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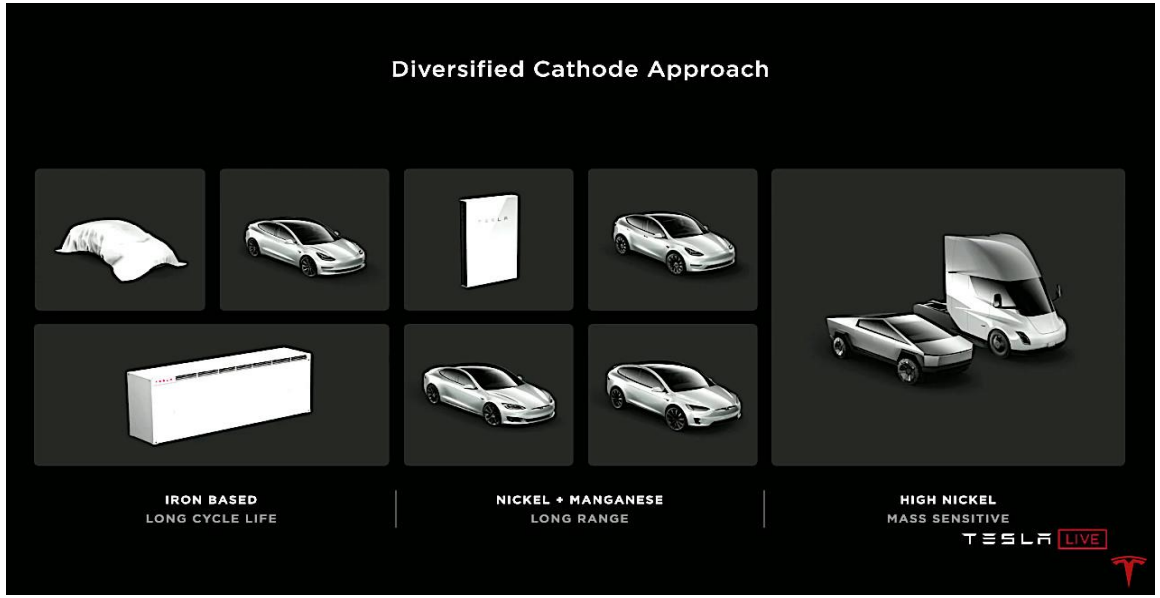
# Battery chemistry and technology roadmaps

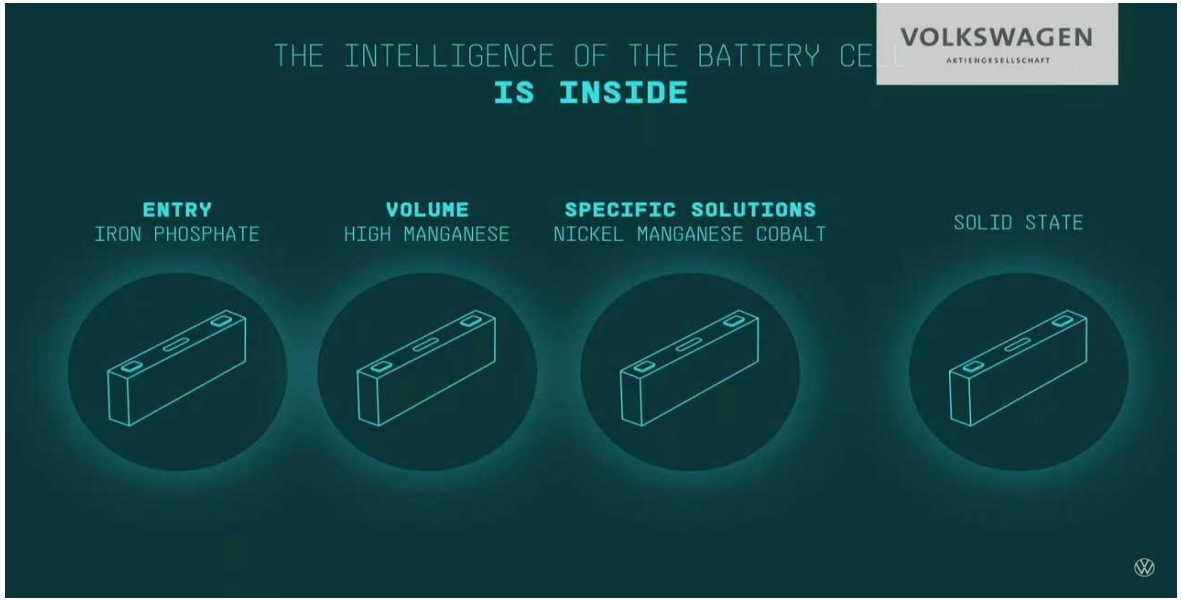
*Jon Regnart*

02 November 2021

# Battery chemistry trends

# The automotive industry is converging around 3 types of battery solutions, but significant divergence occurs between OEMs on specific solutions




| ENTRY LEVEL LOW COST | | | | |
|---|---|---|---|---|
| LFP | Na-ion | Mn-rich | Na-Ni-Cl | NFA |

| HIGH VOLUME PERFORMANCE | | | | | |
|---|---|---|---|---|---|
| NCA | NMC | NCMA | eLNO | Gr-Si Blend Anodes | Mn-rich |

| HIGH PERFORMANCE, SPECIALIST APPLCIATION | | | | | | |
|---|---|---|---|---|---|---|
| Ultra-High Ni Blends | Silicon Anodes | Lithium Metal Anodes | Solid State Electrolyte | Li-S | HV-Spinel Cathodes | Rapid Charge Anodes |

# There are also cross cutting technology themes that affect all categories and are being pursued due to regulation or market dynamics

## CROSS-CUTTING TECHNOLOGY THEMES

| LCA CONSIDERATIONS | | | MANUFACTURING IMPROVEMENTS | | | SAFETY CONSIDERATIONS | | | SUPPLY CHAIN VULNERABILITY | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Battery Recycling | Dry Electrodes | Metal-to Electrode | Dry Electrodes | Lithiation Techniques | Metal-to Electrode | HV Liquid Electrolytes | New Current Collectors | Next-Gen Separators | LFP | Na-ion | Li-S | Mn-rich |

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# Nickel rich chemistries are predicted to be a large part of the European cathode market

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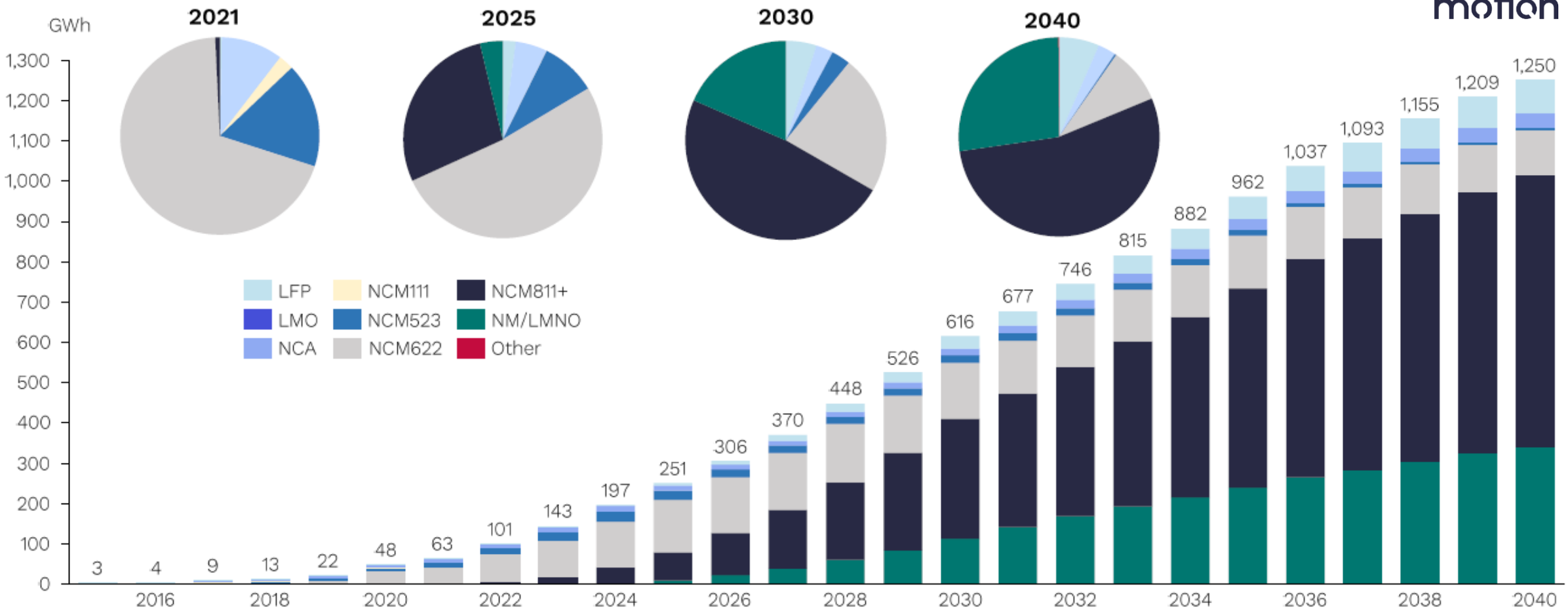
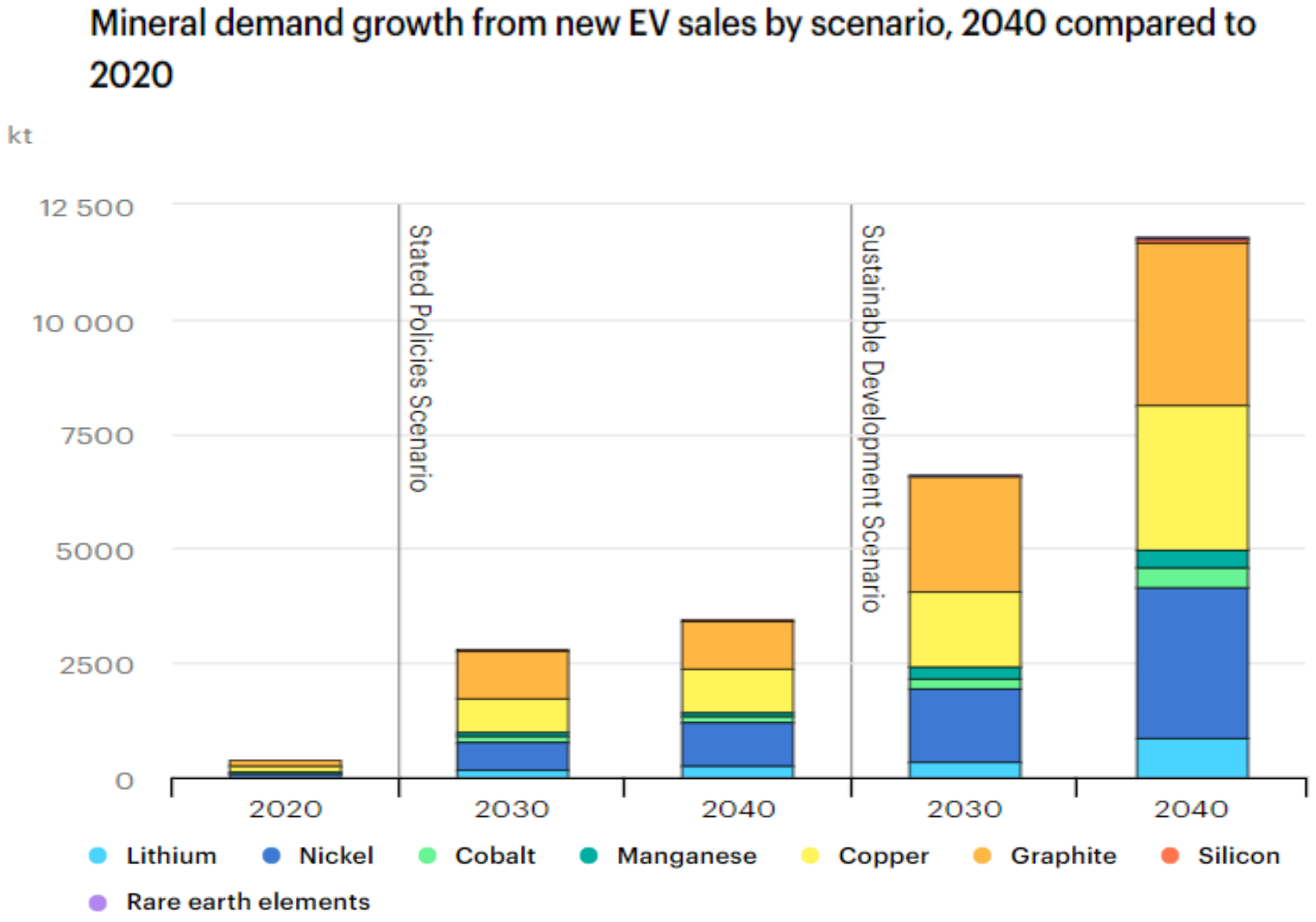
## EU / EFTA / UK PC & LDV EV Cathode Outlook by Battery Chemistry

rho motion



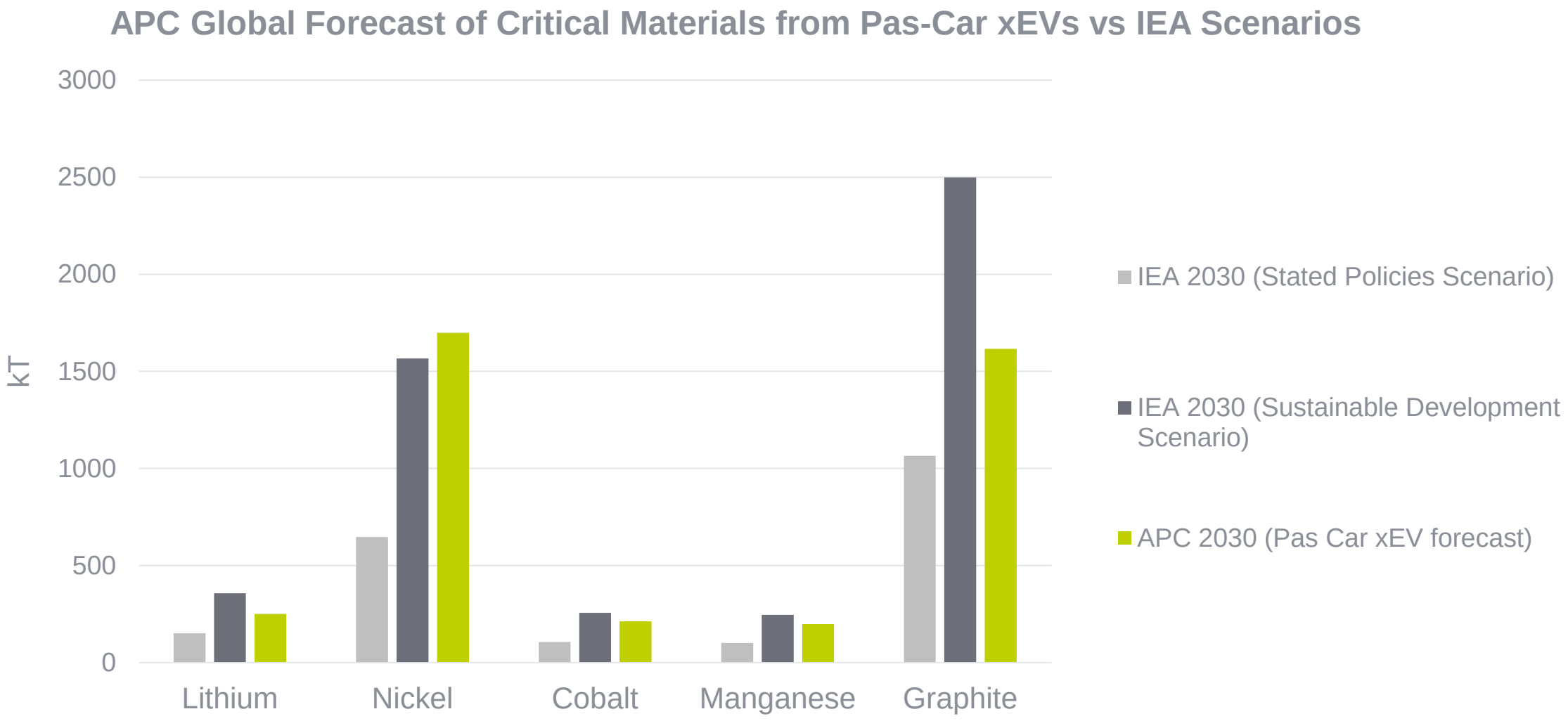
# What does this mean for raw material demand / supply?

# The International Energy Agency predict a massive spike in critical and rare materials as a result of burgeoning EV demand.

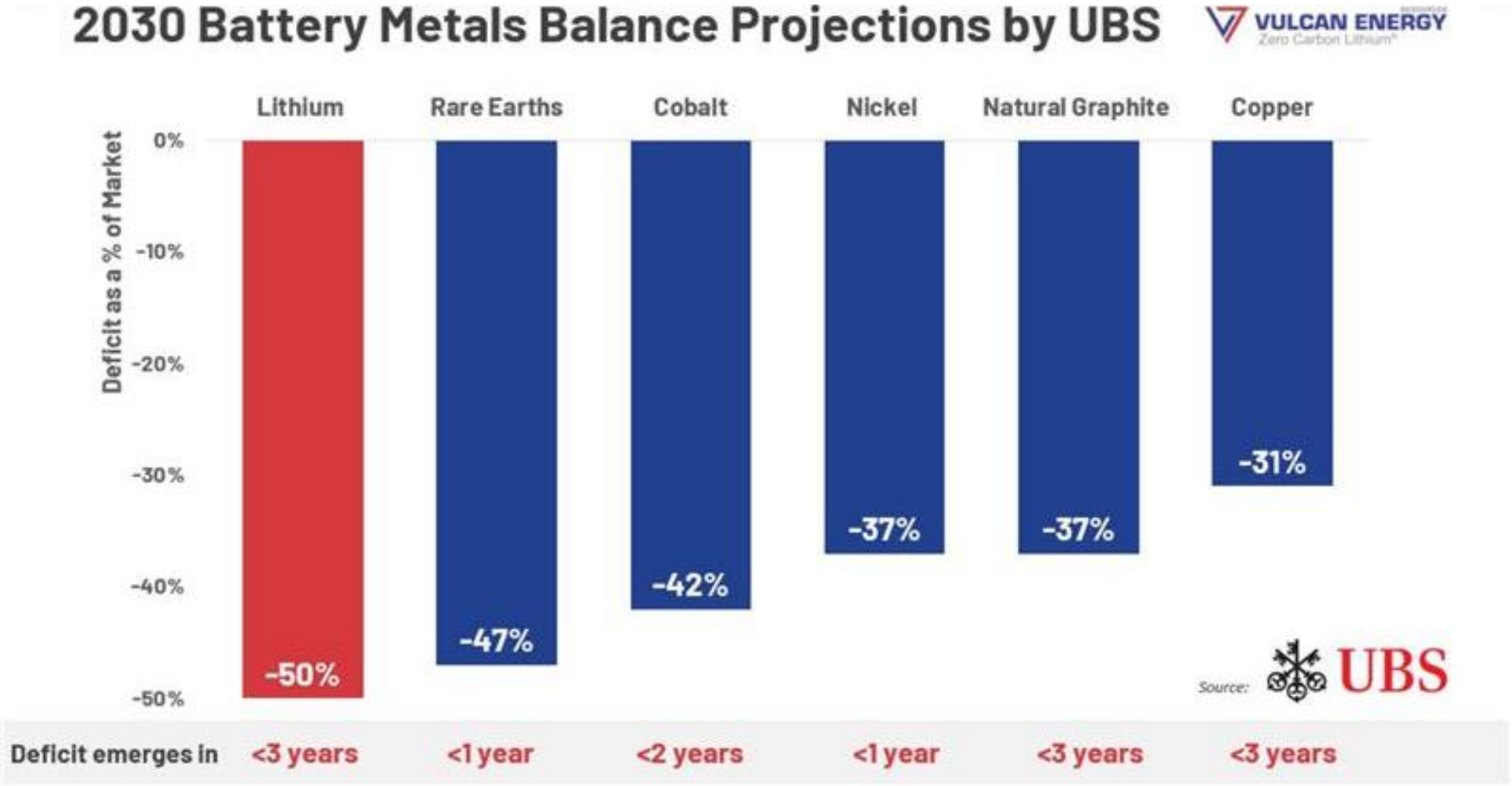



***Source:*** *International Energy Agency, 2021.*

# APC's own demand forecast align more closely with IEA's "Sustainable Development Scenario" than their Stated Policies Scenario



# Demand of xEV batteries and e-machines will outstrip supply in the next few years, so a coherent strategy is urgently required



# What does this mean for LCA?

# The Advanced Propulsion Centre* launched the updated Automotive Council product & technology roadmaps, with a new fuel cell roadmap at LCV2020

## Product Roadmaps

Light Duty Vehicle <3.5t

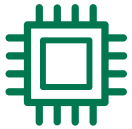
Heavy Goods >3.5t & Off-highway Vehicle

Bus & Coach

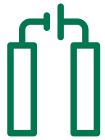
## Technology Roadmaps

Electrical Energy Storage

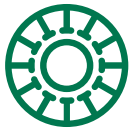
Lightweight Vehicle & Powertrain Structures



Power Electronics



Fuel Cell



Electric Machines

Thermal Propulsion Systems

*** On behalf of the Automotive Council and with considerable support from BEIS**

Roadmap 2020

# Electrical Energy Storage

## Cell Materials and Manufacturing Roadmap

Technology indicators for 2020-2035 can be seen on page 2

automotive council UK

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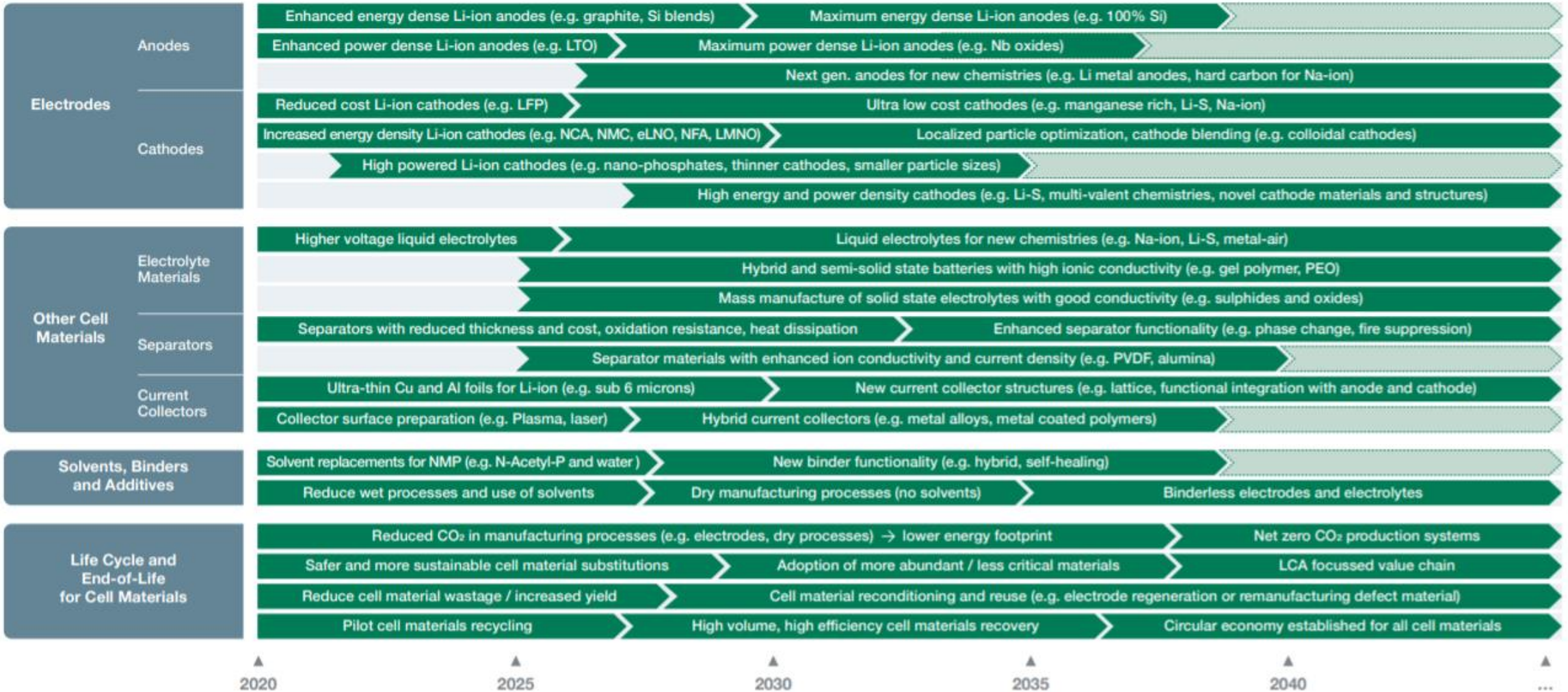
*This roadmap represents a snapshot-in-time view of the global automotive industry propulsion technology forecast for mass market adoption. Specific application-tailored technologies will vary from region to region.*

***Dark bar:*** *Technology is in a mass market application. Significant innovation is expected in this time frame*

***Transition:*** *Transitions do not mean a phase out from market but a change of R&D emphasis*

***Dotted line bar:*** *Market Mature – technology has reached maturity. Likely to remain in mass market until it fades out where it's superseded*



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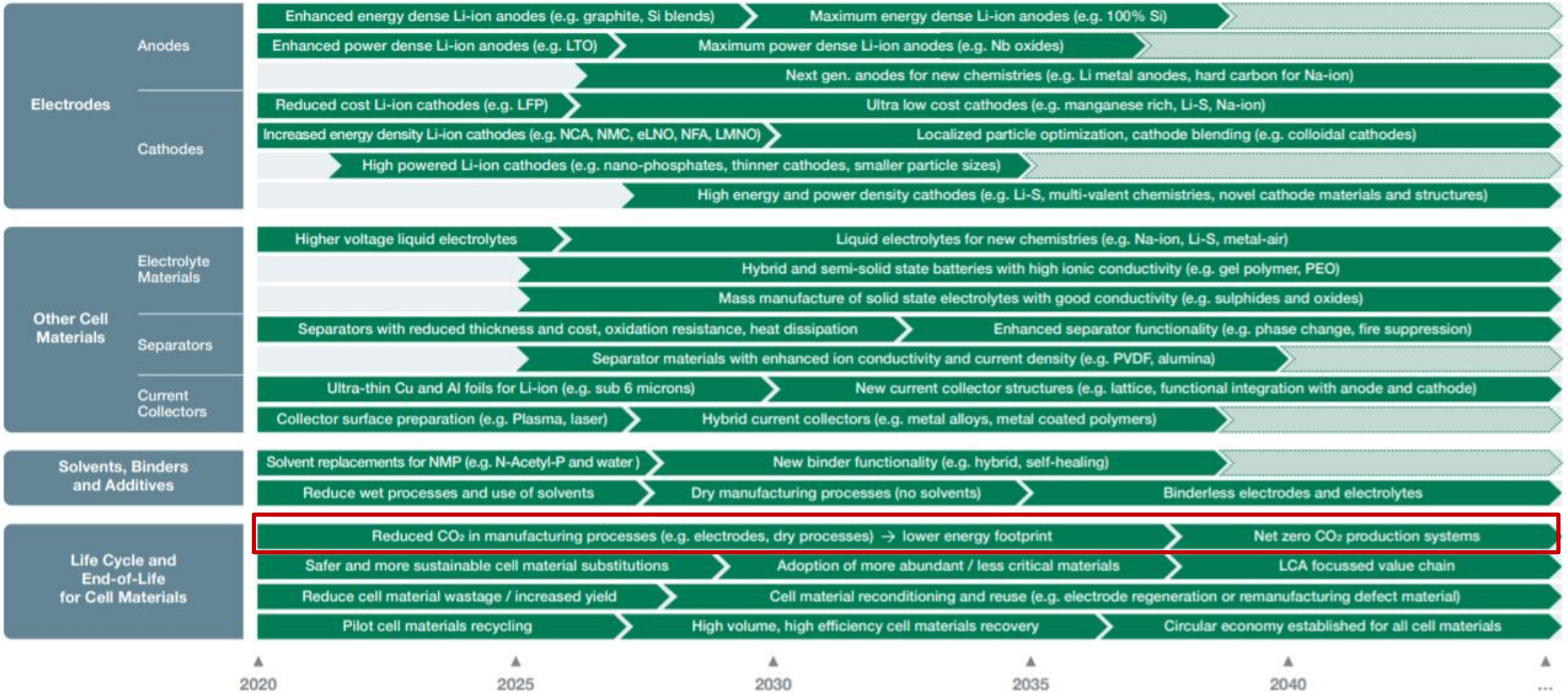
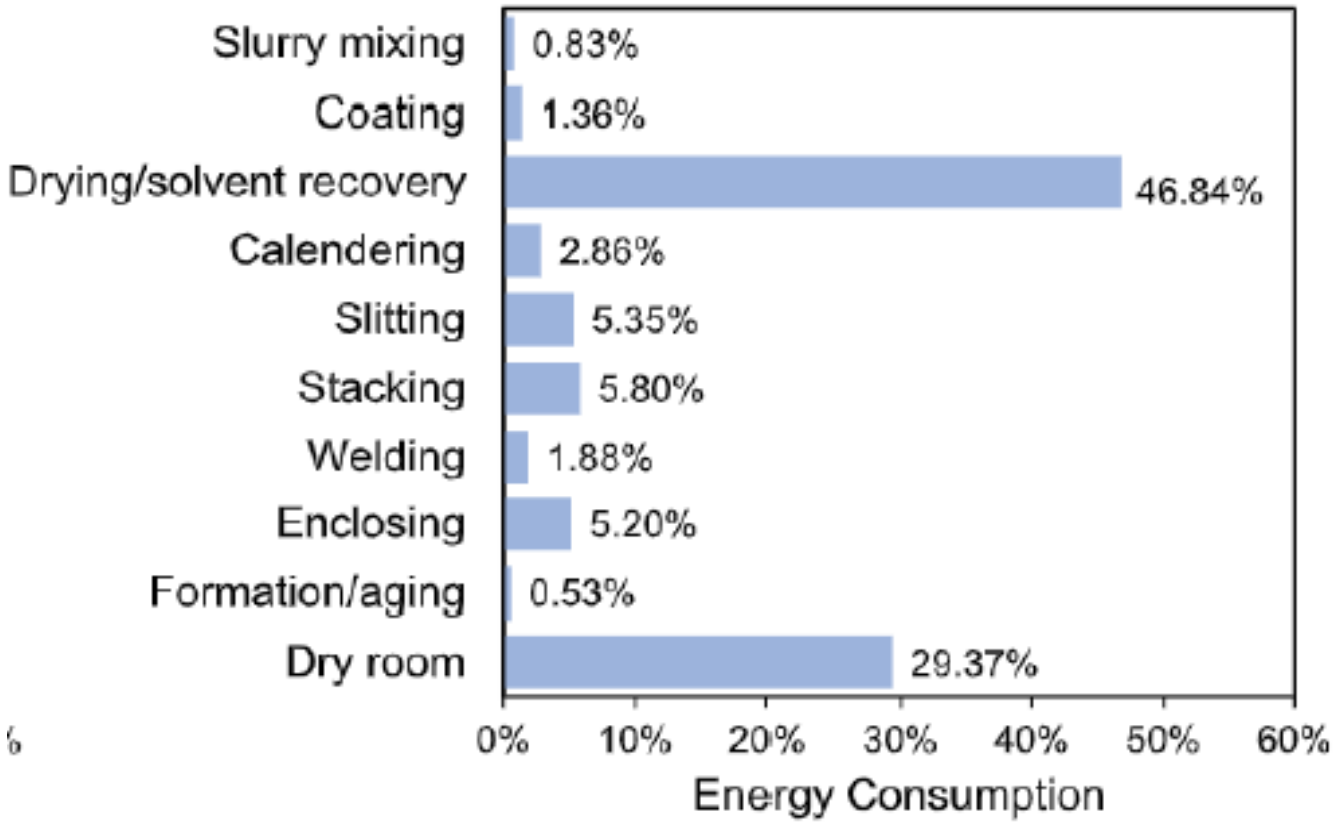


# OEMs are realizing that the most environmentally damaging elements of their supply chains are battery cell manufacturing and their raw materials

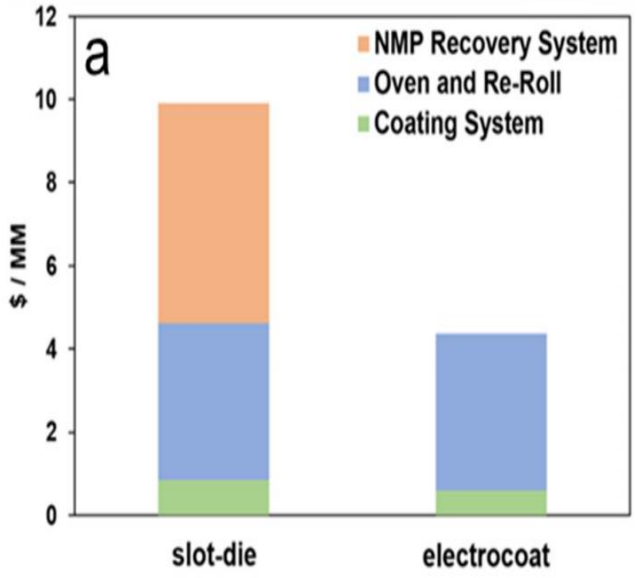




***Source:*** *Wang, et.al, 2021.*

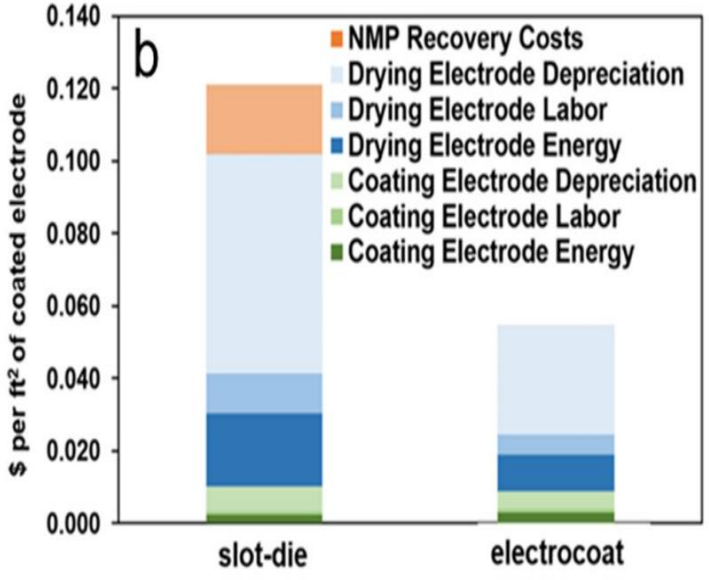
# Dry electrode manufacturing is both environmentally friendlier, reduces cell manufacturing costs and is chemistry agnostic

**Why Dry Electrodes:** Dry electrode manufacturing reduces the cost of cell assembly OPEX and CAPEX. It does this through the removal of an expensive and toxic solvent NMP which needs to be vented and requires certification to use.

CAPEX COSTS




OPEX COSTS

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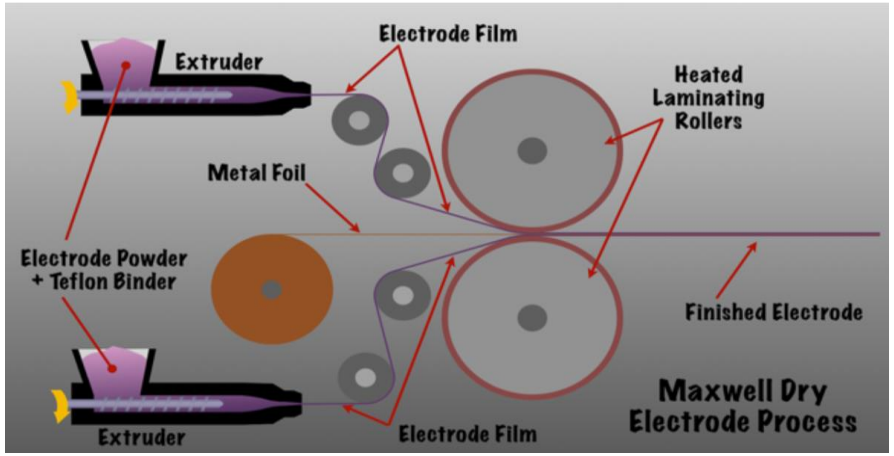


OTHER COMPANIES COMMITTED TO DRY ELECTRODES

LG
Fraunhofer
AM Batteries
PPG
broadbit

Roadmap 2020

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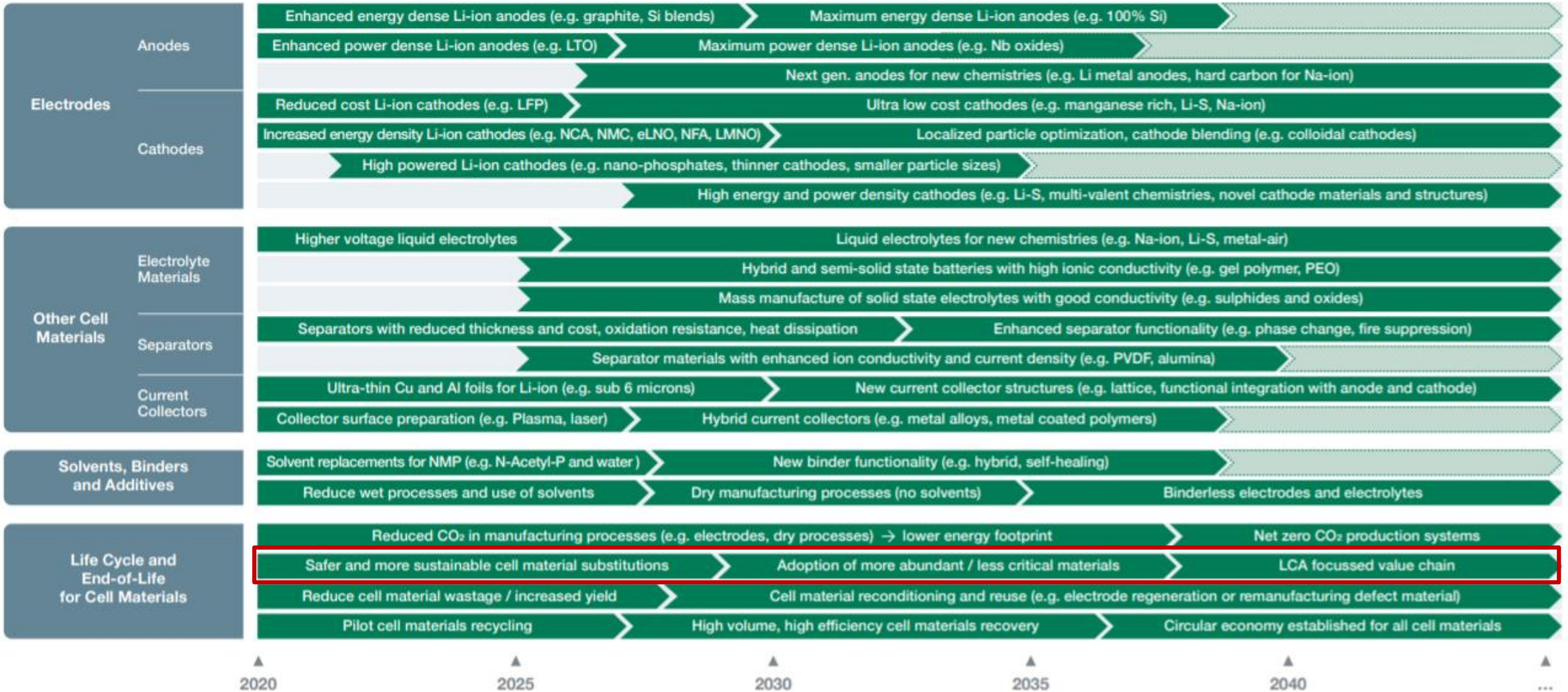

# Materials used to reduce costs and improve battery energy density are likely to expect shortages in the future, leading to a host of new options

**1991** – Sony's first camcorder with LCO battery

**2010** – Nissan's 1st generation LEAF uses LMO battery

**2013** – BMW use NMC111 for the i3 from Samsung

**Present Day**

- Nickel shortages
- Ethics of cobalt
- Lithium shortages
- Carbon taxes

**2008** – Tesla uses 6,800 LCO laptop cells in the Roadster

**2012** – Tesla opts for NCA cylindrical cells for the Model S from Panasonic

## Future Options to Reduce Critical Material Dependency

- Sodium-ion
- Manganese Rich
- LFP
- Lithium Sulfur
- 0% Co NCA / NMx
- ?

LCO – Lithium Cobalt Oxide LMO – Lithium Manganese Oxide LFP – Lithium Iron Phosphate NCA – Nickel Cobalt Aluminum NMC – Nickel Manganese Cobalt

Roadmap 2020

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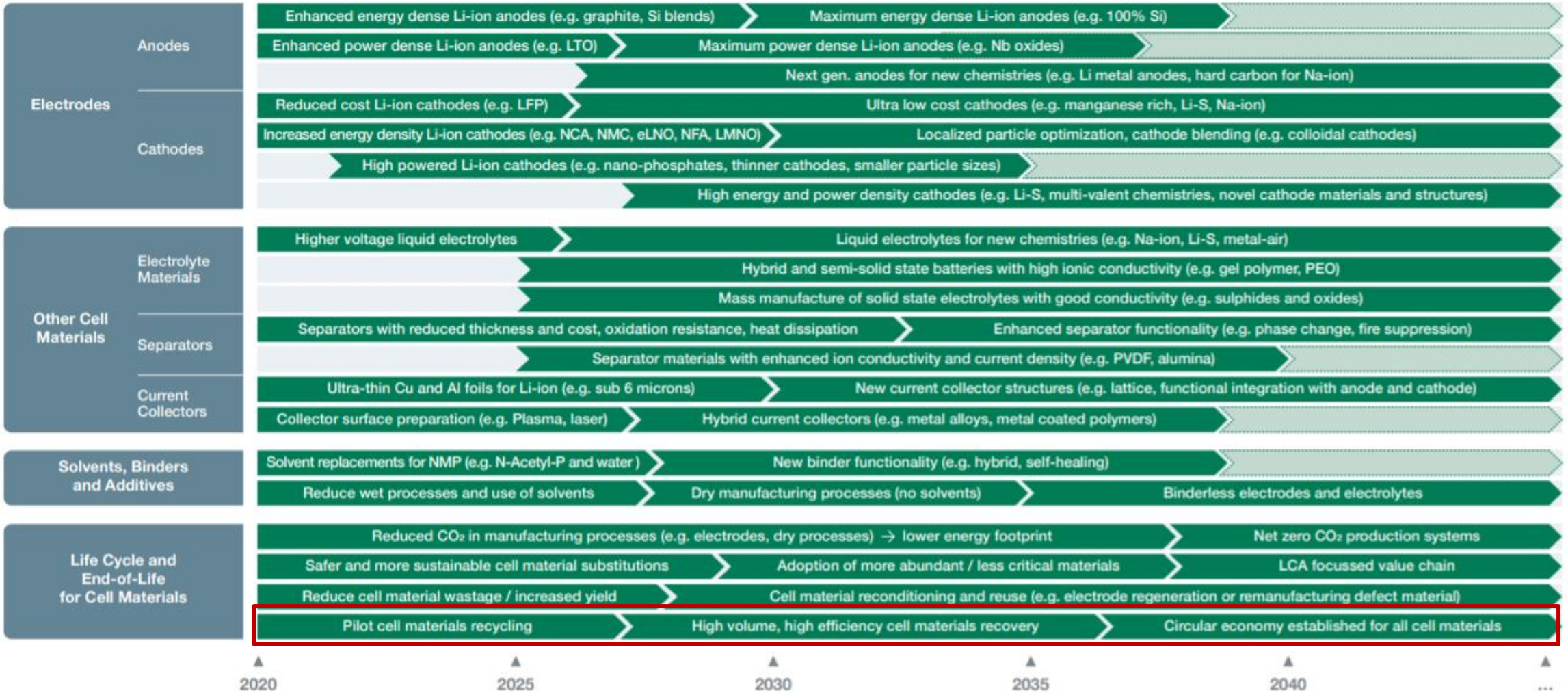


# EU EV Battery Directive – Executive Summary

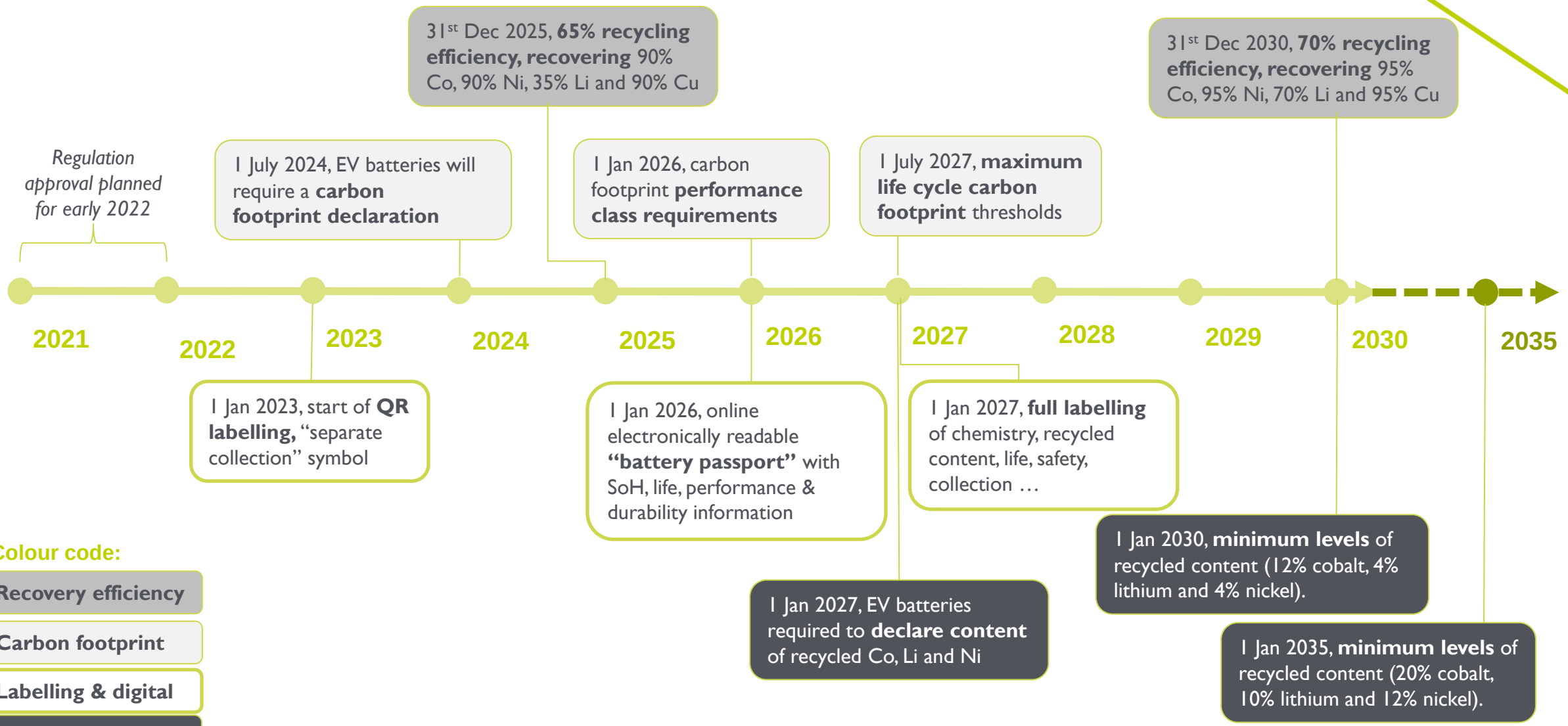
On 10 December 2020, the European Commission published its proposal for a new **Sustainable Batteries Regulation** to ensure that all batteries placed on the EU market are **sustainable, circular and safe**.

**Four main EV related themes**

- Recycling efficiency and recovery rates
- Labelling requirements and digital data
- Carbon footprint declaration
- Minimum levels of recycled content required

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020PC0798&qid=1613426366165

# Proposed EU EV battery regulation introduction timeline




**Colour code:**

- **Recovery efficiency**
- **Carbon footprint**
- **Labelling & digital**
- **Recycled content**

# Key takeaways

OEMs are **converging around 3 categories of batteries** to suit their future EV portfolios

**Specific chemistry choices diverge** between OEMs within those 3 categories

**The burgeoning demand** for nickel, lithium & graphite **embeds CO2 in the battery supply chain** as the extraction and refining of these materials are energy intensive

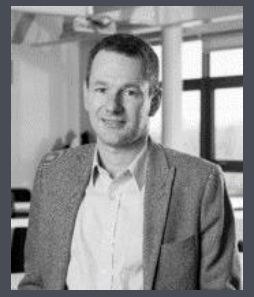
**Refined battery materials and electrode manufacturing** processes are the most energy intensive. Dry electrode manufacturing could drastically reduce energy consumption.

Battery chemistries like **LFP, sodium ion & manganese-rich** that use more abundant materials can lower costs and environmental impacts

**Recycling batteries can reduce reliance on primary materials** which reduces the environmental footprint while also lowering costs

# Thank you for listening, we look forward to working with you …

Get in touch if you'd like to know more about the roadmaps, our supply chain analysis or trends insight

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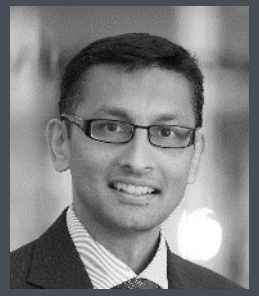


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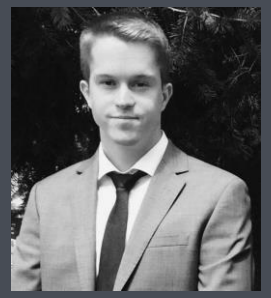


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**APC Insight supported the Uni of Birmingham Policy Commission on Strategic Materials**