Repowering Americans: A Decentralized Approach towards Energy Generation for Ensuring National Security and Municipal Resilience

Victoria Glasgow, AICP

George Mason University’s Schar School of Policy and Government

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Dr. Todd La Porte

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Abstract

America's current energy infrastructure is susceptible to more frequent severe weather and security threats, yet cultural and fiscal factors limit the country's ability to respond to such challenges. An evaluation of current and historical events, meteorological trends, interviews, and the evolution of the U.S. power grid provides a better understanding of a system which is complex, crucial, and increasingly vulnerable. In strengthening the grid, policymakers must come to understand that centralized energy generation is approaching a tipping point of ineffectiveness and obsoletism which is being perpetuated via subsidies and a disingenuous organization framework. Renewables and microgrids are a promising way to strengthen municipalities and prevent catastrophic failure, yet private utility companies must be supported in a new policy and economic landscape if they are to successfully adapt to a new model.

Keywords: energy, grid, power, solar, electricity

Introduction

As populations rise and new technologies are adopted by American society, our demand for energy will continue to increase. This condition is often met with an optimistic belief that scientific innovation will prevent the consequences of an uncurbed appetite. However, while improving energy efficiency is a crucial element of tempering unprecedented demand, it is more practical to reimagine the organization of existing technologies rather than wait for new ones to be deployed. The reality is that our quickly advancing world requires more energy than previously anticipated and operates under conditions that were unforeseen a century ago. Perpetuating our current energy system leaves Americans vulnerable to supply chain fluctuations, international volatility, extreme weather events, and even infrastructural sabotage.

The most compelling way in which policymakers, energy commissions, and power providers can secure the delivery of energy services is by incorporating decentralized and renewable power sources within all communities, regardless of whether they are urban or rural. The need to proliferate renewable energy throughout our built environment goes beyond reducing emissions. While it is well-established that replacing fossil fuels with alternative sources has a positive effect on human health, environmental quality, and regulating climate conditions, this paper will focus on security and resiliency as the driving factors for decentralized energy grids. Furthermore, in the spirit of anticipating all challenges, this paper will address how renewables might increase susceptibility to energy disruptions and how these new challenges might be mitigated.

A research paper that fails to offer solutions does its readers a disservice. After exploring the science and current state of America's power grid, this paper will identify the political landscape that needs to be navigated in order to implement these energy alternatives, what must change, and what such a path looks like. Government cannot force Americans to use less energy, but policy can provide them the means to achieve reliable energy independence.

Current State of the Energy Grid: Best Practices and Trends

In 1858, Queen Victoria and President Buchanan exchanged their first transatlantic telegram once the world's first telegraph cable was lain across the Atlantic (Marsh, 2019). This leap in communication tested engineers' theories on transmission theory: some believed thicker cables would require more electricity, while others argued that delays would depend on the cable's length. After much deliberation, the resulting cable was composed of seven woven copper strands wrapped together in latex, then covered in hemp and bound with iron clasps before it spanned 2,000 miles to connect two continents.

Unbeknownst to the engineers, this design caused significant distortion when messages were relayed, and the line failed within weeks of its opening (Marsh, 2019). Analyses on the recovered cables have shown that the conductivity of the iron sheath, which was wrapped around the cable to strengthen it, interfered with the copper wires' electromagnetic fields (Cogan, 1985). James Clerk Maxwell would later develop a theory that explained the interrelationship between magnetism, electricity, and light, but these concepts were not settled at the time the transatlantic engineers deployed their project (Rautio, 2014). Even today, there is a common misconception that electricity is carried by electrons which push each other through a wire. Instead, electricity travels in electromagnetic fields around the wires, whose surface charges guide the tumbling electrons through a circuit and into their destination – where collisions with the source's atoms yields power for users (Technology.Org, 2021).

Today's energy infrastructure does not experience the trans-Atlantic misfortunes of 1858. However, some aspects of our grid are reminiscent of 19^{th}-century limitations. The basic structure of delivering energy to customers has remained more or less the same ever since America's first AC hydroelectric generator opened in 1891 (McBride & Siripurapu, 2022; Hughes & Rudolph, 2013). For most of the grid's history, power has been generated when a turbine rotor's blades are spun via forcing a fluid through it, which rotates a magnet around the attached generator's copper coils (EIA, 2021). This movement of different poles creates a difference in charges at either end of the conductive wire, generating voltage – the drift of electrons – and an energy field. Most of the world uses alternating current (AC), in which the spinning magnetic poles intermittently reverses the magnetic and electric fields every half-cycle: because both fields flip at the same time, the energy field travels the same way regardless of phase (Technology.Org).

The most crucial benefit of alternating current is its ability to be transformed into a higher or lower voltage. When two sets of coils are in proximity to each other, the changing magnetic field in one set induces voltage in the other (All About Circuits, n.d.). Because a higher voltage – or a faster drift of electrons – is needed to carry the energy field across long distances with minimal energy loss, electricity that is produced by a power plant must then be "transformed" to 44k-750k volts for transmission (McBridge & Siripurapu, 2022; Woodford, 2021). This is done in transmission substations, where placing a larger number of coils in proximity to a lower number of charged coils ramps up voltage and reduces current (All About Circuits, n.d.; Gerrity & Lantero, 2014). Energy then travels long distances through transmission lines which attach to large steel structures that typically have no trees or structures nearby (Aspen Environmental Group, n.d.). The system may or may not include transmission substations and subtransmission lines, which lower voltage to an intermediate step and isolate it for maintenance. Voltage is then reduced further via distribution substations, which are closer to typical everyday energy consumers than transmission substations, and the energy that neighborhoods ultimately receive has been stepped-down to 120 volts.

In recent years, this traditional system has been updated with modernizing elements. In 1988, Virginia Tech researchers developed a device that time-stamped AC waveform data using a “common time reference such as GPS” (Schweizer Engineering Laboratories, 2015, n.p.). This phasor measurement unit (PMU), also known as a synchrophasor, became more affordable in the 2000s and now instantaneously measures voltage, current, and frequency at more than 2,500 locations in the North American energy grid (Hoffman, 2014; Office of Electricity, n.d.). All of these data are coordinated via a revolutionary monitoring system called EAGLE-I, which was developed by the Department of Energy to collect grid data from power company websites every 15 minutes (Lantero, 2014). EAGLE-I reports real-time data on 75% of the electrical grid, which better informs federal agencies on what actions to take during natural disasters that disrupt energy service.

Not all components of the grid have been modernized, however. 70% of transmission lines and power transformers are over 25 years old, and the average age of power plants is over 30 years old (Gerrity & Lantero, 2014). This does not necessarily mean America’s electric grid is crumbling from age, but it does suggest that we might be relying on infrastructure that leaves little room for innovation and change. Though there are measures in place to prevent catastrophic failures, the breakdown of one of North America’s 2 major or 3 minor grids would yield outages for millions of people (Gerrity & Lantero, 2014).

Fortunately, there are ways to mitigate such an outcome. The Environmental Protection Agency writes that “within each of these [three major energy] regions are interconnected local electricity grids. With multiple ways for the power to flow from generation to load centers, this redundancy seeks to ensure minimal loss of service in case of local failures” (2022). Though this comment is referring to the subregions within America’s three major energy grids, this principle of “redundancy equating resiliency” can be applied to smaller, independent grids on a local level. Microgrids are a separate connection of buildings that tie into both the main energy grid and their own power sources: in times of trouble or repairs, these separate grids can provide their own energy until central power is restored (Lantero, 2014-b). This switch from central to local power sources can be done either manually or automatically, and microgrids can be either alternating or direct current.

Microgrids not only serve as a versatile backup to the high voltage, or “bulk,” energy system: they might also allow for more efficient energy distribution than traditional energy sources. The U.S. Energy Information Administration (EIA) wrote the following about lost electricity in their August 2022 *Monthly Energy Report* (2022-a, pg. 52):

> Most of these losses occur at steam-electric power plants (conventional and nuclear) in the conversion of heat energy into mechanical energy to turn electric generators. The loss is a thermodynamically necessary feature of the steam-electric cycle…In addition to conversion losses, other losses include power plant use of electricity, transmission and distribution of electricity from power plants to end-use consumers (also called “line losses”), and unaccounted-for electricity…**Overall, about two thirds of total energy input is lost in conversion.**

In 2021, 61% of America's energy was produced by steam-electric fossil-fuel power plants, and 19% was from nuclear energy (EIA, 2022-b). While U.S. residents may be receiving enormous amounts of reliable energy from these sources, we are also losing 63% of oil, gas, coal, and nuclear energy as heat. This is an incredibly inefficient way to use available energy sources – but, barring major technological efficiency improvements, is there actually a viable alternative to sating today's energy demands?

A Technically Brief Background on Renewables

The 19th century was an era of innovation. Just as the 19-year long plan for the transatlantic cable was being formulated, the photovoltaic effect was discovered by a young physicist named Edmond Becquerel (Chu & Tarazano, n.d.). This process, also known as the "Becquerel Effect," occurs when a semiconductive or conductive material absorbs light, exciting the electrons and generating voltage. This solar cell technology was later improved upon by Charles Fritts in 1883, who developed a gold-coated selenium medium which was 1-2% efficient; in the 1950s, selenium was swapped for silicon to bump the efficiency rate up to 6%; today, most solar panels are 15-20% efficient (n.d.).

Solar cells are sandwiched between protective glass or plastic and are then connected to form the widely recognized solar panel (Solar Energy Technologies Office, n.d.). Because the source of power for photovoltaics (PVs) is the sun, it is advantageous to operate them where there is plenty of sunlight. PVs are relatively energy-intensive to make, taking 1-4 years to generate the same amount that was used to manufacture them, but this investment usually pays off since PV operating systems have a lifespan of over 30 years (EIA, 2022-c). Additionally, while solar panels are made using hazardous chemicals – cadmium compounds, lead, hexafluoroethane, and silicon tetrachloride – they do not produce pollution in the process of generating energy (EIA, 2022-c; Nguyen, 2018).

These limitations do not outweigh solar's potential, however. A large reduction in solar energy prices – 74% from 2010 to 2020 for United States residential PVs – has led to a revolution in incorporating solar panels on roofs (Solar Energy Technologies Office, 2021). Furthermore, more users are taking advantage of the panels' shade-generating properties to install them over Washington, D.C. parking spaces or even over a 20-mile long bike path, as is the case in South Korea (Good News Network, 2022; Ozdemir, 2021).

As with solar energy, wind power was used by humans much earlier than the 20^{th} century. Windmills have been used to power boats, sawmills, lake drainage, and food production for thousands of years (EIA, 2022-d). The combination of uneven heating of the Earth's surface, the irregular shape of land, and the Earth's rotation all lead to the movement of air that can spin a wind turbine's blades: much like an airplane, the air pressure behind the blade decreases, causing 'lift' and causing the blade to move (Wind Energy Technologies Office, n.d.). The connected spinning rotor is either directly connected to a generator – a direct drive turbine – or goes through a gearbox that "speed[s] up the rotation and allow[s] for a physically smaller generator" (n.d.). Wind turbines can either be horizontal-axis, which are the more common upright three-bladed structures, or vertical-axis turbines that have twisted blades and are situated perpendicular to wind direction.

Wind is intermittent like sunlight, but strategic placements can maximize the utility of wind turbines. Wind speeds are higher above ground level, so the taller the wind turbine, the more electricity it can generate (Hartman, 2022). Land-based turbines average over 300 feet tall with blades at 200 feet; this type is considered the most cost-effective and can generate a range from 100 kilowatts to 3 megawatts (Wind Energy Technologies Office, n.d.). Offshore wind turbines are taller than land-based and, while they require careful construction, are not limited by the limitations of the on-land transportation network (2022). Smaller and individual wind turbines that produce fewer than 100 kilowatts are called “distributed wind,” which are typically is the type incorporated into microgrids. While the fiberglass blades from all types of wind turbines can be difficult to dispose of or recycle, the price of wind power has dropped significantly in the past few decades – to the point where 50% of Iowa and South Dakota’s energy came from wind power in 2021 (Martin, 2020; Hartman, 2022).

Other forms of energy generation are much more traditional. Before fossil fuels became widespread in the mid-1800s, Americans relied on burning organic material from plants and animals – biofuel – for their main source of energy (EIA, 2022-e). Today the use of biomass can be seen in utilizing wood in all forms, agricultural crops and waste, anything organic from municipal solid waste, and even sewage via the production of biogas. As of 2021, 5% of U.S. energy came from such organic sources: 48% of biofuel is used in industry, 31% transportation (ethanol), 10% residential (fireplaces), 9% electric, and 3% commercial. Rather than rely on this type of fuel for its own uses, the United States is a net exporter of densified biomass fuels and wood pellets.

The Earth can be harnessed for energy not just through utilizing biomass but also by taking advantage of its molten core. Geothermal energy can be harnessed either through direct use heating systems, geothermal power plants, or heat pumps, and while it only accounts for .4% of U.S. electricity generation, seven states in the country use geothermal energy (EIA, 2022-f). California provides the largest share of geothermal energy produced (70.5%), but 9.4% of Nevada’s entire electricity consumption is from geothermal sources – nearly 10%. Geothermal is currently not widespread throughout the country, but it could be a pertinent and overlooked energy solution in areas best suited for it.

One of the greatest challenges in utilizing renewables is their reliability. Apart from biofuel, which is another form of combustion generation, renewables produce varying amounts of energy that are resultant of their changing environmental conditions. It is impossible to match energy demand to this variable output, meaning that without batteries, any society wholly dependent on renewables would face alternating energy surpluses and deficits. Leaders in the green energy revolution have conceded that the greatest hurdle keeping renewables from providing all supplied energy is the ability to "store…and dispatch [the generated energy] as needed" (Limb, 2022). Considering how green energy is now cheaper than fossil fuels, batteries could be the keystone for a completely fossil-free world (See Appendix 2).

Fortunately for renewable energy industries, lithium-ion batteries have improved their capacity by 150% since 2011 (Johnson, 2021). In addition to batteries that are dependent on this metal, recent breakthroughs in alternative batteries hint at a promising future in which our energy storage options are not as limited. A Swiss startup named Energy Vault is harnessing the power of gravity and the Alps to lift large blocks with excess energy, then use the kinetic energy of falling blocks to generate electricity in times of need (Reynolds, 2022). Other scientists have turned to algae to solve our energy problems: though the method was only able to power a small computer chip, researchers at the University of Cambridge harnessed the power of photosynthesis to maintain an electric current for six months (Rauwerda, 2022).

Effective alternative batteries need not be nascent technologies, however. Dominion Power has been operating the Bath County Hydro Pumped Storage Facility, a reservoir in the Appalachian Mountains that stores the potential energy which has provided power to 13 states and DC since 1985 (Koronowski, 2013). This pumped storage battery takes advantage of excess energy to pump water to a higher elevation, which can then be used for hydroelectric generation during times of unanticipated demand. Furthermore, a team of Finnish engineers has developed a “sand battery” which uses the excess energy produced by renewables to heat up sand to 500°C (McGrath, 2022). Since low-grade sand loses very little heat over time, it could remain at its high temperature for months, allowing directed air warmed by this sand to heat homes during the winter.

The concept behind heat distribution technology is not new: the University of Virginia has been using steam tunnels to heat its buildings and water since the early 1900s (Lyons, n.d.). However, if there were ways to integrate the transport of heat in our infrastructure, the possibilities for increasing efficiencies are endless: if combustion processes are located close to energy end-users, the wasted heat could be used to heat “water or space in nearby homes and businesses” (C2ES, n.d). Energy efficiency advocates often champion the renewables discussed in this section, but other forms of energy generation have a place in our energy network by virtue of their fruitful byproducts.

There is substantial potential for integrating different technologies, and a more efficient grid is drawing closer to reality. Though the rates are flattening out, there has been a dramatic decrease in the cost of renewables since 2009 (see Appendix 2). Such leveling suggests that the market is ripe for an energy transformation. However, if the electric grid is to permit the integration of these technologies, it must move towards an organization that is not as dependent on the traditional long-distance delivery model that was implemented in the 1890s.

A Changing Environment: The World's Greatest Icebreaker

At the time this paragraph was drafted, Hurricane Ian made landfall on Florida's western shore. Preliminary estimates anticipate that the likely total cost totals $63 billion dollars and more than 25 drowning deaths (Kinnard & Gomez Licon, 2022). This hurricane is not a vagrant, loner storm causing unique devastation: other record-breaking storms have occurred in September of this year alone. The entirety of Puerto Rico lost power when Hurricane Fiona made landfall on the 18th, leaving 764,000 homes and businesses in the dark as of September 26th (Reuters, 2022). Over 500,000 Canadians likewise lost power when the same storm hit Atlantic Canada on September 24, in what may be the "deepest low-pressure system ever recorded on Canadian soil" (Jacobs, 2022; The Weather Network, 2022). The remnants of Typhoon Merbok caused high tides and winds in what ended up being "[western Alaska's] strongest storm in more than half a century" on September 17th , formed over waters that are typically too cold to support tropical cyclones (Beacon, A. & Rosen, 2022; Thoman, 2022). Lastly, on September 18th, Typhoon Nanmadol killed two people and knocked out electricity to 340,000 in what was "one of the biggest storms to hit Japan in years" (Buckland & Takenaka, 2022).

These events are deviations from the norm, but does a warming climate really indicate that society needs to prepare for more frequent and more severe storms? Scientific theory projects that tropical cyclone activity will increase due to higher ocean surface temperatures, but we are still waiting for reliable, comparative data from which to derive changes in hurricane activity: humanity had no way of recording every hurricane instance before satellites and airplanes were reliably utilized starting 1968 (EPA, 2021). However, despite this uncertainty, one thing remains clear: energy outages are happening more often.

There is an inexorable link between power failures and weather events. Though the next section will prove that weather is not the only threat to our energy security, 83% of all reported major outages between 2000 and 2021 were due to weather-related events (Climate Matters, 2022). 58% of these 1,542 outages were due to severe weather such as thunderstorms, 15% were specifically due to tropical cyclones, and 22% were caused by winter weather (2022). A distribution of these outages can be seen on the map in Figure 1. Even more alarming than the outages themselves is the increasing rate of failures: power outages in the 2011-2021 timeframe increased 78% compared to 2000-2010 (2022).

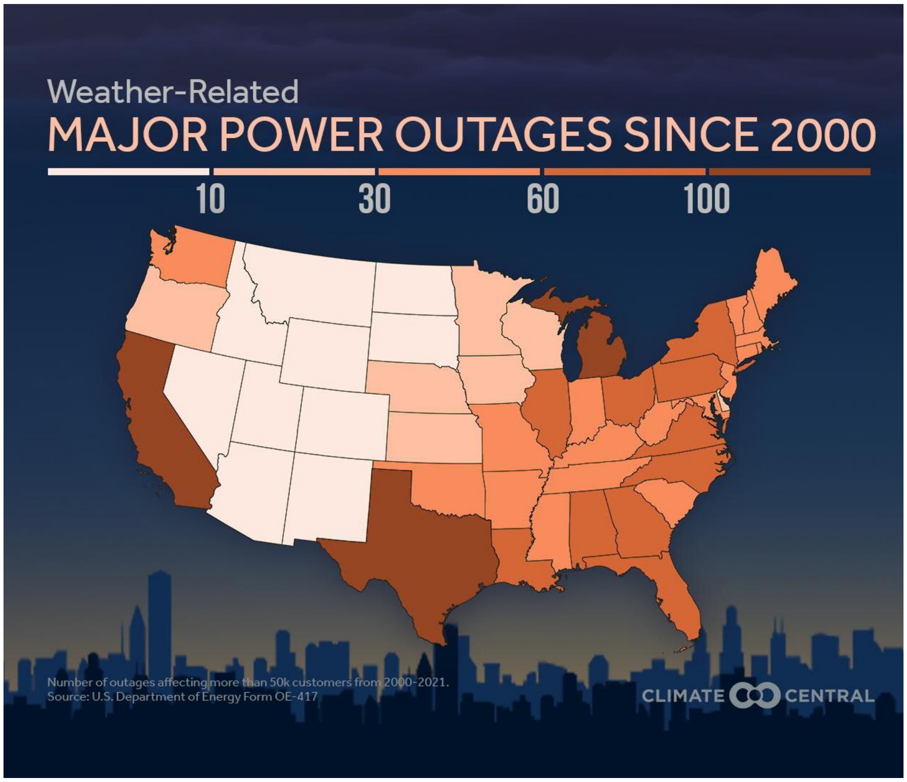

Figure 1. "Weather-Related Major Power Outages Since 2000." Climate Central. Data source: U.S. Department of Energy Form OE-417.

This new propensity of failures is not the result of dramatic, named, and sensationalist storms. As the world warms, the atmosphere can hold 4% more water vapor with each additional degree Fahrenheit (The Week, 2022). This means water is not only released as more storm energy, but the atmosphere wicks this moisture from the ground, further escalating the impacts of storms because "hard, dry ground" leads to "excessive runoff" (2022). Weather data are already reflecting the consequences of more water vapor in the atmosphere. As shown in Figure 2, the percent of land area that experiences one-day precipitation events is steadily increasing. Our future thus includes a contradictory mix of unprecedented droughts followed by hammering deluges on a local level.

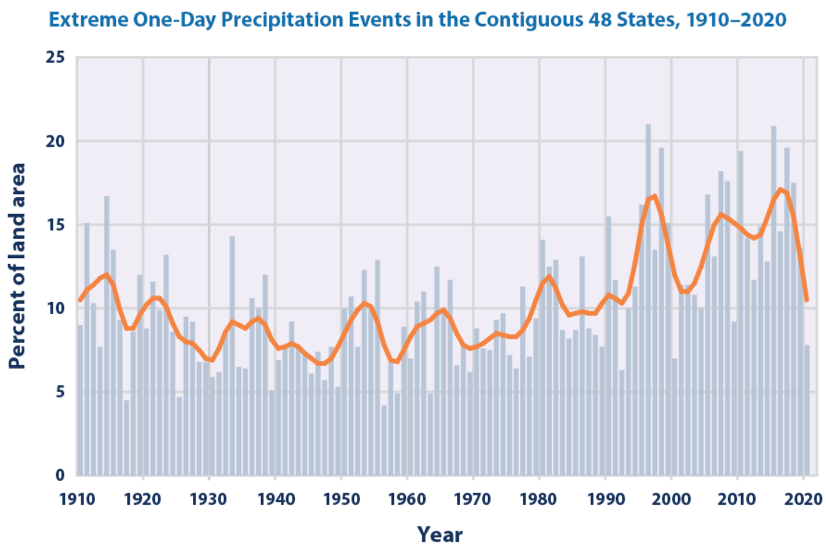

Figure 2. "Extreme One-Day Precipitation Events in the Contiguous 48 states, 1910-2020." The orange line represents the 9-year weighted average. It is worth noting that 2021 was "a record-breaking year" for extreme rainfall in the contiguous US, but that data point is not included in this graph (Climate Central, 2021). Data source: NOAA (National Oceanic and Atmospheric Administration). 2021. U.S. Climate Extremes Index.

What types of challenges does a reinvented electric grid need to prepare for? California learned that not all weather-related threats to infrastructure are caused by direct damage. On August 31, 2022, California sent out its first statewide "Flex Alert" warning of stress on the power grid (Luna et at., 2022). This was in response to the worst heat wave of the year, and residents were urged to reduce energy consumption so that there would be enough energy for cooling during the higher temperature periods. Part of this uncertainty around power supply was due to reduced capacity of hydropower from dried-up reservoirs, further straining load during peak hours. If power was not reduced by consumers, California would have undergone rolling blackouts, potentially endangering human life at a time when the highs climbed to 112°F.

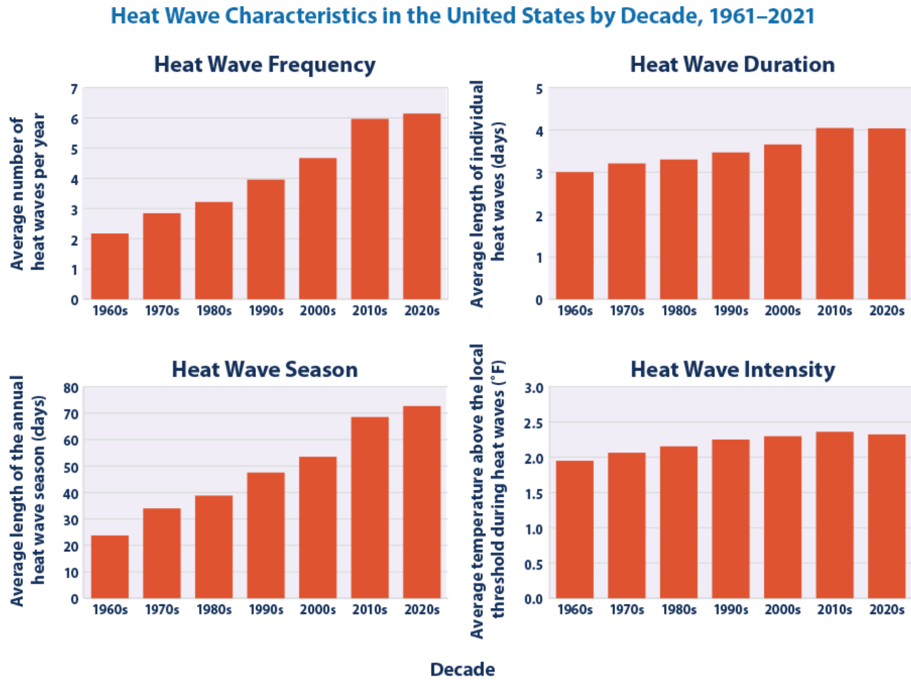

Figure 3. "Heat Wave Characteristics in the United States by Decade, 1961-2021." Data source: NOAA (National Oceanic and Atmospheric Administration). 2022. Heat stress datasets and documentation.

Unfortunately, California's abnormal heat wave is not an anomaly in current conditions. Heat wave frequency, duration, season, and intensity are all growing stronger or longer, as seen in Figure 3. On top of this, daily US highs and lows have been increasing as seen in Figure 4, and the nighttime lows have been climbing at a faster rate than the highs. This is particularly problematic as it signals that there will be a lack of reprieve from daytime temperatures. In terms of the AC demand that California was so worried about, there will be a constant increase in AC use, which will demand more power from the grid for longer periods. As seasonal temperatures climb, as seen in Figure 5, people will need a way to cool their homes during unseasonably warm weather in addition to the nighttime.

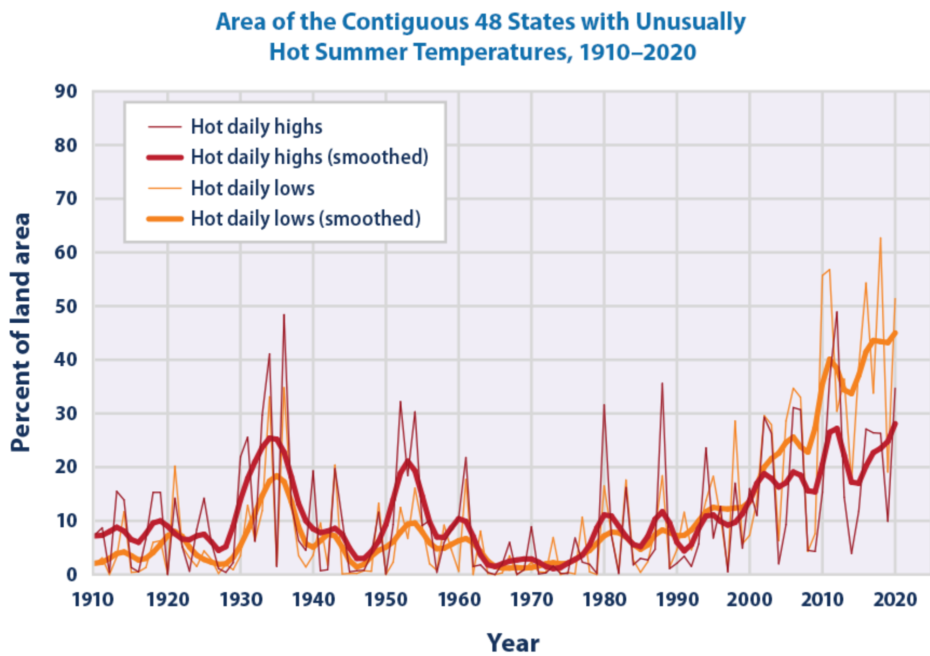

Figure 4. "Area of the Contiguous 48 States with Unusually Hot Summer Temperatures, 1910-2020." Data source: NOAA (National Oceanic and Atmospheric Administration). 2021. U.S. Climate Extremes Index.

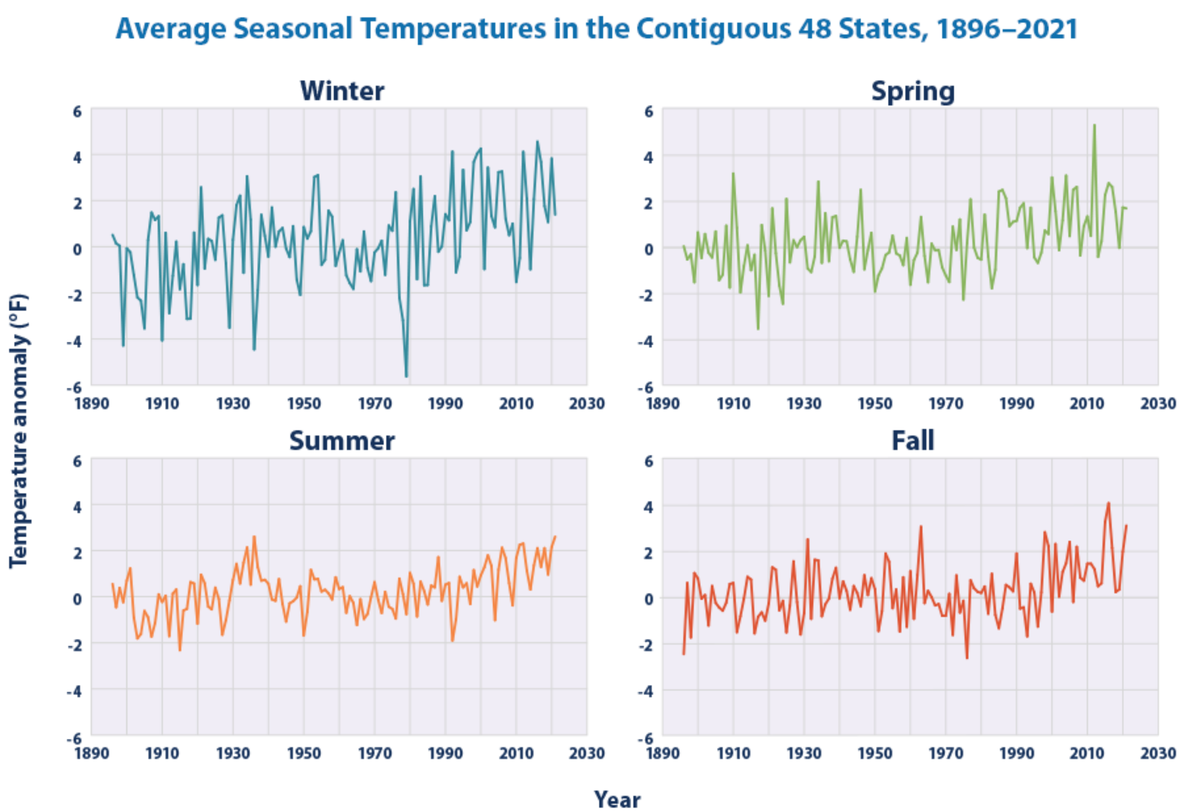

Figure 5. "Area of the Contiguous 48 States with Unusually Hot Summer Temperatures, 1910-2020." Data source: NOAA (National Oceanic and Atmospheric Administration. 2022. National Centers for Environmental Information. www.ncei.noaa.gov.

Considering these changes, insurance companies have a vested interest in hardening the grid. Sea levels are rising, and imminently so: 2021 saw record levels of greenhouse gases (414.7 parts per million) and the highest-ever recorded sea level accompanying it (Deliso, 2022). By 2050, up to 4.4 million acres of land, which includes 650,000 privately owned individual parcels, are projected to be underwater: based on current available assessments, this could cost the economy a minimum of $108 billion in lost property values (Dennis, 2022). Due to underwater topography, the Gulf Coast and the Atlantic are more likely to experience nuisance flooding, which will slowly be perceived as normal as these instances become commonplace. Figure 6 shows how most of America's population is clustered along the East Coast and Gulf. The potential for astronomical damage, therefore, becomes astounding: high populations and more frequent events make the perfect storm for rising property payouts.

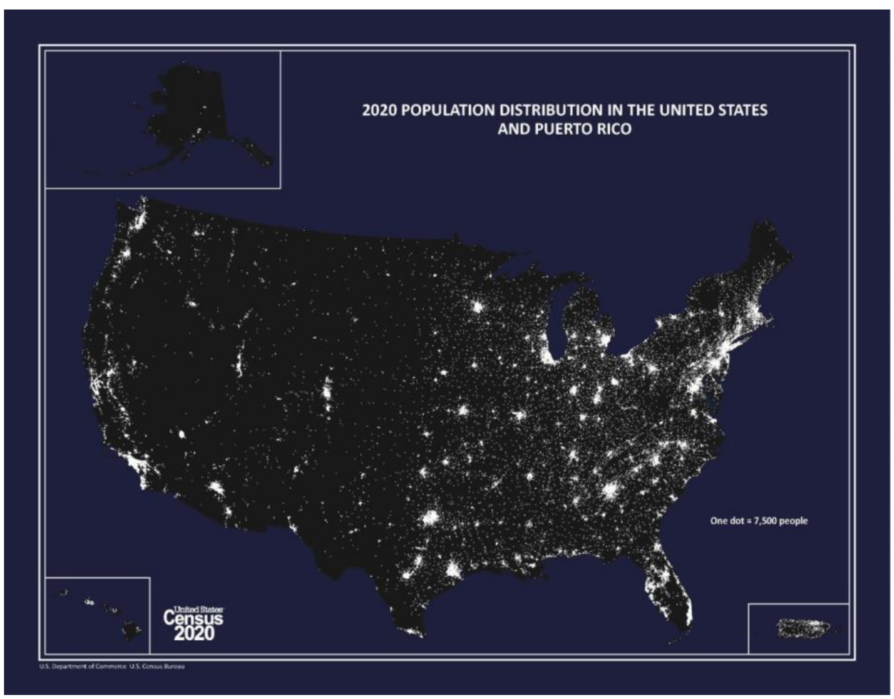

Figure 6. *"2020 POPULATION DISTRIBUTION IN THE UNITED STATES AND PUERTO RICO. Census.gov. October 1, 2021.* *https://www.census.gov/library/visualizations/2021/geo/population-distribution-2020.html*

Insurance policyholders are already seeing climbing costs coupled with rising sea levels. Hurricane Ian revealed how Florida has a “fragile insurance system”: due to high premiums, many Floridians don’t have flood insurance and are not covered by their homeowner’s insurance (Rozsa & Werner, 2022). This only contributes to a vicious cycle in which stronger or more frequent storms makes rates increase, which then makes it harder for homeowners to get or even keep their insurance. Ian’s insured losses are estimated to be $25-40 billion, and insurance companies must increase their revenue to remain solvent (2022). Unfortunately, due to Florida’s hurricanic nature, insurance brokers such as Danielle Lombardo will admit that Florida is particularly risky – especially when insurance companies are based on models that use data from thousands of years, making the recent uptick in storm activity an unforeseen challenge (2022). Figure 7 shows how weather-related losses, both insured and uninsured, have risen since the 1970s. Whether due to more people, more development, or more storms, it cannot be denied that we are losing value due to Mother Nature.

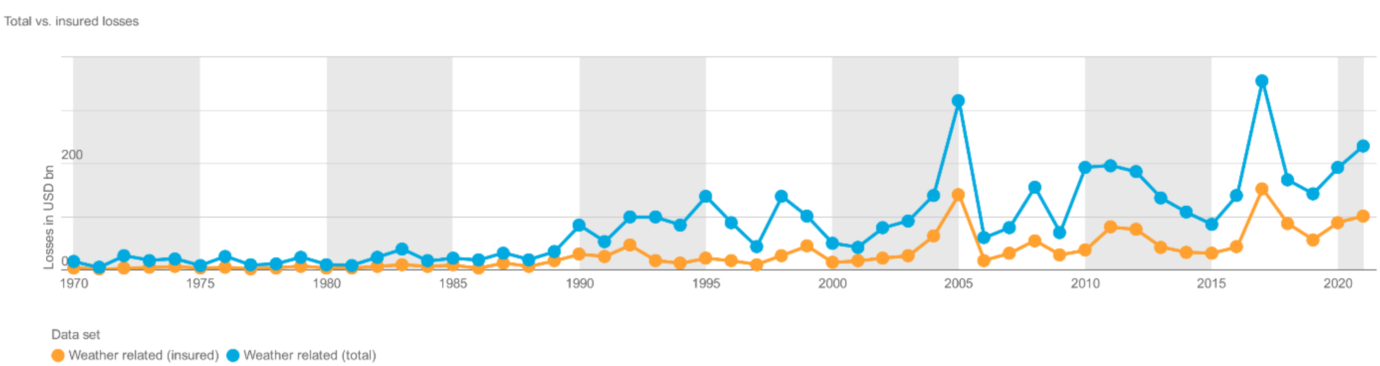

Figure 7: “Total vs. Insured Losses.” 2021. Data source: Swiss Re Institute.

It is no argument that areas such as Florida are more prone to disasters than others, climate change notwithstanding. People have relocated to areas that endure the forces of nature for as long as humanity has been around. This does not suggest that people consciously move to a floodplain, only that they will move somewhere that is not currently underwater. In a world of more frequent and severe weather events, then, do we need to rethink our system of rebuilding considering this costly effort? Surely rebuilding has a benefit when it comes to restoring people's lives, but do governments need to put new standards in place for reconstruction to be truly resilient? Considering how over $1 billion in federal funds has been put towards Hurricane Ian's recovery alone, recovering from relentless weather events will eventually come out of the taxpayer's pocket (FEMA, 2022). Though utilities are not where most of this federal money is being spent, a step towards breaking the cycle of repeatedly spending vast amounts of money on hurricane relief might be to invest in a stronger grid.

Renewables can help supplement energy demands during recovery efforts. The neighborhood of Babcock Ranch in Florida opened its doors to Hurricane Ian victims: though their school did not have a generator, as required by the very state that designated it as an official shelter, the Ranch was able to keep the lights on via its array of 700,000 solar panels (Ramirez, 2022). Babcock Ranch is a planned neighborhood 12 miles from Fort Meyers and was designed with the purpose of climate resiliency (2022). Developers took care to reduce stormwater runoff issues, reduce power outages by burying lines, and allow for self-sufficient energy generation. Other than uprooted trees and shingle-less roofs, the town did not experience major damage and was able to maintain its electricity amid a sea of surrounding municipalities that had none. This neighborhood is a case study of how flexible elements in the grid will only add resiliency. Saving on disaster costs by incorporating microgrids is a benefit, to be sure, but it is not the only one: though they are harder to quantify, the benefits of reliability, self-sufficiency, and security are byproducts of diversified energy sources.

SCADA And Other Alarming Security Challenges

Extreme weather events are not the only threat to the energy grid. In 2018, the Department of Homeland Security disclosed that Russia had hacked "critical [American] infrastructure" – namely, water facilities, gas pipelines, and power plants (Kury, 2018). Though the public does not know the extent to which this infrastructure was compromised, Americans should be more aware that their energy grid is more vulnerable than typically thought. This 2018 Russian infiltration was a result of utility staff opening a nefarious email attachment, and while it easy to blame security lapses on technologically illiterate employees, the true reasons behind our energy vulnerabilities are as convoluted as the grid itself (2018).

To understand how the United States' largest interconnected machine is vulnerable to outside forces, it is imperative to understand how complex the power grid is (Hahn & Govindarasu, 2017). There are 66 balancing authorities involved in providing Americans' power, which regulate over 3000 different utilities. Due to the nature of these authorities, some vulnerabilities are a result of transparent processes. Changing electricity rates is difficult because energy providers must only charge prices which cover reasonable expenses, and this decision must be open to public scrutiny (Kury, 2018). Thus, commissions are legally required to publicly say what they are doing with their customers' money – tipping off any potential attackers about the hurdles they can prepare to overcome. Hacktivists, cybercriminals, and nation-states can then launch more successful campaigns that specifically target utilities (Bailey et al., 2020).

This is not the only explanation for cyberattacks on the energy grid, however. Ever since Supervisory Control and Data Acquisition (SCADA) was deployed in the 1960s to automate energy delivery across large geographical areas and provide operators with real-time information, the U.S. energy grid has relied on a complex network of sensors, meters, and faultdetectors that monitor electricity flow (Electrical Technology, 2015). These systems have since evolved into internet-based ones, and the transition has been as uncoordinated as can be expected when old technology is fused into nascent types. Legacy SCADA systems are increasingly unable to support new safety software, and upgraded workstations may use the same passwords as their old counterparts – if passwords are even utilized at all (Nucleus Command Systems, 2020). The North American Reliability Corporation (NERC) has rules, called the Critical Infrastructure Protection (CIP) alliance, on how electric companies can protect the power grid, but the effectiveness of these standards in practice varies (Hahn & Govindarasu, 2017). The electric industry is used to the slower, pre-internet pace of technological development: thus, while the incorporation of computers and data in its processes makes the grid more responsive, they also make it more vulnerable if there are not adequate protections in place (2017). Interdependencies between physical and cyber infrastructure creates opportunities for external tampering, such as billing fraud for smart home meters or manually sabotaging unlocked physical infrastructure (Bailey et al., 2020). Additionally, NERC standards are hard to comply with due to gaps in site-specific or regional security assessments, and though continuous assessments may be necessary to support high-performing security, these efforts are often not enacted because they sap commission funding (2020). Municipal governments and utility cooperatives therefore may not have security initiatives in place because difficulties in securing funding, along with regulatory inconsistencies across different commissions, has led to a piecemeal approach to utility cybersecurity (Hahn & Govindarasu, 2017; Bailey et al., 2020).

Just because preventative cybersecurity work is expensive does not mean it is fruitless, however. In 2018 dollars, the average annualized cost of a cybercrime in the energy industry was $27.62 million (DOE, 2018). It is unclear how much effective cybersecurity would cost due to the changing nature of the field, but the DOE does denote that scalable, cost-effective technologies would greatly reduce the incidences of cyberattacks (2018). This is not to say that NERC standards are completely ineffective: CIP offers guidance for monitoring the grid and requires multi-factor user authentication, but while NERC standards help protect power plants, they do little to protect low-voltage distribution networks (2017). This is problematic, since to create a truly secure grid, the electric industry needs to ensure that each new device, whether big or small, is adequately protected (2017). Another factor to consider in planning preventative cybersecurity measures is that the rapid pace of technological advancements also hurts the grid. When electrical components are designed over the span of decades while software advances much more rapidly, the minimum standards proposed by regulators may not be enough to protect infrastructure in a rapidly changing world (2017).

These vulnerabilities are apparent to more than just energy commissioners. The Government Accountability Office (GAO) provided a report on Electric Grid Cybersecurity in 2021, reporting that our current reliance on monitoring and control technologies left the grid more susceptible to cyberattacks. While the GAO acknowledged that the Department of Energy (DOE) has been working on cybersecurity, GAO found that efforts were more focused on generation and transmission risks – not distribution factors. This poses a serious concern, considering how distribution systems are relying more and more on remote access. Often these distribution systems do not have protected passwords or encryption, and not only are these control systems easily accessible via the internet, but utilities have increasingly fallen for spearphishing emails. At the time of their report, GAO found that the DOE did not plan to address the distribution system risks, which limits how the DOE can provide federal support to strengthening the grid. While the DOE agrees that they need to examine cyberattack risks more closely and have issued new awards for cybersecurity on distribution systems in 2020, the GAO found that more needs to be done for a secure grid as of their September 2022 monitoring. Considering how U.S. intelligence agencies are now warning the energy sector that they've discovered a new, "highly automated," and "custom-made" malware that targets the country's energy infrastructure, it has never been more appropriate to "[apply] fundamental ICS cybersecurity practices" to defend the grid from this threat – especially since this malware was discovered before it has even been used (Vasquez, 2022).

While the grid's technological and cyber components play a large role in security, some threats are situational. In the beginning of October 2022, OPEC declared that they would slash oil production to curb falling prices (Stein et al., 2022). This threatened to create the secondary effect of raising gas prices in the United States right before an election season where the control of the House and Senate hanged in the balance (2022). Ultimately the decision was made under the influence of Russia and Saudi Arabia, both of which would profit from higher oil prices: Russia, however, would benefit significantly from the decision because it would help finance their war against Ukraine (2022).

Shortly after Ukraine was invaded by Russia on February 24, 2022, Canada, the EU, and the U.S. imposed strict sanctions on Russia and banned the import of Russian fuel to varying degrees, with the EU planning to phase out Russian fossil fuels by the end of the year (IEF, 2022). Soon, however, such commitments would be unnecessary. Russia's underwater pipelines, Nord Stream 1 and 2, were blown up on September 26, eliminating any possibility of reverting back to Russian gas (Merlyn, 2022). Europe's energy woes are further exacerbated because at the same time of this attack, half of France's nuclear reactors were shut down due to corrosion, maintenance, and technical issues resulting from extreme heat and delayed maintenance after the pandemic (Meredith, 2022). France, which typically relies on nuclear for 70% of its electricity, has been forced to import energy (2022). The United States has supplemented Europe’s fuel via liquid natural gas (LNG) exports, reaching a revenue of $25 billion in July compared to 2021’s $13 billion; however, bailing out the E.U. through U.S. LNG stock only reduces our own supply, and domestic U.S. gas costs have been 85% higher in October 2022 than the year prior (Maguire, 2022).

Energy conservation has thus become a necessity in Europe, and while the demand for natural gas and electricity fell from August to November 2022, this is not good news for Europe: such reductions are the result of companies shutting down their industrial plants, threatening the continent’s manufacturing capacity (Denina & Mcfarlane, 2022). The International Energy Agency (IEA) has determined that additional behavioral change is needed on top of these shutdowns to ensure enough fuel for the 2022/23 heating season (Figure 8; Hall, 2022). While the EU has been “working collectively to strengthen the security of its supply,” including measures that diversify supply sources and coordinating demand reductions, the Russian gas restrictions have shown that reliance on other countries for energy supplies, or singularities of fuels, can cause cascading problems (2022). Not only are renewables tempting because the levelized cost of natural gas is far higher than that of offshore wind and solar (see Appendix 2), but it would mean a degree of separation from international conflicts such as what is being experienced in 2022.

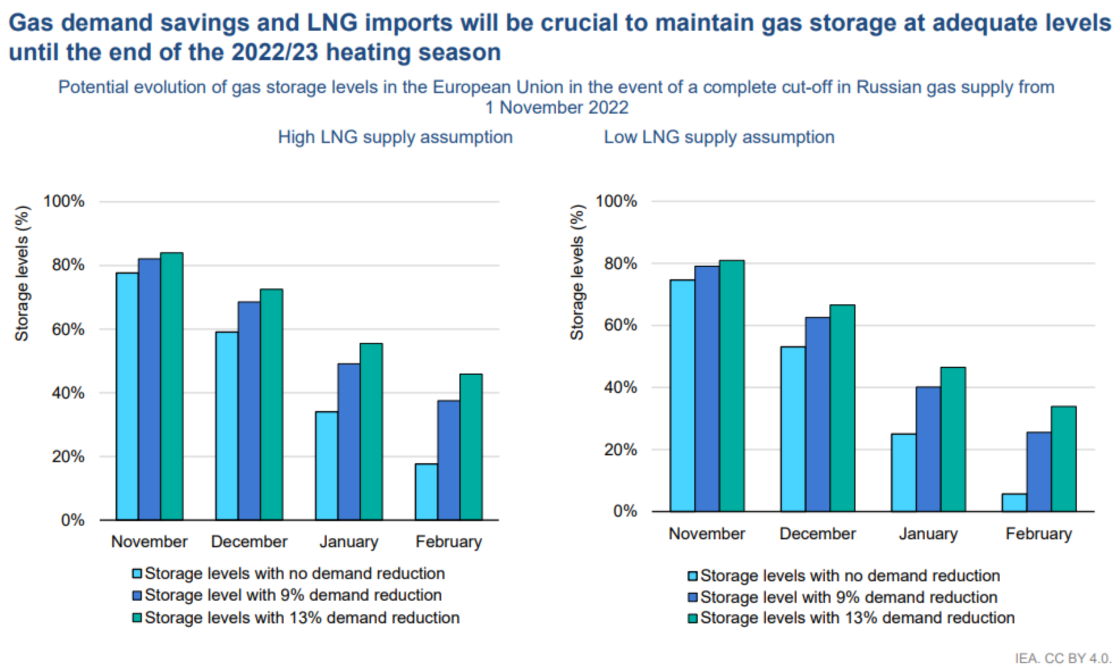

Figure 8: Potential evolution of gas storage levels in the European Union in the event of a complete cut-off in Russian gas supply from 1 November 2022. 2022. Data source: International Energy Agency (IEA).

Addressing these security vulnerabilities depends on two approaches: fostering small-scale security to lessen dependence on long-distance transmission in case it is compromised, and addressing the current structural weaknesses. Both approaches can be addressed via the implementation of microgrids. Having self-contained energy grids that are separable from a larger provider can allow continued operations in the event of a cyberattack while generating one's own electricity in the case that larger sources are compromised (Kury, 2018). While usually built to provide energy in the event of severe storm events, microgrids can be isolated from the rest of the system and prevent a domino-esque catastrophic system failure via an inverter that converts direct current (DC) to alternating current (AC) (2018).

Hahn & Govindarasu write that another approach to improving cybersecurity is to add redundancy to the grid – that is, more connections than strictly necessary – but that this would be an expensive approach (2017). Incorporating more microgrids in the larger grid would achieve this by nature, but just as how interconnections are inherent with microgrids, Russell Carr of Arup concedes that the "main barrier to mass deployment [of microgrids] is the upfront capital costs": designing the ability for microgrids to seamlessly island themselves from the larger grid requires extensive generation and storage infrastructure (n.d.). However, such an expense might be more politically palatable in the face of recent conflicts since microgrids and additional connections protect communities against multiple threats: technological, logistical, and meteorological.

Microgrids as they exist now are not free from similar security threats. Cyberattacks could focus on smart inverters, which are used to "sell back" extra energy to a household's power company (Bailey et al., 2020). Physical access to renewable energy generators and internal access controls via "easily picked locks" can compromise the Operational Technology (OT) network (2020). It is worth noting, however, that such vulnerabilities exist within the current state of our grid: laptops and USB cables are still used to enter OT networks, operations are often outsourced to vendors which introduces risk, and contractors often don't have security requirements for their infrastructure (2020). For protecting SCADA systems, utilities have yet to understand that firewalls are not enough to protect their internet-based systems: anomaly detection and monitoring are necessary, regardless of continual assessment cost (2020). These preventative measures are not being implemented by many utility commissions, which leaves the grid in a state of great vulnerability in the face of modern challenges. Critics of microgrids should understand that opposing any technology that is not perfect only damages the grid's resilience in the long run – especially when today's grid has its own glaring flaws.

It is impossible to completely protect the grid, especially since most security measures are upgraded only after a breach occurs (Kury, 2018). Not all threats can be anticipated or uncovered like the April 2022 foreign malware discovery: sometimes it takes encountering a new danger to learn how to defend against it. To be truly resilient, new systems need to detect and manage anomalous grid communications beyond what it is used to technologically (Hahn & Govindarasu, 2017). In addition to this, in a world that is increasingly complex and fast-paced, our communities need multiple means of obtaining power in order to achieve true resilience. Incorporating new power sources and security measures will prove to be incredibly difficult, however, unless utility commissions and power companies find a way to appease their customers on a local level – a feat which may be more challenging than addressing nascent grid malware.

NIMBYism From a Distance: Cultural Barriers

In 2017, a proposed solar farm in the author's hometown of Spotsylvania County ruffled the feathers of the Wilderness neighborhood residents (Hand, 2020). These homeowners cited environmental, aesthetic, and relevance concerns when they contacted their supervisors to oppose the rezoning and thus the project (2020). When legislative support began to wane, Darden Copeland, the project supervisor, put "all hands on deck" to address these constituent concerns using political campaign tactics (2022). Between mailings, social media, canvassing, and other discussion activities, Copeland's group sought to show constituents how their project would benefit the community and eventually galvanized enough supporters to get the rezoning approved after a three-week campaign (2022).

While successful in this instance, it is not the first nor the last pushback Copeland has experienced: fighting "anti-solar and -wind NIMBYs" (Not In My Backyards) has "become the largest part of [Copeland's] work" (Copeland, 2022). Solar and wind companies must direct their energies towards these factions because such opposition was responsible for blocking 44 of these projects in 2021 alone (2022). Despite how solar and wind farms bring economic benefits to communities, and despite how most Americans support expanding solar and wind energy, there still exists a perception that renewables are not reliable sources of energy – especially among those who lean Republican (Kennedy & Spencer, 2021). Yet cross-sectional, longitudinal, and comparative studies between the U.S. and EU have found that renewables are no less reliable than fossil fuels, and that "Germany enjoys a grid that is more than 900% reliable than the U.S., with double its renewable penetration" (Lee, 2016). So why do these sentiments persist in the U.S. despite conflicting data?

Part of the explanation can be uncovered in recent events. Texas, which has its own power grid, experienced a "deep freeze" in February 2021 that led to deaths, burst pipes, shivering Texans, and at least $195 billion in damage (Domonoske, 2021). Though Governor Gregg Abbot told local news that the power failures were the result of multiple factors, he went onto Fox News and proclaimed that wind and solar, which account for 10% of Texas' power, was at fault for the crisis (2021). Other prominent GOP figureheads went on to paint the image of "frozen windmills" and that renewable energy sources incorporated into the grid could not weather the storm unlike fossil fuels (2021). In reality, every type of power source fell short of demand: infrastructure from gas pipelines to critical processing pipes froze, which could have been prevented with adequate winterization (2021). Yet despite these facts, the rhetoric painted by those who have interests in the fossil-fuel industry stuck with the public. A March 2021 article by the evangelical Liberty University's student newspaper all the way in Lynchburg, Virginia depicts renewables in an unflattering light:

> "…the majority of Texans hate the renewable energy wind turbines that have been placed on our beautiful horizon. **They're not only ugly, but they're also undependable.** When the winter storm broke through Texas, the wind

> turbines froze, and the solar panels were snowed over, deemed useless to frozen Texans. These turbines provided 42% of Texas's electricity on Feb. 7, a number that fell to a meager 8% on Feb. 11…Thanks to state mandates and federal subsidies, wind energy has become more widespread, which **will inevitably lead to another power crisis,** likely as the summer season begins and air conditioners blow at full force."

Notably enough, the student supported their 42% to 8% claim by citing a New York Post opinion piece written by a Texan, who in return cited a Dallas Morning News article that disproved both op-eds: in actuality, the Electric Reliability Council of Texas projected that 67 gigawatts of the grid's winter capacity could be generated by nonrenewables, but only half of this was generated during the freeze due to frozen gas infrastructure (Graves, 2021; Williamson, 2021; Douglas & Ramsay, 2021). Wind was considered to provide "only a fraction" of winter demand, if any at all (Douglas & Ramsay, 2021). Journalistic integrity aside, this misrepresentation presents a clear issue in microgrid integration: the allure of trouncing renewables is powerful, easy to perpetrate, and often emotionally-driven (Martel et al., 2020). Such rallying around a false flag begs the question of how this rhetoric was conceived when all electricity supply varies and no power plant constantly runs 24/7 (Lovins & Ramana, 2021).

The negative perception of renewables could be driven partly by the fossil fuel industry itself. It is no secret that oil and gas companies have lobbying influence in national politics, particularly amongst republicans. For the 2022 election, the oil and gas industry donated more than 5 times what the alternative energy industry lobbied to the tune of $90.4 million versus $16.5 million dollars (Appendix 3, Tables 3a & 3c). Of the top 20 oil and gas donation recipients for this election season, 90% were republicans (Appendix 3, Table 3b). Koch Industries, a multinational conglomerate corporation which is classified as an oil and gas company, donates the most of any oil and gas company listed in OpenSecrets' campaign finance tracker (Appendix 3, Table 3c). The Koch Industry's political action committee KochPAC donated $50,000 to "Texans for Gregg Abbott" who, as previously mentioned, went onto Fox News and made false claims about solar and wind's role in the Texas Deep Freeze (Appendix 3, Table 3d). Incidentally, in December of 2021, Rupert Murdock – founder of Fox News – bought a large cattle ranch close to Yellowstone from Koch Industries, with the selling price unknown (Associated Press, 2021).

The author could find no direct connections of influence in the relationship between Murdoch's media empire, oil and gas interests, and the elected officials who dismiss renewables as viable energy options – indeed, doing so would be beyond the scope of a semester-length project – but she did discover some interesting facts regarding campaign finance. Of the top 20 donors for Abbott (13 if not counting self-funding or repeat donors), 3 were major Texas gas and oil companies (Appendix 3, Table 3e). Of the top 20 donors (18 if not counting self-funding) for Scott Pruitt, 14th Administrator to the EPA, 7 were from oil and gas interests, including Koch Industries (Appendix 3, Table 3f). Pruitt is included in this research because of a notable stance he held as head of the Environmental Protection Agency during the Trump administration. In an interview with Christian Baptist News, held because of Pruitt's position as a Baptist deacon, he revealed the following sentiment (Brody, 2018):

> The **environmental left tells us that though we have natural resources like natural gas and oil and coal,** and though we can feed the world, we should do what? Keep those things in the ground, put up fences, and be about prohibition? That's wrong-headed. And I think it's counter to what we should be about…The

> biblical world view with respect to these issues is that **we have a responsibility to manage and cultivate, harvest, the natural resources that we've been blessed with**…to truly bless our fellow mankind.

Unsurprisingly, Pruitt faced backlash for this proselytizing attitude considering his position as a high-level federal government employee, and he ultimately resigned on July 5th, 2018, following a considerable laundry list of federal spending and conduct violations (Foran & Watkins, 2018). Pruitt's critics did not criticize him for his religion, but rather because he appeared to ignore science in what is a predominantly science-based agency – and his past comments regarding non-Christians proved consequential in a country that allows freedom of religion (Guillen & Holden, 2018).

Republicans, Christians, and renewable naysayers need not be synonymous, however. Katharine Hayhoe, a Texan, a climate scientist, and an evangelical Christian, has made waves by explaining the concept of "Global Weirding" – the changing weather patterns mentioned earlier in this paper – to religious communities (Walters, 2016). Hayhoe has been able to use her background and identity to educate those who were not aware of the full story behind new weather patterns in a way that busts the myths circulated in anti-environmental circles and shows that anthropogenic global warming isn't a result of a "leftwing conspiracy" (2016). Interfaith Power & Light (IPL) is an advocacy group that pushes policy solutions for energy efficiency and renewable energy, especially when energy generation is located close to the source (IPL, 2021). Representative John Curtis (R) of Utah is responsible for forming the Conservative Climate Caucus, which includes 75 conservatives who are committed to educating other legislators on anthropogenic global warming and promoting successful climate policy (Conservative Climate Caucus, n.d.). Even though the CCC maintains that fossil fuels "can and should be a major part of the global solution," this caucus is prudent in reflecting public attitudes considering that a poll run by The Hill found that a strong majority of Republicans favor nuclear (75%), solar (67%), hydrogen (55%), and wind (53%) technologies, along with tax credits that update building improvements and appliances (Dorsey & Hunt, 2022).

One of the most talked facets of environmental resistance is North American coal culture, particularly in Appalachia (Lewin, 2019). Lewin of *Social Problems* found that even though coal producers have economically exploited the residents of coal towns and exposed them to detrimental pollution, residents of coal towns "vigorous[ly] support" coal industries; after analyzing attitudes in Shale County, Lewin found that the biggest contributors to the pro-industry, anti-environmental views was due to feeling neglected by the federal government, a perception that urban America devalues them, and that the coal industry has carefully curated *"coal heritage,"* where environmentalism is seen as an attack on economic opportunity and moral worth (2019). Bell and York of *Rural Sociology* unearthed further evidence that anti-environmental efforts were purposefully crafted: the West Virginian coal industry in particular made a fake "grassroots" group named "Friends of Coal" which worked to center West Virginian identity and economy around coal production (2010). This faux group "exploit[ed] the hegemonic masculinity of the region" and has only doubled down on its efforts in the face of a declining industry (2010).

Sadly, because these planted values are persistent in Appalachia's culture, politicians seek to reflect these values in their service. Senator Joe Manchin famously acts to protect the coal industry despite how most of the jobs in his state have shifted to education and healthcare (Kiersz & Winck, 2021). However, despite the involvement of fossil fuels in influencing policy, legislation that seeks to bolster economic activity in coal towns has been successfully passed.

The Inflation Reduction Act (IRA) of 2022 makes many of its incentives conditional on “labor requirements, domestic manufacturing, and project location” particularly within “energy communities,” or areas whose main economic backbone historically relied upon some sort of energy industry (Pesek & Raimi, 2022). Though the authors of this cited report found that the “law’s definition of energy communities could vary widely depending on interpretation of key phrases” and “excludes other regions with high levels of [fossil fuel] dependance,” it signifies both a need and a receptiveness to intervene in economies where fossil fuels were once the lifeblood (2022). Using more narrow definitions in policy would signal to “coal heritage” sites that the federal government is not neglecting them and, quite possibly, that it is feasible to replace existing and past coal jobs with local renewable employment and fill the employment gaps along with supplementing energy generation (Erickson, 2022).

In the context of social and cultural values, change is scary, hard, and often not politically palatable when constituents have staunch beliefs. Changing anti-environmental attitudes towards renewables will take hard work that must undo years of intentional, generously funded campaigns that sought to secure the future of fossil fuels. Yet changes are still being made – not only by those who recognize the potential of renewables, but by those in office who support and draft bills such as the IRA. As renewable energy becomes cheaper, more efficient, and easier to store, there will come a time when even the most fervent fossil fuel supporter sees the economic opportunity in switching paths.

Livin’ La Vida Local: Municipal Constraints

A technology’s efficient nature does not guarantee its seamless transition, however. Any new adoption of infrastructure must go over the hurdle of permitting and all the fees that accompany it. These processes are made even more difficult to implement if there remain structural, political, and policy constraints that would otherwise allow for a more resilient grid on a local level.

Part of the challenges local governments face is simply the inflexible nature of the built environment and limited funds. In an informal interview with Joan Kelsch, Arlington County's now-retired Green Building Manager, Kelsch expressed that making changes to an already built-up environment was challenging (Personal communication, October 25, 2022). 10 years ago, the County embarked on a microgrid initiative and hired a consultant who was a big district energy advocate to examine the feasibility of a Crystal City microgrid. The area had lots of tall buildings with hydronic heating and cooling, which offered the opportunity for an underground hot water/steam tunnel system. It soon became clear that the largest problem was property ownership and building consensus: everyone in the path of the steam tunnel would have to buy into it, and there was already significant infrastructure (water, electric, stormwater, internet) under the streets that the steam tunnels would have to be designed around.

Underground infrastructure was one small barrier of many for the steam-microgrid initiative, but Arlington County prefers undergrounding utilities for safety, energy protection, and uninterrupted service delivery (J. Kelsch, personal communication, October 25, 2022). Kelsch shared that undergrounding utilities is typically done block-by-block in urban areas. If a new building is being constructed, the County will ask the developer to underground their utilities as part of their project's community benefits. It is difficult for the County to take on undergrounding utilities because doing so costs $10,000 a linear foot: undergrounding is more expensive in places that have sidewalks, and urban areas typically have extensive pedestrian infrastructure.

Energy utility companies recognize that underground cables have smaller voltage drops, low maintenance costs, and less chance of developing faults; the main downsides are the installation cost and identifying potentially damaged areas (Electrical Engineering, 2016). Dominion Energy has implemented a Strategic Underground Program that undergrounded more than 1,700 miles of powerlines across Virginia over seven years in response to increased extreme weather, but the company is not taking requests from customers because power lines are expensive – purchasing all overhead lines would cost the utility company more than $116 billion (Morawski, 2021). However, even if larger utility companies were willing to underground nearly all powerlines in their states, they would still need to get property owners to grant legal easements, and not all property owners are willing to do so, thus jeopardizing entire projects (Dominion Energy, 2021; Morawski, 2021). Providing incentives to property owners might overcome this barrier, but barring the politically unpalatable eminent domain, conducting this type of project depends on local buy-in.

Monetary incentives might be enough to persuade customers, however. In sharing her experiences with Arlington County, Kelsch agreed that developers would have been more willing to make their buildings LEED-certified if the DOE provided funds to pay for the difference (J. Keslch, personal communication, October 25, 2022). As it stands now, Arlington's Green Building Program includes lots of nuances and complexities that can make it difficult to navigate, which can be detrimental to the local government's goals (2022). Developers are spending a lot of money to make their projects happen and thus gravitate towards simpler, clear processes, and are also less likely to invest up front to save money later on down the road. Developers and residents thus share some attributes (2022). Much can be learned from the DOE's Better Buildings Neighborhood Program, which awarded grants to localities for use in green job training, energy efficiency education, and providing loans for energy efficiency retrofits to homes and commercial buildings (Glasgow, 2022). Data collection for the program was limited due to administrative constraints, but one conclusion was that the program's loans were rarely taken advantage of (2022). Direct funding of energy improvements may have achieved greater retrofits considering the socioeconomic conditions of the program's post-recession implementation and that people were reluctant to take out loans amid economic uncertainty (2022).

These conditions provide policy warnings for those seeking to implement effective local-level energy generation programs. Thankfully, there are also successes to mention: Arlington County has taken advantage of economies of scale and bulk purchasing power to implement a robust solar co-op program which, when run by a solar company working on behalf of many property owners, serves to cut through red tape (J. Kelsch, personal communication, October 25, 2022). Solar United Neighbors sponsors multiple bulk neighborhood purchases to make solar affordable: their model has spread across DC, and more than 5,000 families have added solar panels to their homes, generating more than $100 million in economic investment (Solar United Neighbors, 2021).

Such initiatives are needed considering the policy barriers renewables and self-sufficient energy generation providers face. In early 2022, Florida lawmakers tried to pass HB741, an unpopular bill sponsored by Florida Power and Light (FPL) that would cut net metering by 75%, despite how the incentive is backed by 84% of Floridians (Sandoval & Zizo, 2022). DeSantis vetoed the bill in what was considered a win for solar companies, citing financial reasons; FPL later issued a statement that they "remain committed to finding a more equitable net metering solution for all Floridians" – essentially, that their battle is not yet over (2022). In rural Ohio, which is a hotbed of rampant wind energy misinformation, every rural utility-scale wind and solar project needs local or state approval – and misinformation about 'wind turbine syndrome' or falling blades are halting projects that would benefit communities if passed (Simon, 2022). When local officials are not energy experts and people march into public hearings with misconstrued Facebook-mined 'facts,' compromises might be made between "a scientifically based position and a misinformation-based position" (2022). With conditions such as these, educational and homeowner-focused programs are badly needed to switch the dialogue to something more reflective of renewable energy's true benefits.

Solar United Neighbors highlights how "utilities use their monopoly power to stop competition from renewable energy sources, especially solar energy…several have been caught in multi-million dollar bribery scandals and crimes," and there is a resounding truth to this statement (Solar United Neighbors, 2022). As touched upon in this paper's "cultural barriers" section, powerful players with money are trying to slow the adoption of renewable technologies. In 2013, the 60 Plus Association – funded by the Koch brothers – put out a political attack ad targeting solar energy in Arizona (Kasper, 2015; Arizona Solar Facts, 2013). This ad, which made the 'bad guy' a solar energy consumer, is among many Koch brother efforts to fight state policies that favor renewables in Kansas, North Carolina, Arizona, and others (Halper, 2014). For Kansas, the Koch brothers funded Americans for Prosperity, which led the effort to overturn Kansas' 20% renewable energy mandate for its utility commission. While not directly related to the Koch brothers, Arizona's state utility, Arizona Public Service Co. (APS), spent $3.7 million in bankrolling the entirely Republican panel of the Arizona Corporation Commission during an intense solar battle – at the end of which solar customers would be charged $5 per month (2014). North Carolina's largest utility, Duke Energy, likewise lobbied to prevent the state's net metering law, which would allow home or business energy generators such as solar panels to sell excess energy back to the grid (2014). Utility companies have argued against net metering, saying that solar consumers won't pay to maintain the power grid despite drawing from it on cloudy days, but some studies have instead concluded that solar customers actually benefit the entire grid and that any losses from net metering are recuperated (2014).

Again, as reiterated in the "cultural barriers" section, antipathy towards renewables is not necessarily partisan. Barry Goldwater Jr., leader of the group Tell Utilities Solar won't be Killed that focuses on building conservative solar support, succinctly said that "solar companies are becoming popular, and utilities don't like competition" (Halper, 2014). Utilities do have reason to fear, considering the levelized energy prices of renewables compared to fossil fuels (Appendix 2). If utilities do not move away from their traditional centralized model, more people may leave the grid for solar, making it more expensive for remaining customers and thus prompting them to also leave in a cyclic pattern called the 'utility death spiral' (McDonnell, 2021). The current grid has maintained the same status quo for so long that perhaps we cannot blame utilities for having a self-preservation instinct. However, this is not reason to keep our system frozen in the past: utilities can instead turn towards a more managerial role in a new multidirectional network, where thousands of sources and connections are used to generate and store energy (McDonnell, 2021). In response to criticisms for subsidizing solar companies, President Obama called out the Koch brothers in his August 25, 2015 Las Vegas speech (The White House):

> "But when you start seeing massive lobbying efforts backed by fossil fuel interests, or conservative think tanks, or the Koch brothers pushing for new laws to roll back renewable energy standards or prevent new clean energy businesses from succeeding — that's a problem. That's not the American way. That's not progress.

That's not innovation. That's rent seeking and trying to protect old ways of doing business and standing in the way of the future."

Charles Koch defended himself, saying that he was against all subsidies, whether they be for renewables or fossil fuels (Allen, 2015). If Charles Koch truly believes this, and his funding efforts are simply intended for purposes other than blocking the economic free market and legislative agenda, both he and Obama can agree on one thing: fighting a changing market by clinging to old business models is unentrepreneurial and undemocratic.

Energized Solutions to Electrify Constituents

America is experiencing more frequent extreme weather events, has suspect cyber defenses of its energy grid, faces a slew of misinformation that fuels anti-renewable attitudes, and its local governments have financial constraints that prohibit them from deploying new energy measures. In the face of these scenarios, what actions can be taken to strengthen our energy infrastructure and resilience?

Part of the solution in addressing damage from weather events is focusing on the solutions for the other problems addressed in this paper due to their dual-effective nature. While expensive, undergrounding electrical lines is an investment that leads to easier maintenance access, safer infrastructure, and more reliable energy delivery. Incorporating undergrounding as part of road maintenance projects via a partnership between energy companies and state Department of Transportations (DOTs) – or even a funded program between the Department of Energy and U.S. Department of Transportation – would lead to small but continual steps towards a stronger grid.

Utility companies' fear of "utility death spiral" is legitimate, but rather than fight the adoption of renewables and small-scale energy generation with rigid thinking, it would be more pertinent for power providers to take on a "contractor" role in which they manage a complex network of two-way energy flows and storage. Utility companies could facilitate software updates for microgrids. Security measures are badly needed and not as easily implementable household-by-household or business-by-business. This might be the evolutionary step that needs to be taken to stop the discontinuity between legacy SCADA and internet-based systems: having formal security policies for OT that are updated regularly, and merging OT and IT, will reduce the miscommunication and disorganization seen in today's current grid (Bailey et al., 2020). Additionally, utility companies could take a direct role in providing sensitive triggers for islanding and manage inverter standards in a world where renewable reliability depends on inverters (Willson, 2022). Because renewables require inverters due to their DC current, they're vulnerable to tripping in the event of electrical faults, whether the cause of fossil fuel failures or renewables themselves: however, this is not a strong argument against investing in renewables considering how extreme heat and fires have already adversely affected nonrenewable energy delivery, and this is only projected to continue as weather events become more severe (2022).

The Federal Energy Regulatory Commission (FERC) is proposing a rule that mandates that resources which use inverters should provide "accurate and validated models" indicating how the inverters will behave under different circumstances (Willson, 2022). Though some experts say that this rule needs to be bolstered with stronger language ensuring that inverter-based resources will be able to inject and supplement lost power during a tripping event, the FERC rule, combined with the DOE's $26 million funding opportunity for research which demonstrates a feasible 100% renewable grid, provides new opportunities for utility companies to take advantage of a new business climate as well as a meteorological one (2022). Stepping into a new business model does require a certain amount of risk and uncertainty: there would be a lot of physical infrastructure that still has value yet cannot be used, causing a hit to the bottom line of power companies, and some of the skills that older employees have spent a lifetime cultivating may not transfer to a new system. However, one thing remains constant: even if the role of power companies becomes one which provides more two-way energy management, security systems, and renewable integration, the public perception will still be that these companies are providing power so long as energy delivery is seamless. If power delivery is not disturbed under these conditions, which may otherwise become more and more likely by perpetuating the centralized grid in its current state, people will not be aware of any difference from today's status quo.

National policy and federal government can help localities in various ways. The most important action that can be taken is increasing transparency – both in simple programs like SolSmart, which streamlines solar projects for local governments via technical assistance and checkless, but also via models like the Environment for Analysis of Geo-Located Energy Information (EAGLE-I) system, which is a real time situational awareness tool for the country's energy infrastructure. (SolSmart, 2022; Lantero, 2014-a). Transparency can also apply to fossil fuel subsidies and the true cost of nonrenewable energy. This paper has touched upon the influence that fossil fuel companies have in politics, which no doubt perpetuates fossil fuel subsidies to some degree. The International Monetary Fund (IMF) finds fossil fuel subsidies to "have sizable fiscal costs, promote inefficient allocation of an economy's resources, encourage pollution, and [mostly benefit higher income households]" (International Monetary Fund, 2022). While 197 countries agreed to increase their efforts to phase-out fossil fuel subsidies at COP26, these efforts have been hampered due to public attitudes towards increased prices that are a result of reforms. The IMF as such recommends a clear, comprehensive energy sector reform plan; transparent and extensive communication with stakeholders, including what to expect and the true size of current subsidies; phasing-in price increases; taking measures to protect the poor via money transfers or existing programs; and measures to depoliticize energy pricing, such as through automatic pricing mechanisms (2022). All of this can be encouraged via America's existing federalist structure, and federal programs can draw data, information, and advice from local governments on the front lines that will be impacted by such changes.

Ultimately, a decentralized approach to energy generation is needed because the market cannot respond to the demand for energy efficient innovations if they are tempered by subsidies that distort conditions which would otherwise naturally arise. However, utility companies and commissions are not going to take big risks that would overturn their entire business paradigm unless they have federal support. Presidential administrations and federal agencies thus have an opportunity to give power providers a chance to embrace a landscape driven by more renewables and heightened energy security. The political economy certainly presents some pertinent issues – large failures in energy delivery would mean that said administrations would not be reelected – but the very act of working towards a sustainable future which empowers Americans should be touted as an accomplishment. Inaction is costly and taking chances draws attention, but investing in the future can also draw respect and create lasting change.

Conclusion

There is much to cover in the field of energy, and the author is limited by a single semester in which to research a complex and involved topic. Her disappointment stems from the fact that she is technically aware of but unable to cover some crucial elements of the power grid.

SCADA systems and comprehensive ways to increase energy security could have easily encompassed the entirety of this paper; the effects and projections of changing weather patterns are comprehensive and staggering; the cultural and political dynamics of energy generation continue to be convoluted; and it would have been preferable to examine the impacts of microgrids and self-generation in the context of rural, suburban, and urban development patterns. Overall, there is always the fear that one's research might be as illuminating as throwing a match into a dark chasm. Americans have not begun to experience repeated and consistent failures of energy delivery, which makes it hard to profess that microgrids and security measures are sorely needed to prevent catastrophic failures.

Yet today's headlines already hint at a fraying grid. On Sunday, December 4th, OPEC Plus decided against cutting its oil production, causing the countries who are dependent on its exports to breathe a sigh of relief, but also highlighting how keenly international volatility threatens a country's energy supply (Halper, 2022). Also on this day, Moore County in North Carolina experienced an "intentional, willful, and malicious" gunfire attack on two electric substations, putting 45,000 customers without power on a dark and chilly winter night (Rubin et al., 2022). 12,500 people in South Austin, Texas lost power for the second time in two days on December 1st, and a clear reason for these outages has not been provided (Osbourne, 2022). A winter storm left 70,000 customers without power in Washington state and Oregon on November 30th (Taylor & Tumin, 2022). While these instances are not being compared to historical trends, which makes any conclusions about large-scale failure drawn from these cases a hasty generalization, they are just some of many examples where delivery interruptions could be supplemented with separate, decentralized, and local generation capacities if the appropriate infrastructure was in place.

The author would like to end on one final point that, unlike the rest of the paper, is not quantitative. It was noted earlier that energy consumers would not care about where their energy came from as long as it was delivered as per normal: perhaps, though, increased participation and awareness would bring a greater sense of belonging and ownership to one's energy usage and generation. Since anybody can technically participate in solar generation – providing that the legal framework allows for solar permitting – renewables could be seen as inherently democratic, while more top-down energy sources such as nuclear or oil are 'authoritarian' since they must be deployed by central authorities and leave no option for individual participation (Bryant, 2011).

Additionally, the author also concedes that microgrids are not a solution that should be rushed into haphazardly. The only way to see if a new use of a technology, system, or organization works is to do it on a small scale before jumping into it. The most important aspect of energy policy moving forward is to avoid tunnel vision: conversations should be focused on solutions, alternatives, and diversity of sources rather than looking for clear right and wrongs moving forward. Allowing ourselves permission and forgiveness to try a new approach, evaluate it, and abandon it should it not suit our needs must be done in a way that does not penalize those who instigated the alternative method. Based on what was discussed in this paper, renewables should be evaluated based on their profitability to businesses, efficiency, security, and independence from any foreign supplies. In doing so, Americans will have to make trade-offs: there may be more mining of lithium on domestic soil, causing environmental concerns, and perhaps diverting our focus from alternative means of carbon capture to decentralized energy generation is an ineffective means to move forward. Overall, changes will require breaking out of the same energy mold we've been living in for the past hundred and fifty years, yet we must challenge ourselves not to be perfectionists when faced with new technologies. Navigating a new approach to power may be difficult, but just because a transition is difficult does not mean it is not worth it.

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Appendix 1: Efficiency Chart

Energy Generation Type	Thermodynamic Efficiency[1]	Levelized Cost ($/MWh), October 2021[2]
Solar PV - Crystalline	13-22%[3]	$36
Wind	Varies with wind speed; 20-40%[4]	$38
Gas-combined cycle	~58%[5]	$60
Geothermal	14-18%[6]	$75
Coal	33%[7]	$108
Solar Thermal Tower	Up to 97%[8]	$141
Nuclear	38%[9]	$167
Gas-peaker	35-44%[10]	$173

1. Ratio of energy generated to possible energy generation
2. Lazard (2021, October). Lazard's Levelized Cost of Energy Analysis – Version 15.0.
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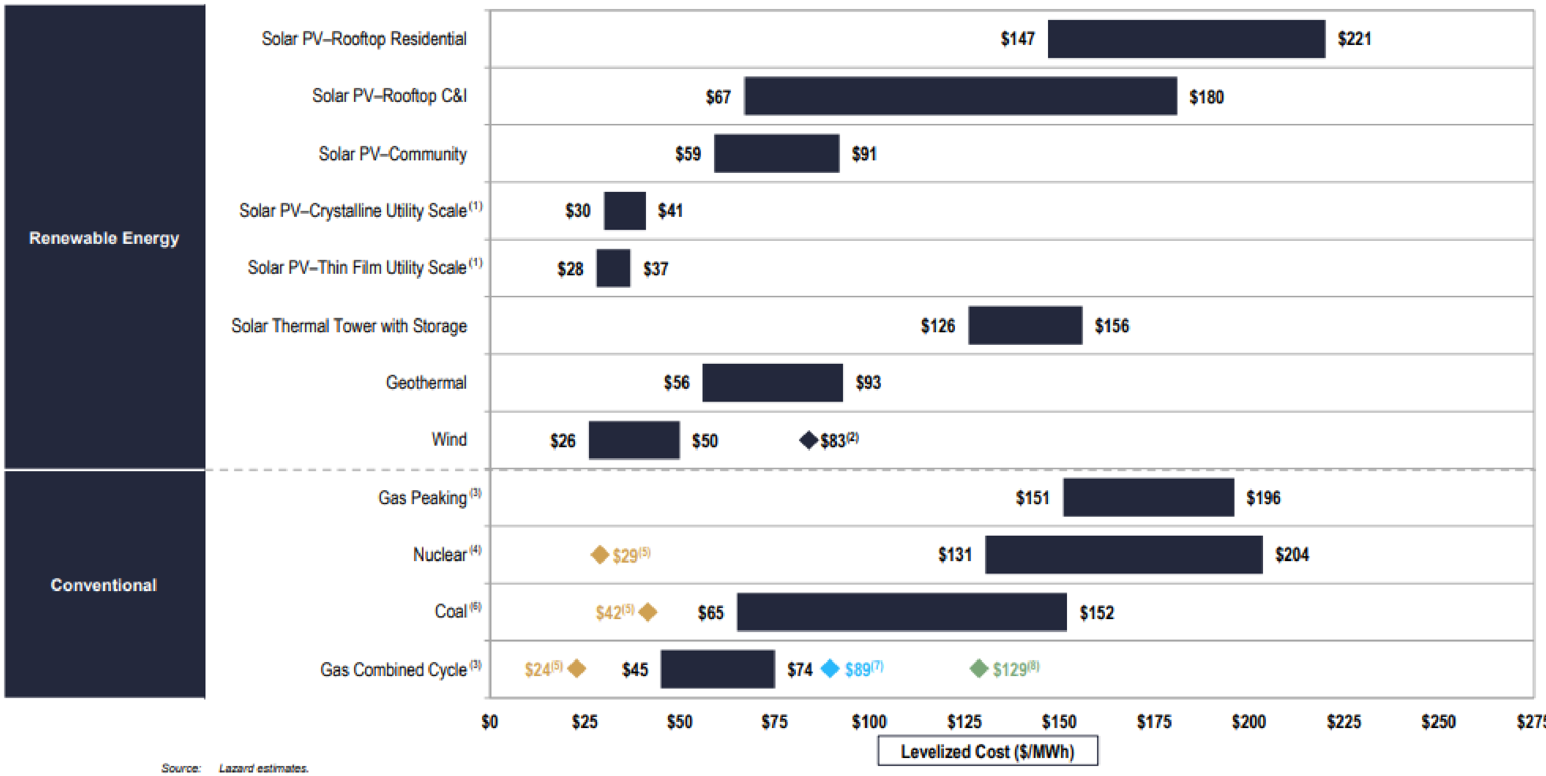
Appendix 2: Levelized Cost of Energy & Storage

LAZARD   LAZARD'S LEVELIZED COST OF ENERGY ANALYSIS—VERSION 15.0

Levelized Cost of Energy Comparison—Unsubsidized Analysis

Selected renewable energy generation technologies are cost-competitive with conventional generation technologies under certain circumstances



Source: *Lazard estimates.*

Note: Here and throughout this presentation, unless otherwise indicated, the analysis assumes 60% debt at 8% interest rate and 40% equity at 12% cost. Please see page titled "Levelized Cost of Energy Comparison—Sensitivity to Cost of Capital" for cost of capital sensitivities. These results are not intended to represent any particular geography. Please see page titled "Solar PV versus Gas Peaking and Wind versus CCGT—Global Markets" for regional sensitivities to selected technologies.

(1) Unless otherwise indicated herein, the low case represents a single-axis tracking system and the high case represents a fixed-tilt system.

(2) Represents the estimated implied midpoint of the LCOE of offshore wind, assuming a capital cost range of approximately $2,500 – $3,600/kW.

(3) The fuel cost assumption for Lazard's global, unsubsidized analysis for gas-fired generation resources is $3.45/MMBTU.

(4) Unless otherwise indicated, the analysis herein does not reflect decommissioning costs, ongoing maintenance-related capital expenditures or the potential economic impacts of federal loan guarantees or other subsidies.

(5) Represents the midpoint of the marginal cost of operating fully depreciated gas combined cycle, coal and nuclear facilities, inclusive of decommissioning costs for nuclear facilities. Analysis assumes that the salvage value for a decommissioned gas combined cycle or coal asset is equivalent to its decommissioning and site restoration costs. Inputs are derived from a benchmark of operating gas combined cycle, coal and nuclear assets across the U.S. Capacity factors, fuel, variable and fixed operating expenses are based on upper- and lower-quartile estimates derived from Lazard's research. Please see page titled "Levelized Cost of Energy Comparison—Renewable Energy versus Marginal Cost of Selected Existing Conventional Generation" for additional details.

(6) High end incorporates 90% carbon capture and storage. Does not include cost of transportation and storage.

(7) Represents the LCOE of the observed high case gas combined cycle inputs using a 20% blend of "Blue" hydrogen, (i.e., hydrogen produced from a steam-methane reformer, using natural gas as a feedstock, and sequestering the resulting CO_2 in a nearby saline aquifer). No plant modifications are assumed beyond a 2% adjustment to the plant's heat rate. The corresponding fuel cost is $5.20/MMBTU, assuming ~$1.40/kg for Blue hydrogen.

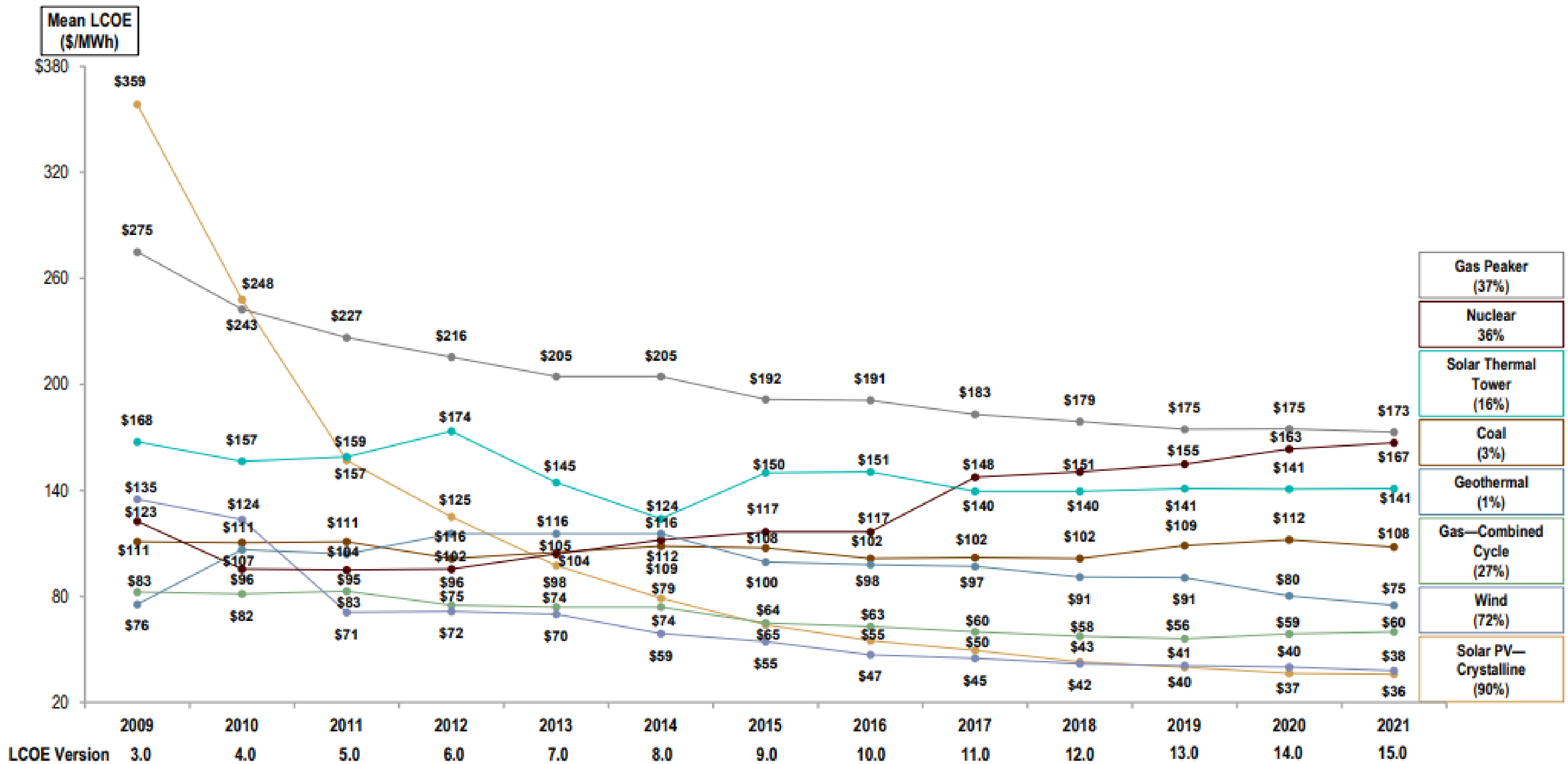
(8) Represents the LCOE of the observed high case gas combined cycle inputs using a 20% blend of "Green" hydrogen, (i.e., hydrogen produced from an electrolyzer powered by a mix of wind and solar generation and stored in a nearby salt cavern). No plant modifications are assumed beyond a 2% adjustment to the plant's heat rate. The corresponding fuel cost is $10.05/MMBTU, assuming ~$4.15/kg for Green hydrogen.

LAZARD LAZARD'S LEVELIZED COST OF ENERGY ANALYSIS—VERSION 15.0

Levelized Cost of Energy Comparison—Historical Utility-Scale Generation Comparison

Lazard's unsubsidized LCOE analysis indicates significant historical cost declines for utility-scale renewable energy generation technologies driven by, among other factors, decreasing capital costs, improving technologies and increased competition

Selected Historical Mean Unsubsidized LCOE Values(1)



LAZARD Copyright 2021 Lazard

Source: Lazard estimates.

(1) Reflects the average of the high and low LCOE for each respective technology in each respective year. Percentages represent the total decrease in the average LCOE since Lazard's LCOE—Version 3.0.

8

Appendix 3: Oil & Gas Lobbying

Table 3a: Alternate Energy Lobbying Total for 2022[1], Top 20 Donors[2]

Client	Affiliate	Total
Renewable Energy Aggregators	-	$1,490,000
Clean Energy Group	-	$926,160
Plug Power Inc	-	$890,500
Invenergy LLC	-	$860,000
American Clean Power Assn	-	$790,000
Hanwha Group	Hanwha Q CELLS America	$670,000
Bloom Energy	-	$600,000
Strata Clean Energy	-	$597,500
Monolith Materials	-	$510,000
Apex Clean Energy	-	$430,000
IP Renewable Energy Holdings	-	$360,000
Highly Innovative Fuels	-	$357,500
Clean Energy Buyers Assn	-	$340,000
Form Energy	-	$340,000
Ameresco Inc	-	$320,000
Fortescue Future Industries	-	$290,000
JinkoSolar	JinkoSolar US	$270,000
nZero	-	$270,000
Pattern Energy Group	-	$270,000
Bayotech Inc	-	$260,000

1. Alternative Energy Lobbying Total for 2022: $16,481,941
2. Source: OpenSecrets (2022). https://www.opensecrets.org/industries/lobbying.php?ind=E1500

Table 3b: Top 20 Politician Recipients of Oil & Gas Donations for 2022 Election Cycle[1]

Candidate	Office	Amount
Manchin, Joe (D-WV)	Senate	$735,859
McCarthy, Kevin (R-CA)	House	$496,106
Pfluger, August (R-TX)	House	$463,396
Lankford, James (R-OK)	Senate	$407,915
Murkowski, Lisa (R-AK)	Senate	$367,849
Hunt, Wesley (R-TX)		$328,550

Cuellar, Henry (D-TX)	House	$299,784
Scalise, Steve (R-LA)	House	$295,622
Kennedy, John (R-LA)	Senate	$289,512
Scott, Tim (R-SC)	Senate	$279,448
Johnson, Ron (R-WI)	Senate	$278,003
Mullin, Markwayne (R-OK)	House	$276,460
Fletcher, Lizzie (D-TX)	House	$274,745
Rodgers, Cathy McMorris (R-WA)	House	$270,511
Rubio, Marco (R-FL)	Senate	$251,345
Hoeven, John (R-ND)	Senate	$242,215
Herrell, Yvette (R-NM)	House	$241,797
Crenshaw, Dan (R-TX)	House	$238,469
Laxalt, Adam (R-NV)		$234,377
Gonzales, Tony (R-TX)	House	$232,087

1. Source: OpenSecrets (2022). https://www.opensecrets.org/industries./recips.php?ind=E01

Table 3c: Top 20 Donors of the Oil & Gas Industry for the 2022 Election Cycle[1,2,3]

Client/Parent	Total Donated
Koch Industries	$8,640,000
Occidental Petroleum	$6,453,000
ConocoPhillips	$6,430,000
Exxon Mobil	$5,430,000
Chevron Corp	$5,390,000
Shell plc	$5,000,000
American Petroleum Institute	$3,640,000
BP	$2,930,000
Phillips 66	$2,880,000
TC Energy	$2,112,500
Marathon Petroleum	$2,070,000
American Fuel & Petrochem Manufacturers	$1,812,500
OAO Gazprom	$1,630,000
Cheniere Energy	$1,580,000
Valero Energy	$1,580,000
Williams Companies	$1,150,000
Enbridge Inc	$1,090,000
PBF Energy	$1,035,080
EQT Corp	$860,000
Equinor	$820,000

1. 60.81% of the 698 oil & gas lobbyists were former government employees
2. Source: OpenSecrets (2022). https://www.opensecrets.org/federal-lobbying/industries/summary?cycle=2022&id=E01
3. $90,423,479 total was spent on Oil & Gas lobbying

Table 3d: Top 10 KochPAC Vendors and Recipients for 2021-2022[1]

Vendor/Recipient	Total Expenditures
National Republican Congressional Cmte	$300,000
Scalise Leadership Fund	$230,000
National Republican Senatorial Cmte	$105,000
Texans for Greg Abbott	$50,000
Intrust Bank	$35,468
Dade Phelan Campaign	$20,000
PA Senate Republican Campaign Cmte (Srcc)	$20,000
Dan Patrick for Lt Governor	$20,000
2021 Senators Classic Cmte	$17,000
2022 Senators Classic Cmte	$17,000

1. Source: OpenSecrets (2022). https://www.opensecrets.org/political-action-committees-pacs/koch-industries/C00236489/expenditures/2022

Table 3e: Top 20 Donors for Governor Gregg Abbott's 2022 Campaign[1]

Amount	Donor	Date	Occupation	Employer	Type
$1,806,764.84	Greg Abbott	6/30/21			ENTITY
$1,000,000.00	Dr Miriam Adelson	9/8/22	Doctor	Self	INDIVIDUAL
$1,000,000.00	Edward Roski Jr	7/29/22	President and Chairman	Majestic Realty Co	INDIVIDUAL
$1,000,000.00	James D Pitcock Jr	6/24/21	Contractor	Williams Bros Construction	INDIVIDUAL
$1,000,000.00	Kelcy L Warren	6/23/21	Executive	Energy Transfer	INDIVIDUAL
$1,000,000.00	Kenny A and Lisa Troutt	6/30/21	Executive	Mount Vernon Investments	INDIVIDUAL
$1,000,000.00	Michael & Mary Porter	6/25/21	Retired	Retired	INDIVIDUAL
$975,000.00	Teri and Matt Andresen	9/16/22	Executive	Headlands	INDIVIDUAL

$500,000.00	Bobby Cox	6/28/21	Executive	Bobby Cox Companies Inc	INDIVIDUAL
$500,000.00	Bobby Cox	9/30/21	Executive	Bobby Cox Companies Inc	INDIVIDUAL
$500,000.00	Carole and James Looke III	9/20/22	Owner	Walter Oil and Gas Corporation	INDIVIDUAL
$500,000.00	Edward Roski Jr	6/30/21	President and Chairman	Majestic Realty Co	INDIVIDUAL
$500,000.00	Edward Roski Jr	4/7/22	President and Chairman	Majestic Realty Co	INDIVIDUAL
$500,000.00	James D Pitcock Jr	6/22/22	Contractor	Williams Bros Construction	INDIVIDUAL
$500,000.00	Jerral W Jones	10/18/22	Owner	Dallas Cowboys	INDIVIDUAL
$500,000.00	Kenneth Fisher	10/12/22	Executive Chairman	Fisher Investments	INDIVIDUAL
$500,000.00	Kenny A and Lisa Troutt	7/29/22	Executive	Mount Vernon Investments	INDIVIDUAL
$500,000.00	S Javaid Anwar	10/25/22	President	Midland Energy Inc	INDIVIDUAL
$450,000.00	Kenny A and Lisa Troutt	3/31/22	Executive	Mount Vernon Investments	INDIVIDUAL
$381,763.88	Stockyards Station	9/14/22			ENTITY

1. Source: TransparencyUSA (2022). https://www.transparencyusa.org/tx/candidate/greg-abbott/donations

Table 3f: Top 20 Donors for Scott Pruitt's 2012 Oklahoma Attorney General Election[1]

Contributer	Type of Contributer	Total $
BALANCE FORWARD	OTHER	$229,984
PRUITT, E SCOTT	INDIVIDUAL	$216,850
ROBSON, JOHN (JOE)	INDIVIDUAL	$17,000
CHICKASAW NATION	NON-INDIVIDUAL	$15,000
AT&T	NON-INDIVIDUAL	$12,000
WARD, LEW O[2]	INDIVIDUAL	$11,700

CHESAPEAKE ENERGY	NON-INDIVIDUAL	$11,500
CANTRELL, MIKE[3]	INDIVIDUAL	$11,000
OKLAHOMA FARM BUREAU	NON-INDIVIDUAL	$10,750
AMERICAN FIDELITY CORPORATION	NON-INDIVIDUAL	$10,500
LOVE, TOM E[4]	INDIVIDUAL	$10,500
DEVON ENERGY	NON-INDIVIDUAL	$10,000
KOCH INDUSTRIES	NON-INDIVIDUAL	$10,000
MEMORIAL PROPERTY HOLDINGS	NON-INDIVIDUAL	$10,000
OKLAHOMA SPINE HOSPITAL	NON-INDIVIDUAL	$10,000
LEVINSON, LEE I[5]	INDIVIDUAL	$10,000
FAIRCHILD, MARIO MAX	INDIVIDUAL	$10,000
COLLINS, ROBERTA	INDIVIDUAL	$10,000
TATOM, JOHN H	INDIVIDUAL	$10,000
MCINTOSH, JAMES W	INDIVIDUAL	$10,000

1. Source: Follow the Money (2012). https://www.followthemoney.org/entity-details?eid=6583668&default=candidate
2. Lew O. Ward was an Oklahoma oil and gas producer, and chairman of the Ward Petroleum Corporation. Source: Oklahoma Hall of Fame. (2016). Gaylord-Pickens Museum. https://oklahomahof.com/member-archives/w/ward-lew-o-2010
3. Mike Cantrell is an Oil and Energy Consultant, and Owner of Pivotal Strategic Solutions. Source: Pivotal Strategic Solutions (n.d.). https://pivotalstrategicsolutions.com/pages/about-us/
4. Tom Love added fuel pumps to a convenience store to create Love's County Store, which was the first shop in the country to combine gasoline and grocery sale items. He added 40 gas stations to Oklahoma and surrounding states during his lifetime. Source: Oklahoma Hall of Fame. (2016). Gaylord-Pickens Museum. https://oklahomahof.com/member-archives/l/love-tom-e-2000
5. Lee Levinson is an attorney who specializes in oil and gas matters and has taught Oil and Gas Transactions at the University of Tulsa College of Law. Source: Levinson Law, PC. (n.d.) https://www.levinsonlawpc.com/firm-overview/lee-levinson/