



GREENPEACE

Research briefing on

BEYOND EXTRACTION:

**Pathways for a 1.5°C-aligned Energy
Transition with Less Minerals**

March 2026

This study is a collaboration between Greenpeace International and the Institute for Sustainable Futures at the University of Technology Sydney

Introduction

Lithium, nickel, copper, and cobalt are often framed by States and industries as "critical minerals" – a reflection of political priorities rather than actual societal needs. As the demand for these minerals is predicted to grow for energy transition technologies as well as other industries, such as big tech and the military sector, supply chains have become a geopolitical battleground. This has governments scrambling to control supply chains, while companies opportunistically pursue extraction, which can infringe on the ancestral lands of Indigenous Peoples.

But behind the headlines of progress and a green future with mineral supplies, there's a stark reality: the environmental devastation and social upheaval often caused by mining.

Child labour, violation of workers rights, appropriation of Indigenous Peoples' lands and resources, threats to peoples living in voluntary isolation, soil and land degradation, water scarcity, forest destruction, and more are all reportedly linked to mining. In particular, mining can undermine Indigenous Peoples' and local communities rights, health, livelihoods, and long-standing relationships with their territories and waters.¹ This is leading some communities to resist a minerals "rush", largely driven by greedy corporations and irresponsible governments, that risks the destruction of vital ecosystems and the disregard of human rights.

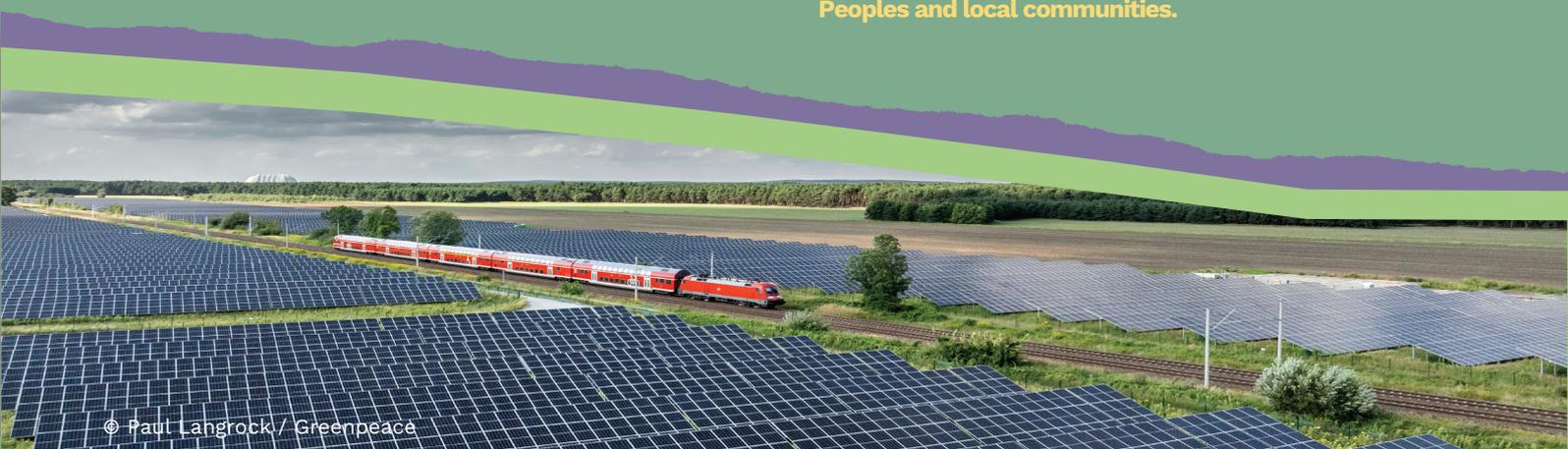
We must achieve an ambitious Paris Agreement-aligned energy transition that safeguards critical ecosystems and centres the rights of Indigenous Peoples and those of local communities. But it requires the right political choices and moral leadership.

Greenpeace's Guiding Principles on Minerals for Energy Transition¹ emphasises prioritising minerals for the energy shift, maximising circularity, and redesigning transportation systems around public and active mobility to cut down the need for new mining and reduce risks for people and nature. Building upon this, "Beyond Extraction: Pathways for a 1.5°C-aligned Energy Transition with Less Minerals" models various 1.5°C-compatible energy scenarios to chart pathways toward mineral sufficiency and efficiency.

Additionally, Greenpeace International has developed a Global Restricted Areas map², which highlights regions that due to their exceptional environmental, ecological, and social importance, must be protected from mining. A global comparison of areas that should be off-limits to mining with the locations of potential mineral reserves reveals that the false dilemma often advocated by the mining lobby – that we must choose between protecting forests or the deep sea in the energy transition – is entirely unjustified.

This research shows that an ambitious energy transition does not require sacrificing crucial ecosystems – whether on land or at sea. Instead, it's about transforming our energy and transport systems: shifting from fossil fuels to abundant, affordable renewables like solar, wind, and smart energy solutions while centring human rights across the supply chain.

Genuine progress means combining sound policies and innovative technologies to keep global warming within 1.5°C while ensuring that the energy transition does not come at the cost of vital ecosystems, human rights, and the lives and livelihoods of Indigenous Peoples and local communities.



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¹ Greenpeace International. 2025. Minerals for Energy Transition: Greenpeace's Guiding Principles. <https://www.greenpeace.org/international/transition-minerals/>

² Restricted Areas Map. <https://maps.greenpeace.org/maps/gpint/restricted-areas/>

Research approach

Scenario analysis was used in this study to explore how different technological and policy pathways can shape future mineral demand from 2024-2050. The study focuses on nine key energy transition minerals: cobalt, copper, dysprosium, graphite, lithium, manganese, neodymium, nickel and vanadium.

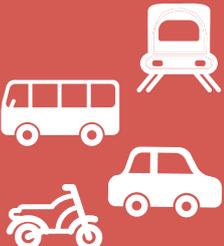
The study scenarios are:

- 1) One Earth Climate Model Net Zero (OECM), aligned with the Paris climate goals and set as a base case for the study;
- 2) Progressive (PRO), and
- 3) Progressive Accelerated Sodium-ion Battery (PRO-Na-ion).

These scenarios have different transport, technology, and circularity assumptions (Table 1) which are designed to show how changes in these assumptions can impact mineral demand.

A key part of all mineral demand calculations are the underlying assumptions about the mineral requirements of the different technologies³ – these were the same across all the study scenarios, but they are a source of some uncertainty given the pace of technological change and the range of values reported in the literature.

Table 1: Selected assumptions across the scenarios. Detailed transport assumptions for Progressive scenarios can be found in Table 13 of the full report.

	Scenario Assumption	OECM	Progressive	Progressive Na-ion
 Climate	Aligned with 1.5°C goal and ambitious energy efficiency improvements	yes		
	Internal combustion energy and plug-in hybrid phase out by	2035	2030	
 Transport & mobility	Passenger vehicles on the road in 2050 (all electric)	2 Billion	1.6 Billion	
	Passenger kilometres by private car, globally	Decrease of 1% annually	Decrease of 1.5% annually	
	Public Transport measures	Road - 36% by public transport in 2050 Rail - global passenger km increase 2% annually	Road - 48.5% by public transport in 2050 Rail - global passenger km increase 2.5% annually	
	Size of cars and batteries	Increasing proportion of smaller cars and 2&3 wheelers.	Higher increase in the proportion of smaller cars and 2&3 wheelers, and overall smaller and more efficient batteries relative to OECM.	
 Battery chemistry	EV Battery Mix in 2050	L(M)FP dominates, followed by NMC and NCA. Minor use of Na-ion	L(M)FP dominates, with less NMC, and minor Na-ion, Li-S	Na-ion dominates, L(M)FP, and minor use of NMC, Li-S
	Energy Storage Battery Mix in 2050	LFP dominates, NMC phased out, some Redox and Na-ion	LFP dominates, more Redox and Na-ion	Na-ion dominates, and smaller amounts of LFP
 Circularity	Recycling	Ambitious rates from 2024 onwards. Rates are increasing up to 2050. See Table 10 of the report.	Rates increase further and faster compared to OECM. See Table 10 of the report.	

L(M)FP = Lithium (Manganese) Iron Phosphate; NMC = Nickel Manganese Cobalt; NCA = Nickel Cobalt Aluminum; Na-ion = Sodium Ion; Li-S = Lithium Sulphur; EV = Electric Vehicle; OECM = One Earth Climate Model.

³ For details, see Table 14 on 'material intensity assumptions' in the full report.



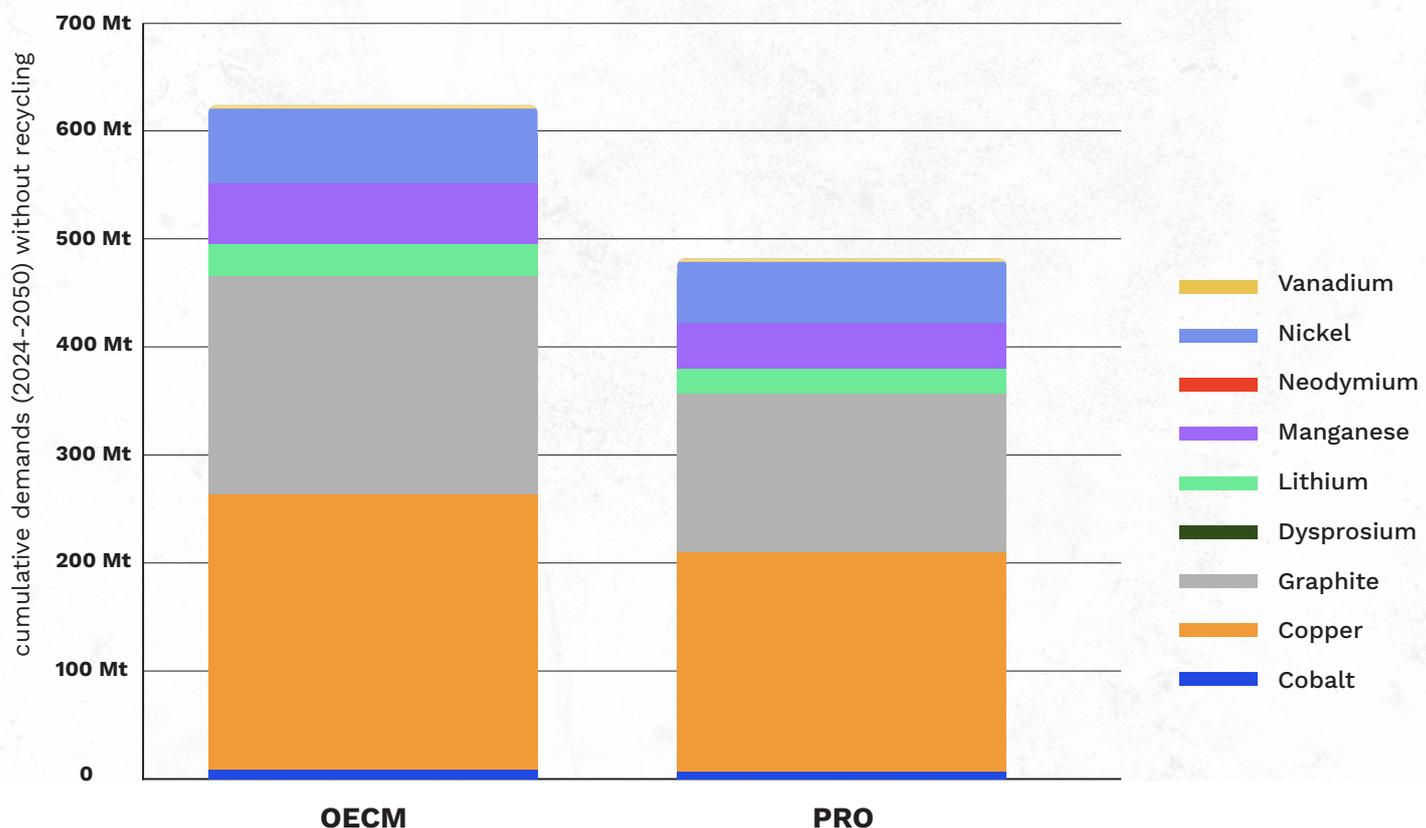
2. THERE IS NO SINGLE SOLUTION – A MIX OF POLICY CHOICES IS REQUIRED



A combination of factors in the PRO scenario reduces the cumulative demand of minerals by 23% compared to the OECM. These include:

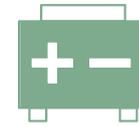
- **Transport modal shift**, prioritising trains and buses, car sharing, and improving infrastructure globally to provide convenient and high-quality mobility solutions. The material requirements of public transport solutions are significantly lower than private transport.
- **Smaller cars with smaller batteries**, which can deliver the same mobility with smaller mineral demands, especially in urban areas. This includes 2 and 3 wheelers, a rapidly growing transport segment in certain regions⁴.
- **Different battery choices**, for EVs and battery energy stationary storage (BESS) can dramatically reduce demand for certain minerals. The PRO scenario assumes a higher proportion of LFP (lithium-iron phosphate) batteries (which do not require cobalt and nickel), and redox flow or sodium ion batteries (which do not require lithium).

Figure 2: Comparison of the cumulative mineral demands (2024–2050) for OECM and PRO without recycling, in tonnes.



⁴ IEA. 2025. Global EV Outlook 2025. <https://www.iea.org/reports/global-ev-outlook-2025/trends-in-other-light-duty-electric-vehicles>

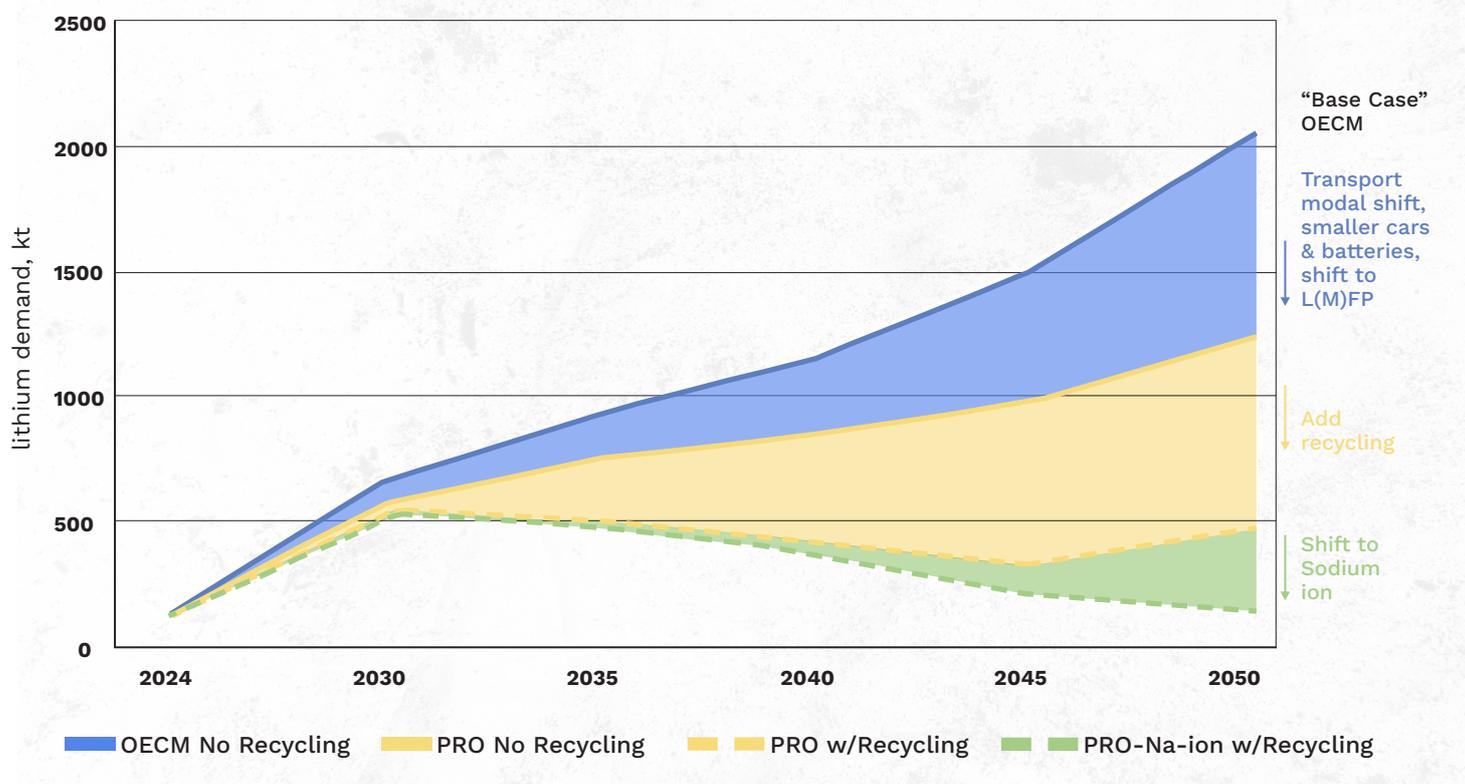
3. ALTERNATIVE BATTERY CHEMISTRIES CAN HELP ALLEVIATE POTENTIAL LITHIUM SUPPLY CONSTRAINTS



Across all scenarios, lithium demand accounts for a larger share of existing reserves (USGS, 2025) compared to other minerals⁵. To address this, the study explores an additional scenario focused on sodium-ion (Na-ion) batteries, a commercial and growing technology that does not require lithium. In the Progressive Na-ion scenario with recycling, a greater adoption of Na-ion batteries for both EVs and stationary battery storage systems reduces lithium by a further 15% compared to PRO.

This study assumes that all Na-ion batteries contain nickel and manganese, resulting in a higher demand for these minerals in PRO-Na-ion than in PRO. Other Na-ion chemistries already in development that do not rely on nickel or manganese⁶, and wider adoption of these alternatives would reduce such trade-offs.

Figure 3: Annual lithium demand in difference scenarios (in kilotonnes).



⁵ See Tables 30, 32, 34 and 36 of the full report

⁶ Xu et al. 2025. Constructs high performance iron-based phosphate sodium-ion batteries via oxygen vacancies strategy. Chemical Engineering Journal, Volume 520, 166248. <https://doi.org/10.1016/j.cej.2025.166248>

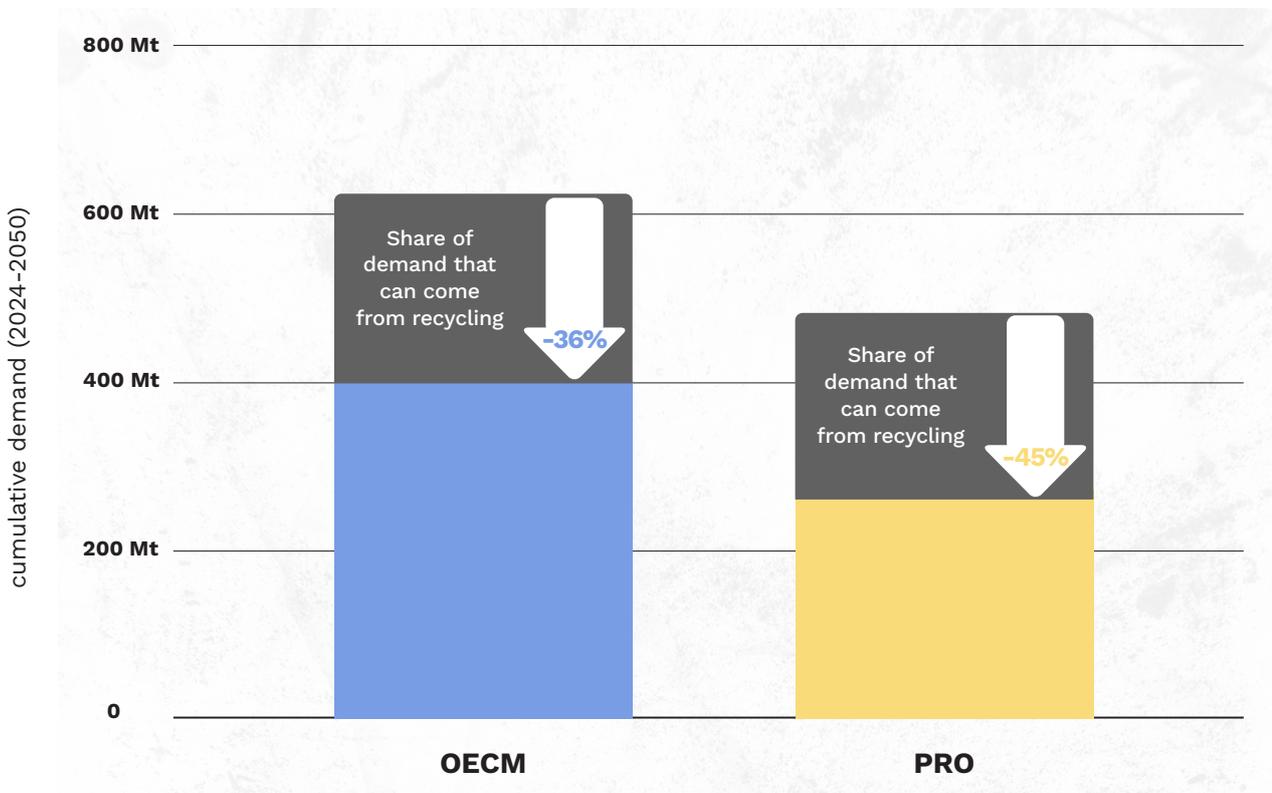
4. RECYCLING DELIVERS MAJOR REDUCTIONS IN MINERAL DEMAND ACROSS ALL SCENARIOS



The study assumes ambitious recycling rates, and that supply from recycling will start to ramp up by 2035 as more secondary feedstock becomes available. Recycling can reduce demand across all minerals studied by a total of 36% (OECM scenario) and 45%

(PRO scenario) (See Figure 4). The impacts vary across different minerals – for instance, nickel is reduced by over 50% and vanadium by over 90% in all cases.

Figure 4: Comparison of cumulative mineral demands (2024-2050) for all 9 minerals, with and without recycling for OECM and PRO.



5. THERE IS NO NEED TO SOURCE MINERALS FROM KEY AREAS OF ECOLOGICAL SIGNIFICANCE FOR THE ENERGY TRANSITION



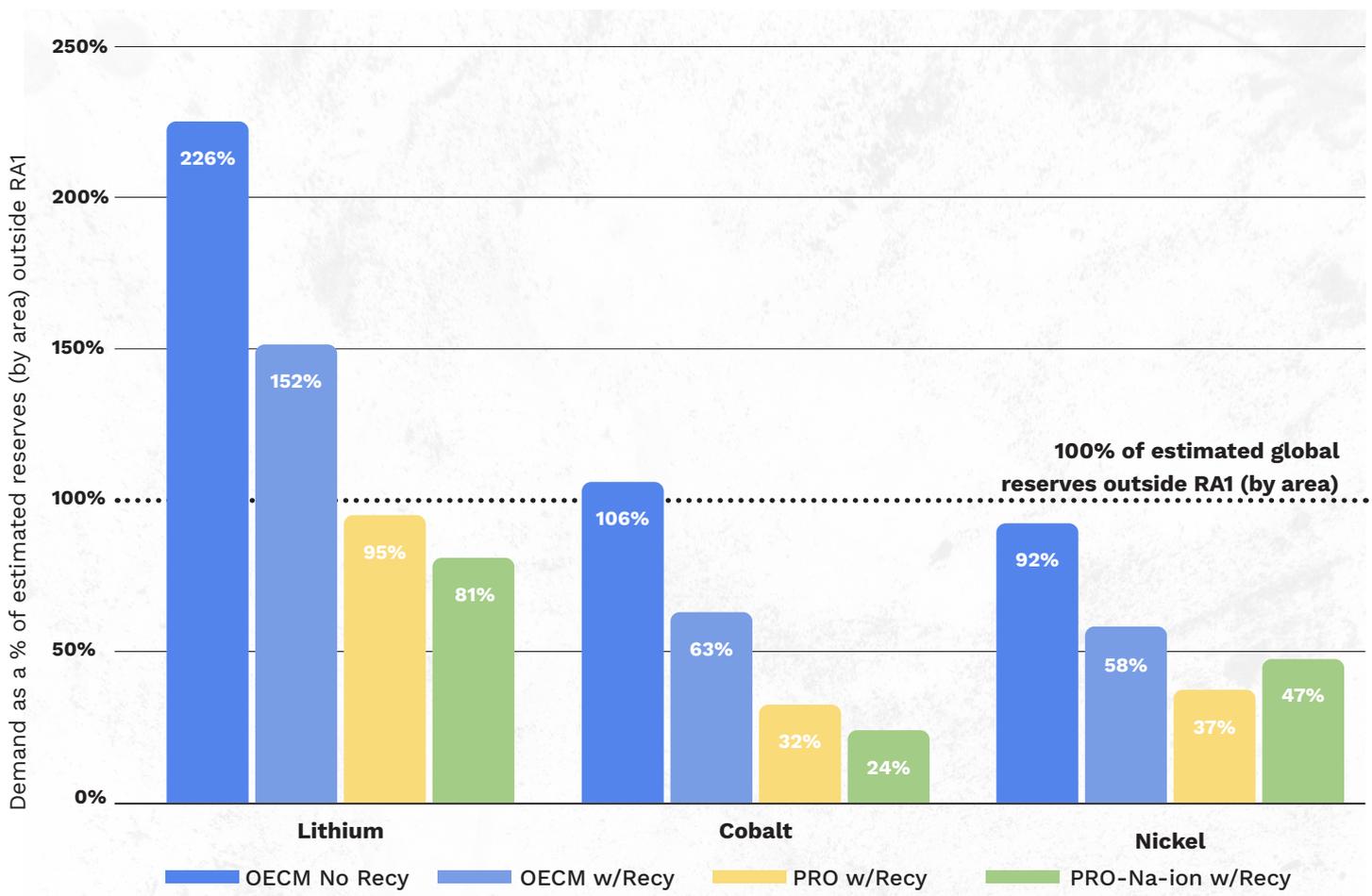
The study compares the scenario demands to global reserves estimates from the United States Geological Survey (2025). However, certain areas (and associated mineral deposits) such as protected areas like Ramsar sites, should be off-limits to extraction because of their critical environmental, ecological, natural, and/or social significance – an overview of these areas is shown in the Global Restricted Areas map.

To understand where development pressures could emerge for nickel, cobalt and lithium, and if these occur in Restricted Areas, Greenpeace International conducted spatial analysis to estimate where global reserves may be located. Using area-based, simplifying assumptions, the quantity of reserves outside of areas

that should be off-limits to mining (“Restricted Areas 1”) was estimated⁷.

Comparing these estimations with the mineral demand projections shows the stark differences between the scenarios. The OECM scenario without recycling would exceed estimated lithium and cobalt reserves outside of areas that should be off-limits (and reach over 90% for nickel). In contrast, the PRO and PRO-Na-ion (with recycling) scenarios can reduce this share significantly (see Figure 5). This analysis suggests that, under the PRO-Na-ion scenario, there are enough minerals to supply ambitious energy transition pathways without having to mine in crucial ecosystems – whether on land or at sea.

Figure 5: Cumulative mineral demand (2024-2050) comparison to estimated reserves (tonnes, by area) outside “Restricted Areas 1 (RA1)” (off-limits to mining)

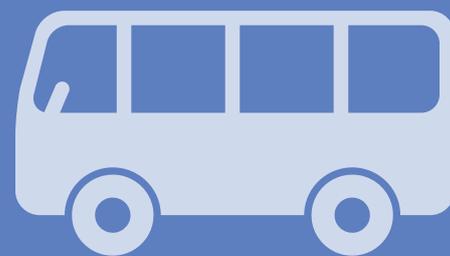


⁷ See Supplementary docs: Development of a Restricted Areas Map for Transition Minerals Mining at a Global Scale: https://www.greenpeace.org/static/planet4-international-stateless/2026/02/831f65de-1_supplementary_development-of-a-global-restricted-areasmap-for-transition-minerals-mining-at-a-global-scale.pdf; and Minerals Mapping Approach and Integration with a Global Restricted Areas Map: https://www.greenpeace.org/static/planet4-international-stateless/2026/02/c3144f50-2_supplementary_minerals-mapping-approachand-integration-with-a-global-restricted-areas-map.pdf

Conclusion and policy recommendations

This study demonstrates that it is possible to have sufficient minerals outside off-limits areas, to support the energy transition needed to avoid catastrophic climate crisis. Energy efficiency measures, increased public transport services and less reliance on individual passenger vehicles, different battery technologies and ambitious recycling can all contribute to reducing the mineral demand for energy transition.

The following policy recommendations are crucial to safeguard an energy transition that is truly green and just:

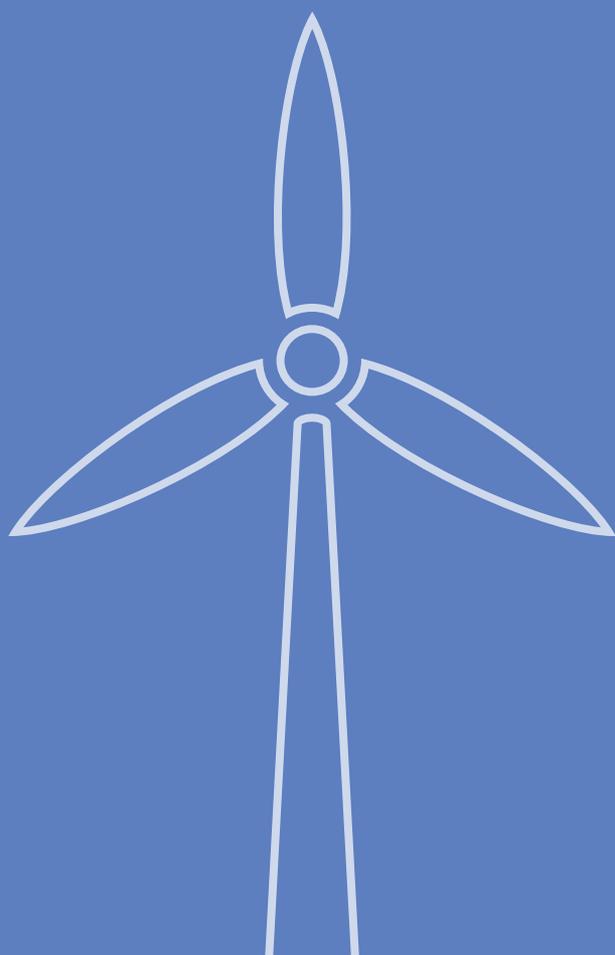


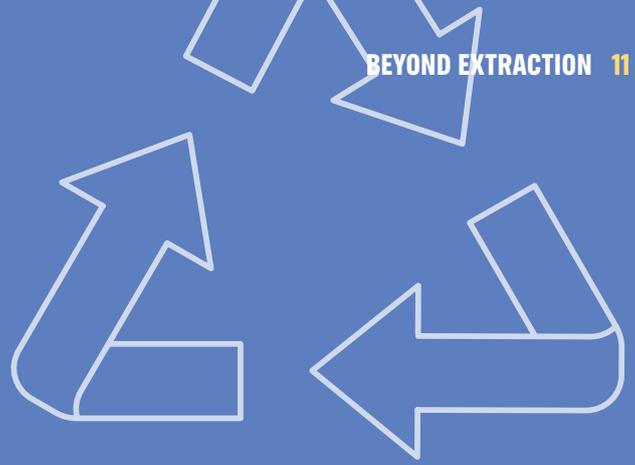
1. Reduce mineral demand through investment and delivery of shared mobility systems like improved public transport and smaller, more efficient cars

Shifting towards shared mobility systems is one of the most effective ways to reduce the need for mineral-intensive electric vehicles and the batteries that power them. Expanding high-quality public transport, car-sharing schemes and other forms of convenient mobility can significantly decrease reliance on individual car ownership. Complementary measures such as right-sizing batteries, avoiding unnecessarily large vehicles (e.g. SUVs in cities) and improving vehicle efficiency, also contribute to reduced mineral demand.

2. Incentivise battery technology substitution towards alternatives requiring less lithium, cobalt, or nickel

Technological innovation over the last decade has transformed the mobility and energy storage battery markets. Lithium iron phosphate (LFP) batteries, now widely commercialised, eliminate the need for cobalt and nickel, reducing pressure on these supply chains. At the same time, sodium-ion (Na-ion) batteries are advancing rapidly, they offer a pathway to significantly reduce mineral demand for lithium. Other emerging chemistries such as redox flow batteries for stationary storage also offer solutions that avoid the use of key minerals. Further market growth of these alternatives in the coming years, as outlined in the Progressive scenarios, can significantly reduce supply gaps and ease potential development pressures for new mines. Innovative energy storage systems that do not require these key minerals, could further reduce the need for batteries in the electricity grid.





3. Design for circularity and scale up recycling

By maximising collection and the recovery of transition minerals from end-of-life renewable technologies, recycling can significantly reduce the need for new extraction. Investing in advanced recycling technologies and collection systems, alongside policy incentives that reward high recycled mineral content in new products, can ensure that transition minerals re-enter the supply chain. All scenarios in the study show significant reductions in primary demand when ambitious recycling assumptions are included. Additional circularity measures like extending technologies' lifespans, improving repairability, incentivising reuse, designing and standardising components for easy disassembly to help with repair and recycling, and enforcing extended producer responsibility (EPR), while not part of the mineral resources calculation model, could also contribute to reducing overall mineral demands.

4. Prioritise mineral use for essential energy transition needs

Minerals are finite resources, and mining for them carries significant social, labour and environmental risks. Therefore, the use of mineral resources should be prioritised where they matter most - in renewable energy applications to phase out fossil fuels. This study focuses on the mineral demands for energy transition, however demand from other uses often compete for the same limited supply. Governments and industries must steer minerals toward critical energy transition infrastructure and other vital uses. Coupled with supply chain transparency, prioritising minerals for energy transition ensures finite minerals are used to advance climate goals that benefit all people and the planet.

5. Protect key 'Restricted Areas' from mining development

Protecting human rights and ecological integrity is a non-negotiable foundation of a just and green transition. Restricted Areas (RA) have high environmental, ecological and natural values, and may include Indigenous Peoples and local community territories. Defining and protecting these RAs is a crucial step in ensuring that mining of transition minerals does not compromise the safeguarding of biodiversity, ecosystem services, natural carbon storage, freshwater systems, oceans and respecting the rights of Indigenous Peoples and local communities. Protecting these areas is essential to staying within the Earth's planetary boundaries⁸ and to prevent the energy transition from repeating the injustices of past extractive models, with Free, Prior and Informed Consent from Indigenous Peoples and local communities as a key prerequisite of any mining development.



⁸ Planetary Boundaries Science (PBSscience). 2025. Planetary Health Check 2025. Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany. https://publications.pik-potsdam.de/rest/items/item_32589_5/component/file_33151/content



Find out more:

Download report “Beyond Extraction: Pathways for a 1.5°C-aligned Energy Transition with Less Minerals” here

https://www.greenpeace.org/static/planet4-international-stateless/2026/02/677b279a-beyond-extraction_energy-transition-with-less-minerals_2026.pdf

For further information on:

1) the definition and development of GPI’s Restricted Areas map see here

https://www.greenpeace.org/static/planet4-international-stateless/2026/02/831f65de-1_supplementary_development-of-a-global-restricted-areas-map-for-transition-minerals-mining-at-a-global-scale.pdf

2) the minerals mapping approach and integration with GPI’s Restricted Areas map see here

https://www.greenpeace.org/static/planet4-international-stateless/2026/02/c3144f50-2_supplementary_minerals-mapping-approach-and-integration-with-a-global-restricted-areas-map.pdf

More details on the One Earth Climate Model developed by UTS-ISF can be found on the OECM website www.uts.edu.au/oecm

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