May 6, 2025

Effect of Tariffs in the EV Battery Industry

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Abstract

This report analyzes the impact of international tariffs on the country-level sourcing strategy of a U.S.-based mineral refiner within the electric vehicle (EV) battery supply chain. We develop an optimization model that incorporates cost, ethical sourcing, country reliability, sustainability, and tariff policy changes across four scenarios.

Motivation

In the last few years, EVs have been the only segment of the automotive industry to register sustained growth. According to the Rocky Mountain Institute, sales of EVs are forecast to surpass demand for Internal Combustion Engine (ICE) vehicles as early as 2026. As a result, demand for EV batteries has seen exponential growth, a trend documented by the International Energy Association.

Prices of EV batteries have been decreasing since 2015, but have recently seemed to be stabilizing. In order to keep battery costs down, it is necessary to increase supply chain resilience even through fluctuations of mineral prices and tumultuous foreign policy updates.

The global distribution of the EV Battery Supply Chain can be divided in five stages: Mining (ore extraction), material processing (refining and purification of concentrates), component manufacturing (cathode and anode), battery cell assembly, and EV production.

Geographically, China dominates the downstream processes (steps 2, 3, 4, and 5) of this network. In the US, there is a lack of material processing, especially because domestic companies are mostly involved with cell assembly plants and final EV production (see: Tesla, America's largest EV manufacturer). However, with tumultuous changes in America's foreign policy taking place in 2025, the US needs to position itself as a capable materials refiner and re-shore steps 2 and 3 of the EV battery supply chain in order to mitigate the economic consequences of these changes.

The composition of a lithium-ion battery is primarily dependent on the following critical minerals:

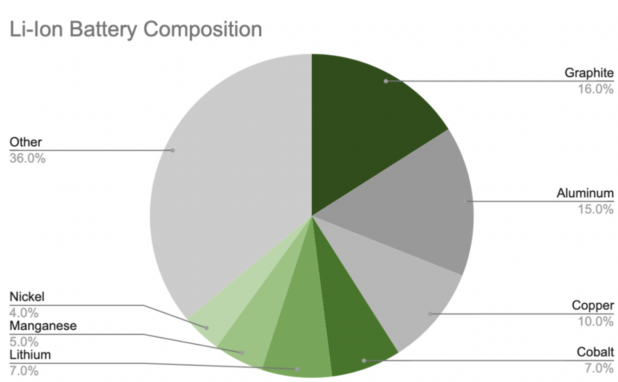

Figure 1: Composition of Lithium-ion Battery

Since these minerals are sourced from different regions around the world, changes in import rules can greatly affect the supply chain for EV cars by driving up material costs, creating bottlenecks, and causing production delays. With this in mind, it is important to understand the different cost scenarios that tariffs can create so that companies can make strategic decisions and secure a competitive advantage in today's market.

Background

On April 2, 2025, U.S. President Donald Trump signed Executive Order 14257, announcing a "reciprocal" tariff strategy aimed at protecting the United States manufacturing sector. These high-priced tariffs would increase prices for companies importing goods to the U.S. from more than 100 trading-partner countries. They were meant to discourage reliance on foreign countries and encourage domestic sourcing and production. This "Liberation Day" announcement triggered a stock market crash and started a global trade war.

The purpose of these tariffs– bringing home manufacturing– would be difficult to realize for U.S. companies, even with the price increase that would result from continuing to import materials and goods from overseas. Bringing manufacturing home requires a big upfront investment that is not available to many companies, who might choose instead to pass the increased prices of their goods onto customers.

Domestically sourcing raw minerals for items such as computer chips is also not something a company like Apple can easily do— mined minerals like silicon and germanium are tied to the countries that have an abundance of raw supply and the resources to extract them. Therefore, instead of moving more of their supply chain domestically, many companies are instead opting to "derisk" from the highest-tariffed countries such as China, and spread their supply chains over more foreign trading partners.

We wanted to investigate how different tariff scenarios (on April 9th, 2025, President Trump issued a 90-day pause on the Liberation Day tariffs, during which another set of tariffs would be imposed) could affect an optimized high-level supply chain strategy of a specific product- electric vehicle batteries.

Data Collection

The necessary parameters for our optimization model are as follows: U.S. EV-battery mineral demand, international mineral supplier countries and their maximum possible import supply of each mineral, cost of each mineral from each supplying country, and transportation cost of each mineral from supplier country to the U.S. We also include tariff rates and ethicality, sustainability, and reliability scores for each supplier country.

To approximate the EV-specific demand for each battery-critical mineral, we first estimated the market size by researching domestic EV sales from 2015 to 2024. We then combined that with the average pack size, 38.6 kWh, to calculate the total energy sold each year. Next, we applied each mineral's share of battery chemistry (by weight percentage) to convert energy into mineral mass. We ran this calculation separately for manganese, nickel, graphite, lithium and cobalt. In practice, our core formula for the demand (in kilograms) of each mineral per year was:

$$\text{EV sales}_{year} \times \text{Avg battery capacity (kWh)} \times \text{Average mineral content (kg/kWh)}$$

We then fit a linear regression on the 2015-2024 demands to project the 2025 demand for each mineral. We further discuss our sources for each parameter in Appendix A.

Sourcing Model

A. Sets, Parameters, and Decision Variables

Sets and Parameters			
I	Set of minerals	R_j	Reliability score of supplier j (0–10)
J_i	Suppliers for mineral $i \in I$	S_j	Sustainability score of supplier j (0–10)
$\mathcal{P}$	Valid mineral-supplier pairs (i, j)	u_{ij}	Capacity of i from j
D_i	Demand for mineral i	λ^{ethics}	Penalty weight for ethics
b_{ij}	Base cost per ton of i from supplier j	$\lambda^{reliability}$	Penalty weight for reliability
c_{ij}	Transport cost per ton of i from j	$\lambda^{sustainability}$	Penalty weight for sustainability
τ_{ij}	Tariff rate on base cost	$\lambda^{diversification}$	Penalty weight for under-diversification
E_j	Ethical score of supplier j (0–10)	T	Target min. number of suppliers per mineral
n_i	Num. of suppliers selected for mineral i	d_i	Diversification slack, $\max(0, T - n_i)$
δ	Min. share of mineral required if selected		
Decision Variables			
$x_{ij} \geq 0$	Tons of i sourced from supplier j	$z_{ij} \in \{0, 1\}$	1 if supplier j is selected for mineral i

B. Assumptions

For the experimentation scenarios A-D, we set λ weights to 0 in order to compare the changes caused by tariffs fairly (controlled variable) and not from the desire to fulfill reliability, ethical practices, or sustainability of a country. All minerals faced the same transportation cost per mile to Etcheverry Hall (chosen to simply represent a location in the United States for the experiment). We assume $T = 3$ as the target minimum number of suppliers per mineral and $\delta = 0.05$ as the minimum percentage of mineral that must be sourced by a country if selected. Lastly, the tariffs are applied as a percentage of the cost of the mineral, excluding the transportation cost.

C. Optimization Formulation

$$\min \sum_{(i,j)\in\mathcal{P}} \Big[\big(b_{ij}(1+\tau_{ij}) + c_{ij} + \lambda^{ethics}(10 - E_j) + \lambda^{reliability}(10 - R_j) + \lambda^{sustainability}(10 - S_j)\big)x_{ij}\Big] + \sum_{i\in I} \lambda^{diversification} \cdot d_i \tag{1}$$

$$\text{s.t.} \sum_{j\in J_i} x_{ij} \geq D_i \qquad \forall i \in I \tag{2}$$

$$x_{ij} \leq u_{ij} \qquad \forall (i,j) \in \mathcal{P} \tag{3}$$

$$x_{ij} \leq u_{ij} \cdot z_{ij} \qquad \forall (i,j) \in \mathcal{P} \tag{4}$$

$$x_{ij} \geq \delta \cdot D_i \cdot z_{ij} \qquad \forall (i,j) \in \mathcal{P} \tag{5}$$

$$d_i \geq T - n_i \qquad \forall i \in I \tag{6}$$

$$d_i \geq 0 \qquad \forall i \in I \tag{7}$$

$$z_{ij} \in \{0, 1\} \qquad \forall (i,j) \in \mathcal{P} \tag{8}$$

The objective function minimizes the total cost of sourcing minerals by accounting for mineral cost, tariffs, logistics, and weighted penalties associated with ethics, reliability, sustainability, and diversification. The penalty terms are formulated to discourage sourcing from countries with lower ESG (Environmental, Social, Governance) scores. The diversification penalty introduces a soft constraint that encourages sourcing each mineral from at least a target number of distinct suppliers. A slack variable d_i captures shortfalls from this target, and the penalty term $\lambda^{diversification} \cdot d_i$ reflects the reliability risk associated with under-diversification. The first constraint (2) ensures demand satisfaction for each mineral. The second (3) limits the quantity sourced from any supplier to a predefined upper bound u_{ij}. The binary variable z_{ij} tracks whether a supplier is used. An additional constraint (5) enforces that if a supplier is selected ($z_{ij} = 1$), they must supply at least a minimum share δ of the mineral's total demand.

After completing the mathematical formulation, we coded it using the `Pyomo` package in `Python`.

D. Sample Model Output

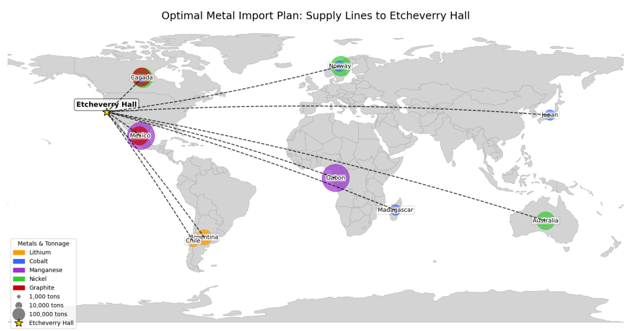

Figure 2: Sample Model Mineral Sourcing Allocation Output

Experimentation Results

A. Before Tariffs

For this scenario, tariffs for all countries are set to 0 and will thus serve as our base model used to compare our other scenarios. Demonstrated by the first graph, the model outputs which countries we use as suppliers for each mineral and the amount.

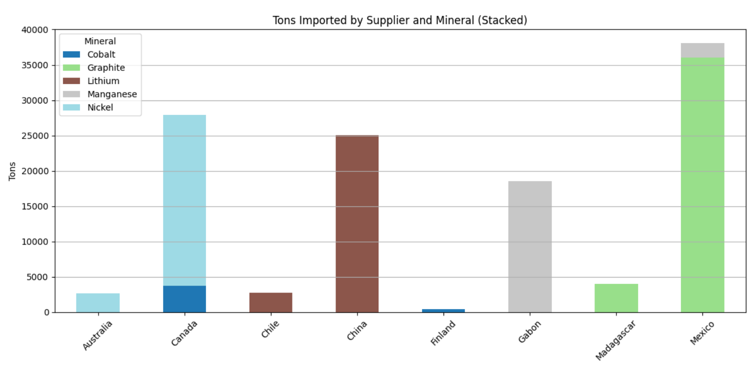

Figure 3: Base Model Mineral Sourcing Allocation with Zero Tariffs

B. "Liberation Day" Tariffs

Liberation Day imposed varying tariffs on countries such as 0, 30, and 104. The changes between this scenario and the base scenario are demonstrated in Figure 4. For example, we can see that the mineral import shift between China and Russia makes sense since China received a high tariff, while Russia did not.

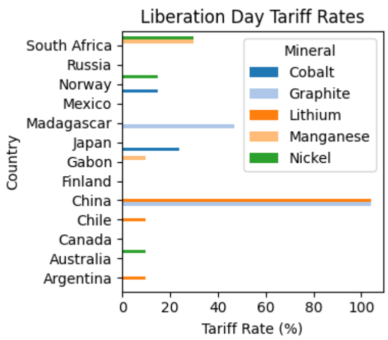

Figure 4: Liberation Day Tariff Rates

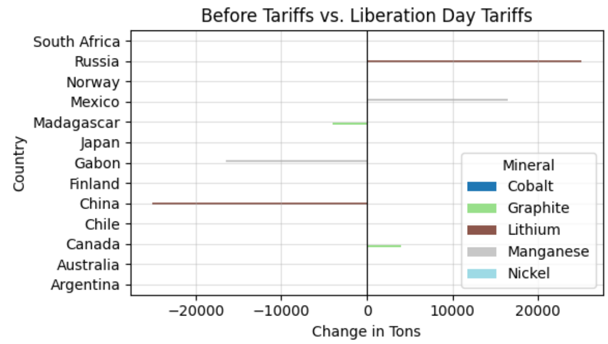

Figure 5: Change in Allocation due to LD Tariffs

C. Current Tariffs

This scenario shows the current tariff rates imposed internationally by the U.S. We notice that given the assumption that tariffs only apply to the cost of goods, then equal weight tariffs can affect some countries more than others (ex. A 10% tariff causes a higher increase on a higher-cost good). As shown in Figure 6, Canada's cobalt share was allocated to Finland because Finland did not receive a tariff.

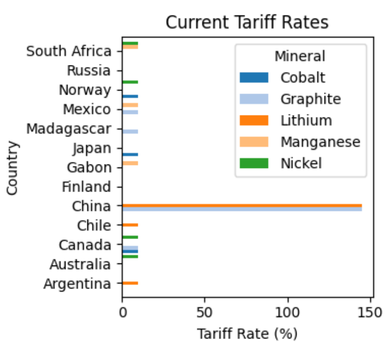

Figure 6: Current Tariff Rates

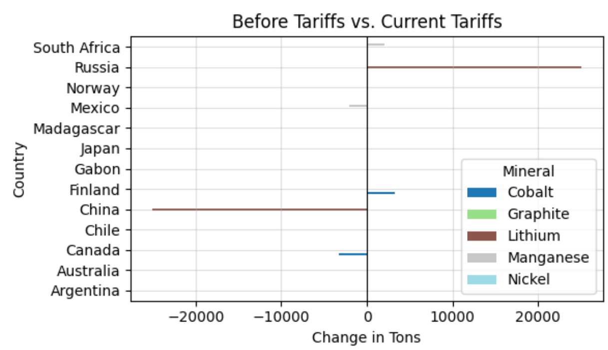

Figure 7: Change due to Current Tariffs

D. Current Tariffs and Free Trade Agreement

To explore another strategic sourcing lens, we introduced a scenario incorporating Free Trade Agreement (FTA) countries. This was motivated by the U.S. government's Clean Vehicle Credit policy, which offers consumer incentives if at least 60% of a battery's supply chain originates from FTA partners.

Incorporating FTA status into our model promotes several goals: lowering costs for consumers, enhancing supply chain resilience through partnerships with trusted allies, incentivizing the shift to clean energy, and aligning with ethical and environmental standards due to stronger labor and environmental protections in many FTA countries. For example, Mexico was retained as a graphite supplier in this scenario due to its FTA status, whereas non-FTA countries like South Africa and Gabon were removed from the graphite sourcing portfolio.

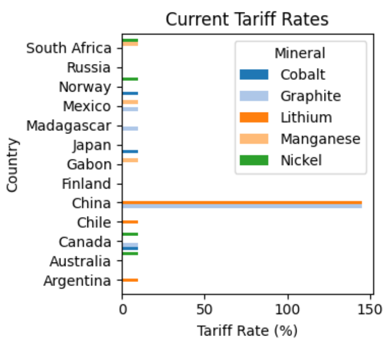

Figure 8: Current Tariff Rates

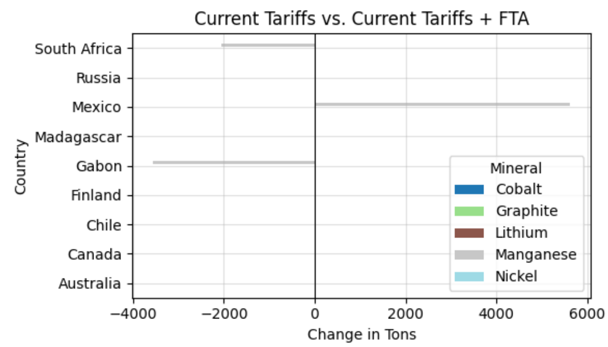

Figure 9: Change due to Current Tariffs and FTA

E. Supplier ESG Scores

Lastly, we created a dynamic widget to explore how supplier portfolios were affected by supplier score weights depending on which factor we value most. In this example, we increase the weight of $\lambda^{reliability}$ from 0 to 100, which removes Madagascar from the optimal solution and allocates its share of graphite to Canada, which is more reliable.

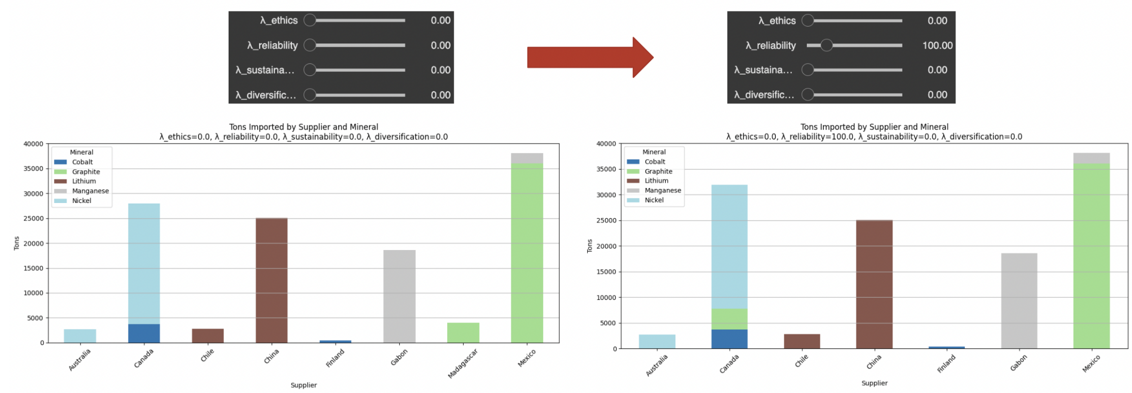

Figure 10: Sample Use of Dynamic Widget for Weight Adjustment

Conclusion

The economics of the Liberation Day tariffs (Scenario B) could shift a large portion of US mineral imports away from China. Our model shows that the proposed policy would redirect imports of lithium and cobalt to countries like Russia, reducing reliance on a single supplier.

In Scenario C, similar tariffs affect more expensive imports. For instance, cobalt imports from Canada decrease, while Finland role as a supplier is strengthened, along with other nations exempt from these taxes.

Free Trade Agreement limitations also redirect sourcing towards allied partners. Mexico remains a key graphite exporter, while countries like South Africa and Gabon are excluded despite their mineral capacity.

These findings highlight how to navigate foreign policy changes, balancing diversification constraints with cost, taxes, and ESG penalties while managing cost increases.

Appendix

1 Mineral Import Assumptions and Methodology

For maximum mineral imports from each supplier country, we used country-specific mineral trade flows from the UN Comtrade database and aggregated totals for the most recent year available, which we assume is close enough to the 2025 import amounts for our purposes. To estimate the share of those imports feeding EV production, we divided our modeled annual mineral demand by the total tonnage imported per mineral.

Mineral base costs were estimated using the UN Comtrade database.[1] Transportation costs were assumed to be factored only on distance from the capital of each supplier country to Etcheverry Hall, using a bulk shipping fee per 1000 miles.[2]

Finally, each supplier country received scores for ethics, sustainability, and reliability, using standardized calculations of Transparency International's Corruption Perception Index[3], Yale Environmental Performance Index[4], and the World Bank Political Stability Indicator[5], respectively, as proxies.

2 Tariff Assumptions

There was some conflicting information about how tariffs are applied to minerals being imported into the US, however one source cited that the US does not apply tariffs to transportation costs of imported goods. If we wanted to include transportation cost, we would simply alter the objective function to multiply tariffs to c_{ij} as well.

3 Raw Data: Mineral Demand, Suppliers, and Costs

Table 1: Minerals, Supplier Countries, and U.S. Demand (2025)

Mineral	**Possible Suppliers**	**Demand (tons)**
Lithium	Argentina, Chile, China, Russia	27,866
Cobalt	Norway, Canada, Japan, Finland	4,142
Manganese	Gabon, Mexico, South Africa	20,638
Nickel	Canada, Norway, Australia, South Africa	26,872
Graphite	China, Madagascar, Canada, Mexico	40,048

[1] https://comtradeplus.un.org/
[2] https://thundersaidenergy.com/downloads/bulk-shipping-cost-breakdown/
[3] https://www.transparency.org/en/cpi/2024
[4] https://epi.yale.edu/
[5] https://data.worldbank.org/indicator/PV.PER.RNK

Table 2: Landed and Logistics Cost by Country and Mineral

Mineral	Country	Landed Cost	Logistics Cost
Lithium	Argentina	86,972	323.32
	Chile	74,000	296.90
	China	73,827	307.04
	Russia	86,629	293.01
Cobalt	Norway	45,711	258.59
	Canada	3,332	121.23
	Japan	26,141	257.13
	Finland	10,057	270.48
Manganese	Gabon	450	419.38
	Mexico	823	94.23
	South Africa	507	526.55
Nickel	Canada	8,155	121.23
	Norway	17,230	258.59
	Australia	8,182	458.56
	South Africa	27,411	526.55
Graphite	China	3,886	307.04
	Madagascar	1,082	549.34
	Canada	1,541.67	121.23
	Mexico	700	94.23

4 Raw Data: Tariffs

Table 3: Tariff Rates (Scenario A: Before Tariffs)

Mineral	Country	Tariff Rate (%)
All	All Listed Countries	0.0

Table 4: Tariff Rates (Scenario B: Liberation Day Tariffs)

Mineral	**Country**	**Tariff Rate (%)**
Lithium	Argentina	10.0
	Chile	10.0
	China	104.0
	Russia	0.0
Cobalt	Norway	15.0
	Canada	0.0
	Finland	0.0
	Japan	24.0
Manganese	Gabon	10.0
	Mexico	0.0
	South Africa	30.0
Nickel	Canada	0.0
	Norway	15.0
	Australia	10.0
	South Africa	30.0
Graphite	China	104.0
	Madagascar	47.0
	Canada	0.0
	Mexico	0.0

Table 5: Tariff Rates (Scenario C: Current Tariffs - as of April 10th, 2025)

Mineral	**Country**	**Tariff Rate (%)**
Lithium	Argentina	10.0
	Chile	10.0
	China	145.0
	Russia	0.0
Cobalt	Norway	10.0
	Canada	10.0
	Finland	0.0
	Japan	10.0
Manganese	Gabon	10.0
	Mexico	10.0
	South Africa	10.0
Nickel	Canada	10.0
	Norway	10.0
	Australia	10.0
	South Africa	10.0
Graphite	China	145.0
	Madagascar	10.0
	Canada	10.0
	Mexico	10.0

Table 6: Ethics, Reliability, Sustainability, and FTA Scores by Country

Country	Ethics Score	Reliability Score	Sustainability Score	FTA (1=Yes)
Argentina	3.7	4.74	4.1	0
Australia	7.7	6.84	5.7	1
Canada	7.5	6.64	6.5	1
Chile	6.3	5.28	5.2	1
China	4.3	3.98	2.8	0
Finland	8.8	6.42	7.7	0
Gabon	2.7	4.32	2.2	0
Japan	7.1	6.90	6.3	1
Madagascar	2.6	3.62	2.4	0
Mexico	2.6	3.74	4.7	1
Norway	8.1	6.78	7.8	0
Russia	2.2	2.74	3.7	0
South Africa	4.1	3.66	4.3	0

5 Optimal Supplier Portfolios

Table 7: Import Quantities by Mineral and Country Across Scenarios (in Tons)

Mineral	Country	No Tariffs	Current Tariffs	Liberation Day Tariffs
Lithium	Chile	2,786.60	2,786.60	2,786.60
	China	25,079.40	0.00	0.00
	Russia	0.00	25,079.40	25,079.40
Cobalt	Canada	3,727.80	414.20	3,727.80
	Finland	414.20	3,727.80	414.20
Manganese	Gabon	18,574.20	18,574.20	2,063.80
	Mexico	2,063.80	0.00	18,574.20
	South Africa	0.00	2,063.80	0.00
Nickel	Canada	24,184.80	24,184.80	24,184.80
	Australia	2,687.20	2,687.20	2,687.20
Graphite	Madagascar	4,004.80	4,004.80	0.00
	Canada	0.00	0.00	4,004.80
	Mexico	36,043.20	36,043.20	36,043.20

Table 8: Cost and ESG Metrics by Scenario

Metric	No Tariffs	Current Tariffs	Liberation Day Tariffs
Landed Cost (USD)	$2,333,165,948.20	$2,675,864,226.20	$2,662,231,692.62
Logistics Cost (USD)	$26,835,992.30	$27,871,014.14	$19,401,418.18
Tariff Cost (USD)	$0.00	$4,657,703,990.00	$2,291,237,804.00
Ethics Score	4.34	3.96	4.05
Reliability Score	4.67	4.40	4.43
Sustainability Score	4.30	4.52	4.97

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