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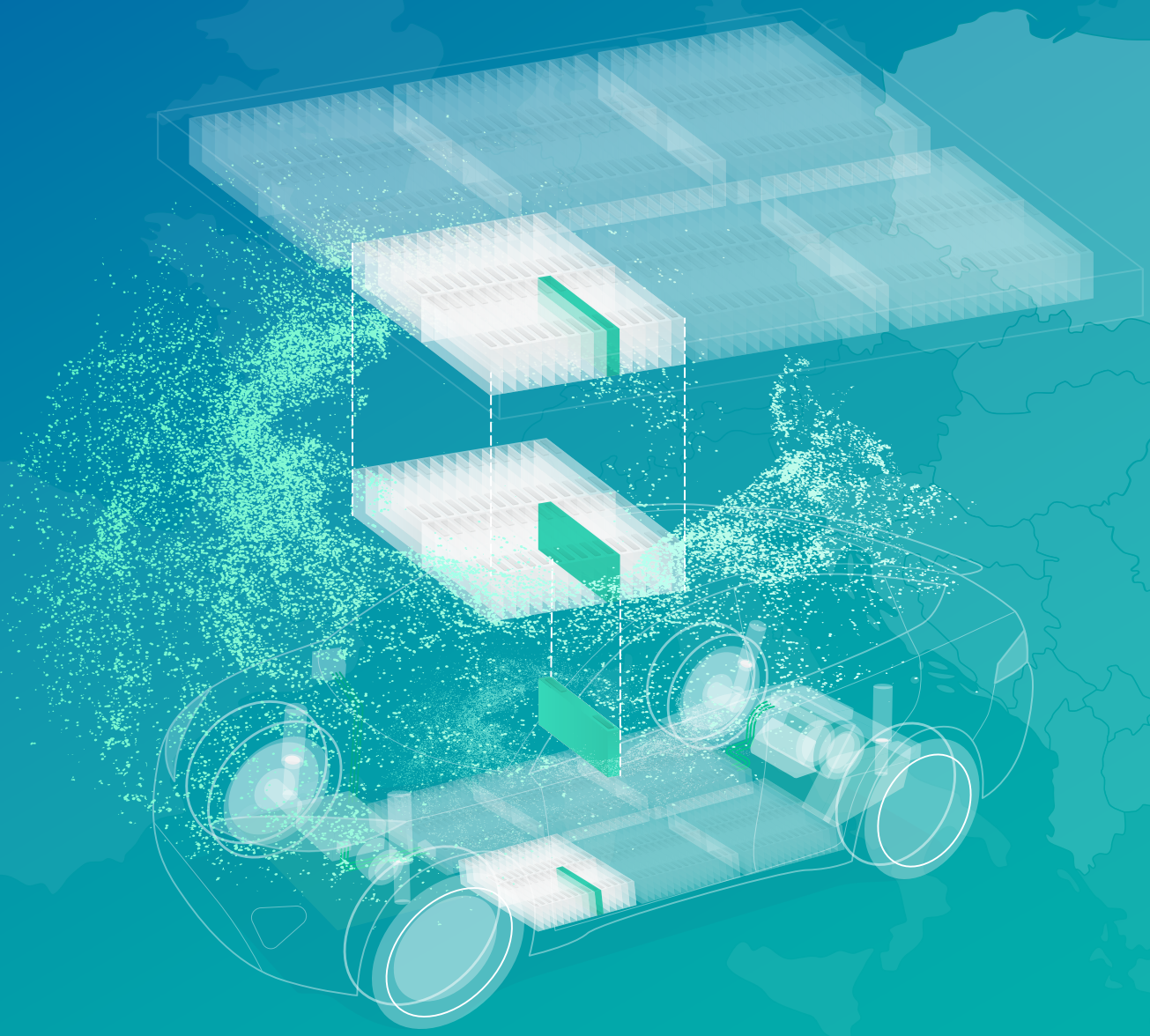
REPORT

Europe runs on Polish lithium-ion batteries

The potential of the battery sector in Poland and the CEE Region



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Dear Readers,

We are pleased to present our report titled “Europe Runs on Polish Lithium-Ion Batteries: The Potential of the Battery Sector in Poland and the CEE Region”. This report was developed with substantial support from market leaders and stakeholders in Poland and Slovakia.

E-mobility is the most significant trend shaping the global transportation sector today. According to the International Energy Agency (IEA), sales of electric vehicles doubled in 2021 compared to the previous year, reaching a record-breaking 6.6 million. This marks a dramatic shift from the approximately 55,000 electric cars sold worldwide back in 2011. In 2021, electric cars accounted for almost 10% of global car sales. Moreover, sales of electric vehicles continued to surge in 2022, with 2 million sold in the first quarter alone, representing a 75% increase from the same period in 2021, projected to exceed 7 million vehicles by the end of the year.

Increased demand for zero- and low-emission vehicles is also recorded in Europe – in 2022, the BEV and PHEV share reached the level of 22.8% – representing 2,588,906 cars sold - and was almost on par with the market share of hybrids (HEVs) that cannot be charged from an external source of energy (23.4%).

To ensure the substantive quality of this publication, we based its drafting on a series of workshops in Poland (organized as part of the Battery Sector Committee to ensure participation and involvement, but not limited to this body) and in the CEE region, which was done with the existing partnerships of CEE GTI and SEVA.

This report addresses the fundamental challenge facing the battery sector in Poland, Slovakia, and the wider CEE region: the need to leverage their potential for production leadership and translate it into innovative and robust research and development capabilities. This requires not only catching up with the existing solutions but also shaping future technologies that can lead the way in the industry.

Given the current market trends, there is no better time than now to examine the key market drivers and support the robust development of this sector.

Enjoy the read.

Maciej Mazur

Managing Director, PSPA
Vice-President, AVERE

Executive summary

The growing demand for electric vehicles contributes to a significant increase in the demand for a key component of this type of vehicle – lithium-ion batteries. According to the BNEF forecasts global lithium-ion battery production capacity is projected to increase eightfold by 2027 reaching 8,945 Gigawatt-hours (GWh).

According to the BNEF ranking for 2022, Poland, Hungary, the Czech Republic, and Slovakia are among the top 30 countries leading the lithium-ion battery supply chain and actively contributing to building the global value chain of the battery sector. Overall, European countries have accounted for 14% of the global battery manufacturing capacity in 2022. While China continues to dominate the market, its share is projected to decrease from 77% in 2022 to 69% in 2027. Europe is expected to host six of the top 10 countries for battery production by 2027, with Poland and Hungary projected to increase their capacity and maintain their high rankings, ranking 6th and 4th, respectively. Hungary, in particular, will benefit from a planned 100 GWh investment from CATL. Other countries in the CEE region, such as Serbia with 16 GWh in Subotica, and Slovakia with 10 GWh, are also poised to become significant players in the global battery value chain. Meanwhile, the US is projected to increase its production capacity by over 10 times, with the support of initiatives such as the EV tax credits in the Inflation Reduction Act. However, both the US and Europe will need to invest $87 billion and $102 billion, respectively, to meet domestic battery demand with fully local supply chains by 2030.

Europe is set to have nearly 50 battery projects in production by 2030, with an estimated capacity of up to 1.8 TWh. In the CEE Region, new investments in existing factories are planned in countries such as Poland, Slovakia, Hungary, the Czech Republic, Latvia, and Serbia. LG Energy Solution Wrocław in Biskupice Podgórne (Poland), the largest electric car battery production center in Europe with dozens of state-of-the-art production lines, currently has a capacity of 86 GWh, which will soon be expanded to 115 GWh.

To reach 4th place in the global ranking, Poland needs to double its production capacity by 2027, surpassing a total production capacity of over 200 GWh.

To unlock the full potential of the Polish battery sector, action is needed in the following key areas:

1. **Growing domestic capacities for raw materials and battery material**
2. **Boosting production of components and batteries**
3. **Enhancing recycling and second-life projects**
4. **Growing skills and talent**

Executive summary

Creating a European value chain for lithium is a complex endeavor. Europe boasts significant reserves of lithium and several mining projects are currently in the preparatory stages. Three such projects are underway in the CEE region, namely in the Czech Republic, Serbia, and Romania.

However, establishing a sustainable lithium value chain in Europe has enormous potential benefits. In addition to the economic opportunity at hand, Europe could set a new environmental standard for lithium mining and refining, which would accrue benefits for the battery and electric vehicle industries.

The imperative of recycling Li-ion batteries cannot be overstated for both environmental preservation and the sustainable growth of the battery industry. Scaling up recycling activities can significantly reduce reliance on virgin raw materials. Projections for end-of-life batteries and production scrap available for recycling estimate a volume of 1.7 million tonnes of cell equivalent battery waste in 2030, representing a 259% increase compared to 2021. The second-life market also plays a crucial role in the entire battery life cycle. Around 73 European companies are directly involved in or support activities for second-life battery applications.

Employment in the battery value chain is expected to increase to a total of 10M jobs in 2030, with more than half of these jobs in developing countries. European Commission expects up to 4M new jobs to be created by 2025 and plans to train 800,000 workers by 2025 (roughly 160,000 workers need to be trained per year). That generates an opportunity for new workplaces in the CEE region thereby strengthening the region's commitment to a global perspective on the battery sector.

Poland plays a leading role in the battery sector supply chain. Lithium-ion batteries already account for more than 2.4% of all Polish exports. The value of exports in the battery sector increased 38-fold over the last six years from around PLN 1 billion (EUR 0.21 billion) in 2017 to over PLN 38 billion (EUR 8.24 billion) in 2022.

The automotive industry in Poland currently sustains nearly 400,000 job positions, including roles in OEMs, suppliers, maintenance and repair, energy production, infrastructure and recycling. In an ambitious scenario, the development of electromobility in Poland is expected to create up to 6,000 new jobs. Poland's major cities host technical universities that offer education in the field of electromobility, producing highly skilled engineers. Moreover, over 4,776 schools in Poland provide education that prepares students for professions in the automotive industry.

Executive summary

The largest li-ion battery factory in the world is currently operating in Poland, launched by LG Energy Solution in Biskupice Podgórne near Wrocław. Its target output will reach 115 GWh per year. Other leading companies in the battery sector are also investing in Poland and these include Northvolt, Umicore, SK hi-tech battery materials, Capchem, Guotai Huarong, BMZ and Mercedes-Benz Manufacturing Poland.

There are multiple R&D initiatives currently underway in Poland, primarily pertaining to recycling and second-life applications. One such endeavor, aimed at gaining expertise in recycling technology and processes, is being undertaken by Elemental Strategic Metals at a new facility in Zawiercie. In addition, Solaris Bus & Coach and TAURON Polska Energia have teamed up to launch a project focused on developing a prototype system for storing electrical energy using decommissioned bus batteries.

Slovakia, which is the world's largest per capita car producer and a leading car manufacturing hub, is home to four original equipment manufacturers (OEMs) and approximately 350 automotive suppliers. Over the past seven years, the entire industry has achieved an annual production capacity of over 1 million vehicles, with the exception of the pandemic year of 2020, during which this milestone was slightly missed. All four OEMs have now launched the production of battery electric and plug-in hybrid vehicles and have been steadily expanding their electrified product portfolios.

The total annual demand for battery capacity in Slovakia may rise to an astounding 60 GWh by 2030 and 80 GWh by 2035.

Despite lacking significant mining capacity for any battery materials or operational cell production capacity, Slovakia boasts a large primary metal producer that traditionally supplies the automotive industry.

Slovakia places a strong emphasis on engineering and STEM education, with technology-focused universities and colleges situated in all of the main industrial hubs across the country. When it comes to academic institutions dedicated to automotive and mobility, three key cities – Bratislava, Žilina, and Košice - stand out as being particularly important.

Both public and private entities in Slovakia are engaged in research and development projects, as well as technology development, pertaining to batteries. The areas of expertise are relatively concentrated and include the development of new battery materials and chemistries, advanced battery management systems (BMS), advanced sensors, and the implementation of artificial intelligence and automation in the recycling process, as well as exploring the potential for second-life applications of batteries.

Executive summary

On December 9, 2022, a preliminary political agreement on the proposed Battery Regulation was reached by the European Parliament and the Council. Its adoption by both bodies and entry into force is anticipated in the coming months. The objectives of this Regulation are to facilitate the efficient functioning of the internal market and establish a more circular battery economy, while also mitigating and reducing any negative impacts on the environment and human health. However, the agreement must now be officially adopted by each institution prior to taking effect in 2023.

To sustain the growth of the battery industry in the CEE region, prompt and decisive action is necessary, such as implementing substantial budgets or subsidies for energy prices. This is crucial in order to mitigate the risk of investment being diverted from European countries. The rise in electricity costs across the EU is also contributing to increased operational expenses (OPEX). Furthermore, with the emergence of distortions to the transatlantic level playing field, resulting from the US Inflation Reduction Act (IRA) and similar support schemes in Canada, Japan, and South Korea, it appears that investments in the EU are either being put on hold or redirected elsewhere.

1

Battery market

1

Battery market

In 2022, five European countries established their presence in the ranking of battery cell manufacturing capacity, totaling 164 GWh, which constitutes 14% of the total share. Poland secured the second position with a 6% contribution, largely due to the significant input of LG Energy Solution's Wrocław – the largest gigafactory in Europe.

Poland, along with Hungary, emerged as strong representatives of the CEE region, making a significant impact on the ranking with a combined capacity of 111 GWh, accounting for 9% of the global share. However, with an impressive capacity of almost 900 GWh (77% of the total share), China unquestionably dominates the ranking.

Battery manufacturing capacity by country in 2022

Rank	Country	2022 Battery cell manufacturing capacity, GWh	% of total
#1	China	893	77%
#2	**Poland**	**73**	**6%**
#3	USA	70	6%
#4	**Hungary**	**38**	**3%**
#5	Germany	31	3%
#6	Sweden	16	1%
#7	South Korea	15	1%
#8	Japan	12	1%
#9	France	6	1%
#10	India	3	0.2%
	Other	*7*	*1%*
	Total	**1,163**	100%

– The countries of Central and Eastern Europe

Source: BloombergNEF

The BNEF ranking for 2022 has placed Poland, Hungary, the Czech Republic, and Slovakia among the top 30 leading countries in the global lithium-ion battery supply chain. This ranking is based on 45 metrics across five key themes, including the availability and supply of raw materials, battery cell and component manufacturing, local demand for electric vehicles and energy storage, infrastructure, innovation and industry, as well as ESG considerations. Most European countries, except Finland and the Czech Republic, have dropped in the ranking as compared to the previous year. Hungary is set to increase its battery manufacturing capability and is expected to meet Poland in the ranking[1]. The strength of Poland, Hungary and the Czech Republic is the potential for further development in e.x. in terms of broadening sustainable supply chain, existing factories are conducive to the implementation of related investments, and availability of investment incentives from public administration.

2022 global lithium-ion battery supply chain ranking[2]

Country	Raw materials	Battery manufacturing	ESG	Industry, innovation and infrastructure	Downstream demand	Overall ranking
China	1	1	17	9	1	1
Canada	3	8	6	4	10	2
USA	6	4	16	5	2	3
Finland	9	15	2	1	11	4
Norway	18	10	1	3	7	5
Germany	21	6	4	7	2	6
South Korea	17	2	10	6	5	7
Sweden	21	9	3	2	8	8
Japan	13	3	8	12	8	9
Australia	2	15	9	13	11	10
France	24	10	5	10	5	11
UK	26	15	7	8	4	12
Czech Republic	**23**	**10**	**11**	**11**	**18**	**13**
Poland	**24**	**5**	**15**	**16**	**15**	**14**
Hungary	**26**	**6**	**13**	**14**	**20**	**15**
Chile	7	18	14	23	19	16
Turkey	15	18	21	15	13	17
India	13	10	26	21	13	18
Vietnam	20	10	20	18	17	19
South Africa	8	18	19	17	26	20
Brazil	4	18	23	22	20	21
Indonesia	5	18	22	27	25	22
Argentina	11	18	12	19	26	23
Slovakia	**26**	**18**	**18**	**25**	**24**	**24**
Thailand	26	18	24	20	16	25
Philippines	10	18	29	28	22	26
Mexico	16	18	27	26	23	27
Morocco	19	18	25	24	28	28
DRC	11	18	30	29	30	29
Bolivia	26	18	28	30	28	30

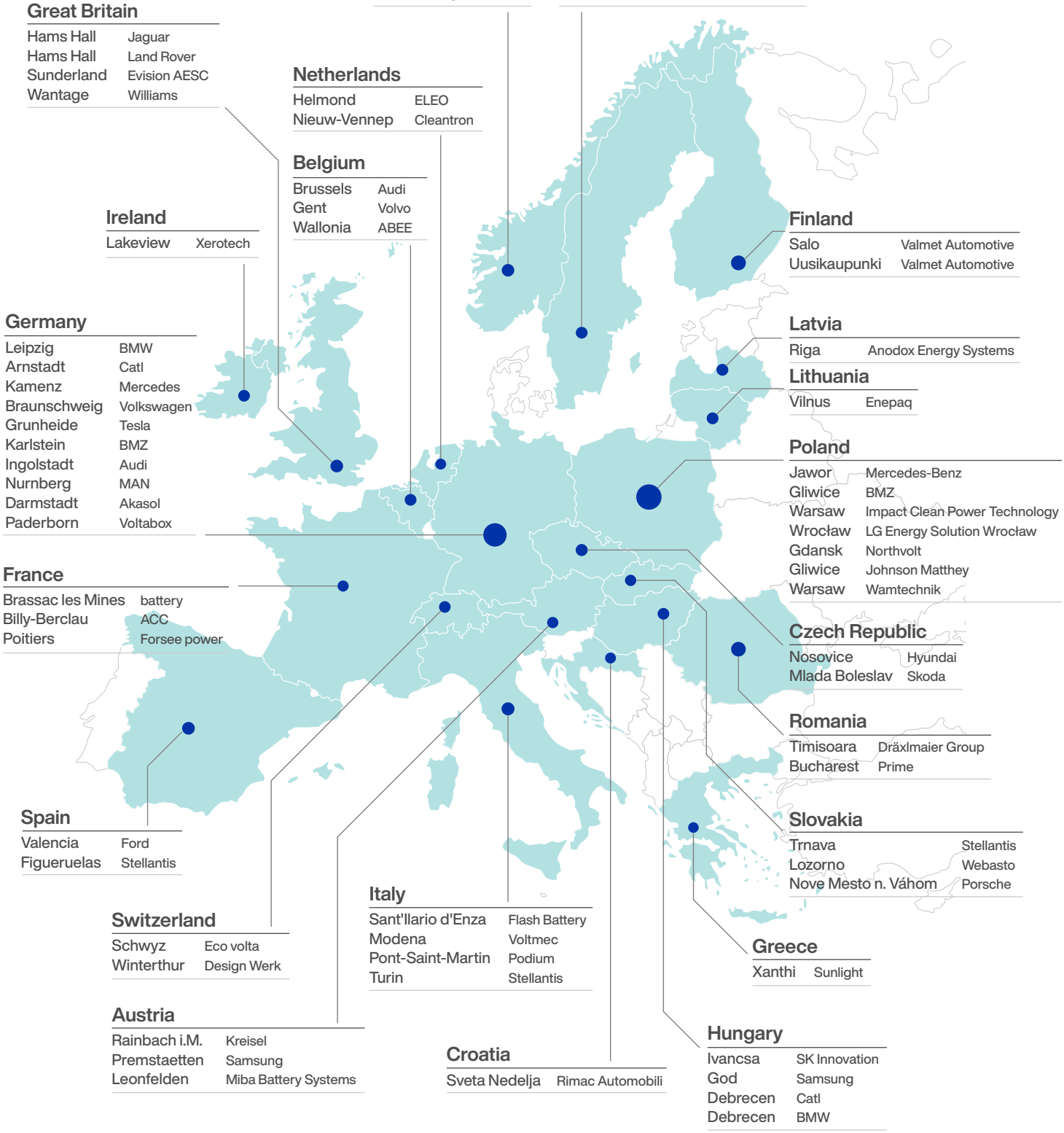
– The countries of Central and Eastern Europe

Source: BloombergNEF

[1] https://about.bnef.com/blog/u-s-narrows-gap-with-china-in-race-to-dominate-battery-value-chain/

[2] https://www.volta.foundation/annual-battery-report;
https://www.energy-storage.news/bloombergnef-china-dominates-global-battery-supply-chain-again-with-followers-in-flux/;
https://about.bnef.com/blog/chinas-battery-supply-chain-tops-bnef-ranking-for-third-consecutive-time-with-canada-a-close-second/

European manufacturers of modules and packs



Sweden

Sodertalje	Scania
Gothenburg	Volvo

Norway

Trondheim	Siemens
Godvik	Norway Electric Systems

Great Britain

Hams Hall	Jaguar
Hams Hall	Land Rover
Sunderland	Evision AESC
Wantage	Williams

Netherlands

Helmond	ELEO
Nieuw-Vennep	Cleantron

Belgium

Brussels	Audi
Gent	Volvo
Wallonia	ABEE

Ireland

Lakeview	Xerotech

Finland

Salo	Valmet Automotive
Uusikaupunki	Valmet Automotive

Germany

Leipzig	BMW
Arnstadt	Catl
Kamenz	Mercedes
Braunschweig	Volkswagen
Grunheide	Tesla
Karlstein	BMZ
Ingolstadt	Audi
Nurnberg	MAN
Darmstadt	Akasol
Paderborn	Voltabox

Latvia

Riga	Anodox Energy Systems

Lithuania

Vilnus	Enepaq

Poland

Jawor	Mercedes-Benz
Gliwice	BMZ
Warsaw	Impact Clean Power Technology
Wrocław	LG Energy Solution Wrocław
Gdansk	Northvolt
Gliwice	Johnson Matthey
Warsaw	Wamtechnik

France

Brassac les Mines	battery
Billy-Berclau	ACC
Poitiers	Forsee power

Czech Republic

Nosovice	Hyundai
Mlada Boleslav	Skoda

Romania

Timisoara	Dräxlmaier Group
Bucharest	Prime

Slovakia

Trnava	Stellantis
Lozorno	Webasto
Nove Mesto n. Váhom	Porsche

Spain

Valencia	Ford
Figueruelas	Stellantis

Italy

Sant'Ilario d'Enza	Flash Battery
Modena	Voltmec
Pont-Saint-Martin	Podium
Turin	Stellantis

Switzerland

Schwyz	Eco volta
Winterthur	Design Werk

Greece

Xanthi	Sunlight

Austria

Rainbach i.M.	Kreisel
Premstaetten	Samsung
Leonfelden	Miba Battery Systems

Croatia

Sveta Nedelja	Rimac Automobili

Hungary

Ivancsa	SK Innovation
God	Samsung
Debrecen	Catl
Debrecen	BMW

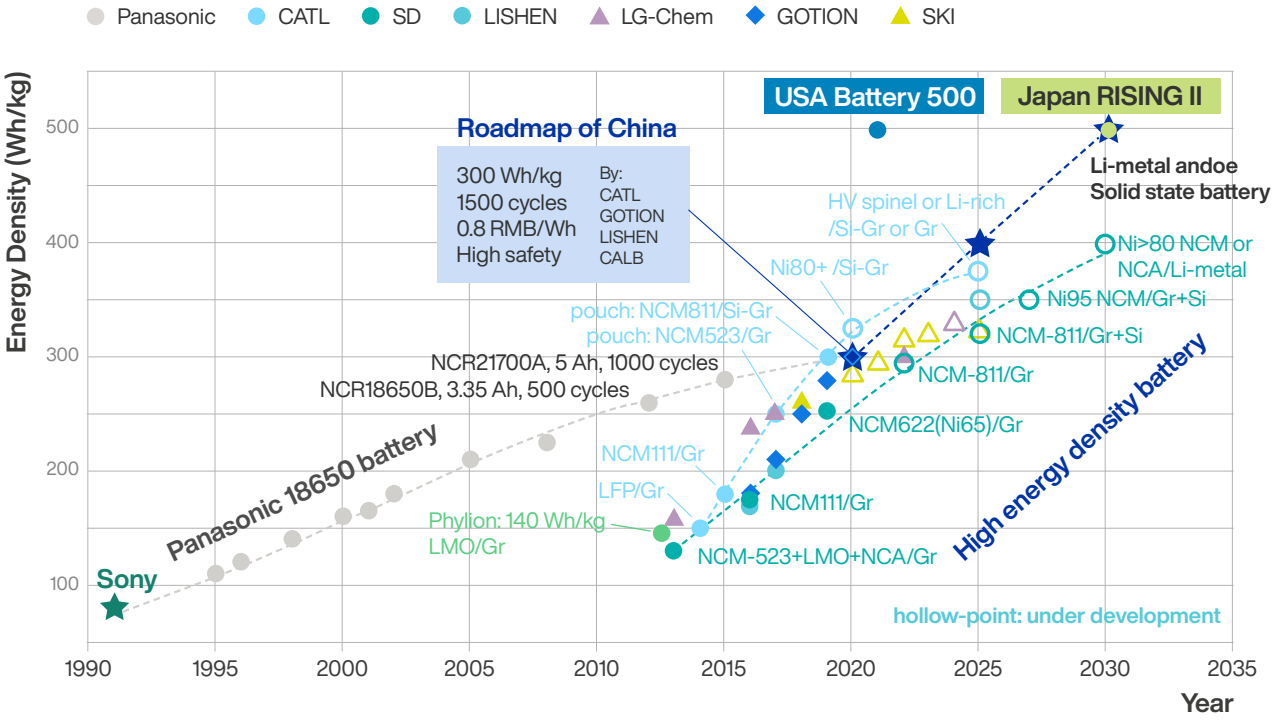
Source: Battery-News.de

1.1 Battery industry

1.1.1 Key technologies

Several associations and countries have published performance targets for battery roadmaps aimed at automotive applications. It is worth noting that the expectations for the lithium-metal solid-state battery are consistent across all roadmaps. However, it is important to keep in mind that these roadmaps are primarily focused on the transport sector, and therefore, other battery chemistries that are significant for other market segments may not be included.

Sustainable batteries roadmap to 2030 and beyond



Source: Nanowerk.com

Key Battery Chemistries

Different battery chemistries exhibit distinct performance characteristics such as energy density, power density, nominal voltage, cycle life, self-discharge rate, safety, temperature operations, and recycles value. All of these properties have an impact on the final cost per kWh. For instance, NMC chemistry is distinguished by its high energy density (Wh/kg) and has an average cost per kWh. On the other hand, LFP chemistry is known for its cost-effectiveness per cycle on a cell level ($/kWh), but its energy density is average.

Performance Metrics for Key Battery Chemistries

Bad | Poor | Average (Avg) | Good | Great

Performance Metrics for Key Battery Chemistries	Li-Ion (NMC811-Gr)	Li-Ion (NCA-Gr)	Li-Ion (LFP-Gr)	Li-Ion (LCO-Gr)	Li-Ion High Voltage (LNMO)	Lithium Metal (High Ni-Li)	Silicon (High Ni- Majority Silicon)	Sodium ion (NaMOx) **Not Commercial	Lithium Sulfur Battery (LSB) **Not Commercial	Solid State Sulfidic Lithium Metal Anode **Not Commercial	Solid State Oxidic Lithium Metal Anode **Not Commercial
Gravimetric Energy Density Wh/kg (cell level)	265-290	250-280	160-200	180-200	150-165	400-450	325-350	~150	**~500	**300 to #	**300 to –
Volumetric Energy Density Wh/L (cell level)	~735	~550	~390	~400	280-300	~800	750-900	~190	**~600	**~800	**~800
Power Density W/kg (cell level) (5Ah, 3C rate)	1100	700	200	380	1400	2000	1100	1000	500	**	**
Nominal Voltage (V)	3.7 (2.5–4.2)	3.6 (3.0–4.2)	3.2 (2.5–3.65)	3.6 (3.0–4.2)	4.0 (3.0–5.0)	3.7 (2.5–4.2)	3.7 (2.5–4.2)	3 (1.0–4.2)	2.1 (1.8–2.4)	3.7 (2.5–4.2)	3.7 (2.5–4.2)
Cost $/kWh (Cathode BOM) (Q1 2022 pricing)	$57.00	$52.00	$62.20	$82.60	$41.70	$67-75	$55-60	**	**~$10 estimated	Typically High Nickel ~$60	Typically High Nickel ~$60
Cost $/kWh (cell level at GWh+ production) **Materials and Production Cost only	$113.77	$107.97	$118.17	$138.57	$97.67	$124.07	**	**	**$58.61 estimated	**Higher than traditional Li-Ion / Li Metal	**Higher than traditional Li-Ion / Li Metal
Cost $/kWh/Cycle (cell level at GWh+ production)	$0.0758	$0.1080	$0.0591	$0.1848	$0.2605	**	**	**	**$0.5861 estimated	**Higher than traditional Li-Ion / Li Metal	**Higher than traditional Li-Ion / Li Metal
Cycle Life (C/2+ rate)	1500	1000	2000	750	250-500	200-400	500	**	**150	**250-500	**250-500
Self Discharge (Qual)	Avg	Avg	Avg	Avg	Bad	Bad	Avg	**Avg	**Bad	**Good	**Good
Calender aging (Qual)	Avg	Avg	Avg	Avg	Bad	Avg	Avg	**Avg	**Avg	**Bad	**Bad
Rate Capability (Qual)	Avg	Avg	Avg	Good	Avg	Good	Good	**Avg	**Poor	Good	**Poor
Safety (Qualitative)	Poor	Poor	Avg	Poor	Good	Bad	Poor	**Good	**Avg	**Poor	**Good
High Temperature Operation (60C+)(Qual)	Bad	Bad	Bad	Bad	Bad	Bad	Bad	**Good	**Good	**Good	**Good
Low Temperature Operation (10C-)(Qual)	Avg	Avg	Avg	Avg	Avg	Avg	Avg	**Bad	**Bad	**Bad	**Bad
Recycle Value (Li, Co, Ni, Cu) for Cost/Effort	Avg	Avg	Poor	Avg	Bad	Avg	Avg	**Bad	**Poor	**Poor to Bad	**Poor to Bad
Possible Form Factors and Challenges	No Restriction	No Restriction	No Restriction	No Restriction	No Restriction	No Restriction	*High Swelling*	No Restriction	No Restriction	*manufacturing limitations*	*manufacturing limitations*

Source: Battery Talk: Battery Application Break Down 1/01/2023

Different applications, particularly in the automotive industry, demand specific performance requirements. Not all battery chemistries are suitable for all modes of transportation. For instance, NMC and NCA chemistries perform well in sports cars, and have average suitability for mopeds, motorcycles, and sports utility vehicles, but are poor for heavy-duty trucks. Solid-state batteries, which are currently under strong development but not yet commercialized, are proposed to be a good fit for pickup trucks.

Application Matched to Preferred Performance Metrics

Bad | Poor | Average (Avg) | Good | Great

	Application Matched to Preferred Performance Metrics	Li-Ion (NMC811-Gr)	Li-Ion (NCA-Gr)	Li-Ion (LFP-Gr)	Li-Ion (LCO-Gr)	Li-Ion High Voltage (LNMO)	Lithium Metal (High Ni-Li)	Silicon (High Ni- Majority Silicon)	Sodium ion (NaMOx) **Not Commercial	Lithium Sulfur Battery (LSB) **Not Commercial	Solid State Sulfidic Lithium Metal Anode **Not Commercial	Solid State Oxidic Lithium Metal Anode **Not Commercial
Automotive	Moped (Wh/Kg > Cost > Self Discharge)	Avg	Avg	Good	Poor	Poor	Bad	Avg	Poor	Bad	Bad	Bad
	Motorcycle (Rate > Wh/L > Wh/Kg)	Avg	Avg	Poor	Poor	Bad	Avg	Good	Bad	Poor	Avg	Avg
	Sports Car (Wh/L > Rate > Cycle Life)	Good	Good	Avg	Avg	Poor	Bad	Avg	Bad	Bad	Poor	Poor
	Sedan (Cost > Wh/L > Cycle Life)	Poor	Poor	Avg	Poor	Avg	Bad	Bad	Avg	Poor	Bad	Bad
	Sports Utility Vehicle (Wh/L > Cost > Cycle Life)	Avg	Avg	Avg	Avg	Poor	Bad	Poor	Bad	Poor	Bad	Bad
	Pickup Trucks (Wh/L > Wh/Kg > Cycle Life)	Poor	Poor	Poor	Bad	Bad	Bad	Avg	Bad	Avg	Good	Good
	Heavy Duty Trucks (Wh/Kg > Cycle Life > Cost)	Poor	Poor	Poor	Bad	Bad	Bad	Poor	Bad	Good	Bad	Bad

Source: Battery Talk: Battery Application Break Down 1/01/2023

Expert's opinion

As we all know the potential of the market is huge and growing. Poland is currently considered the largest exporter of batteries in the EU. Those two aspects open up many opportunities and develop the market itself. There are many new technologies on the horizon and many new suppliers of various parts of the value chain. Just think of nearly 40 Gigafactories that have been announced. Let`s add to this high-quality local EMS, already built and future Li-Ion recycling facilities, and we have a recipe for successful growth.

One of the hottest topics these days is safety. Safety in many aspects – both technical and utility. Batteries need to be designed to prevent thermal runaway and to be safe for the user. This leads to new materials that can prevent thermal runaway or limit and protect against fire in extreme cases. Here we can also see a development in sensors and algorithms that can measure the behaviour of batteries and single cells. When it comes to utility we need to have a stable and safe charging process. Electric car fires are spectacular in their form, hence today's fears and many myths.

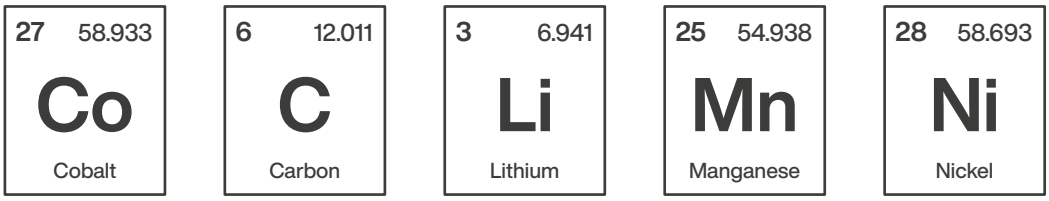
The second life of batteries exists just for big batteries and is usually on the ESS market. Usually, Second Life will depend on the end customer – they design and build a strategy for the product, but this consideration has to be started in an early stage of the battery system design process, otherwise, it will be too complicated and too expensive to re-built batteries and re-use them. It is said that the market is just filling up with batteries and scenarios are being defined about current market trends. Not to mention the impressive development of recycling technology, which will ensure an increase in the proportion of secondary raw materials used in the production of new batteries, and in the future will lead us to circular production

Filip Gabryelewicz
Product Manager, Wamtechnik

1.1.2 Raw materials and other materials used in the industry

The process of decarbonizing society involves a significant transformation from reliance on fossil fuels to dependence on minerals. This is a serious matter that requires careful attention. Europe must make a firm commitment to procure raw materials sustainably, taking into account environmental, ethical, and social considerations. This effort is particularly crucial for the European battery industry, which heavily relies on minerals such as lithium, nickel, graphite, and cobalt. Unfortunately, the current state of the battery industry falls short of expectations, with obscure and intricate sourcing methods that cause significant environmental and social impacts. Europe has a unique opportunity to adopt a different approach.

Five battery minerals are considered critical for Li-ion batteries:



Cobalt

Graphite
(a crystalline form of the element carbon)

Lithium

Manganese

Nickel

The selection of raw materials used in batteries can vary depending on their chemical composition, and certain nations play a more vital role than others in the supply chain of these metals. According to BNEF, the leading 25 nations supplying battery metals in the Li-ion supply chain for 2020 and 2025 have been identified, with notable appearances from Poland, Hungary, and the Czech Republic.

Top 25 Nations Producing Battery Metals for the EV Supply Chain

Country	2020 Rank	2025 Projected Rank	Change in Rank
Argentina	12	8	+4 ▲
Australia	2	2	0 ■
Brazil	3	7	-4 ▼
Canada	4	3	+1 ▲
Chile	6	4	+2 ▲
China	1	1	0 ■
Czech Republic	**17**	**17**	**0** ■
Democratic Republic of Congo (DRC)	8	10	-2 ▼
Finland	11	10	+1 ▲
France	17	17	0 ■
Germany	17	22	-5 ▼
Hungary	**22**	**22**	**0** ■
India	9	13	-4 ▼
Indonesia	7	4	+3 ▲
Japan	12	8	+4 ▲
Mexico	12	12	0 ■
Philippines	9	13	-4 ▼
Poland	**22**	**22**	**0** ■
South Africa	5	4	+1 ▲
South Korea	17	16	+1 ▲
Sweden	22	17	+5 ▲
Thailand	22	22	0 ■
UK	17	17	0 ■
USA	15	13	+2 ▲
Vietnam	16	17	-1 ▼

– The countries of Central and Eastern Europe

Source: BloombergNEF

The production of batteries is an activity that relies heavily on raw materials. To decrease our reliance on virgin raw materials, we can scale up recycling activities, which would ultimately lead to a significant reduction in dependency. However, in the immediate future, recycling alone may not provide enough recyclable batteries to completely replace the use of virgin raw materials. As a result, primary raw materials extraction will still be necessary to meet the production demands of batteries.

Creating a European value chain for lithium will be a challenging undertaking. Although Europe boasts substantial lithium resources and several commercial mining projects are currently underway, it's important to recognize that these initiatives have faced significant resistance, particularly from local communities.

However, establishing a sustainable lithium value chain in Europe would yield enormous benefits. In addition to the economic potential, Europe could set a new benchmark for environmentally responsible lithium mining and refining, which would benefit the battery and electric vehicle industries.

Cobalt has rightfully received significant attention in recent years, with approximately 70% of global cobalt mining occurring in the Democratic Republic of Congo (DRC). Unfortunately, health and safety issues have been reported in connection with cobalt extraction in the region. Although the majority of cobalt mined in the DRC is derived from industrial sources, artisanal mining still accounts for a significant share, upwards of 30%. Given that cobalt is a crucial raw material for battery production, the OECD and the World Economic Forum have called for stronger engagement with the artisanal mining sector and the formalization of their practices. However, the formalization of artisanal mining is a complex process that will likely require an extended period of time.

Manufacturers have identified and acknowledged the challenges associated with sourcing critical raw materials, and are leveraging their resources and expertise to develop and implement potential solutions independently.

Expert's opinion

Raw material sourcing at Northvolt

The decarbonization of society implies a fundamental shift from dependence on fossil-fuels to dependence on minerals. This matter cannot be treated lightly: Europe must commit to a determined approach to sourcing raw materials sustainably, encompassing environmental, ethical and social aspects. This initiative is especially relevant to the European battery industry, which is heavily reliant on raw materials – in particular, lithium, nickel, graphite and cobalt. What we see in today's battery industry is far from ideal. Raw material sourcing is opaque, complex, and carries a high environmental and societal footprint. Europe has the chance to do things differently.

Battery manufacturing is a raw materials intensive activity. Ultimately, we can significantly reduce our dependency on virgin raw materials through scaling up recycling activities.

In the more immediate timeframe, as recyclable battery volumes are not sufficient to fully replace use of virgin raw materials, primary raw materials extraction will be necessary for battery production. This point underscores the need to ensure we source raw materials in the best possible way. To this end, we have developed a comprehensive raw materials strategy for sustainable sourcing. We prefer to source raw materials directly from mines and refineries. By simplifying and shortening our supply chains, we improve the traceability of our raw materials and enables a more direct relationship with each individual supplier. An initiative which will take some time, but will improve both the sustainability performance and security of supply for the battery industry, is the development of a European raw materials supply chain. Our selection of raw materials suppliers follows a comprehensive due diligence process, geared towards assessing suppliers across a full spectrum of sustainability areas. Into our selection process we have incorporated best practice from international standards including the UN Guiding Principles on Business and Human Rights and OECD Due Diligence Guidance.

In December 2021, we announced the Northvolt-Galp joint venture 'Aurora' which aims to serve as a springboard for the development of an integrated lithium value chain aligned with European ambitions. The principal goal of Aurora is to establish Europe´s largest and most sustainable integrated lithium conversion plant, with an initial annual production capacity of up to 35,000 tons of battery grade lithium hydroxide – a critical material required by the lithium-ion battery manufacturing industry. The start of operations at the plant is targeted for 2026. Additionally, we stand to improve Europe's security of supply for a critical raw material for which global demand is set to skyrocket in coming decades.

Northvolt

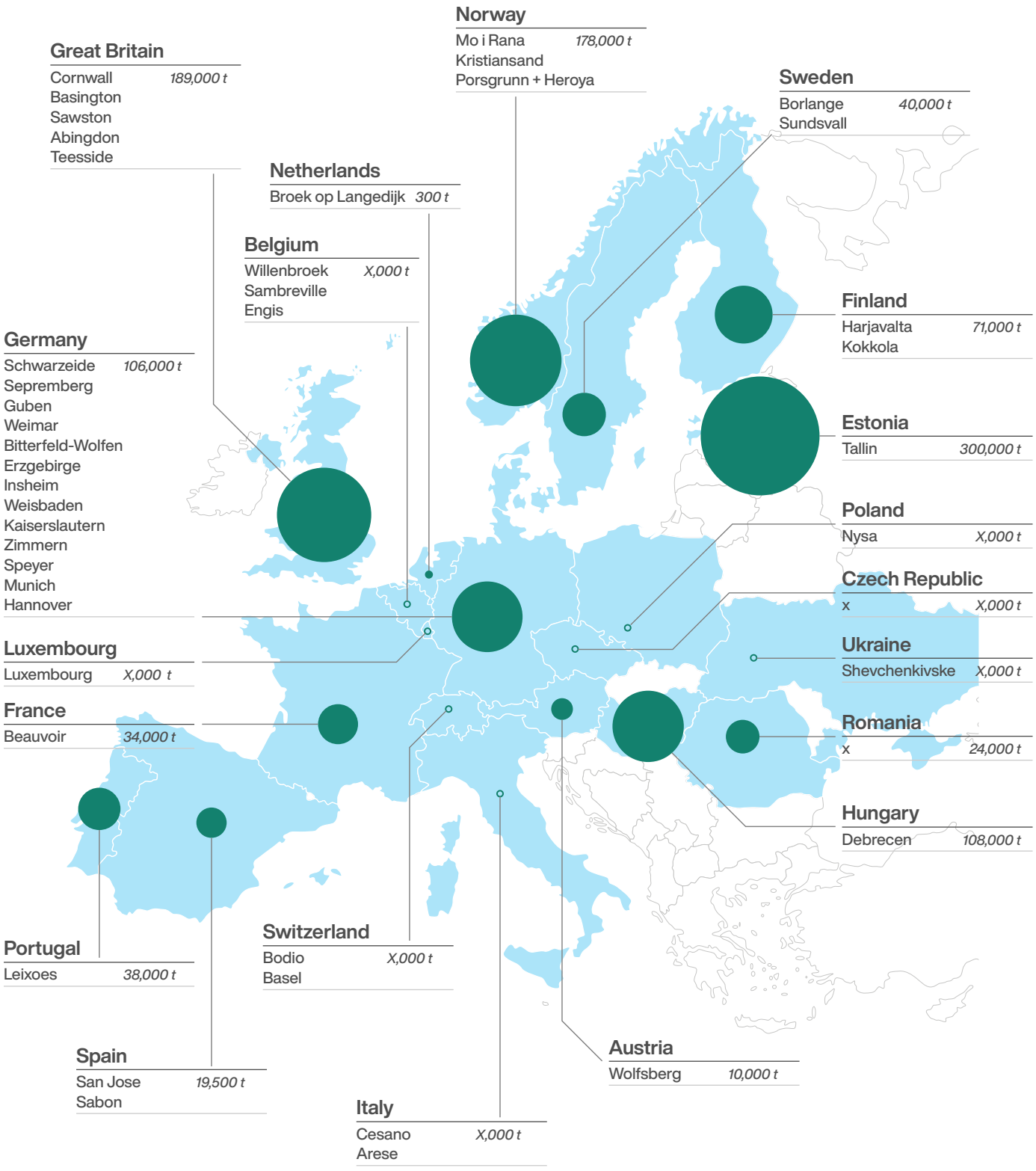
A comprehensive list of lithium projects in Europe reveals planned initiatives in the Czech Republic, Serbia, and Romania, which are expected to have a combined capacity of approximately 19.7 kt Li by the year 2030.

Lithium projects in Europe

Company / Project	Country	Estimated Capacity in 2030 (kt Li)
CEZ Group & European Metals – Cinovec Project	**Czech Republic**	**4.8**
Rio Tinto – Jadar Project	**Serbia**	**10.9**
RockTech Lithium	**Romania**	**4.0**
AMG Lithium – Bitterfeld-Wolfen Project	Germany	3.3
Bondalti Chemicals & Neometals	Portugal	3.3
British Lithium	UK	3.9
Cornish Lithium	UK	1.3
Cornish Lithium & Geothermal Engineering	UK	0.4
Deutsche Lithium – Zinnwald Lithium Project	Germany	2.0
EnBW & Karlsruhe Institute of Technology	Germany	0.2
Eramet – EuGeLi Project	France	2.3
European Lithium – Wolfsberg Lithium	Austria	1.7
Green Lithium	UK	8.3
Imerys – Emili Project	France	5.6
Infinity Lithium Corp. & Valoriza Mineria – San Jose	Spain	3.2
Keliber Oy	Finland	2.5
Lithium de France	France	6.0
Livista Energy	UK	5.6
LusoRecursos Portugal Lithium	Portugal	3.5
Northern Lithium	UK	1.2
Northvolt & Galp – Aurora Project	Portugal	5.8
RockTech Lithium – Guben	Germany	4.0
Viridian Lithium	France	4.1
Vulcan Energy Resources	Germany	6.6

– The countries of Central and Eastern Europe

Battery active materials (cobalt, lithium, nickel) manufacturers in Europe
(in tons)

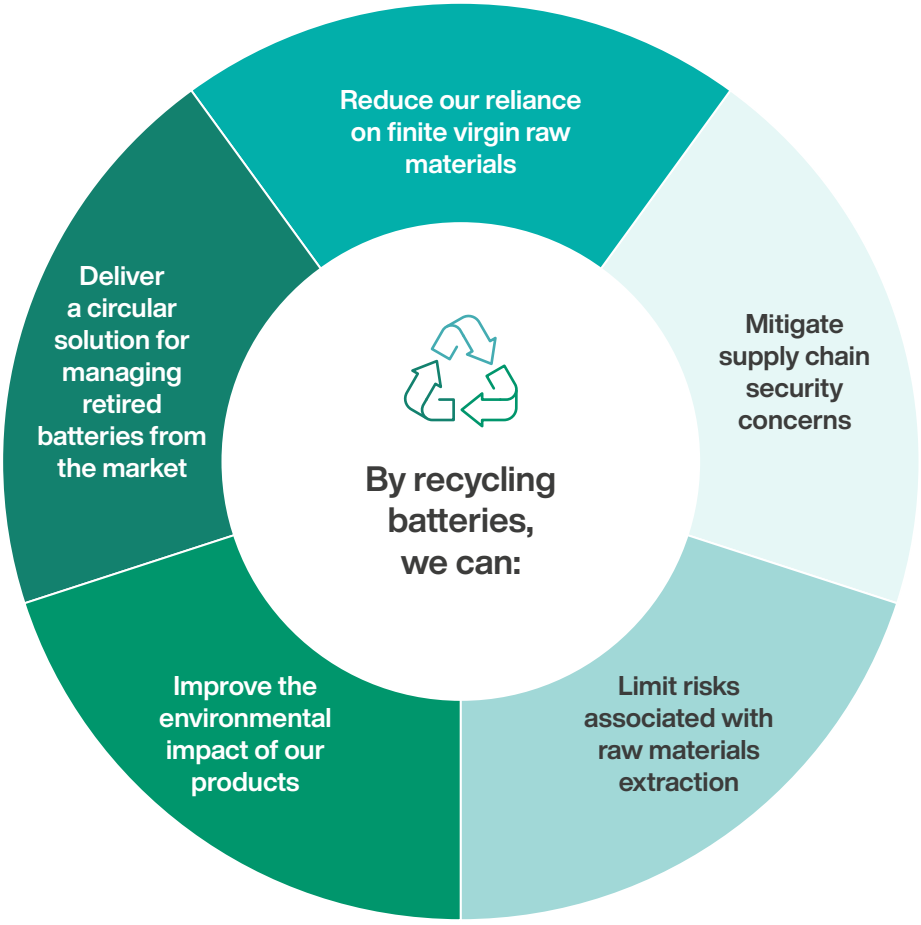


Source: Battery-News.de

1.1.3 Recycling and second life

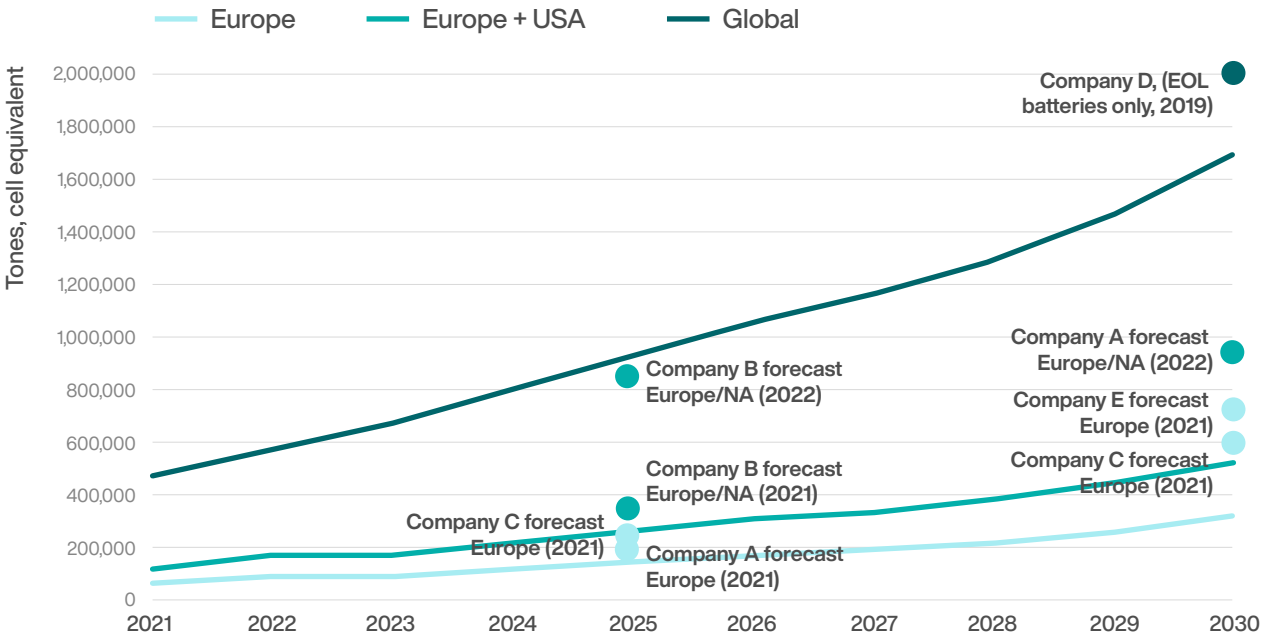
The recycling of Li-Ion batteries plays a vital role in promoting environmental sustainability and supporting the growth of the battery industry. Improper disposal of Li-Ion batteries in landfills can result in the release of hazardous metals and chemicals into the environment. Conversely, recycling these batteries can help curb demand for the production of new ones, conserve valuable resources, and mitigate greenhouse gas emissions.

Battery recycling is a crucial element in transforming the battery industry. With the worldwide growth of lithium-ion battery production, we face the dual challenges of ensuring a sustainable supply of raw materials and providing a sustainable solution for end-of-life batteries. Fortunately, battery recycling provides an effective solution to these challenges.



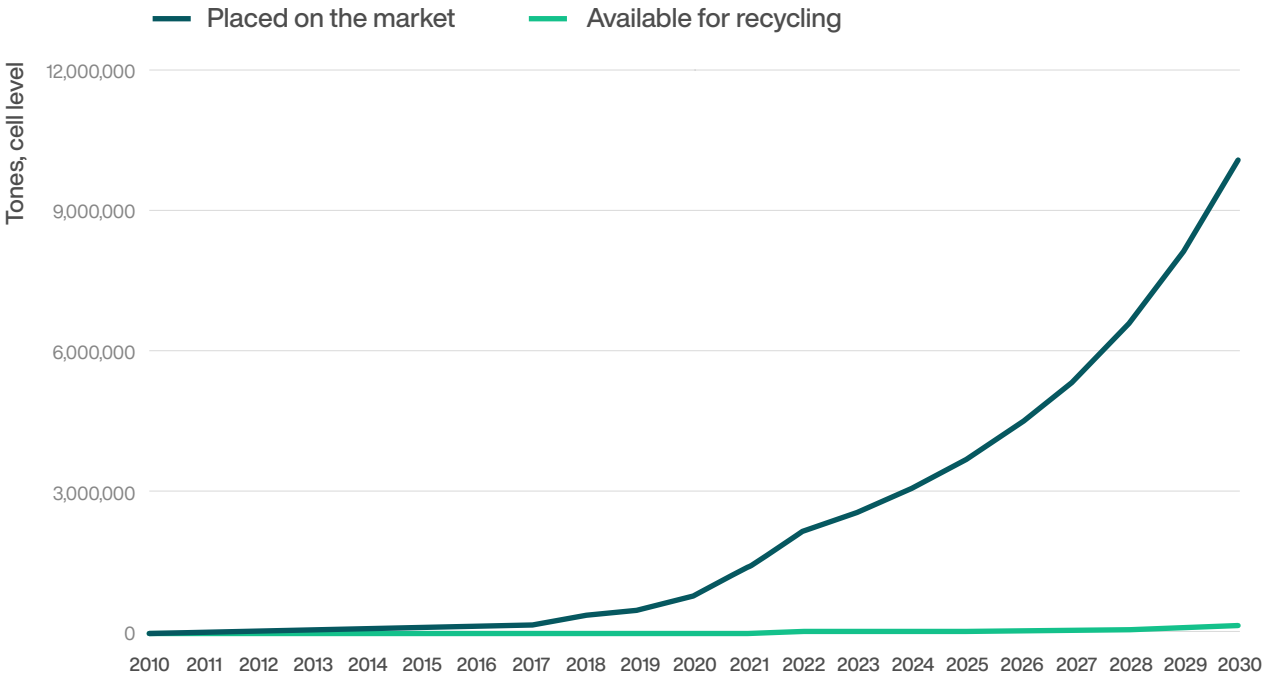
The forecast for the volume of end-of-life batteries and production scrap available for recycling predicts a significant increase to 1.7 million tonnes of cell equivalent battery waste by 2030, representing a 259% rise compared to 2021. Approximately 60% of this waste will be available in the Asian market, while Europe and the United States are expected to account for between 25% and 30% of the annual volume by 2030.

Circular Energy Storage's forecast for battery waste material available for recycling compared to other estimates (EOL batteries + production scrap)



Source: Circularenergystorage.com

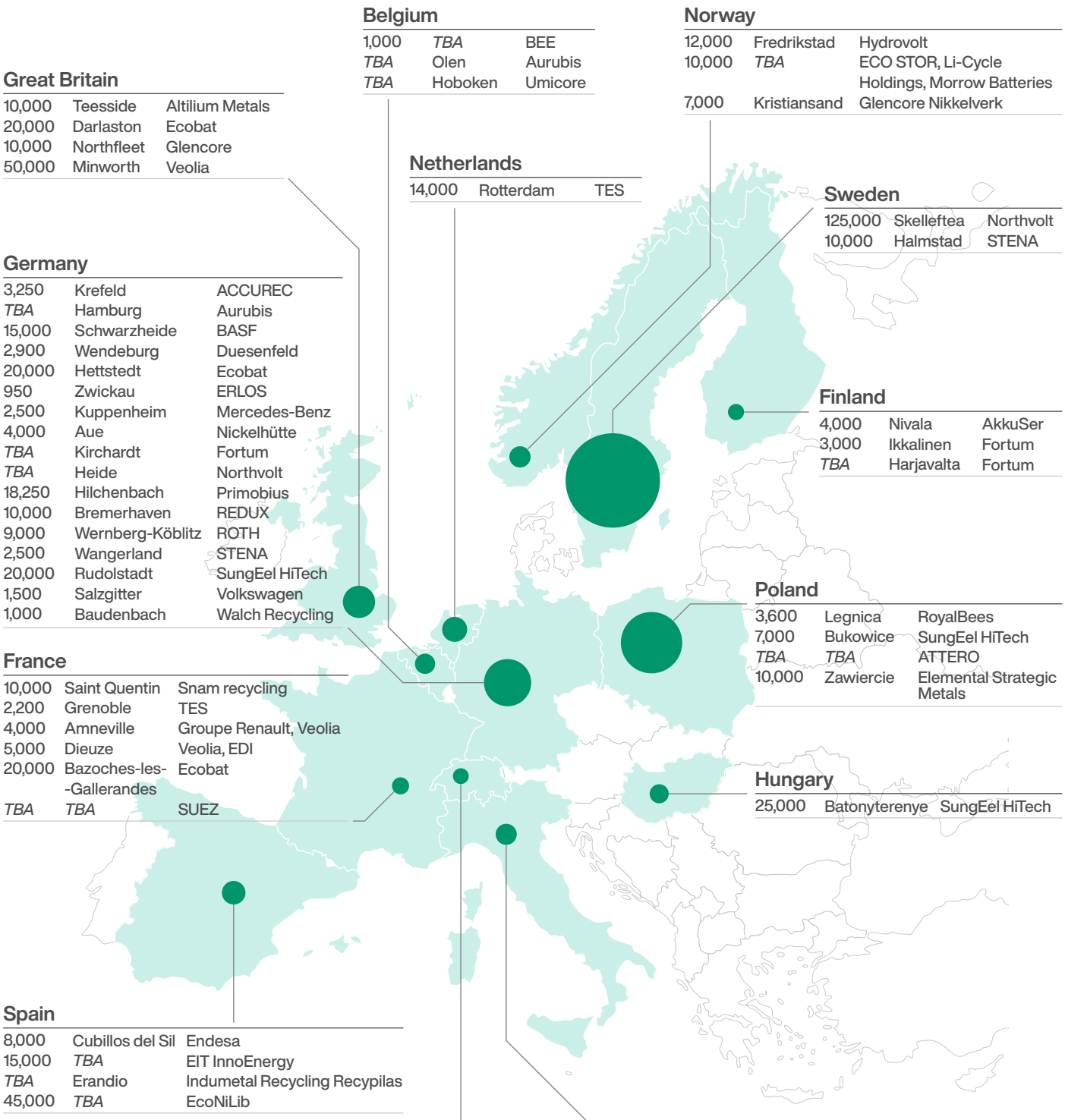
Light duty EV batteries placed on the global market vs available for recycling



Source: Circularenergystorage.com

An outline of lithium-ion battery recycling initiatives across Europe

Capacity (t/a)



Great Britain

10,000	Teesside	Altilium Metals
20,000	Darlaston	Ecobat
10,000	Northfleet	Glencore
50,000	Minworth	Veolia

Belgium

1,000	*TBA*	BEE
TBA	Olen	Aurubis
TBA	Hoboken	Umicore

Norway

12,000	Fredrikstad	Hydrovolt
10,000	*TBA*	ECO STOR, Li-Cycle Holdings, Morrow Batteries
7,000	Kristiansand	Glencore Nikkelverk

Netherlands

14,000	Rotterdam	TES

Sweden

125,000	Skelleftea	Northvolt
10,000	Halmstad	STENA

Germany

3,250	Krefeld	ACCUREC
TBA	Hamburg	Aurubis
15,000	Schwarzheide	BASF
2,900	Wendeburg	Duesenfeld
20,000	Hettstedt	Ecobat
950	Zwickau	ERLOS
2,500	Kuppenheim	Mercedes-Benz
4,000	Aue	Nickelhütte
TBA	Kirchardt	Fortum
TBA	Heide	Northvolt
18,250	Hilchenbach	Primobius
10,000	Bremerhaven	REDUX
9,000	Wernberg-Köblitz	ROTH
2,500	Wangerland	STENA
20,000	Rudolstadt	SungEel HiTech
1,500	Salzgitter	Volkswagen
1,000	Baudenbach	Walch Recycling

Finland

4,000	Nivala	AkkuSer
3,000	Ikkalinen	Fortum
TBA	Harjavalta	Fortum

France

10,000	Saint Quentin	Snam recycling
2,200	Grenoble	TES
4,000	Amneville	Groupe Renault, Veolia
5,000	Dieuze	Veolia, EDI
20,000	Bazoches-les--Gallerandes	Ecobat
TBA	*TBA*	SUEZ

Poland

3,600	Legnica	RoyalBees
7,000	Bukowice	SungEel HiTech
TBA	*TBA*	ATTERO
10,000	Zawiercie	Elemental Strategic Metals

Hungary

25,000	Batonyterenye	SungEel HiTech

Spain

8,000	Cubillos del Sil	Endesa
15,000	*TBA*	EIT InnoEnergy
TBA	Erandio	Indumetal Recycling Recypilas
45,000	*TBA*	EcoNiLib

Switzerland

500	Wimmis	Batrec
100	Freienstein	Kyburz
8,000	*TBA*	Librec

Italy

TBA	Scarmagno	Italvolt & American Manganese

Source: Battery-News.de

The proposed EU legislation specifies that by 2030, the recycling processes for lithium-ion batteries should achieve a yield of 95% for cobalt, copper, and nickel, and a 70% yield for lithium. Moreover, by 2027, battery products must be labelled to indicate the amount of recycled content used in their production.

Expert's opinion

Here is how we are delivering this future with Revolt – our in-house program for battery recycling. As of 2020, we estimate that Europe could recycle an estimated 33,000 tons of batteries per year, but by 2030 the volume of batteries reaching end-of-life is expected to reach 250,000 tons per year. Recognizing the importance of establishing a circular battery industry, we commenced our recycling activities several years ago. Seeking first to develop and demonstrate an effective battery recycling process, a pilot recycling plant was brought online at Northvolt Labs in 2020. Through 2021, the plant was used to optimize our complete recycling process and to maximize its effectiveness, as measured by its yield of battery-grade materials through a novel hydrometallurgical technique. In November 2021 we produced our first cathode material from 100% recycled nickel, manganese and cobalt, and validated its electrochemical performance in battery cells. We are establishing industrial-scale recycling capacities in parallel to our ramp-up of battery manufacturing capacity.

We estimate that at present, producing cathode active material with only recycled materials results in a carbon footprint that is 78% lower than the cathode produced with virgin raw material. Together with the practical experiences of our pilot recycling plant, our LCA analysis is informing not only our continued development of the recycling process itself but also our other activities.

All of this is being done to secure not only our targets but also those of the EU.

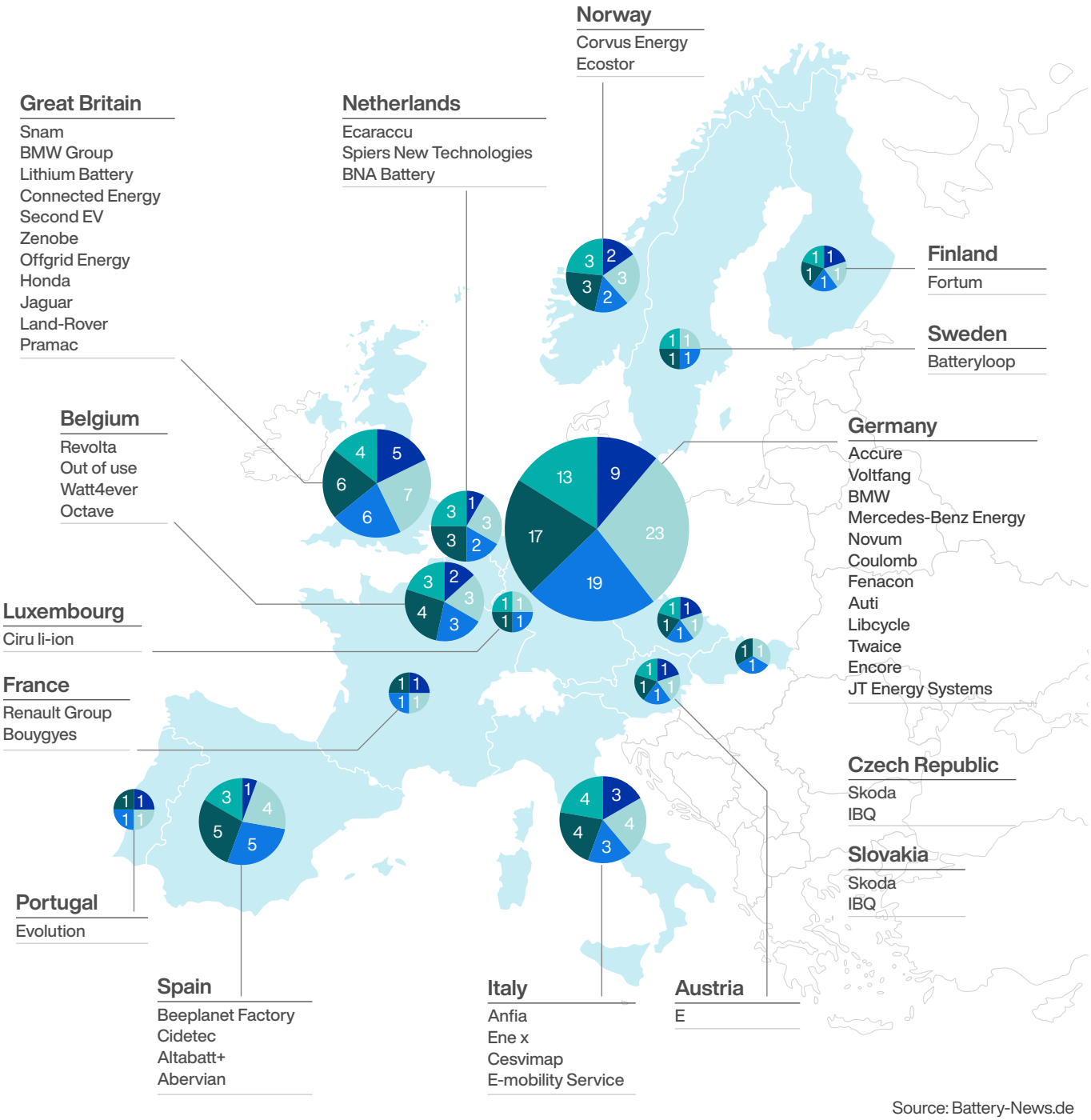
Northvolt

The second life market is a crucial aspect of the overall battery life cycle. Currently, there are ongoing discussions about the feasibility of repurposing electric vehicle batteries for use in stationary energy storage systems. Several large-scale stationary energy storage systems have been built using batteries sourced from, for example, warranty replacements, and these systems have demonstrated good operational performance. Another potential way of reusing EV batteries involves repurposing them for applications such as the conversion of internal combustion engine vehicles, residential energy storage systems, or the electrification of boats. However, due to the differences in types and capacity between available pieces, repurposing EV batteries presents significant challenges. Additionally, modules or cells, such as those extracted from the Tesla Model 3, can also be directed to the refurbished cell market.

Below is an up-to-date presentation of 73 European companies that are involved in or offer support for second-life applications of batteries. The map is divided into five categories:

1 / Collection and transportation to the facility
2 / Identification and status determination
3 / Choosing the end-of-life strategy
4 / Technical processing
5 / Integration and installation

EU companies associated with second-life batteries
As of November 2022



Source: Battery-News.de

1.1.4 Human resources and required skills

According to McKinsey's research, it is estimated that a new battery-manufacturing plant with a total capacity of 30 to 40-gigawatt hours (GWh) per year could directly create as many as 3,200 jobs. A similar number of jobs could be added indirectly through suppliers and construction as well as through catering and basic services sectors. As a result, battery manufacturing could generate significant growth in GDP, especially if an ecosystem of related industries develops.[3]

According to the World Economic Forum, employment in the battery value chain is expected to increase to a total of 10M jobs in 2030, with more than half of these jobs in developing countries.

The European Commission also expects the creation of up to 4 million new jobs by 2025 and aims to train approximately 800,000 workers by the same year, equating to roughly 160,000 workers requiring training per year. To achieve this, EIT InnoEnergy has joined forces with Member States of the European Battery Alliance to launch the EBA250 Academy, which aims to develop curricula and training content based on the industry's requirements in collaboration with local training professionals, with the goal of "reskilling and upskilling" workers.[4]

According to a survey conducted by the Alliance for Batteries Technology, Training and Skills (ALLBATS), the battery sector in Europe is facing a shortage of skills and competencies in battery cell production, as well as a lack of proper educational resources. This is particularly problematic in a new and developing industry such as the battery industry, where relevant experience and documented skills are often lacking, resulting in more general job advertisements. The survey highlights the importance of internal training and the need to improve automation and digitalization knowledge in the future. However, one of the greatest strengths of the European battery sector is the willingness of automotive OEMs to address these gaps.[5]

Overview of the job roles and skills

A total of 27 job roles have been identified as crucial for promoting the sustainable development of the battery sector. These positions were thoroughly analyzed and ranked based on their relevance to the industry. The cross-section of roles encompasses a wide range of specializations, including engineers, technicians, managers, and blue-collar workers. Among these, the recycling engineer role was found to be the most crucial for industrial stakeholders.

[3] https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/capturing-the-battery-value-chain-opportunity
[4] https://www.eba250.com/eba-academy/about-eba-academy/?cn-reloaded=1
[5] https://www.project-albatts.eu/Media/Publications/19/Publications_19_20210601_185540.pdf

Importance of specific job roles for the industrial stakeholders – survey results

Job Roles	Rating scale 0.00–5.00
Recycling Engineer	4.71
Software Developer	4.70
Battery Material Engineer	4.67
Battery System Engineer	4.50
Battery Design Engineer	4.45
Safety Manager	4.29
Manufacturing Engineer	4.23
Embedded System Engineer	4.10
Test Engineers	4.00
Electrical Engineer	4.00
Production Engineer	3.99
Process Engineer	3.94
Cell Module Engineer	3.88
Battery Pack Engineer	3.88
Battery Dismantle Technician	3.86
Battery Maintenance and Service Technician	3.84
Cell Inspection Technician	3.80
Compilance Engineer	3.75
Quality Specialist	3.74
Recycling Auditor	3.71
Supply Chain Manager	3.67
Battery Test Mechnician	3.50
Warranty Manager	3.43
Machine Operator	3.11
Material Handler	3.09
Eletrician Assembler	3.00
Battery Repairer	2.83

Source: Alliance for Batteries Technology, Training and Skills, 2019-2023, Survey Results for Battery Sector

In addition to hard skills, such as designing, engineering, technical or managerial expertise, the survey conducted among industrial stakeholders indicated that they also place great value on soft and transversal competencies and knowledge, such as teamwork, foreign languages, communication, and presentation skills. The results of the survey were ranked, with problem-solving and troubleshooting emerging as the most crucial soft skill.

Importance of the soft and transversal skills/competencies and knowledge for the industrial stakeholders – survey results

Skills/competencies and knowledge	Skills index
Problem-solving and Troubleshooting	410.57
Teamwork	408.81
Computer Literacy	408.00
Foreign Languages	407.56
Communication	406.78
Planning and Analytical Skills	406.17
Reporting and Documantation Management	406.04
Presentation Skills	405.67
Meeting Deadlines	405.35

Source: Alliance for Batteries Technology, Training and Skills, 2019-2023, Survey Results for Battery Sector

The battery value chain presents a significant opportunity for job creation, with a multitude of new roles emerging. The EBA Academy has identified a range of skills that are crucial at each stage of the battery value chain, from raw materials and active materials, through cells and battery packs, to applications and recycling, and even second life applications. These skills have been categorized into two subgroups: academic level (white-collar) and vocational & professional.

Crucial skills by stage of the battery value chain[6]

	Raw Materials	Active materials	Cells and Battery Packs		Applications			Recycling & 2nd life
White Collars	Electrochemistry	Electrochemistry	Inorganic chemistry	Packing and security	EV topologies	Smart buildings	Solar Energy Storage	Material properties and life cycles
	Material refinement and purification processes	Wet chemistry processes	Materials science	Testing and Monitoring	Charging Infrastructures	Sustainability	Control and regulation of wind turbines	Rare resources processing and recovery
	Environmental management	Cleanroom processing	Electrochemistry and cell design	Data science	Vehicle to Grid	Energy management	Coupling to fuel cells	Chemical resources
		Integration of processes in the environment	Energy storage	Mechanical Engineering	Sustainable mobility	Power plants	System optimisation	Separation processes and technologies
		Materials synthesis	Power and energy density	Systems Management	Business models	Smart grids, off grids and micro grind	Cost calculation	Electrochemistry
			Energy conversion efficiency	DC system design	Policy and Regulation	Battery banks	LCA	Control and processing
			Performance factors and optimisation	Thermal and kinetic properties	Batteries in trains and planes	Business models	Policy and Regulation	Circular economy models
			Modelling and simulation			Policy and Regulation		Environmental management and legislation
			Data Science					Standarisation
Vocational & Professional	Materials extraction and refining	Chemical processes	Physical processes	Electromechanical manufacturing	EV Fundamentals	Energy installations	Robotics and Automation	Materials extraction and refining
	Sourcing	Physical processes	Mixing, coating, drying	Automation engineering	Operation, diagnostics and repair	EV charging systems	Renewables and Electrical Grids	Chemical and physical processes
	Logistics	Design of chemical equipment	Measurement and control	Vehicle technology	Systems	Automation and control	Digital skills	Logistics
	Measurement and Control	Measurement and Control	Chemical safety	Electronics	Electric motors and controllers	Electronics	Electrical safety	Digital skills
	Chamical safety	Chemical safety and waste management	Waste management	Electrical safety	Diagnostics tools and equipment	Digital		Chemical and electrical safety
	Waste management		High speed mechanical assembly			System security		Waste management
	Environmental management							

[6] https://www.volta.foundation/annual-battery-report;
https://www.energy-storage.news/bloombergnef-china-dominates-global-battery-supply-chain-again-with-followers-in-flux/;
https://about.bnef.com/blog/chinas-battery-supply-chain-tops-bnef-ranking-for-third-consecutive-time-with-canada-a-close-second/

1.1.5 Forecasts and market perspective

According to the BNEF ranking, the overall lithium-ion manufacturing capacity is expected to soar eightfold between 2022 and 2027. Despite China's continued dominance in the industry, its market share is projected to decrease from 77% in 2022 to 69% in 2027. Europe, on the other hand, is set to host six of the top 10 countries for battery production by 2027. Both Poland and Hungary are expected to maintain their high 6th and 4th positions, with the latter receiving a significant boost from a planned 100 GWh CATL investment. Meanwhile, the US is projected to increase its production capacity by over 10 times, largely due to the stimulation of EV tax credits in the Inflation Reduction Act.

According to Bloomberg, both the US and Europe will need to invest $87 billion and $102 billion, respectively, to meet domestic battery demand with fully local supply chains by 2030. This, coupled with significant investment plans in Germany and Sweden, is expected to result in a decline in Poland's ranking from second to sixth, though this still remains a high position to be considered.

Market Driving Forces

- → Forecasted growing demand for electric vehicles (passenger cars, heavy-duty vehicles, public transportation, marine) and battery energy storage
- → Increasing social awareness of zero-emission transport
- → Positive environmental impact
- → Targeting the circular economy goals
- → Focusing on innovation

Top 10 countries by projected battery production capacity in 2027

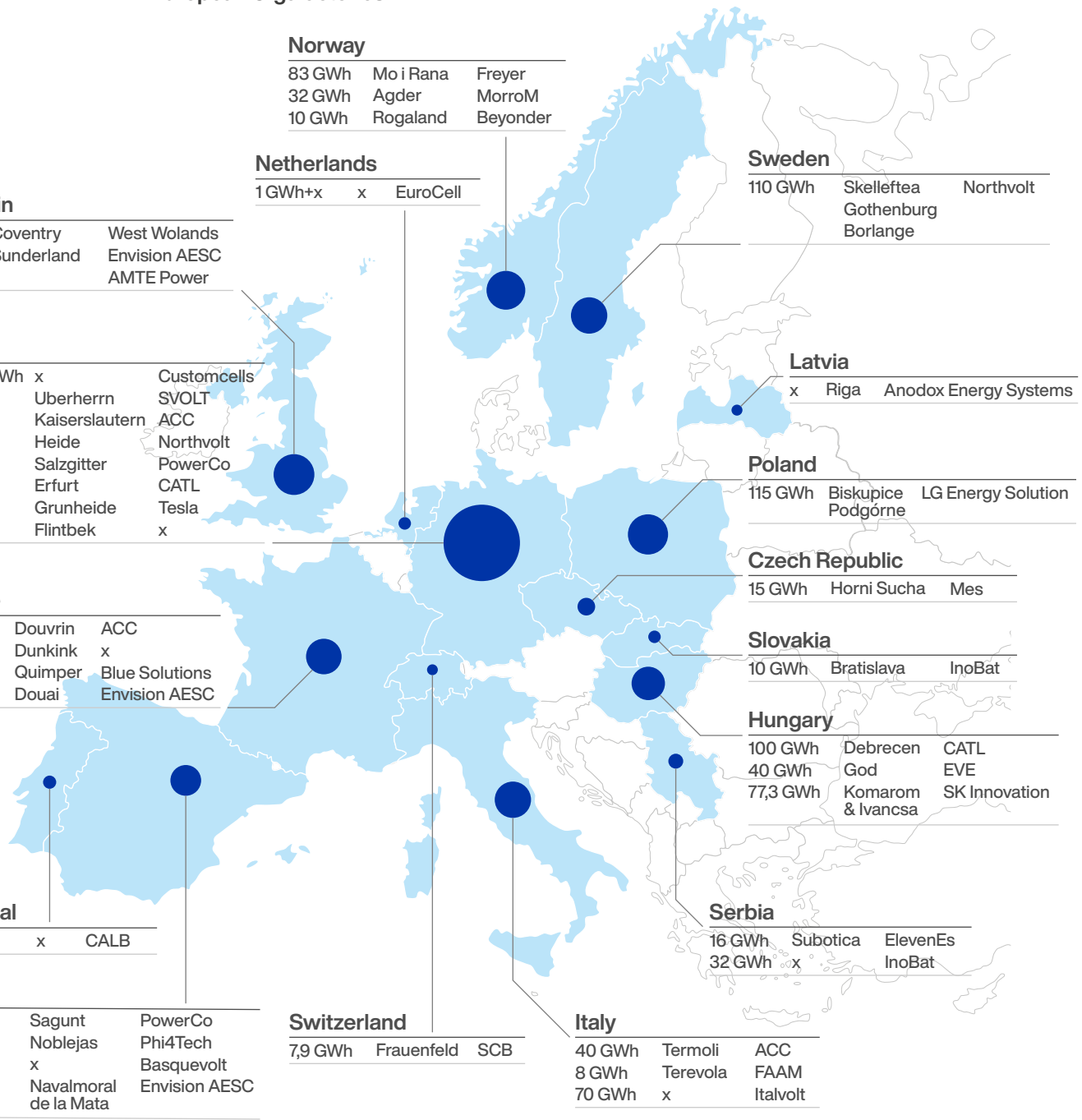
Rank	Country	2027 Battery cell manufacturing capacity, GWh	% of total
#1	China	6,197	69%
#2	USA	908	10%
#3	Germany	503	6%
#4	**Hungary**	194	**2%**
#5	Sweden	135	2%
#6	**Poland**	112	**1%**
#7	Canada	106	1%
#8	Spain	98	1%
#9	France	89	1%
#10	Mexico	80	1%
	Other	*523*	*6%*
	Total	**8,945**	100%

– The countries of Central and Eastern Europe

Source: BloombergNEF

Europe is set to witness the production of nearly 50 projects with an estimated capacity of up to 1.8 TWh by 2030. Furthermore, new investments are in the works for existing factories in the CEE region, including Poland, Slovakia, Hungary, the Czech Republic, Latvia, and Serbia. Notably, LG Energy Solution Wrocław in Biskupice Podgórne, the largest electric car battery production center in Europe, boasts a capacity of 86 GWh, which is expected to increase to 115 GWh in the near future. In Hungary, the biggest activities include CATL's planned 100 GWh capacity factory in Debrecen and SK On Hungary's investment in Komarom & Ivancsa, expected to enable a cap acity of up to 77.3 GWh by 2028. Other countries in the CEE region, such as Serbia with 16 GWh in Subotica and Slovakia with 10 GWh, are also set to make their mark in the global battery value chain.

European Gigafactories



Norway

83 GWh	Mo i Rana	Freyer
32 GWh	Agder	MorroM
10 GWh	Rogaland	Beyonder

Netherlands

1 GWh+x	x	EuroCell

Great Britain

60 GWh	Coventry	West Wolands
35 GWh	Sunderland	Envision AESC
10 GWh+x	x	AMTE Power

Germany

40 GWh+3,5 GWh	x	Customcells
24 GWh	Uberherrn	SVOLT
40 GWh	Kaiserslautern	ACC
60 GWh	Heide	Northvolt
40 GWh	Salzgitter	PowerCo
100 GWh	Erfurt	CATL
200 GWh	Grunheide	Tesla
10 GWh	Flintbek	x

France

40 GWh	Douvrin	ACC
50 GWh	Dunkink	x
1,5 GWh	Quimper	Blue Solutions
30 GWh	Douai	Envision AESC

Portugal

45 GWh	x	CALB

Spain

40 GWh	Sagunt	PowerCo
20 GWh	Noblejas	Phi4Tech
10 GWh	x	Basquevolt
30 GWh	Navalmoral de la Mata	Envision AESC

Switzerland

7,9 GWh	Frauenfeld	SCB

Italy

40 GWh	Termoli	ACC
8 GWh	Terevola	FAAM
70 GWh	x	Italvolt

Sweden

110 GWh	Skelleftea Gothenburg Borlange	Northvolt

Latvia

x	Riga	Anodox Energy Systems

Poland

115 GWh	Biskupice Podgórne	LG Energy Solution

Czech Republic

15 GWh	Horni Sucha	Mes

Slovakia

10 GWh	Bratislava	InoBat

Hungary

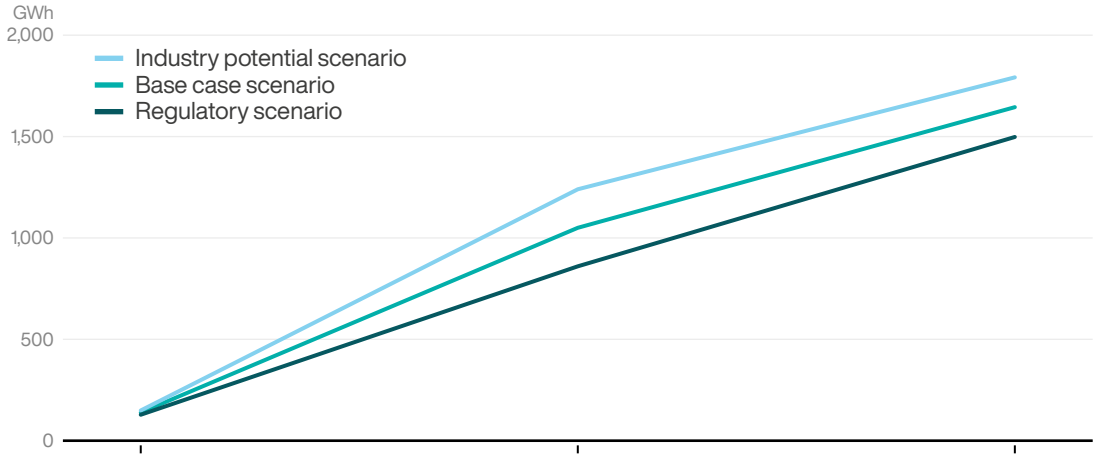
100 GWh	Debrecen	CATL
40 GWh	God	EVE
77,3 GWh	Komarom & Ivancsa	SK Innovation

Serbia

16 GWh	Subotica	ElevenEs
32 GWh	x	InoBat

Source: Battery-News.de

European demand for batteries



	2022	2030	2035
Regulatory scenario	128	860	1,498
Base case scenario	139	1,050	1,645
Industry potential scenario	149	1,240	1,792

Source: Transport & Environment

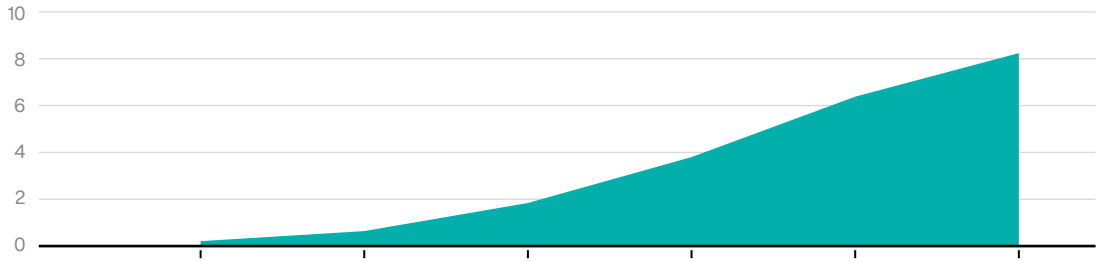
1.2 Battery industry

1.2.1 Poland

Production potential

Poland plays a leading role in the battery sector supply chain. Lithium-ion batteries already account for more than 2.4% of all Polish exports. The value of exports in the battery sector increased 38-fold over the last six years from around PLN 1 billion (EUR 0.21 billion) in 2017 to over PLN 38 billion (EUR 8.24 billion) in 2022. Poland is the leader of the lithium-ion battery supply chain in Europe and will maintain this position until at least 2027. It also holds a high-ranking place globally.

Export of lithium-ion batteries in Poland



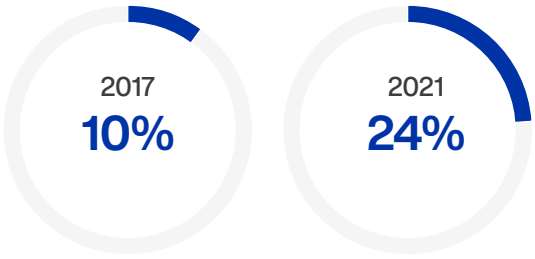
	2017	2018	2019	2020	2021	2022
Billion PLN	1.0	3.0	8.6	17.8	29.9	38.6
Billion EUR	0.21	0.64	1.84	3.8	6.38	8.24

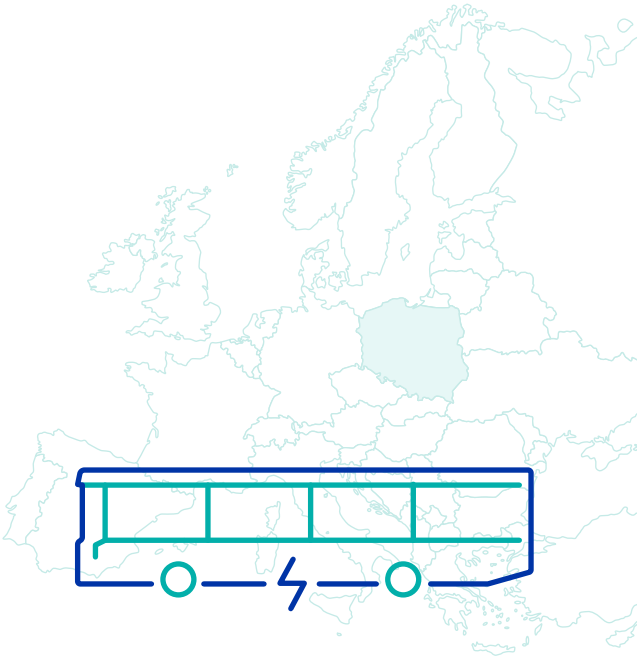
Source: Polish Central Statistical Office

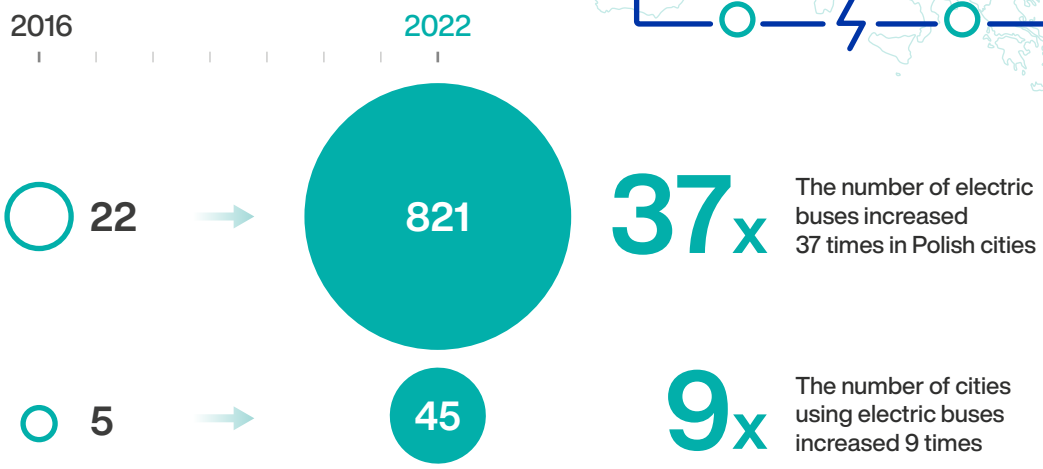
The rapidly growing e-mobility sector requires greater state support to enable a wide range of beneficiaries to take advantage of the shift towards electric propulsion. This includes current automotive industry employees, Polish companies adapting to the new reality, and end users, i.e., customers. The Polish electric bus market, spearheaded by Solaris Bus & Coach, has been a major driver of growth in the Polish battery market.

No 1

Poland's share of exports of e-Buses in EU



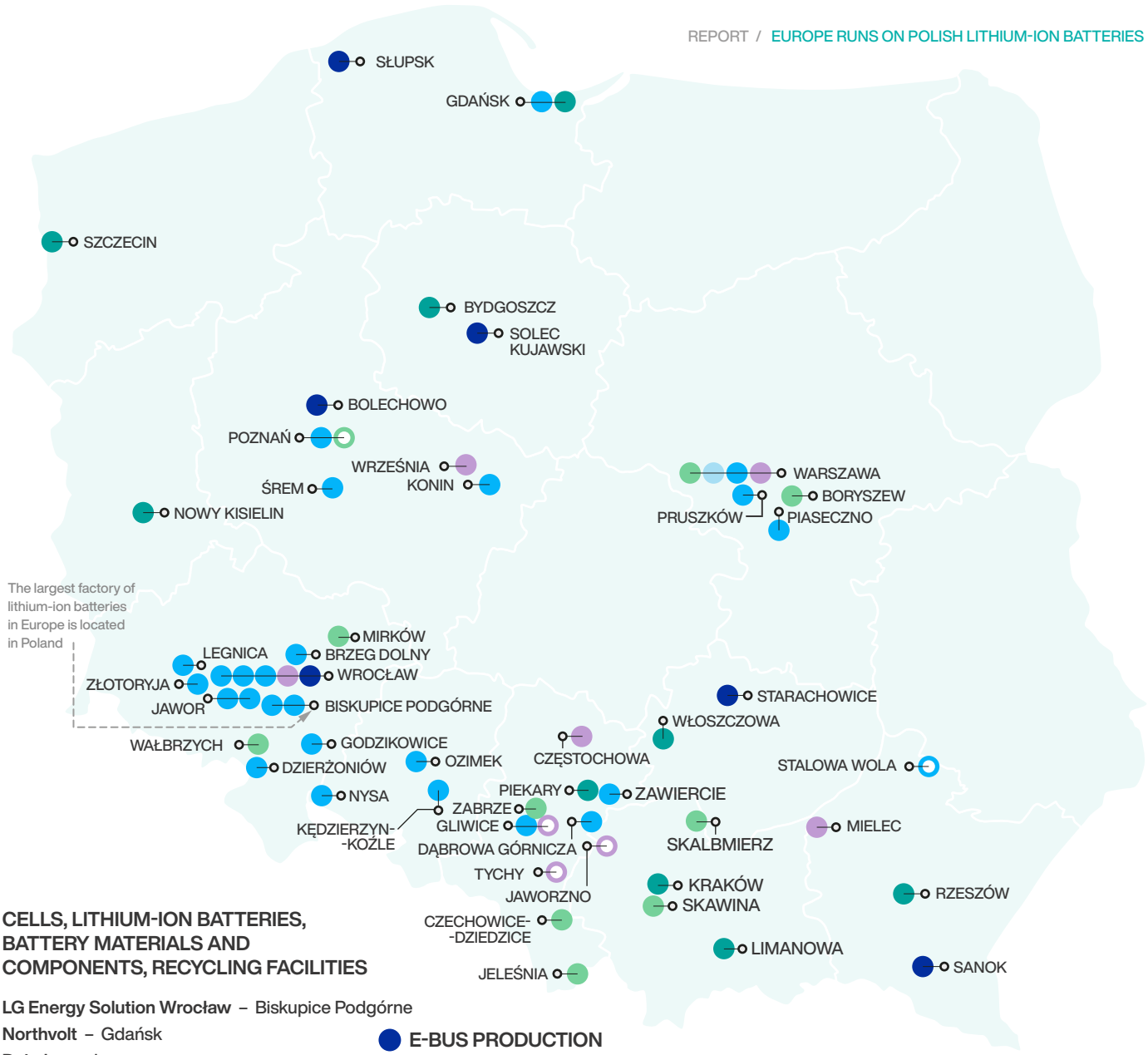




Source: "Poland Drives e-Mobility 2022" report by PSPA

Key market stakeholders

The largest li-ion battery factory in the world is currently operating in Poland, launched by **LG Energy Solution** in Biskupice Podgórne near Wrocław. Its target potential is expected to reach 115 GWh per year. Other leading companies in the battery sector are also investing in Poland and these include Northvolt, Umicore, SK hi-tech battery materials, Capchem, Johnson Matthey, Guotai Huarong, BMZ and Mercedes-Benz Manufacturing Poland.



CELLS, LITHIUM-ION BATTERIES, BATTERY MATERIALS AND COMPONENTS, RECYCLING FACILITIES

LG Energy Solution Wrocław – Biskupice Podgórne
Northvolt – Gdańsk
Daimler – Jawor
BMZ – Gliwice
Umicore – Nysa
Guotai Huarong – Godzikowice
LS EV Poland – Dzierżoniów
Impact Clean Power Technology – Warszawa
Johnson Matthey – Konin
Capchem – Śrem
PCC Rokita i Shida – Brzeg Dolny
SK IE Technology – Dąbrowa Górnicza
Exide Technologies – Poznań
SK Nexilis – Stalowa Wola (planned)
Foosung Poland – Kędzierzyn-Koźle
Dongshin Motech Poland – Wrocław
Mercedes-Benz Manufacturing – Jawor
Ele-DriveCo – Pruszków
Wamtechnik – Piaseczno
Enchem Poland – Biskupice Podgórne
Rare metals – Ozimek
Elemental Strategic Minerals – Zawiercie
Royal Bees Recycling – Legnica
SungEel Hi-Tech – Złotoryja
Bafang Electric – Wrocław
Myatu Europe Intelligent Techn. – Wrocław

E-BUS PRODUCTION FACILITIES

Solaris – Bolechowo
Volvo Buses – Wrocław
MAN Bus – Starachowice
Scania Production – Słupsk
ARP E-vehicles – Solec Kuj.
Autosan – Sanok

EV CHARGING STATIONS PRODUCTION FACILITES

Garo Polska – Szczecin
Ekoenergetyka-Polska – Nowy Kisielin (near Zielona Góra)
Enelion – Gdańsk
PRE Edward Biel – Piekary
Kolejowe Zakłady Łączności – Bydgoszcz
EC Enginneering – Kraków
Phoenix Contact E-Mobility – Rzeszów
ZPUE – Włoszczowa
GreenCell – Kraków
Z.U.P. EMITER – Limanowa

EV POWERTRAIN COMPONENT PRODUCTION FACILITIES

MEDCOM – Warszawa

EV'S MADE IN POLAND

Volkswagen Poznań – Września
Triggo – Warszawa
Melex – Mielec
Stellantis – Tychy, Gliwice (planned)
Izera – Jaworzno (planned)
Frugal – Wrocław
Velex – Częstochowa

EV CONSTRUCTION COMPONENT PRODUCTION FACILITIES

Valeo Siemens eAutomotive – Czechowice-Dziedzice
Ningbo Tuopu Group – Poznań (planned)
Mitsui High-tec – Skalbmierz
Korea Electric Terminal – Zabrze
Maflow – Boryszew
Medcom – Warszawa
APTIV – Jeleśnia
Bspl. – Skawina
Bosch – Mirków
Toyota Motor Manufacturing Poland – Wałbrzych

Source: "Poland Drives e-Mobility 2022" report by PSPA

LG Energy Solution

LG Energy Solution, a split-off from LG Chem, is a global manufacturer of lithium-ion batteries for electric vehicles, mobility, IT, and energy storage systems. With 30 years of experience in revolutionary battery technology and extensive research and development (R&D), the company is the top battery-related patent holder in the world with over 25,000 patents. Its robust global network, which spans North America, Europe, Asia, and Australia, includes battery manufacturing facilities established through joint ventures with major automakers such as General Motors, Stellantis N.V., Hyundai Motor Group, and Honda Motor Co., Ltd.

At the forefront of green business and sustainability, LG Energy Solution aims to achieve carbon-neutral operations by 2050, while embodying the value of shared growth and promoting diverse and inclusive corporate culture.

LG Energy Solution Wrocław was established in Biskupice Podgórne in 2016, making it the first and largest electric car battery production center in Europe. The Greenfield investment in Wrocław brought state-of-the-art technology to Poland and has made the country a leader in the industry. The plant spans an area of approximately 100 hectares and is equipped with dozens of modern production lines. Currently boasting a capacity of 86 GWh, the plant is expected to reach 115 GWh soon.

SK Hi-Tech

In mid-2021, the **SK hi-tech battery materials Poland** plant was inaugurated in Dąbrowa Górnicza as part of a Korean investment. The factory produces separators, which are vital components in constructing lithium-ion batteries used in electric vehicles. Operating in the Katowice Special Economic Zone, this facility is the first of four planned factories by the company in Poland. Currently, over 400 people are employed at the Korean site, with the employee count expected to reach 1,000 with the launch of subsequent plants. The main recipients of the separators are European and American companies.

SK Nexilis

SK Nexilis plans to build a plant in Stalowa Wola, which will produce 50,000 tons of copper foil per year in the initial stage of the investment. The copper foil will be supplied to customers across Europe, while ensuring environmental protection and social responsibility. This will enable Stalowa Wola to become an important industrial center in the production of lithium-ion batteries for electric cars, with copper foil being one of the key components in the process. As one of Poland's largest investors, SK Nexilis has allocated an estimated PLN 3 billion (EUR 0.64 billion) to this strategic program for the country's economic development. The construction of the factory in Stalowa Wola is the largest greenfield investment in the Tarnobrzeg Special Economic Zone.

Mercedes -Benz

Mercedes-Benz constructed a factory within the Wałbrzych Special Economic Zone, which manufactures batteries for both plug-in hybrid passenger cars and pure electric cars for internal use. The factory began operating in autumn of 2020, with an annual production of 72,000 traction batteries in 2021. 80% of this production is for plug-in hybrid cars, while 20% is for electric cars. Mercedes-Benz Manufacturing Poland's Jawor factory is projected to produce over 100,000 units of batteries for PHEV drives and BEV vehicles. The production employs 300 individuals, and completed systems are solely delivered to Mercedes factories worldwide.

BMZ Poland

BMZ the Innovation Group, which supplies intelligent power supply and energy storage systems based on lithium-ion technology, has also opted for production in Poland. Operating since 2010 in Gliwice, **BMZ Poland** currently manufactures lithium-ion batteries used to power electric bicycles, scooters, power tools, utility vehicles and buses. The systems have been manufactured in a factory located in the Katowice Special Economic Zone since 2017.

Impact Clean Power Technology

Impact Clean Power Technology (ICPT) is a leading manufacturer of cutting-edge battery systems for the transportation, robotics and stationary energy storage sectors across Europe. The company boasts three main product lines, which include heavy-duty battery systems designed for the transport and industrial sectors, stationary energy storage for the renewable energy market and hydrogen fuel cell systems. ICPT's products are primarily used in public transport, stationary energy storage, marine applications and industrial robotics. The company's customers consist of Polish and foreign electric vehicle manufacturers, such as buses, streetcars, trolleybuses, yachts, and companies operating in the industrial, power, railroad and telecommunications sectors. As of 2021, Impact Clean Power Technology S.A. held a 15% share in the European electric bus battery market. Established in 2007, the company currently sells its battery systems in Europe, New Zealand and the United States. To date, ICPT has delivered over 20,000 systems, with battery vehicles having travelled more than 100 million miles globally. ICPT is currently constructing its Gigafactory, which will significantly increase its production capacity to up to 5 GWh per year, compared to its current 1 MWh per day. The battery systems will be based on lithium-ion cells using LTO, LFP and NMC chemistries, with production slated to begin in 2024.

Ele-DriveCo

Since 2008, **Ele-DriveCo** has been developing lithium-ion cell technology-based batteries for zero-emission vehicles in Pruszków. The company focuses on designing and producing drive components and traction batteries for two- and four-wheeled electric vehicles. Their products are created using top-quality components from renowned manufacturers such as Panasonic, Samsung, and Delta.

Wamtechnik

Wamtechnik is a leading Polish power supply systems company, specializing in the production of both rechargeable and non-rechargeable battery packs. With 30 years of experience, Wamtechnik has successfully executed hundreds of projects across all available chemistries, supported by its own Power Systems and Certification Laboratory. The company delivers batteries to a wide range of industry sectors, from professional electronics to utilities, smart metering devices, and e-mobility applications.

At Wamtechnik, battery modules are manufactured based on the world's most reliable cell manufacturers, such as Panasonic, Murata, Saft, LG-Chem, Samsung SDI, Maxell, and others. The modules are designed for lean assembling based on DFMA, achieving high energy density while being cost-effective. Every product is equipped with an advanced battery management system (BMS). Wamtechnik generally develops custom modules based on client requirements, while also producing standard modules for a variety of applications, ranging from 12V to 96V. Furthermore, Wamtechnik covers the market of lithium-ion replacement of Lead Acid Batteries and Energy Home Storage Systems.

Wamtechnik specializes in designing and manufacturing battery packs and systems. The scope of applications varies from small energy sources (single Wh energy) for professional electronics to typical 100 Wh – 1 kWh modules for industrial equipment (power tools, small e-mobility, AGV, etc.), and up to tens of kWh high voltage systems for professional e-mobility (such as construction machinery) and stationary energy storage (ESS).

Source:
Wamtechnik

Northvolt

Northvolt is a European supplier of sustainable, high-quality battery cells and systems. Founded in 2016 to enable the European transition to a decarbonized future, the company has made swift progress on its mission to deliver the world's greenest lithium-ion battery with a minimal CO_2 footprint and has grown to over 3,500 people from over 100 different nationalities. Northvolt has to date secured more than $55 billion worth of contracts from key customers, including BMW, Fluence, Scania, Volkswagen, Volvo Cars and Polestar, to support its plans, which include establishing recycling capabilities to enable 50 per cent of all its raw material requirements to be sourced from recycled batteries by 2030.

Northvolt's facilities for the production of battery energy storage solutions are located in Gdańsk, Poland, which is home to a supply chain ecosystem of the electromechanical industry, with great access to end customers in Europe. In spring 2019, Northvolt Poland's first production facility entered operations – assembling modules and systems for several customer programs. Northvolt is presently developing the full-scale battery systems assembly factory, Northvolt Dwa. Located in Gdańsk, the facility will be highly automated and ramp up to reach an annual production capacity of 12 GWh. An investment of $200 million is being made into Northvolt Dwa, which will cover 50,000 sqm. The development will unfold in two stages, with an initial output of 5 GWh and an estimated staff of production date in 2023. Alongside the factory, an engineering R&D centre will be established. These facilities will receive lithium-ion battery cells from Northvolt Ett located in Sweden.

Northvolt Dwa Industrial

Northvolt Dwa Construction November 2022

Source: Northvolt

Durapower

Compremum has reached an agreement with the Singaporean technology company **Durapower** and the Polish company Elmodis (backed by the Japanese Meiden Group), outlining the primary terms of the final contract for the establishment of a factory in Poland that will manufacture batteries and energy storage systems. This plant, which will produce cutting-edge energy storage systems, is expected to provide employment for roughly 300 individuals. The lithium-ion battery modules manufactured at this facility will be a crucial component of energy storage. The Compremum group's Faradise company has already acquired more than 8 hectares of land in the Kleszczów commune, where the Bełchatów Power Plant is currently operational, for the implementation of this investment.

Capchem

Capchem is a global leader in research and development, production and sales of battery electrolytes and other electronic chemistry products and functional materials. The company was founded 26 years ago in Shenzhen, a hub of innovation called China's Silicon Valley. Today, they employ over 3,300 people in 18 facilities around the world, including 13 production plants. The company focuses primarily on technology, supplying products to the world's most famous brands, such as Panasonic, LG Chem, Tesla and Apple. The electrolyte produced by Capchem is, among others, in iPhone batteries, Samsung phones, Porsche, Volkswagen and BMW electric cars, IBM computers, Bosch equipment and even Medtronic pacemakers. As part of an investment worth over EUR 50 million, Capchem is constructing a state-of-the-art and secure factory with a production capacity of 40,000 m³ of electrolyte per year in Śrem, near Poznań. The facility in Śrem will supply manufacturers of lithium-ion batteries in the European market.

Umicore

Poland currently lacks significant mining capacity for battery materials, however, it boasts one noteworthy project on a European scale. In 2021, **Umicore** inaugurated a cutting-edge greenfield plant in Nysa, marking the first cathode materials plant in Europe. The facility began commercial production in the second quarter of 2022 and will provide employment opportunities for up to 400 people. Umicore's goal is to become the region's preferred employer, and it has placed safety and the environment at the forefront of its priorities for both its employees and neighbors. With over 200 years of experience in metal treatment, Umicore has been manufacturing cathode materials for rechargeable batteries for more than two decades. Cathode materials are critical components of rechargeable Li-ion batteries, playing a pivotal role in determining their overall performance. The materials produced in Nysa are sold to battery cell manufacturers who then produce the batteries for electric vehicles.

Key investments in Poland

There are several key investments in Poland aiming at adding value to the global battery value chain across various phases of the life cycle.

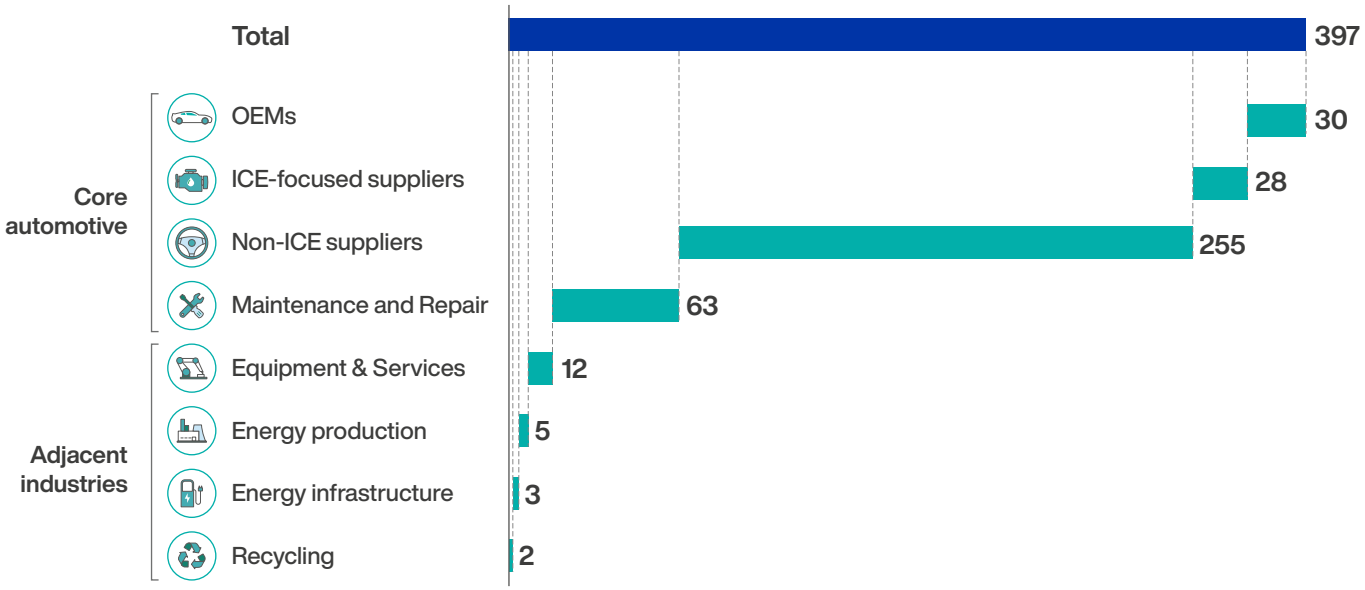
Company	Investment region	Employment	Investment value
SK Hi-Tech Battery Materials Poland (South Korea)	Dąbrowa Górnicza Silesian voiv.	**852 employees**	**EUR 840 mln**
SK Nexilis (South Korea)	Stalowa Wola Subcarpathian voiv.	**500 employees**	**EUR 646.6 mln**
LG Energy Solutions (South Korea)	Biskupice Podgórne Lowe Silesian voiv.	**500 employees**	**EUR 380 mln**
Northvolt (Sweden)	Gdańsk Pomeranian voiv.	**500 employees**	**EUR 165 mln**
Capchem Poland (China)	Śrem Greater Poland voiv.	**60 employees**	**EUR 50 mln**
Elemental Strategic Metals	Zawiercie Silesian Voivodeship	–	**EUR 81.3 mln**
Compremum (Poland), Durapower (Singapur), Elmodis (Poland/Japan)	Łódź Special Economic Zone	**300 employees**	**EUR 42.3 mln**

Source: Polish Investment & Trade Agency (PAIH)

Human resources

The automotive industry in Poland currently sustains nearly 400,000 job positions, including roles in OEMs, suppliers, maintenance and repair, energy production, infrastructure and recycling. In an ambitious scenario, the development of electromobility in Poland is expected to create up to 6,000 new jobs.

Number of employees (2020, in thousands)



ICE – internal combustion engine; OEM – original equipment manufacturer

Source: "How will e-mobility change the Polish labour market? Green sectors of the future" report by BCG & PSPA

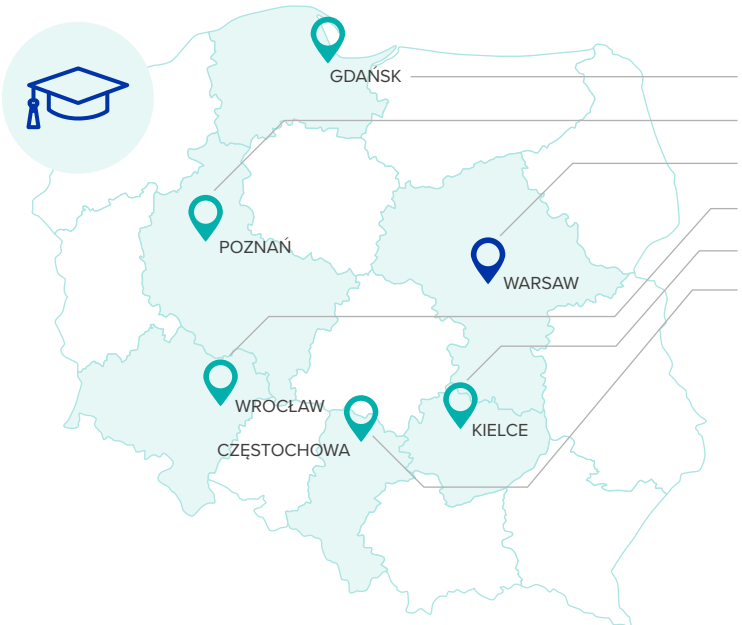
The development of electromobility in Poland may contribute to the creation of up to 6,000 new jobs

2030 figures shown	Production volume	Sales volume	BEV car parc	Public charging	Private charging	Net job impact
Pessimistic scenario	604k	584k	751k	95k	450k	-17k
Intermediate scenario	621k	604k	905k	95k	543k	-5k
Ambitious scenario	660k	626k	1,023k	95k	1,110k	+6k

Source: "How will e-mobility change the Polish labour market? Green sectors of the future" report by BCG & PSPA

Poland's major cities host technical universities that offer education in the field of electromobility, producing highly skilled engineers. Moreover, over 4,776 schools in Poland provide education that prepares students for professions in the automotive industry.

Polish universities educate engineers in the electromobility sector



- **Gdańsk University of Technology**
- **Poznań University of Technology**
- **Warsaw University of Technology**
- **Wrocław University of Science and Technology**
- **Kielce University of Technology**
- **Częstochowa University of Technology**

64.9%

of all vocational schools in Poland provide education in professions dedicated to the automotive industry

4,776

schools in Poland educate people who can find employment in professions in the automotive industry

Source: "Poland Drives e-Mobility 2022" report by PSPA

The voice of a polish industry representative

Which types of people (education and training) will be needed and how many?
All of them to be honest preferably with technical skills. Our company is currently seeking production workers, various types of engineers, and specialists in quality control and purchasing. We strongly believe that individuals who may not have employment opportunities or are seeking opportunities for professional development should consider retraining and joining the lithium-ion battery industry. As the market for these batteries continues to grow, it presents significant opportunities not only in Poland, but globally as well.

Amidst the ongoing crisis, there is an evident shortage of employees across all sectors. The scarcity of skilled professionals with experience in batteries is a significant concern. The hunt for talent is intense. It is worth noting that this industry is still in its infancy and is growing at an extraordinary rate, providing ample opportunities for development and growth.

Poland boasts an array of excellent universities, and there are many talented individuals with high-level qualifications. Recently, we have observed that certain fields of study are adapting their curricula to meet the growing needs of the battery market. It is worth noting that the battery market extends far beyond just the batteries themselves. Many other industries are inextricably linked to it.

Wamtechnik collaborates directly with universities, providing lectures, coaching, and employment prospects to students. It is a challenging task as there are many competitors, given Poland's status as the largest battery exporter in the EU.
To leverage the potential of our academia, we require additional public funding. Typically, the EU and the private sector fund the development of new technologies and research, but this approach should be re-evaluated. We also suggest that the government should support the battery industry by providing refresher courses.
At present, any employee with battery experience is in high demand.

Wamtechnik

R&D activities

There are various research and development (R&D) initiatives underway in Poland, with a focus on recycling and second-life applications. For instance, Elemental Strategic Metals is developing innovative recycling technologies and processes that will be implemented in a new facility located in Zawiercie. Meanwhile, Solaris Bus & Coach, in collaboration with TAURON Polska Energia, has launched a project aimed at creating a prototype system for storing electrical energy using retired bus batteries.

Innovative recycling technologies and processes

Elemental Strategic Metals is a company that specializes in developing and implementing advanced technology for the processing, recovery, and refining of strategic and precious industrial metals. Their latest endeavors also include the innovative application of these valuable metals in new industrial fields, specifically in the area of electromobility and the production of Li-ion batteries.

Elemental Strategic Metals is undertaking an ambitious project aimed at increasing the recycling volume of Li-Ion batteries and catalysts, and recovering crucial metals for the European battery industry and electromobility. This project has been approved by the European Commission under the Important Projects of Common European Interest (IPCEI) program, with a total project value of PLN 383,959,417.00 (EUR 81,946,538.57), and co-financing of PLN 332,036,045.00 (EUR 70,864,792.90).

As part of this endeavor, the company will construct a pilot plant in Zawiercie that will employ innovative recycling technologies, using mechanical recycling and refining methods to recover metals of strategic importance. The pilot plant will have an initial capacity of 4,000 tons per annum, with the potential to reach a maximum of 16,000 tons per annum. The plant is expected to be operational in Q3/4 2023 and is currently under construction in the Economic Activity Zone.

The company has already acquired collection permits for more than 10,000 tons of Li-Ion batteries, and intends to leverage the pilot plant to ramp up the recycling volume of batteries. The company is committed to upholding transparent, sustainable, and environmentally responsible business practices, and aims to contribute to a greener and more sustainable future for the community as a whole.

Source:
Elemental Strategic Metals

Actions to recycle used batteries undertaken by the companies

When the useful life of an electric bus battery ends, it retains significant energy storage capabilities that can be repurposed for other applications, effectively extending its lifecycle. This approach promotes the sustainable utilization of scarce and precious raw materials, which is crucial in the current e-mobility revolution.

Solaris is a company that understands the issue of battery degradation after use in a bus, and is actively planning for second-life battery projects that involve reusing batteries even after they have lost some of their capacity and parameters. Some of the first electric vehicles delivered by the company years ago have now traveled more than half a million kilometers, requiring the replacement of batteries in some of them. Fortunately, the batteries installed in Solaris buses are designed for second-life projects, such as their use in stationary energy sources.

Reusing energy storage systems helps reduce the need for mining additional raw materials. Additionally, a storage system composed of used batteries is a critical element of the modern grid, which brings together the production of energy from both conventional and renewable sources. By recycling batteries, it is possible to recover highly valued metals that have limited resources available.

In February 2021, Solaris and TAURON Polska Energia jointly launched a project called “Second Life ESS” aimed at developing a prototype system for storing electrical energy using retired bus batteries.

Solaris collaborates with organizations specializing in eco-management and recycling of used lithium-ion batteries. They require these organizations to recover 100% of recyclable battery waste materials, including lithium, cobalt, manganese, and nickel, without transferring them to a landfill.

Source:
Solaris Bus & Coach

1.2.2 Slovakia

The short- and long-term demand for batteries will be primarily driven by the significant shift in the automotive industry toward electrification across all vehicle segments. This transformation has become even more pronounced in the Central and Eastern European (CEE) region, particularly in the Visegrád Group (V4) countries, which have a strong focus on the automotive industry.

Slovakia, the leading hub for car manufacturing and the world's largest per capita producer, is home to four OEMs[7] and around 350 automotive suppliers. The industry's total annual production capacity has exceeded 1 million vehicles for the past seven years, except for 2020 when this milestone was only slightly missed due to the pandemic. Presently, all four OEMs have commenced the production of battery electric and plug-in hybrid vehicles, and have been continuously expanding their electrified product range.

In light of the upcoming EU regulation on CO_2 emissions for passenger and light-duty vehicles, Slovakia's entire automotive industry is poised for a radical transformation. This is because 74% of the country's current export markets have already announced their plans to ban ICE vehicles by 2035.

Production potential

According to a joint study conducted by SEVA, Globsec, and Slovakia's Automotive Industry Association, it is estimated that the annual demand for batteries from the existing four OEMs with production will increase to a minimum of 38 GWh by 2030 and 62 GWh by 2035. These projections were based on relatively conservative assumptions, such as the existing OEMs maintaining almost half of their ICE product portfolio in 2030 and still producing some fossil fuel cars in 2035 for non-EU customers. However, these assumptions may be too conservative, and the electric transformation could occur much faster than anticipated.[8]

Forecast for battery demand in Slovakia by existing four OEMs

	2030	2035
Total vehicle production	1,000,000	1,000,000
Share of EVs from the entire production	54%	89%
EVs produced	540,000	890,000
Average battery size (kWh)	70	70
Total demand for battery capacity (GWh)	38	62

[7] Volkswagen, Stellantis, Kia, Jaguar Land Rover

[8] Slovakia Automotive Industry 2.0: The time is now to retool for the e-mobility era, March 2022, https://www.seva.sk/wp-content/uploads/2022/04/AutoFocus-Report-FINAL-29_2_22.pdf

It is highly likely that the demand for batteries will experience a significant acceleration, characterized by faster delivery times and higher capacity requirements. This can be attributed to a recent announcement by Volvo Cars, a Swedish OEM, regarding its investment in a new production facility in Slovakia. This facility is expected to launch 250,000 vehicles annually starting in 2026-27. Given the manufacturer's strategic shift towards an all-electric portfolio by 2030, it is highly probable that the entire production capacity will be devoted solely to electric vehicles. Consequently, **the total annual demand for battery capacity may rise to an astounding 60 GWh by 2030 and 80 GWh by 2035**.

Key market stakeholders

Slovakia's automotive industry is a strong driver for the battery demand.

Unitech Slovakia

Unitech Slovakia operates as a subsidiary of Unitech Group, a Korean supplier in the automotive industry. Unitech Slovakia specializes in producing a diverse range of top-quality products such as thermal and battery structural adhesives, battery housing sealants, thermal adhesives, thermal gap pads and fillers, compression pads, and other related products that cater to the battery industry. The list of automotive customers includes Korean and European OEMs and EU-based battery cell manufacturers.

Panasonic

Panasonic Industrial Devices Slovakia is a subsidiary of the Panasonic Group, which specializes in producing electronic components for the battery industry. Panasonic supplies OEMs and the automotive industry, including components for the battery value chain. Among its products are EV battery management systems, voltage inverters, electronic units for EV power drives, and film capacitors, which are all designed to meet the exacting demands of global OEMs.

Mubea

Mubea Tailored Products operates as a subsidiary of the German automotive supplier, Mubea. With a forward-thinking approach to business, Mubea has invested a substantial amount of 120 million EUR into the development of cutting-edge cooling systems for EV batteries. Set to commence production in late 2023, the launch of this second facility in Slovakia aims to bolster the existing capacity for catering to the demands of global OEMs.

Porsche

Porsche Werkzeugbau is a subsidiary of Porsche AG, a German OEM. Porsche is investing over 1 billion EUR into the assembly facility for the EV battery modules and packs, with an expected launch of the first phase in 2024, reaching the full capacity in 2026.

Manz Slovakia

Manz Slovakia operates as a subsidiary of Manz, a German supplier in the automotive industry. With a focus on delivering advanced production solutions, Manz Slovakia specializes in manufacturing integrated assembly lines, including those dedicated to battery cell production. The scope of its operations encompasses the entire production cycle, ranging from development and design to prototype construction, assembly, installation, and after-sales servicing.

Volkswagen

The Bratislava plant, which commenced operations in 1991, holds the distinction of being the first **Volkswagen** site to boast an electric car portfolio. In 2013, the production launch of the iconic VW e-up! served as a testament to the plant's forward-thinking approach to innovation. The VW e-up! received a facelift in 2019, accompanied by some noteworthy technology upgrades. The plant subsequently launched the production of e-up! twins – Škoda CITIGO iV and Seat Mii electric, which gained popularity among consumers until their discontinuation in 2021. In a bid to accelerate the transition towards sustainable transportation, all C-SUV models manufactured at the Bratislava plant received a plug-in hybrid version in 2020, including the VW Touareg PHEV and Audi Q8 PHEV. VW announced that besides the currently produced fully BEV e-up!, it is going to be launching the production of a fully electric Porsche Cayenne.

28% of the 2021 production volume, which amounted to around 86,000 vehicles, was either fully or partly electrified, marking a year-on-year increase of 5%. Currently, Volkswagen produces 17% of all cars in an electrified version.

Stellantis

Established in 2006 by **Stellantis**, the Trnava plant has carved out a niche for itself as a hub for sustainable transportation. The plant's portfolio includes the battery-electric Peugeot e-208, which began production in 2019. As the first site within the Stellantis Group to venture into the realm of electric vehicles, the Trnava plant's forward-thinking approach has paved the way for the assembly line of battery packs. These battery packs not only support the plant's own production but also cater to the needs of other Stellantis Group plants.

Stellantis, in a bid to expand its portfolio of electric vehicles, unveiled its plan to invest a whopping 180 million EUR. As part of this initiative, the company aims to launch four new electric models on a new platform in the B segment by 2023. With the completion of this project, the plant is expected to hit its full production capacity by 2024.

Kia

The Žilina **Kia** plant, which commenced operations in 2006, has been making strides in the production of electrified models. The plant kicked off the production of its electrified Ceed Sportswagon PHEV in 2019, followed by the XCeed PHEV in 2020. In 2022, the plant added the production of the Kia Sportage PHEV to its repertoire, with an estimated annual production of 50,000 electrified models out of a total of 311,000. Kia produced 16% of all cars in 2022 in the electrified version. Moreover, the plant has plans in the pipeline for a new battery electric model in the C segment, set to launch between 2024 and 2025.

Kia JLR

The **JLR** plant in Nitra, launched in 2018, produces electrified Land Rover Defender PHEV.

Volvo Cars will launch BEV production in 2027 from its facility in Košice. Volvo's recent investment of 1.2 billion EUR will create an annual manufacturing capacity of 250,000 vehicles with a potential ramp-up to 500,000 BEVs.

Material resources

Slovakia currently lacks significant mining capacity for any battery materials or operational cell production. However, the country does have a large primary metal producer that has traditionally supplied the automotive industry. Moreover, some Gigafactory-scale battery cell plants are expected to soon be established in Slovakia, with InoBat being the first publicly announced project.

Slovalco, a subsidiary of Norsk Hydro, a renowned Norwegian supplier of aluminium and metals, owns a cutting-edge metallurgy plant that produces aluminium[9] via electrolysis. The facility specializes in manufacturing aluminium alloys in the form of extrusion ingots and primary foundry alloys shaped as ingots.[10] Slovalco serves a diverse clientele that includes several prominent players in the automotive industry, including those involved in producing housing for batteries and electric motors.

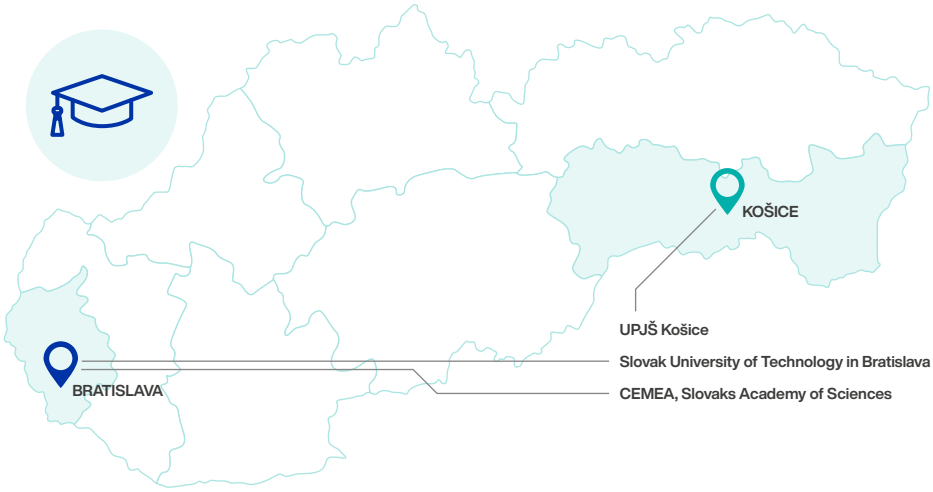
[9] A typical Li-ion battery (60 kWh) contains around 35 kg of aluminum. Aluminum (as foils) are used as current collectors for cathode. Aluminum is also used for cell casing and battery pack housing.

[10] As a reference, in 2021, Slovalco's total production of finished aluminum products (197,250 tons) included 133,475 tons of extrusion ingots and 63,774 tons of primary foundry alloys.

Human resources

University-level STEM degree education is critical. The education and cultivation of new talent for the growing battery industry could pose the greatest obstacle to its rapid expansion on a larger scale. In this regard, Slovakia has a robust education system that prioritizes engineering and STEM curricula, with technology-focused universities and colleges located in all of the country's major industrial centers. Regarding academic institutions specializing in automotive and mobility, the most important cities are Bratislava, Žilina, and Košice.

At present, there is no all-encompassing academic program specifically focused on batteries offered by any of Slovakia's universities. However, the country's leading technical universities do offer programs that target specific segments of the battery value chain, primarily within the fields of electronics, mechatronics, automotive technologies, and information technology. Some of these universities also provide chemistry-oriented programs. While batteries are covered as part of electrochemistry and physical chemistry, they are not a standalone topic.



Slovak University of Technology in Bratislava

The largest university in Slovakia provides a diverse range of undergraduate and graduate programs that primarily focus on mechatronics engineering, with concentrations in automotive technology, e-mobility, electronic systems, and IT. These programs are offered through two faculties, each specializing in their respective areas. Typically, students are provided with hands-on internships with industrial partners and can take part in the university's ongoing development of electric vehicles.

UPJŠ Košice

The University offers a Master's program in Chemistry that includes a dedicated Doctorate program with a focus on physical chemistry. The aim of this program is to prepare professionals and specialists with advanced knowledge for research and development in the battery industry. Graduates are equipped with theoretical and experimental knowledge in advanced electrochemistry, chemical kinetics, physical nanomaterials chemistry, and other related fields.

CEMEA, Slovaks Academy of Sciences

Established in 2017, the Center for Advanced Materials Application of the Slovak Academy of Sciences (CEMEA SAS) is a prominent national R&D facility dedicated to the development and testing of cutting-edge battery technologies and chemistries. CEMEA SAS brings together top teams from six R&D institutes within the SAS network and offers a unique opportunity to pursue a PhD degree in battery technology.

At the heart of its research efforts, CEMEA is engaged in material sciences and the development of new technologies that rely on surface and interface modification. The organization's research is primarily concentrated on four key areas: firstly, the innovative synthesis of inorganic-organic materials for electrodes; secondly, the preparation of protective electrode layers through the use of atomic layer deposition (ALD); thirdly, characterization using advanced operando tools; and finally, the standard electrochemical characterization of electrolyte materials.

R&D activities

Slovakia's public and private entities are actively engaged in battery-related R&D projects and technology development. While the scope of their endeavors is impressive, the focus is relatively concentrated on specific areas of expertise. The public and private R&D teams are dedicated to advancing:

- → new battery materials and chemistries, particularly for the third (optimized Li-ion) and fourth (Li-ion and Li-metal with solid electrolyte) battery generations
- → cutting-edge battery management systems (BMS)
- → advanced sensor technologies
- → the implementation of artificial intelligence and automation in the recycling process and second-life applications of batteries

Slovakia's Academy of Sciences, along with a few technical universities and private companies, are the driving force behind these initiatives. While a significant portion of this R&D is financed by the public sector, only a handful of projects are privately funded and driven. Currently, no major multinational enterprises have established their R&D capabilities in the battery value chain within the country. Private underinvestment in battery-related R&D is consistent with the overall lack of private investment in R&D-intensive innovations within the national economy.[11] Consequently, it is not surprising that companies generate a low number of patents and innovations, a challenge that extends beyond battery technologies and innovations.

[11] For illustration, in 2019, only 0.45% of the national GDP was allocated to R&D from private resources.

Developing new battery technologies requires significant synergy between the personal and financial resources of both the public and private sectors. Such initiatives demand an enormous number of talented individuals, particularly in the engineering and STEM-related fields. Additionally, R&D efforts can be time-consuming and uncertain, with many promising breakthrough technologies ultimately proving to be commercially unfeasible. As such, close cooperation between the public and private sectors is vital to achieving the necessary synergy. Regrettably, the collaboration between industry and academia remains the 'Achilles heel' of Slovakia's R&I system, with these two sectors remaining largely isolated from one another.[12]

Slovakia's battery industry is further hindered by a shortage of startups and innovative ventures arising from either academic or private settings. In recent years, only a handful of startup companies have emerged, focusing primarily on cell production, components such as sensors, and battery recycling and second-life applications. While there are several reasons for this shortage, including those previously discussed, an underdeveloped startup ecosystem in general also fails to stimulate entrepreneurship. Access to risk financing, entrepreneurial services for startups, and various forms of financial assistance from the public budget is severely limited.

National Battery Center as a backbone and joint platform for the battery R&D

In 2021, the Slovak Academy of Sciences established the National Battery Center (NBC) in conjunction with key technical universities and industry clusters. This initiative serves to connect the research and development capacities of public and private stakeholders and facilitate the transfer of domestic innovations and technologies to the market. By creating a strategic cooperation platform for public and private research, the NBC aims to remove current hurdles and bottlenecks within the innovation ecosystem and financing.

The NBC's primary objective is to develop and commercialize battery technologies and systems, spanning the EU Technology Readiness Level (TRL) 1 to 6, ranging from fundamental and applied research to prototype and industrial stages. The center covers the most relevant and promising parts of the battery value chain in Slovakia through three topical streams: Active materials and cells, Battery systems and management, and Recycling and second use of batteries. The R&D topics are aligned with the short-term and midterm priorities outlined in Batteries Europe, a European Technology and Innovation Platform, and the Battery 2030+ Initiative.

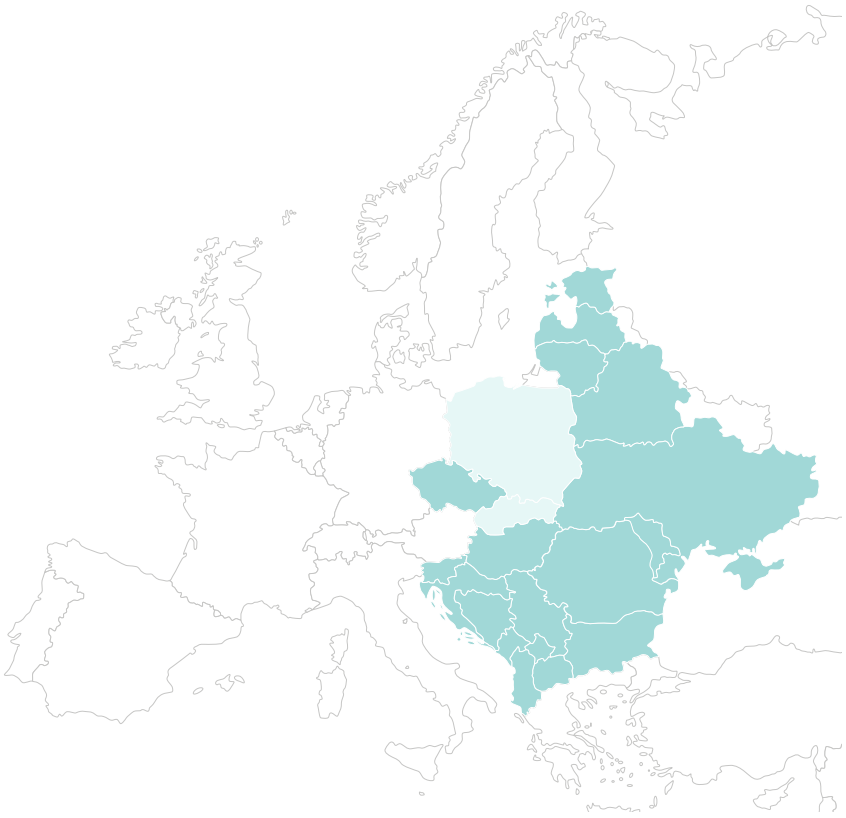
The NBC is committed to facilitating technology transfer between public R&D and private industry, with the primary goal of deploying and commercializing battery technologies in the market. Real-life testing and validation of research results in an industrial environment, as well as transferring technologies and intellectual property into industrial deployment, are among the key objectives of the initiative. Furthermore, the NBC aims to incubate and accelerate innovations by promoting the creation of new battery startups and spin-off companies. Technology transfer will be achieved through small-scale validation projects in a real industrial environment, providing a proof of concept.

[12] RIO Country Report 2017: Slovakia, JRC Science for Policy Report, 2018.

EU's Important Projects of Common European Interest in Slovakia focused on batteries:

1. **ZTS VV** – Disassembly of EV batteries, AI diagnosis and regeneration, assembly for 2nd use of batteries
2. **Energy-Aqua** – Energy storage systems
3. **InoBat Auto** – battery R&D centre as the first phase of a larger gigafactory for the battery cell production
4. **InoBat Energy** – R&D and launch of the production for the flow batteries applied in the energy sector

1.3 Key investments in the rest of the CEE region



Croatia

Rimac Automobili is a Croatian car manufacturer headquartered in Sveta Nedelja, Croatia, that develops and produces electric sports cars, drivetrains and battery systems. The company was founded in 2009 by Mate Rimac. Rimac Automobili's first model, the Concept One, was the world's fastest-production electric vehicle. While manufacturing and marketing high-performance vehicles under its brand, Rimac also develops and produces battery packs, drivetrain systems, and vehicles for other companies.

Czech Republic

The Cinovec project, situated 100 km from Prague in the Czech Republic, is currently underway under the direction of European Metals Holding. Its objective is to yield almost 30,000 metric tons of battery-grade lithium annually over a period of 25 years. As per European Metals' pre-feasibility study in 2022, Cinovec has the potential to emerge as the world's lowest-cost hard rock lithium producer, with the capability to generate lithium at a cost of USD 5,000 to USD 6,000 per metric ton.

Hungary

On August 12th, 2022, Contemporary Amperex Technology Co., Limited (CATL) made an official announcement regarding its investment of 7.34 billion euros to establish a 100 GWh battery plant in Debrecen, situated in eastern Hungary. This new plant will be the second battery plant in Europe for CATL, following its German plant. Covering an expansive area of 221 hectares in the Southern Industrial Park of Debrecen, this ambitious project aims to cater to the cell and module requirements of European automakers. Debrecen, located at the heart of Europe, is in close proximity to several auto plants of CATL's customers such as Mercedes-Benz, BMW, Stellantis, and Volkswagen, providing CATL's Debrecen plant with a strategic advantage in meeting the battery demands of the European market. This investment will further CATL's global production network development, and facilitate the acceleration of e-mobility and energy transition in Europe. In addition to this, CATL is committed to reducing its carbon footprint in battery manufacturing, and plans to utilize electricity from renewable energies while considering partnering with local firms to develop solar power in the country.

Latvia

The Swedish company Anodox Energy Systems has announced plans to produce electric vehicle batteries in Latvia, with the first factory in the Port of Riga expected to be operational by December 2022. A second factory for rapidly growing LFP cell technology will be established soon after. A total of €50 million will be invested and up to 300 new jobs will be created.

The planned LFP factory is to be the first of its kind in Europe. “This means that the battery production cycle will be completed in Latvia, from raw material to complete system,” says Kaspars Rožkalns, director general of the Latvian Investment and Development Agency. “From Riga, the finished products will be delivered to customers in Scandinavia, Germany and the rest of Europe.”

Lithuania

ENEPAC is a specialist in Battery Management Systems and Battery Modules for both prototype and industrial applications. Their products find utility across a vast range of applications such as Formula SAE, Autonomous Robotics, Autonomous Drones, Automotive, Agriculture, Electric Go-carts, Electric Golf Carts, Industrial, Motorcycles, Bikes, Scooters, among others. ENEPAC has built an ecosystem of Li-ion Battery Modules that enable swift prototyping and product development for a wide range of applications. Although the modules can be utilized for numerous applications, their genesis stems from a design specifically tailored for Formula SAE teams. To complement this offering, ENEPAC has developed a Battery Management System (BMS), with its Tiny BMS measuring individual voltages of parallel cell groups while managing load and charger switches.

Serbia

Jadarite is a new mineral deposit containing lithium and boron that was discovered by geologists in 2004 near Loznica in the Jadar Valley in Western Serbia. The high-grade, large-scale deposit is a promising addition to the world's supply of materials for low-carbon technologies, such as the batteries used for electric vehicles and renewable energy storage. The Jadar deposit and its unique mineral, Jadarite, contains high-grade mineralization of boron and lithium. Jadar will be capable of producing three products on an annual basis, all in powdered form:

- ~ 58,000 tonnes of refined battery-grade lithium carbonate
- 160,000 tonnes of boric acid
- 255,000 tonnes of sodium sulphate

Romania

The proposed project RockTech Lithium will refine lithium-bearing rock into high-purity lithium hydroxide, which is needed by the electric vehicle industry and its suppliers to manufacture batteries for electric vehicles. The proposed Converter is expected to produce approximately 24,000 metric tons of lithium hydroxide per year, equivalent to the volume needed to equip around 500,000 electric cars with lithium-ion batteries. With an estimated capital cost of approximately €400 million, the proposed Converter is expected to provide significant and enduring economic benefits, including the direct and indirect creation of more than 500 jobs during its construction and operation.

2

The regulatory environment and policy recommendations

2

The regulatory environment and policy recommendations

On December 9, 2022, the European Parliament and the Council reached a preliminary political agreement on the text of the proposed Battery Regulation. Its adoption by the European Parliament and the Council and its entry into force are expected in the upcoming months.

The Battery Regulation will apply in all the EU Member States without the need for its implementation into national law, as is the case with directives. This means that businesses placing batteries on the market will have to comply with the provisions of the Regulation and meet the obligations imposed on them by the deadlines set in the Regulation.[13]

The objectives of this Regulation are to:

- → contribute to the efficient functioning of the internal market,
- → establish a more circular battery economy while preventing and reducing any adverse impacts of batteries on the environment and human health,

  while preventing and reducing any adverse impacts of batteries on the environment and human health.

The agreement now needs to be officially adopted in each institution before entry into force in 2023 although an additional application period will be provided. However, a large number of provisions are still subject to specification via delegated/implementing acts.[14]

[13] https://www.osborneclarke.com/insights/should-electric-vehicle-battery-manufacturers-prepare-regulatory-revolution
[14] AVERE Summary of the Battery Regulation

Expert opinion

Europe is well on its way to building a domestic battery industry. With the rise of the European battery industry, our region has the unique opportunity to take the lead in setting the global standard for the sustainability of this sector. But without speedy adoption of the EU Battery Regulation with ambitious timelines for sustainability-related requirements, this opportunity is at risk of being lost.

We must encourage the use of clean energy in battery production in Europe. The reason is simple: if battery manufacturing expands based upon fossil-fuelled energy sources, the associated carbon costs will be tremendous.

By 2030, we expect some 1,000 GWh of lithium-ion battery demand in Europe. If this volume of batteries were produced on a fossil-fuel-powered grid – comparable to those powering most existing battery factories – we can expect a CO_2 footprint of some 100 million tons per year. In contrast, by embracing renewable energy and circularity, that same footprint would be only one-tenth of that. A simple yet effective means of encouraging the adoption of renewable energy for battery manufacturing is through carbon footprint labelling and a subsequent ban on batteries with the highest carbon intensities. The European Commission has proposed exactly this. Transparency on this crucial aspect of a battery's environmental impact will shift the industry towards sustainability through encouraging activities which reduce the carbon footprint, including the adoption of renewable energy for production, efficient recycling, use of recycled materials in battery production and improved practices for raw materials sourcing.

Northvolt

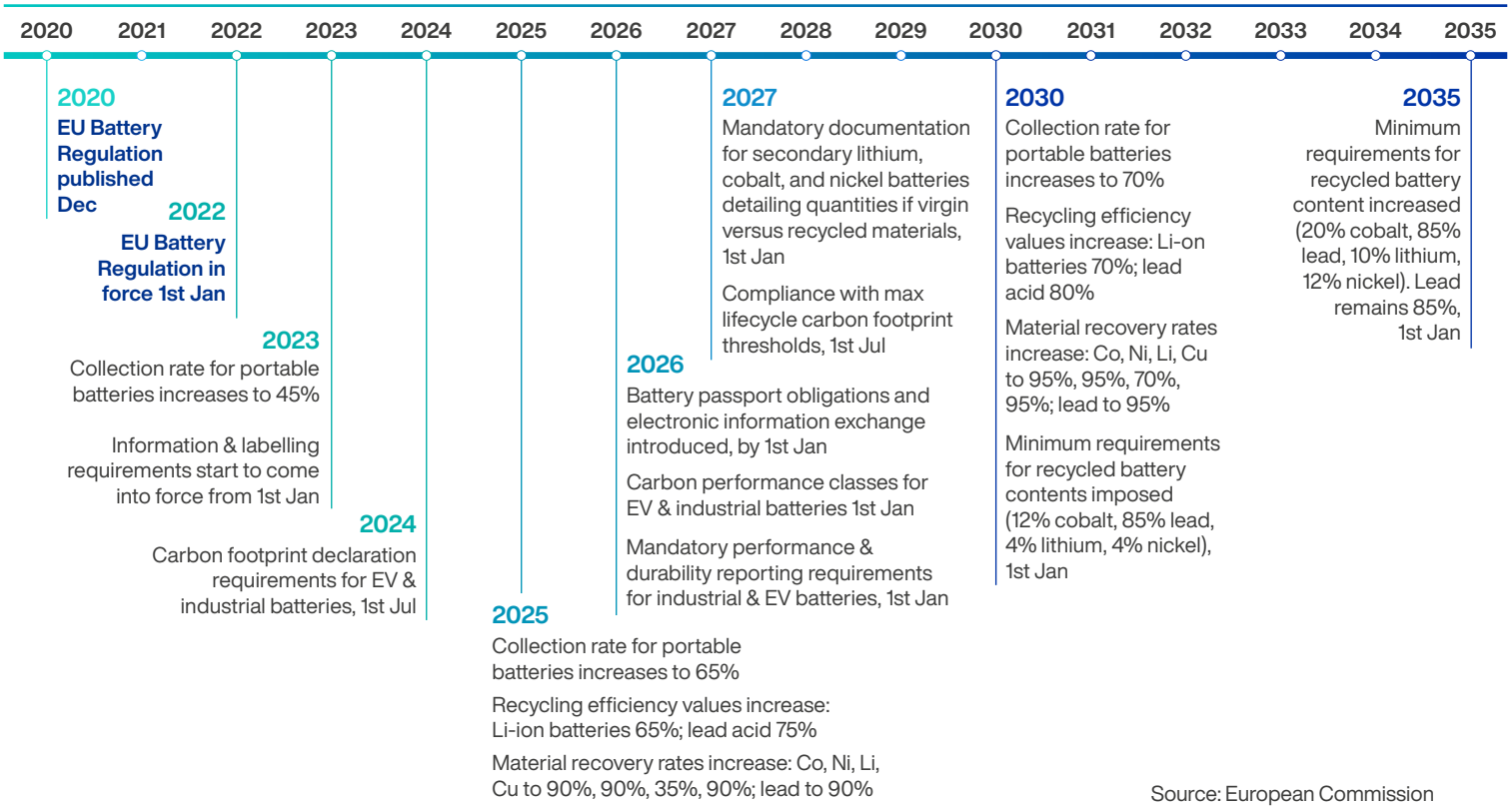
Today's battery industry consumes massive amounts of power generated from burning fossil fuels. The industry standard results in 100 kg CO_2e per kWh of batteries produced. By powering battery manufacturing with renewable energy, and embracing other sustainable practices, we can reduce emissions to 10 kg CO_2e per kWh. If Europe's demand for batteries in 2030 were produced at this level, we would avoid the carbon emissions equivalent to twice the annual $C0_2$ emissions of Sweden.

The European Commission (EC) and the European Parliament Environment Committee (EP) propose introducing requirements in three steps for batteries placed on the European Union market, irrespective of where batteries have been produced:

1. Carbon footprint declaration requirements from 1 July 2024 EC / EP
2. Carbon footprint performance class labels from 1 July 2025 EP / 1 January 2026 EC
3. A ban on the worst performing batteries from 1 January 2027 EP / 1 July 2027 EC

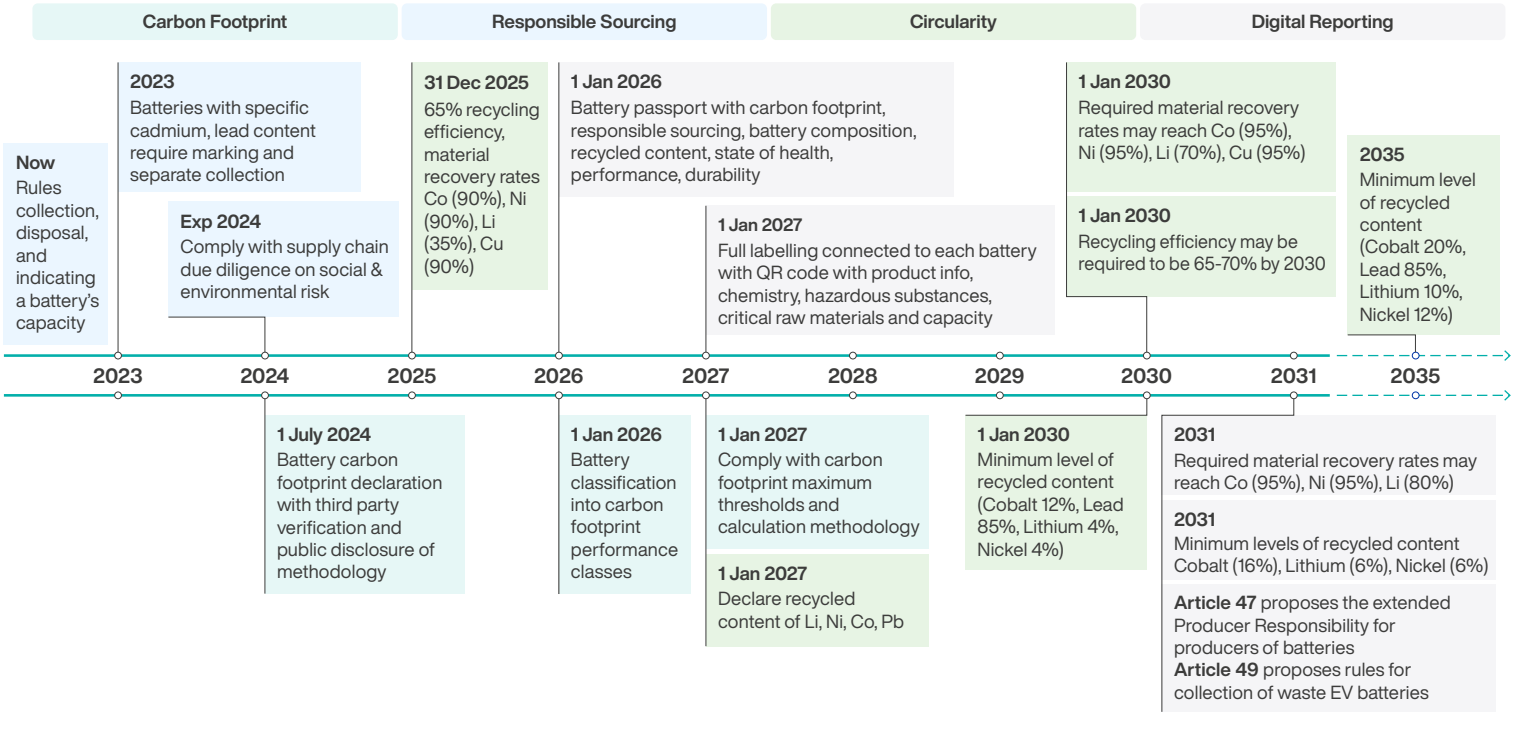
The European Commission and the European Parliament Environment Committee have diverged on timeframes for the implementation of the requirement, as indicated above.

The EU Battery Regulation Roadmap



Source: European Commission

Milestones for the EU Battery Regulation



Source: European Commission

Expert opinion

What are the implications for the Polish industry?

All entities associated with the battery market are poised to be impacted by EU regulations, though the extent of the impact is yet to be determined. A considerable number of batteries produced exceed the 2 kWh limit, but some are employed in Light Electric Vehicles (LEV) and must adhere to the new regulations. Specifically, the recently defined Light Means of Transport (LMT) sector will introduce multiple aspects to meet new requirements. While various challenges are forthcoming, the industry is proactively adapting to the transition. For instance, Wamtechnik is already collaborating with recycling companies and boasts a wide range of suppliers throughout Europe. It is worth noting that customers currently expect batteries to be manufactured in the EU, with most components sourced domestically.

Wamtechnik

3

Recommended activities for the development of the battery industry

3

Recommended activities for the development of the battery industry

According to experts, the surging demand for electric vehicles and their critical components presents a significant challenge for the automotive industry, particularly regarding ensuring a stable supply of lithium-ion cells over the long term. This scenario presents vast opportunities for the battery sectors in Poland, Slovakia, and the broader Central and Eastern European (CEE) region, as well as for entities that are considering constructing additional battery and component production facilities.

The growth of the European battery industry is currently under threat due to geopolitical developments and an overreliance on Asia, resulting in supply chain shortages. Furthermore, escalating electricity costs in the EU are driving up OPEX, and the US Inflation Reduction Act (IRA) and similar support schemes in Canada, Japan, and South Korea are causing distortions in the transatlantic level playing field, leading to investments in the EU being either stalled or redirected to other regions.

Moreover, uncertainties surrounding EU and/or national financial support are delaying investments in the EU battery value chain, as they are unable to match the appealing CAPEX and OPEX incentives offered by the USA via the IRA. The EU and national frameworks for industrial permitting lack the speed and clarity of other global economies, such as the USA, contributing to additional risks and delays in investment and project execution.

Urgent attention must be given to **critical issues and actions concerning the sustainable development of the battery industry in Poland, Slovakia, the broader CEE region, and the European Union as a whole**. These include:

1. **Growing domestic capacities for raw materials and battery material**
2. **Boosting production of components and batteries**
3. **Enhancing recycling and second-life projects**
4. **Growing skills and talent**

The thorough analysis of the Central&Eastern European lithium-ion battery industry as presented above and based on the extensive review of the Polish and Slovak markets, shows that the primary challenge is related to a seeming lack of a long-term strategy, in a broad sense. The manufacturing capacities and growing importance of the region appears to constitute a strong foundation which is not supported by local policies of a lasting nature. The authors of this study are hence inclined to form strategic recommendations which refer to the need of a stable, reliable and unwavering framework for the industry to thrive on and foster the CEE as an EU powerhouse for lithium-ion battery competitiveness.

This long-term, strategic approach to further developing the lithium-ion battery industry is based on three key areas, i.e. competitiveness, competence and net-zero industry. The three areas are mostly interconnected and may overlap in some of the recommended activities or steps. This is also because the apparent best way forward in terms of developing this market is to shape a comprehensive approach.

1. Recommendation
Developing Competitiveness

The lithium-ion battery industry is now responsible for 2% of the Polish annual export value. This is a datapoint which is often brought up by Polish stakeholders. This shows of course, how much of an economic factor this industry can become. Moreover though, the lithium-ion battery industry is a strong component of a wider ecosystem, the new mobility sector of assorted aligned industries all together representing a far more significant economic impact. The entirety of this value chain (including but not limited to renewable energy sources and R&D efforts) can generate as much as 1.63% of the Polish GDP by 2025 and reach up to 2.03% by 2030[15]. This, of course, may occur only if a sustainable, stable and market-oriented policy is deployed in the next decade by both the EU, as well as local State Member policies – in case of the data above, in Poland, which is highly representative of the CEE region.

The second area, which dictates the support of CEE competitiveness is the need to establish a strong industrial capacity in this region. This goes further than the current manufacturing potential based on the proximity of go-to markets and sea access, as well as costs labor and infrastructure development.

To drive this process at an adequately accelerate rate, the following policy steps should be taken:

1. Streamlining the permitting and Environmental Impact Assessment (EIA) process to expedite the launch of new mining and raw materials processing capacities in the country.
2. Implementation of policies at the EU and national levels to stimulate the economy and prevent a recession.
3. The need for the creation of a complex support program for the sector, which would include investment support for new production (as per pillar II of GDIP) but also the training aid for new competence, talent development and reskilling current workforce (as per pillar III of GDIP):
   - → Defining real needs,
   - → Funding (EU Funds, revision of RRF),
   - → Designing the project architecture (operator, rules, legal basis, procedure).
4. Elaborating investment resources, support programs, and financial incentives, with availability of investment incentives from public administration.
5. Developing and managing innovation by building an ecosystem of collaborating stakeholders from private and public sectors that is as independent as possible from competition from Asia or America to achieve the important aim of cost reduction.
6. Urgently implementing an emergency package of measures at the EU, member state, and local levels to accelerate and de-risk investments, speed up industrial projects, and level the global playing field.

[15] „Wpływ elektromobilności na rozwój gospodarczy w Polsce" (eng. The impact of electromobility on the development of the Polish economy"), PSPA„ Warsaw 2022

7. Comparing the appeal of current rules for regional investment aid vs. TCTF rules (intensity, scale, notification limits, notification compatibility, procedures, project implementation periods).

8. Ensuring the efficient transition of the energy production capacity, which must be based on renewables. For many of the CEE States this means that the regulatory framework provides no hurdles (like distance limits) for wind energy and provides rational investments in the grid (to enable smart gird solutions, but also allow for the safe development of a prosumer energy market – with no risk of "overburdening" the national grids).

2. Recommendation
Developing Competence

The Central&Eatern European region, as well as other EU Member States have a small chance of inventing the new technology for battery chemistry, one which may in time take over the current lithium-ion based solutions. However, the development of innovations in terms of Battery Management System technology, thermal sensors and casing, as well as other electronic systems within the batteries may constitute a viable way for the CEE to become a hub for future battery solutions. The region has a vast force of qualified engineers and advanced IT resources, as well as being one of the most digitalized regions of not only the EU, but also on the global scale. The pool of qualified personnel that can shape the competence in this regard is quite significant. In Poland alone, there is ample workforce which can be unlocked for the battery segment within the automotive industry. Studies show, that there are as many as 280,000 Polish engineers employed within the internal combustion engine technologies, all of which will undergo a transition towards the zero emission powertrain[16].

Programs dedicated to reskilling and raising awareness regarding the new technologies related to the development of zero emission transport must be developed on the national level. The approach must enable the affordability and accessibility of these programs, as most stakeholders prone to enroll will likely lack the financial potential to do so inherently. The CEE national programs should emulate the approach of pan-European program such as the the European Battery Alliance Academy, but with a more public and accessible form available as well.

The list of policies which should be considered in this process consists of:

1. Supporting innovations, research, and development opportunities, brain circulation, and encouraging startups in the battery value chain to compete on cell datasheet values, such as energy density.

2. Developing education programs to provide trained and educated staff, including retraining staff from conventional automotive or other sectors of the economy.

[16] "How will e-mobility change the Polish labour market? Green sectors of the future", PSPA and BCG Boston Consulting Group, Warsaw 2021

③ Reshaping the governing policies of state-run research and development institutions in order to support reskilling program and postgraduate technical education in the lithium-ion battery industry.

④ Public-private partnerships should be at the foundation of these policies, where manufacturers of the entire value chain can contribute with the precise needs for potential employees, while state academic institutions can ascertain the scientific acumen of the lecturers and teaching program.

3. Recommendation
Developing a zero-emission value chain

The leading global manufacturers in the e-mobility value chain are pursuing the goal to have only renewable energy sources as a foundation for energy supply. This is a key challenge for countries such as Poland and many other CEE States, as coal is the main source of energy production (nearly 80% of the Polish energy mix). This problem is often amongst the key decision-making factors, where investor coming into the market decide to choose different locations, which offer a better "green" share of the energy available. Poland has seen an over 100% rise year-to-year in private PV installations, but PV farms and wind farms are still scarce and the legal hurdles to develop them at a massive scale are still abundant in the Polish regulatory framework. This is common for the CEE and is at the cornerstone of long-term policy priorities for the region. The full implementation of the provision of the RED III will be crucial to accelerate this process, as a phase of enacting the Fit for 55 package, but much more needs to be done on the national level. This process relies on an approach which does not waver during the change of political power. It must be etched into political awareness that energy policies must remain outside and protected from the language and content of political campaigns.

The lithium-ion battery industry, however offers an additional synergy in terms of positive environmental impacts. One, which is often viewed as exactly the reverse. The resources and critical raw material used in this industry have a large chance of creating the perfect sustainable and circular system – as they may be recycled in large quantities. The think tank Transport&Environment supported these arguments with data which was presented in the findings of their 2021 study "Batteries vs oil: A comparison of raw material needs". We learn that under the current battery regulatory framework of the EU, it is assumed that up to 30 kg of rare metals may be "lost" in the recycling process for and EV (the authors assess the size of this waste as a football). Whereas, a conventional ICE vehicle (petrol or diesel) generates burns 300-400 more fuel in terms of weight which would amount to 17,000 liters of fuel. If the barrels were stacked, they would be 90 m high. In addition, by 2035, the EU will need only 20% of the lithium and nickel, as well as 65% of the current cobalt imports because these material will already be recycled in sufficient amounts for reusage.

Therefore, the potential is clearly discernible, but needs strong, stable and lasting policies implemented with conviction. Some of the activities and policies which can support this include:

1. Evaluation of the impact of European regulations on batteries, including the circular economy, adaptation of entities introducing batteries to the market to comply with the provisions of the regulation and fulfill obligations within the indicated deadlines.
2. Encouraging the reuse and development of recycling technology for batteries to create a closed production, operation, and disposal cycle, with a positive impact on waste management.
3. Ensuring availability of electronic components, semiconductors, single cells, and raw materials for batteries.
4. Supporting organization which invest into reducing emissivity during production processes and utilizing green energy in production plants.
5. Ensuring the efficient transition of the energy production capacity, which must be based on renewables. For many of the CEE States this means that the regulatory framework provides no hurdles (like distance limits) for wind energy and provides rational investments in the grid (to enable smart gird solutions, but also allow for the safe development of a prosumer energy market – with no risk of “overburdening” the national grids).

List of abbreviations

EV	Electric vehicle
BEV	Battery electric vehicle
PHEV	Plug-in hybrid electric vehicle
ICE	ICE - Internal combustion engine
LEV	Light Electric Vehicles
LMT	Light Means of Transport
E-bus	Electric bus
DC	Direct current
AC	Alternating current
Li-ion	Lithium-ion
GWh	Gigawatt-hour
OEM	Original equipment manufacturer

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Gratitude to the contributors for their input in their subject matter expertise on specific materials:

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Northvolt Systems Poland

Solaris Bus & Coach

Wamtechnik

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PROJEKT GRAFICZNY I SKŁAD

Magda Furmanek

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