Fuel Cells for Stationary Applications

Highlights

■ **PROCESS AND TECHNOLOGY STATUS –** Fuel cells are one of the cleanest and most efficient technologies for electricity and heat generation. They can achieve electrical efficiencies of up to 60% net AC, produce negligible air pollutants such as sulphur and nitrogen oxides, and emit relatively little CO_2 per unit of energy produced. Where they are fuelled with hydrogen they emit no CO_2 at all. The fundamental operating concept is the direct electrochemical conversion of a fuel (e.g. methane, hydrogen) into electricity and heat: charged ions passing through an electrolyte create a voltage difference between an anode and a cathode, and an electric current in an external circuit. This can be achieved in a variety of ways and as such there are several types of fuel cells, each of which utilises a different electrolyte material, operates at different temperatures (from ambient to >1000°C) and faces their own unique technical challenges. Fuel cell systems are applicable in a wide range of stationary applications, including large scale power generation, combined heat and power (CHP) for industry and buildings, off-grid energy and backup power services, but also in transport (vehicles) applications and for mobile power-packs. At present they are best categorised as an emerging class of technologies beginning to enter a phase of commercialisation, where cost reductions must be achieved alongside improvements in technical performance, particularly in relation to increasing their operating lifetimes. The recent successes in small scale residential cogeneration devices in Japan, and in large scale power supply projects in South Korea, suggest a bright future for this class of technologies is possible.

■ **TECHNOLOGIES, PERFORMANCE AND COSTS –** The main varieties of fuel cells in stationary applications are Polymer Electrolyte Membrane Fuel Cells (PEMFC), Solid Oxide Fuel Cells (SOFC), Molten Carbonate Fuel Cells (MCFC) and Phosphoric Acid Fuel Cells (PAFC). At present, PEMFC is the technology of choice for small scale residential applications with 40,000+ installations in Japan, whilst MCFC is mostly used for large stationary applications. However, SOFC is a strong contender in both of these segments with potential long-term advantages in terms of reduced balance-of-plant (BoP) requirements and top-end electrical efficiency. SOFC-based products are now entering the commercial market with rapidly growing market share. The performance of stationary fuel cell systems is focused on three high-level parameters; net electrical efficiency, overall efficiency in the case of cogeneration, and durability. Net AC electrical efficiencies are currently in the range of 30% - 50%, with overall (i.e. heat plus power) efficiencies up to 90%. In the future, net AC electrical efficiency could increase to 60%. Durability continues to be the crucial technical challenge, with lifetimes exceeding 40,000 operating hours required. Research on methods to avoid fuel cell power output and efficiency degradation over time is a focus of activity. In terms of costs, fuel cell systems are currently much more expensive than conventional alternatives such as gas turbines. Micro-CHP systems (with a typical size of 0.7 to $1kW_e$) are currently approx. US$25,000 per system in Japan, whilst larger systems range from US$4,000 to US$12,500 per kW_e. However, larger systems may reach costs as low as US$3,000 per kW_e by 2020 while micro-CHP could become competitive at approximately US$3,500 per system in the long term.

■ **POTENTIAL & BARRIERS –** Given the range of applications, it is clear that fuel cells have enormous market potential. For the residential sector, a 10% market share in home heating is not unreasonable within the coming two decades. This would result in cumulative installation upwards of $70GW_e$ if limited to the key markets of Japan, South Korea, USA and Europe. Furthermore, scale-up of the size of large scale installations will drive growth over the coming decade and will push down costs. The IEA has projected a possible 5% share of total global capacity in 2050, but this could be an underestimate depending on technological progress. The positioning of fuel cells as ultra-clean flexible low-carbon generators opens opportunities for them to play an important role in emerging "smart" energy networks, balancing output from intermittent sources such as wind, and potentially being a cost-effective partner to other technologies such as heat pumps in the decarbonisation of heat supply. The key barriers for fuel cells are a current lack of appropriate financial support to underpin their market introduction and cost reduction by increased production, and some examples of poorly structured regulatory and market arrangements for small generators. Ultimately, fuel cell systems will need to be at least partially fuelled with renewable gases (e.g. hydrogen, bio-methane) to play a significant role in very low carbon energy systems.

PROCESS & TECHNOLOGY STATUS

Fuel cells are one of the cleanest and most efficient technologies for generating electricity and heat [1]. They convert a range of gaseous fuels, primarily methane or hydrogen, into electricity and heat. No combustion of the fuel is involved. Instead, the fuel undergoes electrochemical conversion directly into electricity and heat [2]. The fuel cell stack has no moving parts, operates without noise, and has zero or low pollutant and CO_2 emissions at the point of use. Their adoption can reduce national dependence on fossil fuels as an energy source, improve energy security and energy system reliability, and can be cost-effective [2].

Fuel cell systems are applicable in a large range of applications, including heat and power in residential and commercial buildings, high temperature processes and power in industry, off-grid power, backup power services, both light and heavy transport, and portable micro-scale

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