National Infrastructure Commission
1 Horse Guards Road
London
SW1A 2HQ

8 January 2016

**National Infrastructure Commission call for evidence:**

**4. Electricity interconnection and storage**

Dear Sir/Madam

Shire Oak Energy ("SOE") is a UK based renewable energy development company focused on delivering innovative yet replicable energy solutions. SOE has significant experience in the development and delivery of renewable energy projects across the UK across different technologies. Through these development activities and within the wider context of an increasing volume of intermittent renewable generation in the UK energy mix, SOE has identified a significant requirement for additional flexibility in the UK electricity System (the "System"). In 2013 SOE began investigating the potential for additional Hydro Pumped Storage ("HPS") facilities in the UK. Over the last 3 years SOE has built up a portfolio of potential HPS projects ranging from 50MW up to hundreds of MW in capacity.

SOE welcome this call for evidence on delivering future-proof energy infrastructure and in debating the value of additional storage and interconnection to the UK System. Our submission focuses on the National Infrastructure Commission's key questions – our response will provide some context on how HPS could meet current and future System demands and our perspective on the current barriers and changes required that would facilitate the roll-out of new HPS plant in the UK.

**Introduction**

The current paradigm shift within the UK energy market (and indeed wider European markets) is being driven by a widespread move away from conventional, centralised, thermal, synchronous generation towards intermittent, embedded, non-synchronous generation. This change has various impacts on the overall stability and management of the UK System. An increase in intermittent generation creates a higher risk of imbalance, a reduction in thermal synchronous plant reduces overall system inertia increasing the risk of frequency based events due to a higher rate of change of frequency ("RoCoF"). An increase in distributed embedded generation creates visibility based management issues and amplifies regional effects.

National Grid is largely managing this change, which is happening now, through the procurement of additional flexibility from providers that are able to offer the services required to operate the System within the statutory limits set out in the System Security and Quality of Supply documentation ("SSQS"). Energy storage will play an increasingly important role in the management of this change due to its ability to mitigate imbalance risk in situations of over and under supply and in the provision of ancillary services required to operate the system with reduced inherent inertia and susceptibility to frequency based events.

### 4.1 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?

The introduction of UK and EU-wide renewable energy targets coupled with the implementation of financial support structures for renewable technologies has resulted in a widespread roll-out of renewable energy in the UK over the last 5 years from 9.2GW in 2010 to 24.6GW by 2014[1] with the largest change seen in solar PV. With such a rapid increase in the development of intermittent sources of energy, generally replacing baseload generators, the complexity of balancing supply and demand has increased significantly. Energy storage currently gives National Grid some of the tools necessary to help smooth out these disparities over a range of timescales, from days ahead to real time. HPS can also provide some of the ancillary services required to manage a network with inherently less mechanical and thermal inertia and a higher risk of increased RoCoF.

At a strategic level, there is recognition of the significance of HPS to the electricity market. The National Grid in Future Energy Scenarios (July 2015) states that electricity storage could be significant for the future balancing toolkit. Also, National Policy Statement EN-1 states that the only viable utility scale energy storage is HPS, and as there are only a limited number of these facilities in the UK, the development and deployment of these technologies is not yet at the necessary scale. The NPS also acknowledges that an energy pathway with a high level of renewables will require more storage into the future, which means that HPS will play an important role in a low carbon electricity system.

Furthermore, Houses of Parliament Post Note 492 (April 2015) endorses the role of HPS facilities to help the cost efficiency of the electricity supply by reducing the network capacity need. The Post Note states that a future energy storage sector could save UK consumers billions of pounds and also contribute further billions to GDP. The Carbon Trust in collaboration with Imperial College London showed that with the right development incentives, by 2050 energy storage could be delivering £10bn per annum in value to the UK consumer[2].

HPS is tried and tested – conventional HPS (which uses fresh water) currently provides 98.3% of the worlds installed energy storage capacity. The system uses electricity from the System to pump water from a lower reservoir to a higher reservoir. Pumping typically occurs during the night when electricity demand and price is low. During the day, the water is released back through hydro turbines to generate electricity again to meet morning and evening peaks and sudden spikes in consumer electricity demand. This cycle of pumping and generating generally repeats on a daily basis. Therefore, HPS is a way of storing electricity by turning electrical energy into stored (or potential) energy and back again. It is currently the only technology capable of providing significant levels of responsive storage at reasonable capital and operational cost (see Figures 1 and 2).



1 DUKES 2015: https://www.gov.uk/government/statistics/digest-of-united-kingdom-energy-statistics-dukes-2015-printed-version

2 Imperial College London: https://www.carbontrust.com/media/129310/energy-storage-systems-role-value-strategic-assessment.pdf

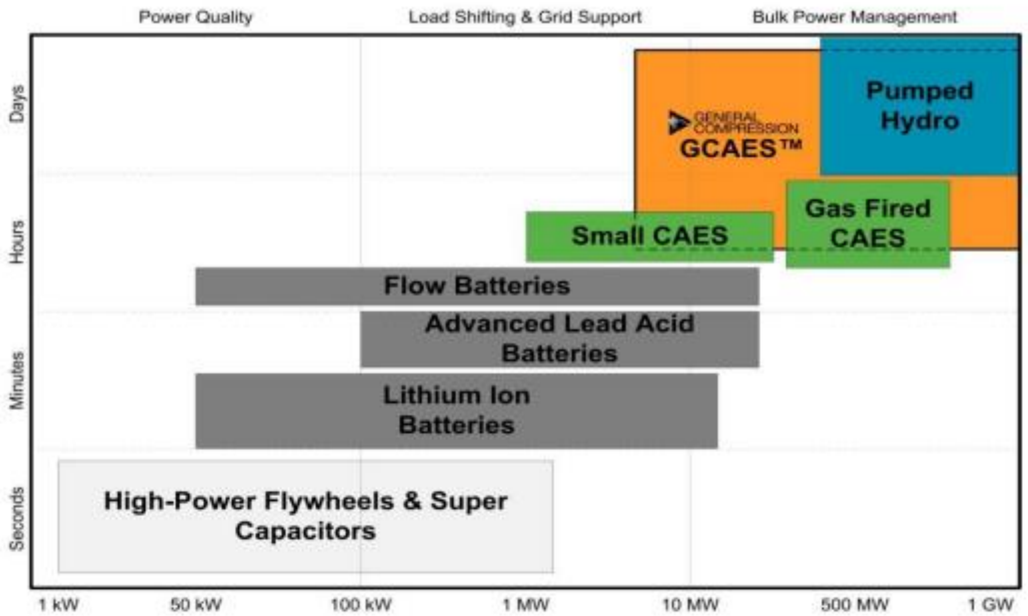


*Figure 1: Energy storage technologies, applications and scale. Source; Clean Energy Council, 2015*

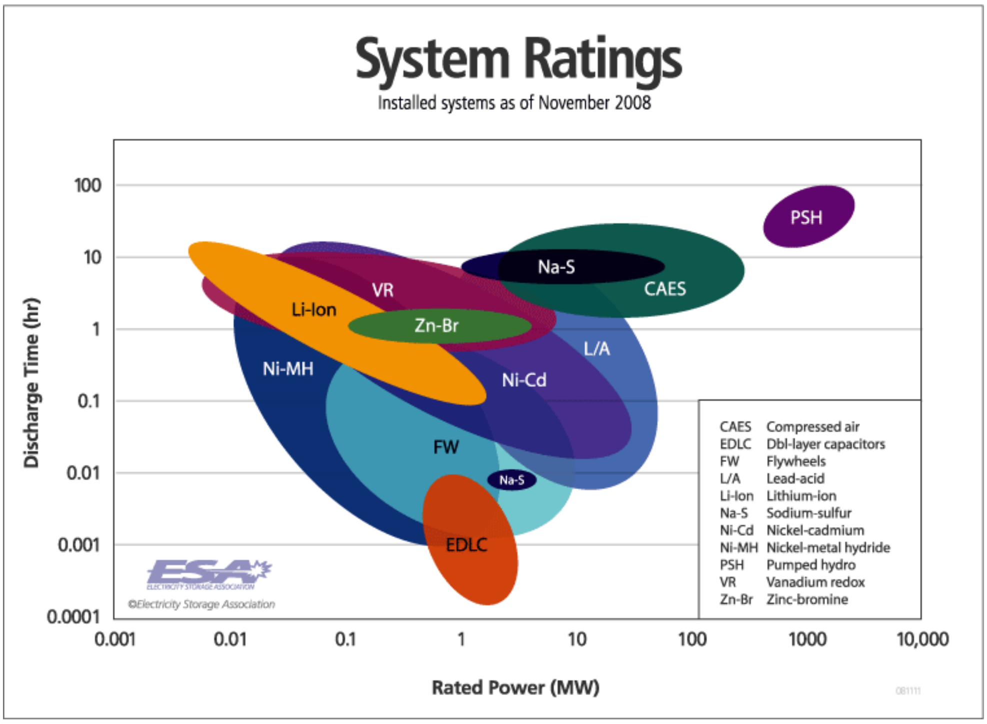


*Figure 2: Current energy storage technology capabilities. Source: Electricity Storage Association*

The UK has a track record in HPS though no development has taken place since the early 1980s; the following four conventional HPS plants are installed and operating in the UK:

| Scheme | Location | Capacity | Operator | Completed | Cost (2012) |
|---|---|---|---|---|---|
| Dinorwig | Wales | 1,728MW | GDF Suez | 1984 | £1,820m |
| Cruachan | Scotland | 440MW | Iberdrola | 1965 | £273m |
| Ffestiniog | Wales | 360MW | GDF Suez | 1963 | |
| Foyers | Scotland | 300MW | SSE | 1969 | |

More recently, planning permission was secured by Quarry Battery Company for a 49.9MW fresh water HPS scheme in the Snowdonia National Park. As Snowdonia Pumped Hydro, this developer is now seeking to increase the consented capacity of the project to 99.9MW through the Nationally Significant Infrastructure Project consenting process.

In addition to balancing supply and demand, HPS can also provide a series of ancillary services which contribute to the minimising of costs to consumers over the longer term, provide essential grid balancing services and support the stability of the System in an environment of increasing non-synchronous generation, reducing inertia and increased susceptibility of RoCoF events. There is a clear ambition at a national and international level to continue to improve the security, affordability and sustainability of the UK's energy mix. A robust energy storage network, at all scales, is vital to the successful deployment and management of a renewables-focused electricity network.

HPS provides further value to the UK consumer through the avoidance of expensive infrastructure upgrades that will likely be required to cope with the additional intermittent capacity connecting to the System. Energy storage provides the flexibility to manage supply and demand in real time and to buffer discrepancies between the two.

Many of the issues identified by National Grid are caused directly by factors in the Distribution Network rather than the Transmission System. There is a need for greater visibility and clarity to the System Operator over embedded generation and its performance which can currently only be observed and managed as a reduction in demand on the Transmission System. Whether this requires the creation of a new independent System Operator, an overhaul of National Grid's remit or the development of a Distribution System Operator ("DSO") model is debatable. SOE believe the mechanics of any new framework is more important than which particular body is responsible for operating the System.

HPS is generally connected to the Transmission System and dispatched by the System Operator. SOE is investigating the potential for Distribution Network connected HPS projects. The incentives and routes to market for this sort of scheme are not yet fully developed but SOE believe that the value of flexible plant within Distribution Networks, close to the source of significant embedded intermittent generation must be explored further. The efficient monetisation of embedded energy storage will rapidly incentivise a significant volume of development, managing the issues faced in the Distribution Network at their source without wider implications for adjacent Grid Supply Points or the Transmission System. A suitable market for embedded storage could have significant welfare benefits to the UK overall.

SOE believes that the current Balancing Mechanism, and the changes made through the recent Electricity

Balancing Significant Code Review to move to a single cash-out price for imbalance penalties, adequately captures and assigns responsibility for issues caused by imbalance. Transmission connected renewables are equally exposed to imbalance risk as conventional plant. Extending this concept to ancillary services, the main drivers for the level of frequency based services procured by National Grid is driven by the nature of conventional plant – large single generators that set the maximum infeed loss levels against which the System must be protected. Renewable units are generally modular and do not present such singular challenges to the System with the loss of single units.

Therefore, despite the strategic recognition and some policy support for electricity storage, and a track record for the technology in the UK, this is not translated to a market that functions to facilitate deployment of HPS. SOE believe that through reform of markets and innovation of technology, a new suite of potential HPS sites can be made available for development. We describe some of the barriers and considerations for resolving these barriers in response to question 2, below.

**4.2 What are the barriers to the deployment of energy storage capacity?**

Given the issues highlighted above and the potential cost savings to consumers available through HPS development, the UK has a time-limited opportunity to capitalise and facilitate a move towards a System with the necessary capabilities to transition to a low carbon energy mix over the next 20 years. Development of HPS projects takes 5-7 years from conception to delivery yet the drivers for HPS development are making their presence felt now.

The ability of the UK to increase renewable penetration and to be a global leader in the transition to sustainable, clean, affordable and secure energy production is dependent on the innovative development of a suite of energy storage facilities at all levels, from the domestic lithium ion battery scale to the Transmission System connected GW-capacity HPS scale. There is clearly already a disparity between the UK and other EU countries – Portugal has found the optimal ratio of energy storage to renewable capacity to be 1:3.5. This leaves the UK drastically under prepared with a current ratio of 1:8.7. This logic would see the UK increase its energy storage capacity from 2.8GW to 7GW immediately, without considering the possible doubling of renewable generation on the System by 2020.

Despite this clear and well-founded argument for increased development of energy storage there are still major barriers to new investment in this sector in the UK.

**Short term nature of contracts and markets**

The relatively high capital cost of large scale HPS projects requires long term debt financing. The lack of secure, long-term contracts with National Grid or through another mechanism has created a significant barrier for new investment into the storage market in the UK. Several developers in the UK have progressed HPS projects through the consenting process yet are unable to build out the projects due to a lack of bankability under current frameworks and contracts.

National Grid currently offer a maximum two year contract, leaving investors exposed to market risk beyond this timescale. Most new build HPS projects will be financed over 15-20 years creating a disparity between market dynamics and inherent risk.

**Prohibitive connection and Use of System charges**

HPS projects are liable for the same connection charging mechanism as conventional generators that are not providing System balancing and stability services. The cost of new connections reflects the additional capacity that the System in any particular region will have to cope with. HPS projects are operated in a way in which reduces System stress thus deferring the need for costly infrastructure upgrades with must be recovered through connection charges and Use of System charging.

As HPS imports and exports energy it attracts demand and generation Transmission System Use of System ("TNUoS") charges. These charges are levied by National Grid in order to claw back the cost of maintaining the infrastructure necessary to operate the System with the parameters of the SQSS. Given that HPS is generally taking actions to reduce System stress there is a valid argument for the exemption of HPS project from these charges.

Balancing System Use of System ("BSUoS") charging is also applied to HPS projects. These charges are levied by National Grid in order to recover the costs of imbalance in the System and the balancing actions that National; Grid has to take in each Settlement Period. The same argument is applicable to the levy of BSUoS charges on HPS projects given they are actively participating in the balancing mechanism as a tool for National Grid to reduce the impact of imbalance events on the System.

**Triad generation benefits**

Embedded generators are rewarded for providing energy to a distribution network during triads (loosely defined as the three settlement periods in which demand was highest). As HPS provides energy balancing and grid stability services it is highly likely that plant will be generating during triad settlement periods. However under the current framework Transmission System connected generators are not rewarded for generating or providing services during triads.

**Development of alternative HPS sites**

Conventional HPS makes use of mountainous landscapes with existing bodies of water with a significant difference in altitude between them but within a reasonable distance of each other. This tends to mean locations are limited to inland areas remote from settlements. To date, only one HPS scheme globally has employed the use of the sea as its lower reservoir, severely limiting the development of such schemes to a portfolio of fairly unique terrestrial environments. This limitation is due to a number of factors; the lack of knowledge and expertise (and therefore perceived risk) in the application of pump-turbines in alternative and marine environments; the cost of bespoke generators, drive trains and pump-turbines (where no standardization has occurred) and the perceived and real environmental impacts associated with the manipulation of the interface between marine and terrestrial environments and the safety concerns over the construction of artificial reservoirs near to conurbations. Innovation is necessary to overcome these barriers to greater roll-out of HPS facilities. For example, the development and demonstration of a seawater-based facility for the first time in the UK (indeed the EU) will stimulate the development of multiple comparable projects presenting opportunities for HPS facilities with lower economic, environmental and societal impacts in locations previously unconsidered by utilities, governments and developers alike.

**Addressing the barriers**

Investment in HPS need to be facilitated through changes to the existing routes to market and additional markets specifically devised to support HPS schemes. We would encourage further consideration of the following points:

- A storage-specific, technology-specific or new-entry specific capacity market auction with guaranteed long term contracts segregated from the wider auction where existing plant will always drive the clearing price down to a level that is unacceptable to new entrants, especially those with limited storage available, thus precluding them from other routes to market (the 2014 auction ended up at £19.40/kW, 40% of the CONE- cost of new entry, the 2015 auction settled at £18/kW). The current capacity market mechanism can only secure the longevity of existing and ageing gas, coal and HPS plant where there is little or no investment or operational modification required in order to benefit from the capacity market.

- Refinement of the capacity market auction process to allow HPS plant to compete directly with other technologies through its superior operational ability to respond quickly and to provide ancillary services.

- Further clarity on the role of embedded demand side response and storage. Also, increasing the responsibility of DNOs to manage their networks autonomously rather than passive role and reliance on National Grid to balance the system via the DSO model. This argument is becoming increasingly relevant as the volume of embedded generation grows. Mechanisms to allow embedded storage providers to work directly with DNOs ultimately decentralising the management and administration of the UK's electricity network should be discussed by industry and Government.

- Longer term firm frequency response contracts beyond 24 months to incentivise new entrants. The decreasing level of mechanical and thermal inertia on the system will create the need for further FFR providers in the future. HPS plant excels in this market and changes to the contracts with National Grid to provide more security and confidence in the market could incentivise new entrants.

- New ancillary services directly focused around the provision of synchronous inertia to the network.

- Dedicated contacts for difference for storage providers on a case-by-case basis (as is the case for nuclear), recognising the long-term value, energy security and sustainability that additional storage can bring to the UK.

- The development and implementation of hybrid-CfD structures that do not incentivise a purely volume based generation pattern. Structures that reward availability, response time and deferred investment in infrastructure.

- A request for National Grid, DECC, and regulators to give more guidance to the industry on what is required in terms of plant physical characteristics; storage capacity ramp-up and ramp-down times, response times, location, generation capacity.

### 4.3 What level of electricity interconnection is likely to be in the best interests of consumers?

The EU interconnection targets are a major driver to the development of new interconnection projects. These targets call for 10% interconnection by 2020 at a country level and 15% by 2030. The current pipeline has the potential to deliver up to 10GW of additional interconnection capacity in the UK.

In addition to a strong policy commitment, interconnection projects are provided incentives, EU subsidies and underwriting of minimum revenue streams, that results in interconnectors having significant competitive advantages over UK domestic generators and UK based storage. For instance, six of the eight interconnector projects proposed have been granted cap-and-floor structures by Ofgem.

Interconnectors are also exempt from the Carbon Price Support levy that would apply to UK domestic generators. Exemption from TNUoS, BSUoS and grid losses provide further competitive advantages to interconnector energy over domestic.

The effect of interconnection on UK welfare should be considered carefully. The impact of subsiding interconnection should be fully understood to inform the level of interconnection to the UK. It is SOE's view that the current level of interconnection to Europe in the UK could be sufficient to provide the required energy security alongside UK renewables and enhanced UK based storage and energy management solutions.

On the other hand, with appropriate pricing and volume controls to ensure a stable and fair market, the interaction between UK based HPS and interconnection could become increasingly important to the ongoing security and sustainability of supply. If UK based energy storage is integrated with interconnection, there is a balance to be struck in terms of opening a bigger and potentially more competitive market to support the HPS sector while ensuring that HPS facilities continue to support domestic networks at transmission and distribution scale. Interconnection alongside UK based HPS can both facilitate a move towards a more integrated and holistic management of energy, driving efficiencies in the best interests of consumers as we drive towards a low carbon economy.

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

**Market and system reform**

In the Republic of Ireland, Eirgrid have undergone a rapid and extensive operational overhaul driven by the development of large amounts of wind power. Ireland currently has 9GW of conventional plant and

3GW of wind power with a total peak demand of 6.8GW and a baseload demand of around 2.3GW. With only 1GW of interconnection to the UK, Eirgrid has developed operational frameworks that allow a high level of intermittent penetration while being able to operate the network securely and reliably. Eirgrid's DS3 system provides operational decisions to manage System Non-Synchronous Penetration of up to 55% with ambitions to increase this to 75% of the energy mix. This is an unprecedented level of non-synchronous generation penetration. DS3 has allowed the volume of wind penetration to increase rapidly while curtailment actions have decreased. This has been achieved by changes to RoCoF parameters, additional system services, revised operational policies and new control centre tools. This has seen a shift in revenue streams to generators moving away from energy payment dominated incomes to increased proportions of income from capacity payments and ancillary service provision. The availability of regulated tariffs fixed for five years and annual auctions with contracts for up to 15 years to encourage new investment have been pivotal in the changes seen in the Irish energy market over the last five years.

**Independent Government backed studies facilitating investment**

The roll-out of significant solar and wind generation in the USA also provides a useful source of learning for the UK in the net value of energy storage, in particular HPS which is currently the only technology capable of providing large volumes of energy over longer timeframes with fast response times at a reasonable cost. The USA Department for Energy has supported several detailed studies into modelling the value of advanced (variable speed) HPS in the United States. Led by Argonne Laboratories, the studies looked at revenue streams attracted by HPS projects in various locations through the provision of various balancing and stability services and through energy arbitrage (buying cheap and selling at peak). The analysis then went further to look at the displacement effect that the development of HPS would have on alternative services, plant and upgrades to the system infrastructure required to operate securely with increased levels of non-synchronous plant. A holistic analysis was then applied to the findings to reveal the overall system savings attributable to the development of HPS, thus illustrating the net welfare effect of supporting HPS development. These studies showed that under a base renewable scenario, California could expect to see a 3.36% cost saving with the development of fixed speed and variable speed HPS plant. Under a high wind development scenario this cost saving rose to 9.12%. The commitment from Government to support a holistic, in-depth analysis of the market, the dynamic effects, and benefits such as value for money, promoted targeting of investment and investor confidence to facilitate the energy storage sector.

**Technological innovation**

The Yanbaru Seawater Pumped Storage Power Station in Okinawa, Japan was commisioned in 1999 and provides valuable learning in terms of technology innovation necessary for greater deployment of HPS in the U, particulary utilisation of innovative landscapes and seawater based schemes. It has an installed capacity of 30MW and provides grid balancing and other ancillary services. Several innovative steps were taken to mitigate the operation of the pump-turbine in a seawater environment including corrosion preventative methods for parts of the pump-turbine through the use of paints, stainless steel and adjustable cathodic protection based on relative water velocities since corrosion is accelerated under higher water velocities. Similar protective techniques were devised for the wicket gates, gearing, turbine runner, shafts and draft tubes. Bio fouling issues were tackled through the monitoring of water velocities and the use of water repellent coatings.

**Conclusions**

- As part of a Europe-wide paradigm shift in the energy mix, the UK is seeing a rapid move towards non-synchronous, embedded generation both close to and far from demand centres. This represents a significant change from the centralised generation foundation that the UK System was designed and built upon. As such, major change in the operation and management of the System is required. The operational and market effects of these changes are making themselves felt now. The time to act is now.
- HPS is currently the only technology capable of providing large scale energy storage at reasonable cost with fast response times that are required for the safe and efficient operation of the System.
- HPS is a tried and tested technology and has been operational in the UK since the 1960s with four existing sites and potential for further development in alternative locations including industrial sites and seawater based schemes.
- The flexibility and System support services provided by HPS facilitates the continued take-up of renewable energy in the UK alongside conventional generation. The development of a suite of energy storage across the UK will reduce the overall cost to the consumer, improve UK welfare and enable the UK to meet its emission reduction targets.
- Significant barriers exist to the development of energy storage. A change to market frameworks to allow more flexible yet longer term contracting with National Grid, Distribution System Operators and/or a new independent Operator with visibility across the System, would encourage new investment into energy storage.
- Interconnection to the UK may improve energy security, but there is a balance to be struck to ensure that investment in UK based energy projects, and the UK energy market is not undermined.
- Ireland provides an excellent example of the innovation and change that is required to facilitate an increased penetration of non-synchronous plant into the System. Case studies in the USA have shown that significant cost savings can be achieved through the development of HPS on a system with a high proportion of renewable energy.
- SOE has a pipeline of HPS sites across the UK ready for development. An evolved market and regulatory environment could facilitate SOE to deliver significant storage capacity to the UK System enabling the transition to a low carbon energy mix.

Please contact me on [phone number redacted] or [email address redacted] if you consider, based on our submission, that further information or discussion will assist your considerations.

Yours faithfully

**Michael Edge**

**Development Manager**

**Shire Oak Energy Ltd**