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Gases for Life

The business case for industrial gas company investment in Liquid Air Energy Storage

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The industrial gases sector and specifically the process of air separation and liquefaction is one of the most electricity-intensive industrial processes, perhaps behind only production of aluminium and chlorine (electrolysis).

For the production of liquid oxygen and nitrogen costs equivalent to ca. 50% of sales are typically incurred for the purchase of electricity. A single air separation plant may have a power consumption well over 20MW.

Managing the cost of electricity is therefore a key aspect of business strategy in the industrial gases sector. This is typically the responsibility of energy specialists, who work closely with production management to arrange suitable contracts with energy suppliers that minimise total cost within the constraints of efficient operation.

There are two issues of concern:

- **Total cost:** although electricity prices are currently depressed due to the continuing European financial crisis and recession, most forecasts suggest electricity prices will continue to rise until 2030 (see Figure 1).

	Current Policy Initiatives			
	2005	2020	2030	2050
Gross electricity generation (TWh)	3274	3645	3780	4621
Shares in gross electricity generation				
RES share	14,3%	34,5%	43,6%	48,8%
Nuclear share	30,5%	23,9%	20,7%	20,6%
Fossil fuel share	55,2%	41,6%	35,7%	30,6%
CCS share	0,0%	0,7%	0,8%	7,6%
Prices in €				
ETS (€(08)/t CO2)	0,0	15,0	32,0	51,0
Average electricity price (in €(08)/MWh)	113,1	148,5	159,0	159,9

Figure 1: Roadmap 2050 - Impact assessment and scenario analysis. Source: European Commission

- **Price Volatility**: even before the introduction of significant amounts of renewable generation, European power prices were fairly volatile.

Electricity market vs. FTSE 100

Figure 2: Electricity prices vs FTSE100 share indext. Source: EDF Energy, 'Fact Sheet – Energy Price Volatility'

As the proportion of renewables in Europe's production mix increases, so the volatility may be expected to increase still further. This is exemplified by the rising frequency of 'extreme' events where wholesale prices even become negative:

> "In the first couple of weeks of 2012, the frequency of negative hourly prices in the Central West European power markets, mainly in Germany, multiplied compared to previous quarters.. ..
> In January 2012 there were five days with negative prices for several hours. On the 22nd of January 2012 between 06:00 and 07:00 in the morning the hourly German power price was -100.1 €/MWh, implying that power producers *had to pay* twice as much as the usual price magnitude *in order to sell* the produced electricity in the market. **The main reason for the more frequent occurrence of negative prices was the increasing share of wind generation in the power mix** coupled with inflexible load and relatively mild weather in January."
> Source: DG ENERGY, 'Quarterly Report on European Electricity Markets', MARKET OBSERVATORY FOR ENERGY, VOLUME 5, ISSUE 1: January 2012 – March 2012

Rising volatility and rising total cost mean that for an industrial gases company there is rapidly increasing value and substantial competitive advantage to be gained by optimising both the consumption and the purchase of electricity. Indeed, the two are inter-related since forward contracts offered for a power demand which may be expected to fit better to the generators' production profile will generally be more attractively priced.

The key power consumers at an industrial gases facility are the main air compressors prior to the cold box for air separation, which have limited turn down and flexibility, and the subsequent liquefaction units for the production of liquid oxygen and nitrogen.

One approach to reducing cost is to use that flexibility which does exist in the operation of an air separation facility, especially in liquefaction, to match energy demand as far as is possible with lower prices on spot markets. In order to be able to take advantage of such opportunities for price arbitrage it is typical to purchase only a portion of a company's total electricity demand forward.

A second, related approach is to sell such flexibility to the network operator as a service (so called 'positive reserve'), so that the network operator can require power demand to be cut at short notice if so needed to help balance the grid – subject to certain conditions which ensure that the consequent shutdown is not too arduous for the gases company. The prices paid for grid balancing services are typically in two parts: 'availability', per MW per year, and 'utilisation', per MWh.

Recently accepted prices in the UK Short Term Operating Reserve (STOR) market for seasons beyond year 5 of the scheme (i.e. 2011/2012) are around £100/MW/year plus £200/MWh:

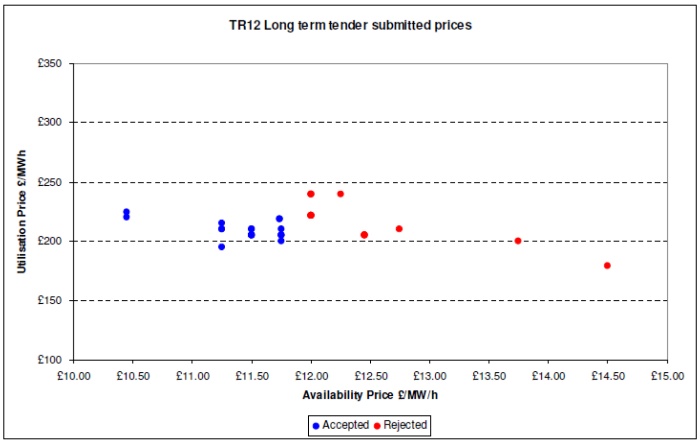

Figure 3: Short Term Operating Reserve tenders 2011/12. Source: , STOR Market Information Report: TR 12', National Grid[1]

The demand for 'positive reserve' amongst grid operators is set to increase with the increasing share of production from renewables. In a recent (2010) consultation the UK's National Grid forecast growth for positive STOR under the 'Gone Green' scenario of over 75%:

[1] http://www.nationalgrid.com/NR/rdonlyres/DF4A00A0-DEF2-4D1C-AD96-8101C6630216/44031/MIR_TR12.pdf

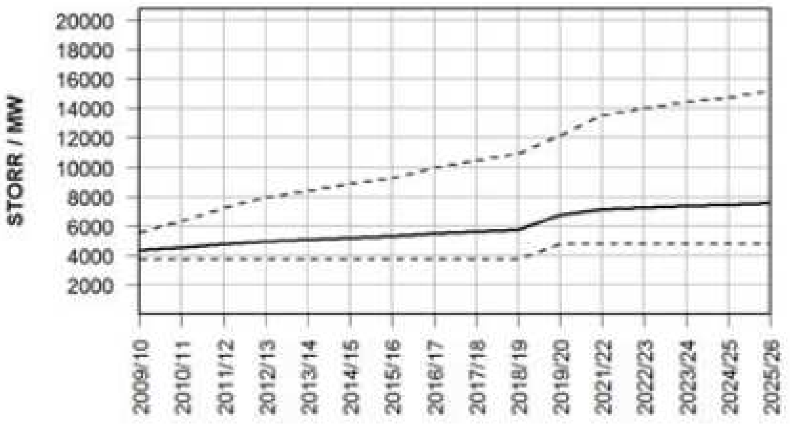

Figure 4: Future Balancing Services Requirements: Reserve Source: National Grid[2]).

The costs of delivering such 'positive reserve' for an industrial gases company are twofold:

- the costs of inconvenience due to production being interrupted at short notice,
- the costs of opportunities missed as a consequence of being shut down.

The volume of positive reserve an industrial gases company could deliver in this way is limited by the power demand of the unit(s) that can be shut in on request by the network operator.

Figure 5: Air separation plant at Siegen, Germany. Source: Messer Industriegase GmbH

This constraint could be eased if, in addition to the electricity demand shut in, it were possible for an industrial gases company to supply power back to the network operator from the cryogenic product previously produced and already stored in large tanks on site.

[2] http://www.nationalgrid.com/uk/Electricity/Balancing/services/FutureRequirements/

The possibility of using a pre-existing liquid nitrogen storage tank in a dual role, both as store of liquid nitrogen and as a store of energy, is a potentially useful synergy available to a cryogenic electricity storage (CES) system at an industrial gases site. Further synergies arise because a liquefaction unit for refilling the tank is also already at hand[3] and there may be various ways by which the excess cold that arises when electricity is generated from the cryogenic product can be efficiently returned to the production process. Theoretically at least, the only substantial additional investment required may be for the power turbine.

The additional costs for an industrial gases company of providing such extended positive reserve - providing power back to the grid during a time of shutdown ordained by the grid operator - are:

- the direct costs of liquid nitrogen consumed;
- the capital costs of additional investments and modifications (e.g. power turbine);
- the costs of opportunities subsequently missed on the gases market due to liquid nitrogen volumes being consumed for energy generation;
- less the value of the cold energy reclaimed.

According to the European Industrial Gases Association (EIGA)[4], the benchmark specific electricity consumption necessary for the production of liquid nitrogen is 0,549MWh/t.[5] If 50% of this energy can indeed be recovered in the form of cold, stored if necessary and re-used efficiently on-site when producing electricity from liquid nitrogen, then the net energy cost per tonne of liquid nitrogen passed through the turbine is 0.275MWh/t.

Presuming that the energy produced from each tonne of liquid nitrogen, as Highview Power Storage suggests, might be in the range 0.1-0.15MWh (where higher values assume the availability of waste heat), the overall round-trip efficiency may be 35-55%. This would probably be adequate to cover costs since the ratio of average electricity prices paid by 'very large' UK industrial consumers in 2012[6] to the prevailing utilisation price is about the same ratio (80/200 = 40%).

The 'availability' payment, currently around £500/year for a system comprising a 5MW turbine and corresponding storage and liquefaction capacity at an industrial gases production facility, would therefore need to cover the capital costs of additional investments and modifications, opportunity costs and the level of profitability desired. Current availability payments are clearly too low to cover these costs, but can be expected to rise significantly in liqht of the sizeable additional reserve capacity prequired by 2020 according to National Grid projections.

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[3] It is to be recognised however that both tank and liquefier may be found to be undersized if now expected to perform a dual role, serving both industrial customers and the grid operator. If so, additional investments may be necessary.

[4] http://www.eiga.org/fileadmin/docs_pubs/PP-33-Indirect_CO2_emissions_compensation_Benchmark_proposal_for_Air_Separation_Plants.pdf

[5] At 285 K and 1.013 bar.

[6] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65940/7341-quarterly-energy-prices-december-2012.pdf

It is only to be expected that early investments in a novel technology such as Liquid Air Energy Storage can only proceed with financial support from government. In return, by supporting such a project with an industrial gases company, government would obtain a demonstration of a cryogenic energy storage system at commercial scale at much lower cost and risk than through a stand-alone project. On this basis, further investments at other industrial gases sites and stand-alone sites could be expected to go ahead with reduced even no support from government.