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ISSN 1755-3857
www.gasworld.com
July 2013
Issue 98

gasworld magazine

Carbon dioxide

Supply and quality issues

Can the supply chain challenges be overcome – and how?

Economic climates and the global dry ice market – what impact?

"There would be abundant opportunities for merchant CO_2 from a variety of waste streams..."

Inside this issue: CO_2 recovery • Interview with SACGA • Liquid air gasworld

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Paper from responsible sources
FSC www.fsc.org
FSC® C010219

Printed by wyndeham roche
www.wyndeham.co.uk

Welcome

It's arguably one of the most renowned gases in the public domain and rarely seems to get a good press – yes, our focus this month is on carbon dioxide.

Fundamental to a wealth of applications, and a list that continues to grow, you could almost question why carbon dioxide (CO_2) gets such a bad press. From food-grade CO_2 for the food and beverages business to a strong rejuvenation in enhanced oil recovery operations as a result of the shale gas boom and fracking, CO_2 is in vigorous demand in both developed and emerging economies.

Historically, major CO_2 markets have been located in North America, Europe, and Japan, but new demand hubs are up-and-coming in the developing world markets, highly driven by beverage carbonation, and cylinder gas needs. Concurrent with infrastructure and economic growth in developing world markets, there will also be more CO_2 found in other applications over time.

> "...there will also be more CO_2 found in other applications over time"

Meeting these demand hubs, however, is not always so easy. There are sourcing and quality issues in the global CO_2 supply chain, and developing markets are sometimes restricted due to expensive, small sources from combustion alone. This is something that CO_2 consultant and regular **gas**world writer Sam A. Rushing explains in his lead feature month.

For a gas that is so often given a bad press for its global warming potential (GWP) and carbon footprints, carbon dioxide is increasingly in favour in something of a 'green' application – dry ice blasting. While this is an application that we generally explore in greater detail in **gas**world's annual *Green Issue*, this July issue also sees IceTech talk us through some of the trends in the dry ice market from page 48.

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Liquid air

Nitrogen economy or false economy?

As liquid air continues to gather pace and plaudits, **gas**world looks at its feasibility, at the heart of which are industrial gases and expertise.

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When **gas**world's exclusive supplement broke ground with the first real exploration of the liquid air concept in October last year, few would have been familiar with the notion and its potential; a proven energy storage technology that could play a critical role in Britain's low carbon energy future.

Since then, the liquid air project has gathered considerable momentum, both in the mainstream and technical press and behind the scenes on its finer details.

All of which culminated in the launch of a comprehensive new report in May, titled 'Liquid Air in the energy and transport systems: Opportunities for industry and innovation in the UK'.

The use of liquid air could increase UK energy security, cut greenhouse gas emissions, and create a storage industry worth at least £1bn pa and 22,000 jobs, the report found. Published by the Centre for Low Carbon Futures (CLCF), the report concludes that liquid air technologies could also significantly increase the efficiency of road vehicles, particularly in Britain's fleets of buses, vans and refrigerated lorries.

Key advantages are cited as including:

- An abundant and cost-free feedstock
- Cryogenic liquid production, its distribution infrastructure, and its equipment supply chain are mature
- Storage is at low pressure and there is no fuel combustion risk
- For grid-based storage, no geographical constraints as with pumped hydro or large-scale compressed air energy storage
- The energy density of liquid air compares favourably to low-carbon competitors
- For transport applications, very fast refuelling times are possible
- Cost competitive to other low-carbon technologies

Can it work?

So liquid air is heralded as a pioneering solution to the problem of energy storage, capturing 'wrong time' energy – such as excess renewable energy produced at night when there is too little demand – and storing it to provide peak time electricity and/or low carbon transport fuel.

It can be used in proven grid-scale energy storage systems (Highview Power Storage has been running a pilot plant hosted by SSE in Slough for two years) and a number of novel engine designs.

It has also often been pointed out that this could have significant benefits – and added revenues – for the gases industry. The production of liquid nitrogen and liquid oxygen, the main components of liquid air, has of course been pioneered by the industrial gases industry for over a century.

The properties of liquid nitrogen and liquid air are similar, so it is felt that a cryogenic energy vector could be provided by either; the gases industry has surplus liquid nitrogen production because there is four times as much nitrogen as oxygen in the atmosphere, but much less demand for it commercially. It is estimated that there is currently an estimated 8500 tonnes per day of off-peak gaseous nitrogen available for liquefaction which, if harnessed and used as transport fuel, would be enough to power the equivalent of 6.5 million car kilometers daily.

It is therefore projected that, aside from the experience and expertise that could be provided to the liquid air network, a 'nitrogen economy' could inject added revenues to the gases industry in the future as it makes use of a surplus product. If it takes off as hoped, a nitrogen economy could not only help to decarbonise energy supply, but could also be the stimulus for an even more prosperous industrial gases business. With the industry essentially at the heart of this new energy frontier, what is its response to liquid air?

When asked about the idea in an exclusive interview with **gas**world in Paris last year, Air Liquide's Vice-President of R&D Olivier Delabroy was cautiously optimistic – describing it as 'clearly our territory' and something 'we cannot ignore'.

Delabroy explained that Air Liquide already utilises liquid air for energy storage in some of its air separation plants and associated liquefaction units, using it to leverage the price differences between peak and off-peak consumption. This, he clarifies, is something the company does because it is easy to integrate and exploit. Taking the technology beyond this kind of usage, however, and into deployment as an energy vector in its own right, is something that requires more planning.

"I think that you have to compare with alternative technologies," he said. "Today we are carefully looking at that, the key factor or indicator is of course the spread of electricity that you have between the maximum daily price and the minimum. The higher the optimum that the peak and off-peak is, the more economical this technology can be and obviously the current energy-electricity spread is going to increase maybe drastically with the development of renewables."

The debate around grid balancing is usually presented in terms of the need for additional gas-fired plants to run when the wind drops or there are shortfalls in other means of energy. But there is a powerful case for additional grid storage to absorb excess 'wrong time' energy and warehouse it for when required, preventing it from being wasted and allowing power plants to run more efficiently – enter liquid air.

Liquid air is based upon the science that air can be turned into a liquid by cooling it to around -196ºC using standard industrial equipment. Around 700 litres of ambient air becomes one litre of liquid air, which can then be stored in an insulated vessel. When heat (including ambient or low-grade waste heat) is reintroduced to liquid air it boils and regasifies, expanding 700 times in volume.

This expansion can be used to drive a piston engine or turbine to do useful work. The main potential applications are in electricity storage, transport and the recovery of waste heat. Liquid air is capable of converting low-grade waste heat into power at very high levels of efficiency, because of its low starting temperature (-196ºC). This compares favourably to other waste heat recovery technologies whose maximum theoretical yields are limited to about 20% at 100°C.

It is upon this science or basic principles that much of the debate in the industry seems to rest – conversion efficiencies and the return on energy input.

Question marks linger concerning the losses recorded during energy conversion. Every time a conversion is made from one form of energy to another, a percentage – however small – of the original energy is lost, despite the continuing advances in both turboexpander and air compressor technology.

In addition to expectations of the overall cycle efficiencies, debate has raised the fact that there could still be considerable need for electrical power to run the main air compressor in the air separation plants – which would typically rely on coal or gas-fired power generation in a region like the US, for example. Are these shortcomings? Does this actually render the nitrogen economy a false economy?

Prodeep Mookerjee, Owner of Redesign Consult FZE and formerly of Carbonic International, does not appear to think so, commenting, "Nitrogen is net surplus in the air gases market and it is this attribute of being available 'free' or at least 'cheap' (below attributable cost) that makes it interesting in a scenario where 'waste heat' or low-grade heat is also available."

"There is energy to be recovered, left over from gross energy already expended for other purposes, and typically low grade heat available from alternative energy routes. This latter source gives the subject resonance. Here's a value-added activity, a coming together of energy sources that have synergistic attributes – the sum is more than the parts. Behold, the 'Nitrogen Economy'."

Another question concerns the impact of liquid air on nitrogen as a product. While it is true that there is currently surplus product in the market at present, it is challenged whether nitrogen would no longer be just the by-product that it is now – and would in fact become a hot commodity. This could, in turn, have an effect on pricing structures.

> **"My guess would be that energy storage in conjunction with renewables for wrong-time energy storage is a very real possibility..."**

Then there is the infrastructure – will it prove costly to install the support infrastructure, a challenge in common with hydrogen? This is countered by the fact that liquid air technologies are based on standard components and mature supply chains, and an extensive cryogenic distribution network exists in all industrialised countries.

Support

There is already clear evidence that those in the know about gases and liquid air are interested in the project via the strategic partnership between the Messer Group and Highview Power Storage, the proponents behind liquid air.

Messer officially supported the CLCF study of energy storage using liquid air and, ahead of the report's launch, experts from the energy sector met at the company's headquarters in Bad Soden, Germany to discuss electricity storage with liquid air – the results of which informed the study.

Messer is continuing to work on this with Highview Power Storage and Tim Evison, in charge of Business Development at Messer in Bad Soden, said in a statement, "I am delighted to see the level of excitement that the possibilities of cryogenic technologies have created across such a broad swathe of experts from academia, energy and industry."

"Specifically as regards to energy storage, there is a clear need for technology development to ensure future grid stability and to optimise the economics of a power supply based on renewables. The report confirms that liquid air is one attractive approach which should be pursued by industry, the energy sector, universities and government in partnership."

Asked what his first impressions of the liquid air concept were, Thames Cryogenics' European Sales Manager David Cooke, told **gas**world, "From a commercial point of view, obviously I'm very interested in the potential of liquid air as there are real business opportunities in it for my company by way of cryogenic piping."

"Is it all a pipe-dream? I'm not educated enough to have gone through all the figures and facts and come to a conclusion based on the science, but to my mind, a lot of people who are clever enough have come away with the conclusion that it is viable."

"My guess would be that energy storage in conjunction with renewables for wrong-time energy storage is a very real possibility and whilst it won't happen overnight, I'd be very surprised if there weren't commercial plants operating by the end of the decade. As for liquid air in the automotive sector, I think this might be further off and will probably enter by way of niche markets initially, and then as a hybrid solution in conjunction with other technology."

The Dearman Engine Company is in fact currently on track to demonstrate a first engine for waste heat hybrid and combined power and cooling, later this year. This can meet the here-and-now challenges facing niche, but still significant, markets and could therefore be deployed sooner than the next decade, we understand.

Perhaps there is one final, topical thought to adjourn this discussion with – the rise in LNG. There is an urgent need for electricity storage solutions in Europe, because the transition to renewables has seen a surge in electricity generation from wind and solar power. Liquid air electricity generation can turn waste heat into power at high levels of efficiency, while exploiting waste cold from LNG re-gasification at UK import terminals would cut the electricity required for air liquefaction by almost 60%, and costs by half.

As the world wakes up to the prospect of LNG-fuelled economies, does this widen the window of opportunity for liquid air as an energy vector? ❑