Management of used electric vehicle batteries in Africa

Considerations on technical, organisational and economic aspects

Andreas Manhart & Fred Adjei | Nairobi, 25.04.2024

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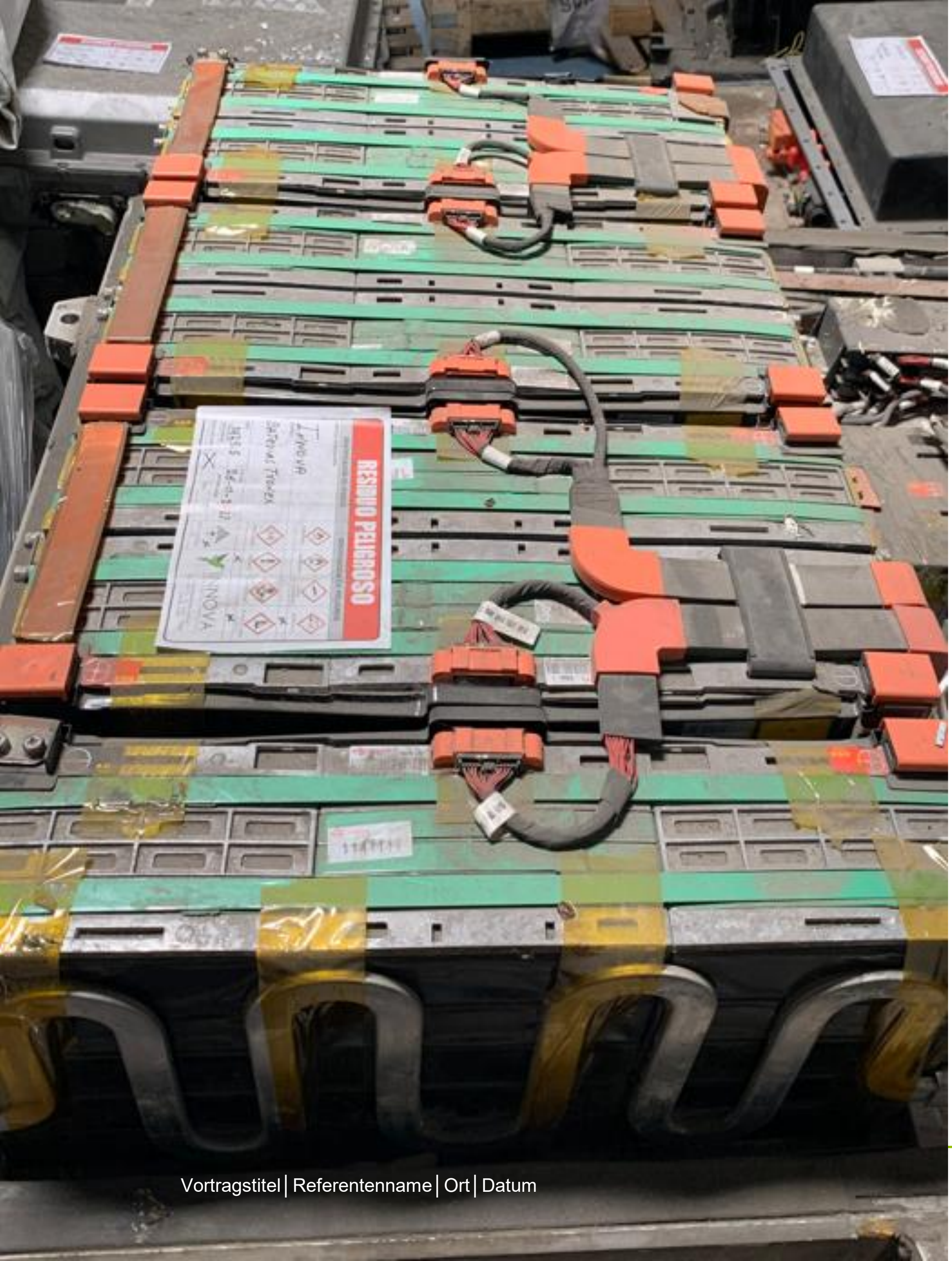

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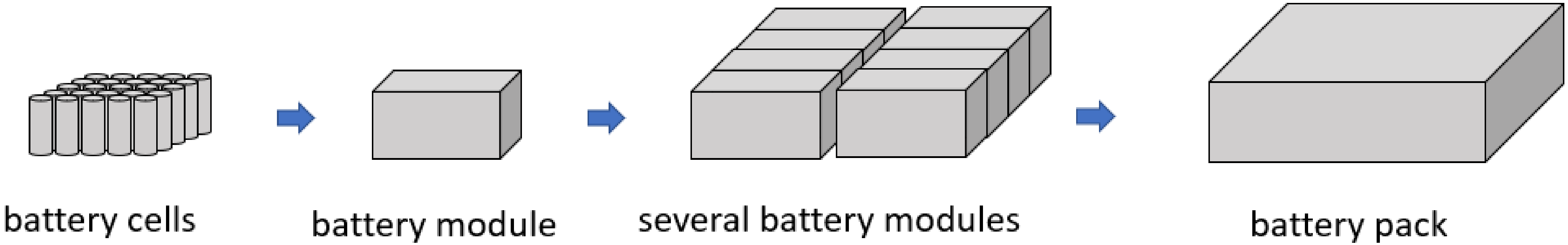
Agenda

1) Some battery basics
2) The economy of Li-ion battery recycling
3) Battery testing & reuse
4) Li-ion battery recycling
5) Will EPR be the solution?
6) Summary

Picture: Oeko-Institut

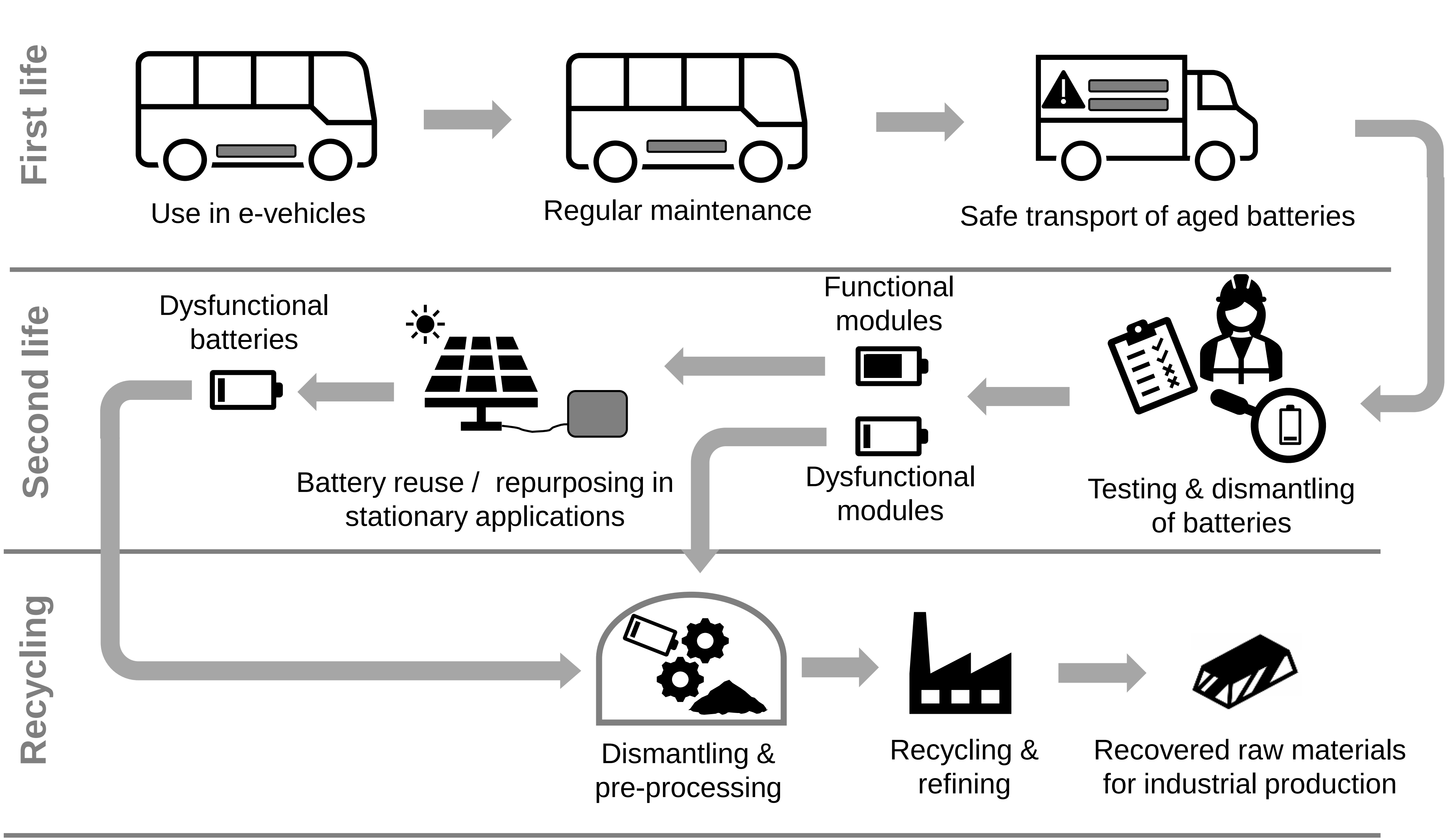
Battery cells, modules & packs

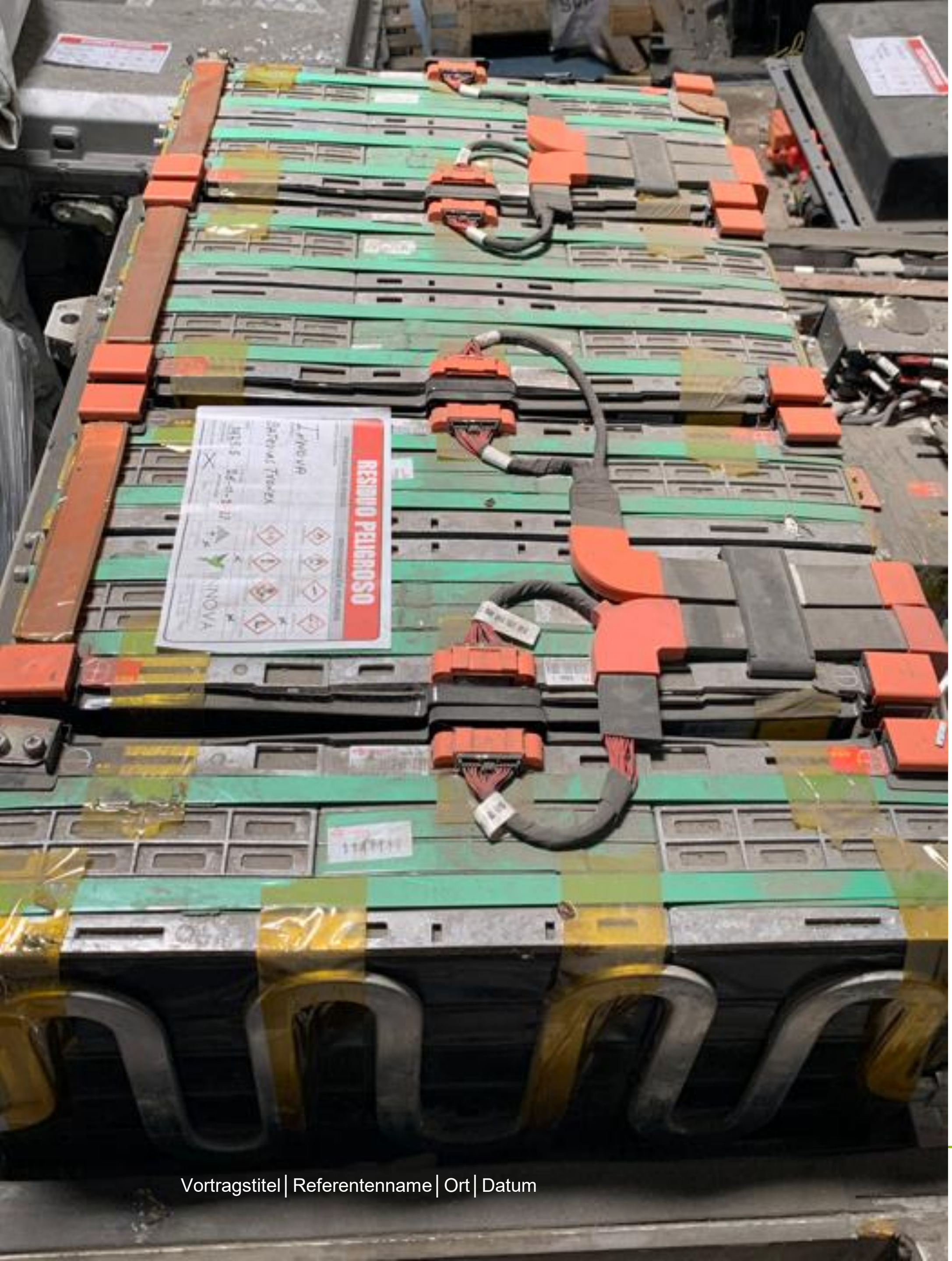


End-of-life challenges of e-vehicle batteries

1. **Electrical shocks:** Battery repairs and dismantling are high voltage operations.
2. **Hazardous substances:** All types of Li-ion batteries contain various constituents that can have considerable negative impacts on human health and the environment if not managed properly.
3. **Embedded raw materials:** Li-ion batteries contain raw materials that are considered as critical for economic development and expansion of green-energy technologies (lithium, graphite, cobalt, nickel…).
4. **Fire risks:** Batteries with residual charge may overheat, catch fire and even explode after damages (‘thermal runaway’). This may occur days or weeks after a damage happened.

Ideal management pathway of vehicle batteries





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Economics of battery recycling

Indicative material composition of a NMC electric vehicle battery

Element	Content	Application
Aluminium	25.2 %	Cell & module case, cathode current collector
Graphite	12.5 %	Anode active material
Co, Mn, Ni	13.6 %	Cathode active material with Co (2.7%), Mn (2.7%), and Ni (8.2%)
Copper	14.0 %	Cables, anode current collector
Lithium	1.5 %	Cathode active material, conductive salt
…	…	Plastic, organic substances…

Source: Brückner et al. (2020): Industrial Recycling of Lithium-Ion Batteries – A Critical Review of Metallurgic Process Routes.

- A broad variety of sizes, designs and sub-chemistries
- No clearly dominating material
- The name giving Lithium is only contained in small traces
- Recyclers focus on recovering Cobalt, Nickel & Copper

Economics of Li-ion battery recycling

Main types of Li-ion battery chemistries used in electric vehicles

	NMC (Lithium nickel manganese cobalt oxide)	**LFP (Lithium iron phosphate)**
Energy density	150-260 Wh/kg	90-180 Wh/kg
Cathode materials	Li, Ni, Mn, Co	Li, Fe, P
Copper content	~ 7 %	~ 7-8 %
Cobalt content	~ 6 %	0 %
Nickel content	~ 4 %	0 %
Trends	Used in demanding applications (high required mileage)	Rapidly growing market shares (~5% in 2019, ~40% in 2022)
Indicative recycling costs (gate fees)	~ 0 - 1650 €/t + additional charges for larger batteries (~ 500 €/t)	~ 1000 - 2000 €/t + additional charges for larger batteries (~ 500 €/t)

Sources: Weyhe & Yang (Accurec); Battery University 2021, Wunderlich-Pfeifer 2022, electrive.net 2022

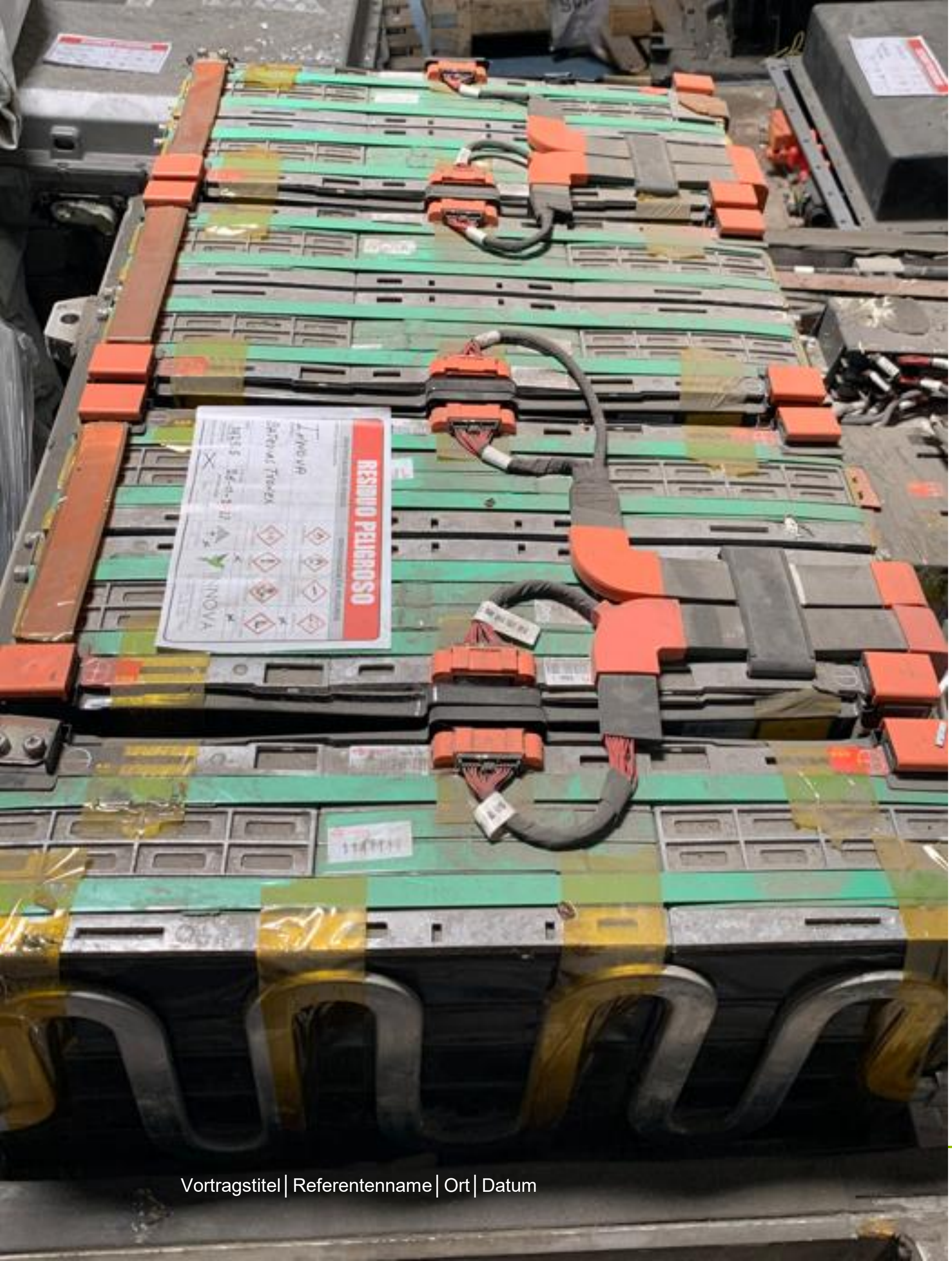
Economics of Li-ion battery recycling

Interim conclusion:

Sound end-of-life management of e-vehicle batteries may be associated with **net costs**!

But:

Some types of management are likely profitable (although partly sub-standard)



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Battery reuse

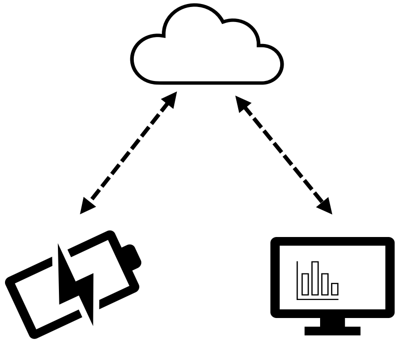
Battery reuse is a significantly higher economic potential than recycling (preservation of value)

Battery diagnostics is key to identify functional / dysfunctional models and cells and the assess the second (& third) life potential.

Two types of battery testing methods:

1. Physical testing through dismantling, charging, discharging → measurements of these charging cycles.

2. Using the sensor data that are installed in electric vehicle batteries → significantly less time intensive, may also done remotely, but requires (reading) access to the Battery Management System (BMS)



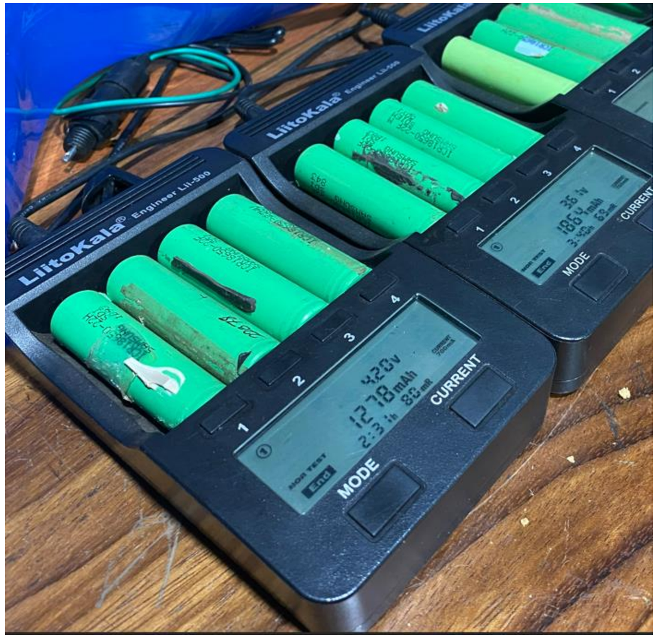
Relevant battery diagnostic data

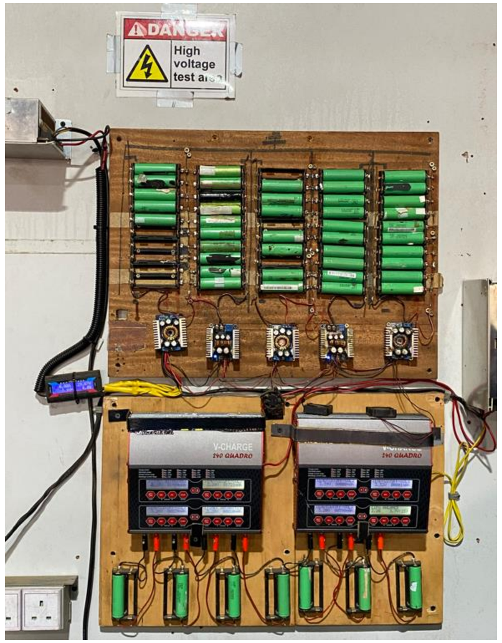
Signal	Unit	Value resolution	Time resolution
Battery current over time	A	0.1 A	≤ 1 sec
Battery voltage over time	V	0.1 V	≤ 1 sec
Cell temperature (avg/min/max) over time	°C	0.1°C	≤ 10 sec
Cell voltage (avg/min/max) over time	V	0.001 V	≤ 1 sec
Battery state of charge (SoC) over time	%	0.1 %	≤ 10 sec
Accumulated charge throughput	As	0.1 As	≤ 60 sec

To be continuously sampled, time-synchronous, provided through a standard output interface, in a digital format compatible with publicly available software.

Battery reuse already practiced in Africa

There are already Li-ion battery reuse activities in most countries:



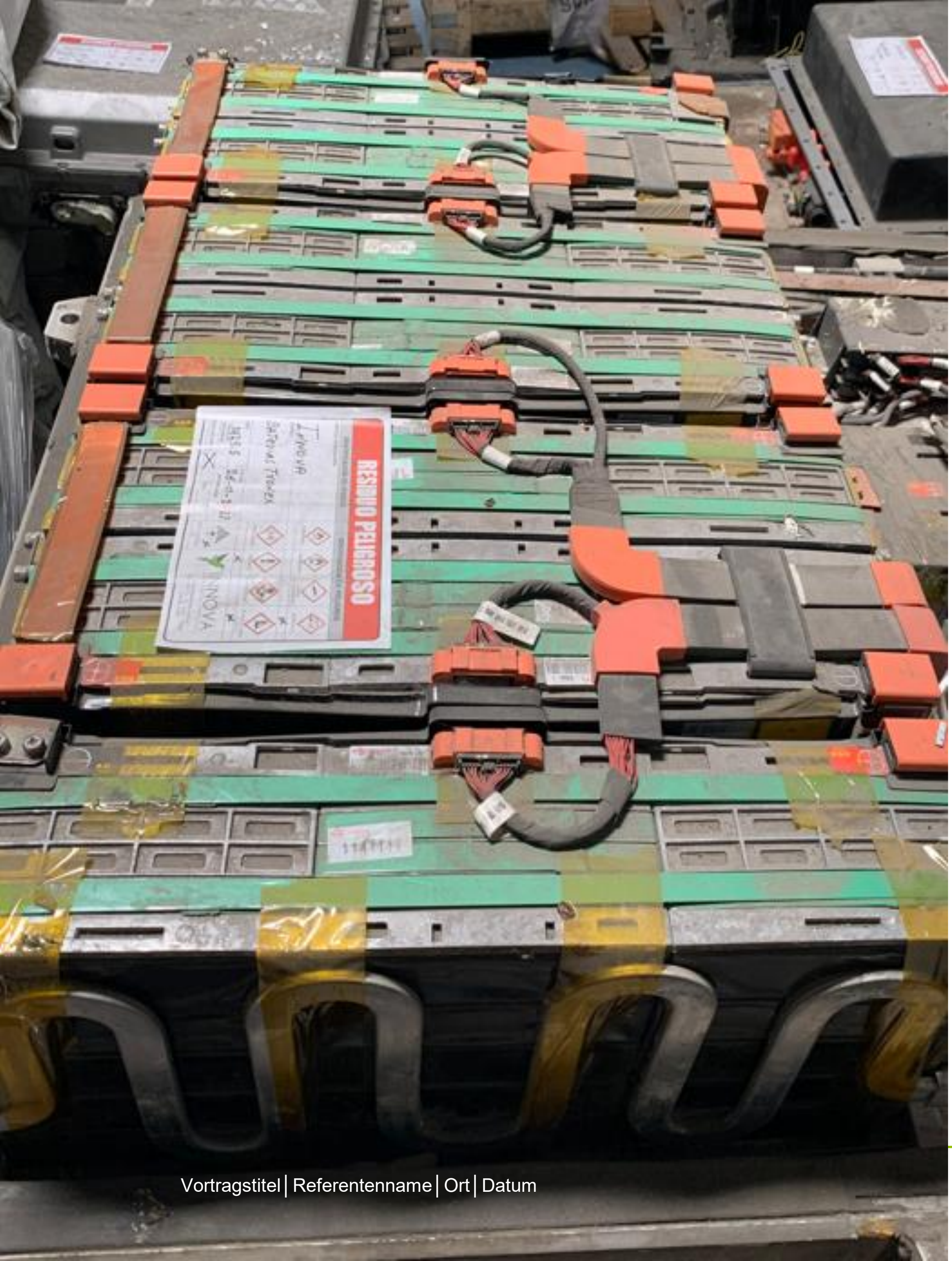


Testing of cylindrical cells for reuse
(not from electric vehicles)

Battery from reused cells (sub-standard → unsafe products)

Rechargeable lanterns with second life battery cells

Pictures: Oeko-Institut



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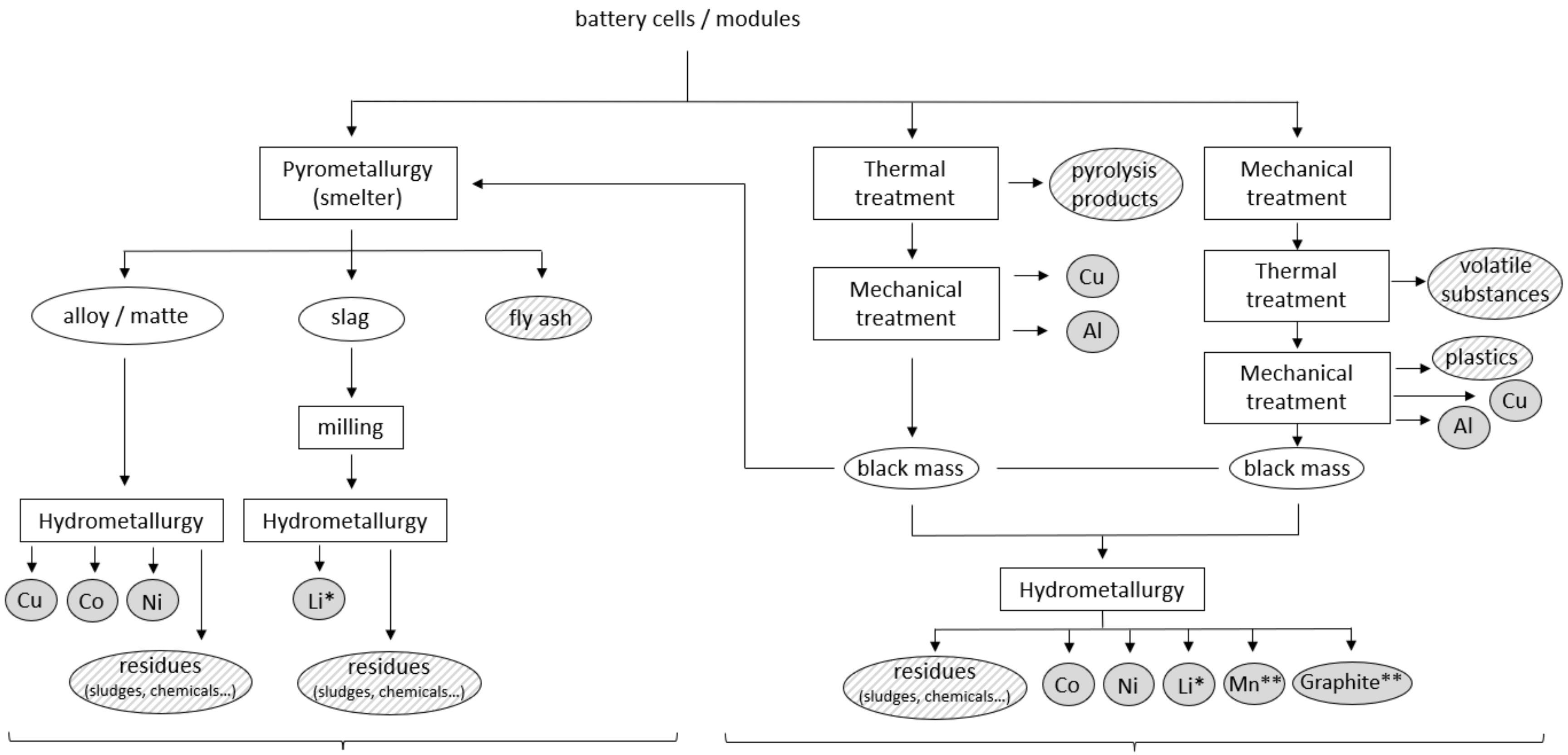
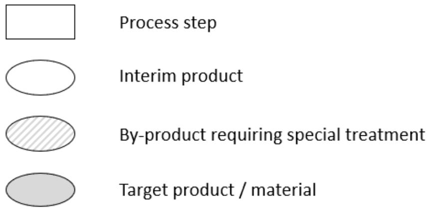


Pyrometallurgy with subsequent hydrometallurgical treatment

Mechanical processing with subsequent metallurgical treatment of black mass



* Recovery challenging (technically and/or economically)
** Not yet recovered on an industrial scale

Pyrometallurgy

Battery cells & modules smelted in a furnace

Off-gas treatment to remove dust, fume and acidic emissions

Smelter output: Copper alloy with trace elements (cobalt, nickel…) → hydrometallurgical treatment

Mechanical treatment

- Battery cells or modules are shredded and copper, aluminium, plastics and black mass separated
- Process requires due care and is difficult to be conducted in a controlled and safe manner:
  - Fires & explosions during shredding are common (not all cells can be fully discharged before shredding)
  - Li-ion batteries contain substances that are highly corrosive. High wear and tear of shredding equipment.
  - The electrolyte and binders must be removed. Otherwise, the generated black mass is chemically still active and prone to accidents during shipment (bursting of drums…)
  - Embedded chemicals and elements partly hazardous (process must be well contained to protect workers and neighbouring communities)

Black mass output destined for shipment & further treatment to recover cobalt and nickel

Open question: what about black mass for LFP batteries that do not contain nickel and cobalt?

Li-ion battery recycling already practiced in Africa

Export of Li-ion batteries for recycling

(costly, requires notification according to Basel Convention procedures)

Copper foils and black mass from manual (!) Li-ion battery dismantling

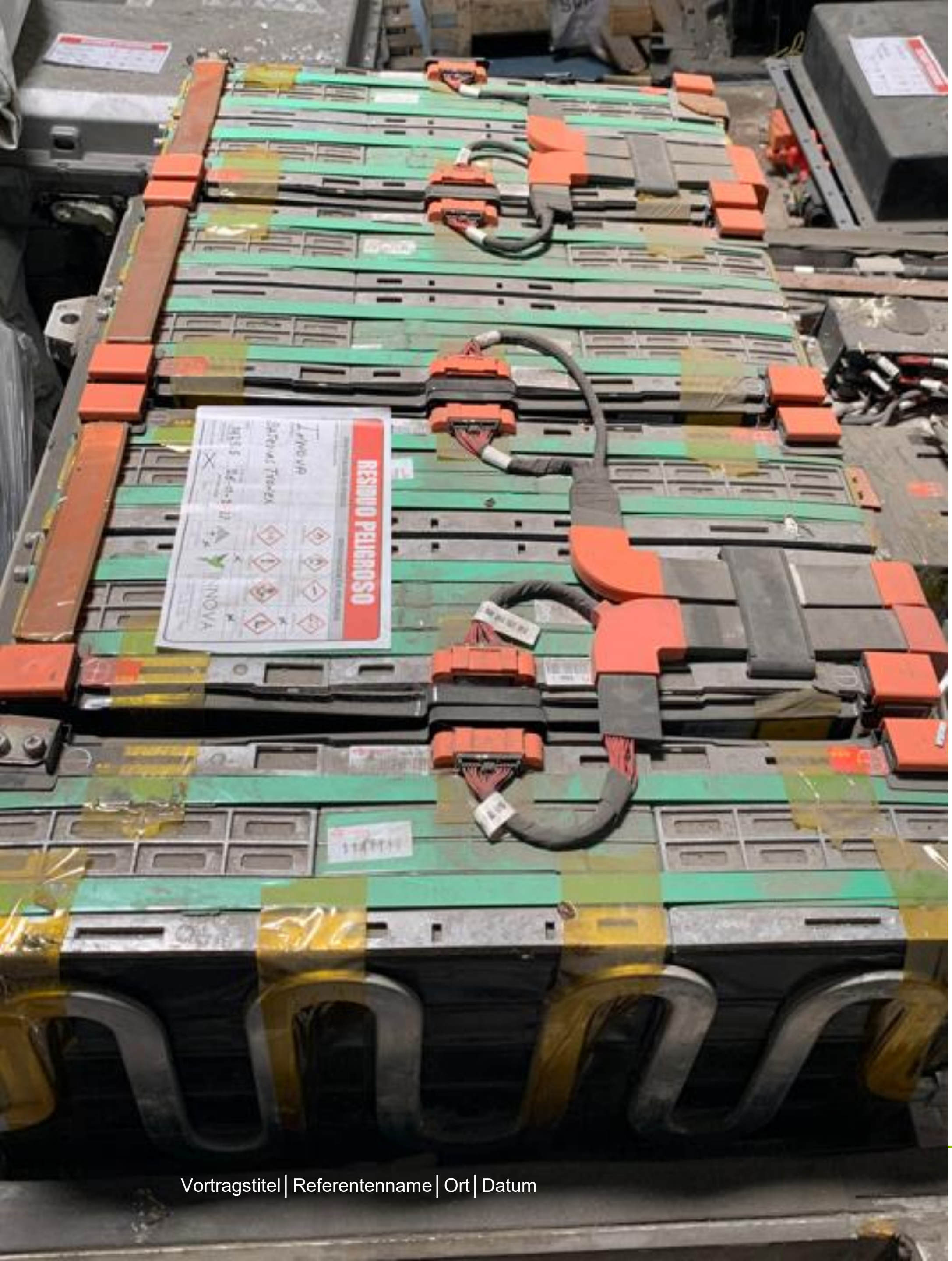
Focus is on cobalt rich batteries from mobile phones and laptops

Smelter for copper scrap

(limited further information)

Some recyclers aim at installing battery shredders in their facilities → no information on an operational facility so far

Pictures: 1: Closing The Loop, 2: Mountain Research Institut, 3: Undisclosed



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About EPR

Production → **Use** → **End-of-life**

"Traditional" Producer Responsibility:

- Sound production
- Functionality
- Product safety
- …

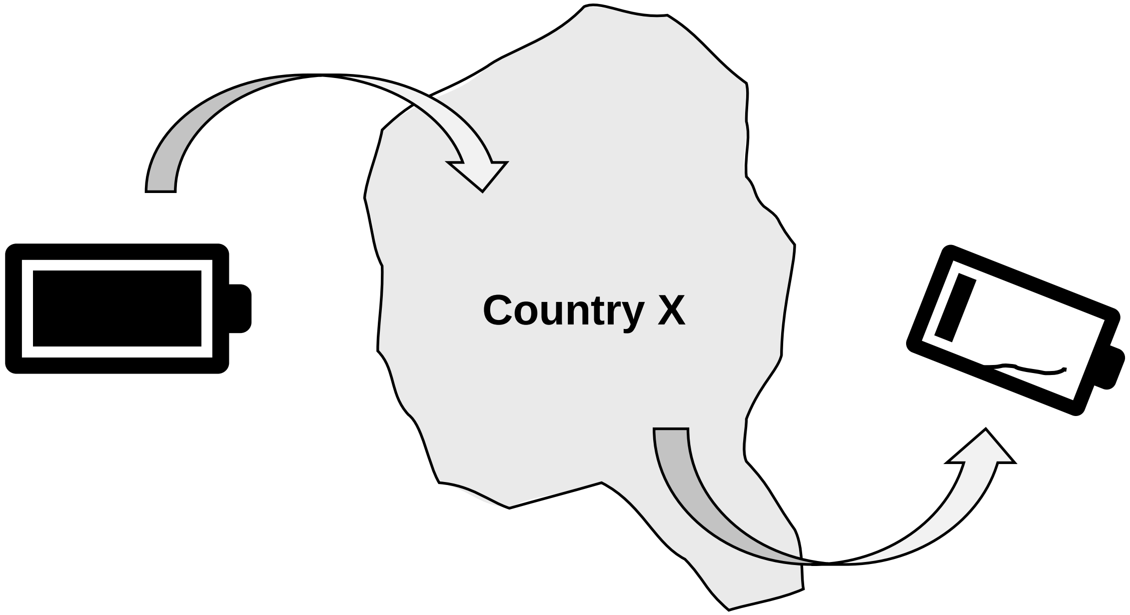
Extended Producer Responsibility:

- Sound end-of-life management

➡ Producers shall take over logistical & financial responsibility to pick-up and soundly manage obsolete batteries

➡ Either individually, or through a Producer Responsibility Organisation (PRO)

About EPR

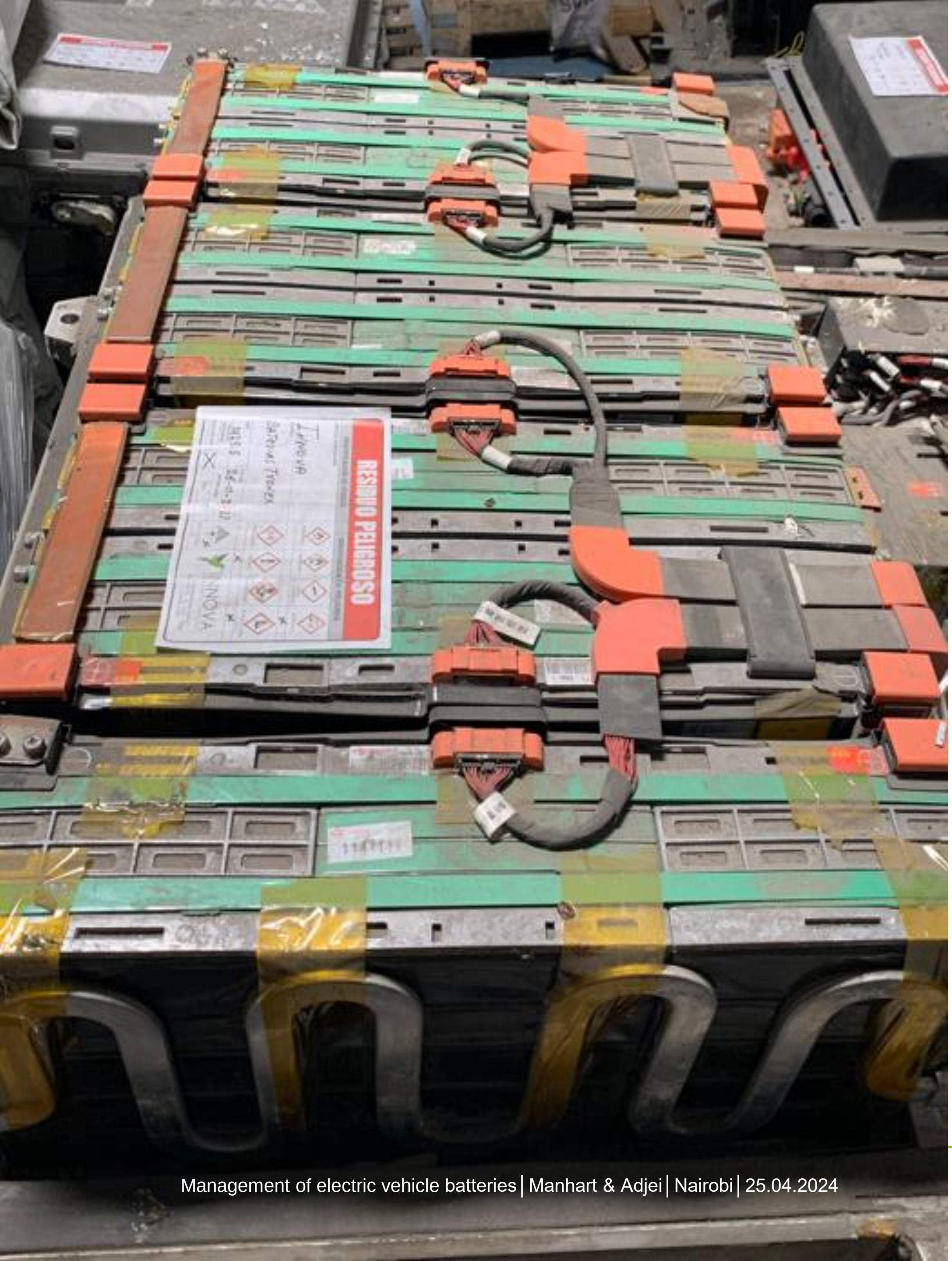


Various African countries have passed EPR legislation requiring producers & importers to collect and adequately manage end-of-life e-waste and batteries:

- Ghana: Act 917 from 2016
- Ethiopia: E-waste Regulation 425 from 2018
- Nigeria: Battery policy
- Rwanda: …
- …

Is EPR the solution?

- EPR systems require a legal framework and are complex to be implemented. They require constant attention by governments and authorities (a law is not enough…).
- EPR systems can strengthen flows towards certain treatment options. The treatment options (facilities) must be monitored by authorities.
- Discussions around “international EPR systems” are ongoing but will not yield tangible results anytime soon.
- There are further (partly still unexploited) levers:
  - Batteries owned by government bodies (schools, offices, car fleets) should be given to best performing recyclers.
  - Large corporates controlling battery volumes (e.g. telecoms, transport companies) can be directly required to give end-of-life batteries to best performing recyclers.
  - Large vehicle producers/importers can be required to collect and manage their (and other) batteries → “EPR light”



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Summary (I/II)

- The question whether used and end-of-life electric vehicle batteries will be collected and soundly managed at their end-of-life will strongly depend on the possibility to make economic gains with such processes.
- Material compositions and complexity of handling points towards a situation in which some batteries might be collected, partly reused and recycled, while others are left behind (dumped). In case the African markets continue to be effectively unregulated, there is a high likelihood that such management will be mostly sub-standard.
- Current trends in battery sub-chemistry lead to lower raw material values, putting a question mark behind some forms of currently promoted recycling approaches (battery shredding to recover black mass).
- Reuse of batteries, module and cells has a high potential but will also rely on the question if battery diagnostic data will be accessible to vehicle owners and third parties (currently uncommon).

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Summary (II/II)

- EPR is extensively discussed and partly already required by law in various African countries.
- Despite such legal requirements, EPR systems did not yet have larger tangible impacts on end-of-life battery markets in most African countries.
- Discussions around "international EPR systems" are ongoing but will not lead to tangible systems anytime soon.
- While EPR is an important tool to make producers and importers co-responsible for sound management, it is not a silver bullet to resolve end-of-life challenges.
- Further aspects to be considered:
  - Requirements for management from government owned / controlled batteries
  - Requirements for big battery using sector (telecom, transport agencies, banks…)
  - Requirements for big producers and importers of electric vehicles ("EPR light")
- EPR does not replace the need to monitor, regulate and (if necessary) sanction business activities around battery reuse and recycling.

Thank you for your attention

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