The COVID-19 Boost for Clean Electricity

Accelerating Clean Energy Development Through Pandemic-Era Measures

THE UNPRECEDENTED PANDEMIC RAISES A NUMber of uncertainties and implications in achieving the goal of a clean electricity future. During the peak of COVID-19, more than 100 countries implemented full or partial lockdowns to contain the pandemic. The lockdowns had significant impacts on global renewable energy deployments. This article analyzes data collected from countries and regions around the world, from prepandemic to postpandemic times. We also analyze the challenges and opportunities for clean energy development brought by the pandemic. Visions and suggestions for postpandemic development are also presented. To provide the readers with a quick overview of the global clean energy development progress, we summarize the

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latest goals and achievements of different countries and regions in Table 1. More details are articulated in the following discussions.

This article focuses on clean energy, while some literature may focus on renewable or sustainable energy. Although clean energy and renewable energy overlap to a large extent, there are some differences. Some energy sources may be renewable but not clean, such as biomass, while natural gas may be considered clean (or nearly clean in comparison with coal) but not renewable. Nuclear power is also considered a clean energy source by some countries, especially in Europe and North America, although its future is uncertain due to policy and regulation. In this article, all discussions are about clean energy (wind, solar, hydro, natural gas, and nuclear) unless specified otherwise.

Prepandemic Clean Energy Development Status

The Paris Climate Accords, or the Paris Agreement, were established by 196 parties at the 2015 United Nations Climate Change Conference. This agreement strives to keep the rise in mean global temperature to well below 2 °C (3.6 °F) above preindustrial levels and limit the increase to 1.5 °C (2.7 °F). Figure 1, taken from a 2014 Intergovernmental Panel on Climate Change report, shows the percentage share of worldwide emissions from different economic sectors in 2010. Electricity and heat production are shown to be the largest emissions driver. Figure 2 illustrates the yearly shares of global generation from coal and low-carbon sources before the COVID-19 pandemic. Globally, CO_2 emissions are on the decline, but the reduction is moving too slowly to meet the Paris Agreement commitment. Before the unprecedented COVID-19 pandemic, many countries had been taking various actions to accelerate the emission reduction, but progress has been uneven and slow.

In the United States, the landmark Energy Policy Act of 2005 established a federal investment tax credit for clean energy resources. Adding to this landmark policy, the Environmental Protection Agency's Clean Power Plan was unveiled in August 2015 to reduce CO_2 emissions and combat climate change. The plan set the goal of a 32% cut from 2005 levels by 2030 and set emissions goals for individual states. The Environmental Protection Agency also issued carbon pollution standards for new, modified, and reconstructed power plants. These were the first-ever national standards that addressed carbon pollution from power plants. In the first long-term strategy report, released in 2016, a target was set to reach near-complete decarbonization of electricity and reduce emissions economy-wide by 80% or more from 2005 levels by 2050. However, the Clean Power Plan was replaced by the Affordable Clean Energy rule in June 2019. The new rule aimed to reduce power plant emissions without actually setting caps on them.

In China, the 13th Five-Year Plan for Energy clearly stated the following goals for the 2015~2020 period: increase the share of nonfossil energy consumption from 12% to 15%, increase the share of nonfossil energy generation from 27% to 31%, and decrease the share of coal consumption from 64% to 58%. China achieved these targets ahead of schedule, in 2019, where nonfossil energy accounted for 15.3% of national primary energy consumption, suggesting optimistic prospects in clean energy development. Before the COVID-19 pandemic, China issued a number of policy guidelines to encourage clean energy development and gradually improved policy coverage of clean energy consumption, construction management, and

table 1. The goals and achievements of countries and regions around the world.

Area	Goals by 2030	Goals by Midcentury	Achievements So Far
North America (United States)	35% CO_2 emissions cut from 2005 levels	≥80% emissions cut from 2005 levels by 2050 Nearly decarbonized electricity	40% CO_2 emissions cut from 2005 levels in 2020
North America (Canada)	40%–45% greenhouse gas (GHG) emissions cut from 2005 levels	Net zero by 2050	82% clean electricity in 2021
Asia (China)	Peak CO_2 emissions by 2030 or earlier Wind and solar exceed 1,200 GW 25% nonfossil share in primary energy consumption	Carbon neutrality by 2060	Wind and solar total 634 GW 16.6% nonfossil share in 2021 primary energy consumption (66% of 2030 goal)
Europe (European Union)	≥55% GHG emissions cut from 1990 levels	80%~95% GHG emissions cut Net zero by 2050	34% GHG emissions cut from 1990 levels in 2020 22% renewable share in 2020 gross final energy consumption
Central America	75% renewable capacity share	50% GHG emissions cut ≥90% renewable capacity share Net zero by 2050	66% and 80% renewable generation share in 2019 and 2020
South America (Brazil)	No explicit target for energy sector 50% GHG emissions cut from 2005 levels, mainly through forestation	No explicit target for energy sector	86% and 79% renewable generation share in 2020 and 2021
South America (Chile)	20% renewable generation share by 2025 Disconnect ≥50% of coal generation by 2026	70% renewable generation share by 2050 Decommission all coal power plants by 2040	27% renewable generation share in 2021 (excluding conventional hydro)

electricity prices. The National Development and Reform Commission and the National Energy Administration jointly issued eight incentive policies and measures and the Notice on Actively Promoting Subsidy-Free Price of Wind Power and Photovoltaic Power Generation. The National Energy Administration also issued the Notice on Establishing and Improving Renewable Energy Power Consumption Guarantee Mechanism, pointing out the necessity of establishing a renewable energy consumption system that targets individual provinces.

The European Union (EU) encouraged the transition toward a cleaner and more sustainable economy in the past decade through concrete design and the implementation of clean energy policies. Since 2009, a series of commitments have been put in place for the decarbonization of the EU's energy consumption. The Climate–Energy 2020 Package, published in 2009, established energy and climate targets for 2020. The Energy Roadmap 2050 set the target to reduce greenhouse gas (GHG) emissions by 80%–95% from the 1990 level by 2050. These commitments are not binding on member states but are useful in defining the EU's future climate commitments. In 2014, the EU renewed its commitment and was aiming to reduce GHG emissions by at least 40% from 1990 levels by 2030. Following the Paris Agreement, a large number of legislative actions were adopted to enable the delivery of this commitment.

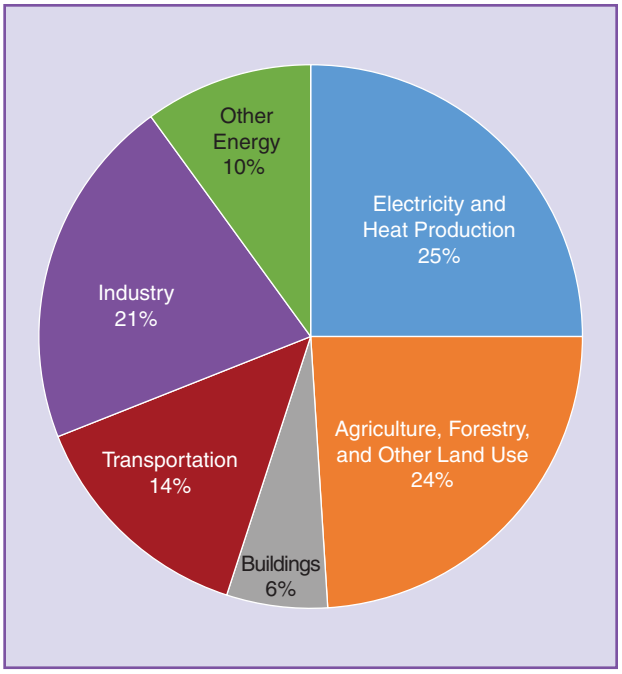

figure 1. The shares of global greenhouse gas emission by economic sector in 2010. (Source: Intergovernmental Panel on Climate Change: https://www.ipcc.ch/report/ar5/wg3/; redrawn with permission.)

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An EU regulatory review process, launched in 2016, led to the new Clean Energy Package for All Europeans. This package, approved in May 2019, consists of regulations and revisions for existing directives. It is divided into the five pillars of the Energy Union Strategy: 1) energy security, 2) energy markets, 3) energy efficiency, 4) decarbonization of the economy, and 5) research, innovation, and competitiveness. The main objectives set out in the Clean Energy Package are as follows: 1) a target of 40% GHG emissions reduction by 2030, 2) a 32% share of renewable energy on gross final energy consumption, and 3) a 32.5% reduction in primary energy consumption compared to the baseline scenario. Finally, with the European Green Deal, presented in December 2019, the European Commission aimed to transform the EU into a modern, resource-efficient, and competitive economy, ensuring net-zero emissions of GHGs by 2050, economic growth decoupled from resource use, and no person or place left behind.

In South America, the existing emission profiles of some countries have shaped the way that their clean development strategies are conceived. For example, Chile has ambitious decarbonization targets and important developments in its energy transition. As early as 2008, Chile set a legally binding target for a nonconventional renewable generation share of 10% (energy production) by 2025, updated to 20% in 2013. In 2015, Chile set an ambitious target of 70% renewables by 2050. In 2017, it became the first country in the region to set a US$5/ton carbon tax. In 2018, Chile reached a visionary public–private agreement to decommission the country's entire fleet of coal power plants by 2040. Moreover, after this agreement, leading generation companies expedited the decommission date of some large coal power generating units. This agreement publicly advertised a new plan that would disconnect more than 50% of coal generation installed capacity by 2026. Featuring a 12-GW peak demand and 32 GW of total installed generation capacity, the Chilean system had 10 GW of wind and solar power generation installed between 2011 and 2021 on a pure market basis and without subsidies. Investment rates rose despite the pandemic, and the legally binding target of 20% has been largely surpassed, as the renewables share represented 27% in 2021.

In contrast, Brazil is a country where renewable energy already accounts for 80% of the electricity supply mix, and the electricity sector accounts for only 4% of the country's CO_2 emissions. This high renewable share and low-emission electricity generation are due not only to the country's large hydropower share but increasingly to other clean energy sources, as wind and solar are currently the most competitive technologies in the expansion mix. Consequently, Brazil has never had a formal target for clean energy development. Similarly, in Central America's Regional Electricity Market, which includes the countries of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama, most of the installed generation capacity and production were found in renewable sources. For instance, 66.4% of the installed capacity in the region came from renewable sources, and 66% of the electricity was produced in a renewable way in 2019. The share of renewables has grown faster than nonrenewable ones for several decades. Despite having other natural resources, all countries in this region commonly exploit hydroelectric energy on a large scale.

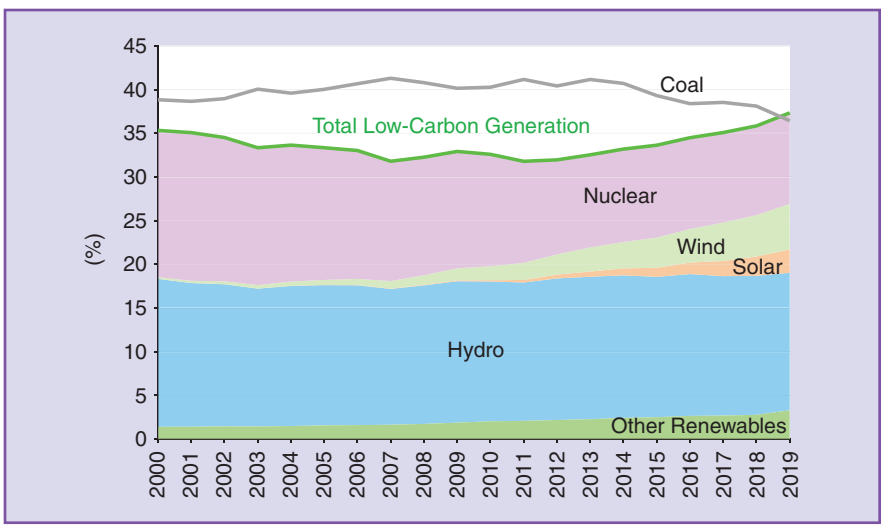

figure 2. The global generation shares from coal and low-carbon sources in 2000–2019. (Source: International Energy Agency: https://www.iea.org/data-and-statistics/charts/global-generation-shares-from-coal-and-low-carbon-sources-1971-2020; redrawn with permission.)

Government stay-at-home orders during the COVID-19 pandemic caused a decline of electricity demand and a subsequent increase in the share of renewable energy over total demand in some regions.

A Dress-Rehearsal of the Clean Electricity Future

Government stay-at-home orders during the COVID-19 pandemic caused a decline of electricity demand and a subsequent increase in the share of renewable energy over total demand in some regions. Figure 3 shows a comparison of hourly wind and solar shares to the total demands in Italy. There was a stark contrast between April 2019 (blue dots) and April 2020 (red dots). The total demand in April 2020 was much lower than the demand in April 2019, but the renewable energy share of April 2020 was much higher than that of April 2019, with a number of hours reaching 60% or higher renewable penetration. More interestingly, the yellow dots forecast these values in 2030, according to the Italian National Energy and Climate Plan, with a much higher renewable energy share and even a significant number of hours of over generation. The high renewable energy shares experienced during COVID-19 gave Italy and many countries a dress rehearsal of what they may experience in the clean electricity future.

Wind and solar are variable resources that depend on the weather. As variable generation shares increase, policies and market reforms are needed to increase clean firm power and enhance system flexibility to integrate high shares of renewable energy in a reliable and affordable manner. During the last two years, several policy and market innovations were made to prepare the power system for this clean electricity future.

Clean firm power sources (see Long et al. in the "For Further Reading" section) are reliable carbon-free resources that can be used whenever and for as long as they are needed. They can help mitigate challenges posed by variable resources by providing energy during periods of low wind and solar production. Examples of clean firm power include geothermal power, natural gas generation with carbon capture and storage, nuclear power, long-duration energy storage, and, potentially, hydrogen and other fuels with net-zero lifecycle emissions. The U.S. Infrastructure Investment and Jobs Act of 2021 provided US$20 billion to establish the Office of Clean Energy Demonstrations, under the Department of Energy, and support clean energy technology demonstration projects (e.g., clean hydrogen, carbon capture, grid-scale energy storage, and small modular reactors). In Canada, hydro installation continues to grow, while nuclear capacity remains steady. The Small Modular Reactor Action Plan, released in December 2020, turned the 2018 Small Model Reactor Roadmap into action and advanced Canada's nuclear techniques. In China, the installation capacity of nuclear and hydropower has increased. The installation of the Baihetan Hydropower Project, the world's second-largest hydropower plant, with an installed capacity of 16 GW, was completed in May 2022. Nuclear generation has steadily increased, with an average annual growth rate of 8% during the pandemic.

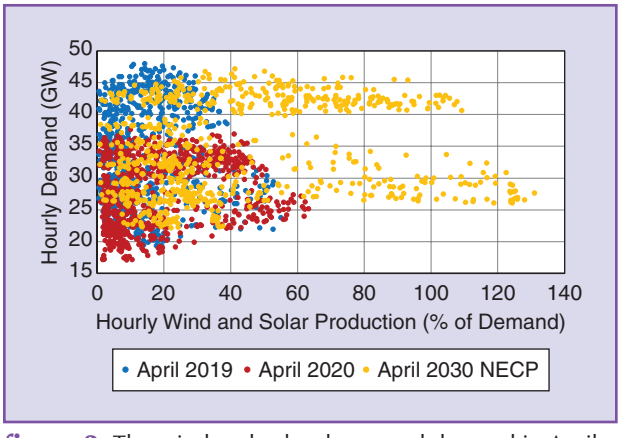

figure 3. The wind and solar shares and demand in April 2019 versus April 2020 versus simulated April 2030, based on the Italian National Energy and Climate Plan (NECP). (Source: NECP; redrawn with permission.)

Flexibility is also essential for balancing demand and generation at all times as variable renewable energy shares grow. Especially in the United States and Europe, distributed energy resources, such as electric vehicles; heating, ventilation, and air conditioning equipment; and distributed solar generation, could serve as significant sources of flexibility by 2030. Electric vehicles and batteries can charge from the grid when solar generation exceeds demand and discharge that energy later to the grid when needed. Many consumers have programmable thermostats that can reduce air conditioning use when supplies run low. Homeowners and businesses with rooftop solar panels can charge power to the grid or store it for later use or sale. On 17 September 2021, the U.S. Federal Energy Regulatory Commission approved the landmark Order 2222, which demands that market operators come up with plans for allowing aggregated distributed energy resources to participate in wholesale markets. In October 2021, a position paper, "Assessment of Future Flexibility Needs," from the European Network of Transmission System Operators for Electricity, introduced flexibility metrics to quantify potential future flexibility gaps in ramping and scarcity periods, which could appear

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due to increasing variability of demand and supply and other uncertainties.

In South America countries, such as Brazil and Chile, the need for flexibility was observed, as well. During that same period in 2020–2021, the area was also experiencing the worst drought in its 90-year historical record. In Brazil, strong multi-institutional and interministerial coordination actions sought alternative sources of supply and demand reduction, and renewables proved to be a strong component of the Brazilian strategy for security of supply, as wind and solar together delivered 13% of the 2021 electricity demand (see Figure 4). One initiative allowed for more flexible operation of the bulk transmission grid, which began to operate under an N-1 reliability criterion instead of the typically used N-2. This change resulted in a 30% gain in transmission capacity, which maximized the utilization of clean energy production in transmission-constrained regions of the country. Chile also suffered under extreme drought during the pandemic and consequently experienced a significant blackout risk in 2021. This risk can be worsened if decarbonization, particularly regarding the disconnection of thermal power plants, is not planned accordingly in the future. Hence, authorities have been working on a set of regulatory and market design initiatives to foster system flexibility for more reliable and resilient decarbonization. The need for energy storage facilities is becoming apparent to displace thermal power generators' "firm" capacity and thus implement an effective decarbonization process.

Accelerating the Energy Transition Through Green Recovery

Recovery from the pandemic is a great opportunity to accelerate clean energy transitions. Specifically, this is an opportunity to accelerate the construction of clean energy infrastructure, promote the transformation of the energy system, and improve public awareness of the consumption of clean energy. These efforts will, in turn, hedge against climate risks. While there is no preceding pandemic in the post-World War II era to look to for comparison, some other social economic crises of the past may provide comparable case studies. The stimulus plans for the green recovery of the whole globe

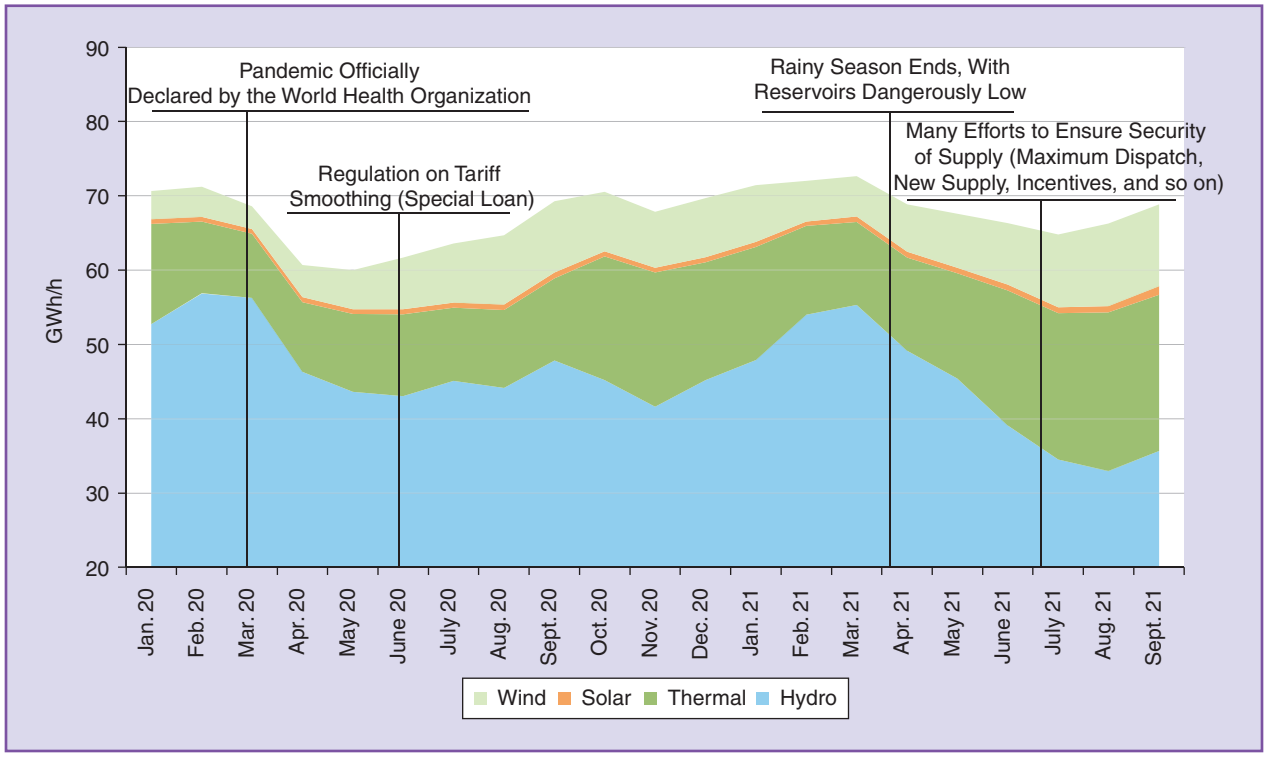

figure 4. The average monthly generation in Brazil during the pandemic.

reached US$714 billion, as of March 2022. As a comparison, the global green spending during the 2007–2009 financial crisis was around US$521 billion, as Figure 5 shows.

In North America, the economy during the COVID-19 pandemic had some similarities to that of the Great Recession, from 2007 to 2009. In the United States, the year 2008 was an election year, as was 2020. In response to the great economic recession, the American Recovery and Reinvestment Act was signed in early 2009 to jump-start the economy and create or save millions of jobs. That recovery act provided the Department of Energy with US$4.5 billion to modernize the electric power grid. The current administration learned from these past experiences and took action immediately after taking office by rejoining the Paris Agreement, updating the U.S. Nationally Determined Contribution (NDC), launching the Federal Sustainability Plan, and passing the Infrastructure Investment and Jobs Act. These actions contributed to a clean and sustainable build back. The Infrastructure Investment and Jobs Act, effective November 2021, included an investment of US$7.5 billion to build a national network of electric vehicle chargers and US$5 billion for electric school buses. As mentioned previously, this act also provides US$20 billion to establish the Office of Clean Energy Demonstrations to support clean energy technology demonstration projects.

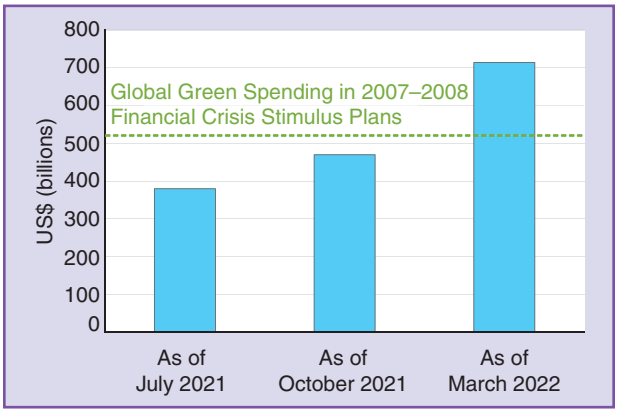

figure 5. The global sustainable recovery spending by governments in response to COVID-19 as compared to green spending levels enacted during global financial crisis. (Source: International Energy Agency: https://www.iea.org/reports/sustainable-recovery-tracker/key-findings; redrawn with permission.)

Canada has also been working to align pandemic recovery efforts with climate actions. The target areas include energy storage, clean energy infrastructure development, energy efficiency, zero-emission vehicles and carbon capture, utilization, and storage. The Net-Zero Emissions Accountability Act of 2021 established Canada's updated NDC to reduce emissions by 40%–45% below 2005 levels by 2030 and to reach net zero by 2050, a substantial increase of ambition beyond the 2017 NDC. This NDC target applies to all economic sectors, including electricity generation. To achieve this target, Canada announced its updated climate plan in late 2020, A Healthy Environment and a Healthy Economy, to invest in wind, solar, and power storage and to reduce remote coastal communities' reliance on diesel. Figure 6 depicts forecasts of Canada's energy generation mix made in 2019 and 2021. In the newer forecast, coal and oil generation as well as the use of natural gas are reduced. Meanwhile, the predicted amount of wind and solar are greatly increased in the newer forecast. In 2021, Canada achieved 82% nonemitting electricity despite the pandemic, as compared with that of 81% in 2019. The United States and Canada started a high-level dialogue in early 2021, seeking collaborations on combating climate change. Targeted areas include zero-emission vehicles and cross-border clean energy infrastructure.

In Europe, the economic crisis caused by the pandemic took a different shape than previous crises. Considering Italy as a case study, the country's electricity requirement was

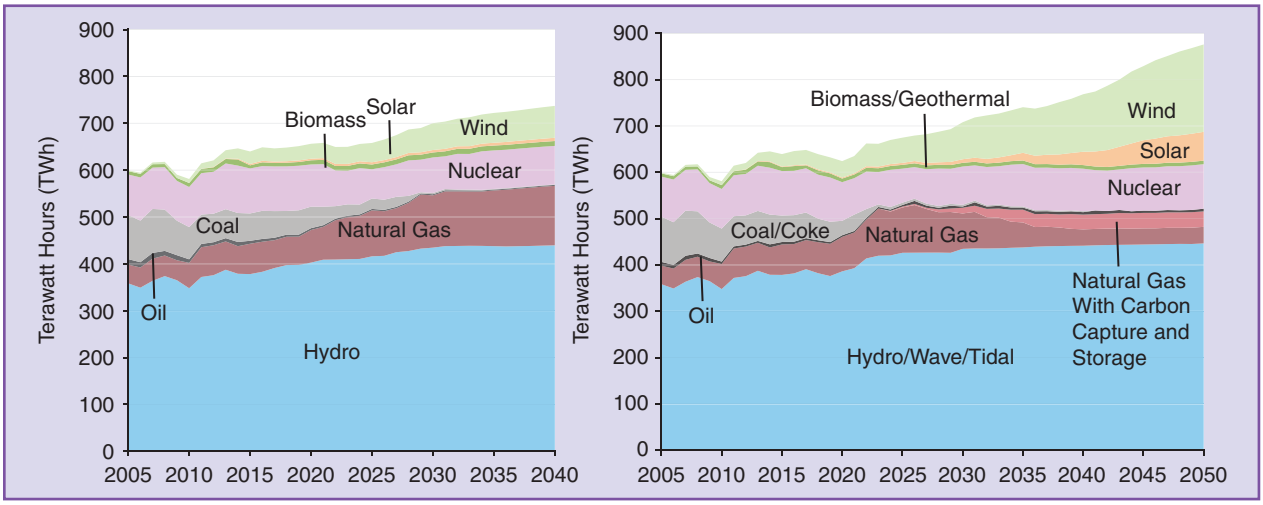

figure 6. Canada's generation mix forecast of 2019 versus that of 2021. (Source: Canada's Energy Future 2019 and Canada's Energy Future 2021; redrawn with permission.)

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approximately 301 TWh in 2020 (–5.8% compared to 2019), which is the lowest value observed since 2000 (298 TWh). On the other hand, the industry sector seemed to stay less affected compared to hardships faced in 2009. Industries were only partially slowed down in 2020: the economy showed a recession in the first part of the year, followed by a quick and marked recovery in the second part, resulting in a V cycle, with only a 2.7% reduction in annual total electricity consumption. This crisis was therefore managed as a new challenge with substantially different effects on the national economy than the crisis of 2009, in which the highest price was paid by the industrial sector (21-TWh losses, which was –13.8% compared to the previous year), as shown in Figure 7. After each crisis, there are signs of recovery from the implementation of strong policies and allocated funds for economic recovery, exemplified by the European Economic Recovery Plan of 2008 and the NextGenerationEU recovery plan of 2020.

One-third of the €1.8-trillion investment from NextGenerationEU and the EU's seven-year budget will finance the European Green Deal. The financial tools are designed to facilitate and accelerate the energy transition. The European Green Deal was announced in 2019, before the pandemic. Its confirmation through the presentation of the 2030 Climate Target Plan, which took place in September 2020, is therefore not to be understood as a direct consequence of the pandemic. As part of the European Green Deal, the European Commission proposed raising the 2030 GHG emissions reduction target, including carbon removals, to at least 55% compared to 1990 emissions levels, by taking actions required across all sectors, including increased energy efficiency and renewable energy. In July 2021, the commission came forward with the Fit for 55 package of proposals for the revision of its climate, energy, and transport-related legislation to shape current laws to meet the 2030 and 2050 ambitions (see Table 2). The package of proposals aims to provide a coherent and balanced framework for reaching the EU's climate objectives, which ensures a just and socially fair transition. The Fit for 55 package includes several legislative proposals and policy initiatives, e.g., an EU emissions trading system, member states' emissions reduction targets, emissions and removals from land use, land use change and forestry, clean energy, energy efficiency, alternative fuels infrastructure, energy taxation, a carbon border adjustment mechanism, and others. In this pandemic period, with a generalized push toward the sustainability of the economy in every respect, we expect that what happened can be a driving force for the transition.

Similar green recovery actions in China emphasize decarbonization. In 2020, China announced its most important commitment to environmentally friendly energy consumption, the Dual Carbon Goals, which include 1) peaking CO_2 emissions by 2030 and making the best efforts to peak early and 2) achieving carbon neutrality by 2060. Under the Dual Carbon Goals, it is forecast that the share of clean energy in the incremental energy consumption during the 14th Five-Year Plan (2021–2025) will reach 80%, which is

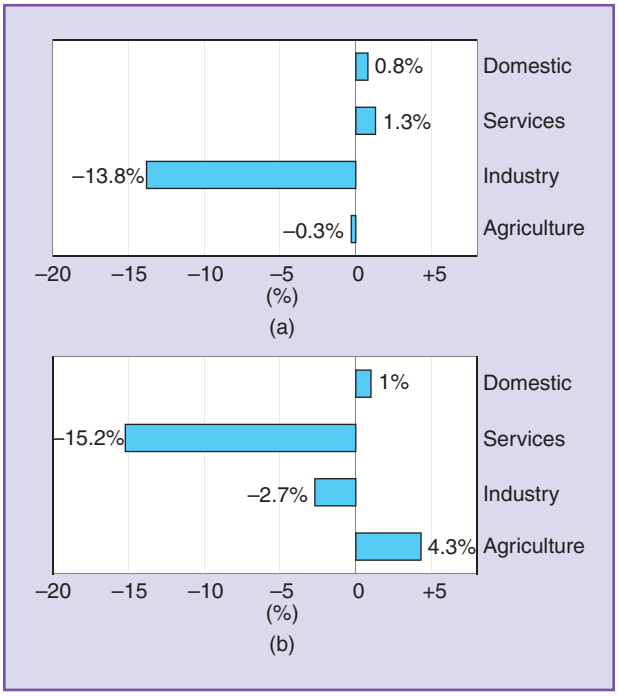

figure 7. A comparison of the electricity consumption change by sector in Italy (a) 2009 and (b) 2020 crises, with respect to the previous year.

table 2. The renewed 2030 EU targets.

2030 EU Targets	Emissions Reduction With Respect to 1990	Energy Efficiency	Renewable Share in Final Consumption
Clean Energy Package (2016)	–40%	–32.5%	≥32%
Green Deal and Fit for 55 (2019–2021)	–55%	–36% ~ –39%	≥40%

This is an opportunity to accelerate the construction of clean energy infrastructure, promote the transformation of the energy system, and improve public awareness of the consumption of clean energy.

20% higher than that of the 13th Five-Year Plan (2016–2020). The 14th Five-Year Industrial Green Development Plan puts forward the goal of accelerating the low-carbon transformation of energy consumption and increasing the share of clean energy consumption, striving to achieve more than 50% of renewable energy in China's total installed capacity during the 14th Five-Year Plan and as soon as possible. In 2021, the National Development and Reform Commission announced a 2.3 billion-renminbi (about US$350-million) stimulus plan for improving energy efficiency and reducing carbon emissions in selected industries.

The pandemic episode in Brazil was quite different from other past crises, as it involved a combination of difficulties: an extreme drought (similar to 2001), risks to distribution companies' financial health (as in 2014), a significant slowdown in economic activity (as in 2014 and the 1980s), and a demand-side shock. Many lessons learned in those past events were applied successfully to this event. In particular, a framework initially put in place in 2014 to procure a loan and smooth out tariff increases over several years was used in 2021 to facilitate distribution companies' cashflow. In this same vein, the ability of institutions to coordinate in the face of the hydrological crisis in 2021 was certainly influenced by their inability to act in advance of the severe drought in 2001, which led to forced electricity rationing. Although Brazil had not yet faced such a large number of simultaneous challenges, the government's actions in 2021 were informed by past crises.

New Challenges During Pandemic

Workforce shortages and supply chain disruptions are the two main factors affecting clean energy development during the pandemic. These two factors are correlated. Worldwide lockdown policies and the affected workers created a temporary workforce shortage for many businesses and industries, including the clean energy industry. This workforce shortage, together with international trade restrictions, caused supply chain disruptions. Such disruptions, in turn, led to financial difficulties and subsequently increased the level of unemployment along the supply chain and across the industry. As a result, the workforce shortage issue deteriorated. While countries and regions worldwide encountered these similar challenging factors, situations were not exactly the same due to different backgrounds and different COVID-19 policies.

In the United States, more than 620,000 clean energy workers were estimated to be out of work by June 2020, an 18% decline over the prepandemic employment level. Energy efficiency, the biggest segment of the U.S. energy sector, took the biggest tumble, with nearly 272,000 jobs lost. The losses peaked at the end of May 2020. About 313,000 jobs had been regained by the end of 2020, with the largest gains in the areas of wind, energy storage, and clean vehicle manufacturing. The job growth in these areas was due to policy changes in numerous states as well as the market signal to expand clean energy during the 2020 election. Both wind and solar installations fell in 2021 compared to 2020, as the industry faced a series of challenges, including supply chain issues and international trade barriers. Residential solar sales and installation were hit particularly hard early in the pandemic, due in part to homeowners' financial concerns.

In Canada, jobs in the power sector remained resilient during the pandemic. But wind and solar installations dropped dramatically in 2020, mainly due to delayed construction work and supply chain disruptions. The pandemic also impacted other clean electricity developments under construction. For example, the Muskrat Falls dam project was delayed by a quarter or so, due to social distancing restrictions. It was estimated that the pandemic cost impacts were roughly US$150 million, which is more than 1% of the total budget of the project.

In the EU, rapid changes in border control protocols and processes due to the rapidly changing pandemic situation also brought about challenges to cross-border trade flows. The trade flows of the EU with non-EU countries, for example, with Asia, were able to resume earlier than intra-EU trade, as the pandemic began earlier in those non-EU countries, which managed to control the crisis earlier and resumed operations and trade earlier. The production volume in the heating, ventilation, and air conditioning sector was also disrupted due to social distancing measures in the EU. Further, there was also disruption in the flow of energy professionals within the EU as border controls and restrictions were placed on nonessential travels. This disruption led to delays in operations, maintenance, and new construction works for hydropower, wind, and nuclear energy sectors.

In China, the installed capacity of all types of clean electricity sources continued to grow a significant amount during the pandemic. But the annual growth rate of the installation capacity of nuclear and solar declined during the pandemic. The annual growth rate of the installed capacity of nuclear was only 2% in 2020, and that of solar generation in 2021 dropped to 20% from 24% in 2020.

Such a situation is very likely related to the workforce shortage and supply chain issues during the pandemic.

It should be noted that international trade has undergone some drastic changes, which may significantly impact the development and reconfiguration of the supply chain for clean energy transitions. This nontechnical factor may be highly volatile with a deep impact to worldwide clean energy development.

Visions and Suggestions for the Next Step in Postpandemic Development

While there are different challenges and opportunities within different countries, there is a worldwide common interest toward a clean energy future. The following general observations and suggestions may serve as references in promoting clean electricity in the postpandemic era:

- ✔ *Further development of a remote working model for the power industry*: Lockdowns on different scales due to a pandemic or other reason may or may not appear during future decades. Prearranged remote working plans may benefit the whole industry, including clean electricity, if lockdowns happen and may provide working flexibility for daily tasks.
- ✔ *New load profile brought by working from home as a rehearsal of future clean electricity operation*: Working from home is at an unprecedented large-scale level during the pandemic. It has certain impacts on load profiles within different countries, usually causing flatter demand curves. Such changes yield possible new market designs for a postpandemic time. Also, these changes of load profiles signified the renewable penetration level and may serve as a rehearsal of the clean electricity future.
- ✔ *Restoring the confidence of clean electricity investors*: Policy supports, including but not limited to taxation and other fiscal stimulus plans, are critical. Transparency is another important aspect. Whenever possible, policymakers should release information on upcoming policy and ease the concerns of investors and lenders that are hesitating.
- ✔ *Preparing for future extreme weather events*: Extreme natural events happened along with the pandemic, causing greater challenges to the reliable and safe operation of some power grids. In the next few decades, more and worse extreme weather events may continually attack vulnerable regions. Groundbreaking technologies and market designs should be encouraged to maintain normal grid operation and clean development in these areas.

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