Distributed Generation and Energy Storage for Resiliency

Roberto C. Baldizon[1]

[1] Luszol LLC, Miami (USA)

Abstract

The energy industry is known as one where widespread technological adoption moves rather slowly due to the high capital costs of switching current equipment, behavior, and culture. It is important to note that for a change to be impactful in the energy industry, it would have had to reach larger scales than what an impactful breakthrough innovation would mean for other industries. Over the long term, and through cumulative observation of system deployment, disregarding of current socio-political, economic trends, the longer-term outlook for Solar plus Storage remains bullish. The reason for such optimistic forecast for the industry lies in that distributed generation products deployed in the market already provide users with energy resiliency, independence, reliability, and security, all which are becoming continuously more valuable as the effects of climate change aggravate. Distributed generation from renewable energy sources, such as solar plus storage is proving to be a viable solution for areas of the world prone to natural disasters, where the local electrical grid infrastructure lacks the sturdiness and adaptability to withstand such events.

Keywords: Resiliency, Independence, Reliability, Security, Climate Change, Storms, Hurricanes, Distributed Generation, Solar, Storage, America, Storms, Caribbean, Batteries,

1. Introduction

The story of our planet started with an initial explosion of concentrated matter, known as the big bang. After this initial boom, all the matter it contained started spreading through space. When this matter started interacting with one another and then started accumulating and reacting to form our galaxies, stars, planets, and moons, respectively. For a planet to hold an ecosystem which will sustain life, it would have to be at the right distance from its star, of specific size and have an adequate mix of elements in its atmosphere to enable the existence of water in a liquid state. Luckily, for us, our planet met with all such requirements to breed life.

Our world, like all the other planets, is continuously changing. One of the most significant variables which drive change is the change in the gaseous mixture of its atmosphere. An adequate mix of gases in the atmosphere would enable for the existence of surface water in a liquid state, and fair weather to sustain complex life forms at that given time. Thus, changes in this gaseous mixture lead to a significant impact on global weather and ecosystems. At this time, life forms evolved during this epoch may no longer be able to survive on this planet, leading to a significant extinction event. This type of event has happened in our planet's history five times already.

After the fifth massive extinction event, through time and with luck, our species has survived and flourished. Nature has set the right field for our species to develop, but we deserve some credit as well since human-made events have also enabled us to reach high levels of development. The utilization of nature as tools such as fire, the domestication of animals, the invention of irrigation, the invention of the wheel, the printing press, among other great feats have pushed our people forward to this day. The industrial revolution, which increased global gross domestic product logarithmically compared to previous time, enriching England, Germany, and the United States to the level of economic superpowers, was one of such events. Since the industrial revolution involved the utilization of machines to replace physical labor, a new type of fuel was required rather than food for the workforce and cattle.

Moreover, since energy can not be created or destroyed but just transformed, then a source of choice for fuel for this revolution was coal as it was abundant and easy to extract in all these regions. As coal pushed these economies forward, greenhouses gases a byproduct of its' use started accumulating in the atmosphere. The pace at which such emissions where being produced increased as the rest of the world started developing, while global population emissions and energy needs increased exponentially.

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The historical events previously discussed are depicted by the four famous graphs displayed in figure one, which summarizes how climate change is just a natural response to such changing circumstances. These graphs were obtained from the United Nation's IPCC Synthesis Report Summary and are available online for download. It is important to note that climate is a long term phenomenon, for which it is critical to observe the overall trends observed through the graphed historical data in these four graphs, not just yearly recorded weather, which might lead to erroneous conclusions. In these four graphs, we can observe that as global greenhouse gases increase (shown in Graph C), due to an increase of human emissions (shown in Graph D), global temperatures increases (shown in Graph A), thus leading to higher sea levels as well (shown in Graph B).

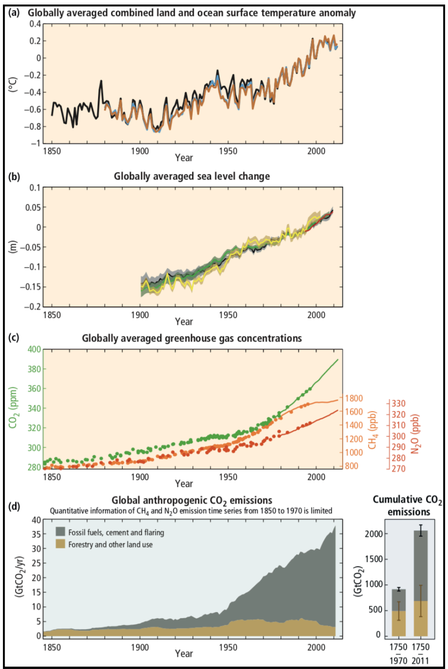

Figure 1. 4 Graphs that Summarize Climate Change.
** Source UN IPCC Synthesis Report

Rising global temperatures and sea levels would have a global impact on our weather. The effects of changes in weather, as seen in figure two from the UN IPCC Synthesis report, can cause changes in precipitation patterns causing draughts. Which with continuously increasing global demand could lead to rising prices in food due to lower crop yields, and hunger in parts of the world which rely on subsistence farming to survive. In similar industries, like farming and livestock, greenhouse gases emissions increase with economic development, so does the consumption of animal-based protein from higher living standards, thus leading to the exponential reduction in the global aquatic population, already causing issues in the fishing industry as fisheries erode (1). Like the Mayan, and Roman civilizations the overconsumption of our ecosystems endangers our way of life, except now we are doing it on a global scale.

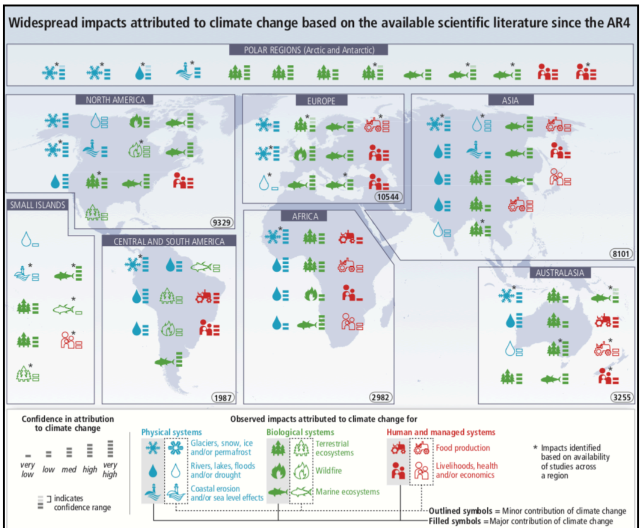

Figure 2.Global Impact of Climate Change, as Natural Phenomena, and Disasters.
** Source UN IPCC Synthesis Report

2. Effects of Weather on an Electrical Grid

Electricity usage for lighting came as a byproduct of scientific advancement pushed by the industrial revolution as inventions such as the lightbulb by Edison. It was not until late in the 19th century that Newcastle in England became the first city in the world to use such lightbulbs for street lighting using electricity. Most technology developed during that time to transmit and distribute electricity from generating sources is still the same that we use today in the 21st century, as seen in figure 3, taken from Kenward and Urooj's Climate Central Report, which displays and explains a traditional electrical grid. Developed nations, such as the United States which has more than 5 thousand power plants utilize more than 450 thousand miles of high voltage transmission lines to provide electricity to more than 140 million customers. Traditionally, a large scale centralized electricity-generating facility would produce electricity to be then transmitted to a network of cables. This electricity travels at high voltages to reduced resistances losses to distribution centers where this electricity is then stepped down into a voltage sent to final customers. This system works wonderfully, under normal circumstances, and achieves meager costs by utilizing economies of scale.

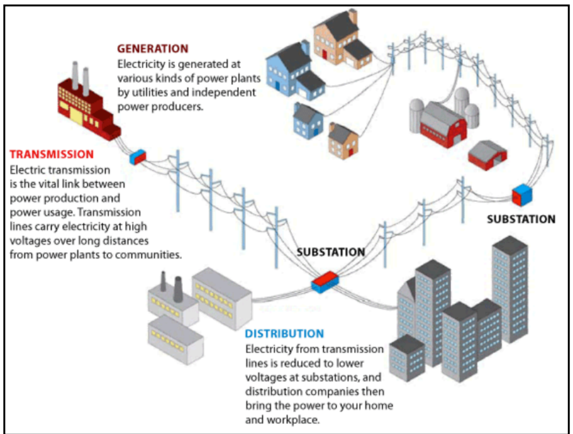

Figure 3. Traditional Electrical Grid.
** Source Climate Central Report

Although our global electrical grid works, it is not perfect, and it fails continuously. Initially, the grid used to fail more because of incapacity of operators and lack of required infrastructure, and resources, which is still the case in many developing regions of our world. The developed world has practically eliminated grid failures due to operator error or lack of infrastructure or resources. Nevertheless, there are still times when such systems fail, especially tied to weather in the United States, as seen in figure 4 taken from the Climate Central report. As seen in this graph, most power outages originate from storms and severe weather due to heavy precipitation and strong winds disrupting some of the many cables that need to be hold in place to sustain a typical working grid. The number of power outages displayed in this graph seems low, taking into account that these systems work all year round and that most of this outages last a brief time (2). Nevertheless, even these small grid failures may represent significant losses of life and money when they hit fragile infrastructures such as Hospitals' ICUs.

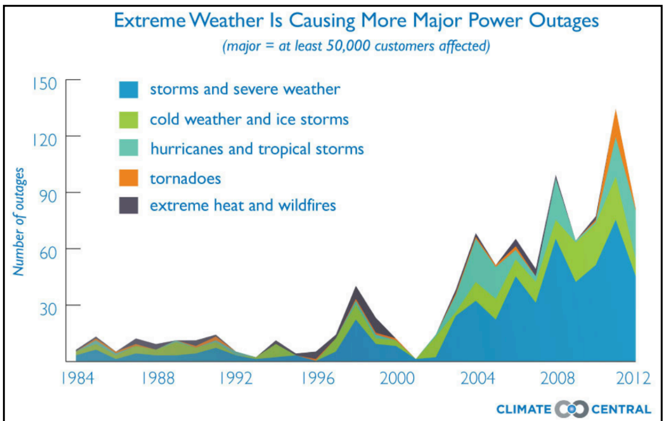

Figure 4. Power Outages & Weather.
** Source Climate Central Report

Although most outages in a developed nation such as the United States resolve in a manner of minutes, a smaller number of outages might last days or even months. Such low frequency but high impact events have the potential to have a substantial negative financial impact in local economies with long-lasting effects. Natural disasters, seen in figure 5 taken from an NOAA resource, already have a negative billionaire impact on the United States' economy yearly due to damages in private property and national infrastructure (3).

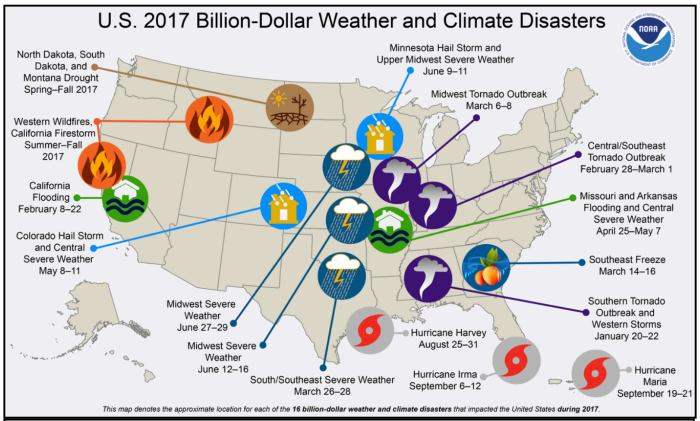

Figure 5. Economic Impact of Natural Disasters.
** Source NOAA

3. Puerto Rico after Hurricane Maria

In 2017 Puerto Rico, a territory of the United States, was struck by three hurricanes causing significant damages and becoming one of the most significant case studies of the impact that natural disasters can have in our global electrical grids. Puerto Rico has been struggling with an economic slow down for decades, leading to a population decline as people have decided to move to the mainland US after failing to find a job and sustain themselves there. Such economic troubles, and continuous political disturbances linked to corruption cases and an overly bureaucratic government had also weakened the island's electrical infrastructure. Such a weak grid stood no chance when Hurricane Maria's path, displayed in figure 6, plunged through critical transmission lines, leaving most of the island in the dark.

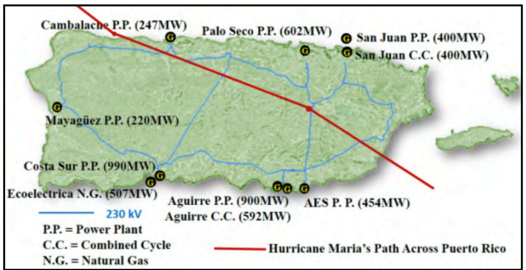

Figure 6. Puerto Rico's Grid and the Impact of Maria.
** Source IEE Journal

The aftermath of Hurricane Maria was chaotic, as it had destroyed practically everything in its path. As displayed in figure 7, even some of the concrete poles, which were supposed to be the most reliable link of Puerto Rico's distribution gird were destroyed during the storm, thus making the outage last for months.

Figure 7. Impact of Hurricane Maria on Puerto Rico's Electrical Distribution Grid.
** Source IEE Journal

An already poor electrical infrastructure and a bureaucratic and corrupt system led to a prolonged recovery for the islands' infrastructure. Political and administrative hurdles furtherly delayed the pace at which the repair took for months since they could not ask for assistance from other utilities from mainland US with better equipment and a better-trained workforce. Thus it took 75 days for most substations, and transmission segments to be repaired, leading to more than 150 days until many users got electricity service available back in their locale. During these 150 days, the lucky and affluent ones were able to get batteries or generators that would at least work for their minimal needs (like water pumping, lighting, or cooking) but most of the population suffered during these months, lacking even the most basic services for survival. Such catastrophic scenario led to clogged ports where even the aid sent was not getting to people in time, resulting in thousands of dead and billions of dollars in economic losses.

Luckily for Puerto Rico, most generating facilities were not struck by Maria, except for some like the Solar Utility Project in Humacao. This solar array, as seen in figure 8, was destroyed, thus showing us that renewables, when not used with their competitive advantage can be as problematic as traditional fossil fuel centralized electricity generating plants (4).

Figure 8. Impact of Hurricane Maria on Puerto Rico's Utility Solar Project in Humacao.
** Source IEE Journal

4. Lessons Learned & Recommendations

What happened in Puerto Rico should be taken as a case study of the potential chaotic impact that a grid failure due to storms can come to be. When our electrical grids are disrupted in unprecedented ways by low probability storms that hit which confabulate with other variables to lead to disaster, even in a territory of the most economically developed nation on Earth. Fortunately, some industries have been experimenting with energy strategies which are proving to be much more resilient than alternatives. Industries, such as telecommunications earn revenue through selling for utilization of their infrastructure when utilized in services. Therefore for these industries, downtime without electricity affects their bottom line, which has incentivized indirectly the implementation of innovative power engineering strategies such as micro-grids coupled with distributed generation and storage. Having such micro-grids in place in Puerto Rico in 2017, at least in critical points of such infrastructure could have saved money and lives.

As Kwasinski, describes in an IEEE's journal article, telecommunications infrastructure could be made more resilient by coupling it with interdependent micro-grids with electrical generation and storage as seen in figure 9, which in this case is wind turbines, solar panels, and batteries. It is in this fashion that distributed generation solutions such as wind and solar could gain a competitive advantage with traditional sources since they can be scaled accordingly, and they need nothing else but natural phenomena to work. Solar energy, even more than wind, has tremendous availability worldwide which could enable micro-grids to run interdependently with local grids for energy resiliency, independence, and security.

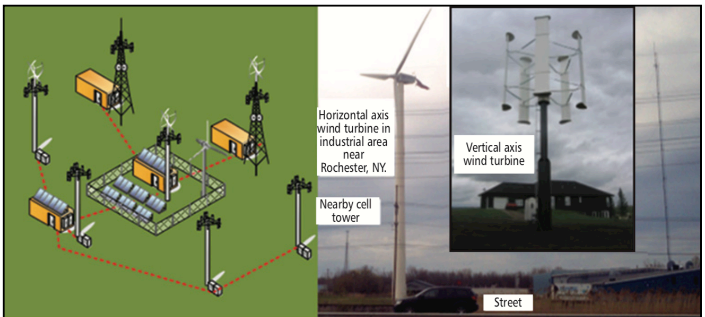

Figure 9. Micro-grids Utilizing Distributed Generation Plus Storage to Increase the Resiliency of the Telecommunication Industry.
** Source IEE Journal

Micro-grids, coupled with distributed generation and storage such as wind or solar plus batteries would not only make the grid more resilient but also more reliable in the long term. This interconnected micro-grids, coupled with sensors, switches, and communication equipment, could lead the way to the transformation of our global grid into a smarter one. In such a grid where data is gathered and utilized in real-time with other tools such as computing power and algorithms, our electric infrastructure could reach unprecedented efficiency and resiliency levels.

The total investment required of a bigger, more robust grid to reach the adaptability which micro-grids coupled generation, and storage with switches, monitoring, and communication equipment can lead to would be huge. Such scale would mean that this strategy would not be able to be implemented equally on a global scale, leading to long term risk regardless. On the other hand, just using switches, monitoring, and communications would increase efficiency but also not solve the problem of geographical movements of populations and industries. Thus as Kwasinski discussed, a hybrid approach is the most effective way to reach such results (5).

5. Conclusion

Awareness of climate change has been rising globally, leading to governments and corporations to push the industry forward, eventually making solar and wind reach grid parity in many regions of our world. Nevertheless, even in the best-case scenarios, if we manage to keep emissions low, the effects which our civilizations have already had on our planet will lead to at least changes in precipitation patterns and global temperature. This, as little as they might be, still have the potential for high economic and social impact as discussed, on a global scale. Therefore, we should take advantage of the already installed distributed generation resources such as rooftop solar to make our grids more resilient. Coupling these systems together with storage and smart technology such as the internet, sensors, computing power, communications, monitoring equipment, blockchain, and machine learning would be able to provide electricity reliably and resiliently to the people of the world regardless of higher frequency or strength of storms in the future.

6. Acknowledgments

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