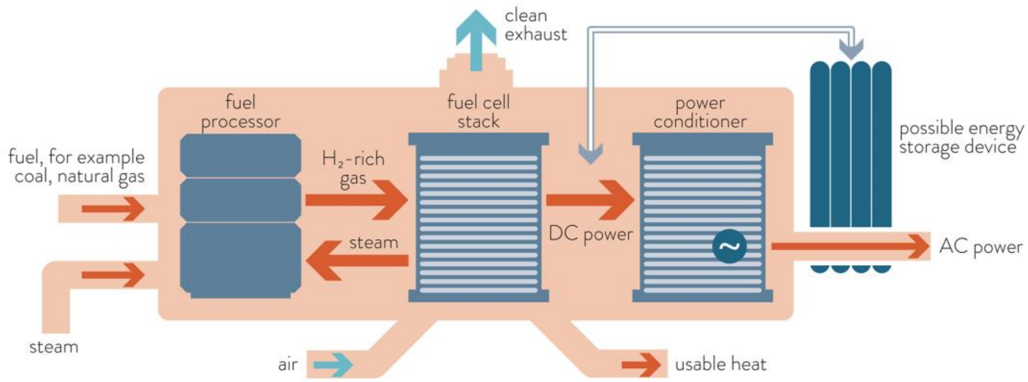
COAL AND STATIONARY FUEL CELLS

Reducing the carbon footprint of modern society is widely regarded as a top priority. The Paris Agreement of 2015 represents an historic milestone for the energy sector and confirmed the near globally-agreed target of limiting future temperature increases to below 2°C, as well as pursuing efforts towards 1.5°C. To meet this target, the energy generation sector needs to achieve higher efficiency and lower emissions (HELE) while meeting increasing energy demand. Apart from promoting the use of renewable energy resources, several countries are also seeking innovative technologies for the conversion of fossil fuels, including coal. One of the most promising of these energy technologies is stationary fuel cells.

Fuel cells are electrochemical devices that convert the chemical energy of the reactants directly into electricity and heat with high efficiency. They generate electricity continuously, as long as there is a source of fuel. The one-step nature of this process from chemical to electrical energy has several advantages over conventional power generation methods, which have multiple steps from chemical to thermal to mechanical to electrical energy. The potential advantages include high efficiency with combined heat, cooling and power (electrical efficiency of up to 60%, combined efficiency in cogeneration of more than 90%), high power density, small carbon footprint, low emissions, low noise and high-quality power. Fuel cells integrated with coal-fired power plant could produce concentrated CO2 ready for capture. They are modular in nature and do not suffer large energy penalties when scaled down to a small size.



Schematics of a fuel cell power system

Applications for fuel cells include large-scale stationary power generation, distributed combined heat and power (CHP), and portable power. Due to their small size and high efficiency, both the development and deployment of fuel cells for CHP and small- to medium-sized stationary power systems are moving fast. This activity is driven by support from governments through tax credits and state incentives. Japan, South Korea, the USA and some European countries lead the market. The USA ranks first for fuel cell capacity and is home to world leading manufacturers: FuelCell Energy (FCE) Inc, Doosan Fuel Cell America, and Bloom Energy. Japan is first for delivery systems due to the successful upscaling of the Ene Farm micro cogeneration power systems. However, South Korea has the world's largest fleet (in MW) of stationary fuel cell systems, including the biggest fuel cell power plant, the 59 MW Gyeonggi Green Energy park in

Hwasung City. Currently, natural gas is the fuel used for all commercially available fuel cells systems. If gasified coal were the fuel of choice, hydrogen and syngas from coal could be used.

For large-scale stationary power generation, integrating a coal gasification process with high temperature fuel cells (IGFC) is an option to create ultra-high efficient and low emissions power generation systems. Even with carbon capture added, the IGFC plant may have higher efficiency than a pulverised coal combustion (PCC) or integrated gasification combined cycle (IGCC) plant without carbon capture and it would consume significantly less water. Theoretical research on IGFC is an active topic in coal-fired power generation academic studies. However, due to the high cost of the prototypes, even at a laboratory scale, no experimental test for an IGFC system has been performed to date. The US Department of Energy (DOE) promotes R&D on fuel cell technologies through research programmes such as 'Solid State Energy Conversion Alliance (SECA)' and aims to demonstrate a 10 MW IGFC system by 2020 and a 50 MW IGFC system by 2025. Currently Japan leads the field and the first IGFC demonstration plant with carbon capture and storage (CCS) is planned to go live in 2021 as a result of the CoolGen project in Osaki, Hiroshima.

Direct carbon fuel cells (DCFCs) are also being developed. DCFCs represent a way to convert carbon's chemical energy to electricity efficiently without forming the pollutants associated with conventional combustion, such as particulates, NOx, SOx, and mercury. The carbon in coal is completely oxidised into CO_2 which is ready for CCS. There is no need for water in the process. If DCFCs become operational and commercially available, they could revolutionise power generation, especially from coal. However, the mechanisms of the reactions in DCFCs are not fully understood. Various electrochemical aspects, such as the number of electrons transferred, the role of the reverse Boudouard reaction and possible intermediate chemical reactions between the anodic species are still under investigation. Overcoming the practicalities of bringing a solid reactant containing contaminant ash into adequate contact with an electrode appears to be a significant issue, especially if the technology is scaled up. DCFC technology is still in its infancy and far from demonstration. DCFCs using internal pyrolysis or closely integrated gasification may have a greater prospect of success.

Stationary fuel cell systems can be part of the solution to meeting environmental targets for emissions and increasing power generation efficiency. The big challenges for stationary fuel cells are the cost and cell durability. Until now, fuel cells and related technologies have been built at very low volumes. Market demand has been insufficient to enable investment in advanced manufacturing. Reducing the cost of manufacture can benefit all aspects of fuel cell systems, including hydrogen production and storage systems, and hydrogen infrastructure. For coal-fed fuel cell systems, commercialisation also depends on improvements in hydrogen and syngas retrieval from coal gasification. Support from governments is critical to progress stationary fuel cell applications until they are ready to enter the market.

IEA Clean Coal Centre is a collaborative project of member countries of the International Energy Agency (IEA) to provide information about and analysis of coal technology, supply and use. IEA Clean Coal Centre has contracting parties and sponsors from: Australia, China, the European Commission, Germany, India, Italy, Japan, Poland, Russia, South Africa, Thailand, the UAE, the UK and the USA.

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