Response to the consultation on:

A Smart, Flexible, Energy System: a call for evidence.

Response prepared by Prof. S. D. Garvey (Seamus.Garvey@nottingham.ac.uk) on behalf of the "IMAGES" consortium. IMAGES (**I**ntegrated **M**arket-fit **A**ffordable **G**rid-scale **E**nergy **S**torage) is a ~£4M EPSRC-funded project involving the Universities of Nottingham, Warwick and Loughborough as well as British Geological Survey. The project involves 7 leading academics directly as well as two geological experts:

Nottingham:	Prof. S. D. Garvey
Warwick:	Prof.s J. H. Wang, M. Waterson and R.S. MacKay
Loughborough:	Prof.s P.C. Eames and M. Giulietti and Dr. M. Thomson
BGS	Dr. D.J. Evans and Dr. J. Busby.

This response addresses Questions 1,3,4,5,6,47 and 48. It also adds two further comments at the end.

Responses to questions on energy storage

We welcome this development in OFGEM thinking on storage and the responses that follow should be seen in this light.

(1) Have we identified and correctly assessed the main policy and regulatory barriers to the development of storage? Are there any additional barriers faced by industry? Please provide evidence to support your views.

Under the restricted definitions of "storage" presented here, yes the main barriers appear to be correctly identified. In these definitions, "storage" is assumed to take energy from the electricity grid and return it there. There is a very significant class of "storage" solutions that can interrupt energy on its transformation path from primary forms (e.g. wind, solar, nuclear etc) towards becoming electricity and can store it there. This class of energy storage solutions does not face some of the challenges identified (for example the double-charging of levies) but does face some additional barriers due to lack of recognition. EMR, for example, explicitly prejudices against system solutions that can deliver both renewable energy generation and energy storage.

The systems in this class are referred to as "GIES" (generation integrated energy storage) systems and they are discussed in detail in [1] – which also notes several examples.

(2) Have we identified and correctly assessed the issues regarding network connections for storage? Have we identified the correct areas where more progress is required? Please provide evidence to support your views.

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(3) *Have we identified and correctly assessed the issues regarding storage and network charging? Do you agree that flexible connection agreements could help to address issues regarding storage and network charging? Please provide evidence to support your views.*

Our broad view is that storage provides benefits to many parties, amongst them distributors and consumers, and that the network charging framework should recognise this.

The document correctly identifies that storage is presently doubly-penalised by network charges. The document does identify the issues correctly and we agree that "flexible" charging is entirely appropriate. There are numerous possible models of this flexible charging and it makes sense to choose a model that incentivises the most effective use of the network asset. With the correct models, it is not necessary to distinguish between load / storage / generating units.

Most network charging models would have a flat component of charge for network use and a variable component of charge – both of which might be time-dependent. That is, at any one time, t, the charge made to a load / storage / generator might be … $c = A(t) \times |i| + B(t) \times i$ where i represents the current pushed into the network by the load / storage / generator. For pure loads,

$i < 0$ at all times. For pure generators, $i > 0$ at all times. With storage, i would be negative or positive depending on whether the storage was withdrawing energy or injecting it respectively.

It is critically important, and highly sensible, that $B(t)$ should be allowed to be negative for at least some proportion of time and that $A(t)$ should always be small relative to some measure of the average “size” of $B(t)$. Then, the network charges might (properly) be negative for storage at certain times whilst they would be positive at other times and overall (averaged over time), it would be guaranteed that storage would be paying positive network charges. These functions ($A(t)$ and $B(t)$) should be different for each node in the network. At nodes where there is predominantly generation present, $B(t)$ should be positive for most if not all of the time to incentivise the siting of loads close by. Similarly, at nodes dominated by consumption, $B(t)$ should be negative for most if not all of the time to incentivise the siting of generation close by.

This area is one that deserves close study through modelling and we strongly recommend that such modelling is commissioned from some competent quarter. From the perspective of operation, every user of the network (whether load or storage or generator) would appreciate advance knowledge of $A(t)$ and $B(t)$. It is very likely to be appropriate to set $A(t)$ constant for simplicity (at least on a year-by-year basis) and for $B(t)$ to be mainly pre-determined but not completely so.

We note that the use of even rapidly variable $A(t)$ and $B(t)$ as network charging functions is perfectly consistent with the objective here to exploit smart technologies to the full.

(4) *Do you agree with our assessment that network operators could use storage to support their networks? Are there sufficient existing safeguards to enable the development of a competitive market for storage? Are there any circumstances in which network companies should own storage? Please provide evidence to support your views.*

We would strongly recommend that network operators should not own storage outright. To permit this will corrupt the market. Even the possibility that a network operator might not apply the same terms to other storage operators and will inhibit essential investment. It seems acceptable for network operators to propose suitable locations and other parameters for storage to outside companies. It may even be defensible for them to own proportions of storage assets where this could indeed help to accelerate investments.

(5) *Do you agree with our assessment of the regulatory approaches available to provide greater clarity for storage? Please provide evidence to support your views, including any alternative regulatory approaches that you believe we should consider, and your views on how the capacity of a storage installation should be assessed for planning purposes.*

We agree wholeheartedly that greater clarity is essential to encourage the implementation of storage. This is not solely required with respect to regulatory approaches. It is also essential with respect to charging. Note, as in our response to question (4), that we consider it to be both possible and completely appropriate to treat loads, storage and generation in exactly the same way and thus to make the regulation much simpler overall for all parties. If this were done, it would not be necessary to agonise over how to “class” energy storage. It is simply another “prosumer” on the network.

(6) *Do you agree with any of the proposed definitions of storage? If applicable, how would you amend any of these definitions? Please provide evidence to support your views.*

The definitions provided in paragraphs 31 and 32 (and implicitly assumed throughout the rest of the briefing document) are restrictive and the restriction is a very serious matter prejudicing against the development of a class of solutions that could be more cost effective for the energy consumer. We alluded to this in our response to question (1) and support this observation with reference [1]. It is especially important, also, to recognise that synchronous condensers, although presently motivated by power-factor correction, do provide the most robust and fastest response energy storage conceivable (identical to the service provided by the spinning inertia of turbo-alternators). Synchronous condensers do not withdraw or inject any power from the grid (other than their running losses) if the frequency remains constant but as frequency is falling they naturally inject power. Correspondingly, as frequency rises they naturally withdraw power. The present definitions do, in fact, cater for the useful function that pure synchronous condensers can provide onto the system provided that power flows are resolved sufficiently finely in time. Page 5 of the consultation document (point 5e) refers to “minute-by-minute” balancing of the grid and we respectfully comment that this is not sufficiently fine time resolution. The grid inertia time constant is only a few seconds and it is becoming shorter as National Grid’s own System Operability Framework [2] recognises.

Synchronous condensers and variations on these are already proving that they will play a vital part in future grids [3] and some applications of these, [4], are certainly not consistent with the definitions of energy storage provided.

Within the options provided in paragraph 38, we view option (d) as coming the closest to a useful definition of storage for the purpose of discussing regulatory treatment. However, (as per the response to Q3), we consider that it should be possible to construct a regulatory treatment that deals simultaneously and equitably with loads / storage units and generation in a seamless way. If this were done, clearly there would be no need for a definition of storage that was distinct from loads or generators.

Responses to questions on innovation

We welcome this attention by OFGEM on innovation. We would concur that one of the most important targets to meet is that the environment should be conducive to all developments brought into the market that have the potential to deliver strong savings for UK energy consumers.

(47) *Can you give specific examples of types of support that would be most effective in bringing forward innovation in these areas?*

We assume that "these areas" is intended to mean the areas described in paragraphs 11 – 19 of section 6. The support already noted in the document would appear entirely appropriate for "these areas" but we recommend that a broader definition of energy storage in particular is borne in mind in this connection. (See response to Q1).

(48) *Do you think these are the right areas for innovation funding support? Please state reasons or, if possible, provide evidence to support your answer.*

The present grouping of proposed subjects (with the present definitions of energy storage) does not include any mention of exploring the potential for integrating energy storage with generation (see [1] and response to Q1). See also [5]. These systems could have very strong potential for the UK.

Further Comment

(a) The word "robust" (or "robustness") appears only four times in the call for evidence document. Three times, it is connected with aggregators and DSR. In the one other occasion, it is used with respect to the capacity market. The word has much broader significance. Robustness is a key property of the energy system of any advanced society. The term "smart" underpinning all of this consultation intrinsically implies maximising the use of intelligence. Overall, it is clear that smart approaches can add huge value but they can also degrade robustness. We urge that care is exercised to examine what are the effects on system robustness as the grid becomes more "smart". Real system inertia and simple local backup control systems to relate net power flow according to frequency may be almost redundant in a smart system when all elements are operating as they should but these properties buy the time required for remedial responses when some subsystems fail.

(b) The UK has very significant resources that could be tapped for energy storage[1]. When decisions are made concerning major (multi- £bn) investments in UK infrastructure, it is

[1] At an event entitled "The Future of CAES in the UK" held in "The Shard building (12/092016), Dr. David Evans from British Geological Survey reported that the UK has conservatively got the potential to store >50TWh of exergy in the form of compressed air held in caverns formed within deep underground salt beds in the Cheshire basin alone.

important to think not only about the effects of these investments on the UK energy system but also about the effects that these investments could have on industry and employment within the UK. Technologies that exploit immense quantities of raw material not innately present in the UK should possibly be favoured less than those where all expertise and materials required are indigenous.

References

[1] S.D.Garvey, P.C.Eames, J.H.Wang, A.J.Pimm, M.Waterson, R.S.MacKay, M.Giulietti, L.C.Flatley, M.Thomson, J.Barton, D.J.Evans, J.Busby and J.E.Garvey. *On Generation-Integrated Energy Storage*. Energy Policy 86, pp544-551, 2015. (Open access available at http://www.sciencedirect.com/science/article/pii/S0301421515300458)

[2] National Grid. System Operability Framework 2016. http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/System-Operability-Framework/

[3] http://www.gepowerconversion.com/press-releases/largest-motor-ever-produced-peterborough-out-door

[4] M.Ostman, R.Leikas, A.Ouni and N.Wagar. *Electricity network balancing for renewable energy integration with a hybrid generating system including a synchronous condenser*. http://pennwell.sds06.websds.net//2013/vienna/pge/papers/T7S5O3-paper.pdf

[5] S.D.Garvey. Summary of: *"Why the solution to a future energy crisis lies in our past"*. A discussion event held in the Palace of Westminster (on October 25th, 2016). Copy now available at … http://tinyurl.com/GIES-at-Westminster