Written evidence submitted by WMG

About WMG

WMG is an academic department at the University of Warwick and an international role model for successful collaboration between academia and the public and private sectors, driving innovation in applied science, technology and engineering.

As one of the largest academic departments at the University of Warwick and the lead centre for the High Value Manufacturing Catapult strategic objectives of Vehicle Electrification and Connected and Autonomous Vehicles (CAV); WMG is a leading multidisciplinary group with expertise in both collaborative R&D and world-class education and skills provision.

What contribution could battery electric vehicles make to achieving net zero by 2050?

As the UK Carbon Emissions data for 2020 shows, territorial carbon dioxide emissions from the UK transport sector were 97.2 Million tonnes (Mt), accounting for 29.8% of all territorial carbon dioxide emissions, compared to 33.1% in 2019. This decline was impacted by the COVID-19 pandemic, with emissions 19.6% (23.7 Mt) lower than in 2019, and 22.5% lower than in 1990[1].

The Committee on Climate Change has identified that Battery Electric Vehicles (BEVs) and their associated technologies must play a key role in delivering net zero by 2050.

Specifically, their 2019 report states that to achieve their 'Further Ambition' we will need *"all cars and vans to be electric by 2050, and for the vast majority of HGVs to be either electric or hydrogen powered."* This would lead to overall emissions of 2 Million Tonnes of carbon dioxide equivalent (MtCO2e) in 2050, compared to c100 MtCO2e today[2] and would require all vehicles sold in the UK to be BEVs by 2030 at the latest.

As well as this essential contribution to transport decarbonisation, Batteries can also support overall decarbonisation. They can offer storage to balance

[1]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/972583/2020_Provisional_emissions_statistics_report.pdf P11

[2] https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf P146

supply and demand from intermittent renewable supplies. Here, batteries can sit either at industrial premises (downstream of the meter) or on the network itself (upstream of the meter) offering network storage capability to balance overall demand and allowing greater reliance on renewable energy..

In addition, BEV Battery second life has high potential to integrate vehicle batteries into home/office supply to reduce pressure on grid, again reducing reliance on non-renewable energy sources.

There is also potential for the emergence of a specific market for new battery and fuel cell technologies to serve in grid balancing and storage. For example, Redox Flow batteries have a strong profile of performance, cost and stability for grid use[3] if challenges in development can be overcome, such as finding appropriate redox couples and associated electrolytes for Redox flow batteries.

To achieve these breakthroughs, there is a need for investment in R&D in battery simulation, measurement, repurposing, commercialisation of these technologies and skills.

There are therefore several primary routes for battery technologies to contribute to decarbonisation.

The first is the electrification of personal vehicles, ranging from personal vehicles to public transport and commercial transport.

In personal vehicles, battery technology has already reached mass adoption, with 13.4% of new vehicles registered so far in 2021 being either Plug-in Hybrid Vehicles (PHEV) or fully Electric vehicles. This increases to 37% of New Vehicles having some form of battery power, when Hybrid (HEV and Mild-Hybrid Vehicles (MHEV) are included[4].

As you extend from personal to commercial, niche and specialist vehicles, we are also seeing the development of EVs in the Construction, Freight, delivery and public transport systems, with product ranging from mini-diggers[5], to vans, trucks, busses, and very light rail[6].

---

[3] https://www.energy-storage.news/blogs/redox-flow-batteries-for-renewable-energy-storage
[4] https://www.smmt.co.uk/vehicle-data/evs-and-afvs-registrations/
[5] https://www.jcb.com/en-gb/news/2018/03/zero-emissions-mini-so-quiet-it-gives-jcb-something-to-shout-about
[6] https://revolutionvlr.com/vehicle/

The next key area role for battery EV development is that the same technologies can be applied to support energy storage on distribution networks and home/office/industry storage.

Looking further ahead to 2050, there are several new routes for battery technology and chemistry on the horizon which could contribute to delivering our Net-Zero commitments in sectors both within transport and beyond it.

The Faraday Institution has produced a useful overview of many of these technologies and their likely applications in their recent report "High-energy battery technologies"[7] Many of these won't appear in the mass-market before 2030, but can be expected to contribute to decarbonisation beyond that.

- **Solid State batteries** Effort here will be focussed on the challenge of scaling up to pack size required for vehicle and domestic use and research is now being focussed on this scale up challenge, strongly supported by motor manufacturers.

- **Lithium-Sulfur Batteries** could offer lower cost/kwh and potentially higher energy density. Oxis Energy in the UK is currently deploying these batteries in sectors such as Maritime and Aviation, where there is a need for extended range between charges.

- **Sodium-Based Batteries,** have the potential to be lower cost and easily mass manufactured, but current Sodium Ion batteries (NIBs) are significantly larger and less energy dense than Li-Ion batteries (LIBs), limiting their useful application. As research develops, however, it should be possible for Sodium batteries to get close to Li-Ion performance at significantly lower cost.

There are also potential for future developments in Sodium Batteries such as Sodium-Oxygen, (Na/O^2), Sodium-Sulfur (Na/S) and solid-state batteries (Na-ASSBs). A recent paper[8] from Dr Ivana Hasa et al of WMG concluded that these technologies could

"represent a significant game change, leading to an enormous gain in terms of performance, safety or cost. However, despite important advancements, their technological readiness level is still far from application. At the present moment, only NIBs can be considered as serious contenders to LIBs"

[7] https://faraday.ac.uk/wp-content/uploads/2020/01/High-Energy-battery-technologies-FINAL.pdf

[8] Ivana Hasa, Sathiya Mariyappan, Damien Saurel, Philipp Adelhelm, Alexey Y. Koposov, Christian Masquelier, Laurence Croguennec, Montse Casas-Cabanas, "*Challenges of today for Na-based batteries of the future: From materials to cell metrics*", Journal of Power Sources, Vol 482, 2021,

- **Multi-valent battery chemistry** Using Multi-Valent metals as battery anodes could increase their energy as they can transfer more than one electron per atom. The metals that could be used include magnesium, calcium, zinc and aluminium. The challenge for researchers is finding a cathode material which is a suitable partner.

How well is Government policy aligned with high-level commitment for growth of battery electric vehicles to support its net zero ambition?

We should recognise UK has a good strategy, funding and support mechanism in place.

Since the establishment of the Faraday Battery Challenge in 2017 We have moved fast to establish investments in research, innovation and industrialisation. Initiatives like the Faraday Institution, The Advanced Propulsion Centre, the Catapult networks and the Office for Zero Emission vehicles have worked effectively to create innovation and scale in the UK. The Faraday battery challenge in particular has achieved an academically and technically fast moving and successful record.

To take one example of this, Germany's equivalent of the UK Battery Industrialisation Centre (UKBIC) is Forschungsfertigung Batteriezelle (FFB) in Munster. Their initiative, supported by the Fraunhofer Network and the University of Aachen is only at the planning stage, while UKBIC is close to operation. Equally, with AESC in Sunderland, we have one of the innovators in Battery manufacturing at scale in Europe.

However, we should not underestimate the scale of the efforts being made to support manufacturing across Europe. The FFB alone represents a 750mn Euro investment from the German Federal Government and the State Government of North Rhineland-Westphalia.

In comparison, while the government have made strong commitments for future investment as part of the 'Plan for Growth', the 'R&D Roadmap', 'the 10-point plan for a Green Industrial Revolution' and for overall R&D investment both in terms of targets and the ambitions for Tax policy for R&D, this has not yet translated into clarity on the future support for innovation overall, or specifically in Batteries and Fuel Cells.

Currently both InnovateUK and the Industrial Strategy Challenge Fund (ISFC) have commitments for funding on limited timescales, while the R&D Tax system is under review.

Certainty of future funding for R&D, Industrialisation and incentives would be a strong way to derisk commitments by industry. The recent dismantling of the Industry Strategy has also caused concern over whether and how the ISCF programmes will continue to be supported.

It is important to note how important timing is in these decisions. For example, the commitment to ban the sale of ICE vehicles from 2030 is effectively converted into a 2027 target by the introduction of Rules of Origin restrictions on the import and export of Vehicles as part of the UK-EU Continuing Relationship. This should have a helpful effect of attracting Battery manufacture to the UK and Europe, but if the UK does not secure battery manufacturing at scale by this date, manufacturers will rely on EU based manufacturing.

Strong FTAs with other important overseas automotive markets would incentivise UK manufacturers who export to those markets to locate their battery manufacturing in the UK rather than the EU where both are treated equally under the EU Trade and Co-operation Agreement.

What natural advantages in terms of access to raw materials, renewable energy supply, technological readiness, IP or other competitive advantage does the UK have to encourage development of battery manufacture in the UK?

Support from the Faraday Battery Challenge has put the UK in a competitive international position in advanced research areas such as Solid state and Sodium-ion and Lithium-Sulfur. We are also leading in supporting the industrialisation of new Battery technologies with UKBIC.

The UK has a potential strength that its car manufacturers tend to be in more premium markets, and are likely to be early adopters of advanced battery technologies – which may incentivise battery manufacturers to produce such products in the UK.

There is an opportunity for the UK to supply batteries and their materials to manufacturers in UK and possibly Europe. It is unlikely that we will export to either US/East Asia, although there may be an opportunity in developing and licensing the manufacture of technologies around battery development.

What action is needed to support investment and establishment of UK gigafactories? What should the Government do to ensure that gigafactories have a safe, reliable power supply which meets net zero requirements?

There are several challenges which will need to be addressed if we are to become a leader in cell and battery manufacture:

- Demand – Potential Battery and Cell manufacturers need certainty of demand before making the significant capital investment required to manufacture are scale. A clarity of purchasing signal from Original Equipment Manufacturers (OEMs) is needed here. Only two or three UK OEMs have the production volumes needed to justify a Gigafactory based on their own demand alone.

- Land availability and cost – Battery Manufacture at scale requires a large site, (Tesla's Giga-Berlin is 300 Hectare/740 acre, or approximately a thousand football pitches). As UK land prices are often high in desirable locations, this can present a challenge as can identifying suitable sites and acquiring the land at pace.

- Energy costs, availability carbon intensity – While energy costs make up a relatively small share of the overall cost of Battery cell production (around 5USD/kWh of an overall cost of 130USD/kWh) it is one of the few elements which vary significantly by location, along with Labour, Land cost and depreciation. Battery manufacture requires 30-50MW supply, and there are few sites available in the UK with such a supply. The cost and time to provide such a supply is often prohibitive. Lastly, as the car industry is expected to move from regulation by tailpipe emissions to regulation for life cycle emissions, the carbon content of the electricity used to make batteries becomes critical. The UK has the fastest decarbonising grid in the UK, and is cleaner than say Germany, but is at a disadvantage relative to France, Norway and Sweden for instance.

- Road/shipping infrastructure Large scale battery manufacture needs excellent transport links and if not in place already, these will need to be supported.

- Planning/Permitting The development of such a large site at speed requires planning co-ordination at a regional and national level, as impacts of the programme will be felt. Timing of delivery is a major factor in site selection as plants turn over £bns per year, so months lost in planning and permitting are hugely expensive.

- **Skills** As we shift from ICE manufacture to BEV, skills at all levels will need to be supported, across Battery manufacturing, supply-chains, maintenance and re-use. A typical Gigafactory employs thousands of skilled workers.

- **Capex** A typical large-scale Battery manufacturing facility will require an overall capital investment in the other $3-5bn.

In considering how the UK offer to Battery manufacturers compares internationally, it should be noted that Germany and Eastern Europe are making very competitive offers, as their land price, infrastructure support and labour cost can be effectively managed.

Further, the EU has declared battery manufacturing a subject of social significance, so state aid rules don't apply to offers of support, allowing packages like that offered to Tesla to build Giga-Berlin, reportedly standing at 1bn euros[9].

In Poland and Hungary, special economic zones have been set up that offer tax relief to EV battery producers. The European Commission has also recently approved €3.2 billion of public funding, from Belgium, Finland, France, Germany, Italy, Poland and Sweden, for pan-European research across the battery value chain.

To be competitive with these offers a package of around £750mn per plant is likely needed covering all the above elements, with this on offer to the first two or three investors in order to deliver the manufacturing at scale and the supporting supply chain required.

Are the UK supply chain opportunities around supply of batteries and power electronics, machines and drive supply chain clear?

[9] https://www.reuters.com/article/us-germany-tesla-funding-idUSKBN2A12SF

What action is needed to support growth of associated power electronics, machines and drive supply chain, including securing supply of raw materials and material processing?

The challenges are largely similar to the above- but timing of investment in Battery production is also key.

A Supply Chain company wants to see a clear customer established in the market in the near future. For example, if you were to invest in Cathode manufacture in the UK, you would want to know what the likely demand for your product would be in you national and regional market, and where the best location for your production would be.

Specifically, you would want to see UK gigafactories established in the UK before committing to significant investment yourself. The time lag associated with these “chicken and egg” decisions {which exist throughout the supply chain) is a major challenge which could be addressed by mechanisms to de-risk early investments and to give greater clarity of demand.

The Government has announced £1 billion of funding to support the electrification of UK vehicles and their supply chains. Is this figure sufficient? How should it be split between supply chains and gigafactories?

The UK has the right mechanisms in place to support investment in battery manufacture, but the quantum of support overall is not currently at the level of other European nations, particularly when higher land costs and energy costs are considered.

As noted above, a package of around £750mn per plant is likely needed to attract the first two or three investors in order to deliver the manufacturing at scale required.

In addition, the forward visibility of funding availability in the UK is poor due to short spending review periods. This disadvantages us with respect to leveraging private investment as we are unable to co-invest over the typical 5-10-year planning horizons used by industry and the typical 5-year horizons used by the investment community

It would be particularly useful to have early specifics on the commitment in the ‘Plan for growth’ to spend nearly £500 million to support the UK’s electric vehicle manufacturing industry in the next four years, as part of the £1 billion package of support for the development and mass-scale production of electric vehicle batteries and associated EV supply chain.

What steps should be taken to ensure the UK workforce has the necessary skills to staff gigafactories and their supporting supply chains?

As a result of effort springing from the Industrial Strategy of 2017, and predecessor initiatives such as the Automotive Council and the Catapults the UK research workforce has improved significantly, but does need to keep growing.

On manufacturing, we will have skills shortages running from Level 3 to level 7. A 2019 Faraday Institute study[10] suggests that by 2040 the UK will create

"83,000 new jobs by 2040, around 8,000 would be created in EV manufacturing, 26,000 jobs in battery manufacturing, 47,000 jobs in the battery supply chain and 2,000 jobs in battery R&D. The shift toward EVs will also necessitate the retraining of auxiliary personnel, including vehicle technicians, mechanics and electricians, as well as staff at service stations"

Clearly, delivering the skills needed at scale for this shift will be a major challenge, and require co-ordination between HE and FE skills providers, Local Authorities, Training commissioner and employers.

The employer-led model for technical education proposed in the recent skills bill should help to support this shift, but it is key that standards are set to industry needs and that employers and providers are given funding and system flexibility needed to support skills adaption among both existing and new employees, perhaps through offering greater flexibility in use of the apprenticeships levy or by sectoral piloting of the lifetime loan entitlement for higher technical education, which is currently only planned to be introduced in 2025.

What action can Government take to support growth of secondary markets to extend lifetime use of EV batteries? What steps should be taken to ensure that EV batteries are recycled at the end of their lives and not simply sent to landfill?

[10] https://faraday.ac.uk/wp-content/uploads/2019/06/Exec-Summary-Report_May2019_FINAL.pdf

The growth of the electric vehicle market highlights the need for effective recycling and reuse of Batteries and associated systems.

A recent report by WMG modelled that by 2040, the UK will require 567,000 tonnes of cell production, requiring 131,000 tonnes of cathodic metals. Recycling can potentially supply 22% of this demand (assuming a 60% recycling rate and 40% reuse or remanufacture).[11]

A recent report from the High Value Manufacturing Catapult sets out the scale of the opportunity.

"By 2040, the UK will require 140GWh worth of cell production capability, representing 567,000 tonnes of cell production, requiring 131,000 tonnes of cathodic metals. Recycling can supply 22% of this demand (assuming a 60% recycling rate and 40% reuse or remanufacture"[12].

The UK does not currently have a Battery recycling facility at scale. Across Europe, there are a number of industrial and pilot facilities being developed.

For example, REDUX, based in Bremerhaven, Germany , has set up a commercial battery recycling facility, capable of recycling 10,000t of Li-Ion batteries per year.

Equally as important as Battery recycling is ensuring Battery second life applications.

In the auto sector the typical battery warranty is 8 years to 80% of range and power. Most will go longer than this, but vehicles with smaller batteries will be the first to be retired from automotive use, as the impact of only offering 80% of range is far greater if the original range is <100km.

Typically, temperature, storage and frequency management on grid is less demanding than in automotive, to the point that used auto batteries could be deployed in grid storage, domestic or work applications and still offer 6-10 years of useful life. The main challenge for these second life applications is the cost associated with the triage and repurposing of the battery pack.

---

[11] Sattar, A, "Battery recycling: An end-of-life ecosystem" https://warwick.ac.uk/fac/sci/wmg/people/wmginsight/battery-recycling/

[12] https://warwick.ac.uk/fac/sci/wmg/business/transportelec/22350m_wmg_battery_recycling_report_v7.pdf p3

One example of supporting the development of second life applications is the work of the UK Energy Storage Lab to develop a new grading system for used automotive batteries from Nissan Leaf EVs.

This partnership between Nissan, WMG, Element Energy and Ametek, supported by BEIS developed a safe, robust and fast methodology for grading used automotive Lithium-ion batteries, at pack level. This methodology was successfully transferred to a pilot second-life facility, where a target of 1MWh of second-life energy storage was achieved.

At present the business case for this is at best marginal, and this could get worse as the cost of new batteries falls. Future regulation around battery management systems could assist in ensuring that used vehicle batteries are more easily assessed and integrated to second life applications.

Currently, there is an ongoing consultation on a revision to the EU Battery directive, which looks to increase the amount of battery mass to be recycled, the proportion of valuable metals to be recycled and create a standard requirement for the recycling of lithium in new batteries.

While the UK will not be governed by these standards, we should look to match or even exceed the requirements of the EU, as the increased global demand for batteries will inevitably lead to higher demands for future recycling of batteries.

Achieving these goals could be supported by both delivering a UK based battery recycling facility and by technological solutions, for example, deploying sensors within battery cell which transmit information on battery status, both supporting a market for second-hand batteries by verifying the health of the battery and signposting potential for reuse, and by identifying the most appropriate recycling and re-use process for the battery.

What measures should the Government take to ensure that minerals for battery electric vehicles are sourced in a responsible way?

There are significant issues with the sustainability of current battery technology, both in terms of environmental impact and availability.

As C.W Babbitt has noted [13]

[13] Babbitt, C.W. Sustainability perspectives on lithium-ion batteries. Clean Techn Environ Policy 22, 1213–1214 (2020). https://doi.org/10.1007/s10098-020-01890-3

"Raw material impacts typically stem from the resources that provide LIBs with their necessary electrochemical functionality, including the typically graphitic anode and the cathode, which is usually comprised of lithium, cobalt, nickel, and manganese in varied concentrations…

…Cobalt is primarily sourced in the Democratic Republic of the Congo, a region historically characterized by political instability, social impacts in the mining sector, and lack of supply chain transparency. The global reliance on such a concentrated supply chain introduces risks of resource shortages or price spikes due to disruptions"

One challenge will be to reduce reliance on Congo based Cobalt, by opening up alternative sources, for example in Australia, Tonga and Zimbabwe[14]

Longer-term, it will be vital to pursue research that has the potential to reduce the reliance on mined cobalt and other resources. There is plenty of research going on to end the reliance on cobalt in BEVs, whether by using lithium-iron-phosphate batteries (already commercially available), or developing technologies such as Sodium-Ion.

May 2021

[14]Fu X, Beatty DN, Gaustad GG, Ceder G, Roth R, Kirchain RE, Bustamante M, Babbitt CW, Olivetti EA (2020) Perspectives on cobalt supply through 2030 in the face of changing demand. Environ Sci Technol 54(5):2985–2993