**Energy**
Volume 169 Issue EN4
**Editorial**
Argent

ice | proceedings

**Proceedings of the Institution of Civil Engineers**
Energy 169 November 2016 Issue EN4
Pages 141–142 http://dx.doi.org/10.1680/jener.2016.169.4.141



# Editorial

**Steve Argent** BSc(Hons), CEng, FIET, MIAM, Eur-Ing
Associate (Energy), Ove Arup & Partners, Solihull, UK

Thanks to a stimulating career in electricity supply that has encompassed project development and assessment, economic regulation and policy and, more recently, consulting around the world, I appreciate the challenges of low-carbon-dioxide generation and the technologies potentially available to manage the impacts of its operational characteristics. Using storage to help in the essential balance of instantaneous supply and demand has long been an interest, as has how to select 'optimum' development options and promoting renewables growth in countries accustomed to reliance on fossil fuels. I am therefore honoured, as a member of the *Energy* editorial board, to have been invited to write the editorial for this issue. The scope of papers within the *Energy* journal ranges from strategy and policy through to detailed technical papers. All undergo rigorous peer-review and have helpful reference lists for readers wishing to explore topics further.

In this issue, the first full paper presents a comparison of large-scale energy storage technologies, particularly related to the Energiewende in Germany, and the second paper considers the merits of conversion of existing hydro generation facilities to pumped storage, based on water resource and electric price variability. Readers should also be aware of the report *Electricity Storage: Realising the Potential* published by the Institution of Civil Engineers (ICE) on 27 October 2015 (Miller, 2015). The third paper considers biofuelled renewable generation and recognises both the benefits and economic viability challenges of algal biomass. It proposes a solution where an algal biorefinery can be designed to produce valuable by-products as well as biofuel and hence enhance the economic sustainability. The briefing which precedes the papers explains the wind and solar resources in Oman, a country reliant on fossil fuels, together with emerging plans to develop such renewables commercially. It too recognises the challenges posed by wind and solar variability and highlights the potential role of storage in the longer term. This formed the basis of an ICE local branch learned event in May 2016 (the presentation slides are available on the ICE website (Hill, 2016)).

Similar to demand-side management, storage of electricity provides many benefits as it helps to manage variability and unpredictability in renewable output better, permits better optimisation of grid network asset use and potentially enhances security of customer supplies. The use of pumped storage dates back to shortly after the birth of the electricity supply industry (~1890s in Italy and Switzerland). In the UK, Ffestiniog power station in North Wales was the first major pumped storage plant (360 MW commissioned in 1963).

The first paper, by Dr Florian Klumpp (of Fichtner), is based on a comparison of large-scale energy storage technologies undertaken by Fichtner on behalf of the Lower Saxony government (Klumpp, 2016). This focusses on three grid-scale storage technologies – pumped hydro, compressed air energy storage (CAES) and hydrogen – and seeks to compare these on a lowest cost of energy (LCOE) basis. The assumed operation is recognised to be significant when calculating a levelised cost per MWh of generation (e.g. the Department for Energy and Climate Change's reports in the UK and similar reports in the USA, Australia and Europe), but assumed operation becomes even more critical when considering the economics of storage. The paper uses three dispatch scenarios (7 cycles/d, 1 cycle/d and 1 cycle per 30 d) to represent short-, medium- and long-term storage. It concludes that pumped storage and CAES are favoured for short- to medium-term storage, but that hydrogen storage shows distinct promise for longer-term storage. The paper notes that the capital cost required to achieve such long-term storage is much higher than for short- to medium-term storage and suggests that low round-trip efficiency of hydrogen storage (20–40%) is less critical for longer-term storage. However, this is highly sensitive to the assumed marginal price of electricity used during storage and clearly if the price is low (or negative) the inefficiency costs are smaller. The paper is silent on whether future electricity markets will continue to pay significant premiums for intermittent renewable energy produced during periods when it may be stored inefficiently, but I note that capacity markets are already paying significant premiums to ensure security of supply at peak periods. The paper also recognises the competing demands for salt cavern underground storage of CAES and hydrogen.

The second paper, by Mahmoudimehr *et al.* (2016) of the University of Guilan in Iran, develops a novel map for deciding on the type of hydro power plant. This paper recognises that differing water resource (inflow rate) and electric market/price variability will influence whether simple hydro generation or pumped storage is optimum – and in particular the merits of converting existing hydro to pumped storage. The main focus of the paper is on optimisation techniques and the merits of the dynamic programming approach. The results are

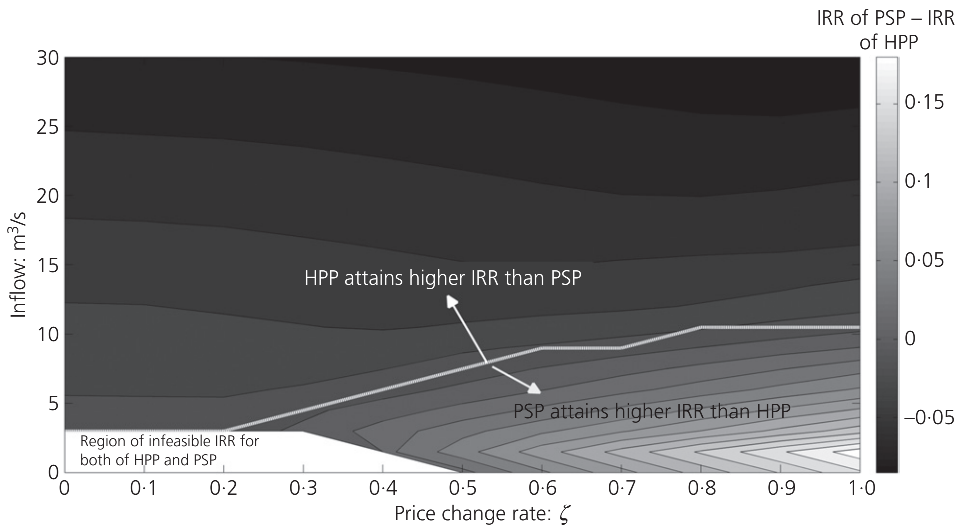


**Figure 1.** Example contour map presentation of results in the paper by Mahmoudimehr *et al*. (2016)

presented in a helpful contour map style (Figure 1) and confirm the importance (and sensitivity) of the optimisation to the input data and assumptions used.

The third paper, by Lian-Dong Zhu, Shuhao Huo, Shah Rukh Ahakeel and Zhaohua Li, reports on collaborative work between Hubei University, China and Vaasa University, Finland considering the sustainable development and challenges of an algal biorefinery (Zhu *et al*., 2016). Microalgae are a potential feedstock for biofuels, capturing energy by way of photosynthesis; however, biofuel energy sources (such as maize) tend to compete with food production and therefore have sustainability issues. Current microalgal biofuels tend to be produced in small (laboratory)-scale facilities requiring electricity, nutrients and chemical reagents which make them uneconomic. This paper explores the cost reductions potentially possible by upscaling and byproduct utilisation, and shows that the production of multiple bio-products from microalgal biomass may offer a sustainable and economic microalgal industry. Key issues/uncertainties are considered – including water footprint and the energy balance (when bio-product harvesting, drying, extraction and refining are included).

The briefing article by Tariq Umar and Sam Wamuziri of A'Sharqiyah University considers the conventional wind and solar resources in Oman (Umar and Wamuziri, 2016). This notes that although Oman is not currently utilising its renewable energy resources, there is considerable potential. It also notes that Oman trails behind some other Gulf States at the moment. The Omani Vision 2020 seeks to increase renewable utilisation. Electricity storage is briefly mentioned but is not considered further.

## REFERENCES

Hill M (2016) *Conventional and Renewable Energy Resources of Oman*. Institution of Civil Engineers, London, UK. See https://www.ice.org.uk/news/conventional-and-renewable-energy-resources-oman (accessed 19/09/2016).

Klumpp F (2016) Comparison of large-scale energy storage technologies. *Proceedings of the Institution of Civil Engineers – Energy* **169(4)**: 148–160, http://dx.doi.org/10.1680/jener.14.00043.

Mahmoudimehr J, Sorouri A and Feshalami BF (2016) A novel map for deciding on the type of a hydro power plant. *Proceedings of the Institution of Civil Engineers – Energy* **169(4)**: 161–178, http://dx.doi.org/10.1680/jener.15.00020.

Miller G (2015) *Electricity Storage: Realising the Potential*. Institution of Civil Engineers, London, UK. See https://www.ice.org.uk/media-and-policy/policy/electricity-storage-realising-the-potential (accessed 19/09/2016).

Umar T and Wamuziri S (2016) Briefing: Conventional, wind and solar energy resources in Oman. *Proceedings of the Institution of Civil Engineers – Energy* **169(4)**: 143–147, http://dx.doi.org/10.1680/jener.16.00011.

Zhu LD, Huo S, Shakeel SR and Li Z (2016) Algal biorefinery for sustainable development and the challenges. *Proceedings of the Institution of Civil Engineers – Energy* **169(4)**: 179–186, http://dx.doi.org/10.1680/jener.16.00001.