Innovate UK

The Innovate UK response to the National Infrastructure Committee's call for evidence on Electricity Interconnection and Storage.

1. Innovate UK is the UK's innovation agency, a non-departmental public body sponsored by BIS. It is the prime channel through which the Government incentivises innovation in business. Innovate UK is business-led. Our governing board and executive team is comprised of experienced business innovators and experts. We work with people, companies and partner organisations to find and drive the science and technology innovations that will increase productivity and exports and grow the UK economy.

2. We are working to:
   - accelerate UK economic growth by nurturing small high-growth potential firms in key market sectors, helping them to become high-growth mid-sized companies with strong productivity and export success;
   - build on innovation excellence throughout the UK, investing locally in areas of strength;
   - develop Catapult centres within a national innovation network, to provide access to cutting edge technologies, encourage inward investment and enable technical advances in existing businesses;
   - turn scientific excellence into economic impact and deliver results through innovation, in collaboration with the Research Community and Government; and,
   - evolve our funding models to explore ways to help public funding go further and work harder, while continuing to deliver impact from innovation.

3. In line with our strategy[1] we operate across Government and advise on polices which relate to technology, innovation and knowledge transfer. We also support Government departments to become more efficient by supporting them in developing innovative solutions through harnessing the creativity that businesses can offer.

4. Innovate UK was established in July 2007 (as the Technology Strategy Board). We have committed more than £1.5 billion to date and independent evaluations have established that overall Innovate UK has created over £6 of GVA for every £1 it has invested and 7 jobs for every business it has invested in. Over the last 8 years this has added up to delivering a total of £7.5Bn and 35,000 jobs. The private sector more than matches that investment, doubling the power of public sector money, and we have directly supported over 6,500 companies. We work with nearly every University in the UK to stimulate the commercialisation of leading-edge academic research and innovation.

5. The energy sector has grown into one of Innovate UK's key priorities. Our aim is to help innovative UK businesses to take advantage of the opportunities that a rapidly changing energy system will present, both in the UK and in overseas markets. Over the last parliament we have invested up to £60m per year in support of hundreds of innovative businesses developing new products across the energy sector, from new supply technologies, through to new network-

[1] 'Concept to Commercialisation: A strategy for business innovation, 2011-2015'. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360620/Concept_to_Commercialisation_-_A_Strategy_for_Business_Innovation_2011-2015.pdf

based products and energy use efficiency services. Our 2012 – 2015 energy strategy articulates our objectives in this sector.[2]

6. Innovate UK supports businesses in two main ways. Firstly, we provide funding to allow development of high potential, ground-breaking new technologies and products that are too early and too risky for the private sector to fund alone. Secondly we help businesses connect to the right partners, expertise, test facilities, financiers and influencers that can accelerate their route to market. Examples of this support are the Catapult centres, launched by Innovate UK to provide critical expertise and test facilities to businesses in developing new products. Two of these are in the energy sector; Offshore Renewable Energy Catapult in Glasgow and Blyth, and Energy Systems in Birmingham.

7. A growing part of our energy portfolio is in 'energy systems' (by which we mean the development of an optimised, flexible, reliable and cost-effective system of energy supply across electricity, heat and gases). The experience gained in funding projects in this field, alongside setting up the Energy Systems Catapult has provided a great wealth of knowledge about the possibilities that will be provided by new technologies, products and services in optimising and enhancing flexibility of the energy system in the near future. This submission is written through this lens, intending to ensure awareness of the art of the possible in enabling network flexibility.

8. In summary this submission makes the following points, illustrated by our experience and projects:
    - Storage, Interconnection and demand response are three methods of providing critical flexibility to the network at times of stress. They should all be evaluated and incentivised on the same terms and built out in the most cost-effective way. There is little benefit in establishing a storage target or an interconnection target without a full evaluation of these technologies against the flexibility that can be provided by demand response or other methods.
    - We see a very large potential for demand response to provide cost-effective balancing services to the network enabled by new technologies such as sensor and communications developments, digital trading and aggregation platforms, new power electronics and more local engagement in balancing distributed generation to enable energy resilience. There is a risk of over-investing in new high capital infrastructure if the potential of these new resources, products and methods is not taken into account
    - Enabling the widest range of actors to take part in balancing the grid can enable lower bills for users and minimise investment costs. There are barriers in regulation that stop this from happening at present.
    - New business models that provide value across the range of actors in the network, and serve the needs of the end user will be just as important in enabling these opportunities as new technologies. Disruptive thinking from outside the sector can help accelerate the development of flexible grid systems but need to be encouraged alongside flexible and innovative regulation. We are starting to see Ofgem understanding the importance of this.
    - The pace of change in this sector is rapidly increasing. We are seeing a very high demand for support in this area from businesses, and multinational energy technology companies starting to engage heavily in these new ways of balancing the energy networks. It is essential that infrastructure is planned with these emerging technologies in mind to avoid saddling energy users with higher bills than necessary for decades to come. Our detailed submission follows.

[2] Innovate UK energy strategy at https://www.gov.uk/government/publications/energy-strategy-2012-to-2015

Q1. What changes may need to be made to the electricity market to ensure that supply and demand are balanced, whilst minimising cost to consumers, over the long-term?

9. **Summary of Q1 key points:**
    - The goal should be an electricity market that provides for the needs of current market stakeholders but is also very flexible to allow for future innovative disruptive business models that are likely to emerge at very short notice from outside the traditional energy sector e.g. the digital/ICT sectors in particular.
    - Innovate UK has a significant role to play in bridging the gap between current/future innovators interested in this sector by working with stakeholders such as DECC, Ofgem, and Elexon.

10. Supply and demand balancing methods are extremely varied, encompassing both supply and demand side tools at multiple scales, with many different types of stakeholders participating. Providing future low cost balancing tools (such as increased demand response, of which storage is a subset) which meet the needs of all users in the system will require innovation and creativity to bring forward new business models and technologies.

11. Below are two relevant types of business model that are becoming visible through Innovate UK funded projects:
    - Local energy use, and business models that encourage locally sourced energy to be used locally, such as for community benefit (reduced energy costs) and network operator management of asset life (through reduced thermal stress, and therefore investment deferral). Current market mechanisms and network use charging methodologies do not encourage this.
    - Micro energy trading, the ability for the owner of a small-scale low carbon technology asset to trade their energy or capacity on an ad hoc basis to another party who may or may not be local. This effectively means that this asset owner is a micro “ad hoc” energy supplier, which some existing market mechanisms do not cater for.

    New business models are emerging rapidly that enable these kinds of demand response in reaction to local or national grid needs, enabled by data and communications technologies emerging from across the economy. Future infrastructure plans need to take account of the pace of change in these emerging areas to avoid building infrastructure that is not fit for the 2020s and beyond.

12. In some of the above business model scenarios, storage is just one (but not an essential) type of energy resource involved. Over the coming 18 months as the above projects conclude, we will have a much clearer picture as to whether innovations of the above nature will lead to a significant reduction in the energy costs for those involved, though they do align with strong community (and individual energy user) interest in taking more control of energy locally and personally.

13. Innovations of the above nature will drive the need for changes in the way the current supplier model works, potentially requiring changes to the financial transaction and cost recovery processes that underpin the current energy system. Such reforms are not trivial as the current mechanisms are already extremely complex and based on the current industry structure. This challenge is something recognised by Ofgem and DECC. Elexon are also an essential party to facilitate this change and are forming a new innovation working group in early 2016 to engage with this agenda, and Innovate UK will support this knowledge and innovation bridging process.

Q2. What role can changes to the market framework play to incentivise this outcome:

- **Is there a need for an independent system operator (SO)? How could the incentives faced by the SO be set to minimise long-run balancing costs?**

14. Other parties are better positioned than Innovate UK to answer this question.

- **Is there a need to further reform the "balancing market" and which market participants are responsible for imbalances?**

15. Innovate UK is currently running a number of innovation development and demonstrator projects that show that the current balancing market is able to bring in new market participants and offer end value for customers. If successful they could engage end users more effectively in energy use, and energy management (such as making use of demand response, time of use tariffs, encouraging local energy production and use), enabling end users to reduce their energy costs[3].

16. The transparency that provided by the current mechanisms effectively rewards energy efficient use, and conversely disincentives high cost or polluting energy use. While Innovate UK does not currently have specific balancing market reform recommendations to make at this time, anything that increases the degree of transparency or fuller access to market mechanisms is welcomed.

17. There is potentially great benefit in enabling as wide a range of actors to participate in balancing as possible. If time of use pricing were available to all users, they could take advantage of new technologies and business models that enable them to minimise energy use at times of high price and vice-versa. Innovate UK has recently funded Tempus Energy to develop their technology designed to enable this for small businesses and domestic consumers, delivering lower energy costs and a more balanced grid.

Q3. To what extent can demand-side management measures and embedded generation be used to increase the flexibility of the electricity system?

18. **Summary of Q3 key points**
    - There are very significant opportunities in enabling demand response to deliver flexible network balancing resources by harnessing existing assets that are either unused or underutilised.
    - Catalysing new business models that enable fragmented benefits across the system to be aggregated to its full value is key to unlocking additional demand side and embedded generation capacity.
    - Using existing assets to provide balancing flexibility at key times of grid stress are likely to be much more cost effective, and therefore prioritised over build and operation of new assets, whether additional storage, generation or transmission.

19. Demand side measures
    Innovate UK believes there are significant opportunities to provide additional demand response capacity (DSR) using existing assets both to reduce system load when required but also to increase load (responsibly) when required. Evidence to support this:

[3] The list of projects in our localised energy systems programme is available at: https://interact.innovateuk.org/documents/1524978/14654581/Localised%20energy%20systems%20-%20a%20cross-sector%20approach%20-%20Competition%20results

- A recent DECC commissioned study[4] concluded that there is significant additional demand side response (DSR) potential in the future in many application areas. The study considers different future scenarios (based on the National Grid Future Scenarios modelling[5]) and given there are many uncertainties and variables the report makes it difficult to give a conclusive forecast.
- Below are some comparisons of asset capacities from Innovate UK sources that support that view. They are demand response/storage assets that are either currently completely unused currently, are only partially used or have significant future potential:

20. Assets currently unused for demand response
    - Hot water typically held in domestic hot water tanks where the sole heat source is electric immersion heaters – "in store" at any point in time = 23GWh approximately[6]. There will also be a hot water storage opportunity in commercial applications though this has not been quantified.
    - Distributed battery storage such as fork lift trucks.

21. Assets currently only minimal demand response capacity used
    - Cold stores/chillers.
    - Electric storage heaters. These are used in approx. 10% of UK dwellings[7]. Although many of these are aligned with Economy 7 tariffs, this is a passive use incentive system, not providing the active or dynamic value that such resources could provide if engaged in DSR, providing 3GW[8] of demand response load
    - Commercial building (e.g. air conditioning) and buildings heated by heat pumps (e.g. domestic). By treating the building effectively as a thermal battery short term by intelligently increasing or decreasing the activity of those systems over short (sub 30 minute) electricity network balancing can be achieved with effectively the same functionality an electricity storage asset. This opportunity will grow with the anticipated take up of heat pumps.
    - Industrial and commercial capability that is currently untapped or underexploited such as in the food and drink sector.

22. Future asset bases with demand response opportunity
    - Electric vehicle (EV) and plug-in hybrid vehicles (PHEV). The current electricity storage capacity of these vehicles on the UK roads 0.5GWh (based on Society of Motoring Manufacturers and Trader vehicle sales figures, assuming Nissan Leaf EV capacity for all EV, and Toyota Prius capacity for PHEV), rising to a capacity of 2GWh by 2020 and 4GWh by 2025 (assuming a year on year sales growth rate of 5). These figures are a very cautious minimum – the like for like 2015/2014 UK EV sales saw a 50% rise, and PHEV nearly 150% rise in sales.
        - This could provide significant capacity for demand response and Vehicle-to-Grid capability in the future with the right business models and infrastructure provision.

[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/467024/rpt-frontier-DECC_DSR_phase_2_report-rev3-PDF-021015.pdf
[5] http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Future-Energy-Scenarios/
[6] https://www.reading.ac.uk/web/FILES/tsbe/Saker_TSBE_Conference_Paper_2013.pdf
[7] https://www.reading.ac.uk/web/FILES/tsbe/Saker_TSBE_Conference_Paper_2013.pdf
[8] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/467024/rpt-frontier-DECC_DSR_phase_2_report-rev3-PDF-021015.pdf

- The Ofgem Low Carbon Network Fund (LCNF) funded SSE project “My Electric Avenue[9]” project has highlighted this as a credible opportunity from the perspectives of both energy system operators and vehicle user (assuming optional participation).
  - The TSO has just completed a study of the potential for EV and PHEV battery use[10] for grid frequency support, concluding a very positive outlook for the value to the network for balancing services.
  - Innovate UK believes business models will emerge that will support this opportunity.
- Second life (end of vehicle life, but still functionally useful for other energy applications) batteries from electric vehicles (and potentially the smaller batteries in plug-in hybrids), will start to become available in the next 6-7 years and in progressively larger numbers as the rising population of vehicles on the roads ages. These have the potential for re-use as grid support storage assets.
- Forecast 30% minimum bus fleet conversion to battery electric by 2025 (Western Power Distribution data sourced in its Electric Boulevards project[11]) based on surveys of bus operators.

23. The majority of the above areas have “turn up” capacity potential as well as demand reduction, effectively offering the characteristics of storage.

24. Embedded generation measures
Commercial scale. At larger embedded generation sites, Network operators already operate curtailment of large scale distributed generation in some circumstances, agreed with the asset owners as a means to achieve lower connection charges and manage local thermal constraints. An example is the UK Power Networks LCNF funded Flexible Plug and Play Project[12] an approach which enables increased embedded generation connection at different scales and voltage levels with acceptable levels of curtailment. This affects commercial wind, solar, and CHP connections and is an arrangement that has the potential for more wide-scale deployment.

25. **Micro scale.** At this scale (typically on a customer side of the meter), management methods for generation output are being explored by a number of Innovate UK projects[13], either coupling micro generation with storage, or incentivising local energy use. Specific examples of Innovate UK projects that are developing new balancing demand response capabilities are:
- **Project Upside** – providing aggregation of a wide range of distributed energy assets including demand side and storage. One of the assets targeted in this project are uninterruptible power supplies, with an estimated 2GWh of storage accessible to the Upside business model
- **Project EFES** – providing local energy balancing with distributed micro generation and storage, balanced against local energy use

26. In the case of both of these, the challenge they are seeking to address is to aggregate fragmented small scale resources and monetise value that is also fragmented and spread across different stakeholders in the system. This is a key innovation opportunity area for Innovate UK, supporting entrepreneurs in finding ways to draw together these fragmented benefits in bringing creative new business models and technologies to market, liaising with the necessary policy and regulatory

[9] http://myelectricavenue.info/
[10] http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Technology-reports/
[11] http://www.westernpowerinnovation.co.uk/Projects/Electric-Boulevards.aspx#FAQLink53;javascript:void(0);
[12] http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Flexible-Plug-and-Play-(FPP)/
[13] https://interact.innovateuk.org/documents/1524978/14654581/Localised%20energy%20systems%20-%20a%20cross-sector%20approach%20-%20Competition%20results

change processes in support, as well developing new supply chains for innovative solutions to be commercialised.

27. As an example of the business model challenge, in the aforementioned My Electric Avenue[14] project the effect of electric vehicles on the local low voltage grid infrastructure was studied. It estimated that the benefit "to the DNO" of time being able to time shift EV charging (e.g. into the middle of the night) as circa £20 per home per year to a DNO in avoided deferral. This alone is not felt to be a sufficiently compelling value proposition in its own to engage end users successfully or support a business model that delivers this functionality alone. However from a TSO innovation project[15] there is an additional opportunity to add in another piece of fragmented value that of providing grid frequency support services with Vehicle-to-Grid functionality, adding circa £25 per vehicle per year potential benefit for the vehicle owner/driver. The table below summarises the creative challenge of finding a business model that can aggregate and monetise these different types of fragmented value.

Function description	Beneficiary	Value to beneficiary	Benefit criteria
Remotely "managed" charging	DNO	Circa £20	This benefit is only applicable when the vehicle is charging (or needs charge) and is connected to a weak or thermally constrained part of the network, with the greatest likelihood that this would be called during the evening peak
Vehicle-to-Grid	TSO	Circa £25	This benefit could be realised at any time of the day and is generally not location-specific

Q4. What are the barriers to the deployment of energy storage capacity?

28. **Summary of Q4 key points**
    - Regulatory and market cost mechanism changes need addressing.
    - Successful creativity to increase DSR capacity using existing and emerging energy resources will reduce business case for dedicated "new" storage assets.
    - Battery technology costs will continue to reduce, forecast by circa 50% by 2020.
    - From an energy system functionality perspective network operators view storage as no different to DSR in their "tool box" for network balancing.
    - Justifying new storage assets for network balancing is likely to be a more capital intensive option than most other flexibility tools (interconnectors being the main exception).

29. Background
    - Transmission and distribution network operators do not envisage business as usual storage deployment within the current RIIO ED1 period from the perspective of thermal management or investment deferral. In the longer term it is very uncertain what the storage needs for the UK energy system will be, and the extent to which it will be needed. One of the objectives of the new Energy Systems Catapult is to inform this thinking.
    - There is currently very active TSO engagement with providers seeking new system frequency control capability, including many storage providers.
    - Storage is regarded functionally by distribution network operators as a means of providing demand response capability, and hence when seeking future additional demand response capability for thermal management they will be agnostic as to whether that capability is provided by storage or other means, For example contracting in the capability to reduce or

[14] http://myelectricavenue.info/

[15] http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Technology-reports/

increase load in a particular locality they look for the least cost means of achieving this whether that be by customer demand reduction, customer demand increase, or storage.

The perceived barriers to storage are described in the following two sections:

30. Barriers to the use of existing/future storage assets in grid support
    In answer to question 3 we listed storage assets that are either not utilised for grid support or where there is only a limited amount of utilisation, the most significant being:
    - Electrically heated hot water tanks, both domestic and commercial.
    - Storage heaters.
    - Cold stores/chillers.
    - Electric and plug in vehicles for demand response and vehicle to grid.

31. The principal barriers to the deployment of the above opportunities are:
    - Less appetite/interest by innovators in thermal (both hot and cold) storage innovations. An analysis of the funding for research and innovation projects funded by both EPSRC and Innovate UK, showed the number of funding awards for electricity storage outnumber the number of funding awards for thermal storage by a ratio of 7:1. A common view in the innovation community is that thermal storage isn't regarded as exciting as electricity storage.
    - The above factor leads to a limited engagement in exploring technology/business models that exploit commercial opportunities where thermal storage might be controlled in a manner that provide grid support. That isn't to say there is no activity; there are some examples of healthy activity such as increasing use of DSR for the control of aggregated commercial refrigeration loads and the commercial building/facilities sector is starting to engage in this area.
    - Active funding support to encourage demonstrators and the formation of new business models is a barrier to progression in these areas and Innovate UK is now assessing this funding priority amongst its other funding priorities going forward.

32. Increasing the future exploitation of the above resources could be achieved if opportunities were taken early to future-proof thinking and solutions where possible. Examples are:
    - Given the potentially significant balancing resources that will be available from electric and plug-in hybrid vehicles the automatic provision of Vehicle-to-Grid capability in charging points should be considered at the earliest opportunity.
    - Remote control provision for all new storage heaters to enable future innovation and business models to take advantage of.

33. **Barriers to dedicated new grid support storage**
    Non-technical barriers
    The barriers to deployment of new storage vary depending on the location of deployment. For example for network operator owned storage the barriers are more regulatory (e.g. legal status of storage) whereas for micro storage on a user's property lack of availability of time of use tariffs are a barrier to market. Below is a list of the main non-technical barriers:
    - Availability of time of use tariffs (smart meters rollout is essential to enable this).
    - Network Use of Service (UOS) cost mechanisms are extremely complex and do not work in a way that easily enables or encourages local and self-use of energy.
    - Ability to stack services on a given resource (i.e. to use a particular asset to provide different types of DSR service to different stakeholders). Network operators (especially the TSO) need different levels of certainty for different types of demand response and so have traditionally required asset exclusivity for different demand response functions. It is fully

recognised by the TSO that this makes the business case for dedicated storage weak currently and that as it increases its confidence in different asset and service types, that this requirement will soften in time and so improve the business case for storage usage.

- Status of storage from a regulatory perspective. For network owned storage this is a barrier. Storage is currently classed as a generation asset in the current regulatory model, and therefore does not fit with the regulatory definition the network operators have to work within.
- Successful acquisition of more DSR capacity is a barrier, for example every 1GWh of DSR capacity that can harnessed for grid support reduces the need and weakens the case for storage.

34. **Technical barriers**

- Technology cost (a factor at all scales and for all technology types). Industry predictions regarding the rate of fall in costs for battery storage vary but costs are typically quoted to fall by 50% by 2020, driven largely by the growth in electric and hybrid vehicles.
- Use of storage incurs energy conversion efficiency losses. These vary depending on the storage technology used. The technology most commonly used for electricity storage is Lithium Ion batteries which in grid applications demonstrate round trip efficiencies reported of approximately 80% (Northern Powergrid CLNR Project report)[16]. Low loss power electronic devices would improve this but they are not deployed in these applications because of their cost (of the order of >10x conventional technology).
- With energy conversion losses above of 20% this loss manifests itself as heat, forced air cooling of the equipment is required. Network operator trials have highlighted noise from cooling as being problematic with local residents in the vicinity of larger storage installations.
- There are a number of alternatives to battery storage in other energy vectors such as flywheels, compressed air, hydrogen, liquid air but their technology maturity is generally weaker and costs higher than Lithium Ion.
- Internet of things (IOT) market development. The information connectivity that will come from smart meters and IOT data for example has the potential to make an enormous impact and enable network operators to draw on DSR/storage resources in ways that we cannot conceive. As a comparator, the iPhone App store had 5000 Apps on it in 2009 – it now has 1.5 Million. The sort of business model creativity that produced Airbnb, Uber, and Waze is therefore anticipated to be a key opportunity in creating business opportunities that support the needs of energy balancing and end user engagement.

Q5. Are there specific market failures/barriers that prevent investment in energy storage that are not faced by other 'balancing' technologies? How might these be overcome?

35. **Summary of Q5 key points**

- The principal economic barrier is cost/investment costs, which will inherently be more expensive than DSR control of an existing asset.
- Because of its technical origins the dialogue around storage has historically been one of "technology push". Now that the agenda is shifting towards one of anticipated future commercial deployment there needs to be a clear and methodical focus across the sector on the range of likely common usage case scenarios and the economic case for each. This will provide the most effective and structured approach to evaluating the comparative

[16] http://www.networkrevolution.co.uk/wp-content/uploads/2015/03/CLNR-G026-Project-Closedown-Report-FINAL-V2.pdf

economics with DSR and the clearest view of barriers and investment cases for each use scenario.

36. Market failures/barriers
   - As a demand response tool, deployment of new storage assets for grid support is disadvantaged in its business case compared with DSR of existing assets because of the investment cost and management cost inherent a new asset resource. Despite this and the other barriers identified above, a number of network operators have been approached by third parties in recent months interested in connecting storage at distribution level to provide frequency balancing services to the TSO, wishing to engage early in what they see as an attractive sustainable future growth sector.
   - There is poor clarity of the commercial viability of storage deployment given the range of potential applications, the different benefits and barriers case to each and the different technology options.

37. Overcoming the barriers specific to storage
   Building and addressing the last point above, Innovate UK believes that there is a need for the sector to focus on the market failure/barriers to storage in a different way to how it has done so to date. The following are observations and sector characteristics for background:
   - This part of the energy sector has historically been heavily driven by "technology push'.
   - There are many different application scales (we believe of the order of 10-12) generic deployment/usage scenarios for electricity storage ranging from storage operated at the transmission level through to micro storage (e.g. domestic) at the other end of the scale.
   - The benefits, barriers, business models and technologies for each scenario are different in all cases.

38. The result of the above is a very complex and confusing picture with dialogue frequently segmented into separate areas of technologies, benefits, barriers, trials, without a clear picture for understanding or communicating the current commercial viability or outlook for the aforementioned 10-12 scenarios. This lack of clear perspective is in itself is a barrier to progress because it is hindering successful engagement of broader stakeholders.

39. Innovate UK has recently been advocating with stakeholders that a move away from "technology push" thinking to a thought process and communication approach that focuses around the above common scenarios on an individual case basis, so effectively describing the commercial picture for each of the 10-12 scenarios. So for each scenario in turn this would include:
   - The benefits and beneficiaries.
   - The options for monetising the fragmented benefits from the beneficiaries.
   - The barriers specific to that scenario:
     - what actions are needed to break them down?
     - which barriers will fall away naturally with time and when?
   - The most likely appropriate business model.
   - The most favourable technologies.
   - An overall view of the strength of the commercial viability for that scenario.

40. As well as providing a focus and clarity for the storage sector such a "commercial case scenarios" approach would also aid the development of business models or monetisation methods for other balancing innovation opportunities with other types of DSR asset. Innovate UK has found stakeholders very receptive to adopting this focus.

Q6. What is the most appropriate scale for future energy storage technologies in the UK? (i.e. transmission network scale, the distributed network or the domestic scale.)

41. **Summary of Q6 key points**
    - Given the size, diversity and varied history of our electricity network, storage is likely to prove to be needed and economically viable at various system levels and scales. There is unlikely to be an 'ideal size or scale".
    - There are too many variables in take up of low carbon technologies and in the future energy source mix to warrant simplistic rules on the extent to which storage will be required or timing of need.
    - Scale and location of storage should be led by the need of the application, deployed as and when those needs arise or when needs are identified as part of normal network planning. In all cases, taking careful consideration of the future likely scenarios known at that time for that locality is essential in order to minimise unnecessary infrastructure cost and avoid locking in solutions or assets that subsequently create other problems or unnecessary costs downstream.

42. Commentary to support the above

    Network/commercially deployed storage

    It is not possible to predict when and where storage will be the best balancing solution to deploy because of the significant unpredictability of low carbon technology deployment, both in type, extent and geographic location, uncertainty of our future energy source mix and uncertainty to which other balancing opportunities are exploited. Having a wide range of energy balancing and network management options (storage being just one) that can be deployed very quickly on a needs basis is the best approach to minimise additional infrastructure cost, and therefore cost to customer, and provide the most reliable solution for their local need. The network operator LCNF innovation programmes demonstrate the breadth of solutions being trialled directly in support of this aim.

43. The UK network is extremely diverse in its nature, local design, asset age, scale, load profile. The network operators have installed storage 14 locations in different LCNF projects all at different power and voltage levels. The chart below shows their power and capacity distribution.

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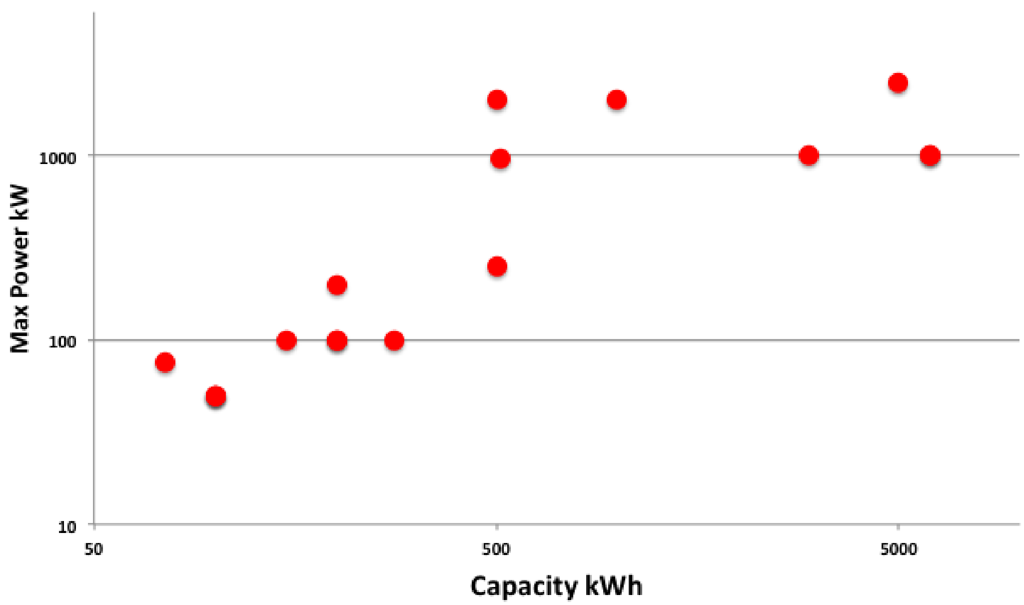

44. A common observation on the outcomes from such trials is that storage could have an appropriate network balancing role at a wide variety of voltage levels and capacities depending on the local need. Network operators may therefore in the future consider storage as a solution, at the scale and voltage level needed to suit the local circumstances as they arise, and balanced against other options for resolving those network constraints such as available conventional DSR.

45. The focus of many of Innovate UK projects is to aggregate smaller assets, including both utilisation of existing and new assets, with a portfolio of innovation projects currently in progress to evaluate the technical and commercial opportunity. The outcomes from these projects will be in the 9-18 month range. It is difficult to say how valuable the aggregation of these more fragmented assets will be from a system balancing point of view, although they certainly have other potential benefits such as energy user engagement. Innovate UK observes that many of the backgrounds and personal skill sets in these projects are from the telecoms and ICT sectors, who as newcomers to the sector, are demonstrating their ability to be both creative in terms of business model and to develop their propositions very quickly. It is important to mention that their ingenuity is focussed on providing sustainable business models that support balancing rather than storage deployment per se, but their creativity provides insight into the "art of the possible" both in terms of demand side system balancing but potentially supply side also.

Q7. What level of electricity interconnection is likely to be in the best interests of consumers?

46. The answer to the degree of interconnection required is dependent on the degree to which balancing tools can be achieved through other and lower cost means such as provision of additional demand response, take up of renewables, and improvements in renewables generation output forecasting.

Q8. Is there a case for building interconnection out to a greater capacity or more rapidly than the current 'cap and floor' regime would allow beyond 2020? If so, why do you think the current arrangements are not sufficient to incentivise this investment?

47. As described above, Innovate UK believes there is a great deal of potential for system balancing functionality that could be released by capturing the value of existing and forthcoming energy storage/demand response capable assets, and that deployment of these will benefit greatly from the digital sector, internet of things, and creative business models. Taking advantage of these anticipated "low investment" balancing tools should be considered as a first priority, and offset the need for high capital solutions such as interconnectors.

48. These "low investment", easy to achieve opportunities also frequently serve to engage end users very positively, and so contribute to improved end use efficiency, something that further interconnector capacity will not achieve.

49. The speed of change of many of the new business models emerging out of use of digital technologies and data means that new demand response opportunities are emerging very quickly. In this climate, it would seem poor use of public money to invest in high capital infrastructure faster than is needed, since the risk of building under-utilised assets is high.

Q9. Are there specific market failures/barriers that prevent investment in electricity interconnection that are not faced by other 'balancing' technologies? How might these be overcome?

50. Please see the answer to the previous question.

Q10. What can the UK learn from international best practice in terms of dealing with changes in energy technology when planning to balance supply and demand?

51. With the exception of the US, the UK is probably one of the world leaders in the development of flexible energy systems. The circumstances in every country are different with different energy source mix, energy use profile, system architecture, legacy equipment and decarbonisation strategies. However, there are significant learning opportunities:
    - At the macro level there is potential learning regarding how other countries plan, and design their future energy systems, in particular the mix of generation technologies, cross vector solutions (e.g. power to gas, market structure) and energy system decarbonisation strategies
    - At the micro level there is likely to be useful value in understanding methods other parties have developed for policy and regulation, monetising and aggregating value streams for different parties with a view to understanding how these could help the UK creativity in terms of business models, and practical innovation solutions.
    - Innovate UK already has a relationship with our peers in France and Germany and will seek to increase this engagement going forwards. For example, France has a unique network balancing environment with its high proportion of nuclear energy generation, and Germany has significant geographical energy balancing issues with a large proportion of its intermittent renewable generation in the North with a large proportion of its industrial energy use in the South.

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