4}*Department of Management, VESIM, Mumbai*

I. EXECUTIVE SUMMARY AND INTRODUCTION

The global push toward decarbonization has cast electric vehicles (EVs) as the cornerstone of a sustainable future. Public perception, largely shaped by the rapid adoption of passenger cars, views the transition to battery power as an inevitable and comprehensive solution for all transport and industrial sectors. The momentum is undeniable, with global electric car sales reaching 17 million in 2024 and the average cost of batteries plummeting by 90% since 2010.¹ However, a closer examination reveals that this prevailing narrative is overly simplistic. A singular focus on battery electrification as a universal solution overlooks significant, and in some cases insurmountable, technical, economic, and geopolitical barriers.

This report moves beyond the successes of the consumer market to present a nuanced, data-driven analysis of why electric vehicle technology, in its current battery-electric form, may not be the optimal or even feasible solution for all applications. The analysis is structured to demonstrate that the challenges are not merely a matter of engineering hurdles to be overcome but are rooted in fundamental limitations of physics, fragile supply chains, and the immense burden on global energy infrastructure. The findings of this report indicate that a pragmatic, multi-faceted approach incorporating a variety of alternative fuels and technologies is not a matter of choice, but a necessity to achieve a fully decarbonized future, particularly for the high-energy-demand, long-distance, and off-grid sectors.

II. FOUNDATIONAL BARRIERS TO UNIVERSAL ELECTRIFICATION

The challenges facing a total transition to battery-electric technology are not isolated to individual sectors; they are systemic issues that form a precarious foundation for the entire electrification movement. These foundational barriers—geopolitical, ethical, environmental, and infrastructural—are intrinsically linked and create a complex web of dependencies and vulnerabilities.

A. The Geopolitical and Ethical Complexities of the Battery Supply Chain

The seemingly clean transition to electric vehicles is, in reality, a global resource re-mapping. In the 20th century, oil was the strategic asset that drove foreign policy and economic power. In the 21st century, that strategic importance has shifted to the critical minerals essential for battery production, such as lithium, cobalt, and nickel.³ The supply chain for these materials is characterized by a high degree of geographic concentration, which creates significant strategic chokepoints and geopolitical vulnerabilities.

The processing of these materials is overwhelmingly dominated by a single nation. China processes approximately 90% of the world's lithium, 72% of cobalt, and 65% of nickel for batteries, and its firms produce more than 75% of all lithium-ion battery cells globally.² This gives China considerable leverage over the global market, raising concerns about supply security for other countries.⁴ The extraction of these raw materials is also geographically concentrated. The "Lithium Triangle," comprising Argentina, Bolivia, and Chile, holds over half of the world's identified lithium resources.⁶ Similarly, the Democratic Republic of Congo (DRC) accounts for a staggering

70% of global cobalt production.³ The political instability and "resource nationalism" in these regions can lead to supply chain disruptions, price fluctuations, and export restrictions.⁴ The aggressive policies of the United States and the European Union to build domestic critical mineral processing and battery manufacturing capabilities are a direct response to these geopolitical vulnerabilities.²

Beyond the geopolitical friction, the battery supply chain is marred by serious ethical and environmental issues. Cobalt mining in the DRC is notoriously linked to grave human rights abuses, including child and forced labor.⁸ The U.S. Department of Labor estimates that at least 25,000 children are working in cobalt mines in the DRC.⁸ Similarly, lithium mining, especially the brine-based extraction method in the "Lithium Triangle," is a highly water-intensive process.¹⁰ Allegations of water shortages and contamination have been leveled against mining companies in water-scarce regions of Chile, where local communities have called the affected areas "sacrifice zones".¹¹ A recent study found that global water models used to estimate water availability for lithium extraction are off by an order of magnitude, concluding that most basins in the Lithium Triangle should be classified as "critically water scarce" even without accounting for future demand.¹⁰ These ethical and environmental challenges are not mere externalities; they are fundamental to the total cost of the technology. The imperative to implement cleaner mining practices, ensure worker safety, and manage water resources sustainably will inevitably increase the cost of raw materials, which in turn could impact the affordability of EVs and slow down the rate of adoption.

B. The Environmental Cost of the Manufacturing Lifecycle

The environmental argument for electric vehicles is often based on the premise of zero tailpipe emissions, but this is a simplistic view that ignores the full lifecycle of the vehicle. The emissions are not eliminated but rather shifted from the point of use to the point of production. The manufacturing of EV batteries is a highly energy-intensive process that results in a significant "front-loaded" carbon footprint.¹² The production of an EV battery alone can

account for nearly 40% of the vehicle's total lifecycle emissions.¹³

The actual environmental benefit of an EV is not absolute; it is directly contingent upon the carbon intensity of the electrical grid where the vehicle is manufactured and, more importantly, where it is charged.¹⁴ An EV produced and charged on a coal-dominated grid will have a significantly larger lifecycle carbon footprint than one manufactured and charged on a grid powered by renewable sources like wind and solar.¹² While numerous studies confirm that an EV is typically responsible for lower total emissions over its lifetime compared to a gasoline car on the average grid, the full decarbonization potential is only realized when the grid itself is clean.¹⁴ This highlights a critical link: the pace of electrification is intrinsically tied to the pace of grid decarbonization.

Furthermore, the end-of-life management of EV batteries presents its own set of challenges. The goal of a "circular economy" through recycling is widely promoted, but the current reality is complex. The economic viability of recycling is often tethered to the market prices of high-value metals like cobalt and nickel, and existing pyrometallurgical methods can be energy-intensive and fail to recover lighter but critical elements like lithium.¹⁶ The immense and rapidly growing demand for these materials means that recycling alone will not be able to meet future needs, making new mining unavoidable for decades to come.¹⁷ The difficulty and economic challenges of recycling mean that the "circular economy" for batteries is an aspirational goal, not a current reality, which reinforces the need for continuous, ethically problematic primary mining.

C. A Fragile Grid: Capacity and Resilience as the Ultimate Bottleneck

The electric grid stands as the ultimate bottleneck to universal electrification. A full electrification of the U.S. vehicle fleet is forecasted to increase maximum net electricity demand by as much as 50%.¹⁸ The American electric grid is aging, with 60% of its distribution lines having surpassed their 50-year life expectancy.¹⁹ The total cost to replace the current U.S. grid is estimated to be approximately \$5 trillion, with

a staggering \$1.5 trillion to \$2 trillion needed by 2030 just to maintain reliability.¹⁹

While passenger vehicles can often be charged overnight at low power, the electrification of heavy-duty vehicles, such as trucks and buses, presents a fundamentally different challenge to the grid. These vehicles require high-power chargers, with capacities reaching up to 14 MW by 2030 for long-haul trucks along freight corridors.²¹ This level of concentrated demand requires massive grid upgrades and new infrastructure, which are costly, slow to implement, and face long lead times.²¹ The problem is not merely whether there is enough electricity available, but whether the existing infrastructure can deliver it to the right place at the right time. While some regions may have unused grid capacity, local distribution transformers and feeders, particularly in urban and industrial “hotspots” where fleet depots are located, will face significant strain without major investment and planning.¹⁸ The rollout of charging infrastructure is therefore a highly site-specific challenge that requires extensive and early collaboration with utilities to prevent localized outages and infrastructure failure.¹⁸

III. THE SPECIFIC SECTORAL HURDLES

The foundational barriers discussed in the previous section manifest in distinct ways across different industries, highlighting why a one-size-fits-all approach to electrification is impractical. The physical, operational, and economic realities of each sector reveal the unique limitations of battery technology.

A. The Automotive Sector (Passenger Cars)

Despite the rapid growth in sales and the visibility of battery-electric passenger cars, significant barriers to mass consumer adoption persist. High upfront costs are a major deterrent for many consumers. For example, a 2022 study found that 75% of consumers in the United States considering an EV purchase intended to spend less than \$50,000, while fewer than half of the options available at the time met this price point.²⁵ Furthermore, a lack of charging infrastructure and the persistent psychological barrier of “range anxiety”—the fear of running out of charge before reaching a charging station—remain the top reasons

for reluctance to switch from a gasoline-powered car to an EV.⁷

While the number of public chargers is growing, the charging landscape is uneven. By the end of 2024, the U.S. had approximately 204,000 public chargers²⁷, but China, in contrast, had an overwhelming 85% of the world's fast chargers in 2021 and 55% of its slow chargers.²⁸ The U.S. network is also fragmented, with a significant portion of chargers being proprietary, such as Tesla’s Superchargers, which constituted 60% of all fast chargers in the U.S. in 2021.²⁸ This creates a two-tiered reality in the automotive sector. For consumers with a garage and the means to install a home charger, the transition is relatively seamless. For the broader, mainstream market that relies on public charging and faces affordability issues, the transition is far more challenging. This creates an equity problem, suggesting that policy interventions are needed to ensure infrastructure deployment keeps pace with demand and addresses the spatial and economic disparities in charger availability.

B. The Logistics Sector: The Limits of Long-Haul Electrification

The challenges of scale and distance in the logistics sector expose a fundamental weakness of current battery technology. The operational demands of moving heavy goods over long distances create a profound mismatch with the capabilities of battery-electric vehicles.

1. Heavy-Duty Trucks & Pickups

The electrification of heavy-duty trucks and pickups faces a core physical limitation: the payload-range-weight problem. Battery packs for electric semis can weigh up to 16,000 pounds, nearly a quarter of the total legal weight limit for a semi and its cargo.²⁹ This added weight directly reduces the amount of cargo a truck can carry, thereby limiting its profitability. In contrast, a diesel truck's engine and fuel tanks are significantly lighter.²⁹

This payload constraint is compounded by the mismatch in refueling time and range. A Class 8 diesel truck with two 150-gallon tanks can travel up to 1,800 miles and be refueled in a matter of minutes.²⁹ The most powerful electric semis, such as the Tesla Semi,

offer a range of 300 to 500 miles, but even with high-power 750 kW chargers, it can take 90 minutes or more to recover a significant amount of range.²⁹ This fundamental mismatch in operational efficiency is incompatible with the demands of long-haul logistics, where every minute of downtime is a lost opportunity.

This is where alternative technologies, such as hydrogen fuel cells, present a compelling alternative. A hydrogen fuel cell truck offers a range of up to 1,000 km (620 miles) and can be refueled in less than 15 minutes, making it a much better operational fit for long-haul duty cycles.³⁰ The lighter powertrain of a hydrogen truck also means a better payload capacity, comparable to a diesel truck.³¹ The data suggests a future of technological specialization: battery-electric powertrains are a strong fit for short-haul and medium-duty fleets with predictable routes and depot-based charging³², while hydrogen fuel cells are a more pragmatic solution for the long-haul sector.

	Battery/Electric	Hydrogen Fuel Cell	Diesel
Range	300 to 500 miles	Up to 1,000 km	Up to 1,800 miles
Refueling Time	90 minutes to hours	Less than 15 minutes	Minutes
Payload Capacity	Reduced by battery weight (up to 16,000 lbs)	Comparable to diesel	High
Infrastructure	High-power (MW) charging depots needed	Hydrogen fueling stations needed	Established diesel stations

Table 1: Comparative Analysis of Heavy-Duty Truck Powertrains.²⁹

2. Maritime Shipping (Container Ships)

The challenge of electrifying maritime shipping is a powerful illustration of the limitations of battery technology and the decisive role of physics. The energy density of heavy fuel oil is simply too great to be replicated by current batteries without massive,

cargo-consuming weight penalties. A typical 100,000-150,000 DWT container ship carries 3,000-4,000 tonnes of heavy fuel oil.³⁶ To match this energy with a lithium-ion battery would require an estimated 60,000-100,000 tonnes of batteries, consuming a significant portion of the ship's cargo capacity and requiring the yearly output of a large battery factory.³⁶ This makes deep-sea electrification with current battery technology physically unfeasible for long-distance voyages.³⁷

	Heavy Fuel Oil / Bunker Fuel	Lithium-Ion Batteries
Energy Density	10 to 12.5 kWh/kg	Approximately 0.25 kWh/kg
Weight for Long Voyage	3,000 to 4,000 tonnes	60,000 to 100,000 tonnes
Volume for Long Voyage	3,000 to 4,000 m ³	60,000 to 100,000 m ³

Table 2: Energy Density of Liquid Fuels vs. Batteries for Maritime Shipping.³⁶

Even for shorter routes, the infrastructure required is staggering. A ship would need fully operational charging facilities in every port, which would require significant and costly upgrades to existing port grids.³⁷ This forces a different conversation for this sector: not about

if we electrify, but about *what alternative fuels* we use. For hard-to-abate sectors like maritime shipping, alternative fuels are not a competing technology but the only viable path to decarbonization. The most promising options are synthetic fuels (e-fuels) and Sustainable Aviation Fuels (SAF).³⁹ These "drop-in" fuels can be produced from waste or renewable sources and are compatible with existing engines and infrastructure, offering up to an 80% reduction in carbon emissions without requiring a complete and physically impossible overhaul of the global fleet or port infrastructure.³⁹

C. The Construction Machinery Sector: A Mismatch of Technology and Application

The operational realities of the construction industry, with its demanding duty cycles, remote locations, and

reliance on existing processes, expose a clear mismatch with current battery-electric technology.

A fundamental operational mismatch exists between the current battery runtimes and the demands of a typical workday. Electric excavators and wheel loaders offer a runtime of 4 to 6 hours on a single charge⁴², while a standard construction workday is typically eight hours or more. This requires a significant change in operational behavior, with operators needing to "top off" batteries during breaks to ensure continuous productivity.⁴³

The infrastructure on most construction sites, particularly those for highways, forests, or remote suburban areas, lacks the robust grid connection needed to charge heavy machinery.⁴⁴ While mobile charging solutions exist, they require their own power source and logistical management, adding a layer of complexity to operations.⁴⁵ The lack of charging infrastructure is cited as a primary concern for end-users considering electric construction equipment.⁴⁴ Furthermore, the technical challenges are significant. Heavy equipment's demanding duty cycles and intensive use of hydraulic systems pose a unique challenge.⁴⁷ The electrification of these machines often involves adapting designs originally intended for engines, which limits battery capacity and efficiency due to space constraints.⁴⁴ This problem is not just about battery life; it is about a conflict between a new technology and a deeply entrenched operational model. The intermittency of charging clashes with the need for continuous productivity on a job site.

	Typical Runtime	AC Level 2 Charging Time	DC Fast Charging Time
Electric Excavator	4 to 6 hours	5 to 6 hours	40 to 60 minutes
Electric Wheel Loader	4 to 6 hours	6 hours	2 hours

Table 3: Operational Profile of Electric Construction Equipment.⁴²

IV. THE FUTURE OF TRANSPORTATION: A MULTI-FACETED ECOSYSTEM

The analysis of these foundational and sectoral barriers leads to a clear conclusion: a singular focus on battery electrification is a flawed strategy. The path to a decarbonized future is not a technological monoculture but a diversified portfolio of solutions, where each technology is deployed where it is most effective.

This future will see a coexistence of multiple decarbonization pathways. Synthetic fuels (e-fuels), produced from captured carbon dioxide and green hydrogen, can serve as a direct "drop-in" replacement for existing liquid fuels.⁴¹ This allows them to be used in existing engines and infrastructure, making them ideal for hard-to-abate sectors like maritime shipping and aviation.⁴¹ However, this pathway faces its own efficiency challenges. Producing e-fuels requires nearly five times more energy than a battery-electric vehicle needs to run⁴⁹, necessitating a massive increase in renewable energy generation to be a viable solution.⁵¹

Hydrogen fuel cell technology, as discussed, is a compelling alternative for heavy-duty, long-haul trucking. It offers superior energy density, a longer range, and a faster refueling time than batteries, and its infrastructure, while costly, is more manageable for large-scale industrial hubs than the distributed megawatt charging needed for a full transition to electric semis.³¹ The future will likely see a specialization of technologies:

- Battery-electric vehicles will continue to be the optimal solution for light-duty vehicles, urban fleets, and short-haul logistics, where predictable routes, depot-based charging, and lower energy demands align perfectly with battery capabilities.
- Hydrogen fuel cells will be best suited for heavy-duty, long-haul trucks and industrial applications that require high power, long range, and rapid refueling, such as certain sectors of construction machinery.
- E-fuels & Biofuels are the necessary solution for hard-to-abate sectors like maritime shipping and aviation, where the sheer energy density and existing infrastructure compatibility are non-negotiable requirements.

V. CONCLUSION AND STRATEGIC IMPLICATIONS

The vision of a fully electrified world is compelling but lacks a foundation in the physical and economic realities of key industries. A singular focus on battery electrification as the only path to a decarbonized future is a flawed strategy that overlooks significant and, in some cases, insurmountable barriers. The transition to a green economy is not a simple swap of one fuel source for another but a complex re-engineering of global supply chains, energy infrastructure, and operational models.

The evidence presented indicates that the most pragmatic and effective path forward is not a technological monoculture but a diversified portfolio of solutions. For policymakers, this means shifting from a one-size-fits-all regulatory framework to one that supports a variety of decarbonization technologies, recognizing that the optimal solution is situational, not universal. For industry leaders, this necessitates aligning research and development with the specific needs of each sector, investing in the technologies that offer the most pragmatic and sustainable solutions for each unique application. Finally, for investors, it is crucial to recognize the nuanced risks and opportunities across different markets. While battery-electric technology is the dominant solution for consumer vehicles, the value proposition of a technology like hydrogen or e-fuels, while less efficient, may be far superior for certain applications due to their operational and infrastructural benefits. The future is not simply electric; it is a complex and highly specialized ecosystem of interconnected technologies, each playing a vital role in a shared journey toward a decarbonized world.

REFERENCE

- [1] Status of battery demand and supply - International Energy Agency, accessed on September 23, 2025, <https://www.iea.org/reports/batteries-and-secure-energy-transitions/status-of-battery-demand-and-supply>
- [2] IEA: Global battery industry has entered new phase - Energy Storage - ESS News, accessed on September 23, 2025, <https://www.ess-news.com/2025/03/07/iea-global-battery-industry-has-entered-new-phase/>
- [3] Global Race for Battery Supply Chain Control Intensifies - Discovery Alert, accessed on September 23, 2025, <https://discoveryalert.com.au/news/battery-supply-chain-geopolitical-battleground-2025/>
- [4] Geopolitical Battery Impacts → Term - Energy → Sustainability Directory, accessed on September 23, 2025, <https://energy.sustainability-directory.com/term/geopolitical-battery-impacts/>
- [5] The highly charged geopolitics of lithium - University of Technology Sydney, accessed on September 23, 2025, <https://www.uts.edu.au/news/2023/03/highly-charged-geopolitics-lithium>
- [6] What Are the Geopolitical Risks of Lithium? → Question - Energy → Sustainability Directory, accessed on September 23, 2025, <https://energy.sustainability-directory.com/question/what-are-the-geopolitical-risks-of-lithium/>
- [7] Top 6 Challenges Facing EV Manufacturers and Shippers - AmeriFreight, accessed on September 23, 2025, <https://www.amerifreight.net/information/top-6-challenges-for-ev-makers-and-shippers>
- [8] From Cobalt to Cars: How China Exploits Child and Forced Labor in, accessed on September 23, 2025, <https://www.cecc.gov/events/hearings/from-cobalt-to-cars-how-china-exploits-child-and-forced-labor-in-the-congo>
- [9] Responsible Sourcing - Cobalt Institute, accessed on September 23, 2025, <https://www.cobaltinstitute.org/responsible-sustainable-cobalt/responsible-sourcing/>
- [10] We are vastly overestimating the amount of fresh water available for lithium mining, says new study - Envirotec Magazine, accessed on September 23, 2025, <https://envirotecmagazine.com/2025/03/26/we-are-vastly-overestimating-the-amount-of-fresh-water-available-for-lithium-mining-says-new-study/>
- [11] Illness, animal deaths and water shortages: life inside Chile's polluted 'sacrifice zones', accessed on September 23, 2025, <https://www.theguardian.com/global-development/2025/sep/22/illness-animal-deaths-water-shortages-chile-polluted-sacrifice-zones-anglo-american-mining>
- [12] Are EV Batteries Bad for the Environment? -

- GreenCars, accessed on September 23, 2025, <https://www.greencars.com/greencars-101/environmental-impact-of-ev-batteries>
- [13] The carbon footprint of electric vehicles: A comprehensive analysis. - CarbonClick, accessed on September 23, 2025, <https://www.carbonclick.com/news-views/the-carbon-footprint-of-electric-vehicles-a-comprehensive-analysis>.
- [14] Scania publishes life cycle assessment of battery electric vehicles, accessed on September 23, 2025, <https://www.scania.com/group/en/home/newsroom/press-releases/press-release-detail-page.html/3999115-scania-publishes-life-cycle-assessment-of-battery-electric-vehicles>
- [15] Electric Vehicle Myths | US EPA, accessed on September 23, 2025, <https://www.epa.gov/greenvehicles/electric-vehicle-myths>
- [16] Battery Recycling Technology Economic Viability → Scenario - Prism → Sustainability Directory, accessed on September 23, 2025, <https://prism.sustainability-directory.com/scenario/battery-recycling-technology-economic-viability/>
- [17] How well can electric vehicle batteries be recycled? - MIT Climate Portal, accessed on September 23, 2025, <https://climate.mit.edu/ask-mit/how-well-can-electric-vehicle-batteries-be-recycled>
- [18] Is the Grid Ready for the Electric Vehicle Transition? - MDPI, accessed on September 23, 2025, <https://www.mdpi.com/1996-1073/18/17/4730>
- [19] Report Modernizing the Electric Grid: State Role and Policy Options, accessed on September 23, 2025, <https://www.ncsl.org/energy/modernizing-the-electric-grid>
- [20] The old, dirty, creaky US electric grid would cost \$5 trillion to replace. Where should infrastructure spending go?, accessed on September 23, 2025, <https://energy.utexas.edu/news/old-dirty-creaky-us-electric-grid-would-cost-5-trillion-replace-where-should-infrastructure>
- [21] NEAR-TERM INFRASTRUCTURE DEPLOYMENT TO SUPPORT ZERO-EMISSION MEDIUM- AND HEAVY-DUTY VEHICLES IN THE UNITED STATES - International Council on Clean Transportation, accessed on September 23, 2025, <https://theicct.org/wp-content/uploads/2023/05/infrastructure-deployment-mhdv-may23.pdf>
- [22] ACT Now: Impacts of the Advanced Clean Trucks Rule on the Electric Grid and Fleets | RMI, accessed on September 23, 2025, https://rmi.org/wp-content/uploads/dlm_uploads/2024/02/impacts_of_the_advanced_clean_trucks_rule_on_the_electric_grid_and_fleets.pdf
- [23] Electric Vehicle Readiness - Alternative Fuels Data Center - Department of Energy, accessed on September 23, 2025, <https://afdc.energy.gov/fuels/electricity-ev-readiness>
- [24] Case Studies - Gridworks, accessed on September 23, 2025, <https://gridworks.org/case-studies/>
- [25] Barriers to Electric Vehicle Adoption: The 4 Key Challenges - Exro Technologies, accessed on September 23, 2025, <https://www.exro.com/industry-insights/barriers-to-electric-vehicle-adoption-in-2022>
- [26] Electric vehicles: The 3 main factors holding back sales - The World Economic Forum, accessed on September 23, 2025, <https://www.weforum.org/stories/2022/10/ev-sales-charging-infrastructure-transport-sector-sustainable/>
- [27] U.S. charging infrastructure deployment through 2024, accessed on September 23, 2025, <https://theicct.org/publication/us-charging-infrastructure-deployment-through-2024-apr25/>
- [28] 10 EV Charging Statistics You Should Know - KORE Wireless, accessed on September 23, 2025, <https://www.korewireless.com/blog/ev-charging-statistics/>
- [29] Benefits and challenges of electric semi-trucks - EV Engineering & Infrastructure, accessed on September 23, 2025, <https://www.evengineeringonline.com/what-are-the-benefits-and-challenges-of-electric-semi-trucks/>
- [30] Fuel cell trucks – When and why do we need them? - Volvo Trucks, accessed on September 23, 2025, <https://www.volvotrucks.com/en-en/news-stories/stories/2022/nov/when-and-why-fuel-cell-truck.html>
- [31] Hydrogen Truck vs Electric Truck: Which is the Best Solution for the Future of your Fleet?, accessed on September 23, 2025, <https://www.symbio.one/en/news-media/newsroom/hydrogen-truck-vs-electric-truck-which-best-solution-future-your-fleet>
- [32] How Truck Electrification Varies with Weight and Application | IDTechEx Research Article,

- accessed on September 23, 2025, <https://www.idtechex.com/en/research-article/how-truck-electrification-varies-with-weight-and-application/32657>
- [33] Understanding the Challenges in the Electric Truck Transition - Vehicle Research, accessed on September 23, 2025, <https://www.worktruckonline.com/10199713/understanding-the-challenges-in-the-electric-truck-transition>
- [34] How a UK hydrogen car industry could cut fuel costs and carbon emissions, accessed on September 23, 2025, <https://www.cranfield.ac.uk/press/news-2023/how-a-uk-hydrogen-car-industry-could-cut-fuel-costs-and-carbon-emissions>
- [35] Comparative Analysis of Infrastructures: Hydrogen Fueling and Electric Charging of Vehicles - JuSER - Forschungszentrum Jülich, accessed on September 23, 2025, https://juser.fz-juelich.de/record/842477/files/Energie_Umwelt_408_NEU.pdf
- [36] Building electric container ships? : r/teslamotors - Reddit, accessed on September 23, 2025, https://www.reddit.com/r/teslamotors/comments/5ylrhk/building_electric_container_ships/
- [37] The future of fuel: the feasibility of electric power for container shipping, accessed on September 23, 2025, <https://www.keystonelaw.com/keynotes/the-future-of-fuel-the-feasibility-of-electric-power-for-container-shipment>
- [38] Why is grid capacity an important consideration for electrified terminals? - Portwise, accessed on September 23, 2025, <https://www.portwiseconsultancy.com/blog/why-is-grid-capacity-an-important-consideration-for-electrified-terminals/>
- [39] Sustainable Aviation Fuel | SAF - SkyNRG, accessed on September 23, 2025, <https://skynrg.com/sustainable-aviation-fuel/>
- [40] Sustainable Aviation Fuels | Port of Seattle, accessed on September 23, 2025, <https://www.portseattle.org/page/sustainable-aviation-fuels>
- [41] Synthetic Diesel Fuel - DieselNet, accessed on September 23, 2025, https://dieselnet.com/tech/fuel_synthetic.php
- [42] What is Emobility? Find all the answers in our FAQ | Volvo CE, accessed on September 23, 2025, <https://www.volvoce.com/united-states/en-us/products/electric-machines/faq/>
- [43] Electric Construction Equipment: Your Charging Questions Answered, accessed on September 23, 2025, <https://www.nussgrp.com/electric-construction-equipment-your-charging-questions-answered/>
- [44] Challenges and Solutions in Electrification Technology: Construction Machinery and Charging Solutions | Article List - YANMAR, accessed on September 23, 2025, <https://www.yanmar.com/global/engine/e-powertrain/journal/article4/>
- [45] Electric Equipment Chargers - HEVI, accessed on September 23, 2025, <https://gethevi.com/electric-heavy-equipment/electric-equipment-chargers/>
- [46] What is mobile EV charging and is it right for your fleet? - BP Pulse, accessed on September 23, 2025, <https://www.bppulse.com/en-us/going-electric/what-is-mobile-ev-charging-and-is-it-right-for-your-fleet>
- [47] Industry Perspectives on Electrifying Heavy Equipment: Trends, Challenges, and Opportunities - MDPI, accessed on September 23, 2025, <https://www.mdpi.com/1996-1073/18/11/2806>
- [48] Synthetic fuel - Wikipedia, accessed on September 23, 2025, https://en.wikipedia.org/wiki/Synthetic_fuel
- [49] E-fuels vs. batteries | INERATEC, accessed on September 23, 2025, <https://www.ineratec.de/en/glossary/e-fuels-vs-batteries>
- [50] why e-fuels in cars make - no economic or environmental sense - Transport & Environment, accessed on September 23, 2025, <https://www.transportenvironment.org/uploads/files/legacy/Efuels-in-cars-briefing.pdf>
- [51] E-Fuels: A Comprehensive Review of the Most Promising Technological Alternatives towards an Energy Transition - MDPI, accessed on September 23, 2025, <https://www.mdpi.com/1996-1073/17/16/3995>