



# Insufficient supply of cross-cutting materials for batteries applications – The neglected serious risk to the carbon neutrality goal

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# Introduction

Disturbances to the supply of cross-cutting materials (i.e. copper and aluminum) which play imperative roles in EVs and energy storage systems.

**Copper** usage: Mostly in wires and as collector foil at anode

**Aluminum** usage: Battery packaging

## The source of supply risks:

- Geographical distribution;
- Environmental, social, and governance (ESG) complexities;
- Geopolitical issues;
- Techno-economic limitations;
- The timeline from mineral discovery to mining production initiation;
- Decreasing quality of ores;
- Limitations in creating a completely closed loop for materials.

## Examples

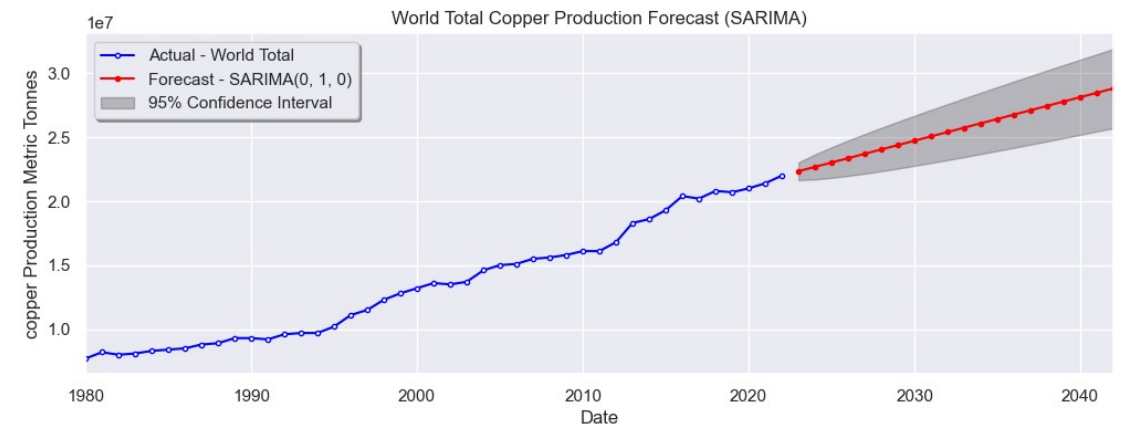
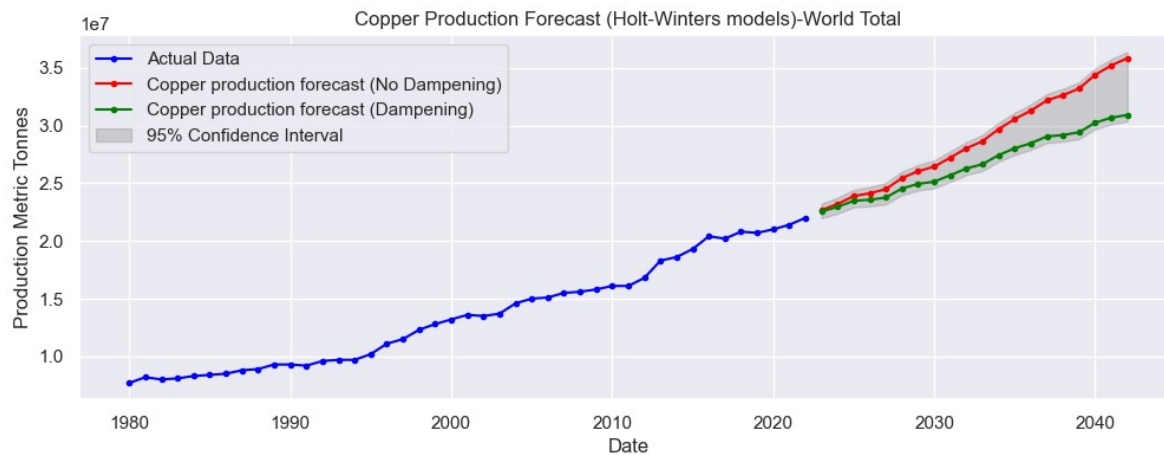
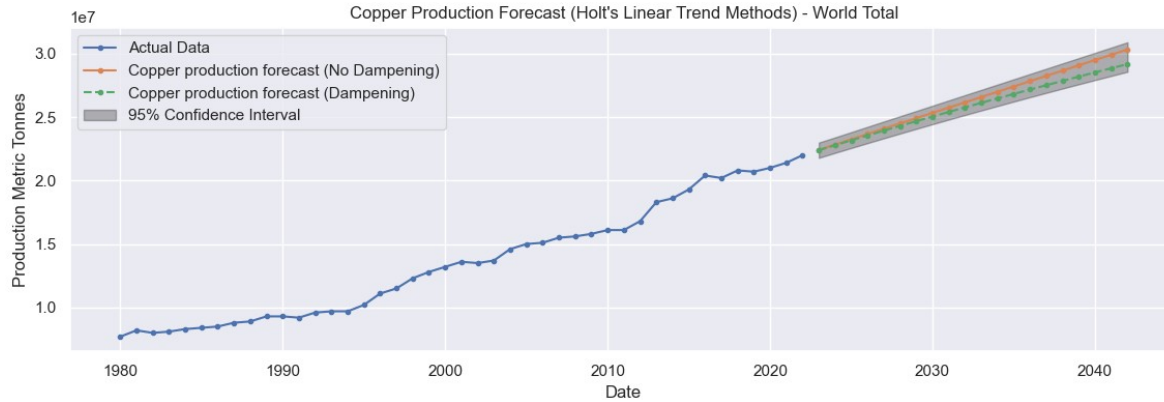
- ✓ Lower ore grades, strikes, and weather-related disruptions resulted in declined **copper** production in Chile in 2019.
- ✓ Shutdowns of powerplants complying with environmental regulations, and high coal prices giving rise to increased **aluminum** prices in China in 2021.

# Methodology

1. Evaluation of the historical mine production of copper and primary aluminum production, and the **challenges disrupting their supply sustainability**.
  - Collecting the data on yearly production of these elements from 1980 to 2022 in different countries using British Geological Survey (BGS) and United States Geological Survey (USGS) databases.
2. Forecasting the future production of these elements which is one of the main prerequisites to **anticipate the dynamics of energy supply security**.
  - Forecast models: Seasonal auto regressive integrated moving average (SARIMA), Holt's linear trend, Holt-winters methods in Python environment.
    - Modeling strategy:
      1. Verification step to find the model parameters fitting the data.
      2. Validation evaluation using in-sample forecasting technique.
      3. Doing the forecasts for the next 20 years.

# Results

## Copper production forecasts

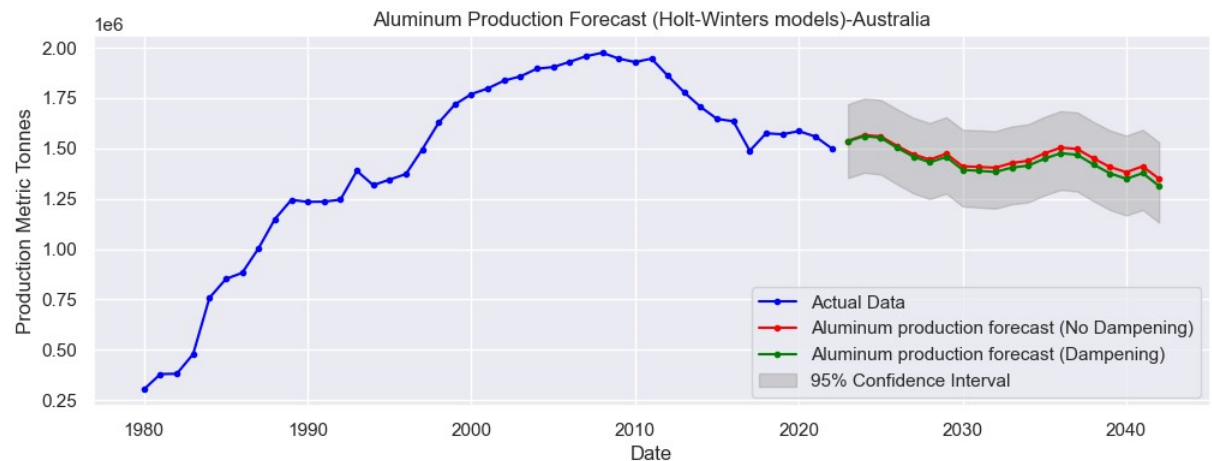
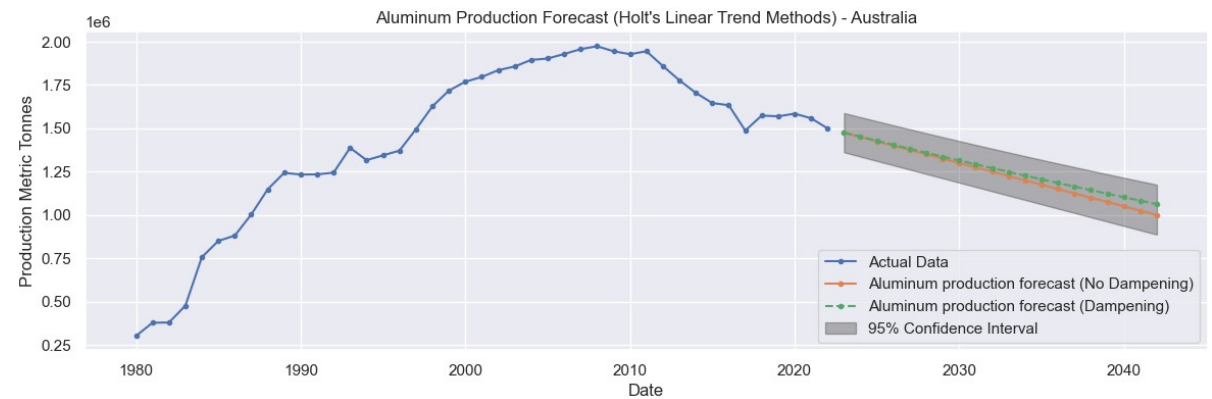
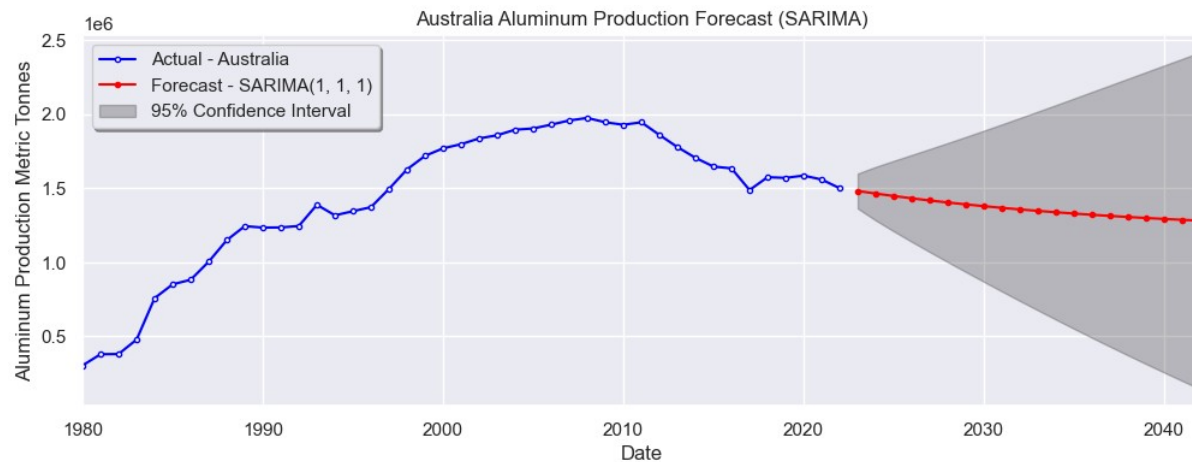


The list of considered countries

Country	Compound annual growth rate
Chile	3,84%
Peru	4,36%
China	5,99%
DRC	3,78%
USA	0,23%
Australia	2,96%
Russia	2,15%
Zambia	0,56%
Indonesia	6,76%
Mexico	3,49%
Canada	-0,71%
Kazakhstan	1,93%
Poland	0,31%
Sweden	1,75%
World total	2,53%

# Results

## Aluminum production forecasts



The list of considered countries

Country	Compound annual growth rate
China	11,94%
Russia	1,48%
India	7,60%
Canada	2,49%
UAE	10,90%
Australia	3,88%
Norway	1,83%
Bahrain	6,24%
USA	-3,94%
Iceland	5,70%
World total	3,53%

# Discussion

Comparing the accuracy and reliability of the various fitted models to the different datasets.

	SARIMA	Multiplicative Holt-Winters	Holt's Linear Trend
Al (Australia)	Evaluation metrics: Root mean squared error (RMSE): 70 000 Mean absolute error (MAE): 57 000	Evaluation metrics: RMSE: 90 000 MAE: 70 000  Evaluation metrics for damped trend: RMSE: 116 000 MAE: 91 000	Evaluation metrics: RMSE: 271 000 MAE: 258 000  Evaluation metrics for damped trend: RMSE: 322 000 MAE: 305 000
	SARIMA	Holt's Linear Trend	Multiplicative Holt-Winter
Cu (World total)	Evaluation metrics: RMSE: 675 000 MAE: 569 000	Evaluation metrics: RMSE: 1 696 000 MAE: 1 662 000  Evaluation metrics for damped trend: RMSE: 1 845 000 MAE: 1 804 000	Evaluation metrics: RMSE: 1 860 000 MAE: 1 786 000  Evaluation metrics for damped trend: RMSE: 1 171 000 MAE: 1 011 000

-  High accuracy
-  Medium accuracy
-  Low accuracy
-  Showing the positive or negative effects of using dampening parameter on the accuracy of Holt's models

# Outlook



By coupling the results from this paper with **future planned studies**, a comprehensive framework can be developed as a guideline for scenario definition.

## **In the framework to be developed:**

1. The repercussions of the current approaches to the mineral supply chains should be evaluated;
2. Environmental, social, political, and economic objectives should be considered; and
3. Regulatory systems to support the value chains without jeopardizing sustainable development goals should be analyzed

**To manage the often difficult trades-off between various dimensions of sustainability at the local and international levels in the whole value chains of critical raw materials.**

Thank you for  
attending!

FORMAS



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