Residential Microgrids in the United States

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

The United States energy grid is failing. Aging infrastructure combined with extreme weather has put electric systems in trouble nationwide. The majority of the power grid was built and installed in the mid 20th century, meaning crucial components such as transmission lines and transformers are reaching their recommended lifespan of 50 to 80 years and will soon need to be replaced with new or different options (Pfeifenberger, 2021). Climate change is also making the grid more vulnerable. Due to the increase in global temperatures, the United States Geological Survey (USGS) warns that more droughts and increased intensity of storms will occur each year (*How Can Climate Change Affect Natural Disasters?*, n.d.). The electric grid infrastructure has failed recently during these massive weather events, putting many Americans at risk. Any newly installed power grid equipment would have to withstand the rise in natural disasters over the coming decades.

Besides aging infrastructure and natural disasters, the US energy grid is completely unprepared for the transport of renewable energies because the transmission lines do not go where clean energy must. The locations of transmission lines were chosen to be around big cities near oil and coal factories, not ideal for transporting solar energy from the Southwest or wind energy in rural middle America to the rest of the country (Clifford, 2023). Overall, the current American energy grid is so old, overworked, and expensive that many Americans have started to look for innovative alternatives as a solution.

In this paper, I explore residential microgrids as a potential solution to the US power grid problems, in part because of my previous summer internship experience at a homes-as-grids startup. A microgrid is an independent electricity grid within a residential home or small community that creates and stores energy (Miranda, 2021). Microgrids typically make use of

clean energy sources such as solar or wind so that no outside power grids or electric resources are required. Recent technological advances in renewable energy have allowed microgrids to become a more feasible option for many homeowners, monetarily and otherwise. Microgrids gives homeowners autonomy over their energy needs and provides freedom from the issues facing the American power grid. In addition, removing these homes and communities from straining the power grid could reduce the weight on the entire system and potentially alleviate some issues for those who stay on the grid.

Methodology

The concept of microgrids was first introduced to me two summers ago during a software engineering internship at Lumin, a local energy startup. Lumin creates smart energy management systems for homes with solar power to "help homeowners automatically or manually control their home's microgrid" (*Lumin Smart*, n.d.). The Lumin Smart electric panels and modular sensors integrate into a customer's home and allow for completely customizable microgrid monitoring and control at the circuit level through a mobile phone application. This was when I first learned about the rising trend of homes-as-grids in the United States and my internship allowed me to see them in action. When I worked at Lumin, I created a web application for the developers to internally create and track software deployments to their fleet of IoT devices. This exposed me to the power of solar energy and the true capabilities of a home on its own microgrid distributed energy system.

Although I have first-hand experience with home microgrids, most of this research uses secondary data collected by expert organizations such as the USGS and US Department of Energy (DOE). The data is a mixture of quantitative and qualitative information to best

understand the current American electric grid and home microgrids in terms of the economy and the environment.

History of Microgrids

The history of the United States electric grid is one of isolation and unsustainable rapid growth. A private company built the very first power station in the late 1800s near New York City (Nichols, 2003). Over the next several decades, many more companies built their own isolated power stations around big cities, bringing electricity to Americans in metro areas but keeping the lines disconnected from other companies. By the 1930s, the electricity transmission system in these locales had become an electrical engineer's worst nightmare: a rat's nest of wires. The federal government stepped in and started regulating the industry, creating larger utility organizations across multiple states (*Power Grid History*, n.d.). This led to the expansion and connection of the grid through the construction of large power plants and transmission lines going not only to cities but also to rural areas. Today all of the electricity in the United States is delivered via the electric grid in the same way: a power plant generates electricity, transformers convert it to high-voltage power at a transmission substation, it travels long distances along high voltage transmission lines, transformers convert it back to low-voltage power at a power substation, and then distribution lines carry the electricity to nearby homes and businesses where a final transformer lowers the voltage again before entering residences (*Delivery to Consumers*, n.d.). The American electric grid is still not seamlessly connected in one entity, but everything is more regulated and coordinated than in the 1900s.

Challenges

For many years, the United States power grid functioned properly and brought reliable electricity to 100% of American citizens (*Access to Electricity*, 2020). When technology was new, the energy sources consistent, and the climate more predictable, the complicated and interconnected network of substations and transmission lines that we call our power grid worked. Unfortunately, that is no longer the case, and it is only going to get worse. The number of power outages between 2011 and 2021 has increased by 64% compared to the previous decade (Ramirez, 2022). As mentioned in the introduction, this is due in large part to aging infrastructure and climate change.

According to the U.S. Energy Information Administration (EIA), there were 700,000 circuit-miles of transmission lines in the United States in 2018 (*EIA Study Examines the Role of High-Voltage Power Lines in Integrating Renewables*, 2018). Over the next decade, approximately 200,000 miles of those lines will need to be replaced (*Advanced-Conductors-on-Existing-Transmission-Corridors-to-Accelerate-Low-Cost-Decarbonization.Pdf*, n.d.). This means that almost 30% of the entire US electric grid has reached end of life or will in the coming decade. Replacing or building new transmission lines takes many years and millions of dollars, not to mention bipartisan government agreement and approval.

The effects of climate change on the power grid have been catastrophic. Due to rising global temperatures, weather around the world is getting more extreme. Recently, severe heat waves, droughts, and floods have all occurred at record numbers in the United States (Hersher, 2023). All these extreme weather events, including increased natural disasters, are severely taxing the power grid infrastructure. In August of last year, for example, hundreds of thousands of residents in California faced imposed blackouts during a record heat wave due to inadequate

energy supplies (Deliso, 2022). California's power grid is currently very centralized and requires substantial amounts of energy to be transported far distances on a limited number of transmission lines, leading to insufficient supply distribution. California regularly has to "ask utility customers to tolerate rolling brownouts and blackouts" (Ezrati, 2023). On the other side of the weather spectrum, a surprise winter cold front in Texas in 2021 caused blackouts which led to the death of 250 people. In January 2022, the DOE released a report saying "America's existing energy infrastructure will not endure the continuing impacts of extreme weather events spurred by climate change" and called for upgrades to the nation's aging electric grid to meet climate goals (*DOE Launches New Initiative From President Biden's Bipartisan Infrastructure Law To Modernize National Grid*, 2022).

Along with the two above issues, the demand for electric energy in the United States is growing at an exponential rate and could soon pose a serious threat. According to the EIA, electricity consumption in America was 13 times greater in 2021 than it was in 1950, and it is expected to continue growing at around 1% per year through 2050 (*Use of Electricity - U.S. Energy Information Administration (EIA)*, 2022). Not only is electricity consumption increasing to amounts difficult for the current grid to manage, but the sources of the energy are also changing. The United States is moving toward more renewable energy sources such as wind and solar to meet sustainable development goals, but these sources are far from most transmission lines. Wind energy is harvested primarily in Texas, Oklahoma, and Iowa, three states that have very few transmission lines. The same goes for solar energy being harvested in the American Southwest (Clifford, 2023). With the United States government planning on ramping up renewable energy creation to take over a much larger share of the power grid, serious rebuilding and repositioning of transmission lines and substations must be undertaken. This could be

extremely disruptive to the power grid and require many years and a considerable sum of money, something the new Infrastructure bill and the "Building a Better Grid" initiative is hoping to accomplish. Studies conducted for this bill show that electricity transmission systems will need to be expanded by 60% by 2030 and tripled by 2050 (*DOE Launches New Initiative From President Biden's Bipartisan Infrastructure Law To Modernize National Grid*, 2022). This will likely not happen fast enough, as blackouts and brownouts are already an issue for the Americans today.

Microgrids as a Solution

Out of all this turmoil and uncertainty, with engineers and politicians arguing over the best large-scale fixes for the huge, disconnected, aging electric grid that powers this country, a new idea started gaining traction: residential microgrids. Microgrids are small, controllable energy systems that can connect to the traditional power grid or operate independently. If the main power grid fails, the microgrid will continue to have power (Wild, 2017). Microgrids are generally powered by renewable resources including solar and wind, but new emerging fuel sources can also be used when made available. Every new microgrid that runs on clean energy sources means less fossil fuels required from the main grid. Many microgrids are even set up to send excess electricity back into the grid, sometimes in exchange for utility rebates, while others are self-sustained or separate (Murphy, 2022). The rise in homes-as-microgrids popularity could reduce the weight on the grid by decentralizing portions (*With Fire Season Approaching, Let's Talk Microgrids*, 2022).

Microgrids at the most basic level are not a new concept in the United States, but incorporating renewable energy and battery storage to create sustainable microgrids is far more

recent. These can be for a single home, a neighborhood, or an entire community. Military bases have been running on microgrids for safety and security reasons for many years as well. Large businesses are also now beginning to turn their factories and manufacturing plants into microgrids too. While in the past, the larger company microgrids were mostly powered by fossil fuels and only separated as a safety net, today they are more likely to use clean energy. As more people learn the benefits of sustainable microgrids, microgrids will grow in popularity for homeowners. For someone moving to California, brownouts and blackouts will be a critical concern if their home only relies on the main grid for power. Although only a miniscule percentage of the electricity in the United States comes from microgrid right now, increasing this percentage would be beneficial for all homeowners, whether they are on a microgrid or not ("Microgrids," n.d.). In this way, microgrids enhance the overall grid resilience.

When I worked for the company Lumin, they collaborated with solar panel installers to create home (or small business) microgrids for their customers using solar energy. The solar panels created electricity, which was sent to different circuits in the house depending on user settings and controls in the Lumin smartphone application. This was all accomplished using a smart electric panel designed and installed by Lumin, as well as individual sensors and Lumin Smart hubs connected to circuits throughout the house. A user could see exactly where their electricity was going in their space. If there was excess electricity, some homeowners chose to send it back into the grid or they could store it using options such as the Tesla Powerwall integrated battery system (*Powerwall*, n.d.). Individual home or business microgrids can also be disconnected from the larger grid entirely and exist only in an isolated system.

Another option that is becoming increasingly popular is microgrid home communities. In November of 2022, the first microgrid community in California was launched. KB Home

homebuilders built the neighborhood community in partnership with the DOE, SunPower, UC Irvine, Southern California Edison, Schneider Electric, and Kia. The homes are entirely electric and solar powered, and each home has its own back-up battery in case of grid outages as well as the connection to the microgrid community. KB Home is hoping that these microgrid communities will help reduce energy usage, provide protection against grid issues in California, and lessen the negative environmental impact (*KB Home Launches First Microgrid Communities in California*, 2022). These smart renewable energy home systems, if adopted in more areas, will greatly reduce the strain on the traditional power grid. Especially in places such as California, where the energy resources and transmission lines are already stretched too thin.

One of the main challenges facing the mainstream integration of microgrids is their excessive costs. Full microgrids for single family homes cost tens of thousands of dollars (Ro, n.d.). Larger community microgrids are much more expensive but the cost is shared amongst homeowners or home buyers, local government, developers, and potentially others ("Microgrids," n.d.). These prohibitive costs are a major barrier to entry for communities looking to install microgrids. Potential solutions are on the horizon though. For one, the cost of renewable energies has been decreasing steadily and thus are more accessible to people of all socioeconomic backgrounds. Photovoltaic (PV) solar panel costs have decreased by around 65% for residential and commercial systems since 2010 (*Documenting a Decade of Cost Declines for PV Systems*, 2021). This is due in part to the improved efficacy of PVs and the increase in availability and competition in the market for panels and installers. New tax credits for investments in renewable energy will also reduce the overall costs of microgrid systems. In 2021, the Pew Research Center reported that 8% of US homes now have solar panels installed versus

just 4% in 2016 (Leppert & Kennedy, 2022). The number of homes with solar and battery storage is much lower but also increasing rapidly.

While individual home microgrids are out of the question for many Americans because of the tremendous upfront investment, mixed-funding community microgrids could become a solution. Several of the microgrids in development now across the country are public-private partnerships, which use funds from public institutions and private entities. States have also begun creating grants and funds for microgrid development ("Microgrids," n.d.). Funds like these, along with clear legal definitions of microgrids and rights for microgrid owners, will help clear the path for community microgrids.

Conclusion

The topics of renewable energies and the American power grid through the lens of residential microgrids are issues currently in the spotlight that could have a tremendous impact on the future. It has been well documented over the past several years that the electric grid that powers the United States, which is technically made up of thousands of smaller connected grids owned by hundreds of companies split into three main regions slapped together in a rather disjointed fashion, cannot continue to function. Whether from climate change, overuse, or aging infrastructure, the grid will fail. In fact, it is already starting. Widespread blackouts, both imposed and unforeseen, are becoming the norm due to extreme weather. The installation of residential microgrids, through government and community support, is one of the best ways to negate and avoid these negative consequences. Microgrids take load off the power grid while providing a reliable, renewable energy system for homeowners.

Recent groundbreaking renewable energy technological advancements have helped the microgrid movement to gain momentum. As has America's growing distrust in the country-wide electric grid as a secure and reliable source of power. Residential microgrids provide a solution that will have positive effects on the environment and grid overall. Although costs and legal challenges are a slight barrier to entry now, the tide is turning to solve these challenges and make microgrids one of the best options for communities in the United States.

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