Rethinking mining demand for battery minerals

Data-driven insights on enabling an efficient, responsible battery supply chain

February 26, 2025

Transforming how we produce and use energy...

A Bold Goal:

1.5°C

↓50% CO_2

BY 2030

To power key sectors...

- Carbon-Free Industry
- Carbon-Free Mobility
- Carbon-Free Buildings
- Carbon-Free Electricity

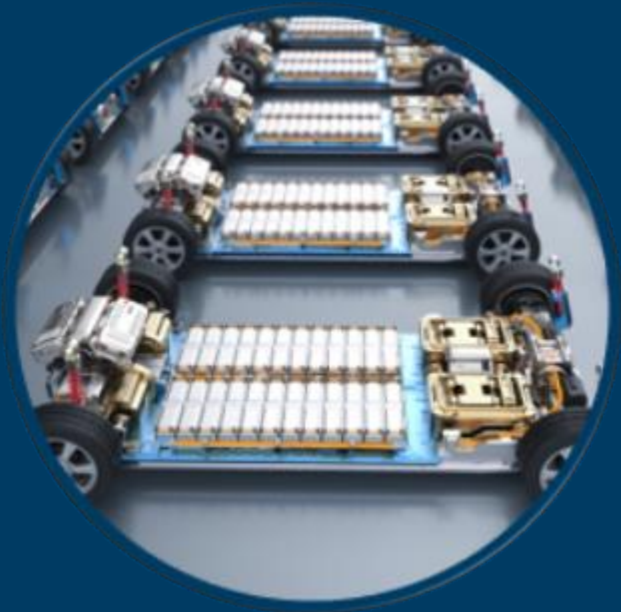
Accelerated by market catalysts...

- Policy
- Finance
- Business Models
- Data & Transparency
- Technology
- Education & Capacity

Across critical global geographies.

- Cities
- China
- India
- U.S.
- Developing Economies

Battery Circular Economy Initiative (BCEI)

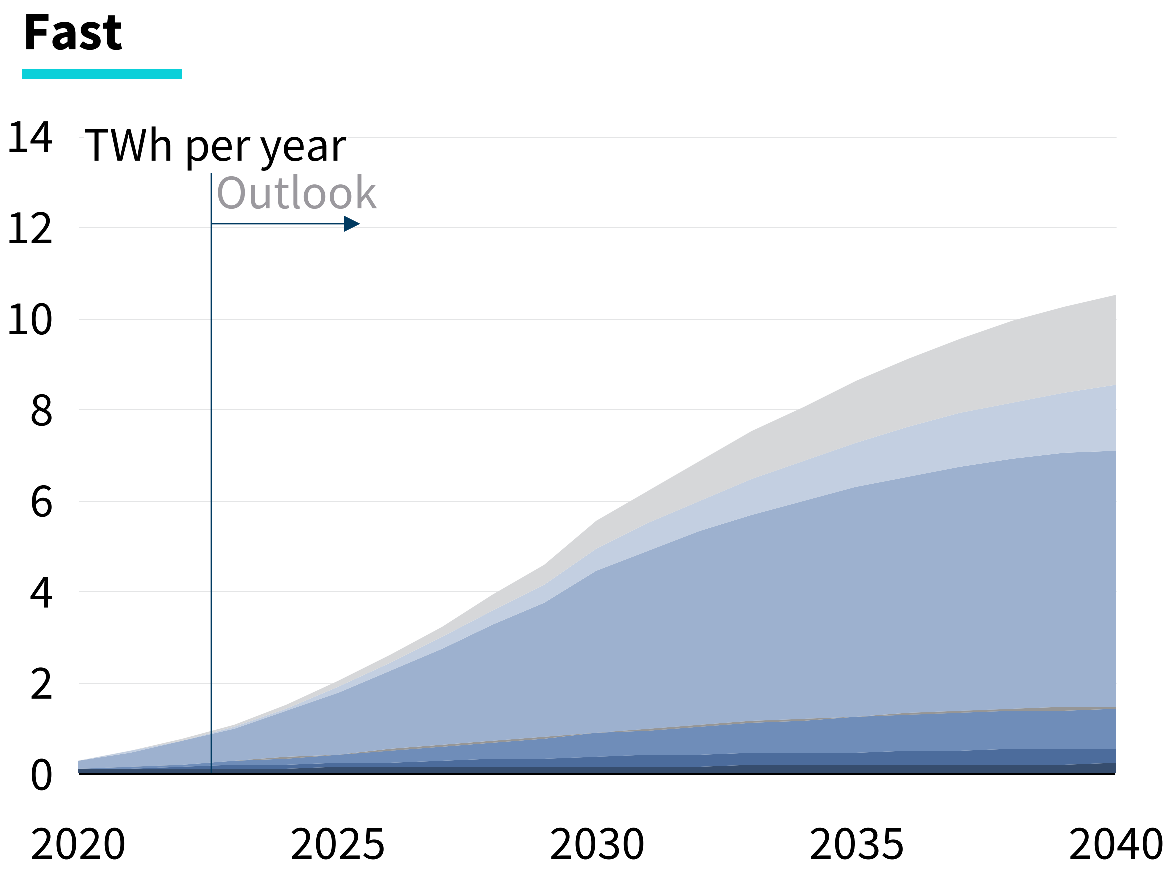


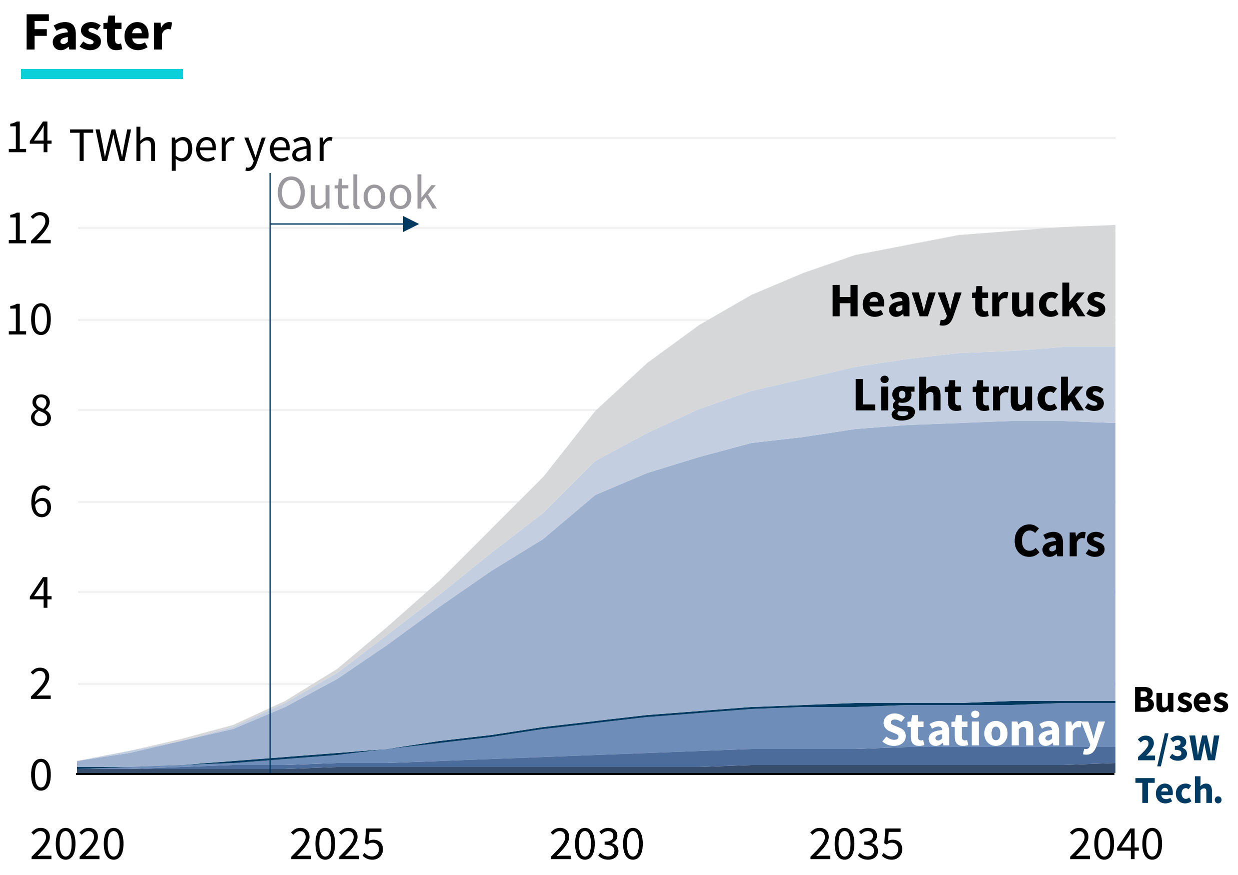
Supply chain does not become the limiting factor for the EV transition.

Materials are sourced responsibly and used efficiently.

Battery demand is growing exponentially

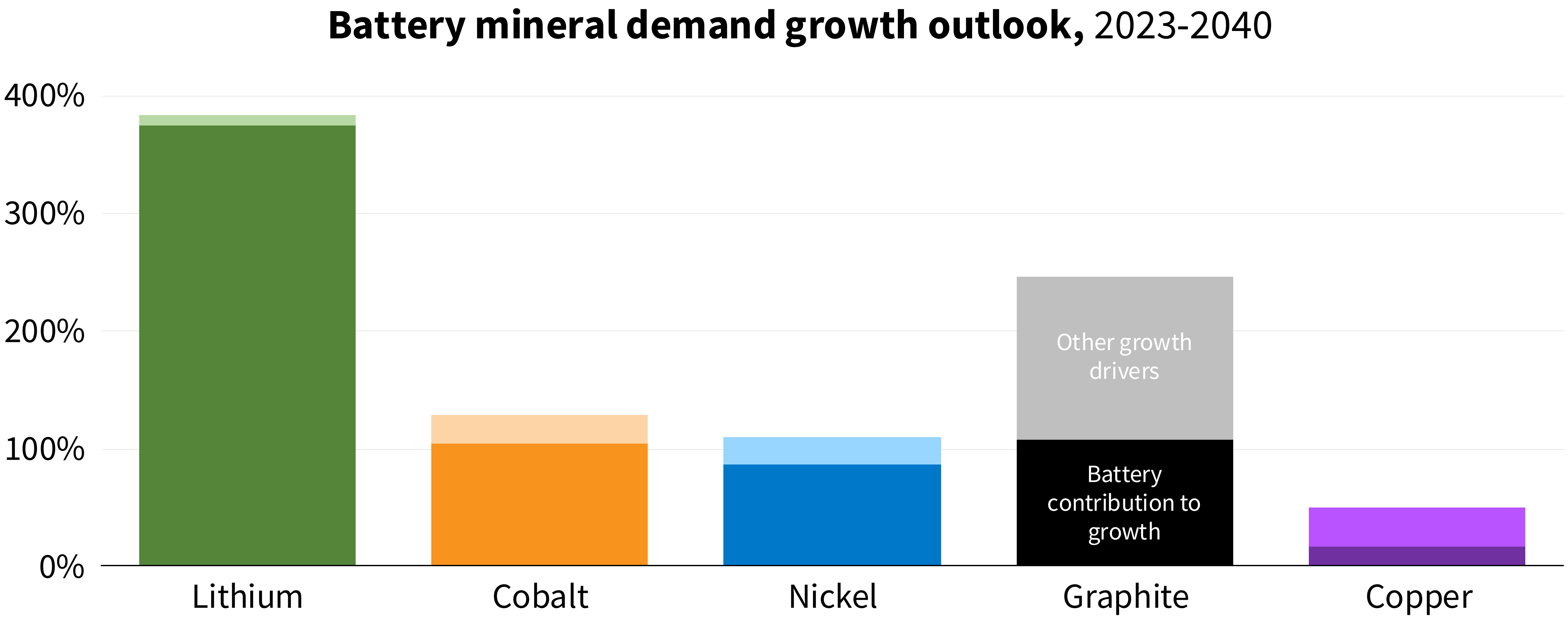
Battery uptake by sector





Source: RMI X-Change Batteries; RMI analysis

…Which means mineral demand will boom



Source: IEA Global Critical Minerals Outlook (2024)

Today's session

How can we bend the curves of supply and demand to reach net zero mineral extraction for batteries?

What do the costs and returns of battery recycling look like if you factor in externalities?

What actions do stakeholders need to take to help us achieve this vision?

Agenda

1. **Bending the curve**
2. **ROI of battery recycling**
3. **Stakeholder action**
4. **Q&A**

There are six alternatives to mining for battery minerals

1. Different chemistries

Switch to battery chemistries that use fewer critical minerals

2. Higher energy density

Pack more energy into a kilogram of battery

3. Recycling

Recover battery minerals at end of life to re-use

4. Reuse and extended life

Use and reuse batteries for longer

5. Efficient vehicles

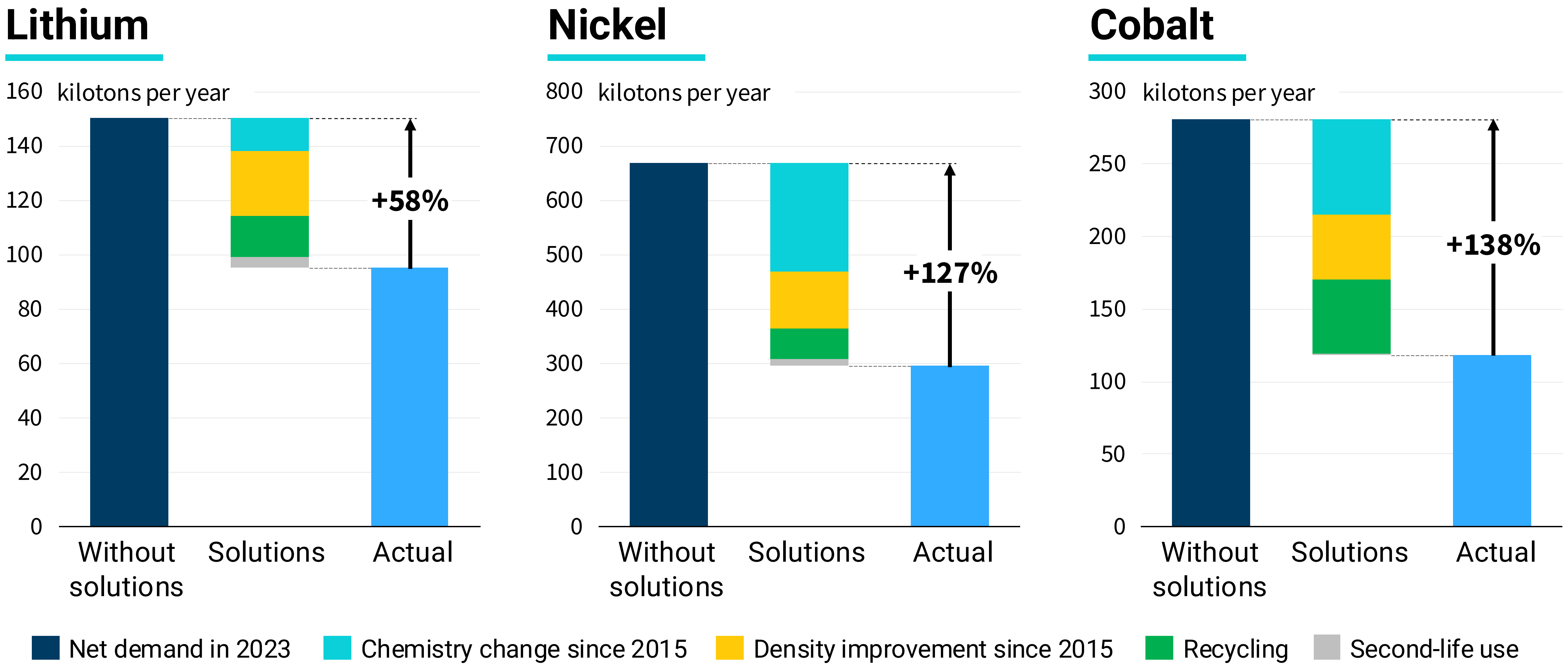
Improve vehicle efficiency and right-size cars for purpose

6. Efficient mobility

Improve urban planning and increase alternate transport

Source: Amory Lovins, "Six Solutions to Battery Mineral Challenges" (2022)

Three solutions have already made a major impact



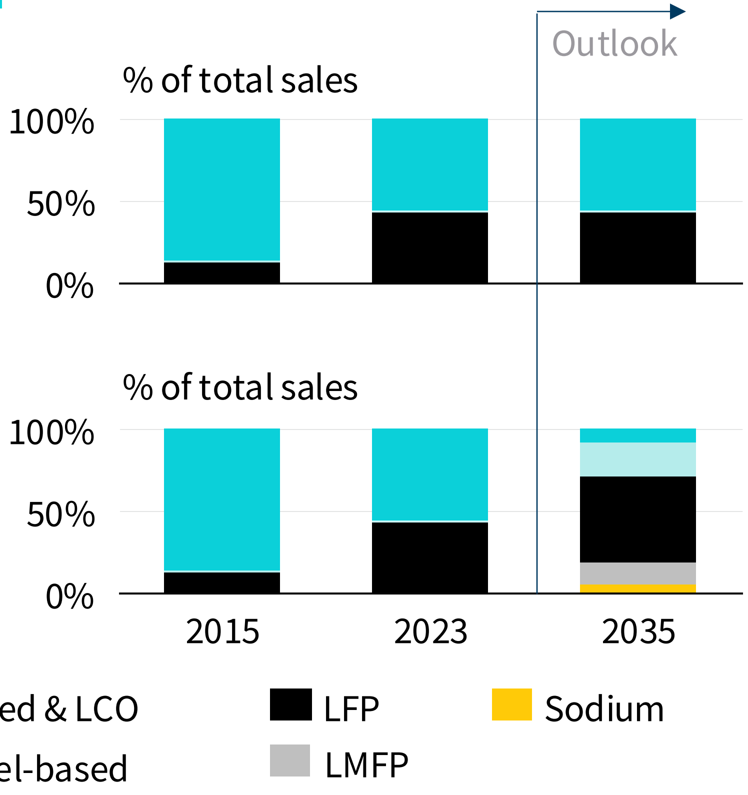
Source: RMI (The Battery Mineral Loop). Recycling includes recycling of production scrap, which is generally economic already.

The impact of chemistry change

Chemistry mix

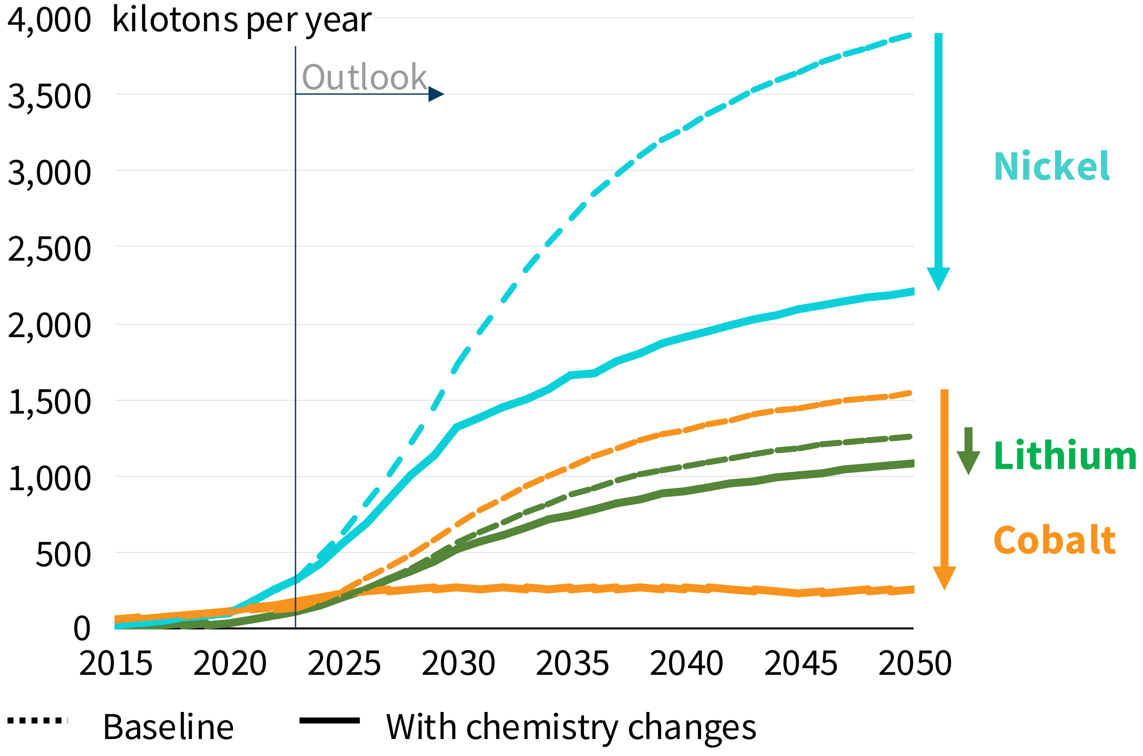
“No solutions” case: no change in chemistry mix after 2023

Continued trend: chemistry mix continues to change after 2023



This outlook only includes simply scaling up current battery mineral demand in line with battery demand. It is not representative of a realistic scenario and is purely illustrative.

Battery mineral demand before & after chemistry mix change - Fast scenario

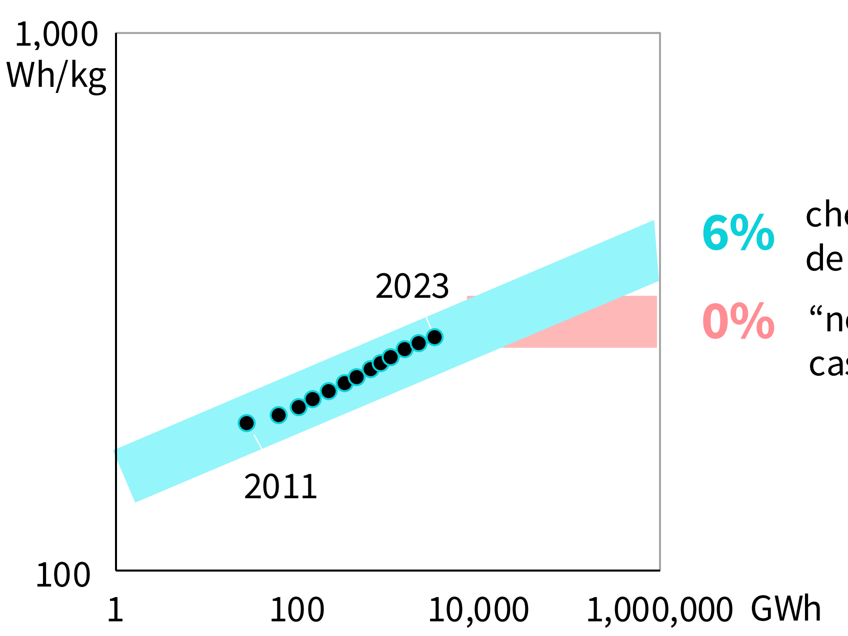


Part of cobalt’s decline is from the sectoral redistribution of demand.

Source: BNEF Long-Term Electric Vehicle Outlook (2024), RMI (The Battery Mineral Loop)

The impact of energy density change

Avg. energy density of traditional LIBs

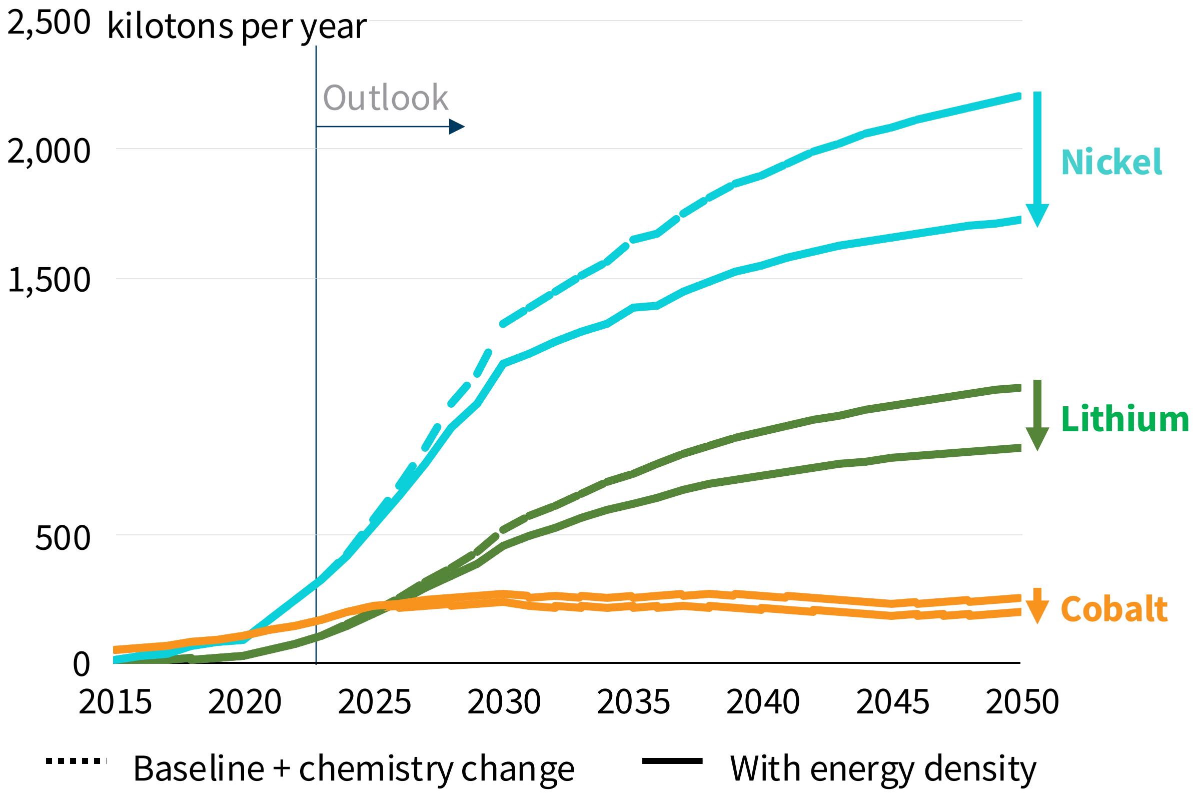


Learning rate

6% chemistry and density change

0% “no solutions” case

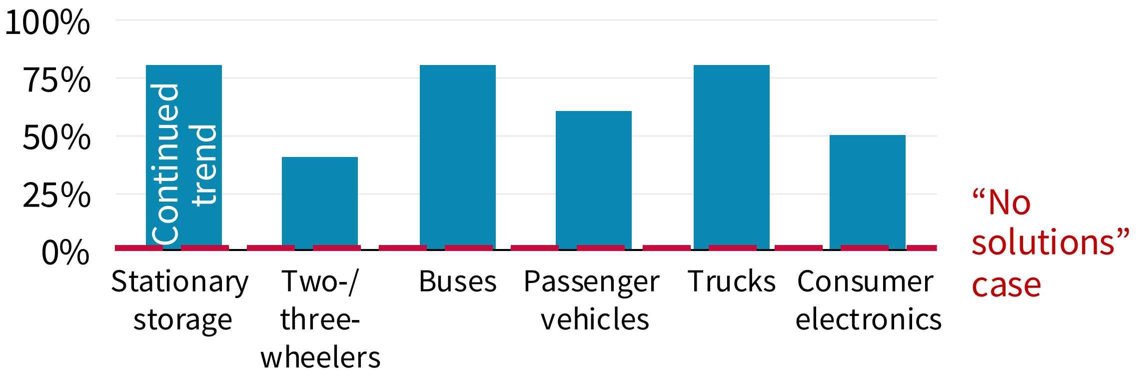
Battery mineral demand before & after density improvements – Fast scenario



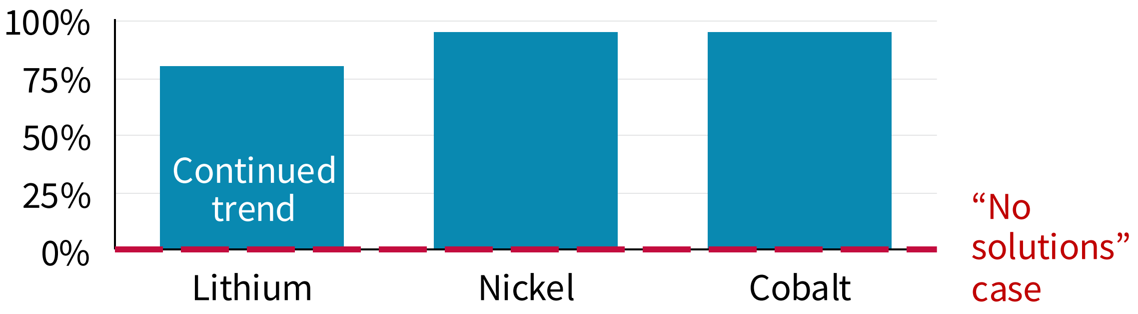
Source: BNEF Lithium-Ion Batteries: State of the Industry (2023), RMI (The Battery Mineral Loop). Outlook chart excludes the density effects of chemistry change to avoid double-counting.

The impact of recycling

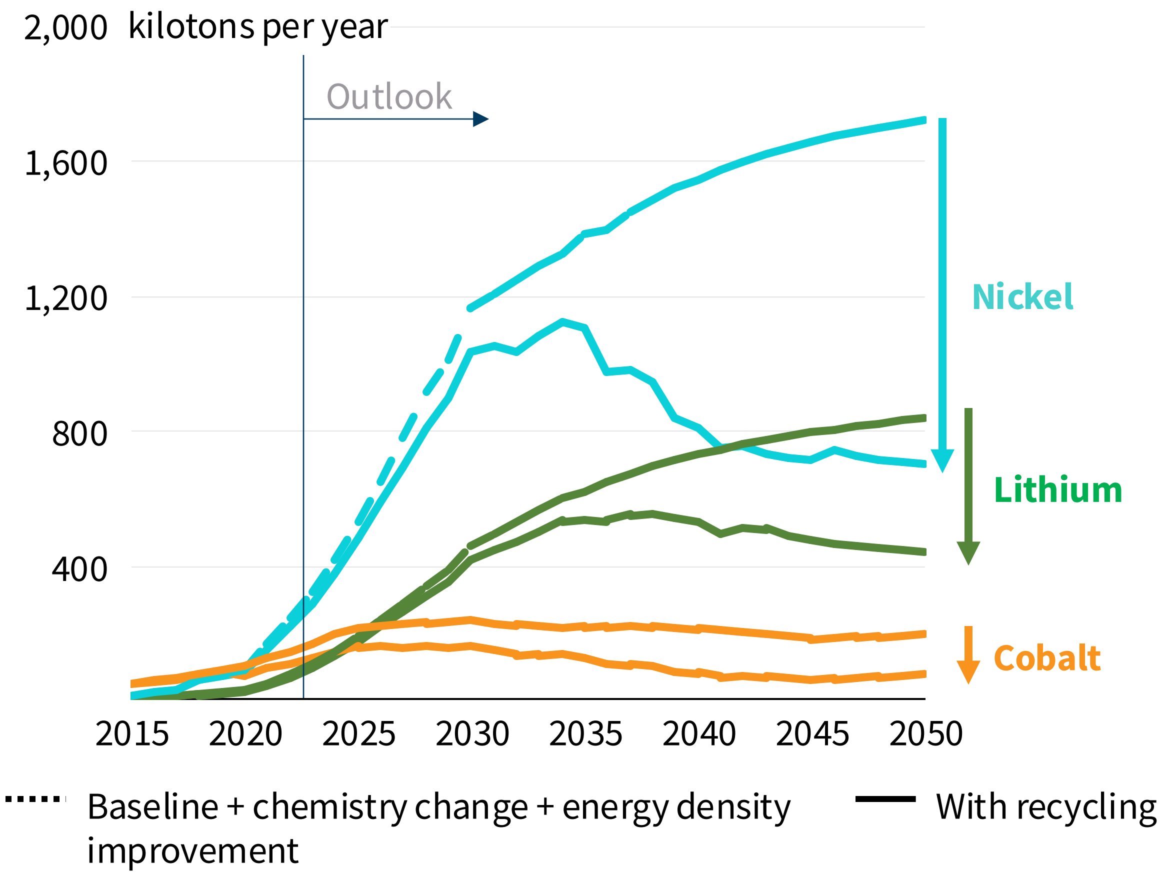
Collection rate



Recovery rate

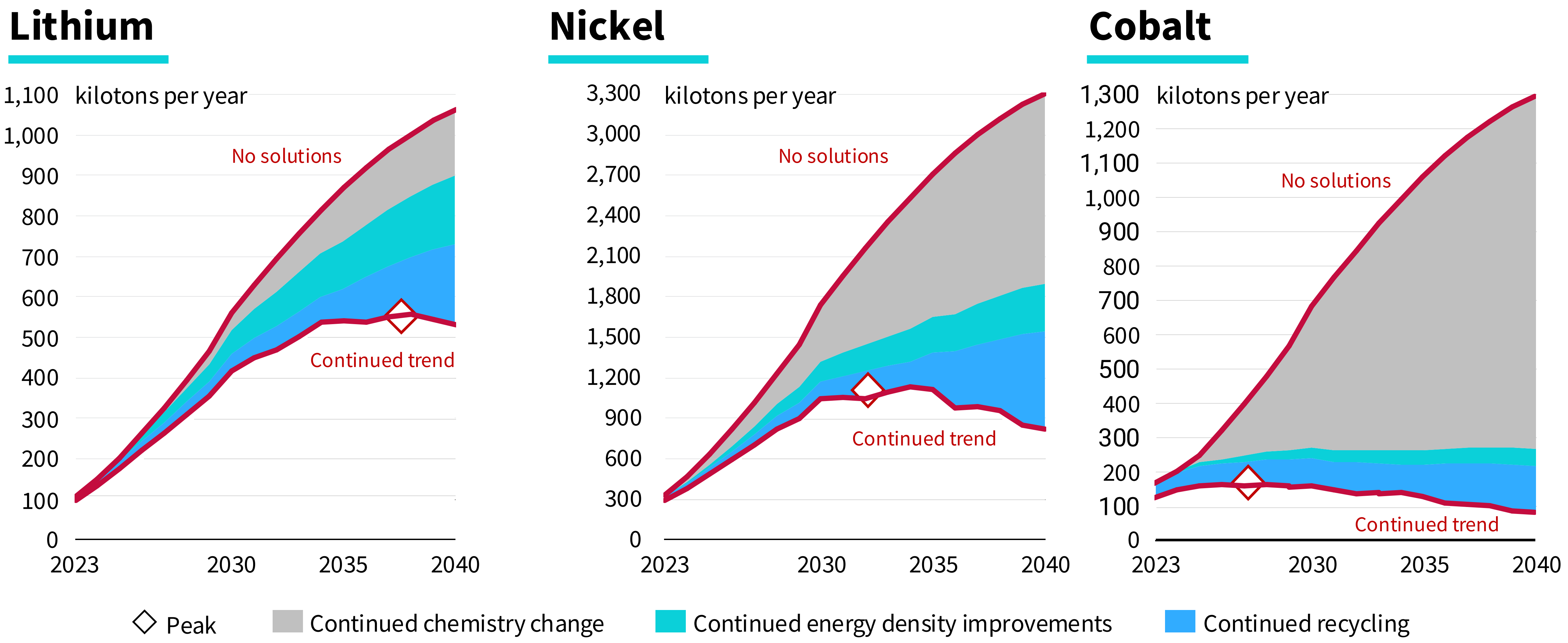


Net battery mineral demand before & after recycling – Fast scenario



Source: BNEF Lithium-Ion Battery Recycling Availability Model (2024), Gaines et al. (2023), RMI (The Battery Mineral Loop)

Peak battery mineral demand in a decade



*Source: RMI X-Change Batteries, RMI (*The Battery Mineral Loop*).*
Note: Part of the effect of cobalt chemistry change comes from the sectoral redistribution of demand.

The accelerated case

A Changing chemistries

- Speed up sodium-ion battery scaling in EVs

B Higher energy density batteries

- Raise learning rate to match top-tier battery level

C Recycling

- Raise collection rates
- Raise recovery rates to best-in-class
- Lower production scrap rate to best-in-class

D Reuse and extend lifetime

- Reuse more batteries in stationary grid storage
- Extend lifetime of EV batteries

E Efficient vehicles

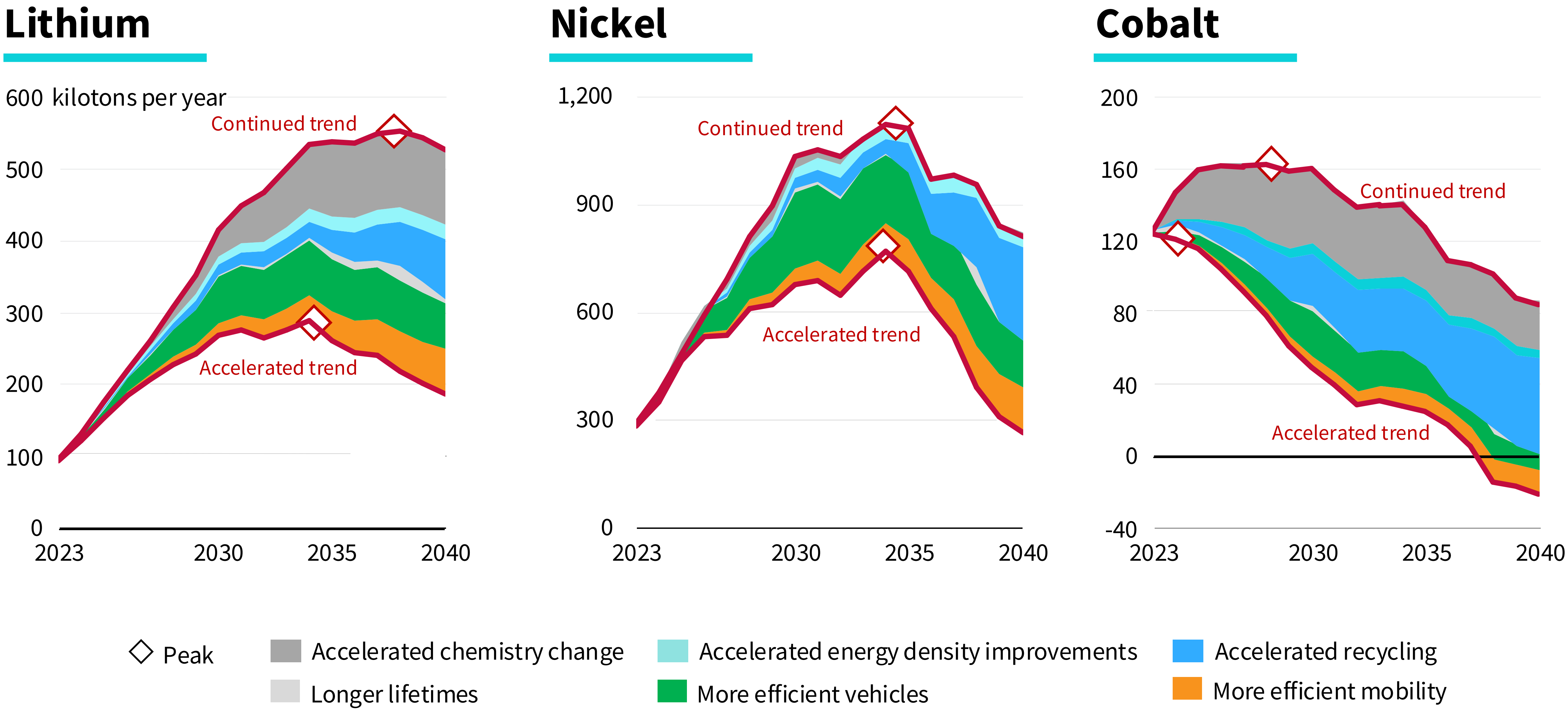
- Cut EV energy needs through better design efficiency and right-sizing

F Efficient mobility

- More modal shifting via electric micromobility, urban planning, active modes, and public transit
- Better freight efficiency

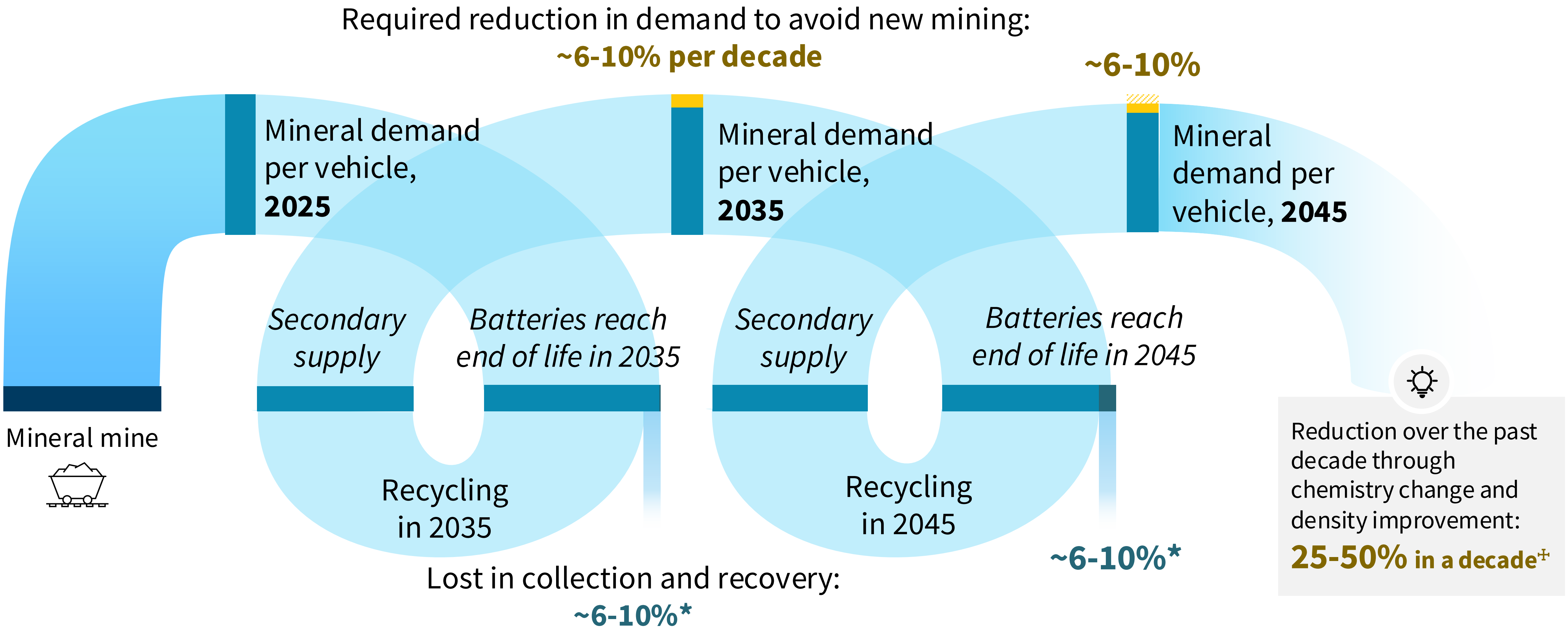
Source: RMI (The Battery Mineral Loop)

Acceleration means a lower and earlier peak



Source: RMI (The Battery Mineral Loop)

Circular self-sufficiency is possible

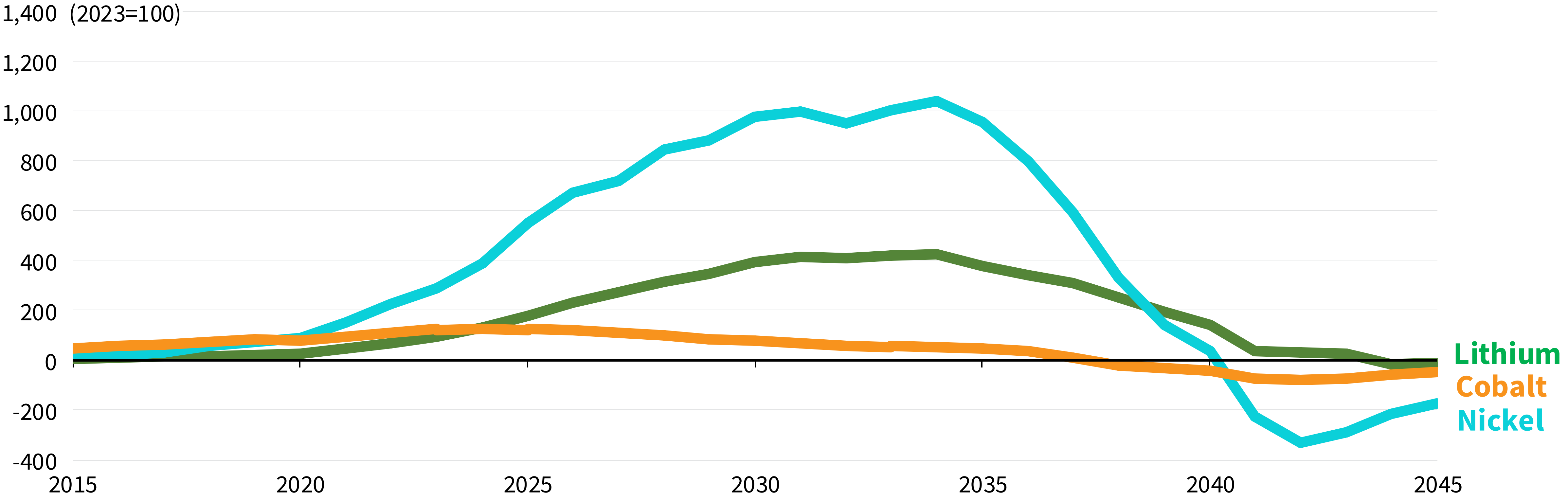


* Accelerated case ⸸ About 25% for lithium, about 50% or more for nickel and cobalt

Source: RMI analysis. Useful battery lifetime of a decade is indicative; lifetimes are likely longer.

Net-zero mineral demand before 2050 is possible

Mineral demand, accelerated trend, faster battery uptake scenario



Assumes recycling of all minerals in batteries.

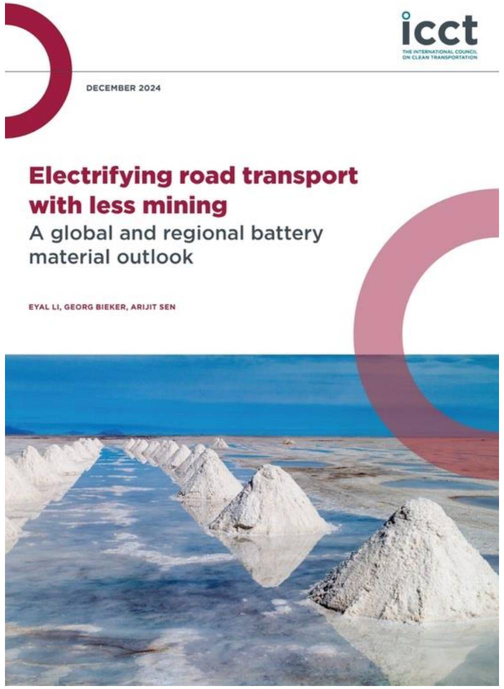
Source: RMI analysis

Now, other groups are arriving at similar findings

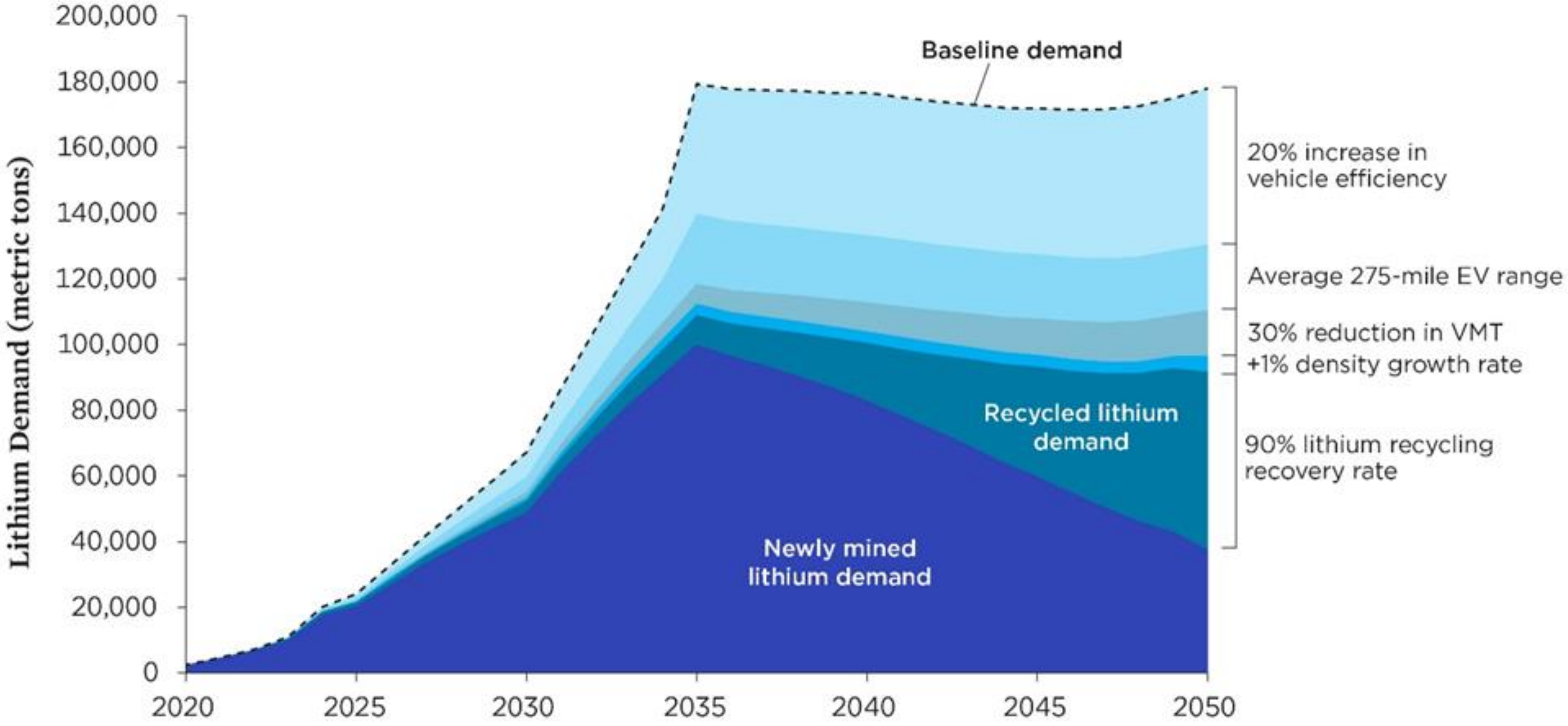
climate + community project

Achieving Zero Emissions with More Mobility and Less Mining

ICCT, December 2024

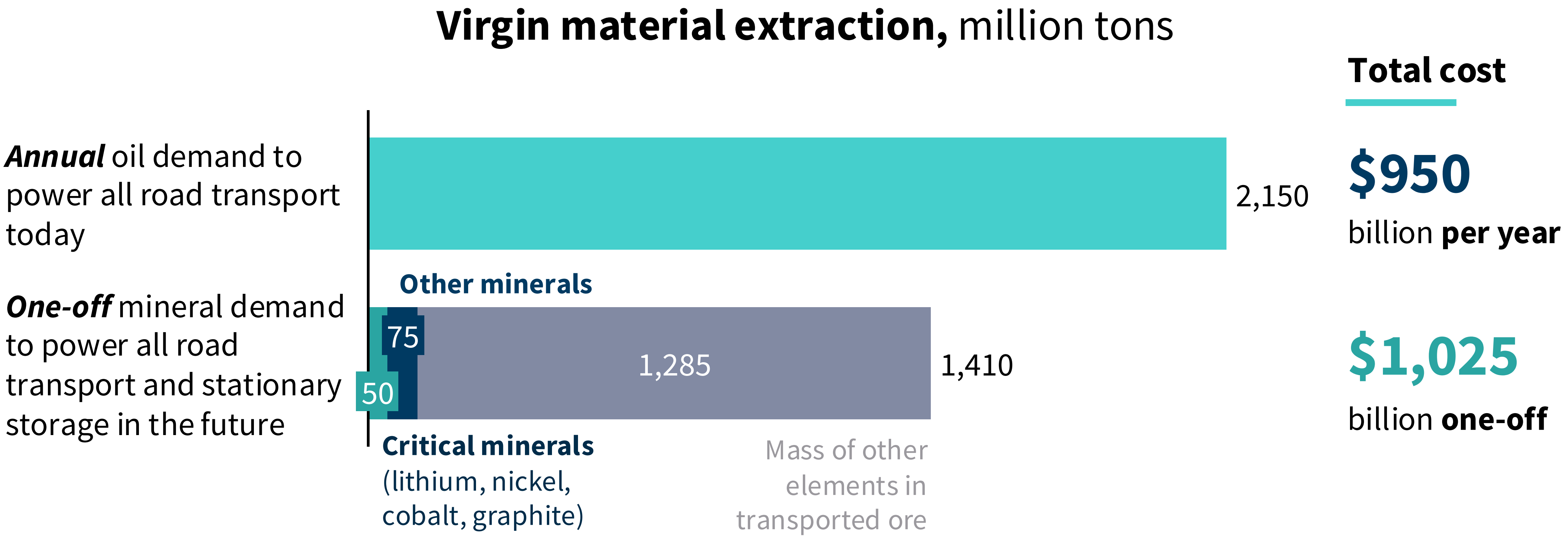


UCS, December 2024



Sources: International Council on Clean Transportation; Union of Concerned Scientists; University of California, Davis

One-off minerals versus continuous oil extraction



Accelerated scenario; faster uptake. Mass of other elements in transported ore are based on the typical mineral concentration of products leaving the mining site — i.e., after typical on-site concentration of natural ore. Cost is calculated based on current wholesale prices for extracted products; no refining or other costs are included.

Source: IEA Global Critical Minerals Outlook (2024), USGS National Minerals Information Center, RMI (The Battery Mineral Loop).

Agenda

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A holistic perspective of recycling is needed

Financial returns

Jobs

Economic growth

Emissions

Land use

Water use

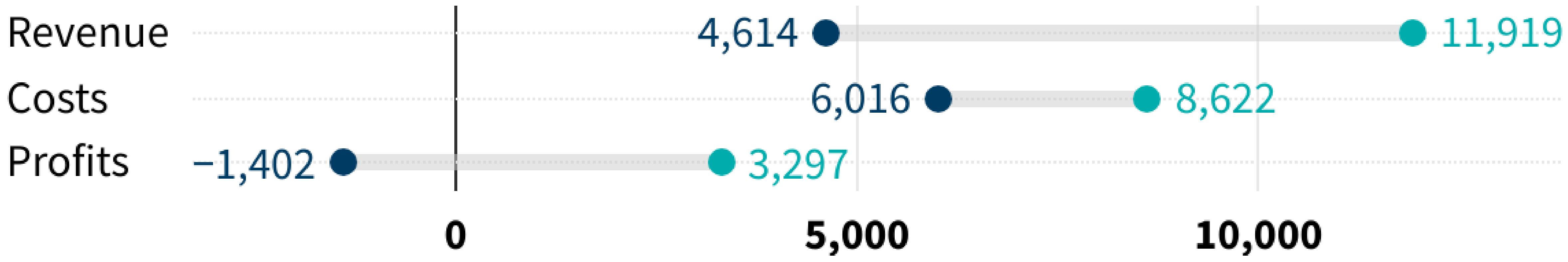
What metrics does a triple bottom-line analysis include?

Financial	Profit pools from EVB recycling
Social	Wages earned and GDP impact of jobs
Environmental	Reductions in: CO2e emissions; water use; land use (all converted into dollar values)

The financial profitability of recycling varies greatly

Value of social benefits remain unaccounted in traditional business models

Revenue and costs in $ per ton battery recycled

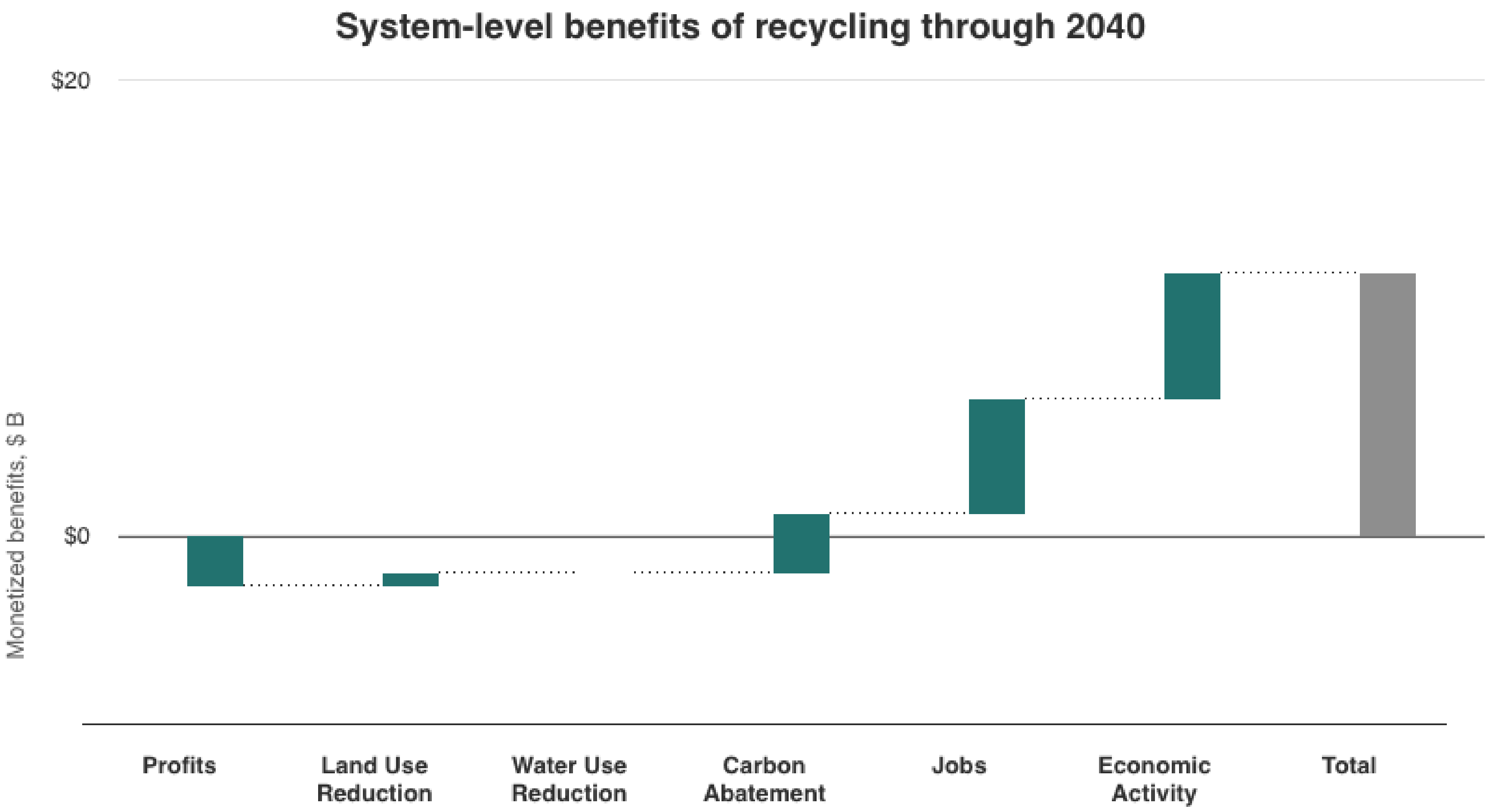


Recycling profits are driven by metal market prices and economies of scale

Source: EverBatt model (Argonne National Lab), RMI Analysis

The value of recycling is not reflected in P&L assessments

A triple bottom-line assessment determines the social value generated

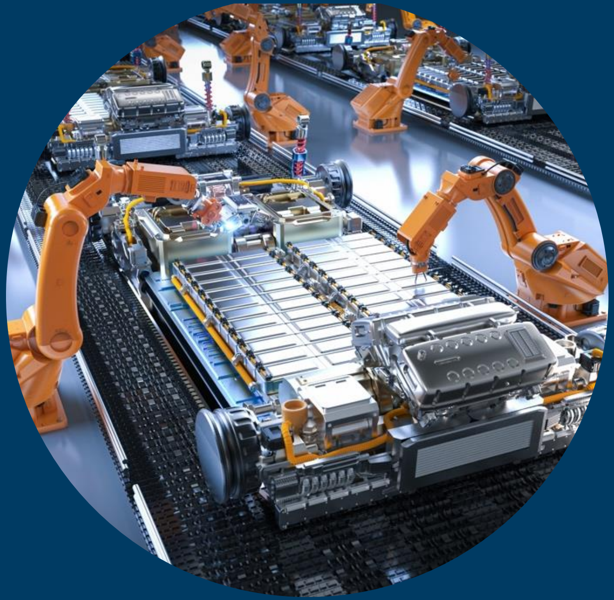


Even in volatile markets, holistic ROI is overwhelmingly positive

Source: RMI analysis

CASE STUDY

Metal Focus: Lithium



Process: Traditional ore mining
Purpose: Baseline

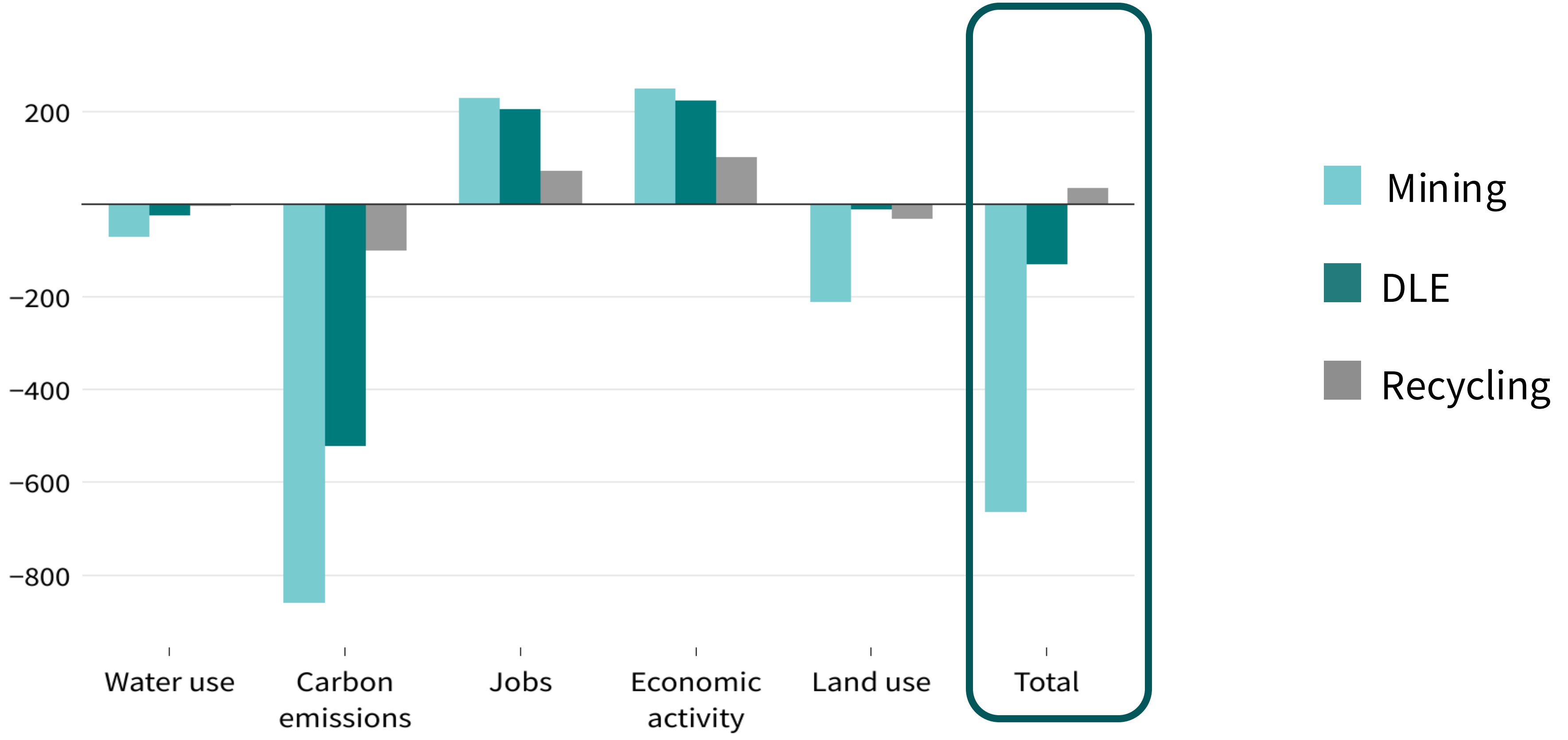
Process: Direct lithium extraction with geothermal
Purpose: Assess impact of technological innovation

Process: Recycling
Purpose: Assess impact of circular approaches

Comparative assessment of externalities

The social and environmental value generated by recycling is $170-$700 greater per ton of LCE

Externalities In $ Per Ton of Lithium Carbonate Equivalent Produced



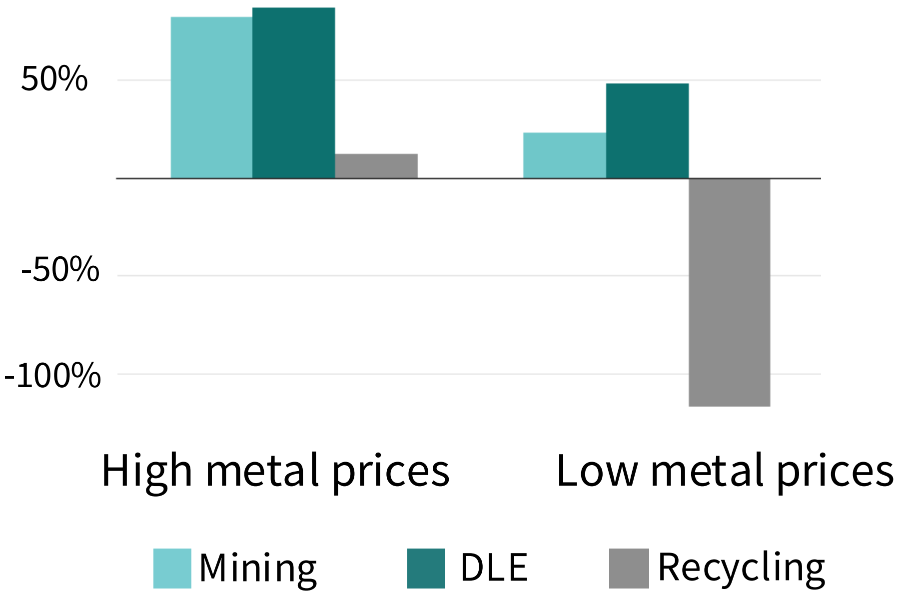
Source: RMI analysis

The case for policy interventions and incentives

Unlocking the social value requires de-risking recycling business models

Recycling of LFP is challenging …

Profit margins sensitivity to metal prices
Profits per ton of LCE produced



… but incentives can help de-risk

Indicative effect of incentives on profit margin
Allocating $2400 in incentives per ton of battery

−42.0% 4.0%

Incentive allocated ($/ton)	1500	1875	2250	2340	2415
Profit Margin	−42%	−23%	−4%	0%	4%

Source: RMI analysis

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BCEI Dashboard: Battery Mineral Loop

USER INPUTS

Preset Scenarios

Baseline | Accelerated

Hit SUBMIT at the bottom of this form to run the simulation.

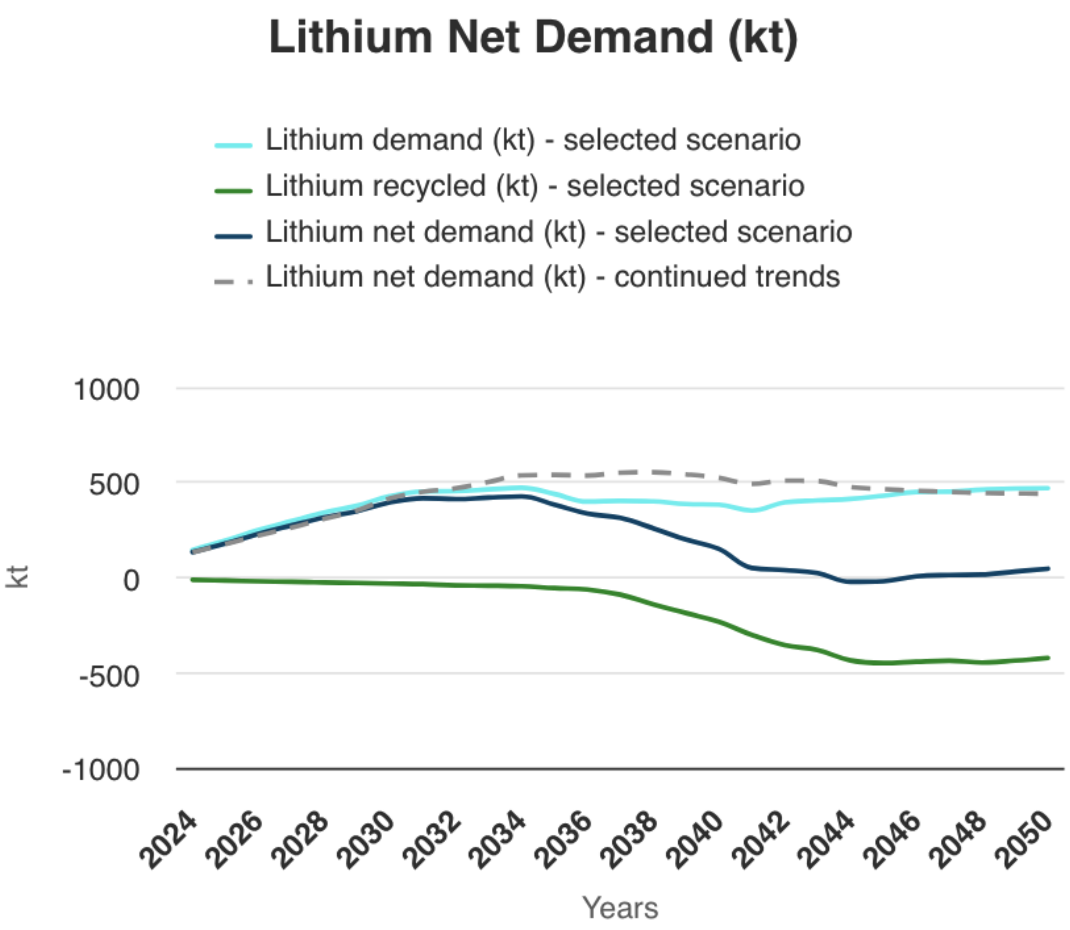
BATTERY DEMAND

BATTERY INNOVATION

EFFICIENCY PARAMETERS

RECYCLING PARAMETERS

RESET | SUBMIT



Cumulative demand

5,367 kt

Reduction in cumulative demand

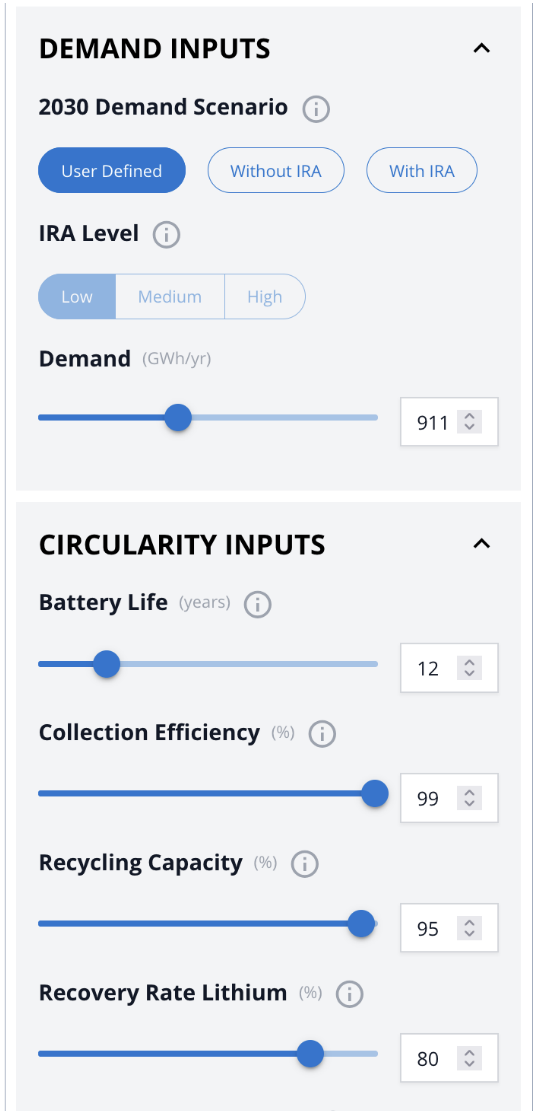
55.0%

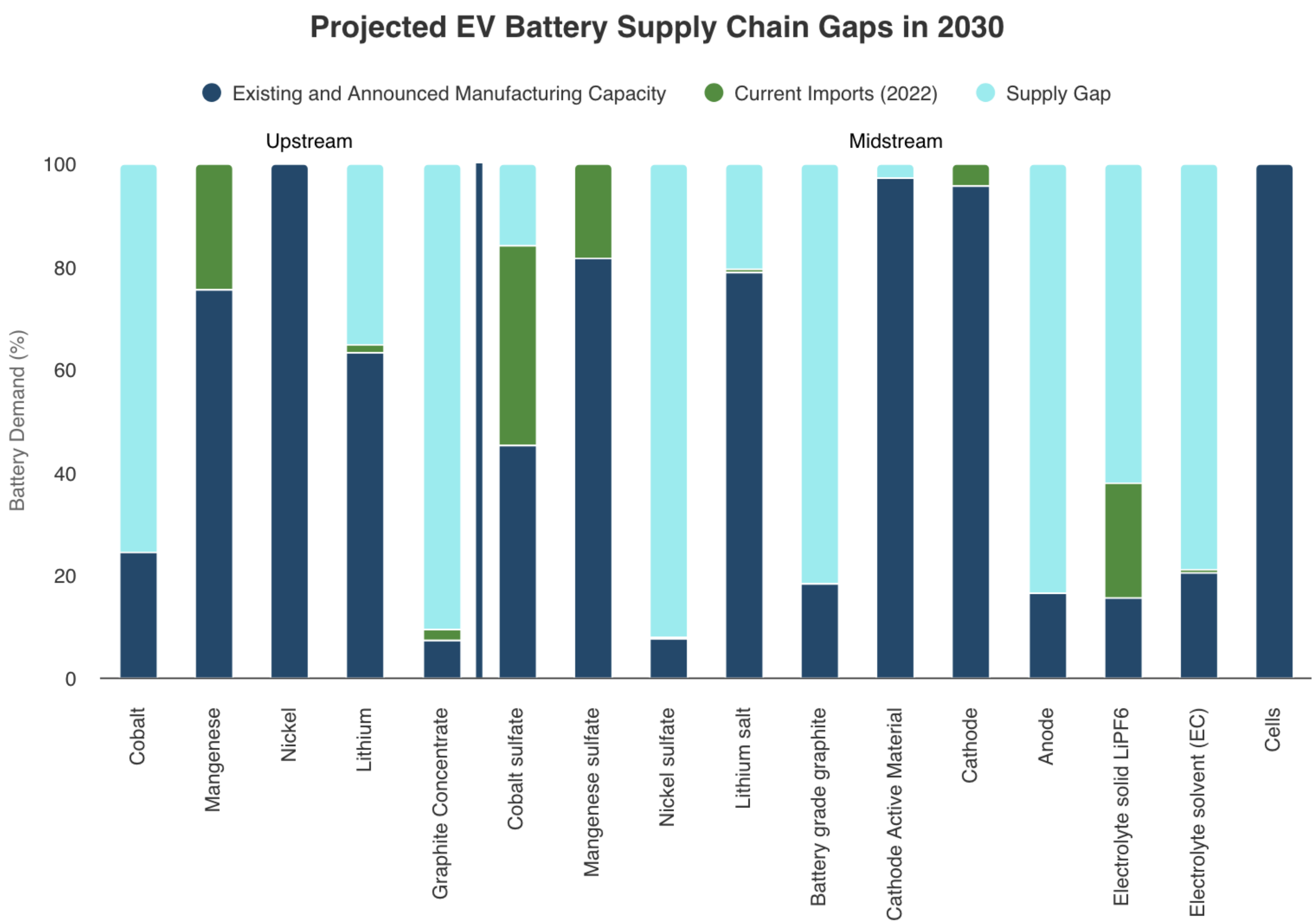
(Reduced demand over baseline)

Peak demand year

2034

BCEI Dashboard: US Supply Chain





Powering the Future

Overcoming Battery Supply Chain Challenges with Circularity

Challenges	**Solutions**
Lack of transparency across the full value chain	Track-and-trace platforms
Battery design and lack of data access	Design change and data standards
Challenging economics of recycling and second life	Policy to address economic and technical challenges
Vulnerabilities and inequitable harms and benefits of value chain design	Regional value chains and cross-border movement
Workforce transition needs	Workforce development and transition

Source: RMI, World Economic Forum, Global Battery Alliance

Q&A

Thank You!

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