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An analysis of the application of a liquid air energy storage system in an industrial application

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As energy prices continue to increase and therefore the cost of peak electricity also likely to increase, the importance of reducing peak electricity demand becomes ever more important. In some cases, peak energy demand management can assist in reducing energy costs. For example, in situations where processes run constantly or industries where the peak demand operate in the 4-7pm national demand peak. In situations where peak demand cannot be reduced, energy storage could be an appropriate option. For industries that have available waste heat or excess chilling processes (i.e. an unused temperature differential), liquid air energy storage could be a suitable technology. The relatively small footprint of LAES can also make it an appropriate solution for sites with limited available space.

Liquid air energy storage lends itself to on-site installation on any site with an energy demand that exhibits diurnal peaks. Due to the increase in storage efficiency experienced by LAES from using external waste heat or indeed waste coolth, LAES lends itself to installation in a wide range of industries. Some of these industries include: Petrochemicals, Water Treatment, Metal processing (e.g. steelworks), glass production, Building Heating Ventilation and Air Conditioning, industrial food production and datacentres are some of the potential market for LAES.

Highview Power has installed a 300 kW pilot plant in 2011 on the site of the Scottish and Southern Energy Slough Heat and Power site. Schemes of this type would be suitable for a number of industrial and users including the water industry. With the aid of any waste process heat, the electrical round trip efficiency of a liquid air energy storage system is significantly increased. Liquid air energy storage also occupies a relatively small geographical footprint when compared to other energy storage technologies such as pumped storage hydro and underground compressed air energy storage, which is important on a site where spatial constraints are likely an important consideration

In the future, LAES could reduce the peak energy demand of industrialised areas. As referred to in chapter 6 of the report, industrial gas production creates a significant surplus of nitrogen (in the region of 8500 tonnes per day); this nitrogen is currently returned to the atmosphere. The existing gas infrastructure could be modified to liquefy this surplus nitrogen. This liquid nitrogen could be tankered to a site utilising LAES or indeed used at the point of generation to reduce the peak energy demand on site. This liquid nitrogen could provide additional energy storage capacity at a lower cost by utilising a waste product. The use of waste liquid nitrogen becomes increasingly attractive if, say, the works is situated near to a location that has a large steel or chemical industry, where it may be financially beneficial to enter into supply agreements with the local gas suppliers which could yield a mutually beneficial situation.

Potential Downsides of LAES

- Waste heat needs to be managed
- There is a risk that the scale of LAES could be inappropriate

- Lower round trip efficiencies unless waste heat in excess of 70 °C is used compared to pumped storage and batteries

An Analysis of the use of a Liquid Air Energy Storage System in a Waste water Treatment Works

The water industry in the UK used 9,016 GWh of energy in year 2010/11[1] with approximately one third of this being used directly for sewage treatment.

The energy consumption profile of the waste water treatment industry follows that of daily energy usage peaks due to waste water assets being most heavily loaded when the population are active. Spot electricity prices are at their highest between 4 and 7 pm. This peak in electricity prices means that there is potentially a significant cost benefit to be achieved by shifting this electricity demand from peak times. In order to reduce the peak electricity demand associated with waste water treatment, an energy storage solution could be installed.

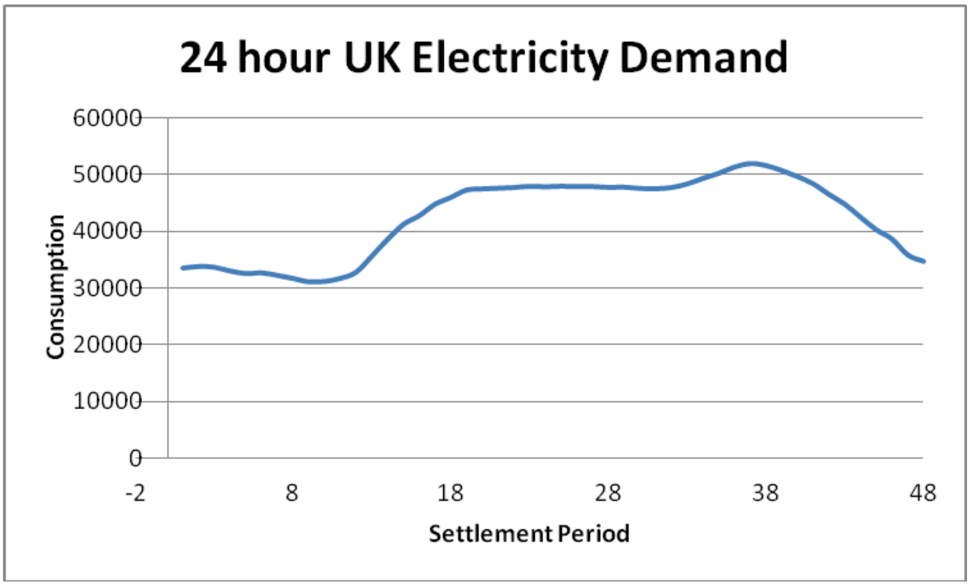

Figure 1 - The UK electricity demand on the 21st of February 2013

As shown in Figure 1, the UK demand peaks between 4 and 7 pm. This demand peak is when spot electricity prices are at their highest.

Case Study: Liquid air Energy Storage in a Sewage Treatment works

For the purpose of this white paper, we are looking at the suitability for installing LAES on a Waste water Treatment Works.

96% of UK residential properties are served by utility owned Waste water Treatment facilities[2]. Diurnal variations in water use patterns mean that the energy consumption at Waste water Treatment Works tends to have energy demand peaks. These demand peaks occur at the same time as national energy demand peaks. It is invariably the case that the utility company may pay a higher price for the consumed electricity at these peak times, these charges can be passed on to industrial users.

1 http://www.water.org.uk/home/news/archive/sustainability/sutainability-indicators-10-11-31-01-2012
2 http://www.defra.gov.uk/publications/files/pb13811-waste-water-2012.pdf

In order to combat the high cost of peak energy, energy storage solutions could be used offset the onsite peak electricity demands to a time where the electricity price is lower. Liquid air energy storage has the potential to store a large amount of energy, and does not require large amounts of space or rely on geographical features in the same way that technologies such as underground Compressed Air Energy Storage and Pumped Storage Hydropower do. LAES would appear to have a higher round trip efficacy than compressed air energy storage and Hydrogen. LAES also offers safer and easier storage than Hydrogen.

Liquid air energy storage is expected to be a modular and scalable solution that can be tailored to the energy requirements of individual sites. The round trip electrical efficiency of liquid air energy storage is further improved if external heat is applied. Waste water Treatment Works have numerous sources of waste heat including waste heat from secondary treatment blowers, waste heat from CHP engines (flue and any heat not required for heating the anaerobic digesters) final effluent is often a higher temperature than ambient.

Many water companies are installing or have already installed renewable energy solutions such as anaerobic digestion and Combined Heat and Power engines along with other technologies such as wind, hydropower or solar photovoltaic. Storing electricity generated by renewable sources as opposed to exporting it allows for the offsetting of high rate imported electricity instead of receiving a lower export rate.

Figure 2 below shows the 24 hour demand profile for a large Waste Water Treatment Works overlaid with the average hourly UK electricity demand[3] showing how the Waste water Treatment Works demand generally follows the UK average demand. The use of an energy storage system could reduce the peak demand significantly by using off peak electricity or excess on site renewable energy in order to reduce the peak energy consumption. This reduction in peak electricity can also serve to reduce the agreed connection rating with the local Distribution Network Operator that the Waste water Treatment Works is connected to, reducing the rating of the connection is likely to reduce the standing charges experienced by the water company. This reduction in the connection capacity can lead to lower electrical infrastructure costs on sites.

[3] http://www.nationalgrid.com/uk/Electricity/Data/Demand+Data/

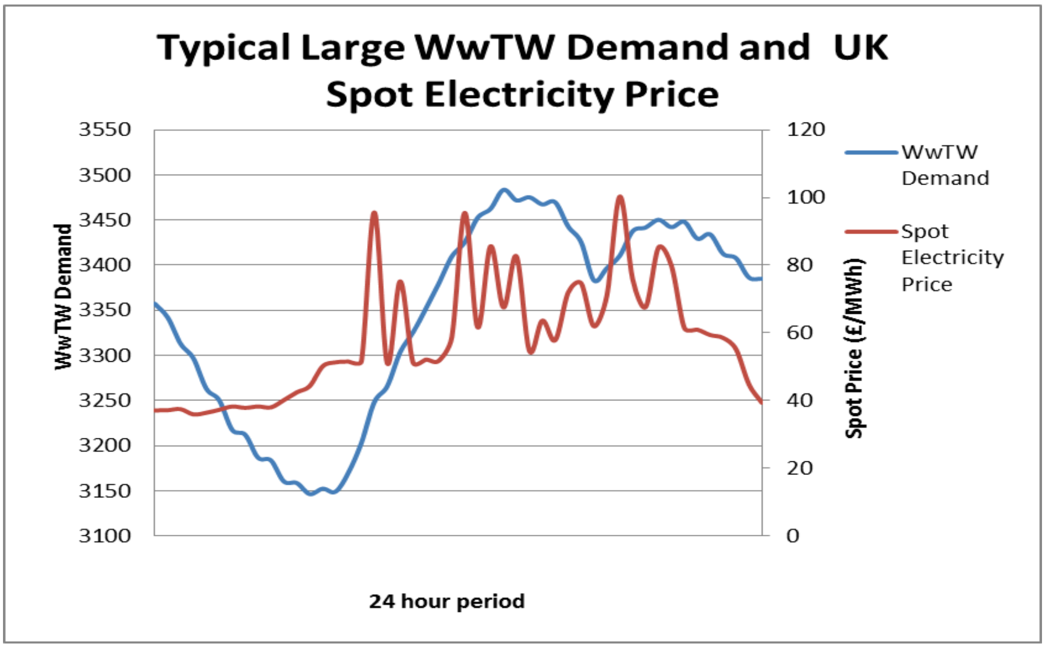

Figure 2 - The demand curve for a Sewage Treatment Works compared to spot electricity prices on February 21st 2013

Figure 2 shows how the electricity spot price and the electricity demand for a Waste water Treatment Works correlate. Note, it is uncommon for water companies to pay spot electricity prices. However, if there was a financial incentive then this may change. It is expected that an electricity cost in the order of £55-60/MWh could lead to a cost benefit for the user.

Example Cost Benefits and Simple Payback

A LAES system in the 3MW size region with an installed cost £1,500 per kW. A 3MW LAES system is therefore expected to cost in the region of £4.5M. For the purpose of this assessment, a round trip efficiency of 60% has been assumed. This is the expected round trip efficiency for an optima LAES system or a system using waste low grade heat.

The waste water company could use the LAES system on one site to offset the peak energy usage on other sites by using a 'netting' or 'sleeving' agreement with their electricity supplier if required in order for the peak stored energy to offset the demand at a number of sites.

As discussed in chapter 9 of this white paper, LAES is also expected to be appropriate for providing STOR. For installations exceeding 3MW this can generates another potential revenue stream of approximately £32,000 per MW capacity per year.

For the simple payback calculation, an off peak electricity price of £40/MWh and a peak energy price of £100/MWh have been used.

Accounting for some liquid air loss and additional charging in order to be able to provide STOR capacity (an additional 10% of off peak electricity), the simple payback has been estimated in the region of 25 years. If a subsidy or capacity mechanism was to be applied, this simple payback would reduce.

External Waste Heat

If waste heat is not available, it may be possible to use closed heat and cold recycle system, tis is expected to have an approximate round trip efficiency in the region of 50-60%. If adequate temperature waste heat is utilised this round trip efficiency can further increase to around 75%.There are a number of potential sources of waste heat that can increase the efficiency of using a liquid air energy storage system. Any temperature above ambient will increase the round trip efficiency, if waste heat at 115°C is utilised, the round trip efficiency can increase to approximately 75%. The potentially available sources of waste heat at a WwTW include:

- *Waste CHP heat*
- *Combustion of excess biogas from the anaerobic digesters*
- *Waste heat from blowers and other electric instruments*
- *Reclaiming heat from digester effluent*
- *Reclaiming heat from final effluent prior to return to the environment*

Although there are a number of waste heat sources at a WwTW, these sources may be spread out throughout the site and are all at a range of temperatures. For example, digested sludge will be at approximately 37°C whereas the final effluent will be only marginally warmer than ambient temperatures. The lack of available useable waste heat at a high enough temperature is an obstacle to the viability of LAES at a WwTW.

Potential Benefits

The main benefits of installing an energy storage system at a Waste water Treatment works:

- *Reduction in energy costs*
- *STOR payments*
- *Reduction in the peak energy import – Potentially reducing connection charges*
- *Higher utilisation of onsite energy generation (if installed)*

Liquid air energy storage could have a significantly lower upfront cost than other energy storage technologies. Due to the use of already mature air liquefaction equipment combined with lower civil engineering requirements compared to other technologies including pumped hydroelectricity and compressed air.

The installation of an energy storage solution increase the utilisation of any on site renewable energy generation therefore further reducing energy costs. Many WwTW have renewable energy installed on site, at times when the renewable energy production exceeds the demand for the site the electricity is exported to the grid at a lower rate than electricity is purchased. If this excess renewable energy is diverted to energy storage instead of exported to the grid, the energy can be used to displace higher cost peak electricity.

Another potential advantage for the Waste water industry is the potential ability to use the air released from a LAES system. The air output from the LAES can be expelled at a pressure above ambient; the exhausted air could potentially be utilised directly into the anaerobic treatment phase meaning that blowers could be switched off or reduced during the times that the LAES is generating. This could lead to a twofold reduction in peak demand at the site.

Alternative Usage Options for a Liquid Air Energy Storage System

At a waste water treatment works, there are a number of processes that use air and rotating machinery, In order to reduce the number of conversion steps in the liquid air energy storage process, using the liquid for air driving mechanical instruments instead of electricity.

Summary

Liquid air energy storage appears to be a technically viable method of energy storage that can be installed on a Waste water Treatment facility. In line with all other energy storage systems, without an additional financial incentive, it is unlikely that the installation of an energy storage system at a WwTW will be financially viable at present.

For a WwTW, it is estimated that a LAES system will have a simple payback of approximately 25years if the storage is also used as STOR along with an on-site energy storage system. This approximately 25 year payback period is estimated without additional subsidy, any future incentives could dramatically reduce the payback period.

Conclusion

LAES appears to be a promising solution that has the potential to offer an energy storage medium with a low upfront cost when compared to other technologies. It has a relatively high energy density when compared to other technologies, is constructed using mostly mature technologies and is expected to be straightforward to operate and maintain.

Given the range of potential uses for LAES, It would be favourable if LAES was implemented in a range of scales in order to benefit different on site usage patterns and enable LAES to compete with other energy storage technologies such as battery energy storage as well as larger technologies such as Compressed Air Energy Storage and pumped storage hydro.

In order to ensure that LAES is a cost effective energy storage solution, it is important that the design and supply chain is managed in a way that uses the existing mature air liquefaction systems to drive down LAES costs.

To enable LAES to gain a foothold in industry, it will be important to educate industry in order to gain an understanding of the relevance of energy storage technologies such as LAES and to understand how LAES could be beneficial.