Batteries Europe

Overview of International R&D&I Battery Funding and Global Benchmarks for Battery KPIs

June 2024

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ABBREVIATIONS AND ACRONYMS

BEPA	The Batteries European Partnership Association
CEE	Central and Eastern Europe
CRM	Critical Raw Materials
EEC	European Economic Community
ESG	Environmental, social and governance (e.g. standards)
EVs	Electric Vehicles
FDI	Foreign Direct Investment
FTA	Free Trade Agreements
GHG	Greenhouse gas
GVA	Gross value added
IPCEI	Important Project of Common European Interest
IRA	Inflation Reduction Act
KPI	Key Performance Indicator
LiB	Lithium-ion battery
LFP	Lithium Iron Phosphate
METS	Mining equipment, technology and services
NEV	New Energy Vehicles
NiBs	Sodium-ion batteries
NiMH	Nickel-metal hydride
NMC	Nickel Manganese Cobalt
NPI	Nickel pig iron
R&D&I	Research, Development and Innovation
SRIA	Strategic Research and Innovation Agenda
SSB	Solid-state batteries

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1 EXECUTIVE SUMMARY

1.1 Developments in the global battery ecosystem

The global balance of power in the international battery industry and R&D&I community has seen a considerable shift since the first commercialisation and industrial deployment of lithium-based batteries. While **Japan** has established itself as an early technology leader for liquid electrolyte lithium-ion batteries, since 2015 its domestic industry has lost market shares to Chinese and South Korean manufacturers, which benefit from robust government support. In particular, **China** has been rapidly innovating its domestic battery technology. Initially, China's battery policies were strongly technology focused, with the aim to catch up with the leading countries at the time[1]. Additionally, protective policies led many Chinese carmakers, which had previously worked with South Korean and Japanese suppliers, to shift their battery orders to domestic manufacturers in order to benefit from generous subsidies. This aspect has played a crucial role in facilitating the cultivation of a domestic battery value chain in China[2]. After having achieved the maturity of the entire value chain from raw materials to component manufacturing, cell and pack production and electric vehicle application with the help of a comprehensive government subsidy programme, China has become the world´s largest electric vehicle market.[2] International Energy Agency estimates that China accounts for around 75% of battery cell, 70% of cathode and 85% of anode material global production capacity.[3]

China's dominant market position has triggered reactions from other countries and regions, including the **European Union**. Since 2019, two Important Projects of Common European Interest (IPCEI) have been launched in an effort to build up a sustainable and competitive value chain in Europe, involving 12 member states and more than 50 companies. More recently, the European Commission has initiated an anti-subsidy investigation against China's pre-allocated subsidies mechanism and its impact on Europe's industry through the import of subsidised Chinese EVs into the EU[4].

As a particularly forceful countermeasure, the **U.S.** launched the Inflation Reduction Act (IRA) under the Biden administration in 2022. IRA dedicates around $369 billion of federal funds to achieving both climate goals and energy security by boosting the U.S domestic capacity to produce solar panels, wind turbines and EVs. The enormous incentives offered under this measure have since encouraged the relocation of battery production to the U.S. Following the IRA, a substantial uptake in foreign investment announcements in the North American could be observed, leaving the rest of the world behind[5]. The Japanese and the South Korean battery cell producers like Panasonic, LG Energy Solutions, Samsung or SK Innovation, are focusing their current expansion efforts on the

[1] Chie Endo, Tanja Kaufmann, Dr. Richard Schmuch, Dr. Axel Thielmann: Benchmarking International Battery Policies - A cross analysis of international public battery strategies focusing on Germany, EU, USA, South Korea, Japan and China, 2024
[2] Huiwen Gong, Teis ansen n iron ental Inno ation and So ietal ransitions. e rise o C ina's ne energy vehicle battery industry: the coevolution of battery technological innovation systems and policies
[3] https://iea.blob.core.windows.net/assets/961cfc6c-6a8c-42bb-a3ef-57f3657b7aca/GlobalSupplyChainsofEVBatteries.pdf
[4] e 's le tri e i le robe and at Co es e t odiu rou
[5] fDi Markets | https://www.fdiintelligence.com/content/feature/italvolt-gigafactory-hype-or-ripe-81796

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North American market rather than the Asian one. The reason for that is not only the significant U.S. demand for battery cells, but also the fact that the Japanese and South Korean players benefit from IRA tax credits and subsidies, while being protected from competition with Chinese cell producers, who are not eligible for IRA incentives.[6]

The developments in the U.S led to the announcement of new strategies in other markets, such as the 2023 Public-Private Joint Strategy for Battery Industry Development in **South Korea**[7] and the 2023 Green Deal Industrial Plan in the **European Union**[1]. The latter notably included an amendment to the Temporary Crisis and Transition Framework to relax state aid rules for investments in sectors strategic for the transition towards a net-zero economy.

As production capacities are ramping up worldwide, resilience regarding critical raw materials (CRM), is consequently gaining importance in battery policies. This is reflected in R&D&I measures on new, less CRM-dependent battery technologies like sodium-ion batteries, which see increasing focus in Europe and are already regarded as a technology with high commercial relevance in big economies such as **China** and **India**[8], or fluoride and zinc-anode batteries, for which **Japan** has set ambitious goals.

Other notable measures include negotiations of free trade agreements (FTAs), CRM-specific trade agreements with the producing countries, governmental support for domestic mining projects, and protective policies. For example, in the **U.S.** electric vehicles will become ineligible for the $7,500 tax credit under the IRA from 2025 onwards, if their batteries contain critical minerals mined or processed in so-called "foreign entities of concern". In addition to that, the American Battery Materials Initiative launched by the U.S Department of Energy aims to provide $2.8 billion in DOE grants to build a domestic battery raw materials supply chain.

China holds a dominant position in the global material supply chain, but still depends on overseas sources for 93% of its nickel, 98% of its cobalt and 65% of its lithium. One of the major China´s policy goal aims at improving the country's supply of these CRM by strengthening domestic resource exploration and recycling, as well as optimise the oversees supply.[9]

India has removed lithium, among other minerals, from a previous list of atomic minerals, which prevented it from being auctioned to and mined by private companies, in order to accelerate commercial exploitation of its lithium reserves[10].

Meanwhile, the **European Commission** has enacted the Critical Raw Materials Act in 2023, which envisages that 10% of extraction and 40% of refinement of CRM relative to the EU consumption should take place within the EU. Permitting procedures are to be simplified in order to reach this target. However, hurdles for new mining projects in Europe still remain high with regards to

[6] https://source.benchmarkminerals.com/article/in-charts-the-state-of-play-in-europes-battery-market
[7]MOTIE announces post-IRA public-private joint strategy for battery industry | https://www.korea.net/Government/Briefing-Room/Press-Releases/view?articleId=6814&type=O
[8]Inside India's le tri bitions e oding e For es Fuelling e e olution I C 2
[9]https://www.mining.com/web/chinas-reliance-on-foreign-battery-metals-poses-a-challenge-industry/?utm_source=Daily_Digest&utm_medium=email&utm_campaign=MNG-DIGESTS&utm_content=chinas-reliance-on-foreign-battery-metals-poses-a-challenge--industry
[10]https://www.reuters.com/markets/commodities/india-passes-law-allowing-auction-mining-lithium-reserves-2023-08-02/#:~:text=MUMBAI%2C%20Aug%202%20(Reuters),material%20for%20electric%20vehicle%20batteries

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permitting, environmental compliance and public acceptance, as evidenced e.g. by the cessation of Rio Tinto's Lithium mining project in Serbia in 2022[11].

A potential option for the access to critical minerals that is gaining attention is deep-sea mining. A number of nations have been issued exploratory licenses by the U.N. agency that is in charge of the related regulatory activities and the protection of the seabed ecosystems. Deep-sea mining remains controversial due to environmental concerns. In addition to that, the economics are still under debate due to the high expense and challenging logistics[12].

Countries with the benefit of having rich natural resources of critical minerals such as Australia, **Canada** or **Indonesia** strive to develop a domestic battery value chain. **Indonesia** aims to become a global player in EV industry with the capacity to produce 140GWh of battery cells per year by 2030[13], based on its existing nickel industry and government incentives to attract foreign investments and the consumption of local goods. As the world's largest producer of nickel ore (30% of global market)[14], Indonesia is also an attractive partner for more developed economies.

Industry players like Stellantis NV and LG Chem Ltd. have urged the U.S. Treasury to add (among others) Indonesia to the IRA framework by striking free-trade deals on critical minerals[15], and negotiations on a FTA between Indonesia and EU have been ongoing since 2016[16]. While none of these agreements has been concluded at this point amid concerns over Indonesia's performance on labour rights, the environment and governance as well as China's extensive presence in Indonesia's nickel industry[17], **South Korea** and Indonesia have agreed upon bilateral economic cooperation and joint investments in the production of electric vehicles and batteries in Indonesia[18].

With its Critical Minerals Strategy (2022), the Government of **Canada** focuses on opportunities at every stage of the value chain for Canada's 31 critical minerals, prioritising six: lithium, graphite, nickel, cobalt, copper and rare earth elements[19]. Canada's abundant resources offer a significant opportunity to reduce dependence on China, which makes the country an attractive partner for key players such as the U.S. and Europe. The Government of Canada is pursuing the development of a fully integrated domestic battery value chain. Beyond the supply of responsibly sourced critical minerals, this includes significant financial incentives for R&D, large-scale cell manufacturing and midstream production.

[11] https://www.spiegel.de/wirtschaft/serbien-verbietet-rio-tinto-den-abbau-von-lithium-a-72b9de4d-a29c-4a87-a464-b0b55f6d5535
[12] https://www.instituteforenergyresearch.org/renewable/deep-sea-mining-of-critical-minerals-for-ev-battery-production/
[13] Indonesia's Battery Industrial Strategy. CSIS, February 2022
[14] Prospects for Electric Battery Production in Indonesia. ASEAN Briefing, January 2024
[15] https://www.mining.com/web/its-carmakers-against-miners-in-battle-over-china-funded-metals/?utm_source=Daily_Digest&utm_medium=email&utm_campaign=MNG-DIGESTS&utm_content=its-carmakers-against-miners-in-battle-over-chinafunded-metals
[16] https://thediplomat.com/2024/01/how-to-break-the-deadlock-in-the-indonesia-eu-trade-talks/
[17] Cullen S. Hendrix, PIIE, November 2023 | https://www.piie.com/blogs/realtime-economics/us-should-consider-critical-minerals-trade-agreement-indonesia
[18] https://www.electrive.net/2023/08/07/suedkorea-sagt-weitere-emobility-investitionen-in-indonesien-zu/
[19] https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html#a51

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1.2 General information and approach

The aim of this report is to illustrate the main activities in building international battery innovation systems in order to compare and benchmark the European position in this respect. The results should serve as an input to the European Commission for contextualising the Batteries Europe SRIA and for prioritising future European R&D&I activities. This document therefore focuses on the R&D areas and KPIs, based on direct exchange with relevant international R&D&I stakeholders, as well as on the mapping of international policy documents and roadmaps on batteries.

The following chapters analyse R&D&I strategies and KPIs on a country-by-country basis. However, as the availability of data varied between the considered countries and regions, different approaches had to be taken in individual chapters, e.g. for some countries we had to focus only on strategic policy KPIs.

In addition, we were not able to obtain validation of the collected information by local battery experts for all countries, e.g. in case of China the report is based entirely on publicly available information.

Each chapter consists of two parts: a country factsheet and an extended text on battery KPIs with country specific information. The factsheets include information on key domestic stakeholders, strategic national battery documents, main policy goals, current research priorities, as well as details regarding funding instruments. Both main players and the policy documents are linked to the websites for further research. The factsheets can be separately found on the website of Batteries Europe.[20]

Regarding the textual part, in January 2024, Fraunhofer ISI published a cross-analysis of international public battery strategies on behalf of the German Federal Ministry of Education and Research (BMBF).[21] This study provides a comprehensive mapping of the R&D strategies of the EU, the U.S., South Korea, Japan and China until the end of 2022. The Batteries Europe's report takes this publication into account and does not aim to duplicate its contents. Rather, it focuses on updating and supplementing the findings with complementary information, adding emerging markets such as India and relevant resource-rich countries such as Australia, Canada and Indonesia, and including initiatives aimed at industrial deployment, industrial value chain development and raw material supply.

In the case of the European Union, a comprehensive set of KPIs for R&D&I benchmarking has already been developed by the integrated working groups of Batteries Europe and BEPA and is continuously updated. It can be found on the Batteries Europe website[22] and is not duplicated in this report. Instead, the chapter on the European Union highlights in particular Central Eastern Europe to provide complementary information of additional value.

This document provides a global overview of battery R&D&I funding and an international benchmark on key performance indicators. It will be followed by a final "Report on International

[20] https://batterieseurope.eu/results/international-observation/
[21] https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2024/benchmarking-international-battery-policies_2024.pdf
[22] KPIs Benchmarking II, October 2023 | https://batterieseurope.eu/results/kpis-benchmarking-2/kpis-benchmarking-2-october-2023/

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Activities and R&D&I Funding" in December 2024, which will additionally take into account the main takeaways of the two fact-finding missions to Asia and to North America and include further recommendations for the European Commission.

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Battery Innovation System of
European Union

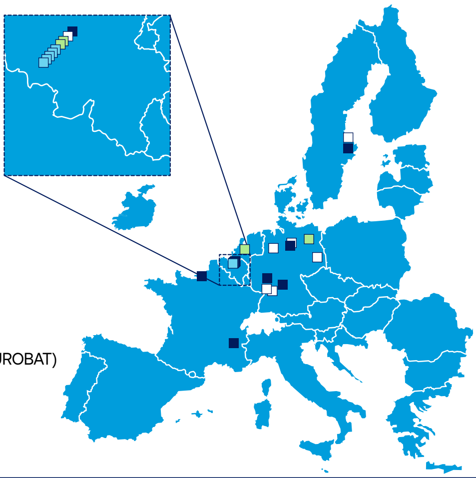
Main Players

POLITICAL ORGANISATIONS

- European Commission (EC)
- Batteries Europe
- Batteries European Partnership Association (BEPA)
- European Battery Alliance (EBA)
- IPCEI Batteries
- National governmental agencies

INDUSTRY ASSOCIATIONS

- European Portable Battery Association (EPBA)
- Association of European Industrial Battery Manufacturers (EUROBAT)
- European Automobile Manufacturer's Association (ACEA)
- RECHARGE
- European non-ferrous metals association (Eurometaux)



RESEARCH ORGANISATIONS

- LiPLANET
- Battery 2030+
- Fraunhofer Research Institution Production (FFB)
- European Energy Research Alliance (EERA)
- CELEST
- ProZell
- InZePro
- greenBatt
- ALBATTS

COMPANIES

- ACC (Batteries)
- BASF (Materials)
- Northvolt (Batteries)
- PowerCo (Batteries)
- Umicore (Materials, Recycling)
- Varta (Batteries)
- Verkor (Batteries)

Further detailed maps here

Strategic Documents

2018 · 2019 · 2020 · 2021 · 2022 · 2023

- Strategic Action Plan on Batteries
- European Green Deal
- Circular Economy Action Plan
- Batteries Europe SRIA
- BEPA SRIA
- 2030 Climate Target Plan
- Horizon Europe Work Programme
- Ecodesign for Sust. Products Regulation (prop.)
- Green Deal Industrial Plan
- Critical Raw Materials Act (prop.)
- EU's Net Zero Industry Act (prop.)
- EU Battery Regulation
- Battery Directive (prop.)

Policy Goals

2030

- **GHG emissions:** Reduction by 55% compared to 1990 levels, which will require significant decarbonisation efforts across all sectors, including the battery industry
- **Domestic production:** At least 40% (90% for batteries) of the demand in clean technologies should come from European production
- **Circularity:** Boost recycling of batteries and recovery of valuable materials
- **Sustainability:** Establish sustainable and transparent requirements for batteries (carbon footprint, ethical sourcing of raw materials, security of supply)
- **EU consumption:** 10% of extraction and 40% of processing should take place in the EU. 15% of the raw materials are to be obtained from recycling No more than 65% of raw materials may be imported from a single third country
- **Zero-emission:** Target for new city busses
- **Recycling targets:** Materials recovered from spent batteries: 50% by 2027 and 80% by 2031 for lithium and 90% by 2027 and 95% by 2031 for cobalt, copper, lead and nickel. Proportion of recovered materials in new batteries. 16 % for cobalt, 85 % for lead and 6% each for lithium and nickel from 2031; 26% for cobalt, 12% for lithium and 15% for nickel from 2036.

2035

- **Zero-emission:** Target for all new cars and vans.

2050

- **Carbon neutrality:** Including measures to support the development of sustainable and resource-efficient battery technologies.

Region Specific Information

In the European Union, the establishment of competitive and domestic battery value chain is essential for a fast transition towards climate neutrality. Europe focuses on producing "green" batteries following sustainability criteria such as climate protection, circular economy, raw material governance and economic efficiency. By introducing a battery pass, transparency is provided to create awareness for sustainable as well as ethical factors which are guaranteed by due diligence obligations for economic operators. To establish a resilient battery value chain, the European Union aims to build up a local battery production and material sourcing along with strong international trading partnerships. Moreover, diversity, pilot lines and national funding are characteristic for the European battery ecosystem.

Research Priorities

+ Lithium-ion batteries + innovative and enhanced batteries for EVs from material design to battery system design + stationary energy storage + higher energy materials + high-performance batteries + materials and production technology + reduction of the amount of critical raw materials needed + reduction of GHG during the production process + recycling technology + digital twins + cell design + life cycle assessment

Funding Instruments

TIME	FUND	FOCUS	BUDGET
2019–2031	IPCEI: Important Projects of Common European Interest	A European-wide initiative that aims to build up a sustainable and competitive battery value chain in Europe. 12 EU member states provide funding for more than 50 companies for first industrial deployment of innovative battery technologies.	€ 3.2 billion
2021–2027	Horizon Europe Programme and Co-Programmed Partnership Batt4EU	The aim of BATT4EU is to establish a European battery value chain by 2030. The objectives are to increase battery energy and power densities and charging rates, improve cycle lifetime, reduce battery costs, implement best-in-class operations for manufacturing and recycling, and reduce the carbon foodprint. Battery research is also funded through other calls, such as those launched by the ERC and the EIC.	€ 95.5 billion (€ 925 million for BATT4EU)
2023–2025	TCTF: Temporary Crisis Transition Framework	Support measures in sectors which are key for the transition for the net-zero economy. Enabling the investment support for the manufacturing of batteries, solar panels, wind turbines, heat-pumps, electrolysers as well as financial support to build up the recycling industry for critical raw materials.	€ 1.287 billion (transition measures)
2020–2030	Innovation Fund	The Innovation Fund aims to help businesses invest in clean energy and industry to boost economic growth, create local future-proof jobs and reinforce European technological leadership on a global scale.	€ 38 billion

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Batteries Europe

VDI | VDE | IT

2.1 General overview of the EU battery developments

The European Union is strategically enhancing its battery industry, aiming to keep in step with the Asian and the U.S. markets. The EU's efforts include forming the European Battery Alliance and launching the Clean Mobility Package to boost domestic battery cell production and reduce CO_2 emissions. These initiatives also cover comprehensive strategies from raw material extraction to battery recycling, promoting sustainable practices across the battery value chain. Europe plans to establish up to 20 large battery factories by 2025 to meet both domestic and global demand, and to avoid past oversights such as in the solar panel industry where it lost ground to China.[23]

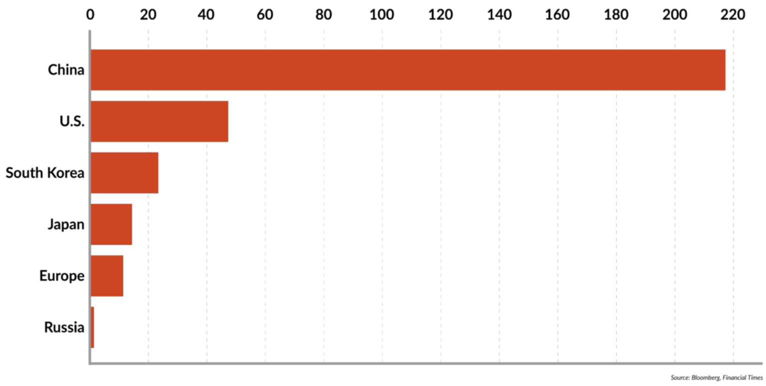

Figure 1 Europe is a laggard when it comes to battery production
Source: Bloomberg Financial Times

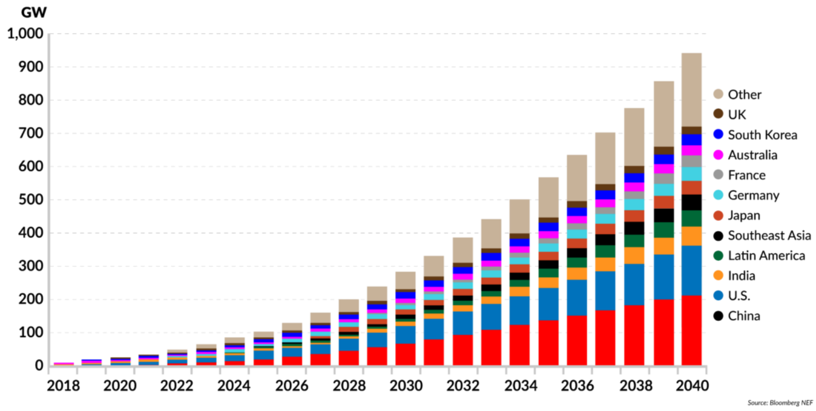

Figure 2 Energy storage could grow to the equivalent of 7 percent of the total installed global power capacity by 2040
Source: Bloomberg NEF

[23] https://www.gisreportsonline.com/r/battery-industry/

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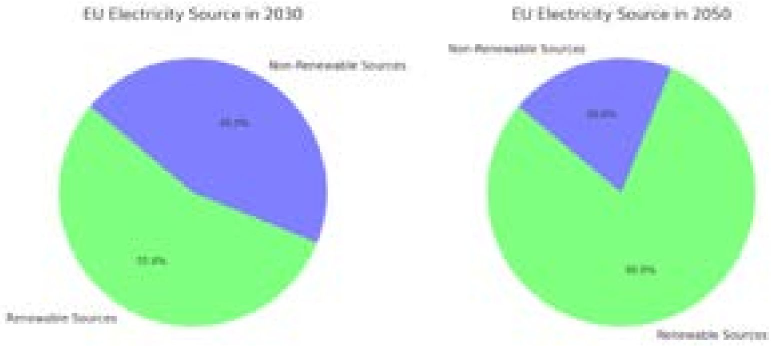

Figure 3 The source of electricity in the European Union for 2030 and 2035
Source: Batteries Europe

The battery supply chain has a very dynamic nature with Europe focusing on enhancing its production capabilities and reducing reliance on imports. Looking at the bottleneck, the global demand for battery raw materials like nickel, graphite, and lithium is expected to rise dramatically by 2040. Although China will remain a key supplier, Europe is striving for diversification and increased domestic production. Supply shortages and market tightness for certain materials are anticipated in the near future. The EU is also aiming to boost circularity in the battery value chain to lessen dependency on raw material imports.[24] [25] [26]

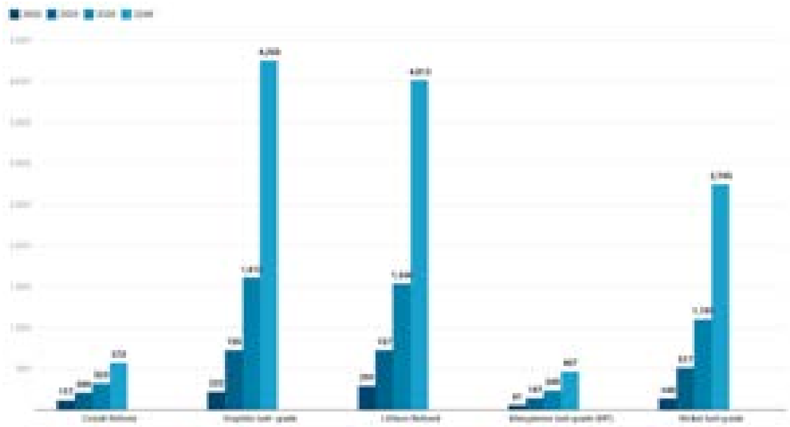

Figure 4 Forecast of battery demand globally from processed raw materials [kt]
Source: JRC analysis at https://rmis.jrc.ec.europa.eu/analysis-of-supply-chain-challenges-49b749

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[24] https://rmis.jrc.ec.europa.eu/analysis-of-supply-chain-challenges-49b749
[25] https://bepassociation.eu/our-work/sria/
[26] https://link.springer.com/chapter/10.1007/978-3-031-48359-2_7

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The European demand for battery cells is expected to outstrip EU-based battery cell production in 2030 by more than 450 GWh (rising to 850 GWh by 2035). Europe will most certainly have to rely on production originating from other regions, especially China, to address this gap. The majority of Europe's battery cells will be produced in Germany (30%), followed by Hungary, France, Poland and Sweden (up to 1,200 GWh by 2035). European-owned companies should account for 32% of battery cells produced in Europe by 2030, while the Chinese- and South Korean-owned companies will account for 33% and 20% respectively).[27]

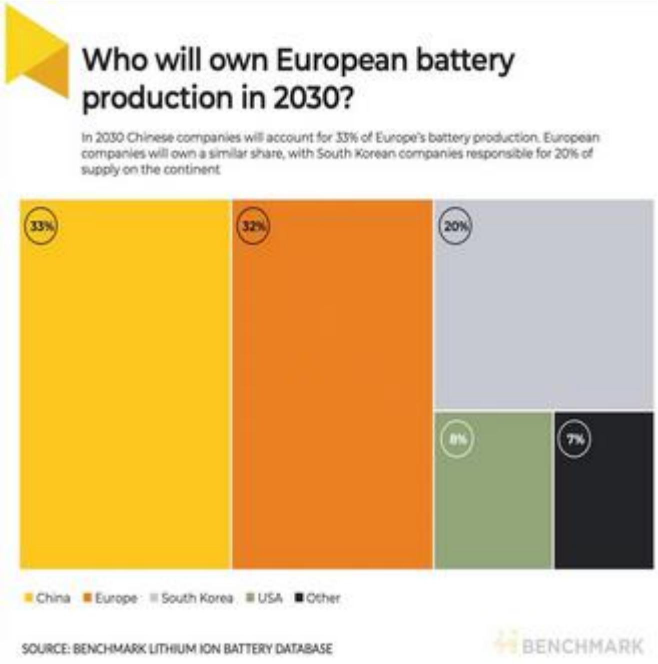

Figure 5 Who will own European battery production in 2030?
Source: Benchmark Mineral Intelligence

In the context of battery development in the EU, KPIs outline crucial battery performance characteristics for specific applications. These include technical and cost metrics such as energy density, power density, cycle life, and cost per kWh at the pack level. Recent strategies in battery research focus on improving traditional lithium-ion technologies and developing advanced concepts like sodium-ion, metal-air batteries, and solid-state batteries with polymer electrolytes. These innovations are expected to significantly enhance all KPIs, though exact timings for market readiness are still uncertain. The developments aim for substantial longevity in battery life, potentially reaching over 15,000 cycles in future years.

[27] https://source.benchmarkminerals.com/article/in-charts-the-state-of-play-in-europes-battery-market

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Technology/application	KPI goals: technological parameters	KPI goal: cost at pack level	Time to market
Generation 3	50–400 Wh/kg, 750–1,000 Wh/l	< 100 €/kWh	2025+
Li-ion batteries for mobility applications	700 W/kg, 1500+ W/l		
	3,000+ cycles (high-capacity applications)/2000+ cycles (high voltage applications)		
Generation 4	400+ – 500+ Wh/kg, 800+ – 1,000+ Wh/l	< 75 €/kWh	2030+
Li-ion batteries for mobility applications	Up to 3000 cycles		
Generation 5	500+ Wh/kg, 1,000 Wh/l	< 75 €/kWh	2030+
Li-ion batteries for mobility applications	At least 800 cycles at 80% DoD		
Li-ion batteries for stationary storage applications (commercial high-power applications) (a longer lifetime of 10,000+ cycles is defined for utility-scale applications)	500+ Wh/l 6,000+ cycles	< 75 €/kWh	2030
“Beyond lithium”	Na-ion systems: 180 Wh/kg, 500 Wh/l 15.000+ cycles Metal-air systems: 200+ Wh/kg, 800+ Wh/l 2,000–5,000 cycles	<0.05 €/kWh/cycle corresponds to 100 €/kWh for 2,000 cycles, e.g.	2030+
Solid-state battery (SSB) with polymer electrolyte	440 Wh/kg, 900 Wh/l	n.a.	2030

Table 1 Objectives and outcomes of advanced material development
“+” denotes “or more than”/“or later.” Li: lithium. Na: sodium

Source: https://link.springer.com/chapter/10.1007/978-3-031-48359-2_7/tables/2#ref-CR12
Based on https://bepassociation.eu/wp-content/uploads/2021/09/BATT4EU_reportA4_SRIA_V15_September.pdf *and* https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2022/SSB_Roadmap.pdf

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Market segment, market size (2030)	KPI goals	Comparison to KPI projections			
		Gen. 3 Li-ion	Gen. 4-5 Li-ion	Na-ion, metal-air	SSB with polymer electrolyte
Mobility: light-duty BEV (1.000 - 2.500 GWh/a) and medium to heavy-duty BEV (200 GWh/a)	450 Wh/kg, 1.000 Wh/l	(+)	(+)	(-)	(-)
	1.000 W/kg, 2.200+ W/l	(-)	n. a.	n. a.	n. a.
	2.000 cycles (light)	(+)	(+)	(+)	n. a.
	6.000 cycles (medium to high)	(o)	(+)	(+)	n. a.
	85 EUR/kWh (light),	(o)	(+)	(-)	n. a.
	150 EUR/kWh (medium to high)	(+)	(+)	(-)	n. a.
Mobility: light duty PHEV (100 – 150 GWh/a)	350 Wh/kg, 800 Wh/l	(+)	(+)	(o)	(+)
	1.750 W/kg, 3.850 W/l	(-)	n. a.	n. a.	n. a.
	>2.000 cycles	(+)	(+)	(+)	n. a.
	120 EUR/kWh	(+)	(+)	(+)	n. a.
Mobility: Off-road mobile machinery[1] (30 GWh/a) and BE or hybrid electric ship with energy battery (4 GWh/a)	350 Wh/kg, 800 Wh/l (Ship: 1.000 Wh/l)	(+)	(+)	(o)	(+)
	>6.000 cycles (Ship: > 10.000)	(o)	(-)	(+)	n. a.
	200 EUR/kWh (Ship: 75 EUR on cell level)	(+)	(+)	(+)	n. a.
Mobility: BE or hybrid electric aircraft with power battery (up to 5 GWh/a)	450 Wh/kg, (power density n/a)	(+)	(+)	(-)	(-)
	>3.000 cycles	(o)	(-)	(+)	n. a.
	200-300 EUR/kWh	(+)	(+)	(+)	n. a.
Stationary applications	>250 Wh/kg, >700 Wh/l	(o)	(+)	(-)	(+)
	>700 W/kg, >1.400 W/l	(+)	n. a.	n. a.	n. a.
	15.000 cycles	(-)	(-)		n. a.
	70 €/kWh on module level		(o)		n. a.

Figure 6 Comparing KPI goals on the demand side (market segments/applications) to KPI projections on the supply side (technology-specific)

Colours: goals are met (+, green), application goals are not met (–, red), ambiguous (o, yellow) because the KPI goals on the supply side are not clearly defined or specified. “n.a.”: KPI estimate is not available in the considered literature
Source: https://link.springer.com/chapter/10.1007/978-3-031-48359-2_7/tables/3

2.2 Battery landscape in the CEE

The battery-related KPIs benchmarking for the whole European Union, including the future expected values, has already been jointly prepared by Batteries Europe and BEPA and published in October 2023 and can be found on the Batteries Europe website.[28] In addition to that, the factsheet on the UE includes general information on the European key domestic stakeholders, strategic national battery documents, main policy goals, current research priorities, as well as details regarding EU funding instruments.

Preparing the general overview on the battery ecosystem in the European Union, we discovered that the R&D activities and the newest developments for countries like Germany, France or Norway are quite

[28]https://batterieseurope.eu/results/kpis-benchmarking-2/kpis-benchmarking-2-october-2023/

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well covered in the released publications, while Central and Eastern Europe (CEE) is often omitted. As the CEE is emerging as a dynamic hub for automotive manufacturing and fresh FDIs in the battery sector, marking it as a relevant region in Europe's battery industry landscape, analysing the KPIs and various segments of the battery value chain, we decided to concentrate on the countries of the CEE region in this report.

The surge in interest in CEE is primarily fuelled by four countries - Poland, the Czech Republic, Slovakia, and Hungary, collectively known as the Visegrád Four (V4) group. These nations are witnessing robust competition for investment in the battery sector, setting a high standard of attractiveness that even draws investments from neighbouring CEE countries such as Romania, Serbia, Bulgaria, Slovenia, and Croatia, which have also seen an uptick in battery industry investments in recent years.

The push towards EVs is driving a substantial increase in the demand for lithium-ion batteries, a critical component for this new wave of transportation. Forecasts from Bloomberg New Energy Finance anticipate a dramatic expansion in global lithium-ion battery production capacity, expecting an eightfold increase by 2027 to reach 8,945 GWh.

In the 2022 ranking, Bloomberg New Energy Finance places Poland, Hungary, the Czech Republic, and Slovakia among the top 30 countries leading the charge in the lithium-ion battery supply chain, underscoring their significant contributions to the global battery sector's value chain.[29] Europe is on track to become a powerhouse in battery production, with six of the top 10 countries located in the continent by 2027. Notably, Poland and Hungary are projected to enhance their capacities significantly, with Hungary positioned fourth globally, thanks in part to CATL's planned 100 GWh investment. Furthermore, other CEE nations, including Serbia with a 16 GWh facility in Subotica and Slovakia with a 10 GWh capacity, are set to emerge as key contributors to the international battery value chain, solidifying the region's pivotal role in powering the future of mobility.

The analysis of battery performance KPIs across various market segments reveals varying levels of alignment between current technology capabilities and market demands. For prominent sectors like light to heavy-duty vehicles, the expectations are generally aligned with the capabilities of upcoming fourth and fifth-generation lithium-ion batteries. However, there is a noticeable gap in meeting the needs of smaller market segments, such as airborne transport, where further research and development are necessary.

For large-scale mobility applications, including passenger and freight transport, sodium-ion batteries are seen as a promising solution to meet high cycle life demands. Meanwhile, off-road machinery and waterborne transport require batteries with very high energy densities and exceptionally long lifetimes, which current and near-future lithium-ion and metal-air technologies struggle to meet.

The emerging solid-state batteries, particularly those with polymer electrolytes, might address the power density requirements by 2030 for these challenging applications. Overall, while lithium-ion technologies continue to advance, there is a clear need for new battery solutions to fully enable broad electrification across all transport modes and stationary applications.

[29] https://pspa.com.pl/wp-content/uploads/2023/05/PSPA_Europe_Runs_on_Polish_Li-Ion_Batteries_Report_EN.pdf

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2.3 Raw materials in the CEE

2.3.1 Czech Republic

Considering the CEE countries, mainly the Czech Republic is developing in this segment of the battery value chain, but Hungary may follow in the future.

The Cinovec deposit in the Czech Republic stands out as Europe's largest lithium reserve, nestled near the quaint village of Cinovec, approximately 100 km northwest of Prague, close to the border with Germany. This reserve has been identified as holding a significant portion of the world's lithium, positioning it as a vital component in the rapidly expanding lithium market, crucial for the development of batteries and energy storage solutions. The project, spearheaded by European Metals Holdings, is on track to yield an impressive annual production of lithium hydroxide throughout its operational lifespan.[30]

Parallelly, the Chvaletice manganese project, orchestrated by Mangan Chvaletice, a branch of Euro Manganese, is set to deliver high-purity manganese products to Europe's lithium-ion battery industry. Praised for its unique capacity to provide a secure and ethically produced supply of high-purity manganese, the initiative focuses on reprocessing historical tailings, underscoring a commitment to environmental stewardship. Although direct state subsidies were not mentioned, the project is hinted to entail significant infrastructural advancements and job creation, likely supported by governmental aid or incentives.

CEZ, the Czech energy giant, has already allocated one billion Czech crowns (equivalent to €40.8 million or $43.5 million) for purchasing land designated for a lithium processing facility[31]. Although production specifics remain undefined, the vast lithium resources in Czechia, notably the largest in Europe, are poised to draw attention from global battery manufacturers.

Previously, Volkswagen expressed interest in establishing a gigafactory within the nation. However, given the sluggish sales of electric vehicles, the company appears to have revised its plans. Despite this, the potential for attracting other interested parties remains high.

In a significant move, the Czech government has unveiled plans to construct a gigafactory dedicated to battery production for EVs in the Karviná region, located in the country's east. Valued at CZK 200 billion, this foreign investment is expected to generate new employment opportunities, bolster energy security, and enhance the Czech Republic's competitive edge. Prime Minister Petr Fiala, while announcing this initiative, refrained from disclosing the investor's identity, citing confidentiality agreements. This development signifies a pivotal step towards strengthening the nation's position in the global battery production and electric vehicle sector.

[30] https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2024/benchmarking-international-battery-policies_2024.pdf
[31] https://www.dw.com/en/lithium-the-czech-republics-white-gold-rush/a-66821017

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2.3.2 Hungary

MOL, a major player in Hungary's energy sector, is set to harness lithium from the underground waters of southeast Hungary. This alkali metal represents a significant step towards innovative resource utilisation. MOL's experts have developed a sustainable approach, planning to extract lithium from water already brought to the surface during hydrocarbon extraction processes. This method promises a more environmentally friendly alternative to traditional mining techniques employed globally.

The ambition to make Hungarian lithium commercially available within a few years reflects a commitment to pioneering in the green energy sector. Despite the high costs associated with test production, potentially running into millions of euros, and the substantial investment required for expansion, that could cost tens of millions of Euros, MOL is eager to leverage its extensive oil industry expertise towards fostering renewable energy and advancing a low-carbon future. Acknowledging the challenges and risks involved, MOL is optimistic about the prospects of domestic lithium extraction. With long-term plans aiming for the production of several thousand tonnes of lithium annually, MOL is poised to become a significant contributor to the global lithium market, marking an important milestone in Hungary's journey towards sustainability and energy independence.

2.4 KPIs for lithium-ion batteries in CEE

By 2027, Europe is poised to become a powerhouse in battery production, home to six of the top 10 countries in this rapidly growing sector. Notably, Poland and Hungary are on track to enhance their production capabilities significantly, securing respectively the 6th and 4th spot in the global rankings. Hungary stands out with a major boost from CATL's planned investment of 100 GWh, signalling a bright future for the country's battery industry.

Within the CEE region, Serbia and Slovakia are set to make their mark on the international stage, with Serbia planning a 16 GWh facility in Subotica and Slovakia aiming for a 10 GWh capacity. These developments underscore the region's emerging role as a key contributor to the global battery value chain.

Activity in the CEE region is booming, with new investments earmarked for enhancing existing plants in several countries, including Poland, Slovakia, Hungary, the Czech Republic, Latvia, and Serbia. A standout example is the LG Energy Solution facility in Biskupice Podgórne, Poland. As currently the largest electric car battery production centre in Europe, it boasts an impressive capacity of 86 GWh. Plans are already underway to expand this to 115 GWh, further cementing the region's pivotal position in meeting the growing demand for electric vehicle batteries.

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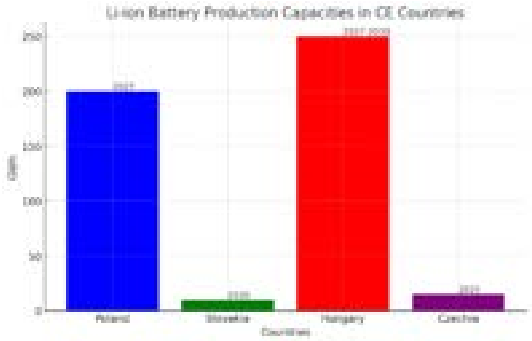

Figure 7 Li-ion Battery Production Capacities in CE Countries
After: https://pspa.com.pl/wp-content/uploads/2023/05/PSPA_Europe_Runs_on_Polish_Li-Ion_Batteries_Report_EN.pdf

2.4.1 Poland

Poland is on a path to secure the 4th spot in the global battery production rankings by 2027, aiming to more than double its current capacity to exceed 200 GWh. In support of this ambitious goal, the European Investment Bank has committed to a €480 million loan agreement with LG Chem Wroclaw Energy. This Polish subsidy of the LG Chem Group was established specifically to spearhead the development of the group's battery manufacturing capabilities in Europe. The EIB's contribution is set to cover approximately one-third of the overall project expenses, which are projected at €1.5 billion.[32]

Thanks to the European Investment Banks support, the project is poised to achieve an annual production capacity of more than 35 GWh. This capacity is sufficient to supply over 500,000 zero-emission EVs each year, marking a significant step forward in the shift from traditional fossil fuel-powered vehicles to a more sustainable, electromobility-based transportation system. With the roll-out of this new investment programme, the facility's production is expected to soar to around 65 GWh. This expansion will position the Polish operation as one of the world's leading lithium-ion cell manufacturing sites, further cementing its role in the global battery production landscape and contributing to the broader transition towards sustainable transport solutions.

In Poland, lithium-ion batteries have become a substantial part of the nation's exports, contributing more than 2.4% to the total export figures. Over the past six years, the battery sector's export value has seen an exponential increase, surging from approximately PLN 1 billion (€ 0.21 billion) in 2017 to over PLN 38 billion (€ 8.24 billion) in 2022. This thirty-eight-fold growth underscores the rapid expansion and the pivotal role of the battery industry within the Polish economy, signalling its importance on a global scale.[33]

[32] https://pspa.com.pl/wp-content/uploads/2023/05/PSPA_Europe_Runs_on_Polish_Li-Ion_Batteries_Report_EN.pdf
[33] https://pspa.com.pl/wp-content/uploads/2023/05/PSPA_Europe_Runs_on_Polish_Li-Ion_Batteries_Report_EN.pdf

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2.4.2 Slovakia

By 2030, Slovakia's annual demand for battery capacity is projected to reach a remarkable 60 GWh, with expectations to climb even further to 80 GWh by 2035. This reflects an increase in the country's energy storage needs, highlighting the growing importance of battery technology in Slovakia's economy.

2.4.3 Czech Republic

The Czech Republic recognises the potential in battery production but, interestingly, has not earmarked any specific funds for this sector in its National Plan. Instead, the government has prioritised battery recycling, acknowledging the challenges and critical importance of this process. Given Europe's limited and rare resources, recycling becomes not just a matter of environmental concern but also a strategic necessity.

The approach to battery policy in the Czech Republic is expected to be shaped by a combination of factors. These include the country's overarching energy goals, environmental considerations, economic strategies, and its commitment to international collaborations. Furthermore, aligning with the European Union's initiatives will likely play a significant role in shaping the Czech Republic's direction in the battery industry, reflecting a balanced consideration of local resources and global commitments.

2.4.4 Hungary

The country primarily relies on FDIs, with state support being offered on a case-by-case basis. A significant shift is anticipated with the roll-out of the Strategy for Industrial Development, which was ratified by the government in March 2024. This strategy delineates a series of measures aimed at fostering companies with intricate development agendas. Specifically, it underscores the importance of bolstering the growth of domestic suppliers and the industrial application of R&D endeavours.

Furthermore, the strategy outlines initiatives to alleviate operational costs and tax burdens for companies engaged in industrial production, thereby creating a more conducive environment for their basic functions. From 2025, new support programmes designed to stimulate the manufacturing and services sectors will be introduced.[34]

A crucial aspect of this strategy is its commitment to bridging the gap between R&D and industrial support policies. This integration aims to ensure that developments eligible for support receive comprehensive backing throughout the entire value chain from research inception to market introduction. Special emphasis is placed on prioritising marketable developments that promise higher added value, particularly within Hungary.

While the strategy refrains from specifying the exact level of aid to be provided, it hints at a tailored approach to aid allocation, taking into consideration the central budget's capacity to absorb such expenditures. This approach signifies a thoughtful balance between encouraging innovation and managing fiscal constraints.

[34] https://www.portfolio.hu/gazdasag/20240409/nagy-bejelenteseket-tett-nagy-marton-679381

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2.5 Conclusions

In conclusion, Central and Eastern Europe has emerged as a vibrant nexus for automotive manufacturing and a magnet for foreign direct investments (FDIs) in the burgeoning battery sector. This development is not merely a reflection of current economic trends but a testament to the strategic foresight of nations within the Visegrád Four (V4) - Poland, the Czech Republic, Slovakia, and Hungary - as well as other CEE countries like Romania, Serbia, Bulgaria, Slovenia, and Croatia. These nations have recognised the pivotal role of advanced battery technologies in powering the next generation of EVs, thereby contributing to the global shift towards sustainable mobility.

The technological feasibility of meeting the set KPIs for lithium-ion battery production within the region is high. With substantial investments and a focus on enhancing production capacities - as seen with Hungary's planned 100 GWh investment from CATL and Poland's ambitions to exceed 200 GWh by 2027 - these countries are well-positioned to lead in the battery production domain. The expansion of LG Energy Solution's facility in Poland to 115 GWh and the development of new capacities in Serbia and Slovakia further underscore the region's commitment to establishing a strong foothold in the global battery value chain.

Fields of innovation extend beyond mere production capacities. The strategic focus on battery recycling, especially in the Czech Republic, addresses the critical challenge of resource scarcity and environmental sustainability. This approach, coupled with the leveraging of lithium and manganese reserves for battery production, illustrates a comprehensive strategy that balances industrial development with environmental stewardship.

Looking forward, the CEE region must continue to cultivate a robust ecosystem for R&D and innovation, particularly in battery technology. The Strategy for Industrial Development approved by Hungary in March 2024 outlines a proactive approach to supporting domestic suppliers, reducing operational costs, and bridging the gap between R&D and industrial application. This strategy highlights the necessity of integrating technological advancements across the entire value chain, from research inception to market entry, ensuring that developments with higher added value are primarily implemented within the region.[35]

To maintain its trajectory towards becoming a global leader in battery production and technology, the CEE region must navigate the complexities of technological advancement, economic strategy, and environmental sustainability. Continued investment in R&D, coupled with strategic international collaborations and adherence to EU initiatives, will be crucial. By fostering innovation and prioritising sustainable practices, the CEE can not only meet its set KPIs but also set new benchmarks in the global battery industry, driving the transition towards a more sustainable and electrified future.

[35] https://www.portfolio.hu/gazdasag/20240409/nagy-bejelenteseket-tett-nagy-marton-679381

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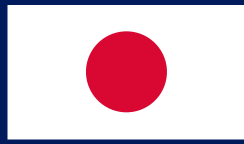
Battery Innovation System of **Japan**



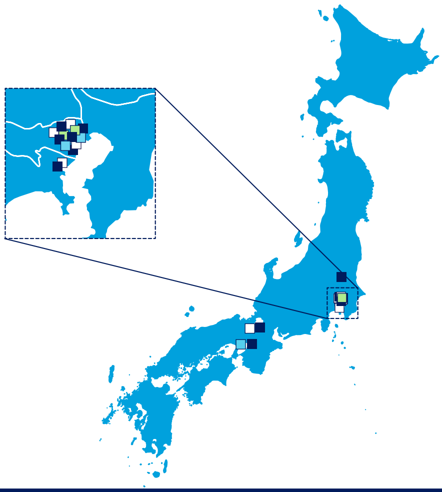
Main Players

POLITICAL ORGANISATIONS

- Ministry of Economy, Trade and Industry (METI)
- Ministry of Education, Culture, Sports, Science and Technology (MEXT)
- The New Energy and Industrial Technology Development Organization (NEDO)

RESEARCH ORGANISATIONS

- National Institute of Advanced Industrial Science and Technology (AIST)
- National Institute for Materials Sciences (NIMS)
- Kyoto University
- Waseda University
- Tokyo Institute of Technology



INDUSTRY ASSOCIATIONS

- Consortium for Lithium Ion Battery Technology and Evaluation Center (LIBTEC)
- The Battery Association of Japan (BAJ)
- The Battery Association for Supply Chain (BASC)

COMPANIES

- AESC
- Asahi Kasei (Materials)
- GS Yuasa International Ltd (Batteries)
- Mitsubishi Chemical Corporation (Materials)
- Panasonic Energy (Batteries)
- Prime Planet Energy & Solutions (Batteries)
- Resonac (Materials)
- Sumitomo Metal Mining (Materials)

Strategic Documents

- **2018**: **5th Strategic Energy Plan**
- **2020**: **Green Growth Strategy through Achieving Carbon Neutrality in 2050**
- **2021**: **Energy White Paper**; **6th Strategic Energy Plan**
- **2022**: **Battery Industry Strategy**

Policy Goals

2030

- **Domestic production capacity** of EV and energy storage batteries at 150 GWh/year
- **Annual production** of 600 GWh (20% share of the global battery market)
- **All-solid-state batteries** full-scale commercialised
- **GHG emissions in Japan** reduced by 46% from 2013 levels
- **Recruitment:** 30.000 trained workers for battery manufacturing and supply chains
- **Prices:** In-vehicle battery pack price of max. 10.000 yen/kWh, a system price of max. 70.000 yen/kWh for household storage batteries with solar panels, and a system price of max. 60.000 yen/kWh for storage batteries installed in factories and other business sectors

2035

- **Innovative battery chemistries** (such as fluoride batteries, zinc batteries and polyvalent ion batteries) commercialised
- **Electrified vehicles** (EV, FCV, PHEV, and HV): 100% of new sold passenger vehicles

2050

- **Carbon neutrality**

Country Specific Information

As an early technology leader, Japan began funding lithium-ion batteries, especially the development of solid-state batteries and certain types of alternative batteries. Total battery funding by NEDO between 2009–2022 (for Solid-EV and RISING 1, 2 and 3 projects) is estimated by ca. 58 billion yen. In the Battery Industry Strategy (2022), the government revised Japan's conventional battery strategy from solid-state batteries to new-generation high-performance batteries. It aims to strengthen the domestic production base of liquid-electrolyte lithium batteries, increase production capacity, and secure the domestic and global market for lithium-ion batteries so that Japanese companies do not further lose the market competition before solid-state batteries are commercialised. Japan imports about 90% of its primary energy requirements and is vulnerable to energy supply disruptions overseas. In recent years, new energy security factors have been studied. These include expanded use of renewable energy to respond to climate change and cyber security improvements that will enable mass deployment of renewable energy.

Research Priorities

Next-generation batteries + solid-state batteries + innovative and enhanced batteries for EVs from material design to battery system design + fluoride battery + zinc-anode battery + high-performance batteries, materials and production technology + reduction of the amount of critical raw materials needed + reduction of GHG during the production process + recycling technology

Funding Instruments

TIME	FUND	FOCUS	BUDGET
2021–2030	NEDO: Green Innovation Fund (The development of next-generation batteries/motors)	High-performance batteries, battery matherials, recycling technology	120.5 billion yen
2021–2025	NEDO: RISING-3	Next-generation batteries for EV	2.4 billion yen in 2023
2021–2022	METI programmes to expand lithium-ion battery production	• Large-scale production/ recycling technology • Clean Energy Vehicles and Infrastructure (to encourage the purchase of EVs, PHEVs and FCVs and the development of charging and hydrogen fuel infrastructure) • Acceleration of introducing stationary batteries aiming to increase the ratio of renewable energy	100 billion yen 53 billion yen 13 billion yen in 2021
2023–2027	NEDO: SOLID-Next	Material evaluation technology for all-solid-state batteries	1.8 billion yen in 2023

Effective: May 1, 2024 / 1 Yen = 0,0060 Euro

Batteries + Europe

Batteries Europe Secretariat is an EU-funded project that has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement N. 101069676.

VDI | VDE | IT

3.1 Overview

Japan has a rich history of backing the advancement of lithium-based batteries. Through institutions like NEDO (New Energy and Industrial Technology Development Organisation) and funding agencies under the Ministry of Economy, Trade and Industry (METI), as well as those under the Ministry of Education, Culture, Sports, Science and Technology (MEXT), collaborative research programmes involving academia, government, and industry have received substantial funding. This is reflected by its global patent share (2016-2020) of 37.1%.[36]

Despite Japan's strong support for solid-state batteries in the past decade, these alternatives are not yet poised to replace liquid LiBs. The Japanese liquid LiBs market share has strongly declined since 2015 to Chinese and Korean manufacturers, who benefited from robust government support for liquid batteries. To counter this trend and mitigate the risk of increasing dependence on foreign suppliers, METI's Battery Innovation Strategy has outlined three main targets[37]:

- Establish the manufacturing base of 150 GWh for liquid LiBs by 2030.
- Secure a 20% global market share (even if it expands to 3000 GWh in 2030) for Japanese companies.
- Secure technology leadership in solid-state batteries through full-scale commercialisation around 2030.

Specific measures related to technology, business, market and environment are set to achieve these target KPIs	Target by 2030
Energy density (high capacity)	700-800Wh/l (pack)
Power density (high capacity)	500 W/kg (pack)
Energy density (high power)	200-300 Wh/l (pack)
Power density (high power)	2000-2500 W/kg (pack)

Table 2 Japanese KPIs for next-generation batteries (including SSBs) until 2030
Source: : NEDO, "Green Innovation Fund, Funding guideline of development of next-generation batteries/motors projects https://www.nedo.go.jp/content/100939533.pdf in Japanese

3.2 KPIs for lithium-ion batteries

The Japanese government acknowledges the key role of batteries to achieve carbon neutrality in 2050. To tackle Japan's loss of competitiveness, a shift of priorities towards securing a domestic manufacturing base of 150 Gwh by 2030 is targeted, which represents a 7.5 fold increase with respect to 2022 production (20 Gwh).[38] Several funding programmes, mostly based in public-private partnerships, have

[36] S. Annegret, T. Hettesheimer, C. Neef, T. Schmaltz, S. Link, M. Stephan, J. L. Heizmann and A. Thielmann, "Alternative Battery Technologies Roadmap 2030+," Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe, 2023
[37] METI, "Battery Industry Strategy," 31 August 2022. [Online]. Available: https://www.meti.go.jp/policy/mono_info_service/joho/conference/battery_strategy/battery_saisyu_torimatome.pdf
[38] Renewable Energy Institute, Battery Storage to Efficiently Achieve Renewable Energy Integration (Tokyo: REI, 2023), 58 pp

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been launched to support battery production and to stimulate domestic demand for both mobility and stationary applications.[39]

KPI	Target by 2030
Battery cost	<10,000 JPY/kWh (c. 64€/KWh)[40]
Domestic production capacity	150 GWh/year[37]
Global market share	600 GWh (20% of total)[37]
Global patent share	42%[36]

Table 3 Japanese KPIs for Li-ion batteries.
Source: See references in the table

3.3 KPIs for solid-state batteries

Japan aims to maintain its leadership in ceramic-based solid-state batteries (with a high focus in sulfide-based technology). Under the "Green Innovation Fund" an energy density of more than two times current levels i.e. over 700-800 Wh/L is targeted, together with the establishment of a trial production line for stacked soft-pack ASSBs. Examples of targeted specifications for sulfide- or oxide-based ASSBs in the SOLID-EV NEDO plan are (although specific targeted specifications of a battery pack will be set during the project)[41]:

KPI	Target by 2030
Full-scale commercialisation	Achieve
Technology leadership	Maintain
Energy density	700-800Wh/l (pack)
Specific energy	400 Wh/kg (pack)
Energy density (high power)	200-300 Wh/l (pack)
Power density(high power)	2500 W/kg (pack)
Autonomy for EVs	480 km
Cost	63.7€/kWh
Charge time	20 minutes (rapid), 6 hour (normal)
Calendar lifetime	15 years
Cycle lifetime	2000 cycles
Vehicle temperature range	-30-60ºC

Table 4 Japanese KPIs for solid-state batteries
Source: NEDO, "The basic plan of Development of Material Evaluation Techniques for Advanced and innovative Batteries (Phase 2) https://www.nedo.go.jp/content/100881230.pdf

3.4 KPIs for alternative battery technologies

[39] Analysis of international public Battery Strategies focusing on Germany, EU, USA, South Korea, Japan and China. Fraunhofer ISI 2024
[40] https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/pdf/ggs_full_en1013.pdf
[41] Analysis of international public Battery Strategies focusing on Germany, EU, USA, South Korea, Japan and China. Fraunhofer ISI 2024

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Research on Zn-air batteries and fluoride-ion shuttle batteries has been conducted within the RISING2 project (2016-2020).[42] The RISING3 project[43] has widened the focus towards other Zn cell chemistries (for example cathodes based on carbon materials) and maintains the focus on fluoride-ion shuttle batteries. The latter are based on conversion reactions in which a metal anode is combined with a metal fluoride cathode. The aim is to achieve commercialisation in 2035. While these technologies offer advantages in safety and cost reduction, challenging KPIs have been set.

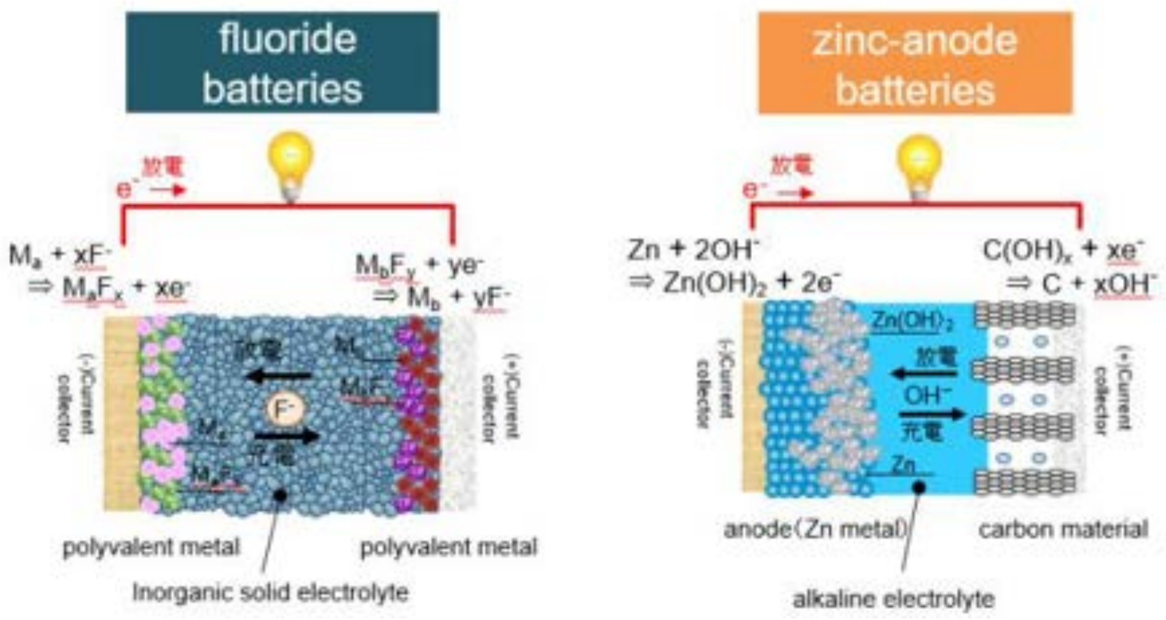

Table 5 Fluoride Battery and Zinc-Anode Battery
Source: https://www.nedo.go.jp/english/activities/activities_ZZJP_100193.html

[42] https://www.rising.saci.kyoto-u.ac.jp/rising2/en/
[43] https://www.nedo.go.jp/english/activities/activities_ZZJP_100193.html

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Fluoride batteries:

KPI	Target by 2025	Target by late 2030s
Specific energy	>500 Wh/kg (cell level)	>400 Wh/kg (pack level)
Energy density	1000 Wh/l (cell level)	900 Wh/l (pack level)
Charging rate	>1 C	-
Cycle life	>90 % SoH after 100 cycles	>2000 cycles
Rapid charging time	-	<20 mins
Calendar lifetime	-	>15 years
Battery cost	-	<10000 yen/kWh (64€)

Table 6 Japanese KPIs for Fluoride batteries
Source: https://www.rising.saci.kyoto-u.ac.jp/en/

Zinc-anode batteries:

KPI	Target by 2025	Target by late 2030s
Specific energy	>200 Wh/kg (cell level)	>200 Wh/kg (pack level)
Energy density	>500 Wh/l (cell level)	>400 Wh/l (pack level)
Charging rate	>3 C	
Cycle life	>90 % SoH after 100 cycles	>2000 cycles
Rapid charging time	-	<20 mins
Calendar lifetime	-	>15 years
Battery cost	-	<10000 yen/kWh (64€)

Table 7 Japanese KPIs for Zn-anode batteries
Source: https://www.rising.saci.kyoto-u.ac.jp/en/

3.5 KPIs for battery recycling

Japan places a high emphasis on recycling, targeting high recovery rates for critical battery materials such as lithium, nickel, and cobalt through a domestic recycling system by 2030 in order to achieve a cost equivalent to market price.[44],[45]

[44] METI, "Battery Industry Strategy," 31 August 2022.[Online]. Available: https://www.meti.go.jp/policy/mono_info_service/joho/conference/battery_strategy/battery_saisyu_torimatome.pdf
[45] NEDO, "Green Innovation Fund, Funding guideline of development of next-generation batteries/motors projects (Japanese Only)," 11 November 2021. [Online]. Available: https://www.nedo.go.jp/content/100939533.pdf

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Material	Recovery Rate Target on metal basis
Lithium	≥70%
Nickel	≥95%
Cobalt	≥95%

Table 8 Japanese KPIs for metal recovery rates in batteries
Source: NEDO, "Green Innovation Fund, Funding guideline of development of next-generation batteries/motors projects https://www.nedo.go.jp/content/100939533.pdf in Japanese

3.6 Conclusions

Japan's strategic position in the battery technology and recycling industry demonstrates a proactive and forward-thinking approach to addressing the challenges of energy storage and environmental sustainability. The country's public battery strategy highlights a strong commitment to research and development, aiming for leadership in next-generation battery technologies, including solid-state and alternative battery technologies. Japan's goals for 2030 indicate a significant push towards reducing the cost of lithium-ion batteries, expanding domestic production capacities, and achieving substantial global market share. Additionally, Japan is also committed to sustainability but also aims to mitigate raw material supply risks.

Technological feasibility assessments for the KPIs vary, with ambitious targets for new and emerging technologies such as fluoride ion shuttle and zinc-anode batteries. These ambitious goals reflect Japan's strategy to lead in innovation and secure a competitive edge in the global battery market.

Japan's policies and investments in battery technology and recycling demonstrate a balanced approach to achieving economic growth, environmental protection, and energy security. Estimates consider that 22.000 workers will be in charge of battery manufacturing by 2030 and 30.000 workers will be involved in the entire battery supply chain (including materials). The country's efforts to foster collaboration between government, industry, and academia are crucial for realising these ambitious targets.

This project has received funding from the European Union's Horizon Europe
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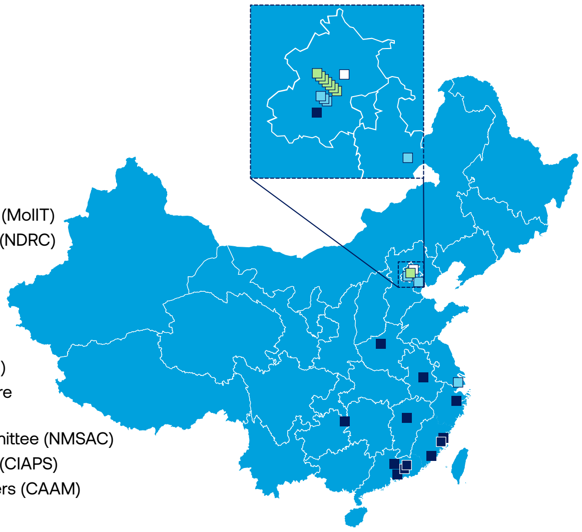
Battery Innovation System of China

Main Players



POLITICAL ORGANISATIONS

- Central Committee
- State Council
- Ministry of Science and Technology (MoST)
- Ministry of Finance (MoF)
- Ministry of Industry and Information Technology (MoIIT)
- National Development and Reform Commission (NDRC)
- National Manufacturing Strategy Advisory Committee (NMSAC)

INTERMEDIARY ORGANISATIONS

- China Electric Vehicle Association (China EV 100)
- China Automotive Technology & Research Centre (CATARC)
- National Manufacturing Strategy Advisory Committee (NMSAC)
- Chinese Industry Association of Power Sources (CIAPS)
- Chinese Association of Automobile Manufacturers (CAAM)

RESEARCH ORGANISATIONS

- 15 State Key Laboratories
- China Society of Automotive Engineers (China SAE)

COMPANIES

- BTR New MATERIAL (Materials)
- BYD (Batteries)
- CALB (Batteries)
- CATL (Batteries, Recycling, Raw Materials)
- CNGR (Materials)
- Easpring (Materials)
- EVE (Batteries)
- Gangfeng Lithium (Raw Materials, Batteries, Recycling)
- GEM (Recycling)
- Gotion High Tech (Batteries)
- Huayou Cobalt (Raw Materials)
- Ronbay (Batteries)
- Xiamen Tungstan (Materials)

Strategic Documents

2015
- Made in China 2025
- Automotive Power Battery Industry Specification Conditions

2017
- Action Plan for the Development of Automotive Power

2020
- Energy-Saving and NEV Technology Roadmap 2020
- EV Traction Battery Safety Requirements (GB 38031-2020)

2021
- 14th Five-year Plan (2021-2025)
- Industrial Development Plan for Electric Vehicles 2021-35

Country Specific Information

Since 2015, China has been rapidly innovating its domestic battery technology to catch up with the leading countries. After maturing the entire value chain from raw materials to component manufacturing, cell and pack production and EV application with the help of a comprehensive government subsidy programme, China has become the largest market share in the battery industry and started to adopt a more technology-open approach. It accounts for around 75% of global battery cell production capacity, 70% of cathode capacity and 85% of anode capacity. To strengthen its global market position, China now needs to focus not only on performance targets such as energy density, but also on qualitative parameters such as safety, management of emissions in the manufacturing process or recycling. Although most KPIs are still set by ministries, we are now seeing an increasing influence of intermediary organisations and key entrepreneurs on policy making.

Research Priorities

+ Liquid-lithium + solid-state + alternative batteries + lithium-manganese-cobalt-oxide (NMC) batteries + hydrogen energy and fuel cell technologies + new materials e.g. CO-free cathode, nano-Si/C anodes, different kinds of both inorganic and polymer electrolytes, solid separators and super binders + sodium-ion batteries + energy storage for industrial plants and households + fast stacking, smart sensors, multi simulation and digital factories of critical raw materials needed + reduction of GHG during the production process + recycling technology + digital twins + cell design + life cycle assessment + large cylindrical battery + large energy storage cell

Policy Goals

2025

- **Raw materials:** Improve supply of lithium, nickel and cobalt by strengthening domestic resource exploration and recycling, as well as optimise overseas supply
- **Energy dencity:** Achieve a breakthrough of a new power battery system, e.g., lithium-sulfur batteries, metal-air batteries and solid-state batteries with energy density on cell level reaching 500 Wh/kg
- **Recycling:** Reach international advanced levels in actual recycling - recovery rate for nickel, nobalt, manganese ≥ 98%, for lithium ≥ 85%, for rare earths and valuable metals ≥ 97%
- **Costs:** Halve the cost of fuel cell systems to CNY 4.000/kW (this target was set in 2019, but experts predict it will reach CNY 1.000/kW in 2025)

2030

- **CO_2 emissions:** Reduce the emissions by 65% per unit of GDP compared to 2005 levels
- **Fuel cell vehicles:** One million fuel FCEV on the road

2035

- **Electric vehicles:** Achieve more than 50% NEV sales for total vehicle sales and more than 95% of NEV pure electric
- One million FCV on the road between 2030 and 2035

2060

- **Carbon neutrality**

Funding Instruments

Source: Fraunhofer ISI, Meta-Roadmapping of International Public Battery Strategies (to be published)

TIME	FUND	FOCUS	BUDGET
2021-2026	National Key R&D Program "New Energy Vehicles"	▪ Efficiency and performance of electric vehicles ▪ All-solid-state lithium-metal battery technologies	CNY 0,86 billion (ca. CNY 47,8 million for battery projects)
2021-2024	National Key R&D Program "High Safety All-climate Power Battery System Technology"	▪ High safety ▪ All-climate battery technologies	CNY 60 million
2021-2025	National Key R&D Programme: High-end Functional Material	▪ High energy density lithium metal-based secondary batteries	CNY 0,659 billion (ca. CNY 18,8 million for battery projects)
2021-2025	National Key R&D Programme: Technology of Energy Storage and Smart Grid	▪ High safety, long cycle life, low-cost LIB, solid state LIB as well as metal-sulfur based batteries for energy storage and smart grid	CNY 0,667 billion (ca. CNY 100 million for battery projects)

June 20, 2023; 1 CNY = 0,13 EUR

Batteries + Europe

Batteries Europe Secretariat is an EU-funded project that has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement N. 101069676.

VDI | VDE | IT

4.1 Overview

China, recognised as the world's largest consumer of commodities, is set to invest a staggering US$ 2.3 trillion this year in thousands of significant projects, as reported by Bloomberg[46]. In the realm of battery manufacturing, European countries contributed to 14% of the global capacity in 2022. Although China remains the market leader, its dominance is expected to slightly diminish, decreasing from 77% in 2022 to 69% by 2027.[47]

In 2020, the State Council of China unveiled the New Energy Vehicle (NEV) Industry Development Plan spanning from 2021 to 2035. This comprehensive programme aims to guide the high-quality development of the NEV industry, setting a clear policy framework for the upcoming years.

For 2022, China allocated over 38.4 billion yuan (approximately €4.9 billion) in subsidies to foster NEVs, marking a gradual increase from previous years. This is a slight increase from 37.5 billion yuan (approx. €4.7 billion) in 2021 and 31.3 billion yuan (approx. €4.0 billion) in 2020. This financial commitment underscores China's dedication to electrifying its transportation sector.

The NEV Development Plan outlines five strategic tasks critical to advancing the industry:

- Enhance the capacity for technological innovation.
- Establish a new industrial ecosystem supportive of NEVs.
- Encourage the integrated development of related industries.
- Upgrade infrastructure to support NEVs.
- Foster international cooperation and openness in the NEV sector.

Among its key measures, the plan emphasises the importance of creating an efficient power battery recycling system. This includes implementing a scheme that holds producers responsible for their vehicle batteries, bolstering the management of battery traceability, supporting the innovative use of batteries beyond their primary life, and advancing technologies for safe and effective recycling and extraction of valuable elements from end-of-life power batteries. These ambitious goals reflect China's strategic direction toward electrification and sustainable transportation, signalling a transformative period for the global automotive and battery industries. Additionally, the plan advocates for strengthening the power battery value chain, urging companies to boost the production capacity of critical materials like lithium, nickel, cobalt, and platinum.

[46] https://www.mining.com/web/the-fossil-fuel-elephant-in-the-electrification-room/
[47] https://pspa.com.pl/wp-content/uploads/2023/05/PSPA_Europe_Runs_on_Polish_Li-Ion_Batteries_Report_EN.pdf

This project has received funding from the European Union's Horizon Europe
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4.2 Goals by 2025

Following policy goals for batteries by 2025 have been defined for China: [48,49]

- Substantial exports of power batteries and driving motors, as part of the "Made in China 2025" initiative.
- Improved supply of lithium, nickel and cobalt by strengthening domestic resource exploration and recycling, as well as optimise overseas supply.
- A technological leap in power battery systems, including lithium-sulphur, metal-air, and solid-state batteries, aiming for an energy density on cell level reaching 500 Wh/kg.
- Actual vehicle recycling rate that aligns with international advanced level standards: recovery rate for nickel, cobalt, manganese ≥ 98%, for lithium ≥ 85%, for rare earths and valuable metals ≥ 97%.
- Cost reduction of fuel cell systems to CNY 4.000/k0W.[50]
- Electric vehicle (EV) sales constituting about 20% of all new vehicle sales.

4.3 Goals by 2035

Following policy goals for batteries by 2035 have been defined in China: [51]

- NEV shall account for more than 50% of total vehicle sales, with pure electric accounting for more than 9 % of NEV and vehicles in public sector fully electrified (NEV Industry Development Plan).
- Power battery technology is expected to be in an international leading position with complete, independent and controllable industry chain.

4.4 R&D Priorities

Advancements in the battery sector are characterised by significant breakthroughs in essential materials and components. These developments are geared towards achieving batteries with high capacity and energy density, enhanced safety, and prolonged cycle life.

The focus on the value chain encompasses a pivotal shift towards technological transformation, with a set benchmark test slated for 2025, and the goal for commercialisation targeted for 2030. This strategic timeline underscores the industry's commitment to refining battery technology before it is rolled out on a large-scale.

In terms of application, the emphasis is placed on electric vehicles (EVs) across all categories, from compact cars to commercial vehicles, alongside the deployment of batteries in large-scale energy

[48] C ina's e nergy e i le Industrial Development Plan for 2021 to 2035
[49] https://theicct.org/wp-content/uploads/2021/12/China-new-vehicle-industrial-dev-plan-jun2021.pdf
[50] https://www.electrive.net/2019/09/04/china-will-eine-million-brennstoffzellenfahrzeuge-bis-2030/
[51] https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2024/benchmarking-international-battery-policies_2024.pdf

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storage systems. This broad application spectrum highlights the versatile potential of battery technology in revolutionising both transportation and the way we store and use energy.

2021 National Key R&D Programme	Total Programme Budget	Funding Priorities (budget breakdown to battery projects)
High-end Functional and Smart Materials	4 years duration, 6 key technology tracks, 35 projects, ¥0.659 billion funding	High energy density lithium metal-based secondary batteries approx. ¥18.8 million funding
New Energy Vehicles	5 years duration, 6 key technology tracks, 18 projects ¥0.86 billion funding	All solid-state LIB technology, approx. ¥47.8-million funding

Table 9 China´s 2021 National Key R&D Programme
Source: https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2024/benchmarking-international-battery-policies_2024.pdf

4.5 Outlook to Taiwan

In July 2021, Taiwan unveiled its National Development Plan for the period of 2021 to 2024. This strategic document highlights the importance of vehicle batteries, categorising them under "strategic stockpile industries". It identifies these batteries as crucial industrial materials, pivotal for bolstering domestic supply chains and achieving technical independence. The plan emphasises the goal of advancing the technology and distinctiveness of vehicle batteries, with an eye toward meeting the diverse needs of the market. Furthermore, it aims to strategically broaden the application of vehicle batteries across various sectors. To this end, Taiwan has committed a substantial investment of $168.3 billion to support the electrification of transportation vehicles, marking a significant step towards sustainable mobility and energy innovation.[52]

4.6 KPIs for lithium-ion batteries by 2025

The 2018 National Key Research and Development Programme underscores a strategic focus on enhancing battery technology, targeting a notable enhancement in product performance. This includes ensuring high safety standards, extending the battery cycle life, and reducing costs to make the technology more accessible.

The programme places a strong emphasis on optimising the value chain, aiming for large-scale automated production and application. This approach is designed not only to streamline manufacturing processes but also to support the secondary use and recycling of batteries. The goal is to foster the

[52] https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2024/benchmarking-international-battery-policies_2024.pdf

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development and industrialisation of new lithium-ion power batteries, with an ambitious target to achieve widespread applications by 2030.

In terms of practical applications, the programme is dedicated to expanding the use of the advanced batteries across various sectors. This includes their deployment in electric vehicles (EVs) of all sizes and categories, as well as their integration into large-scale energy storage solutions. The focus on such broad applications reflects a comprehensive vision to leverage battery technology in driving the future of sustainable mobility and energy management.

The benchmarking document on international battery policies of Fraunhofer ISI indicates the following KPIs for lithium-ion batteries by 2025[53]:

Battery safety until 2025: In the EV Traction Battery Safety Requirements (GB 38031-2020), in case of cell thermal runaway, the system should operate without fire and explosion for 5 minutes, leaving time for occupants to escape safely. It looks quite ambitious; conventional high-energy batteries contain combustible liquid electrolyte, which makes them prone to fire in the event of misuse (physical damage or short circuit). The goal should lie in stopping the spread of fire and prevent explosive events.

Specific energy (for semi-solid-state Li-ion and Ni rich Mn based Li-ion cells) ***until 2025***: 400 Wh/kg (cell level). It looks ambitious; cell-level specific energy of >350 Wh/kg is unlikely to be achieved with conventional (non Li-metal) Li-ion technology based on intercalation/insertion type active materials.

Specific power until 2025: ≥1 300 W/kg

Charging rate (for fast charging type) ***until 2025***: <15 min. It looks ambitious; charging rates >4C are feasible for high-power batteries, but challenging to implement in high-energy cells and likely to lower cycle life and result in lower charging efficiency due to resistive losses (accompanied by heat generation).

Cycle life until 2025: ≥ 2 000 cycles. It looks realistic; high cycle numbers >2000 cycles are possible with LIBs but may not be required for EV applications. However, stationary energy storage systems (ESS) or heavy-duty electric vehicles (i.e. trucks) require these high cycle numbers.

Calendar lifetime until 2025: ≥ 10 years. It looks realistic; the warranty on most EV batteries is 8 years. Longer calendar life is desirable in ESS applications.

Battery cost (cell level) ***until 2025***: ≤ 0.6 ¥/Wh (≤76 €/kWh). It looks realistic; cell level costs below 86 €/kWh will be challenging to realise on the short-term, as battery raw material prices are currently surging. Given the strong battery value chain and raw material availability in China, this mid-term target is realistic, especially for Ni, Co-free cell chemistries.

[53] https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2024/benchmarking-international-battery-policies_2024.pdf

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4.7 KPIs for solid-state batteries by 2025 and 2030

The benchmarking document on international battery policies of Fraunhofer ISI indicates the following KPIs for solid-state batteries by 2025 and 2030[53]:

Specific energy until 2025: 500 Wh/kg (cell level). For semi-solid-state Ni-rich cathode (cell ≥ 400 Wh/kg). It looks realistic; this specific energy target is achievable with lithium-metal based SSBs.

Cycle life until 2025: ≥ 5,000 cycles/12 years. It looks ambitious; achieving high cycle numbers will be challenging for SSBs.

Battery cost (cell level) ***until 2025***: ≤ 1.5 ¥/Wh (≤190 €/kWh). It looks realistic; the target battery cost for SSBs is high (in contrast to roadmap targets the other world regions). However, this cost target seems realistic, given the expensive raw materials (Li metal and solid electrolyte), novel processing routes, and more demanding processing environment.

Specific energy until 2030: 500 Wh/kg (cell level), 400 Wh/kg (pack/module level). This energy content target for Li-metal-based or anode-free SSBs is realistic.

Cycle life until 2030: ≥ 6,000 cycles/15 years. It looks ambitious; achieving high cycle numbers will be challenging for Li-metal based SSBs due to potential immobilisation of electrochemically active lithium and resistance build-up due to chemo-mechanics of the solid-solid interfaces.

Battery cost (cell level) ***until 2030*** ≤ 1.1 ¥/Wh (≤139 €/kWh). It looks realistic; with ongoing ramp-up (economies of scale) and improving technological Ni maturity of SSBs, this cost target for 2030 seems realistic.

The mass production capacity of solid-state batteries is estimated to reach 25 GWh in 2025 and 250 GWh in 2030.

4.8 KPIs for sodium-ion batteries by 2025

The Chinese government is keenly fostering the development of the country’s nickel-metal hydride (NiMH) battery industry, aiming to ensure a stable battery supply while spearheading the advancement of next-generation battery technologies. In pursuit of these objectives, Chinese companies are engaging in strategic partnerships, merging capital and technology to expedite the journey towards early mass production.

However, the ecosystem for enhancing NiMH batteries through advanced electrode materials and electrolytes is still evolving within China. This scenario is poised to accelerate collaboration among Chinese supply chain entities, enhancing the momentum towards achieving mass production. Notable industry milestones include strategic collaborations, such as the partnership between Natrium Energy and local chemical firms to scale-up the production of electrolytic solutions, and significant investments by Great Power, a frontrunner in lithium-ion batteries (LiBs) and energy storage systems, into a start-up specialising in hard carbon anodes.

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Despite the progress, establishing a robust supply chain for NiMH batteries in China, ensuring consistent quality, and securing cost benefits will require time. According to Verified Market Research, the global market for NiMH batteries is projected to reach a value of US$2.5 billion annually by 2028.[54]

While the current lithium-ion battery (LiB) market continues to grow, the future of the NiMH battery market remains uncertain, with its transformation into a major market not immediately forthcoming. Nevertheless, in countries like India and China, where there is substantial demand for electric mobility and renewable energy, the NiMH batteries, known for their cost effectiveness, hold considerable promise. The potential for these batteries is significant, especially if costs are reduced and robust supply chains are established to cater to the needs of these vast markets. Such developments could lead to broader applications and geographic reach for NiMH batteries.

China, with its supportive policies, established battery industry, and vast domestic market, is in a prime position to nurture the NiMH battery sector. The country is strategically planning to seize industry leadership by setting relevant technology standards and implementing supportive policies to cultivate business models by 2025, laying the groundwork for future growth and innovation in the battery industry.

4.9 KPIs for alternative battery technologies by 2024/2025

The Chinese government is channelling its research and development efforts towards enhancing alternative battery technologies. The primary objectives are to achieve batteries that offer a long cycle life, high efficiency, and low cost.

In terms of the value chain, the emphasis is on developing large-scale energy storage solutions that are less reliant on scarce resources. This strategic approach aims to mitigate dependency on materials that are limited in supply or subject to volatile market conditions.

Regarding applications, the focus is on leveraging these advancements in battery technology for energy storage systems, which are crucial for managing renewable energy sources more effectively. Additionally, there is a potential application in electric vehicles (EVs), particularly those designed for shorter ranges. This dual application strategy underscores a broader aim to support sustainable energy and transportation solutions. For metal-sulphur based energy storage batteries, the objectives are the following[54]:

Specific energy (cell level): ≥500 Wh/kg. It looks realistic; this specific energy target has already been achieved in prototype cells. Li/S cells are known for their high specific energy [Wh/kg] with low excess of electrolyte.

Specific power: ≥1,500 W/kg. It looks ambitious; Li/S batteries are typically not high-rate batteries, as the kinetics of conversion-type cathodes such as sulphur are slow.

Cycle life: ≥2,000 cycles. It looks ambitious; achieving high cycle life (>1 000 cycles) is a major challenge for Li/S batteries due to the solubility of polysulfides in the electrolyte, which induces self-discharge.

[54] https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2024/benchmarking-international-battery-policies_2024.pdf

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Cost (cell level): ≤0.6 ¥/Wh (≤76 €/kWh). It looks realistic; given the very low cost of the cathode active material (sulphur), the use of lithium metal is the major cost contributor, which could put this realistic target at risk.

4.10 KPIs for battery recycling by 2025

The "Made in China 2025" initiative has established ambitious environmental benchmarks, including a target for the comprehensive utilisation rate of industrial solid waste to achieve the level of 79%. This goal is a part of a broader effort not only to advance technology and enhance product performance, but also to emphasise the sustainable secondary use of batteries. These uses encompass energy storage and the development of efficient charging and swapping systems, alongside the recycling of valuable materials.

In line with the Mid- and Long-term Development Plan for the Automotive Industry, China aspires to elevate the actual recycling rate of vehicles to globally competitive standards by 2025. Specifically for batteries, the plan mandates impressive recovery rates for critical metals: at least 98% for nickel, cobalt, and manganese; a minimum of 85% for lithium; and no less than 97% for rare earths and other significant valuable metals. Furthermore, the strategy outlines that the process of material restoration should achieve a recovery rate of at least 90%.[55]

These stringent targets underscore China's commitment to fostering a circular economy within its automotive and battery sectors, reducing environmental impact while securing a sustainable supply of critical materials.

Recycling recovery rate targets by 2025

- of nickel, cobalt, manganese ≥ 98%,
- of lithium ≥ 85 %,
- of rare earths and other major valuable metals ≥ 97 %.

It all looks quite ambitious; the material recovery rates are very high, especially for lithium. For reference, the EU Battery Regulation proposal targets a recovery rate of 90% for copper, cobalt, nickel, while 35% for lithium by 2025 (or 2030).

Material recovery rate: in case of material restoration process, the material recovery rate ≥ 90%. It looks quite ambitious. For reference, the EU Battery Regulation proposes a 65% recycling efficiency for 2025 and 70% by 2030.

[55] https://www.adb.org/sites/default/files/publication/705886/14th-five-year-plan-high-quality-development-prc.pdf

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4.11 Recent developments: Chinese draft of the Lithium-Ion Battery Industry Standard Conditions (May 2024)

On the 8th May 2024, the Ministry of Industry and Information Technology (MIIT) published a draft document "Lithium battery industry normative conditions" aimed at regulating China´s rapidly growing lithium battery industry. The rules proposed by MIIT are designed to accelerate the transformation and to promote sustainable and high-quality development within the sector. This comes as an update to previous conditions published in 2021. The document is solicited for comments, with standards expected to be implemented before the end of May 2024.[56,57,58,59,60,61]

The normative conditions will not be legally binding and are instead aimed at encouraging and guiding the sector - stressed that lithium-ion battery companies must avoid projects that purely expand capacity.

The proposed regulations address several key issues facing China's lithium-ion battery supply chain, including unbalanced regional development, mismatched supply and demand, inconsistent product quality, and insufficient innovation. The regulations also cover various aspects of the industry, such as plant layout, production processes, product performance, safety and quality control, environmental protection, and social responsibility. Besides, the rules set specific standards for energy density, cycle life and other technical parameters for different types of lithium-ion batteries.

Furthermore, the draft regulations cover the environmental impact of the lithium-ion battery industry. These rules impose stricter controls over manufacturing processes to adhere to contemporary environmental standards, which include reducing pollution and optimising resource use. Among others, projects built on farmland and ecological zones should be shut down or put under strict controls and should be gradually removed. The focus on sustainable practices intends to minimise the industry's ecological footprint by curbing emissions and improving the energy efficiency of battery production. By establishing stringent standards for energy density and cycle life, the regulations promote the development of batteries that require less frequent replacement, potentially reducing waste.

Lithium-ion battery manufacturers are also required to invest at least 3% of their main business revenue in research and development.

The analysis of the draft regulation based on available sources, a tabular summary of the KPIs and their comparison with the data in the Fraunhofer paper[62] and the Batteries Europe Benchmark KPIs[63] can be found in the Annex 1.

56 https://www.miit.gov.cn/jgsj/dzs/gzdt/art/2024/art_56ad1373916c4aafac1bfb9934a48b79.html
57 https://www.jurist.org/news/2024/05/china-plans-to-strengthen-lithium-battery-industry-regulations/
58 https://business.inquirer.net/458011/china-issues-draft-guidelines-to-rein-in-lithium-battery-industry#ixzz8aqlJbrwD
59 https://www.reuters.com/world/china/china-issues-draft-rules-regulate-booming-lithium-battery-expansion-2024-05-08/
60 https://rhomotion.com/news/chinese-government-lays-out-strict-regulations-for-the-lithium-ion-battery-industry/
61 https://www.miit.gov.cn/jgsj/dzs/gzdt/art/2024/art_56ad1373916c4aafac1bfb9934a48b79.html
62 https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2024/benchmarking-international-battery-policies_2024.pdf
63 https://batterieseurope.eu/results/kpis-benchmarking-2/kpis-benchmarking-2-october-2023/

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4.12 Conclusions

In the span of the 14th Five-Year Plan (2021-2025)[55], China has consistently emphasised the importance of research and development in the battery sector, as underscored by the National Key R&D Programme. With three pivotal R&D programmes launched in 2021 dedicated to battery technology, China has earmarked a substantial investment of 227 million yuan (approximately €29 million) for these initiatives. This financial commitment, coupled with an open call for proposals, signifies the country's strategic focus on pioneering battery projects. This concerted effort reinforces China's ambition to consolidate its status as the global leader in battery manufacturing, aligning with its broader environmental objectives to significantly curtail CO_2 emissions.

Simultaneously, China is expanding its battery research and development endeavours, seeking innovative and superior solutions for the market. Investment in education and research infrastructure forms a cornerstone of this strategy, fostering the discovery of new technologies aimed at enhancing the efficiency and safety of battery systems.

Looking ahead, China's battery production capacity is poised for remarkable growth, projected to reach 400 GWh by 2025, and doubling to 800 GWh by 2030. This trajectory not only underscores China's manufacturing prowess but also highlights its commitment to meeting the escalating global demand for batteries.

Technological Feasibility Assessment for KPIs

The ambitious targets set for battery production capacity are underpinned by significant investments in R&D and a solid foundation in manufacturing infrastructure. The targeted production capacities of 400 GWh by 2025 and 800 GWh by 2030 are technologically feasible, given China's track record of rapid scale-up in manufacturing capabilities and its strategic focus on battery technology innovation. The substantial research funding earmarked for battery technology further enhances the feasibility of achieving these KPIs, enabling breakthroughs that can address current technological bottlenecks.

Fields of Innovation

China's pursuit of battery technology excellence is likely to catalyse innovations in several key areas:

- Material Science: With a focus on discovering and optimising new battery materials that offer higher energy density, longevity, and safety at reduced costs.
- Manufacturing Processes: Innovations in battery production techniques that enhance efficiency, scalability, and environmental sustainability.
- Recycling and Lifecycle Management: Development of more effective recycling processes to improve the sustainability of battery materials and reduce dependency on raw material extraction.

In conclusion, as China progresses through the 14th Five-Year Plan period, its strategic investments in R&D, alongside its focus on education and technological innovation, are pivotal to its vision of leading the global battery market. By advancing material science, refining manufacturing processes, and enhancing recycling and lifecycle management, China is not only poised to meet its ambitious

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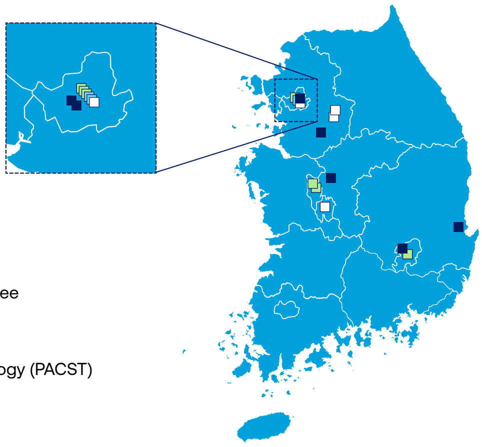
production targets but also to contribute significantly to the global transition towards cleaner energy solutions.

Battery Innovation System of South Korea

Main Players



POLITICAL ORGANISATIONS

- Ministry of Trade, Industry, and Energy (MOTIE)
  - Korea Energy Technology Evaluation and Planning (KETEP)
  - Korea Evaluation Institute of Industrial Technology (KEIT)
- Ministry of Science and ICT (MSIT)
- President's Office and Presidential Transition Committee

INDUSTRY ASSOCIATIONS

- Presidental Advisory Council on Science and Technology (PACST)
- Korean Battery Industry Association (KBIA)
- Battery R&D Association of Korea (KORBA)

RESEARCH ORGANISATIONS

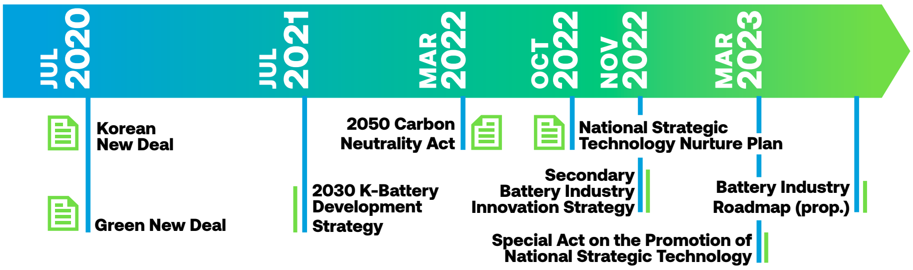
- Korea Institute of Science and Technology (KIST)
- Samsung Advanced Institute of Technology (SAIT)
- Korea Electronics Technology Institute (KETI)
- Electronics and Telecommunications Research Institute (ETRI)

COMPANIES

These three entities invested in the K-battery-programme:

- EcoPro Materials (Materials)
- LG Energy Solution (lithium-sulfur batteries, all-solid-state batteries
- LNF (Materials)
- POSCO FutureM (Materials)
- Samsung SDI (cobalt-free nickel-manganese batteries)
- SK Innovation

Strategic Documents



Policy Goals

2025–2028

- **Second life:** Create a 2.2GWh public ESS market to expand demand for second use batteries
- **Recycling:** Cobalt sulfate – 22.000 tons/year, nickel sulfate – 62.500 tons/year, manganese sulfate – 7.100 tons/year, lithium hydroxide – 26.800 tons/year
- **Commercialisation of next-generation batteries:** lithium-sulfur, solid-state, and lithium-metal batteries by 2025, 2027, 2028, respectively

2030

- **World's leadership:** Become the undisputed global leader for next-generation secondary batteries
- **Sales:** Batteries – KRW 166 trillion (40% of the global market), materials/parts/equipment - KRW 60 trillion (20% of the global market), battery exports - USD 20 billion
- **Recycling:** cobalt sulfate – 32.300 tons/year, nickel sulfate – 122.500 tons/year, manganese sulfate – 10.800 tons/year, lithium hydroxide – 26.800 tons/year
- **GHG emissions** reduced by 40% below 2018 levels
- **Electrified vehicles:** 1.8 million FCEVs on the road
- **Cathode material:** Quadruple the country's cathode production capacity in five years from 380,000 t. in 2022 to 1.58 million t. by 2027

2050

- **Carbon neutrality**
- **Electrified vehicles:** 100% emission-free vehicles

Country Specific Information

South Korea is the centre of global secondary battery R&D and a leading manufacturing base, but it is still necessary to ensure a stable supply chain and core competencies. The next ten years will be crucial for the development of next-generation secondary batteries, such as all-solid batteries. Battery policy or programmes are set by the central government and the Korean President, who is the ultimate authority on research matters. However, industry is strongly involved in the decision-making process and investment measures. The level of battery manufacturing technology, such as energy density, is currently similar in China, South Korea and Japan, but Korea has a slight advantage in productivity (quality control level). On the other hand, South Korea has a weak domestic materials ecosystem and is highly dependent on imports. Therefore, it is necessary to diversify the supply chain and expand the domestic production base in order to achieve the goal of global leadership. The K-Battery development strategy shows a clear R&D focus on commercialising three types of advanced batteries: solid-state, lithium-sulfur and lithium-metal batteries by 2027, 2025 and 2028 respectively.

Research Priorities

+ All-solid-state, lithium-sulfur and lithium-metal batteries + next-generation element technology to increase ion conductivity, lifespan, safety, cell performance + lithium metal-air batteries + innovative technologies (e.g. organic matter) + high nickel cathode and silicon anode materials + single-walled carbon nanotube + intelligent batteries (self-detection, suppression and healing of risk) + streamlining of the drying process + cutting-edge technologies such as AI and digital twins + nanocoating for silicon anode materials

Funding Instruments

TIME	FUND	FOCUS	BUDGET
2020–2025	Korean New Deal – the pillar Green New Deal – upgraded in 2021 (Green New Deal 2.0)	Strengthening climate action and realize a green economy. Focus on green infrastructures, renewable energy, and fostering green industry.	Total for Korean New Deal: KRW 220 trillion (KRW 73,4+ trillion for the pillar Green New Deal)
2020		Future waste resource base collection centre	KRW 17.1 billion
	Tax Exemption Restriction Act	Key battery technology recognised as a national strategic technology → tax support up to 50% for R&D expenditures and up to 20% for facility investment (machines, infrastructure, laboratories, etc.)	
	Incentive Programmes of Export-Import Bank of Korea and Korea Development Bank	High safety, long cycle life, low-cost LIB, solid state LIB as well as metal-sulfur based batteries for energy storage and smart grid	KRW 1.5 trillion
2023–2030	Public-private joint R&D innovation fund (MOTIE + Battery Industry + private investment sector)	Key industry sectors, including semiconductors, secondary batteries and nuclear power generation (40 R&D projects in 11 major industry fields); development and early commercialisation of advanced battery technologies, including solid-state batteries	KRW 13.5 trillion (KRW 6.2 trillion by 2027, KRW 7.3 trillion by 2030) industry: KRW 20.5 trill.

June 20, 2023; 1 KRW = 0,00071 EUR

Batteries + Europe

Batteries Europe Secretariat is an EU-funded project that has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement N. 101069676.

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5.1 Overview

The current leading role and ambitious programmes of the South Korea together with main players of its domestic battery ecosystem, the list of strategic documents, country specific information, current research priorities, policy goals and funding instruments have been comprehensively reported by the factsheet of the Korean battery innovation system elaborated by Batteries Europe in the frames of international observation.[64] In addition, the Benchmarking International Battery Policies report produced by Fraunhofer ISI describes the country's public strategy giving details on technical KPIs[65]. This document will therefore concentrate on additional information gathered by analysing the South Korean 2030 Secondary Battery Industry (K-Battery) Development Strategy released in October 2022.[66]

South Korea that likewise Japan, Europe and the United States, lags China in traditional lithium batteries, complementary to securing lithium-ion super-gap technology competitiveness (that is improving the high performance, safety and productivity currently in use) as identified in South Korean Secondary Battery Industry Innovation Strategy, is placing additional effort on the following next-generation battery technology: lithium-sulphur (to be commercialised by 2025, solid-state batteries (to be commercialised by 2027), and lithium metal (to be commercialised by 2028), to pull ahead the merits as summarised in the following table:

	All solid-state battery	Lithium-sulfur battery	Lithium metal battery
Characteristic	(Electrolyte) liquid → solid	(cathode material) nickel → sulfur, carbon	(anode material) graphite → metal
Merit	Maximum safety	Light weight, flexible	Improved energy density

Table 10 Characteristics of various battery technologies in South Korea
Source: 2030 Secondary Battery Industry (K-Battery) Development Strategy

Other new research will be supported, namely: lithium-metal-air, multivalent-ion, organic based, lithium-air cathode materials, dual/multivalent-ion materials, redox couples and sodium-ion cathode materials.

5.2 KPIs for lithium-ion batteries

The main research priorities related to improve stablished lithium technology are related to improving performance, safety and productivity.

[64] Battery Innovation System of South Korea (batterieseurope.eu)
[65] Benchmarking International Battery Policies. A cross analysis of international public battery strategies focusing on Germany, EU, USA, South Korea, Japan and China January 2024
[66] 2030 Secondary Battery Industry (K-Battery) Development Strategy

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For the electric vehicle market that might reach over 80% of battery market share by 2030 the target KPIs are specifically improving energy density, driving distance, charging speed, price and safety as summarised in the table below:

	Energy density	Distance driven	Charging speed	Price	Safety
Now	250~300Wh/kg	300~400km	30~40 min	137$/KWh	Ext. detection, ignition delay
Target	> 350Wh/kg	> 600km	15 min	< 60$/KWh	Self Diagnosis and Healing

Table 11 South Korean target KPIs lithium-ion batteries by 2030
Source: 2030 Secondary Battery Industry (K-Battery) Development Strategy

The overall South Korean vision of being secondary battery No. 1 country, is leveraged on a threefold strategy and action list, namely:

- Securing unique No. 1 technology → Public-private cooperation large-scale R&D promotion.
- Establishment of a global leading base → Creation an ecosystem of solidarity and cooperation.
- Expansion of secondary battery market → Creation of public and private demand markets.

5.3 KPIs for solid-state batteries

The targeted KPIs for solid-state batteries for the periods 2025-2028 and 2030 are summarised the following table:

	2020	2025 - 2028	2030
All solid-state	300Wh/kg pilot cell	400Wh/kg commercialisation technology	Vehicle demonstration

Table 12 South Korean target KPIs for all solid-state batteries
Source: 2030 Secondary Battery Industry (K-Battery) Development Strategy

In the development race of solid electrolytes, South Korea key players are active in several material innovation research for different specific applications.[67]

[67] COBRA, Solid-sate electrolytes, April 2023

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5.4 KPIs for sodium-ion batteries

The development of new sodium-based cathode material is identified as one of the seven next-generation materials.

5.5 KPIs for alternative battery technologies

As presented South Korea bet for the following early adoption of alternative battery technologies:

1. Lithium-sulphur: Through the development of lithium-sulphur batteries that can be miniaturised and lightweight, new markets such as lightweight secondary batteries for aviation and drones and flexible secondary batteries for textiles and electronic devices are created.

2. Lithium metal: Development of secondary batteries for electric vehicles that maximise energy density and safety at the same time by applying lithium metal anode materials to all solid-state batteries.

The targeted KPIs for lithium-sulphur and lithium metal batteries for the periods 2025-2028 and 2030 are summarised the following table:

Category	2020	2025 - 2028	2030
Lithium-sulphur	･400Wh/kg pilot cell ･UAV (hybrid) demonstration	･Development of small and flexible batteries ･Commercialisation technology for UAVs	Aircraft application
Lithium metal	Development of cathode materials	400Wh/kg commercialisation technology	Vehicle demonstration

Table 13 South Korean target KPIs for lithium-sulphur and lithium metal batteries
Source: 2030 Secondary Battery Industry (K-Battery) Development Strategy

5.6 KPIs for battery recycling

Within the target to establish a stable material supply chain South Korea ambitious expanding the use of recycled materials (nickel, cobalt, etc.) to the level of meeting the demand for domestic electric vehicles with the following KPIs targets for the period 2025 and 2030:

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Category	2020 (tonnes/year)	2025 (tonnes/year)	2030 (tonnes/year)
Cobalt sulfate	8,400	22,000	32,300
Nickel sulfate	13,200	62,500	122,500
Manganese sulfate	2,400	7,100	10,800
Lithium hydroxide	0	17,400	26,800

Table 14 South Korean target KPIs for recycling
Source: 2030 Secondary Battery Industry (K-Battery) Development Strategy

Other strategic targets related to recycling are:

- Establishment of a demonstration centre for the development of eco-friendly lithium secondary battery recycling technology, such as process automation, energy consumption reduction, and low-carbon remanufacturing technology to ensure economic safety.
- Accumulation of recycling resource data after analysis of major mineral material flows, calculation, and management of recycling rate by mineral type.
- Establish a new battery certification procedure for the export of used electric vehicles to prevent leakage of high-performance batteries and strengthen the mandatory conditions applicable to subsidised vehicles (operation period, etc.).
- Eco-friendly technology rare metal recycling companies:
    a) Support for the development of greenhouse gas reduction external business methodologies,
    b) Review of ways to provide financial benefits.
- Comprehensive support for discovering secondary battery mineral recycling companies and financial manpower R&D through the "Rare Metals 100 Core Company Support System".

5.7 Conclusions

Batteries are among a group of 12 technologies that the South Korean government will nurture, identifying that the geopolitical composition of science and technology is at the centre of international relations, and that public and private sector collaboration should join forces to foster the hegemony of its industry[68], targeting expected efficiencies as summarised in the following table:

[68] Korea to announce national strategy to become a technology hegemon, Release Date: October 28, OPR: Public Relations Division, MSIT, Contact Information: Kim Seo-Young (+82-44-202-4034), Roh Myung-Jong (+82-44-202-6752)

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	2020	2030
Secondary battery sales	22.7 trillion won	166 trillion won (40% of the global market)
Subchapter sales	4.3 trillion won	60 trillion won (20% of the global market)
Secondary battery exports	$7.5 billion	$20 billion

Table 15 Expected efficiencies by 2030
Source: 2030 Secondary Battery Industry (K-Battery) Development Strategy

South Korea intends to go beyond conservative recovery targets and lead structural changes with the ambitious Green New Deal[69] towards a low-carbon society and its 2030 secondary battery industry development strategy aims to leap forward as No. 1 country in secondary battery.

The ambitious plan for 2030 covers a wide range of actions to reinforce the whole battery value change:

<u>Public-private large-scale R&D promotion:</u>

- Early acquisition of next-generation secondary battery technology.
- Securing sub-chapter element technology for next-generation secondary batteries.
- Securing lithium-ion battery super-gap technology competitiveness.

<u>With a stable supply chain creating a strong ecosystem:</u>

- Establishment of a stable secondary battery supply chain.
- Fostering core companies.
- Expansion of secondary battery professional training.
- Establishment of institutional foundation in response to global trends.

<u>Creation of public and private demand markets:</u>

- Activation of the post-consumer secondary battery market.
- Expansion of demand base for secondary batteries.
- Creating new industrial conditions for secondary battery services.

[69] oeas's reen New Deal. Towards a Low-Carbon Society, Ministry of Economy and Finance

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Battery Innovation System of USA

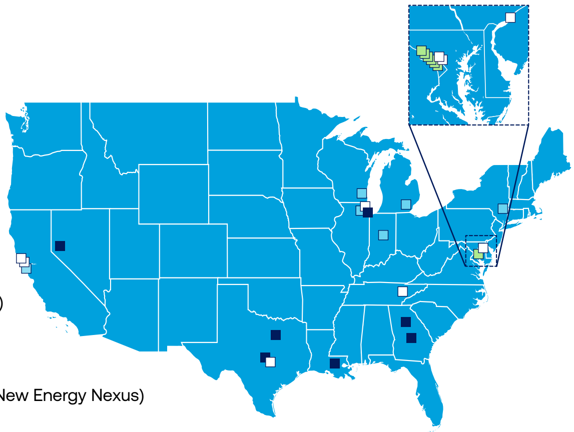
Main Players

POLITICAL ORGANISATIONS

- Federal Consortium for Advanced Batteries (FCAB): Collaboration of DOA, DOC, DOS and DOD
- Funding: Department of Energy (DOE)
  - Office of Energy Efficiency and Renewable Energy (EERE)
  - Vehicle Technologies Office (VTO)
  - Advanced Research Projects Agency-Energy (ARPA-E)
  - Office of Basic Energy Sciences (BES)
  - Department of Energy's Loan Programs Office (LPO)
  - Office of Electricity (OE)

INDUSTRY ASSOCIATIONS

- Li-Bridge Aliance (NAATBatt International / NY-BEST / New Energy Nexus)
- United States Advanced Battery Consortium (USABC)
- Responsible Battery Coalition



RESEARCH ORGANISATIONS

- National Laboratories:
  - Joint Center for Energy Storage Research (JCESR)
  - Battery500 Consortium
  - Berkeley Lab Energy Storage Center
  - Oak Ridge (ORNL)
  - ReCell Center
- Universities:
  - UT Austin
  - Drexel University
  - UC Berkeley

COMPANIES

- Albemarle (Refining)
- BlueOvalSK (Batteries)
- Ecobat (Recycling)
- GM General Motors (Batteries)
- SK Battery America (Batteries)
- Tesla (Batteries)
- Redwood Materials (Recycling)

Strategic Documents

- JUN 2021 – National Blueprint for Lithium Batteries 2021–2030
- NOV 2021 – Bipartisan Infrastructure Act
- MAR 2022 – Defense Production Act
- AUG 2022 – Inflation Reduction Act
- OCT 2022 – American Battery Materials Initiative

Country Specific Information

Fighting climate change is one of the main priorities for the Biden administration. The goal of creating a sustainable and competitive battery value chain is motivated not only by economics, but also by national defence, which requires reliable, secure and advanced energy storage technologies. The US is heavily dependent on imports of critical minerals, including rare earths. With the IRA, which is a forceful response to China's dominance, the US aims to both stimulate its economic goals and increase its resilience. The IRA offers enormous incentives and encourages to relocate battery production to the US. In addition, the Biden administration is strengthening US end-of-life reuse and recycling of critical materials, domestic battery materials, electrode, cell and pack manufacturing, and investing in the next generation of EV batteries to advance US battery technology leadership. The US has adopted a more technology-open strategy in its R&D funding programmes. The strategy focuses on functional parameters and objectives rather than on a specific cell chemistry.

Research Priorities

First-generation or advanced lithium-ion batteries + elimination of cobalt and nickel in Li-ion battery cathodes + aqueous batteries (alternative batteries such as a Fe-air battery), non-aqueous batteries, solid-state batteries and multifunctional batteries + high-performance separators and electrodes built with solid-ion-conductors for LIB and fuel cell use + dry coating of electrodes + sodium-ion batteries

Policy Goals

2030

- **Domestic supply chain:** A secure domestic battery materials and technology supply chain that supports long-term US economic competitiveness and job creation, enables decarbonisation, meets national security requirements, and is capable of meeting its own demand for energy storage capacities
- **Critical materials:** Independence on critical materials such as cobalt, nickel, and graphite, reducing battery supply chain vulnerability
- **Recycling:** Re-introducing 90% of key materials into the battery supply chain
- **KPIs for battery technologies** (incl. solid-state and Li-metal): Achieve a production cell cost by 50% to < $60/kWh, 500 Wh/kg, 1.000 charge/discharge cycles and cobalt- and nickel-free by 2030 (almost no specific KPIs on energy densities and technologies)
- **Carbon emissions** reduced by 40%
- **Electrified vehicles:** 30% ZEV sales for all new medium- and heavy-duty commercial vehicles

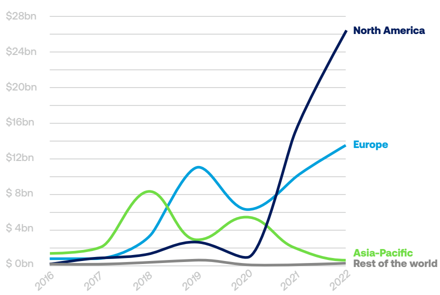
2050

- **Climate neutrality**
- **Electrified vehicles:** 100% ZEV sales for all new medium- and heavy-duty commercial vehicles

Main Funding Instruments

FUND	FOCUS AND BUDGET
Clean Energy Investment Plan	Historically high public investments in clean technologies ($2 billion)
Bipartisan Infrastructure Act	Investments in a domestic battery supply chain (over $6 billion)
DOEs Loan Programs Office (LPO)	Loans to manufacturers of advanced technology vehicle battery cells and packs for re-equipping, expanding or establishing manufacturing facilities in the US ($17 billion in ATVM Program)
DOEs Funding Programs	e.g. "Battery Materials Processing and Battery Manufacturing" and "Electric Drive Vehicle Battery Recycling and Second Life Applications" ($3.1 billion)
Inflation Reduction Act (IRA)	A major climate bill that aims to curb inflation while advancing clean energy solutions ($369 billion)
Investing in America Agenda	Investments to strengthen American supply chains, and help ensure coal, oil, and gas workers benefit from the new clean energy economy ($14 billion)

Announced foreign investment projects*
in battery manufacturing by region



Source: fDi Markets
*Including US interstate projects

Effective: May 31, 2023 / 1 US-Dollar=0,9 EUR

Batteries Europe

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6.1 Overview

The U.S. battery strategy - funding policies and incentives included - is led by Department of Energy (DOE) through dedicated offices: Office of Energy Efficiency and Renewable Energy (EERE); Vehicle Technologies Office (VTO); Advanced Research Projects Agency-Energy (ARPA-E); Office of Basic Energy Sciences (BES) and Loan Programs Office (LPO). There are also other important public-private players like the national laboratories and the Battery500 Consortium. The latter is a partnership led by Pacific Northwest National Laboratory (PNNL) between national labs and universities. In 2016, the VTO launched an innovation center for the consortium.[70] In early 2022, the Electric Vehicles at Scale Consortium (EVs@Scale Lab Consortium) was also launched by VTO. The main goal is to establishing a secure and scalable infrastructure necessary to support the transition to an electric fleet: by 2030, tens of millions of light-, medium-, and heavy-duty electric vehicles (EVs) are projected to hit American roads. The U.S. Department of Energy's Electric Vehicles at Scale Lab Consortium brings together national laboratories and key stakeholders to conduct infrastructure research and development in order to address challenges and barriers for high-power EV charging infrastructure that enables greater safety, grid operation reliability, and consumer confidence.

During the last years, several strategic documents and important actions were taken in the U.S.. The Energy Storage Grand Challenge Roadmap[71], issued in December 2020, defines as key objective to develop and domestically manufacture energy storage technologies that can meet all U.S. market demands by 2030. The Roadmap outlines three concepts to accelerate innovation across a range of storage technologies: Innovate Here, Make Here, Deploy Everywhere. DOE has identified initial cost targets detailed in the table below.

Cost related KPIs by 2030	Target value	Note
Levelised cost of storage for long-duration stationary applications.	$0.05/kWh	A 90% reduction from 2020 baseline costs by 2030
Manufactured cost for a battery pack	$80/kWh	For a 300-mile range electric vehicle, a 44% reduction from the current cost of $143 per rated kWh

Table 16 Cost related KPIs by 2030 in the U.S.
Source: The Energy Storage Grand Challenge Roadmap

In June 2021 the National Blueprint for Lithium Batteries 2021-2030[72] was published. It was developed by the Federal Consortium for Advanced Batteries as a guidance for "investments to develop a domestic lithium battery manufacturing value chain that creates equitable clean-energy manufacturing jobs in America while helping to mitigate climate change impacts". The vision beyond this document is to

[70] https://www.pnnl.gov/innovation-center-battery500-consortium
[71] https://www.energy.gov/energy-storage-grand-challenge/articles/energy-storage-grand-challenge-roadmap
[72] https://www.energy.gov/eere/vehicles/articles/national-blueprint-lithium-batteries

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establish a secure battery materials and technology supply chain that supports long-term U.S. economic competitiveness and equitable job creation, enables decarbonisation, advances social justice, and meets national security requirements.

The key goals to secure this vision are:

- Secure access to raw and refine materials and discover alternatives for critical minerals for commercial and defense applications.
- Support the growth of the U.S. materials-processing base able to meet domestic battery manufacturing demand.
- Stimulate the U.S. electrode, cell, and pack manufacturing sectors.
- Enable the U.S. end-of-life reuse and critical materials recycling at scale and a full competitive value chain in the U.S.
- Maintain and advance the U.S. battery technology leadership by strongly supporting scientific R&D, STEM education, and workforce development.

The Inflation Reduction Act (IRA) of 2022 stands as a significant climate legislation with the aim to mitigate inflation while advancing clean energy solutions. Allocating $369 billion, the IRA endeavours to finance energy and climate initiatives aimed at reducing carbon emissions by 40% by 2030 and increasing the material sourcing target to 80% by 2026.[73] The legislation incentivises diverse sources of clean energy, including energy storage, nuclear power, clean energy vehicles, hydrogen, and CCUS, under the condition that they maintain carbon neutrality. Additionally, the IRA extends and introduces Investment Tax Credits (ITCs) and Production Tax Credits (PTCs) tailored to support clean energy generation.[74]

Funding has prompted $59 billion in new EV investments announced by international companies in the U.S.-based production facilities in the first year after IRA.[75] [76]

Since IRA, demand projections for various EV metals have surged by 12% to 15%, according to S&P Global's report.[77] By 2035, the demand for lithium, nickel, and cobalt is anticipated to be 23 times its 2021 levels, with copper demand doubling within the same timeframe. Nonetheless, regulatory hurdles in mine permitting are impeding the IRA's objectives. Significant quantities of lithium are expected to be accessible to the U.S. industries, thanks to increasing supplies from Australia and Chile. However, the report highlights that nickel and cobalt supplies are unlikely to satisfy demand. Moreover, recycling efforts are unlikely to yield sufficient raw metals over the next decade to match the anticipated growth

[73] https://www.mining.com/web/column-us-hits-the-ev-accelerator-to-cut-chinese-metals-ties/
[74] https://www.weforum.org/agenda/2022/08/why-the-u-s-inflation-reduction-act-is-an-important-step-in-the-transition-to-clean-energy/
[75] https://www.mining.com/web/the-four-biggest-hurdles-in-americas-ev-transition/?utm_source=Battery_Metals_Digest&utm_medium=email&utm_campaign=MNG-DIGESTS&utm_content=the-four-biggest-hurdles-in-americas-ev-transition
[76] reen in est ent in enti es in S Boston Consulting rou
[77] https://www.spglobal.com/marketintelligence/en/mi/research-analysis/us-ira-and-critical-mineral-supply-challenge.html

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in global demand. Consequently, the U.S. is poised to expand its mineral partnerships as it relies on imports. One notable agreement was signed with Japan in March 2023.

Currently we can also observe an intense lobbying battle that has pitted U.S. automakers trying to lower the cost of electric vehicles against mining companies, materials producers and labour unions eager to fast-track domestic production of critical minerals.[78] Moreover, the pace of rulemaking has hindered billions of dollars in investments by automotive companies and battery suppliers who are awaiting the updated regulations.[79]

6.2 KPIs for lithium-based batteries

The U.S. programmes and strategies focus on functional parameters and targets (consequently, more technology-open). The U.S. focuses on a small number of core KPIs, while there are almost no specific KPIs on energy densities and technologies. For example, the Battery Blueprint's medium-term goal is to showcase battery technologies that achieve a production cell cost by 50% to less than $60/kWh (for the years 2030 to 2035), a specific energy of 500 Wh/kg (at the cell level already by 2030)

Li-ion technology	Specific energy	Cost	N° charge/discharge cycles	Other target
By 2030	500 Wh/kg	less than $ 60/kWh	1,000	Co- and Ni- free

Table 17 U.S. KPIs for lithium based batteries
Source: the National Blueprint for Lithium Batteries 2021-2030

The technical KPIs contained in that strategic document are applying also to other lithium-based technologies such as solid-state, lithium metal and lithium-sulphur. The Battery500 Consortium declares that they are "focusing on two of the most promising battery chemistries to achieve the 500 Wh/kg goal: Li-metal anodes with high-voltage/high-capacity metal oxide cathodes and Li-metal with sulphur cathodes. The Battery500 Consortium is working also to "achieve 1,000 charge/discharge cycles, and reduce the cost of cells to significantly less than $100/kWh[80].

[78] https://www.mining.com/web/its-carmakers-against-miners-in-battle-over-china-funded-metals/?utm_source=Daily_Digest&utm_medium=email&utm_campaign=MNG-DIGESTS&utm_content=its-carmakers-against-miners-in-battle-over-chinafunded-metals
[79] https://www.mining.com/web/a-year-into-bidens-climate-agenda-the-price-tag-remains-mysterious/?utm_source=Daily_Digest&utm_medium=email&utm_campaign=MNG-DIGESTS&utm_content=a-year-into-bidens-climate-agenda-the-price-tag-remains-mysterious
[80] https://www.pnnl.gov/innovation-center-battery500-consortium

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New battery chemistries[81]	Cost	Driving range	Charge time	Calendar Life
Electric vehicle batteries	≤ \$100/kWh - ultimately \$80/kWh	300 miles	≤ 15 minutes	10 years

Table 18 KPIs recommended by Battery500 Consortium
Source: Battery500 Consortium

The United States Advanced Battery Consortium LLC (USABC)[82] is a subsidiary of USCAR (U. S. Council for Automotive Research) and has the mission to develop electrochemical energy storage technologies that advance commercialisation of next generation electrified vehicle applications, enabled by a cooperative agreement with DOE. In support of its mission, USABC has developed mid- and long-term goals to guide its projects and measure its progress.

The key objectives are to develop advanced battery cell and system technologies supported by materials, sub-systems, manufacturing and recycling technologies. USABC publishes technical goals and associated test procedures to guide the development of electrochemical energy storage systems. Technical gaols in this case are specific for lithium-ion technology and have a high level of details. As an example *Table 19* reports the table about cell materials goals.

USABC Cell Active Material Requirements

Table 1. USABC Cell active material gap chart – CY 2025 Commercialization.

Level	End of Life Parameter at 30°C[1]	Unit	USABC Positive Electrode Goal	USABC Negative Electrode Goal	Program Goal	Test Method
Material	Available Specific Capacity	mAh/g	> 250	> 2000		C/3 CC-CV Charge, C/3 CC Discharge
	Available Capacity Density	mAh/cc	> 675	> 3600		
	Nominal Voltage	V vs Li/Li⁺	> 4.3	< 1.0		
	Irreversible Capacity Loss	%	< 10	< 10		
	Coating Level	mAh/cm²	> 4	> 4		
	High Rate Charge Power	mA/g	> 800	> 6400		80% ΔSOC in 15min
	Peak Specific Discharge Power	mA/g	> 500	> 4000		30 Second Pulse
	Cost[2]	\$/kg	< 10	< 5		3500 MT/yr (Anode) 28000 MT/yr (Cathode)
Cell	Swelling	%	< 5	< 10		-
	Calendar Life	Years	> 15	> 15		-
	Cycle Life	Cycles	> 1000	> 1000		DST

[1] The values in this table represent the performance of the complete electrode (including all active and inactive materials) in a full cell environment at end of life.
[2] Active material cost only

Table 19 Technical goals for cell active materials from USABC
Source: https://uscar.org/usabc

[81] https://www.energy.gov/eere/vehicles/batteries-charging-and-electric-vehicles
[82] https://uscar.org/usabc/

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6.3 KPIs for battery recycling

The National Blueprint for Lithium Batteries[83] includes goals focused on recycling. The target by 2030 is to create incentives for achieving 90% recycling of consumer electronics, EV, and grid-storage batteries.

6.4 Conclusions

Fighting climate change is one of the main priorities for the Biden administration. The goal of creating a sustainable and competitive battery value chain is motivated not only by economics, but also by national defence, which requires reliable, secure and advanced energy storage technologies. The U.S. is heavily dependent on imports of critical minerals, including rare earths.

The overall U.S. battery strategy is quite ambitious and well supported through policies and DOE funded consortia dedicated to different key segments. With the Inflation Reduction Act (2022), which is a forceful response to China's dominance, the U.S. aims to both stimulate its economic goals and increase its resilience. The IRA offers enormous incentives and encourages relocating battery production to the U.S.

In addition, the Biden administration is strengthening U.S. end-of-life reuse and recycling of critical materials domestic battery materials, electrode, cell and pack manufacturing, and investing in the next generation of EV batteries to advance U.S. battery technology leadership. The strategy focuses on functional parameters and objectives rather than on a specific cell chemistry.

The U.S. has adopted a more technology-open strategy in its R&D funding programmes – the same key targets are defined for each technology. This approach allows a broader competition, but on the other hand sets targets that could be very ambitious for emerging new chemistries. Consequently, the U.S. battery research could narrow down to few more promising technologies, losing the variety of different low TRL research and thus the possibility of ground-breaking discovery.

[83] https://www.energy.gov/eere/vehicles/articles/national-blueprint-lithium-batteries

This project has received funding from the European Union's Horizon Europe
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Battery Innovation System of Canada

Main Players

GOVERNMENT ORGANISATIONS

- Natural Resources Canada (NRCan)
- Innovation, Science and Economic Development Canada (ISED)
- Environment and Climate Change Canada (ECCC)

RESEARCH ORGANISATIONS

- National Research Council Canada (NRC)
  - Battery Performance and Safety Evaluation Research Facility
  - Microgrid Testing and Training Facility
  - Energy, Mining and Environment Research Centre – Battery Material Innovation Team
- Natural Sciences and Engineering Research Council of Canada (NSERC)
- University of Calgary, Dalhousie University, University of Waterloo, Western University

INDUSTRY ASSOCIATIONS & THINK TANKS

- Battery Metals Association of Canada (BMAC)
- Accelerate Canada's ZEV Supply Chain Alliance
- Energy Futures Lab
- The Transition Accelerator
- The Mining Association of Canada
- Energy Storage Canada
- Clean Energy Canada

COMPANIES

- E-One Moli Energy (Batteries)
- E-zinc (Batteries)
- Electra Battery Materials (Materials)
- Electrovaya Inc. (Batteries)
- Li-Cycle Holdings (Recycling)
- Lithion Technologies (Recycling)
- Moment Energy (Energy Storage)
- Nano One (Materials)
- Nouveau Monde Graphite (Components)
- Novonix (Batteries)

Strategic Documents

2019
- **Impact Assessment Act**
- **Canadian Minerals and Metals Plan**

2020
- **Mines to Mobility Report**

2021
- **XBR**
- **Investment Canada Act - Amendment**

2022
- **Roadmap for Canada's Battery Value Chain**
- **2030 Emissions Reduction Plan**
- **Canadian Critical Minerals Strategy**

2023
- **Accelerate's Battery Innovation Roadmap**

Policy Goals

2030

- **Zero-emission vehicles (ZEVs):** Regulations requiring 60% of new light-duty vehicle offered for sales; aim of reaching 35% of total medium-and heavy-duty vehicles sales with interim 2030 regulated sales requirements that would vary for different vehicle categories based on feasibility
- **Production:** 1.3M EVs produced domestically, 100GWh capacity in place domestically
- **Greenhouse gas emissions:** Reduction of 40-45% below 2005 levels
- **Recruitment:** The battery value chain created a significant amount of new jobs

2035

- **Zero-emission vehicles (ZEVs):** Regulations requiring 100% of new light-duty vehicle offered for sales; medium-and heavy-duty vehicles regulation to require 100% MHDV offered for sales to be ZEVs by 2040 for a subset of vehicle types based on feasibility
- **Net-zero electricity system**

2050

- **Net-zero emissions**

Country Specific Information

Cars and automotive parts are Canada's second largest export, trailing only behind oil and gas. The energy transition poses significant challenges to both the internal combustion vehicle and the oil and gas industry. For geographical reasons, the US is Canada´s most important export market and cooperation partner. To secure Canada`s place in the global economy of a net-zero world, Canadian federal government has announced a significant number of clean energy and technology incentives and programmes against the backdrop of the American IRA. The Government of Canada is committed to establishing a sustainable battery innovation and industrial ecosystem. While large-scale cell manufacturing and midstream production remain key challenges, the supply of responsibly sourced critical minerals presents a great opportunity to become a significant player in the battle against China's dominance. However, Canada is seeking to mine and process lithium, nickel, cobalt, manganese, iron, phosphate, copper, rare earths and graphite domestically, to streamline permitting for new mining projects and to mine value from waste as part of the transition to a more circular economy.

Research Priorities

Next generation batteries + innovative and enhanced batteries for EVs from material design to battery system design + Li-ion cells + graphite-silicon composite anode + optimizing energy storage (grid) + high-performance batteries, materials and production technology + reduction of GHG during the production process + recycling technology + secondary sources for battery minerals + mining value from waste or reducing mining's environmental footprint

Funding Instruments

TIME	FUND	FOCUS	BUDGET
2011 - Present	Energy Innovation Program (EIP)	Advance clean energy technologies that will help Canada meet its climate objectives, while supporting the transition to a low-carbon economy. The EIP funds research, development and demonstration projects, and other related scientific activities.	Over $70 million annually
2022 - 2030	2030 Emissions Reduction Plan	Economy-wide measures such as carbon pricing and clean fuels, while also targeting actions sector by sector ranging from buildings to vehicles to industry and agriculture. These measures will drive reductions while creating jobs for workers and opportunities for businesses.	$9.1 billion
2024 - 2027	Critical Minerals Research, Development and Demonstration (CMRDD)	Investment into the production and processing of critical minerals. The programme aims to scale-up fundamental research to pilot-scale and demonstration projects.	$2 billion
2024/25 - 2029/30	Strategic Innovation Fund (SIF)	Providing major investments in innovative projects across all sectors of the economy. The Net Zero Accelerator (NZA) is the segment of the SIF that delivers funding to support large-scale investments in key industrial sectors to help Canada achieve net zero, including developing the domestic battery ecosystem.	$8 billion +
2023 - 2035	Smart Renewables and Electrification Pathways Programme (SREPs)	Smart renewable energy and electrical grid modernization projects.	$4.5 billion

Effective: February 1, 2024 / 1 CAD =0,69 EUR

Batteries Europe Secretariat is an EU-funded project that has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement N. 101069676.

7.1 Overview

Unlike most other highly developed economies, Canada is rich in natural resources and is well-positioned to be one of the leading forces in the global battery market. This is encouraged by aspirations of leading battery and automotive manufacturers around the world, including the U.S., Europe, Japan and South Korea, to mitigate China´s dominance of critical materials supply chains. The Canadian federal government is pursuing the development of a fully integrated domestic battery value chain. This includes significant financial incentives for R&D, large-scale cell manufacturing and midstream production, as well as increasing the supply of responsibly and sustainably sourced critical minerals.

Canada has a strong battery innovation pedigree and ecosystem, with Canadian universities, industry and government having made ground-breaking contributions to advancing battery technology over the past 40 years. The federal government directly and indirectly supports this ecosystem through programmes targeting clean-tech and energy development, manufacturing scale-up and recycling, and others that target upstream supply chain extraction and refinement. Among others, federal research centres of Natural Resources Canada (NRCan) and the National Research Council of Canada (NRC) conduct R&D in battery-related technologies, ranging from geoscience, minerals processing, materials discovery and applications, to recycling.

7.2 Critical Minerals

Canada stands as a leading force in mining equipment, technology, and services, boasting a robust mining industry poised to emerge as a significant global provider of raw materials to the battery sector. With its commitment to a transparent regulatory framework, Canada upholds high standards of environmental, social, and governance (ESG) practices, encompassing heritage and environmental preservation, gender equity, workplace safety, and respect for human rights.

With the Critical Minerals Strategy (2022)[84], the Government of Canada focuses on opportunities at every stage of the value chain for Canada's 31 critical minerals, prioritising six: lithium, graphite, nickel, cobalt, copper and rare earth elements. Driving research, innovation and exploration is the first of six strategic focus areas under the Strategy.

Actions taken under the Critical Minerals Strategy include an investment of CAD$79.2 million for public geoscience and exploration to better identify and assess mineral deposits, a 30% Critical Mineral Exploration Tax Credit for targeted critical minerals, a CAD$47.7 million investment for targeted upstream critical mineral R&D under the Critical Minerals Research, Development and Demonstration Program. Furthermore, the Canadian government is investing CAD$144.4 million under the Critical Minerals Technology and Innovation Initiative for critical mineral research and development, and the deployment of technologies and materials to support critical mineral development for upstream and midstream segments of the value chain in Canada.[85]

[84] https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html#a51
[85] https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html#a51

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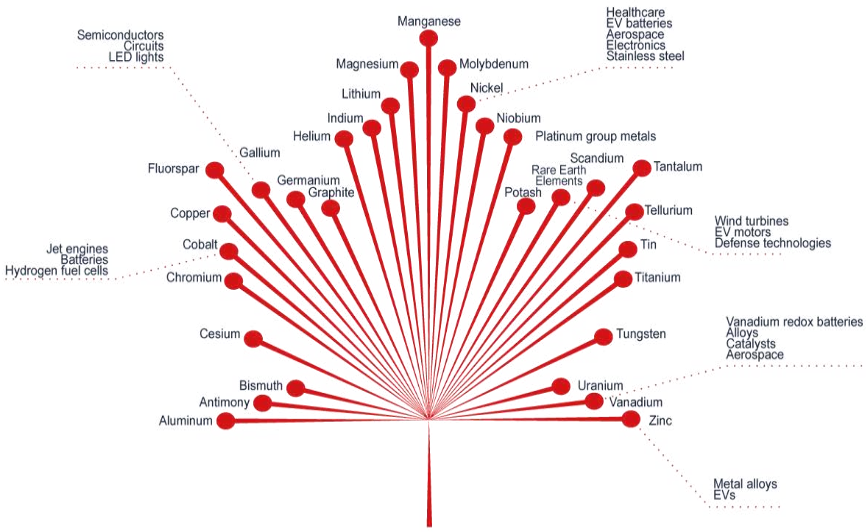

Table 20 Critical Minerals in Canada
Source: https://www.canada.ca/en/campaign/critical-minerals-in-canada/critical-minerals-an-opportunity-for-canada.html

In 2023, Canada's production from mines of cobalt and nickel amounted to an estimated 2,100 metric tons and 132.4 kilo tons, respectively.[86] While the lithium[87] and manganese[88] productions from mines are projects under development, there have been ongoing investments and projects involving domestic as well as foreign companies in all critical mining sectors, examples of which are listed below.

- *Panasonic Energy* and Quebec's *Nouveau Monde Graphite* have struck a deal, where *Panasonic* will buy battery-grade graphite from *Nouveau Monde* once it is in commercial production. *Nouveau Monde* also secured a $50 million investment from *Mitsubishi, Pallinghurst*, and *Investissement Quebec* to support its path to commercialisation and integrate its mining project and battery materials plant[89].
- *LG Energy Solutions* has entered into a binding term sheet with *Electra Battery Materials*, to play the role of its exclusive licensed cobalt sulphate facility in North America, to supply 7,000 tons of cobalt sulphate over a three-year period, beginning in 2023[90].
- On May 16, 2024, Canada and the U.S. announced the first co-investment of the two countries in two Canadian companies developing deposits of critical minerals – Fortune Minerals Limited located in the Northwest Territories (NWT) and Lomiko Metals, Inc. in Quebec.[91] The investment in Fortune will advance engineering and processing for the development of the company's NICO project in NWT to ensure a reliable North American supply of bismuth, in addition to cobalt, copper and gold. The investment in Lomiko will fund pilot plant testing to convert flake graphite into battery-grade material.

[86] https://mine.nridigital.com/mine_apr24/top-10-nickel-producing-countries-2023
[87] https:// natural-resources.canada.ca/our-natural-resources/minerals-mining/mining-data-statistics-and-analysis/minerals-metals-facts/lithium-facts/24009
[88] https://canadianmanganese.com/woodstock-project/
[89] https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html#a51
[90] https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html#a51
[91] https://www.canada.ca/en/natural-resources-canada/news/2024/05/government-of-canada-and-the-united-states-co-invest-to-strengthen-critical-mineral-value-chains.html

This project has received funding from the European Union's Horizon Europe
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7.3 Midstream Processing and Manufacturing

Competing in a fast-evolving global market with low profit margins is a prominent challenge facing new and established battery industry players. Gaining a competitive foothold in this market requires targeted investment in innovation to where it is needed most. R&D across the battery value chain requires investments to increase technology readiness levels, since this is too costly for academia and SMEs alone, but also deemed too risky for established industry. The Government of Canada is aiming to address this "missing middle" in battery innovation to offer pathways for Canadian battery innovators to accelerate scaled production and secure off-take agreements. Some examples of Government of Canada action in this area are shown below.

In March 2024, the Office of Energy Research and Development (OERD) of the Department of Natural Resources Canada launched the Battery Industry Acceleration Call for Proposals, with the aim to accelerate battery value chain decarbonisation, security, and competitiveness for Canada[92]. The call has four focus areas:

1. Improved performance (i.e., energy, power, safety, and lifespan), affordability, supply chain resiliency, and/or environmental footprint of batteries.
2. Demonstrating improved performance and/or cost of batteries for mobility and/or stationary storage applications.
3. Scale-up of non-commercial chemistries, advanced manufacturing processes, and/or processing techniques of battery production.
4. Novel use cases and/or business model innovation for batteries.

Through its Advanced Clean Energy Program, the National Research Council of Canada (NRC) is leveraging its expertise in battery metals, materials, recycling and safety to enable sustainability in batteries and foster the development of the EV industry in Canada. In 2023, the NRC launched the Critical Battery Materials Initiative, which uses artificial intelligence-powered labs to accelerate and link discoveries in new battery materials with more economically and environmentally sustainable approaches to processing battery minerals[93]. This is aimed at addressing the gap identified in Canada's battery materials' midstream supply chain, between critical mineral mining and battery manufacturing. Two technology areas are being developed to deliver on the initiative's objectives:

1. **Midstream battery minerals processing acceleration platform** to develop more efficient and sustainable processing pathways to produce battery materials from raw and recycled source materials.
2. **Battery materials acceleration platform** to discover new battery materials with optimized performance, safety, and sustainability characteristics.

[92] https://natural-resources.canada.ca/the-office-the-chief-scientist/funding-partnerships/opportunities/grants-incentives/energy-innovation-program/battery-industry-acceleration-call-for-proposals-applicant-guide/25705
[93] https://nrc.canada.ca/en/research-development/research-collaboration/programs/critical-battery-materials-initiative

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7.4 End-of-Life and Recycling

Canada is home to world-leading battery recycling companies such as Li-Cycle and Lithion Recycling, which have innovative processes that can recover and recycle up to 95% of critical materials from lithium-ion batteries. With batteries from the first generations of mass-deployed EVs expected to reach their end-of-life cycle by the end of this decade, the battery recycling sector is anticipated to undergo accelerated growth and innovation in both technology and processes.

Advanced R&D on battery recycling technologies is being carried out by federal government research centres, notably at National Research Council of Canada and the Department of Natural Resources Canada’s Canmet MATERIALS laboratory.

7.5 Conclusions

Canada's strategic positioning in the global battery market is poised for significant growth and influence, driven by strong fundamentals, including plentiful natural mineral resources, concerted government support, clean and affordable electricity, highly educated workforce, ESG credentials, and deep economic integration with the U.S. Unlike many highly developed economies, Canada's abundant resources offer a significant opportunity to reduce dependence on China, in line with the aspirations of key players such as the U.S., Europe, Japan and South Korea. Through investments in research, development and innovation, Canada aims not only to consolidate its position in the current lithium-ion battery market, but also to lead advances in next-generation solid-state batteries and novel battery technologies with exponentially higher energy densities. In addition, Canada's commitment to sustainability and responsible mining practices underscores its role as a leader in environmental stewardship and governance, further enhancing its attractiveness as a reliable partner in the global supply chain. With the strategic initiatives outlined in the Critical Mineral Strategy and investments across the value chain, Canada is positioned to be one of the central players in the battery sector, driving innovation, sustainability and economic growth for years to come.

This project has received funding from the European Union’s Horizon Europe
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Battery Innovation System of **Australia**

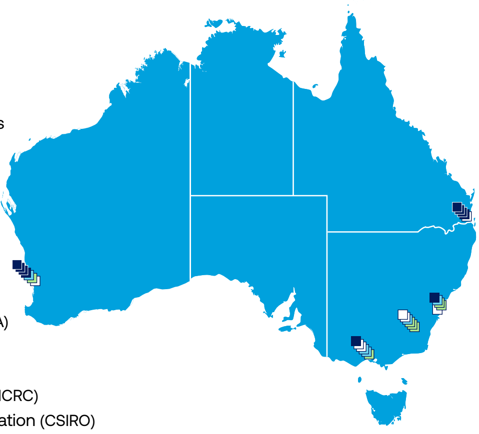
Main Players

POLITICAL ORGANISATIONS

- Australian Government
  - Department of Industry, Science, Energy and Resources
  - Critical Minerals Facilitation Office
  - Export Finance Australia
  - Australian Renewable Energy Agency (ARENA)
  - Clean Energy Finance Corporation (CEFC)
  - Clean Energy Regulator (CER)
- Battery Stewardship Council
- Government of Western Australia
  - Minerals Research Institute of Western Australia (MRIWA)

RESEARCH ORGANISATIONS

- Future Battery Industries Cooperative Research Centre (FBICRC)
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Australian National University (ANU) Battery Storage and Grid Integration Program
- University of Wollongong (UOW) Battery Storage and Grid Integration Program
- Monash Energy Institute at Monash University
- University of Queensland (UQ) Energy Initiative
- Battery Research and Innovation Hub - Deakin University



INDUSTRY ASSOCIATIONS

- Australian Battery Industry Association (ABIA)
- Minerals Council of Australia (MCA)
- Association of Mining and Exploration Companies (AMEC)
- Clean Energy Council (CEC)
- Association for the Battery Recycling Industry (ABRI)

COMPANIES

- Allkem (Raw materials)
- Australian Mines Limited (Raw materials)
- Century Yuasa (Batteries)
- Li-S Energy (Batteries)
- Enersys Australia (Batteries)
- Lithium Australia (Materials development)
- Envirostream (Recycling)
- IGO (Raw materials)
- Pilbara Minerals (Raw materials)
- Talison Lithium (Raw materials)

Strategic Documents

- **2020**: **Modern Manufacturing Strategy**
- **2021**: **Low Emissions Technology Statement** (LETS 2021); **Global Resources Strategy**
- **2022**: **Australian Critical Minerals Strategy**; **Technology Investment Roadmap**
- **2023**: **Critical Minerals Strategy**
- **2024**: **National Battery Strategy**; **Australian Made Battery Plan (proposal)**

Policy Goals

2030

- **Clean hydrogen:** Production under AUD$2/kg
- **Energy storage:** Electricity from storage for firming under AUD$100/MWh
- **Carbon capture and storage (CCS):** CO_2 compression, hub transport and storage under AUD$ 20/t of CO_2
- **Soil carbon:** Soil organic carbon measurement under AUD$ 3/ha/year

2035

- **Ultra low-cost solar:** Solar electricity generation at AUD$ 15/MWh

2040

- **Low emissions materials** (steel and aluminium): Steel production under AUD$ 700/t and aluminium production under AUD$ 2.200/t

2050

- **Net zero emissions**

Country Specific Information

Australia is a world leader in mining equipment, technology and services (METS) and a major global supplier of lithium, cobalt, rare earths, nickel and manganese. Its battery materials mining industry uses world-class expertise and technology in exploration, development, production, processing and environmental management. Lithium exports alone are expected to more than triple in value to AUD$16 billion by 2022–23. Australia's transparent regulatory framework ensures the highest environmental, social and governance (ESG) standards, including heritage and environmental protection, gender equality, workplace safety and the promotion of human rights. With growing concerns about the risks of geographic concentration of critical minerals, Australia has the potential to become a reliable and secure alternative supplier of raw materials and producer of processed materials. However, Australia needs to invest in diversifying further down the value chain, not just in the mining of raw materials. There is also a need to develop recycling and battery waste management. The new Australian government is currently reviewing climate and energy policy and sees renewable energy and batteries as a key factor of meeting CO_2 reduction targets. In this context, it is introducing schemes to support the large-scale uptake of batteries, and to promote both recycling and battery manufacturing.

Research Priorities

Expertise in mineral extraction and refining + hydrogen + lithium-ion, sodium-ion, vanadium flow batteries + super anode + future electrolyte systems + microgrid battery deployment + electrochemical testing + cathode active material + recycling and circular economy applied to batteries + lithium hydroxide

Main Funding Instruments

TIME	FUND	FOCUS	BUDGET
ongoing	CEFC	Clean energy projects; commercialisation of renewable energy and low emissions technology projects through loans and equity investments (AUD$ 1 billion in 2023 to turbocharge green financing options for household energy upgrades)	AUD$ 10 billion
ongoing	CER	Accelerate carbon abatement in Australia; emissions reduction projects	ca. AUD$ 2,5 billion
Since 2012	ARENA	Global transition to net zero emissions by accelerating the pace of pre-commercial innovation; early-stage research and development projects; solar, wind and other renewable energy technologies, as well as energy storage and grid integration; key technologies, including industrial energy efficiency and regional micro grids; low emissions technologies in all sectors, including agriculture and transport	over AUD$ 1,8 billion on early stage R&D projects AUD$ 1,4 billion for 2031–32
2021–2022	Export Finance Australia, Northern Australia Infrastructure Facility loans and Modern Manufacturing Initiative grants	Support to Western Australian battery and critical minerals projects	over AUD$ 1,6 billion
2023	Critical Minerals Strategy via the Northern Australia Infrastructure Fond	Resources projects that are vital to the energy transition	AUD$ 500 million

Effective: May 31, 2024 / 1 AU$-Dollar= 0,62 EUR

Batteries Europe Secretariat is an EU-funded project that has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement N. 101069676.

8.1 Overview

Australia has several initiatives to accelerate the development of the battery industry, such as established communities and research centres. The Australian Battery Society[94] founded in 2018, aims to be a hub for exchanging ideas, information and contact between industry, policy makers and battery scientists. The cooperative research centre Future Battery Industries Cooperative Research Centre (FBICRC)[95] coordinates 15 projects across the battery value chain. FBICRC has also commissioned two reports from the consulting company Accenture: Future Charge[96], published in 2021, and Charging Ahead[97], published in 2023, which detail the potential for Australia in the global battery industry. A National Battery Testing Centre has been established and "has developed world class testing facilities suitable for a range of different battery types, systems and sizes."[98]

The Australian government has committed to launching a National Battery Strategy and in February 2023 an issues paper was released by the Department of Industry, Science and Resources, seeking feedback and input to the strategy, which is currently under preparation. The issues paper[99], based heavily on the Future Charge report, outlines the current state of Australia's battery industry, and broadly highlights Australia's advantages in the market and government funds for developing the industry. Suggestions for measurable goals in terms of what market share the country aims for are not given in the issues paper.

On 23rd May 2024, Australia unveiled its National Battery Strategy, an integral component of the government's Future Made in Australia agenda. This Strategy aims to enhance Australia's resilience and security, stimulate economic growth by expanding the country's battery manufacturing capabilities, and develop essential skills. Achieving these goals will help Australia reach its target of 82% renewable energy and secure its position in global battery supply chains.

The vision for 2035 is for Australia to become a globally competitive producer of batteries and battery materials. This would ensure secure and resilient battery supply chains, provide affordable and reliable energy for Australians, boost productivity, create wealth and opportunities, and support the global energy transition.[100]

Meanwhile on a regional level, Western Australia launched the Future Battery Industry strategy in 2019[101] while Queensland have recently launched a battery industry strategy for 2024-2029.[102]

[94] https://australianbatterysociety.org/
[95] https://fbicrc.com.au/
[96] Future Charge: Building Australia's Battery Industries (2021) - Accenture
[97] Charging Ahead: ustralia's battery o ered uture Final report March 2023 Accenture
[98] Future Battery Industries CRC Activity Report 2023
[99] National Battery Strategy, Issues Paper, February 2023 Australian Government, Department of Industry, Science and Resources.
[100] https://www.industry.gov.au/publications/national-battery-strategy
[101] https://www.wa.gov.au/system/files/2020-10/Future-Battery-Industry-Strategy-Western-Australia-January-2019.pdf
[102] Queensland Battery Industry Strategy: 2024-2029 (2023) Queensland Government

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8.2 Job creation potential and economic benefit

The battery sector industries could create 61,400 new jobs and add A$16.9 billion (Australian dollars) gross value added (GVA) to the economy by 2030, according to a recent report commissioned by the Future Battery Industries CRC and developed by Accenture.[103] The same report also mentions that if the focus is held alone on raw materials production for batteries, it is envisaged that ca 31,600 of new jobs would result, with a financial benefit of A$10.4 billion GVA by 2030.

8.3 Education

Education and training of new engineers and scientists in the field of Future Energy Storage Technologies has been a priority of the Australian Research Council who have invested A$4.4 million along with a further 6.7 million from industry and universities into the storEnergy initiative.[104] This initiative investigates among other topics advanced Li-ion, super-capacitors and solid-state Li and Na batteries. In addition, the Future Battery Industries has its 15 projects across the battery sector and has established and developed a series of industry masterclasses to "showcase innovative science and technology, help companies implement the latest research, and connect industry stakeholders along the value chain."[105]

8.4 Raw materials

Australia is a world leader in mining equipment, technology and services (METS) and has a well-developed mining sector with the potential to be a major global supplier of raw materials to the battery industry. Australia's transparent regulatory framework ensures the highest environmental, social and governance (ESG) standards, including heritage and environmental protection, gender equality, workplace safety and the promotion of human rights.

"Australia currently produces eight of the nine key elements required for the battery value chain and has commercial reserves of graphite – the remaining element."[106] It ranks top ten for economically demonstrated battery mineral resources: nickel (1st); zinc (1st); lithium (2nd); vanadium (2nd); cobalt (2nd); bauxite – aluminium/high purity alumina (2nd); manganese ore (4th) and graphite (8th).[107] These elements are all necessary for lithium-ion (NMC) batteries and vanadium flow batteries.

[103] Charging Ahead: ustralia's battery o ered uture Final report March 2023 Accenture

[104] https://storenergy.com.au/about-us/
[105] Future Battery Industries CRC Activity Report 2023
[106] Value Proposition Battery Manufacturing Victoria State Government
[107] National Battery Strategy, Issues Paper, February 2023 Australian Government, Department of Industry, Science and Resources.

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Table 21 Comparison of leading mining countries by mineral production and reserves in 2021 (Percentage of world total)
Source: Charging Ahead: Australia's battery powered future – Final report March 2023– Accenture

"Australia leads the world in lithium production, while possessing high levels of reserves for other critical minerals."[108] The Investment Territory progress and outlook report 2022 to 2023 states: "Avenira Limited's Lithium Cathode Battery Manufacturing project will produce lithium-ferro-phosphate (LFP) battery cathode material. In stage one of the project, 10,000 to 30,000 tonnes per year of battery grade LFP powder will be produced, which will be scaled-up in future stages".[109] In addition, the report highlights Core Lithium Ltd, which initiated production at Finniss Lithium project, close to Darwin Port in the Northern Territory in 2022. At full capacity, this mine will generate 173.000 tonnes per annum of spodumene concentrate with 5.8% Li2O content.

Furthermore, "the Western Australia lithium producers are some of the lowest cost producers globally, producing at approximately half the cost of Chile."[110] Lithium raw material extraction and refining has been a key activity in Australia and A$7 billion have been invested into this field between 2016 and 2022.

8.5 Raw and advanced materials - research projects

While this is not an exhaustive overview of all Australian projects in the raw and advanced materials sector, it is a view of the projects are described below are from Future Battery Industries CRC Activity Report 2023.[111]

<u>Nickel and Cobalt Extraction Project:</u> A project aimed to extract nickel and cobalt from mining waste found that recoveries of more than 80% could be achieved through the production of a mixed sulphide

[108] Western Australia: A Global Battery and Critical Minerals Hub (2022) Australian Government
[109] Investment Territory: 2022-2023 Progress and Outlook (2023)
[110] Queensland Battery Industry Strategy: 2024-2029 (2023) Queensland Government
[111] Future Battery Industries CRC Activity Report 2023

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product. Future Battery Industries CRC state in the 2023 Activity Report that a pilot plant was under construction in Fremantle in Western Australia and expected to be commissioned by the end of 2023.

Lithium Extraction Project: This project consists of 12 sub projects across five universities and focuses on maximising production of Australia's lithium resources by improved processing.

Super Anode Project: This work focuses on producing a fast charging, high-capacity hybrid anode with a target of a capacity of 800 mAh/g. In addition, there is an aim in the reduction of graphite wastage of up to 30%. This project is expected to deliver a demonstration at pouch cell level by the end of the project.

Cathode Precursor Production Pilot Plant: An important milestone for Future Battery Industries was the opening of the Cathode Precursor Production Pilot Plant in which the current focus to date has been on NMC622 but future focus will be newer chemistries. The plant consists of four production units, which are able to run simultaneously with varying compositions and conditions.[112]

Future Electrolyte Systems Project*:* This work covers electrolytes, separators and electrode binders for lithium-ion batteries primarily. This project is divided into several subprojects. To date two subprojects have been listed one which investigates water-based anode binders and the second which investigates high purity alumina coated separators used with new electrolytes for batteries operating at elevated temperatures,

Development of Vanadium Electrolytes Project: The aim of this project will be to investigate the effect of additives and the impact of impurities in the electrolyte on the performance of Vanadium Redox Flow Batteries.

8.6 Battery cell manufacturing

Currently there appear to be no established giga-scale manufacturing of lithium-ion batteries in Australia. There have been recent reports of Li-S Energy who develops lithium sulphur and lithium metal batteries commission manufacturing equipment for phase 3 of their 2 MWh production facility at Geelong, Victoria.[113]

8.7 Battery cell manufacturing and testing research projects

The National Battery Testing Centre has been established to allow Australian battery manufacturers to certify their products in Australia, instead of overseas testing. Testing of single cell batteries and large-scale batteries have been commenced.

In addition, a facility for constructing lithium-ion batteries is under construction and will allow testing and benchmarking of components. "Benchmark designs for coin cell, cylindrical cells and pouch cells have been completed and cross-validation testing is underway."[114]

[112] https://fbicrc.com.au/cathode-facility-officially-launched/ accessed 04/04/2024
[113] https://www.lis.energy/portfolio/li-s-energy-shares-tour-of-10m-phase-3-battery-production-facility/
[114] Future Battery Industries CRC Activity Report 2023

This project has received funding from the European Union's Horizon Europe
Research and Innovation Programme under Grant Agreement N. 101069676

8.8 Battery pack development and integration

There are extensive deployments of battery systems in Australia in particularly for stationary storage and many companies who build battery systems. There has been announced some initiatives to develop large-scale facilities to develop battery systems beyond cells, such as Energy Renaissance based in the Hunter region of New South Wales.

Some notable examples of the deployments of stationary storage and those involved are provide here. Neoen and Tesla cooperate on several large lithium-ion battery storage projects in Australia. The Hornsdale Power Reserve in South Australia was installed in 2017 with a 100 MW/129 MWh capacity and upgraded in 2019 with an additional 50 MW/64.5 MWh.[115] The Victorian Big Battery was put in operation in 2021, and after completion of the second stage, the battery will provide 300 MW/ 450 MWh.[116] The latest project is the Collie Battery being constructed in Western Australia, which has an approval for 1 GW/4 GWh, where the first stage will provide 219 MW/877 MWh.[117]

Several other big battery storage initiatives are planned across Australia. In New South Wales, the 850 MW/1,680 MWh Waratah Super Battery is being constructed by Akaysha Energy.[118] The project is expected to finish by 2025. Western Australia expects to finish stage 2 of the Kwinana Big Battery, set to provide 200 MW/800 MWh.[119] The Big Canberra Battery project in Australian Capital Territory is installing a 250 MW/500 MWh battery energy storage system.[120] The company Pacific Green has to large battery storage projects planned: Limestone Coast Energy Park in South Australia, scheduled for construction in 2024, will have a capacity of 500 MW/1.5 GWh when finished;[121] and Portland Energy Park in Victoria with a 1 GW/2.5 GWh capacity when construction is finished in 2025.[122] The energy company Firm Power has proposed several battery storage projects across Australia, including two 500 MW/1 GWh projects in Queensland.[123]

Many of the installed storage battery systems installed in Australia use lithium-ion batteries, but in 2023 a 250 kW/1.45 MWh sodium-sulphur NAS® battery was installed in Western Australia.[124] Installed at the IGO Nova nickel-copper-cobalt mine site, it is the first of its kind in Australia. The Australian Renewable Energy Agency is also funding a project by Yadlamalka Energy to install and operate a Vanadium Flow Battery co-located with a solar farm in South Australia.[125]

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[115] https://hornsdalepowerreserve.com.au/
[116] https://victorianbigbattery.com.au/
[117] https://colliebattery.com.au/
[118] https://www.energyco.nsw.gov.au/construction-starts-waratah-super-battery
[119] https://www.synergy.net.au/Our-energy/SynergyRED/Large-Scale-Battery-Energy-Storage-Systems/Kwinana-Battery-Energy-Storage-System-2
[120] https://www.act.gov.au/our-canberra/latest-news/2023/april/contract-signed-to-help-deliver-big-battery
[121] https://limestonecoast.energypark.au/ https://www.pacificgreen.com/aus/projects/limestone-coast/
[122] https://portland.energypark.au/
[123] https://firmpower.com.au/
[124] Future Battery Industries CRC Activity Report 2023
[125] https://arena.gov.au/projects/co-located-vanadium-flow-battery-storage-and-solar/

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8.9 Battery pack development and integration research projects

Microgrid Deployment Project is investigating the use of modelling for the optimising of two microgrids, which will work with a solar array.[98] The Mine Operational Vehicle Electrification Project is developing tools to ease mine electrification through optimisation of charging infrastructure and modelling of different energy systems to support the mining industry in choosing electric vehicles.[98]

8.10 Recycling sector

While the Battery Stewardship Scheme[126] has been established since 2020 to increase the recovery and recycling of end-of-life hand held batteries in order to minimise the negative effects on environmental health and to increase safety, it currently is focus on only on small consumer batteries. In 2022 it was estimated on 10% of handheld batteries were collected for recycling in Australia. However, The Australian Battery Society estimated in 2021 that there is "a potential $3.1 billion lithium-ion battery recycling industry"[127] and there are efforts to strengthen the capacity for battery recycling. It has been recognised by the Australian government that in the "demand for materials and constrained supply in the coming years means that the recycling of batteries may become cost effective for certain battery chemistries."[99]

The importance of recycling has been recognised among the industry involved in the Future Battery Industries CRC and by the Australian government as is highlighted in the CSIRO report from 2021.[128] The report suggests that recovery of lithium- ion battery electrolyte may be done relatively cost effectively while graphite recovered may not be pure enough to reuse in battery processes.

8.11 Second-life batteries

It is highlighted in the CSIRO report that the cost of repurposing batteries is currently not clear as there are a host of conflicting reports and in addition the continued price drop of first life batteries threatens the use of second life batteries. It is estimated that the cost of second life batteries must remain under of $50/kWh (vs. 150 to $200/kWh for new batteries currently) up until 2025 in order to remain a competitive alternative to directly recycling.

8.12 Recycling sector research projects

The Australian Research Council launched in 2023 a research hub for micro recycling of battery and consumer waste[129] in addition to supporting a grant for the establishment of a training centre for battery recycling[130], which focuses on recycling mixed battery materials, promoting 2nd-life re-use, redesigning high performance batteries towards a battery circular economy, and advancing the supporting

[126] https://www.dcceew.gov.au/environment/protection/waste/product-stewardship/products-schemes/battery-stewardship
[127] Li-ion R&I in Australia (2021) Australian Battery Society
[128] Australian landscape for lithium-ion battery recycling and reuse in 2020 Current status, gap analysis and industry perspectives, CSIRO Report EP208519 | 25 February 2021
[129] https://www.arc.gov.au/news-publications/media/media-releases/research-turning-waste-high-value-products
[130] https://dataportal.arc.gov.au/NCGP/Web/Grant/Grant/IC230100042

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regulatory landscape. The Future Battery Industries CRC also has a project focusing on lithium-ferro-phosphate (LFP) batteries developing an initial flowsheet for the recycling process and in addition, aims to recover graphite from the anode and PVDF binder material.[131]

[131] Future Battery Industries CRC Activity Report 2023

This project has received funding from the European Union’s Horizon Europe
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Battery Innovation System of **India**

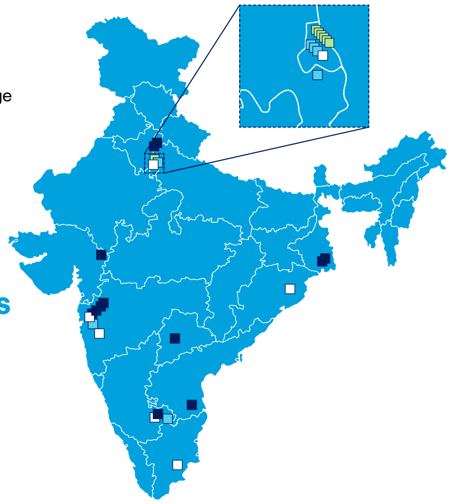
National Ecosystem

GOVERNMENT ORGANISATIONS

- The Union Ministry of Environment, Forest and Climate Change
- Ministry of Mines
- Ministry of Road Transport and Highways (MORTH)
- Ministry of Heavy Industries
- Ministry of New and Renewable Energy (MNRE)
- The National Institution for Transforming India (NITI Aayog)
- Department of Science and Technology

INDUSTRY ASSOCIATIONS & THINK TANKS

- Indian Battery Manufacturers Association
- Society Of Manufacturers Of Electric Vehicles (SMEV)
- India Energy Storage Alliance (IESA)
- RMI India Foundation
- WRI India
- CEEW



RESEARCH ORGANISATIONS

- Central Electrochemical Research Institute (CECRI)
- International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI)
- Centre for Materials for Electronics Technology (CMET)
- Institute of Minerals and Materials Technology (IMMT)
- National Chemical Laboratory (NCL)
- NonFerrous Materials Technology Development Centre (NFTDC)

COMPANIES

- Amara Raja Batteries (Batteries)
- Epsilon Advanced Materials (Anode and Catode)
- Exide Industries (Batteries)
- Hbl Power Systems (Batteries)
- Himadri Chemicals (Anode and Cathode)
- Khanij Bidesh India (Raw Materials)
- LivGuard (Batteries)
- Luminous (Lead Acid)
- OLA (Batteries and EVs)
- Reliance Industries (Batteries)
- Tata-Agratas (Batteries)

Strategic Documents

- **JUN 2021** – **National Programme on Advanced Chemistry Cell (ACC) Battery Storage**
- **MAY 2022** – **Energy Storage Vision 2030 for India**
- **AUG 2022** – **Battery Waste Management Rules**
- **SEPT 2022** – **Need for Advanced Chemistry Cell Energy Storage in India**
- **OCT 2022** – **Amendments to technical requirements for REESS or batteries for EVs**
- **AUG 2023** – **The Mines and Minerals Amendment Bill**
- **tbd** – **Battery Swapping Policy (draft)**

Policy Goals

2030

- **Battery production capacity:** 120 GWh
- **Supply capacity:** 500 GW of installed non-fossil fuel energy
- **EV transition:** Substitute 30% of private cars, 70% of commercial vehicles, 80% of two and three-wheelers and 100% of government vehicles to EVs; annual EV sales: 10 million;
- **Energy Storage Obligation (ESO):** 4% of total energy consumed from solar and/or wind with/through energy storage

2070

- **Net-zero emissions**

Country Specific Information

India is one of the world's fastest growing economies. The goal of enhancing its global standing is being pursued through significant investments across the entire domestic battery value chain, facilitated by schemes such as the Production-Linked Incentive (PLI). The battery industry is undergoing a major transformation to reduce its heavy reliance on imports. In this respect, India is open to international collaboration, with particular interest in the United States and Europe. In June 2023, it became a member of the Minerals Security Partnership (MSP), an initiative led by the US and comprising 12 other countries and the European Union, aimed at establishing critical energy minerals supply chains.

The shift in the Indian battery value chain includes a focused effort to strengthen domestic manufacturing capacities. The middle and downstream parts of the battery value chain are already well developed, however cell manufacturing and recycling still need to make progress. Recognising the potential of sodium-ion batteries (NiBs), India is actively moving towards its large-scale production.

Research Priorities

Next-generation batteries + sodium-ion batteries + innovative and enhanced batteries for EVs from material design to battery system design + Li-ion cells + lithium-manganese-cobalt-oxide (NMC) batteries + hydrogen energy and fuel cell technologies + optimizing energy storage (grid) + high-performance batteries, materials and production technology + reduction of GHG during the production process + recycling technology + cathode, anode and electrolyte

Funding Instruments

TIME	FUND	FOCUS	BUDGET
2023-2029	Production Linked Incentive (PLI) Scheme 'National Programme on Advanced Chemistry Cell (ACC) Battery Storage	Setting up domestic production capacities of advanced chemistry cells for at least 5 GWh and totalling up to 50 GWh battery capacity	$ 2,5 billion
2023-2033	PM-eBus Sewa	Deploy a total of 10,000 electric buses in 169 Indian cities within ten years and to create the infrastructure, including charging technology, to operate the e-buses	$ 6,8 billion (576 billion INR)
2019-2024	FAME India Scheme II	Second Stage of Fame India I supporting electrification of public and shared transportation as well as creation of the charging infrastructure	$ 1,2 billion

Effective: February 1, 2024; 1 INR = 0,011 EUR

Batteries Europe

Batteries Europe Secretariat is an EU-funded project that has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement N. 101069676.

VDI|VDE|IT

9.1 Overview

Since 2017, India has started the transformation process towards electrification and has added plans to strengthen its national battery manufacturing and value chain capabilities. The Indian government has appointed the National Institution for Transforming India (NITI) Policy Commission, established in 2015, to play a key role in defining India's battery strategy.

The NITI serves as public policy think tank, and the nodal agency tasked with catalysing economic development. Its initiatives include a number of strategic topics (called “verticals”) and missions, including the “E-mobility: National Mission on Transformative Mobility and Battery Storage”. This is a multi-disciplinary mission, which will facilitate cooperative federalism, extensive stakeholder and inter-ministerial consultation, as well as implementation of an end-to-end policy framework for transforming the mobility landscape.

In September 2018, the vision for the future of mobility in India was outlined, based on 7 C’s: Common, Connected, Convenient, Congestion-free, Charged, Clean and Cutting-edge mobility.

It has been declared that: “Affordable, accessible, inclusive and safe mobility solutions are primary strategic levers for rapid economic development as well as for improving ‘Ease of Living’. Shared, connected and clean mobility solutions are increasingly becoming the key principles of effective mobility solutions across the world. Given its commitment to climate goals, India needs to adopt effective strategies to place itself as a key driver of the mobility revolution in the world.”[132] To achieve these goals, India needs to focus on different aspects: manufacturing, specification and standards, regulatory framework, incentives, demand creation and R&D.

The focus on mobility is also evident from the FAME India Scheme: FAME Phase II 2019-22 programme to support EV target: 7,000 buses, 500,000 three-wheelers, 55,000 LDVs and 1 million two-wheelers.[133] Around 1.35 billion USD has been invested as fiscal incentives supporting this scheme. Moreover, the government of New Delhi also set, in 2020, the target of 25% share of EVs in sales by 2024.[133] The FAME scheme was revised in 2021: the validity of the flagship scheme is extended till 2024; upfront incentives for 2Ws were increased, the ‘Aggregation Model’ for 3Ws was adopted and OPEX Model and ‘Lighthouse Cities’ approach for the electric buses.[134]

9.2 National Mission on Transformative Mobility and Battery Storage

In March 2019, India’s union cabinet approved the setting up of a National Mission on Transformative Mobility and Battery Storage, to drive clean, connected, shared, sustainable and holistic mobility initiatives. The mission was to draw up a five-year phased manufacturing programme (PMP) until 2024, to support setting up a few large-scale, export-competitive integrated batteries and cell-manufacturing gigaplants in India and to localise production across the entire EV value chain. [135]

[132] https://www.niti.gov.in/verticals/e-mobility-national-mission-transformative-mobility-and-battery-storage
[133] https://www.iea.org/data-and-statistics/data-tools/global-ev-policy-explorer
[134] https://fame2.heavyindustries.gov.in/Index.aspx
[135] https://www.niti.gov.in/verticals/e-mobility-national-mission-transformative-mobility-and-battery-storage

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The National Mission for Transformative Mobility and Battery Storage is an Inter-Ministerial Steering Committee, chaired by NITI, with the aim to improve the air quality along with reducing India’s oil import dependence and enhance the uptake of renewable energy and storage solutions.

To achieve this, the mission shall recommend and drive strategies for transformative mobility and Phased Manufacturing Programmes for EVs, EV components and batteries and is further tasked to develop roadmaps to implement domestic battery manufacturing. The National Mission on Transformative Mobility and Battery Storage will determine the contours of PMP, and will finalise the details of such a programme. The details of the value addition that can be achieved with each phase of localisation, will be finalised by the Mission with a clear Make in India strategy for electric vehicle components, as well as batteries. The Mission's objective is then to coordinate with key stakeholders in Ministries/ Departments and the states to integrate various initiatives to transform mobility in India.[132]

9.3 National Programme on Advanced Chemistry Cell (ACC) Battery Storage

The National Programme on Advanced Chemistry Cell (ACC) Battery Storage was approved in 2021 with budgetary outlay of $2.48 billion. This scheme aims to strengthen the ecosystem for electric mobility and battery storage in the country. Through this scheme, the government of India intends to incentivise potential investors, both domestic and overseas, to set-up giga-scale ACC manufacturing facilities with emphasis on maximum domestic value addition.

The scheme envisages setting up of a cumulative ACC manufacturing capacity of 50 GWh for ACCs and an additional cumulative capacity of 5 GWh for niche ACC technologies.

Cell manufacturing is a critical part in the India´s battery value chain that requires significant R&D. While some work in this direction has been going on, efforts in finding the fine balance between the chemistry, the process and the costs is critical. India has produced cells, but the level of competitiveness does not come close to the numbers available internationally. 200 Wh/Kg cells at a cost of $135/KWh and having 2,500 cycles in Indian temperature conditions. It is vital that R&D efforts enable the country to deploy its own technology in the coming years, as the annual demand for cells is estimated to be close to 25 GWh by 2025.[136]

9.4 Skill development programmes

Since 2019, there has been a special focus on education and skills to support the missions and India´s overall strategy. To date, nine Indian Institutes of Technology have launched dedicated programmes for EVs.

The demand for trained labour in India has grown across industries, necessitating the introduction of a world-class skill development programme to meet the challenge of providing the skills required by a growing economy. The National Skill Development Corporation (NSDC) was established to bridge the existing gap between demand and supply of skills. It aims to promote skill development by catalysing the establishment of large, quality, for-profit training institutions. It also provides funding to build

[136] Research & Development in Electric Vehicle Technologies. https://e-amrit.niti.gov.in/reports-and-articles

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scalable and profitable vocational training initiatives. NSDC acts as a catalyst for skills development by providing funding to enterprises, companies and organisations that provide skills training.

Among the various initiatives undertaken by NSDC, the following are those that enable skills development in the field of electric mobility: Automotive Skills Development Council (ASDC); Skill India Portal; Skill Council for Green Jobs (SCGJ); DHI Centre of Excellence for Electric Mobility.[137]

The India Energy Storage Alliance (IESA) as also launched, since 2016, the IESA Academy to address the need for skill development in the energy storage sector.[138]

9.5 Raw materials and batteries recycling

The recommendations of the NITI think tank on raw material and battery recycling focus on the following main points:

- India does not have the natural resources for any of the battery materials (e.g. lithium, cobalt, manganese, nickel and graphite). Moreover, the international prices of these materials are very volatile and rising. Therefore, to avoid future dependence on imports of these materials, India should focus on recycling used lithium-ion batteries. It is possible to recover up to 95% of lithium and cobalt, 93% of nickel and manganese, and 90% of graphite.
- It is imperative that India develops zero-effluent processes for recycling used lithium-ion batteries. A significant amount of lithium-ion batteries used in electronic products such as mobile phones and laptops are currently discarded as waste. The country needs to put in place mechanisms to collect these batteries and recover their materials. As electric vehicles are gradually adopted in India, it is necessary to put in place regulations for mandatory collection, sorting and recycling of this precious resource.
- It should also be ensured that this urban mining is strictly a zero-effluent process, with no negative impact on the environment. Any foreign technology collaborations should adhere to the same stringent environmental requirements. In addition, the Hazardous Waste Management and Handling Rules 2016 and other relevant laws should be amended to allow the import of lithium battery waste for recycling in India, rather than the current situation of exporting this vital material to other countries. The collection of e-waste to recover rare earth metals for magnets and materials for batteries will be critical for the growth of the industry.[139]

[137] https://e-amrit.niti.gov.in/skill-center
[138] https://indiaesa.info/iesa-contacts-menu/547-skills-development
[139] Research & Development in Electric Vehicle Technologies. https://e-amrit.niti.gov.in/reports-and-articles

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9.6 Importance of e-mobility

The huge domestic market for e-mobility is the main driver of India´s EV and battery strategies. It is estimated that 11-13 million EVs will be sold annually in India by 2030, led by e-2Ws, where penetration is expected to reach 35-40% by 2030. e-3Ws, e-4Ws (shared) and e-buses will also see significant EV adoption (between 15-25%), over the next decade, driven by favourable economics, increased vehicle options and government push towards electrification.[140]

India has recently taken major steps towards green energy and electrification. At COP26 (Glasgow, 2021), a net zero target for India by 2070 was announced. As the transport sector is one of the largest emitters, vehicle electrification will be crucial in helping India achieve this goal. To support India's EV adoption trajectory, the Indian government has launched several initiatives aimed at developing a full-fledged EV manufacturing ecosystem in the country. Each of the three Production Linked Incentive (PLI) schemes - ACC PLI, Auto PLI and Auto Components PLI - has seen strong industry participation and is expected to localise various parts of the EV value chain. Similarly, the Phased Manufacturing Program (PMP) for EVs has created strong localisation momentum, leading to accelerated development of a local supplier base for various components. However, these policies only address certain parts of the value chain and structural gaps remain in key areas.

In May 2022, a joint report by NITI Aayog and Boston Consulting Group (BCG) was released. The report examines India´s potential to become a global leader in e-mobility. Based on an in-depth analysis of the EV value chain, benchmarking of global best practices in EV policies and discussions with industry experts, a 16-point action agenda is proposed in the following four key thrust areas to address challenges and further develop the local EV value chain (Table 22).

- Enable EV component manufacturing at scale by creating an enabling ecosystem and a level-playing field for select high priority components.
- Ensure consistent availability of critical and strategic EV and battery raw materials to strengthen mineral security of the nation.
- Foster centrally coordinated multi-stakeholder efforts for R&D in EV innovation.
- Facilitate industry-academia collaboration for re-skilling and up-skilling the Indian workforce in line with skills and competencies needed to emerge as a leader in the growing Battery & EV manufacturing ecosystem.[140]

[140] https://www.niti.gov.in/sites/default/files/2023-07/Niti-Aayog_Report-VS_compressed_compressed.pdf

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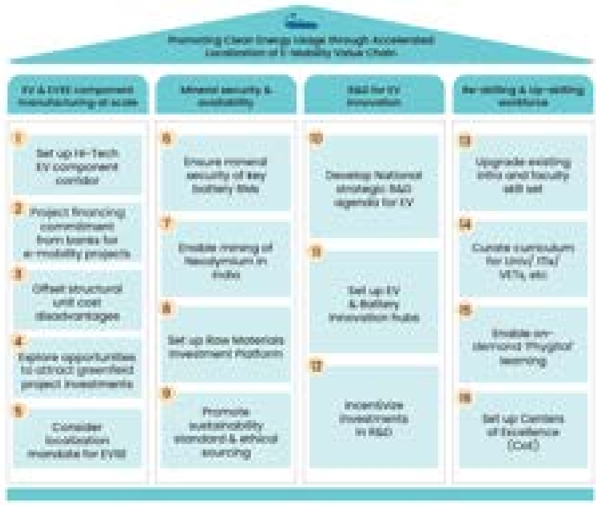

Table 22 16-point action agenda from the report "Promoting Clean Energy Usage Through Accelerated Localisation of E-Mobility Value Chain"
Source: https://www.niti.gov.in/sites/default/files/2023-07/Niti-Aayog_Report-VS_compressed_compressed.pdf

9.7 Conclusions

India, recognised as one of the world's fastest expanding economies, is strategically advancing its global presence by channelling substantial investments across the entire domestic battery value chain. This endeavour is facilitated by initiatives like the Production Linked Incentive (PLI). A significant transformation is underway within the battery industry to diminish its heavy reliance on imports. India is actively seeking international partnerships, with a keen focus on collaboration with the United States and Europe.

The shift in the Indian battery value chain includes a focused effort to strengthen domestic manufacturing capacities. The middle and downstream parts of the battery value chain are already well developed, however cell manufacturing and recycling still need to make progress. Recognising the potential of sodium-ion batteries (NiBs), India is actively moving towards its large-scale production.

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Battery Innovation System of Indonesia

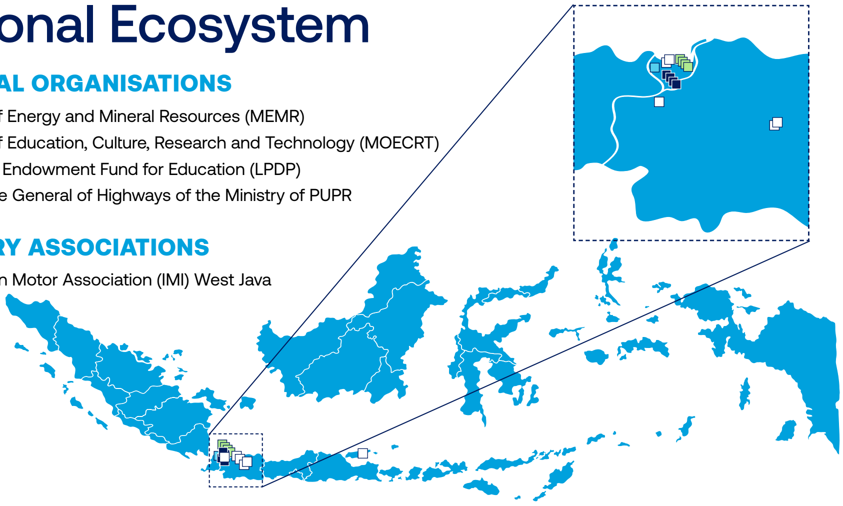
National Ecosystem

POLITICAL ORGANISATIONS

- Ministry of Energy and Mineral Resources (MEMR)
- Ministry of Education, Culture, Research and Technology (MOECRT)
- Indonesia Endowment Fund for Education (LPDP)
- Directorate General of Highways of the Ministry of PUPR

INDUSTRY ASSOCIATIONS

- Indonesian Motor Association (IMI) West Java



RESEARCH ORGANISATIONS

- The Indonesian Science Fund (DIPI)
- National Research and Innovation Agency (BRIN)
- National Battery Research Institute (NBRI)
- Telkom University

COMPANIES

- Antam (Mining)
- Indonesia Battery Corporation (Antam, Inalum, Pertamina, PLN)
- Mining Industry Indonesia (Mining)
- Vale Indonesia (Mining)

Strategic Documents

2018
- **Making Indonesia 4.0**

2019
- **Presidential Decree Number 55**

2020
- **Ministerial Regulations Number 27**
- **Minister of Finance Regulation Number PMK-153/PMK.010/2020**
- **Regulation of the Ministry of Commerce No. 100 of 2020**

2021
- **Electric Vehicle Production Roadmap**

Policy Goals

2025

- **Production:** Plans to produce 400,000 EVs
- **Transition:** Reach 2.5 million electric vehicle users

2030

- **Production:** Plans to produce 600,000 EVs, as well as 140 GWh battery capacity per year
- **Growth:** Become a top 10 global economy
- **Export:** Raise the industry net export rate to 10% of GDP
- **Productivity:** Achieve labour productivity that is twice the value of labour costs
- **Investing:** Allocate 2% of GDP to R&D, technology and innovation
- **Transition:** Complete EV transition for 13 million motorcycles

2035

- **Production:** Plans to produce 1,000,000 EVs

2060

- **Carbon neutrality**

Country Specific Information

As one of the fastest growing economies and the world's largest producer of nickel (a key component in lithium-ion batteries), Indonesia has huge potential to become one of the leading forces in the EV and battery industries of the future. As a result, the government is setting ambitious targets to be achieved by enacting regulations that will attract investment in the sector to create a domestic EV market. Leveraging of the country's vast natural resources, investment in R&D, transition of public transport, as well as tax incentives for companies investing in Indonesia are key drivers of the economic transition. Standardization of batteries and EVs is another current issue being pursued by the Indonesian government to make electric vehicles more accessible to the general public. International companies, mainly from China and South Korea, are already investing and setting up projects, further boosting Indonesia's ambitions to become a global top player in the EV industry.

Research Priorities

Innovative and enhanced batteries for EVs from material design to battery system design + Li-ion cells + high-performance batteries, materials and production technology + reduction of GHG during the production process + recycling technology

Funding Instruments

TIME	FUND	FOCUS	BUDGET
2020 - now (Tax incentives)	Tax incentives	Various tax incentives for companies to invest in the sector ranging from tax holiday of 100% of corporate income tax (CIT) to tax allowance and exemption from Import tax.	No information on budget
2022 - now (Competitive Fund)	Competitive Fund	Promotes collaborative research between universities and the industry, in order to align the development of science and technology in higher education with the real needs of the business and industrial world.	$ 83 million (Rp 1.2 trillion)
2022 - now (Matching Fund)	Matching Fund	Deploy a total of 10,000 electric buses in 169 Indian cities within ten years and to create the infrastructure, including charging technology, to operate the e-buses.	$ 70 million (Rp 1 trillion)

Effective: April 1, 2024; 1 Rp = 0,000058 EUR

Batteries Europe

Batteries Europe Secretariat is an EU-funded project that has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement N. 101069676.

VDI|VDE|IT

10.1 Overview

Indonesia aims to become a global player in EV industry by developing a domestic battery value chain with capacity to produce 140 GWh battery cell per year by 2030[141], based on having the world largest nickel reserves, its nickel industry and government incentives to attract foreign investments and the consumption of local goods.

The policy incentives date to 2019 with the adoption of Presidential decree No 55/2019, which defined domestic EV industry as a national priority, and emphasised the need to increase the national energy efficiency, while moving towards a clean and renewable energy to achieve the goals of Paris Agreement for 2050. The objectives are to reduce GHG emissions by 29% in 2030 compared to business-as-usual scenario by promoting local production of raw materials (especially nickel), to develop the battery value chain, to become an automotive export hub and a regional leader in EV production[141].

The development of the battery value chain has its roots in the natural resources. Indonesia is the largest producer of nickel: it holds reserves estimated in 21M tonnes (22% of global reserves) and is the world's largest producer on nickel ore (30% of the global market)[142]. These raw materials have been mainly used by the stainless-steel sector, but the need to develop lithium-ion batteries for the EVs industry enforced the government to impose a ban on nickel ores export and the obligation to purify the raw nickel locally before exporting.

The initial ban of 2014 had a twofold objective: i) to preserve the nickel ore reserves in order to supply the domestic nickel pig iron (NPI) and smelting industries and ii) to augment the lower grade ore processing industry in order to boost both the battery industry development and the nickel supply chain. The ban has evolved over the years, relaxing for other minerals to combat the impact of COVID-19 on the industry. As a side effect, the ban has facilitated the attraction of foreign investment to process nickel and cobalt, and boosted the domestic industry. Nowadays, China is the major investor in nickel processing industry in Indonesia but there is the concern about its impact on domestic supply chain as the companies might have fixed contracts to export their production for Chinese companies. A risk that the government is considering minimising by increasing the export taxes on nickel products.[141]

To develop upstream of the value chain, the plans of the government are to facilitate the operation of new nickel smelters plants (19 were foreseen for 2023), to diversify the production of nickel related products (cobalt manganese and nickel cobalt aluminium) and to increase the production of nickel pig iron for the stainless-steel industry[143]. Indonesia is boosting also other materials needed for battery production, e.g. by expanding precursor cathode and anode materials production and lithium refineries, even if those refineries would require high volume of lithium imports from Australia. To supply the domestic industry, it is expected to import 600,000 tons of lithium from Australia from 2024 onwards. Upstream mineral industry is reinforced by being the sixth producer of manganese, copper, and aluminium[144].

[141] Indonesia's Battery Industrial Strategy. CSIS, February 2022
[142] Prospects for Electric Battery Production in Indonesia. ASEAN Briefing, January 2024
[143] Decarbonization of transport: EV & EV battery development plan in Indonesia. KPMG Indonesia, July 2021.
[144] Indonesia Battery Corporation: https://www.indonesiabatterycorp.com/en/about-us

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Downstream, the strategy of the government goes in two directions: to develop the domestic EV market in order to contribute to the GHG reduction, and to facilitate foreign investments in the sector. Midstream, the goal is to develop the battery production focusing on cell manufacturing and pack assembly relying on national companies, such as PT Century Batteries Indonesia, PT GS Battery or PT Nipress Energi Otomatif, and global players, such as Tesla, Panasonic, LG Chem, AESC or Samsung.[143] As for downstream, both streams are supported by fiscal and non-fiscal incentives for EV industry.

The achievement of producing 140 GWh battery cells per year by 2030 relies on three main challenges: to boost foreign and national investments by building EV battery plants, to develop the recharging infrastructure and to increase the adoption of EVs.[143]

The strategic plan of the government has set the goal of increasing the adoption of EVs to 13M e-motorcycles and 2,2M of EVs. The planning needs to be understood in perspective, as back in 2019 only 24 EVs and 15,000 e-motorcycles were sold in the country, while in 2023 there were 20,000 EVs and 74,000 e-motorcycles. The massive adoption is being pushed by incentives to support the domestic production. The government subsidises the local production with a reduction of Value Added Tax (VAT) from 11% to 1% for EVs and e-buses containing more than 40% of components produced in the country[142], and 5% of VAT if the content is 20-40%. In the case of the e-motorcycles the incentives are in terms of cost reduction if the domestic components are minimum of 40%. The implementation of the measures would be gradual allowing the import of foreign components, such as battery cells, and increasing up to 80% of local production by 2030. The progressive deployment of the measures needs to be encompassed by the development of domestic EV manufacturing industry - a must to become an EV hub.

Now the EV battery cell and EV productions are highly dependent on foreign companies that receive incentives to install their plants in Indonesia. Hyundai and LG Energy Solution had a joint venture to build a plant with an annual capacity production of 10 GWh for 150,000 battery electric vehicles based on E-GMP[141,142]. The plant would be running in 2024. Similar plans have been announced by other companies such as CATL, with its investment plan of $5 billion, Toyota, BYD, Neta, Honda and Suzuki, which are carmakers with plants planned or under construction. Indonesia expects to become an automotive hub exporting 200,000 electric cars by 2025, about the 20% of total exports per year.[143]

The chosen chemistry for the batteries is mainly NCM and NCA, based on the abundant nickel reserves and cobalt availability, but the other cheaper chemistries such as LFP - without nickel or cobalt - could be a threat for the domestic industry. The lack of national battery cell producers involves that the chemistries and technologies key performance indicators are the ones of the foreign companies.

The governmental battery strategy is lead by the Indonesian Battery Corportaion created in 2011 by the four main State-Owned-Enterprises (SOE) related to the battery value chain: upstream mining and refining nickel for batteries (Inalum and Antam mining companies), midstream to build precursors, cathode, battery cells and packs plants and recycling (Pertamina, oil and gas company) and downstream to distribute and recycle batteries (PLN, electric utility company). PLN and Pertamina collaborate in recycling the end-of-life of batteries. The Indonesian regulation implies that foreign companies need to collaborate with IBC to install and produce in the country. This partnership could contribute to the necessary knowledge and technology transfer to deploy the domestic industry and to reduce the impact on job force due to the replacement of combustion engines manufacturing industry by the electric one.

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The expectation is that by 2024 the EV battery companies begin their production: new plants to refine nickel and high pressure acid leach, owned by Antam, and the manufacturing plant for cathode and anode precursor, owned by Pertamina and Inalum, start into operation. By 2025, Pertamina and PNL will start production in their cell to pack manufacturing plants.

IBC aims to diversify the EV battery ecosystem by 2030. Its strategy is depicted below:

Table 23 Overview of IBC's business portfolio
Source: IBC. https://www.indonesiabatterycorp.com/en/future-project/ambisi-2030

10.2 Key facts about Indonesia´s potential

Indonesia is a 'new-comer' in the world`s battery ecosystem and as such lacks of own battery cells and EV production Key Performance Indicators. In the Table 24 some of the main facts that give a view over its potential to became a major player have been summarised.

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Facts	Figures
EV battery production capacity	140 GWh in 2030 (4-9% of the global demand)[142]
Nickel production	21 million tonnes (22% of global reserves)[142]
Nickel production (Class 1)	Nearly 195,000 tonnes (overtaking Canada and Australia)[145]
Battery-grade chemicals refining capacity	800 tonnes of manganese sulphate, expected to increase in coming 5 years[145]
Lithium-ion cell manufacturing capacity	25 GWh by 2025 and could be increased to 80 GWh by 2030[145]
Government target for EV penetration	13 million electric motorcycles and 2.2 million EV in 2030[141]
Auto market in the ASEAN region (Association of Southeast Asian Nations)	32% of the regional market with 1,151,284 cars sales in 2028[143]
Car ownership in the ASEAN region	5th position with 87 per 1000 citizens. First in the ranking, Brunei with 711.

Table 24 Key facts about Indonesia´s battery ecosystem

10.3 Conclusions

The strategy to develop the battery value chain relies on raw materials, especially on large nickel reserves and industry. Based on its strengths upstream, Indonesia has defined the roadmap to become a global player developing the domestic battery value chain, from mining to recycling.

The inclusion on national priorities the development of domestic EV industry and the reduction of the GHG emissions was the kick start to design the strategy, back in 2019, supported by national incentives to attract foreign investment and to buy domestic electric products, ban to non-processed mineral exports and the need to partner with International Battery Corporation (IBC).

The ambitious plan could be at stake by the low penetration of EVs among the population and the comeback of cheaper chemistries that do not contain nickel.

[145] https://evmarketsreports.com/indonesia-to-lead-sea-battery-manufacturing-by-2030/

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11 GENERAL CONCLUSIONS

In the recent years, we observe some differences in the national battery strategies, depending on various factors, including the availability of battery raw materials, geopolitical landscape, commitment to sustainability, and access to financial resources for research and development, as well as skilled workers and scientists.

Japan's proactive stance in battery technology and recycling underscores its commitment to energy storage and environmental sustainability. Japan aims to mitigate raw material supply risks with its ambitious goals for 2030, including cost reduction and market expansion. Japan aims to secure a competitive edge and lead in innovation in next-generation battery technologies, including solid-state and alternative battery technologies. Policies and investments reflect a balanced approach to economic growth, environmental protection, and energy security, with pivotal collaboration between government, industry, and academia.

During **China**'s 14th Five-Year Plan (2021-2025), significant emphasis has been placed on battery research and development, with substantial investments of 227 million yuan. This investment, along with dedicated R&D programmes and an open call for proposals, demonstrates China's strategic commitment to pioneering battery projects and consolidating its position as a global leader in battery manufacturing. With projected production capacities of 400 GWh by 2025 and 800 GWh by 2030, China's focus on technological innovation and infrastructure development underscores its dedication to meeting global battery demand. Through innovations in several key areas, like in material science, manufacturing processes, as well as recycling and lifecycle management, China aims not only to meet ambitious production targets but also to contribute to the global transition to cleaner energy solutions.

South Korea is prioritising battery technology as one of twelve key technologies, recognising its significance in global relations and aiming for industry hegemony through public-private collaboration. Both the ambitious Green New Deal and the 2030 Secondary Battery Industry Development Strategy focus on leading the secondary battery sector, with plans to advance R&D, secure technology competitiveness, and establish a robust supply chain and institutional framework. Additionally, efforts are underway to stimulate demand markets and create favourable conditions for secondary battery services, signalling a comprehensive approach towards achieving leadership in the field.

The current **U.S.** administration prioritises combating climate change and aims to establish a sustainable and competitive battery value chain for national security and economic reasons. With heavy reliance on critical mineral imports, the U.S. battery strategy is ambitious and well supported by policies like the Inflation Reduction Act, targeting economic resilience and reducing dependence on China. Investments in recycling of critical materials, manufacturing, and next-generation EV batteries underscore the focus on advancing the U.S. battery technology leadership, though the technology-open strategy in its R&D approach. It may risk in limiting breakthroughs by favouring established technologies over the emerging ones.

Canada is positioned for substantial growth in the global battery market due to strong fundamentals, including plentiful natural mineral resources, concerted government support, highly educated workforce, ESG credentials, and deep economic integration with the U.S. Canada has the critical

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materials needed for the clean energy transition, including batteries, emphasizing sustainability, responsible mining, and supply chain resiliency and reliability.

Australia boasts leadership in mining equipment, technology and services, positioning itself as a potential key global supplier to the battery industry due to its well-established mining sector. The country's robust regulatory framework prioritises environmental protection, social responsibility, and governance standards. Despite the absence of large-scale battery manufacturing, Australia is actively fostering development of the battery industry through various initiatives and research centres, leveraging its strengths and government support. Efforts include education and training programmes to cultivate expertise in future energy storage technologies. Furthermore, Australia sees widespread deployment of battery systems, especially for stationary storage.

India, amidst its rapid economic growth, is strategically investing in its battery industry across the entire value chain, bolstered by initiatives like the Production Linked Incentive. With a strong push to reduce its heavy reliance on imports, India is actively seeking partnerships, particularly with the U.S, and Europe. Efforts are focused on strengthening domestic manufacturing capabilities, particularly in cell manufacturing and recycling, while also recognising the potential of sodium-ion batteries and moving towards large-scale production. This transformation underscores India's commitment to establishing itself as a significant player in the global battery market.

Indonesia's strategy to develop its battery value chain relies on its large nickel reserves and industry expertise, positioning the nation to become a global player. The focus on domestic electric vehicle industry development and greenhouse gas emissions reduction, initiated in 2019, spurred national incentives and policies to attract foreign investment like banning non-processed mineral exports and promoting domestic electric products. However, challenges persist with low EV penetration rates among the population and the resurgence of cheaper battery chemistries lacking nickel, potentially affecting the ambitious plan's success. Collaboration with international partners remains crucial for Indonesia's battery industry roadmap.

The **EU** is strategically bolstering its battery industry to compete with Asian and U.S. markets by establishing initiatives and comprehensive policies, promoting sustainable practices across the whole battery value chain. With plans to establish new large battery factories, Europe aims to meet both domestic and global demand and to reduce import dependency, focusing on enhancing production capabilities, diversifying the domestic production, and boosting circularity. Despite China's dominance, Europe is also striving for increased domestic production of battery raw materials like nickel, graphite, and lithium. However, challenges loom with anticipated supply shortages and market tightness materials in the near future. Moreover, Europe's push towards electric vehicles is driving significant demand for lithium-ion batteries, highlighting the need for substantial investment in battery production and technology. To sustain this trajectory, continued investment in research and development, international collaborations, and adherence to sustainability initiatives will be crucial.

In conclusion, the success of any country's battery strategy hinges upon several critical factors. Firstly, the availability of battery raw materials plays a pivotal role, as secure and sustainable access to resources such as lithium, nickel, graphite, and cobalt is essential for robust battery production. Additionally, the geopolitical composition of the region and its relationships with key suppliers and competitors shape the landscape of the battery industry, influencing trade policies and market dynamics. Moreover, a country's commitment to sustainability and environmental stewardship is

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paramount, as the global shift towards clean energy solutions necessitates adherence to stringent environmental standards and practices throughout the battery value chain. Lastly, the availability of financial resources for research and development, as well as a skilled workforce capable of driving innovation and technological advancement, are indispensable elements for the successful execution of a country's battery strategy. By addressing these key considerations and fostering a conducive environment for collaboration and investment, countries can position themselves as leaders in the rapidly evolving battery industry, driving progress towards a more sustainable and electrified future.

Recognising the multifaceted nature of these challenges, international collaboration emerges as a crucial enabler for success. By fostering partnerships and cooperation on a global scale, countries can leverage collective strengths, mitigate resource constraints, share technological expertise, and pool financial resources. Through international collaboration, nations can navigate complex geopolitical dynamics, ensure sustainable practices across the battery value chain, and accelerate innovation to drive the transition towards a cleaner, more resilient energy future. In an increasingly interconnected world, collaboration serves as a cornerstone for unlocking the full potential of the battery industry, paving the way for shared prosperity and environmental stewardship across borders.

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12 ANNEX 1: Summary of the draft Chinese "Lithium-Ion Battery Industry Standard Conditions (2024)" based on available internet sources

1. Industrial Layout and Project Establishment

- Lithium battery enterprises and projects must comply with national laws and regulations related to resource utilization, ecological and environmental protection, energy conservation, and safety production.
- Projects must not be established in areas designated for permanent farmland, ecological protection, or other regions where industrial construction is prohibited by law. Existing enterprises in these areas should be closed or relocated as required by law.
- Enterprises are encouraged to focus on technological innovation, product quality improvement, and cost reduction instead of merely expanding production capacity.

2. Production Operations and Technological Standards

- Enterprises must be legally registered in China, have independent production, sales, and service capabilities, and invest **at least 3% of their main business revenue in R&D**.
- Encouraged to establish green factories, participate in joint construction of pilot platforms, and hold technological invention patents.
- Must adopt advanced, energy-efficient, environmentally friendly, safe, and intelligent production processes and equipment.
- Detailed technical requirements for monitoring and controlling various production processes (e.g., electrode coating, drying, burr control, alignment, injection environment control).

3. Product Performance

- Specifies performance standards for different types of lithium batteries:
    - Consumer lithium batteries: ≥260Wh/kg energy density for single cells, ≥200Wh/kg for battery packs, and a cycle life of ≥800 times with ≥80% capacity retention.
    - Small and large power lithium batteries: Detailed requirements for energy density, cycle life, and safety.
    - Energy storage lithium batteries: ≥155Wh/kg energy density for single cells, ≥110Wh/kg for battery packs, and a cycle life of ≥6000 times with ≥80% capacity retention.
- Performance requirements for cathode and anode materials, separators, and electrolytes.

4. Safety and Quality Management

- Enterprises must comply with safety production laws and regulations, implement safety measures, and establish safety management systems.
- Required to establish emergency response capabilities, create safety and quality traceability systems, and ensure products meet mandatory safety standards.

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- Lithium battery transportation must comply with relevant international and national regulations.

5. Resource Utilization and Environmental Protection

- Projects must meet national land use standards, conserve land, and conduct environmental impact assessments.
- Enterprises should obtain pollution discharge permits, prevent soil and groundwater pollution, and manage waste properly.
- Encouraged to use clean energy, implement energy-saving technologies, and conduct carbon footprint calculations for their products.

6. Health and Social Responsibility

- Enterprises must evaluate and mitigate occupational health risks, comply with occupational disease prevention laws, and establish occupational health and safety management systems.
- Required to pay taxes and social insurance contributions for employees.

7. Supervision and Management

- Enterprises voluntarily prepare application materials based on the standard conditions and submit them to the Ministry of Industry and Information Technology (MIIT) through provincial authorities.
- MIIT, along with other departments, will verify compliance, announce qualified enterprises, and conduct periodic inspections.
- Enterprises that fail to meet the conditions or violate regulations may have their qualifications revoked.

8. Supplementary Provisions

- The standard conditions apply to lithium battery production, including cells and battery packs, as well as related materials (cathode, anode, separator, electrolyte).
- Updates to technical indicators will be issued as needed, reflecting technological advancements.
- The document will be effective from a specified date in May 2024 and is subject to interpretation and revision by MIIT based on industry development and macroeconomic control requirements.

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Tabular summary of the KPIs of the draft of the new Chinese "Lithium-Ion Battery Industry Standard Conditions (2024)" and their comparison with the data in the “Benchmarking International Battery Policies” of Fraunhofer ISI (January 2024) and the Batteries Europe KPIs Benchmarking (October 2023)

KPIs	Lithium-Ion Battery Industry Standard Conditions (2024)	Fraunhofer ISI Paper	Batteries Europe KPIs Benchmarking
Production and Technology KPIs			
R&D Investment	At least **3%** of the main business revenue must be allocated to research and development annually		
Production Accuracy	**Electrode Coating**: Thickness and length control accuracy must be within 2µm and 1mm, respectively.		
	Moisture Control: Control accuracy for moisture content must be within or better than 10ppm		
	Burr Control: Electrode burr control accuracy must be within or better than 1µm.		
	Alignment Control: Electrode alignment accuracy during winding or stacking must be within or better than 0.1mm		
	Environmental Control: Dew point temperature for injection environments must be ≤ -30°C		
	Voltage and Resistance Control: For battery pack production, single-cell open-circuit voltage and internal resistance control accuracy must be within or better than 1mV and 1mΩ, respectively		

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Product Performance KPIs			
Consumer Lithium Batteries	**Energy Density**: ≥260Wh/kg for single cells, ≥200Wh/kg for battery packs.		
	Cycle Life: ≥800 cycles with ≥80% capacity retention		
Power Lithium Batteries	**Small Power Batteries**: ≥140Wh/kg for single cells, ≥110Wh/kg for battery packs. Cycle life of ≥1000 cycles with ≥70% capacity retention.		
	Large Power Batteries: **Energy Type**: ≥230Wh/kg for single cells with ternary materials, ≥165Wh/kg for battery packs. **Power Type**: Power density ≥1500W/kg for single cells, ≥1200W/kg for battery packs. Cycle life of ≥1500 cycles with ≥80% capacity retention.	2025: 400 Wh/kg 2030: > 400 Wh/kg 2035: >500 Wh/kg	2023: 250 Wh/kg 2027: 400 Wh/kg 2030: > 400 Wh/kg 2035: >500 Wh/kg 2050: 750+ Wh/kg
Energy Storage Lithium Batteries	**Energy Density**: ≥155Wh/kg for single cells, ≥110Wh/kg for battery packs		
	Cycle Life: ≥6000 cycles with ≥80% capacity retention.		
Material Performance KPIs			
Cathode Materials:			
	Lithium Iron Phosphate: ≥155mAh/g specific capacity.		
	Ternary Materials: ≥180mAh/g specific capacity.		
	Lithium Cobalt Oxide: ≥165mAh/g specific capacity		

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	Lithium Manganese Oxide: ≥115mAh/g specific capacity		
Anode Materials:			
	Carbon (Graphite): ≥340mAh/g specific capacity		2023: 330-355 mAh/g 2027: 360 mAh/g 2030/35: 374 mAh/g
	Amorphous Carbon: ≥280mAh/g specific capacity		
	Silicon Carbon: ≥480mAh/g specific capacity		
Separators			
	Dry Process Uniaxial Stretching: Tensile strength ≥120MPa (longitudinal), ≥10MPa (transverse); puncture strength ≥0.133N/μm.		
	Dry Process Biaxial Stretching: Tensile strength ≥110MPa (longitudinal), ≥25MPa (transverse); puncture strength ≥0.133N/μm.		
	Wet Process Biaxial Stretching: Tensile strength ≥110MPa (longitudinal), ≥90MPa (transverse); puncture strength ≥0.204N/μm.		
Electrolytes			
	Water Content: ≤20ppm.		
	Hydrogen Fluoride Content: ≤50ppm.		
	Metal Impurities: Sodium ≤2ppm, other metals ≤1ppm each		

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	Sulphate Ion Content: ≤10ppm.		
	Chloride Ion Content: ≤5ppm.		
Energy Consumption KPIs			
	Lithium Battery Production: ≤400kgce/10,000Ah (~ 90 kWh / kWh)		2023: 50 kWh / kWh 2030: 25 kWh / kWh 2035: 10 kWh / kWh
	Cathode Material Production: ≤1400kgce/ton (~ 11.396 kWh/t)		12.566 kWh/t
	Anode Material Production: ≤3000kgce/ton (~ 24.420 kWh/t)		11.0 kWh/t
	Separator Production: ≤750kgce/10,000m (~ 6105 kWh/10.000m)		
	Electrolyte Production: ≤50kgce/ton (~ 407 kWh/t)		
Safety and Quality Management KPIs			
	Compliance with safety production laws and standards.		
	Implementation of safety management systems and emergency response capabilities.		
	Meeting mandatory safety standards for lithium battery products.		
	Establishing a quality management system including control processes		

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	for quality, internal and external short-circuit prevention, and quality records.		
Environmental Protection KPIs			
	Adherence to environmental impact assessment regulations and pollution discharge permits		
	Implementation of measures to prevent soil and groundwater pollution		
	Proper classification, collection, storage, transportation, utilization, and disposal of solid wastes like used organic solvents and waste batteries		
	Development of energy consumption and carbon footprint accounting systems.		
Social Responsibility KPIs			
	Compliance with occupational health and safety laws		
	Implementation of occupational health and safety management systems.		
	Payment of taxes and social insurance contributions for employees.		

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