www.ijprems.com
editor@ijprems.com

INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)
(Int Peer Reviewed Journal)
Vol. 05, Issue 02, February 2025, pp : 1241-1249

e-ISSN : 2583-1062
Impact Factor : 7.001

DECARBONIZATION STRATEGIES FOR TRANSPORTATION AND SUPPLY CHAINS: CHALLENGES, INNOVATIONS, AND FUTURE PATHWAYS

Pritam Pratibhan Misra[*1]

[*1]Sustainable Procurement, ESG Analyst, Masters Of Technology, Department Of Mechanical Engineering, Indira Gandhi Institute Of Technology, India.

DOI: https://www.doi.org/10.58257/IJPREMS38764

ABSTRACT

The transportation and supply chain sector plays a crucial role in global trade and economic growth but is also a significant contributor to greenhouse gas (GHG) emissions, accounting for nearly 37% of global CO_2 emissions. With increasing regulatory pressures, consumer awareness, and corporate sustainability commitments, industries are actively seeking decarbonization strategies to transition toward low-carbon supply chains. This paper explores key drivers of supply chain emissions, highlighting the role of transportation in environmental impact. It reviews innovative strategies such as electrification, alternative fuels, AI-driven route optimization, and renewable energy integration in logistics operations. Case studies of industry leaders like Walmart, Apple, Maersk, Unilever, and Tesla illustrate the real-world implementation of decarbonization efforts. Despite technological advancements, challenges such as high capital costs, infrastructure limitations, regulatory fragmentation, and data transparency hinder rapid adoption. The study emphasizes the need for collaborative policies, investment in clean technology, and scalable solutions to achieve net-zero emissions in global supply chains. By addressing these challenges and leveraging emerging technologies, businesses can enhance sustainability, improve operational efficiency, and contribute to global climate goals.

Keywords: Decarbonization , Supply Chains, Sustainable Transportation, Greenhouse Gas (GHG) Emissions, Scope 3 Emissions, Electrification Of Logistics, Alternative Fuels, Renewable Energy Integration, AI In Logistics, Carbon Accounting, Net-Zero Supply Chain Goals.

1. INTRODUCTION

1.1 Background and Context

The global supply chain is the lifeblood of modern economies, ensuring the movement of raw materials, semi-finished products, and finished goods from producers to consumers. It consists of multiple interconnected networks, including manufacturing, warehousing, transportation, and distribution, operating across diverse geographic regions.

However, traditional supply chains heavily rely on fossil fuel-powered transportation and energy-intensive processes, making them a major contributor to greenhouse gas (GHG) emissions. According to the World Economic Forum (WEF), the logistics and transportation sector alone accounts for nearly 37% of global CO_2 emissions, with road transport contributing over 72% of total transport-related emissions.

In recent years, the impact of climate change, regulatory pressures, and consumer awareness has forced organizations to rethink their supply chain strategies. The Paris Agreement (2015) and the UN Sustainable Development Goals (SDGs) emphasize the need to limit global warming to below 1.5°C, urging industries to adopt decarbonization strategies.

1.2 The Need for Decarbonization in Transportation and Supply Chains

1.2.1 The Environmental Impact of Supply Chain Emissions

Carbon emissions from supply chains originate from multiple sources:

- Scope 1 emissions: Direct emissions from company-owned transportation and logistics operations.
- Scope 2 emissions: Indirect emissions from purchased electricity used in warehouses, distribution centers, and office buildings.
- Scope 3 emissions: Indirect emissions from upstream and downstream activities, including supplier production, outsourced transportation, and product usage.

Among these, Scope 3 emissions account for up to 80-90% of a company's total carbon footprint, making them the most challenging to track and reduce.

www.ijprems.com
editor@ijprems.com

INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)
(Int Peer Reviewed Journal)
Vol. 05, Issue 02, February 2025, pp : 1241-1249

e-ISSN : 2583-1062
Impact Factor : 7.001

1.2.2 The Business Case for Decarbonization

Transitioning to a low-carbon supply chain is not just about compliance—it also provides long-term competitive advantages. Businesses that adopt sustainable transportation and logistics experience:

- Cost savings: Lower fuel expenses from electrified fleets and fuel-efficient transportation.
- Regulatory compliance: Adhering to carbon pricing mechanisms and emission reduction mandates.
- Brand reputation enhancement: Attracting eco-conscious consumers and investors.
- Resilience against disruptions: Reducing dependence on volatile fossil fuel markets.

For example, companies that invested early in renewable energy and low-carbon logistics, such as Apple, Walmart, and Maersk, have gained significant cost advantages and regulatory incentives.

1.3 Research Objectives and Scope

This study explores the critical role of transportation in supply chain decarbonization, outlining:

1. The impact of transportation emissions on global supply chains.
2. Strategies for reducing carbon footprints through green logistics.
3. Challenges and barriers companies face in implementing decarbonization.
4. Case studies of industry leaders (Walmart, Apple, Maersk, Unilever, Tesla).
5. Policy implications and recommendations for achieving net-zero supply chains.

2. ROLE OF TRANSPORTATION IN THE SUPPLY CHAIN

2.1 Importance of Transportation in Supply Chain Management

Transportation is the lifeline of the supply chain, ensuring the seamless movement of raw materials, intermediate goods, and finished products across different regions. A well-functioning transportation system enhances supply chain resilience, reduces costs, and improves customer satisfaction.

Key Roles of Transportation in Supply Chain:

Function	Description	Example
Movement of Goods	Transfers raw materials from suppliers to manufacturers and finished products to consumers.	Shipping raw cotton from India to textile mills in Bangladesh.
Linking Supply Chain Nodes	Connects suppliers, manufacturers, distributors, and retailers.	Warehouses receiving bulk stock from factories and distributing to retail stores.
Inventory Management	Helps optimize stock levels by enabling just-in-time (JIT) deliveries.	Toyota's lean manufacturing relies on precise logistics to reduce storage costs.
Customer Satisfaction	Ensures on time and reliable deliveries to meet customer expectations.	Amazon Prime’s same-day delivery services.
Cost Efficiency	Reduces logistics expenses through optimized transport routes and multimodal networks.	UPS uses AI-powered route optimization to save 10 million gallons of fuel annually.

2.2 Contribution of Transportation to Supply Chain Performance

An efficient transportation system significantly improves supply chain performance by enhancing speed, reducing costs, and increasing adaptability.

2.2.1 Speed & Reliability

- Fast transportation reduces lead times, improving overall supply chain efficiency.
- Example: DHL’s Go Green Plus program integrates electric trucks and optimized routes for faster, low-emission deliveries.

2.2.2 Cost Reduction

- Optimized logistics lowers fuel consumption and operational costs.
- Example: FedEx saves 200 million liters of fuel per year using AI-driven vehicle dispatch.

www.ijprems.com
editor@ijprems.com

INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)
(Int Peer Reviewed Journal)
Vol. 05, Issue 02, February 2025, pp : 1241-1249

e-ISSN : 2583-1062
Impact Factor : 7.001

2.2.3 Flexibility & Adaptability

- Enables businesses to adapt to demand fluctuations and disruptions.
- Example: During the COVID-19 pandemic, logistics firms re-routed shipments to accommodate lockdown restrictions.

2.3 Modes of Transportation in Supply Chains

The choice of transport mode affects cost, speed, emissions, and reliability. Supply chains often combine multiple modes to maximize efficiency and minimize environmental impact.

Mode of Transport	Best Use Case	Advantages	Challenges
Road (Trucks, Vans)	Short to medium distances, last-mile delivery.	Fast, flexible, door-to-door service.	High emissions, traffic congestion.
Rail (Freight Trains)	Long-distance bulk transport (coal, steel, grain).	Cost-effective, lower carbon footprint than road.	Requires specialized infrastructure.
Air (Cargo Planes)	Urgent, high-value goods (electronics, pharmaceuticals).	Fastest transport mode, global reach.	High emissions, expensive.
Water (Ships, Barges)	Global trade of heavy and bulk goods (oil, containers).	Lowest cost per ton-km, energy-efficient.	Slow transit, affected by port congestion.
Multimodal (Intermodal Transport)	Combining different modes for optimized logistics.	Maximizes efficiency, reduces cost & emissions.	Requires coordination across multiple carriers.

2.4 The Role of Technology in Transportation Efficiency

2.4.1 AI & Machine Learning for Route Optimization

- AI-driven logistics systems optimize routes, reducing fuel consumption.
- Example: UPS' ORION system saved 100 million miles annually, reducing 10 million gallons of fuel consumption.

2.4.2 IoT & Real-Time Tracking

- Smart sensors and IoT devices provide real-time location and condition tracking of shipments.
- Example: Maersk's Remote Container Management (RCM) monitors temperature-sensitive cargo like pharmaceuticals and perishable food.

2.4.3 Block chain for Transparency

- Ensures secure, immutable logistics data to track product origin and reduce fraud.
- Example: IBM's Food Trust lock chain enhances traceability for grocery supply chains, ensuring ethical sourcing.

2.5 Environmental Impact of Transportation in Supply Chains

Transportation accounts for a large share of global carbon emissions. The sector's emissions breakdown is as follows:

- Road transport: 72% of total transport emissions.
- Aviation: 11% of global transport emissions.
- Shipping: 10% of transport-related emissions, projected to rise 50% by 2050.

2.5.1 CO_2 Emissions by Transport Mode

Mode	Emissions (g CO_2 per ton-km)	Environmental Concerns
Road (Diesel Trucks)	120–180	High CO_2 emissions, reliance on fossil fuels.

Rail (Electric Freight)	10–30	Low emissions if powered by renewable energy.
Shipping (Heavy Fuel Oil)	3–10	Maritime pollution, sulfur emissions.
Air Cargo (Jet Fuel)	500–600	High emissions, contrail effects on climate.

3. DECARBONIZATION STRATEGIES FOR SUPPLY CHAINS

To transition toward net-zero emissions, supply chains must implement a combination of technological, logistical, and policy-driven strategies. The following section outlines key decarbonization strategies across different aspects of the supply chain.

3.1 Transitioning to Low-Emission Transport

One of the most effective ways to decarbonize supply chains is by reducing emissions from transportation. This can be achieved through the below measures:

3.1.1 Adoption of Electric and Hydrogen-Powered Vehicles

- Electric Vehicles (EVs) for Last-Mile Delivery:
  - Amazon has ordered 100,000 electric delivery vans from Rivian, aiming to cut last-mile emissions.
  - FedEx plans to make its entire pickup and delivery fleet 100% electric by 2040.
- Hydrogen Fuel Cell Trucks for Long-Haul Transport:
  - Daimler and Volvo have collaborated to develop hydrogen-powered heavy trucks to decarbonize freight.
  - Nikola and Hyundai are deploying hydrogen fuel cell trucks in Europe, Japan, and the US.

3.1.2 Sustainable Aviation Fuels (SAFs) and Green Maritime Fuels

- Aviation Sector:
  - United Airlines has invested in SAFs that can reduce lifecycle carbon emissions by 80% compared to conventional jet fuel.
  - The EU has mandated that at least 2% of aviation fuel be SAFs by 2025, increasing to 63% by 2050.
- Shipping Sector:
  - Maersk and CMA CGM are developing ships that run on green methanol and ammonia, which produce zero sulfur emissions and lower NOx emissions.
  - The IMO (International Maritime Organization) has set a goal to cut global shipping emissions by 50% by 2050.

3.2 Optimizing Logistics and Routing

Optimizing transport and warehousing processes can significantly reduce emissions without requiring major infrastructure changes.

3.2.1 AI-Driven Route Optimization

Using AI and machine learning, logistics companies can:

- Reduce fuel consumption by finding the most efficient delivery routes.
- Minimize empty runs by optimizing vehicle loading capacity.
- Adapt routes in real-time based on traffic congestion and weather conditions.

Example:

- UPS' ORION system (On-Road Integrated Optimization and Navigation) has helped reduce fuel consumption by 10 million gallons annually by optimizing delivery routes.

3.2.2 Modal Shift: Moving from Road to Rail or Water Transport

- Rail and water transport have a significantly lower carbon footprint compared to road transport.
- Companies are shifting long-haul freight from trucks to trains to cut emissions.

Mode of Transport	Average CO_2 Emissions (g CO_2 per ton-km)	Emission Reduction vs. Road (%)
Road Transport (Diesel Trucks)	120–180	-
Rail Transport	10–30	70–90% reduction
Inland Waterways (Barges, Ships)	3–10	90–95% reduction

3.3 Renewable Energy Integration in Warehousing and Distribution

Warehousing and distribution centers consume significant amounts of energy for refrigeration, lighting, and automation. Decarbonization efforts focus on:

3.3.1 Solar and Wind-Powered Warehouses

- Amazon, Walmart, and IKEA are powering their warehouses with on-site solar panels.
- Tesla's Giga-factories run entirely on renewable energy, setting an example for sustainable manufacturing.

3.3.2 Electrification of Cold Storage and Ports

- Cold chain logistics accounts for 25% of food transportation emissions.
- Companies are transitioning from diesel-powered refrigeration units to battery-electric cooling.
- Green Ports are emerging, where ships plug into shore power instead of idling on fossil fuels.

Renewable Energy Solution	Application	Impact
Solar Panels	Warehouses, logistics hubs	Reduces dependency on fossil fuels
Wind Energy	Port operations, warehouses	Lowers carbon footprint
Hydrogen Fuel Cells	Heavy-duty trucks, forklifts	Provides zero-emission alternatives

3.4 Sustainable Packaging and Circular Economy

The packaging industry is responsible for a large portion of Scope 3 emissions. Key practices:

3.4.1 Using Recyclable and Biodegradable Packaging

- Unilever and Nestlé have committed to 100% recyclable packaging by 2025.
- McDonald's is shifting to fiber-based and plastic-free packaging.

3.4.2 Lightweight Packaging to Reduce Transport Emissions

- PepsiCo has reduced plastic in its bottles by 20%, leading to lower emissions in transportation.
- Nike's shoebox redesign cut packaging weight by 50%, reducing logistics-related carbon emissions.

3.4.3 Reverse Logistics for Waste Reduction

- IKEA and Dell have implemented take-back programs where customers return used products for recycling.
- Loop offers a circular packaging service where consumers return containers for refill and reuse.

3.5 Carbon Accounting, Supplier Collaboration, and Policy Compliance

Companies must track and report carbon emissions across their supply chains.

3.5.1 Carbon Footprint Tracking & AI-Powered Analytics

- Walmart's Project Gigaton helps suppliers track and reduce 1 billion metric tons of CO_2 emissions by 2030.
- Microsoft Cloud for Sustainability uses AI to measure and report real-time emissions across the supply chain.

3.5.2 Supplier Engagement and Carbon Reduction Initiatives

- Apple's Supplier Clean Energy Program ensures that all suppliers use 100% renewable energy by 2030.
- Ford and BMW have introduced low-carbon aluminum and steel sourcing strategies.

3.5.3 Carbon Pricing and Government Regulations

- The EU's Carbon Border Adjustment Mechanism (CBAM) will tax carbon-intensive imports, pushing suppliers to reduce emissions.
- China's National Carbon Market now covers more than 2,000 companies, creating an incentive for emission reductions.

Regulation	Region	Impact
Carbon Border Adjustment Mechanism (CBAM)	EU	Tariffs on high-emission imports
Corporate Sustainability Reporting Directive (CSRD)	EU	Requires detailed ESG disclosures
US Inflation Reduction Act (IRA)	USA	Tax incentives for clean energy

Summary of Decarbonization Strategies

Strategy	Key Methods	Impact
Low-Emission Transport	Electric vehicles, hydrogen-powered trucks, biofuels	Reduces transportation emissions
Logistics Optimization	AI-driven route planning, modal shift	Lowers fuel consumption
Renewable Energy in Warehouses	Solar panels, wind energy	Cuts operational emissions
Sustainable Packaging	Recyclable materials, lightweight packaging	Reduces Scope 3 emissions
Carbon Tracking & Supplier Engagement	AI-powered analytics, mandatory carbon reporting	Improves transparency & compliance

4. CHALLENGES IN DECARBONIZATION

Decarbonizing transportation and supply chains is a multifaceted endeavor fraught with significant challenges. These obstacles stem from technological limitations, economic factors, infrastructural deficits, and complex regulatory landscapes.

4.1 Technological and Infrastructure Challenges

a) Battery Limitations in Heavy Transport: Electrifying heavy-duty vehicles presents unique challenges due to the substantial weight and size of batteries required for long-haul operations. The energy density of current battery technology often results in reduced payload capacities and increased vehicle weights, impacting overall efficiency. Additionally, the development of high-capacity charging infrastructure, such as chargers rated up to 3 megawatts, is necessary to meet the rapid charging needs of heavy transport, necessitating significant grid upgrades, especially in rural areas. Hydrogen Fuel Distribution: While hydrogen presents a promising alternative fuel, its storage and distribution pose challenges. Hydrogen gas has a low volumetric energy density, requiring it to be compressed or liquefied for transport, processes that are both energy-intensive and costly. Establishing a nationwide hydrogen refueling infrastructure demands substantial investment and technological advancements.

4.2 Economic Challenges

a) High Initial Capital Expenditure: Transitioning to low-emission technologies often involves significant upfront costs. For instance, electric and hydrogen-powered vehicles typically require higher initial investments compared to their fossil-fuel counterparts. Small and medium-sized enterprises may find these costs prohibitive without access to affordable financing or subsidies.

b) Supply Chain Disruptions: The shift towards sustainable materials and technologies can lead to disruptions in existing supply chains. Sourcing critical minerals for batteries, such as lithium, cobalt, and nickel, is concentrated in specific regions, making supply chains vulnerable to geopolitical tensions and market volatility.

www.ijprems.com
editor@ijprems.com

INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)
(Int Peer Reviewed Journal)
Vol. 05, Issue 02, February 2025, pp : 1241-1249

e-ISSN : 2583-1062
Impact Factor : 7.001

4.3 Regulatory and Policy Challenges

a) Fragmented Regulatory Frameworks: The absence of unified global standards for emissions and sustainability practices leads to a complex regulatory environment. Companies operating across multiple regions must navigate varying regulations, which can impede the implementation of cohesive decarbonization strategies.

b) Insufficient Policy Incentives: In some regions, the lack of robust policy incentives, such as tax credits or grants for adopting green technologies, slows the transition to sustainable practices. Policymakers play a crucial role in creating an enabling environment that encourages investment in decarbonization efforts.

4.4 Data and Transparency Challenges

a) Data Collection and Quality: Accurately measuring emissions, especially Scope 3 emissions, requires comprehensive data from all supply chain partners. The diversity of data sources, coupled with inconsistent reporting standards, leads to low-quality and fragmented data, making it challenging to assess and manage carbon footprints effectively.

b) Transparency and Trust: Building trust among stakeholders necessitates transparency in reporting emissions and sustainability practices. However, concerns over data privacy and competitive advantage can hinder the open sharing of information, impeding collaborative decarbonization efforts.

4.5 Social and Environmental Justice Challenges

a) Resource Extraction Impacts: The extraction of minerals essential for green technologies often occurs in developing countries, leading to environmental degradation and social injustices. For example, cobalt mining in the Democratic Republic of Congo has been associated with human rights violations and significant ecological harm. Equitable Transition: Ensuring that the benefits of decarbonization are equitably distributed is crucial. Workers in traditional energy sectors may face job displacement, and without proper reskilling programs and support, the transition to a green economy could exacerbate social inequalities.

Despite its importance, the transportation sector faces several challenges affecting supply chain efficiency:

Challenge	Impact	Potential Solutions
Rising Fuel Prices	Increases logistics costs.	Investing in EVs and alternative fuels.
Infrastructure Deficiencies	Limits efficiency, particularly in developing regions.	Public-private partnerships to build better transport networks.
Regulatory Complexities	Varying emission standards across countries.	Harmonization of global sustainability regulations.
Supply Chain Disruptions	Delays due to geopolitical events and natural disasters.	AI-powered predictive analytics for risk management.
Driver Shortages	Labor shortages increase costs and delivery times.	Adoption of autonomous freight transport technologies.

5. CASE STUDIES: COMPANIES LEADING IN DECARBONIZATION

The global supply chain is undergoing a major transformation as companies take significant steps to reduce their carbon footprint and integrate sustainable practices into their logistics and operations. Several leading corporations have pioneered decarbonization efforts, setting benchmarks for others to follow. These companies employ renewable energy, electric and hydrogen-powered transport, circular economy principles, and digital optimization technologies to drive sustainability across their supply chains.

This section explores the decarbonization initiatives of Walmart, Apple, Maersk, Unilever, and Tesla, highlighting their strategies, impact, and challenges.

5.1 Walmart's Project Gigaton: A Global Effort to Reduce Supply Chain Emissions

Walmart, the world's largest retailer, launched Project Gigaton in 2017 to eliminate one billion metric tons of greenhouse gas emissions from its global supply chain by 2030. Given that over 95% of Walmart's emissions come from its supply chain, the company recognized that meaningful change required collaboration with suppliers, logistics providers, and manufacturers.

The initiative focuses on six key areas: energy, waste, packaging, agriculture, forests, transportation, and product use. Walmart actively encourages its suppliers to commit to measurable sustainability targets. The company provides resources, training, and incentives for suppliers to transition to renewable energy, improve packaging sustainability, and optimize transportation routes.

By 2024, Walmart had already reduced emissions by 750 million metric tons, showing significant progress. One of the standout strategies under this initiative is route optimization and fleet electrification. Walmart has integrated electric and hydrogen-powered trucks into its supply chain and is working towards 100% renewable energy-powered stores and warehouses.

Despite its success, Project Gigaton faces challenges related to supplier compliance, data transparency, and infrastructure limitations in emerging markets. Walmart is tackling these issues by enhancing reporting mechanisms and developing AI-powered carbon tracking systems.

5.2 Apple's Supplier Clean Energy Program: Driving Renewable Energy in Manufacturing

Apple has been a leader in corporate sustainability, committing to achieving carbon neutrality across its entire supply chain and product lifecycle by 2030. The company has recognized that while its own operations are already carbon neutral, the majority of its emissions (Scope 3) come from suppliers and transportation.

In response, Apple launched the Supplier Clean Energy Program, which mandates that its suppliers transition to 100% renewable energy. The company provides support through funding, infrastructure partnerships, and policy advocacy to accelerate this shift. As of 2023, over 70% of Apple's major suppliers had switched to renewable energy, significantly reducing the company's overall carbon footprint.

Apple has also made strides in low-carbon logistics. It has optimized its supply chain by shifting more of its freight from air to sea transport, a move that reduces emissions by 95% per ton-kilometer. Additionally, Apple has increased the use of recycled aluminum in MacBooks and iPhones, decreasing the environmental impact of raw material extraction.

However, Apple faces challenges related to supplier resistance in regions with limited renewable energy infrastructure. To address this, the company is investing in large-scale solar and wind projects in China, India, and Southeast Asia, ensuring that suppliers have access to clean energy alternatives.

5.3 Maersk's Carbon-Neutral Shipping: Leading the Maritime Industry's Green Transition

As one of the world's largest container shipping companies, Maersk is at the forefront of decarbonizing the maritime industry. Recognizing that the shipping sector accounts for nearly 3% of global carbon emissions, Maersk has committed to achieving net-zero emissions by 2040.

A major part of Maersk's strategy is the adoption of green fuels. The company has ordered dual-fuel vessels capable of running on methanol, ammonia, and biofuels, significantly reducing emissions compared to traditional heavy fuel oil. In 2023, Maersk introduced its first-ever carbon-neutral shipping route, using green methanol-powered vessels to transport goods between Europe and Asia.

In addition to alternative fuels, Maersk is optimizing its logistics network by implementing AI-driven route planning and speed optimization, reducing unnecessary fuel consumption. The company is also investing in shore power, allowing ships to plug into electric grids at ports instead of burning fuel while docked.

Despite these advancements, Maersk faces challenges in scaling up green fuel production and securing long-term affordability. Alternative fuels are still costlier than conventional shipping fuels, making widespread adoption difficult. To overcome this, Maersk is forming strategic partnerships with renewable energy companies and advocating for global carbon pricing mechanisms to level the playing field.

5.4 Unilever's Circular Economy Approach: Sustainable Packaging and Logistics

Unilever, a global consumer goods giant, has embedded sustainability into its supply chain strategy by focusing on waste reduction, sustainable packaging, and emissions-free logistics. The company has committed to achieving net-zero emissions across its entire value chain by 2039 and is actively working to eliminate single-use plastics and transition to fully recyclable packaging by 2025.

One of Unilever's key initiatives is the use of recycled and biodegradable packaging materials. The company has introduced plant-based detergent bottles, aluminum refillable deodorants, and paper-based ice cream tubs. These innovations reduce the need for virgin plastic, lowering the company's carbon footprint.

Unilever has also optimized its transportation network by integrating electric delivery fleets and increasing reliance on rail and water transport. In Europe, the company has reduced road transport emissions by 40% by shifting shipments from trucks to low-carbon rail freight.

Despite these efforts, Unilever faces challenges in scaling up its circular economy initiatives, particularly in regions with weak recycling infrastructure. The company is addressing this by investing in closed-loop recycling systems and collaborating with governments to develop better waste management frameworks.

5.5 Tesla's Electrification of Freight Transport: The Future of Green Logistics

Tesla has revolutionized the electric vehicle industry, and it is now making strides in decarbonizing freight transport. The launch of the Tesla Semi, an all-electric heavy-duty truck, represents a major shift towards emissions-free long-haul transportation.

The Tesla Semi, introduced in 2023, boasts a 500-mile range per charge and a 20% lower total cost of ownership compared to diesel trucks. Companies like PepsiCo, Walmart, and UPS have already pre-ordered large fleets of these trucks, accelerating the transition to clean freight transport.

Tesla is also developing a network of Megachargers to support its electric trucking ecosystem, ensuring rapid charging infrastructure for long-haul routes. Additionally, the company is exploring battery swapping technology, which could eliminate downtime for recharging and make electric freight transport even more viable.

However, Tesla faces challenges related to battery production scalability and supply chain constraints for key minerals like lithium and cobalt. The company is addressing these issues by investing in battery recycling programs and securing long-term mineral supply agreements with sustainable mining partners.

6. CONCLUSION

The Road Ahead for Supply Chain Decarbonization

The case studies of Walmart, Apple, Maersk, Unilever, and Tesla highlight the diverse approaches companies are taking to achieve supply chain decarbonization. Whether through renewable energy adoption, electrified transport, alternative fuels, or circular economy principles, these industry leaders are setting new sustainability standards.

However, common challenges persist, including cost barriers, regulatory hurdles, infrastructure limitations, and supplier engagement issues. The success of these initiatives will depend on global cooperation, technological advancements, and robust policy frameworks that support long-term investments in sustainability.

As more companies embrace net-zero supply chain strategies, the transition towards decarbonized logistics and transportation will accelerate, paving the way for a more resilient, efficient, and environmentally friendly global economy.

7. REFERENCES

[1] World Economic Forum. (2025). Supply chain and manufacturing transformation: Key takeaways. World Economic Forum

[2] United Nations. (2015). Paris Agreement on Climate Change. Retrieved from https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

[3] International Energy Agency. (2023). Transport and Climate Change: Pathways to Net Zero. https://www.iea.org/reports/transport

[4] Apple Inc. (2023). Supplier Clean Energy Program Progress Report. Retrieved from https://www.apple.com/environment/pdf/Apple_Supplier_Clean_Energy_Program_Update_2023.pdf

[5] Maersk. (2024). Decarbonizing Global Shipping: The Role of Green Fuels and AI-driven Logistics. https://www.maersk.com/news/articles/2024/01/15/decarbonizing-global-shipping

[6] Tesla Inc. (2023). Tesla Semi and the Future of Electrified Freight Transport. https://www.tesla.com/semi

[7] Walmart. (2024). Project Gigaton: Reducing 1 Billion Metric Tons of CO_2 Emissions. walmartsustainabilityhub.com

[8] Unilever. (2023). Sustainable Packaging and Circular Economy Initiatives. https://www.unilever.com/planet-and-society/waste-free-world/sustainable-packaging/