



Charging Ahead

*Building your battery
business in the UK*



HM Government





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HM Government

An invitation to visit the UK

*The UK is one of the best places to invest and grow a business.
We want you to see for yourself how our world-leading research and
industrialisation programmes can add long-term value to your business.*

We would like to introduce you to the agencies working across multiple sectors to accelerate our transition to electric vehicles and support high growth businesses.

They will introduce you to the people and organisations you will need to work with, and help you get the most out of what the UK offers.

We are ready to showcase the astonishing breadth of our automotive heritage and how it is preparing for an electric future. And finally, we would like to demonstrate the depth of the UK Government's commitment to making your business a success.

We can assure you of a warm welcome



Welcome to the UK

A unique location for your battery business

The UK is the ideal place to develop and produce the batteries which will power our electrified future. The UK Government has made a long-term commitment to be at the forefront of the design, manufacture and adoption of zero emission vehicles. A comprehensive funding package, recently boosted by a further investment of up to £1 billion, is accelerating the development of key automotive technologies and factories of the future. In addition, the market is being developed through customer incentives and the deployment of new charging infrastructure.

We have an impressive depth of research, development and industrialisation capability, including 18 of the world's top 100 universities, 14 research and technology organisations and 20 major automotive R&D sites. This thriving, connected and compact ecosystem is ready to support your innovation.

We are a major exporter of vehicles and technology, with a long history of international automotive partnerships and an unrivalled ability to attract inward investment.

We are the number one major European economy for ease of doing business, supported by low taxes and a skilled and adaptable workforce. Global talent is attracted to our diverse and vibrant society. Our globally renowned chemicals industry is well placed to support large-scale battery cell manufacturing.

Our green credentials are outstanding — we are the leading G20 economy for our low carbon transition and are developing exciting new ways to reuse and recycle batteries.

As the world changes to electric propulsion, vehicle makers and battery suppliers are seeing significant opportunities for growth which will drive the need for cutting-edge technologies. Analysts predict that up to 13 battery cell production facilities will be needed by 2040 to meet demand. This document gives you a glimpse of how the UK can support that growth.

We invite you to visit the UK to explore what we have to offer, to see the results of our investment, to meet our experts and to experience the passion we have for electric vehicles.

An extra

£1 billion

available to develop key technologies and factories of the future



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A battery powered future

This document sets out the case for the UK as the ideal place to develop and produce the batteries which will power our electrified future. With rapidly improving economics and a strong regulatory push to cleaner technologies restricting the sale of internal combustion engine vehicles, it is estimated that by 2040 over 70% of vehicles (passenger cars, vans, trucks, and buses) sold in Europe will be electric.

While the manufacture of electric vehicles will use fewer mechanical parts than today's vehicles, they will need a large number of new electric and electronic components. Significant advances in the core technologies which underpin electrification — in power electronics, electric machines and drives — will be needed to deliver the performance improvements demanded by manufacturers and customers. The battery, the most expensive part of the vehicle, accounts for 35-45% of the total cost and therefore represents a significant opportunity for competitive advantage.

Battery packs are challenging to transport, necessitating their production (and the prior cell production) close to vehicle assembly. Sourcing from nearby battery

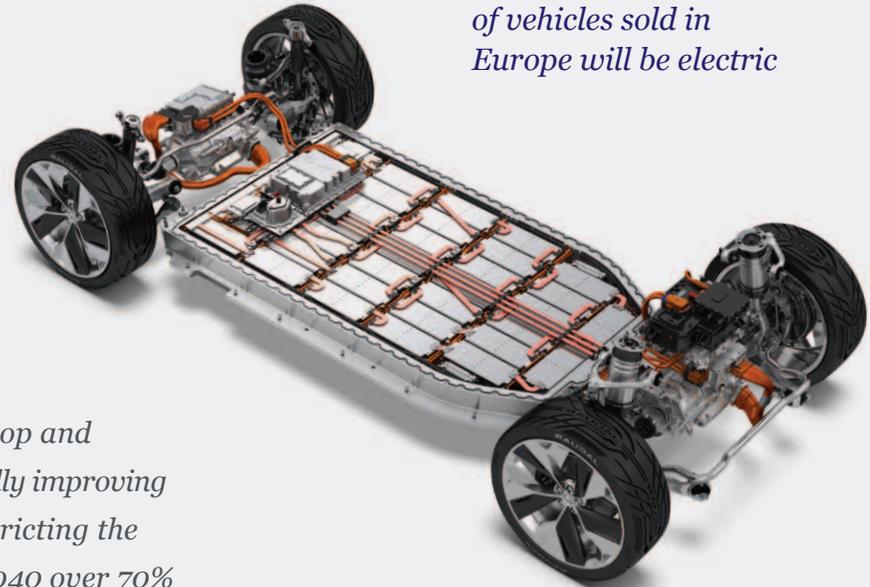
manufacturers allows vehicle manufacturers to reduce supply-chain risks, including transport concerns for dangerous goods and working-capital issues, while enabling co-development and troubleshooting of battery cells, packs, and electric vehicles. It is not only important to localise the supply chain for production, but to consider the costs of mandated disposal, reuse or recycling at end of life.

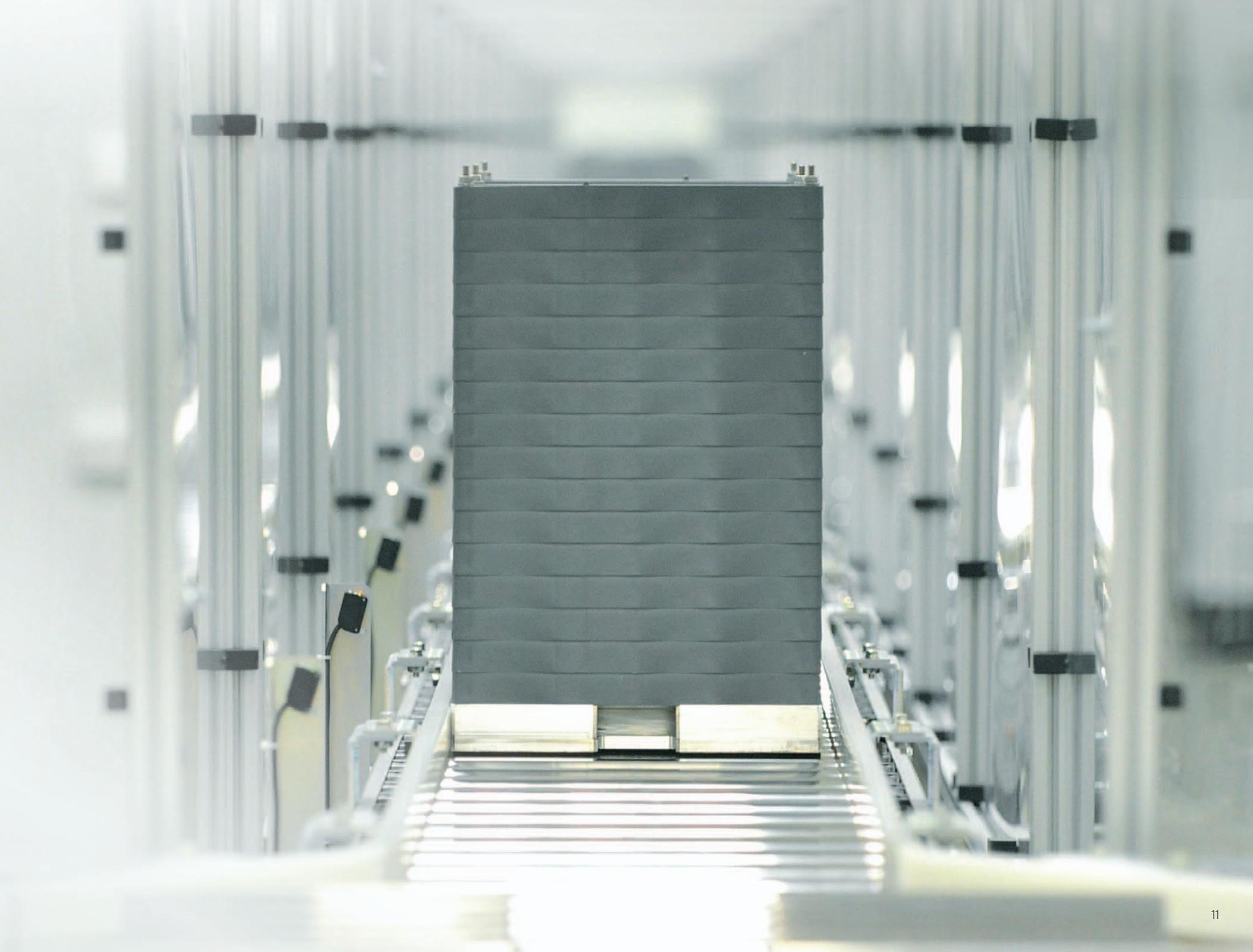
The majority of batteries currently used in electric vehicles are lithium-ion. Although these offer significant performance advantages compared to other rechargeable battery chemistries, including low maintenance and relatively high energy density, it is widely accepted that significant new battery developments will be needed to support mass market adoption.

By 2040 over

70%

of vehicles sold in Europe will be electric





Number 1

*major European economy
for ease of doing business*

Lowest
corporation tax
in the G7

A great place for international business

The UK is a global player. With the fifth largest economy in the world, demand for British vehicles and technology is at record levels. We have a long and successful history of collaboration and pride ourselves on our support for global partnership, attracting significant investment from major automotive manufacturers since 1911. We are the number one major European economy for ease of doing business, with a skilled and flexible workforce, the ability to attract the best talent and generous incentives for foreign businesses.



A great place for profits

One of the lowest corporation tax rates in the G7

The UK doesn't deduct dividend withholding tax, allowing full repatriation of net profits to overseas shareholders

R&D tax credit worth 12% of qualifying expenditure

A great place for skilled labour

We attract global talent to our diverse and vibrant society and make it easy for people to work here

Our skilled workforce is flexible and adaptable, ready to rise to the challenges of making electric vehicles

Labour costs in other major vehicle manufacturing countries have consistently risen faster than in the UK

Attracting foreign direct investment

The UK leads Europe in its unrivalled ability to attract foreign direct investment projects, securing more last year than France and Germany.

A major exporter of vehicles and technology

The UK exports around 1.2 million vehicles to over 160 different countries every year. Not just passenger cars, but over 84,000 commercial vehicles from four manufacturers.

The UK is also home to eight bus and coach manufacturers and over 60 specialist and niche vehicle manufacturers (including several leading premium brands).

The sector is also supported by a strong and growing supply chain of over 2,500 companies, working in the automotive industry, within a small geographic area. 17 of the world's 20 biggest automotive suppliers have a UK base.

44% of the components in British-built cars come directly from UK suppliers. These components help to build 6,400 cars and 10,500 engines a day — the majority of which are shipped worldwide.



International partnerships

Ford has been a part of the UK automotive industry since 1911 and employs over 13,000 staff across three production sites and one R&D site.



Nissan has been a massive success — from the Bluebird to the best-selling and most technologically advanced electric vehicle on the market, the Leaf. Nissan Sunderland has been in the UK since 1984, it also has a further R&D facility in Cranfield and they employ a total of around 7,000 employees.



Toyota have invested nearly £3 billion in the UK since setting up its first site in 1992.



BMW came to the UK in 2000 investing nearly £2 billion in its four production and R&D facilities, employing over 8,000 people in engineering and manufacturing roles. The resurgence of the MINI brand is a significant partnership, boosted by the production of the new UK-built MINI Electric.



Over

2,500

*companies working in the
automotive supply chain*



Around

1.2 million

*vehicles exported to over
160 countries*



Leading innovation

Innovation will be at the heart of the electric revolution. The UK Government has put research and innovation at the centre of its ambitions. A sustained increase in R&D expenditure to 2.4% of GDP by 2027 will deliver the goal to put the UK at the forefront of technological change and become the most innovative country in the world.

6 out of 10

F1 teams have a UK HQ and all Formula E battery development is based in the UK

Investing in R&D

We spend £34.8 billion on R&D every year

The automotive sector alone spends £3.75 billion and other sectors critical to batteries including chemicals and energy are investing heavily

A top tier innovator

The UK has been in the top five of the Global Innovation Index for the last ten years — the Index ranks the innovation performance of 130 countries around the world on their capacity for and success in innovation

Our rich history of scientific discovery includes the lithium-ion battery, which was invented in the UK and currently powers millions of vehicles around the world

Around
£35 billion
of R&D investment in
the UK each year



Building the UK skills base

The transition to electrification will have a substantial impact on the existing and future workforce. The automotive industry is actively engaging with the UK Government to support the transformation of manufacturing level skills across both vehicle manufacturers and the wider supply chain. The UK's world renowned labour flexibility and strong labour relations will ensure the industry can capitalise on the opportunities available.

A stronger, greener future

We are focussed on enabling real-life changes which will transform people's lives, creating new industries and new jobs. In addition to being a leader in addressing climate change, we are solving the *Grand Challenges* facing our society — including the *Future of Mobility* — and making the UK the best place to work and grow a business.

Supporting zero emission vehicles

The Road to Zero strategy launched in July 2018 sets out 'to put the UK at the forefront of the design and manufacturing of zero emission vehicles, and for all new cars and vans to be effectively zero emission by 2040'. The UK Government has provided one of the most comprehensive packages of support for the transition to zero emission vehicles in the world, worth nearly £1.5 billion by 2020 and has recently announced up to £1 billion of additional funding.

A long held ambition

The UK Government (working with industry through the *Automotive Council*) recognised over ten years ago that the decarbonisation of transport was going to be a major challenge, not just for the UK as a nation, but globally.

To match these ambitions, £1 billion of public and private matched investment has been committed to low carbon propulsion technology through the *Advanced Propulsion Centre*, while over a quarter of a billion

pounds is being invested into battery development through the *Faraday Battery Challenge*.

A further £80 million is being committed to a wide ranging programme called *Driving the Electric Revolution*, which will advance the key technologies and manufacturing processes needed to develop comprehensive UK supply chains in power electronics, motors and drive systems needed for electric vehicles.

£1 billion
*for low carbon
propulsion technology*



Range Rover PHEV



Showing its continued commitment, the UK Government has recently announced up to £1 billion of additional funding to develop UK supply chains for mass production of key technologies including cells, modules and packs as well as electric motors, power electronics and hydrogen fuel cells, along with their component and materials supply chains. The new money will also support further research and development into new, advanced electric vehicle technologies, helping to super-charge the uptake of zero emission vehicles in the UK.

Plus an extra

£1 billion

available to develop key technologies and factories of the future



Incentivising consumers

The UK Government is not only investing in the technologies for zero emission vehicles, it is investing in the market.

£900 million has been provided in consumer incentives, giving grants to buy electric vehicles and plug-in hybrids. Today there are already over 600 thousand electrified vehicles on UK roads, which includes around 200 thousand plug-in hybrid and battery electric vehicles.

With continued development, we expect price parity between electric and internal combustion engine vehicles around 2025. This will lead to significant

growth in demand — the *Faraday Institution* predicts that by 2030, 64% of all new cars bought by UK consumers will be electric.

Investing in charging

To give consumers the confidence to switch to an electric vehicle there needs to be charging infrastructure — and that means charge points at home, at work and on the public highways.

£400 million of public and private matched investment has been committed to charging infrastructure across the country. This new funding will complement existing local schemes, and home and workplace grants.

£900 million

*provided in grants
to buy electric vehicles
and plug-in hybrids*

64%

*of all new cars bought
by UK consumers will
be electric by 2030*

Demand for UK produced batteries

The Faraday Institution, working with McKinsey Energy Insights and Oxford University, forecast a requirement for UK-based battery manufacturing capacity of 60-200 gigawatt-hours per annum by 2040 – the equivalent of 4 to 13 battery cell production facilities operating at around 15 gigawatt-hours per site.



Demand for automotive batteries

The growth of the UK electric vehicle production and battery production industry will depend on a range of factors, including global vehicle sales; growth in electric vehicle battery power; rate of decline in electric vehicle battery costs; global emissions regulations and the import – export environment. The model forecasts UK electric vehicle domestic production between 1.1 and 2 million vehicles per annum by 2040. The UK battery production to meet this demand will be between 60-200 gigawatt-hours per annum, representing 5-17% of forecast European battery production capacity. The UK's strong premium vehicle sector will drive early demand for larger battery packs and leading technologies.

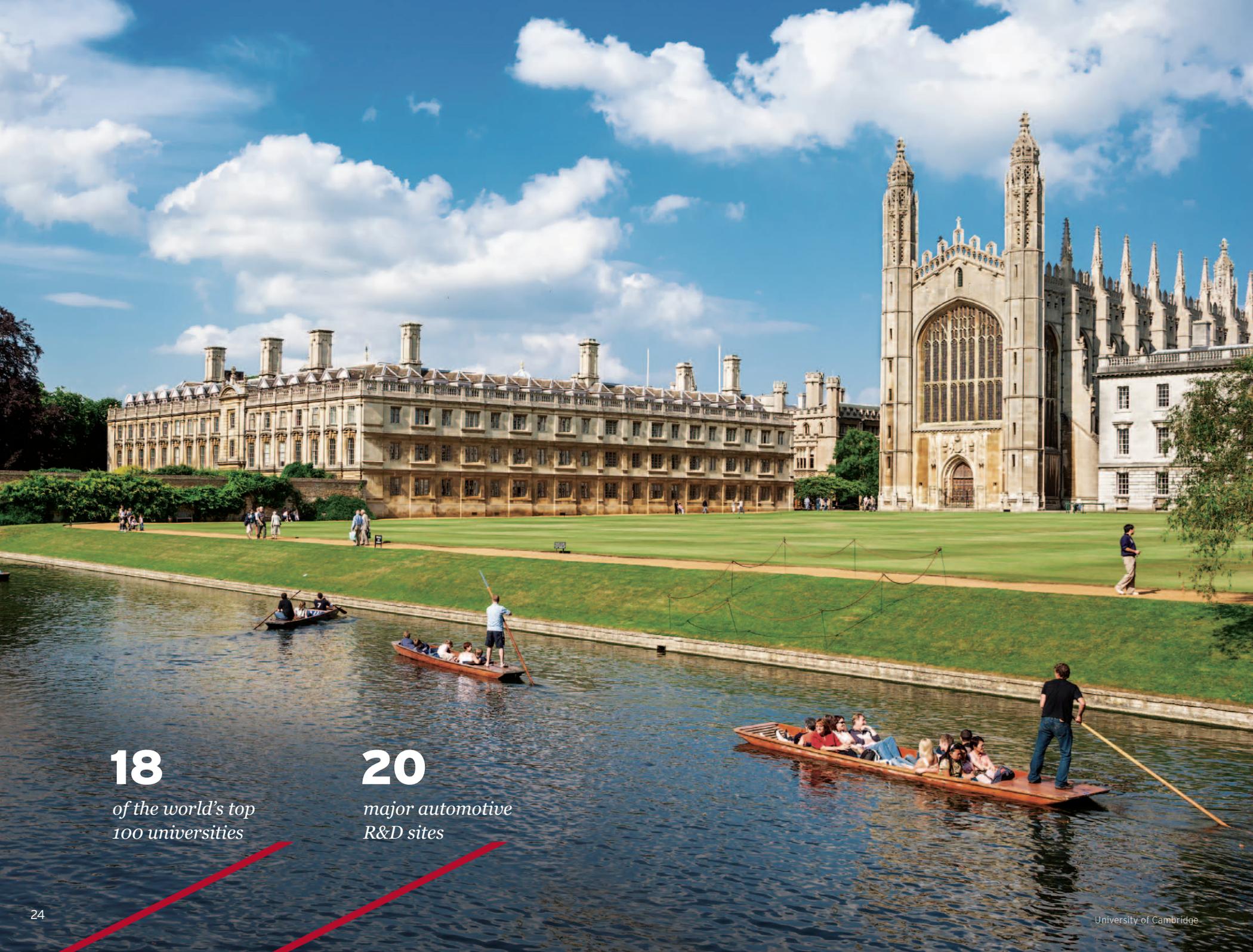
Up to
200
*gigawatt-hours of battery
production needed per
annum by 2040*

Up to
13
*battery cell production
facilities needed by 2040*



Beyond automotive

Aerospace is on a path to increased electrification across all classes of aircraft including powering onboard equipment and propulsion systems. The industry requires a new generation of high energy and power density batteries, able to operate in the demanding environments involved with aircraft. They must achieve the highest standards of safety and performance. This will require new chemistries, battery and thermal management technology and advanced manufacturing processes to produce these niche, high-performance battery systems. Other sectors of importance to the UK economy including marine, off-highways vehicles and motorsport are all accelerating efforts to electrify, which will only increase demand for batteries.



18

*of the world's top
100 universities*

20

*major automotive
R&D sites*

Research, development and industrialisation

The UK is home to an impressive depth of research, development and industrialisation capability. With 18 of the world's top 100 universities, 14 research and technology organisations and 20 major automotive R&D sites, this thriving, connected and compact ecosystem is supporting globally renowned innovation. Several initiatives are directly accelerating the industrialisation of low carbon propulsion technologies, including batteries.

Supporting new battery innovation

A pioneering research and development programme, the £321 million *Faraday Battery Challenge*, backed by £274 million of UK Government investment, is helping the UK become a world leader in electric vehicle battery development and production.

Academia and industry working together

Founded two years ago, the *Faraday Institution* at the *Harwell Science and Innovation Campus* is the UK's independent institute for electrochemical energy storage science and technology, supporting basic research, training and analysis.

£114 million

in applied research and development



The institution brings together scientists and industry partners on research projects to reduce battery cost, weight, and volume; to improve performance and reliability and to develop whole-life strategies including recycling and reuse.

Applied research and development

Innovate UK has so far supported 62 feasibility studies and collaborative research and development projects over three rounds, driving forward applied research and development, and securing the participation of over 120 organisations.



9

Catapult centres transform high potential ideas into new products



£129 million

*investment in UK Battery
Industrialisation Centre*

Industrialisation

*The UK Battery Industrialisation Centre will enable industry, via open access, to scale up and commercialise advanced technologies central to the development and manufacture of batteries. With an initial focus on the automotive sector, it is firmly embedded in the *Future of Mobility Grand Challenge* and will maximise its ability to work across the sector to support the entire UK supply chain. It will take innovative concepts and prove how they can be manufactured at scale.*



Acceleration

Nine physical centres, where the very best of the UK's businesses, scientists and engineers work side-by-side on late-stage research and development, the *Catapults* transform high potential ideas into new products and services. They are innovating in many areas relevant to electrification and battery technology.

Collaboration

The Advanced Propulsion Centre drives collaboration across UK Government, industry and academia in low carbon propulsion technologies. Its role is unique — in its first five years, it has built consortia delivering £886 million of UK Government and matched industry investment across 51 projects involving over 178 partners. These highly collaborative projects accelerate the development of low carbon technology from research to commercialisation.

They also provide unique opportunities to join up the emerging supply chains. In its 2018 International Competitiveness report, the *Automotive Council* found university and industry research collaboration in the UK to be the second most effective in the world, behind only the US.

A strong chemical supply chain

60% of the value of today's lithium-ion cells is accounted for by chemicals, so it is critical to have a competitive local supply chain. The UK Government commissioned a comprehensive analysis of the battery supply chain, identifying the strengths and opportunities available to inward investors. It shows that the UK is well placed to support large-scale battery cell manufacturing.



The UK chemicals industry

All of this is underpinned by our hugely successful chemicals industry, which exports over £50 billion in products and services a year and invests over £9 billion a year in R&D and capital.

Chemicals account for

60%

of the value of today's lithium-ion cells

UK chemical manufacturing expertise

VALE is the largest nickel miner in the world, as well as a significant cobalt miner. It has a ~40kT refinery in the UK, the second largest in Europe, where high purity nickel powder production was invented. It currently produces battery grade powders and pellets that are found in batteries of the largest manufacturers.

Johnson Matthey is a global market leader in several battery chemistries and world leader in cathode active materials. Headquartered in the UK with a number of globally leading R&D centres and manufacturing in the UK.

Phillips 66 is the largest synthetic needle coke producer globally. Its Humber facility in the UK is the only large-scale operation of its kind in Europe and currently supplies the Chinese battery market, where it holds a significant market share.

Mitsubishi, one of only two European players, has restarted its extensive electrolyte plant to supply a number of cell manufacturers.







Over
50%
*of UK electricity is generated
using low carbon sources*

Clean energy and recycling

The complete lifecycle of a vehicle is important to manufacturers – from production sustainability through to recycling. A large amount of electricity is needed to make vehicle batteries – requiring an energy supply with abundant renewable sources. The UK has the fastest rate of decarbonisation among the G20 economies and is positioned to offer battery manufacturers some of the lowest carbon electricity in Europe, at competitive prices.

Tax relief on energy makes UK electricity competitive

Batteries are an eligible manufacturing sector for a reduction in energy costs. Cost relief of 20 to 25% for businesses meeting energy intensity tests makes the cost of the UK's green electricity comparable to baseline industrial electricity costs in most other major European economies.

Fastest rate of decarbonisation

The UK laid down its first commitment to fully decarbonise the grid in 2011 and is implementing funding and regulatory reform to encourage decarbonisation throughout the energy sector.

Earlier this year, the UK reached its first 1,000 hours of coal-free energy. Since 2000, the UK has achieved the fastest low carbon transition of all G20 economies and the UK Government plans to close all remaining coal-fired plants by 2025. This will deliver some of the lowest carbon electricity in Europe – making the UK the best place to invest to develop clean, low carbon battery technology.

Optimising reuse and recycling

The number of end of life electric vehicles is currently low, but will increase as sales rise. Many batteries will find use in secondary applications supporting home energy storage for example. The valuable elements within the batteries can be recycled for use in new batteries, enhancing the security of supply.

The *Faraday Institution's* ReLIB (Reuse and Recycling of Lithium Ion Batteries) project aims to establish the technological, economic and legal infrastructure required to ensure the sustainable management of lithium-ion batteries when they reach the end of their useful life in electric vehicles.

Up to

25%

*reduction in energy costs
for battery manufacturing*

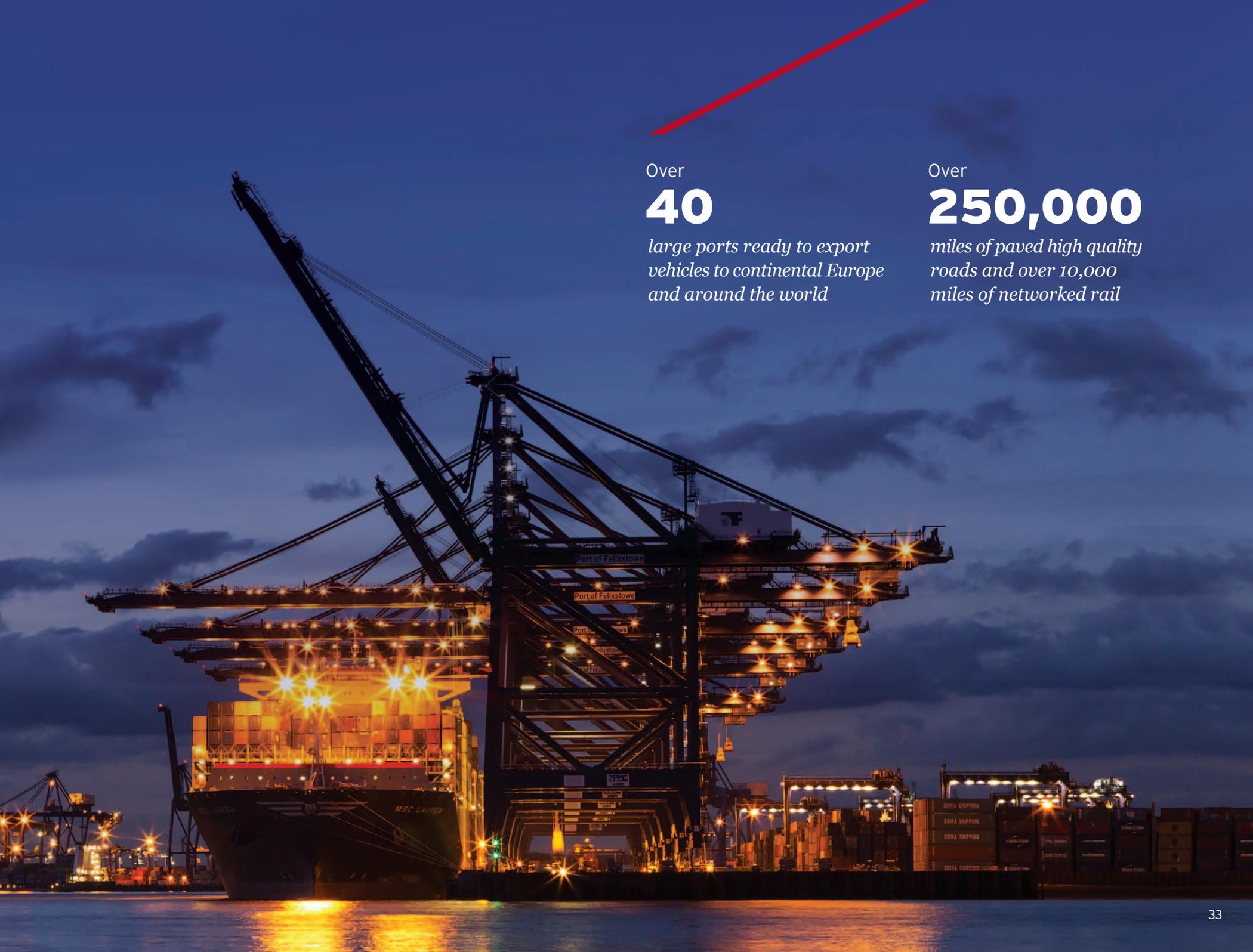
Infrastructure

Effective transport matters for battery businesses. Our relatively compact geography and a comprehensive road, rail and port network means that we can get around, we can share ideas and we can collaborate effectively. Not only this, we can also support production and supply in a very efficient way with ready access to international markets.

A reliable transport network

With over 40 large ports, a quarter of a million miles of paved high quality roads and over 10,000 miles of networked rail, the UK's transport infrastructure is world-class. All of our major manufacturing hubs are serviced by international airports within a short drive.





Over

40

*large ports ready to export
vehicles to continental Europe
and around the world*

Over

250,000

*miles of paved high quality
roads and over 10,000
miles of networked rail*

Site options

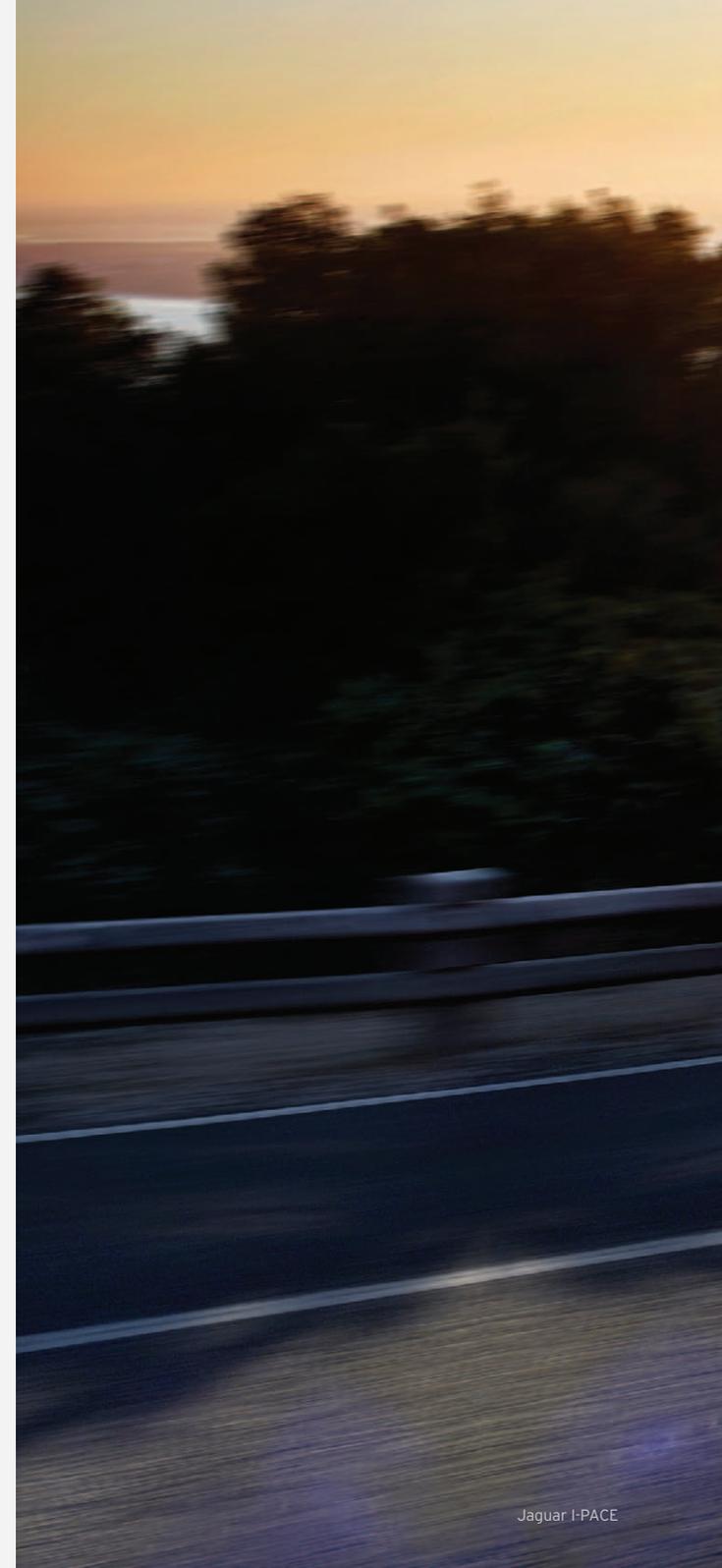
The UK Government has collated a list of potential sites in relatively close proximity to car manufacturing locations across the UK for consideration. These have been evaluated against a number of criteria including availability and planning status, size of the site, labour availability and cost, accessibility (road, rail, sea and air) and proximity to major OEMs, and energy provision. We are also on-hand to help fast-track the planning and permitting for these sites. We would welcome the opportunity to discuss your exact needs and support finding the best location for you.

Close to major **OEMs**

linking seamlessly into the automotive supply chain

Close to major **transport links**

with quick access to the UK road, rail, sea and air network





Key contacts

The Department for Business, Energy and Industrial Strategy (BEIS)

Ashley Roberts

Head of Automotive Innovation and Technology Policy
ashley.roberts@beis.gov.uk

Lindsay Goater

Head of Automotive Transformation
lindsay.goater@beis.gov.uk

Department for International Trade (DIT)

Simon Fisher

Head, Automotive and Advanced Engineering
simon.fisher@trade.gov.uk

Martin Wood

Supply Chain Specialist
martin.wood1@trade.gov.uk

Advanced Propulsion Centre UK

Ian Constance

CEO
ian.constance@apcuk.co.uk

Faraday Battery Challenge

Tony Harper

ISCF Challenge Director
tony.harper@innovateuk.ukri.org

Jacqui Murray

Deputy Challenge Director
jacqui.murray@innovateuk.ukri.org

UK Battery Industrialisation Centre (UKBIC)

Jeff Pratt

Managing Director
jeff.pratt@ukbic.co.uk



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For additional printed copies please contact the marketing and communications team at the Advanced Propulsion Centre
T: 02476 528 700 E: info@apcuk.co.uk

We have done our utmost to ensure that all information and recommendations cited in this document are based upon good research and our wealth of experience.

We provide the data in good faith, and, as such, accept no liability. Please feel free to contact us and we would be delighted to advise you on any specific queries you may have.



Nissan Leaf
Back cover: Range Rover PHEV

