FutuRaM

Future availability of secondary raw materials

An assessment of what the FutuRaM Project results mean for battery recyclers

Franziska Maisel, Max Tippner - TU Berlin

E-Waste World Conference Frankfurt – 17.06.2026

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

EU Framework Programmes

Funded by the European Union

TECHNISCHE UNIVERSITÄT BERLIN

Future Availability of Secondary Raw Materials

Goal: Urban Mine Platform – Knowledge database of secondary strategic and critical raw materials (CRM) within EU27+4

4 year project
June 2022 – May 2026

Consortium of 28 partners
from 11 countries

- Batteries
- Electrical and Electronic Equipment
- Vehicles
- Slags and Ashes
- Mining Waste
- Construction and Demolition Waste

www.futuram.eu

Modelling Approach for Batteries

Composition	Stock and Flow Model	Recycling and Recovery

Battery composition on component, material and element level

p - product
c - component
m - material
e - element

Market share of cathode chemistries

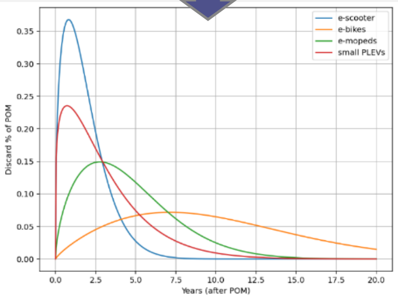
Battery stocks

Lifetime parameters for LMT applications

Modelled with a lifetime distribution (Weibull function)

Put-on-the-market batteries

EVs, LMT, Portable, Industrial, SLI



Batteries waste generated

Collected batteries

Unknown whereabouts (gap)

Other flows (exports & municipal waste)

Recycling rates of elements and transfer coefficients of recycling technologies

Recycling of batteries

Losses during battery recycling

Recovered quantities of secondary raw materials

Lithium, cobalt, nickel and copper

Material Flow Analysis for EU27+4 countries

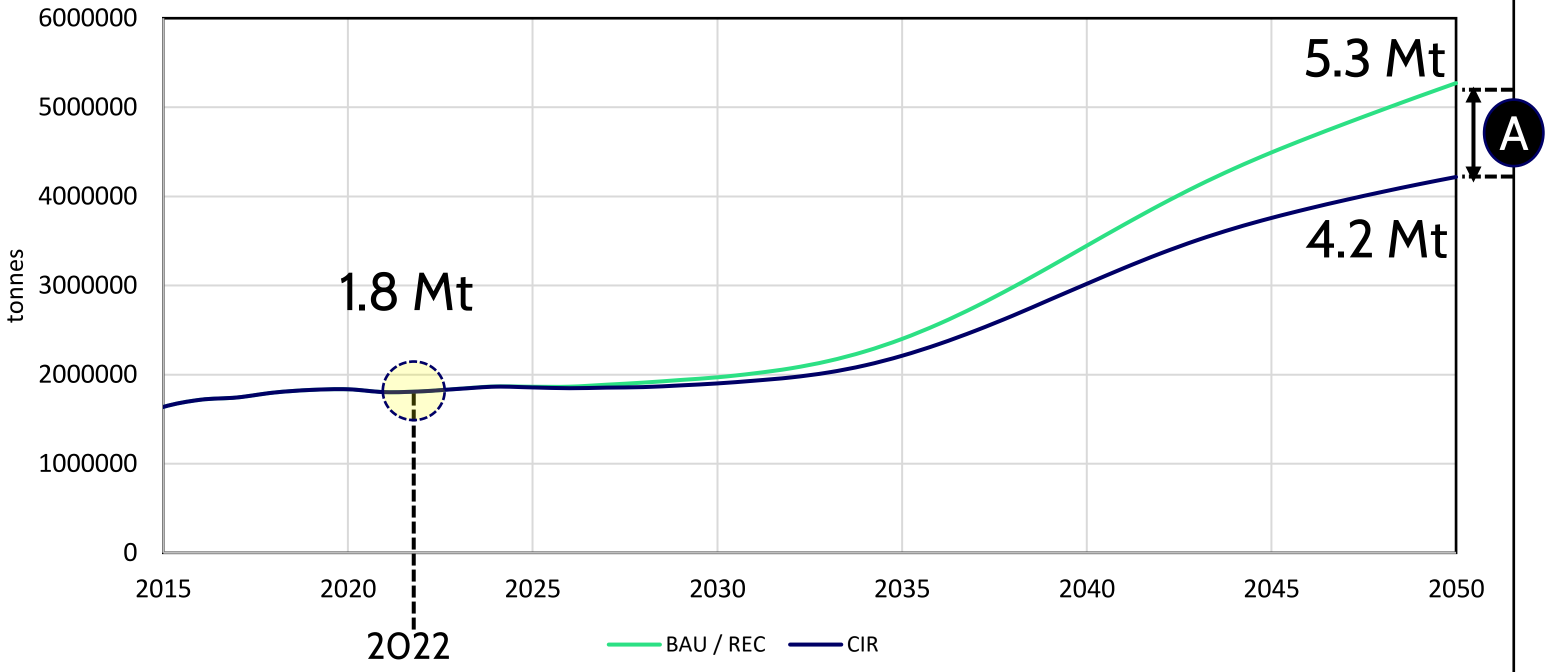
Scenario modelling from 2023 to 2050 within business-as-usual (BAU), recovery (REC) and circularity (CIR) scenario

Results – Battery Waste Generated (WG)

Waste generated

1.8 Mt/year in 2022

In 2022: 106 kt/year of CRMs
In 2050: 1.2 Mt/year
to 1.5 Mt/year of CRMs



A Roughly 20% of battery waste can be avoided through circular measures by 2050

- Increased 2nd-Life ratio of EV batteries
- Switch to smaller EVs
- Increased lifetime of batteries in use by 30% by 2050 for portable, industrial and LMT

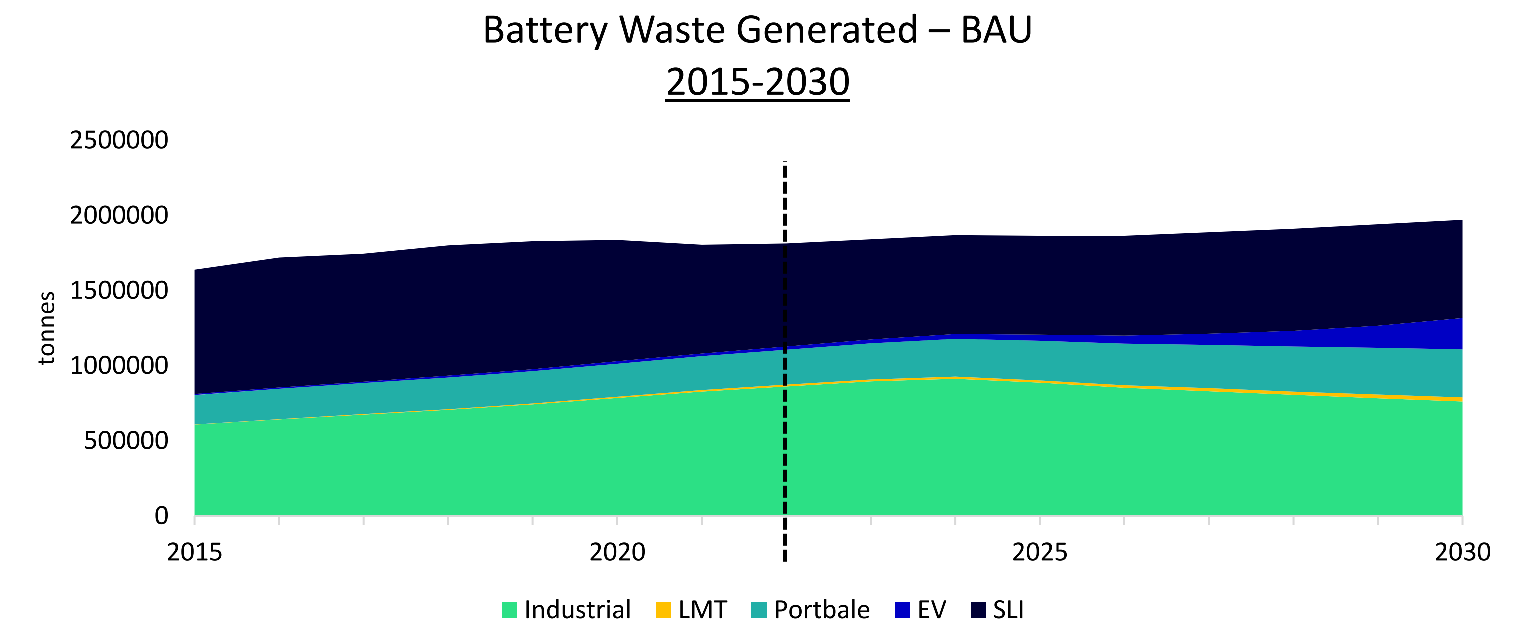
Results

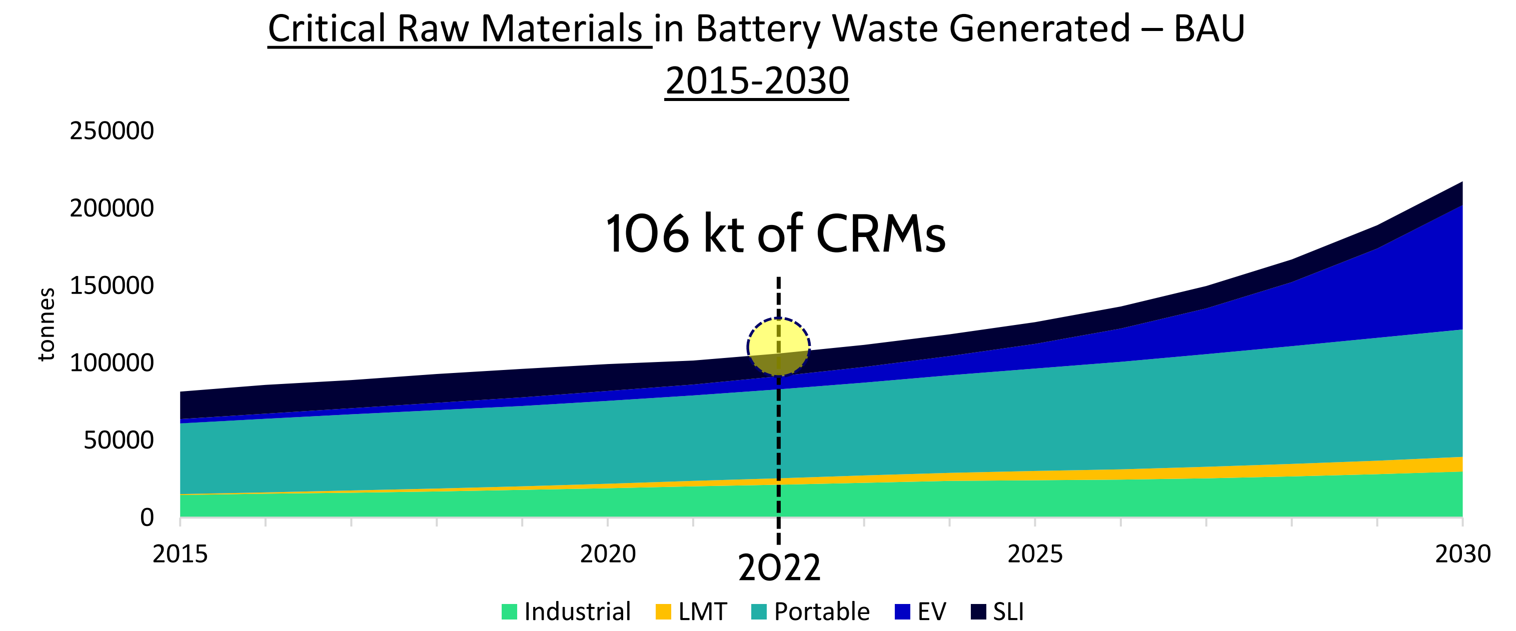
Waste generated

1.8 Mt/year in 2022

In 2022: 106 kt/year of CRMs
In 2050: 1.2 Mt/year
to 1.5 Mt/year of CRMs

Most CRMs can be found in portable batteries by 2022





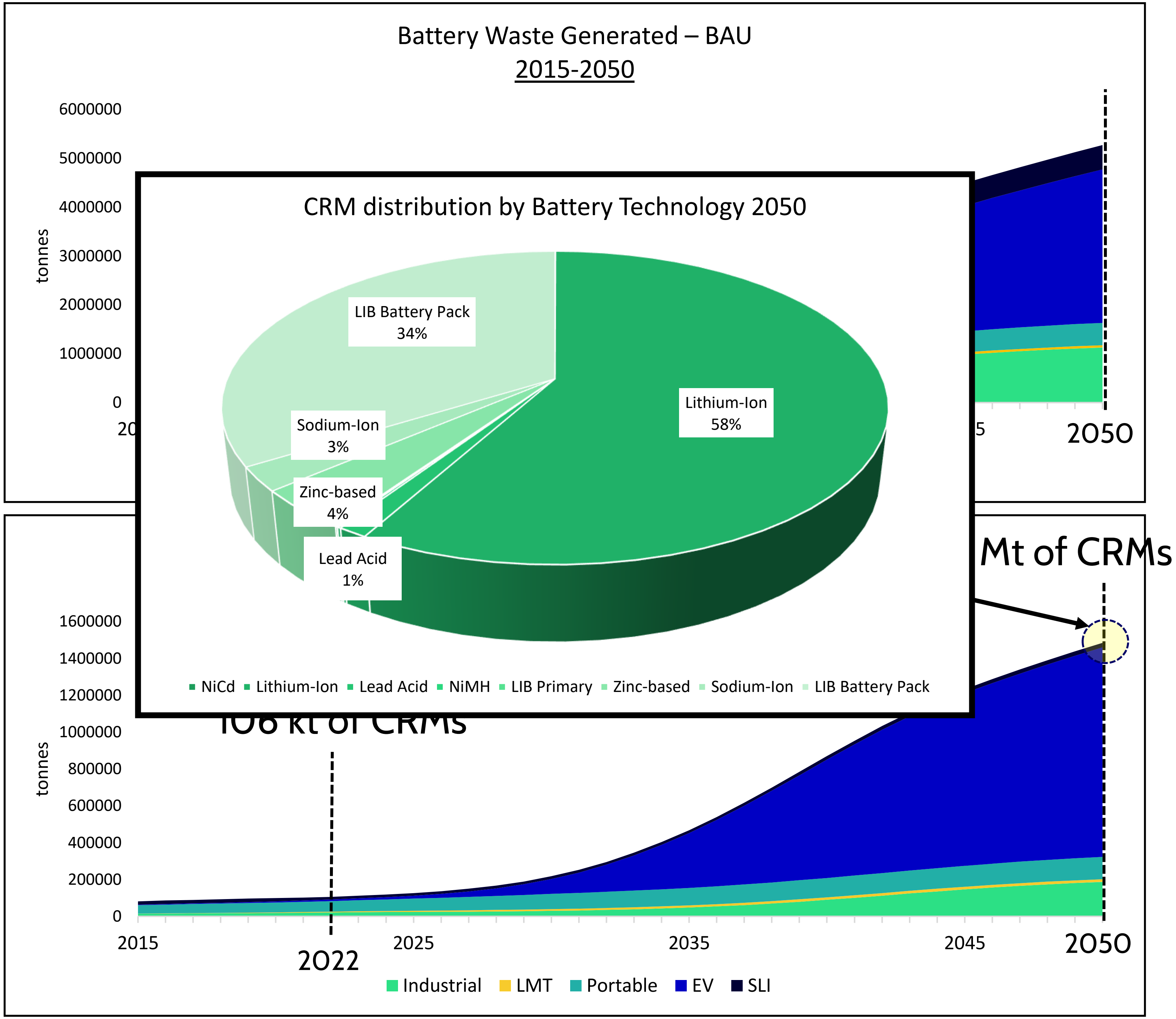
Results

Waste generated

1.8 Mt/year in 2022

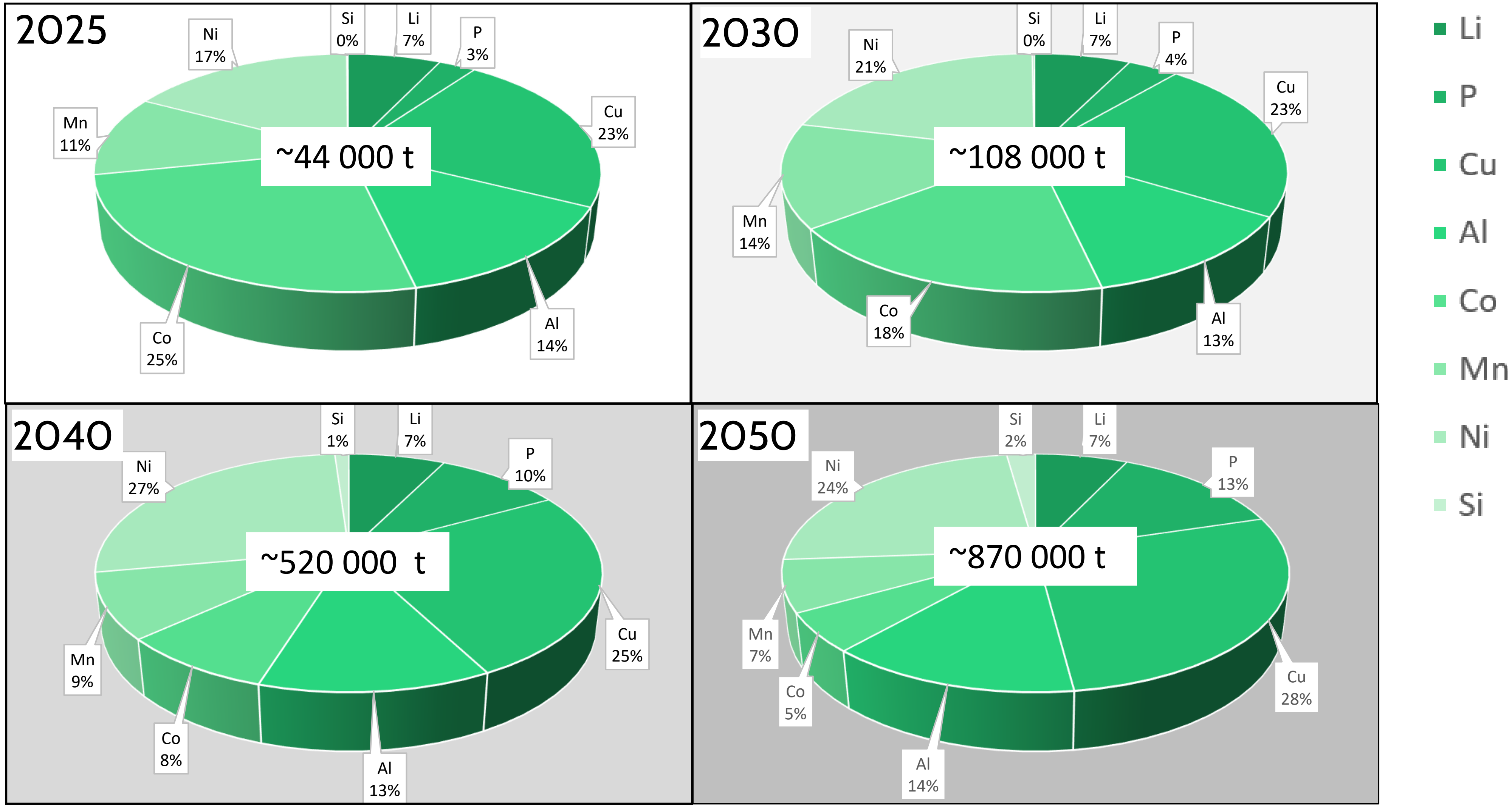
In 2022: 106 kt/year of CRMs
In 2050: 1.2 Mt/year- CIR
BAU - to 1.5 Mt/year of CRMs

Most CRMs will be embedded in EV batteries (including pack) by 2050 by far



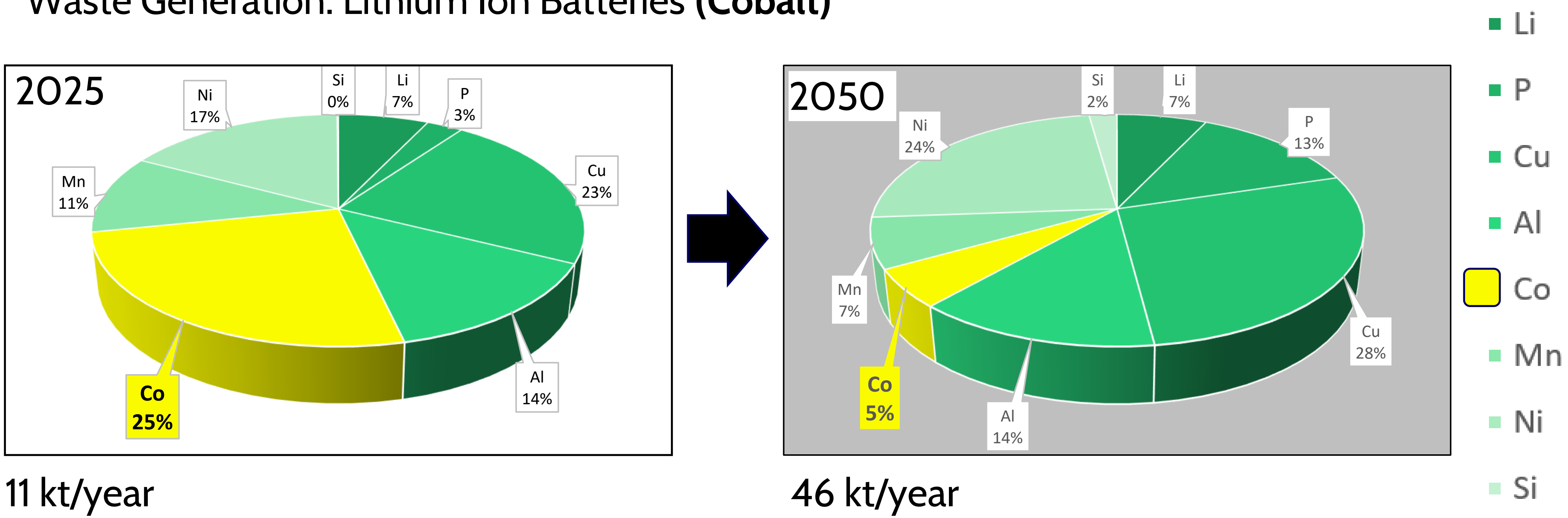
Results – Evolution of CRM distribution in LIB Cells

Waste Generation: Lithium Ion Batteries



Results – Evolution of CRM distribution in LIB Cells

Waste Generation: Lithium Ion Batteries **(Cobalt)**



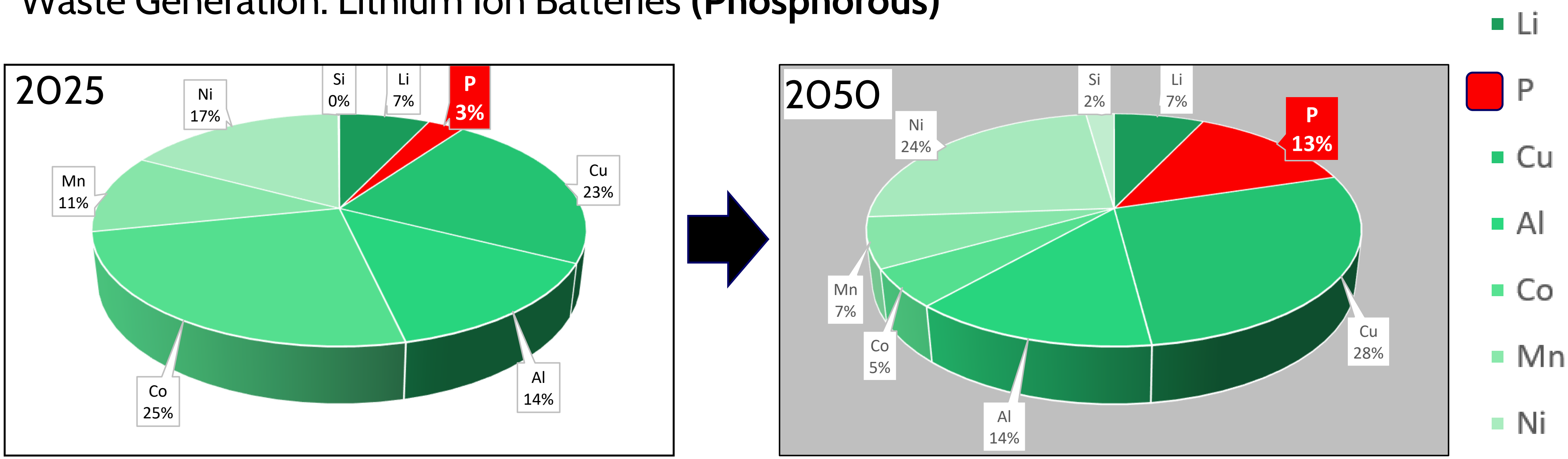
11 kt/year

46 kt/year

- In 2025: A lot of LCO portable batteries & high cobalt containing NMC become waste
- In later years, EVs dominate waste batteries in mass
  - High-nickel cathode chemistries
  - LFP batteries further displaces cobalt containing batteries

Results – Evolution of CRM distribution in LIB Cells

Waste Generation: Lithium Ion Batteries **(Phosphorous)**



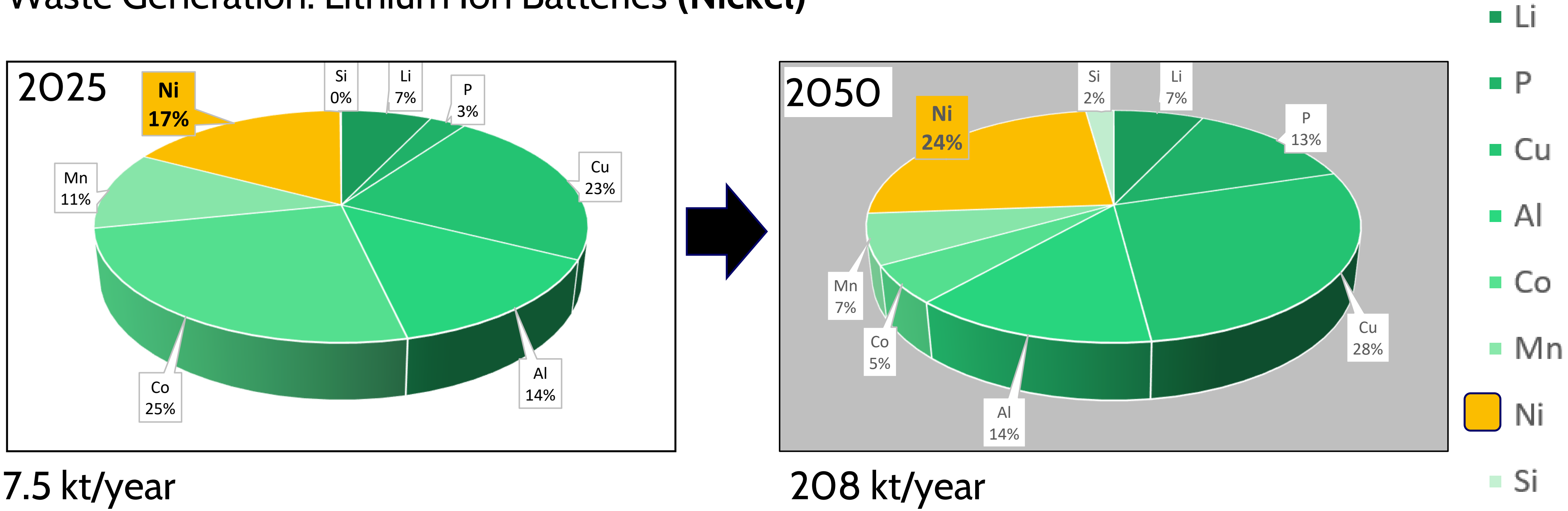
1.2 kt/year

115 kt/year

- LFP waste batteries still very limited
- LFP EV market shares currently already increasing
- Rapid employment of LFP Energy Storage Systems (ESS)

Results – Evolution of CRM distribution in LIB Cells

Waste Generation: Lithium Ion Batteries **(Nickel)**



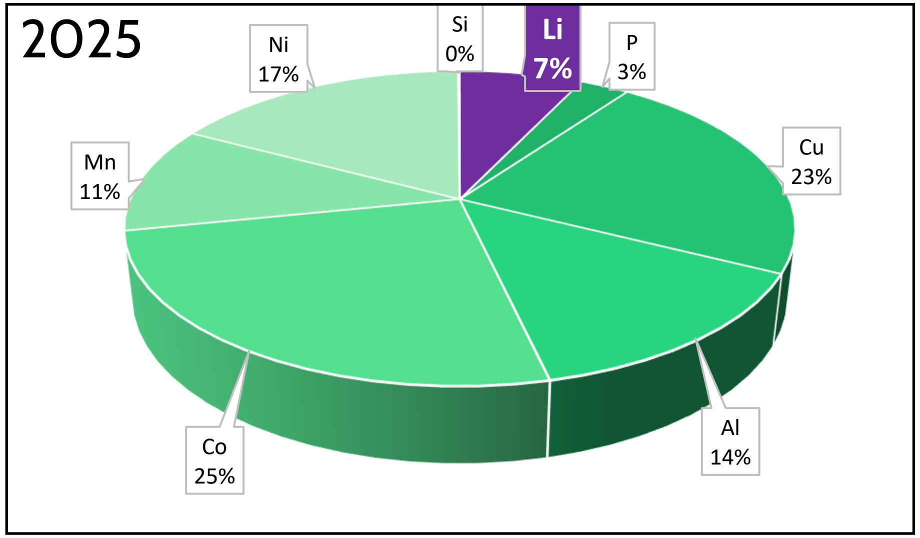
7.5 kt/year

208 kt/year

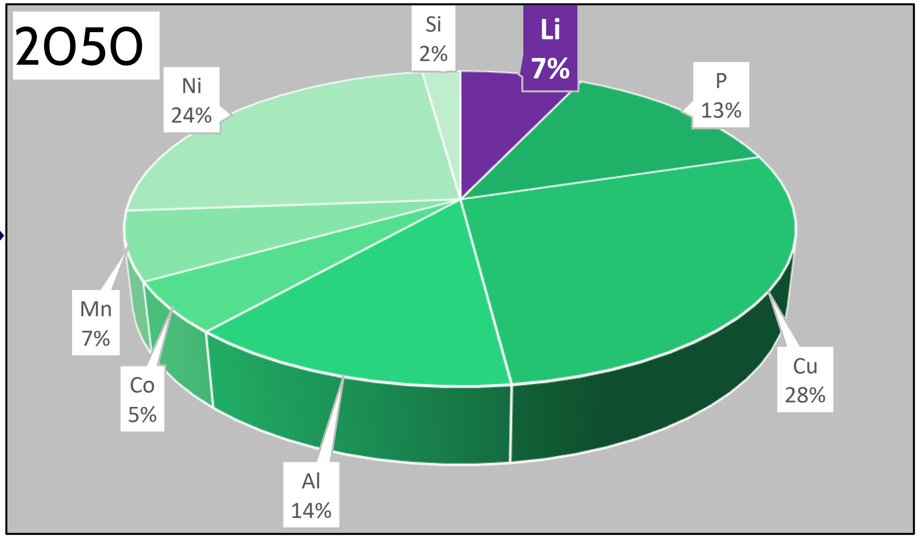
- High-nickel cathode chemistries in EVs
- The effect of high-nickel cathode employment being damped by partial displacement of LFP

Results – Evolution of CRM distribution in LIB Cells

Waste Generation: Lithium Ion Batteries **(Lithium)**



3 kt/year



61 kt/year

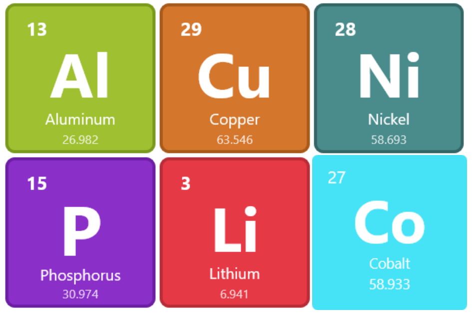
- Lithium remains stable over the years albeit small variations in different cathode chemistries

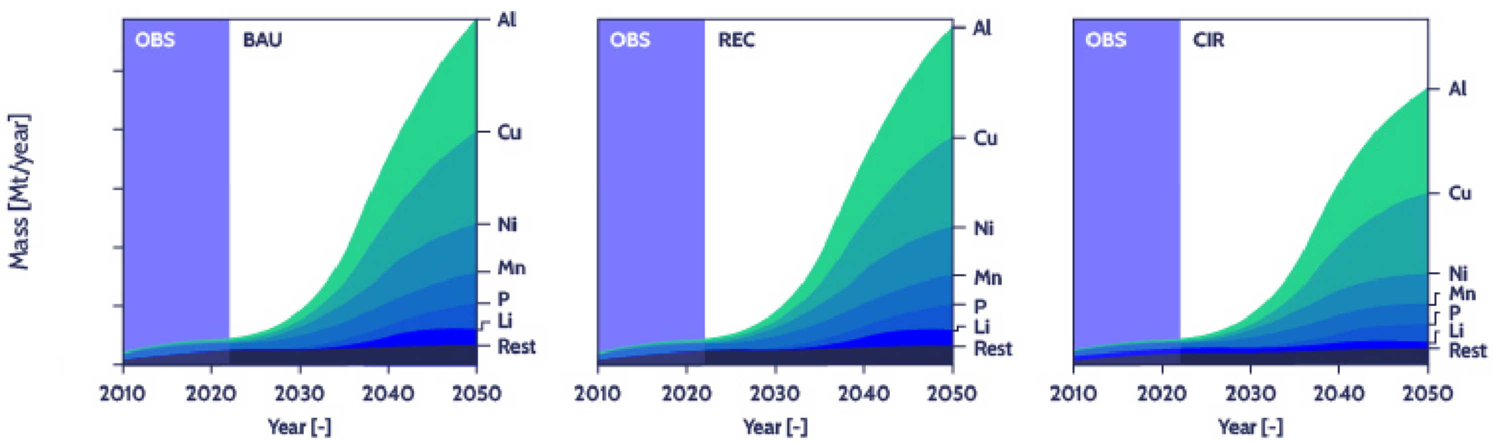
Results – Waste Generated – All Batteries

Waste generated

1.8 Mt/year in 2022

In 2022: 106 kt/year of CRMs
In 2050: 1.2 Mt/year
to 1.5 Mt/year of CRMs

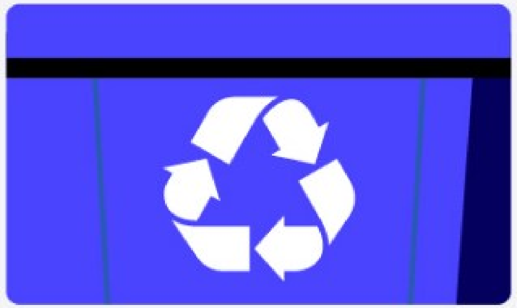




Estimated total amount of CRMs embedded in Waste Generated

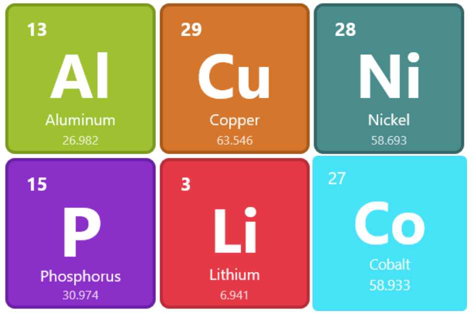
Material	2022	2050
Aluminium:	6 kt/year	450-480 kt/year
Copper:	7 kt/year	346-386 kt/year
Nickel:	10 kt/year	123-213 kt/year
Phosphorous:	0.6 kt/year	78-118 kt/year
Lithium:	2.2 kt/year	38-61 kt/year
Cobalt:	8.2 kt/year	30-48 kt/year

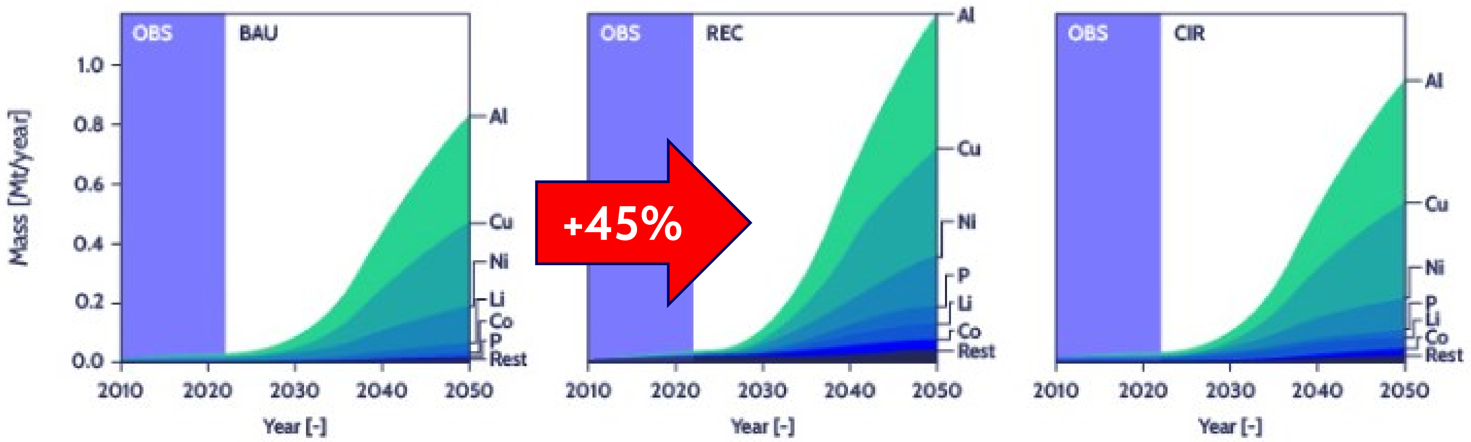
Results – CRM Recovered – All Batteries



1.2 Mt/year in 2022
(67% of waste generated)

In 2022: 37 kt/year of CRMs
In 2050: 827 kt/year
to 1.2 Mt/year of CRMs





Estimated total amount of CRMs recovered

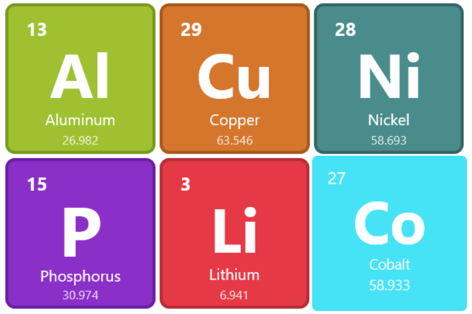
Material	2022	2050
Aluminium:	3.4 kt/year (57%)	360-420 kt/year
Copper:	3.9 kt/year (56%)	290-360 kt/year
Nickel:	4.3 kt/year (43%)	105-170 kt/year
Phosphorous:	0.2 t/year (~0%)	30-50 kt/year
Lithium:	90 t/year (~4%)	32-56 kt/year
Cobalt:	0.9 kt/year (~10%)	23-37 kt/year

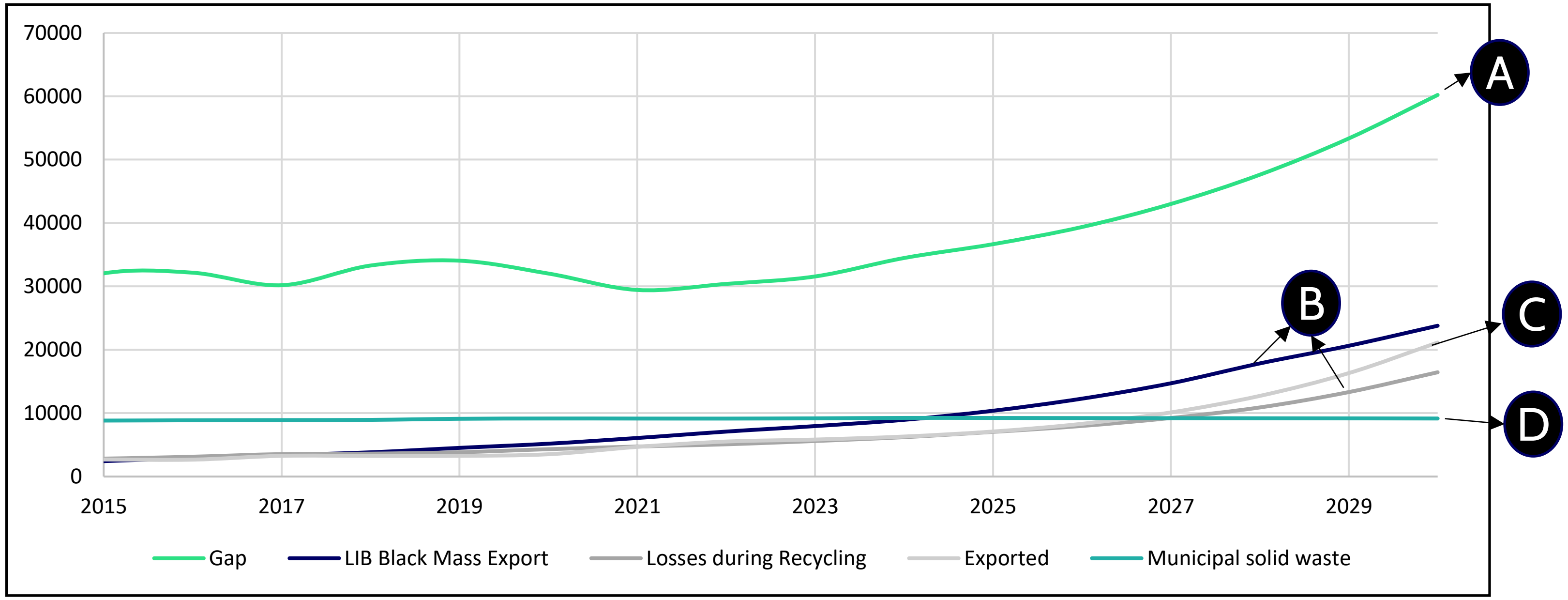
Results – Critical Raw Materials lost

Not recovered as secondary raw materials

0.6 Mt/year in 2022
(33% of waste generated)

In 2022: 69 kt/year of CRMs
In 2050: 223 kt/year
to 640 kt/year of CRMs





- A – Main cause of CRM losses due to „unkown whereabouts“ (Gap)
- B – LIB black mass CRM exports are currently higher than all losses from all battery types combined during recycling processes
- C – Losses through used EV exports expected to rise
- D – Losses wrongfully discarded in municipal solid waste

Higher recovery and better tracking can close CRM gaps

Higher Recovery

- Vast potential in CRM recovery
- Greatest losses of CRMs currently are through „unknown whereabouts“ (gap)
- Reduce black mass exports
- Increase recovery through technological innovation
- Expand recovery for P and Mn

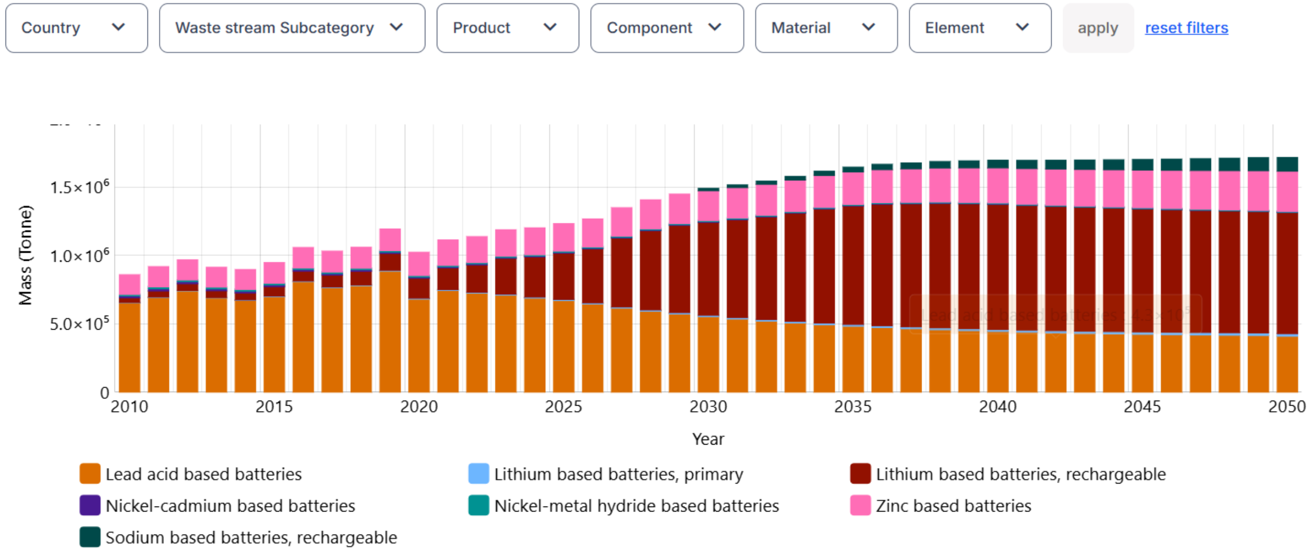
Better Tracking

- Improved tracking of CRMs to further improve targeted policies
- New reporting under (EU) 2025/2289 good step forward
- Battery Passport (introduction 2027)

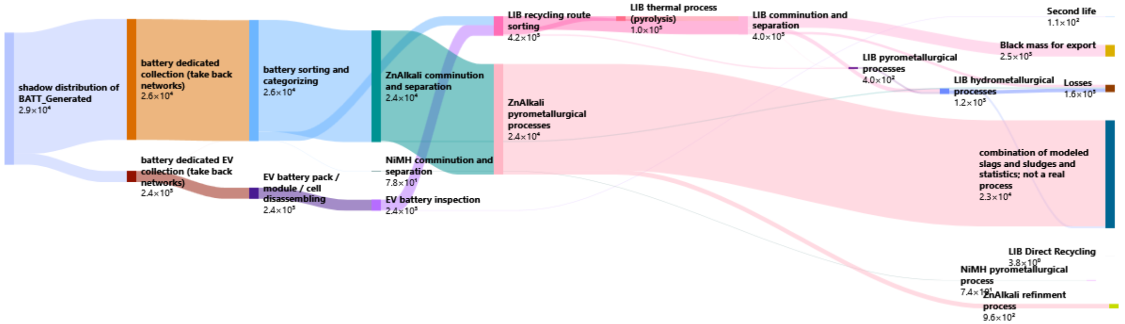
UMP Urban Mine Platform

Your gateway to data on secondary & critical raw materials in Europe

Stocks and flows of batteries



Recovery of elements and materials



SCAN ME

https://www.urbanmineplatform.eu/

Thank you for your attention!

Franziska Maisel

Scientific Researcher

Department of Environmental Engineering

Technische Universität Berlin (TUB)

franziska.maisel@izm.fraunhofer.de

Max Tippner

Scientific Researcher

Department of Environmental Engineering

Technische Universität Berlin (TUB)

max.tippner@izm.fraunhofer.de

Links

- UMP https://www.urbanmineplatform.eu/
- D4.1 (Future Trends of 2RM) https://zenodo.org/records/17579480
- D4.1 Suppl. Information https://zenodo.org/records/17897477
- Composition https://zenodo.org/records/18503230
- Stock and Flow Data https://zenodo.org/records/20487485
- Recovery Model Data https://zenodo.org/records/20487485
- Transfer Coefficients https://zenodo.org/records/18299510

Battery Scenarios

BAU

Management of end-of-life batteries remains largely unchanged. The lack of technological innovation and regulatory incentives leads to a continued low recovery rate of valuable materials from battery waste.

REC

End-of-life batteries become a crucial source of secondary raw materials, primarily due to the increased adoption of electric vehicles and renewable energy storage systems. Technological innovation drives the recovery and recycling process, ensuring valuable materials are extracted from waste batteries for reuse.

CIR

Battery waste treatment undergoes a massive transformation. The shift towards electric vehicles and renewable energy storage significantly increases the quantity of end-of-life batteries. However, thanks to new regulations, technological advancements, and business models, the majority of battery components are recycled or reused.

References of the battery flows

	Portable batteries	Industrial batteries	LMT batteries
POM	Avicenne, Eurostat	Avicenne	JRC*
BATTERY TYPES / BATTERY CHEMISTRY	Given in BATT Keys by Avicenne	Given in BATT Keys by Avicenne	Estimation of chemistry market shares
LIFETIME	ProSUM (Möbius study)	ProSUM (RECHARGE)	JRC*
COLLECTED BATTERIES	Collection schemes	90% collection rate	GRS, Collection rates
COMPLEMENTARY WASTE FLOWS	German Environmental Agency (Waste bin) Unitar (Exported)		

**JRC Report Available for collection, 2023*

Transfer Coefficients of Battery Recycling

LIB Batteries

Thermal Process (Pyrolysis)

- Electrolyte 0% — Organic solvent
- Casing 0% — Plastics
- Separator 0% — Plastics
- Binder 0% — Plastics

Rest of the whole battery: Al and steel casing, current collectors, cathode and anode active material

Mechanical Processes (Shredding, Separation)

- AlAndAlAlloys 93,78%, Ferrous metals 93,78%, Fe 93,78% — Casing
- Al 83,71% — CC Cathode
- Cu 89,64% 90% 90% — CC Anode

BLACK MASS

S 85,25%	Fe 85,25%	Li 85,25%
Al 85,25%	O 85,25%	Mn 85,25%
Cl 85,25%	P 85,25%	Ni 85,25%
Graphite 85,25%		Co 85,25%

90%
95%

Chemical Recovery Process (Hydrometallurgy)

Graphite	Co	Li	Ni	Mn
0%	79,42%	92,00%	91,22%	93,00%
23%	90%	92%	99%	93%
48%	98%	92%	99%	93%

2025
2032
2050
CC = Current Collector