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Editorial

Crises and opportunities in terms of energy and AI technologies during the COVID-19 pandemic

The global COVID-19 pandemic that began at the end of 2019 has dealt a substantial blow to the entirety of human society. The novel coronavirus has infected more than 5.6 million people globally, and has directly caused the deaths of more than 355,000 people as of May 28th [1]. Because the coronavirus is highly transmissible and lethal, some countries, spearheaded by China, promptly shut down most social and production-related activities and asked residents to quarantine at home to stop the spread of the coronavirus in the early stages of the epidemic. These methods effectively blocked the spread of the coronavirus and reduced infection, and many other countries followed suit and enacted similar polices. However, this series of actions has caused a severe economic recession. According to the Chinese National Bureau of Statistics, the gross domestic product (GDP) declined by 6.8% year-on-year in the first quarter of 2020. In contrast, China had achieved a sequential GDP growth of 1.5% in the fourth quarter of 2019 before the onset of this pandemic [2]. The GDP of the United States also fell by 5.0% in the first quarter of 2020 relative to the previous quarter, released by the Bureau of Economic Analysis [3]. China, the first country to detect the coronavirus and report cases, has enacted a number of solutions to limit the spread of the coronavirus that led to a substantial GDP drop. The positive outcome is that China has become the first country to have fully limited the epidemic and restarted the economy [4]. However, many countries are still in the depths of the coronavirus crisis, and the economic situation might worsen further. The unemployment rate in the United States was 4.4% in March; in April, it had risen to 14.7% [5].

On a global scale, the shutdown of a large number of social activities not only caused economic decline, but also resulted in a sharp reduction in energy consumption. For future energy development, the need for diversity and localisation have attained wide consensus. The development of renewable energy sources to reduce the environmental pollution caused by the utilisation of fossil fuels and maintain the sustainability of human beings is of great importance. Moreover, promoting the construction of energy storage infrastructure is conducive to ensuring the security and stability of energy supplies. In addition, artificial intelligence (AI) technology has promoted revolutionary innovations in the past decade by freeing human minds and significantly improving efficiency in many fields. AI can also boost future energy development and enable smart energy technologies. This paper aims to discuss the impact of the global COVID-19 pandemic on energy supplies and utilisation, as well as the crises and opportunities it has created for the future development of energy and AI technologies.

Changes in energy supply and utilisation under COVID-19

Changes in energy supply and utilisation under COVID-19 have been caused by most residents maintaining either active or passive home quarantine, while most social and many production activities have been suspended or even reversed. China's total electricity consumption was 5493 TWh in the first quarter of 2020, which represents a year-on-year decline of 4.2%. Examining the contributions of different industries, the primary (agriculture), secondary (manufacturing), and tertiary (service) industries increased by 4%, decreased by 3.1%, and decreased by 19.8%, respectively, while the domestic electricity consumption of urban and rural residents increased by 5.3% [6]. During the pandemic, people have availed of very little catering and consumed very little entertainment; thus, the tertiary industry has suffered the greatest decline. The domestic electricity consumption increased because most people were staying at home. These drastic changes in electricity demand directly test the strain capacity of the national and regional power grids, which is also related to the energy mix of the electricity supply.

Fig. 1 shows the energy mix of the electricity supplies in India, China, and Germany in 2019 [7-9]. Three-quarters of India's electricity was derived from coal. Currently, the decline in electricity demand has directly resulted in a decrease in the use of coal by power plants. India's electricity demand has fallen by 30% since the pandemic began, and electricity production from coal-thermal power plants has been reduced by nearly 65 GW [10]. The mining and coal industries face the severe problem that many clients have refused to accept supplies and make payments [10]. China also faces a similar situation owing to the large proportion of energy production that is accounted for by coal. According to the Chinese National Bureau of Statistics, the overall power generation decreased by 4.6% in March 2020 compared with the same period in the previous year, and thermal power generation decreased by 7.5% [11].

In addition to electricity, the COVID-19 pandemic has also led to a sharp decline in oil consumption as a result of the recessions in the global manufacturing and transportation industries. The International Energy Agency (IEA) estimated in March that the global daily oil consumption would decrease by 2.5 million barrels during the pandemic, although oil demand was still expected to increase in the long term [12]. However, by April, when the pandemic had become even more severe, the IEA predicted that the demand in 2020 for all fuels except renewable sources would shrink by the greatest margin observed in the last decade. Moreover, the annual oil demand was predicted to fall by 9%, which would result in an oil consumption level equivalent to that last observed in 2012 [13]. In addition, the major oil-producing countries refused to reduce production in the early stages of the pandemic, which led to a substantial drop in international oil prices. The West Texas intermediate (WTI) oil price dropped from $60 per barrel in 2019 to $10–30 per barrel now. Moreover, oil-producing countries such as the United States, Saudi Arabia, and Russia also suffered heavy blows due to the wild fluctuations in oil prices. The COVID-19 pandemic will facilitate the transformation of the global oil and gas market from a seller's market to a buyer's market. As a result, the advantages to buyers may be

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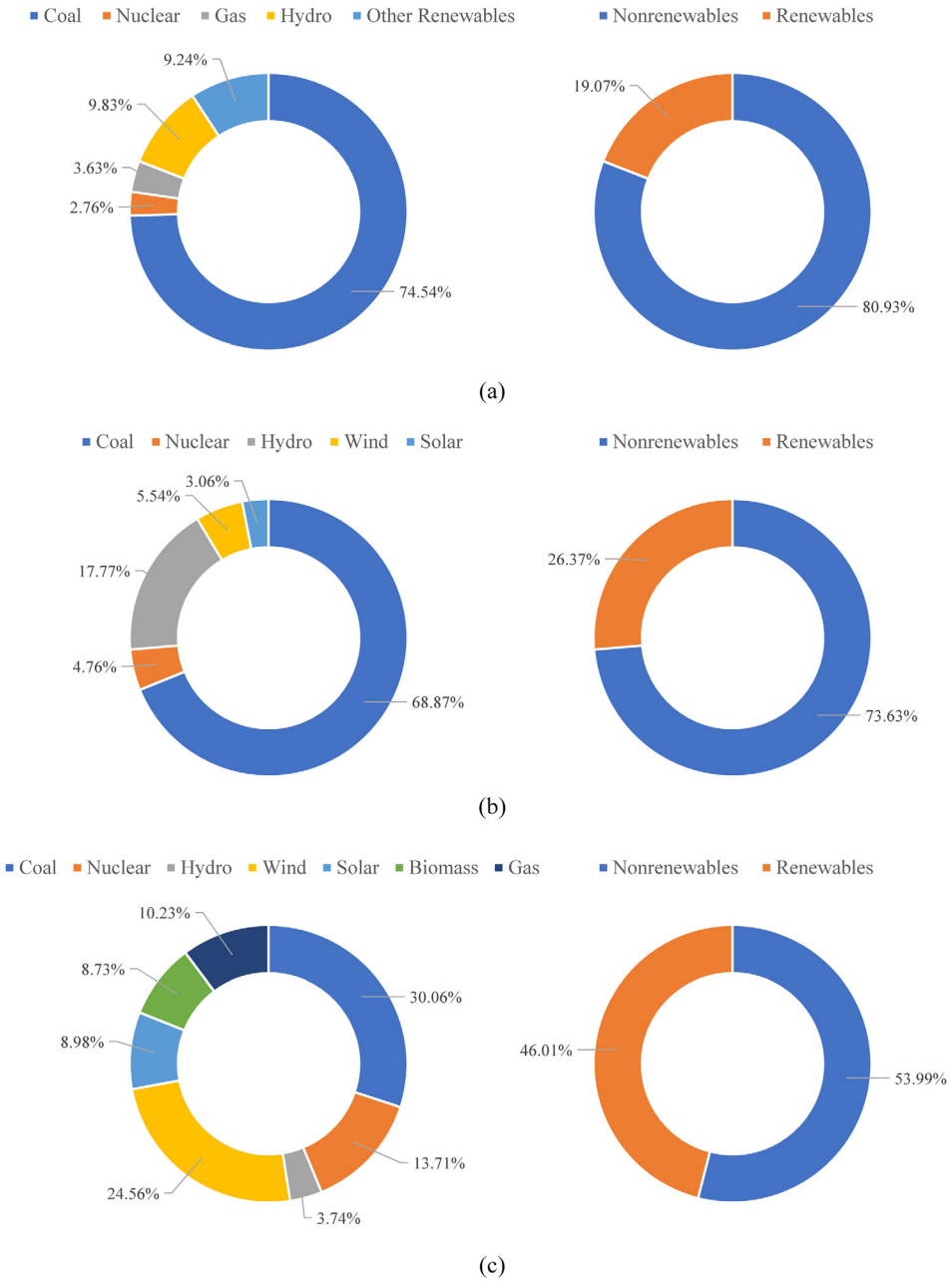

Fig. 1. Energy mix of the electricity supplies in (a) India, (b) China, and (c) Germany in 2019 [7-9].

improved, and the political and monopolistic attributes of oil and gas may weaken, thus allowing the commodity and open attributes to be enhanced [14].

Opportunities for renewable energy

This pandemic will accelerate the exit of coal from electricity supplies. The world has become increasingly less reliant on coal for power generation. Renewable energy thus may be the only winner of this historic decline in energy demand [15]. During the pandemic, China is actively promoting diversity and localisation of fuel supplies. China's wind and solar power generation increased by 18.1% and 8.6% year-on-year in March 2020, respectively, contrary to the decline in thermal power generation [6]. Energy supplies in Britain are undergoing a similar transformation. Even before the pandemic, coal-generated supplies in the country have already been dwindling for years. Britain's COVID-19 lockdown and warm climate together saw over three weeks of coal-free electricity generation [16]. Meanwhile, the amount of renewable-generated electricity reached a record high [17]. India is also deploying more solar and hydroelectric power stations [18].

The reduction in energy consumption has also significantly reduced carbon emissions and air pollution. Carbon emissions in China were estimated to decrease by 18% in February and March of 2020, owing to the decline in coal and fuel consumption in manufacturing and transportation [19]. According to the satellite images released by NASA and the European Space Agency, the levels of NOx and other air pollutants over Europe, the United States, China, and other areas have decreased significantly since the onset of the COVID-19 pandemic [20,21]. However, some scholars have proposed that the reduction in carbon emissions and pollution during the pandemic will be only temporary, and the adverse factors will rebound quickly after the pandemic ends [22]. Nevertheless, these positive environmental changes are still worth our consideration.

Reducing the use of traditional fossil energy is critical for improving the environment and ensuring sustainable development by human beings. Therefore, now is an appropriate time to promote the usage of clean and renewable energy sources.

In the context of an economic depression, renewable energy infrastructure is also widely regarded by many governments as a dynamic development point to revive the economy and stimulate consumption after the pandemic. Thus, economic recovery becomes another driving force for the promotion of renewable energy. As the first country to control the pandemic and restart work, the Chinese government issued a notice on promoting financial subsidy policies for electric vehicles (EVs) in April to encourage the further commercialisation and promote the use of EVs [23]. The State Grid Corporation of China also launched a new round of charging pile construction in April with the plan to deploy 78,000 charging piles, which is expected to directly drive the recovery of related industries [24]. The European Union also included a green transition in their COVID-19 stimulus plan to increase photovoltaic deployment [25]. The Israeli government plans to invest $7.1 billion in a new round of energy and water infrastructure construction to promote economic recovery from the effects of the COVID-19 pandemic, $1.8 billion of which is planned to be used to deploy 2 GW of photovoltaic power generation facilities [26].

Energy storage: securing the energy supply with renewable resources

Developing renewable energy and increasing energy diversity can free us from dependence on fossil energy and ensure the sustainability of human development. However, compared with thermal and nuclear power, renewable resources, especially wind and solar, are more unstable. Not only does the instability of renewable energy power generation create unbearable pressure on the grid and users, but the generation time of renewable resources does not always correspond to the time of electricity demand. Therefore, an excessive proportion of electricity from renewable energy is not conducive to ensuring energy security. Germany has suffered these consequences. In 2019, the proportion of renewable energy in the energy mix of the electricity supply in Germany reached 46% [9]. Energy consumption in Germany is particularly high in the winter, while wind turbines and photovoltaic systems struggle to supply sufficient electricity during this period owing to the uncertain wind and insufficient solar inputs [27]. The continued high temperatures in Europe in the summer of 2019 also caused a significant increase in electricity consumption, while the grid in Germany came close to experiencing blackouts on three days in June [28]. German electricity prices also soared to the highest level in Europe [29].

Its weather dependence makes it difficult to apply renewable energy electricity generation for transportation and heating. In particular, when a country or region suffers a sudden disaster, such as the current coronavirus pandemic, an excessive reliance on renewable energy may not ensure stable supply of energy and electricity, and can result in more serious consequences. Therefore, with the development of renewable energy and increasing energy diversity, energy security and energy supply stability must be ensured simultaneously. At present, it is possible to maintain an appropriate proportion of fossil or nuclear energy in the energy mix of the electricity supply, with the fossil or nuclear power plants working when wind or solar power falls. In the future, fossil power generation will be gradually phased out, and the development of energy storage infrastructure based on renewable resources will become the mainstream method to ensure energy supply stability, especially under sudden emergencies.

Fig. 2 shows the current mainstream energy storage technologies. Energy storage technologies aim to provide energy services for specific applications across different components of the grid. These are particularly suitable for dealing with the rapid response of smart grids in the future, and thus can improve the reliability and elasticity of the grid [30]. For different user groups, the benefits of energy storage include the following [31].

Households: energy storage promotes the widespread use of renewable and distributed energy.

Businesses: energy storage reduces energy costs by decreasing downtime and production losses.

Electric companies: energy storage helps manage changes in supply and demand and improves the operation of the power generation, transmission, and distribution systems.

To create balance in power systems, deploying energy storage stations is the trend of the future. In the Made in China 2025 strategy proposed in 2015, the development of energy storage technology was prioritised [32]. The Chinese National Development and Reform Commission has issued guidance on promoting energy storage technology on multiple occasions. The detailed demands of this guidance have included: accelerating the development of distributed and intelligent energy; promoting the coordinated development of various energy production services and equipment manufacturing; promoting the efficient management and trading of energy; developing distributed energy storage services to achieve hybrid configuration of the grid; and promoting the innovation and development of the hydrogen industry and related facilities [30]. In Hunan Province, China, the newly built pumped-storage hydropower stations and battery storage power stations provided capacities of 520 and 15 million kWh respectively, for the storage of renewable energy from Mar 27th to Apr 15th [33]. The most recently issued policy in Hunan also states that energy storage equipment is a necessary supporting facility for wind power generation, and its capacity should reach 20% of the power generation capacity [34]. In 2016, the White House issued more than 30 administrative actions to increase energy storage equipment by more than 1.3 GW [35]. During the COVID-19 pandemic, distributed photovoltaic systems and energy storage devices have been considered as essential basic services in California [36]. These distributed power devices and energy storage devices provide residents with the indispensable electricity to meet home demand during the pandemic. In the context of increasing the proportion of renewable energy generation, energy storage deployment will continue to increase.

AI leads the future of energy

During this pandemic, AI technology and big data have shown extraordinary potential to solve problems and increase efficiency. Jia et al. [37] developed a spatio-temporal distribution model of risk sources with the use of big data to assess the community infection risk of the coronavirus with time in different regions. It is heartening that any country can use the proposed method to achieve rapid and accurate risk assessment and thus properly allocate limited resources. AI has also played a significant role in the diagnosis of coronavirus patients [38].

In the energy field, AI has gradually become integrated into every corner. The typical applications can be divided into three types.

Infrastructure and equipment management: AI is used to manage equipment, including fault detection, control, and diagnosis in facilities. For example, the State Grid used big data to determine the fault point and make advance preparations for emergency repairs between Jan 25th and Feb 18th in Hubei province at the height of the pandemic; this action saved an average of 30 min on each power supply repair. AI technology has led to substantial savings in terms of human resources, has improved emergency repair efficiency, and has reduced the risk of infection for individuals [39].

Load forecasting: AI is used to predict the load in a future period. Based on time intervals, load forecasting can be generally divided into three categories [40]: long-term load forecasting (one to ten years in the future), medium-term load forecasting (one month to one year in the future) and short-term load forecasting (one hour to one day or one week in the future). These forecasts can be used for long-term power system planning, efficient operation and maintenance of power systems, and power system scheduling, respectively. For example, the AI load pre-

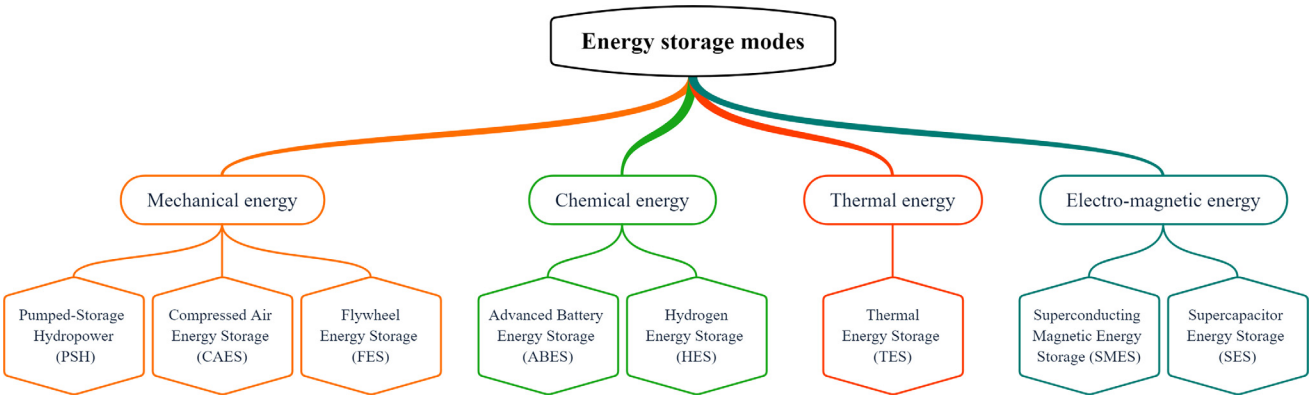

Fig. 2. Energy storage modes.

diction management systems with high accuracy launched by many regional grid companies in China have been used to implement dynamic regulation of the power production and distribution [41]. During this pandemic, grid companies in China have also used big data regarding electricity usage to estimate the work resumption rate, and thus dynamically regulate the electricity price to reduce the expenses of working enterprises [42].

Generation forecasting: AI is used to predict the amount of electricity generated from renewable sources. As mentioned above, wind and solar power are highly unstable, and AI technology can be helpful to predict their generation capacity or generation changes in future periods to improve the stability and security of the whole power system. For example, Hasan et al. [43] used a three-stage AI model to effectively predict the wind power generation one hour in the future.

Prospects

The COVID-19 pandemic has affected and will continue to affect energy utilisation, markets, and technologies. Although the pandemic has wreaked havoc on human society, it will facilitate a rapid rise of renewable energy that contributes to the sustainable development. The construction of renewable infrastructure will also expedite economic recovery for the post-pandemic world. Based on the renewable-dominated framework, building large-scale and distributed energy storage infrastructure will become a major method to ensure the security of energy supply. AI technologies which have played a vital role in fighting against the pandemic, will also assist in future development of energy by making energy clean, efficient and smart.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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