BSAN7208 Visual Analytics Assignment 2:
Data-Driven Insights for Sustainable Investment in Australian Critical Minerals

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Export Finance Australia

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Contents

1. Executive Summary

Export Finance Australia (EFA) is managing a $1 billion expansion of the Critical Minerals Facility (CMF), announced in April 2025. The funding is aimed at growing Australia's critical minerals sector and expanding downstream processing to meet global demand while creating jobs and supporting the clean energy transition.[1] Strategic allocation of these expanded CMF funds relate to UN Sustainable Development Goals 7 (affordable clean energy), 9 (industry and infrastructure), and 13 (climate action) by financing projects that improve supply chain resilience for renewable technologies.

This report employs interactive data visualisations to analyse Australia's critical minerals sector across four dimensions: export dynamics, geographic concentration, global competitive position, and environmental risks. I analysed datasets from the Department of Industry, Science and Resources (Resources and Energy Quarterly 2025); Geoscience Australia (Operating Mines 2024); the Energy Institute (Global Lithium Production); and DCCEEW (CAPAD 2024 protected areas). Interactive features – including filtering, tooltips, and spatial querying – enabled exploratory analysis revealing insights obscured in static representations.

Key Findings:

Lithium dominance but downstream gaps. Australia produces 35% of global lithium as of 2024, overtaking Chile in 2014. Lithium export values exceeded nickel for the first time in 2021, marking a major shift in Australia's mineral exports. However, most of this is raw spodumene concentrate shipped to China for processing, creating strategic dependency.

Geographic concentration in Western Australia. Spatial mapping with zoom functionality showed that Western Australia hosts most lithium and nickel operations by production volume. REE production is spread across Queensland, New South Wales, and Western Australia but at much smaller scales, representing an opportunity for growth.

ESG risks could affect market access. Overlaying mine locations with CAPAD protected areas revealed notable spatial overlap in Western Australia, raising concerns about biodiversity and Indigenous land rights. Interactive querying identified specific sites where mining encroaches on conservation zones. If not addressed, these ESG risks could damage Australia's credibility with international partners who are implementing stricter sustainable sourcing requirements.

Recommendations for $1 Billion CMF Expansion Allocation:

1. **Support REE scaling across multiple states:** Provide offtake agreements for geographically distributed REE projects to create alternatives to Chinese processing dominance. **Recommended allocation:** 30% or A$300 million.
2. **Invest in downstream processing:** Require domestic refining in offtake agreements to capture higher-value lithium hydroxide and carbonate production. **Recommended allocation:** 30% or A$300 million.
3. **Prioritise Western Australian infrastructure:** Build on existing production clusters by funding shared processing facilities, ports, and logistics. **Recommended allocation:** 25% or A$250 million.
4. **Embed ESG safeguards:** Make biodiversity assessments, Free Prior and Informed Consent protocols, and independent verification mandatory for CMF expansion, with better terms for projects demonstrating strong ESG outcomes. **Recommended allocation:** 15% or A$150 million.

These recommendations aim to position Australia as a responsible, higher-value critical minerals supplier whilst reducing risks that could undermine long-term market access and partnerships with Japan, South Korea, the EU, and the United States.

[1] Prime Minister and Cabinet 2025, 'Albanese Government to establish critical minerals strategic reserve', Australian Government, Canberra, 24 April, viewed 18 October 2025, https://anthonyalbanese.com.au/media-centre/albanese-government-to-establish-critical-minerals-strategic-reserve.

2. Introduction & Purpose

In April 2025, the Albanese Government announced a $1 billion expansion of the Critical Minerals Facility (CMF),[2] bringing total CMF capacity to $5 billion. Distributed over four years (2025-2029), this expansion enables Export Finance Australia (EFA) to provide additional concessional loans, guarantees, and equity investments to critical minerals projects aligned with Australia's Critical Minerals Strategy 2023-2030.[3] EFA is evaluating how to strategically allocate this expanded capacity to enhance supply chain resilience while supporting Australia's clean energy transition commitments.

The objectives and scope of the CMF correspond to several United Nations Sustainable Development Goals (SDGs): [4]

- SDG 7 (Affordable and Clean Energy) by ensuring stable supply of lithium, rare earths, and nickel needed for renewable technologies;
- SDG 9 (Industry, Innovation and Infrastructure) through financing of refineries, separation plants, and processing facilities that expand Australia's downstream industrial capacity; and
- SDG 13 (Climate Action) by diversifying global supply chains to accelerate decarbonisation, whilst requiring careful management of local environmental and social risks, including biodiversity impacts and Indigenous land rights.

Problem Statement: How should EFA strategically allocate its $1 billion CMF expansion to maximise Australia's contribution to global critical minerals supply chains whilst mitigating environmental and social risks?

This report employs interactive data visualisations to analyse Australia's critical minerals sector, addressing three core questions:

a) Which critical minerals should be prioritised to strengthen Australia's role in global clean energy supply chains?

b) How should funding be allocated across mining, processing, and infrastructure to maximise long-term value creation?

c) What environmental and social risks may constrain expansion of critical minerals mining, and how should these be addressed?

By addressing these questions, the report aims to support EFA's investment decision-making in a manner consistent with national interests, partner expectations, and the United Nations SDGs.

I have analysed four authoritative public datasets, detailed further in Section 5 ('Data Sourcing & Preparation'):

a) Resources and Energy Quarterly (June 2025 historical data), from the Australian Department of Industry, Science and Resources (DISR);

b) Australian Operating Mines (2024), from Geoscience Australia (GA);

c) Statistical Review of World Energy (2025), Lithium Production dataset, from the Energy Institute; and

d) Collaborative Australian Protected Areas Database (CAPAD) (2024), from the Department of Climate Change, Energy, the Environment and Water (DCCEEW).

3. Analysis & Findings

In this section I evaluate Australia's position in the global critical minerals supply chain by analysing domestic and international production volumes, export values, geographic distribution of mines, and potential social and environmental risks. The focus is on lithium (spodumene), nickel, and rare earth elements (REEs) – all of which

[2] Prime Minister and Cabinet 2025, 'Albanese Government to establish critical minerals strategic reserve', Australian Government, Canberra, 24 April, viewed 18 October 2025, https://anthonyalbanese.com.au/media-centre/albanese-government-to-establish-critical-minerals-strategic-reserve

[3] Department of Industry, Science and Resources (DISR) 2023, Australia's Critical Minerals Strategy 2023-2030, Australian Government, Canberra, viewed 18 October 2025, https://www.industry.gov.au/sites/default/files/2023-06/critical-minerals-strategy-2023-2030.pdf.

[4] United Nations 2015, Transforming our world: the 2030 Agenda for Sustainable Development, United Nations General Assembly, New York.

are designated as critical minerals for the renewable energy transition under the Australian Government's Critical Minerals List.

I added interactivity to the visualisations labelled **Figures 1**, **2**, **4** and **5**. Readers can access these interactive features by running the R code provided in Appendix B of this report. The accompanying video presentation also demonstrates these interactive features.

3.1 Export dynamics

Figure 1 illustrates the rapid rise of lithium exports since 2011 through a time series with added interactivity that supports commodity filtering and tooltip information. While nickel exports have historically dominated by volume, interactive isolation reveals lithium has experienced exponential growth in the past decade, reflecting surging demand from the global electric vehicle and battery sectors.

Figure 2 further underscores this shift in economic importance. For decades, nickel generated greater export revenues than lithium. However, leveraging the interactive features of this chart by hovering over the 2021-2022 period reveals that lithium revenues overtook nickel for the first time in 2022, remaining at elevated levels despite some volatility. This sharp inflection point aligns with global price spikes in lithium carbonate and spodumene, demonstrating Australia's growing leverage in energy transition supply chains

Fig 1: Australian Lithium and Nickel Export Volumes (1990-2024)

Lithium exports surge by 7.6x from 2016 to 2024

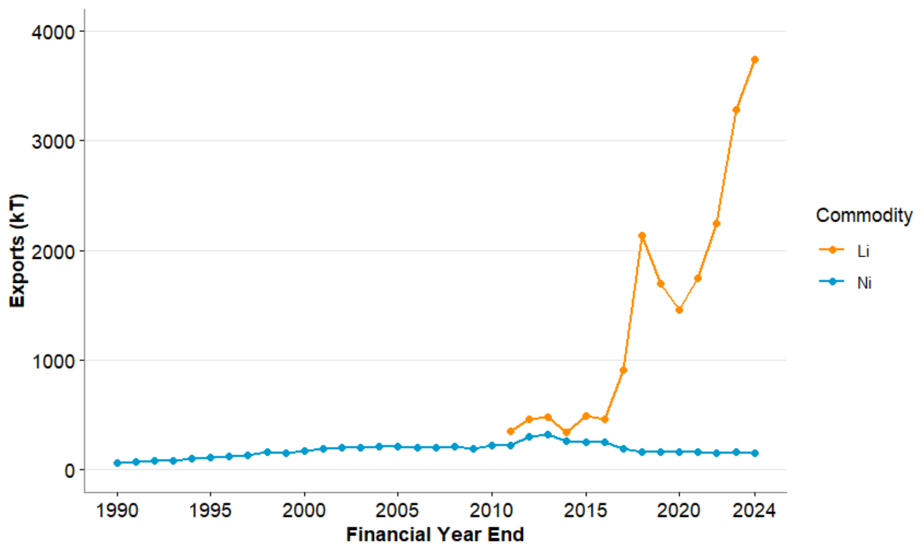
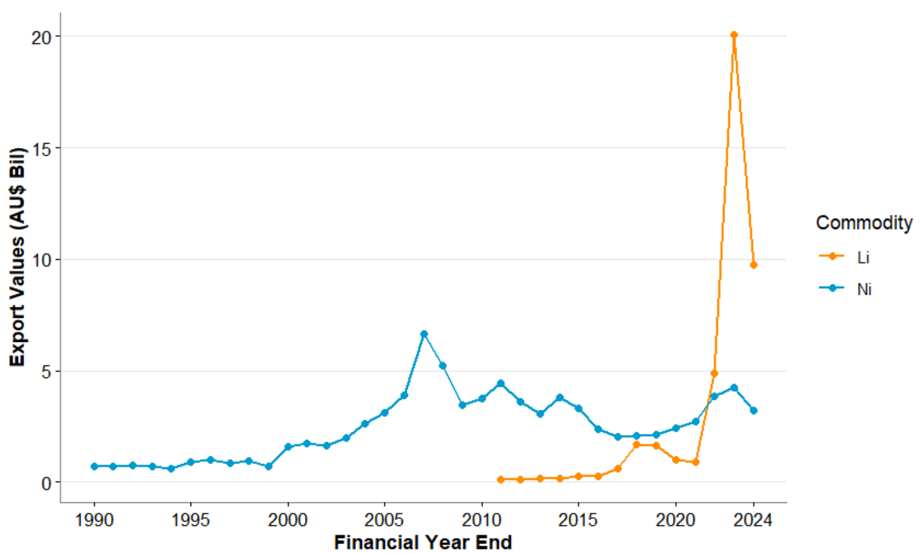


Fig 2: Australian Annual Export Values (FOB), Lithium and Nickel (1990-2024)

Lithium export values overtake Nickel in 2021, remaining at elevated levels into 2024

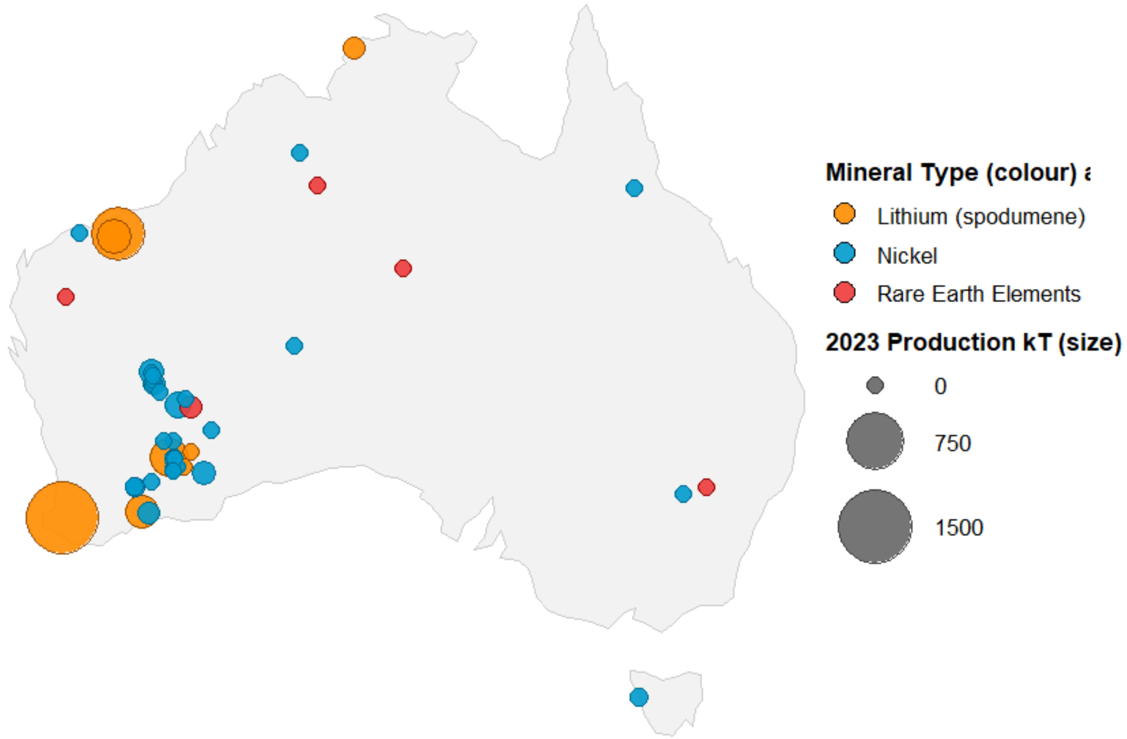


3.2 Geographic concentration

Figure 3 maps operational mines across Australia producing lithium, nickel, and REEs, scaled by 2023 production volumes. Pan and zoom interactions enable detailed examination of Western Australia's mining clusters, which reveal the State as the dominant hub for all three minerals, hosting the largest spodumene and nickel operations. Tooltips revealed by hovering over mine locations enables drilling down to learn precise production figures and mine name.

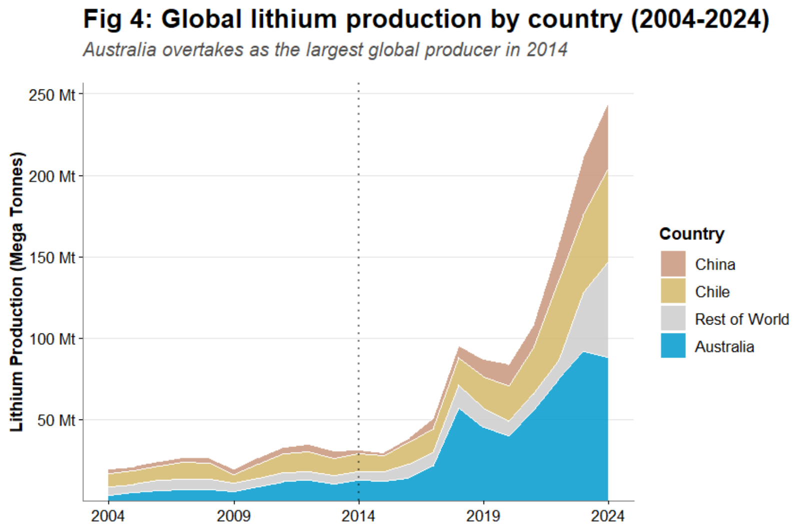
In contrast, REE production is more geographically dispersed, with smaller-scale operations in Queensland and New South Wales. Importantly, government policy anticipates significant scaling of REE extraction and separation capacity over the coming decade (DISR Critical Minerals Strategy 2023), positioning Australia to reduce reliance on China's near monopoly in this segment.

Fig 3: Australian Mines Producing Select Critical Minerals (2023)



3.3 Australia's role in the global lithium supply chain

Figure 4 tracks global lithium production by country from 2004 to 2024 using a stacked area chart. The visualisation reveals Australia's rapid ascent as the dominant global producer. Around 2014, Australian production began accelerating sharply, overtaking Chile in the same year to become the world's largest supplier and continuing to increase its global share. By 2024, Australia accounts for 88 mega tonnes. This amounts to 37.5% of global output, driven primarily by Western Australia's hard rock spodumene operations highlighted in the previous **Figure 3**.

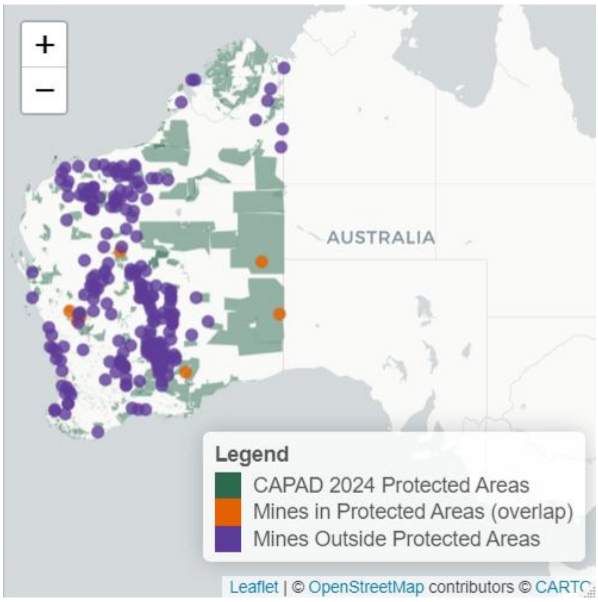


3.4 Environmental and social risks

Figure 5 overlays the location of operational mines in Western Australia with designated protected areas under CAPAD 2024 using an interactive map interface. Zoom and pan interactions enable detailed inspection of specific overlap regions. Hover-over tooltips allow the viewer to identify the mine, the minerals produced, and the protected zone and type, providing detailed insights about the nature and degree of ESG risks at each location. The analysis shows minor overlap between mining activity and ecologically sensitive zones at 8 different locations, raising concerns about biodiversity loss, water stress, and land-use conflict.

Expansion of critical minerals mining to meet export targets is therefore directly linked to ESG risks, including potential impacts on Indigenous land rights and conservation areas. These risks, if unmanaged, could undermine the credibility of Australia's critical minerals strategy in the eyes of international partners such as Japan and the EU, where sustainable sourcing requirements are tightening.

Fig 5: Mines in WA and Protected Areas Overlap



4. Recommendations

The analysis highlights both the scale of opportunity for Australia in the global clean energy transition and the risks that may undermine this position if left unaddressed. On this basis, the following recommendations are proposed for allocation of the A$1 billion CMF expansion:

4.1 Support scaling of rare earths across multiple states

Figure 3 demonstrates that REE production remains geographically dispersed and significantly smaller in scale compared to lithium and nickel operations. While Western Australia dominates lithium extraction, REE deposits span multiple states yet lack the capital investment needed to reach competitive production volumes. This fragmentation leaves Australia producing only a minor fraction of global REE supply despite substantial reserves.

To unlock this potential, EFA should allocate approximately **30% of the CMF expansion (A$300 million)** towards regional infrastructure development, such as rail, energy, and ports, which enable scaling of REE extraction and processing in states beyond Western Australia. This allocation supports SDG 9 (Industry, Innovation and Infrastructure) by developing regional processing capabilities and reducing dependence on foreign supply chains.

4.2 Invest in downstream processing and onshoring

Figures 1 and **2** together highlight Australia's performance in minerals exports, demonstrating its strong mining capability. **Figure 4** reveals its dominance in primary lithium production. However these advantages do not extend to refined products required for battery manufacturing. The current export model centers on low value spodumene concentrates shipped to China for processing into the actual inputs for battery cells. This structural dependency exposes Australia to supply chain disruption risks while forfeiting the substantial value-addition that occurs downstream. Capturing greater value requires moving beyond extraction.

EFA should allocate approximately **30% of CMF expansion (A$300 million)** to downstream processing infrastructure, with priority given to lithium, nickel, and REE. This investment advances SDG 7 (Affordable and Clean Energy) and SDG 9 (Industry and Infrastructure) by enhancing local infrastructure that ensures a reliable supply of materials essential for the renewable energy transition.

4.3 Prioritise infrastructure in Western Australia as the critical hub

Figures 1, **3**, and **4** collectively establish Western Australia's dominance across the critical minerals value chain. The state hosts Australia's largest lithium and nickel operations and accounts for the majority of production driving the country's 35% share of global lithium output.

Given the concentration of critical minerals in WA, EFA should allocate approximately **25% of CMF expansion (A$250 million)** to mine-adjacent infrastructure in the state including roads, ports, renewable power connections, and logistics. This promotes an economies of scale for shared infrastructure at the same time as it increases export efficiency and competitiveness, thereby supporting SDG 9 (Industry, Innovation and Infrastructure).

4.4 Embed ESG safeguards in all funded projects

Figure 5 highlights areas of overlap between mining operations and protected zones, indicating that further expansion of critical minerals extraction may intensify pressure on ecologically sensitive zones and Indigenous lands.

To align with SDG 13 (climate action) and broader ESG commitments, EFA should make funding conditional on environmental and social risk management. This includes prioritising projects located at safe distances from ecologically sensitive areas, supporting biodiversity offsets, and ensuring meaningful consultation with Indigenous communities.

Recent research underscores the importance of robust geospatial ESG mapping for decision-making in mining (Lebre & Owen, 2025). A dedicated funding stream of approximately **15% of CMF (A$150 million)** should therefore be earmarked not only for ESG monitoring and rehabilitation but also for advancing data-driven mapping approaches that improve accountability over time.

5. Data Sourcing & Preparation

5.1 Data sources

This report draws upon four authoritative public datasets:

#	Source	Data set	Format	Details
1	Department of Industry, Science and Resources (DISR)	Resources and Energy Quarterly (June 2025, historical data)	.xslx, multiple worksheets	Quarterly report detailing historical and forecast data on Australia's major resource and energy commodities (production, exports, prices). Available at: https://www.industry.gov.au/publications/resources-and-energy-quarterly-june-2025 (accessed 18 October 2025).
2	Energy Institute (with major processing by Our World in Data)	Statistical Review of World Energy (2025) – Lithium Production dataset	.csv	Global dataset showing annual lithium production by country from 1995–2024. Available at: https://ourworldindata.org/grapher/lithium-production (accessed 18 October 2025).
3	Geoscience Australia (GA)	Australian Operating Mines 2024	.csv	Geoscience Australia dataset mapping mine locations, commodities, and operational status across Australia as of Dec 2024. Available at: https://ecat.ga.gov.au/geonetwork/srv/api/records/0227d2c4-1d78-4aaa-87af-f43b981b520b (accessed 18 October 2025)
4	Department of Climate Change, Energy, the Environment and Water (DCCEEW)	Collaborative Australian Protected Areas Database (CAPAD) 2024	.shp .json	National GIS database of terrestrial and marine protected areas (to 30 Jun 2024) with area, category, and management attributes. Available at: https://fed.dcceew.gov.au/datasets/ec356a872d8048459fe78fc80213dc70_0/ (18 October 2025).

5.2 Data selection rationale

The datasets were selected because they provide policy-relevant coverage of Australia's critical minerals sector from a range of authoritative sources, capturing long-run export dynamics (#1), Australia's position in the global critical minerals production context (#4), mine-level production and location (#3), and biodiversity sensitivities (#4). I consider the datasets to be authoritative and policy-relevant because they have been compiled and published by the government bodies responsible for monitoring and policy development in the domains under study. The datasets together enable both economic and ESG analysis to underpin investment recommendations.

5.3 Data preparation & transformation

The datasets were sourced in a range of formats as shown in the above table 5.1.

While the .csv were the most familiar to work with, these still required operations R to clean, harmonise and merge the data before they could be utilised for analysis and visualisation.

.xlsx files were also familiar to work with; however, for example, dataset #1 contained relevant data for this report across multiple worksheets in the same file. These required time-intensive processing, selection, and filtering in Excel before they could be imported into Rstudio for further cleaning and harmonisation; packages like **readxl** were leveraged for this purpose.

The geographic data files, particularly the CAPAD datasets (#4), were the most challenging to work with. These included large files of over 20MB that I imported and processed in Rstudio using packages like **sf** (for spatial data reading, transformation, and overlay), and **dplyr** (for data manipulation and joining operations). I opted to focus on State-level data in order to lighten the data volume to facilitate processing and simplify overlay operations.

Adding interactive features to the visualisations presented additional challenges. Converting static ggplot2 visualisations to interactive versions using Plotly introduced several technical issues. The interactive versions did not render identically to their static counterparts – for example, **Figure 4**'s dual legend for country groupings was removed in the Plotly conversion, and subtitles disappeared entirely, requiring manual workaround code to restore them.

Adding tooltip functionality required modifying the original ggplot code by including aes mappings with the text parameter. Data preparation steps were changed to ensure tooltip information was properly formatted.

Rendering time increased substantially for interactive visualisations, particularly **Figure 5** (mines over CAPAD protected areas), which relied on large shapefile geometries exceeding 20MB. This spatial overlay required the sf package to process complex polygon data, resulting in load times of 15-20 seconds in the Shiny application compared to near-instantaneous rendering of static maps.

5.4 Data quality and limitations

Several data quality and comparability issues must be acknowledged.

a) The DISR export data only covers activity up to end-2024, omitting performance for 2025.
b) The GA mines dataset is comprehensive for major operations, but smaller or newly opened mines might not be included in the December 2024 version. Some production volumes for individual mines had to be estimated because the actual figures were kept confidential for commercial reasons.
c) Differences in data definitions and collection methods across sources add uncertainty to exact quantitative comparisons. In particular, categories such as "rare earth elements" are not always consistent across datasets.
d) Spatial accuracy also limits the ESG analysis. The mine-CAPAD overlays indicate proximity but not actual impact. A mine located just outside a protected zone may still cause emissions or degradation affecting nearby ecosystems or communities. True ESG verification requires field data and environmental assessments beyond this study's scope.

Overall, the findings provide strong directional insight for strategic planning but are not suited for detailed compliance assessment. Future work should integrate Indigenous Protected Area and emissions data, near-real-time export updates, and satellite monitoring to improve both temporal accuracy and environmental precision.

6. Statement on AI Usage

Artificial intelligence tools (Claude AI) were used selectively to support the development of this report. AI assistance was used to:

a) Debug R visualisation code to resolve rendering issues and other errors
b) Review and clarify theoretical concepts covered in this course
c) Assist in researching current government policy on the CMF and related initiatives
d) Proofing and streamlining report structure, grammar, and clarity of expression

All analysis, visualisation design, and written content represent my own work. All AI outputs were critically reviewed, edited for accuracy, and finalised by the author.

7. References

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Heer, J. & Shneiderman, B. 2012, 'Interactive dynamics for visual analysis: A taxonomy of tools that support the fluent and flexible use of visualisations', *Queue*, vol. 10, no. 2, pp. 30–55.

Lèbre, É, Owen, JR, Corder, GD & Kemp, D 2025, 'ESG mapping of the Australian mining sector: The state of play on mobilising spatial datasets for decision making', Energy Policy, vol. 190, 113017

Munzner, T. 2014, *Visualisation analysis and design*, CRC Press, Boca Raton, FL.

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Tufte, E.R. 2001, *The visual display of quantitative information*, 2nd edn, Graphics Press, Cheshire, CT.

Ware, C. 2020, *Information visualisation: Perception for design*, 4th edn, Morgan Kaufmann, Cambridge, MA.

Appendix A: Design evaluation for new & updated visualisations

A.1 New Visualisation – Global Lithium Production (Figure 4)

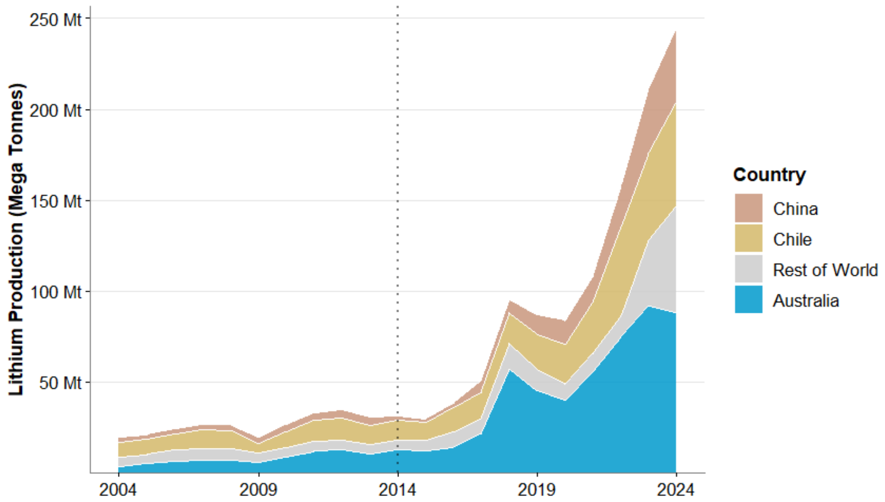
Building on Assessment 1, I incorporated a global lithium production dataset from the Energy Institute to contextualise Australia's competitive position. The visualisation (**Figure 4**) employs a stacked area chart constructed using ggplot2's grammar of graphics:

- **Data:** Annual lithium production volumes (mega tonnes) by country, 2004-2024
- **Layers:** geom_area() with white strokes for visual separation between countries; geom_vline() for annotation marking Australia's overtake point
- **Scales:** Continuous y-axis (production volume); temporal x-axis (years); categorical colour scale for countries
- **Coordinates:** default system with standard aspect ratio
- **Facets:** None (single panel all countries)

I chose a stacked chart as it follows Munzner's (2014) principle of using area marks for part-to-whole relationships, enabling users to assess both country trajectories and aggregate growth simultaneously. The colour scheme saturates Australia in high saturation light blue while muting other producers in beige and grey tones, applying Ware's (2020) principle that saturated colours attract visual attention to analytically significant data.

Fig 4: Global lithium production by country (2004-2024)

Australia overtakes as the largest global producer in 2014



A.2 Updates to Existing Visualisations

I revised Assessment 1 visualisations based on principles from Tufte, Munzner, Few, and Ware, focusing on perceptual effectiveness and information density.

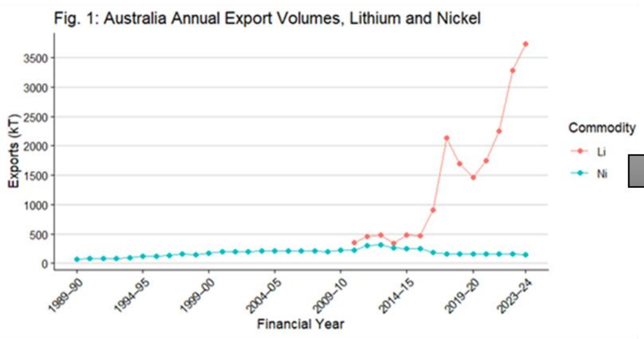
Colour accessibility improvements: I replaced the original blue-red-green palette in **Figures 1**, **2** and **5** with blue-red-orange, improving accessibility for colourblind users (approximately 8% of males). Ware (2020) demonstrates this combination maintains perceptual separation across common colour vision deficiencies. In **Figure 5**, I encoded mines overlapping protected areas in orange while keeping non-overlapping mines purple, using colour as a "selective attention" cue to highlight risk zones (Ware, 2020).

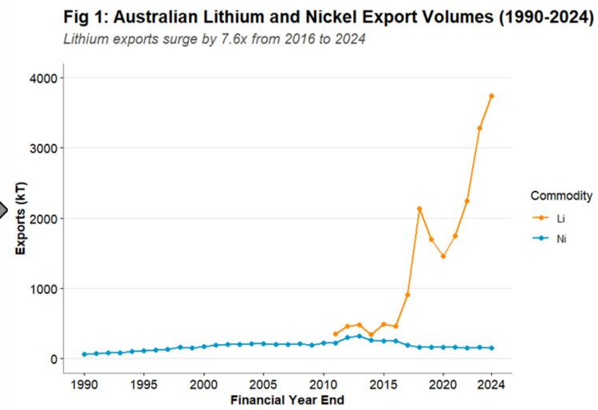
Subtitles highlighting key insights: I added italicised subtitles to figures (e.g., "Lithium exports surge by 7.6 times from 2016 to 2024" in **Figure 1**), following Few's (2012) guidance that titles should communicate findings rather than merely label content. This reduces cognitive load by directing readers to the primary analytical message before they parse the details.

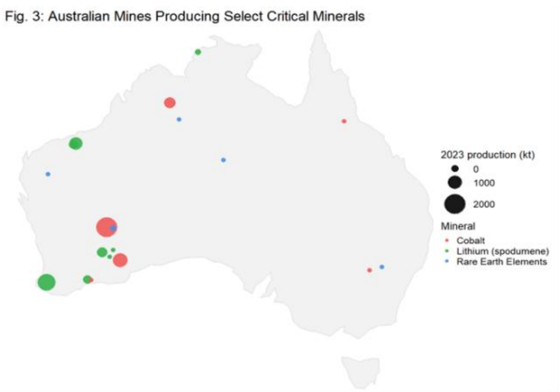
Annotations for significant data events: In **Figure 4**, I added a dotted vertical line at 2014 marking when Australia overtook Chile as the world's largest lithium producer. Tufte (2001) advocates direct annotation of significant data events to guide interpretation and eliminate ambiguity about what the visualisation is trying to show.

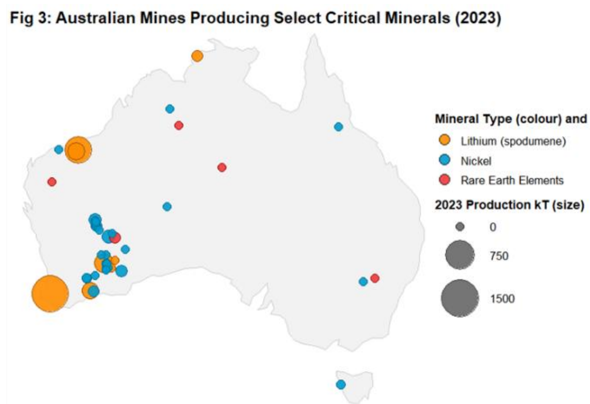
Data-ink ratio optimisation: I applied Tufte's principle of data-ink maximisation by eliminating redundant chart elements. In **Figures 1** and **2**, I simplified fiscal year labels (“1989-90” simplified to “1990” with y-axis explanation), and lightened y-axis tick marks from every 500 kT to every 1,000 kT. I thereby removed visual clutter and achieved significant ink savings. I also lightened gridlines to 20% opacity so they provide reference without competing with data encodings (Few, 2012).

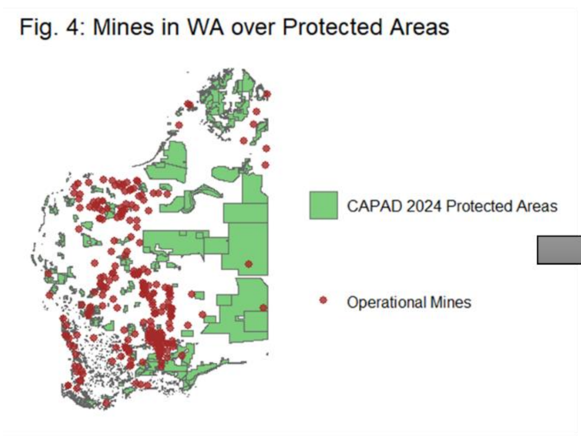
Original A1 visualisations | **Updated A2 visualisations**

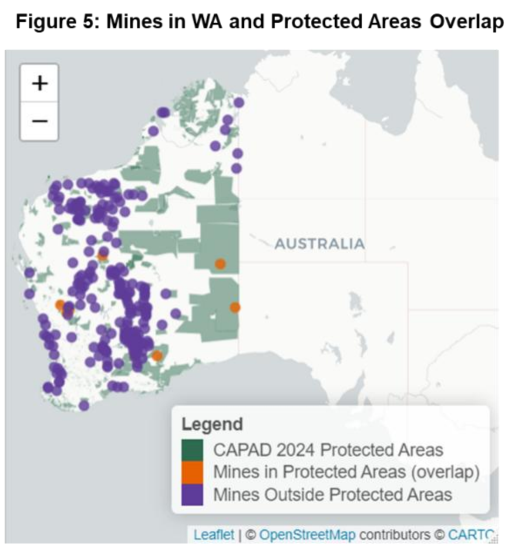












A.3 Interactive features

I implemented interactive capabilities using Shiny and Plotly, guided by Heer and Shneiderman's (2012) taxonomy of interaction techniques:

- **Figures 3 and 5 (mine location maps):** Pan and zoom interactions enable precise identification of spatial overlaps between mines and CAPAD zones that remain ambiguous in static views. Zooming reveals mine clustering patterns in Western Australia, with granularity impossible in fixed-scale maps. Tooltips implement "details-on-demand", allowing users to query specific mines for commodity type, production volume, and protected area category without cluttering the visualisation.

- **Figures 1 and 2 (time series):** Filtering and tooltip selection allow users to isolate individual commodities, revealing trends obscured in aggregate views. This implements Munzner's (2014) "reduce" operator, enabling focused analysis of specific data subsets while maintaining context through retained visual structure.

These design revisions address the Assessment 1 feedback requirement for academic justification of visualisation choices while demonstrating how interactive features facilitate exploratory analysis beyond static chart capabilities.

A.4 Visualisation critiques

I improved the visualisations from Assessment 1 based on established design principles. However, best practices in data visualisation can vary widely depending on context and analytical purpose, and there are many competing theoretical frameworks. Consequently, the design choices made here represent one approach among several defensible alternatives, and room for critique remains.

Figures 1 and **2** (time series showing mineral export volumes and values) could have benefited from including additional critical minerals beyond lithium and nickel. However, data availability acted as a constraint. I applied four criteria for mineral selection: minerals must be critical to the renewable energy transition, sufficiently abundant in Australia to warrant study, have both export volume and value data available from DISR, and have continuous data coverage across the 1990-2024 time series. Few minerals beyond lithium and nickel met all four criteria simultaneously, leading me to focus the analysis on these two commodities rather than compromising data quality or temporal consistency.

Figure 3 (Australian critical minerals map) presented legibility challenges despite adding interactive pan and zoom functionality. Data points for Western Australian mines cluster in several regions, making individual sites difficult to distinguish even at higher zooms. Further work could implement clustering algorithms that improve visibility at lower zoom levels. This approach would be supported by the "overview first, zoom and filter, details-on-demand" approach (Heer and Shneidermann, 2012). An alternative would be to take the “small multiples” approach (Tufte, 2001), where maps are separated for each mineral type. However this would sacrifice direct spatial comparison, and add to the processing, memory, and storage demands on the hardware system.

Figure 4 (static, stacked area chart for global lithium production) would have benefited from interactive features, given the density of the dataset (Munzer, 2014). Temporal sliders for custom date ranges or filtering controls by country would enable deeper country-by-country comparisons and examination of narrow time periods of interest. However, implementing these features exceeded my technical capabilities with the current toolset. Dynamic filtering of stacked area charts requires the visualisation to automatically recalculate the axis and restack remaining countries when filters are on, which require advanced Shiny programming beyond the current scope. Future iterations could employ more sophisticated frameworks that provide greater control over dynamic chart reconstruction.

Appendix B: R Code

```
# ------------------ VIZ 1: MINERALS EXPORT VOLUMES ------------------ #
# Load required packages for plotting
install.packages("ggplot2")
library(ggplot2)
library(plotly)

# Create dual-line plot for Li and Ni export volumes with interactive tooltips
p1 <- ggplot(data = df, aes(x = FY_end)) +
  # Lithium line and points with hover text
  geom_line(aes(y = Li_xvol, color = "Li"), linewidth = 0.8, na.rm = TRUE) +
  geom_point(aes(y = Li_xvol, color = "Li",
               text = paste0("FY: ", FY, "\n", "Export Volume: ", round(Li_xvol, 1), " kT")),
            size = 1.5, na.rm = TRUE) +
  # Nickel line and points with hover text
  geom_line(aes(y = Ni_xvol, color = "Ni"), linewidth = 0.8, na.rm = TRUE) +
  geom_point(aes(y = Ni_xvol, color = "Ni",
               text = paste0("FY: ", FY, "\n", "Export Volume: ", round(Ni_xvol, 1), " kT")),
            size = 1.5, na.rm = TRUE) +
  labs(title = "Fig 1: Australian Lithium and Nickel Export Volumes (1990-2024)",
      subtitle = "Lithium exports surge by 7.6x from 2016 to 2024",
      x = "Financial Year End", y = "Exports (kT)", color = "Commodity") +
  theme_classic() +
  # Set x-axis breaks at 5-year intervals plus 2024
  scale_x_continuous(breaks = c(seq(1990, 2020, by = 5), 2024)) +
  scale_y_continuous(breaks = seq(0, 4000, by = 1000), limits = c(0, 4000)) +
  # Define custom colours for minerals
  scale_color_manual(values = c("Li" = "darkorange", "Ni" = "deepskyblue3")) +
  theme(plot.title = element_text(face = "bold", size = 15, hjust = 0),
       plot.subtitle = element_text(size = 12, color = "grey30", hjust = 0, margin = margin(b = 15), face =
"italic"),
       plot.caption = element_text(hjust = 0, color = "grey50", size = 9),
       axis.text = element_text(size = 11), axis.title = element_text(face = "bold", size = 11),
       axis.line = element_line(color = "grey50"),
       panel.grid.major.y = element_line(color = "grey90", linewidth = 0.5))
p1
# Convert to interactive plotly chart with custom tooltips
ggplotly(p1, tooltip = "text")

# ------------------ VIZ 2: MINERALS EXPORT VALUES ------------------  #
install.packages("ggplot2")
library(ggplot2)

# Create dual-line plot for Li and Ni export values (AU$ billions)
p2 <- ggplot(data = df, aes(x = FY_end)) +
  # Lithium export values
  geom_line(aes(y = Li_xval, color = "Li"), linewidth = 0.8, na.rm = TRUE) +
  geom_point(aes(y = Li_xval, color = "Li",
               text = paste0("FY: ", FY, "\n", "Export Value: $", round(Li_xval, 1), " Bil")),
            size = 1.5, na.rm = TRUE) +
  # Nickel export values
```

```
  geom_line(aes(y = Ni_xval, color = "Ni"), linewidth = 0.8, na.rm = TRUE) +
  geom_point(aes(y = Ni_xval, color = "Ni",
                 text = paste0("FY: ", FY, "\n", "Export Value: $", round(Ni_xval, 1), " Bil")),
             size = 1.5, na.rm = TRUE) +
  labs(title = "Fig 2: Australian Annual Export Values (FOB), Lithium and Nickel (1990-2024)",
       subtitle = "Lithium export values overtake Nickel in 2021, remaining at elevated levels into 2024",
       x = "Financial Year End", y = "Export Values (AU$ Bil)", color = "Commodity") +
  theme_classic() +
  # Dynamic y-axis based on max values in dataset
  scale_y_continuous(breaks = seq(0, max(df$Li_xval, df$Ni_xval, na.rm = TRUE), by = 5)) +
  scale_x_continuous(breaks = c(seq(1990, 2020, by = 5), 2024)) +
  scale_color_manual(values = c("Li" = "darkorange", "Ni" = "deepskyblue3")) +
  theme(plot.title = element_text(face = "bold", size = 13, hjust = 0),
        plot.subtitle = element_text(size = 12, color = "grey30", hjust = 0, margin = margin(b = 15), face =
"italic"),
        plot.caption = element_text(hjust = 0, color = "grey50", size = 9),
        axis.text = element_text(size = 10), axis.title = element_text(face = "bold", size = 11),
        axis.line = element_line(color = "grey50"),
        panel.grid.major.y = element_line(color = "grey90", linewidth = 0.5))
p2
ggplotly(p2, tooltip = "text")

# ------------------ VIZ 3: CRITICAL MINERALS INTERACTIVE MAP ------------------ #
# Load mine production data
library(readxl)
df7_updated <- read_excel("C:/Users/gemao/My Drive/05 Further Education & Learning/2024-25
UQ/BSAN7208 Visual Analytics/A1/Datasets/7-mines (ni updated).xlsx")
View(df7_updated)
# Load spatial and mapping libraries
library(ggplot2)
library(sf)
library(rnaturalearth)
library(rnaturalearthdata)
library(tidyverse)
library(plotly)

# Prepare mine data: format production values and rename REE
df8 <- df7_updated %>%
  mutate(Production_2023 = paste0(`2023 production (kT)`, ' kt'),
         Mineral = case_when(Mineral == 'REE' ~ 'Rare Earth Elements', TRUE ~ Mineral)) %>%
  arrange(desc(`2023 production (kT)`))

# Get Australia shapefile for map boundary
aus <- rnaturalearth::ne_countries(country = "australia", returnclass = "sf")

# Create spatial bubble map with mines sized by production volume
minesplot <- ggplot() +
  # Australia basemap
  geom_sf(data = aus, fill = "grey95", color = "grey80", linewidth = 0.4) +
  # Mine locations as points with size mapped to production
  geom_point(data = df8, aes(x = Longitude, y = Latitude, fill = Mineral, color = Mineral,
                             size = `2023 production (kT)`,
```

```r
                    text = paste0("Mine: ", Mine, "<br>", "Mineral: ", Mineral, "<br>",
                                  "Production: ", Production_2023, "<br>", "Status: ", Status)),
             shape = 20, stroke = 0.5, alpha = 0.5) +
  # Zoom to mainland Australia
  coord_sf(xlim = c(112, 154), ylim = c(-44, -10), expand = FALSE) +
  # Define mineral colour palette
  scale_fill_manual(name = "Mineral Type (colour) and",
                    values = c("Nickel" = "#0072B2", "Lithium (spodumene)" = "#E69F00",
                               "Rare Earth Elements" = "#2D9B7E")) +
  scale_color_manual(values = c("Nickel" = "#004D80", "Lithium (spodumene)" = "#CC7A00",
                                "Rare Earth Elements" = "#2D9B7E"), guide = "none") +
  # Size legend for production volumes
  scale_size_continuous(name = "2023 Production kT (size)", range = c(1, 12),
                        breaks = c(0, 500, 1000, 1500), labels = c("0", "500", "1000", "2000")) +
  guides(fill = guide_legend(override.aes = list(size = 4), order = 1),
         size = guide_legend(override.aes = list(fill = "grey40", color = "grey20"), order = 2)) +
  labs(title = "Fig 3: Australian Mines Producing Select Critical Minerals (2023)", x = NULL, y = NULL) +
  theme_void() +
  theme(plot.title = element_text(face = "bold", size = 14, hjust = 0),
        plot.subtitle = element_text(size = 12, color = "grey30", hjust = 0, margin = margin(b = 15)),
        plot.caption = element_text(hjust = 0, color = "grey50", size = 9),
        legend.title = element_text(face = "bold", size = 11),
        legend.text = element_text(size = 10))
ggplotly(minesplot, tooltip = "text")

# ------------------ VIZ 4: LITHIUM PRODUCTION AUS VS ROW ------------------ #
library(ggplot2)
library(tidyverse)
library(scales)

# Load global lithium production dataset
df_lithium <- read_csv("lithium-production.csv")
colnames(df_lithium) <- c("Country", "Code", "Year", "Production_kt")

# Filter to 2004-2024 and remove aggregate regions (keep only countries)
df_lithium <- df_lithium %>%
  filter(Year >= 2004 & Year <= 2024) %>%
  filter(!Country %in% c("World", "High-income countries", "Low-income countries",
                         "Lower-middle-income countries", "Upper-middle-income countries",
                         "Oceania", "Africa", "Asia", "Europe", "North America",
                         "South America", "Central America", "Middle East",
                         "European Union", "OECD Countries", "G20"))

# Calculate global production totals by year
global_totals <- df_lithium %>%
  group_by(Year) %>%
  summarise(Total = sum(Production_kt, na.rm = TRUE))

# Identify top 3 producing countries in most recent year
top_countries <- df_lithium %>%
  filter(Year == max(Year)) %>%
  arrange(desc(Production_kt)) %>%
```

```
  head(3) %>%
  pull(Country)
print("Top 3 lithium producing countries (latest year):")
print(top_countries)

# Group countries into Top 3 + Rest of World categories
df_area <- df_lithium %>%
  mutate(Country_Group = ifelse(Country %in% top_countries, Country, "Rest of World")) %>%
  group_by(Year, Country_Group) %>%
  summarise(Production_kt = sum(Production_kt, na.rm = TRUE), .groups = 'drop') %>%
  mutate(Production_Mt = Production_kt / 1000)  # Convert to megatonnes

# Order countries by peak production (for stacking order)
country_order <- df_area %>%
  group_by(Country_Group) %>%
  summarise(Max_Production = max(Production_Mt)) %>%
  arrange(desc(Max_Production)) %>%
  pull(Country_Group)
df_area$Country_Group <- factor(df_area$Country_Group, levels = rev(country_order))

# Data validation
print("\nData summary:")
print(summary(df_area))
print("\nSample of prepared data:")
print(head(df_area, 15))

# Colour palette: Australia highlighted, others muted
colors <- c("Australia" = "#2D9B7E", "Chile" = "#D4B86A",
           "China" = "#C9977C", "Rest of World" = "#CCCCCC")

# Create stacked area chart showing production by country over time
p_area <- ggplot(df_area, aes(x = Year, y = Production_Mt, fill = Country_Group)) +
  geom_area(alpha = 0.85, color = "white", linewidth = 0.3) +
  scale_fill_manual(values = colors, name = "Country") +
  scale_x_continuous(breaks = seq(2004, 2024, by = 5)) +
  scale_y_continuous(labels = comma_format(suffix = " Mt"),
                  breaks = function(x) { b <- pretty_breaks(n = 6)(x); b[b != 0] },
                  expand = expansion(mult = c(0, 0.05))) +
  labs(title = "Fig 4: Global lithium production by country (2004-2024)",
       subtitle = "Australia overtakes as the largest global producer in 2014",
       x = "Year", y = "Lithium Production (Mega Tonnes)") +
  theme_classic() +
  theme(plot.title = element_text(face = "bold", size = 16, hjust = 0),
        plot.subtitle = element_text(size = 12, color = "grey30", hjust = 0, margin = margin(b = 15), face =
"italic"),
        plot.caption = element_text(hjust = 0, color = "grey50", size = 9),
        legend.position = "right", legend.title = element_text(face = "bold", size = 11),
        legend.text = element_text(size = 10), panel.grid.minor = element_blank(),
        panel.grid.major.x = element_blank(),
        panel.grid.major.y = element_line(color = "grey90", linewidth = 0.3),
        panel.background = element_blank(), plot.background = element_rect(fill = "white", color = NA),
        axis.text = element_text(size = 10), axis.title = element_text(face = "bold", size = 11),
```

```r
      axis.line = element_line(color = "grey50"))

# Add vertical line marking year Australia became #1 producer
overtake_year <- 2014
p_area <- p_area + geom_vline(xintercept = overtake_year, linetype = "dotted", color = "black",
                              linewidth = 0.6, alpha = 0.5)
print(p_area)

# ------------------ VIZ 5: MINES AND CAPAD OVERLAP MAP------------------ #
# Load spatial analysis libraries
library(sf); library(ggplot2); library(dplyr); library(ozmaps); library(leaflet)

# Check coordinate reference system of mine data
st_crs(df_ga)

# Filter WA mines and create spatial points (GDA94 projection)
mines_wa <- df_ga %>% filter(State == "WA") %>% st_drop_geometry() %>%
  st_as_sf(coords = c("Longitude","Latitude"), crs = 4283)

# Get WA state boundary from ozmaps package
wa_boundary <- ozmap_states %>% filter(NAME == "Western Australia") %>%
  st_transform(4283) %>% st_cast("MULTIPOLYGON")

# Clean CAPAD protected areas: fix invalid geometries, keep only polygons
capad_wa_clean <- capad_wa %>% st_make_valid() %>%
  filter(st_geometry_type(.) %in% c("POLYGON","MULTIPOLYGON"))

# Verify spatial extents match
st_bbox(mines_wa); st_bbox(capad_wa_clean); st_bbox(wa_boundary)

# Create static map showing mines over protected areas
capad_plot <- ggplot() +
  geom_sf(data = wa_boundary, fill = NA, color = "grey60", linewidth = 0.5) +
  geom_sf(data = capad_wa_clean, fill = "darkgreen", color = "grey40", linewidth = 0.2, alpha = 0.6) +
  geom_sf(data = mines_wa, color = "darkred", size = 2, alpha = 0.8) +
  labs(title = "Mines in Western Australia over CAPAD 2024 (Terrestrial)") +
  theme_minimal(base_size = 11) +
  theme(panel.grid.major = element_blank(), panel.grid.minor = element_blank(),
      axis.text = element_blank(), axis.ticks = element_blank())

# Prepare data for interactive Leaflet map (WGS84 projection)
capad_wa_leaflet <- capad_wa %>% st_transform(4326) %>% st_make_valid() %>%
  filter(st_geometry_type(.) %in% c("POLYGON","MULTIPOLYGON"))
mines_leaflet <- st_transform(mines_wa, 4326)

# Disable spherical geometry for spatial join
sf_use_s2(FALSE)

# Spatial join: identify which mines fall within protected areas
mines_with_capad <- st_join(mines_leaflet, capad_wa_leaflet, join = st_within) %>%
  mutate(in_capad = !is.na(PA_ID),
       mine_color = ifelse(in_capad, "#E66101", "#5E3C99"))  # Orange if overlap, purple if not
```

```r
# Create interactive Leaflet map with protected areas and mines
leaflet() %>%
  addProviderTiles(providers$CartoDB.Positron) %>%
  # Add protected areas as green polygons
  addPolygons(data = capad_wa_leaflet, fillColor = "#2D6A4F", fillOpacity = 0.5,
              color = "#2D6A4F", weight = 0.1, label = ~paste0(NAME," (",TYPE,")"),
              popup = ~paste0("<b>",NAME,"</b><br>Type: ",TYPE,"<br>IUCN Category: ",IUCN)) %>%
  # Add mines as coloured circles (orange = in protected area, purple = outside)
  addCircleMarkers(data = mines_with_capad, radius = 4, color = ~mine_color,
                   fillColor = ~mine_color, fillOpacity = 0.8, stroke = TRUE, weight = 1,
                   label = ~lapply(paste0("Mine: ", Name, "<br>Status: ", Status,
                                          "<br>Commodity Group: ", `Commodity Group`), htmltools::HTML),
                   popup = ~paste0("<b>", Name, "</b><br>Commodity: ", `Commodity Group`,
                                   "<br>Status: ", Status)) %>%
  # Add legend explaining colours
  addLegend("bottomright", colors = c("#2D6A4F","#E66101","#5E3C99"),
            labels = c("CAPAD 2024 Protected Areas","Mines in Protected Areas",
                       "Mines Outside Protected Areas"), title = "Legend", opacity = 1)

# ------------------ SHINY APP -------------------- #
# Load Shiny and required libraries for interactive dashboard
library(shiny); library(ggplot2); library(plotly); library(leaflet)
library(sf); library(DT); library(dplyr)

# Define UI with multiple tabs for different visualisations
ui <- fluidPage(
  titlePanel("Australian Critical Minerals Analysis"),
  tabsetPanel(
    # Tab 1: Export volume and value trends
    tabPanel("Export Trends",
             fluidRow(column(12, h3("Lithium and Nickel Export Analysis"), p(""))),
             fluidRow(column(12, plotlyOutput("volumePlot", height = "400px"))),
             br(),
             fluidRow(column(12, plotlyOutput("valuePlot", height = "400px")))),
    # Tab 2: Spatial map of critical mineral mines
    tabPanel("Critical Minerals Map",
             fluidRow(column(12, h3(""), p(""))),
             fluidRow(column(12, plotlyOutput("mineralsMap", height = "600px")))),
    # Tab 3: Global lithium production comparison
    tabPanel("Lithium Production",
             fluidRow(column(12, h3(""), p(""))),
             fluidRow(column(12, plotOutput("areaPlot", height = "600px")))),
    # Tab 4: Interactive Leaflet map of WA mines and protected areas
    tabPanel("Mines & Protected Areas (Map)",
             fluidRow(column(12, h3("Western Australia Operational Mines and CAPAD Protected Areas"),
                             p("Orange markers indicate mines within protected areas, purple markers indicate mines
outside protected areas"))),
             fluidRow(column(12, leafletOutput("capadMap", height = "600px")))),
    # Tab 5: Data table of mines overlapping protected areas
    tabPanel("Mines & Protected Areas (Table)",
             fluidRow(column(12, h3("Mines Overlapping with CAPAD Protected Areas"),
```

```
                p("Table showing all mines located within Western Australia protected areas"))),
        fluidRow(column(12, DTOutput("overlapTable"))),
        br(),
        fluidRow(column(12, downloadButton("downloadData", "Download as CSV"))))))

# Define server logic: render each visualisation output
server <- function(input, output, session) {
  # Render plots p1 and p2 as interactive plotly charts
  output$volumePlot <- renderPlotly({ ggplotly(p1, tooltip = "text") })
  output$valuePlot <- renderPlotly({ ggplotly(p2, tooltip = "text") })
  output$mineralsMap <- renderPlotly({ ggplotly(minesplot, tooltip = "text") })
  output$areaPlot <- renderPlot({ p_area })
  # Render interactive Leaflet map with mines and protected areas
  output$capadMap <- renderLeaflet({
    leaflet() %>%
      addProviderTiles(providers$CartoDB.Positron) %>%
      addPolygons(data = capad_wa_leaflet, fillColor = "#2D6A4F", fillOpacity = 0.5,
              color = "#2D6A4F", weight = 0.1, label = ~paste0(NAME, " (", TYPE, ")"),
              popup = ~paste0("<b>", NAME, "</b><br>Type: ", TYPE, "<br>IUCN Category: ", IUCN)) %>%
      addCircleMarkers(data = mines_with_capad, radius = 4, color = ~mine_color,
                 fillColor = ~mine_color, fillOpacity = 0.8, stroke = TRUE, weight = 1,
                 label = ~lapply(paste0("Mine: ", Name, "<br>Status: ", Status,
                                "<br>Commodity Group: ", `Commodity Group`), htmltools::HTML),
                 popup = ~paste0("<b>", Name, "</b><br>Commodity: ", `Commodity Group`,
                           "<br>Status: ", Status)) %>%
      addLegend(position = "bottomright", colors = c("#2D6A4F", "darkorange", "#5E3C99"),
            labels = c("CAPAD 2024 Protected Areas", "Mines in Protected Areas (overlap)",
                   "Mines Outside Protected Areas"), title = "Legend", opacity = 1)
  })
  # Render data table with filtering options
  output$overlapTable <- renderDT({
    datatable(mines_overlap, options = list(pageLength = 25, scrollX = TRUE),
          rownames = FALSE, filter = "top")
  })
  # Download handler for CSV export
  output$downloadData <- downloadHandler(
    filename = function() { paste("mines_in_capad_", Sys.Date(), ".csv", sep = "") },
    content = function(file) { write.csv(mines_overlap, file, row.names = FALSE) }
  )
}
# Launch Shiny application
shinyApp(ui = ui, server = server)
```