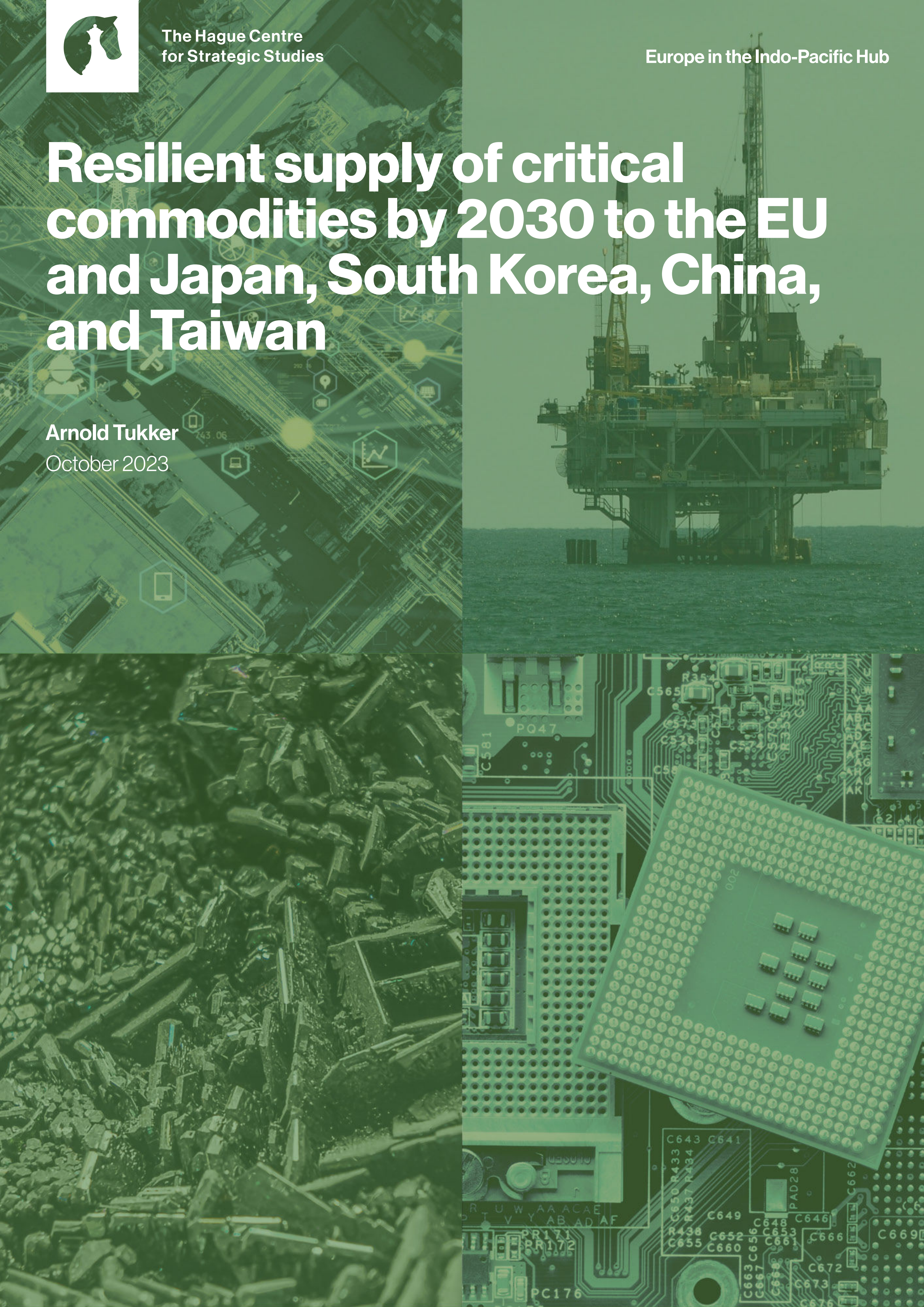
The Hague Centre
for Strategic Studies

Europe in the Indo-Pacific Hub

Resilient supply of critical commodities by 2030 to the EU and Japan, South Korea, China, and Taiwan

Arnold Tukker

October 2023



The Hague Centre
for Strategic Studies

Resilient supply of critical commodities by 2030 to the EU and Japan, South Korea, China, and Taiwan

Author:
Arnold Tukker

Editors:
Paul van Hooft, Benedetta Girardi and Alisa Hoenig

This paper is part of the HCSS Europe in the Indo-Pacific Hub.

November 2023

The research for and production of this report was made possible by a financial contribution from the Taipei Representative Office in the Netherlands to the Hague Centre for Strategic Studies. The conclusions and recommendations presented in this report are the result of independent research. Responsibility for the content rests with the authors and the authors alone.

1. Introduction

The Hague Centre for Strategic Studies (HCSS) organized a workshop on supply chain security for critical economic inputs in Den Haag, the Netherlands, on the 7th of March 2023. The focus was on the supply of critical commodities by 2030 to the EU and Japan, South Korea, China, and Taiwan. The commodities central in the project the workshop is part of include (1) the energy carriers crude oil and liquified natural gas (LNG), (2) the critical raw materials cobalt and silicon, and (3) semiconductors. Each workshop contributor was asked to writea short discussion piece on topics such as accessibility of the materials in 2030, diversity of sources of supply, avenues for enhancing and reducing the security of supply (e.g. political, environmental, technical, physical), and potential changes in overall supply and diversity of supply. A comprehensive discussion of these topics for the mentioned commodities would be a study in itself. For this reason, I will concentrate on general aspects of resilient supply and give some top-level thoughts on the specifics of each commodity. In the next sections I will discuss;

a) General backgrounds on the criticality and resilience of supply
b) Then, by type of product:
    a. Current diversity and security of supply
    b. Drivers for enhancing and reducing security of supply
    c. Accessibility in 2030

2. Backgrounds of criticality and supply resilience

There are various ways of assessing the criticality of the supply of commodities. Usually, two main criteria are used – Economic importance and Supply risk. The EU criticality methodology assesses the Economic importance as the value added created with the material in relevant sectors, and looks at the potential for substitution. The Supply risk was initially assessed by global supply concentration and factors such as country governance, environmental risks, trade restrictions, and supply chain bottlenecks[1]. Refinements were suggested by looking more at the actual import concentration of specific countries[2], next to the potential of providing supply by recycling. We refer to the most recent EU critical materials report for an overview of the method applied by the EU[3].

A limitation of these methods is that, particularly initially, they tend to look at the mining stage only. The 2014 European Rare Earth Competency Network (ERECON) report written as a reaction to the 2011 Rare Earths crisis highlighted that a focus on the mining stage would not be enough. At that point, China had become the globe's main supplier of Rare Earths. It had overtaken the US as main supplier by strategically investing in mining and separation technologies. The People's Republic could also produce Rare Earths cheaper, since the supply was largely a byproduct of an iron ore mine. The US Mountain Pass mine, in the 1990s the dominant supplier, could not compete and closed. No one cared about the fact China now supplied 90% of the market. Around 2010, China foresaw it would need its own Rare Earth supply for its own industry, and the resulting export restrictions caused drastic price hikes and shock waves in the high tech industry outside China[4]. The ERECON report noted, however, that diversification of supply by opening mines in the West would not be of help. China had also made significant progress in the separation and benefaction stages, essential to obtaining Rare Earths like Nd in pure form, and, on top of that, had bought up Japanese patents for making strong NdBFe magnets, resulting in a dominant position on the global magnet market[5].

For this reason, more recently, authors have started to assess market concentration in various steps in the supply chain. In this, one should take into account not only market concentration

1 EU Ad Hoc Working Group on Defining Critical Raw Materials. *Report on critical raw materials for the EU. Ref. Ares(2015)1819503 - 29/04/2015*, European Commission, 2014.

2 Eskinder D. Gemechu et al., "Import-Based Indicator for the Geopolitical Supply Risk of Raw Materials in Life Cycle Sustainability Assessments," *Journal of Industrial Ecology* 20, no. 1 (2016): 154–65, https://doi.org/10.1111/jiec.12279.

3 Gian A. Blengini et al.. *Study on the EU's list of Critical Raw Materials – Final Report.* Brussels: European Commission,2020.

4 Arnold Tukker, "Rare Earth Elements Supply Restrictions: Market Failures, Not Scarcity, Hamper Their Current Use in High-Tech Applications," *Environmental Science & Technology* 48, no. 17 (2014): 9973–74, https://doi.org/10.1021/es503548f.

5 European Rare Earth Competency Network. *Strengthening the European Rare Earth Supply Chain. Challenges and policy options.*, 2014. https://ec.europa.eu/docsroom/documents/10882.

in a geographical sense, but also in terms of the ownership of production facilities[6 7]. A more overarching approach is not to look at the supply of a specific material itself, but to look at how the whole system of using and producing a material and the involved actors is organized [8 9] – consistent with the notion that resilience is a property of a network or system, and not of a flow or node[10].

The ERECON exercise, in which I served as a working group lead and where I was one of the three co-authors of the report, provided various lessons about problems around the security of the supply of materials and commodities that seem of a general nature.

a) Opening new mines or oil/gas fields (relevant for cobalt, silicon, oil, LNG) takes significant time, typically 5-10 years.
b) Particularly in areas where demand is difficult to forecast due to quick technical development (e.g. for cobalt and rare earths), investment in new supply can be a significant risk. Particularly if the field is served by relatively small players that have limited financial leverage, as it was in the case of Rare Earths, the situation is not conducive to timely investment in new supply options. Inelastic supply with all its implications is the consequence.
c) Security of supply implies creating redundancy in supply chains. This creates duplications that, by definition, enhance the cost of supply. Willingness to bear such costs often tends to be low, until a clear crisis emerges (and fades away again, when the crisis eases[11]). This pattern was visible in the 2010-2011 Rare Earth supply crisis, but also in the last decade when many European countries made themselves dependent on Russian gas despite the fact that this created an obvious geopolitical risk (and which played itself out after the start of the Russian-Ukrainian war).
d) The investment in risk capital required to create redundancy in the initial stages of supply chains is often low to very low (100s of millions of dollars once off for opening a new mine) compared to the value of end products that contain critical materials (10s of billions of dollars per annum).
e) Firms producing such end products operate, however, in a totally different field and have totally different expertise and competencies than firms involved in the initial stages of supply chains. Together with point c), this makes it difficult to channel capital available at the end of the value chain to the beginning of the value chain to create redundancy.
f) Whereas China applies a guided economy model, in which the state in several cases backs investment risks, such market support is uncommon and politically usually not seen as acceptable in the US and the EU. This implies governments are not in the position to supply risk capital to create supply chain redundancy, although this concerns a very moderate sum equivalent to a minor infrastructure project or a handful of intercontinental airplanes.

6 Susan van den Brink et al., "Resilience in the Antimony Supply Chain," *Resources, Conservation and Recycling* 186 (2022): 106586, https://doi.org/10.1016/j.resconrec.2022.106586.

7 Susan van den Brink et al., "Identifying Supply Risks by Mapping the Cobalt Supply Chain," *Resources, Conservation and Recycling* 156 (May 2020): 104743, https://doi.org/10.1016/j.resconrec.2020.104743.

8 Benjamin Sprecher et al., "Framework for Resilience in Material Supply Chains, With a Case Study from the 2010 Rare Earth Crisis," *Environmental Science & Technology* 49, no. 11 (May 12, 2015): 6740–50, https://doi.org/10.1021/acs.est.5b00206.

9 Nabeel A. Mancheri et al., "Resilience in the Tantalum Supply Chain," *Resources, Conservation and Recycling* 129 (February 2018): 56–69, https://doi.org/10.1016/j.resconrec.2017.10.018.

10 Donella H. Meadows, *Thinking in Systems: A Primer* (London: Earthscan, 2009).

11 The ERECON report remarks tersely: 'As prices declined, the attention of investors, CEOs and policy-makers quickly faded, even though the future supply of rare earths is still far from secured'. ERECON report,14

3. Criticality and supply resilience of specific commodities

3.1. Oil and LNG

The future of energy carriers such as oil and LNG cannot be assessed without taking the efforts at embarking on an energy transition into account.

In its World Energy Outlook 2021, the International Energy Agency (IEA) expects a slight rise in oil production from around 90 Million barrel per day in 2020 in the stated policy and announced pledges scenario, but a significant reduction to around 70 Million barrel per day by 2030 in the net-zero scenario[12]. Production seems well diversified, with the US, Russia, Saudi Arabia, Canada, Iraq, China, UAE, Brazil, Iran and Kuwait responsible for some 70% of global production[13]. With oil relatively easily transportable, it is relatively easy to re-shuffle supply-demand pair countries, as currently seems to happen with Russian oil in relation to sanctions connected to the Russian-Ukrainian war. The main challenge for Western countries seems to be finding a replacement for Russian oil (some 10-15% of current global production) and to avoid issues with the OPEC bloc.

Natural Gas production globally was just over 4.000 Bio m3 in 2020, and much more concentrated than oil production, with the US, Russia and Iran responsible for about half the supply[14]. As with oil, the IEA predicts gas demand will slightly rise and peak by 2030 in the stated policy and announced pledge scenarios[15]. In the net-zero scenario, there is a reduction of about 10% in demand by 2030. While oil is usually transported via sea-going tankers, pipelines are still the dominant mode of transportation for natural gas. This can lead to regional dependencies, as recently dramatically illustrated by the reliance of European countries on Russian gas, and the problems caused by the disruptions resulting from the sabotage of the Nordstream I and II pipelines. LNG allows for transportation by vessels, but requires dedicated terminals where the gas is liquified and purified. For global trade, and the security of supply of specific countries, the availability of LNG terminals in exporting and importing countries is hence essential. Making an assessment of current and future available LNG terminal capacity by country falls outside the scope of this essay.

12 "World Energy Outlook 2021" (International Energy Agency, 2021).

13 "International - U.S. Energy Information Administration (EIA)," US Energy Information Administration, accessed September 6, 2023, https://www.eia.gov/international/data/world/petroleum-and-other-liquids/annual-petroleum-and-other-liquids-production?pd=5&p=00000000000000000000000000000000vg&u=0&f=A&v=mapbubble&a=-&i=none&vo=value&t=C&g=0000000000000000000000000000000000000000000001&l=249-ruvvvvvfvtvnvv1vrvvvvfvvvvvfvvvou20evvvvvvvvvnvvvs0008&s=94694400000&e=1640995200000&.

14 "Key World Energy Statistics 2021" (International Energy Agency, n.d.).

15 IEA,note 12

3.2. **Cobalt and silicon**

In a recent study on Cobalt, CML researchers established: 'We conclude that the risks for supply chain disruptions are high. Firstly, the cobalt market is highly concentrated, with more than half of the cobalt mined in the Democratic Republic of the Congo, and almost half of the cobalt refined in China. Secondly, almost all cobalt is mined as a by-product of copper and nickel. Finally, political stability in production countries is considered to be medium to very weak'[16]. It is not a surprise that Cobalt is hence on the criticality list of the EU and other countries. Future Cobalt demand is mainly determined by the mobility transition – in current Electric Vehicle Battery types, Cobalt is an essential element. Estimates for future demand vary highly, though. A study by IRENA estimates demand in 2050 at some 0.5-0.6 Mt per year [17], a quadrupling compared to current global demand. However, a recent study suggests an aggressive mobility transition may lead to an annual demand of over 1 Mt/year. The latter study suggests a cumulative demand that is higher than the currently known 7.6 MT reservesfu-ture[18 19]. Uncertainties are significant, however – new battery technologies like Sodium-Ion[20], a breakthrough in automated driving leading to massive EV sharing, and a possible preference for small cars with small batteries, all could bring the demand for Cobalt down significantly compared to expectations[21].

Silicon is another material on the EU's critical materials list. According to the US Geological Survey (USGS), China is, with 60-70% of worldwide supply, the dominant silicon producer globally, with Brazil and Norway following with a modest 4-5% each. USGS, however, also notes that reserves in production countries are ample compared to demand – silicon is essentially produced by reducing sand with pure coke[22]. Most of the around 10 Mio ton silicon/yr. is produced as ferrosilicon that finds its way to the steel industry. Just over 30% is produced as silicon metal, mainly used in the aluminium industry. Again, China dominates the silicon metal production with 70-80% of the global total. Some 20% of the silicon metal is further upgraded and purified, and finds its way to the solar cell and semiconductor markets[23]. Silicon will see a significant demand change as component in PV cells, but in absolute terms this is a small fraction of total silicon metal production. Silicon intensity in PV has halved since 2008 and is expected to reduce further until 2030. Silicon demand for PV cells is expected to rise from 400 kt in 2020 to 800 kt in 2030 in the IEA's Sustainable Development Scenario while staying stable afterwards[24]. Silicon may also see a steep demand change for use in batteries, but volumes are small compared to its use in PV.

16 van den Brink et al., "Identifying Supply Risks by Mapping the Cobalt Supply Chain."

17 Dolf Gielen, "Critical Materials for the Energy Transition" (International Renewable Energy Agency, 2021), https://www.irena.org/-/media/Files/IRENA/Agency/Technical-Papers/IRENA_Critical_Materials_2021.pdf.

18 Chengjian Xu et al., "Future Material Demand for Automotive Lithium-Based Batteries," *Communications Materials* 1 (2020): 1–10, https://doi.org/10.1038/s43246-020-00095-x.

19 "Mineral Commodity Summaries 2022" (US Geological Survey, January 2022), https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf. - Cobalt

20 Alexandre Ponrouch and M. Rosa Palacín, "Post-Li Batteries: Promises and Challenges," *Philosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences* 377, no. 2152 (August 26, 2019): 20180297, https://doi.org/10.1098/rsta.2018.0297.

21 Chengjian Xu et al., "Future Greenhouse Gas Emissions of Automotive Lithium-Ion Battery Cell Production," *Resources, Conservation and Recycling* 187 (December 2022): 106606, https://doi.org/10.1016/j.resconrec.2022.106606.

22 "Mineral Commodity Summaries 2022." - Silicon

23 Emily K. Schnebele, "2018 Minerals Yearbook. Silicon [ADVANCE RELEASE]" (US Geological Survey, 2021), https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb1-2018-simet.pdf.

24 "The Role of Critical Minerals in Clean Energy Transitions. World Energy Outlook" (International Energy Agency, 2022), https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

3.3. **Semiconductors**

Semiconductors can be found in almost all current electrical and electronic technologies (computers, cell-phones, but also medical devices, washing machines, and cars). Their functionalities are highly diverse depending on the application. Lumping all semiconductors into one category hence does not seem helpful to understanding the supply chain resilience of a specific country – insight is needed into what kind of industry for what kind of production in a specific country needs what kind of semiconductor, in relation to which firm in which country can produce this. This requires an assessment at a level of detail that falls beyond the scope of this essay.

4. Conclusion

We see in all investigated cases, perhaps with the exception of Cobalt, that supply chain resilience is not a matter of scarcity or even concentration in deposits. Oil, gas, and silicon are widely available. Oil does not seem to be a critical resource for the countries central in this study given the quite diverse supply. The critical factors are, in all cases, technical infrastructure to create redundancy in supply chains. For LNG, this concerns relying on terminals instead of gas transport via pipes. For silicon, it relates to the capacity to produce highly refined metal grades suitable for the semiconductor and PV industries from the most abundant resource on Earth (sand). For Cobalt, the situation is different in the sense that, if the EV mobility transition will continue using Cobalt containing batteries, cumulative Cobalt demand will outstrip known reserves. These known reserves are, further, largely located in an instable country (Congo). Surveying and identifying new deposits in a diversity of countries is one way out. Engineering out Cobalt from batteries, which seems a realistic prospect, is another option. The result is somewhat like a Catch-22 situation – due to uncertainty in future demand, there may be insufficient incentive for surveying and opening new mines, but this, in turn, could easily lead to a supply crisis in the future. Here, creating more certainty about future demand is the key to avoiding problems.

Bio?

The Hague Centre
for Strategic Studies

HCSS
Lange Voorhout 1
2514 EA The Hague

Follow us on social media:
@hcssnl

The Hague Centre for Strategic Studies
Email: info@hcss.nl
Website: www.hcss.nl