Round Table 4 - MESSER GROUP

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Messer Group headquarters, Bad Soden

Participant	Company
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C Biondonio	EnBW
G Brett	Highview Power
D Buss	Messer Group
C Erdmann	Messer Group
T Fox	Institution of Mechanical Engineers
T Evison	Messer Group
R Ewald	Privat
K Gütling	Hessisches Ministerium für Umwelt, Energie, Landwirtschaft und Verbraucherschutz
J Hoffmann	Thyssen Krupp
A Hopert	Innovationszentrum Niedersachsen Strategie und Ansiedlung GmbH
I Jeromin	Mainova AG
A-K Kippels	H2BZ-Initiative Hessen || flow-advice
J Klier	Institut für Luft- und Kältetechnik gemeinnützige Gesellschaft mbH
T Kneiske	Fraunhofer Institut für Windenergie und Energiesystemtechnik
A Kopp	E.ON Gas Storage GmbH
P Laux	Messer Group
H Lienkamp	Infraserv GmbH & Co. Höchst KG
M Maino	Highview Power
R Morgan	University of Brighton
A Müller	DB AG
M Oles	Thyssen Krupp
T Peters	Highview Power
C Pels-Leusden	Beuth Hochschule für Technik Berlin
K Pimpertz	Stadtwerke Duisburg
A Price	Electricity Storage Network
D Reuter	Messer Group
U Sager	CFA Partners
C Schöfinius	Privat
K-H Tetzlaff	H2-Patent GmbH
C-A Tran	Mainova AG
A Bracht	Hessen Agentur
J von Horatio	Gravity Power GmbH
A Wauschkuhn	EnBW
J Wolf	Wasserstoff-und Brennstoffzellen-Initiative Hessen e.V.

PRESENTATIONS

Introduction to Liquefaction
Dirk Reuter
VP Production Europe
Messer Group

The German need for energy storage
Dr. –Ing. Ingo Jeromin
Referent of the technical management board
Mainova AG

The portfolio of energy storage technologies
Dr. Joachim Wolf
CEO of hydrogen and fuel cell initiative
Hessen

Liquid Air Energy Storage – how it works
Dr. Rob Morgan
Principle research fellow, University of Brighton
Gareth Brett
CEO, Highview Power Storage

Liquid Air Energy Storage – UK thinking
Dr. Tim Fox
Head of Energy practice, IMechE
Anthony Price
Director, UK Electricity Storage Network

1. Suitability of LAES in the Power Network

Liquid Air Energy Storage (LAES) is a large-scale energy storage system with a long life. The technology is best described as filling the gap between the largest batteries and the smallest pumped hydro storage systems.

When considering for which operational cycles LAES is best suited within the power network, the participants were keen to highlight two out of the three ancillary service markets with different needs:

- Tertiary reserve or "minute reserve" where, response is required within 15 minutes and 4 hours of power must be provided. There is an energy charge in this market and currently, the 4 largest operators in Germany provide 2,500MW of reserves.

- Secondary reserve, response must be within 5 minutes and even though there is no energy charge, there is a higher capacity charge.

- The primary reserve market is unlikely to be suitable for the technical performance of liquid air.

It was suggested that financial modeling is required in order to deduce which market is most profitable and suitable for the given technology.

Participants pointed out that the plan in Germany is to build considerable storage capacity in the future. As the proportion of renewables increases, so the need grows for longer term energy storage – even for seasonal energy storage. At the moment, the expectation is that this need will be met by considerable quantities of pumped hydro, compressed air and power to gas.

Compressed air energy storage is currently the main thrust of the 'plan' for energy storage in Germany, as proposed by the German Advisory Council on the Environment.

LAES is a close cousin of compressed air energy storage, but has the attractive feature of using a phase change (which naturally takes place at constant temperature) to store energy at potentially higher efficiencies than if using pressure (which inevitably gives rise to heat).

2. LAES as part of the portfolio of technologies to meet future storage needs in Germany

The attendees posed the question of whether there will there be a demand for LAES in Germany over the next five to ten years. The consensus response was that in the longer term, the plan is to deploy a large amount of storage from a variety of technologies - perhaps including LAES. The scale of LAES may be suitable for deployment at the Stadtwerke level.

Relevant technologies are being developed now in Germany to be used to meet future needs. Liquid air should form part of this technology development portfolio.

<u>In comparison to compressed air</u>

The storage of energy using air liquefaction has clear advantages versus energy storage using air compression:

- There is existing infrastructure in Germany for air separation and liquefaction which might be used to reduce the cost of early investments;
- There is existing cryogenic engineering expertise in Germany, which is a world-leader in the industrial gases industry;
- Storing energy using a phase-change, which naturally takes place at the same temperature, is technically more efficient than using a change in pressure;
- The density of energy storage using liquid air is higher than compressed air due to the phase change of air to liquid;
- There are no geological requirements for liquid air energy storage compared to cavern based compressed air.

<u>In comparison to pumped hydro</u>

- Compared with pumped hydro, liquid air energy storage is less efficient, however, there are severe limitations for further development of pumped hydro storage in Germany and using pumped hydro services sourced from outside Germany (e.g. Norway) would incur transmission losses.
- Pumped hydro is geographically constrained whereas liquid air energy storage facilities can be placed wherever needed.

The round table considered it important to explore how different types of storage methods may be applicable for different cycles, grid locations, operating conditions and geography. They agreed that the government has an obligation to help develop all technologies, which might help meet the needs of the energy network. The market will then decide which method is the best in which service, site or geography.

3. The cost of LAES

The participants all recognized that the most crucial point is to get the business case right for the technology. Economics are particularly important because at current prices in the Minutenreserve a storage system costing more than 500€/kW would not be viable.

The round table agreed that many relevant components for liquid air energy storage are available today. This means a liquid air energy storage system may prove to be cost effective since less early investment is needed.

It was suggested that a small 'demonstration' plant would be useful to learn about any problems or unforeseen costs, including the connection of industrial installations for supply back to the grid.

4. Commercialisation and Policy

The participants established that the current market situation is difficult. It seems that liquid air technology may be best suited to meet the coming need for longer term storage given low current prices in balancing markets. Having said this, they also recognized that there will always be a market for grid balancing.

Indeed, the market is already changing and the demand for storage is rising. The network's need for balancing must be met. The assumption is that there will ultimately be a change in the market rules to encourage investment. Which technology has a better chance will then depend on political decisions. It would make most sense to prove what the technology can do at the moment and focus on synergies with other processes.

There is a strong lobby for power-to-gas and hydrogen. There is also a significant amount of R&D funding available for basic innovative technologies, however it was suggested that it might be difficult to define liquid air energy storage as an innovation because it uses currently available components. The innovative aspects of LAES lie in the integration both of existing technologies and of differing industrial processes. It will be necessary to lobby for support and to raise general awareness about the potential benefits of liquid air energy storage.

It was suggested that it may be difficult to obtain financial support for first-build LAES plants due to the "lack of innovation" in terms of hardware, i.e. the fact the technology uses mature components was seen as a barrier to access any potential development funding in Germany. This received a mixed response as some of the participants compared this to CAES technology (particularly small scale, including adiabatic and isothermal systems) that uses a similarly mature component platform, yet has attracted significant public funding, alongside hydrogen technologies.

It was pointed out that the aim in Germany by 2050 is to provide 80% of its energy through renewables, but it is unclear how a market for storage will emerge to support this. By 2050, 25% of the costs of renewables are expected to be due to storage, so it makes sense to prepare for this cost and to ensure that appropriate technologies are being developed. Indeed, aggregate renewable electricity costs suggest a market for energy storage services in Germany which in 2020 may already be worth €3-4bn.

The government does give technology subsidies for energy storage. They see the need to look at technologies that can be deployed in 5 or 10 years time. The round table agreed that liquid air technology is new and interesting as an alternative to pumped hydro and compressed air energy storage. It would certainly be interesting to have a demonstration project in Germany.

5. Next steps

When any step change is made in energy infrastructure, the country must be well prepared to avoid serious problems emerging. It is crucial how authorities react and work with existing participants to prepare the technological solutions and investments required. In Germany there are many community groups that make decisions because they think it is the right decision, not – perhaps – because it is economic. Authorities, power companies and communities are open-minded about new technologies.

It was pointed out that no single technology is *the* solution, but rather it can only be part of the solution. It is vital for economic efficiency that a broad portfolio of technologies be developed.

The operating cycles most appropriate for liquid air energy storage are the same as those proposed for pumped hydro and compressed air energy storage. A natural way to start with LAES would be to co-locate with either an existing industrial gas plant with liquid production on site, an LNG regasification terminal and/or other industrial installations generating waste heat. A demonstration project would highlight the technology's benefits and potential.

The round table discussed the idea that members might collectively review possible sites and applications for LAES, in order to make recommendations for a trial location.

6. Conclusions

The storage of energy using air liquefaction has clear advantages versus energy storage using compressed air and pumped hydro, predominantly due to the existing infrastructure in the industrial gases industry in Germany and the pre-existing expertise in liquefaction and cryogenic engineering. Specifically, liquid air energy storage has advantages over the alternatives in terms of geographic flexibility (vs. pumped hydro), energy density and efficiency (vs. compressed air).

The participants recognized that it is crucial to get the business case right for the technology. At current prices in the Minutenreserve an investment of over 500€/kW in a storage system cannot be made to pay for itself.

However, the market for storage services is changing rapidly. The market needs more balancing services and need for longer term storage begins to arise as a result of the growing share of energy produced from renewables.

Germany presents some interesting market opportunities as cities and towns have a strong community focus which may lead to development of local energy projects, including energy storage and there is interest amongst German authorities at state and national levels in using public funds available now in Germany (and Europe) for energy storage in order to support the development of liquid air technology.