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cepStudy

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Weaponizing Social Media in Geopolitics

A Case Study on the Critical Metals Debate

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Russia's war against Ukraine and recurrent Iranian cyberattacks highlight the need to understand the digital threat landscape faced by the EU. Based on a new dataset of 4 million tweets, this paper presents a systematic analysis of the online debate regarding critical metals and its potential for manipulation.

► The EU's cybersecurity threat landscape not only includes direct cyberattacks on infrastructure but also indirect ones like disinformation campaigns, deepfakes, and social media influence operations.

► This paper analyses the Twitter (now known as X) debate on critical metals, examining the network of actors, key problems, solutions, and the importance attached to specific metals. The analysis identifies potential vulnerabilities that could be targeted by disinformation campaigns.

► A case study on lithium shows that sustainability concerns and supply gaps, related to mining, dominated the Twitter debate between 2020-2022. Stakeholders' responses to criticism indicate possible loopholes that could be used by disinformation campaigns aiming to hinder the EU's diversification of supply routes.

► Embedding digital defence measures into the risk management of critical raw materials is essential to counter the risk of foreign disinformation campaigns. In light of the upcoming EU elections in 2024, we emphasise the urgency of implementing effective cybersecurity measures and developing strategies to combat foreign information manipulation with respect to critical metals such as lithium.

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1 Introduction: Hard and soft cyberattacks

The threat to Western societies from cyberattacks, i.e. the use of digital technologies for disruptive purposes, suddenly became clear with the Russian invasion of Ukraine. On the eve of the war, Russian hackers launched more than 200 cyberattacks on Ukrainian companies and authorities with the goal of weakening Ukrainian communications and defence capabilities.[1] Tellingly, one of the first missiles to be fired in this war was targeted at a data center. As of July 2023, hackers linked to the Russian government were still targeting defence organizations in Ukraine but also in Europe in general.[2] This development highlights the need to better understand the digital threat landscape faced by the European Union (EU). After two years of ongoing Russian cyberattacks against Ukrainian infrastructure, and following the Iranian government's major cyberattack against Albanian systems in 2022,[3] NATO member states recently endorsed a communiqué at their Vilnius summit that formalized coordinated cyber-responses to such attacks and clarified the relationship between the collective-defense clause and major cyberattacks.[4] As observers expect further significant cyber announcements from NATO at the Berlin Cyber Defence Summit scheduled for 29-30 November, it is crucial to point out the existence of additional, more covert methods of using digital technologies to disrupt the West and its economic sovereignty.

In addition to direct, "hard" threats to the digital infrastructure, as recently encountered in Ukraine and Albania, there are also indirect, "soft" ones, which are far less easy to detect but in no way less serious. According to the European Union Agency for Cybersecurity (ENISA), the European cybersecurity threat landscape currently also includes ransomware, malware, social engineering, phishing, threats against data and against availability (e.g. so-called denial of service attacks), destruction of Internet infrastructure, disinformation (including AI-based deepfakes), and supply chain targeting.[5] In particular, Russia's hybrid warfare uses so-called cyber influence operations, i.e. covert propaganda, to unsettle the online discourse in Western countries.[6] In the last couple of years, the range of actors conducting such operations has expanded considerably, including fake online personas on social media platforms.[7] At the beginning of the Ukraine war, for example, Ukrainians saw three times as much Russian propaganda as usual, while in the USA the proportion rose by 90 percent.[8] Similarly, pro-Beijing social media accounts engage in state-backed online campaigns targeting audiences in Paraguay, Costa Rica, Chile, and Brazil, in order to "micromanage narratives and obtain information from dissidents residing abroad".[9] Overall, throughout 2022, social media platforms like Twitter, now known as "X", enabled the Kremlin to conduct a substantial disinformation campaign

1 Microsoft, Digital Defense Report. 2022, https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE5bUvv?culture=en-us&country=us.
2 Microsoft Threat Intelligence auf Twitter. https://t.co/mWoyzOoydF" / Twitter.
3 POLITICO Pro | Article | Albania weighed invoking NATO's Article 5 over Iranian cyberattack.
4 NATO - Official text: Vilnius Summit Communiqué issued by NATO Heads of State and Government (2023), 11-Jul.-2023.
5 ENISA Threat Landscape 2022, ENISA (europa.eu), p. 4.
6 See: Steven Lee Myers, Russia Reactivates Its Trolls and Bots Ahead of Tuesday's Midterms, New York Times (Nov. 6, 2022), https://www.nytimes.com/2022/11/06/technology/russia-misinformation-midterms.html.
7 Quoted after: FBI & CISA, Foreign Actors Likely to Use Information Manipulation Tactics for 2022 Midterm Elections, https://www.cisa.gov/sites/default/files/publications/PSA-information-activities_508.pdf (7 November 2022).
8 Microsoft, Digital Defense Report. 2022, https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE5bUvv?culture=en-us&country=us.
9 Chinese State-Linked Information Operation Revealed Social Media Account Takeover Potential (nisos.com).

targeting the EU, reaching an aggregate audience of at least 165 million and generating at least 16 billion views.[10]

Since 2015, the EU has significantly improved its capacity to tackle such instances of so-called Foreign Information Manipulation and Interference (FIMI). The EU Diplomatic Service defines FIMI as "a mostly non-illegal pattern of behaviour that threatens or has the potential to negatively impact values, procedures and political processes", adding that such activity is "manipulative in character, conducted in an intentional and coordinated manner" and might involve "state or non-state actors".[11] In February 2023, the European External Action Service (EEAS) published its first report on foreign information manipulation and interference threats, which highlights Chinese disinformation networks on Twitter and Facebook and describes a Russian FIMI ecosystem centred on Telegram and Twitter.[12] Overall, social media platforms such as Telegram, Twitter and Facebook were the most frequently used channels to distribute harmful content, according to the EU's research.[13]

In the following Study, by way of an example, we would like to zoom in on one specific area in which one might expect anti-European information operations in the near future, namely the public debate on critical metals. With Europe's shift towards fossil-free technologies, secure access to a range of metals like lithium and rare earths has become essential for maintaining the position of European downstream industries on global markets, and to safeguard the vision of strategic autonomy and European sovereignty. In its new draft of a Critical Raw Materials Act, the European Commission has proposed a wide range of instruments to improve the supply management of these resources[14] including measures for risk monitoring and prevention. Based on an in-depth analysis of the debate on Twitter, our paper argues that such monitoring activity should also include the consideration of attack potentials for disinformation campaigns in the area of critical raw materials. In fact, a recent study of strategic operations affecting the US discourse detected several influence campaigns targeted at rare earth mining companies that are challenging Chinese market dominance in this field.[15] To improve resistance to such campaigns, a necessary first step is to map the current online debate about critical metals and identify specific vulnerabilities that could be targeted by disinformation campaigns.

Thus, the objective of this cepStudy is to identify networks, narratives, and sensitive areas, in the Twitter debate about critical metals, which could be exploited by future FIMI campaigns. This is based on a novel, self-constructed dataset consisting of more than four million tweets (4,056,822 observations). To analyse this large number of texts, we use a mix of digital, quantitative methods from the field of Natural Language Processing (NLP)[16] and qualitative methods of discourse analysis, based on a close reading of representative tweets. At the same time, we look at a whole range of metals

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[10] European Commission, Directorate-General for Communications Networks, Content and Technology, Digital Services Act – Application of the risk management framework to Russian disinformation campaigns, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2759/764631.

[11] Tackling Disinformation, Foreign Information Manipulation & Interference | EEAS Website (europa.eu).

[12] 1st EEAS Report on Foreign Information Manipulation and Interference Threats. Towards a framework for networked defence (February 2023), EEAS-DataTeam-ThreatReport-February2023-02.pdf (europa.eu), pp. 10, 17.

[13] 1st EEAS Report on Foreign Information Manipulation and Interference Threats. Towards a framework for networked defence (February 2023), EEAS-DataTeam-ThreatReport-February2023-02.pdf (europa.eu), p. 22.

[14] European Commission (2023). Proposal for a regulation of the European Parliament and of the Council establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) 168/2013, (EU) 2018/858, 2018/1724 and (EU) 2019/1020 (COM(2023) 160 final).

[15] https://www.mandiant.com/resources/blog/dragonbridge-targets-rare-earths-mining-companies.

[16] See: Julia Silge and David Robinson, Text Mining with R: A Tidy Approach (Beijing; Boston: O'Reilly, 2017); Fotis Jannidis, Hubertus Kohle, and Malte Rehbein, eds., Digital Humanities: eine Einführung (Stuttgart: J.B. Metzler Verlag, 2017).

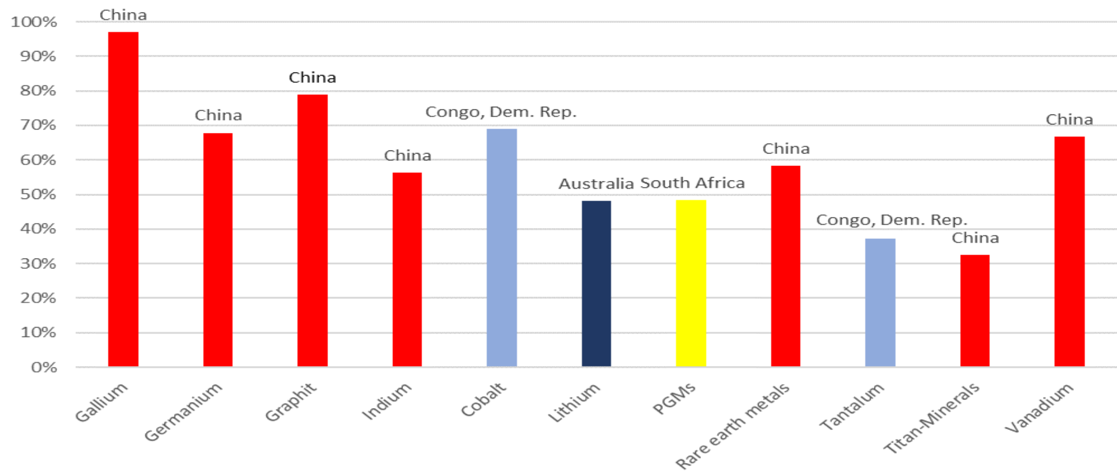
considered critical by the European Commission. For most of the stakeholders that we identified (see section 3 below), the business field consists of a portfolio of diverse metals. Furthermore, we cover not only messages directly related to raw materials policy but also those tweets in which companies generally promote the technological or economic importance of critical metals. In this way, we hope to map the points of attack which might arise for hostile online influencing campaigns in the coming years.

The paper is structured as follows. We start with a brief introduction to the topic of critical metals, describing their essential role in the green transition and indicating frequent areas of debate (Section 2). Then, we present our measurement strategy and sample selection process (Section 3). Based on this, we provide a quantitative overview of the tweets about critical metals and related policies in our sample (Section 4). Here, we differentiate between countries and supply chain position. After creating a subsample focused on lithium, we analyse in detail the arguments prevalent in the Twitter debate (Section 5). This includes an overview of the network of actors included in our sample, again differentiated by country of origin and business focus. We finish with a conclusion in Section 6.

2 Background: Policy issues related to critical metals

The impending transition to a post-fossil age not only means abandoning oil and gas, but also creates new raw material requirements. Whether batteries, fibre optic cables or fuel cells: The key technologies that are indispensable for our future prosperity are tailored to the special properties of certain materials. Most of these materials are so-called rare metals, such as cobalt, lithium, or rare earth metals, that are technically difficult or impossible to replace. At the same time, global demand will increase dramatically in the coming years, which will further intensify the competition for access to raw materials.[17] Progress in the energy transition and digitization is therefore only partly driven by knowledge and political will, and to a large extent by the sheer availability of raw materials.

Figure 1: Global market shares of the most important producers in 2020



Sources: USGS Mineral Commodity Surveys (2022); own calculations. The calculations here refer in each case to mining production (extraction). Exceptions: Gallium, Germanium and Indium (refined metal production).

[17] European Commission (2020). Critical Raw Materials for Strategic Technologies and Sectors in the EU – A foresight study. https://ec.europa.eu/docsroom/documents/42882

To obtain industrially usable materials from the raw materials under consideration, several processing steps have to be passed through in all cases. These basically include extraction, i.e. mining the ores, and a subsequent multi-stage smelting process. The individual processing steps are not necessarily concentrated only in the producing country. Complex processes in particular can be outsourced to countries with the corresponding specialized expertise or cost advantages, which China, for example, possesses in the processing of cobalt. Dependencies in the raw materials sector thus arise not only from the physical location of deposits, but also from the global distribution of smelting capacities. Nevertheless, international production statistics mostly focus on the primary stage of resource extraction. In the case of particularly rare metals, only a few producing countries dominate globally. China’s dominance is particularly striking (see Figure 1). Not only was the People’s Republic the world’s most important supplier of eight of the twelve raw materials in 2020, but its market share was also over 50% for six raw materials, and even over 75% in the case of gallium and graphite. Only Congo has a similarly prominent position in the field of cobalt mining. In the area of smelting, China’s general dominance can be considered even greater; at this level, it also extends to cobalt and lithium, for example.[18]

These dependencies make raw material procurement particularly vulnerable, not only to technically induced disruptions in supply chains, but also to political and regulatory influences in individual countries of origin. This can affect trade policy, as both China’s temporary introduction of export quotas for rare earths[19] and the recent disputes over export restrictions on gallium and germanium[20] have shown. However, especially in developing countries, this can also affect general political stability.

In addition to a supply risk, the current procurement channels are also subject to price and environmental risks. The latter start with the greenhouse gas emissions caused by extraction and smelting. These can be both direct – escape of gases from the ground – and indirect – material and energy consumption along the supply chain – in nature. In the case of some future raw materials, toxins frequently associated with the deposits, such as arsenic and mercury, can also pose an environmental risk, especially if contamination of the groundwater cannot be ruled out.[21] In the case of lithium, depending on the geological conditions, high water consumption can also be a problem.[22] Serious conflicts with international standards are also reported with regard to the social situation of miners and safety standards during mining.[23]

[18] Wolf, A. (2022). Europe‘s Position on Raw Materials of the Future. cepInput No. 11 /2022. https://www.cep.eu/en/eu-topics/details/cep/europas-umgang-mit-den-rohstoffen-der-zukunft-cepinput.html

[19] Mancheri, N. A. (2015). World trade in rare earths, Chinese export restrictions, and implications. Resources Policy, 46, 262–271.

[20] MIT (2023). China just fought back in the semiconductor exports war. Here’s what you need to know. MIT technology review. https://www.technologyreview.com/2023/07/10/1076025/china-export-control-semiconductor-material/

[21] Kaunda, R. B. (2020). Potential environmental impacts of lithium mining. Journal of Energy & Natu-ral Resources Law, 38(3), 237–244.

[22] Bustos-Gallardo, B., Bridge, G., & Prieto, M. (2021). Harvesting Lithium: Water, brine and the in-dustrial dynamics of production in the Salar de Atacama. Geoforum, 119, 177–189.

[23] Sovacool, B. K. (2021). When subterranean slavery supports sustainability transitions? Power, pa-triarchy, and child labor in artisanal Congolese cobalt mining. The Extractive Industries and Society, 8(1), 271–293.

The increase in demand expected in the future has led to a surge in exploration and investment activities worldwide, including in Europe. The recent major discoveries in Germany[24], Sweden[25] and Norway[26] are prominent examples of this trend. With increased political and public attention, and the EU's attempts to attain strategic autonomy, the stakes become increasingly high, which increases the likelihood that foreign actors might draw on subtle information campaigns to manipulate domestic audiences. As mentioned in the introduction, this has already happened in the US, where fake accounts were created to emphasise the environmental dangers of mineral extraction, with the underlying goal of preventing new sites from being established. If successful, this might perpetuate Western dependency on Chinese resources. To understand whether similar FIMI campaigns might become a threat to Europeans, too, a larger research project is required. This paper attempts to make a first step in this direction by mapping the online discourse on critical metals on Twitter, with a particular focus on lithium. To analyse the online communication behaviour of the identified stakeholder network and the public discourse on critical metals, we analyse relevant Twitter statements by means of Natural Language Processing (NLP). In the next section, we describe our data collected for this empirical exercise.

3 Data and methods: How to scrape Twitter data

Sparked by allegations that Russia had supported US President Trump's election campaign, Twitter's Safety & Integrity team started publishing public archives of data related to state-backed information operations (IOs) in October 2018. Twitter defines state-backed IOs as "coordinated platform manipulation efforts that can be attributed with a high degree of confidence to state-affiliated actors" and that are "typically associated with misleading, deceptive, and spammy behaviour".[27] Until early 2022, this identification campaign led to the release of 48 datasets of attributed platform manipulation campaigns originating from 17 countries, spanning roughly 200 million tweets.[28] The datasets include the full texts of the respective tweets and a wide range of accompanying metadata, such as the name of the user, the number of accounts following the user, and the time of publication. As can be seen from Figure 2, most publicly known campaigns captured by internal Twitter data can be traced back to well-known players such as China, Russia, and Saudi Arabia. Except for 2021, it is also clear that the number of manipulative accounts is strongly increasing over time. More surprising is the inclusion of Spain, the only EU member state in the dataset. This refers to the removal of 259 accounts in September 2019 that Twitter employees identified as falsely boosting public online sentiment in Spain.

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24 Taylor, K. (2021). Lithium from German geothermal plants could supply a million electric vehicles a year from 2025. Euractive. 1.Dezember 2021. https://www.euractiv.com/section/energy/news/lithium-from-german-geothermal-plants-could-supply-a-million-electric-vehicles-a-year-from-2025/

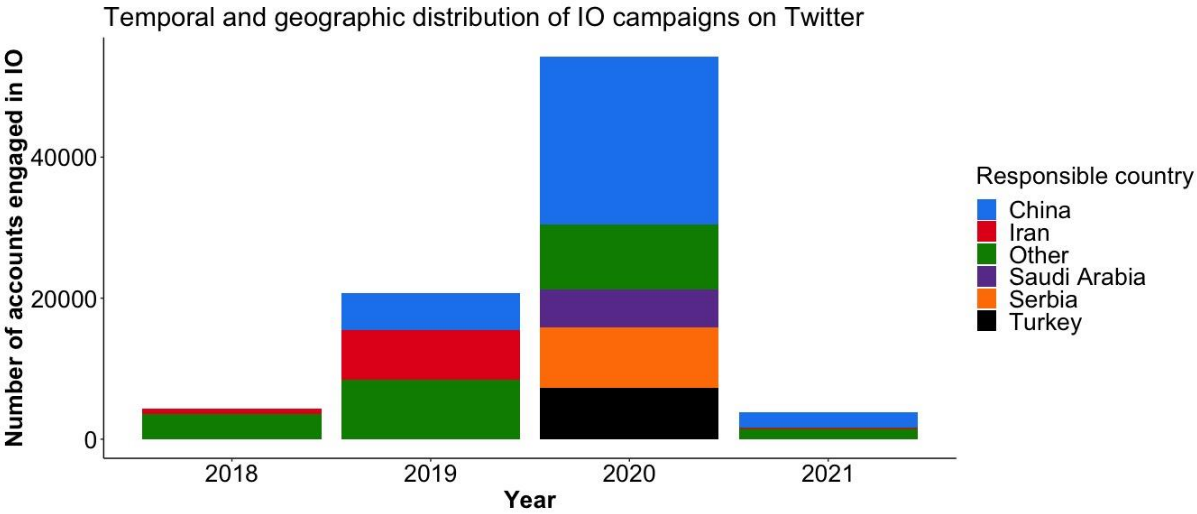
25 Reid, J. (2023). Sweden finds Europe's largest deposit of rare earth metals, which could become 'more important than oil and gas'. CNBC. 12.Januar 2023. https://www.cnbc.com/2023/01/13/sweden-mining-company-lkap-finds-big-deposit-of-rare-earth-metals.html

26 Paddision, L. (2023). Norway discovers huge trove of metals, minerals and rare earths on its sea-bed. CNN. 30.Januar 2023. https://edition.cnn.com/2023/01/30/business/norway-minerals-seabed-deep-sea-mining-climate-intl/index.html

27 Pickles, Nick (2020), United States House of Representatives Permanent Select Committee on Intelligence, "Emerging Trends in Online Foreign Influence Operations", HHRG-116-IG00-Wstate-PicklesN-20200618.pdf (house.gov).

28 https://blog.twitter.com/en_us/topics/company/2021/disclosing-state-linked-information-operations-we-ve-removed (2 November 2022). With the advent of the Twitter Moderation Research Consortium, Twitter discontinued these releases.

Figure 2: Confirmed IO campaigns on Twitter



Source: own analysis, based on internal data from Twitter's former Safety & Integrity team.

However, analysing the underlying tweets contained in these classified IO campaigns shows that so far, strategic metals have not played a role in larger cyber warfare attempts. For instance, in the most recent bulk release of this type of data by Twitter (as of writing, in December 2021), the only IO campaign explicitly mentioning "metals" stemmed from Uganda, where a network of 418 accounts engaged in coordinated inauthentic activity in support of Ugandan presidential incumbent Museveni – and even here, the term was only used once in relation to the country's primary metal manufacturing sector (and three times in total). Nevertheless, this does not mean that there are no strategically placed tweets in this area; they simply have not been part of one of these larger IO campaigns that have been already identified by Twitter's Safety and Integrity team in the past.

In the following study, we therefore went beyond the publicly available IO datasets and constructed a novel dataset by using the Twitter API (v2) for research purposes, which was still available when we started work on this project (November 2022).[29] In particular, we were granted so-called academic research access for our project, which at the time enabled us to programmatically access the complete archive of public tweets, based on a particular search query, and to pull 10 million tweets per month. Our sample of tweets covers the time period from the beginning of 2012 to October 1, 2022. We started in 2012 because usage of Twitter in Europe has been growing rapidly until then and has stabilised since. Following Ehrmann and Wabitsch,[30] we suspect that different types of users were represented less in the earlier years, such that changes over time could reflect changes in sample composition. Starting in 2012 will therefore reduce this potential bias, while still giving us significant data. We stopped the sample in early October 2022 to ensure that the heavy changes in user numbers and user base after Elon Musk's acquisition of Twitter do not bias the results.

To create a sample of tweets relevant to our topic, our first step was to identify key actors from the critical metals business. Our starting point for this was the *Critical Raw Materials Alliance* (CRM

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[29] Upon successful application, researchers received access to the Twitter Developer Portal. This service was provided for free and for non-commercial use only.

[30] Ehrmann, M. & Wabitsch, A. (2022), Central bank communication with non-experts – A road to nowhere?, Journal of Monetary Economics 127, pp. 69-85.

Alliance).[31] This is an industry association founded explicitly to promote the creation of European value chains for critical raw materials. According to own statements, its network of members covers almost all of the raw materials currently considered critical by the European Commission.[32] Unlike the *European Raw Materials Alliance* (ERMA), an alternative network initiated by the European Commission, the CRM Alliance is purely focused on stakeholders from the business side, thus representing the voice of the industry. Currently, it exhibits only 17 direct members. However, the majority of these are not single firms, but industry associations themselves. Hence, the indirect network is much larger. We set up our sample of relevant actors by including both direct members of the CRM Alliance and the members of its member associations. In this way, a sample comprising 234 distinct organizations (associations + firms) is generated. The complete list of organizations is presented in the Appendix (Table A1). Due to the global outreach of the industry associations involved, it includes suppliers from all parts of the world. Moreover, the set of firms covers all parts of the critical raw materials' life cycles and supply chains, from mining companies to traders and recycling companies. Hence, our sample can claim a high degree of representativeness both in terms of space and business functionality.

Table 1: Attributes recorded for the organizations in the sample

Attribute	Explanation	Measurement
Name	Name of the organization	Short and long name
Country	Country of origin	Headquarter location
Organization type	Company or Association	Assignment
Supply chain	Position in the supply chain[33]	NACE codes (for companies)
Relationship to crm Alliance	Membership in crm Alliance / crm Alliance member associations	List association
Twitter	Presence on Twitter	Twitter handle
Company Website	Presence as webpage	URL

Source: own representation.

Members were identified based on members lists available on the webpages of the respective associations. The single members were verified and characterized manually by visiting the companies' websites. Those firms that did not exhibit a web presence in English language, or whose webpage produces a security warning, were excluded from our sample. Moreover, members of the *International Magnesium Association* (IMA) and *Euro Alliages* were excluded in general, since their field of business is focused on raw materials currently not classified as critical by the European Commission. Based on

[31] https://www.crmalliance.eu/

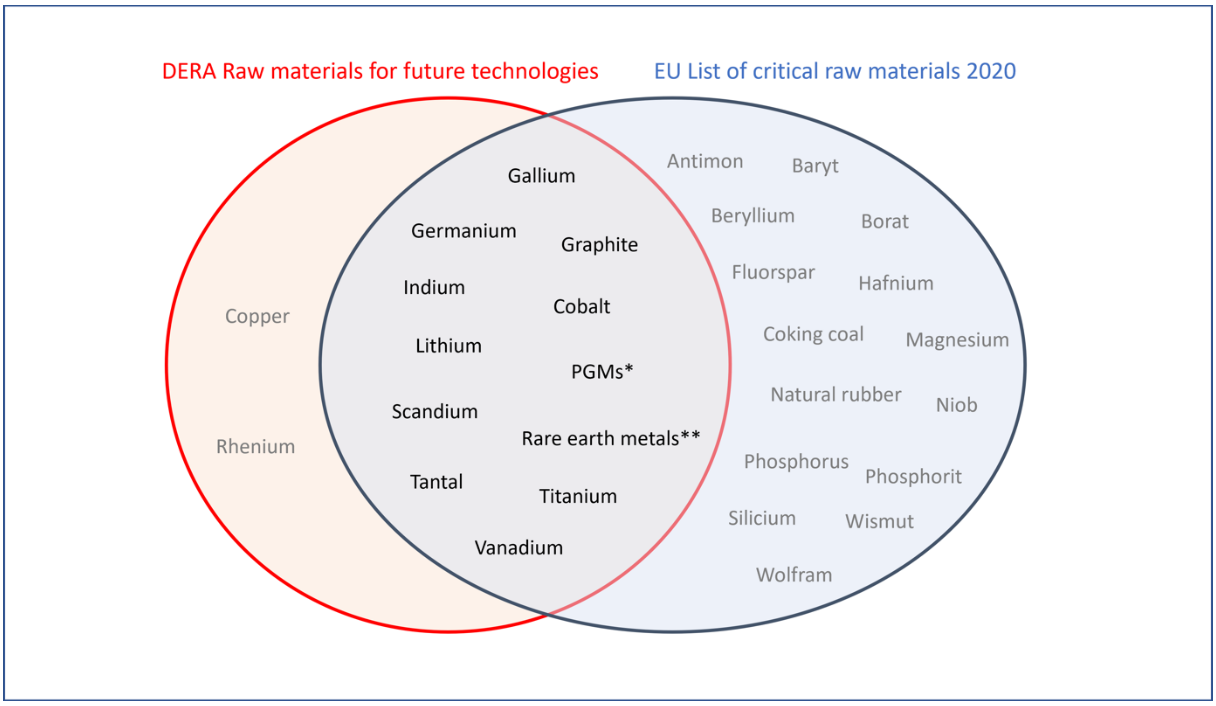
[32] European Commission (2020). Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2020) 474 final.

[33] In the case of vertically integrated firms, the activity most upstream is captured, to stress the relevance of raw material sourcing in the current debate.

the information provided on the websites, the attributes presented in Table 1 are assigned to the organizations covered.

For the chosen time period, we filtered and scraped all English tweets – as identified by Twitter's language filter – through Twitter's Advanced Search using the R package "academictwitteR."[34] Here, we took a two-pronged approach. First, we collected all tweets written by relevant stakeholders, which we identify through their membership in the CRM alliance as described above (see Appendix Table A1). Of the 234 organizations in total, 118 possess a Twitter account at the time of our analysis (e.g. @BetaTechnology). Since most of these accounts are rather reluctant to tweet, capturing all tweets by our list of user accounts does not lead to an excessive number of tweets, so we expanded the database further. In this second step, we searched freely via the Twitter API using terms to find more relevant tweets. This has the advantage that we can, on the one hand, analyse the communication strategy of the relevant stakeholders and, on the other hand, uncover possible differences to the arguments in the general debate on the topic. In this way, we can identify potential points of attack for (dis)information campaigns. Regarding the search terms used in this query, we limit ourselves to the following general expressions: "critical raw materials," "rare metals," "critical minerals," "critical metals," and "rare minerals."

Figure 3: Selection of specific raw materials as search terms



Source: Wolf (2022).

In addition to these general expressions, we use the names of selected raw materials that are included in the current EU list of critical raw materials,[35] so that we have an objective reference point. After some experimentation with the Twitter API, we decide to focus on those materials on the EU list that

[34] Barrie, Christopher and Ho, Justin Chun-ting. (2021). academictwitteR: an R package to access the Twitter Academic Research Product Track v2 API endpoint. Journal of Open Source Software, 6(62), 3272, https://doi.org/10.21105/joss.03272.
[35] Blengini et al. 2020. Study on the EU's list of Critical Raw Materials, Final Report, p. 5.

were also identified as relevant for future technologies in a recent study by DERA[36] (see Figure 3). In this way, we ensure that all results stay relevant and focus on those elements which will be of particular strategic value in the years to come – and thus of potential interest for FIMI campaigns on social media. This leaves us with the following 12 critical raw materials and their respective search terms: gallium, germanium, graphite, indium, cobalt, lithium, PGMs, scandium, Rare Earth (Metals),[37] tantalum, titanium, vanadium. As there are much more tweets mentioning specific metals than tweets about "critical minerals" in general, we limit this part of the search to the most relevant months, i.e. from January 2020 to October 2022. As a robustness check, this choice also seems justified by looking at basic descriptive statistics of the collected data (see Figures 4 and 5 in Section 4), which show that social media engagement with specific critical metals only increased substantially in the course of 2020. This makes it unlikely that we might miss essential tweets from previous years.

Table 2: Composition of the critical raw material Twitter dataset

Selection criteria **(period)**	**Explanation**	**Empirical observations**
Stakeholder (2012 – 2022)	Members of the CRM alliance and its member associations represent the European value chains for critical raw materials. All tweets from stakeholders with an active account were collected.	261,206 tweets
General terms (2012 – 2022)	By searching for all tweets containing the general expressions critical raw materials, rare metals, critical minerals, critical metals, and rare minerals, we hope to capture the broader policy discourse.	320,754 tweets
Specific materials (2020 – 2022)	All 12 raw materials listed on both the current EU list of critical raw materials and the DERA Raw Material list for future technologies	3,474,862 tweets
Total		**4,056,822 tweets**

Source: own representation.

Overall, this procedure results in 261,206 tweets for the stakeholders, 320,754 tweets referring to critical metals in general (as approximated by the general expressions listed above), and 3,474,862 tweets mentioning a specific strategic raw material from the combined EU and DERA lists of critical raw materials. Combining all three samples leads to an overall dataset consisting of 4,056,822 tweets, or 126,901,894 words (tokens), grouped by 11,077,331 sentences. Note that our dataset covers

[36] Marscheider-Weidemann, F.; Langkau, S.; Baur, S.-J.; Billaud, M.; Deubzer, O.; Eberling, E.; Erdmann, L.; Haendel, M.; Krail, M.; Loibl, A.; Maisel, F.; Marwede, M.; Neef, C.; Neuwirth, M.; Rostek, L.; Rückschloss, J.; Shirinzadeh, S.; Stijepic, D.; Tercero Espinoza, L.; Tippner, M. (2021). Rohstoffe für Zukunftstechnologien 2021. DERA Rohstoffinformationen 50, Berlin.

[37] For the web scraping, we only search for the expression "rare earth", as this will capture also all instances of "rare earths" in the plural and of references to "rare earth metals", will making sure that we also capture those tweets that omit the word "metal(s)".

original tweets (this also entails tweets where the majority of content is copied from another tweet, but often a comment or remark is added) and replies, but not retweets or quote retweets. As individual tweets can be picked up multiple times (e.g. if a tweet is sent by one of the listed stakeholders and mentions one of the specific 12 critical raw materials, it will be scraped twice), there is a certain amount of double counting (to be precise, counting the tweet identification numbers reveals that 154,077 tweets appear at least twice in the dataset). Advertisements, i.e. promoted tweets by paying firms, were excluded. This is complemented with plenty of relevant metadata such as timestamp, username, or device used. In addition, we identify the number of times each of the selected tweets gets liked or retweeted. Table 2 presents summary data on the composition of our novel dataset.

Next, we control our dataset in several steps to ensure that the final samples are not contaminated by tweets that are substantially unrelated to the critical raw materials, following the steps proposed in the specialized economics literature for cleaning a Twitter dataset.[38] This means that we start by looking at random subsamples of tweets, giving us a broad idea of what types of other tweets our data collection method extracted. As recommended by Ehrmann and Wabitsch,[39] we double-check for the language of tweets, because despite the language filter of the Twitter Advanced Search, tweets in other languages can be returned. For this robustness check, we use three different R packages to automatically classify each tweet's language.[40] However, when manually checking a random selection of tweets classified as non-English, we soon realized that the language detection provided by the Twitter API is pretty accurate and more coherent than these automated, external classification solutions.[41] As the risk for false negatives is higher than for false positives, we do not remove any tweets based on automatic language detection.[42] Furthermore, in contrast to Ehrmann and Wabitsch, we do not drop all tweets by users who have tweeted less than 100 times in their entire Twitter history, as this would lead to a significant loss of tweets, given that critical raw materials have been, for most of the period studied, a niche topic that does not draw a lot of attention (in contrast to ECB communication studied by Ehrmann and Wabitsch). Moreover, we are specifically interested in disinformation campaigns, which are initially often driven by fake accounts with low numbers of overall tweets and followers. As we are interested in these types of "outliers," dropping users or tweets for cleaning purposes would be contradictory to the objectives of this paper. The final sample size is thus 4,056,822 observations.

[38] Ehrmann, M. & Wabitsch, A. (2022), Central bank communication with non-experts – A road to nowhere?, Journal of Monetary Economics 127, pp. 69-85.

[39] Ehrmann, M. & Wabitsch, A. (2022), Central bank communication with non-experts – A road to nowhere?, Journal of Monetary Economics 127, pp. 69-85.

[40] For this robustness check, we use three different R packages. First, we draw on TextCat, an R implementation of the text categorization algorithm developed by Cavnar and Trenkle. See: K. Hornik, P. Mair, J. Rauch, W. Geiger, C. Buchta and I. Feinerer (2013). The textcat Package for n-Gram Based Text Categorization in R. Journal of Statistical Software, 52/6, 1–17; W. B. Cavnar and J. M. Trenkle (1994), N-Gram-Based Text Categorization. In "Proceedings of SDAIR-94, 3rd Annual Symposium on Document Analysis and Information Retrieval", 161–175. Second, we rely on two R packages that give access to Google's (Chromium's) "cld" libraries. Specifically, we use and compare the results from the cld2 and cld3 packages. The distribution of the resulting language variables is available from the authors upon request.

[41] See also the discussion on: https://stackoverflow.com/questions/8078604/detect-text-language-in-r.

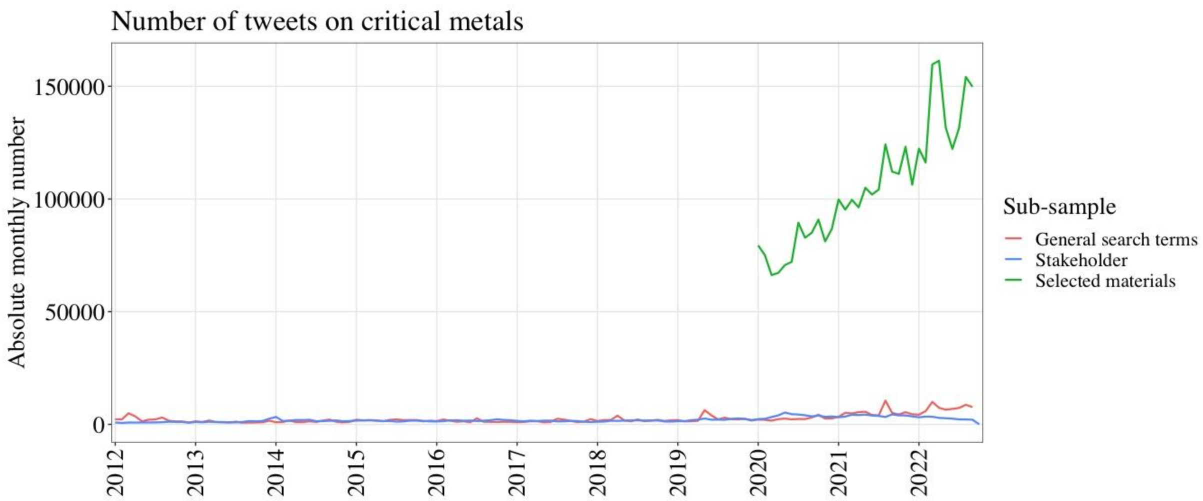
[42] For instance, many tweets labelled by TextCat as "german" or "middle frisian" are actually English. By comparison, the "cld" libraries are more robust, but they likewise miss-classify actual English tweets as, for instance, French. Restricting the dataset to those tweets that are classified by both "cld" libraries (versions 2 and 3) as "English" would reduce its size to 3,057,450 tweets, i.e. a loss of almost 1 million observations.

4 Aggregate statistics: Critical metals on Twitter

4.1 Overview

As a means of overview, Figure 4 tracks the evolution of tweets in our dataset over time, distinguished by the search pattern used to collect them from the Twitter Archive. The resulting empirical pattern shows that the English-speaking social media debate on critical metals has reached a whole new level, in terms of the number of tweets, in the past two years, with steadily increasing numbers of posts related to the topic of mining rare metals. The start of this upward trend somewhat coincides with the EU's 2020 publication on critical raw materials, which has also guided our research design, and with the change in the Commission presidency from Juncker to von der Leyen. Partly, this simply reflects that most of the tweets mention specific materials, which we only searched and extracted for the period 2020 to 2022. However, a closer look at the other two pillars of our dataset shows that they also exhibit their all-time peaks in mid-2020 and mid-2021, respectively. One takeaway for the subsequent analysis is, thus, whether the EU's publication and the increased engagement pattern after 2020 have coincided with a change in sentiment or argumentation regarding critical metals in Europe – or perhaps the presence of influence campaigns in this field, both public and covert. In general, one can say, based on this figure, that interest in different rare metals on social media has grown over the past years, probably related to the pandemic-induced supply side shortages and changes in the geo-political environment, and has now clearly reached an unprecedented, all-time high. This is additional motivation for conducting our empirical study and in the following, we will investigate the drivers of this growing public interest in more detail.

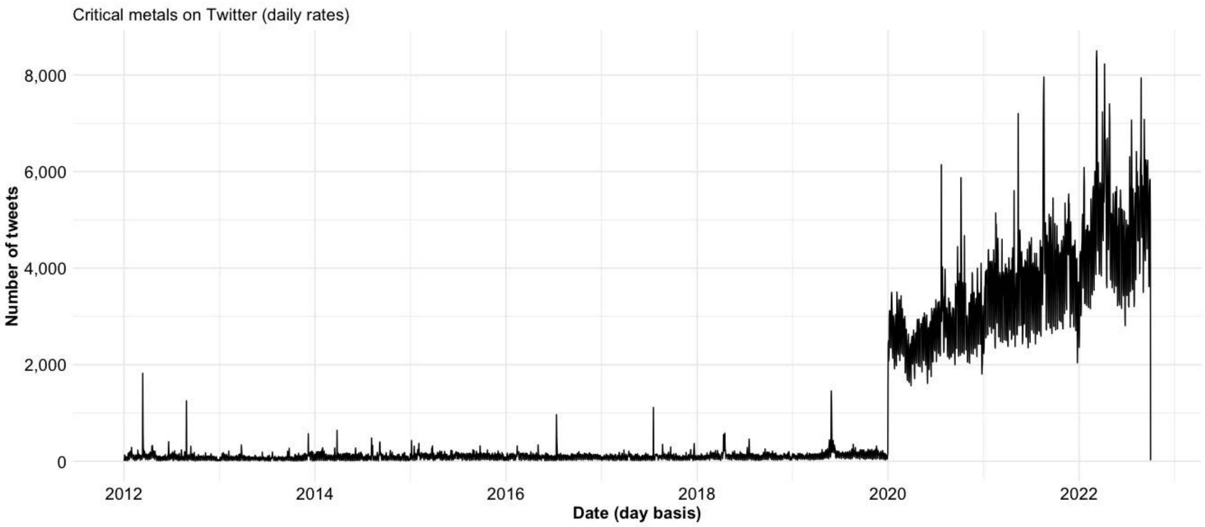
Figure 4: Our Twitter sample covering messages related to critical metals



Source: own representation.

By plotting aggregated numbers on a daily level, we see that English language Twitter activity surrounding critical raw materials is highly volatile (Figure 5), which is less visible when looking at monthly trends. While there is, again, a noticeable upward trend over time, social media activity regarding this specific topic has several highly individual "peaks," followed by phases of more calm. Intuitively, this corresponds to the fact that the debate on critical materials that EU economies need is a very specific topic that is not frequently reoccurring due to, e.g. anniversaries etc., but needs an external "driver" that stimulates debate on this topic. Figure 5 is also in line with the academic literature on social media, which generally finds that tweets are less autocorrelated than, e.g., daily means in survey responses and can be seen as a "function of events that produce large public reactions".[43] Moreover, tweet behavior typically corresponds to a circadian pattern, i.e. the physical-mental 24-hour cycle.[44]

Figure 5: Daily pattern of our Twitter dataset



Source: own representation.

Recall that we chose the starting date for our sample to ensure that we are not picking up an upward trend in Twitter activity that is due to an increasing adoption of Twitter as social medium. It is evident from the aggregated Twitter activity figures shown above that we avoid this pitfall: even if there was a slight upward trend in Twitter user numbers after 2012, this does not correlate at all with the stable pattern that we observe for most of the period between 2012 and 2020 and it clashes, in particular, with the strong upward trend in critical metal tweets *after* 2020, which was not accompanied by a similarly strong arrival of new Twitter users. For the later analysis, we capture the following communication events regarding critical metals by the European Commission, which we source from the relevant institutions' websites:

- May 2014: Publication of the second list of critical raw materials by the European Commission
- September 2017: Publication of the third list of critical raw materials by the European Commission
- September 2020: Publication of a Communication on Critical Raw Materials Resilience ("Action plan on Critical Raw Materials") by the European Commission, together with the fourth list of critical raw materials and a foresight study

After describing our data collection process and providing an initial overview of the novel dataset on social media activity regarding critical metals, we proceed with analysing patterns in this text data.

[43] Pasek, J., McClain, C. A., Newport, F., & Marken, S. (2020). Who's Tweeting About the President? What Big Survey Data Can Tell Us About Digital Traces? Social Science Computer Review, 38(5), 633-650, here: p. 637.
[44] Ten Thij, Marijn & Bhulai, Sandjai & Kampstra, Peter. (2014). Circadian Patterns in Twitter.

4.2 Patterns

We start the analytical section by looking at the role played by members of the CRM Alliance, as defined in our stakeholder list. For the subset of 261,206 tweets written by these organisations between 2012 and 2022, we identify the most influential stakeholders by calculating and then combining two measures. First, we determine Average Likes (AvgLikes) by counting all liked tweets and then taking the mean. Similarly, we calculate Average Retweets (AvgRetweets) as the mean of all counted retweets. This exercise reveals, for instance, that three key players in the social media discourse on critical metals and rare materials are Glencore (AvgLikes: 32.8; AvgRetweets: 6.97), PilbaraMinerals (AvgLikes: 45.3; AvgRetweets: 6.86), and Rio Tinto (AvgLikes: 11.2; AvgRetweets: 6.75). The top 15 most influential stakeholders on Twitter, as approximated by these measures, are listed in Table 3 below. The complete data for all stakeholders can be found in the Appendix (Table A2).

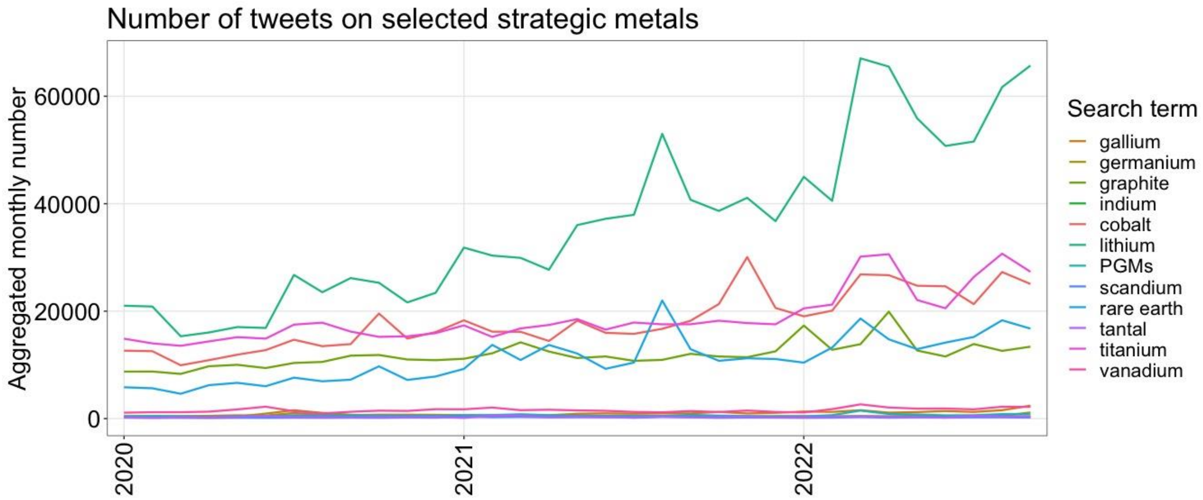
Table 3: Top-15 most influential critical metals stakeholder on Twitter.

TWITTER USER	AVERAGE LIKES	AVERAGE RETWEETS
GLENCORE	32.8	6.97
PILBARAMINERALS	45.3	6.86
RIO TINTO	11.2	6.75
BUSHVELD MINERALS	23.1	6.71
ALLKEM LIMITED	17.2	4
JERVOIS GLOBAL	17.0	3.77
AUXICO RESOURCES CANADA	11.1	3.44
ANGLO AMERICAN	10.1	2.99
INVINITY ENERGY SYSTEMS	8.65	2.68
ELECTRA BATTERY MATERIALS CORPORATION	12.6	2.67
VANITEC	8.31	2.65
WOOD MACKENZIE	2.82	2.54
UK ATOMIC ENERGY AUTHORITY	5.19	2.49
ORANO GROUP	10.4	2.47
AUSTRALIAN STRATEGIC MATERIALS (ASM)	6.65	2.23

Source: own analysis.

Next, we investigate which rare materials have played a particularly influential role in the online discourse. Recall that we created our dataset partly by collecting all tweets mentioning at least one of the 12 critical materials listed by both EU and DERA. By measuring the frequency with which specific materials from this list have been actually referred to, we can gauge how relevant they have been deemed from a public perspective. This, of course, should not be mistaken as a sign of their actual geopolitical or economic relevance. But it might point to blind spots in the discourse if we find, for instance, that certain critical metals have not been discussed at all in the Twitter public sphere or if attention is only given to those metals that are useful for consumption goods, such as necklaces, instead of those relevant for powering the digital revolution and green transition. To extract the words from the text of each tweet we need to use several functions from the "tidytext" R package, including the removal of URLs, emojis, numbers, uninformative terms known as stop words (such as "the", "of", and "to"), hashtags, and usernames.[45] This confirms to standard pre-processing steps in the NLP literature.[46] On the basis of this pre-processed corpus, we can visualize selected word frequencies.

Figure 6: Number of tweets on selected strategic metals (2020-2022)



Source: own analysis.

We begin by plotting the frequency with which the selected 12 critical metals listed by both EU and DERA are mentioned in the social media discourse. For sake of visibility, we aggregate the daily counts on a monthly basis. Moreover, we start the graph in 2020, to avoid confusion regarding the break in our sample (recall that explicitly mentioned metals were only collected for the last three years). From the resulting visualization, we can distinguish three groups (see Figure 6). First, it becomes clear that lithium is, by far, the most referenced critical metal on Twitter. Since starting to record its term frequency in our dataset, i.e. since January 2020, there is a clear upward trend in references to lithium, which reach an all-time maximum in March 2022 with 67,058 explicit references. At no point in our sample is there another metal that surpasses lithium on an aggregated monthly level, which is why the later qualitative analysis focuses – as a case study – on this particular metal. Next, we can identify a group of relevant critical metals that are frequently mentioned, albeit on a significantly lower level than lithium. This group consists of titanium (maximum: 30,705 references in August 2022), cobalt (maximum: 30,067 references in November 2021), rare earths (maximum: 21,974 references in August 2021), and graphite (maximum: 19,906 references in April 2022). The remaining seven metals can be regarded as a third group, as they are barely mentioned: gallium, germanium, indium, PGMs, scandium, tantalum, and vanadium. Thus, the data suggests that so far, these metals' relevance is overlooked in the public discourse. This is of particular interest in light of recent developments in China, which plans to restrict exports of gallium and germanium as part of its tit-for-tat-fight with the

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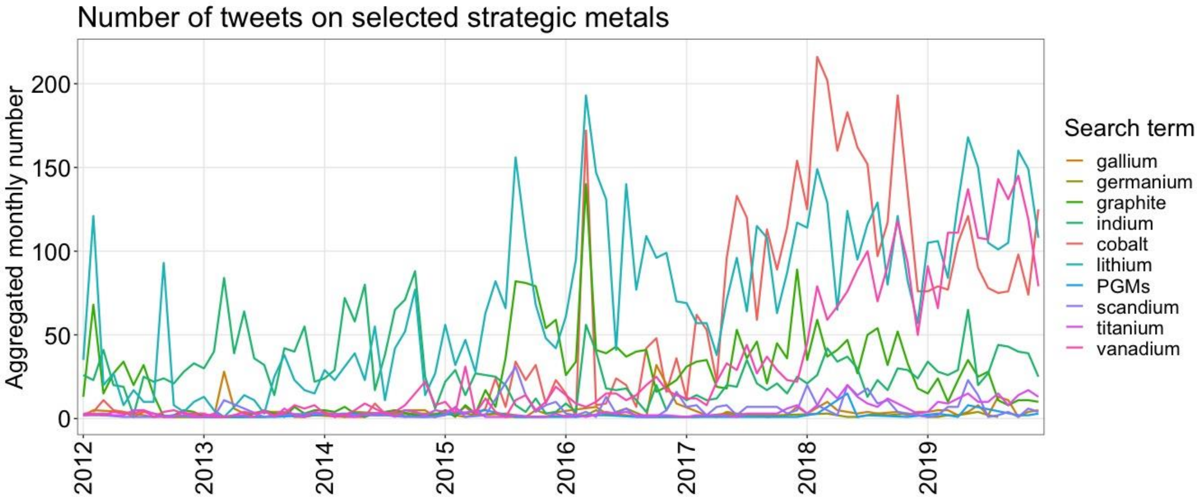
45 See: https://medium.com/@traffordDataLab/exploring-tweets-in-r-54f6011a193d (28 November 2022).

46 See: Julia Silge and David Robinson, Text Mining with R: A Tidy Approach (Beijing; Boston: O'Reilly, 2017); Fotis Jannidis, Hubertus Kohle, and Malte Rehbein, eds., Digital Humanities: eine Einführung (Stuttgart: J.B. Metzler Verlag, 2017); Stephen Robertson, 'Digital Humanities', in The Oxford Handbook of Law and Humanities, by Stephen Robertson, ed. Simon Stern, Maksymilian Del Mar, and Bernadette Meyler (Oxford University Press, 2019), 85–103.

US on strategic chips.[47] While these metals might therefore now turn to key elements in the geo-political race towards Artificial Intelligence, our data suggest that have been largely neglected in the public discussions on Twitter.

Figure 7: Number of tweets on selected strategic metals (2012-2019)



Source: own analysis.

To deepen our knowledge of the public relevance of the selected metals, we calculate the frequency with which these individual materials were mentioned in the pre-2020 period of our sample. In other words, we check whether some of these metals were referenced in the tweets by the stakeholders or in tweets arguing generally about rare metals and rare earths. In this way, it becomes possible to see which specific metals play a significant role in the general debate about critical raw materials and sovereignty. As “rare earth” has also been one of the general search terms and we already know from the preceding Figure 6 that it plays an outsized role, we omit it here and rather focus on the trajectories of the remaining 11 individual metals. The results are plotted in Figure 7. Again, three observations stand out: First, individual metals are also discussed in general tweets about critical raw materials, albeit, of course, to a much smaller extent than in the post-2020 period that includes direct reference tweets (as can be inferred from the y-axis, most months record about 100 tweets on each individual metal). Second, there is a clear development over time: Just as we can observe a rising interest in social media between 2020 and 2022, we see a positive trend for the period between 2012-2020. The turning point seems to lie around the year 2016. Third, one can distinguish relative changes in the rhetoric importance played by specific metals. Initial interest was mainly on lithium and graphite. Since 2017, there is increasing interest in cobalt and, lately, also in vanadium.

[47] MIT (2023). China just fought back in the semiconductor exports war. Here’s what you need to know. MIT technology review. https://www.technologyreview.com/2023/07/10/1076025/china-export-control-semiconductor-material/

Table 4: Three top tweets in terms of likes

#	Text	Number of likes	User (date)
1	If you use a smart phone, spare a minute to show your support for the people of Congo. Roughly 60% of the world's cobalt supply is mined in Congo. Cobalt is used to produce lithium-ion batteries used in smartphones, laptops and electric cars. This has led to high HR violations! https://t.co/VJBvMXsZ4J	134,551	Ibiyode (2020-10-15)
2	rare photo of the moon hugging the earth https://t.co/s9ekDys1cR	100,320	EUPH0RIAL0VE (2020-10-11)
3	@stats_feed Price of lithium has gone to insane levels! Tesla might actually have to get into the mining & refining directly at scale, unless costs improve.\n\nThere is no shortage of the element itself, as lithium is almost everywhere on Earth, but pace of extraction/refinement is slow.	63,076	elonmusk (2022-04-08)

Source: own analysis.

Before we attempt to understand the most pressing issues discussed in our dataset in the next section, we aim to convey a first qualitative impression of the underlying dataset. To do so, we rank all tweets by the absolute number of likes gained from other users and look at the top tweets in close reading. As can be seen from a glance, not all tweets deal with rare earths in the strict sense; we also captured tweets that mentioned the terms "rare" and "earth" in a looser sense (for example, describing a picture taken from the earth and the moon). This justifies our choice of omitting "rare earths" in Figure 7. However, there are also many tweets with direct relevance to the policy debate on critical metals (Section 2). By way of example, we plot in Table 4 three of the top tweets extracted in this way. Tweet number 1, written in 2020, raises the issue of human rights violations in Congo, where in fact most of the world's cobalt supply is produced. Tweet number 2 is an example for one of the unrelated tweets captured by our keyword search strategy. Tweet number 3 is from Elon Musk, the owner of electric vehicle company Tesla, who in April 2022 argued in an influential tweet that the price of lithium had increased a lot and that Tesla might therefore have to get into the mining and refining directly at scale. The fact that Musk, as an entrepreneur and manufacturer of electric vehicles, can send particularly influential tweets about a key component of these vehicles and thus potentially influence the price, raises fundamental questions about the digital ecosystem and the connection between social media and critical metals. This connection is even more problematic today, after we finished constructing our sample, as Musk has since acquired Twitter and can thus influence this social medium in even more direct ways, including regarding the source code and algorithmic sorting of the news feed itself.[48]

[48] How Elon Musk Uses Twitter (investopedia.com).

5 Discourse analysis using the example of lithium

5.1 Lithium tweets in general

To illustrate the content of Twitter discussions on critical metals in our sample, we perform a discourse analysis of influential Tweets on lithium, a metal of critical importance for battery production. To this end, the sample was filtered by the search term “lithium”, which leaves us with more than three million tweets (3,282,536 observations). We then proceed with a mixed-methods approach for analysing the underlying discourse. First, we look at the tweets in a qualitative fashion with close reading. To do so, the subsample of lithium tweets was ranked according to influence, with influence proxied by the number of likes. Then, the top 300 tweets according to this ranking underwent a first manual content screening. This led to the classififcation of 222 tweets as off-topic, because they did not cover mining issues, but mentioned lithium in other contexts (e.g. consumption of lithium pills). That left us with 78 mining-related Tweets considered adequate for a discourse analysis. In this analysis, the type of arguments made in relation to the lithium mining were distilled and classified. The following attributes were assigned to the tweets: revealed attitude towards lithium mining (positive/negative), argument category, specific argument(s) made, solution to mining-related issues proposed (if any). As argument categories, three categories were specified that define the spectrum of current policy concerns related to the origin of critical metals (see Section 2) quite well: pricing, supply risik, and sustainability.

The second pillar of our mixed-method appraoch draws on NLP methods to analyse all tweets contained in the lithium subsampe by algorithmic means.[49] In particular, we use digital methods that allow us to invetigate similar dimensions of the discourse as in the preceding qualitative analysis: so-called sentiment analysis to capture emotions, as well as frequency of words to reflect commonly used arguments and solutions. On the one hand, sentiment analysis involves the use of computational methods to determine the emotional tone or sentiment expressed in a piece of text, whether it is positive, negative, or neutral.[50] This process helps to automatically gauge people’s opinions, attitudes, or emotions towards a specific topic, which is why this method is often applied in social media monitoring. This makes it a suitable method to extract sentiment towards mining from large collections of tweets.[51] On the other hand, one can quantify the amount of important arguments or criticism raised in a corpus of texts by using domain-specific word lists that categorize words.[52] This is known as dictionary analysis. By counting the occurrence of these chosen words associated with arguments and criticisms, respectively, in the corpus, one can gauge the extent to which elements are expressed

[49] For an overview, see: Julia Silge and David Robinson, Text Mining with R: A Tidy Approach (Beijing; Boston: O’Reilly, 2017); Fotis Jannidis, Hubertus Kohle, and Malte Rehbein, eds., Digital Humanities: eine Einführung (Stuttgart: J.B. Metzler Verlag, 2017); Stephen Robertson, ‘Digital Humanities’, in The Oxford Handbook of Law and Humanities, by Stephen Robertson, ed. Simon Stern, Maksymilian Del Mar, and Bernadette Meyler (Oxford University Press, 2019), 85–103.

[50] Bing Liu, Sentiment Analysis: Mining Opinions, Sentiments, and Emotions (Cambridge: Cambridge University Press, 2015); Mika V. Mäntylä, Daniel Graziotin, and Miikka Kuutila, ‘The Evolution of Sentiment Analysis—A Review of Research Topics, Venues, and Top Cited Papers’, Computer Science Review 27 (February 2018): 16–32.

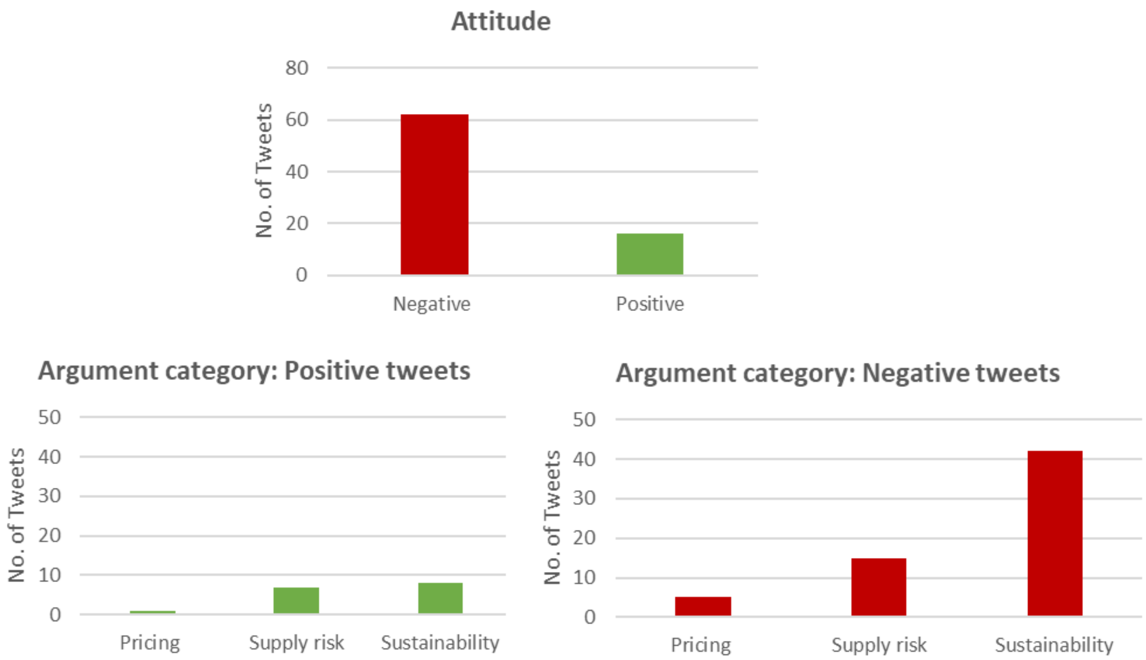
[51] Abdullah Alsaeedi and Mohammad Zubair, ‘A Study on Sentiment Analysis Techniques of Twitter Data’, International Journal of Advanced Computer Science and Applications 10, no. 2 (2019): 361–74.

[52] A classic paper on this is: Tim Loughran and Bill Mcdonald, ‘When Is a Liability Not a Liability? Textual Analysis, Dictionaries, and 10-Ks’, The Journal of Finance 66, no. 1 (February 2011): 35–65; see also: Rice and Zorn, ‘Corpus-Based Dictionaries for Sentiment Analysis of Specialized Vocabularies’. For methodological pitfalls, see: Christian Rauh, ‘Validating a Sentiment Dictionary for German Political Language—a Workbench Note’, Journal of Information Technology & Politics 15, no. 4 (2 October 2018): 319–43.

throughout the text data. In the following, we always start with the qualitative results, which are then contrasted with the quantitative ones.

We begin with a qualitative analysis of the sentiment contained in the 78 top lithium tweets. The general attitude expressed towards lithium mining in this sample is overwhelmingly negative. About three fourth of all tweets voice criticism about lithium extraction. More than half of them adress sustainability concerns as the major issue. Most of the sustainability arguments focus on the threat of local environmental damage caused by mining activities. It is by far the most popular among all arguments raised by the tweets in the subsample (see Figure 8). Most of the tweets remain unspecific about the nature of the damage. Explicit examples given are soil contamation, pollution and water use. Less prevalent, but still frequent, are arguments related to human rights violation. The incidence of child labour in mining is often mentioned as a specific human rights issue. Significantly less frequent were arguments related to the specific supply risks associated with lithium. Most of the comments made refer to the risk of geological shortage caused by the expected strong demand increases of the future. Just one tweet addresses market dominance as a supply threat. Similarly, only a small minority of tweets targets pricing issues, most of them warning about a future price rise.

Figure 8: Attitudes and types of arguments concerning lithium mining in our subsample



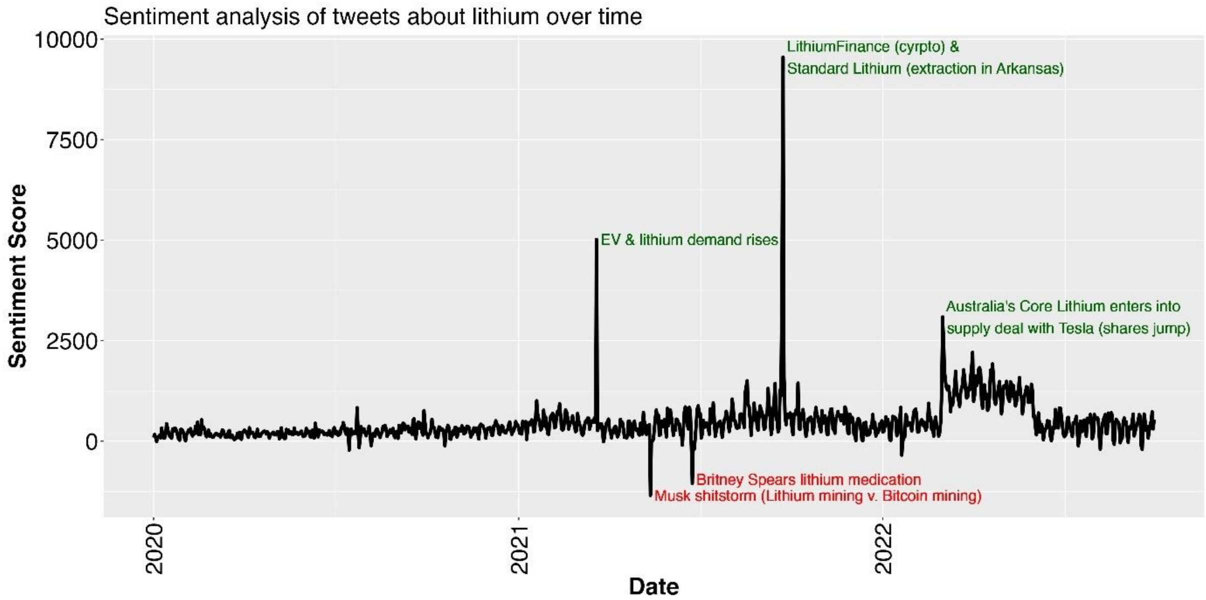
Source: own analysis.

We can contrast this with the sentiment extracted by means of a dictionary analysis. Dictionaries are commonly used in sentiment analysis to assign sentiment scores to individual words based on their polarity (positive, negative, or neutral).[53] Essentially, they are simply long list of words that evoke

[53] Jakob Fehle, Thomas Schmidt, and Christian Wolff, 'Lexicon-Based Sentiment Analysis in German: Systematic Evaluation of Resources and Preprocessing Techniques', in Proceedings of the 17th Conference on Natural Language Processing (KONVENS 2021, 2021), 86–103, https://aclanthology.org/2021.konvens-1.8; Alessio Guerra and Oktay Karakuş, 'Sentiment Analysis for Measuring Hope and Fear from Reddit Posts during the 2022 Russo-Ukrainian Conflict', Frontiers in Artificial Intelligence 6 (5 April 2023): 1163577; Maite Taboada et al., 'Lexicon-Based Methods for Sentiment Analysis', Computational Linguistics 37, no. 2 (June 2011): 267–307; Douglas R. Rice and Christopher Zorn, 'Corpus-Based

emotions in humans, with each word receiving a corresponding score that typically ranges from -1 (very negative) to +1 (very positive). Each word in a text is looked up in the sentiment dictionary, and its associated sentiment score is retrieved. By summing up the sentiment scores of all words in a text, a sentiment value for the entire text can be calculated, indicating its overall emotional tone.

Figure 9: Sentiment analysis of tweets about lithium over time



Source: own analysis.

Calculating these scores for our Twitter sample yields interesting results that complement the qualitative analysis (see Figure 9). As can be seen, on aggregate, there are more positive than negative sentiment words contained in lithium tweets. At least partly, this can be explained by many small accounts focused on day-to-day trading, which typically report (or re-tweet) positive news about successful lithium extraction or predictions about future price rises, which would, theoretically, translate in increased trading activity and potential financial gains for them. Often, the implicit goal is to persuade other users that investing in a particular metal is also a profitable business for them, which is reminiscent of a snowball system and points to the way in which social media usage might increase market volatility, betting, and, ultimately, economic irrationality (see, e.g., the recent discussion about so-called meme stocks). While positive sentiment dominates overall, some of the negative outliers are also of interest. While the negative spike related to revelations about Britney Spears lithium medication would be clearly classified as off-topic, the most negative point of the curve occurs in spring 2021, when Elon Musk tweeted negatively about the environmental effects of Bitcoin mining, in an attempt to counter criticism regarding the negative environmental issues related to lithium mining, which he needs for the production of his Tesla cars. This led to a “shitstorm” by Bitcoin-admirers, which explains the high number of negative sentiment words on Twitter on that day. On a more general level, this finding again underlines the large discourse influence that Musk enjoys on Twitter – a sort of market ordering power that might be questioned due to his vested interests in the field. We also find that while positive sentiment words dominate from a quantitative perspective, very negatively worded tweets often contain the most interesting arguments in the context of a discourse analysis, since they

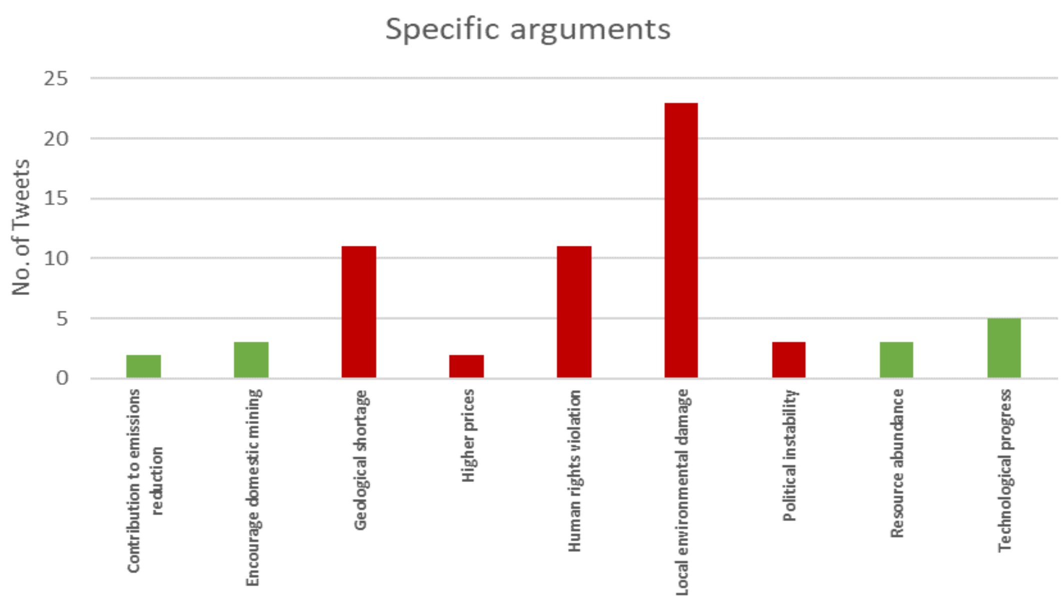
Dictionaries for Sentiment Analysis of Specialized Vocabularies’, Political Science Research and Methods 9, no. 1 (January 2021): 20–35.

engage more deeply with the topic of critical metals and mining (besides aiming to push specific stocks or prices).

Turning back to the qualitative analysis, only a small share of the tweets pointing to specific issues include concrete recommendations for remedies (see Figure 10). This aligns with the perception of Twitter as a medium where one can easily voice concerns or popular opinions, but which is less suitable for developing more lengthy, complex policy discussions. The solutions proposed in the identified tweets do not exhibit a clear focus, but are balanced among the different pillars of typical strategies for more secure and sustainable resource supply, like e.g. the action plan propagated by the European Commission.[54] Recommendations made multiple times are a switch to resource recycling as supply channel, investments in domestic extraction practices, the enforcement of sustainable mining practices and research efforts in the field of material substitution. The motivation behind all these solutions is a mixed one: attempts to increase supply security and to improve sustainability go hand in hand.

The topics addressed by tweets with positive attitude are quite balanced. Arguments from the categories supply risk and sustainability are almost on a par. Among the sustainability arguments, the contribution of lithium-based technologies to the fight against climate change is merely mentioned twice. Instead, comments focus on technological progress in the area of recycling and material substitution, as well as on the spread of sustainable mining practices. A mentioned positive aspect associated with supply risk is the sufficient availability of geological resources for domestic lithium mining.

Figure 10: Frequency of specific arguments made concerning lithium mining in our subsample

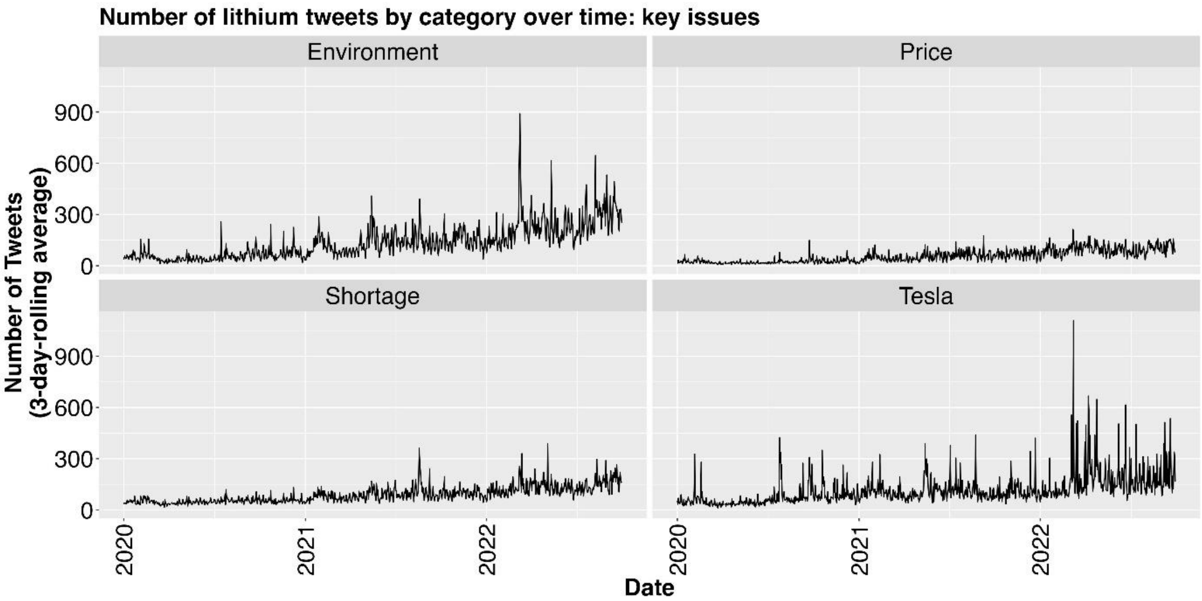


Source: own analysis.

[54] European Commission (2020). Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability. Communication from the Commissions to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2020) 474 final.

Again, we can contrast this with the quantitative perspective. For this, we can repurpose the dictionary approach introduced above. Instead of using standard dictionaries with sentiment words, we can also construct our own dictionaries that include specific expressions[55]. Here, we list words that are indicative of the topics (see Figure 11) and solutions (see Figure 12) discussed on Twitter. For the category "environment" we use the following word list: "environment", "climate", "sustainable", "emission", "green", "toxic". For arguments about Tesla: "tesla", "musk". For discussions about price ("price"), we search for: "price", "prices", "pricing", "usd", "$/tonne". And for possible warnings for supply shortages, as expressed during the Covid pandemic, we filter for the terms: "shortage", "demand", "lack", "rare". As for the potential solution scenarios, we also create four categories with four associated dictionaries. Regarding the solution of extended mining, we choose the list: "mining", "extract", "extracting", "mine". For proponents of more trade to counter an acute lack of metals ("trading"), i.e. a market-based solution, the words searched for are: "trade", "trading", "transaction", "partners", "market", "exchange", "invest", "buy", "sell". The category "recycling" consists of: "recycle", "recycling", "reuse", "recovery", "re-purpose", "remanufacture", "upcycle", "reclaim", "reutilize", "convert", "recondition", "salvage", "regenerate", "restoration". And finally, the debates for more search, i.e. "exploration", is covered by: "exploration", "exploring", "mineral", "prospecting", "drilling", "new". To smooth the corresponding frequency curves and provide better visualisations, we calculate three-day-rolling means. Applying the eight dictionaries to our corpus in this way leads to three key insights.

Figure 11: Number of lithium tweets by category over time: key issues



Source: own analysis

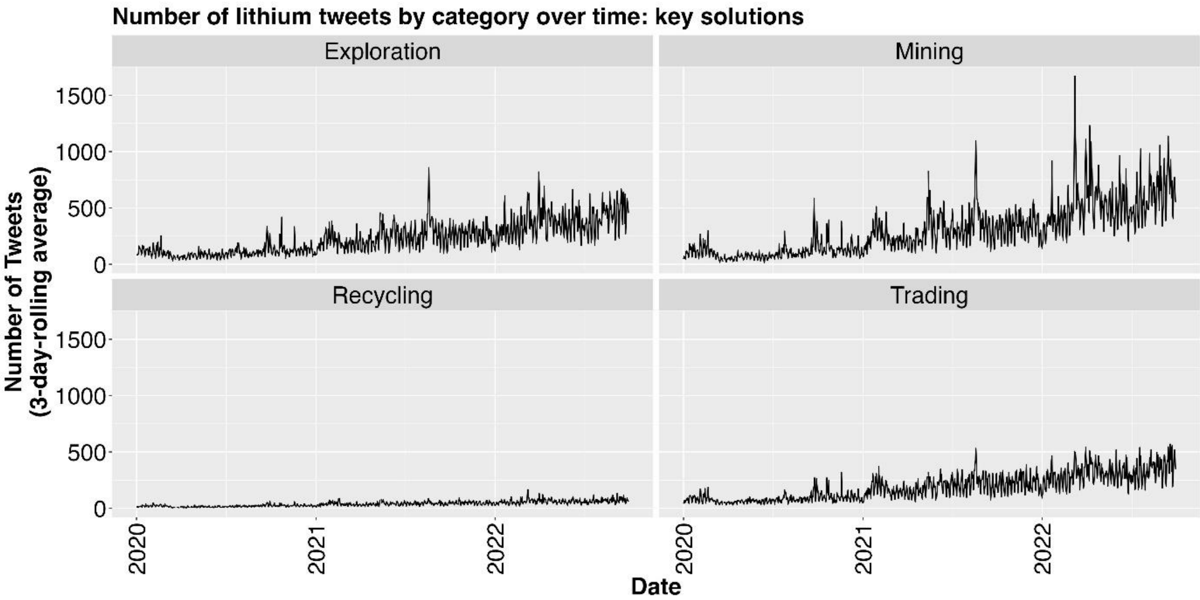
First, in terms of topics, there is a strong increase in interest in 2021 and particularly in 2022 about environmental aspects of lithium mining, which goes significantly beyond the interest shown in price fluctuations and in potential shortages (see Figure 11). Although this aligns with our qualitative analysis, which suggested that many "green" concerns such as soil contamation, pollution and water use play a role in negative tweets about lithium, this is still a very surprising and interesting finding,

55 Tim Loughran and Bill Mcdonald, 'When Is a Liability Not a Liability? Textual Analysis, Dictionaries, and 10-Ks', The Journal of Finance 66, no. 1 (February 2011): 35–65; see also: Rice and Zorn, 'Corpus-Based Dictionaries for Sentiment Analysis of Specialized Vocabularies'.

given that the period of analysis overlaps with the Covid pandemic, which in general raised the issue of supply-side shortages, and given that many of the Twitter accounts engaging in the lithium discourse are apparently involved, as noted, in day-to-day trading activities. The result suggests that besides this narrow group focused on economics, finance, and trading, there is also a more public discourse about critical metals focused on the environment and human rights. Again, this overlaps with the qualitative evidence discussed earlier.

Secondly: Although the environment category dominates issues such as price and shortages, it is telling that the highest peak among the four categories relates to Tesla, although this topic was approximated with only two words, namely "Musk" and "Tesla" (in contrast to the three other categories, whose dictionaries encompass numerous words). Recall that this result does not refer to the general, broad interest in Musk on Twitter – rather, this shows that even in a niche field such as tweets explicitly dealing with lithium, he is perceived as an influential actor whose opinions spread virally.

Figure 12: Number of lithium tweets over time: key solutions



Source: own analysis.

Thirdly, and somewhat counterintuitively, we find that the most frequently discussed solutions on Twitter relate to more exploration and more mining, i.e. extraction (see Figure 12). By comparison, the discourse about recycling is much less present online and the corresponding frequency curve is clearly less visible. This is reminiscent of the "not in my backyard"-style of argumentation and opens the possibility for foreign FIMI campaigns, which might exploit the sentiment of Westerners who are concerned about the environmental impact of mining rare metals but ignore the benefits of recycling. The minimal online discussion of recycling is disappointing from a scientific point of view, as many experts agree that only with substantial efforts at recycling will Western societies adapt to the challenges of the climate crisis while reducing their dependencies on other geographical regions in the world.

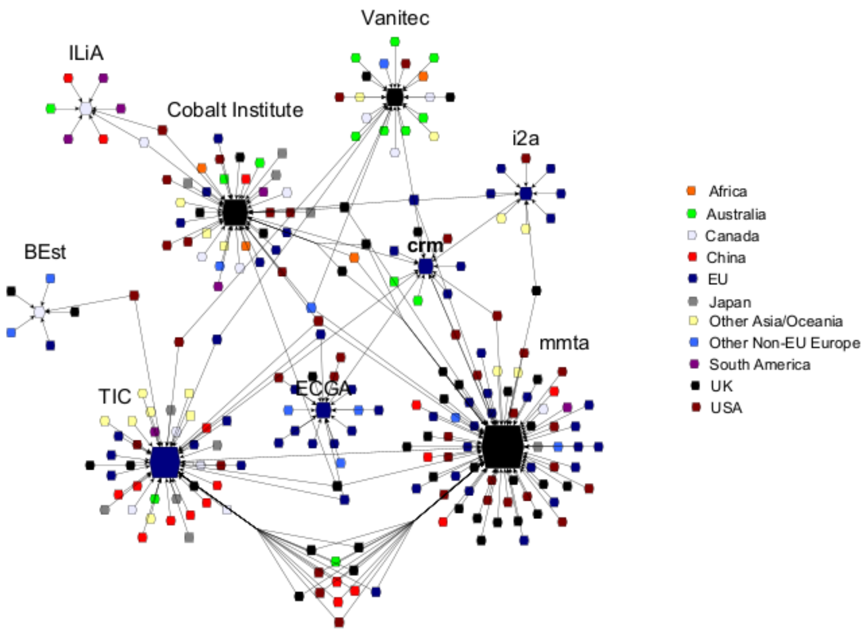
5.2 Lithium tweets by industry stakeholders

To compare these impressions from the general online debate with the communication efforts of the mining industry, this section engages in a similar exercise as above specifically for tweets by the industry stakeholders included in our dataset (see Section 3). In this way, we hope to shed light on their communication strategy and aim to assess if it captures the general mood, i.e. the topics and sentiments identified earlier, to a sufficient degree. If this is not the case, this might create discursive space for potential future attackers, i.e. malign foreign actors that aim to fuel existing fears and resentments in the field of mining in order to ensure that the West keeps importing critical metals from less democratic areas of the world and thus retains its status of dependency. At the end of the section, we use again computational NLP methods to reflect on our qualitative results gained from a network study.

To begin with, we depict the connections of the stakeholders included in the form of an organic network, with nodes representing firms/associations and edges representing their memberships. Figure 13 distinguishes firms/associations by country of origin (headquarter locations), while Figure 14 does so by position in the supply chains. The geographical comparison already sketches an interesting pattern. First, despite the fact that the *crm Alliance* was explicitly founded to influence EU policies, companies from the EU merely represent a minority. This is only different for the *International Antimony Association* (i2a) and the *European Carbon and Graphite Association* (ECGA). However, presumably due to the high specificity of the materials represented by these two organizations, they both exhibit only a comparative small number of members. Chinese companies, by comparison, are particularly well-represented in the comparatively big *crm Alliance* member association. Moreover, quite intuitively, the country patterns also echo the global distribution of raw material reserves and production capacities. For instance, the concentration of Australian companies in *Vanitec*, an association representing firms involved in the supply chain of Vanadium production, matches the significant resource reserves documented for this metal in Australia.[56] The distribution by supply chain position also reveals an interesting heterogeneity. For example, the *Minor Metals Trade Association* (mmta), the biggest association in terms of membership, not only represents a large number of metal traders, but also companies from almost all other parts of the supply chain (except for machinery and chemical products). By comparison, the smaller associations tend to be more vertically specialized. At the same time, mining companies tend to cluster in metal-specific associations, only a comparatively small share of them is member of more than one of the associations.

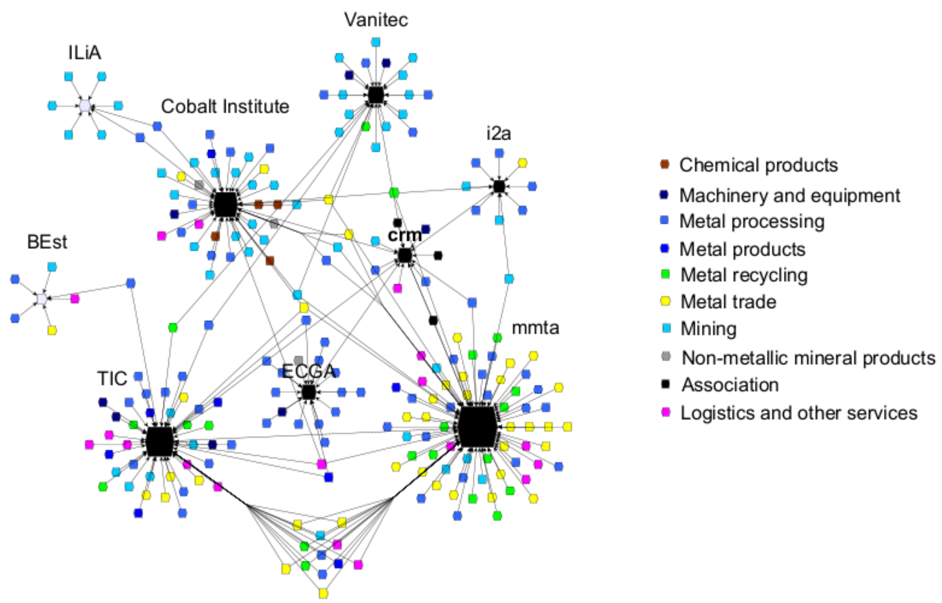
[56] USGS (2022). Mineral Commodity Summaries 2022 – Vanadium. U.S. Geological Survey.

Figure 13: Network of organizations distinguished by country of origin



Source: own analysis; nodes: organizations; edges: membership relations; size of nodes: number of members.

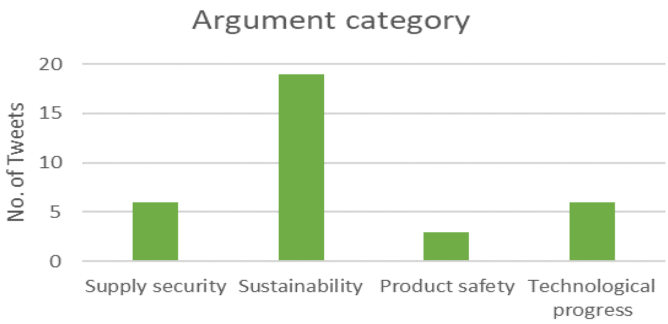
Figure 14: Network of organizations distinguished by position in the supply chain



Source: own analysis; nodes: organizations; edges: membership relations; size of nodes: number of members.

To distil the most relevant tweets from this network of stakeholders, we followed the same strategy as above: Selection of the Top 300 tweets based on the number of likes and subsequent elimination of tweets not directly touching upon arguments related to lithium mining. In doing so, we had to deal with the fact that the bulk of tweets consisted of pure company advertisement not involving any positive or negative arguments regarding lithium per se. Accordingly, these advertisement tweets had to be eliminated, leaving us with only 34 tweets suitable for our analysis. Note that these were not "paid" advertisements on Twitter, which were already excluded from our sample when accessing the Twitter API (see Section 3 above), but supposedly "normal" tweets posted by the stakeholder accounts which were, nevertheless, purely focused on making advertising claims and thus not informative.

Figure 15: Frequency of argument categories in industry stakeholder tweets

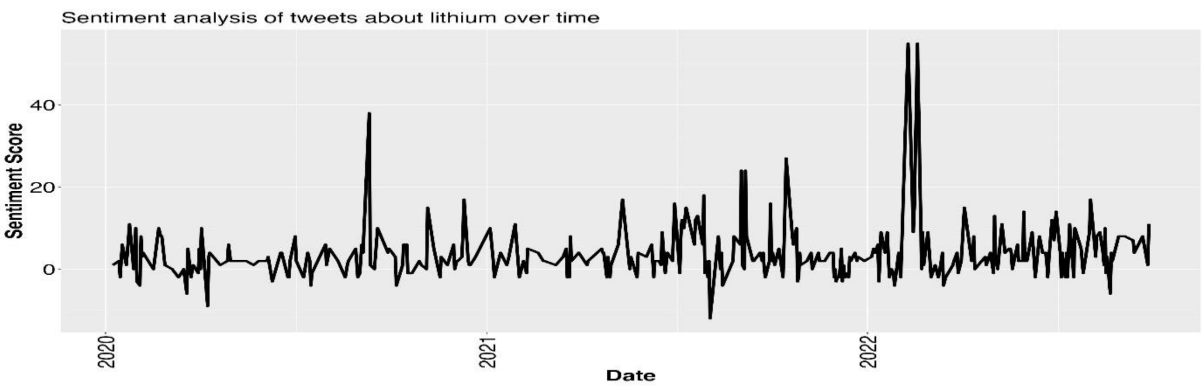


Source: own analysis.

As to be expected, the tweets almost exclusively express a positive attitude towards lithium mining. Interestingly, sustainability exhibits a similar dominance as an argument category as in the case of our subsample from the general debate (see Figure 15). However, the specific arguments made are predominantly not responses to the main sustainability issues raised by the critics (see Section 5.1) – damages to the local environment and human rights violations – but focus on improvements in resource recycling. The latter issue is largely missing in the general debate, as shown in the previous section. Hence, there are signs for some misalignment of the debate on sustainability aspects between industry stakeholders and the wider public. For arguments related to supply security, the picture looks different. Industry stakeholders are stressing the size of their geological deposits and extraction capacities, thus directly addressing the concerns of a shortage voiced in the general debate.

We contrast this with a quantitative view on the stakeholder tweets. First, we look at the sentiment scores (see Figure 16). This mirrors the qualitative interpretation – almost all stakeholder tweets contain, in aggregate, positive sentiment, with a notable peak in early 2022. Due to the much smaller sample size (restricting the dataset to all lithium tweets by stakeholder accounts), however, the patterns depicted in this, and the following, figure are less reliable.

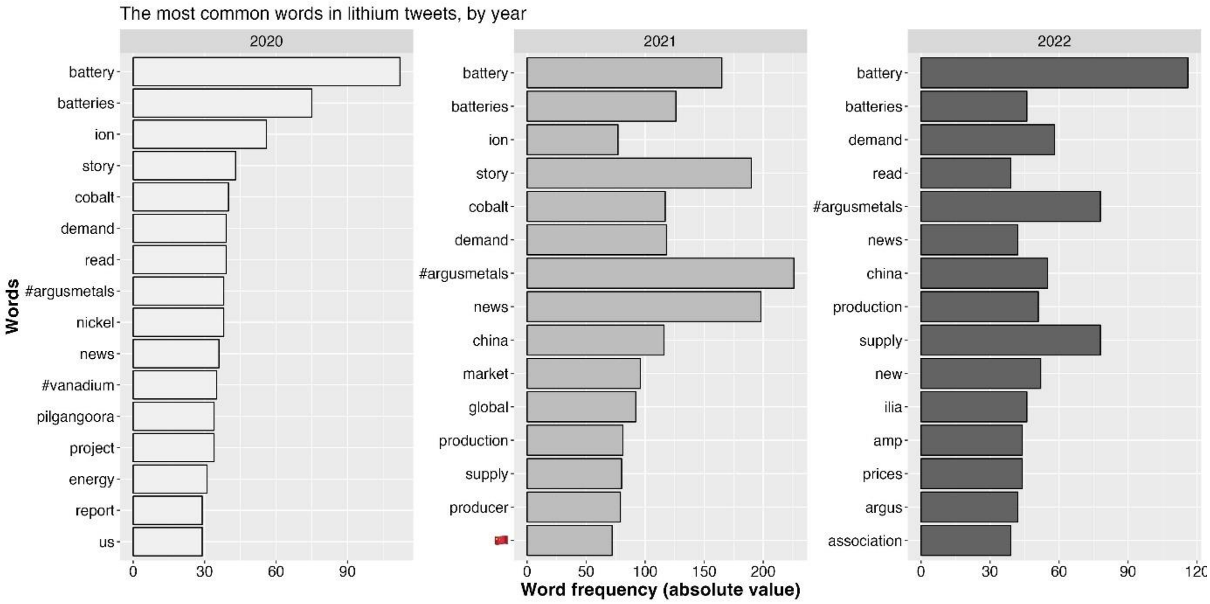
Figure 16: Sentiment analysis of stakeholder tweets about lithium over time



Source: own analysis.

As the stakeholder sample of lithium tweets is too small for applying dictionary analysis, we check their content by calculating the most frequent terms employed by stakeholders (see Figure 17). In all three years analysed here – 2020, 2021, and 2022 – stakeholders primarily dealt with the issue of lithium batteries in their official communication on Twitter. Other frequently mentioned metals in this context were cobalt and nickel. However, we can also see some shifts over time. After the outbreak of the Covid pandemic, the supply dominance of China becomes more relevant in stakeholder posts: tellingly, terms such as "China", "supply", and "production" appear only in the top word lists for 2021 and 2022, but not in the list for 2020.

Figure 17: The most common words in stakeholder tweets about lithium, by year



Source: own analysis.

5.3 Lithium tweets targeting Europe

Finally, we return to our initial motivation regarding possible FIMI campaigns (see introduction) by searching our lithium dataset for all tweets that could relate to the EU and its rare earth strategy. In doing so, we want to explore to what extent the general English-language Twitter debate on lithium already shows signs of possible communicative strategies or even disinformation that are negatively directed against Europe. Specifically, we filter the lithium sub-dataset for all tweets containing "EU", "Europe" or "Commission". Including the latter term contains some risk of extending our search too much, as in the American language context "Commission" is also used in various other contexts, but we wanted to ensure that we do not to miss any important tweets that directly concern the EU Commission. In line with the previous analyses, we then extracted the 300 most influential tweets, again defined by number of likes, and analysed this sample through qualitative close reading. Here, we briefly outline our impressions and insights from this exercise by way of example.

Repeatedly, we find Twitter users who promote bitcoin and gold in their everyday business and then try to spread negative sentiment about the EU with alarmist tweets, claiming, for example, that the EU would ban lithium because of its toxicity and thus thwart the energy transition. While this is based on real media reports, it is deliberately exaggerated and dramatised, perhaps because certain stocks have been shorted by these private traders. Many other thematic tweets also deal with why the future, in a broad sense, does not lie in Europe, including criticism of European environmental protection, the continent's lack of lithium reserves, or the war in Ukraine, which is sometimes linked to conspiracy theories. In general, there is a clear anti-European sentiment in most of these tweets, which are usually not countered by other users or official EU accounts. Given Musk's sacking of much of Twitter's content moderation team and considering the legal obligations stemming from Digital Services Act (DSA), whose enforcement started at the end of August 2023, it is not clear whether Twitter, now X, will be able to handle similar instances of disinformation in the future.

To illustrate potential avenues for future miscommunication campaigns, Table 5 presents three tweets among the 300 extracted tweets that express specific criticism concerning European mining projects. Tweet number 1 represents a reaction to the Commission's communication surrounding the announcement of the European Chips Act. Referring to the announcement of future domestic extraction of rare earths inside the EU, the user directly targets the credibility of sustainability guarantees by EU officials. By asking rhetorically whether the announcement should be understood that sustainability criteria apply only to EU-internal mining, it implicitly accuses the EU of double standards. In doing so, it indirectly alludes to the massive environmental and human rights issues that exist at current mining sites for critical metals such as rare earths. The question raised is why the EU has not yet advocated for sustainability improvements in supplier countries if these issues have priority in EU policymaking. The implicit message is that for an EU-internal mining industry sustainability goals serve primarily as a cover of pecuniary intentions.

Table 5: Selected tweets expressing criticism towards European lithium mining

#	Text	Number of likes	User (date)
1	In rolling out the European Chips Act today, EU talks about possible extraction of rare earth within EU member states but stressed that it will do so with full respect to the environment. Does it suggest when it's extracted outside EU, such environment concern will be dismissed?	742	chenweihua (2022-02-08)
2	Germany has the world's largest lithium deposits, but isn't extracting it, neither is anyone else in the EU. Could it be because these countries don't want to destroy their environments, but are OK with destroying Serbia's environment?	450	malagurski (2021-11-20)
3	UK ambassador @SianCMacLeod claims to care for environment while supporting Rio Tinto to dig deep lithium mine in fertile Mačva? She supports destruction of the best soil in Europe and endangering [sic!] water supply of densely populated area with millions of citizens	365	savski_nasip (2020-12-24

Source: own analysis.

Tweet number 2 aims with its message in a similar direction. Its background is the debate on the large lithium reserves in the Jadar Valley in western Serbia. The British-Australian mining group Rio Tinto has been operating an exploration project there for several years. The start of large-scale mining was planned for 2026. It was hoped that the region would cover a large proportion of Europe's lithium demand. However, the project led to massive protests by residents, as fears about possible environmental damage (including drinking water contamination) could not be allayed by the project company. As a result, the Serbian government stopped the project in January 2022[57]. The tweet points to the equally large lithium reserves in Germany. The fact that they have not been mined so far is seen as an admission that Germany recognizes strong negative environmental effects of lithium mining and wants to avoid them in its own country. Germany would, on the other hand, agree with outsourcing mining to EU neighbouring countries such as Serbia, as the environmental damage would be borne by the population there. Again, the accusation of double standards is raised in connection with sustainability issues and the credibility of sustainability goals is called into question. The episode is of particular interest as our analysis has shown that Rio Tinto is among the most influential Twitter stakeholders of the mining industry, at least in terms of followers and likes (see above). Nevertheless, this influence seems not strong enough to effectively counter this very public criticism.

Tweet number 3 also deals with the discussion about lithium mining in Serbia. Here, not the EU or a member state, but the British ambassador in Serbia is criticized for allegedly supporting the Rio Tinto project. Here, too, critical reference is made to the expected negative environmental effects, specifically high-water consumption and damage to the local soil.

In summary, the tweets indicate that the (perceived or existing) credibility problem in sustainability issues could be a likely target of future (mis)communication campaigns against EU-led mining projects in the field of critical metals, be they projects inside or outside the EU. In the end, only a transparent and scientifically sound monitoring system of environmental effects can help against this threat. Moreover, the EU and its member states need to communicate honestly the existing trade-offs between sustainability goals and domestic economic interests, and to be fair in their assessment of the actions by third countries. Otherwise, accusing the EU of double standards will be an easy target for anti-European FIMI campaigns in the future.

6 Conclusion

This paper presents the first systematic analysis of the Twitter discussion on critical metals, based on a novel dataset containing 4,056,822 tweets. By applying Natural Language Processing (NLP) methods, the content of a large sample of tweets on this subject was analysed in both quantitative and qualitative terms. The analysis revealed interesting patterns regarding firstly the main stakeholders involved in this debate, secondly the key problems and solutions discussed online, and thirdly the respective importance attached to certain critical metals. Since early 2020, the daily number of tweets on the subject have shown a clear upward trend, reflecting the growing interest in critical metals at a time of shifting geo-politics and pandemic-induced supply shortages. At the same time, the respective Twitter activity was characterized by significant volatility, driven by trading activities and Elon Musk's oversized and algorithmically amplified role in the debate. A series of dates were identified on which Twitter discussions about critical metals skyrocketed. These dates show no clear connection to the timing of political communications by EU institutions, suggesting that the discourse is mainly driven by business news and scandals and cannot be shaped by political communication on this issue, which is often ignored. This impression is confirmed on close reading. Moreover, Twitter activity was not distributed equally across the range of critical metals included but showed a clear focus on a few metals like lithium, titanium and cobalt over the whole time period considered. While these metals play a crucial role in the current digital-green transformation taking place in Western economies, their over-emphasis produces a blind spot when it comes to other important metals that will be needed in

[57] Balkan Insight (2022). 'It's [Not] Over': The Past, and Present, of Lithium Mining in Serbia.

the coming years, such as gallium and germanium, which were recently targeted by China but play almost no role in the public discourse on Twitter. In the case of lithium, apart from comments made by speculators who frequently tweet about this issue, the significant online interest can partly be explained by influential comments made by Musk, who needs this metal for his Tesla car production and is concerned about future supply. As we argued, the strength of Musk's discursive influence, which emerged clearly in both the quantitative and the qualitative analysis, amounts to a dominant position on Twitter which has market distorting effects that might be seen critical and lead to calls for regulatory action.

Due to its significant role in the online discourse, surveyed with aggregate statistics, our subsequent case study focused on lithium. For this, we employed a mixed-methods approach that combined quantitative NLP methods, such as sentiment analysis and dictionary analysis, with qualitative close reading. This in-depth discourse analysis revealed a range of mining-related issues frequently discussed on Twitter. At the forefront were sustainability concerns related to environmental damage and human rights violations which represented one main area of criticism expressed by Twitter users. Insufficient supply potential is a further concern that is frequently mentioned. Proposed solutions to the concerns touch on a range of options and are surprisingly similar to those being looked at in the current policy debate at the European level. Comparing this general debate to a specific analysis of influential tweets by stakeholders from the mining industry reveals signs of some misalignment. Whilst they take sustainability questions seriously, stakeholders seldom responded directly to the specific sustainability concerns surrounding mining but preferred to communicate alternative technology solutions like metal recycling and material substitution. This might indicate a lack of argumentative ammunition vis à vis the criticism which could potentially provide a loophole for future malicious disinformation campaigns that aim to leverage public distrust in order to prevent the West from diversifying its supply routes. This is not a hypothetical scenario: In the US, research has already uncovered such FIMI campaigns targeting the US online discourse about critical metals.[58] While we did not find clear evidence for such behaviour targeting European constituencies, our analysis suggests that similar threats could eventually arise for the European discourse, too, with the EU preparing for the implementation of its Critical Raw Materials Act.

From our findings, combined with the studies cited in the introduction, it is clear that the EU needs to create adequate legislation – beyond the new Digital Services Act (DSA) – and develop technical capacity to better detect inauthentic online behaviour. It is particularly important to create pressure on the relevant media companies to implement effective controls. Previous research found that Facebook is not doing enough to stop inauthentic behaviour on its platform, at least where this is happening in smaller markets, including Europe.[59] However, the recent wave of layoffs at X, and at Facebook's owner Meta, have fuelled concerns that these social media platforms no longer have sufficient capacity for content moderation and monitoring. The EU must counteract this by threatening to impose penalties, for example under the DSA, and by calling for ex-ante approaches, such as 'slow content transmission', that reduce the spread of disinformation.[60] Ideas could also come from the EU's

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58 https://www.mandiant.com/resources/blog/dragonbridge-targets-rare-earths-mining-companies.

59 Patrik Szicherle, Csaba Molnár, THE RUSSIA-UKRAINE WAR IN SOCIAL MEDIA. Inauthentic online behavior in the V4 concerning Russia's war against Ukraine, Political Capital, May 2022, https://www.politicalcapital.hu/pc-admin/source/documents/pc_v4_social_media_war_ukraine_20220505.pdf (6 December 2022).

60 Detailed proposals can be found in our cepNetwork study: Anselm Küsters, Eleonora Poli, Camille Réau, Victor Warhem (2023), The threat of digital populism. A comparative look at Germany, Italy, and France (forthcoming).

current actions in the context of Russia's war against Ukraine: Since 2014, the EU has imposed sanctions on individuals and organisations that threaten Ukraine's sovereignty. In August 2023, the list was expanded to include the spread of disinformation, with the aim of cracking down on Russian FIMI campaigns.[61] By analogy, the EU should embed digital defence measures in its risk management strategy for critical raw materials, in order to lower the exposure of future strategic raw material projects in Europe to the risk of foreign disinformation campaigns. In light of the upcoming 2024 EU elections, this is a pressing matter.

61 Sanktionen gegen russische Desinformanten verhängt - Tagesspiegel Background.

7 Appendix

Table A 1: List of industry stakeholders

Name short	Industry (NACE codes for companies)	Twitter Handle	Name short	Industry (NACE codes for companies)	Twitter Handle
5N Plus	Manufacture of basic precious and other non-ferrous metals (24.4)	-	Materion	Manufacture of basic metals (24); Manufacture of fabricated metal products (25)	@MaterionCorp
A&R Merchants	Wholesale of metals and metal ores (46.72)	-	MERSEN	Manufacture of fabricated metal products (25)	-
Advanced Alloy Services	Wholesale of metals and metal ores (46.72)	-	Metaal Transport	Warehousing and storage (52.1)	-
Advanced Material Japan	Wholesale of metals and metal ores (46.72)	-	METAL DO	Recovery of sorted materials (38.32)	-
AHK group	Support activities for other mining and quarrying (09.90); Wholesale of metals and metal ores (46.72)	@AhkGroup	Metal Events	Other professional, scientific and technical activities (74.9)	@MetalEventsLtd
ALBEMARLE	Manufacture of basic chemicals (20.1)	@AlbemarleCorp	Metal Partner	Wholesale of metals and metal ores (46.72)	-
Allkem	Mining of non-ferrous metal ores (07.2)	@Allkemltd	METALINK	Manufacture of basic precious and other non-ferrous metals (24.4)	-
Ambatovy	Mining of non-ferrous metal ores (07.2)	@AmbatovyJV	METRACO	Wholesale of metals and metal ores (46.72)	-
AMC group	Recovery of sorted materials (38.32)	-	MFG	Manufacture of basic precious and other non-ferrous metals (24.4)	-

AMG Antimony	Manufacture of basic chemicals (20.1)	-	MinTerra FZE	Wholesale of metals and metal ores (46.72)	-
AMG Brasil	Mining of non-ferrous metal ores (07.2)	-	Mitsui & Co.	Wholesale of metals and metal ores (46.72)	@citra_citrasa
AMG Graphite GK	Manufacture of basic chemicals (20.1)	-	Mitsui Kinzoku	Manufacture of basic precious and other non-ferrous metals (24.4)	-
AMPERE Alloys	Wholesale of metals and metal ores (46.72)	-	mmta	Minor metals supply chain (including RREs)	@MMTAExec
AngloAmerican	Mining of non-ferrous metal ores (07.2)	@AngloAmerican	MOLYMET	Manufacture of basic precious and other non-ferrous metals (24.4)	-
ARA Corporation	Wholesale of metals and metal ores (46.72)		Morgan Advanced Materials	Manufacture of other non-metallic mineral products (23)	@MorganAdvanced
Argus Media	Market research (73.2)	@ArgusMedia	MPIL	Manufacture of basic chemicals (20.1)	-
ASI	Technical testing and analysis (71.2)	-	MSC	Manufacture of basic precious and other non-ferrous metals (24.4)	-
ASM	Mining of non-ferrous metal ores (07.2)	@ASM_aus	MTALX	Wholesale of metals and metal ores (46.72)	-
Atlantic Vanadium Pty	Mining of non-ferrous metal ores (07.2)	-	MTU Aero Engines	Manufacture of air and spacecraft and related machinery (30.3)	@MTUaeroeng
Australian Vanadium	Mining of non-ferrous metal ores (07.2)	@AusVanadium	NANJING YOUTIAN METAL TECHNOLOGY	Manufacture of basic precious and other non-ferrous metals (24.4)	@ZrHfTi
Auxico	Mining of non-ferrous	@AuxicoResources	Neometals	Recovery of sorted	@neometalsltd

	metal ores (07.2)			materials (38.32)	
Avon Specialty Metals	Recovery of sorted materials (38.32)	@avonmetal	New Zealand Steel	Manufacture of tubes, pipes, hollow profiles and related fittings, of steel (24.4)	@newzealandsteel
BeSt	Beryllium supply chain	-	NGK	Manufacture of basic precious and other non-ferrous metals (24.4)	-
Beta Technology	Manufacture of air and spacecraft and related machinery (30.3)	@BetaTechnology	NYACOL	Manufacture of basic chemicals (20.1)	-
BGV Group Management	Mining of metal ores (07)	-	Ocean Minerals	Mining of non-ferrous metal ores (07.2)	-
BlackRockMetals	Mining of non-ferrous metal ores (07.2)	-	Orano	Removal services (49.4.2)	@Oranogroup
Borchers	Manufacture of paints, varnishes and similar coatings, printing ink and mastics (20.3)	@MillikenChem	ORION METAL TRADE	Wholesale of metals and metal ores (46.72)	-
Brazilian Nickel	Mining of non-ferrous metal ores (07.2)	@BrazilianNickel	Oxkem	Manufacture of basic chemicals (20.1)	-
Bushveld Minerals	Mining of non-ferrous metal ores (07.2)	@BushveldMin_Ltd	PCD Lucette	Manufacture of basic chemicals (20.1)	-
Buss & Buss	Recovery of sorted materials (38.32)	-	Pilbara Minerals	Mining of non-ferrous metal ores (07.2)	@PilbaraMinerals
CAI Customs Alloys	Manufacture of basic precious and other non-ferrous metals (24.4)	@ACIAlloys	PLANSEE	Manufacture of fabricated metal products (25)	@PlanseeSE
Campine	Manufacture of basic	@CampineNV	Platinum Metals	Manufacture of basic	-

	chemicals (20.1)			precious and other non-ferrous metals (24.4)	
CAN	Mining of non-ferrous metal ores (07.2)	-	PLAXYS	Recovery of sorted materials (38.32)	-
Carbomax AB	Wholesale of metals and metal ores (46.72)	-	PMA	Manufacture of basic precious and other non-ferrous metals (24.4)	-
CBMM	Manufacture of fabricated metal products (25)	-	QEM	Mining of non-ferrous metal ores (07.2)	@QEMlimited
CellCube	Manufacture of batteries and accumulators (27.2)	@stina_resources	Quimialmel	Mining of non-ferrous metal ores (07.2)	-
CMOC	Mining of non-ferrous metal ores (07.2)	-	Rafaella Resources	Support activities for other mining and quarrying (09.90)	@RafaellaRFR_
Cobalt Institute	Cobalt supply chain	@CobaltInstitut	RC INSPECTION	Support activities for transportation (52.2)	-
CobaltBlue	Mining of non-ferrous metal ores (07.2)	@HoldingsBlue	Rheinfelden Carbon	Manufacture of basic chemicals (20.1)	-
Colorobbia	Manufacture of other porcelain and ceramic products (23.4)	@GrupoColorobbia	RIoTinto	Mining of non-ferrous metal ores (07.2)	@RioTinto
Commexim	Manufacture of basic precious and other non-ferrous metals (24.4)	-	RJH Trading	Mining of non-ferrous metal ores (07.2)	-
CoNiChem	Manufacture of basic chemicals (20.1)	-	S&P Global Platts	Market research (73.2)	@SPGlobal
Cook Islands Investment Corporation	Provision of services to the community	-	SABIC	Manufacture of basic chemicals (20.1)	@SABIC

	as a whole (84.2)				
CoreMax	Manufacture of chemicals and chemical products (20)	-	SANDVIK	Manufacture of machinery for mining, quarrying and construction (28.92)	@SandvikGroup
COVA	Manufacture of basic chemicals (20.1)	@GraphiteCOVA	SANGRAF	Manufacture of basic chemicals (20.1)	@sangrafintl
Cronimet	Recovery of sorted materials (38.32)	@CRONIMETgroup	Scandinavian Steel	Manufacture of basic precious and other non-ferrous metals (24.4)	-
CRU	Market research (73.2)	@CRUGROUP	Schmelzmetall	Manufacture of basic precious and other non-ferrous metals (24.4)	-
D Block Metals	Recovery of sorted materials (38.32)	-	schunk	Manufacture of machinery and equipment (28)	@SCHUNK_HQ
Darton Commodities	Wholesale of metals and metal ores (46.72)	-	Select Alloys and Materials	Wholesale of metals and metal ores (46.72)	-
Doe Run	Mining of non-ferrous metal ores (07.2)	-	SGL Carbon	Manufacture of basic chemicals (20.1)	@sglcarbon
Duferco	Manufacture of basic iron and steel and of ferro-alloys (24.1)	-	Shaanxi Head-Moly Industry	Mining of non-ferrous metal ores (07.2)	-
eac corporation	Manufacture of basic precious and other non-ferrous metals (24.4)	-	Shepherd	Manufacture of basic chemicals (20.1)	-
Earth Metals LLC	Mining of non-ferrous metal ores (07.2)	-	Sherrit	Mining of non-ferrous metal ores (07.2)	@Sherritt_Intl
ECGA	Graphite supply chain	@Ecga_C	Showa Denko	Manufacture of basic chemicals (20.1)	@showadenko

EGE KIMYA	Manufacture of basic chemicals (20.1)	-	SJM ALLOYS & METALS	Recovery of sorted materials (38.32)	-
Electra	Manufacture of basic chemicals (20.1)	@ElectraBMC	Somika	Mining of non-ferrous metal ores (07.2)	-
Elemental Metals	Wholesale of metals and metal ores (46.72)	-	Sovereign International	Wholesale of metals and metal ores (46.72)	-
ELG Utica Alloys	Manufacture of basic precious and other non-ferrous metals (24.4)	-	SPECIAL METALS	Manufacture of basic precious and other non-ferrous metals (24.4)	@SpecialMetalsOK
Elite Material Solutions	Engineering activities and related technical consultancy (71.1.2)	-	SPECIALTY METALS RESOURCES	Mining of non-ferrous metal ores (07.2)	-
Elkem	Manufacture of basic chemicals (20.1)	@Elkem_ASA	SPMP	Mining of non-ferrous metal ores (07.2)	@SPMPOMAN
ELSID	Manufacture of basic chemicals (20.1)	-	SQM	Mining of non-ferrous metal ores (07.2)	-
Environmetals LLC	Support activities for transportation (52.2)	-	Stachow-Metall	Recovery of sorted materials (38.32)	-
Eramet	Mining of non-ferrous metal ores (07.2)	@GroupeEramet	Stapleford Minerals and Metals	Wholesale of metals and metal ores (46.72)	-
ERG	Mining of non-ferrous metal ores (07.2)	-	Strategic Minerals Europe	Mining of non-ferrous metal ores (07.2)	-
esmalglass itaca	Manufacture of other porcelain and ceramic products (23.4)	@esmalglassitaca	Sumotino Metal Mining	Mining of non-ferrous metal ores (07.2)	-
Euro Alliages	Ferro-Alloy production	@EuroalliagesEU	Superior Graphite	Manufacture of basic chemicals (20.1)	@supergraphite
Euromet SA	Wholesale of metals and	-	TAIKE TECHNOLOGY	Manufacture of basic precious and	-

	metal ores (46.72)			other non-ferrous metals (24.4)	
Exotech	Recovery of sorted materials (38.32)	@Exotech_Inc	TAM	Transporting and storage (H)	-
F&X Electro-Materials	Manufacture of basic precious and other non-ferrous metals (24.4)	-	Tanaka Chemical Corporation	Manufacture of basic chemicals (20.1)	-
FERRO	Manufacture of paints, varnishes and similar coatings, printing ink and mastics (20.3)	-	TANIOBIS	Manufacture of basic precious and other non-ferrous metals (24.4)	-
FIR METALS & RESOURCE	Manufacture of fabricated metal products (25)	-	Tantec	Manufacture of fabricated metal products (25)	-
FORTIS METALS	Manufacture of basic precious and other non-ferrous metals (24.4)	@FortisMetals	Technology Metals Australia	Mining of non-ferrous metal ores (07.2)	@TechnologyMetal
FORTUNE	Mining of non-ferrous metal ores (07.2)	@FortuneMineral	Telex Metals	Recovery of sorted materials (38.32)	-
Ganfeng Lithium	Mining of non-ferrous metal ores (07.2); Manufacture of basic chemicals (20.1); Manufactures of batteries and accumulators (27.20)	@GanfengOfficial	Terra Commodities	Wholesale of metals and metal ores (46.72)	-
GLENCORE	Mining of non-ferrous metal ores (07.2)	@Glencore	Thaisarco	Manufacture of basic precious and other non-ferrous metals (24.4)	-
Globe Metal Recycling	Recovery of sorted	@GlobeMetal	Tianqi Lithium	Mining of non-ferrous	@TianqiLithiumAU

	materials (38.32)			metal ores (07.2)	
Globe Metals & Mining	Mining of non-ferrous metal ores (07.2)	@globemetals	TIC	Tantalum and niobum supply chains	-
GMI	Wholesale of metals and metal ores (46.72)	-	TITAN INTERNATIONAL	Manufacture of basic precious and other non-ferrous metals (24.4)	-
GOLDMANN	Wholesale of chemical products (46.75)	-	TNG	Mining of non-ferrous metal ores (07.2)	@tng_limited
Goodwin Alloy Products	Manufacture of basic precious and other non-ferrous metals (24.4)	-	Todini	Wholesale of chemical products (46.75)	-
GrafTech	Manufacture of basic chemicals (20.1)	-	Tokai Cobex	Manufacture of basic chemicals (20.1)	-
grillo handel	Wholesale of metals and metal ores (46.72)	-	TOPSOE	Manufacture of basic chemicals (20.1)	@topsoe_official
Grondmet	Wholesale of metals and metal ores (46.72)	-	Tradium	Wholesale of metals and metal ores (46.72)	@TRADIUMGmbH
HALCYON	Wholesale of metals and metal ores (46.72)	-	TRANZACT	Wholesale of metals and metal ores (46.72)	-
Hempel Intermetaux	Wholesale of metals and metal ores (46.72)	-	Traxys	Wholesale of metals and metal ores (46.72)	-
HHT	Wholesale of metals and metal ores (46.72)	-	Treibacher	Manufacture of basic precious and other non-ferrous metals (24.4)	@Treibacher
Honda Trading	Wholesale of metals and metal ores (46.72)	-	Tropag	Wholesale of metals and metal ores (46.72)	-
Hudson Metals	Wholesale of metals and metal ores (46.72)	-	Tungco	Recovery of sorted materials (38.32)	@Tungco_Inc

i2a	Antimony supply chain	@Antimony_i2a	U.S. Vanadium	Manufacture of basic chemicals (20.1)	@usvanadium
ICD Alloys & Metals	Manufacture of basic precious and other non-ferrous metals (24.4)	@ICDAlloysMetals	UK Atomic Energy Authority	Regulation of and contribution to more efficient operation of businesses (84.13)	@UKAEAofficial
ILiA	Lithium supply chain	@ILiA_lithium	ULBA	Manufacture of basic precious and other non-ferrous metals (24.4)	-
IMAT	?	-	Umicore	Recovery of sorted materials (38.32)	@UmicoreGroup
IMERYS	Manufacture of basic precious and other non-ferrous metals (24.4)	-	US Strategic Metals	Mining of non-ferrous metal ores (07.2)	-
INDIUM Corporation	Manufacture of non-ferrous metals (24.45)	@IndiumCorp	USGS	Provision of services to the community as a whole (84.2)	@USGS
International Magnesium Association	Magnesium supply chain	@INTLMagOrg	VALE	Mining of non-ferrous metal ores (07.2)	@valeglobal
INVINITY	Manufacture of batteries and accumulators (27.2)	@InvinityEnergy	Vanadium Resources	Mining of non-ferrous metal ores (07.2)	@VanadiumResVR8
Jaingxi Tuo Hong	Manufacture of basic precious and other non-ferrous metals (24.4)	-	VanadiumCorp	Mining of non-ferrous metal ores (07.2)	@VanadiumCorp
Jean Goldschmidt	Recovery of sorted materials (38.32)	-	Vanitec	Vanadium supply chain	@VanitecVanadium
Jervois	Mining of non-ferrous metal ores (07.2)	@Jervois_Global	VDM	Metal trade	@vdm_metall

Jiujiang Fuxing Tai Trade	Wholesale of metals and metal ores (46.72)	-	VENATOR	Manufacture of paints, varnishes and similar coatings, printing ink and mastics (20.3)	@VenatorCorp
Johnson Mattey	Manufacture of basic chemicals (20.1)	@Johnson_Matthey	Verde Magnesium	Other non-ferrous metal production (24.45)	-
JSW SA	Mining of coal and lignite (05)	@jsw_sa	Veritek	Support activities for transportation (52.2)	-
Juijiang Jin Xing	Manufacture of basic precious and other non-ferrous metals (24.4)	-	Vianode	Manufacture of basic chemicals (20.1)	-
KEMET	Manufacture of electrical equipment (27)	@KEMETCapacitors	VISHAY	Manufacture of electrical equipment (27)	@VishayIndust
KENNAMETAL	Manufacture of fabricated metal products (25)	@Kennametal	Vital Materials	Manufacture of fabricated metal products (25)	@VitalMaterials
KGHM	Mining of non-ferrous metal ores (07.2)	-	VUM	Manufacture of basic chemicals (20.1)	-
KURUMSAK MINERALS	Mining of non-ferrous metal ores (07.2)	-	Westbrook Resources	Manufacture of basic precious and other non-ferrous metals (24.4)	-
Lambert Metals	Wholesale of metals and metal ores (46.72)	-	wogen	Wholesale of metals and metal ores (46.72)	@WogenResources
Largo Resources	Mining of non-ferrous metal ores (07.2)	@largo_inc	WOMET	Wholesale of metals and metal ores (46.72)	-
LCM	Manufacture of basic precious and other non-ferrous metals (24.4)	@LCM_Metals	Wood Mackenzie	Market research (73.2)	@WoodMackenzie
Lipmann Walton	Wholesale of metals and	@LipmannWalton	Ximei	Manufacture of basic precious and	-

	metal ores (46.72)			other non-ferrous metals (24.4)	
London Chemicals & Resources	Recovery of sorted materials (38.32)	-	Yanling Jincheng	Manufacture of basic precious and other non-ferrous metals (24.4)	-
London Metals	Wholesale of metals and metal ores (46.72)	-	Yano Metals	Recovery of sorted materials (38.32)	-
Magnium Australia	Aluminium production (24.42)	@magnium_au	ZCC	Manufacture of fabricated metal products (25)	-
Managem	Mining of non-ferrous metal ores (07.2)	@Managem_group	Zhuzhou Keneng	Manufacture of basic precious and other non-ferrous metals (24.4)	@Keneng_EU
Maritime House	Recovery of sorted materials (38.32)	-			

Source: own analysis

Table A 2: Influence of relevant stakeholders on Twitter

Twitter user	AvgLikes	AvgRetweets
Glencore	32.8	6.97
PilbaraMinerals	45.3	6.86
Rio Tinto	11.2	6.75
Bushveld Minerals	23.1	6.71
Allkem Limited	17.2	4
Jervois Global	17.0	3.77
Auxico Resources Canada	11.1	3.44
Anglo American	10.1	2.99
Invinity Energy Systems	8.65	2.68
Electra Battery Materials Corporation	12.6	2.67
Vanitec	8.31	2.65
Wood Mackenzie	2.82	2.54
UK Atomic Energy Authority	5.19	2.49
Orano Group	10.4	2.47
Australian Strategic Materials (ASM)	6.65	2.23
Vanadium Resources Limited	8.37	2.16
Technology Metals Australia Limited	9.84	2.05
SABIC I سابك	74.3	19.1
USGS	27.3	18.1
Ganfeng Lithium	20.5	17.6
U.S. Vanadium	7.18	1.89
MTU Aero Engines	7.88	1.80
Australian Vanadium	9.20	1.75
Sherritt International	4.76	1.70
LARGO	5.06	1.63
Topsoe	4.20	1.62
Elkem ASA	3.84	1.44
SGL Carbon	3.81	1.34
Kennametal	0.915	1.34
Neometals Ltd	3.88	1.22
Umicore	3.21	1.15
Eramet	3.46	1.14
Cobalt Institute	3.74	1.09
Johnson Matthey	2.13	1.05
New Zealand Steel	1	1
Venator	3.07	0.977
VanadiumCorp VRB	3.09	0.939
International Lithium Association (ILiA)	3.5	0.935
SCHUNK GmbH & Co. KG	0.981	0.910

CRU Group	1.25	0.906
QEM	2.79	0.884
Albemarle Corp.	2.23	0.880
Less Common Metals Ltd	2.07	0.877
Magnium Australia	0.2	0.864
Vale Global	5.23	0.847
Argus Media	0.810	0.832
Brazilian Nickel	3.14	0.830
S&P Global	1.45	0.819
TNG Limited	2.48	0.8
Vishay	1.77	0.720
Milliken Chemical	1.48	0.652
Rafaella Resources	3.15	0.630
VDM	2.12	0.625
KEMET Electronics	1.81	0.605
Fortune Minerals	1.21	0.529
Materion Corporation	1.40	0.518
BetaTechnology	1.37	0.503
Fortis Metals	0.5	0.5
EUROALLIAGES	0.6	0.462
Sandvik	1.33	0.443
Antimony_i2a	1.18	0.426
Ambatovy	2.27	0.424
SPMP	2.75	0.417
European Carbon and Graphite Association	0.923	0.385
Metal Events Ltd	0.531	0.383
Wogen Resources	1.38	0.375
Morgan Advanced	0.751	0.337
Plansee	1.45	0.303
Special Metals INC.	1.09	0.273
IMA	0.517	0.245
Superior Graphite	0.672	0.220
TRADIUM GmbH	1.2	0.2
CellCube Energy Storage Systems Inc.	0.476	0.2
Indium Corporation	0.445	0.194
Managem	0.0909	0.182
MMTA Executive	0.187	0.152
Lipmann Walton & Co Ltd	1.11	0.138
esmalglass-itaca	0.917	0.125
CRONIMET	1.23	0.0909
Graphite COVA GmbH	1	0.0909
JSW S.A.	1.38	0.0769

Tungco	0.165	0.0706
Avon Metals 2012 ltd	0.0789	0.0263
ICD Alloys & Metals	0.778	0.0252
Exotech, Inc	0.126	0.0194
Zhuzhou Keneng New Material Co., Ltd.	1.47	0.0139
Globe Metal	0.0337	0.0112
YOUTIAN METAL	0.143	0
ACI Alloys	0.138	0
Campine NV	0	0
TianqiLithiumAU	0	0

Source: own analysis

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