THE FARADAY INSTITUTION
UK GIGAFACTORY OUTLOOK (JUNE 2022)

UK electric vehicle and battery production potential to 2040

FARADAY REPORT – ANNUAL GIGAFACTORY STUDY 2022

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 step up a notch, 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 previous report in 2020, European gigafactory capacity projected for 2030 has more than doubled from 450 GWh (Gigawatt hours) per annum to over 1,100 GWh, with over 40 plants now expected to be open and producing cells by the turn of the decade. Germany is a leading location for manufacturers (with 12 gigafactories open or planned) along with Hungary, France and Italy. The Tesla plant in Germany is the largest planned, with a proposed capacity of up to 100 GWh. Globally, there are now around 300 gigafactories and 6,400 GWh of lithium-ion battery capacity in the pipeline.[1]

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. Britishvolt has started the construction of a new 38 GWh plant in Northumberland, which will directly employ 3,000+ people. A second Envision AESC plant in Sunderland has recently received planning permission for 11 GWh of capacity and AMTE has set out plans for a new 10 GWh plant in one of three sites to be operational by 2025. Coventry Airport has also been identified as a preferred gigafactory site and Jaguar Land Rover has declared the Jaguar brand will be all electric by 2025.

> **"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.**

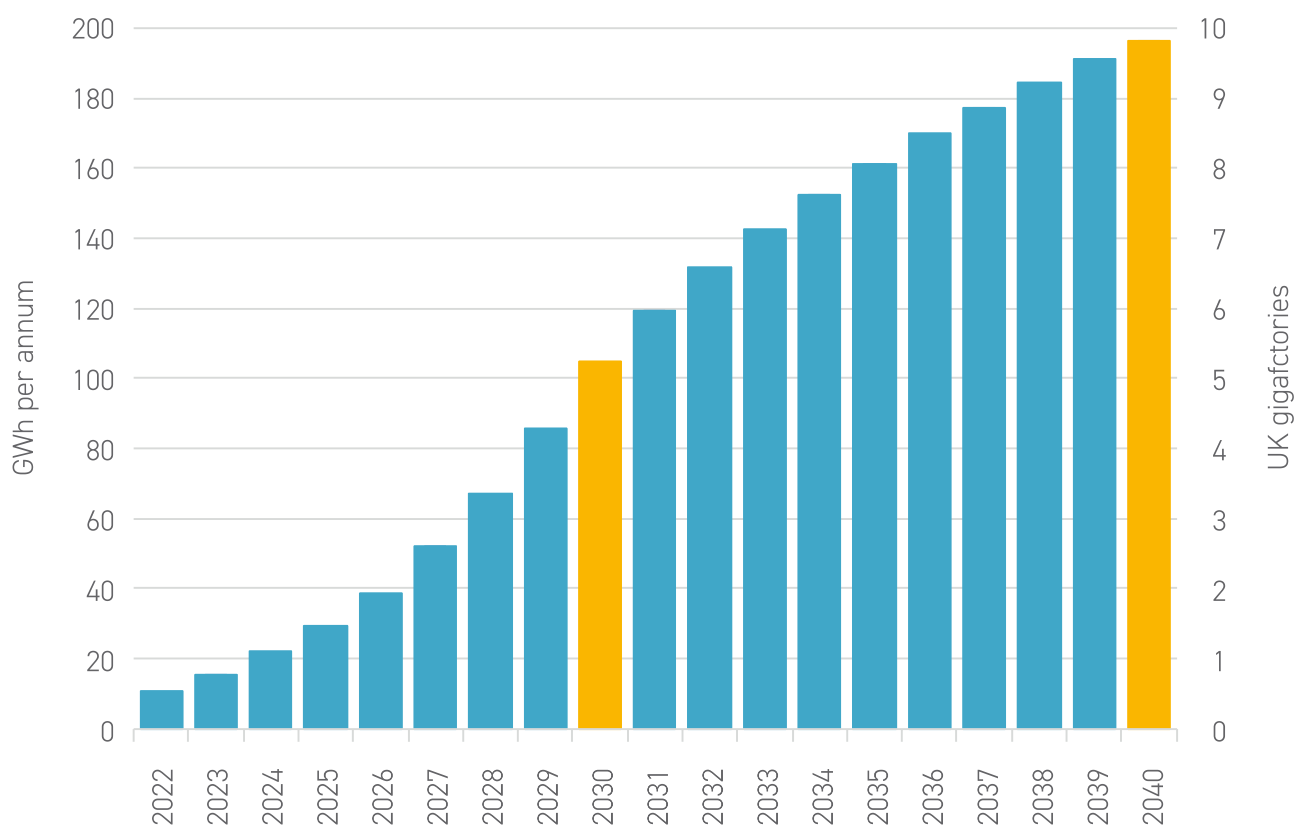
The UK Government has played its part by making bold policy commitments, increasing investor confidence in the UK as a location to do business. Key initiatives include the Net Zero legislation, Ten Point Plan for a Green Industrial Revolution, Decarbonisation Transport strategy, the establishment of an Automotive Transformation Fund (ATF) to support gigafactory investment and an end to the sales of new ICE vehicles by 2030. 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 over 100 GWh per annum in 2030, predominately for private cars and light commercial vehicles (LCVs). This demand is the equivalent of five large gigafactories running at full capacity, but at present there are only two substantial UK plants in the pipeline. Gigafactories take at least five years to reach operational capacity, so investment and location decisions to meet battery demand in 2030 are all likely to be made in the next 2 to 3 years. Over this timescale, automotive manufacturers will be deciding where to locate future EV model production, in the UK or mainland Europe.

Substantial work has been done to generate a strategy and clear roadmap for re-skilling and up-skilling the workforce to enable battery production.[2] 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.

[1] Benchmark Minerals Intelligence (May 2022). Lithium-ion Battery Gigafactory Assessment.
[2] The Opportunity for a National Electrification Skills Framework and Forum (September 2021).

Figure 1: Potential demand for UK-produced batteries



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, nearly 200 GWh of supply will be needed in the UK to satisfy the depend for batteries for private cars, commercial vehicles, HGVs, buses, micromobility[3] and grid storage. This demand is equivalent to ten gigafactories in 2040 with each plant running at a capacity of 20 GWh per annum.[4] 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 1.8 million passenger and light commercial EVs, and the manufacture of HGVs, buses and small lightweight 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

[3] Micromobility covers lightweight vehicles including e-bikes, scooters, skateboards and three wheelers.
[4] The ten gigafactories estimate is illustrative as companies such as Britishvolt and Envision AESC could build plants with capacity in excess of 20 GWh per annum.

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.

"The UK is well placed to have a leading position in next generation batteries such as solid-state, lithium-sulfur and sodium-ion technologies. The UK is already home to global experts in battery research and to well-established companies. We must move quickly to exploit this competitive advantage by establishing large-scale domestic manufacturing in the UK while continuing to fund long-term battery research," Professor Pam Thomas, Chief Executive Officer, The Faraday Institution.

Despite progress and encouraging news, 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. The UK needs to grab the opportunity with concerted and coordinated effort through, for example, the following actions:

- Continue to communicate the attractiveness of the UK as a global and regional battery manufacturing location to global investors;
- Accelerate the allocation of the remaining funds from the ATF towards potential UK gigafactories;
- Identify prospective sites for gigafactories and the construction of associated physical, transport and energy infrastructure by the local, regional and national government;
- Develop the requisite EV battery skills and training infrastructure;
- Provide long term commitment to mission-based research into next generation batteries that are cheaper, lighter weight, longer-lasting, safer, manufacturable and fully recyclable;
- Develop a strategy to localise and create an efficient, resilient and sustainable UK supply chain to improve availability and affordability of key battery materials for battery production; and
- Develop a strategy to create the conditions for a new lithium-ion battery recycling industry in the UK to flourish.

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. We need a timely and coordinated effort by government and industry leaders to attract more gigafactories to the UK, develop a resilient, sustainable and efficient supply chain, build up skills capability and secure the future of the UK automotive industry.

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,[5] 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.

We have accordingly focussed not on the upside scenario, but on the actions necessary to stabilise 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 introducing incentives for industry investment in the UK, such as the development of the ATF, which has provided funding for the Britishvolt and Envision AESC 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.

[5] 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.

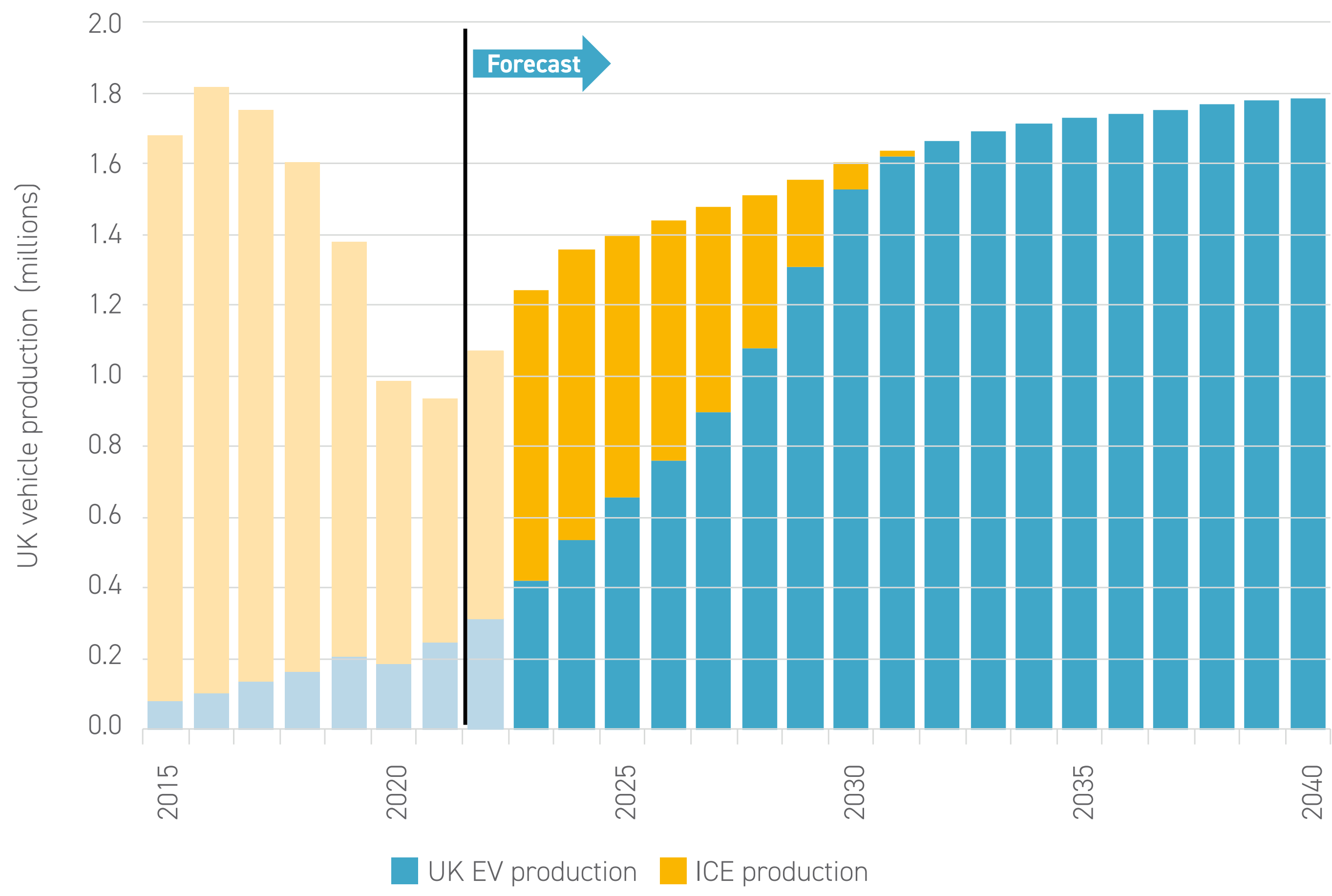
UK vehicle production

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, we have 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 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 expected to recover from the pandemic induced recession, but the pace of recovery is uncertain. In the base case, it is assumed that the UK automotive industry will gradually recover and reach pre-pandemic levels of vehicle production of about 1.6 million by 2030.[6]

Above trend growth is assumed over the next 3 years as the UK and global automotive industry rebounds after the pandemic. After 2025, UK vehicle production is projected to grow at a more gradual pace of 2% per annum, with EV production increasing by a faster 7% per annum due to the UK's Net Zero policy, emissions regulations, consumer preferences and the decline in EV battery costs.

Figure 2: Potential UK vehicle manufacturing to 2040



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

By 2040, the UK automotive industry is projected to manufacture around 1.8 million private cars and commercial vehicles by 2040. 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 future size of the UK automotive industry, given that around 80% of vehicles manufactured in the UK were exported in 2020,[7] 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.

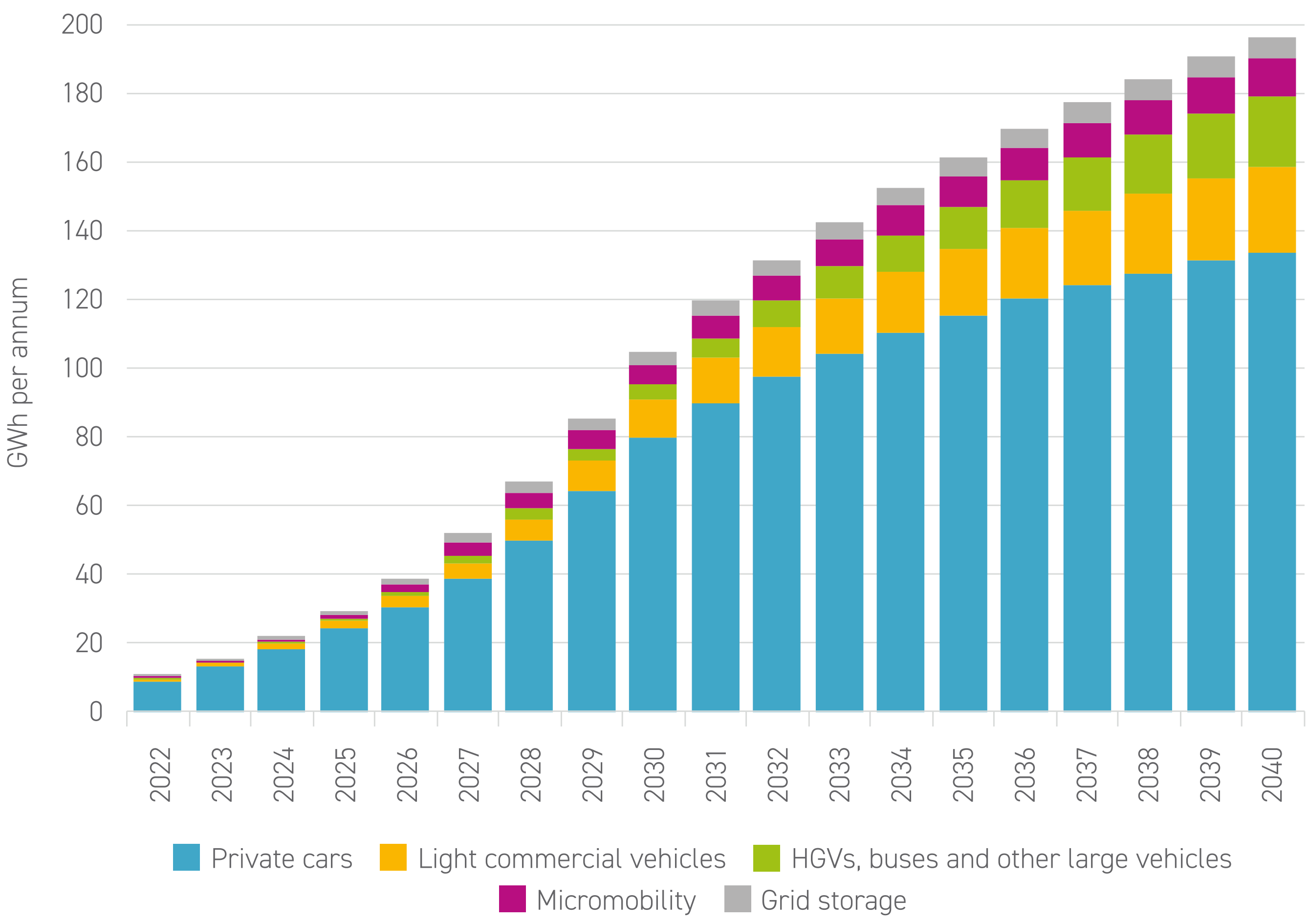
UK lithium-ion battery demand

Under the base case scenario, the Faraday Institution battery demand forecasting model projects that demand for UK EV battery manufacturing capacity will reach just over 100 GWh per annum in 2030 and nearly 200 GWh per annum in 2040.[8]

This implies a need in the UK for five and ten battery manufacturing plants in 2030 and 2040 respectively, assuming each plant has a capacity of 20 GWh per annum.[9] UK demand in 2030 represents around 10% of the projected 1,000 GWh per year of European battery production capacity in 2030.

Batteries manufactured for private cars and light commercial vehicles in 2040 accounts for around 80% of total UK battery demand, with the remainder manufactured for HGVs, buses, micromobility and grid storage.

Figure 3: Potential demand for UK-produced batteries by end use



[7] SMMT Vehicle and Manufacturing Data (2020). Vehicles numbers comprise 'Passenger Cars' and 'Commercial Vehicles'.
[8] This is our base case scenario. Using optimistic and pessimistic assumptions we forecast that demand for UK-produced batteries ranges from a low of 80 GWh per annum to a high of 240 GWh per annum by 2040.
[9] 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 p.a. but often then increase capacity in steps to 15, 20 and 30 GWh p.a. as they mature.

An EV's battery makes up 40% of its value although this is declining each year as manufacturing costs fall. If batteries were (implausibly) sourced 100% from overseas suppliers, the level of UK imports would increase by about £12 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.

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.

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.* 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.

* BNEF (April 2021). A route for solid-state battery adoption: Europe and US.

The Faraday Institution's solid-state battery research project (SOLBAT[10]), for example, is now proceeding to the next stage of commercialisation through the creation of a consortium.[11] Along with the Faraday Institution and the University of Oxford (the lead university on the SOLBAT research project), the consortium includes Johnson Matthey, Britishvolt, Emerson & Renwick, the UK Battery Industrialisation Centre and the WMG, University of Warwick. The ambition is to develop world-leading prototype solid-state batteries, with a focus on sustainable mobility applications.

In other technologies, the Faraday Institution's NEXGENNA project,[12] along with prominent manufacturers and material development companies such as Faradion Ltd, AMTE Power Ltd 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.[13] 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.

[10] SOLBAT project
[11] UK-based consortium established to develop prototype solid-state batteries (19 August 2021).
[12] NEXGENNA project
[13] LiSTAR project

Employment and supply chain impacts

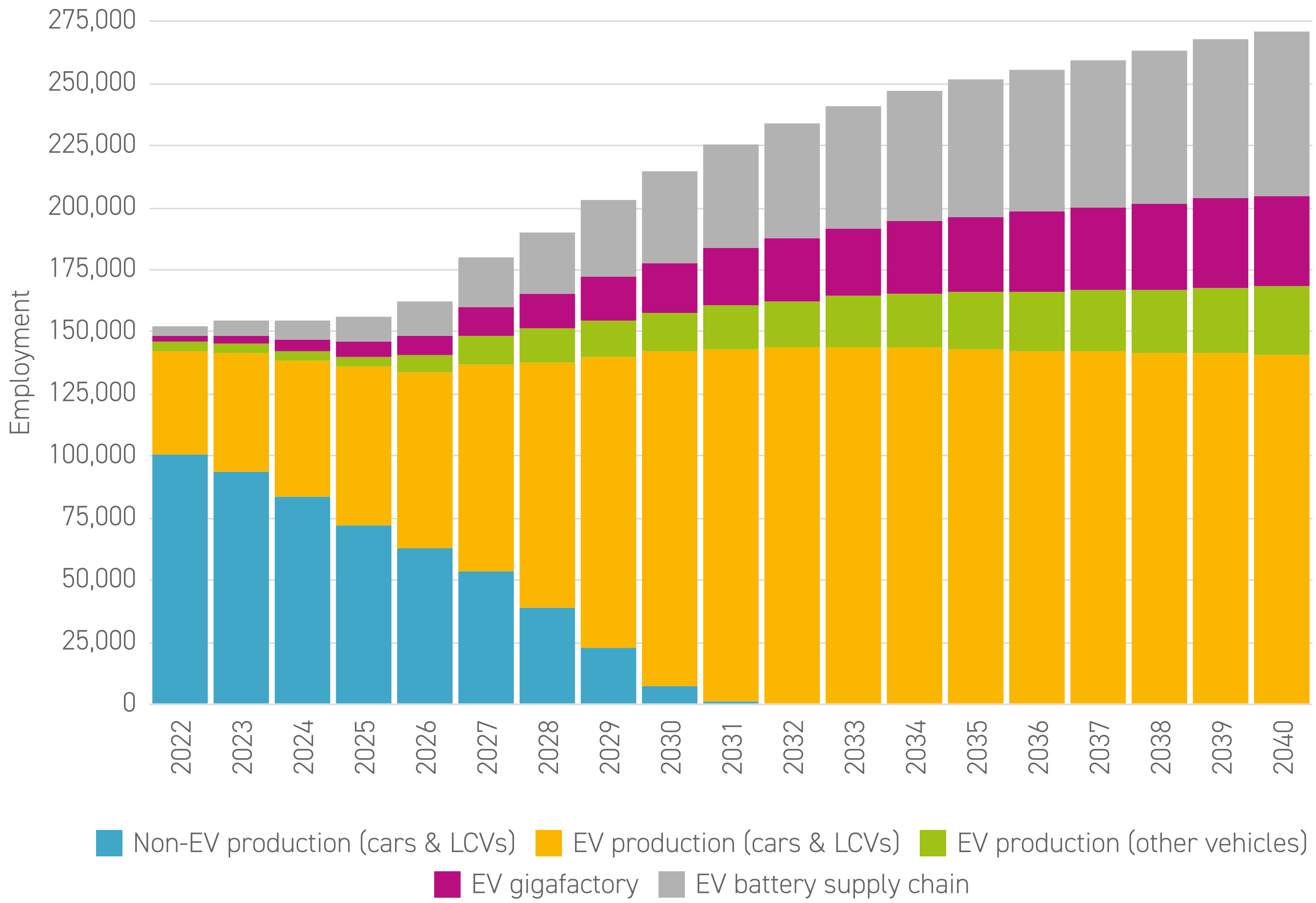
Employment impacts

The global transition from manufacturing ICE vehicles to EVs will have a considerable impact on the UK labour market. Under the base case scenario, we expect 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 a 58% increase over the pre-pandemic employment of 170,000 jobs[14] and an even bigger increase on the 150,000 estimated to be employed in 2020 and 2021, when the industry experienced a significant downturn during the pandemic.

Within this new EV automotive industry, about 145,000 jobs will 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, a substantive number of new people will need to be recruited and trained for these new industries.[15] Around 35,000 new jobs will be supported in UK battery manufacturing plants, with a further 65,000 jobs in the battery supply chain.

Figure 4: Potential employment in the UK automotive and battery industry to 2040



[14] Average employment in the automotive industry over the 2015-2019 period (before the impact of the pandemic).
[15] Under our base case scenario, consistent with the 2020 study, we assume labour productivity growth of 1.4% per annum growth in EV and ICE vehicles.

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[16] and an additional 40 jobs per GWh per annum for battery module and pack assembly[17]) 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 700,000 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.).[18]

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 a £4.8 billion opportunity by 2030.[19] The UK is already home to several leading chemical engineering and materials companies.

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 example, the UK has the second biggest nickel refining factory in the EU and Cornish Lithium is currently investigating mineral potential in Cornwall.[20]

The Government's Ten Point Plan for a Green Industrial Revolution is clear on the opportunity: "We must take advantage of the once in a generation opportunity to build a world-leading EV supply chain here in the UK."

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.

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.

[16] Joint Research Centre, European Commission (2017). EU competitiveness in advanced Li-ion batteries for e-mobility and stationary storage applications – opportunities and actions.
[17] 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).
[18] Based on the ratio of direct to wider automotive industry employment, SMMT motor industry facts 2021.
[19] Automotive Batteries, April 2019, by the Advanced Propulsion Centre UK and Innovate UK, supported by KTN & WMG, University of Warwick, authored by E4tech.
[20] Cornish Lithium and Geothermal Engineering are collaborating to build a zero carbon, lithium extraction pilot plant at an existing site in Cornwall.

Establishing a sustainable, efficient and resilient battery supply chain will require a joint effort by industry and the Government. Key actions to take include the following:

- Develop a government-wide supply chain strategy for the supply of critical raw materials;
- Establish battery recycling facilities and wider UK recycling industry to supply a substantive proportion of the raw material required for EV batteries;
- Encourage and support industry groups to simplify transport and storage rules and regulations;
- Develop a critical materials strategy to diversify the UK supply chain away from a reliance on the Democratic of the Congo for cobalt and South America for lithium;
- Improve transparency, traceability and accountability throughout the mining supply chain through multi-lateral policy development and reduce the reliance on China;
- Undertake multi-lateral engagement with other countries and NGOs to develop a global approach to the ethical sourcing of minerals including traceability.

With the concentration of resources in China, it is all the more important for the UK to develop an indigenous battery supply chain as soon as possible. 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.

Skills requirements

The government's commitment to electrification of transport and battery production represents the largest shift in industrial skills for the UK in a generation. Whilst the emergence of UK gigafactories will increase the demand for manufacturing employment, much critical work remains to be done to ensure a pipeline of skilled workers is available to fill these opportunities.

The National Electrification Skills Framework and Forum (Box 2) launched in 2021 provides a roadmap for automotive, battery production and other sectors seeking to electrify. Although this initiative is a large step forward in skills development in the UK, coordinated support from government, local government, training providers and industry will be needed over the longer term to ensure the right provision will be offered.

"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 time." Matt Howard, Chief Strategy Officer, The Faraday Institution.

Beyond immediate and near-term skills needs, the UK will also need to build and enhance career pathways into green careers as outlined by the Green Jobs Taskforce.[21] Key recommendations from the taskforce include a well-sequenced STEM curriculum, effective teaching of the knowledge and skills required for green jobs, the attraction and retention of talented teachers, the provision of green careers advice and the enhancement of training pathways.

Box 2: The National Electrification Skills Framework and Forum

The Electrification Skills Framework and Forum 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.[22] The framework, developed by the WMG, University of Warwick, the High Value Manufacturing Catapult (HVMC) and the Faraday Institution, offers a structure and an integrated approach across employers, training providers and accreditation organisations. Although initially based on training for the automotive sector, the framework is intended to cover battery cell production and other sectors and industries involved in electrification.

A Foresighting and Skills Value Chain approach[23] 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[24] (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 to be funded through ESP and the Faraday Institution for completion in 2022.

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

[21] Green Jobs Taskforce: Report to Government, Industry and the Skills Sector (July 2021).
[22] 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.
[23] 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.
[24] 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.

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Different skills and qualification levels will be required by the gigafactory workforce depending on the complexity of the role, as illustrated in Table 1.

Table 1: 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
	Pro-cess/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, per-formance evaluation, defect analysis	L6
	Practitioners	Process controls, confirmation of part/supply specification. Per-formance evaluation, defect analysis	L4
Other (9%)	IT	Process controls, confirmation of part/supply specification. Per-formance evaluation, defect analysis	L6
	Data Management	Process controls, confirmation of part/supply specification. Per-formance evaluation, defect analysis	L6
Management (1%)	Process Leadership	Achievement of KPIs, conformance to legislation etc	L4
	Engineering Man-agement	Senior management of engineering processes across the organi-sation, innovation, compliance, budget etc	L7

Production staff and maintenance and engineering technicians account for around 60% 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 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 GSCE, BTEC, ONC and OND. Supplementary training, outside of the existing standards, will need to be developed and provided specific to the unique considerations for battery production, for example on the risks of working with chemicals and hazardous materials in a production environment.

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

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.[25]

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, though these numbers are not factored into Table 1.

[25] Examples drawn from The Opportunity for a National Electrification Skills Framework and Forum.

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Policy context and competitive landscape

The UK currently offers a competitive business environment for attracting prospective battery cell producers when compared with other countries in Europe. The UK is the fifth largest vehicle manufacturer in Europe[26] 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 Government 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 on the government 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 Government 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. A Ten Point Plan for a Green Industrial Revolution was announced by the Prime Minister in November 2020 (Box 3).[27] This included a £1 billion fund to support UK electrification with £500 million earmarked for the development of gigafactories in the UK. Initial investment from this fund has included a £100 million commitment towards the Britishvolt plant in Northumberland.[28] Regional funding is also being used to support gigafactory investment, such as the £42 million pledged to the Envision AESC Sunderland plant through the Local Growth Deal.[29]

Ambitious plans to support the transition to Net Zero in the UK transport sector have also been put in place.[30] This includes the introduction of a zero emission vehicle mandate to codify the commitment to end the sales of new petrol and diesel cars and vans by 2030 and for all cars sold to be zero emissions capability by 2035.[31] Initial proposals for legally binding uptake trajectories are for a minimum of 27%, 80% and 100% of all new UK car sales by each manufacturer to be zero emissions by 2025, 2030 and 2035 respectively.[32]

Other related strategies and policy initiatives include Build Back Better,[33] Industrial Decarbonisation Strategy[34] and Decarbonising Transport.[35] 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.[36]

The UK Government has also provided support to develop the UK battery research ecosystem through investment in the Faraday Battery Challenge (FBC) programme and initiatives such as the Advanced Propulsion Centre.

The FBC investment of £330 million between August 2017 and March 2022 aims to support a world-class scientific, technology development and manufacturing scale-up capability for 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 comprised of 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
- The UK Battery Industrialisation Centre,[37] which enables UK-based companies of all sizes to develop manufacturing capabilities for battery technologies to get them to market quickly (Scale-up).

[26] SMMT Motor Industry Facts 2021.
[27] UK Government (Nov 2020). The Ten Point Plan for a green industrial revolution.
[28] BBC News (21 January 2022) Britishvolt: Electric car battery plant gets millions in funding.
[29] South Tyneside Council (October 2021). Envision AESC welcomes planning permission for UK-first 'at scale' gigafactory to support electric vehicle production in North East.
[30] UK Government (October 2021). Net Zero Strategy: Build Back Greener.
[31] UK Government (20 February 2020). Outcome and response to ending the sale of new petrol, diesel and hybrid cars and vans.
[32] Department for Transport (April 2022). Policy design features for the car and van zero emission vehicle (ZEV) mandate.
[33] Build Back Better: Our plan for growth (March 2021).
[34] Industrial decarbonisation strategy (March 2021)
[35] Decarbonising transport: a better, greener Britain (July 2021).
[36] UK Government (April 2022). British energy security strategy.
[37] UK Battery Industrialisation Centre website.

Box 3: Accelerating the shift to zero emission vehicles

Point 4 in the Ten Point Plan for a Green Industrial Revolution focuses on incentivising the transition to electric vehicles in the UK and maximising the benefits for the UK economy. Specific policies include:

- End the sale of new petrol and diesel cars and vans by 2030
- Requirement for all vehicles to be 100% zero emissions from 2035
- Investment of £2.8 billion to support jobs and investment in the UK and reduce greenhouse gas emissions and air pollution:
  - £1 billion to support the electrification of UK vehicles and their supply, with £500 million of this towards developing UK gigafactories
  - £1.3 billion to accelerate the roll out of charging infrastructure
  - £582 million to extend the Plug-in Car, Van, Taxi and Motorcycle grants to 2022–2023
- Consultation on the date for phasing out the sale of new diesel HGVs.

A further £350 million was subsequently allocated in the UK Government's Net Zero Strategy towards the electrification of UK vehicles and supply chains.

Source: The Ten Point Plan for a green industrial revolution (November 2020); Net Zero Strategy: Build Back Greener (October 2021).

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,[38] 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[39] 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 landscape

European countries and governments are also working hard to secure and grow a new battery industry. The European Commission approved €3.2 billion of funding in 2019 for an 'Important Project of Common European Interest' (IPCEI) to support battery research and innovation across Belgium, Finland, France, Germany, Italy, Poland and Sweden through to 2031.[40] It subsequently approved an additional €2.9 billion of state aid in 2021 for a second IPCEI project called European Battery Innovation, with scope across the entire battery value chain.[41] Country-level commitments within this programme include, for example, €1.5 billion of funding by the German government.[42]

The European Battery Alliance (EBA), launched in 2018 by the European Commission is a lead player in both these programmes. The EBA has a mission to create a "competitive and sustainable battery cell manufacturing value chain in Europe".[43] 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.[44]

Individual countries are also making additional funding commitments. France is planning to allocate €4 billion of the funds outlined in the 'France 2030' plan for its automotive industry with an ambition to regain EV leadership in Europe. Germany is subsidising battery manufacturing and gigafactory inward investment and special economic zones have been set up in Poland and Hungary offering tax relief to EV battery producers.

[38] UK Innovation Strategy: Leading the future by creating it (March 2021).
[39] UK Research and Development Roadmap (July 2020).
[40] European Commission (9 December 2019). State aid: Commission approves €3.2 billion public support by seven Member States for a pan-European research and innovation project.
[41] European Battery Alliance (26 January 2021). EU approves €2.9 billion state aid for a second pan-European research and innovation project along the entire battery value chain (EuBatIn).
[42] Germany ramps up electric vehicle battery production with big state subsidies (2 July 2020).
[43] European Battery Alliance website.
[44] Battery 2030+ website.

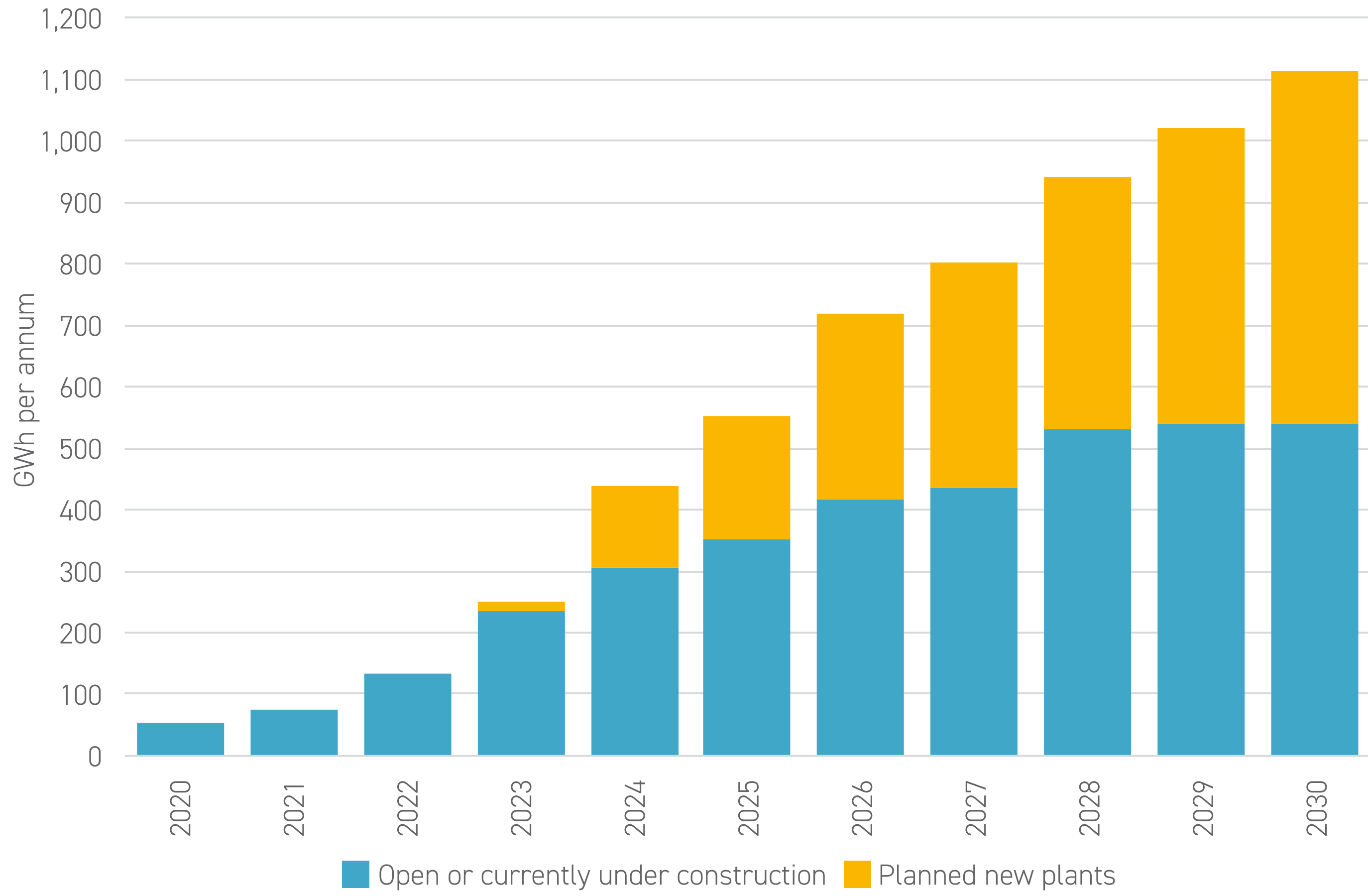
European gigafactory developments

The UK has had some early successes in building new gigafactories, as evidenced by the Britishvolt plant under construction in Blyth[45] and a second Envision AESC plant in Sunderland recently receiving planning permission.[46] Future prospects include interest from AMTE Power to build a battery factory in northeast England, Scotland or Wales,[47] and plans by the West Midlands Combined Authority to use Coventry Airport as a preferred gigafactory site should investment be secured.[48,49] This demonstrates that the UK is an attractive location for battery manufacturing companies to build their European plants and that investors believe that UK plants can compete on the global stage in an industry that is increasingly focused on cost.

However, the UK Government, industry stakeholders and research organisations need to keep up the pace and focus. Without continued effort and action, the UK may not secure the development of a largescale domestic EV battery supply industry and could therefore fail to maximise the potential economic benefits from the EV transition. Given the lead-times involved and the ending of new sales of petrol and diesel vehicles, it will only be 2 to 3 years before most investment decisions in Europe on where to locate new production lines for EVs will have been made.

The UK will need to move quickly. New battery manufacturing plants in Europe have increased substantially over the past few years. Total battery manufacturing capacity in Europe is now expected to reach around 1,100 GWh per year by 2030 (Figure 5). Germany is the leading location of choice accounting for 34% of capacity in 2030, followed by Hungary (10.5%), France (8.8%) and Italy (8.7%). UK battery manufacturing plants could reach a combined capacity of 57 GWh by 2030, equivalent to around 5.1% of total GWh capacity in 2030.

Figure 5: European lithium-ion gigafactory battery manufacturing capacity to 2030



[45] Britishvolt powers ahead with plans to build transformational UK battery gigaplant to meet EV demand (21 January 2022).
[46] Envision AESC welcomes planning permission for UK first 'at scale' gigafactory to support electric vehicle production in North East (6 October 2021).
[47] The Coventry centre helping to drive Britain's electric car dreams (April 2022).
[48] Gigafactory proposals to be brought forward by public-private partnership in West Midlands (16 February 2021).
[49] West Midlands gigafactory consultation.

Across Europe, over 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 4.

Box 4: Examples of key European gigafactories

Britishvolt, Blyth (United Kingdom). Granted planning permission in July 2021 to construct a manufacturing plant in Blyth, Northumberland. A 2023 start date for production is expected, with the plant constructed in three phases to reach a capacity of 30 GWh by 2027 and a potential full capacity of 38 GWh.

Envision AESC, Sunderland (United Kingdom). Envision AESC plans to construct a second UK battery plant in Sunderland with an initial capacity of 11 GWh and a target date of 2024 for operation. A potential final expansion stage could increase capacity to 38 GWh.

CATL, Erfurt (Germany). First phase of construction was completed with an initial capacity of 14 GWh rising to 24 GWh. An annual 60 GWh production capacity is expected from 2026. CATL has guaranteed to supply Honda with 56 GWh of cells to 2027 through a 'memorandum of understanding' partnership.

Freyr, Mo i Rana (Norway). Plans to construct a manufacturing plant in Mo i Rana have been agreed. Initial operations are expected to start in late 2022 with a capacity of 35 GWh planned for 2025. A further 8 GWh is planned to be developed in the Scandinavia region.

LG Energy Solutions, Wroclaw (Poland). Current capacity of 24 GWh in 2022, with plans to increase capacity to around 65 GWh per annum and possibly 100 GWh.

Italvolt, Milan (Italy). Plans announced for the construction of a plant near Milan or Turin with an initial capacity of 45 GWh and potential for expansion to 70 GWh. The opening of the first phase is expected in spring 2024.

Morrow Batteries, Agder (Norway). Construction is scheduled to start in 2023 for this 32 GWh capacity plant in the Agder region. Built in four stages with 8 GWh of initial capacity and in operation from 2024.

Northvolt, Skellefteå (Sweden). Recently opened with an initial capacity of 16 GWh per annum in 2022. Expected to rise to 32 GWh by 2024 with the potential to expand to 60 GWh.

Northvolt, Salzgitter (Germany). A joint venture between Northvolt and Volkswagen and expected to open in 2024. Phase 1 capacity of 16 GWh per annum and plans to expand to 24 GWh per annum at a later date. Capacity corresponds to 300,000 to 500,000 EV batteries per annum.

Samsung, Göd (Hungary). Capacity of 30 GWh per annum in 2022 with plans for future expansion to 40 GWh.

SK Innovation, Komárom (Hungary). Two plants in Komárom. The first plant opened in 2020 with a capacity of 7.5 GWh. The second plant is under construction with a planned capacity of 9.8 GWh and production scheduled for 2022.

SVOLT, Überherrn (Germany). Construction is underway with the first production expected in 2023 and potential capacity of 24 GWh by 2027.

Tesla, Grünheide (Germany). Construction of the 'Giga Berlin' or Gigafactory 4' plant started June 2020. Initial capacity of 100 GWh per annum when fully operational with long-term potential to increase to 200-250 GWh per annum.

Verkor, Auvergne-Rhône-Alpes (France). Plans announced for this plant to open in 2023 in the Auvergne-Rhône-Alpes region. Initial capacity of 16 GWh per annum, with potential is increase to 50 GWh at a later date.

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

A flurry of deals between EV battery manufacturers and vehicle producers have also been announced over the past few years. For example:

- BMW has deepened its relationship with CATL and Samsung[50] and signed a long-term contract with Northvolt,[51]

[50] BMW Group forges ahead with e-mobility and secures long-term battery cell needs (November 2019).
[51] BMW Group continues to drive electromobility: Long-term supply contract with Northvolt for battery cells from Europe concluded (16 July 2020).

- Renault has relationships with LG Energy Solutions,[52] Verkor[53] and Envision AESC;[54]
- Nissan has strengthened its relationship with Envision AESC;[55]
- Mercedes-Benz has outlined plans to build four gigafactories in Europe;[56]
- Britishvolt have signed battery cell development agreements with Aston Martin[57] and Lotus;[58]
- Volkswagen has relationships with LG Chem,[59] QuantumScape[60] and Northvolt,[61] with plans for six gigafactories in Europe;[62]
- Stellantis and Total-Saft have formed the 'Automotive Cells Company' joint venture with plans to build two gigafactories in France and Germany;[63]
- Stellantis (and previously PSA) has a long-standing relationship with LG Energy Solutions;
- Volvo and Northvolt are looking to identify a European gigafactory site.[64]

In the UK, there are a handful of volume automotive producers (factories producing more than 100,000 units per year). These are Nissan, Jaguar Land Rover (JLR), BMW Mini, Stellantis-Vauxhall and Toyota. There is no reason to suppose that these firms will naturally gravitate towards establishing all, or even any serious proportion, of their European battery manufacturing capacity in the UK. If, on the contrary, they enter long-term relationships with overseas battery suppliers, then the chances of securing UK gigafactories will diminish.

The UK Government could increase the probability of the securing gigafactories even further by helping to facilitate the winning of new volume EV model lines to UK-based plants through strategic engagement with potential investors. Should half of the production of a single volume model of a larger vehicle produced in the UK be fully electrified, this would generate nearly enough demand for one additional gigafactory in the UK.

Various promising initiatives have already been announced by UK vehicle manufacturers. JLR already has a portfolio of fully electric, plug-in hybrids and mild hybrid EVs and has stated in their 2021 global Reimagine strategy that the Jaguar brand will be all electric by 2025.[65] A key part of the strategy is the new battery pack assembly centre at Hams Hall near Birmingham, which is expected to use 900 million battery cells in production each year.[66] The manufacture of a fully-electrified Mini started at the BMW Mini plant in Oxford in 2020 with plans for the Mini to be first BMW Group brand to go fully electric in the early 2030s.[67] Significant private investment is also being attracted into the EV manufacturing sector, such as the recent £230m Ford Halewood[68] and the £100m Stellantis Ellesmere Port[69] announcements.

[52] Renault Group places France at the heart of its industrial strategy for EV batteries (June 2021).
[53] Verkor partners with Renault Group to gear up its battery manufacturing in France, Verkor (28 June 2021).
[54] Automotive News Europe (5 November 2021). Envision scales back Renault gigafactory project in France.
[55] Envision AESC aims for 38 GWh in Sunderland (October 2021).
[56] Mercedes-Benz to build eight battery factories in push to become electric-only automaker by 2030 (July 2021).
[57] Britishvolt and Aston Martin partner to develop high performance battery technology (March 2022).
[58] Britishvolt & Lotus sign MoU to collaborate on next generation battery cells (January 2022).
[59] Reuters (4 October 2018). LG Chem to supply EV batteries to Volkswagen from late 2019.
[60] QuantumScape and Volkswagen sign agreement to select location for joint venture pilot-line facility. Business Wire (14 May 2021).
[61] Volkswagen Group News (9 June 2019). Volkswagen and Northvolt form joint venture for battery production.
[62] Power Day: Volkswagen presents technology roadmap for batteries and charging up to 2030 (15 March 2021).
[63] VW, Stellantis, Renault enter new battlefields in EV race (23 August 2021).
[64] Volvo Cars and Northvolt to open Gothenburg R&D centre as part of SEK 30bn investment in battery development and manufacturing (10 December 2021).
[65] Jaguar Land Rover Reimagine Global Strategy (February 2021).
[66] New Assembly Centre, Hams Hall.
[67] Mini celebrates production milestone - 20 years of the modern Mini (26 April 2021).
[68] Ford invests £230m to make electric car parts in UK (17 October 2021).
[69] Vauxhall owner Stellantis to invest €30bn in electric vehicles (8 July 2021).

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.

We asked leading battery firm executives to list the factors that have the most impact on their decisions to locate in one country rather than another. Proximity to customers (i.e., EV manufacturers) emerged as the most important factor. 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. But the battery manufacturers also told us that they were influenced by investment incentives, timely permitting and licensing arrangements, cheap and clean energy and a skilled and productive workforce. We need to recognise 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 in 2020.[70]

These responses were not surprising, given that the majority of costs of lithium-ion battery cells are not production-location specific. Most notably, raw materials make up over half of the cost of a lithium-ion battery 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 ranks 11th out of 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 following five categories: 'raw materials', 'cell and component manufacturing', 'environment', 'regulations, innovation & infrastructure' and 'battery demand'. The position of the UK in each category is shown in Table 2.

Table 2: UK battery supply - global ranking

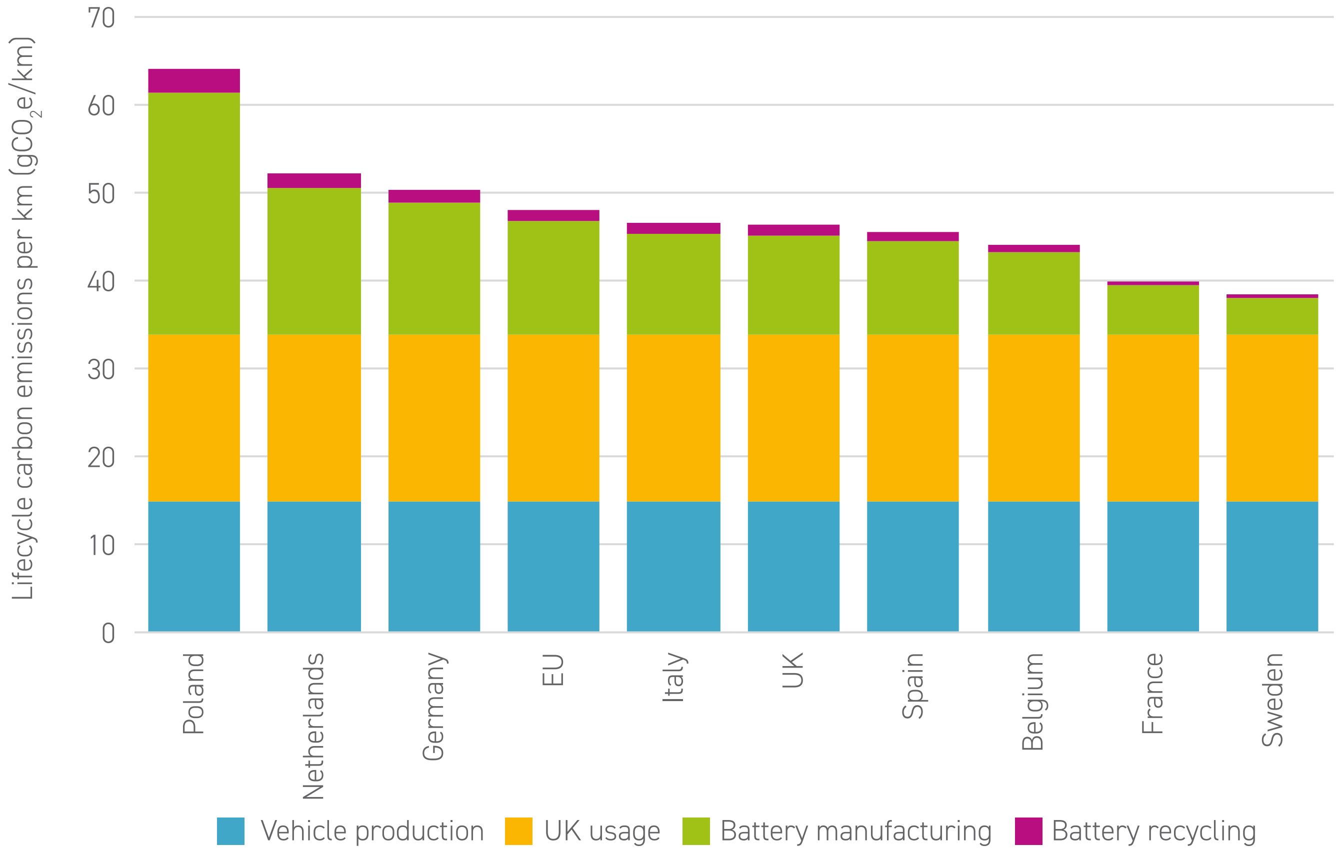
Ranking category	2021	2026
Raw materials	24	22
Manufacturing	8	9
Environment	9	7
Regulations, innovation & infrastructure	8	8
Battery demand	5	5
Overall ranking	**11**	**11**

Source: BNEF 2021, Global Lithium-Ion Battery Supply Chain Ranking 2021-2026. Ranking out of 30 countries.

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 6.[71] 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.

[70] IPCC. Climate Change 2022. Mitigation of Climate Change.
[71] Faraday Insight 12 (November 2021). The UK: A low carbon location to manufacture, drive and recycle electric vehicles.

Figure 6: Total life cycle carbon emissions from UK EVs sold in 2025, by location of manufactured EV battery



A strong UK recycling industry would also attract manufacturers to build gigafactories in the UK, particularly manufacturers interested in using recycled materials to produce EV batteries rather than using newly mined raw materials. However, there is currently a lack of EV battery recycling facilities in the UK. Announcements by Veolia[72] to open a new electric vehicle battery recycling plant in the UK and the joint venture between Britishvolt and Glencore to develop a world-leading ecosystem for battery recycling in the UK are steps in the right direction. These developments are promising, 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, a government strategy is needed to create the conditions for a new lithium-ion battery recycling industry in the UK to flourish.

Confidence in the UK as a location for business investment is strong and growing. The recent UK-EU free trade agreement has improved investor confidence in the UK. New rules of origin will clearly need to be met by UK automakers, but there are six years of transitional relief for automakers to orientate their supply chains towards the UK and EU market. Although this is a relatively long transitional period, both the temporary and permanent rules from 2027 mean that it is highly important to the UK automotive industry that gigafactories are built in the UK and with a well-developed local supply chain.

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

[72] Veolia to open new electric vehicle battery recycling plant in UK (12 January 2022).

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 we risk 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. Action by government and industry leaders is needed to attract gigafactories to the UK, develop the 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.

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European Gigafactories

GWh Capacity 2025 & 2030

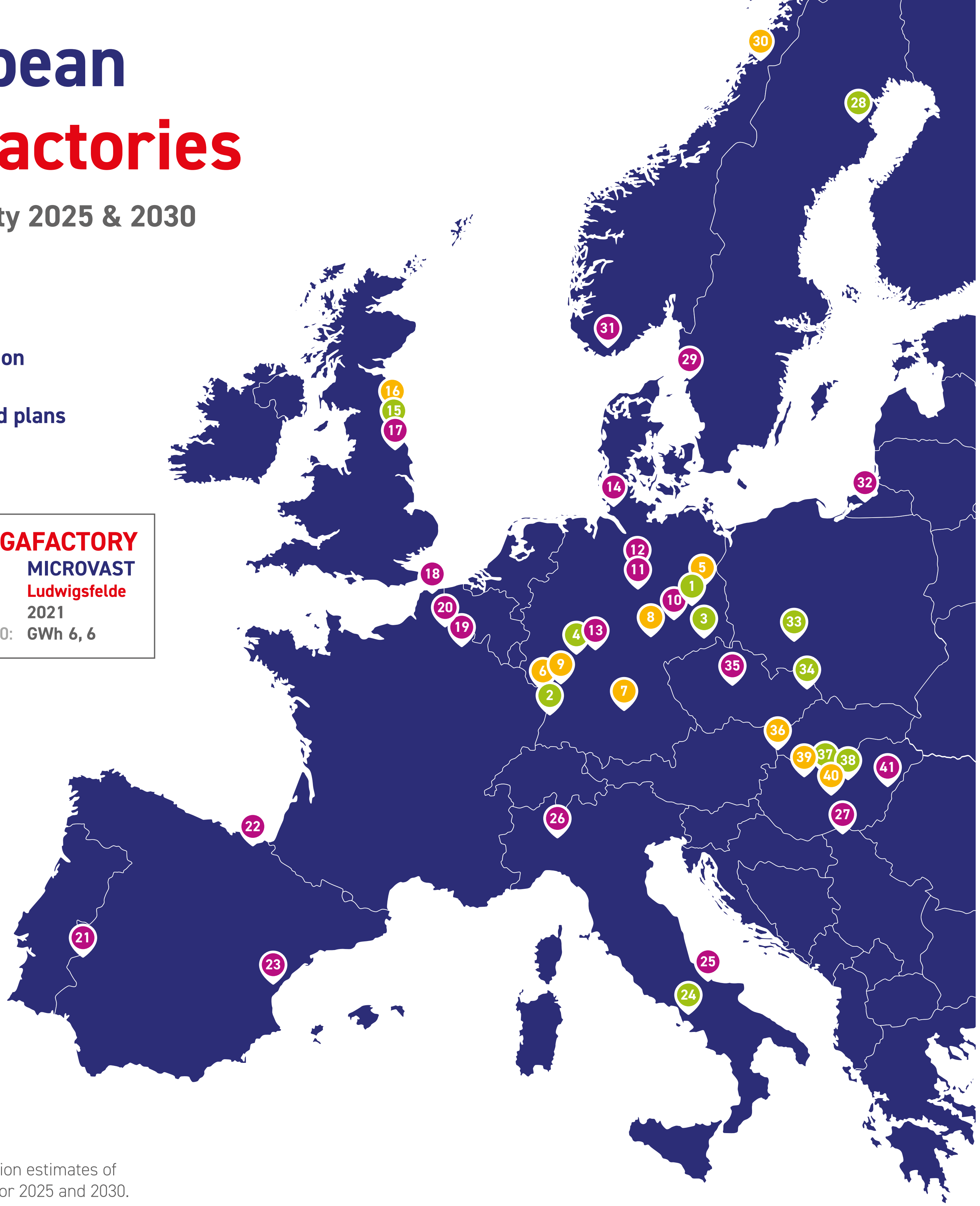
Open

Construction

Announced plans

EXAMPLE GIGAFACTORY

Manufacturer:	MICROVAST
Location:	Ludwigsfelde
Opening date:	2021
Capacity 2025, 2030:	GWh 6, 6



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

GERMANY

1 MIRCOVAST
Ludwigsfelde
2021
GWh 6, 6

2 LECLANCHÉ
Willstätt
2021
GWh 2, 2

3 BLACKSTONE RESOURCES
Saxony
2021
GWh 5, 5

4 AKASOL
Darmstadt
2021
GWh 2.5, 2.5

5 TESLA
Berlin
2022
GWh 30, 100

6 SVOLT
Überherrn, Saarland
2023
GWh 24, 24

7 VARTA
Nördlingen
2024
GWh 10, 10

8 CATL
Erfurt
2022
GWh 24, 60

9 AUTOMOTIVE CELL COMPANY
Kaiserslautern
2023
GWh 8, 24

10 FARASIS
Bitterfeld-Wolfen
2024
GWh 10,16

11 NORTHVOLT
Salzgitter
2024
GWh 16, 40

12 QUANTUMSCAPE
Salzgitter
2025
GWh 1, 21

13 BMZ
Karlstein
2023
GWh 4, 8

14 NORTHVOLT
Heide
2025
GWh 16, 60

UK

15 ENVISION AESC
Sunderland
2012
GWh 1.9, 1.9

16 BRITISHVOLT
Blyth
2023
GWh 20, 30

17 ENVISION AESC
Sunderland
2024
GWh 11, 25

FRANCE

18 VERKOR
Dunkirk
2025
GWh 16, 50

19 ENVISION AESC
Douai
2024
GWh 9, 24

20 AUTOMOTIVE CELL COMPANY
Douvrin
2023
GWh 8, 24

SPAIN

21 PHI4TECH
Badajoz
2023
GWh 10, 10

22 BASQUEVOLT
Euskadi
2023
GWh 2, 10

23 VOLKSWAGEN
Sagunto, Valencia
2026
GWh 0, 20

ITALY

24 FAAM RESEARCH CENTRE
Teverola 1 & 2
2021
GWh 3, 3

25 STELLANTIS
Termoli
2025
GWh 8, 24

26 ITALVOLT
Scarmagno
2024
GWh 45, 70

SERBIA

27 ELEVEN
Subotica
2024
GWh 8, 16

SWEDEN

28 NORTHVOLT & VW
Skellefteå
2021
GWh 32, 60

29 NORTHVOLT
Gothenburg
2025
GWh 16, 50

NORWAY

30 FREYR
Mo I Rana
2023
GWh 35, 35

31 MORROW BATTERIES
Agder
2024
GWh 8, 32

RUSSIA

32 ROSATOM
Kaliningrad
2026
GWh 0, 12

POLAND

33 LG ENERGY SOLUTIONS
Wroclaw
2018
GWh 65, 65

CZECH REPUBLIC

34 MAGNA ENERGY STORAGE
Horní Suchá
2020
GWh 8, 15

35 CEZ
North Bohemia
2024
GWh 10, 10

SLOVAKIA

36 INOBAT
Bratislava
2024
GWh 10, 10

HUNGARY

37 SK INNOVATION
Komárom 1
2020
GWh 7.5, 7.5

38 SAMSUNG
Göd
2018
GWh 40, 40

39 SK INNOVATION
Komárom 2
2022
GWh 9.8, 9.8

40 SK INNOVATION
Ivancsa
2024
GWh 10, 30

41 EVE ENERGY
Debrecen
2026
GWh 0, 30

CONTACT

Stephen Gifford
Chief Economist
stephen.gifford@faraday.ac.uk

For skills

Matthew Howard
Chief Strategy Officer
matt.howard@faraday.ac.uk

www.faraday.ac.uk
01235 425125

THE FARADAY INSTITUTION

UK Research and Innovation