Government Office for Science

Sir Mark Walport FRS FMedSci

Chief Scientific Adviser to HM Government and
Head of the Government Office for Science
1 Victoria Street
London SW1H 0ET

www.gov.uk/go-science

Rt Hon Greg Clark MP
Secretary of State for Business, Energy and Industrial Strategy
Department for Business, Energy and Industrial Strategy,
1 Victoria Street,
London
SW1H 0ET

3 March 2017

Reviewing the case for a new research institution to act as a focal point for work on battery technology, energy storage and grid technology

Secretary of State,

In the Industrial Strategy Green Paper (published in January 2017), you asked me to "…*review the case for a new research institution to act as a focal point for work on battery technology, energy storage and grid technology, reporting in early 2017*…". I have completed my evaluation of the case and set out my conclusions in detail in annex A. To summarise;

The global policy imperative to tackle climate change by reducing greenhouse gas emissions creates major challenges in decarbonising energy generation across sectors. Energy storage is a key technology for optimising intermittent renewable energy sources and balancing the grid, but in the shorter term is of particular pertinence for decarbonising transport as the automotive sector transitions from internal combustion engines to hybrid and full electrification. This requires novel powertrain and mobile energy storage solutions. The human health impacts of vehicle emissions add particular impetus to this transition. It is not at all obvious that the current structure of the European automotive manufacturing footprint will meet these new needs. This poses both a risk to the UK automotive sector, and an opportunity if these changes can be anticipated.

In the context of the green paper, the industrial strategy question which my evaluation addresses is whether the UK has science and innovation excellence that can usefully be brought to bear on the convergence of these policy issues, in an industrial context.

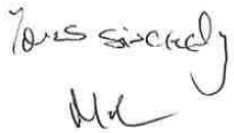
Through a process of intense engagement with the UK battery science community and industry, my overall conclusion is that the UK does indeed have world class science capability that could be deployed to powerful effect on this industrial challenge if Government were to evolve its current science and innovation model a further logical step. This would involve creating an overarching 'application inspired' approach to explicitly join up research funding at three levels; fundamental research, innovation, and scale-up. I believe that an overarching strong governance structure – effectively a 'programme of programmes' – could achieve this, and that this energy storage challenge (which I suggest is called the Faraday Challenge) provides a timely and valuable opportunity to demonstrate such an approach, which could then form the basis of a model for industrial strategy challenges more widely.

Whilst UK research funding has previously been applied at all three of these levels (research, innovation, and scale-up), there has never been a programme of programmes that is explicitly and formally linked across these levels and scaled to address a specific industrial challenge. Doing so would drive improved efficiency of translation of UK science excellence into desirable economic outcomes, would leverage significant industrial investment in the form of a 'deal' with industry, and would send a strong investment signal globally (that could also be exploited to explore the possibility of securing a Tier 1 battery company investment to help manage the automotive technology transition).

I have included in my evaluation recommendations on the attributes and conditions that I believe are required for such a step forward in the UK's science and innovation system to succeed. They include functions such as funding excellence through competition, the need for globally credible leadership, the need for a strong mission oriented governance framework to include industry and funders, and the pragmatic use of existing assets, institutions, mechanisms, and resources, where doing so does not compromise the identity and effectiveness of this new way of working – the Faraday Challenge.

My assessment of the state of the science and of the nature of the communities that will need to come together to deliver the Faraday challenge, has convinced me of the value of a very clear and focussed mission. That being the case, I suggest that the first phase of the challenge be constructed around the mobile low carbon energy storage needs of the automotive industry, exploiting the cooperative leadership of the Automotive Council and the industry relationships with the science community that this evaluation has benefitted from. This should be later reviewed to consider wider grid storage options, particularly as market expansion of electric vehicles creates options for secondary battery use.

I am pleased to have advised on this specific challenge, as it has created the opportunity to step back and examine aspects of the UK's fast evolving science and innovation ecosystem. It is clear to me that the links between science and the economy have come a long way in a relatively short period of time. The timely development of the Industrial Strategy green paper alongside significant reforms to the research landscape through the creation of UKRI, creates the opportunity to take this a further logical step by improving the transmission mechanism from science to the economy through the powerful lens of a specific industrial strategy challenge. I am happy to advise on an ongoing basis as you take account of this evaluation.



Sir Mark Walport

Chief Scientific Adviser to HM Government

Annex A

Reviewing the case for a new research institution to act as a focal point for work on battery technology, energy storage and grid technology

Secretary of State,

In the Industrial Strategy Green Paper (published in January 2017), you asked me to "…*review the case for a new research institution to act as a focal point for work on battery technology, energy storage and grid technology, reporting in early 2017*…". I have completed my evaluation of the case and set out my conclusions below.

Demand - convergence of policy imperatives for a sustainable economy

The global policy imperative to tackle climate change by reducing greenhouse gas emissions creates major challenges in decarbonising energy generation across sectors. Energy storage is clearly a key technology for ultimately optimising intermittent renewable energy sources and balancing the grid, but in the shorter term is of particular pertinence for decarbonising transport as the automotive sector transitions from internal combustion engines to hybrid and full electrification. This requires novel powertrain and mobile energy storage solutions. The human health impacts of nitrogen dioxide and particulate emissions from combustion products add particular impetus to this transition.

This technology transition presents risks and opportunities for the UK's automotive manufacturing sector, which with the exception of JLR, largely consists of multinational Original Equipment Manufacturers (OEMs) serving the European market. Electric engines are an entirely different technology to internal combustion engines, and add a new strategic consideration – the sourcing of the large and heavy battery component which may be more than 50% of the vehicle value. Transportation costs favour the battery and final vehicle assembly being in close proximity. It is not at all obvious that the current structure of the European manufacturing footprint will meet these new needs. This poses both a risk to the UK automotive sector, and an opportunity if these changes can be anticipated. In the context of the green paper, the industrial strategy question which my evaluation addresses, is whether the UK has science and innovation excellence that can usefully be brought to bear on the convergence of these policy issues, in an industrial context.

Evaluation process

You are aware that Oxford University submitted a proposal for a 'Faraday Institute' for No10's consideration some months ago, which has been widely shared amongst Departments. Whilst in my view that proposal in its original form had quite significant limitations, it did provide a useful starting point for engagement with the UK science community, BEIS, Innovate UK (IUK), EPSRC, industry, and others as part of my evaluation. This has been an iterative process, addressing three challenges;

a) Whether the UK science community has globally competitive capability that could be better exploited in an industrial strategy context

b) Whether the UK science community can agree on how they could work together in a new and different way – as a synergistic strategic collective rather than a large number of small uncoordinated groups – to address the key industrial challenges, and

c) Whether the UK science community could work effectively with UK industry, and particularly the automotive industry, on agreeing the key industrial challenges and the innovation architecture that could most effectively address these.

My conclusions derive from my own experience and expertise, from a qualitative assessment of the UK's science capabilities, from advice from key stakeholders such as IUK, EPSRC, and the BEIS CSA (Professor John Loughhead), from a day long expert workshop hosted by the Royal Society, from multiple meetings that I and my officials have had with experts and industry, and from an iterative challenge process where the automotive industry (through the auspices of the Automotive Council) and the science community collaborated on a joint document that evolved responses to my challenges.

Definitions

R&D taxonomy varies widely, for the purposes of this evaluation I'm using the following terms:

a. Research: basic or fundamental science. Whilst basic science is often required as a precursor to solving challenges at higher technology readiness levels (TRLs), this is not a linear relationship – fundamental science can sometimes be directly applicable close to market.
b. Innovation: market and product driven problem solving, often leading to proof of concept.
c. Scale-up: manufacturing driven problem solving, often starting from a proof of concept and aimed at innovation in the manufacturing process, to scale up production and drive down cost.

Industrialisation: The construction or modification of commercial scale manufacturing facilities so typically not R&D, however it's the desired commercial outcome of the pathway through research, innovation, and scale-up.

Evaluation conclusions – addressing risks and opportunities

My evaluation reaches the following conclusions:

1. The UK has world class expertise across a range of areas in battery science (e.g. electrochemistry and materials science) that are directly relevant to solving near term and strategic challenges in energy storage in automotive and wider application areas. Harnessing this expertise in a coordinated 'application-inspired' fundamental research programme that cooperatively exploits the UK's strengths has the potential to create a step change in progress that would also significantly increase the UK's visibility and attractiveness to globally mobile investment.

2. This also creates an opportunity for a new approach to industrial strategy challenges, that is – to join up and coordinate across scientific research, innovation, and scale-up funders in a 'programme of programmes' led by a strong industry, science, and government partnership, to maximise the efficiency of translation of science into beneficial economic outcomes. Through the leadership shown by Oxford University and the Automotive Council in working with my office, potential leading industry and science partners have demonstrated a high degree of collaborative capability in reaching a joint position for this review on a rapid timescale. This gives me considerable optimism that such a 'programme of programmes' can succeed, but getting the governance right will be crucial.

3. A well-coordinated national scale science research programme that exploited the best of the UK's considerable capability in battery science, and whose objectives were 'application-inspired' and validated by industry, would send a strong signal to the automotive industry that the UK Government is serious about getting ahead of the game on battery R&D and has an industry-focussed strategic vision. This could play well in board level investment decisions, increasing the opportunity for battery related industrial collaborative R&D investments in the UK, and increasing the 'stickiness' of UK automotive manufacturing investments, including attracting and anchoring investments in the nascent electric vehicle supply chain whilst this market is still relatively fluid.

4. A globally competitive UK battery research programme that made the UK's science excellence much more visible creates a second very significant opportunity – that of attracting foreign direct investment from a major Tier 1 cell supplier (e.g. LG Chem, Panasonic, Samsung), for whom the UK automotive sector is a major and growing client. In the best case the twin incentives of a) a world leading national scale battery research programme geared to the automotive industry, and b) a dense cluster of high value OEM clients with growing demands, could attract both R&D and manufacturing. This could help to secure a second very significant benefit, that of incentivising UK automotive OEMs to locate battery module and pack manufacturing facilities in the UK, which in turn would help to anchor their vehicle assembly operations here and reduce disinvestment risks. **I recommend as a matter of urgency that BEIS work with DIT and the Automotive Council to explore these FDI opportunities (see 7 below).**

5. The opportunity to take UK science and innovation capabilities to the next level through a new 'application-inspired' research programme coordinated at national scale, and a strong governance framework to link this effectively through to innovation and scale-up activities – essentially a 'programme of programmes' – strongly suggests that such an overall programme at this stage would best be targeted at the immediate demand of automotive energy storage, rather than more widely at grid storage technologies. Clearly the benefits of the basic research will in any case be widely applicable, however the level of coordination required across science innovation and scale-up activities is such that it will benefit considerably from the focus provided by the clear technology challenge of the automotive transition. Once this new science and innovation model is demonstrated, there will be later opportunities to broaden scope and/or replicate to other challenges.

Evaluation conclusions – addressing implementation issues

In my view a research programme in this area, explicitly joined up through strong governance with innovation and scale-up activities, would prove a powerful new way of working for the science community and could provide a model for addressing industrial strategy challenges in other areas. The leadership and governance arrangements do however need careful construction to maximise benefits and avoid pitfalls. I recommend that the design of a programme adheres to the following attributes:

1. Application-Inspired fundamental research: The collaborative R&D programme should be directed towards challenges defined by industry.

2. Current and strategic challenges – balanced risk portfolio: To create sustained UK science leadership, as well as addressing current challenges, the research programme should also examine strategic longer term challenges which may be higher risk (e.g. sodium technology which is not currently in market, but if successful could bring prices down substantially). So whilst the challenges need to be industry led, the science community needs to have a significant input into defining strategic research which might not be on the current radar of industry.

3. Single national scale science programme, driven by excellence: The new way of working for the science community would be to maximise the UK's national expertise by harnessing research teams across the country in a single coordinated research programme addressing industry defined challenges. To maintain excellence, leadership of projects within the research programme should be competitively won by teams who would then join the research programme.

4. Exploiting existing assets in a networked model with a strong centre: There are a number of centres of excellence in different research domains around the country, many of whom have invested significantly in diverse specialised capital equipment. It would not be good value for money to attempt to duplicate this expertise and equipment in a single new centre, nevertheless there is merit in a single location focussing strong leadership for this initiative, which leads a distributed network (hub and spoke) of projects exploiting the diverse national skill-set. To drive a high quality centre and the reality and perception of due process in line with Haldane principles, I recommend that the central location and its leader be decided through competition according to a set of criteria derived from the attributes listed here, alongside a centre putting up significant institutional collateral and demonstrating strong industrial collaborative capabilities to drive value for money. The functions of the centre then will be;

    a. Show strong visible leadership and investment showcase
    b. Corral the UK battery science community to agree its priority strengths, including in longer term more strategic higher risk science
    c. Negotiate research programme objectives with industry (including strategic areas industry will not be sighted on, important to sustaining scientific leadership)
    d. Competitively commission a national scale set of projects to deliver on these objectives
    e. Run quality assurance and monitoring and evaluation, and an annual re-evaluation of the above

5. Strong Governance across two dimensions: This initiative alongside the creation of UKRI creates the opportunity to evolve the next step of the UK's innovation approach in two ways; 1) for the science community to work collaboratively to a single national research programme, so that the whole is more than the sum of the parts (rather than a sub-optimal set of uncoordinated projects) and; 2) for the research programme to be complemented by parallel innovation and scale-up programmes. These two dimensions will require two linked governance mechanisms;

    a. An industry-led senior programme board to agree priorities across the entirety of science, innovation, and scale-up programmes and to recommend industrialisation objectives to Government. This needs to include funders (including UKRI, EPSRC, IUK, Advanced Propulsion Centre (APC)) and industry, and to have the power to agree objectives that improve join up across these partners to maximise return on investment across the whole 'programme of programmes'. During the early focus on the automotive energy storage challenges, it makes sense for the well-established Automotive Council to lead the challenge definition and to be central to governance arrangements.

    b. A science-led research programme board to negotiate and agree the science programme objectives with the senior programme board, and to oversee project commissioning, quality assurance, and monitoring and evaluation. Whilst the science challenges should be industry led, the research board should also nominate strategic research objectives (e.g. sodium ion energy storage) for the purpose of maintaining the UK science base at the cutting edge of next generation technology.

    I do not have particular views as to the detail of this governance arrangement, except that form should follow the functions outlined here, so it needs the authority to drive agreement between funders for the overall purpose of efficient translation of science into the economy. Efficiency suggests also that existing governance and delivery channels should be co-opted where useful and where this does not compromise the coherence and identify of this new endeavour.

6. Industrialisation: This is mostly market driven, and ideally can be nudged by Government as an outcome of supported innovation and/or scale-up projects, or as a consequence of good marketing of the UK's science and innovation ecosystem to investors. Where national and local Government have seen industrial strategy advantages, they have used various instruments (e.g. RGF grants) to support industrialisation. The senior programme board should make recommendations to Government on industrialisation objectives, and specifically in the short term, **on priorities for attracting a Tier 1 manufacturer to the UK (see 7 below)**, as well as examining the potential to grow indigenous supply and supply chain.

7. **Attracting a Tier 1 manufacturer to the UK**: As the automotive industry transitions to hybrid and pure electric powertrain and the multinational OEMs adjust to the new strategic context of making and sourcing novel powertrain technology, it is not obvious that their future needs will be met by their current European manufacturing footprint. A key strategic consideration will be making and/or sourcing the large and heavy battery component and its supply chain. Transportation costs favour this being close to vehicle assembly. Whilst the large battery 'pack' is a competitive differentiator between OEMs, its fundamental component (the cell or pouch) is not, it is a commodity product sourced in bulk from Tier 1 companies such as Panasonic, LG Chem, and Samsung. The creation of a world leading UK battery science institution and research programme will be of great interest to Tier 1 companies with respect to research investment. However it also creates an impetus (alongside the attraction of a dense cluster of OEM clients), that could potentially make the UK an attractive place for manufacture, which in itself could help manage UK automotive disinvestment risks as OEMs are more likely to locate battery pack assembly and retain vehicle assembly here. **I recommend as a matter of urgency that BEIS work with DIT and the Automotive Council to mount a campaign seeking to attract such a Tier 1 manufacturer to the UK.**

8. Competitiveness, project management and quality assurance: Whilst the research programme should agree research priorities in line with industry needs and strategic considerations (a balanced risk portfolio), projects should be competitively commissioned within the programme to ensure excellence. Competition winners would become part of the collaborative R&D programme for the duration of their project. The programme should have

standard project management accountability and QA processes in line with those currently employed by IUK and APC. The programme board should have the power to close projects which are not delivering.

9. Intellectual Property and Standards: The programme IP regime should maximise returns to the UK economy, either through open IP arrangements or through more constrained arrangements where industry is putting in significant contributions which will ultimately benefit the UK tax payer. There are a number of areas where technical standards may ultimately drive competitiveness (e.g. in physical chemical and electrical properties, performance, tolerances, and connectivity) and BEIS should work with the National Physical Laboratory, the science community, and the Automotive Council to consider what part the development of standards might play in the overall programme for the purposes of maximising UK competitiveness.

10. Creating global visibility for UK science and innovation strengths: The research programme should work with DIT on global marketing opportunities, both in terms of generic marketing of the UK's science and innovation ecosystem, and marketing the battery research programme to specific FDI opportunities while this nascent supply chain is most capable of being influenced on international investment location.

11. Programme structure – The 'Faraday Challenge': The 'Faraday Challenge' should refer to the entire 'programme of programmes' (coordinating research, innovation, and scale-up programmes) and has the potential to take the evolution of the UK's science and innovation model a significant step forward, increasing the efficiency of translation of science into the economy. In contrast to current basic research programmes which are more broadly based and not explicitly linked to specific innovation and scale-up programmes, the industry defined challenges here are more tightly focussed and explicitly linked to innovation and scale up programmes by strong governance arrangements (see 5). The clear industry benefits should form the basis of a 'deal'. The quid pro quo for Government investment should be clear up-front commitments from industry (for example commitments to match funding the scale-up programme). There are choices about how to structure this, and BEIS needs to examine the merits of building existing relevant funding streams from EPSRC, IUK, and the APC into an overarching structure that includes a science research programme, the latter being a networked hub and spoke model with the hosting institution and leader chosen competitively (Faraday Challenge – Research Programme). Overall the differentiators between this industrial strategy 'Faraday Challenge', and existing research programmes, are;
    a. tight industrial focus (industry defined challenges)
    b. strong governance across research, innovation, and scale-up
    c. formal leadership and significant contributions from industry
    d. scientific and funding pathways through to industrial outcomes defined
    e. scale commensurate with desired industrial outcomes, i.e. a globally credible investment signal

12. Strong credible leadership: Just as the science programme board should be led by a senior globally credible science leader, the senior programme board leader should be an individual with credibility in industry, appointed through competitive selection.

13. Fast start: In parallel with competitive processes to host the science programme and lead the senior programme board, BEIS should investigate 'fast start' interim processes (e.g. shadow programme boards) to create a sense of pace and give the earliest possible strong investment signal to the automotive and battery industries, as was done with the APC (which quickly launched a shadow team and scale-up programme, while the hosting and senior leadership competitions were launched in parallel). The fast start should include the FDI campaign in 7.

14. Preparing the ground for wider energy storage challenges: It is clear that the science programme will have much greater potential applications than the automotive industry, particularly as energy storage demand grows. The senior programme board should review the programme scope annually to assess whether the benefits of wider scope exceed the potential risks to the new model in diluting attention. Certainly at the five year stage I would expect the overall programme to start to encompass wider objectives (grid and others).

15. Funding and collaborative partnerships - requirements: I would expect the programmes to follow standard practice in industrially led research by requiring industry contributions, at approximately 10% for research, rising to 33% for innovation and 50% for scale-up. For innovation and scale-up, programmes could incentivise HEI and SME collaborations by requiring these as partners in any project application. On overall funding my conclusions are that scale is important both in delivering on industrial strategy challenges at pace, and in sending investment signals globally that the UK merits serious attention. Taking account of Government's recent experiences on research council, IUK, and scale-up programmes (such as APC and Alan Turing Institute), I recommend of the order of £125-£150m each for the research and innovation programmes over 5 years. Given success rates through these stages, scale-up typically requires a smaller number of investments, but at significantly higher value, and attracting higher levels (50%) of industry funding. I would suggest scale-up funding of the order of £100m (matched). On industry led scale-up priorities, it would seem sensible to consider the Automotive Council's existing technology road maps for electrification as the starting point, but these should also take account of the strategic research identified in conclusions 2, and 5b, which have the potential to have implications at all technology readiness levels. On scale-up implementation, BEIS should consider the merits of the Automotive Council's proposal on an open access highly flexible prototyping and piloting production facility, and alignment with the recommendations of Richard Parry-Jones' ongoing review. BEIS would need to evaluate in detail profiling needs, and the extent to which existing funding streams and mechanisms could genuinely be incorporated into new governance arrangements and contribute wholly to the aims of the programmes (e.g. from EPSRC, IUK, and APC). BEIS would also need to consider these recommendations against other industrial strategy priorities not addressed by this evaluation.

16. Future proofing and course correction – 10 year vision, 5 year plan: The research, innovation and scale up programmes should build technology road maps with a 10 year outlook, from which 5 year plans should be made, clearly setting out the assumptions and levels of uncertainty involved at each roadmap step. These should be formally revisited annually.

17. Life cycle / second life issues: Early examination of life cycle and second life issues is essential to the ultimate form of new markets. At present the carbon cost of battery manufacture means that it takes some years for electric vehicles to become more carbon efficient than conventional vehicles. Fleet appetite for electric vehicles is also critically affected by any potential secondary battery life, which impacts on vehicle depreciation rates. Recycling opportunities also potentially impact secondary markets (by affecting disposal costs). Recycling considerations also affect primary design criteria, so should be considered from the outset. Richard Parry-Jones is currently reviewing UK market issues around EV uptake and manufacture, so BEIS should ensure that any relevant considerations of his review are built into design criteria for the battery research programme.

18. Skills: Increasing demand for energy storage in the automotive industry and more widely could be usefully anticipated by industrial strategy policy teams. Skill demands will go up at all levels, from doctoral and post-doctoral research skills, to graduate chemists, electro-chemists, and engineers (including systems engineers) to a large demand for technical skills in electrical and electronic engineering. I recommend that BEIS and DfE examine these skills demand/supply issues with a view to considering whether there is a case for additional interventions.

19. Applying this model more widely: A national scale coordinated research programme addressing a specific set of industry challenges, explicitly joined up to innovation and scale-up programmes with strong governance oversight of the whole in a single 'Faraday Challenge' programme of programmes, is a new way of working that has the potential to greatly increase the efficiency of translation of science into economic benefit. I recommend that BEIS apply this model to the energy storage challenge with a view to testing its applicability for other industrial strategy challenges.