The Impact of the COVID-19 Pandemic on the Energy Sector

Giorgio Agostini, Christian Berger, Delaney Hall, Salaar Khan, Michael Pennington and Mohamed Awwad
Department of Industrial and Manufacturing Engineering
California Polytechnic State University
San Luis Obispo, CA 93407, USA
gagostin@calpoly.edu, chberger@calpoly.edu, dhall10@calpoly.edu, mkhan12@calpoly.edu, mapennin@calpoly.edu, mawwad@calpoly.edu

Abstract

The purpose of this paper is to explore the impact of the COVID-19 pandemic on the energy sector. With the widespread closures of business and decrease in travels due to the pandemic, there have been significant falls in electricity, coal, gas, and nuclear power consumption. Disruptions in manufacturing facilities and pauses on construction projects bring uncertainty about energy growth in 2021. In the past, similar drops in emissions occurred such as the global financial crisis of 2008 but resulted in a rebound of global CO_2 emissions when the market recovered. However, the pandemic brings forth unique risks and uncertainties for industries and governments in having to balance safety with progress. For this COVID-19 related recession, governments have the chance to pivot energy consumption by incentivizing renewable energy sectors like wind, solar, hydrogen, and energy storage that reduce the carbon footprint. Investing in renewables could stimulate economic recovery and aid in the transition to a more sustainable future. However, we see significant declines in such investments. We investigate how the energy industry was affected by and could recover from the challenges set forth by the pandemic and how this recovery could incentivize clean energy technologies.

Keywords
Sustainability, COVID-19 Pandemic, Renewable Energy, Fossil Fuels, Climate Change

1. Introduction
As the world has transitioned to working from home, social distancing measures, and meeting virtually instead of traveling, the energy sector has experienced significant changes. Demand for fossil fuels has taken a hit due to fewer people driving and flying. More people staying home means more homes to power in the most sustainable way possible. And perhaps above all, society has undergone a climate reckoning, with governments across the globe urgently enacting environmental policies to slow rapidly rising temperatures year after year. Modernizing our energy infrastructure will require an incredible amount of research into the economic, social, political, and environmental motivations and methods of doing so.

1.1 Objectives
The objective of this paper is to analyze the effect of COVID-19 on the world's existing energy infrastructure and the resulting acceleration of the development of renewable energy sources. In addition, this paper aims to describe the pre-and post-pandemic energy policies and practices of governments around the world.

2. Literature Review
2.1 Climate Change
Due to the COVID-19 pandemic, lockdowns were imposed across the world that resulted in interesting effects on the environment in addition to a reduced spread of the virus (Rumbaugh et al. 2020). Emissions from transport, industrial

technology, and aircraft have all decreased. This means that there has been a great reduction in greenhouse gases like carbon dioxide that affect the climate (Weber et al. 2020).

Climate change is not a novel topic. It can be traced back as far as the Industrial Revolution in the 1800s, when the burning of fossil fuels greatly picked up. These fossil fuels would release what we now call greenhouse gases, which keep more heat in the atmosphere and therefore raise the global temperature over time. Currently, we are witnessing a 1.8 degrees F global average increase. If we do not reduce our fossil fuel emissions, our planet will be hotter than it has been in 55 million years by 2100 (Mutel 2020).

Like COVID-19, climate change has negative impacts on health, such as increased asthma, allergies, and heart attacks. It also negatively impacts the environment, increasing humidity and precipitation in many areas. For example, Iowa's annual precipitation has increased from 32 to 38 inches, and extreme downpours have increased by 37% in the Midwest United States. The ocean has seen these negative effects, too, with an average temperature increase of 2.7 degrees F and a lower oxygen concentration. Although a reduction in emissions will not eliminate current climate change, it can change the course of climate change by lessening the future intensity and effects. COVID-19 may be able to help us begin this positive change (Mutel 2020).

Even though the disease was found a few decades back, it wasn't until more recently that it so negatively affected humans. The transmission and fatality rates of the coronavirus increased exponentially, causing the world to shut down in ways it has not in decades. One of the greatest environmental impacts of coronavirus has been on air quality. There has been a very apparent decrease in smog and pollution levels and increased marine life activity. For example, air pollution levels decreased by 50% from 2019 to 2020 in New York. In China, NO_2 emissions have decreased by almost 30% and carbon emissions have decreased by about 25% (Bhat et al. 2021). After the initial lockdowns, studies also showed 35% decreases in particulate matter (Mutel 2020). These reductions have resulted in improved air quality in several large cities across the globe (Bhat et al. 2021).

2.2 Oil, Gas, and Coal

Due to the sudden halt in business and leisure travel, perhaps no other energy sector has been more significantly impacted by COVID-19 than fossil fuels (Jouret et al. 2020). For the first time in modern history, fossil fuel consumption has shrunk on such a dramatic scale that it will leave a permanent scar on the energy industry as a whole.

B.P.'s 2020 Energy Outlook explores three different scenarios predicting how governments will change energy policy post-pandemic, which in turn will determine consumer demand for fossil fuel products in the coming years. In the first baseline scenario, which assumes governments won't implement any dramatic changes in their energy policy, "business-as-usual" (Figure 1), B.P. predicts that the increase in oil demand will drop by a modest 3 million barrels per day by 2025, peak in 2030, and decrease by a steady 2 million by 2050. In the two more aggressive policy scenarios, "rapid" and "net-zero", it is assumed that governments have already reached their peak oil consumption in 2020 and are currently experiencing an accelerated decrease (Bousso 2020).

Reflecting a dip in confidence in the fossil fuel industry by consumers, investment by banks also fell by an average of 9% in 2020, although levels remained greater than in 2016, a year after the Paris Climate Agreement was signed. The world's 60 largest banks financed $750.73 billion to the industry in 2020, down from $823.68 billion in 2019 but still higher than $709.23 billion in 2016 (Laidlaw 2021).

The major causes of concern within financial institutions are the long-term environmental impacts of fossil fuels, which are creeping closer with each passing year. As countries increasingly shift toward renewable energy sources, investors fear they will be left with stranded assets in what will then be considered obsolete fossil fuels. According to a report sponsored by the Rainforest Action Network, BankTrack, the Indigenous Environmental Network, Oil Change International, Reclaim Finance, and the Sierra Club, U.S.-based banks have consistently been the highest stakeholders in fossil fuel-related infrastructure for decades. However, even these banks have made recent efforts to roll back investments in fossil fuels and align their lending practices with the Paris Agreement. JPMorgan Chase & Co., for example, cut their funding to these projects by 20% between 2019 and 2020, aiming to bring total investment down to zero by 2050 (Laidlaw 2021).

These commitments by American financial institutions have been met with skepticism, however. The environmental groups who published the aforementioned report have stressed that any "net-zero" emissions goals set by investment banks pre-pandemic are null and void unless they re-commit to these goals in 2021, despite any post-pandemic boom the fossil fuel industry may experience. The impact of COVID-19 on climate change will be discussed more in-depth later in this report.

2.3 Electricity and Nuclear

Like other energy sectors, nuclear energy has been negatively impacted by the global decrease in electricity demand caused by COVID-19. As the workforce shifted from working in offices to working at home, the electricity demand greatly decreased in the commercial and industrial sectors and increased in the residential sector, the U.S seeing an average increase of 20% in residential electricity consumption (Elavarasan, R. 2020). This shift, along with the vast closures due to COVID-19, resulted in a large decrease in total energy demand and ultimately in the closure of over 19 U.S. energy companies during 2020 (Jiang et al. 2021). Outside of the U.S, this drop in demand can be observed in countries such as France, Italy, and Spain, which all saw over a 10% decrease in electricity demand. While not as drastic as the fall in fossil fuel demand, nuclear energy is projected to be down 3% globally and about 15-20% down in France, where it is the greatest energy supplier.

Additionally, the nuclear energy sector has been the victim of supply chain disruptions, most notably in nuclear fuel and development. Uranium mines and facilities, most located in countries such as Kazakhstan, Canada, and Namibia, have faced large disruptions due to COVID-19 and faced several closures (Combs, J. 2020). This has resulted in a 33% increase in global uranium prices and, bringing it to its highest since 2016. Material and equipment required in electrical distribution saw a significant shortage as well, resulting in delays in maintenance and repairs. Furthermore, the development of new facilities has been halted due to COVID-19 health precautions. Material delay and limited worker capacity have slowed, if not halted power plant development around the world, making the expansion of nuclear energy difficult. Such disruptions are just recently being resolved in 2021, and we shall expect to see their impacts as far as 2025 (Combs, J. 2020). In China, which has the highest levels of new reactor development, the slowed global economy has also proved a threat for the expansion of nuclear energy as the need for expansion has been diminished.

Despite these issues, nuclear energy has remained resistant to many of the impacts of COVID-19. While the price of nuclear fuel has increased, nuclear plants use supplied fuel for as much as three years, allowing them to persist past the shortage (World Nuclear Association 2020). A 2020 report found that operating costs were not significantly increased in 2020 despite the pandemic and that in future years it is expected to decrease (IEA 2020). Additionally, due to nuclear power’s strong culture for health and safety, operations have been able to continue with limited closures (Power Technology 2020). Many plants have been quick to implement safety protocols that limit travel, require essential staff to live onsite, and quarantine symptomatic personnel, which due to the already decreased demand for electricity, have not significantly impacted the ability to meet the demand for nuclear energy.

2.4 Sustainable Energies: Wind, Solar, and Hydrogen

The wind energy sector fared better than other renewables under COVID-19 protocols because of its globally distributed supply chain. Jiang et al. (2021) discuss how wind facilities have shorter investment cycles that make it a relatively cheaper renewable option, and numerous regions develop wind generation technologies. However, turbine blade production has been interrupted by the strain on the world’s supply chain. The decreased production of manufactured steel has lowered the raw materials supply for producing turbines, so various wind generation facilities around the world have halted development or closed. Wind energy facilities require long-term maintenance work, which has retained employment for the skilled workforce such as engineers and site managers.

In the 2010s, the development of photovoltaic cells for solar energy production soared in regions that receive an abundance of sunlight and solar irradiance levels, such as Malaysia and neighboring countries in Asia. Solar farms make up a substantial amount of renewable energy production, but the manufacturing is dominated by China and solar energy production is mostly centered in Asia. Lack of awareness about this circumstance caused the solar industry growth rate to decrease more than any other renewable energy type after implementing COVID-19 protocols. World governments have realized this disastrous pandemic impact on solar energy distribution, so they must provide proper solar energy incentives moving forward. As more regions of the world receive vaccinations, the better incentives for solar farms can distribute the solar energy job market and supply chain to diverse regions.

Efforts by the World Energy Council, International Energy Agency, International Renewable Energy Agency, and National Hydrogen Associations to promote hydrogen energy have resulted in minor implementations, such as hydrogen-fueled trains, boats, and planes. The leaders in pushing hydrogen fuels are Europe, Australia, China, Japan, South Korea, and the United States. Hydrogen, however, is currently among the smallest renewable energy industries. Water and air unintentionally became cleaner due to the COVID -19 pandemic shutdowns, which made countries realize the chance to maintain these environmental health benefits with a rapid clean energy transition. Dincer (2020) has compiled the Carbon/Hydrogen (C/H) ratio for various energy sources, and hydrogen ranks even better than natural gas. Wood has a C/H ratio of about 9 kg CO_2/kg H_2, coal at around 6 kg CO_2/kg H_2, oil at around 3 kg CO_2/kg H_2, natural gas at around 1.5 kg CO_2/kg H_2, and hydrogen at almost zero kg CO_2/kg H_2. As countries work towards a future with zero carbon emissions, there comes a possibility that hydrogen funding/incentives will grow and become among the main renewable energy sources.

The progress of renewable technologies has slowed down because of fewer global investments and incentives, but they still show better economic resilience than the nonrenewable energy industries like fossil fuels. Lower global energy consumption caused by COVID-19 presents a unique opportunity for governments to incentivize clean, low-carbon energy technologies such as wind, solar, and hydrogen. Governments were concerned about the transition from fossil fuels to renewable energy industries. Still, the alarming energy insecurity caused by the pandemic shows the demand growth rate for renewables is in a far better position than non-renewables. With the increasing availability of vaccines, possibilities open for an increase in job growth in the renewable energy workforce and industry.

2.5 Energy Storage

A carbon-neutral future achieved through renewable energy is contingent on a well-developed system of energy storage. When the sun is not shining, or the wind is not blowing, energy reserves need to meet the population demand. The COVID-19 pandemic has shown that strategic energy supply methods are important for energy security, but that must be accompanied by strategic storage methods. Chiaramonti (2020) discusses the E.U. Green Deal and how legislation emphasis is put on supply, but not on investing towards storage for that supply. The goal of decarbonization by 2050 will need to minimize Europe's energy imports, which are currently over half of their consumption in 2018. Pandemic recovery policies will need to advocate for well-designed energy storage methods to transition to the sustainable low-carbon future gradually.

There are a variety of mechanical, electrical, chemical, electrochemical, and thermal energy storage methods that can serve as energy storage systems. Amrouche (2016) lists the varieties of electrical storage batteries, including Nickel-cadmium, Nickel-zinc, Nickel-hydrogen, Sodium-sulfur, Sodium nickel chloride, Lithium-ion, and flow batteries. Hydrogen is unique in that its low-density best suits storage methods like compression, liquefication, and metal hydride. Governments were reluctant to promote these methods of energy storage, but the restrictions imposed by COVID-19 now show how insecure energy supply is in many countries. The costs, efficiency, and stability of renewable energy have been better than fossil fuels, but developments in energy storage methods will be needed to lower renewable energy production costs and better integrate them into the world energy supply chain.

2.6 Government Reactions: Global Perspective

The challenges set forth by the pandemic are unique, and the government is seen as an institution to lessen the burden being placed on the individual. The confinement to houses due to lockdown procedures have led to a loss of income that when coupled with the need to pay utility bills, has touched on the backbone of the energy industry across countries.

The G20 member countries that comprise the 19 member countries such as the United States, Brazil, India, etc., and the European Union contribute to 80% of the world's primary electricity consumption. Thus, imbalances or fluctuations within this group can lead to a domino effect destabilizing the world economy. Despite facing the same risk of the coronavirus, these critical countries have reacted with differing policies to mitigate risk for their citizens while still seeking to stabilize the energy sector. For example, several countries such as the United Kingdom, Canada, and even certain states in the United States declared no line disconnection or shutoffs for households that could not afford their electricity bills. Malaysia declared a 30% discount on the energy billing rate for three months. Other countries offered differing levels of support, such as allowing for a delayed payment plan or the ability to expunge the rates totally (Qarnain et al. 2020).

The differing government responses can be seen in Table 1 below, as summarized by the work of Qarnain, Muthuvel, and Sankaranarayanan (2020).

3. Future Shocks, Loads, and Tools

Governments face a unique challenge in addressing not only the world during the pandemic but also the shifts that linger on in the newly adjusted world. The increase in time spent at home, the migration to rural areas away from urban centers made possible due to work from home brought forth a very different geographical distribution to the same energy load. Will trends such as these persist long after or return to their pre-pandemic levels?

The concept of economic shock helps us look at the pandemic and provide a starting point for dynamic institutions such as governments and the energy industry to address their roles going forward. An economic shock is described as "a negative impulse signal which causes reactions and counter-reactions that evolve in a closed feedback loop" (Navon et al. 2021). The pandemic can be categorized as an economic shock to the long-established power and energy industries. However, it is left to be seen if the counter-reactions will shift the energy makeup of nations by either promoting or delaying long-term integrations of renewable energy sources. The Global Trends in Renewable Energy Investment 2020 paper detailed that the pandemic represents an inflection point where "the stakes are high. If this chance is missed, it may be even more difficult to find the funding to decarbonize the energy system in a post-COVID-19 global economy characterized by elevated government debt and squeezed private sector finances" (Ajadi et al. 2020).

The interconnectedness of demographic changes and their effect on energy load management asks the question of whether it is a possibility to interconnect grids, whether that be between neighboring countries, such as the multinational grid operation of the European Union, as larger systems are more immune to changes. Countries such as Israel and Japan and states such as Texas, with their isolated grids, referred to as "electric islands," will likely have to adapt to the future risk of pandemics.

The future needs dynamic models that can capture the relationships and trends that exist between demographics and load capacity along with being able to react to disruptions caused by events like the pandemic. Tools utilizing new technologies such as neural networks could provide the gateway in being able to forecast accurately the actions needed to mitigate risk.

Table 1: The Differing Responses by Countries to the Pandemic in relation to the Energy Sector (Qarnain et al 2020)

Malaysia	The people of Sabah Province will get a 30% discount on electricity bill for 3 months starting from 1 April 2020
Australia	Australian Government supports its energy customers with the help of the third party like deferred payments of energy bills and arranged the option of finance, it ensures at the time of crisis none is deprived of electricity in homes and commercial buildings.
Canada	It classified the electricity sector under "National Strategy for critical infrastructure", The Ontario energy board applied no administrative charges and suspension of service interruptions until Pandemic existed.
United States	There will be no service interruption while the prevalent pandemic times, the utility customers won't lose the service due to non-payment of bills
India	The Indian government announced a three-month moratorium for state-owned electricity distribution companies to make payments for their power purchased by them, it also reduced the payment security to 50% for future power purchases
Argentina	Suspension of disconnection of electricity services for non-payment of bills up to three consecutive bills or alternate bills, starting from 24 March 2020
France	For all business establishments, from midnight of 16 March 2020 for 30 days all utility bills including electricity bills.
Germany	Those who are affected by the loss of income can defer electricity payments till 30 June 2020.
Italy	Article 4 of Decree No.6 suspends all electricity bills until 30 April 2020
United Kingdom	No power interruption for energy users, the energy supply is ensured with support and initiatives from the Government of the U.K.
China	The government reduced the prices of electricity.
Indonesia	Free electricity for the people below a certain income level starting from 24 April 2020
Japan	Japanese government requested all the electricity companies to present a bill on providing a moratorium for electricity bill payment for 3 months.

4. Results and Discussion

4.1 Numerical Results

Jian et al. (2021) analyzed that the growth rate for wind has decreased by 0.2%, photovoltaics (solar) by 6.2%, hydropower by 1.7%, bioenergy by 5%, and all others by 4.3% from the year 2019 to 2020. Over 70% of module manufacturing for photovoltaics is managed in China, which explains the decreased growth rate in solar energy technologies for the year 2020. As a whole, renewables faced an average decreased growth rate of 1.9% due to COVID-19 policies. Although renewable energy experienced these drops, the demand for primary renewable energy increased by 0.79%. Other energy sources faced decreases in primary energy demand, such as a 4.99% decrease for gas, 7.73% for coal, and 9.12% for oil. This averaged a 6.05% decrease in demand for non-renewables.

4.2 Graphical Results

Figure 1 below shows the predicted change in liquid fossil fuel consumption over the next 30 years relative to the three government climate policy scenarios outlined in B.P.'s 2020 Energy Outlook.

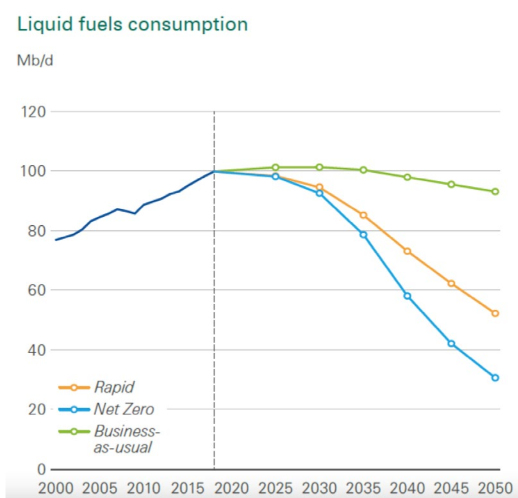

Figure 1. Predicted liquid fuels consumption (Bousso 2020)

International Energy Agency data compiled by Jiang et al. (2021) provides the projected change rates for primary energy demand from 2019 to 2020. The renewable energy sector floats at a positive 0.79% change rate, while other energy types such as coal, oil, gas, and nuclear experienced an average change rate of negative 6.05%. The renewable energy industry proves itself to be resilient even in a worldwide pandemic, which is highlighted with the visualization in Figure 2 below.

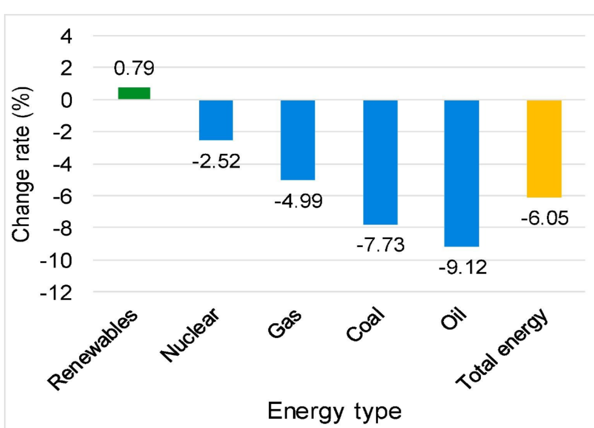

Figure 2. 2020 Projected Change Rates for Energy Types (Jiang et al. 2021)

Although renewable energy has fared better than any other energy type during the COVID-19 pandemic, it still experienced a decrease in growth due to halted government funding. With the world gradually reopening, it is key that governments reinvest in renewables to promote energy security and economic resilience. The visualization in Figure 3 below details how the growth rates for various renewable energy types have decreased from 2019 to 2020.

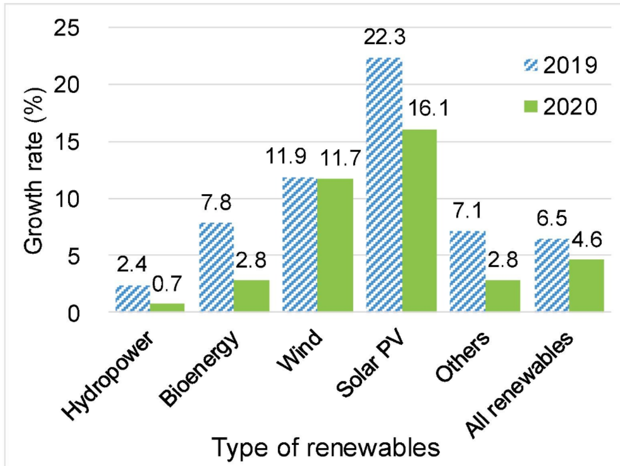

Figure 3. 2019-2020 Growth Rates for Energy Types (Jiang et al. 2021)

Furthermore, the pandemic demonstrated the limitations of forecasting models of load management that did not consider demographic and socioeconomic changes. Figure 4 demonstrates that there was no significant change in the forecasting error for 2020 before lockdown for Spain and France as compared to the previous year's averages. However, as Figure 5 demonstrates, the error in 2020 during the lockdown months was much higher as compared to previous norms for each of the two countries.

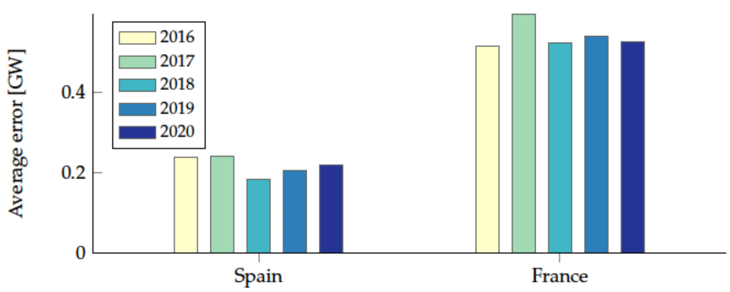

Figure 4. Average daily load forecasting error in Spain and France from 2016 - 2020, excluding the lockdown months of 2020 (Navon et al. 2021)

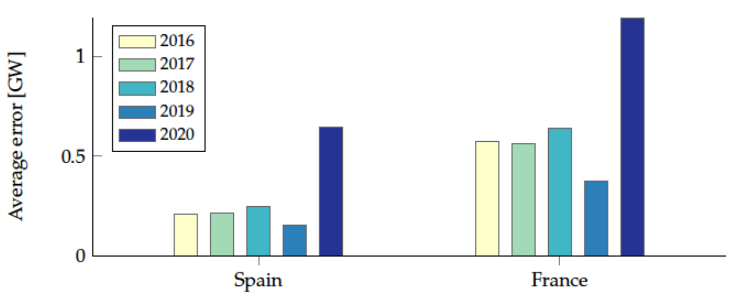

Figure 5. Average daily load forecasting error in Spain and France from 2016 - 2020, during the lockdown months (Navon et al. 2021)

5. Conclusion

COVID-19 has presented the world with a unique opportunity. It has forced change that once seemed out of reach. The rapid reduction in emissions has laid the groundwork for transitions to occur in the way we use energy. However, it is unfeasible to expect energy reductions to last as the virus's prevalence fades and people return to their "normal" lives. Travel will become popular again, and businesses will be able to handle a greater capacity. Due to oil and coal's current low prices, there is a strong chance that we will increase our dependency on them over renewable energy sources.

In 2008, the financial crisis resulted in greenhouse gas emission reductions of 1%, but it was short-lived. By 2010, carbon emissions grew 5.1%, reaching a record high (Le Quéré et al. 2020). This was the result of both the economy naturally returning to its previous state as well as government stimulation of the oil and gas economy. Because climate change is a slow process, the effects are not so immediate but pose a serious threat to human health and life as we know it. Yet, if we use this base of emission reductions to shift to an increase in renewable energy use and low carbon infrastructure, we may be able to have a greater positive impact, both environmentally and economically. As the economy rebuilds itself in the wake of COVID-19, increasing investment in renewable energy can increase employment, stimulate the economy, and, of course, lower carbon emissions. The COVID-19 global crisis resulted in a rapid response from the government, showing us that it is possible to induce a rapid change in a worldwide emergency (Khanna 2021). However, this example also solidifies that both policymakers and individual consumers will need to commit to the change necessary to curb climate change.

As 2021 progresses, there will be many opportunities to expand upon this research as more COVID-19 pandemic impacts take effect. An example of such will be the projected shortage in truck drivers expected to occur this summer, potentially having supply chain impacts on many energy sectors such as gasoline (Isidore 2021). Additionally, a review of alternations in companies' risk evaluation procedures due to the COVID-19 pandemic should be studied as infrastructure is put in place to avoid hazard risk. In the same vein of consideration should be a further study in government responses to the COVID-19 pandemic and how these responses to hazard risk affect consumer demand. These studies, if conducted over the next year, can further the research of this paper, with the potential to lay indicators for future global issues such as climate change.

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Biographies

Giorgio Agostini is a fourth-year Industrial Engineering student at Cal Poly, San Luis Obispo, with great interest in the power and utility industry. He has interned as a Data Analyst/Project Administrator for Pacific Coast Well Drilling, a water well construction company based out of Paso Robles, California. This upcoming Summer 2021, he will intern in Pomona, California, for the Transmission and Distribution Department of Southern California Edison. He plans to continue his career in this industry by working for a power/utility company that could improve their efficiency with industrial engineering practices.

Christian Berger is studying Industrial Engineering at Cal Poly, San Luis Obispo. He is interested in integrated systems of people, information, and materials. He is a part of the systems optimization club, consulting club, and the Cal Poly SLO Chapter of the Institute of Industrial Engineers. His senior project with Boeing focuses on conducting a feasibility analysis of retrofitting overhead cranes used for 737, 747, 777, and 787 airliner assembly. After completing his undergraduate degree, Christian will join KPMG as an I.T. Advisory Associate in their consulting arm.

Delaney Hall is a senior at Cal Poly, San Luis Obispo, majoring in Industrial Engineering with a minor in Psychology. She is greatly interested in human factors and analyzing how business decisions affect consumers as well as employees. On-campus, she has been involved in New Student and Transition Programs in addition to a couple of teachers' assistant programs. Previously, she worked at ChromaWay in Sweden, where she updated and documented a process for the company to offset their carbon emissions as well as learned a great deal about the blockchain industry. She has also worked as an Environmental Intern at Delicato Family Vineyards, where she was exposed to the numerous air quality requirements for wineries. In the future, she plans to find an environmentally conscious industrial engineering career with an emphasis on ergonomics.

Salaar Khan is a senior Industrial Engineering student at Cal Poly, San Luis Obispo. He is interested in the electric vehicle sector and previously served as an operations lead for a high-performance automotive injector company in Carmel Valley, California, where he oversaw the product testing and shipping operations. He is involved with the Formula SAE and system optimization clubs on campus and is a member of the Cal Poly SLO Chapter of the Institute of Industrial Engineers. Upon graduation, Salaar hopes to work in the electric vehicle industry in a role that serves to bridge the gap between the business and technical sides of the company.

Michael Pennington is a 5th year Industrial Engineering student at Cal Poly, San Luis Obispo. Before pursuing his current education, Michael was a civil engineering student working for CalTrans and was heavily involved in Engineers Without Borders. It was in the latter organization that he traveled to Nicaragua and lived for several weeks in a remote village, developing a water distribution system for the local community. After a change in interest, Michael left Cal Poly and civil engineering to pursue a career in the restaurant industry as a cook and a part-time brewer. On the kitchen line, he developed his interest in process improvement, ultimately leading him to pursue an education at Cal Poly. Since then, Michael has been heavily involved in the department as a Teacher Assistant, organizing the open house, and participating in clubs such as metal casting.

Mohamed Awwad is an Assistant Professor in the Department of Industrial and Manufacturing Engineering at California Polytechnic State University (Cal Poly), San Luis Obispo, CA. He received his Ph.D. and M.S. degrees in Industrial Engineering from the University of Central Florida, Orlando, FL, USA. Additionally, he holds M.S. and B.S. degrees in Mechanical Engineering from Cairo University, Egypt. Before joining Cal Poly, San Luis Obispo, Dr. Awwad held several teaching and research positions at the State University of New York at Buffalo (SUNY Buffalo), the University of Missouri, Florida Polytechnic University, and the University of Central Florida. His research and teaching interests include applied operations research, logistics & supply chain, blockchain technology, distribution center design, unconventional logistics systems design, and Operation Research applications in healthcare and the military.