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Editorial

Dedication to Clean Power and Promotion of the Energy Revolution

Dazhao Gu

China Energy Investment Corporation Limited, Beijing 100011, China

The discovery and application of electric power triggered the second wave of industrialization and became one of three global technological revolutions since the 18th century. Since then, electrification has changed the livelihoods of people. Electric power is also an important carrier of clean energy, where clean, low-carbon, and smart global electric power technologies have been developing rapidly. Clean power improves the standard of living of people worldwide and slows global warming. With rapid growth in renewable energies, the production of cleaner power has become a popular global trend.

The power sector makes a significant contribution to global greenhouse gas emissions. The International Energy Agency (IEA) reported that in 2018, the electricity and heat sector produced 1.39×10^{10} t of CO_2 or 44% of the 3.19×10^{10} t of global CO_2 emissions from fossil-fuel combustion [1]. The rate of CO_2 emissions from electricity generation dropped from approximately 603 g CO_2 per kilowatt hour in 2000 to 522 g CO_2 per kilowatt hour in 2018 [2]. With the growth of renewable energy generation, there was a concurrent increase in the efficiency of fossil fuel generation. Despite this, the CO_2 emission rate must be further reduced in the power sector to combat global warming.

In a recent report, the IEA stated that a major acceleration is required in clean energy innovation in order to achieve net-zero CO_2 emissions by 2070 [3]. The IEA cataloged 400 technologies to reduce CO_2 emissions; 61 of these technologies were in the power sector, either in generation, storage, or infrastructure. Approximately one-third of these power-sector technologies are in the market. Achieving this net-zero emissions target will require existing energy technologies to be less expensive and demonstrate improvements in performance, alongside the development and deployment of new, innovative technologies.

This is a global problem, as illustrated by a range of international papers in this Clean Power Technology special issue of *Engineering*. Batterham introduces the topic of clean power technology, noting that there are large global differences in terms of public perspectives, government policy support, and underlying resources and infrastructure. This is an important point: There is no "one-size-fits-all" solution to the pressing need for cleaner, low-carbon energy.

Greig focuses on the energy sector transitions required to limit the global average temperature rise from greenhouse gas emissions in terms of areas crucial to deep de-carbonization of the energy sector. The papers contained in this special issue provide information on recent progress in most of these foundational areas.

Hydrogen may provide a clean alternative to conventional fossil fuels for power generation, and its development and utilization have set an important direction for the next iteration of world energy technology reform. Several aspects of this topic are presented. Hartley and Au provide an overview of Australia's National Hydrogen Strategy, emphasizing the need for technological improvements and technological scale-up for hydrogen to become economically viable. Brear provides an overview of the various pathways to produce hydrogen, including the economics of "green" hydrogen produced from renewable energy. Hu et al. review the current status of power-to-hydrogen (P2H) technology whereby electricity from renewables is used to produce hydrogen via electrolysis. They focus on storage and transportation, which are technical barriers to large-scale and cost-effective adoption. Liu et al. provide an overview of recent developments in flow biomass fuel cells and biomass electrolysis for hydrogen production.

Over half of the electricity in the world is produced from coal [4]. Wang reviews the progress to date for 101 coal-fired plants in China, resulting in particulate matter (PM), SO_2, and NO_x emissions, which are below the emission limits of gas-fired power plants.

Tremendous progress has been made in reducing PM, SO_2, NO_x, and Hg emissions from coal-fired plants, However, technology to capture CO_2 emissions from coal plants (and other industrial sources) has only been deployed at full scale on a few plants and a handful of industrial sources. Decarbonizing the power sector requires the wide deployment of carbon capture. The most advanced technology for power plants is CO_2 capture from aqueous solvents. Alivand et al. review methods to improve the kinetics of CO_2 absorption in tertiary amine solutions via the addition of nanoporous carbon promoters to solvents.

Solar electricity generation continues to increase worldwide. Thin-film solar cells based on $Cu(In_x,Ga_{1-x})Se_2$ (CIGS) have demonstrated high power conversion efficiency comparable with silicon cells at the laboratory scale. However, CIGS modules fabricated at the industrial scale have been characterized by significantly lower efficiencies. Two papers in the special issue focus on methods to

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improve manufacturing of CIGS modules in order to achieve the potential high efficiency at an industrial scale.

Ramírez Quiroz et al. report on an imaging technique to improve the industrial process associated with fabricating CIGS modules. This process may enable increased efficiency by reducing losses from cell interconnects. Yang et al. develop and test a promising ionomer-based encapsulant for thin-film CIGS cells, which can spontaneously absorb and/or desorb moisture whilst preventing moisture from entering the cells.

What does the future hold for clean power technology? These predictions are difficult to make, given the various shocks to the world energy system in 2020. One aspect is clear; there will be an increasingly urgent need for clean power technology in the coming decades.

This special issue of the Chinese Academy of Engineering (CAE)'s journal, *Engineering*, focuses on the efficient exploitation of clean power technology. This issue follows from a 2019 International Forum on Clean Power Technology on the same topic held in Beijing in May, 2019, sponsored by the CAE, Chinese Society for Electrical Engineering, and CHN ENERGY. We invite readers to experience the breadth and depth of research, development, and demonstration around the world in clean power technology in the pages of this special issue. I would like to express my appreciation to the authors who contributed to the articles. I am also grateful to the reviewers who contributed their time and expertise. This issue would not have been possible without the dedication and professionalism of the authors and the reviewers.

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