Li-Cycle®

# Opportunity for Closing the Loop in the Lithium-ion Battery Supply Chain

June 17th , 2020

Presented To: CALEPA Lithium-Ion Battery Recycling Advisory Group

# PRESENTATION CONTENTS

# LI-CYCLE OVERVIEW

**Year Founded:** 2016

**Service:** Closed-loop lithium-ion battery resource recovery

**Key Partners:** CALSTART, MaRS, Responsible Battery Coalition, NAATBatt International, Suppliers Partnership for the Environment

**Key Investors:** TECHMET, bdc, DELPH25, PELLA Resources Limited, Bioindustrial Innovation Canada – A Sustainable Chemistry Alliance

**Awards:** 2020 Global Cleantech 100, 2020 Clean16 – Outstanding Contributors to Clean Capitalism, CV Magazine Energy Innovator Awards 2019, Start Up Energy Transition, CleanEquity Monaco 2018, Mississauga Board of Trade Business Awards of Excellence 2018 Winner

# LI-CYCLE VISION


To be the most sustainable, vertically integrated, and globally preeminent lithium-ion battery resource recovery company

# LI-CYCLE EXECUTIVE TEAM, BOARD AND ADVISORS

## Leadership & Team

**Tim Johnston**
Exec. Chairman
*Mech. Eng., CFA*

**Ajay Kochhar**
President & CEO
*Chem. Eng.*

**Kunal Phalpher**
CCO
*Elec. Eng., MBA*

**Bruce MacInnis**
CFO
*CPA and CA*

**Chris Biederman**
Chief Process Engineer
*Sr. Chem. Eng. Mgr.*

**Ala Hussain**
Eng. & Const. Mgt.
*Sr. Civil Eng. Mgr.*

**Ethan Callender**
HSEQ Manager
*HSE, Quality Expert*

## Board of Directors

**Tim Johnston**
Exec. Chairman
*Co-Founder*

**Ajay Kochhar**
Exec. Director
*Co-Founder*

**Anthony Tse**
Non-Exec. Director
*Critical Materials*

**Mark Wellings**
Non-Exec. Director
*Capital Raising*

**Rick Findlay**
Non-Exec. Director
*Business Ops. & Scaling*

**Alex Lowrie**
Non-Exec. Director
*Financial Mgt.*

**Brian Menell**
Non-Exec. Director
*Strategic Growth*

## Advisory Board

**Adonis Pouroulis**
Senior Advisor
*Mining & Metals*

**Yuan Gao**
Technical Advisor
*Li-ion Battery Expert*

**Ahmad Ghahreman**
Technical Advisor
*Ph.D. Hydromet.*

**Chris Berry**
Energy Metals Advisor
*Leading Co & Li Analyst*

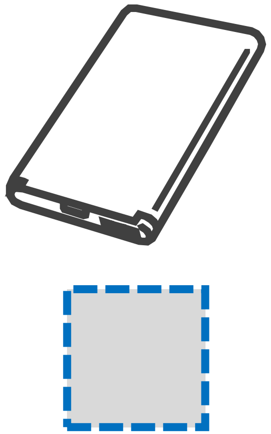
# EXPONENTIAL LI-ION BATTERY DEMAND GROWTH

## Lithium-ion battery demand globally has risen dramatically over the last 10 years, and is only beginning

*Global demand depicted below with accurate relative scale*

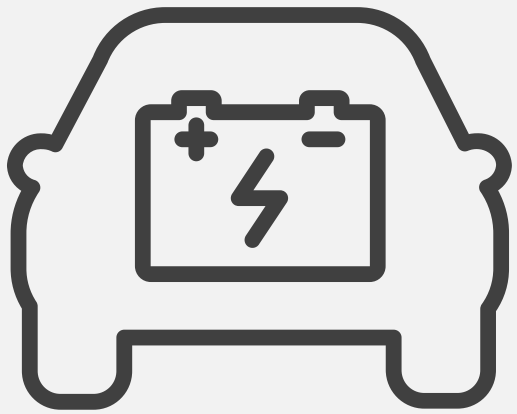
**2010**

*4 GWh*



**2020**

*80 GWh*

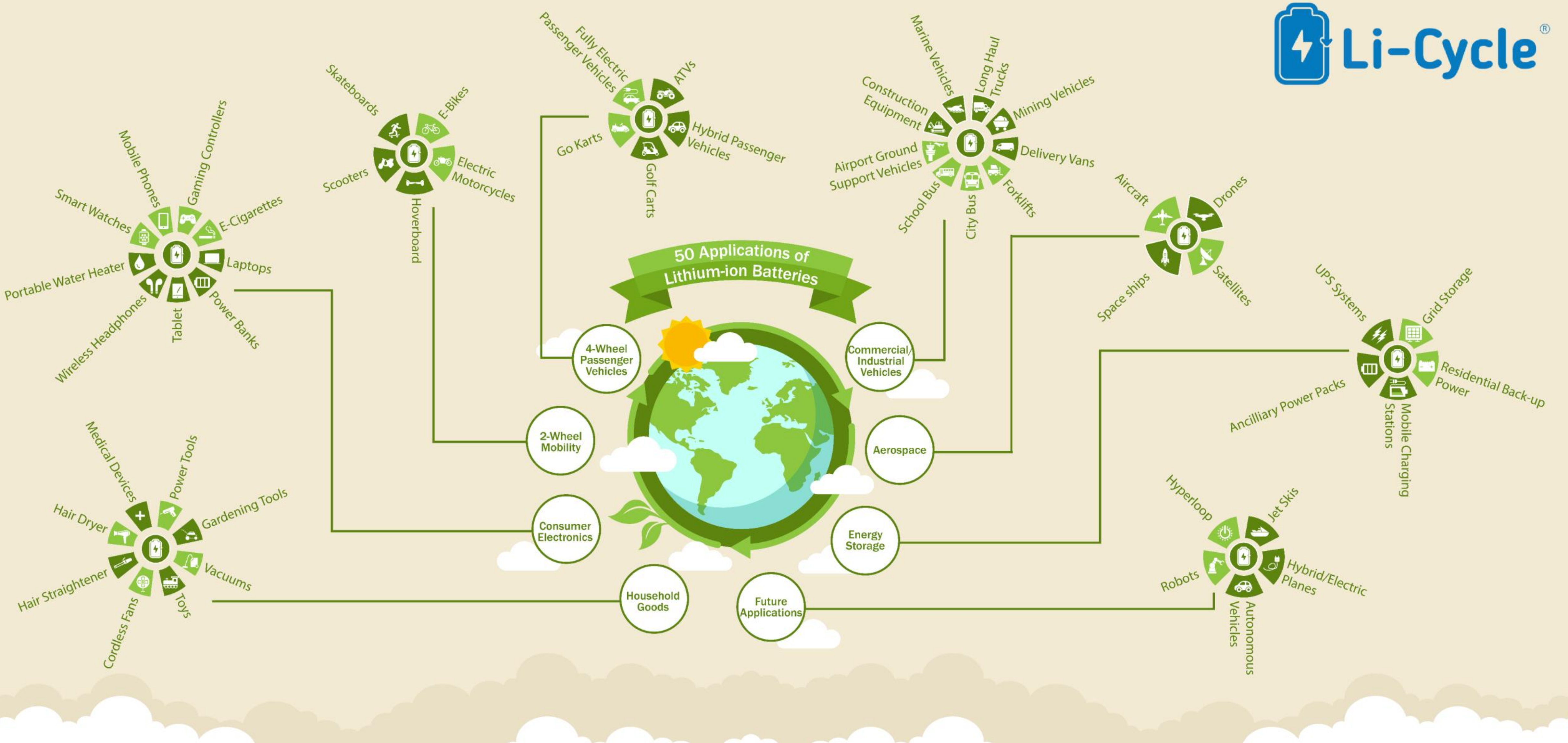


**2030**

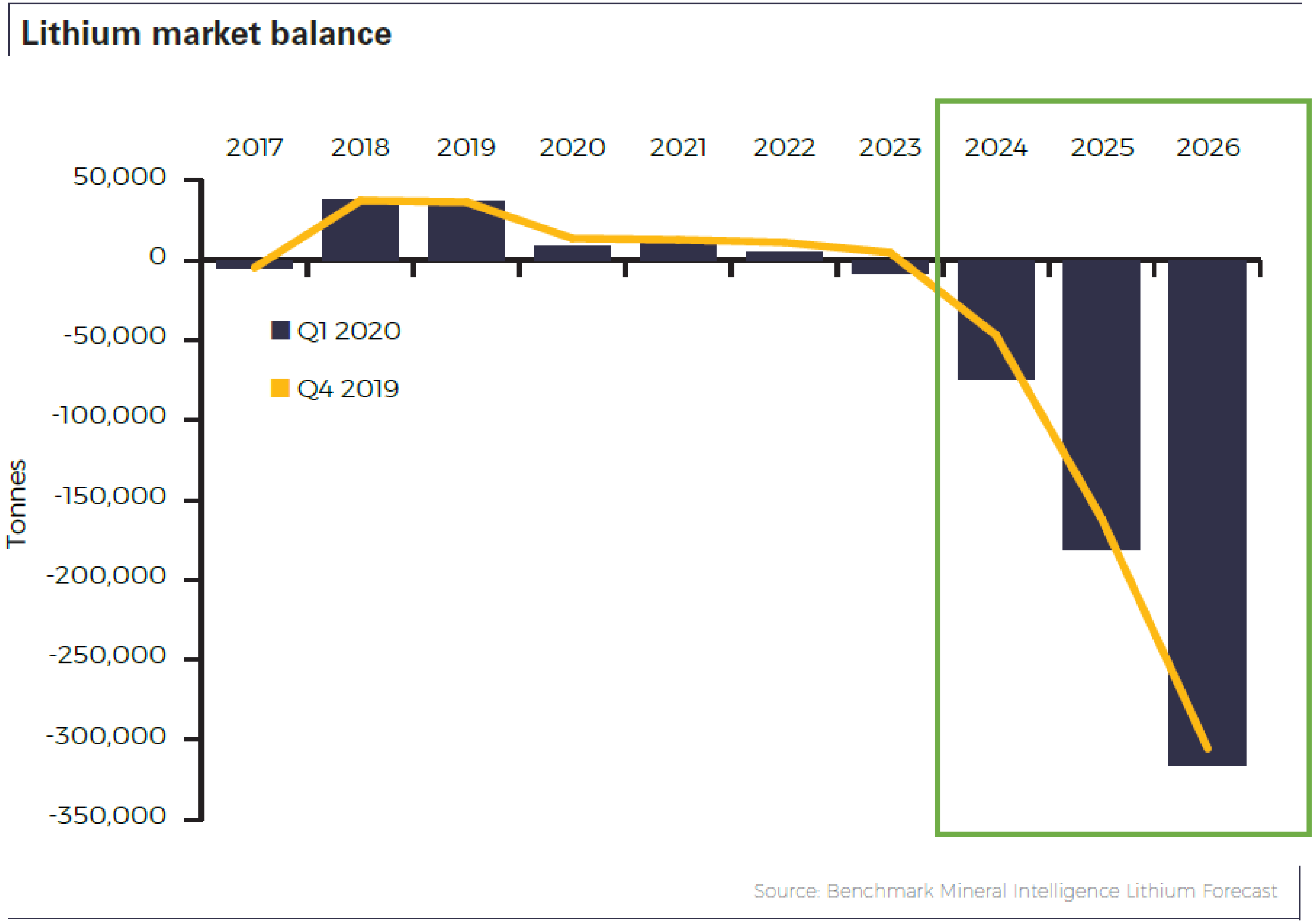
*760 GWh*

*Samsung SDI

# GROWING NUMBER OF USES FOR LI-ION BATTERIES



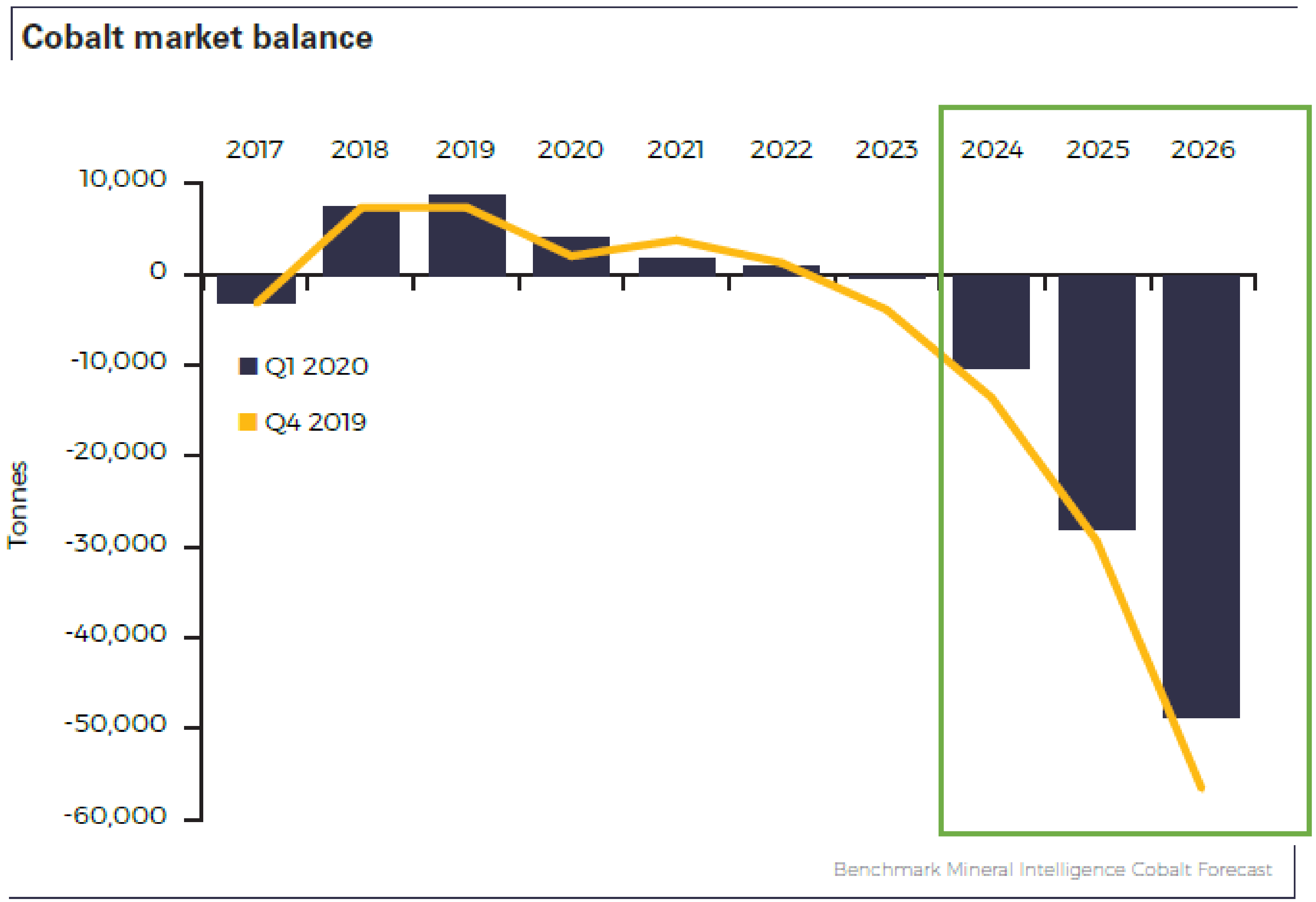
# INCREASING DEMAND FOR MATERIALS IN SHORT SUPPLY – LITHIUM




**OPPORTUNITY FOR NEW MATERIAL SOURCES**

Source: Benchmark Mineral Intelligence

# INCREASING DEMAND FOR MATERIALS IN SHORT SUPPLY – COBALT

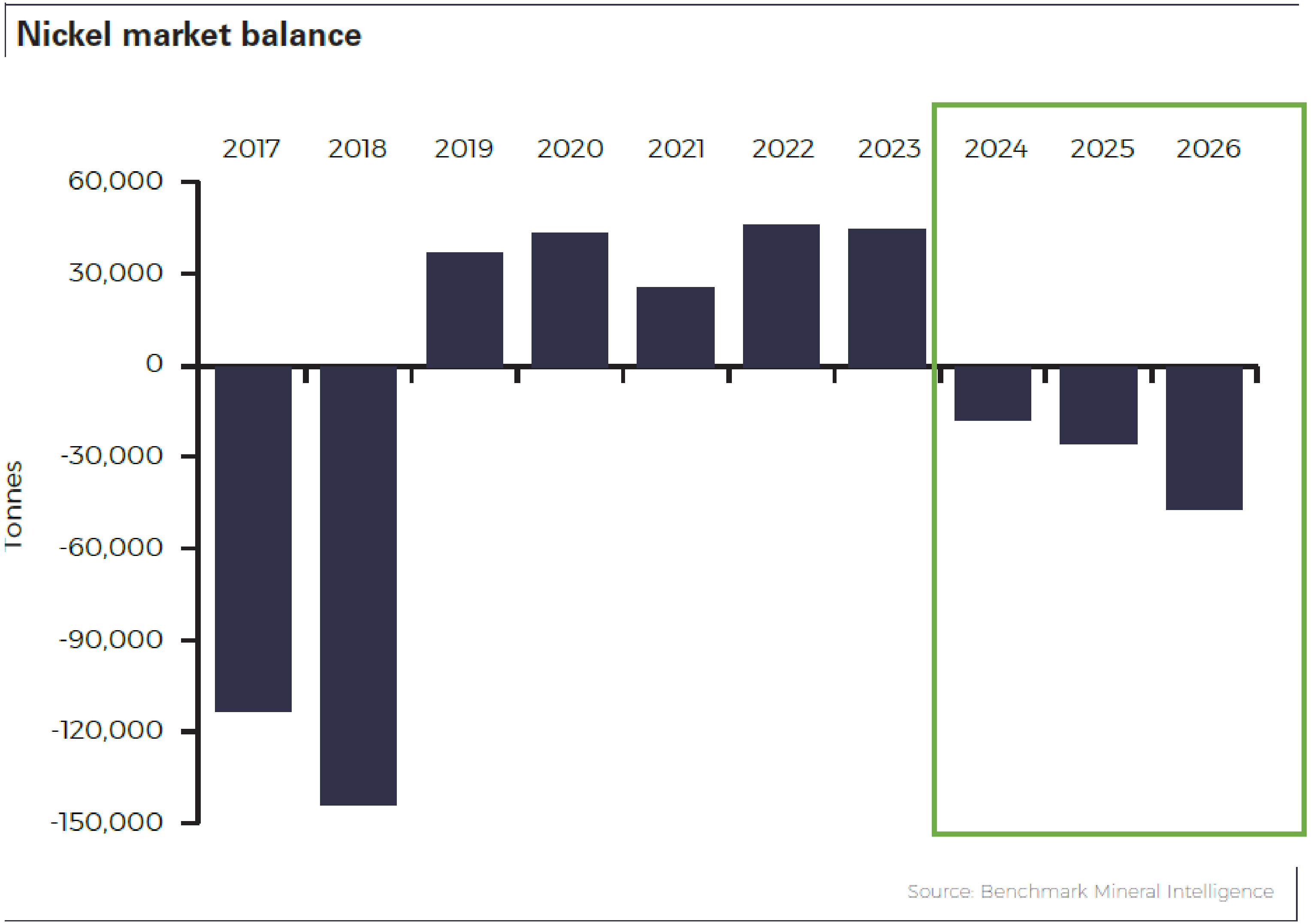



**OPPORTUNITY FOR NEW MATERIAL SOURCES**

Source: Benchmark Mineral Intelligence

# INCREASING DEMAND FOR MATERIALS IN SHORT SUPPLY – NICKEL






**OPPORTUNITY FOR NEW MATERIAL SOURCES**

Source: Benchmark Mineral Intelligence

# LOCAL US PRODUCTION OF BATTERY MATERIALS IS LIMITED

## Critical Material Uses

| *Energy* | *Technology* | *Industrial* | *Steel* | *Batteries* | *Research* |
|---|---|---|---|---|---|
| HAFNIUM | GERMANIUM | BERYLLIUM | MAGNESIUM | LITHIUM | HELIUM |
| RHENIUM | INDIUM | ZIRCONIUM | CHROMIUM | COBALT | RUBIDIUM |
| TANTALUM | GALLIUM | TUNGSTEN | TIN | ANTIMONY | CESIUM |
| URANIUM | RARE EARTHS | ALUMINUM | TELLURIUM | GRAPHITE | BISMUTH |
| | | PGMs | MANGANESE | NICKEL | |
| | | BARITE | VANADIUM | | |
| | | FLUORSPAR | NIOBIUM | | |
| | | ARSENIC | | | |
| | | SCANDIUM | | | |
| | | STRONTIUM | | | |
| | | TITANIUM | | | |
| | | POTASH | | | |

### LEGEND (USA)

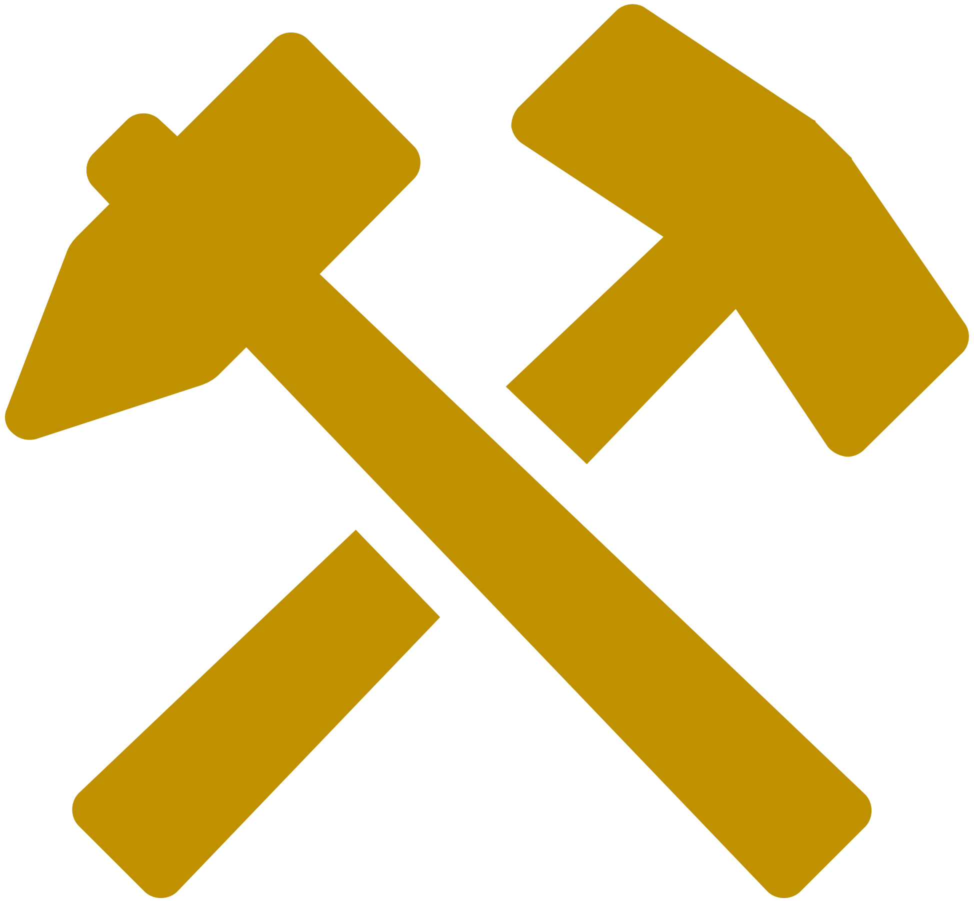
LESS RELIANT ON IMPORTS

100
100
100
100
100
100
100
100

COMPLETELY RELIANT ON IMPORTS

Source: U.S. Department of the Interior, Bureau of Land Management

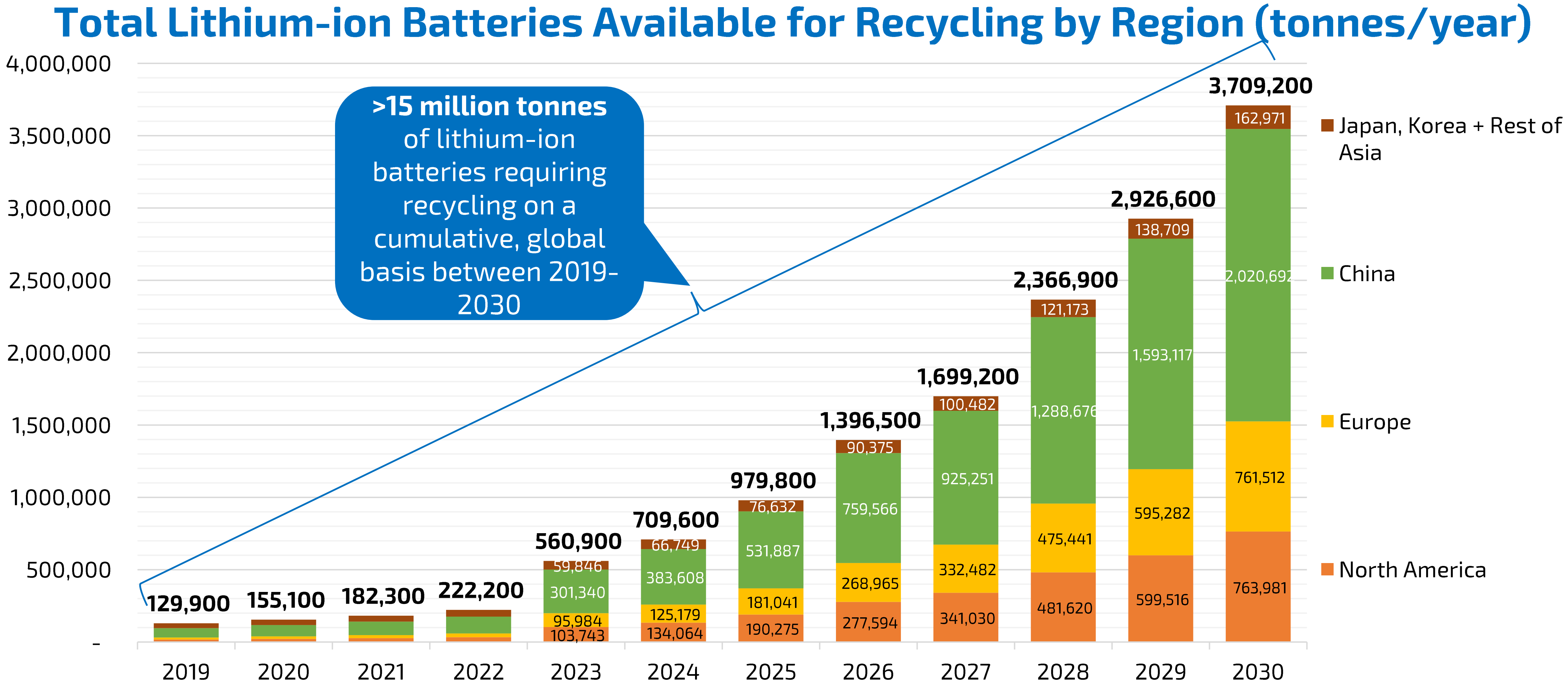
# WHAT ARE THE SOURCES FOR BATTERY MATERIALS?



Mining

Recycling

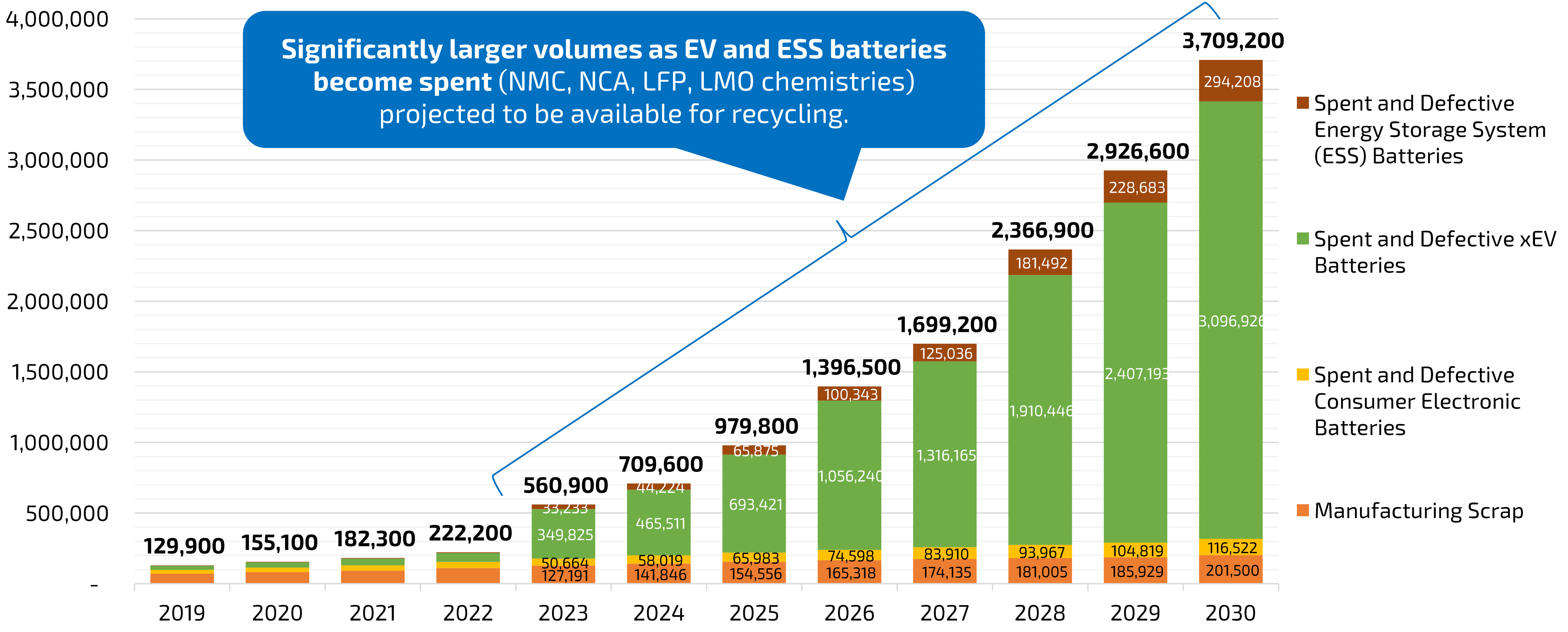
# ARE THERE ENOUGH BATTERIES FOR RECYCLING?




SOURCE: Li-Cycle Total Addressable Market forecasts (various sources therein)

# ARE THERE ENOUGH BATTERIES FOR RECYCLING? (CONTD.)

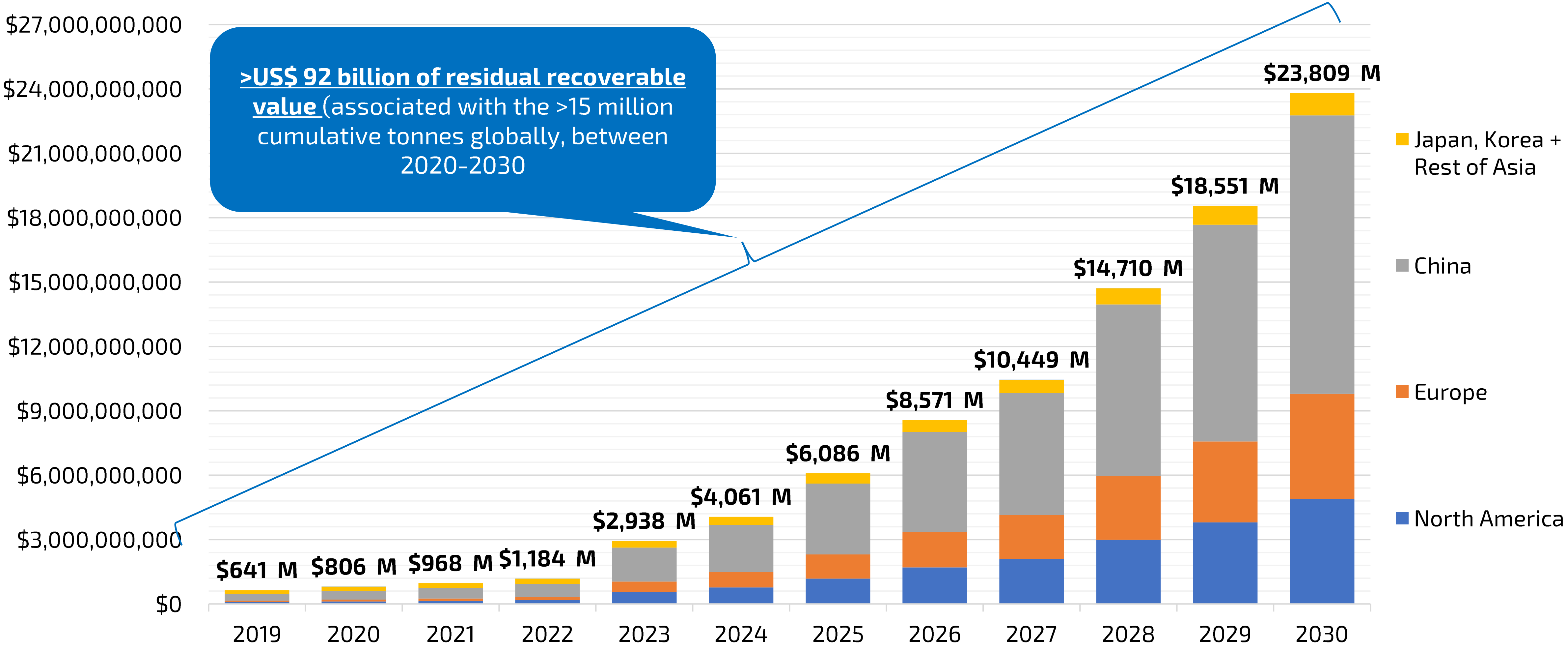
## Total Lithium-ion Batteries Available for Recycling by Application/Sector (tonnes/year)




SOURCE: Li-Cycle Total Addressable Market forecasts (various sources therein)

# WHAT IS THE VALUE OF RECYCLED MATERIALS?

## Total Recoverable Value by Region (US$/year)

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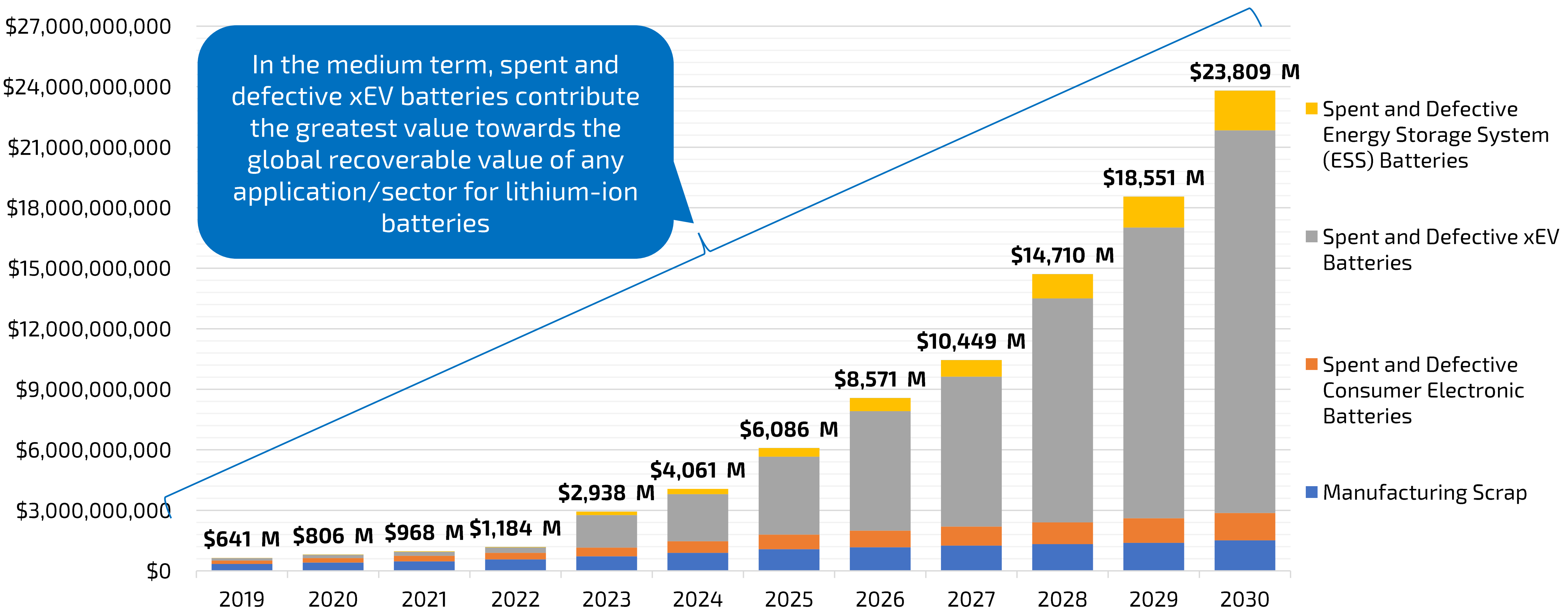



SOURCE: Li-Cycle Total Addressable Market forecasts (various sources therein)

# ENVIRONMENTAL BENEFITS OF RECYCLED MATERIALS

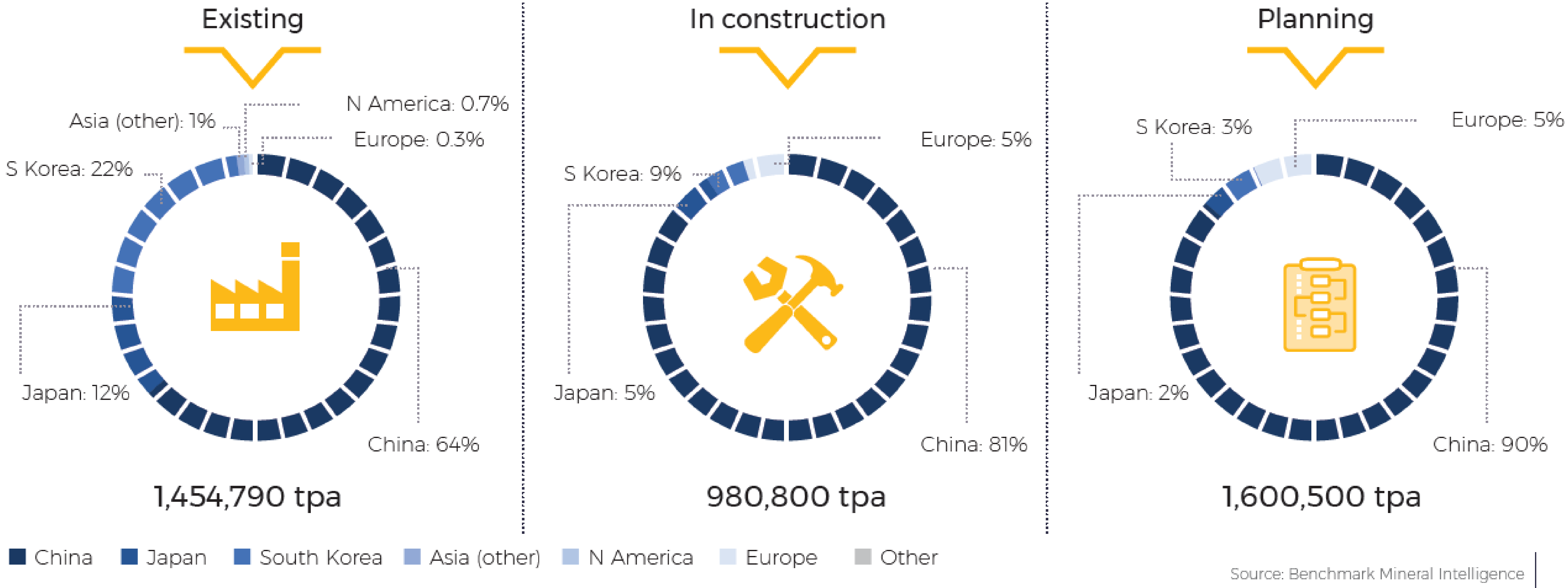
## Third Party Life Cycle Analysis Results

*GHG Emissions Reductions provided below are the emission reductions associated with recovering 1 tonne of each battery material using Li-Cycle Technology in comparison to mining and refining these materials*

| 3 Li LITHIUM | 25 Mn MANGANESE | 27 Co COBALT | 28 Ni NICKEL |
|---|---|---|---|
| 8.9 t CO2 | 7.0 t CO2 | 40.7 t CO2 | 8.1 t CO2 |

# GAP IN SUPPLY CHAIN WILL PERSIST EVEN WITH RECYCLING

## Cathode capacity update




Source: Benchmark Mineral Intelligence

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# END-OF-LIFE OPTIONS: BEFORE LI-CYCLE

## Export it

Batteries are shipped blindly overseas and are often lost, landfilled abroad, or lead to fires

*Image of an actual fire caused by a Li-ion battery, resulting in 34 fatalities*

## Trash it

"Nationally we're losing a facility a month, burned to the ground by battery fires"

*President, Dem-Con Waste Management*

## Reuse it

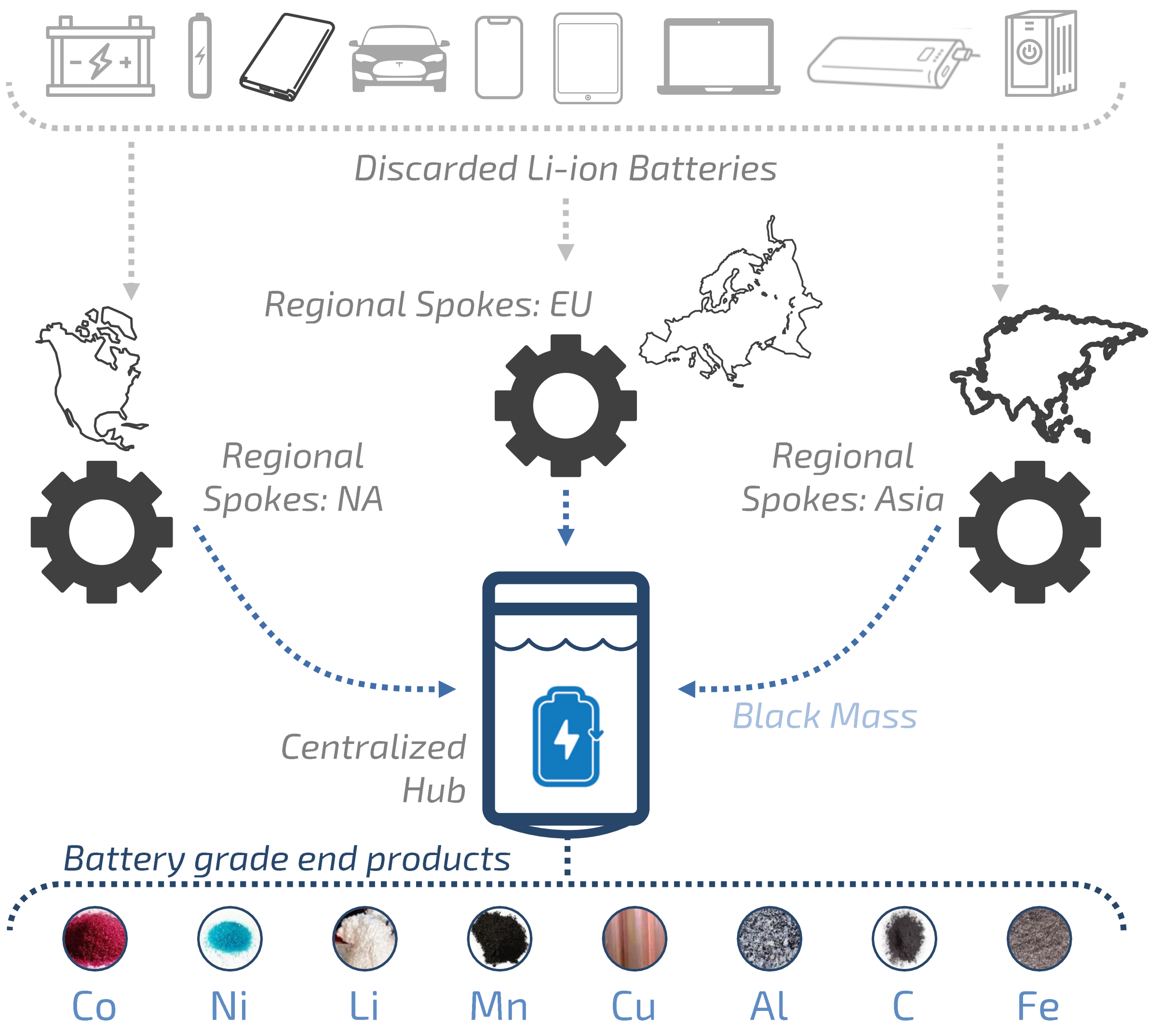
Costs circa $60/kWh to repurpose batteries. With new battery costs now <$100/kWh, the business case for reuse is rapidly eroding

## "Recycle" it

Current methods recover under 50% of raw battery materials, and only 30% of raw material costs

# PROVEN LI-CYCLE TECHNOLOGY

**Li-Cycle's patented Spoke and Hub technologies recover 95% of all li-ion battery materials**—extracting high-grade materials for battery production, at a cost competitive to mined and refined material



# TECHNOLOGY – KEY INNOVATIONS AND VALUE PROPOSITION

| Incumbent Recycling Technologies (i.e. pyrometallurgical processing/smelting) | | Li-Cycle Hub-and-Spoke Technologies |
|---|---|---|
| • High cost resource recovery<br>• Not tailored for Li-ion batteries; old, inherited technology | **COST** | • Lowest cost resource recovery<br>• 'Fit-for-purpose'/tailored for all types of li-ion batteries |
| • ≤50% recycling efficiency rate/recovery | **RECYCLING EFFICIENCY AND RECOVERY RATES** | • 80-100% recycling efficiency rate<br>• ≥95% functional material recovery |
| • Manual dismantling with a high risk of thermal runaway<br>• Discharging of batteries necessary before processing | **SAFETY** | • Safe and automated size reduction of Li-ion batteries<br>• Safely processes fully charged batteries |
| • Significant solid waste (slag)<br>• Effluent water<br>• Heavy metals in air emissions<br>• High energy consumption | **ENVIRONMENTAL IMPACT** | • No solid waste; all end-products return to the economy, with various pathways being developed (e.g. for plastics)<br>• Zero discharge facility<br>• Zero impact air emissions<br>• Low energy consumption |

# COMPETITIVE LANDSCAPE – RECYCLING TECHNOLOGIES

| | Li-Cycle Technology™ | Cathode-to-Cathode | Smelting or Thermal Pre-Treatment & Refining | Thermal or Mechanical Pre-Treatment only |
|---|---|---|---|---|
| **Technology Description** | **Mechanical & Hydrometallurgical** | Cathode Production | Pyrometallurgical & Hydrometallurgical | Pyrometallurgical, or Mechanical, or Other |
| **Technology Stage** | **Commercial** | Lab Scale, Pilot | Commercial | Commercial |
| **Input Material** | **Complete battery, charge and state agnostic** | Cathode only | Battery cells or modules, discharged or charge agnostic, chemistry specific | Predominantly battery cells only, must be discharged, chemistry specific |
| **Recovery Rate** | **95%** | 30% (cathode proportion only) | ≤ 50% | ≤ 50% |
| **Li-ion families covered** | **All, 14+** | Select, 5 | Select, 3 | Select, 3 |
| **'Future Proofed'** | **Yes** | No | No | No |

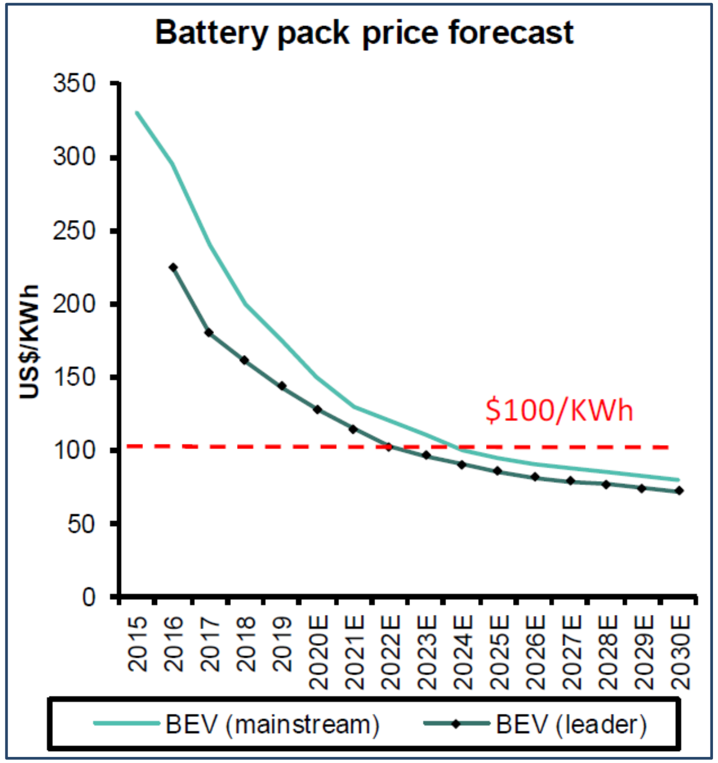
# QUALITATIVE ENVIRONMENTAL BENEFITS

Low environmental risk
Medium environmental risk
High environmental risk

| | Li-Cycle | Smelting/ Pyrometallurgy | Artisanal/Small-Scale Recycling | Landfilling |
|---|---|---|---|---|
| Process Description | Mechanical and 'wet chemistry'/ hydrometallurgical process | High temperature processing, typically >1,100°C | Manual dismantling. Typically coupled with partial disposal | Disposal in the open and/or in landfills. Possible combustion |
| Human health impact | **Low risk.** Safe and automated battery dismantling. All products are safe and saleable | **Medium risk.** Potential low safety standards in smelter | **Very high risk.** Toxic metal exposure and battery combustion | **Very high risk.** Battery combustion and/or explosion risk |
| Water impact – surface water, groundwater | **Low risk.** Water reused and recycled within the process | **Medium risk**. Effluent water streams could contain heavy metals | **Very high risk.** Toxic heavy metals leach into drinking water | **Very high risk.** Toxic heavy metals leach into drinking water |
| Air quality and climate impact | **Low risk**. Virtually no particulate matter (PM) and $CO_2$ emissions | **High risk.** Heavy metals in PM emissions, high level of $CO_2$ emissions | **Very high risk.** Heavy metals released as uncontrolled PM emissions | **Very high risk.** Heavy metals released as uncontrolled PM emissions |
| Soil and terrain impact | **Low risk.** No landfilled waste | **Medium risk.** Slag, waste streams are piled and/or landfilled | **Very high risk.** Heavy metals enter soil and contaminate plants | **Very high risk.** Heavy metals enter soil and contaminate plants |

# WHAT ABOUT THE REUSE OF LITHIUM-ION BATTERIES?

*Reuse was traditionally a stopgap measure when economic recycling solutions were previously unavailable. Moreover, as new lithium-ion battery prices continue to fall, there ceases to be an economic case for the reuse of old lithium-ion batteries*




SOURCE: Bernstein

**Considerations for second life applications of lithium-ion batteries:**

- Business case – reused versus a new lithium-ion battery?
- Issues with variability across lithium-ion battery packs and the need for a consistent 'building block' for the scalability of reuse
- Provenance and liability issues – who owns the issues with reused lithium-ion batteries if they arise?

Recycling and reuse will continue to co-exist . However, (i) economically viable recycling, and (ii) the need for secure supply of critical materials are driving a greater proportion of recycling now and into the future

# LI-CYCLE MILESTONES

✔ **Q4 2016:** Li-Cycle proof of concept
**Capacity:** 5 tonne/year

✔ **Q3 2017:** Mini-piloting complete in Canada
**Capacity:** 50 tonne/year

✔ **Q4 2018:** Spoke demo complete in Kingston, Ontario
**Capacity:** 50 tonne/year

✔ **Q3 2019:** First Commercial Spoke in Kingston, Ontario
**Capacity:** 2,500 tonne/year

✔ **Q4 2019:** Hub Demo complete in Kingston, Ontario
**Capacity:** 365 tonne/year

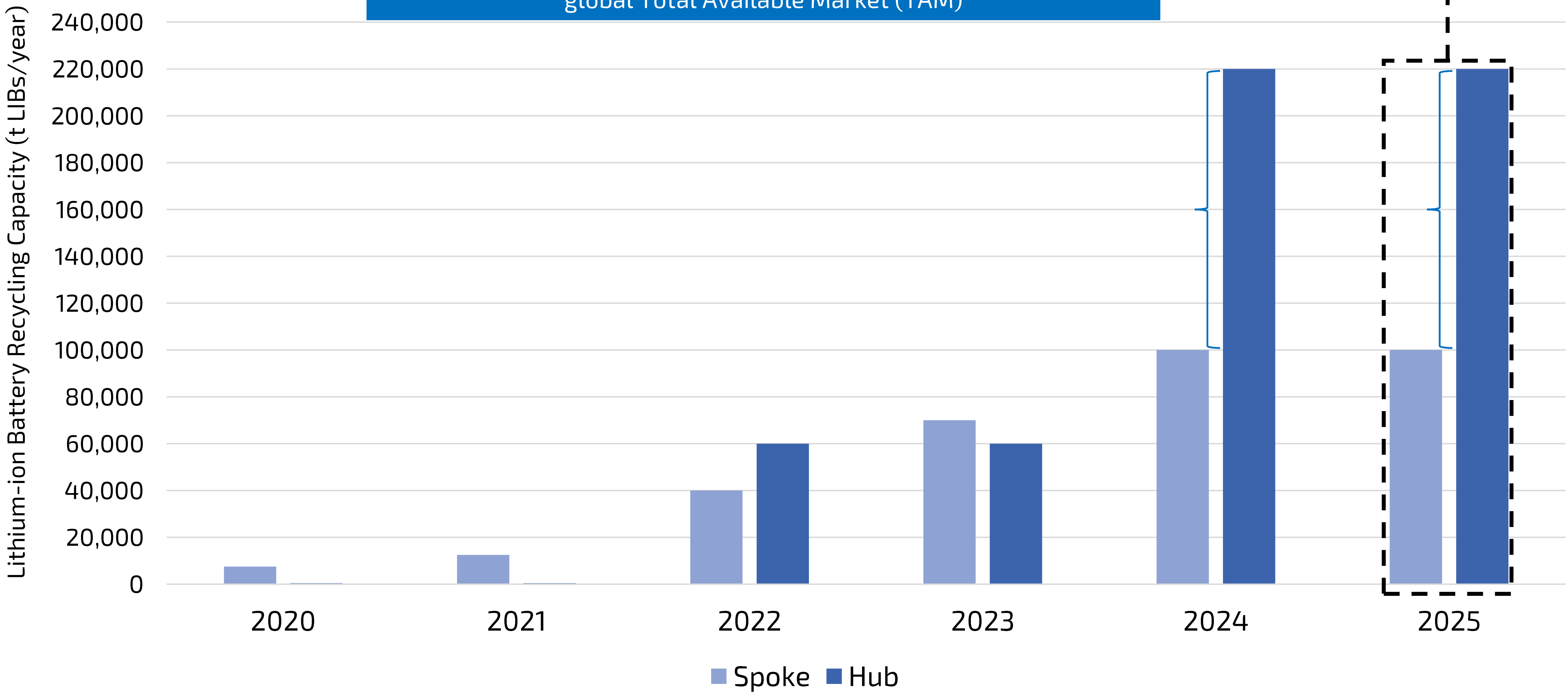
**Q3 2020:** Second Commercial Spoke established in Rochester, New York
**Capacity:** 5,000 tonne/year

**Q4 2021:** Third Commercial Spoke established in Nevada
**Capacity:** > 5,000 tonne/year

**Q4 2022:** First Commercial Hub established in North America
**Capacity:** 60,000 tonne/year

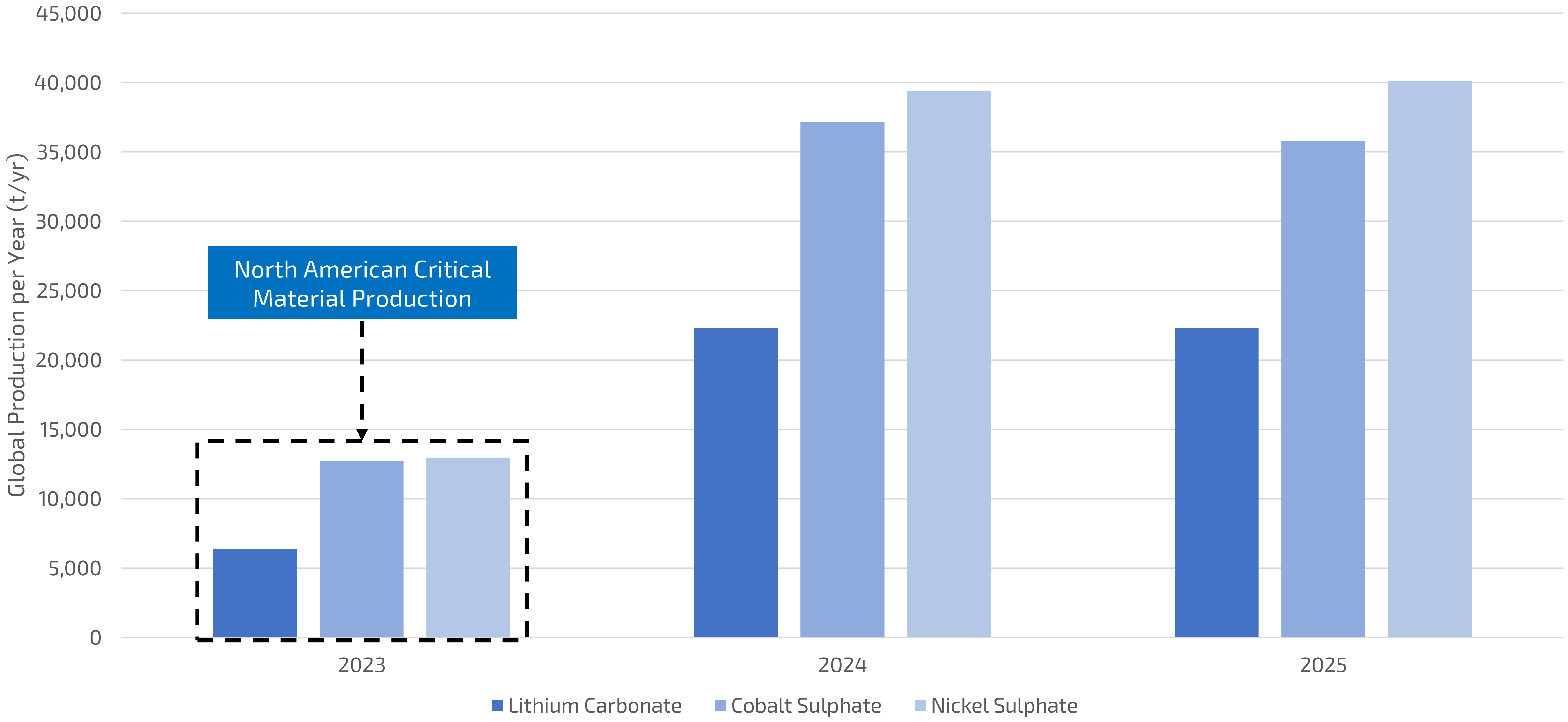
# LI-CYCLE GLOBAL ROLLOUT PLAN

Total resource recovery capacity in 2025 represents ~30% of the global Total Available Market (TAM)



# LI-CYCLE GLOBAL ROLLOUT PLAN – END-PRODUCT PRODUCTION





# PRESENTATION CONTENTS

# HOW TO SUPPORT LI-ION BATTERY RECYCLING IN CALIFORNIA

## EDUCATE

*“Unlike lead acid batteries, there is no practical way to recycle those made of lithium.” – PBS News Hour, July 8th, 2020*

### Problem to be Addressed:

**Ensure the right information is in the public to generate the battery supply for recycling**

## INCENTIVIZE

*Put in place incentives across the value chain from the battery consumer through to the battery producer*

### Problem to be Addressed:

**Increase collection, increase local production and encourage recycled material use in new products**

## LOCALIZE

*Attract critical pieces of the value chain to set up shop in California*

### Problems to be Addressed:

**Gap in critical resource and cathode production in North America. Permitting often a gating factor for site selection**


Li-Cycle®