Round Table 5 – SCOTLAND

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Grant Thornton, Glasgow

Participants	Company
Prof. Ian Arbon (Chair)	**IMechE**
Nathan Goode (host)	Grant Thornton
Dr. Jonathan Radcliffe	Centre for Low Carbon Futures
Dr. Stephen Livermore	Frazer Nash Consultancy
Steve Ruggi	Future Spectrum
Gareth Brett	Highview Power Storage
Toby Peters	Highview Power Storage
David Strahan	Liquid Air Energy Network
Sona Abaryan	Liquid Air Energy Network
Dr. Ing. Christoph Erdmann	Messer Group
David Brown	Scottish Engineering
Neil Ferguson	Scottish Enterprise
Terry Hogg	Scottish Enterprise
Ian Storrie	Scottish Government
Gordon Patterson	Scottish Government
Nigel Holmes	Scottish Hydrogen and Fuel Cell Association
Catherine Birkbeck	Scottish Renewables
Rufus Ford	SSE
David Pearson	Star Refrigeration
William Holt	Strathclyde University
Dr. Zhibin Yu	University of Glasgow

PRESENTATIONS

Toby Peters, on behalf of the Liquid Air Energy Network

The aim of the discussion is to debate and test whether there is an opportunity for Liquid Air Energy Storage (LAES) in Scotland.

On May 9th, the Centre for Low Carbon Futures published a report entitled; "Liquid Air in the energy and transport systems: Opportunities for industry and innovation in the UK". The six-month study concluded that liquid air could:

- Enhance energy security: a single gasometer-style tank of liquid air could make good the loss of 5GW of wind power for three hours;
- Provide zero-emission back-up and reserve services using smaller systems to replace diesel gensets;
- Reduce diesel consumption in buses or freight vehicles by up to 25% using a liquid air Dearman Engine / diesel hybrid;
- Cut emissions from refrigeration on reefer trucks by 80%;

- Raise the possibility of zero-emission liquid air city cars or vehicles at a fraction of current fuel costs and with lower lifecycle vehicle emissions than electric or hydrogen vehicles.

An important part of the debate is what liquid air could mean in terms of opportunities and jobs for the UK. The report concluded that the economic value of grid-based liquid air energy storage could be £1billion per year and 20,000 jobs by 2050.

What makes the technology interesting is that the industry is mature and the infrastructure is already in place. More specifically, LAES has no fuel combustion risk, is seven times more energy dense (by volume) than compressed air, has no geological constraints and is stored at ambient pressure (as opposed to compressed air which is stored at high pressure). Liquid air technologies can benefit from synergies with other processes and technologies, meaning that it is not a competitive technology but an additive one. It is particularly relevant to Scotland because of its potential to balance wind and other renewables, its ability to integrate with industry and its mature supply chain.

Gareth Brett, Highview Power Storage: Overview of liquid air energy storage and process

One of the main advantages of the LAES system is the possibility to integrate with other processes that produce heat to increase the overall round trip efficiency to 60%. Because the temperature of liquid air is low, using even low-grade heat can be interesting. Similarly, locating a liquid air facility near cold sources is also useful as you can use the cold in the liquefaction process. There are huge amounts of cold available at LNG terminals, for example, where efficiency could be raised to as much as 90% even without any waste heat.

LAES plants require modest space – 1500m^2 for a 20MW/80MWh unit – and investment costs are similar to those of pumped hydro, at £1000/kW and £400/kWh. For a non-fossil fuel, its energy density is good; a ‘gasometer’ style tank of the sort used at LNG terminals could hold 15GWh, which is bigger than Dinorwig, Britain’s largest pumped hydro storage plant.

The only danger with this technology is that, if the tank is left for too long, the liquid nitrogen can boil off leaving oxygen-enriched liquid, which is an oxydising agent. However, it takes a long time for this to happen and it can be controlled by monitoring oxygen levels and by adding more nitrogen as and when required. The industrial gases industry uses these tanks near chemical plants so the risks are well known and managed.

William Holt, University of Strathclyde: Potential for LAES in Scotland

William Holt researched the potential for LAES in Scotland for the CLCF report. Scotland has a target to generate the equivalent of its total electricity consumption from renewables by 2020, and to export as much electricity again. Scotland has a decentralised grid, which makes LAES attractive, since it is not geographically constrained.

The Scottish Government has recognised that energy storage could play an important and growing role in energy security and supply management, and has considered energy storage technologies including pumped hydro, compressed air, batteries, hydrogen fuel cell technologies and liquid air. William suggested LAES is based on proven processes, suffers no geographic constraints and benefits from existing supply chain capacity within Scotland – making it an attractive possibility to sit alongside the other technologies.

Previous studies in Portugal have suggested the ratio between renewable wind generation and storage capacity should be 3.5:1. On this basis, Scotland's 2020 target for renewable energy generation would require an installed capacity of 3 GW of storage, potentially 32 x 100MW LAES plants.

There are plans for 7bn investment in Scotland's high voltage transmission network between 2013 and 2021, and LAES could help mitigate these costs by reducing the need for transmission upgrades.

DISCUSSION

1. Energy Storage Technologies

Participants agreed the main competitor for LAES in bulk electricity storage is pumped hydro.[1] Two pumped hydro schemes of 600MW each are being considered in Scotland by SSE, but the company has not yet decided whether to go ahead since the economics are very challenging. Even if they are built, the need for energy storage will still not be satisfied, which suggests a role for other energy storage technologies. Investment costs for pumped hydro are similar to LAES – around £1m/MW – but can be three times higher if the geology is poor. Any future pumped hydro projects are likely to be more challenging physically and financially.

The attendees stressed the need to consider the lifetime costs and performance of different technologies. The performance of pumped hydro, CAES and LAES do not degrade during their lifetime, which is long; batteries do degrade, and their lives are shorter.

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[1] The Hydrogen and Fuel Cell Association added that for very large-scale energy storage, where the energy stored is likely to be more than 10GWhr, hydrogen has been identified as a possible solution. This would use salt caverns or depleted gas fields for the hydrogen storage, with the use of hydrogen fuelled turbines for the power generation. Large salt caverns are already used in Texas for hydrogen storage, up to 10,000 tonnes, and hydrogen capable gas turbines are being tested for CCS duty. It was noted that hydrogen also offers the potential to act as the 'bridge' between power networks and heat networks (ie Grid-Gas or Power-to-Gas concept).

2. Location

The discussion raised the question of whether it is best to locate LAES near sources of power, such as wind farms, or centres of demand, such as cities. Speakers agreed there was a role for both, depending on the location and nature of grid constraints. The discussion recognised that, on the whole, it does not make sense to move liquid air long distances in a road tanker - for distributed generation, for example - since the tanker's capacity is just 3MWh and transport costs are significant. The economics may work for distribution of liquid air as transport fuel, however, since it would displace high cost diesel.

3. Commercial Markets

Natural users of energy storage tend to be utility companies and energy-intensive industrials such as steel, petro-chemical, pulp, paper and food producers.
Unfortunately energy storage does not yet have a place within the energy market; there are no 'ring fenced' revenues to be gained from harnessing 'wrong time' energy.

The debate focused on how to structure a storage incentive system. Some speakers recognised the Treasury is financially challenged, making it increasingly important to find other kinds of incentives. Some felt that as a priority, energy storage must secure its own licence. At the moment it is classified as a generation asset, and this fails to recognise the benefits of being able to absorb 'wrong time' energy. During discussion, it was highlighted that energy storage should be treated as a transmission asset. This would make it easier to see storage as a cheaper method to accommodate renewables.

If there is a significant enough price differential between peak and off-peak power, wind turbine operators would benefit from storing energy and delivering it at peak times. In this case, the market itself would build storage capacity. Currently, however, the diurnal price spread varies from year to year, creating uncertainty that makes it difficult to build a business plan.

The geographical constraints of bulk storage technologies such as pumped hydro and CAES mean there are unlikely to be insuperable barriers to entry for LAES, should a ring-fenced storage market be created. However, other technologies such as renewable generation are financially incentivised (i.e. ROCs and FiTs), and the German example shows it is hard to create a competitive market within a system of subsidies.

4. Future of Energy Storage and Liquid Air

The participants were keen to highlight that investing in energy storage is a strategic issue, since there is no immediate threat to "keeping the lights on", but there will be in 2020, depending on which conventional power stations are closed down over the period. It is possible that by 2015/16, the capacity margin will fall to zero for a short period (a glitch) and demand will not be met. The reality is that unless we find mechanisms to provide extra capacity now, it is likely that fossil fuel plants will be used. Storage is something that requires investment now in order to do the learning and cut costs in future. The challenge is to look to predict how these technologies are going to evolve, which is actually being encouraged by the UK Government under STOR.

Energy storage should be seen as existing to enable renewables, and not as competing with gas or other energy vectors.

5. Transport

Alongside energy storage for electrical systems, we need to consider a broader system including transport. Liquid air is also being developed for transport as a hybrid solution that converts waste heat to power and reduces fuel consumption by up to 25%. Modelling suggests a London bus could achieve this kind of fuel saving with 190kg of liquid air per day, giving a payback in 2-3 years. Liquid air can also be used to provide refrigeration in a combined power and cooling system. This application could provide long-term CO_2 savings of more than 80% and a payback within a year.

The advantage is that, at current liquid nitrogen costs, the transport application already makes economic sense, especially given the excess supply of nitrogen, a by-product of liquid oxygen plants. In the UK, the surplus of nitrogen gas is 8,500 tonnes per day which could in principle be used to power 6.5 million car kilometres or ~ 42,000 buses daily.

There are similar opportunities in South Africa where liquid oxygen plants are being built and nitrogen is being dumped, which could be used as a storage medium to provide energy security in a country with volatile electricity supply.

6. Scotland

Two years ago the Scottish government published an electricity generation policy statement, but has long recognised that electricity is only part of the story. The Scottish Government is committed to emission reductions from heat, is currently developing a heat generation policy statement, and recognises that storage potentially sits somewhere in between electricity and heat generation.

Over the next few years the Scottish Government plans to produce a comprehensive energy policy statement covering electricity, heat, transport and storage. Among other things, the report will look to consider potential roles for the various storage solutions, including their impact on other generation and transmission technologies. The Scottish Government's energy policy is based upon four pillars and should deliver:

- a secure source of supply;
- at an affordable cost to consumers;
- which can be largely decarbonised;

- and which achieves the greatest possible economic benefit and competitive advantage for Scotland, including opportunities for community ownership and community benefits.

It was argued that even if it is not possible to develop the market this minute, the opportunity should not be missed at the risk of being forced to buy the technology from overseas later. The table also recognised that it is necessary to look at the supply chain; civil engineering capabilities etc. where 60% of the supply chain value could be retained in the home market.

7. Conclusions

- If Scotland's 2020 targets imply an installed capacity of 3GW of storage, and if 60% of the value of that storage can be sourced at home, the value to UK/Scotland could be £2bn.

- To develop liquid air in Scotland, we need to demonstrate electricity system benefits and the potential to deliver high value engineering jobs, and develop a supportive market/policy framework.

- The strongest argument in favour of LAES may be the challenge to the Scottish electricity grid posed by the Scottish Government's 'decarbonisation' targets. If community benefits can also be demonstrated it will help.

- It is difficult to export a technology if there is no domestic market. The way for Scotland to capture both electricity system and economic benefits is to become the first mover.

- Liquid air needs to be on UK and EU roadmaps. In the UK, the key is to keep the TSB abreast of technology development. The technology can also be used for Smart Grid applications that require storage.

- It was noted that Scottish Renewables is keen to explore this field and plans to hold events to investigate the issue of energy storage further.