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Title:

Life Cycle Assessment of Tesla's Electric Vehicles: A Sustainable Supply Chain Perspective

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Introduction

The transportation sector is a major contributor to the global greenhouse gas emissions, accounting for nearly one-quarter of energy related CO_2 emissions worldwide (International Energy Agency, 2023). As the world seeks to decarbonize, electric vehicles (EVs) have emerged as a promising solution. However, the sustainability of EVs is not inherent, it depends on the entire lifecycle of the vehicle, from raw material extraction to end-of-life recycling, and on the practices embedded in the supply chain. Tesla, as the global leader in EV production and innovation, provides a compelling case study for examining these issues.

The research problem addressed in this report is the gap between the perceived sustainability of EVs and the complex realities of their life cycle and supply chain impacts. While Tesla's Model 3, for example, has achieved 98% Green NCAP score in Europe (Green NCAP, 2024), life cycle assessments (LCAs) in other regions, such as China, reveal significantly higher emissions due to differences in electricity generations mixes (GAC MOTOR, 2019). This discrepancy highlights the need for a nuanced, data driven evaluation of EV sustainability.

The aims of this paper are threefold:

1) To quantify the environmental impacts of Tesla's EVs through rigorous LCA
2) To analyze the company's supply chain sustainability using the Turker and Altuntas (2014) Sustainable Supply Chain Management (SSCM) framework
3) To develop practical, Triple Bottom Line (TBL) aligned strategies for Tesla and the broader industry

The methodology combines quantitative LCA, qualitative analysis of supplier practices, and regulatory review, all grounded in ISO 14040/14044/14067 standards.

The structure of the paper is that part 1 offers a detailed examination of Tesla, its product ecosystem and the life cycle assessment of the Model 3. Part 2 presents the methodology, including data collection, supply chain analysis, application of the SSCM framework and a comparative LCA. Part 3 develops sustainable supply chain strategies, provides practical recommendations for corporate executives, and addresses TBL and regulatory compliance, concluding with future research directions.

Part 1: Detailed Examination of Tesla and its Electric Vehicles

1.1 Company Profile and Evolution

Tesla Inc. was founded in 2003 with the mission to accelerate the world's transition to sustainable energy. Under the leadership of CEO Elon Musk, Tesla has evolved from a niche luxury EV manufacturer to the world's most prominent producer of electric vehicles, energy storage solutions, and solar technology (Tesla, 2023). The company's vision is not merely to produce zero-emission vehicles but to create an integrated ecosystem of clean energy products, including solar panels, energy storage systems, and a proprietary charging network.

Tesla's growth has been underpinned by aggressive investment in research and development, vertical integration, and a direct-to-consumer sales model. The company's Gigafactories in the US, China and Germany exemplify its commitment to scaling production while maintaining control over quality and sustainability (Tesla, 2023). In 2023, Tesla's Model 3 became the world's bestselling EV, reflecting both the company's market leadership and the growing consumer demand for sustainable mobility.

Tesla's origins trace back to 2003 when engineers Martin Eberhard and Marc Tarpenning founded the company, naming it after inventor Nikola Tesla. With backgrounds in tech entrepreneurship, they aimed to prove that electric vehicles could be powerful, high performance, and desirable, challenging the stereotype of EVs as slow and unappealing. The founders initially developed a premium sports car powered by laptop style lithium-ion batteries, which became the Tesla Roadster through a partnership with Lotus. To fund the project, they turned to Elon Musk, who joined as lead investor in 2004 and later became the CEO in 2008 after internal leadership changes. This transition marked Tesla's evolution from a startup focused on proving EV viability to a company pursuing mass market adoption.

1.2 Vertical Integration and Supplier Partnerships

A defining feature of Tesla's business model is its extensive vertical integration. Unlike traditional automakers, which rely heavily on a network of suppliers, Tesla controls nearly every aspect of its production process, from raw material sourcing to battery manufacturing and vehicle assembly (Tesla, 2023). This strategy enables Tesla to maintain stringent quality standards, drive innovation and respond quickly to market changes

Tesla has established direct partnerships with key raw material suppliers, such as Piedmont Lithium for lithium and Syrah Resources for graphite, to secure ethical and stable sources for its battery production (Tesla, 2023). These relationships are critical in mitigating risks associated with price volatility, supply disruptions, and ethical concerns, particularly in the mining of cobalt usage by 15% and lowered production costs by 15 - 30% through dry cathode technology (Tesla, 2023).

1.3 Life Cycle Assessment of Tesla Model 3

The environmental performance of the Tesla Model 3 varies significantly depending on regional electricity generation mixes. In Europe, the Model 3 achieved a Green NCAP life cycle score of 96 gCO_2e/km, a figure that is 62% lower than the average internal combustion engine vehicle (ICEV) due to the region's cleaner, 40% renewable grid (Green NCAP, 2024). In contrast, a study conducted in China using the GREET and CALCM models found the Model 3's life cycle emissions to be 376 gCO_2e/km, which is 17% higher than comparable ICEVs, primarily due to China's coal heavy electricity grid (GAC MOTOR, 2019).

Battery production is a significant contributor to the Model 3's total life cycle emissions, accounting for 19% (17.9 gCO_2e/km) of the total, driven by the energy intensive processes required for lithium extraction and cell manufacturing (Green NCAP, 2024). Tesla's innovations, such as the 4680 cell, have improved energy density and reduced reliance on high impact materials, but regional variations in manufacturing and grid electricity remain decisive factors.

The Model 3 is also notable for its energy efficiency, achieving 12.4 kWh/100 km in urban driving, which is among the lowest ever recorded in independent testing (Green NCAP, 2024). Its 60 kWh battery enables a 324 km of high speed highway driving, further demonstrating Tesla's engineering leadership.

1.4 Tesla's Sustainability Efforts

Tesla's sustainability initiatives extend beyond vehicle emissions. In 2023, the company recovered enough battery materials to produce 43,000 Model Y vehicles, demonstrating significant progress in closed-loop recycling (Tesla, 2023). Giga Berlin operated on 100% renewable energy, and Giga Shanghai achieved 35% lower energy use per vehicle compared to Fremont (Tesla, 2023). Water usage per vehicle has been reduced by 25% since 2018, and Tesla continues to invest in supplier audits and ethical sourcing, with 14 audits conducted in 2023 and 92% compliance with labor standards (Tesla, 2023).

Part 2: Methodology – Data Collection and Analysis

2.1 Overview of Tesla's Supply Chain

Tesla's supply chain is widely recognized as one of the most ambitious and vertically integrated in the automotive sector. The company's approach is rooted in a philosophy of direct control over key processes and components which enables Tesla to maintain high standards of quality and sustainability while responding rapidly to technological and market changes (Tesla, 2023). This vertical integration encompasses not only vehicle assembly but also the production of critical components such as battery cells, electric motors and power electronics. Tesla's Gigafactories located in Nevada, Shanghai and Berlin are central to this strategy, serving as hubs for both manufacturing and innovation.

At the upstream end, Tesla's supply chain begins with the extraction and processing of raw materials. The company has established direct partnerships with mining and refining firms like Piedmont Lithium, Syrah Resources, and Ganfeng Lithium to ensure a stable and ethical supply of lithium, graphite and other battery minerals (Tesla, 2023). These relationships are crucial for managing both cost volatility and sustainability risks. For instance, the global supply of cobalt, which is a key battery material, has been the subject of scrutiny due to its association with child labor and unsafe working conditions in the Democratic Republic of Congo (DRC). In response, Tesla has increased its direct sourcing from audited mines, achieving 55% direct cobalt sourcing in 2023 and has invested in blockchain based traceability systems to improve transparency (Tesla, 2023, Amnesty International, 2022).

Despite these efforts, the upstream supply chain remains challenging. Full traceability of minerals is difficult, particularly for sub-tier suppliers in regions with weak regulatory oversight. Tesla's supplier code of conduct mandates compliance with international standards such as ISO 14001 (environmental management) and SA8000 (social accountability), and the company conducts regular audits to monitor compliance. In 2023, Tesla completed 14 supplier audits, achieving 92% compliance with labor standards. However, persistent gaps in sub-tier mining operations highlight the limitations of even the most robust audit regimes (Tesla, 2023).

Midstream, the focus shifts to battery and vehicle manufacturing. Tesla's battery innovation has been a cornerstone of its competitive advantage. The introduction of the 4680 battery cell produced in-house has resulted in 16% increase in energy density, a 15 - 30% reduction in production costs and a 15% reduction in cobalt content (Fastmarkets, 2023; Benzinga, 2024). Battery manufacturing is inherently energy-intensive, but Tesla has made significant strides in improving efficiency. For example, Giga Shanghai uses 35% less energy per vehicle than the Fremont factory, and Giga Berlin operates entirely on renewable energy (Tesla, 2023). These measures not only reduce emissions but also help Tesla comply with increasingly stringent environmental regulations in key markets. Beyond battery production, Tesla collaborates with specialized suppliers for critical components: Nvidia provides processing chips for the advanced computing systems that power Autopilot and Full Self-Driving capabilities, while LG supplies high-resolution displays for the minimalist interior interfaces. The company also maintains partnerships with specialized suppliers for chassis, suspension, and braking systems, ensuring that performance and safety requirements are met across all vehicle models.

Downstream, Tesla's logistics and distribution system is designed to minimize environmental impact and maximize efficiency. The company's direct-to-consumer sales model bypasses traditional dealerships, allowing for greater control over the customer experience and supply chain logistics. Vehicles are distributed through Tesla's own logistics network, which employs a sophisticated just-in-time inventory system where stock is received at each facility precisely when required, significantly reducing storage costs and waste. This system is powered by AI-driven demand forecasting that analyzes multiple data points to optimize production schedules and minimize inventory holding, contributing to both cost efficiency and environmental sustainability (Lövenich 2025). Tesla's global Supercharger network, which is expanding rapidly and increasingly powered by renewable energy, supports widespread adoption of EVs by addressing range anxiety and enabling long-distance travel.

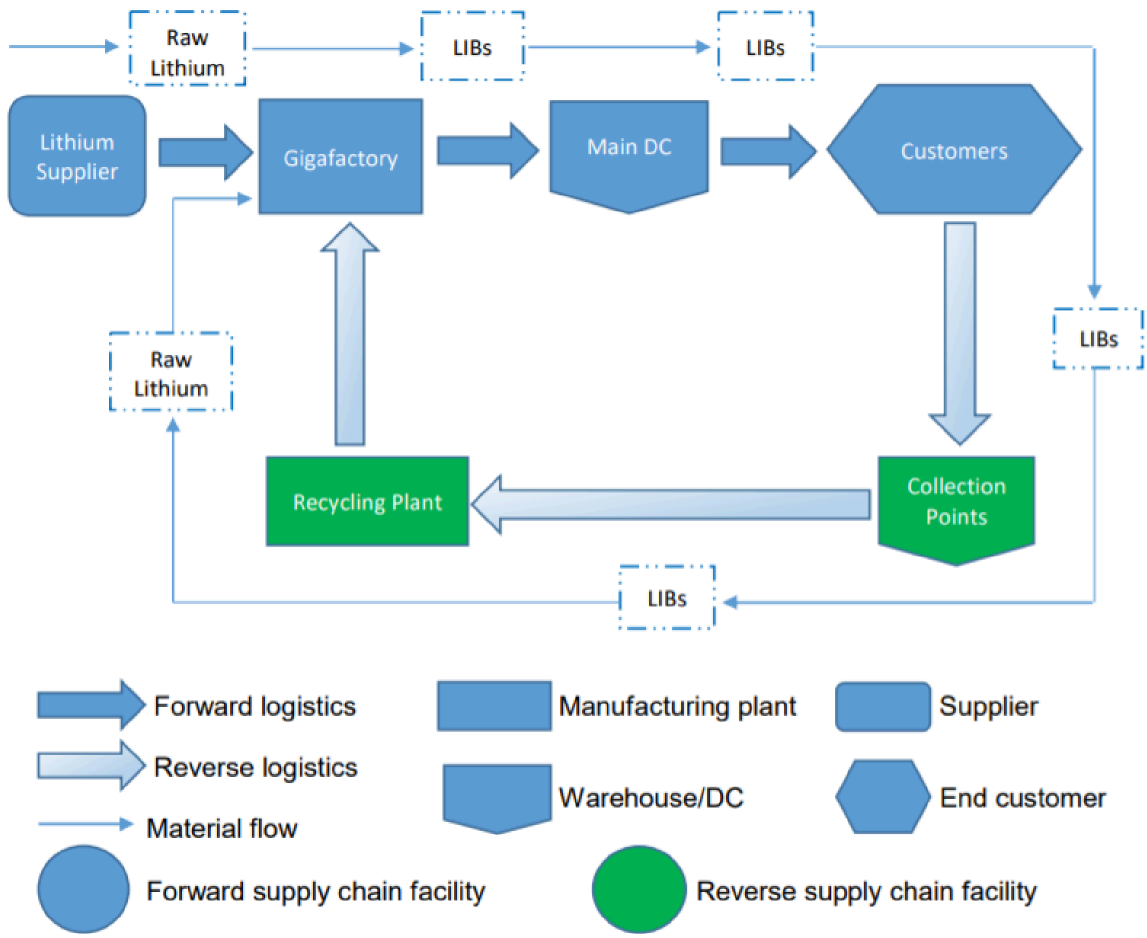

Figure 1: Tesla's Supply Chain Management

The figure above illustrates the comprehensive nature of Tesla's supply chain management system demonstrating the interconnections between raw material sourcing, manufacturing, distribution and end-of-life recycling. As shown in the figure, Tesla's vertical integration creates a closed loop system where each stage feeds back into the overall sustainability framework.

End-of-life management is a critical, though sometimes overlooked, aspect of Tesla's supply chain. The company has developed a closed-loop recycling system that recovers up to 92% of valuable battery materials, such as lithium, cobalt and nickel (Tesla, 2023). In 2023, Tesla recovered enough materials to produce 43,000 Model Y vehicles and 2,300 tons of nickel. These efforts not only reduce the need for virgin mining but also align with principles of the circular economy and help Tesla comply with regulatory requirements such as the EU Waste Electrical and Electronic Equipment (WEEE) Directive and the forthcoming EU Battery Regulation (European Commission, 2023).

Tesla's supply chain is not without its challenges. The company faces ongoing risks related to geopolitical instability, resource nationalism and environmental and social impacts of mining. For example, water use and pollution associated with lithium extraction in South America, and the potential for community displacement in mining regions, remain significant concerns (EureConsult et al., 2020). Tesla's response has been to increase engagement with suppliers, invest in traceability technologies, and participate in industry initiatives such as the Global Battery Alliance and Responsible Cobalt Initiative (Tesla, 2023).

2.2 Application of the Turker and Altuntas SSCM Framework

To systematically evaluate Tesla's approach to sustainable supply chain management, this report applies the Turker and Altuntas (2014) SSCM framework. This framework is particularly relevant for industries with complex, global supply chains and significant environmental and social impacts such as automotive manufacturing.

The Turker and Altuntas (2014) framework, developed through analysis of nine fast fashion companies' sustainability reports, emphasizes integrating environmental, social and economic considerations into procurement decisions beyond traditional cost and speed metrics. The framework advocates for standardizations through certifications like ISO 14001 and SA8000 to attract sustainable suppliers and build stakeholder confidence, while emphasizing that suppliers should be treated as long-term partners for sustainable innovation rather than short term vendors. This partnership approach facilitates implementation of sustainability initiatives and ensures alignment across the entire supply chain ecosystem.

Sustainable Supply Chain Management:

Tesla's commitment to sustainable product design is evident in the engineering of the Model 3, which is designed for maximum efficiency and minimal environmental impact. The Model 3's low drag coefficient (0.21), lightweight construction and advanced battery technology contribute to its energy efficiency, with consumption as low as 12.4 kWH/100km in urban driving (Green NCAP, 2024). Tesla's focus on eco-design extends to material selection, with increasing use of recycled aluminum and steel, and efforts to reduce the reliance on rare earth elements and conflict minerals.

Battery innovation is central to Tesla's sustainability strategy. The 4680 cell, produced in-house, increases energy density and reduces the need for high impact materials like Cobalt. By internalizing battery production, Tesla can better control environmental and social impacts from raw material extraction to end-of-life recycling. The company's closed loop recycling system exemplifies the circular economy in practice (Fastmarkets, 2023; Benzinga, 2024)

Supplier Management for Risks and Performance:

Supplier Management is a critical component of Tesla's SSCM strategy. The company's supplier code of conduct requires adherence to international standards such as ISO 14001, ISO 45001 (occupational health and safety), and SA8000. Tesla conducts regular audits, with a focus on high-risk areas such as cobalt and lithium mining. In 2023, 14 supplier audits were completed, achieving 92% compliance with labor standards, but challenges remain in ensuring full traceability and compliance among sub-tier suppliers (Tesla, 2023).

To address these challenges, Tesla is expanding its use of blockchain technology and third-party verification schemes, such as the Responsible Minerals Initiatives (RMI). The company's risk management strategy also includes diversification of supply sources, long-term contracts with key suppliers, and investment in recycling infrastructure to reduce dependence on virgin materials. Vertical integration allows for rapid response to supply disruptions and greater control over quality and sustainability, but it also increases Tesla's exposure to upstream risks, especially in the context of geopolitical instability and resource nationalism.

Tesla's implementation of the framework's principles is evident in its selective outsourcing model. The company's partnerships with Nvidia for processors and LG for display units demonstrate how Tesla evaluates suppliers not only on innovation and performance but also on their approach to sustainability and ethical manufacturing. This selective approach. Combined with extensive in-house production of critical components like electric motors and battery cells, allows Tesla to maintain control over social and environmental impacts while reducing dependency on external suppliers.

Stakeholder Engagement and Transparency:

Transparency and stakeholder engagement are essential for building trust and ensuring accountability in the supply chain.Tesla publishes an annual Impact Report detailing its environmental, social and governance (ESG) performance, including Scope 1, 2, and 3 emissions, water use and supplier compliance (Tesla, 2023). The company engages with NGOs, industry groups and regulators to align its practices with evolving standards and stakeholder expectations. Participation in initiatives such as the Global Battery Alliance and the Responsible Cobalt Initiative demonstrates Tesla's commitment to collaborative problem solving and continuous improvement in supply chain sustainability.

Critique of Tesla's SSCM Implementation:

While Tesla demonstrates strong alignment with the Turker and Altuntas framework, critical analysis reveals areas requiring improvement.The company observes regulations for subcontractors and performs audits concerning materials such as cobalt and lithium. But does not provide full transparency or make these processes public. Although Tesla shields itself from some risks through vertical integration, the company still faces considerable hurdles with suppliers in ethically or politically volatile regions.

Tesla's sustainability efforts within supply chain management could be described as risk mitigation rather than transformative change. The company does very little to reach out to external stakeholders such as NGOs, trade unions and labor organisations, which has led to criticism for failing to adequately protect labor rights. While Tesla attempts to comply with the framework, these efforts stem from a centralized approach based on control. The organization needs to be more transparent, engage more actively in collaboration and exceed minimum requirements to truly lead in sustainability.

The Turker and Altuntas framework also emphasizes the importance of integrating sustainability into core business strategy. Tesla's vertical integration and focus on innovation are not only business decisions but also sustainability strategies, enabling the company to reduce environmental impacts, manage social risks and enhance economic resilience. However, as the framework suggests, continuous improvement and stakeholder engagement are essential for long-term success.

2.3 Life Cycle Assessment: Methodology and Key Findings

The life cycle assessment (LCA) of Tesla Model 3 is conducted in accordance with ISO 14040, 14044 and 14067 standards, ensuring consistency and comparability with other studies (GAC MOTOR, 2019; Green NCAP, 2024). The functional unit is defined as a 1 km driver, with a total lifetime distance of 240,000 km in the EU and 150,000 km in China, reflecting regional differences in vehicle usage patterns. System boundaries encompass raw material extraction, battery and vehicle manufacturing, use phase (including electricity generation mix), maintenance and end-of-life recycling. Data sources include real vehicle disassembly, supplier reports, standardized emission factors from GREET and CALCM models and regional grid data.

The primary impact category assessed is the global warming potential (GWP), measured in grams of CO_2 equivalent per kilometer (gCO_2e/km). Other impact categories such as water use, resource depletion, and human toxicity are considered qualitatively where data are available. The LCA methodology includes goal and scope definition, inventory analysis, impact assessment and interpretation.

Key Results and Regional Variations:

The Model 3's life cycle carbon footprint varies significantly by region. In the EU, where the electricity grid is 40% renewable, the model 3 achieves a life cycle emission of 96 gCO_2e/km, which is 62% lower than the average ICEV (Green NCAP, 2024). In China, where coal dominates the grid, the Model 3's emissions rise to 376 gCO_2e/km, 17% higher than ICEVs (GAC MOTOR, 2019). Battery production is a major contributor, accounting for 19% (17.9 gCO_2e/km) of the Model 3's life cycle impact (Green NCAP, 2024). The use phase dominates in regions with carbon-intensive electricity, while production impacts are more significant in regions with cleaner grids.

The Model 3 is among the most energy efficient vehicles on the market, with consumption as low as 12.4 kWh/100 km in urban driving and 14.2 kWh/100 km in mixed real world conditions (Green NCAP, 2024). This efficiency is achieved through aerodynamic design, lightweight materials and advanced powertrain technology. Resource use is minimized through the use of recycled materials and closed-loop manufacturing. Tesla's battery recycling system recovers

92% of materials, reducing the need for virgin mining and supporting a circular economy (Tesla, 2023).

Comparative Analysis and Challenges:

Comparative studies show that battery electric vehicles (BEVs) like the Model 3 emit 20% less CO2 than plug-in hybrid electric vehicles (PHEVs) in city driving, but the advantage diminishes in highway scenarios without regenerative braking (San Diego State University, 2023). The Model 3's life cycle emissions are lower than those of ICEVs in regions with clean electricity but may be higher in regions with coal-dominated grids (GAC MOTOR, 2019; Green NCAP, 2024). The primary drivers of variation are the carbon intensity of the electricity grid, battery production impacts, and vehicle efficiency. These factors must be considered when evaluating the true sustainability of EVs.

Despite Tesla's progress, challenges remain. Full traceability of raw materials is difficult, especially for sub-tier suppliers in regions with weak governance. Battery recycling infrastructure is still developing, and the environmental impacts of mining cannot be fully eliminated. Best practices include increased supplier engagement, investment in traceability technologies, and collaboration with industry and regulatory bodies to set higher standards. Tesla's ongoing efforts to improve supply chain transparency, invest in recycling and innovate in battery technology position the company as a leader in sustainable mobility, but continuous improvement and industry-wide collaboration remain essential for achieving long-term sustainability goals.

Part 3: Sustainable Supply Chain Strategy Development

3.1 Integrating the Triple Bottom Line (TBL) in Tesla's Supply Chain

Tesla's supply chain strategy is best evaluated through the lens of the Triple Bottom Line (TBL), which balances environmental stewardship, social responsibility, and economic viability (Elkington, 1997). Tesla's environmental achievements are well documented: the company's Model 3, for instance, avoids up to 51 tons of CO_2e over its lifetime in Europe, and Gigafactories like Berlin and Shanghai have set new benchmarks for energy efficiency and renewable energy integration (Tesla, 2023; Green NCAP, 2024). Its closed loop battery recycling system is something we have already previously mentioned.

Economically, Tesla's vertical integration and continuous innovation have resulted in a 15–30% reduction in battery production costs and improved supply chain resilience (Tesla, 2023). The company's direct-to-consumer sales model, combined with advanced digital supply chain management, has allowed for greater control over inventory and customer experience, supporting profitability and scalability.

However, the social dimension of TBL remains Tesla's most significant challenge. While the company has made progress in supplier audits and compliance (achieving 92% compliance with labor standards in 2023), persistent issues in the traceability of minerals like cobalt and lithium, especially from high-risk regions, indicate more work is needed (Amnesty International, 2022).

A comparative analysis of Tesla’s TBL performance reveals a clear emphasis on environmental and economic factors, with social responsibility lagging behind. This imbalance is not unique to Tesla but is a common challenge across the EV industry, where rapid growth and technological innovation often outpaces the development of robust social safeguards (Turker & Altuntas, 2014).

To prioritize improvement efforts, the following table summarizes Tesla's current performance across TBL dimensions and identifies priority gaps:

Pillar	**Current Strength**	**Primary Gap**	**Target Practice**
Profit	Cost control via vertical integration	shared value with local suppliers	Regional supplier-development partnerships
People	Ethical labor audits	Living wages and workers voice	Grievance mechanisms, worker-representation
Planet	Renewable energy and battery recycling	Water use and biodiversity impacts	Water stewardship, habitat-offset programs
Governance	Public ESG reporting	Board ESG oversight, anti-corruption	Independent ESG committee, incentive linkage

3.2 Regulatory Compliance

Tesla's end-of-life management strategies align with the European Union’s Waste Electrical and Electronic Equipment (WEEE) Directive, which mandates the collection, recycling and recovery of materials from electrical and electronic products (European Commission, 2023). In 2022, Tesla recovered 2,300 tons of nickel through its reverse logistics system, contributing to the circular economy and reducing dependence on virgin mining (Tesla, 2023). The company’s closed-loop recycling system not only meets but often exceeds regulatory requirements, positioning Tesla as a leader in compliance and innovation.

Looking ahead, the EU’s forthcoming Battery Regulation will introduce stricter requirements, including mandatory battery passports, minimum recycled content and carbon footprint declarations (Circularise, 2025). Tesla is preparing to implement digital battery tracking systems, which will enable full traceability of materials and compliance with Article 45 of the new regulation. These efforts will also support Tesla’s broader sustainability goals by facilitating the integration of recycled materials into new battery production and improving transparency across the supply chain.

3.3 Practical Recommendations for Corporate Executives

To further advance sustainability and address current gaps, Tesla's executives should consider the following targeted recommendations:

1. Deepen Supply Chain Accountability: Tesla should expand its supplier audit program, moving beyond tier-one suppliers to include sub-tier mining operations, especially in high-risk regions such as the DRC and South America. Collaborating with third-party organizations and leveraging blockchain technology can improve traceability and verification of ethical sourcing (Responsible Minerals Initiative, 2023). More granularity in it's supplier compliance report and labor practices can further its accountability agenda

2. Regionalize Manufacturing and Sourcing: To reduce transportation emissions and increase resilience to geopolitical risks, Tesla should continue to regionalize its supply chain. This includes sourcing more materials locally for each Gigafactory and replicating the energy efficiency and renewable integration successes of Giga Shanghai and Giga Berlin in future facilities. This would also further the social goal of the TBL by strengthening relationships with local communities and regulators.

3. Scale Circular Economy Initiatives: Tesla should aim to increase the volume of batteries recycled annually, targeting at least 40,000 tons per year by 2030. Investment in advanced recycling technologies and partnerships with specialized recycling firms will be essential. The company should also design new battery packs and vehicles with disassembly and recyclability in mind, facilitating material recovery and reducing life cycle impacts (Green NCAP, 2024).

4. Enhance Community Engagement and Benefit Sharing: Community benefit agreements, support for local education and healthcare, and fair compensation for land use, these initiatives will not only improve social outcomes but also reduce the risk of supply disruptions due to community opposition or regulatory intervention (Amnesty International, 2022).

5. Deploy Digital Worker Voice Platform: Implement a mobile 'Workers Voice' platform for anonymous supply chain feedback and rapid remediation.This technology driven approach would enable real time monitoring of labor conditions across all tiers of suppliers, particularly in high-risk mining regions.

6. Establish Board Level ESG Committee: This would ensure sustainability considerations are embedded in strategic decision making rather than treated as operational compliance issues. Tying executive compensation directly to quantitative ESG targets,

including scope 3 emissions reductions and social impact metrics would also ensure the company is steered in this direction.

3.4 GAI (Global Assessment Initiative)

The Global Assessment Initiative (GAI) emphasizes comprehensive sustainability evaluation, including environmental, social, and governance (ESG) factors (OECD, 2024). Tesla’s current approach aligns well with GAI’s environmental and governance criteria, particularly in emissions reduction, renewable energy use and transparency. However, the company must strengthen its social dimension by improving labor practices, community engagement and supplier diversity.

For the broader industry, Tesla’s experience demonstrates that vertical integration, digitalization, and closed loop recycling are effective strategies for advancing supply chain sustainability.

3.5 Conclusion and Future Research Direction

In conclusion, Tesla has established itself as a leader in sustainable supply chain management through vertical integration, technological innovation, and a strong commitment to environmental performance. The company's achievements in emissions reduction, energy efficiency and battery recycling set industry benchmarks. However, to achieve a truly balanced Triple Bottom Line, Tesla must address persistent social challenges in its supply chain, particularly in the sourcing of critical minerals.

Future research should focus on the development of robust social metrics, the effectiveness of digital traceability solutions, and the scalability of circular economy models in the automotive sector. Comparative studies across regions and manufacturers will also be valuable in identifying best practices and informing policy development. Continuous improvement, more collaboration and transparent stakeholder management will be essential for Tesla and the broader EV industry to realize the full potential of sustainable mobility.

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