The COVID-19 Pandemic: Energy Market Disruptions and Resilience

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Abstract

Direct risks and indirect effects from the COVID-19 pandemic have impacted the operations and resilience of global energy markets. This article considers several aspects of the impacts and responses of these markets as well as energy sector resilience. All major energy markets have been affected, with unprecedented decreases in oil and natural gas demand, alongside operational stress for electric systems. Construction, maintenance, and operations in the industry face personnel constraints and limitations. Meanwhile, the disruptions from public health measures have tested the market's abilities to reliably manage severe demand destruction. Moving forward, there is a need to include demand shocks within energy resilience planning frameworks, and to prepare for multiple concurrent crises.

Keywords: Energy market, Global Energy, Energy Resilience, Pandemic Energy Impacts

Introduction

Due to their nature as critical infrastructure, energy systems and markets should be designed to handle low probability, high impact events. Energy resilience, or the ability to "bounce back" is central to the continued, safe operation of energy services during times of natural and manmade disaster. Without electricity or other energy supply, relief and recovery efforts could be severely compromised. Many energy systems and operations had contingency plans for events like a global pandemic, though in many jurisdictions, especially in the Global South, these plans were constrained by budget and personnel limitations. COVID-19's direct risks to personnel and indirect market effects have severely stressed existing energy systems and their resilience. Although the systems have, overall, performed well, with limited to no interruptions to energy service provision in OECD countries, the pandemic's long duration threatens to exacerbate other resilience risks for the energy system. After COVID-19, energy industries should evaluate their response to

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the pandemic, identify resilience gaps, and prepare mitigation strategies for handling concurrent crises.

This paper reviews aspects of the direct and indirect effects of the pandemic on the energy industry. As will be discussed in detail, the severity of market disruptions from public health measures generally outweighed the operational impacts from energy personnel risks. Oil and natural gas markets faced unprecedented declines in demand, with market impacts exacerbated by both geopolitical concerns and financial factors. While electricity markets experienced more moderate declines, they nevertheless faced operational challenges as demand shifted away from commercial and industrial centers, and planned construction and maintenance became constrained. Falling energy demand has led to large decreases in local air pollutants and greenhouse gas emissions. Pollution levels are expected to quickly return to normal, yet they provide a glimpse of what future clean energy system might bring.

The pandemic's economic fallout also raises concerns about future impacts on energy access, particularly in developing countries, as well as inequality in wealthy countries.[1] The COVID-19 pandemic reveals gaps in insufficient energy services to support health services, environmental pollution from energy production exacerbating respiratory risks, energy service provision being jeopardized by financial fallout, and the potential for disaster relief and recovery to benefit incumbent energy interests.[2]

The following sections explore important implications of the pandemic; oil and gas markets; electricity supply and operations; and policy lessons and recommendations to improve future energy sector resilience.

Oil and Natural Gas Market Chaos

Oil Markets

The oil sector likely faced the most severe market impacts of any energy sector. (This was coupled with a somewhat unrelated global oversupply in the market as we discuss later). As a result of social distancing guidance, stay-at-home orders, and travel restrictions, global demand for petroleum products crashed precipitously between February and April 2020. Travel restrictions had particularly outsized impacts on jet fuel demand, as global business and tourism virtually halted.[3]

1 Gebreslassie. COVID-19 and energy access: An opportunity or a challenge for the African Continent. *Energy Research and Social Science* 68, October 2020. https://www.sciencedirect.com/science/article/pii/S2214629620302681

2 Brosemer, K., et al. The energy crises revealed by COVID: Intersections of Indigeneity, inequity, and health. *Energy Research and Social Science* 68, October 2020. https://www.sciencedirect.com/science/article/pii/S221462962030236X

3 Abu-Rayash, A., & Dincer, I. Analysis of mobility trends during the COVID-19 coronavirus pandemic: Exploring the impacts on global aviation and travel in selected cities. *Energy Research and*

Over the course of the second quarter of 2020, global oil demand fell by 16.4 million barrels per day (mmbbls/d) compared to 2019.[4] Acknowledging continued uncertainty due to ongoing lockdowns, current forecasts indicate overall demand will decline by 7.9 mmbbls/d in 2020, more than 3 times the next greatest annual decline in history. Even though the fall in demand has been largely met by increased storage in the short term, the massive amount of oil going to storage has stressed global oil storage capacity. Subsequently, prices have fallen considerably to reduce supply to balance the market into 2021.

The size of falling demand and the speed at which it occurred surpassed the ability of the global oil cartel to control price levels. Since the rise of U.S. shale oil production in the early 2010's, the Organization of Petroleum Exporting Countries (OPEC) has had to expand its supply controls to a large group of countries to maintain price influence. Called OPEC+, the global oil cartel now contains most of the world's leading exporters. The most important members are OPEC's Saudi Arabia and non-OPEC Russia.[5] Despite some friction, OPEC+ was able to keep prices moderately elevated through early 2020. However, Saudi Arabia and Russia provided most of this market flexibility, losing market share as they cut production to offset supply increases from U.S. shale. When the extent of the pandemic's impact on oil demand emerged in February 2020, OPEC+ began negotiations about how to allocate a supply cut to maintain price levels. However, OPEC+ negotiations broke down in early March, with Saudi Arabia, Russia, and others deciding to increase production to try to maintain market share.[6]

Hence, even as the global pandemic caused an unprecedented fall in oil consumption, global oil producers were poised to actually increase production. Starting the year near the mid-$60s/barrel, oil hovered around $50/barrel in mid-February. Following the breakdown of OPEC+, prices collapsed in the $20-25/barrel range through mid-April. While focus on OPEC+ production preoccupied the market, the reality is that the demand collapse dwarfed any supply response and the temporary supply increase promised by Saudi Arabia and other producers. For April, oil supply was estimated to fall year-over-year by an astonishing 29 million barrels per day, combined with modest production increases to lead to monthly oil demand being 30% lower than oil supply. Sub-$30/barrel oil prices forced OPEC+ back to the negotiating table, working with the International Energy Agency, importers, and others to cut production and protect the long-term health of the

Social Science 68, October 2020. https://www.sciencedirect.com/science/article/pii/S2214629620302681

4 International Energy Agency. Oil Market Report, July 2020. https://www.iea.org/reports/oil-market-report-july-2020

5 Cohen, A. "OPEC Is Dead, Long Live OPEC+." *Forbes* June 2018. https://www.forbes.com/sites/arielcohen/2018/06/29/opec-is-dead-long-live-opec/#6e51d2202217

6 Bordoff, J. "Why This Oil Crash Is Different." *Foreign Policy* March 2020. https://foreignpolicy.com/2020/03/09/opec-russia-shale-oil-price-collapse/

market.[7] However, before these production cuts (the largest in history) could kick in, yet another unprecedented event would occur: negative oil prices at a pricing benchmark.

Compared to electricity and natural gas, oil is relatively easy and cheap to store. During busts, excess oil production is stored in land terminals and sometimes on floating tankers. When markets are in contango, meaning future prices are higher than present prices, storage entities can lock-in profits for stored oil with financial contracts.[8] Part of a healthy market system, this pricing structure facilitates the balancing of global oil markets. As global oil demand collapsed due to pandemic response measures, contango in futures contracts formed to encourage the storage of the entire surplus. Nevertheless, the sheer amount of oil needing to go into storage, as much as 600 million barrels in April alone, raised questions about whether there would be sufficient storage.[9] If there is no demand and no place to store oil, oil supply needs to be shut off at the well head, a costly process that can damage both the well and future oil production.

However, the severity and rapidity at which the pandemic impacted oil markets posed the risk of outpacing the ability of oil storage to handle the excess. In mid-April, oil next-month futures for delivery at the US benchmark hub in Cushing, Oklahoma suddenly crashed to $37/barrel.[10] With demand moribund, the ability of landlocked Cushing to store any more oil was in question. Effectively, holders of future contracts obligating acceptance of delivery were paying anyone that would take their oil delivery. The amount of physical oil traded at this level was limited, because many producers had already locked in deliveries. Nevertheless, subsequent chaos in long-dated delivery months, attributed to financial firms shifting their exposure from the front-month, raises questions about the degree to which oil financial speculation can unduly impact markets at times of severe stress.[11]

Natural Gas Market

As oil and natural gas are often produced from the same well, natural gas markets are closely tied to oil markets. The physical nature of natural gas makes storage

7 Krauss, C. "Oil Nations, Prodded by Trump, Reach Deal to Slash Production." *New York Times*, April 2020. https://www.nytimes.com/2020/04/12/business/energy-environment/opec-russia-saudi-arabia-oil-coronavirus.html

8 Regli, F., & Adland, R. "Crude oil contango arbitrage and the floating storage decision." *Transportation Research E: Logistics and Transportation Review* 122, pp. 100-118, February 2019. https://www.sciencedirect.com/science/article/pii/S1366554518304885

9 Jaffe, A.M. "Oil Ground Zero: Running Out of Storage." April 2020. https://www.cfr.org/blog/oil-ground-zero-running-out-storage

10 Gilbert, A. "Oil prices are negative: What does it mean and what comes next?" April 2020. https://www.fastcompany.com/90493860/oil-prices-are-negative-what-does-it-mean-and-what-comes-next

11 Einloth, J. "Speculation and Recent Volatility in the Price of Oil." FDIC: CFR, August 2009. https://www.fdic.gov/bank/analytical/cfr/2009/wp2009/2009-08.pdf

and transportation more expensive than oil, with the implication that most natural gas markets are regional in nature. With the arrival of U.S. shale production and a concurrent large increase in global liquified natural gas (LNG) trade, natural gas markets are increasingly global.

The resulting decline in natural gas demand due to the pandemic, as well as the crash in oil prices, has had severe effects on global LNG markets.[12] For many importers, oil competes with LNG as the marginal fuel source, and so prices are tightly linked. At the height of the pandemic, Asian LNG import prices fell below $3/MMBtu, barely 1/3 of the level that exporters planned for when making exports decisions. A lack of demand among the largest importers caused declarations of force majeures, pushing LNG cargoes into the spot market. The long-term implications remain unclear, but visions of constantly growing LNG demand may now appear ephemeral.[13]

Although oil and gas markets experienced major disruptions from pandemic response measures, they did not experience particularly severe restrictions on operations from COVID-19 personnel risks. In part, this is due to the collapse in oil demand and prices immediately reducing marginal production. In effect, there was no need to drill additional wells, so personnel were not needed and not exposed. Nevertheless, isolated oil operations, namely offshore oil platforms, posed severe risks to personnel. Their limited medical facilities, great distances from shore, close personal contact in tight quarters made them potential hotspots for infections.[14]

Electricity Sector Resilience

Operational Resilience

Like oil and natural gas, electric demand was reduced by unprecedented levels by pandemic response measures.[15] Nevertheless, the scale of the reduction was less compared to oil, as primarily commercial and industrial demand fell as residential demand increased due to stay-at-home orders. Estimates vary, with peak demand in Italy and Spain falling as much as 21% during the first week of lock downs.[16] In

12 Gilbert, A., and Bazilian, M. "The Oil Price Collapse Could Reshape Global Natural Gas Markets." *Georgetown Journal of International Affairs*. March 2020. https://gjia.georgetown.edu/2020/03/27/the-oil-price-collapse-could-reshape-global-natural-gas-markets/

13 Tsafos, N. "How COVID-19 Will Reshape Global Gas." CSIS March 2020. https://www.csis.org/analysis/how-covid-19-will-reshape-global-gas

14 Conca, J. "Offshore Oil Rigs Are A Special Case for COVID-19." *Forbes*, April 2020. https://www.forbes.com/sites/jamesconca/2020/04/28/offshore-oil-rigs-are-a-special-case-for-covid-19/#7a1541e66b82

15 Gilbert, A., & Bazilian, M. "The effects of coronavirus measures on electricity markets." *Utility Dive*, April 2020. https://www.utilitydive.com/news/the-effects-of-coronavirus-measures-on-electricity-markets/576296/

16 Electric Power Research Institute. "COVID-19 Bulk System Impacts: Demand Impacts and Oper-

the U.S., electricity demand reductions varied by region, depending in part on the ratio between normal commercial and residential load. In March and April, the Midwest, New York, and other regions saw demand lower by 9-16%, while Florida did not experience significant changes.[17] Notably, as a study of Nigerian electricity usage illustrates, both voluntary reactions to the pandemic and mandatory orders reduced electricity demand in commercial and industrial sectors as it grew in residential.[18]

The period of the most severe restrictions was during the spring shoulder season for the Northern hemisphere, somewhat mitigating the impact on seasonally low electric demand. Combined with falling natural gas prices, electricity prices in some areas were at or near record lows. Electricity futures in Europe were estimated to be 20% lower in 2021-2023 due to lower prices now.[19] Due to marginal dispatch of electricity markets, these low prices primarily reduced dispatch of coal and natural gas generation (and diesel in more isolated markets). The path of coal in the United States is indicative. Following years of decline, coal generation declined 36% in March 2020 compared to a year before, with an annual expected decline of about 20% in 2020.[20] As a result, monthly renewable generation from hydro, solar, and wind surpassed coal for the first time.

While the scale of demand reductions is unusual, the electric system is designed to handle supply contingencies, and thus had ample supply during the lockdowns. Electric reliability was not seriously threatened. Due to existing reliability standards and practices, many operational centers and control rooms already had pandemic response or other disaster response plans they were able to implement. The Electricity Subsector Coordinating Council, an industry-led group in the U.S., issued continuously updated guidelines to help utilities implement best practices.[21] Nonetheless, the uncertainty surrounding the pandemic has led to close monitor-

ational and Control Center Practices." March 2020. http://mydocs.epri.com/docs/public/covid19/3002018602R2.pdf

17 Energy Information Administration. "Daily electricity demand impacts from COVID-19 mitigation efforts differ by region." May 2020. https://www.eia.gov/todayinenergy/detail.php?id=43636

18 Edomah, N., & Ndulue, G. "Energy transition in a lockdown: An analysis of the impact of COVID-19 on changes in electricity demand in Lagos Nigeria." *Global Transitions* 2, 2020. https://www.sciencedirect.com/science/article/pii/S258979182030013X

19 S & P Global. "The Energy Transition and What It Means for European Power Prices and Producers: Midyear 2020 Update." June 2020. https://www.spglobal.com/ratings/en/research/articles/200608-the-energy-transition-and-what-it-means-for-european-power-prices-and-producers-midyear-2020-update-11509932

20 Benjamin Storrow. "Can Coal Survive the Coronavirus?" April 2020. https://www.scientificamerican.com/article/can-coal-survive-the-coronavirus/

21 Electricity Subsector Coordinating Council. "Assessing and Mitigating the Novel Coronavirus (COVID-19): A Resource Guide." June 2020. https://www.electricitysubsector.org/-/media/Files/ESCC/Documents/ESCC_COVID_Resource_Guide_v2-03242020.ashx?la=en&hash=D3732CBFB46827AA0331277E8D5CBE0CC4DFC3BF

ing and coordination between regulators, utilities, and other relevant entities. In the U.S., the North American Emergency Reliability Corporation (NERC) delayed implementation of several reliability standards, to provide short-term flexibility.[22] In its spring and summer reliability assessments, NERC also noted how the high uncertainty regarding the global health crisis led to elevated reliability risks.[23]

Beyond operational resilience, financial resilience of the system has thus far performed well, but may become increasingly stressed. The economic effects of pandemic shutdowns limited the ability of many consumers to pay their electric bills. Countries and U.S. states generally instituted utility shutoff moratoriums in response. In the short term, the effects of such moratoriums are generally small as a portion of overall revenue. In the longer term, the continuing nature of the pandemic and its economic effects has led to a reevaluation of moratoriums, jeopardizing electric access when people most need it (in a crisis). Beyond access itself, the high numbers of workplaces instituting work from home has led to a commercial-to-residential demand shift, which can increase residential consumers bills substantially.[24] The largest relative increases could fall on disadvantaged communities, somewhat exacerbating inequality. A widescale utility bill moratorium, to be made up in future rates, could ensure continued energy access, but is unlikely to be implemented.[25]

Supply Chain, Construction, and Maintenance Disruptions

The most noticeable impacts of the pandemic on the electric sector have been the impact on international energy supply chains—threatening construction and deferring of maintenance activities.

With pandemic response measures curbing industrial production, global supply chains for power goods was disrupted.[26] This was especially severe for solar panels, for which China is responsible for 70% of global production. Five of the top ten manufacturers in China fell under quarantine measures. Shipping disruptions

22 North American Electric Reliability Corporation. "Motion to Defer Implementation of Reliability Standards and Request for Shortened Response Period and Expedited Action." April 2020. https://www.nerc.com/news/Headlines%20DL/Motion%20to%20Defer%20Implementation%20of%20Reliability%20Standards.pdf

23 North American Electricity Reliability Corporation. "2020 Summer Reliability Assessment." June 2020. https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SRA_2020.pdf

24 Joseph Daniel. "Heatwaves and COVID Mean Higher Home Electricity Bills: What Do We Do About That?" Union of Concerned Scientists. July 2020. https://blog.ucsusa.org/joseph-daniel/heatwaves-covid-means-higher-electricity-bills

25 Wolfram, C. "Can We Stop Paying Utility Bills for a Bit?" March 30, 2020. https://energyathaas.wordpress.com/2020/03/30/can-we-stop-paying-utility-bills-for-a-bit/

26 Evans, A., & Bazilian, M. "Susceptibilities of Solar Energy Supply Chains." *Global Policy*, April 2020. https://www.globalpolicyjournal.com/blog/16/04/2020/susceptibilities-solar-energy-supply-chains

froze supply deliveries. By the time that industrial production began to recover, the spread of coronavirus began to impact foreign demand. These disruptions led to a large portion of global solar projects being stalled or cancelled. One domestic survey in the U.S. found residential projects had a 19% cancellation rate and a 53% job postponement rate.[27]

Though construction may seem like a low priority for a pandemic, the long lifecycle for electric project development means that projects under construction during such a disruption are necessary for powering its recovery. Boom and bust cycles rarely impact electricity markets, but ensuring that construction continues during a short-term bust is needed to protect reliability in the long-term. This is especially true for zero-carbon infrastructure, which require a continuous and high rate of deployment to meet mid-century climate goals. The only new U.S. nuclear power reactors under construction at Vogtle 3 and 4 have faced substantial construction delays as a result of coronavirus.[28] Of 9,000 workers, dozens began to test positive for coronavirus, forcing the utility to scale back the workforce and slow construction.

On the maintenance side, many power plants and other power infrastructure have had to delay or defer maintenance. The most visible concerns involve seasonal refueling outages for nuclear power plants. As exceptionally large power plants, planned nuclear outages require large numbers of personnel, often from out of town. During outages, utilities typically plan for both refueling and maintenance activities. In 2020, almost every single nuclear power plant in the U.S. had at least one scheduled refueling outage.[29] In response to the pandemic, any maintenance activities that could be deferred were. Nevertheless, refueling was needed to ensure the plants remained operational, with crews often rotating around the country on strict schedules limiting the ability to delay the outage entirely. Local governments raised concerns about these activities due to the large number of out-of-state personnel required.

Although global electricity markets have generally handled the pandemic's effects relatively well, the ongoing nature of the pandemic increases the chance for other natural or human caused disasters to impact sector resilience. Early in the pandemic, utilities and other operators already faced an increase in cyberattacks.[30]

27 Abigail Hopper. "Survey Findings: Things are bad and getting worse." *SEIA*. March 2020. https://seia.org/blog/survey-findings-things-are-bad-and-getting-worse

28 Julian Spector. "Sole US Nuclear Plant Under Construction Plods on Despite Virus Infections." April 2020. https://www.greentechmedia.com/articles/read/covid-19-impacted-productivity-of-vogtle-nuclear-plant-construction

29 Sonal Patel. "COVID-19 Threatens Outages Scheduled at 97% of U.S. Nuclear Sites in 2020." March 2020. https://www.powermag.com/covid-19-threatens-outages-scheduled-at-97-of-u-s-nuclear-plants-in-2020/

30 Leo Simonovich. "Why COVID-19 is making utilities more vulnerable to cyberattack—and what to do about it." *World Economic Forum*. April 2020. https://www.weforum.org/agenda/2020/04/why-

In California, ongoing issues with electric service increasing wildfire risk threatens to make a challenging situation worse as utility shut offs could encourage congregation (while conversely wildfires could cause congregation in shelters). More generally, the arrival of hurricane season in the U.S., one of the chief threats to electric reliability, could strain response and restoration of service.

Policy Complications and Conclusions

Energy reliability and resilience has traditionally been conceived of as a supply problem. Specifically, systems must be designed to ensure that there is sufficient energy supply in times of supply disruption. For electricity, this means ensuring adequate electricity capacity during periods of high demand and coincident supply outages. For oil markets, this has entailed the establishment of strategic storage reserves, with international coordination to ensure domestic markets can survive disruptions.

The unique nature of the pandemic has made clear that resilience measures must also consider demand disruptions. Although less severe than a supply disruption, which clearly threatens the availability of energy services, demand disruptions can nonetheless have powerful, long-lasting impacts. Coal in the United States and other countries may recover in the short-term, but the operational constraints imposed by relatively high levels of renewables on reduced demand systems provide important lessons for future grid operators.[31]

In oil markets, the International Energy Agency (IEA) took a leading role in encouraging countries with spare storage capacity in their strategic reserves to fill that capacity during second quarter supply disruptions. While small in the overall scheme of the pandemic demand collapse, these increased storage injections helped the overall oil system maintain balance as supply ramped down and commercial storage filled. Moving forward, having spare storage capacity in strategic reserves can provide protection against demand disruption. Developing a framework to manage that is needed, as such injections should be guided by system resilience needs, not market price balancing concerns.

The cascading effects of industrial production being curtailed on global electricity projects illustrates the growing risks of global just-in-time supply chains. Market dominance of solar panels by China meant that what originally was a domestic problem curtailed global projects before the problem became global. Shipping proved to be a particular bottleneck. Meanwhile—although internal OPEC+ conflict over controlling prices through supply curtailment were outweighed by

covid-19-is-making-utilities-more-vulnerable-to-cyberattack-and-what-to-do-about-it/

31 Birol, F. "The coronavirus crisis reminds us that electricity is more indispensable than ever." March 22, 2020. https://www.iea.org/commentaries/the-coronavirus-crisis-reminds-us-that-electricity-is-more-indispensable-than-ever

the scale of demand impacts—the episode illustrates the risks of continued influence of oligopoly control of oil production.

Beyond supply chains of physical goods, maintaining high diversity of fuel supplies in electric infrastructure is critical to minimize impacts. Power plants with constant fuel delivery needs, like coal and natural gas facilities, are more vulnerable to supply disruptions. However, even nuclear power plants, generally considered to have a high level of availability due to their 18-24 month refueling cycles, demonstrated their potential vulnerability to a disrupted refueling outage. Electricity supply diversity, particularly with a mix of refueling types and timeframes, can mitigate against short-, mid-, and long-term disruptions.

The severe disruptions to the energy sector posed by the pandemic are occurring in a period of rapid structural change. Driven by the decarbonization imperative, energy security concerns, the energy access challenge, other environmental impacts, and strategic competition for new technologies, global energy systems are rapidly diversifying, downscaling, and focusing on resilience and issues of inequality. The pandemic poses a critical juncture point for the clean energy transition, as government responses in terms of disaster recovery and stimulus will affect the trajectories of systematic change – both technically and socio-economically.[32] Meeting these goals will also require consideration of "just" transition criteria, to ensure that local jobs and communities are able to recover from COVID-19's economic effects as the energy transition continues.[33]

Author Capsule Bios

Alexander Gilbert, a Fellow at the Colorado School of Mines**,** is a complex systems researcher focusing on climate policy, energy markets, nuclear innovation, and space resources production. Drawing on interdisciplinary methods, he evaluates how institutions develop and adopt clean energy and other advanced natural resource technologies. He is a Project Manager at the Nuclear Innovation Alliance, where he focuses on regulatory reform and commercialization for advanced nuclear reactors to mitigate climate change and led research projects to support legislative change and regulatory guidance for international licensing of advanced reactors. Mr. Gilbert was cofounder of the Spark Library in Washington, D.C., where he designed a system to automate energy policy, market, legal, and regu-

32 Kuzembko, C., et al. "Covid-19 and the politics of sustainable energy transitions." *Energy Research & Social Science* 68, October 2020. https://www.sciencedirect.com/science/article/pii/S2214629620302607

33 Henry, M.S., Bazilian, M.D., & Markuson, C. "Just transitions: Histories and futures in a post-COVID world." *Energy Research & Social Science* 68, October 2020. https://www.sciencedirect.com/science/article/pii/S2214629620302437

latory research, and wrote analyses of major energy policy issues in the United States. These included renewable policies, energy markets, carbon capture, and natural gas. He is pursuing a PhD in Space Resources at the Colorado School of Mines, where he focuses on resource governance, environmental protection, and space nuclear power. He is Adjunct Faculty at Johns Hopkins University, where he co-teaches a course on nuclear power technology and regulation.

Morgan Bazilian is Director of the Payne Institute and a Professor of Public Policy at the Colorado School of Mines. Previously, he was lead energy specialist at the World Bank. He has over two decades of experience in the energy sector, and is regarded as a leading expert in international affairs, policy and investment. He is a Member of the Council on Foreign Relations. Dr. Bazilian holds two master's degrees and a Ph.D. in areas related to energy systems and markets, and has been a Fulbright fellow. He is on the editorial boards of Environmental Research Letters, Energy Strategy Reviews, and Energy Research and Social Science. He has published more than 140 articles in learned journals. His book, *Analytical Methods for Energy Diversity and Security*, is considered a seminal piece in the area of energy finance and security. His work has been published in, *inter alia*, *Foreign Affairs*, *Foreign Policy*, *Nature*, *Science*, and the *Proceedings of the National Academy of Science*. Dr. Bazilian is a member of the World Economic Forum's Global Advisory Council on Energy, as well as the Global Advisory Council of the Sustainable Finance Programme at Oxford University. Previously, he was a Deputy Director at the U.S. National Renewable Energy Laboratory (NREL) and a senior diplomat at the United Nations.