
# CRITICAL MINERAL FORECASTING PLATFORM

## Comprehensive Analysis Report for Import-Export Trade Forecasting

## Copper, Lithium, and Graphite

**Plutus Hackathon 2025**

**Presented by: Team PLEO**

**Submission Date: December 30, 2025**

## LIVE DASHBOARD ACCESS

| | |
|---|---|
| **Live URL** | https://mineral-forecasting-plutus.vercel.app/login |
| **Email** | judge@plutus.iitism.ac.in |
| **Password** | Plutus2025! |

## EXECUTIVE SUMMARY

This report presents a comprehensive analysis of India's critical mineral trade patterns for Copper, Lithium, and Graphite using real EXIM data from the DGCI&S; TradeStat portal covering fiscal years 2017-2025. The analysis identifies significant import dependencies and trade deficits that require strategic policy intervention.

### Key Highlights

| | |
|---|---|
| **Total Trade Records Analyzed** | 3,933 |
| **Time Period** | FY2017-18 to FY2024-25 |
| **Minerals Covered** | Copper, Lithium, Graphite |
| **Trading Partners** | 155 countries |
| **Cumulative Trade Deficit** | Approximately USD 36 Billion |

## KEY RESULTS AND FINDINGS

### Import Dependency Analysis (FY2024-25)

| Mineral | Import (USD M) | Export (USD M) | Deficit (USD M) | Dependency |
|---|---|---|---|---|
| Copper | 7,733 | 993 | -6,739 | 89% |
| Lithium | 384 | 109 | -275 | 78% |
| Graphite | 170 | 62 | -108 | 73% |

### Partner Concentration Risk (HHI)

| Mineral | HHI Score | Risk Level | Top Partner |
|---|---|---|---|
| Graphite | 0.52 | Critical | China (48%) |
| Lithium | 0.31 | High | Chile (35%) |
| Copper | 0.18 | Moderate | Indonesia (22%) |

## State-wise Domestic Production

### Copper Production (47,500 MT/year)

| State | Production (MT) | National Share |
|---|---|---|
| Rajasthan | 33,950 | 71.5% |
| Jharkhand | 9,950 | 21.0% |
| Madhya Pradesh | 3,600 | 7.5% |

### Graphite Production (604,500 MT/year)

| State | Production (MT) | National Share |
|---|---|---|
| Tamil Nadu | 325,000 | 53.8% |
| Jharkhand | 180,000 | 29.8% |
| Odisha | 99,500 | 16.5% |

### Lithium

Current Production: 0 MT (100% import dependent)

Discovered Reserves: 5.9 MT in Jammu & Kashmir (Reasi district)

Expected Mining Commencement: FY2026-27

# ML MODEL PERFORMANCE COMPARISON

## Models Implemented

| Model | Description | Approach |
|---|---|---|
| ARIMA | Auto-regressive Integrated Moving Average | Classical time series |
| LSTM | Long Short-Term Memory Neural Network | Deep learning |
| Hybrid | ARIMA base + LSTM residual correction | Ensemble method |

## Performance Metrics

| Model | MAE | MAPE | RMSE | R-Squared |
|---|---|---|---|---|
| ARIMA | 12.5 | 4.2% | 18.3 | 0.89 |
| LSTM | 10.8 | 3.8% | 15.6 | 0.91 |
| **Hybrid (RECOMMENDED)** | **9.2** | **3.2%** | **13.4** | **0.94** |

## Model Selection Rationale

The Hybrid ARIMA-LSTM model is recommended because: (1) Lowest error metrics across all measures, (2) Captures both linear trends (ARIMA) and non-linear patterns (LSTM), (3) Best handles structural breaks such as COVID-19 impact, (4) R-squared of 0.94 indicates excellent fit to historical data.

## FORECAST RESULTS (FY2025-26)

### Copper Import Forecast

| Parameter | Value |
|---|---|
| Annual Forecast | USD 7.92 Billion |
| Confidence Interval (90%) | +/- USD 0.8 Billion |
| Year-over-Year Change | +2.4% |
| Model Used | Hybrid ARIMA-LSTM |

### Lithium Import Forecast

| Parameter | Value |
|---|---|
| Annual Forecast | USD 425 Million |
| Confidence Interval (90%) | +/- USD 45 Million |
| Year-over-Year Change | +10.7% |
| Model Used | Hybrid ARIMA-LSTM |

### Graphite Import Forecast

| Parameter | Value |
|---|---|
| Annual Forecast | USD 178 Million |
| Confidence Interval (90%) | +/- USD 20 Million |
| Year-over-Year Change | +4.7% |
| Model Used | Hybrid ARIMA-LSTM |

## ANOVA STATISTICAL ANALYSIS

### Cross-Mineral Comparison

| Statistic | Value |
|---|---|
| F-statistic | 45.67 |
| P-value | < 0.001 |
| Conclusion | Statistically significant differences in import patterns |

## DATA SOURCES

| Source | Data Type | Records | Period |
|---|---|---|---|
| DGCI&S TradeStat | EXIM Trade Data | 3,933 | FY2017-2025 |
| Indian Bureau of Mines | Production Data | 24 | FY2017-2024 |
| USGS | Global Estimates | - | 2023 |
| Geological Survey of India | Reserves Data | - | 2023 |

## STRATEGIC RECOMMENDATIONS

### Immediate Actions (0-12 months)

1. Establish 3-month strategic copper reserves
2. Sign Free Trade Agreement with Chile for preferential lithium access
3. Implement 10% Production Linked Incentive for domestic graphite processing

### Medium-term Actions (1-3 years)

1. Fast-track Jammu & Kashmir lithium mining permits
2. Develop recycling infrastructure with target of 15% recovery
3. Expand Rajasthan copper production capacity by 50%

### Long-term Actions (3-5 years)

1. Achieve 50% reduction in import dependency
2. Establish domestic battery-grade lithium processing capability
3. Build strategic mineral reserves equivalent to 6-month supply

## RESOURCES FOR JUDGES

| Resource | Link |
|---|---|
| Judges Repository | https://github.com/hkj13/mineral-forecasting-judges |
| Jupyter Notebook | notebooks/mineral_forecasting_models.ipynb |
| Processed Data | data/processed/*.csv |
| Full Report | reports/FINAL_SUBMISSION_REPORT_FORMAL.md |