THE FARADAY INSTITUTION

UK electric vehicle and battery production potential to 2040

Executive summary

The electrification of transport is accelerating across the world, with many countries capitalising on the economic opportunities. The UK has achieved some notable successes in expanding existing and securing new battery manufacturing plants (gigafactories). However, the pace of action needs to accelerate, otherwise the UK will fall behind in the global race and fail to maximise the economic benefits from the transition from the internal combustion engine (ICE) to electric vehicles (EVs).

Since the Faraday Institution's report in 2020, European gigafactory capacity projected for 2030 has more than doubled from 450 GWh (Gigawatt hours) per annum to around 1,350 GWh, with 38 plants now expected to be open and producing cells by the turn of the decade. Germany is a leading location for manufacturers (with seven gigafactories open or planned) along with Hungary and France. The LG Energy Solutions plant in Poland is the largest planned, with a proposed capacity of up to 115 GWh. Globally, there are now around 400 gigafactories and 9,000 GWh of lithium-ion battery capacity in the pipeline.[1] Global revenues for battery cell components, including cathodes, anodes, separators, electrolytes and cell packaging, is expected to reach US$250 billion in 2030.[2]

In the UK, recent announcements have built up a level of excitement about the potential to create a new, dynamic and highly skilled battery industry in the UK. Agratas, a Tata Sons venture, is investing over £4 billion in building a 40 GWh gigafactory in Somerset, with Jaguar Land Rovers (JLR) and Tata Motors identified as key customers and production planned to start in 2026. AESC is also building a second battery plant adjacent to the existing facility in Sunderland with a capacity of 15.8 GWh pa. A feasibility study is underway for a further expansion. A battery manufacturing plant in Coventry, known as the West Midlands Gigafactory, has secured planning permission and discussions are underway with prospective investors to develop a plant with an initial capacity of 20 GWh.

"There is a growing sense of optimism that a highly productive and sustainable battery manufacturing industry can be built in the UK. By 2040, a successful industry could employ 170,000 people in EV manufacturing, 35,000 people in gigafactories and 65,000 people in the battery supply chain." Stephen Gifford, Chief Economist, The Faraday Institution.

Bold policy and government investment commitments have increased investor confidence in the UK as a location to do business. The vision as outlined in the UK Battery Strategy,[3] is for *"the UK to have a globally competitive battery supply chain that supports economic prosperity and the net zero transition. The UK will be a world leader in sustainable design, manufacture, and use, underpinned by a thriving battery innovation ecosystem."*

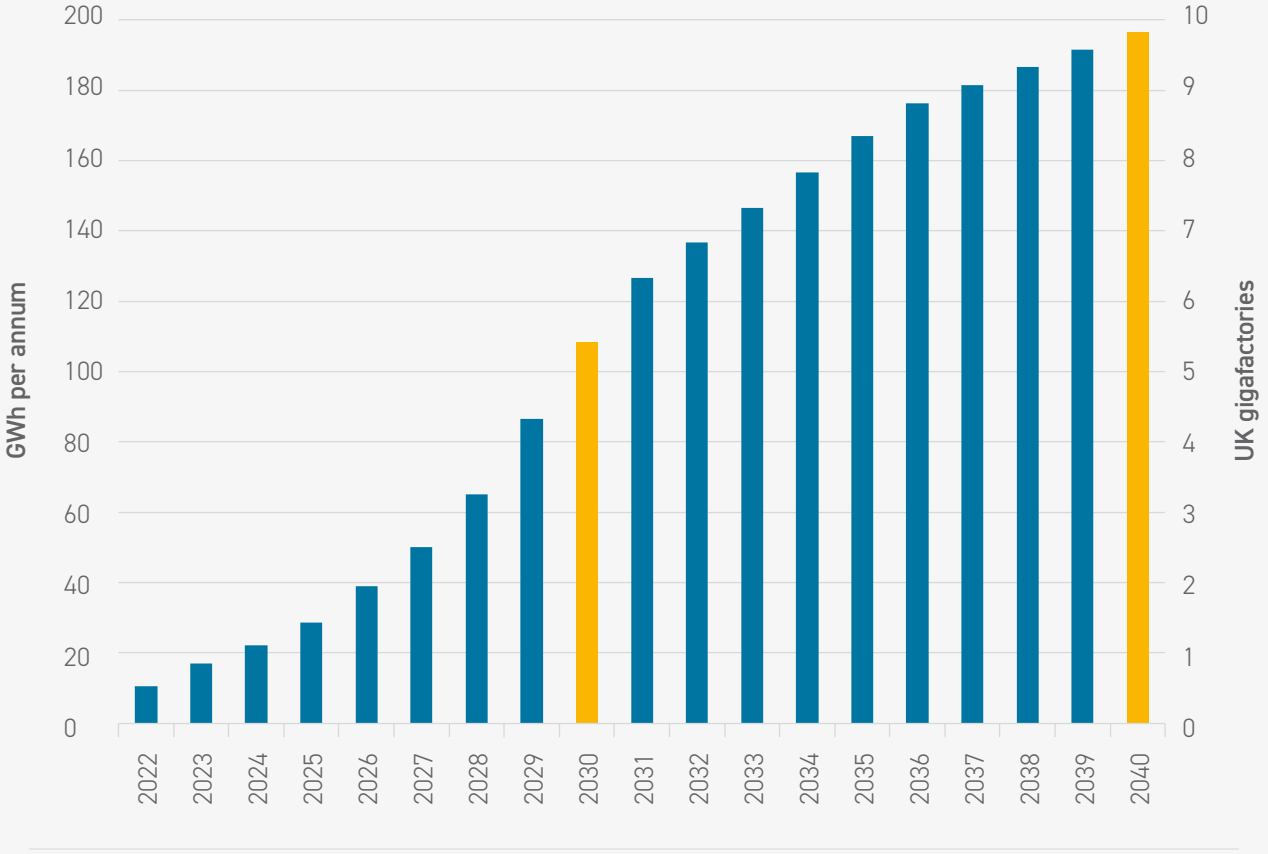
Wider initiatives include the UK Critical Minerals Strategy, Net Zero legislation, Ten Point Plan for a Green Industrial Revolution, Decarbonisation Transport strategy, the establishment of an Automotive Transformation Fund (ATF) to support gigafactory investment and an end to the sales of new ICE vehicles by 2035. All these initiatives provide a healthy and positive signal to investors that the UK means business and is serious about a rapid transition to EVs.

But more needs to be done, and quickly. The UK is making progress but not moving fast enough compared to its competitors in Europe and beyond. Demand for UK EV battery manufacturing capacity will reach nearly 110 GWh per annum in 2030, predominately for private cars and light commercial vehicles (LCVs). This demand is the equivalent of six large gigafactories running at around 90% capacity, but at present there are only two substantial UK plants in the pipeline. Gigafactories take at least five years from the start of planning and construction to reach operational capacity, so investment and location decisions to meet battery demand in 2030 are all likely to be made in the next two years. Over this timescale, automotive manufacturers will be deciding where to locate future EV model production, in the UK or mainland Europe.

[1] Benchmark Minerals Intelligence (August 2023). Lithium-ion Battery Gigafactory Assessment.
[2] McKinsey (April 2024). The battery cell component opportunity in Europe and North America.
[3] Department for Business & Trade (2023). UK Battery Strategy.

Substantial work has been done to generate a strategy and clear roadmap for re-skilling and up-skilling the workforce to enable battery production.[4] Implementation of the strategy will require coordinated support from central government, local government, training providers and industry alongside a well-sequenced STEM curriculum in schools to feed the demand for a future workforce. A skilled workforce will be a significant advantage over European competitors in the race to attract inward investment from global battery manufacturing companies.

Figure 1a: Potential demand for UK-produced batteries



By 2040, around 200 GWh of supply will be needed in the UK to satisfy the depend for batteries for private cars, commercial vehicles, HGVs, buses, micromobility and grid storage

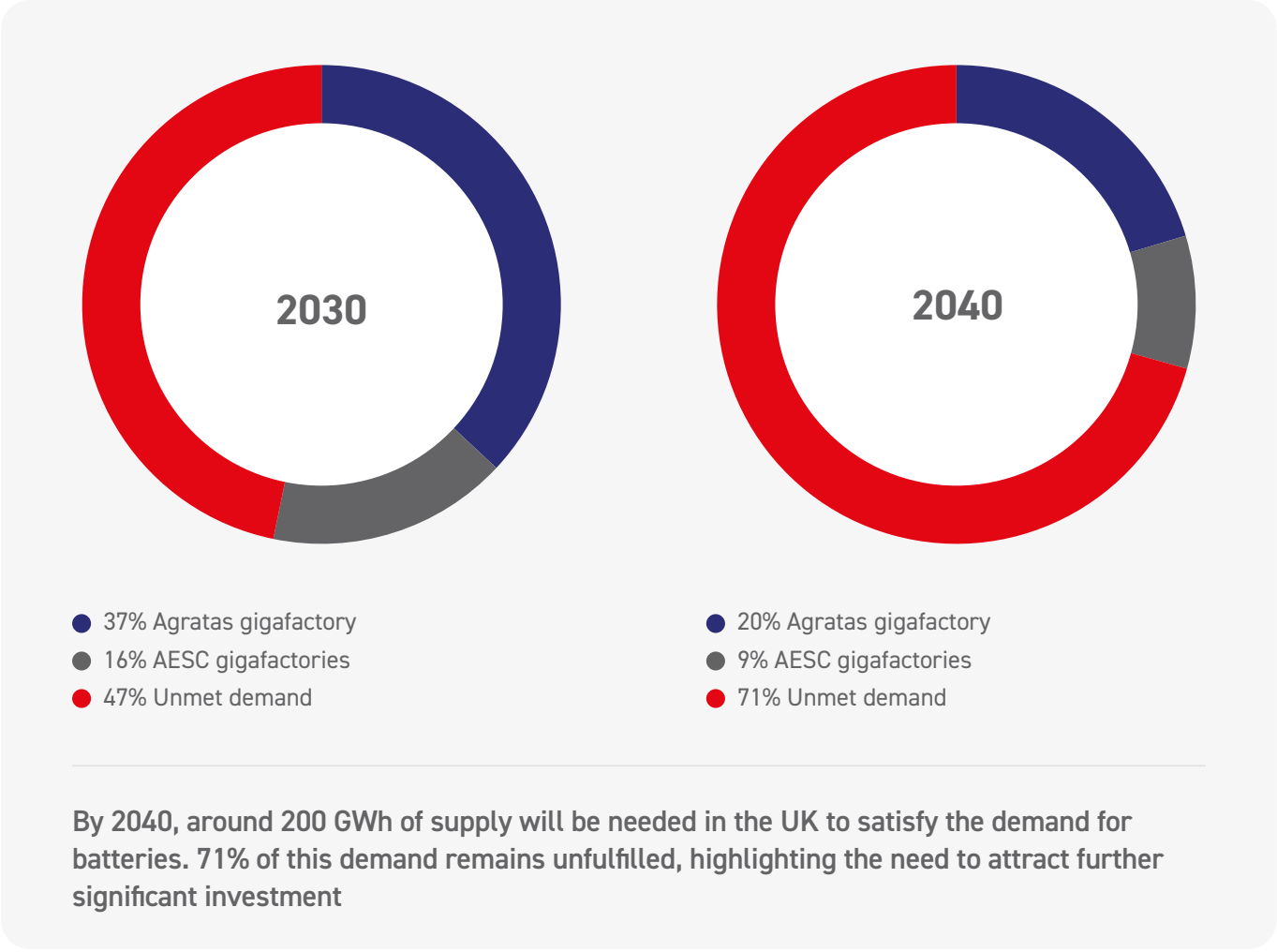
Source: Faraday Institution. Numerical data for figures.

The size of the UK battery industry could grow even further after 2030 as EV demand increases across the world, battery capacity per vehicle rises and batteries are increasingly used in large vehicles such as buses and heavy goods vehicles (HGVs). By 2040, around 200 GWh of supply will be needed in the UK to satisfy the demand for batteries for private cars, commercial vehicles, HGVs, buses, micromobility[5] and grid storage. This demand is equivalent to ten gigafactories in 2040 with each plant running at a capacity of 20 GWh per annum.[6] A substantial economic prize for the UK therefore awaits if new UK battery startups are successful in taking market share and global battery manufactures can be encouraged to set up shop in the UK.

Employment supported in this new EV and battery industry would increase to 270,000 jobs by 2040, a rise of one-half on pre-pandemic employment levels. Around 170,000 of these jobs would be supported by the manufacture of 1.6 million passenger and light commercial EVs, and the manufacture of HGVs, buses and small lightweight

[4] The Opportunity for a National Electrification Skills Framework and Forum (September 2021).
[5] Micromobility covers lightweight vehicles including e-bikes, scooters, skateboards and three wheelers.
[6] The ten gigafactories estimate is illustrative as companies such as Agratas and AESC could build plants with capacity in excess of 20 GWh per annum.

Figure 1b: Met and unmet demand for UK batteries from announced gigafactories (2030 and 2040)



Source: Faraday Institution. Numerical data for figures.

vehicles. In the battery manufacturing industry, 35,000 direct jobs would be created in gigafactories with a further 65,000 jobs in their supply chains. Key opportunities in the battery supply chain include the production of the cathode, anode, electrolyte and separator and battery recycling at the end of the value chain.

Whether batteries are manufactured in the UK is an important determinant of the future health of the UK automotive industry. Without large scale UK battery production, domestic vehicle producers would gradually wind down their production of ICE vehicles, progressively eliminating the jobs of the people directly employed in the UK automotive sector, probably falling in a worst-case scenario to as low as 20,000 by 2040.

The economic opportunity for the UK is not just from lithium-ion batteries. Next generation battery technologies including solid-state, sodium-ion and lithium-sulfur offer exciting opportunities through applications in marine, rail, aviation and heavy goods transportation. Solid-state batteries could be used to improve EV performance through step changes in battery cost, range and safety. Lithium-sulfur is a lightweight technology that has applications in aviation and for heavy vehicles. Sodium-ion could be used for two- and three-wheeled transportation and for grid-scale energy storage to mitigate greater daily, weekly and monthly fluctuations in energy supply from the increased use of wind and solar renewable energy.

Despite progress, encouraging news and the publication of the UK Battery Strategy, it is not yet a given that the UK will be a successful player in a future battery and EV industry. The shake-up and unprecedented change in the global automotive industry will create winners and losers.

"Next-generation batteries – such as solid-state, lithium-sulfur and sodium-ion technologies – offer the UK an opportunity to take a market-leading position globally in applications beyond automotive. By building on current advantages – cutting edge research and world-leading companies - the UK could establish a large-scale domestic manufacturing capability. But the UK must move quickly to exploit its competitive advantage." Professor Martin Freer, CEO, The Faraday Institution.

Concerted and coordinated effort will also be needed to improve the competitiveness of the UK and position the UK position as a leader in cutting-edge battery technology through action in the following areas:

- Attract inward investment to establish new gigafactories and expand existing plants in the UK, enhancing large-scale battery manufacturing capabilities and positioning the UK as a competitive player in the European battery market.
- Strengthen component manufacturing within the UK, focusing on producing vital battery components such as cathodes, anodes, electrolytes, separators and cell casings, to comply with trade agreements and improve supply chain efficiency.
- Invest in the development of UK-based refining and processing facilities for key battery materials such as lithium, nickel, cobalt and graphite to enhance the self-sufficiency of the UK battery supply chain and reduce reliance on imports.
- Enhance supply chain resilience by securing critical raw materials from international agreements with the USA, Canada, Australia and lithium-triangle countries in South America and by establishing a competitive lithium battery recycling industry in the UK.
- Accelerate the exploration and commercial extraction of key battery materials within the UK, especially for lithium and graphite, to reduce dependence on imports and ensure a steady supply of raw materials critical for battery manufacturing.
- Provide long term commitment to mission-based research into batteries that are cheaper, lighter weight, longer-lasting, safer, manufacturable and fully recyclable.
- Intensify investment in pioneering research into next generation battery technologies such as solid-state, sodium-ion and lithium-sulfur.
- Strengthen initiatives to commercialise innovative battery technologies through strategic partnerships and collaboration, focusing on accelerating the path to market readiness.

The UK's battery production sector requires strategic coordination and investment in workforce skills development. Collaborative efforts – such as those supported by the Faraday Battery Challenge – between government, industry and educational institutions to develop diverse, inclusive and nationally standardised training programmes are already underway. While these initiatives mark a significant step forward to address the skills gap and advance the UK's capabilities in battery manufacturing, the rapid pace of technological advancement requires an ongoing and adaptive effort in skills development. It is also crucial that skills initiatives not only persist over the longer-term but also broaden in scope to keep the UK workforce competitive in the global EV market.

The UK established the first European gigafactory in 2010 but is now at risk of falling behind in the race to secure the next generation of battery factories. Timely and coordinated effort by government and industry leaders is needed to implement the UK Battery Strategy and attract more gigafactories to the UK. Developing a resilient, sustainable and efficient supply chain alongside building up skills capability will also be critical to securing the future of the UK automotive industry.

Battery demand by the numbers

Globally

9,000 GWh pa global gigafactory capacity in the pipeline

400 gigafactories in the pipeline

In Europe, 2030

1,350 GWh pa European gigafactory capacity projected for 2030

38 gigafactories expected to be open in Europe by 2030

UK, 2030

6 gigafactories required in the UK by 2030 (assuming each plant has a capacity of 20 GWh pa)

110 GWh pa demand for batteries in the UK in 2030

47% of the demand for UK gigafactories to 2030 has yet to be met by announced plans

4% of Europe's gigafactory capacity in 2030 will be in the UK

UK, 2040

10 gigafactories required in the UK by 2040 (assuming each plant has a capacity of 20 GWh pa)

200 GWh pa demand for batteries in the UK in 2040

71% of the demand for UK gigafactories to 2040 has yet to be met by announced plans

82% of the total UK battery demand to 2040 will be from EVs and light commercial vehicles

Jobs

270,000

UK jobs supported by the EV and battery industry to 2040

Carbon Footprint

12%

UK-manufactured EV batteries sold in 2025 will be 12% greener than the European average

Background

Governments around the world are committed to the electrification of road transport to reach Net Zero and decarbonisation commitments. Car manufacturers have responded. They are investing in the production of EVs,[7] which will result in a corresponding decrease in ICE vehicle production.

The key issue for the UK is the extent to which new generations of EVs will be produced in the UK or whether the UK will gradually cease to be a leading manufacturer of vehicles in Europe. Whether the UK remains a profitable place for manufacturers to locate the production of vehicles will be influenced by the usual location issues such as skills, labour market flexibility, energy costs, taxation rates, the legal system and international trade deals.

However, the most important determinant of the future health of the UK automotive industry will be whether batteries are manufactured in the UK. Since the last update of this report, the case has been clearly made that strong synergies can be achieved when vehicle producers and battery manufacturers are situated in close proximity to one another. These synergies include greater flexibility for just-in-time production, greater reliability of supply chains against geo-political shocks and the formation of a knowledge ecosystem. If new gigafactories are built outside of the UK, there is a high risk that international car makers will also only invest in the production of future EV models in plants outside the UK in order to maximise these synergies.

For this reason, the switch to the production of EVs puts jobs in the UK automotive industry at risk. In a worst-case outcome, with no large-scale UK battery production, domestic vehicle producers would gradually wind down their production of ICE vehicles with an associated reduction in direct employment and indirect supply chain jobs.

At the opposite end of the spectrum of possibilities, the UK in partnership with investors could become a leader in the production of both batteries and EVs. In this scenario, the UK would build upon its strong existing automotive industry, and greatly expand its global market share by establishing itself as a European centre for battery and EV production. This would lead to a substantial increase in UK vehicle production relative to today. However, this outcome will be challenging to achieve and will depend both on successes within the UK and failings elsewhere in Europe.

The analysis therefore does not focus on the upside scenario, but on the actions necessary to maintain the UK automotive industry at pre-pandemic levels and, most importantly, avoid the downside case of a slow decline in the industry. Indeed, Government has already acted since the last report by launching the UK Battery Strategy, which aims to develop a comprehensive value chain and manufacturing ecosystem for batteries. It has also committed significant financial resources towards the construction of the new facilities such as the Agratas and AESC manufacturing plants. However, there is more to be done. For example, there is a need for a unified national skills structure for electrification, which is nationally coordinated to ensure high quality of provision and regionally delivered at the right time for the right job.

The starting point is the question: How can the UK Government and participants in the UK automotive industry build on the success to date and ensure that the UK has sufficient battery assembly plants to sustain a level of EV production in the UK that is broadly similar to pre-pandemic levels of vehicle production. Achieving this will be critical in delivering the UK's vision to establish itself as a globally competitive battery supply chain.

[7] EVs include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs).

UK battery production potential to 2040

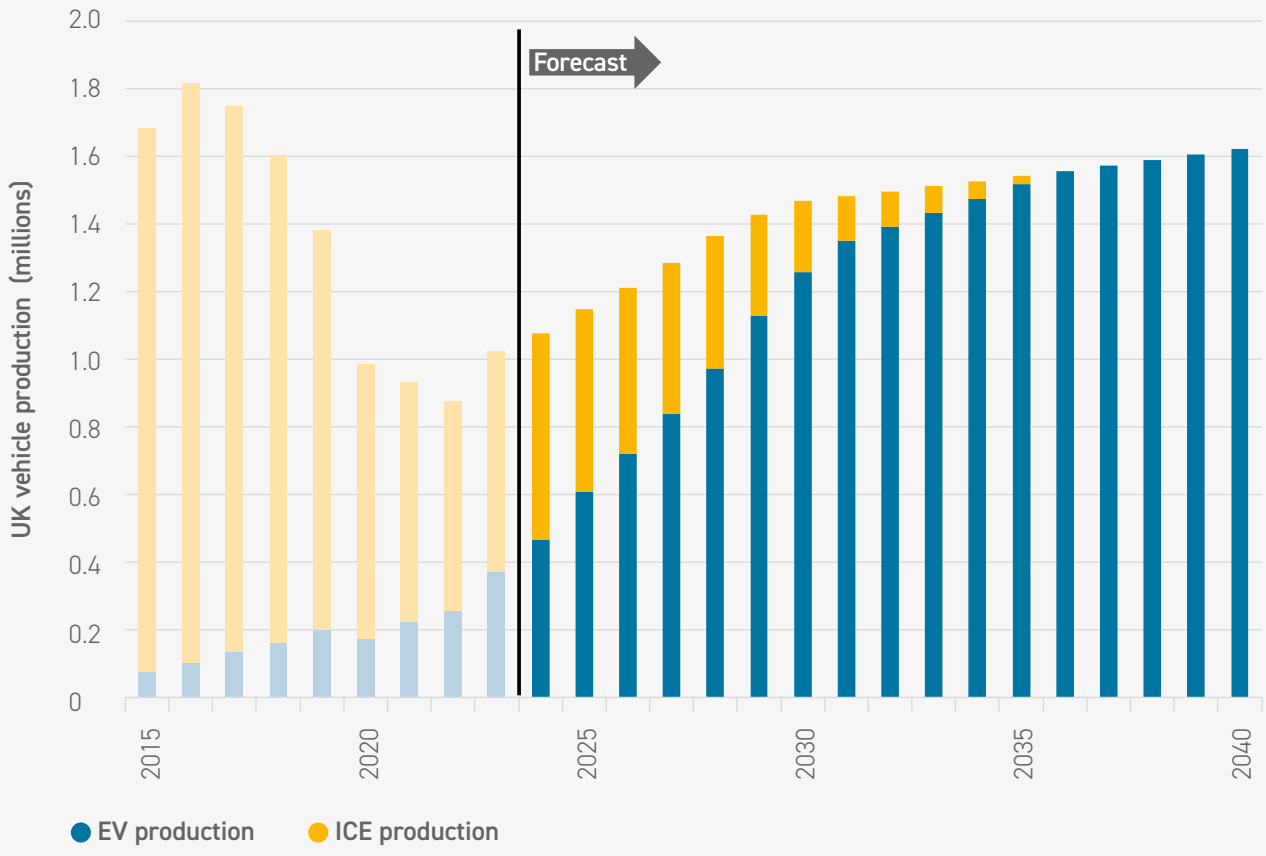
The growth of the UK EV production and battery production industry will depend upon a range of factors, including the volume of global vehicle sales, UK and global emissions regulations, the rate of decline in EV battery costs, growth in EV battery capacity and the import-export environment.

UK vehicle production

The base case projection assumes that the UK automotive sector remains stable over the long-term, as measured by the level of UK vehicle production. In particular, it is assumed that the UK automotive sector recovers to pre-pandemic levels of UK vehicle production by 2030 and that demand for EVs in the UK then keeps pace with the trends in European and global EV demand to 2040.

The UK automotive industry experienced a sharp downturn in 2020-22 period as a result of the global pandemic, with production falling from 1.8 million vehicles manufactured in 2016 to 1.0 million in 2020. The UK automotive industry, similar to other sectors across the UK economy, is recovering from the pandemic-induced recession, but the pace of recovery is slow and uncertain. In the base case, it is assumed that the UK automotive industry will gradually recover to around 1.4 million by 2030.[8] With gradual growth thereafter, the UK automotive industry is projected to reach pre-pandemic levels of vehicle production of around 1.6 million private cars and commercial

Figure 2: Potential UK vehicle manufacturing to 2040



UK vehicle production is projected to recover to 1.4 million vehicles in 2030 and then gradually increase to pre-pandemic production levels of 1.6 million per annum by 2040

Source: SMMT; Department for Transport; Faraday Institution. Numerical data for figures.

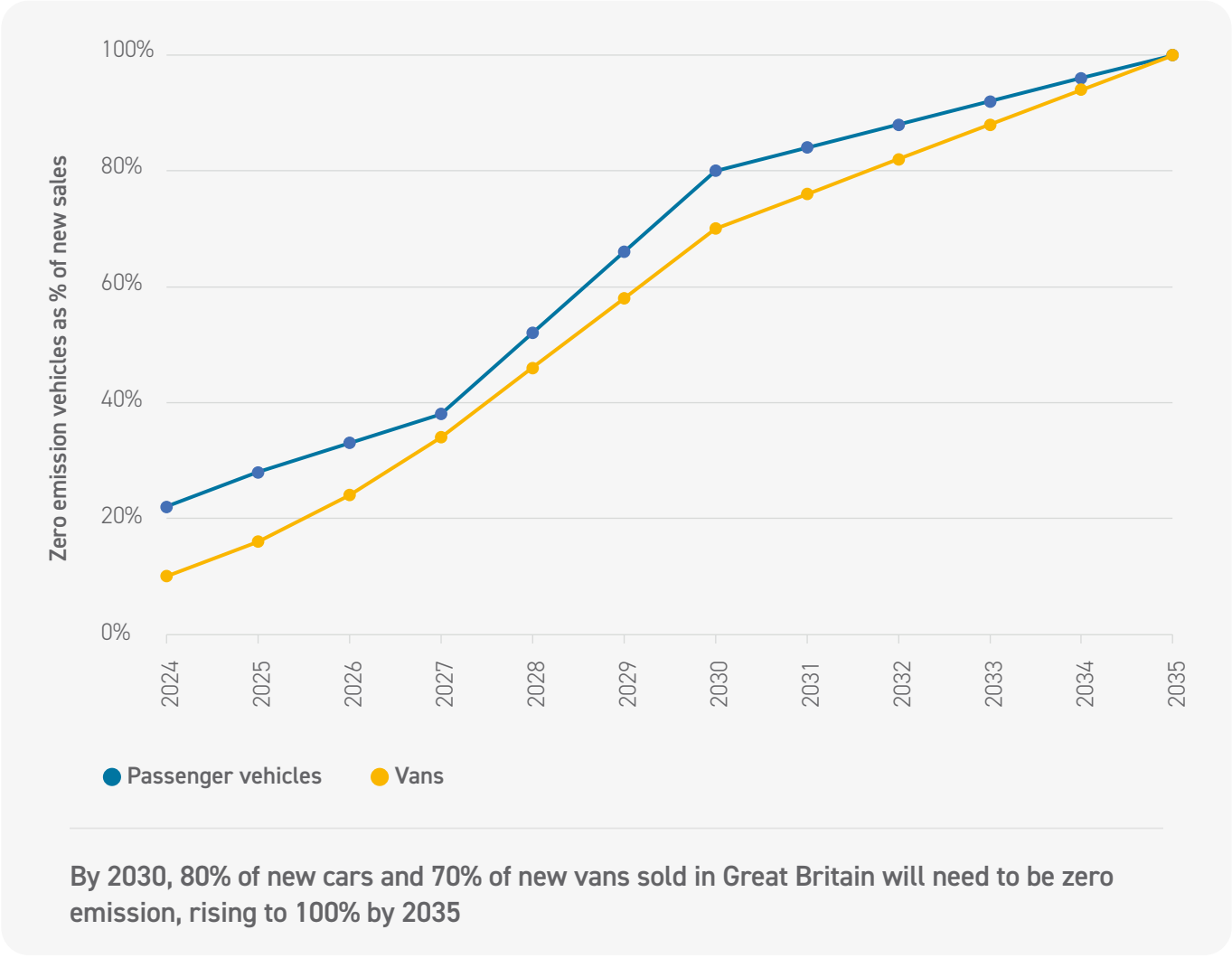
[8] UK vehicle production averaged 1.65 million over the 2015-2019 five-year period.

vehicles by 2040. By this time, around 95% of the vehicles manufactured are BEVs with the remainder fuel cell electric vehicles.

The export market environment has a key influence on the pace of recovery of the UK automotive industry, given that around 80% of vehicles manufactured in the UK were exported in 2020,[9] of which over half are exported to Europe. UK export markets are expected to grow strongly driven by the global economic recovery after the pandemic and by increasing demand outside of Europe and the United States, most notably from Asia.

UK vehicle production is also expected to be heavily influenced by the UK vehicle mandate and EU legislation to end the sale of new cars and vans by 2030. By 2035, 80% of new cars and 70% of new vans sold in Great Britain will need to be zero emission, rising to 100% by 2035.[10]

Figure 3: Pathway for UK sales of zero emission vehicles from 2024 to 2035



Source: DfT Zero Emission Vehicle mandate. Numerical data for figures.

UK lithium-ion battery demand

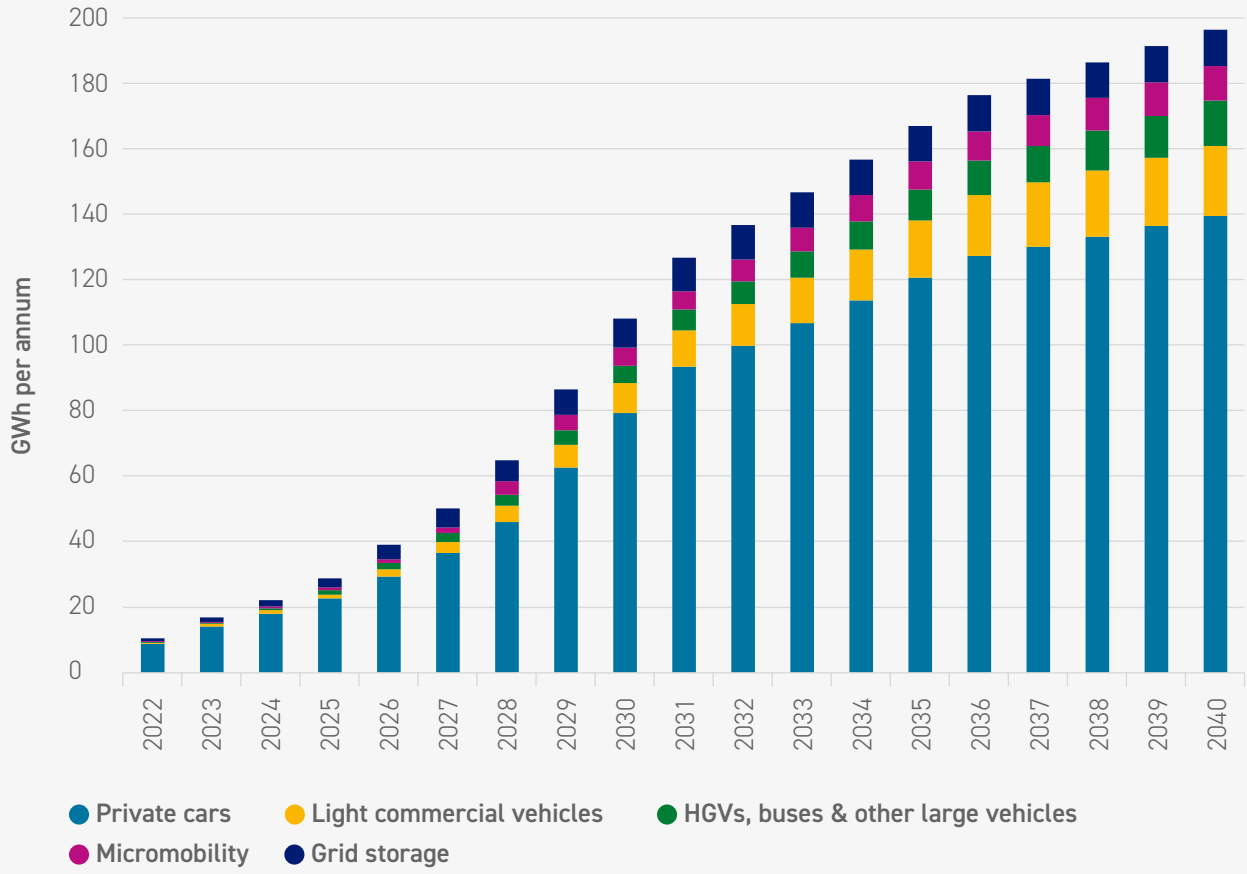
Under the base case scenario, the Faraday Institution battery demand forecasting model projects that demand for UK EV battery manufacturing capacity will reach nearly 110 GWh per annum in 2030 and around 200 GWh per annum in 2040.

[9] SMMT Vehicle and Manufacturing Data (2020). Vehicles numbers comprise 'Passenger Cars' and 'Commercial Vehicles'.
[10] Department for Transport (October 2023). Zero emission vehicle (ZEV) mandate consultation.

This implies a need in the UK for six and 10 battery manufacturing plants in 2030 and 2040 respectively, assuming each plant has a capacity of 20 GWh per annum.[11] UK demand in 2030 represents around 8% of the projected 1,350 GWh per year of European battery production capacity in 2030.

Batteries manufactured for private cars and light commercial vehicles in 2040 accounts for around 82% of total UK battery demand, with the remainder manufactured for HGVs, buses, micromobility and grid storage.

Figure 4: Potential demand for UK-produced batteries by end use



Batteries manufactured for EVs and light commercial vehicles accounts for 82% of total UK battery demand to 2040

Source: Faraday Institution. Numerical data for figures.

A battery accounts for around 27% of the value of a medium-sized EV in 2024, a figure which has declined significantly over the past decade as manufacturing costs have fallen.[12] If batteries were (implausibly) sourced 100% from overseas suppliers, the level of UK imports would increase by about £13 billion per year by 2040. However, given that EV production will almost certainly depend upon the establishment of a secure domestic EV battery supply, the more interesting point is that the accompanying UK battery production facilities represent a considerable industrial opportunity for the UK.

[11] The 20 GWh capacity is illustrative as there is no typical size of a plant. Gigafactories can begin production with a capacity of about 10 GWh pa but often then increase capacity in steps to 15, 20 and 30 GWh pa as they mature.
[12] BNEF (May 2023). Electric Vehicle Outlook 2023.

Next-generation battery markets

The economic opportunity is not just in the manufacture of lithium-ion batteries but in next-generation batteries such as solid-state, lithium-sulfur, and sodium-ion technologies. Each of these battery technologies has the potential to create performance advantages compared to lithium-ion (Box 1).

The UK could take a leading role and specifically to become a global hub in the manufacture of these new technologies for markets in the 2030s and beyond. The UK has world-leading industrial expertise, well-established firms and active research teams across UK universities delivering important scientific breakthroughs on a regular basis.

The Faraday Institution's solid state battery research project (SOLBAT[13]) positions the UK as a leader in solid-state battery innovation, aiming to enhance EV performance, safety and charging times. The aim is to generate new intellectual property and convert this into viable businesses through industrial partnerships or newly created commercialisation vehicles. The Faraday Institution's NEXGENNA project,[14] along with prominent manufacturers and material development companies such as Faradion and Deregallera, provide a competitive advantage for the UK in sodium-ion. The UK is also amongst the leaders in developing high energy lithium-sulfur battery packs with research expertise provided through the LiSTAR project.[15] All of these next generation technologies are also supported by the strengths across the UK manufacturing industry and in the design of high-quality materials.

Box 1: Market opportunities in solid-state, lithium-sulfur and sodium-ion technologies

Potential advantages of solid-state batteries include improved safety, higher energy density (i.e., longer EV range), faster charging times and longer battery life. The technology could become commercially viable in the mass EV market and for small and medium-sized aircraft if these advantages can be secured along with cost-efficient manufacturing processes. These markets are likely to develop in the 2030s given that the costs of solid-state batteries for EVs are expected to reach parity with lithium-ion batteries by around 2033.[16]

Substantial solid-state battery markets are also likely in the late 2020s. These include high value EVs, performance sports EVs, drones and unmanned aerial vehicles (UAVs), offering sizeable economic opportunities for the UK manufacturing industry in the near term.

Compared to lithium-ion, lithium-sulfur technology has potential advantages around weight, cost and safety. Initial markets are likely to develop where range and weight considerations are more important than cost considerations, such as high-altitude pseudo satellites, drones (civilian and military) and UAVs (civilian and military). Lithium-sulfur cells may also be suitable for larger vehicles, such as buses, HGVs, freight trucks, semi-trailers, road trains, vehicle carriers, agricultural vehicles, mobile cranes and other special purpose vehicles. Over the medium-term, lithium-sulfur also has the opportunity to transform the aviation industry, with the potential for sizeable markets linked to short-range aircraft, vertical take-off and landing, personalised aviation and flying taxis.

The manufacture of sodium-ion batteries presents another market opportunity where value could be captured by the UK manufacturing industry. Sodium-ion batteries are useful for applications where cost, operating temperature range and safety considerations are more important than energy density. Applications include home energy storage systems, uninterruptible backup power supplies, and applications requiring safe transportation, as well as replacements for diesel generators and lead acid batteries for starter motors. Sodium-ion technology is particularly attractive for stationary energy storage, supporting the move to solar and wind energy supply across national grids. Niche automotive markets may be attractive, particularly lighter and lower cost applications such as two- and three-wheelers, and in high temperature climates.

[13] SOLBAT project.
[14] NEXGENNA project.
[15] LiSTAR project.
[16] BNEF (April 2021). A route for solid-state battery adoption: Europe and US.

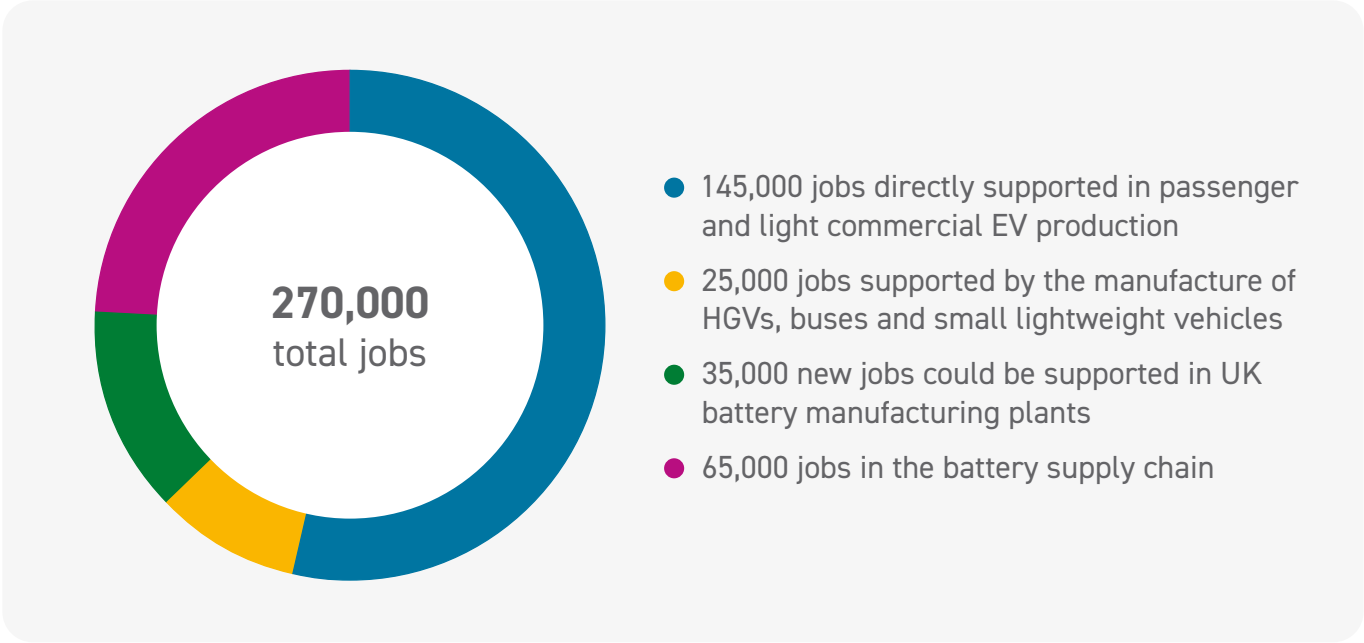
Employment and supply chain impacts

Employment impacts

The global transition from manufacturing ICE vehicles to EVs will have a considerable impact on the UK labour market. Under the base case scenario, it is expected that battery pack, battery cell and electrode manufacturing will all be located in the UK.

In this scenario, the overall industry workforce of the EV and EV battery ecosystem would increase to 270,000 employees by 2040. This is an increase of around one-half over the pre-pandemic employment of 180,000 jobs in 2019[17] and an even bigger increase on the 156,000 estimated to be employed in 2020, when the industry experienced a significant downturn during the pandemic.

Figure 5: Projected employment supported by the EV and battery industry in 2040



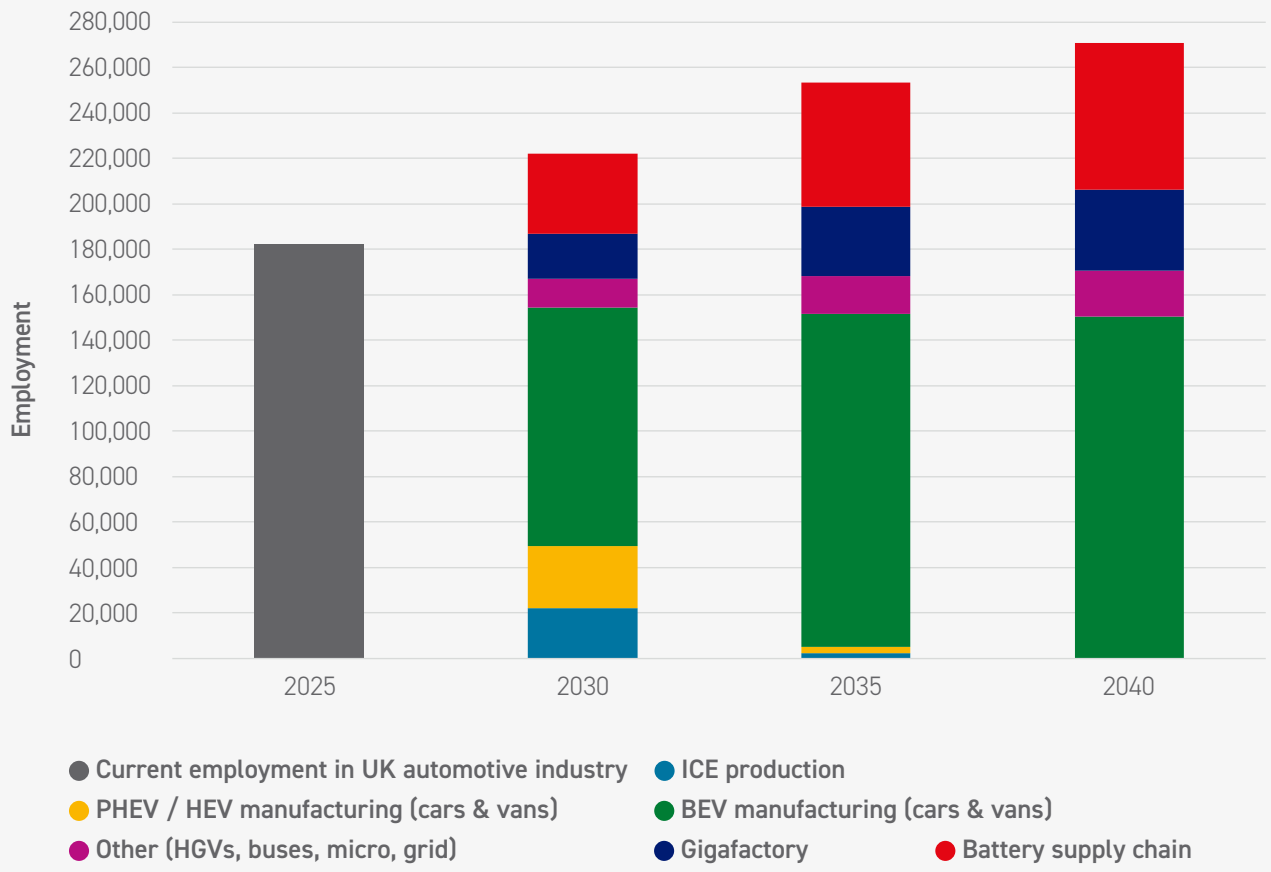
Within this new EV automotive industry, about 145,000 jobs could be directly supported in passenger and light commercial EV production by 2040, with a further 25,000 jobs supported by the manufacture of HGVs, buses and small lightweight vehicles. Although existing workers gradually transferring from ICE production to EV production will make up a large proportion, around 100,000 new full-time equivalent (FTE) jobs will be supported in these new industries.[18] Around 35,000 new jobs could be supported in UK battery manufacturing plants, with a further 65,000 jobs in the battery supply chain.

Employment impacts in the battery industry are based on assumptions that an average of 180 battery manufacturing jobs are supported per GWh per annum (i.e., 140 jobs for battery cell manufacturing[19] and an additional 40 jobs per GWh per annum for battery module and pack assembly[20]) and that 1 gigafactory job supports a further 1.8 jobs in the battery supply chain.

In addition to the direct automotive and battery supply chain impact, a further 600,000 people are estimated to be employed in 2040 in the wider automotive industry and indirect supply chain (logistics, mechanical engineering, construction, finance, administration, sales, marketing etc.).[21]

[17] SMMT Motor Industry Facts 2020.
[18] Future job estimates assume an increase in labour productivity, with vehicle production per employee recovering to pre-pandemic levels by 2035.
[19] European Commission (2017). EU competitiveness in advanced Li-ion batteries for e-mobility and stationary storage applications.
[20] Estimated that 30% more jobs are supported in module and pack assembly, attributing employment impacts in proportion to the percentage split in the price of producing cells and packs (see BNEF 2018, A behind the scenes take on lithium-ion battery prices).
[21] Based on the ratio of direct to wider automotive industry employment, SMMT Motor Industry Facts 2023.

Figure 6: Potential employment in the UK automotive and battery industry to 2040



A thriving industry could support 170,000 full-time equivalent jobs in EV manufacturing, 35,000 jobs in gigafactories and 65,000 in the battery supply chain in 2040

Source: Faraday Institution. Numerical data for figures.

These are the employment estimates under the base case scenario. However, job creation will outpace job losses in the UK only if the UK secures both EV and battery manufacturing. In a worst-case outcome, where the UK does not attract and develop a battery manufacturing industry, there is a risk that the production of EVs could move out of the UK and gravitate towards where the batteries are manufactured.

Supply chain impacts and opportunities

As well as the direct employment within gigafactories, battery production has the potential to create new jobs in the supply chain. Commercial opportunities include cell component manufacturing, including cathode, anode, electrolyte and separator production. UK-based manufacturing businesses in battery cathode materials and electrolyte production already have some presence in the global battery supply chain but there is an opportunity to increase market share. At the other end of the value chain there are economic opportunities around repurposing batteries for reuse and their recycling.

Upstream opportunities also exist for the UK chemicals industry in the refining of raw and processed materials. Large scale battery cell manufacturing would support highly skilled jobs in the UK chemical sector and could be worth a £4.8 billion opportunity by 2030.[22] The UK is already home to several leading chemical engineering and materials companies.

[22] Advanced Propulsion Centre (April 2019). Automotive Batteries.

Substantial amounts of raw materials, such as lithium, cobalt and nickel are needed to manufacture EV batteries. Graphite for the anode, as well as neodymium and dysprosium for the magnets used in electric motors, will also be needed. Whilst the UK does not have abundant reserves available of these raw minerals, there could still be some opportunities of strategic value in terms of increasing security of supply and the diversification of the supply chain. For examples the UK has the second biggest nickel refining factory in the EU and Cornish Lithium is currently investigating mineral potential in Cornwall.[23]

The development of a sustainable, efficient and resilient UK battery supply chain is therefore especially important. It will improve the availability and affordability of key chemicals, materials and components and will be another factor that could attract manufacturers to build gigafactories in the UK. The UK Critical Minerals Strategy and Refresh recognise the importance critical minerals will play for the technologies that are indispensable for the green transition. The strategy is designed to enhance supply chain resilience, secure essential minerals for clean energy technologies and improve national security. The steps to establish a sustainable, efficient and resilient battery supply chain with effort by both industry and the Government are outlined Box 2.

Box 2: The UK Critical Minerals Strategy

The UK Critical Minerals Strategy focuses on accelerating growth of the UK's domestic capabilities, fostering international collaborations to diversify and secure supply chains and enhancing international markets to make them more responsive, transparent and responsible. In particular:

Accelerate the UK's domestic capabilities:

- Maximise what the UK can produce domestically, where viable for businesses and where it works for communities and our natural environment.
- Rebuild our skills in mining and minerals.
- Carry out cutting-edge research and development to solve the challenges in critical minerals supply chains.
- Make better use of what we have by accelerating a circular economy of critical minerals in the UK – increasing recovery, reuse and recycling rates and resource efficiency, to alleviate pressure on primary supply.

Collaborate with international partners:

- Diversify supply across the world so it becomes more resilient as demand grows.
- Support UK companies to participate overseas in diversified responsible and transparent supply chains.
- Develop our diplomatic, trading and development relationships around the world to improve the resilience of supply to the UK.

Enhance international markets:

- Boost global environmental, social and governance performance (ESG), reducing vulnerability to disruption and levelling the playing field for responsible businesses.
- Develop well-functioning and transparent markets, through improved data and traceability.
- Champion London as the world's capital of responsible finance for critical minerals.

The strategy not only addresses the current vulnerabilities and complexities within the UK critical mineral supply chains but also positions the UK as a global leader in the sustainable and strategic management of critical minerals.

[23] Cornish Lithium and Geothermal Engineering are collaborating to build a lithium extraction pilot plant in Cornwall.

Localising more of the battery supply chain in the UK is of strategic value. The global pandemic has not only exposed weaknesses in global supply chains, as evidenced by chip shortages and other bottlenecks in the automotive industry, but it has also increased concern about the dominance and reliance on China for supplies. There are also ethical concerns with the sourcing of some minerals, particularly cobalt supplies from the Democratic Republic of the Congo.

With the concentration of resources in China, it is all the more important for the UK to develop an indigenous battery supply chain and work with partner countries to develop an alternative materials supply chain. China will remain a key leader in the market, but it is unlikely to grow as fast as the market expands in Europe and the US. This will mean more opportunities for the UK and Europe to create their own successful battery supply chain industry.

Regional and local impacts

The concentration of battery production and automotive manufacturing within specific regions – industrial clustering – can yield additional benefits for the workforce and the economy. UK automotive clusters already exist in the West Midlands and the North East, two regions where battery production is expected to grow.

Industrial clustering fosters economies of scale and scope, thereby reducing production costs through shared infrastructure and suppliers. Additionally, it stimulates knowledge sharing, innovation and efficiency gains by bringing related industries into close proximity. In the UK's battery and automotive sectors, clustering facilitates collaboration among manufacturers, suppliers and research institutions, driving advancements in technology and production processes. This synergy bolsters the competitiveness of the entire ecosystem, attracting further investment. Nonetheless, industrial clustering also presents challenges, including heightened competition for skilled labour and resources within these regions. Effective strategic planning and coordination among stakeholders are crucial to maximise the benefits of clustering while mitigating potential drawbacks, ensuring sustainable growth and resilience in the long term.

In the 2023 Autumn Statement[24] a significant economic boost for the West Midlands was announced, unveiling plans for an investment zone set to stimulate up to £5.5 billion in regional growth and create 30,000 new jobs. The zone, spanning the entirety of the West Midlands, will be supported by a combination of tax incentives, direct funding and business rate retention and includes a specific site -- the Coventry-Warwick Gigapark – to attract direct investment for battery cell production.

In 2023, the UK Government and the North East Mayoral Combined Authority jointly announced that the North East Investment Zone will focus on advanced manufacturing and green industries.[25] The investment zone will help leverage significant private funding and aims to help deliver more than 4,000 jobs over the first five years of the programme. It will capitalise on the region's existing strengths, including as a world leader in automotive and advanced manufacturing, EV production, battery manufacturing, the offshore wind sector, and advanced low-carbon materials, to pursue new innovations and further investment to the region. These initiatives are supported by a strong network of universities, research institutions, and Catapults in the area.

Nissan's announcement in November 2023 that it is delivering up to £2 billion of new investment to produce two new EV models in Sunderland was a strong endorsement for the approach adopted by and the sector's strength in the region.[26] Nissan directly employs 7,000 people in the UK, with a further 30,000 jobs supported in the UK supply chain.

[24] HM Treasury (November 2023). Autumn Statement.
[25] UK Parliament Hansard (November 2023). North East Investment Zone.
[26] UK Government News Story (November 2023). Nissan triples investment in electric vehicle production in the UK.

Skills requirements

The government's commitment to the electrification of transport and establishing domestic battery production marks the most significant industrial skills shift for the UK in a generation. Recognised as crucial within the UK Battery Strategy, a proficient workforce spanning the battery value chain and all expertise levels is imperative for a flourishing battery industry.

Competition for skilled workers

By 2040, the demand for EV batteries in the UK could support 270,000 FTE jobs (compared to 180,000 FTE jobs in 2025) across battery manufacturing, EV production, R&D and associated supply chains. Moreover, access to skilled labour will heavily influence companies considering direct investments in the UK. Significant efforts are required to ensure a pool of skilled talent is readily available to fill these opportunities.

As battery production and automotive production become increasingly integrated and clustered, competition for skilled labour could intensify. For instance, JLR aims to hire 250 electrical technicians as part of their electrification drive.[27] AESC, which supplies batteries to the Sunderland Nissan plant, is expanding its production with a second factory that will support 1,000 new jobs when fully operational. Despite the West Midlands and North-East regions having unemployment rates slightly above UK average, the demand for specialised skills may outpace the supply of qualified workers.

Both new recruitment and the retraining of workers from other sectors, such as engine manufacturing, will be needed to meet the growing demand for skilled labour. This is likely to intensify competition for talent and push wages higher. Workers possessing sought-after skills may be more inclined to switch jobs, either within their current region or to other regions in return for higher wages. Such mobility can further escalate wage pressures in regions or industries facing skill shortages.

"The move to electrify transport and toward large-scale battery production represents a massive shift in industrial skills. The UK's engineering and manufacturing workforce can gain a competitive edge over other countries through the provision of a national training curriculum that will ensure the right skills are delivered at the right place and the right time." Matt Howard, Chief Strategy Officer, The Faraday Institution.

To mitigate against skills shortages and provide quality training for sustained growth, collaboration between regional government, local enterprise partnerships, industry, further-education and private training providers is imperative. Coordinated efforts are crucial to meet industrial production targets without encountering workforce shortages or prematurely training individuals for non-existent positions. In the South-West, for example, the Agratas gigafactory in Bridgwater, West Somerset is expected to create 4,000 jobs with thousands more in the supply chain. The company is already working across various bodies to foster workforce development, demonstrating the critical role of collaboration in preparing for these new opportunities.[28]

Such collaboration will be key to successfully management of workforce supply and demand challenges. Combined with a national skills strategy, tailored skills initiatives and a culture of continuous professional development, this holistic approach will enhance the UK's attractiveness for both domestic and foreign investment.

UK skills initiatives

Recognising the challenge of producing large numbers of workers who are also highly skilled, the Faraday Battery Challenge and Innovate UK launched several skills initiatives in 2023 (see Table 1). These initiatives aim to attract a diverse workforce across skill levels through nationally standardised, employer-informed training programmes, while also targeting regions with the highest demand for skilled workers in the battery sector. These

[27] JLR (March 2024). JLR ramps up recruitment with 250 new electrification jobs.
[28] Tata Press Release (July 2023). Tata Group to set up a battery gigafactory in the UK.

skills initiatives not only focus on cell manufacturing but also training in EV battery safety, logistics and end-of-life recycling, ensuring a comprehensive life-cycle approach to workforce development.

Table 1: Key UK skills initiatives

Initiative	Description	Skills level
Electrification Skills Network	£700k to Coventry University to lead a consortium to deliver a coordinated and national approach to re-skilling, up-skilling, and new-skilling the workforce.	Level 2-8
Battery Workforce Training Initiative	£1.2m for the Digital Enhanced Battery Ubiquitous Training (DEBUT) led by University College Birmingham with consortium partners Warwick Manufacturing Group, Cranfield University, RAVMAC and JLR.	Level 2-4 but with the capability for higher level training
	£1.3m for the National Battery Training and Skills Academy led by Newcastle University with consortium partner New College Durham.	
UKBIC Battery Manufacturing Training Programme	Funding provided by the Faraday Battery Challenge to develop 6 free training courses. UKBIC courses include introduction to battery manufacturing and design.	Level 2-5
Battery Manufacturing Technician Apprenticeship	Cogent apprenticeship skills programme for training as electrode technician, cell assembly technician, formation, ageing & testing technician or module & pack technician.	Level 3
Faraday Institution PhD Training Programme	Enhanced training for top doctoral talent across disciplines aligned with the Faraday Institution research projects.	Level 8
Electric Revolution Skills Hub	A digital platform enhancing UK's electrification sector by uniting education and industry for workforce development.	Various

Source: Volta Foundation, 2023 Battery Report; Faraday Institution

In addition to immediate skills requirements, the UK must establish clear career pathways into green industries, as highlighted by the Green Jobs Taskforce.[29] Recommendations from the taskforce emphasise the importance of a well-sequenced STEM curriculum, effective teaching methodologies for green jobs, attracting and retaining talented educators, providing guidance on green careers and enhancing training pathways.

Government commitments, such as the £50 million investment in a two-year Apprenticeship Growth Sector pilot starting from April 2024, hold promise for cultivating talent aligned with the transition to net zero. The approval of the Battery Manufacturing Technician apprenticeship standard by the Institute for Apprenticeships and Technical Education (IfATE) further underscores efforts to bolster employment opportunities in UK battery manufacturing. Developed collaboratively with employers, industry experts and education providers, this apprenticeship will be implemented nationwide to train technicians essential for the sector's development in the years ahead and establish a formal route into the industry. The UK Battery Industrialisation Centre (UKBIC), the nation's 20,000 m^2 battery scale up facility, worked closely with IfATE to develop the standard. In early 2024, UKBIC launched its first public course to support the growth of the industry.

Specific requirements by skill level

Different skills and qualification levels will be required by the gigafactory workforce depending on the complexity of the role and the specialised nature of activities within the battery manufacturing process (see Table 2).

Production, maintenance and engineering roles account for the majority of the workforce in a gigafactory. Recruitment, training and development of operators, technicians, and graduates will require new skilling. Recruitment and development of adult workers may require re-skilling. Continued professional development, or up-skilling, will also be necessary for the existing workforce.

- Production staff are predominantly on-the-job trained against product quality, cost and delivery criteria and operating environment controls. These operators mostly perform codified manual tasks that could not be

[29] Green Jobs Taskforce (July 2021). Report to Government, Industry and the Skills Sector.

Box 3: Electrification Skills Initiatives

The **Electrification Skills Network** (ESN) is led by Coventry University and supported through the project partners Enginuity, WMG, University of Warwick, and UKBIC. Through its framework and forum ESN identifies the key principles and skills needed to make the UK a world leader in battery technology, power electronics, motors and the green industrial revolution.[30] The framework, offers a structured and an integrated approach across employers, training providers and accreditation organisations. The primary focus of the framework will be to support the linkage of employer skills needs to supply via skills providers. The framework is intended to cover battery cell production and other sectors and industries involved in electrification. ESN was formerly named the National Electrification Skills Framework and Forum. ESN also looks to bring together other initiatives in the electrification space, e.g., The ERS Hub, to support industry.

A foresighting and skills value chain approach[31] was used to provide clarity around the required capabilities, competencies and course provision. Existing provision was identified through workshops with industry where technical experts assessed industry capabilities (e.g., EV design and manufacturing strategies) and workforce competencies[32] (e.g., battery assembly operative, technical operator, senior engineer), and mapped these to existing standards and continuous professional development (CPD) courses.

Future CPD courses have also been identified where no suitable curriculum is currently offered. The development of a new curriculum has been supported through the Department for Education's Emerging Skills Project (ESP) led by HVMC with WMG coordinating electrification content with a group of Institutes of Technology. Pilot courses and train-the-trainer content were rolled out in mid-2021, with additional pilot courses in battery cell production funded through the Faraday Institution completed in early 2023.

The **National Battery Training and Skills Academy** (NBTSA) is a collaboration between Newcastle University and New College Durham to train individuals for the growing electrification ecosystem in the region.[33] The NBTSA is providing essential skills and new training for both current and incoming employees of AESC.

New College Durham offers battery-specific training, focusing on levels 2 and 3, on a scaled down manufacturing line to equip operators and engineers with essential skills. Newcastle University will provide equipment for initially pouch cell battery manufacturing line training, to support CPD courses, boot camps and a level 6 degree apprenticeship with a final year focus on batteries. NBTSA will extend support to other organisations needing similar training.

Source: An Opportunity for a National Electrification Skills Framework and Forum (September 2021).

automated due to technical or cost constraints. These operatives come from high volume process sectors or an industry with actual or similar manufacturing ethos, such as food processing or pharmaceutical production. Training for these roles include GCSE, BTEC, ONC and OND. Supplementary training, outside of the existing standards, will be necessary to address unique considerations for battery production such as the risks of working with chemicals and hazardous materials.

- Equipment technicians, typically apprentice trained, work closely with production staff to service and maintain process equipment, for example to ensure electrode processing machines are working efficiently. Equipment technicians also come from high volume process sector or an industry with actual or similar manufacturing ethos.

[30] Many of the standards, units and modules for workers in the automotive and EV battery production sectors will be readily adaptable for other sectors such as the UK's offshore wind sector and the need to upgrade electricity networks.

[31] A skills value chain approach was put forward by HMVC and Gatsby Foundation in Manufacturing the Future Workforce 2020. It argues that the transformation of engineering and manufacturing professions for emerging technologies requires a connected and systematic response across employers, government, innovation bodies, education and training providers.

[32] About 450 competence statements were developed and linked to capability requirements for each role group, with the intent to use them for reviews of apprenticeship standards and qualifications.

[33] Newcastle University news release (September 2023). University to lead skills programme for the regional battery industry.

These two categories typically require level 2 or level 3 qualifications. For example, in production, a Battery Assembly Operative would require a BTEC Level 2 Diploma in Manufacturing and a Battery Electrode & Cell Assembly Technician would require a BTEC Level 3 Certificate in Applied Science.[4]

Table 2: Job types and skills required for a typical gigafactory

Division	Job type	Examples of job activities	Qualification level
Production Staff (50%)	Material Handling	Mixing electrochemically active materials, additives and binders to produce electrode material	L2
	Machine Loading	Slitting electrode into smaller pieces for welding	L2
	Machine Unloading	Drying and stacking	L2
	Module Assembly	Tab and laminate	L2
	Pack Assembly	Injections of electrolyte	L2
	Logistics	Formation and charging, modular and pack assembly, inspection	L2/3
Maintenance and Engineering (30%)	Technicians	Service, maintenance and repair of process equipment	L3
	Senior Engineers	Lead engineers and department heads	L7
	Process/Production Engineers	Problem solving, tool and die, new product introduction, process improvement	L6
	Facility Engineers	Facility management, utilities, building, fire etc	L6
Quality (10%)	Engineers	Process controls, confirmation of part/supply specification, performance evaluation, defect analysis	L6
	Practitioners	Process controls, confirmation of part/supply specification. Performance evaluation, defect analysis	L4
Other (9%)	IT	Process controls, confirmation of part/supply specification. Performance evaluation, defect analysis	L6
	Data Management	Process controls, confirmation of part/supply specification. Performance evaluation, defect analysis	L6
Management (1%)	Process Leadership	Achievement of KPIs, conformance to legislation etc	L4
	Engineering Management	Senior management of engineering processes across the organisation, innovation, compliance, budget etc	L7

Source: Faraday Institution

The remaining positions within the gigafactory are highly skilled, most requiring degree qualifications. Some of the engineering positions such as systems engineer, database development engineer and thermal management engineer would require a very high level of skills and qualifications (e.g., PhDs).

Higher skills (Level 6 and above) would not only be required for the technical nature of cell manufacturing but also to develop a competitive edge by keeping abreast of factory advances such as the industrial Internet of Things, data-driven production, optimisation, automation, materials analysis, continuous improvement and simulation. Gigafactories that intend to conduct their own research and development would rely upon PhD scientists and EngD engineers. Having staff with advanced qualifications could be a source of competitive advantage, although Table 2 does not account for these roles.

Research and development (R&D) capability and talent

The successful design and production of batteries at scale relies on a strong R&D capability, with a PhD-level trained talent base a core component for gigafactories and companies in the wider development innovation ecosystem. With doctoral training typically taking four years, there is a significant lag from the time of investment to employment of skilled staff. There are already considerable recruitment challenges securing highly skilled

scientists and engineers in the battery sector. This will only be exacerbated as the predicted number of new roles are created – as demonstrated by the growth forecasts for R&D departments in UK battery companies.

At the individual firm level, 33% of Fortescue Zero's 30-strong battery R&D team in March 2024 held a PhD. The company has plans to expand through the addition of 200 new battery R&D positions at Begbroke, Kidlington and Banbury. Start-ups have a proportionately higher requirement. For instance, 44% of Breathe Battery Technologies' 34 employees (as of March 2024) hold a PhD. More generally among the 14 spin-outs supported by the Faraday Institution, 45% of their 118 staff (in March 2024) hold PhDs,[34] highlighting the vital significance of such expertise in driving innovation. The cohort has near term plans to expand to 200 employees.

"At the cell end of battery product development the UK does not yet have a sufficiently established talent pool to satisfy demand, hence competition for the limited numbers of engineers and scientists is fierce." Steve Doyle, Evera Recruitment.

[34] Faraday Institution case study (April 2024). Supporting start-ups and launching spin-outs.

UK and European policy context

The UK currently offers a competitive business environment for attracting prospective battery cell producers when compared with other countries in Europe.[35] The UK is the fifth largest vehicle manufacturer in Europe and, following the establishment of the first battery production facility in 2010, has over a decade of experience in EV battery cell and pack production.

UK policy context

The UK was the first major economy to pass legislation to reduce greenhouse gas emissions to Net Zero. The Climate Change Act 2008 committed the UK to an 80% reduction in carbon emissions by 2050. This was updated in 2019 with an obligation to achieve a Net Zero equilibrium, i.e., balancing the amount of greenhouse gas emissions produced with the amount removed from the atmosphere.

The UK has also put in place an extensive strategy and implemented a wide range of policies and incentives to help create a new battery manufacturing industry in the UK. The UK Battery Strategy announced in November 2023 (Box 4) adopts a Design-Build-Sustain approach to enhance innovation, manufacturing and sustainability across the battery ecosystem. This strategy builds on previous initiatives such as the Ten Point Plan for a Green Industrial Revolution[36] and the £1 billion fund to support UK electrification, including £500 million earmarked for the development of gigafactories in the UK. Key government investment includes financial contributions towards the construction of the manufacturing plants by Agratas in Somerset[37] and AESC in Sunderland.[38] Regional funding is also being used to support gigafactory investment, such as the £42 million pledged to the AESC plant through the Local Growth Deal.[39]

Ambitious plans to support the transition to Net Zero in the UK transport sector have also been put in place.[40] This includes the introduction of a zero emission vehicle mandate to ensure that all cars sold in the UK will be zero emissions by 2035.[41,42]

Other related strategies and policy initiatives include UK Critical Minerals Strategy, Build Back Better,[43] Industrial Decarbonisation Strategy[44] and Decarbonising Transport.[45] Battery storage in EVs is also highlighted in the UK Energy Security Strategy as a means to make the energy system more flexible and smarter.[46]

The UK Government has also continued to provide support to develop the UK battery research ecosystem through investment in the Faraday Battery Challenge (FBC) programme and organisations such as the Advanced Propulsion Centre, and through the Automotive Transformation Fund.

The FBC has received £610 million funding since 2017, aimed at supporting the creation of world-class capabilities in scientific research, technology development and the manufacturing scale-up of batteries in the UK. The challenge is focused on developing cost-effective, high-performance, durable, safe and recyclable batteries to capture a growing market. The FBC programme is split into three elements:

- The Faraday Institution comprises 500 researchers undertaking application-inspired battery research across 27 UK universities (Research);
- Collaborative research and development programmes focused on mid-technology readiness levels and run by Innovate UK (Innovation); and

[35] SMMT Motor Industry Facts 2021.
[36] UK Government (November 2020). The Ten Point Plan for a green industrial revolution.
[37] Financial Times (July 2023). UK government pays £500mn in subsidies for Tata battery plant.
[38] Infrastructure Bank (January 2024) UK Infrastructure Bank provides £200 million boost to AESC gigafactory.
[39] South Tyneside Council (October 2021). Envision AESC welcomes planning permission for UK-first 'at scale' gigafactory.
[40] UK Government (October 2021). Net Zero Strategy: Build Back Greener.
[41] UK Government (February 2020). Response to ending the sale of new petrol, diesel and hybrid cars and vans.
[42] Department for Transport (April 2022). Policy design features for the car and van zero emission vehicle mandate.
[43] HM Treasury (March 2021). Build Back Better: Our plan for growth.
[44] HM Government (March 2021). Industrial decarbonisation strategy.
[45] Department for Transport (July 2021). Decarbonising transport: a better, greener Britain.
[46] UK Government (April 2022). British energy security strategy.

Box 4: UK Battery Strategy

The strategy is based around a Design-Build-Sustain approach and includes the following policy initiatives:

- Invest over £2 billion in five years for zero emission vehicles, batteries and supply chains.
- Support large-scale, long-term research and innovation in battery supply chains.
- Allocate £38 million to enhance the UKBIC for new battery technologies.
- Invest £12 million in the Advanced Materials Battery Industrialisation Centre for material scale-up.
- Fund £11 million for 20 projects innovating in battery technology and recycling.
- Encourage R&D centre establishment in the UK by leading battery and EV manufacturers.
- Consider new financial support mechanisms for battery sector start-ups.
- Expand critical mineral trade access and uphold high standards in supply chains.
- Pursue international battery collaboration and develop international standards.
- Assess foreign investments in battery manufacturing for national security.
- Collaborate with industry to accelerate network connection times and strategic investment.
- Enhance manufacturing skills training with a focus on high-demand areas.
- Launch a consultation in 2024 for improved battery collection and end-of-life management.
- Adopt international standards for battery reuse, repurposing and recycling.

A Battery Strategy Taskforce has been set up to advise on delivery of the strategy, emerging risks, security of supply and opportunities for the UK.

Source: Department of Business & Trade (2023). UK Battery Strategy.

- The UK Battery Industrialisation Centre,[47] which enables UK-based companies of all sizes to develop manufacturing capabilities for battery technologies to get them to market quickly (Scale-up).

The FBC strategy is perhaps the only initiative around the world that joins up research, technology development and manufacturing. The FBC aligns closely with the aims and pillars of the UK Innovation Strategy,[48] which emphasises the role of energy storage solutions in achieving Net Zero and the importance of R&D in driving economic prosperity. The UK Research and Development Roadmap[49] sets out the UK's vision and long-term objectives for science, research and innovation and an ambition to cement the UK's reputation as a science superpower, including investment in areas such as batteries, to deliver economic growth and societal benefits.

European policy landscape

The EU continues to show strong support for the development a new battery industry on the continent. The European Commission has approved over €6 billion of funding for 'Important Projects of Common European Interest' (IPCEI) to support battery research and innovation since 2019.[50,51] In addition, the initiative Battery 2030+ coordinates and supports battery research initiatives to enhance and accelerate battery research and production under the umbrella of the EU research and innovation Horizon 2020 programme.[52]

[47] UK Battery Industrialisation Centre website.
[48] Business, Energy & Industrial Strategy (July 2021). UK Innovation Strategy: Leading the future by creating it.
[49] HM Government (July 2020). UK Research and Development Roadmap.
[50] European Commission (December 2019). €3.2 billion pan-European research and innovation project.
[51] European Battery Alliance (January 2021).€2.9 billion for a second pan-European research and innovation project.
[52] Battery 2030+ website.

In February 2023, the EU launched its Green Deal Industrial Plan to increase the competitiveness of Europe's net-zero industries.[53] The plan is focused on four pillars; simplifying the regulatory environment, providing faster access to funding, enhancing skills for net-zero related industries, and facilitating open trade for resilient supply chains. The plan also included three key regulatory proposals covering the full battery value chain, from beginning to end-of-life, as well as addressing regulatory and market issues surrounding stationary storage.

This support is being supplemented by funding commitments from individual countries as well through the Temporary Crisis and Transition Framework. In January 2024 France announced €2.9 billion in state-aid to support investments in green industries such as batteries,[54] while Germany allocated €902 million in funding to Northvolt, providing financial support for their gigafactory project in Heide.[55]

In July 2023, the EU introduced the Battery Regulation Amendment, laying out the structure to achieve sustainable battery production.[56] Under the regulation, several criteria will need to be met to sell batteries in the EU, including:

- Facilitating the repair and end-of-life processing of batteries by making information available to all parties conducting repairs or recycling as well as end users.
- Increasing the recycled material content of batteries, with minimum requirements to be introduced in 2031.
- Giving battery owners access to battery health data to facilitate determining potential future uses of any battery which has reached end of life.

In addition to these requirements, from the 1st of February 2027 all EV and industrial batteries over 2 kWh sold in the EU market will require a unique battery passport that can be accessed using a unique product identifier.[57] The battery passport will contain key information about the battery, including basic characteristics (e.g., production date, cell chemistry) and statistics on performance and durability. This regulation is aimed at improving the sustainable production and recycling of batteries. The UK government have not yet taken a position on the EU Battery Passport regulations. However, the recent UK Battery Strategy consultation contained responses from stakeholders who were supportive of establishing battery passports in the UK market.[3]

[53] European Commission (February 2023). The Green Deal Industrial Plan.
[54] European Commission (January 2024). Commission approves €2.9 billion French State aid scheme.
[55] European Commission (January 2024). Commission approves €902 million German State aid to support Northvolt.
[56] Circularise (August 2023). Battery Regulation EU: Learn about battery passports.
[57] Circularise (December 2023). EU battery passport regulation requirements.

UK and European gigafactory competitor landscape

The gigafactory capacity in the UK continues to grow at a steady pace. The AESC plant in Sunderland is currently under construction and is expected to open in 2025.[58] This facility will have a nameplate capacity of 15.8 GWh, and a feasibility study is underway for a possible further expansion. Agratas, Tata Group's global battery business, announced in 2023 they would be investing over £4 billion towards building a 40 GWh gigafactory to supply JLR with lithium-ion batteries in the UK.[59] The factory will be built in Somerset with production expected to start in 2026.[60] The West Midlands Combined Authority has also identified Coventry Airport as a preferred gigafactory site.[61]

These announcements showcase the UK as an attractive location for battery manufacturing companies to build their European plants. However, there have been some setbacks with both Britishvolt and AMTE going into administration in 2023.[62,63]

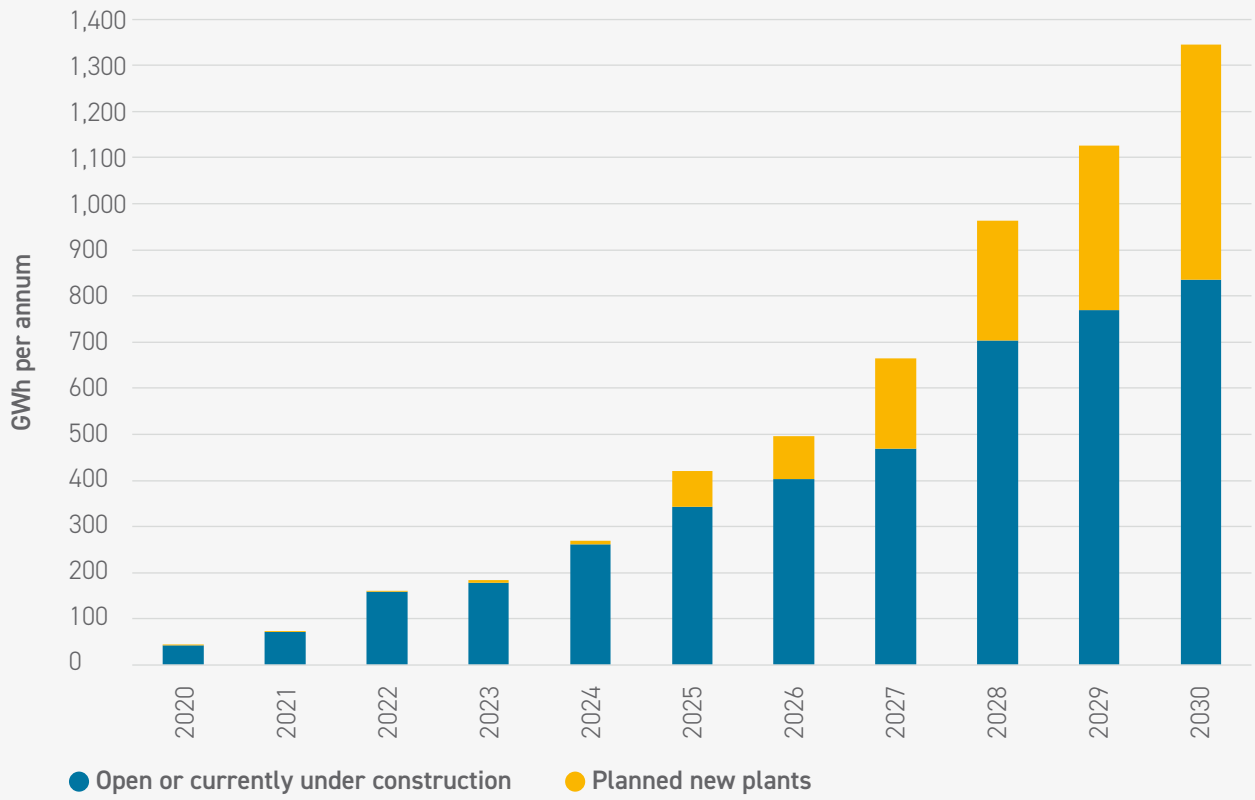
Continued efforts are still needed from the UK Government and industry stakeholders to attract more gigafactories into the UK, but attention also needs to include action to develop the wider EV battery supply industry. As gigafactories begin to be built and commissioned, the need for public intervention will shift away from acquiring capacity to securing a strong supply chain and ecosystem to support these gigafactories. This includes the provision of raw materials and cell components needed for battery production, as well as a recycling industry to efficiently manage the waste from battery production and end of life EVs.

As the UK battery capacity grows so does that of the EU, with gigafactory capacity being bolstered by the European Green Deal, as well as several state-aid initiatives.[64] The total battery manufacturing capacity in Europe is now expected to reach around 1,350 GWh per year by 2030 (Figure 7). Germany continues to be the leading location within Europe, accounting for 21% of capacity in 2030, followed by Hungary (16%) and France (13%) (Figure 8). UK battery manufacturing plants announced or under construction are expected to reach a combined capacity of around 57.6 GWh by 2030, equivalent to around 4% of total GWh capacity in 2030.

Across Europe, 40 battery manufacturing plants are expected to be open by 2030 as illustrated in Appendix A. Examples of larger plants in Europe that are either already open, under construction or planned are outlined in Box 5.

[58] AESC website.
[59] UK Government (July 2023). Tata Group to invest over £4 billion in UK gigafactory.
[60] Electric & Hybrid (February 2024). Agratas to build UK's biggest gigafactory in Somerset.
[61] UK Centre of Electrification - West Midlands Gigafactory.
[62] Guardian (January 2023). Battery startup Britishvolt enters administration as rescue talks fail.
[63] Scottish Financial News (December 2023). Scotland's battery factory dreams.
[64] Batteries European Partnership Association (April 2023). The Green Deal Industrial Plan.

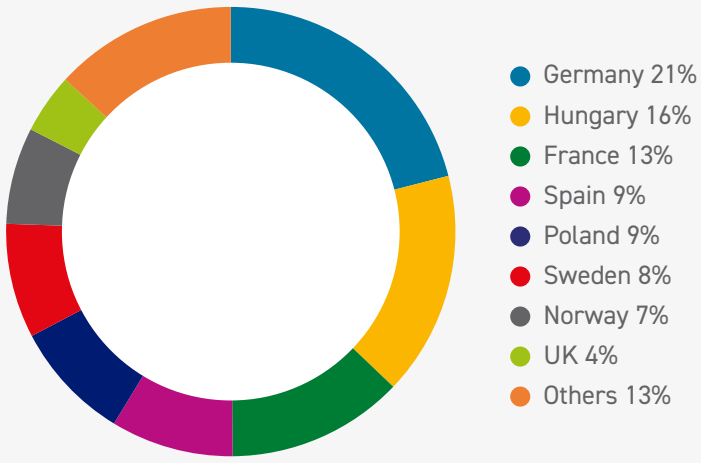
Figure 7: European lithium-ion gigafactory capacity to 2030



Across Europe, 38 battery manufacturing plants are expected to be open by 2030

Source: Faraday Institution. Numerical data for figures.

Figure 8: European lithium-ion gigafactory capacity in 2030 by country



The UK will have 4% of Europe's gigafactory capacity in 2030, behind Germany (21%), and 6 other countries

Source: Faraday Institution. Numerical data for figures.

Box 5: Examples of key European gigafactories

Open / Expanding:

AESC, Sunderland (United Kingdom). AESC is constructing a second UK battery plant with an initial capacity of 15.8 GWh pa. A feasibility study is underway for a possible future expansion.

ACC, Billy-Berclau (France). This facility opened in 2023 and has an initial nameplate capacity of 13 GWh, with plans to expand the factory to 40 GWh. ACC intends on building a further two 40 GWh facilities in Germany and Italy by 2030.

CATL, Erfurt (Germany). Facility currently operating a capacity of 14 GWh, with plans to increase to 24 GWh.

LG Energy Solutions, Wroclaw (Poland). Current capacity of 86 GWh in 2024, with plans to increase capacity to around 115 GWh per annum by 2025.

Northvolt, Skellefteå (Sweden). Opened in 2022 with an initial capacity of 16 GWh per annum. It has the potential to expand to 60 GWh.

Samsung, Göd (Hungary). Capacity of 30 GWh per annum in 2024 with plans for future expansion to 40 GWh.

SK Innovation, Komárom & Iváncsa (Hungary). Two plants in Komárom with a combined capacity of 17.3 GWh. A third facility is currently under construction in Iváncsa with a nameplate capacity of 30 GWh a year.

Construction / Announced Plans:

Agratas, Bridgwater (United Kingdom). Facility is being built on the Gravity Smart Campus near Bridgwater, Somerset. The factory will have a nameplate capacity of 40 GWh, with production expected to begin in 2026.

Morrow Batteries, Arendal (Norway). Construction of the 43 GWh facility started in 2023 with production expected to begin in 2024. The factory will be built in four stages, with an initial capacity of 8 GWh.

Northvolt, Heide (Germany). German state aid totalling €902 million will support the construction of a 60 GWh facility, expecting to begin production in 2026 and reaching full capacity by 2029.

Tesla, Grünheide (Germany). Construction of the 'Giga Berlin' or Gigafactory 4' plant started June 2020. An expansion plan to increase the production capacity of the facility from 50 GWh to 100 GWh was submitted in mid-2023.

CATL, Debrecen (Hungary). CATL announced in 2022 plans to build a 100 GWh facility, although construction has been delayed due to public disapproval at the scale of the project.

Verkor, Dunkirk (France). The facility is planned to be operational in 2025 in the Dunkirk region. Initial capacity of 16 GWh per annum, with potential to increase to 50 GWh at a later date.

Prologium, Dunkirk (France). This is the first 'solid-state battery' gigafactory to be announced in Europe, with a planned capacity of 48 GWh. Production is expected to begin by the end of 2026.

Source: Company websites, Electrive.com, InsideEVs.com, Benchmark Minerals Intelligence, various sources.

Battery manufacturer and automakers commercial relationships

In the UK, there are a handful of volume automotive producers (factories producing more than 100,000 units per year). These are Nissan, JLR, BMW Mini, Stellantis-Vauxhall and Toyota. Both Nissan and JLR have made commitments to produce EVs in the UK,[65,66] with the batteries for these EVs set to be produced in the UK. Meanwhile, Toyota announced in 2020 that it would not invest in electric car manufacturing in the UK until after 2027.[67]

Both BMW Mini and Stellantis-Vauxhall have announced plans to build EVs in the UK. BMW Mini are investing £600 million to upgrade its Oxford factory for EV production, which is currently producing the Mini electric as well as other combustion engine models, with Oxford manufacturing plant exclusively producing EVs by 2030.[68] Stellantis-Vauxhall have begun production of EVs at their Ellesmere Port site,[69] and will manufacture electric vans at its Luton plant from 2025.[70] These announcements could represent over 400,000 EVs by 2030, a significant amount of demand, which would warrant further gigafactory investment in the UK to be able to on-shore the production of cells for these models.

However, there have been no announcements made by BMW or Stellantis for their UK manufacturing plants to source their batteries in the UK in the near future. It is likely that both BMW and Stellantis will procure their cells from Europe. In 2020, BMW signed a long-term supply contract with Northvolt for battery cells,[71] while Stellantis, along with Saft and Mercedes-Benz, formed the 'Automotive Cells Company' (ACC), a joint venture with plans to build three gigafactories in France, Italy and Germany with a combined capacity of 120 GWh.[72] These relationships will likely diminish the chances of securing further UK gigafactories.

In Europe, the relationships between battery manufacturers and automakers continue to shape the landscape. The decision from Stellantis to fund their own battery manufacturing capability is representative of a wider industry shift to vertically integrate battery supply chains within the automotive industry. Tata Sons are doing this in the UK with Agratas and JLR. Stellantis represents a number of large European brands, including Vauxhall, Peugeot, Citroen, Opel, Alfa Romeo and Fiat. Volkswagen entered the battery production business by forming PowerCo, with ambitions for operating (with partners) 240 GWh worth of production capacity by 2030.[73] However, there are also still opportunities for stand-alone battery manufacturers. Verkor, a French battery production start-up, signed a long-term commercial partnership with the Renault Group for 12 GWh a year of batteries for EVs. Northvolt have long standing relationships with BMW and Volkswagen,[74] and recently formed a joint venture with Volvo called NOVO.[75] However, BWM recently cancelled a €2 billion contract with Northvolt due to production delays, although BMW and Northvolt have said they will continue to work together on next-generation cell development.[76]

This announcement demonstrates that there remain significant challenges facing the European battery industry as its scales-up, with factory commissioning taking longer than expected. In addition, the wider EV market is facing a slow-down in sales, with a recent report from Goldman Sachs citing lower cost of used EVs and a lack of fast-charge infrastructure as reasons for the drop in sales.[77]

[65] BBC News (November 2023). Nissan to commit to making new Qashqai and Juke electric models in Sunderland.
[66] JLR (April 2023). JLR to invest £15 billion over next five years.
[67] Guardian (December 2020). Toyota will not invest in electric cars in UK until after 2027.
[68] Mini - Big Investment in Mini Factories.
[69] Stellantis (September 2023). Stellantis announces start of electric vehicle production at Ellesmere Port.
[70] Stellantis (February 2024). Vauxhall Vivaro electric production to start in Luton.
[71] BMW (July 2020). BMW Group continues to drive electromobility.
[72] ACC. About ACC.
[73] PowerCo.
[74] Automotive News Europe (June 2022). BMW, VW backed Northvolt advances on US$12B battery IPO plan.
[75] Autovista24 (December 2021). Volvo and Northvolt finalise joint venture in battery push.
[76] Sifted - Trouble at Northvolt: safety concerns, scrapped orders and a factory up in the air (June 2024).
[77] Goldman Sachs - Why are EV sales slowing? (May 2024).

Factors influencing gigafactory investment decisions

Securing gigafactories and an associated supply chain ahead of European competition is the keystone for a long-term, successful, self-sustaining battery and EV sector in the UK. However, there is two-way causality. Just as the investments in UK gigafactory battery production will depend upon the presence in the UK of major EV production lines, so the presence of EV production lines will depend upon the willingness of the battery manufacturers to invest in the UK. Therefore, UK industry and government stakeholders need to consider carefully how to secure gigafactory investments.

Battery firm executives identify several key factors influencing their decisions to locate operations in one country over another. Proximity to customers (i.e., EV manufacturers) ranks as a primary consideration. So, if the UK can build upon its existing vehicle manufacturing base, it can hope to attract the battery manufacturers and therefore sustain significant EV production.

Other influential factors include investment incentives, timely permitting and licensing arrangements, cheap and clean energy and a skilled and productive workforce. It needs to be recognised that the UK is in a global, country versus country, competition and that others have already formed persuasive propositions. Global competition is fierce given that EVs are the fastest growing segment of the automobile industry, with EVs achieving double-digit market share in many countries over the past few years.[78]

This aligns with cost analysis that shows that the majority of costs of lithium-ion battery cells are not production-location specific. Most notably, raw materials make up around half of the cost of a cell. Only three components of the cost of batteries are location specific, namely direct labour, energy and utility, and depreciation. None of these (other than energy infrastructure costs) can easily be affected by specific government actions and combined they account for only 20% of overall costs.

The readiness of the battery supply chain is another factor that will influence the development of gigafactories in the UK. The UK is ranked 12th among the 30 countries in North and South America, Asia-Pacific, Europe and Africa that are already active in the lithium battery supply chain. Countries were ranked across the five categories outlined in Table 3. The UK achieved a high ranking in downstream demand for EVs and energy storage but a low ranking in the availability of reserves, mined supply and refined supply of raw materials. The ranking of the scale of a country's battery cell and component production and recycling capacity has fallen back from 8th in 2021 to 14th position in 2024.

Table 3: UK battery supply - global ranking

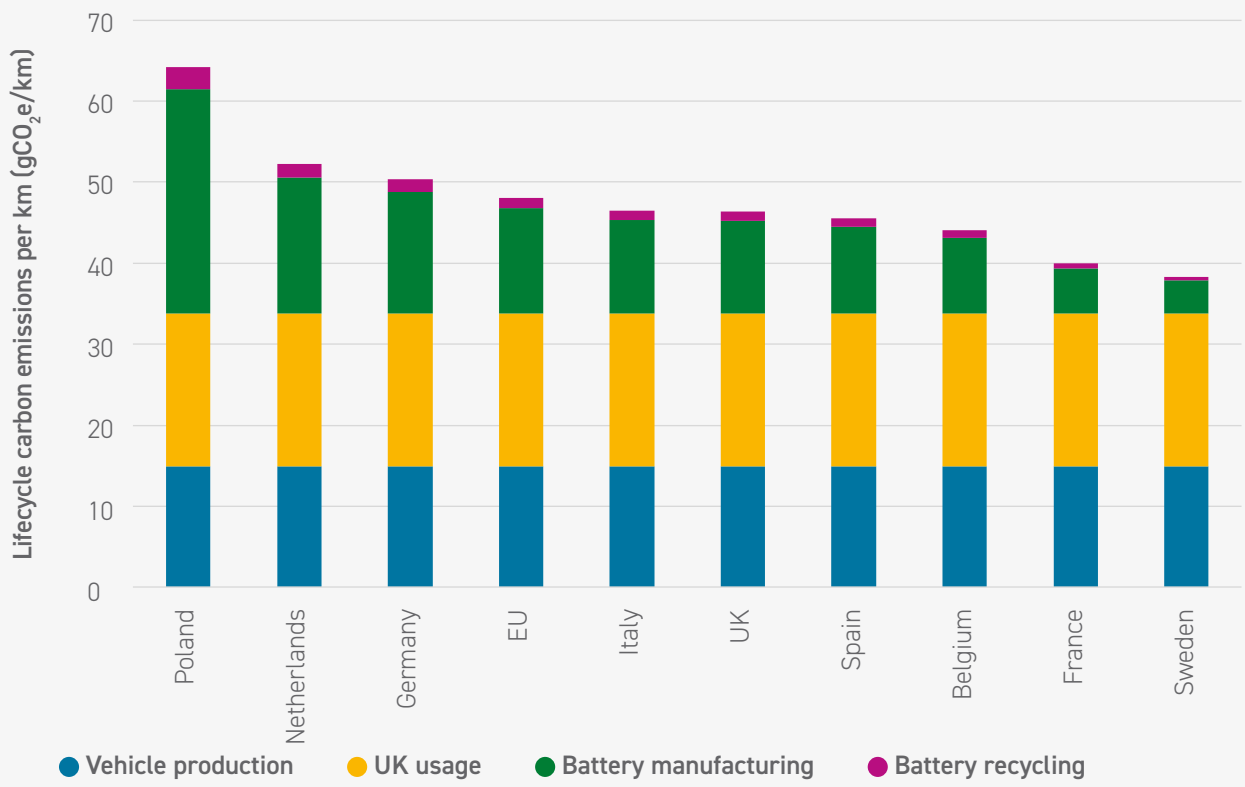
Ranking category	UK rank	
	2021	2024
Raw materials	24	23
Battery manufacturing	8	14
Environmental, social and governance	9	7
Industry, infrastructure and innovation	8	9
Downstream demand	5	4
Overall ranking	11	12

Source: BNEF (February 2024). Global Lithium-Ion Battery Supply Chain

[78] IPCC (2022). Climate Change 2022. Mitigation of Climate Change.

Considerable energy is used in battery production and the renewable versus fossil fuel energy mix varies significantly across Europe. The sustainability of the automotive production process is playing an increasingly important role in the gigafactory siting decisions. The UK is leading the G20 nations with the fastest rate of decarbonisation of the grid. The Faraday Institution estimated that UK-manufactured EV batteries are about 12% greener than the European average, as illustrated in Figure 9.[79] Decarbonisation of the UK grid and the ability to manufacture EV batteries with cleaner energy could attract cell manufacturers to build gigafactories in the UK.

Figure 9: Total life cycle carbon emissions from UK EVs sold in 2025, by location of manufactured EV battery



UK-manufactured EV batteries are about 12% greener than the European average

Source: Faraday Institution. Numerical data for figures.

A strong UK recycling industry would also attract manufacturers to build gigafactories in the UK, particularly those interested in using recycled materials to produce EV batteries rather than using newly mined raw materials. However, the industry is still in its early stages, with substantial recycling capabilities just developing and most facilities either in planning or at pilot stages. Companies such as RS Bruce and Veolia are concentrating investment in pre-treatment facilities, while Recyclus Group, Altilium Clean Technology, ICoNiChem and Ecoshred are focused on black mass treatment. EMR has a broader recycling capability specialising in both pre-treatment and black mass treatment. These developments are encouraging, but the UK can do more to ensure it has adequate recycling infrastructure to meet the substantial recycling volumes needed in 2030 and beyond. Most importantly, implementing the UK Battery Strategy is crucial to enable the new lithium-ion battery recycling industry in the UK to flourish.

[79] Faraday Insight 12 (November 2021). The UK: A low carbon location to manufacture, drive and recycle electric vehicles.

Confidence in the UK as a location for business investment is strong and growing. The 2020 UK-EU free trade agreement has improved investor confidence in the UK. New rules of origin will mean that automakers will need to re-orientate their supply chains towards the UK and EU market by 2027. These rules reinforce the importance of constructing gigafactories in the UK and of developing well-established local supply chains. This will ensure that the UK automotive industry can continue to export at scale to the EU.

Battery cell manufacturing in the UK is likely to be cost-competitive with European competitors such as Germany and France. However, the reality is that although the UK can compete on cost, it is not a level playing field through the widespread use of subsidies, so attracting gigafactories to the UK must be more than just the provision of a low cost-base. In particular, the UK needs to build up the skills base, continue to provide the high-quality research that the UK is known for and match or come closer to matching the financial incentives offered by other European countries to EV battery manufacturing firms.

Despite the UK strengths and progress in securing new gigafactories, it is not a given that the UK will be successful in battery technology and manufacturing. The global automotive industry is going through unprecedented change, not just directly from new battery technology but also indirectly from global economic shocks. This shake-up will create both winners and losers.

The UK is making good progress in securing gigafactories in the UK, but risks falling behind in the European race. Most car producers and battery manufacturers will soon have made their decisions about where in Europe gigafactories will be built. To meet UK 2030 demand, action by government and industry leaders is needed urgently to attract further gigafactories to the UK, develop the wider battery supply chain and secure the future for the UK automotive industry. If successful, the prize for the UK economy and the achievement of Net Zero in the transport sector will be substantial.

European Gigafactories

GWh Capacity 2030

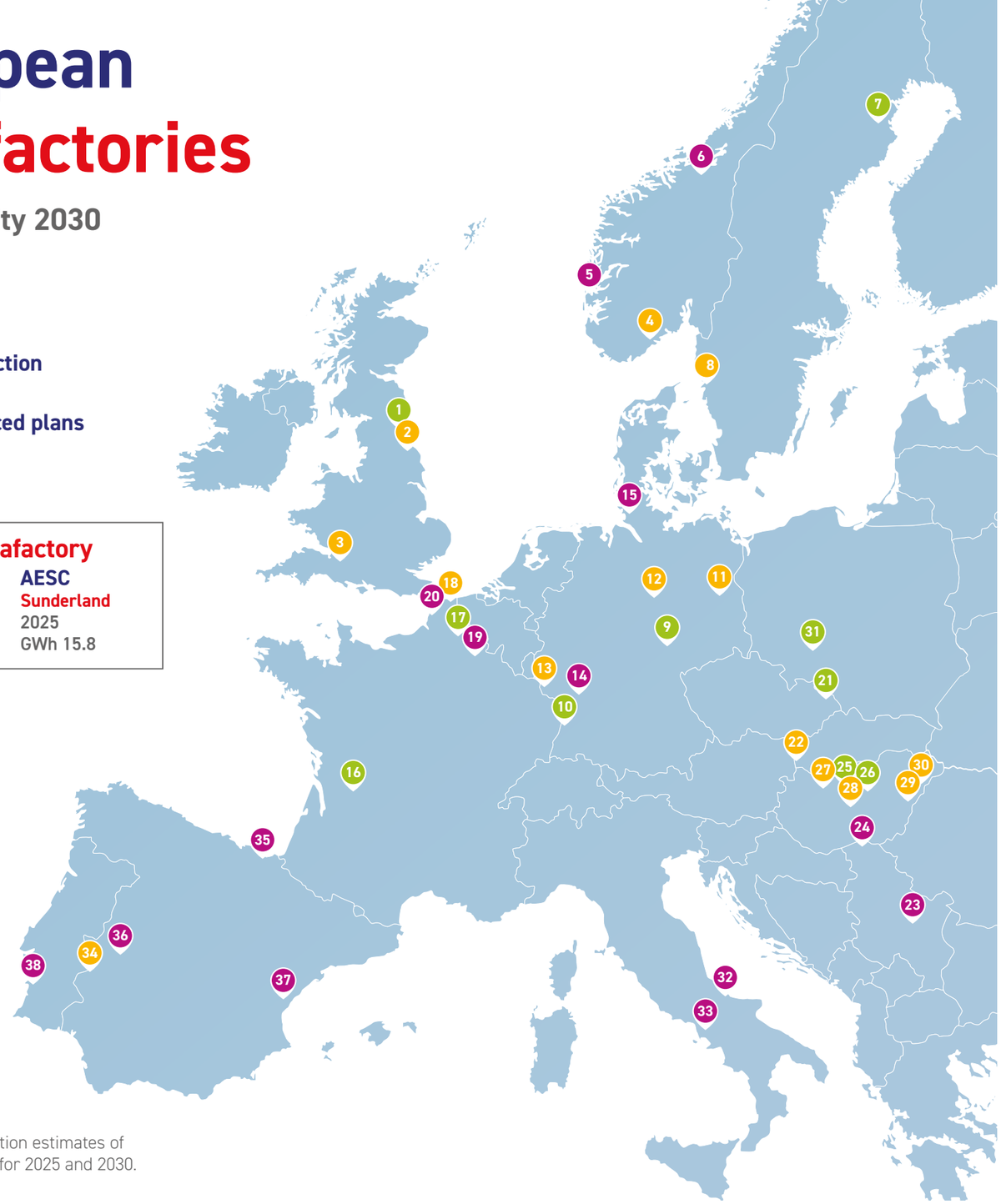
Open

Construction

Announced plans

Example gigafactory

Manufacturer:	AESC
Location:	Sunderland
Opening date:	2025
Capacity 2030:	GWh 15.8



Note: Faraday Institution estimates of operational capacity for 2025 and 2030.

UK

1 **AESC**
Sunderland
2012
GWh 1.8

2 **AESC**
Sunderland
2025
GWh 15.8

3 **Agratas**
Somerset
2026
GWh 40

Norway

4 **Morrow Batteries**
Agder
2024
GWh 43

5 **Beyonder**
Haugaland
2025
GWh 10

6 **Elinor**
Trondheim
2026
GWh 40

Sweden

7 **Northvolt**
Skellefteå
2021
GWh 60

8 **NOVO**
Gothenburg
2025
GWh 50

Germany

9 **CATL**
Erfurt
2022
GWh 14

10 **Leclanché**
Willstätt
2021
GWh 2.5

11 **Tesla**
Berlin
2022
GWh 100

12 **PowerCo**
Salzgitter
2025
GWh 40

13 **SVOLT**
Überherrn, Saarland
2024
GWh 24

14 **Automotive Cell Company**
Kaiserslautern
2025
GWh 40

15 **Northvolt**
Heide
2026
GWh 60

France

16 **Automotive Cell Company**
Nersac
2022
GWh 2

17 **Automotive Cell Company**
Douvrin
2024
GWh 40

18 **Verkor**
Dunkirk
2025
GWh 50

19 **Envision**
Douai
2025
GWh 30

20 **Prologium**
Dunkirk
2026
GWh 48

Czech Republic

21 **Magna Energy Storage**
Horní Suchá
2020
GWh 15

Slovakia

22 **InoBat**
Bratislava
2027
GWh 20

Serbia

23 **InoBat**
Cuprija
2027
GWh 32

24 **ElevenEs**
Subotica
2024
GWh 16

Hungary

25 **SK Innovation**
Komárom 1
2020
GWh 7.5

26 **Samsung**
Göd
2018
GWh 40

27 **SK Innovation**
Komárom 2
2024
GWh 9.8

28 **SK Innovation**
Ivancsa
2024
GWh 30

29 **CATL**
Debrecen
2025
GWh 100

30 **EVE Energy**
Debrecen
2026
GWh 28

Poland

31 **LG Energy Solutions**
Wroclaw
2018
GWh 115

Italy

32 **Automotive Cell Company**
Termoli
2026
GWh 40

33 **FAAM Research Centre**
Teverola 1 & 2
2021
GWh 7.8

Spain

34 **Phi4tech**
Badajoz
2023
GWh 18

35 **BasqueVolt**
Euskadi
2027
GWh 10

36 **AESC**
Caceres
2025
GWh 50

37 **Volkswagen**
Sagunto, Valencia
2026
GWh 40

Portugal

38 **CALB**
Sines
2025
GWh 45

About the Faraday Institution and Faraday Insights and Reports

The Faraday Institution is the UK's independent institute for electrochemical energy storage research, skills development, market analysis, and early-stage commercialisation. We bring together academics and industry partners in a way that is fundamentally changing how basic research is carried out at scale to address industry-defined goals.

Faraday Insights and Reports provide an evidence-based assessment of the market, economics, technology and capabilities for energy storage technologies and the transition to a fully electric UK. These aim to help bridge knowledge gaps across industry, academia and government. If you would like to discuss any issues raised by this "Faraday Insight" or suggest a subject for a future Insight, please contact Stephen Gifford.

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The Faraday Institution is a key delivery partner for the Faraday Battery Challenge at UK Research and Innovation, which is delivered by Innovate UK. The Challenge is making the UK a science and innovation superpower for batteries, supporting the UK's world-class battery facilities along with growing innovative businesses that are developing the battery supply chain for our future prosperity. Its aim is to build a high-tech, high-value, high-skill battery industry in the UK.

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