

DARK BY 2050

KLEIN TOOLS

THE ACCELERATE GROUP

SECTION I: EXECUTIVE SUMMARY

Electrical workers are the gears that turn what has been called the world's largest machine – the electrical system that powers our factories, businesses, and homes. Yet, our country's electrical workers are aging, facing a retirement boom, while the training of new electrician apprenticeships fails to keep up with the growing needs of our electric system. These trends together threaten to put the convenience of easy access to electricity at risk, blocking any progress on achieving a clean energy future, and portending a future of more frequent and longer power outages that plunge the country into a new dark age by 2050.

Klein Tools and The Accelerate Group have worked together to conduct an analysis to look at what will happen if the current electrical workforce trends continue: to understand what the workforce gap will be in the coming years, the impact of that workforce gap on the country's ability to achieve a clean energy future, and the long-term impacts of a significant workforce gap on the ability of the country to maintain its electrical power systems and equipment. Finally, the study examines the cascading societal impacts of frequent and widespread long-duration power outages on the primary needs of society, such as food, water, safety, transportation, and communications, to understand the inter-related nature of these systems, and their dependence on reliable power.

THE STUDY FOUND:

- Due to the age, attrition rate, and new entrant rate, the existing electrical workforce of 770,000 electricians and 110,000 line workers is projected to shrink by 28% by 2050 (Section II)
- To achieve just the “mid-case” scenario of a clean energy future (a mid-range level of renewable energy), electric vehicle charging infrastructure, and building electrification development, the country will need an additional 224,000 electrical workers by 2030, and to sustain and grow that workforce level every year through 2050 (Section III).
- The difference between the projected electrical workforce and the electrical workforce need will exceed 251,000 workers (25%) by 2030, and 462,000 workers (45%) by 2050 (Section III).
- That workforce gap will not hit all industries equally, as electrician positions in industries such as manufacturing, healthcare, telecommunications, and public institutions are decimated by 2040 (Section IV).
- The workforce gap will lead to more frequent and longer-duration outages, as power outages are slower to restore, aging infrastructure fails more frequently, and electrical equipment sits idle, unable to be repaired or replaced (Section V).
- From 2030-2040, millions of Americans will face outages lasting multiple days, creating a cascading effect on communications, water supply, transportation, and even the ability to gain fuel for backup generation (Section V).
- From 2040-2050, those days-long outages give way to months-long outages, making backup generators and gas-fueled vehicles the only reliable source for energy, and a migration in the electrical workforce away from centralized power systems and toward installing individual generators (Section V).

- By 2050, the inability to restore and stabilize the electric system eventually brings about a reality where outages are the new normal: Commercial centers that suffer from extended outages will become abandoned; Industrial facilities may run occasionally when able to obtain fuel. Processed, refrigerated or frozen food becomes infeasible; Telecommunications becomes strained as broadband and distributed cellular infrastructure lies dormant; Residents without the ability to air condition and heat most homes will abandon harsher climates for mild environments (Section V).

To reverse this workforce gap in the United States, the study found that we must train between 107,000 and 224,000 new electrician and line worker apprentices between now and 2030.

SECTION II:

ELECTRICAL WORKFORCE TRENDS

A SHRINKING AND AGING WORKFORCE:

In 2018, there were 770,000 electricians and 111,000 electrical line workers in the United States, according to the Bureau of Labor Statistics.¹ By a significant margin, the largest industry group in which electricians work is construction, with 511,000 electricians, where electricians are primarily responsible for installing electrical wiring, infrastructure and equipment (482,000).² The remaining

¹ Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Employment Statistics, Electricians*, www.bls.gov/oes/

² Ibid

250,000 electricians in the United States work in a variety of fields, from utility system construction, to motor vehicle manufacturing, rail transportation, colleges, universities, and local government.³

Electricians are responsible for routing the conduit, installing the wire, connecting the electric equipment, and connecting homes and buildings to the electric grid – The complex work that make the act of plugging in a TV, computer, or appliance to a wall socket as simple as it is.

Electrical workers also are responsible throughout the energy system chain to ensure that there is power to and through the electrical grid, connecting lines on poles to transformers, switchgear, and substations. More than 57,000 line workers were employed by utilities in 2018, and 35,000 more with private construction companies, responsible for the installation, repair and maintenance of high voltage transmission systems and distribution systems at hundreds of utilities across the country.⁴ This transmission, substation, and distribution network enable the high voltage electricity that is produced by a large power plant – electricity that is more powerful and sustained than a lightning strike – to be able to be stepped down in a safe enough level to turn on a nightlight.

Electrical workers also work to build, maintain and repair large electric power generators, from coal and gas plants, to nuclear facilities and hydroelectric dams, as well as wind and solar farms. They are also required to connect rooftop solar panels to the grid, and upgrade a home's electrical system to handle a new air conditioning or heating system, as well as a new electric car.

Businesses depend on electricians to install chillers, heating systems, fans, and pumps to support buildings that serve populations comparable to small cities inside their walls. Datacenters depend on electricians to install the power supply equipment to run the web sites, apps, software, and services that are the backbone of digital life. The nation's manufacturing sector depends on electricians to install equipment, and keep power quality stable and secure for complex machinery that produces metals, pharmaceuticals, food, vehicles, materials, chemicals, and appliances.

Public health and safety depend on electricians to keep hospital life support systems powered and online, and emergency services connected so they are able to respond quickly to public needs.

Many have called the nation's power grid the world's most complex machine. It is made up of billions of individual components needing to operate seamlessly for the typical user, keeping electricity not just on, but at the right frequency and voltage to meet the needs of any piece of equipment.

³ Ibid

⁴ Ibid

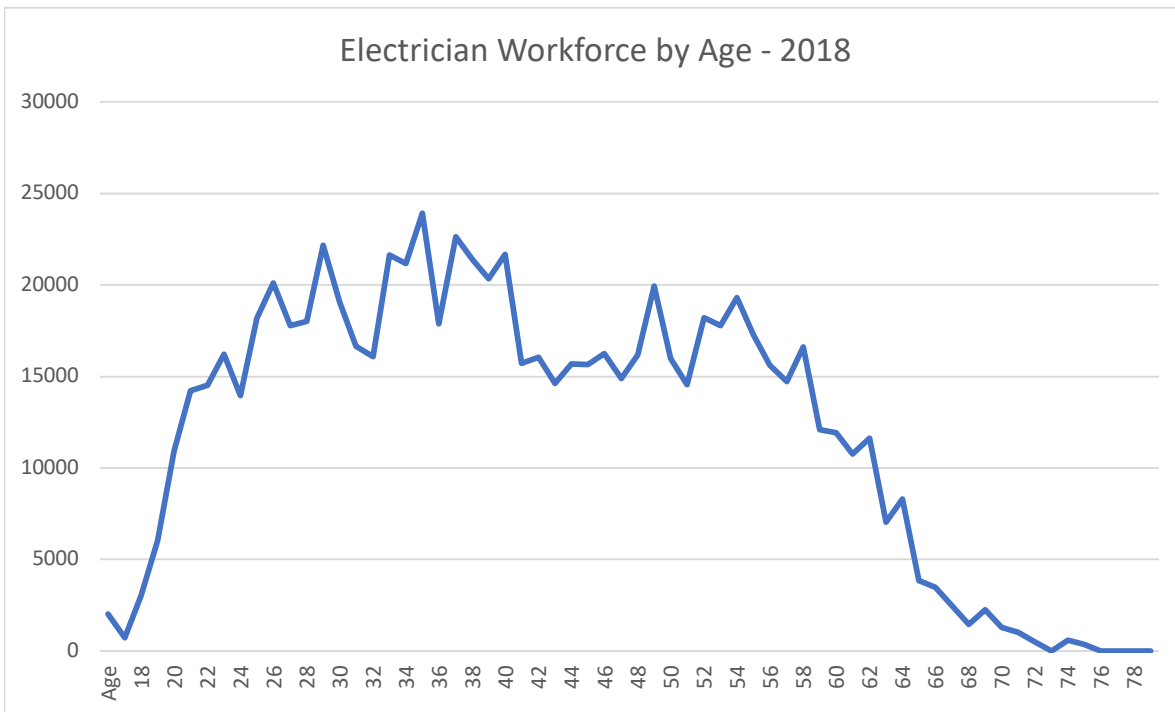
WORKFORCE AGING LEADS TO WORKFORCE REDUCTION

Yet, the electrical workers that build and maintain that machine will face struggles in the coming decades to keep up with the needs of maintaining the nation’s electrical infrastructure as the current workforce ages toward retirement. Without enough new electricians taking their place to achieve basic upkeep of the system, let alone the ambitious energy goals of the country’s political, business, community, and utility leaders, our electrical system from the plant to the light bulb threatens to fall into disrepair and failure.

ELECTRICIANS

According to data from the Census Bureau, the median age of electricians in the U.S. is 41 years old, greater than the construction industry as a whole and similar occupations like plumbers and pipefitters.⁵ Chart 2.1 shows the age distribution of the current electrician workforce, which includes a higher percentage of workers age 50+ than most similar professions. In the chart, this can be identified as a secondary “hump,” and a plateau-like shape to electrician age, rather than a gradually-declining slope. As the workforce population ages, new electrician apprentices will have to enter the workforce at a significant rate to keep up with the retiring population bump.

CHART 2.1



Source: United States Census Bureau, American Community Survey Public-Use Microdata Sample, 2018

⁵ Data compiled from the United States Census Bureau, American Community Survey Public-Use Microdata Sample, 2014-2018 5-year PUMS files, <https://www2.census.gov/programs-surveys/acs/data/pums/2018/5-Year/>

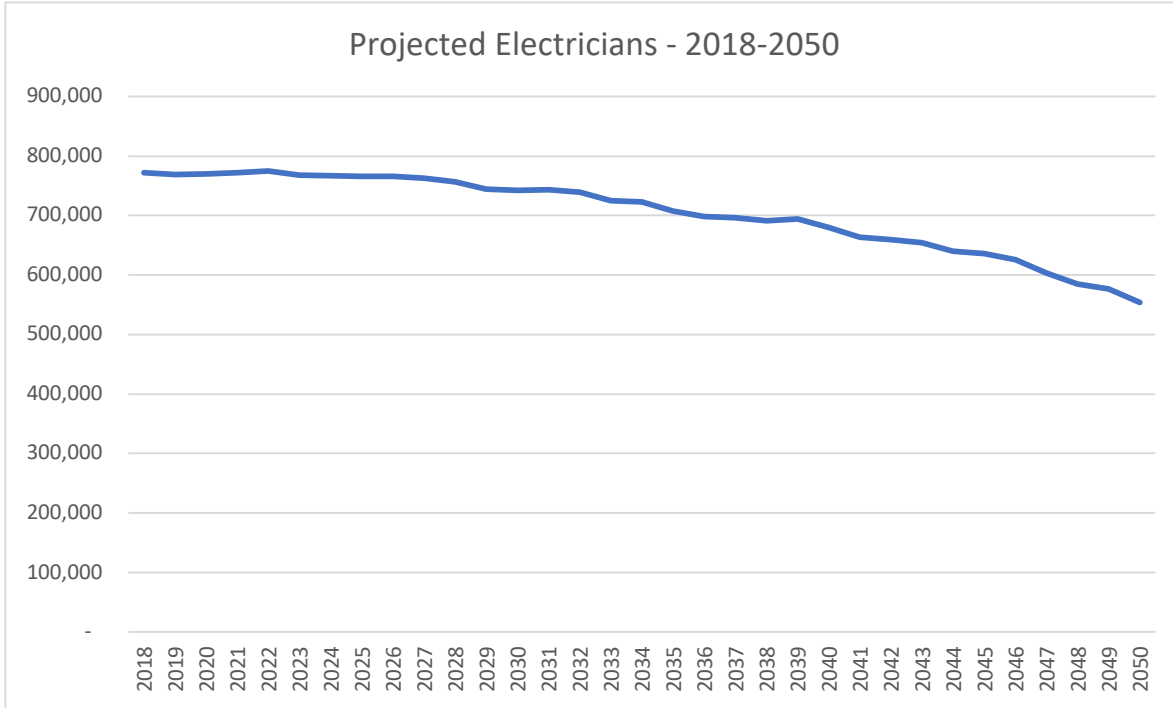
We conducted an analysis to assess the change in the electrician and line worker workforce over the next 10, 20 and 30 years to determine the impact of aging and retirements on the total workforce population as compared to the projected workforce need. This analysis was conducted by evaluating the current workforce population age distribution, age +1 retention trend since 2014, and the growth of new workforce entrants since 2014, using data from the Public Use Microdata Sample (PUMS) from the Bureau of Labor Statistics (BLS). Age +1 retention looked at the annual trend in workforce population changes for age blocks at significant age periods: 17-26, 26-40, 41-60, 61-70, and 71+ to define distinct age group retention slopes. Annual changes in each age group were projected to each subsequent year by using the previous 4-year average slope for the distinct age group. For new workforce entrants (ages 17-26), the projected number of new entrants at every age is based on the previous 5-year average (2014-2018) of new market entrants at each age, with variations in overall market growth trends based on a randomized percentage change within the margin of error to reflect economic cycles.

This projection shows that at the current new occupation entrance rates and annual retention rates the industry has seen for the past 5 years, the electrician workforce will:

- Shrink to 742,466 workers by 2030, a decrease of almost 4% from 2018
- Shrink to 679,397 workers by 2040, a decrease of 12%.
- Shrink to 553,760 workers by 2050, a decrease of 28%.

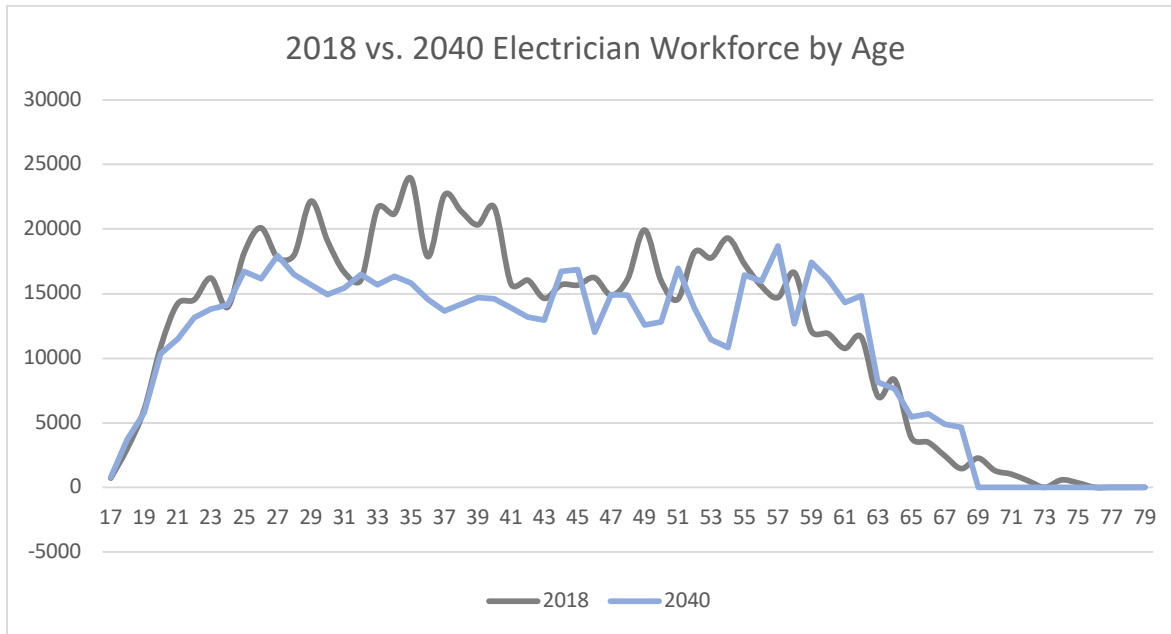
Chart 2.2. provides the projected population of the electrician workforce for each year through 2050, according to this projection model. Chart 2.3 further compares the projected electrician workforce by age in 2040 as compared to 2018. As can be seen, more senior electricians maintain positions in the workforce while new workforce entrants fail to keep up with impending retirements.

CHART 2.2



Source: The Accelerate Group

CHART 2.3



2018 Source: United States Census Bureau, American Community Survey Public-Use Microdata Sample, 2018

2040 Source: The Accelerate Group projection

LINE WORKERS

The median age of line workers in the U.S. is 40 years old, slightly younger than the median age of electricians.⁶ As the workforce population ages, line workers, much like electricians, will have to enter the workforce at a significant rate to keep up with the eventual retiring population.

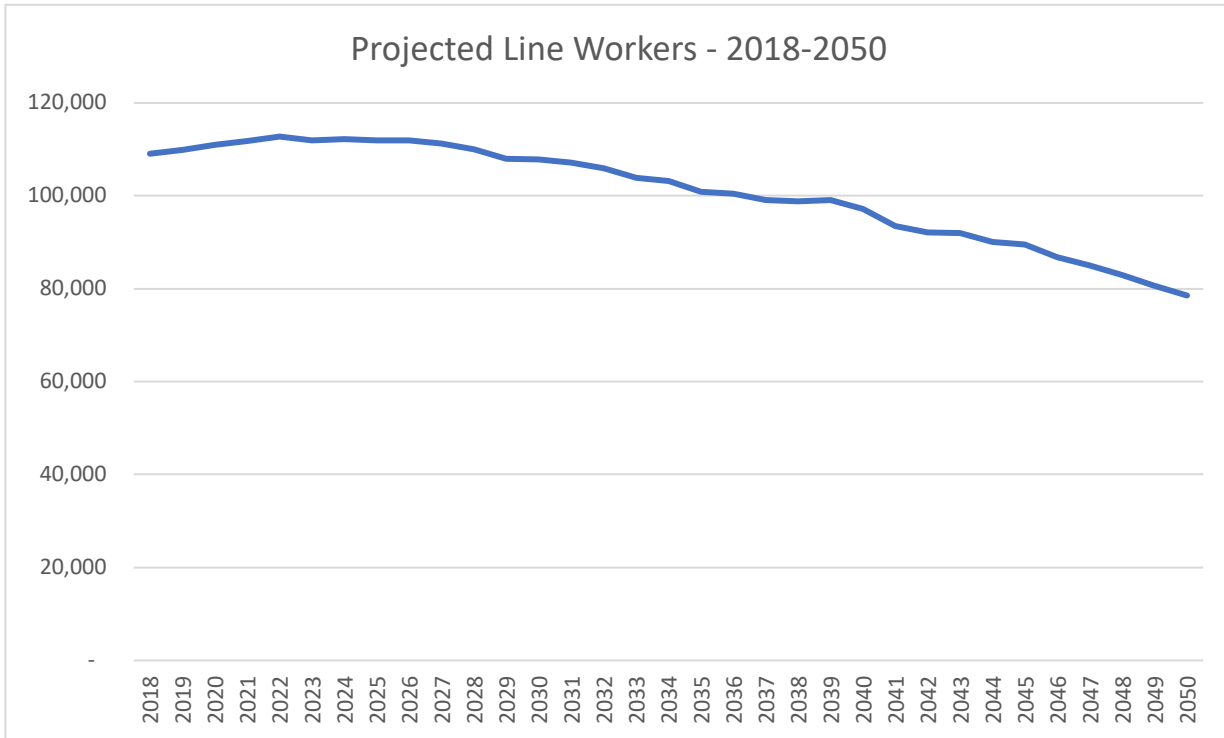
Similar to the electrician analysis, we conducted an analytical projection to assess the change in the electrician and line worker workforce over the next 10, 20, and 30 years to determine the impact of aging and retirements on the total workforce population as compared to the projected workforce need. The analysis was conducted using the same methodology used for the electrician analysis. This projection shows that at the current new occupation entrance rates and annual retention rates, the line worker workforce will:

- Shrink to 108,000 workers by 2030, a decrease of almost 1.2% from 2018
- Shrink to 97,000 workers by 2040, a decrease of 11%.
- Shrink to 78,500 workers by 2050, a decrease of 28%.

Chart 2.4 provides the projected population of the line worker workforce for each year through 2050, according to this projection model.

⁶ Data compiled from the United States Census Bureau, American Community Survey Public-Use Microdata Sample, 2014-2018 5-year PUMS files, <https://www2.census.gov/programs-surveys/acs/data/pums/2018/5-Year/>

CHART 2.4



Source: The Accelerate Group

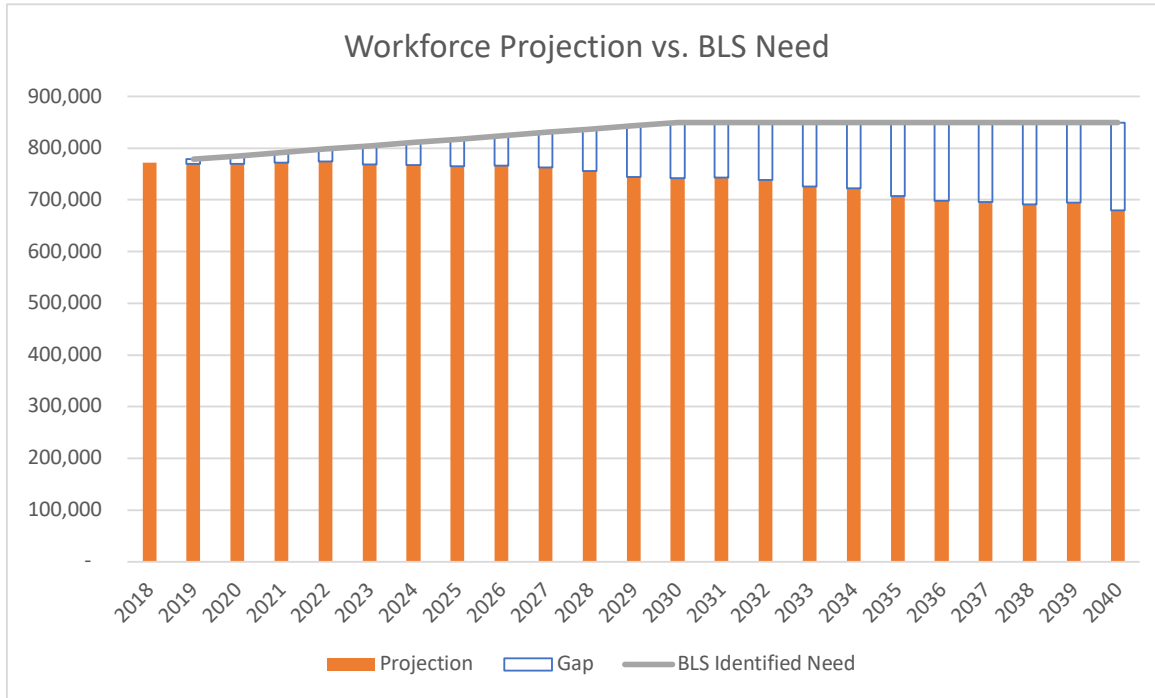
SECTION III: GROWING NEEDS OF THE ELECTRIC SYSTEM

This workforce loss comes in the face of a major projected growth in electrician and line worker need. The Bureau of Labor Statistics (BLS) has estimated that the need for electricians over the next 10 years will grow by more than 10%, based on current policies and trends, and line worker need will grow by 4%.⁷ This would total a projected need for 849,000 electricians by 2030, a gap of nearly 107,000 workers from the projected workforce under the BLS' model.⁸ Chart 3.1 illustrates this workforce gap compared based on the industry growth estimates from the BLS.

⁷ Bureau of Labor Statistics, U.S. Department of Labor, Employment Projections program, <https://data.bls.gov/projections/nationalMatrix?query-Params=47-2111&ioType=o>, accessed August 2020

⁸ Ibid

CHART 3.1



Source: Bureau of Labor Statistics, Employment Projections program, The Accelerate Group projection

CLEAN ENERGY SCENARIO

The gap grows more significant when you factor in growing calls and new policies to accelerate clean energy growth in the United States, by both states and the federal government. Plans to rapidly advance renewable energy development, electric vehicle deployment, and electric building conversion will create a workforce expansion unlike what the industry has experienced since the mass adoption of air conditioning.

In order to better understand the workforce needs required to meet this future, we developed a “Clean Energy Future Workforce Scenario” to evaluate the growth in need of electricians under future clean energy technology adoption projections. Using data from the National Renewable Energy Laboratory’s (NREL) Electrification Futures Study,⁹ developed in 2018 to estimate the adoption of transportation and building electrification technologies through 2050, as well as the NREL REEDS 2019 Standard Scenarios,¹⁰ and the Annual Technology Baseline,¹¹ which project renewable energy technology cost and capability trends, we selected the “mid-case” scenarios to create an assumption of the total amount of renewable energy, electric vehicle charging infrastructure, and building electrification infrastructure expected to be constructed and deployed by 2030-2050.

9 National Renewable Energy Laboratory, U.S. Department of Energy, *Electrification Futures Study, 2018*, <https://www.nrel.gov/analysis/electrification-futures.html>

10 National Renewable Energy Laboratory, U.S. Department of Energy, *REEDS Standard Scenarios*, <https://www.nrel.gov/analysis/standard-scenarios.html>, accessed August 2020

11 National Renewable Energy Laboratory, U.S. Department of Energy, *Annual Technology Baseline*, <https://atb.nrel.gov/electricity/2020/index.php>, accessed August 2020

The resulting Clean Energy Future Workforce Scenario sees a future that requires a significantly greater need for electricians than the Bureau of Labor Statistics' simpler industry growth trend estimates. Through our analysis, we find the Clean Energy Future Workforce Scenario projects the need to construct 57 million home charging stations by 2030, and 167 million by 2050, as well as 2.6 million public charging stations by 2030, and 6.1 million by 2050. It projects the need for 3 million solar rooftops by 2030 (almost 9 million by 2050). It also projects a growing move toward electrification of homes and businesses, away from gas and oil, resulting in the installation of 17 million heat pumps by 2030, and 87 million heat pumps by 2050.

224,000 MORE ELECTRICIANS NEEDED BY 2030

We analyzed the average electrician Full-Time Equivalent (FTE) required for the installation of each solar/wind project, charging station, and heat pump, and the annual average installations required, and extrapolated out the need for additional electricians above and beyond the best case scenario of current electricians. What we found was a need for 224,737 additional electricians in the workforce by 2030, and 246,593 additional electricians in the workforce by 2050, to achieve the new construction requirements of the Clean Energy Future Workforce Scenario. Table 3.2 describes the electricians required for the installation by sector, as uncovered by our analysis. Adding on to the current workforce, the Clean Energy Future Workforce Scenario would require a total of 994,000 electricians in the workforce by 2030, and to maintain that level consistently through 2050.

45% WORKFORCE GAP

Comparing the projected number of electricians in the workforce with the projected need based on the Clean Energy Future Workforce Scenario shows a shocking workforce gap:

- We will have 251,621 fewer electricians than we need by 2030 (25% workforce gap).
- We will have 462,183 fewer electricians than we need by 2050 (45% workforce gap).

Chart 3.3 shows the growing annual gap between the workforce need identified in the Clean Energy Future Workforce Scenario and workforce projection described in Section II.

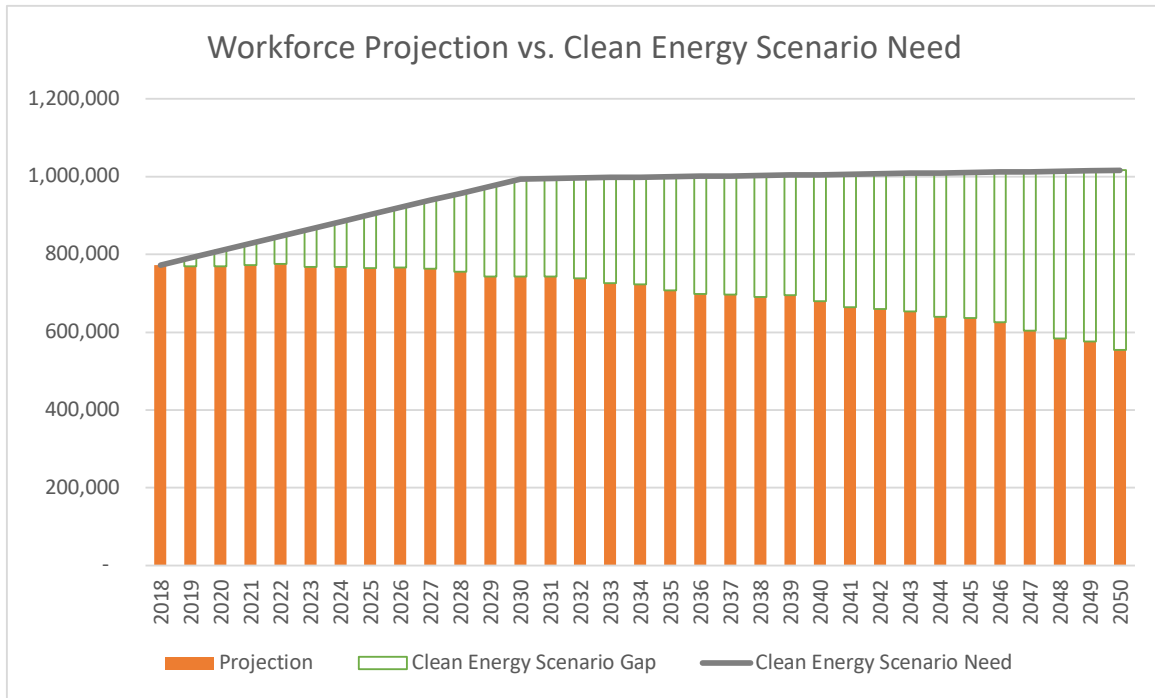
The technologies involved in the Clean Energy Future Workforce Scenario largely would be developed in the home or business, involving a significant amount of electricians, yet likely a much smaller amount of line workers. The impact of the Clean Energy Future Workforce Scenario on additional line worker need would largely be relegated to the large-scale solar and wind farm deployments, and in those scenarios, only the portion of the projects involving interconnection to the larger grid. The impact is estimated to be less than 5,000 line workers annually, and likely even less, as electricians would be largely serving the need.

TABLE 3.2.

Electric Vehicle Infrastructure	By 2030	By 2050
Home charging stations	57,200,000	167,144,283
Public charging stations	2,600,000	6,110,000
Annual Average Electricians Needed	109,108	102,361
Building Electrification	By 2030	By 2050
Residential Heat Pumps (Air)	15,390,057	53,445,342
Residential Heat Pumps (Ground)	247,500	1,500,635
Residential Water Heat Pump (Air)	1,454,823	32,141,180
Annual Average Electricians Needed	107,767	132,176
Renewable Energy	By 2030	By 2050
Solar Rooftops	3,038,698	8,953,480
Solar Farms	1,520	6,321
Wind Farms	499	3,732
Solar Panels	243,185,211	562,892,921
Wind Turbines	44,530	125,357
Annual Average Electricians Needed	7,862	12,056
	By 2030	By 2050
Total Additional Electricians Needed	224,737	246,593
<i>Clean Energy Future Scenario</i>		
Total Electricians Needed in year	994,086	1,015,942
Projected Electricians	742,466	553,760
Gap	251,621	462,183
% of Workforce Needed Missing	25%	45%

Source: The Accelerate Group Clean Energy Future Workforce Scenario Analysis

CHART 3.3



Source: The Accelerate Group projection, The Accelerate Group Clean Energy Future Workforce Scenario analysis

Without a significant increase in the electrician workforce in the next 5-10 years, the policies and ambitions in the “mid-case” scenario mapped out by NREL is completely unattainable. Rooftop solar installations, wind and solar farms, electric vehicle charging infrastructure, residential and business electric heating all depend on the availability of a well-trained workforce of electricians to be developed. Trillions of dollars in investment in a Clean Energy Future Scenario will be delayed or deferred without the skilled workers in place to make it happen.

SECTION IV: IMPACTS

As this workforce gap grows, the reduction in the electrician workforce will not hit all industries evenly. Electricians in lower-paying jobs will move into higher-paying jobs as demand increases, creating a shift in the level of electricians working in different industries. We conducted an analysis to determine which of these industry groups would be hardest hit by the workforce gap, based on the current average pay for electricians in each industry sector, and how the workforce will migrate to higher-paying positions over time. We looked at these impacts at three points in time: 2030, 2040, and 2050.

ELECTRICIANS BY 2030

There are 26 industry groups in which electricians make less than the average pay of an electrician in the construction sector, including at retail electronics and building material dealers, with water, steam, air-conditioning & irrigation system developers, fabricated metal manufacturing, structural metal manufacturing, and federal government services such as the U.S. Navy, U.S. Coast Guard, and U.S. Marines.¹²

Over the next ten years, as a result of the growing workforce gap, our analysis shows these jobs would fall into the highest risk category, potentially losing around 25% of current employment, with the exception of the armed forces positions, as wages cannot keep up with other sectors and there aren't enough electricians able to fill positions.

The largest industry sector where electricians are employed, the construction sector, would continue to employ the vast majority of electricians in 2030. As previously described, investments in renewable energy, transportation and building electrification would face a significant workforce shortage, as the construction sector as a whole would lose 5-10% of its existing electrician workforce capacity, while facing a need of a 40% capacity increase.

Industry sectors that are at a medium risk, on par with the construction sector, by 2030 include those where the average pay is less than the mean of all electricians, and within 10% of the average pay of construction jobs. Industrial sectors in the "at-risk" category include farming, machinery manufacturing, hospitals, and amusement & recreation venues, as well as several in education facilities, including colleges & universities, and elementary & secondary schools. Combined, electricians in these medium "at-risk" industry sectors account for 6% of the country's electrician workforce, and could see a reduction of 10% of their electrician workforce capacity.

A reduction in the electrician workforce will be felt less in industries where average pay is on the upper end of the range, increasing retention and attracting replacement electricians from other sectors. Industry sectors that will see little impact by 2030, according to our analysis, include performing arts companies, petroleum refining, pharmaceutical & medicine manufacturing, and computer systems design, with average salaries all exceeding \$95,000 per year in 2018, but those sectors make up no more than a combined 1% of the workforce.

BY 2040

By 2040, as we described in Section II, it is projected that there will be a 12% drop in the electrician workforce compared to 2018, as well as a 170,000 electrician workforce gap compared to the BLS-projected need, and a 325,000 electrician workforce gap compared to the need identified in the Clean Energy Future Workforce Scenario we modeled in Section III.

¹² Data compiled from the United States Census Bureau, American Community Survey Public-Use Microdata Sample, 2014-2018 5-year PUMS files, <https://www2.census.gov/programs-surveys/acs/data/pums/2018/5-Year/>

Industry sectors in the highest risk category, that saw some losses in 2030, are projected to be completely wiped out by 2040 as higher-paying industry jobs continue to draw the remaining workforce, and new construction demands drive more focus on retention in that sector. Electricians would largely disappear from retail and manufacturing sectors. Colleges & universities, as well as elementary and secondary schools, would see electricians disappear from staff positions.

Workforce reductions would further expand to industry sectors that were once thought safe-havens – industry sectors that paid higher than the average wages for electricians nationwide – but now will struggle to find workers. These new medium-risk industry sectors include electric power generation, transmission & distribution, telecommunications industries, rail transportation, sewage-treatment facilities, electrical equipment and household appliance manufacturing. 25% of the 80,000 workers in the new medium-risk industry sectors would retire or move on to other industry sectors, leaving critical facilities at risk of deterioration and disrepair.

In the construction industry, the electrician gap would begin to become more pronounced, with 18% of construction positions needed unable to be filled under the standard scenario, and 40% of construction positions unable to be filled under the Clean Energy Future Workforce Scenario. The impacts would be significant, leading to complete stalls in the construction sector, as electricians are redeployed to prioritized maintenance and repair needs, and to address new needs due to more frequent and severe outages described in Section V.

BY 2050

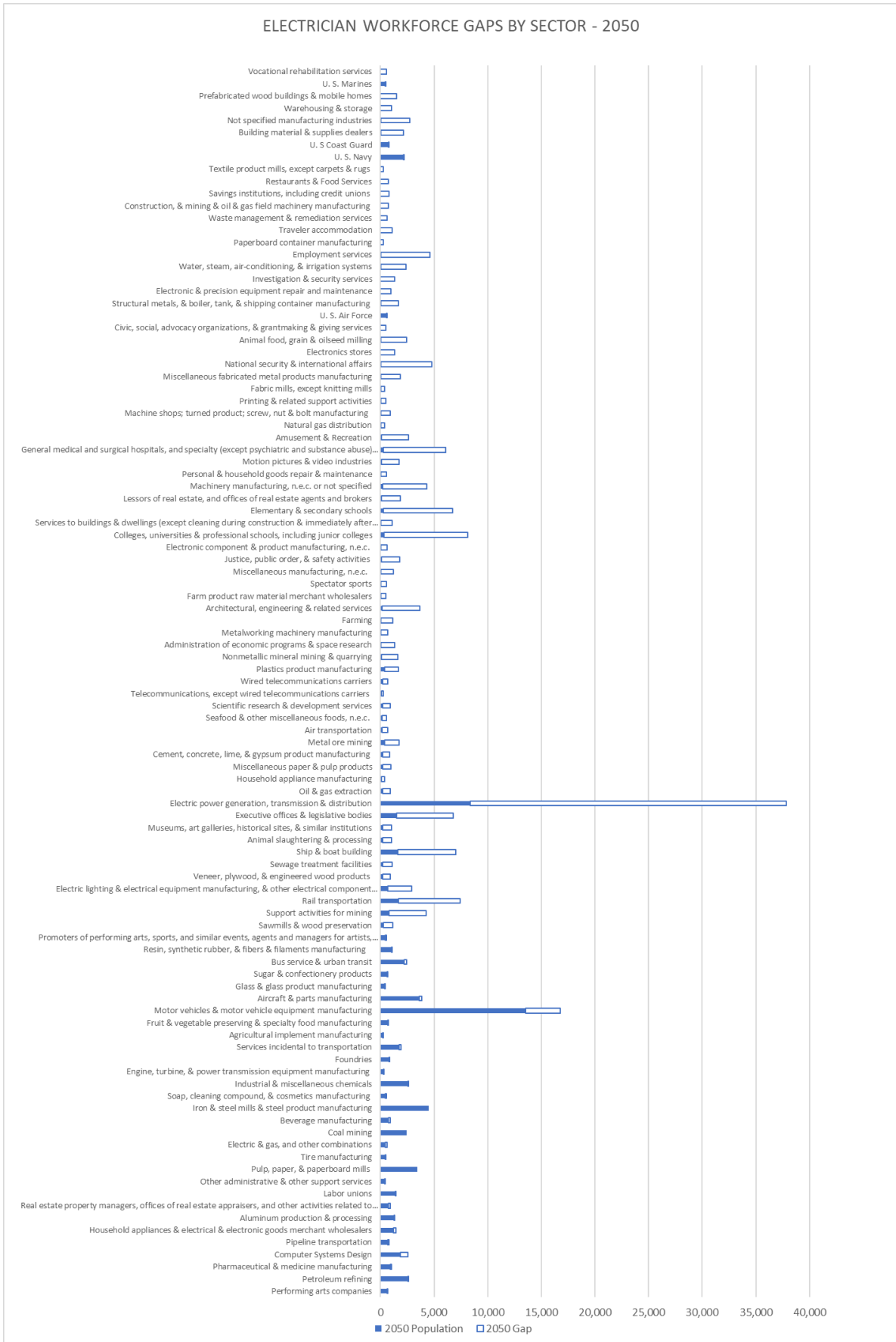
By 2050, as we described in Section II, it is projected that there will be a 28% percent drop in the electrician workforce compared to 2018, as well as a 296,000 electrician workforce gap compared to the BLS-projected need, and a 462,000 electrician workforce gap compared to the need identified in the Clean Energy Scenario.

By this point, all 2040 medium-risk industry sectors would see a loss of 75% of their workforce, leaving critical electric power, electrical equipment and appliance manufacturing, rail transportation, sewage treatment, and telecommunications industries struggling to find qualified electricians to perform basic maintenance, repair, or replacement work.

In the construction industry, the electrician gap would become astronomical, with 35% of needed construction positions unable to be filled under the standard scenario, and 52% of needed positions unable to be filled under the Clean Energy Future Workforce Scenario.

The highest paying industry sectors would largely remain intact, as the average salary level would encourage strong retention and backfill from electricians in other sectors.

ELECTRICIAN WORKFORCE GAPS BY SECTOR - 2050



LINEWORKERS

By 2030, as described in Section II, there is projected to be a 1.2% decrease in the line worker workforce, which will not create dramatic impacts on the overall ability of utilities to manage outage severity and duration. But between 2030 and 2040, that gap will grow to 16,000 line workers.

Unlike the electrician sector, line workers work in primarily two main industry sectors: 74,000 are employed by public and private utilities, either within power generation plants, or supporting transmission and distribution systems, and another 37,000 are employed in the private sector performing utility system construction.¹³ Private sector line workers are paid on average more than those that are employed by utilities, both public and private. A reduction in workforce is expected to primarily harm the ability of a utility to respond to power outages, and to maintain and replace the electrical system as is necessary over time.

During a typical outage, a utility will deploy its line worker personnel to repair downed wires and repair damaged electrical equipment. Depending on the cause of the outage, there could be anywhere between one and thousands of points of failure on the electrical system. When utility line workers are deployed to repair outages, they are forgoing the replacement and upgrading of electrical equipment, causing a cascading effect on the wear and tear on utility infrastructure, and the increased likelihood of equipment failure in the future. Transformers, conductors, and other equipment are typically rated to last between 35-40 years, and delays in replacement schedules can cause equipment failures that can have cascading impacts on the system.

Further, when large-scale outages from natural disasters hit, utility line-workers from across the country are mobilized to support power restoration. When Hurricane Florence hit the Carolinas in 2018, 20,000 utility workers from across the East Coast and Midwest were dispatched to support the workforce of Duke Energy employed and contract linemen, and even then were only able to restore power to most customers after 14 days. Without the supplemental line worker workforce, those outages would have likely lasted more than three months.

¹³ Bureau of Labor Statistics, U.S. Department of Labor, Occupational Employment Statistics, Power Line Installers, www.bls.gov/oes/

SECTION V: SOCIETAL IMPACTS

The reduction in electricians available to perform the maintenance, repair, and construction of critical electrical equipment will start to have a significant effect on the conveniences that residences, businesses, and industry depend on power to enjoy. As described, the primary exposure will be an increase in the number of consumers that have outages for longer periods of time.

Already, the electric power grid is prone to large-scale outage events, exposing the vulnerability of both the electrical system to cascading failure, as well as the dependency of the infrastructure that serves society's needs on electricity.

- Most recently, in California, the public utilities have begun to implement a new policy called “Public Safety Power Shutoffs” to reduce the incidence of old and faulty electrical equipment sparking wildfires during hot, dry, and windy seasons. In 2018 and 2019, millions of customers were exposed to blackouts exceeding 36 hours in order to de-energize lines running through forests and other vegetation ripe for ignition.¹⁴
- In 2018, Hurricane Florence sat over the city of Wilmington, NC for two days, knocking out power to much of the city for weeks, cutting off access to the city, and exhausting the backup fuel supply at the water pumping station, potentially leaving hundreds of thousands of sheltering residents without fresh water.
- In 2017, Hurricane Maria knocked out 80% of the power to the island of Puerto Rico, which took 11 months to get back on to all parts of the island. This was the largest blackout in U.S. history.
- In 2012, Hurricane Sandy knocked out power to 8.5 million customers on the Eastern Seaboard, causing \$70 billion in damages and making downtown Manhattan go dark.¹⁵

But not all outages are weather-related or weather-dependent. In 2003, in one of the most well-known widespread failures of the electric power system, the failure of a few generators in Ohio causing a cascading effect on protection equipment throughout the Northeast, left 55 million without power in New York, New Jersey, Pennsylvania, Connecticut, Rhode Island, Massachusetts, Ohio, Michigan, and Ontario, Canada. Despite the absence of storm damage, it took more than 7 hours to get most customer’s power back on, with some regions facing outages for two days.

These widespread outage experiences have brought lessons on the impacts of outages on the societal impacts of outages at extended periods of times, coupled with the extra needs people and communities face during emergencies.

NEAR-TERM : 2030 - 2040

In 2019, 10 million Americans experienced a power outage of longer than 1 hour, according to the Energy Information Administration.¹⁶ While widespread outages do occur, they are still seen as rare events that have a relative infrequency, and do not require alteration of infrastructure assumptions for alteration.

From 2030 – 2040, however, these frequency and duration of outages will increase significantly, due to the reduction in electrician and line worker workforces. We conducted a scenario planning analysis to determine the impact of the growing workforce gap on the frequency, duration, coincidence, and impact of outages, and examining the impact on primary society needs, such as food, water, safety,

¹⁴ See <https://www.cpuc.ca.gov/deenergization/>

¹⁵ Office of Electricity Delivery & Energy Reliability, U.S. Department of Energy, *Hurricane Sandy Situation Report #20*, November 7, 2020

¹⁶ Energy Information Administration, *Table B.2 Major Disturbances and Unusual Occurrences*, 2019

transportation, telecommunications, and more. This analysis, illustrated in Chart 5.1, describes the impacts that outages can have on those items that provide not only the necessities of a community, but also the expectations of modern living.

As can be seen, not all needs are impacted equally by power outages, as some community infrastructure elements can sustain short-term outages without much impact, while others fail rather quickly. Even those that can sustain short-term outages have never adapted or prepared for more frequent long-duration outages that exhaust short-term backup resources and impact downstream supply chain capacity for delivering basic needs such as fuel, food, and products.

WHAT HAPPENS DURING AN OUTAGE

For outages that are less than a second, or less than a minute, the impacts depend on the local area in which the outage occurred. A homeowner may notice the clock reset on an appliance, or a brief interruption of activities, which likely has no significant impact. For the commercial sector, power-sensitive industries often employ uninterruptible power supply setups for short-term contingencies. For industry, however, the impacts can be more significant. That minute of an outage usually means that a production run has to be scrapped completely, with plant workers having to clean out and restart machines. In food processing, often it means the whole day's production would have to be tossed out. Motors and other heavy equipment face damage and need for repair or replacement.

For outages longer than a minute but less than an hour, the impacts can start to stretch further. Critical public facilities such as hospitals, police, and airports typically are required to have backup generators installed to meet their power needs for a certain amount of time, and those systems will turn on to sustain power to those facilities. Banks and financial institutions will continue to rely on short-term backup power to ride through outages, but will start to plan for eventual shut-downs. The vast majority of businesses, however, do not possess backup power, and will start to close down for security and safety reasons, and because registers, payment processing systems, and computers are non-functional. For most outages under an hour, most operations will simply pause and attempt to wait out the outage, looking for more information on when it will be restored.

Once beyond an hour, however, public services, commerce, and industry start preparing to shut down for the day. Manufacturing production is halted, stores temporarily close, and offices send employees home. Electric-powered transit is not functional, but buses and shuttles help manage any new commute. Additionally, while schools and colleges can ride out temporary outages, once they extend beyond an hour those facilities must begin to cancel classes and programming. Facilities with backup generators are able to maintain critical life support and security functionality, and some may even remain open for business.

At 12 hours, outages typically enter a more strenuous stage. Facilities with backup generators often are required or expected to maintain 12 hours of fuel on-site. Hospitals and other life-support facilities often enter into agreements with utilities or third parties to be prioritized for power

restoration or generator fuel delivery within 12 hours. But in a widespread outage, those timelines become highly strained. Public facilities such as police departments, water treatment facilities, and airports are not typically prioritized over hospitals for fuel, and will begin to shut down operations if they haven't done so already. Banking and finance institutions will run out of backup fuel and close to preserve power for security systems. Freight rail, which faced pauses and holds to avoid collisions while signals were down, shifts to manual operation and control to clear traffic from an outage region. At home, lights, TVs and appliances have been out for hours, and now spaces that were previously cooled or heated lose that conditioning in hot and cold weather environments. Residents that have been relying on cell phones and battery-powered mobile devices to stay connected now face dead batteries, depending on their vehicles to recharge. Long-term care facilities, which already saw a shut-down of life-support and care systems, now face evacuation if hot or cold temperature extremes are experienced, with public building or public buses being deployed as emergency shelter options.

At 24 hours, two larger dominoes begin to fall for communities: gas supply begins to exhaust its emergency backup operations, and communities dependent on water towers lose their capacity and pressure. Both gas and water systems depend on electric pumps to drive pressure through their pipes. Gas utilities typically have backup generators to drive that pressure in outage situations, but those can be limited in power and duration. Water towers create the necessary water pressure to distribute water for communities, but replenishing that clean water supply requires electricity. At 24 hours, many water towers will exhaust their capacity, leaving homes without clean water and fire hydrants without water pressure. Large residential buildings, as well as dormitories and hotels, will require evacuation due to the lack of water pressure for fire prevention. The loss of gas pressure means lack of space heating and water heating in gas-heat dependent cities, even where buildings have backup generators.

Separately, the food supply chain becomes strained as well, with fresh and frozen food dependent on refrigeration spoiling both in homes and grocery stores, as refrigerators lose their safe, cool temperatures. New food production is halted in any outage region, but this only becomes a serious threat to the supply chain if the impacts are felt on a national scale or transportation is cut off to the outage region.

At 36 hours, fuel shortages begin to create new strains. Between 12 and 36 hours, residents flock to gas stations to refuel their vehicles to ensure they have power to recharge mobile devices or evacuate. Open gas stations are limited to those that have backup generation on site. At 36 hours, those gas stations exhaust their on-site gasoline and diesel fuel, as well as their backup generator fuel supply. Yet, high demand for fuel creates delivery time gaps, and massive fuel lines. Fuel refineries have had to significantly slow production, as backup generators allow them to run at only a fraction of their normal capacity, draining fuel supplies from fuel depots.

On the communications side, cell towers begin to shut down, as backup battery or generator capacity is typically limited to 36 hours. While broadband internet and landline telephones can

persist, powered in a limited capacity with backup generators, devices to connect to them – such as modems, phones, computers, devices, home security systems, and other tech – have no power to operate.

At 48 hours, the fuel shortage starts the next stage of waterfall of impacts. While transportation fuel is not absent, lack of local fuel supplies coupled with high demand and delivery delays from depots start to create an impact on other sectors. Critical facilities with backup generation from diesel fuel struggle to get deliveries and face intermittent outages. Non-critical facilities are deprioritized and cannot gain access to any fuel. If outages are localized, food, fuel, water and other supplies can be delivered from other cities and regions, but if outages are widespread, supply chains struggle to meet demand. Buses and public buildings that were serving as emergency shelters exhaust their fuel supply, leaving vulnerable populations at risk, especially in hot and cold weather scenarios.

At 3-7 days of an outage, more critical life-sustaining necessities are at risk, as communities dependent on water pumping stations are threatened by water shutoffs as pumping stations exhaust their on-site fuel supply and struggle to gain replacement fuel. Broadband internet and datacenter operations face challenges gaining replacement fuel for their backup generators. Datacenters in some regions that have switched to solar+storage backup are able to stay online, but may not have access to the internet as local telecommunications infrastructure begins to shut down. Sewage systems, that can generally hold a significant amount of capacity without power systems, will start to reach capacity, overflow, or backflow into homes. Grocery stores that could shift to alternative payment options – such as cash-only – become empty shells as dry goods now become exhausted, and food restocking is dependent on a food supply chain that faces fuel shortages and production shut-downs.

Multi-day outages like these are not simply inconveniences to be measured in loss of employment activity or damages; they become life-threatening themselves. Millions of people will simultaneously face life without heat, air conditioning, water, and food, with limited ability of public agencies to intervene and support populations due to challenges with supply chains and production limitations. Between 2030-2040, this experience with multi-day outages will start to become normal for the vast majority of residents in the United States.

OUTAGE DURATION

SOCIETAL NEED <1 S <1 Min <1 Hour 4 Hours 12 Hours 24 Hours 36 Hours 48 Hours 3 Days 7 Days

Public Safety

Police	Computer systems offline	Backup generator turns on	Backup generation fuel exhausted	Communications cut off					
Fire				Tower-fed fire hydrants lose water pressure			Pumping Station-fed fire hydrants lose water pressure		
Street Lights	Dark streets								

Health and Human Services

Hospital	Damage to mechanical equipment	Interruption of life support systems	Backup generator turns on	Backup generator exhausts fuel supply, refueling faces delays					
Medical Office	Closure								
Long-term Care Facilities	Interruption of life support systems			Possible evacuation to community shelter			On-site food supply exhausted		

Other Energy

Gas	Gas supply interrupted to power plants		Gas supply interrupted to industry	Gas supply interrupted to homes/businesses					
Petroleum	Refineries pause production			Refineries resume production at reduced capacity to match backup generation					

Water

Water Pumping	Pumping Station backup generators turn on			Water Towers empty capacity			Pumping Station generator fuel exhausted		
Sewage	Wastewater treatment backup generator turns on		Backup generator exhausts fuel supply, wastewater builds in system				Wastewater storage begins to reach capacity, sewage backs up into homes/businesses		

Transportation

Traffic Lights	Traffic lights go out								
Public Transportation (Rail)	Trains paused		Transit shut down and evacuated						
Public Transportation (Bus)				Buses used as emergency shelters			Bus fuel exhausted		
Freight Rail			Freight signal system goes offline, trains pause		Manual signaling and traffic management		Slowdown of regional freight traffic to manageable level		
Highway Operations	Traffic management systems go offline	Toll collection operations cease							
Gas Stations			Gas stations with backup generation stay on		Mobile generators delivered to some gas stations		On-site tank fuel exhausted, refills delayed		Intermittent fuel availability due to high demand, refill delays
Electric Vehicles			Electric Vehicles used for backup energy for devices		Battery exhausted, not ability to recharge				
Aviation	Air Traffic Control emergency, flights hold	Backup generators turn on		Backup generator fuel exhausted, flights re-routed/grounded					

Manageable Impacts
Significant, though often localized impacts, dangerous if overlapping
Major, widespread impacts, dangerous everywhere

OUTAGE DURATION

**SOCIETAL NEED
(CONTINUED)**

<1 S <1 Min <1 Hour 4 Hours 12 Hours 24 Hours 36 Hours 48 Hours 3 Days 7 Days

Telecommunications

Cellular Services							Cell tower backup power fails		
Broadband Internet			Backup Generator turns on					Generator fuel exhausted, refueling supplies limited	
Datacenter	UPS kicks in		Backup Generator turns on					Generator fuel exhausted, refueling supplies limited	

Home

Lights		Dark homes							
Appliances		TVs, computers, small appliances lack power			Refrigerators warm, food spoils				
Heating/Cooling		Air conditioning, heat pumps, furnaces lack power			Homes no longer conditioned				
Computers/Devices		Data lost, desktops unusable			Laptops, tablets, cell phones lose charge				
Hot water			Rapid electric water heaters offline		Water heaters become cool				

Food

Grocery Stores			Payment systems don't work, stores temporarily close		Frozen/refrigerated food spoils, thrown out			High demand for dry goods/fresh produce overwhelm stores with limited supply	Dry good supply runs out, delivery delays limit restocking
Food Delivery								Fuel shortages lead to delivery delays	
Food Production	Production runs scrapped	Daily production scrapped		Production halted					

Commerce

Retail			Payment systems don't work, stores temporarily close		Retail closed, insecure				
Office		Data lost		Employees sent home, productivity halted	Work from home if possible			Likely system-wide outage limits work-from-home	
Banking/Finance	UPS kicks in		Backup Generator turns on		Backup generator exhausts fuel supply, banks close				

Industry

Product Manufacturing	Production runs scrapped	Daily production scrapped		Production halted					
Materials Manufacturing	Production runs scrapped	Daily production scrapped		Production halted					
Chemical Manufacturing	Production runs scrapped	Daily production scrapped		Production halted					
Agriculture				Dairy and processing facilities production halted					

Manageable Impacts
Significant, though often localized impacts, dangerous if overlapping
Major, widespread impacts, dangerous everywhere

OUTAGE DURATION

SOCIETAL NEED
(CONTINUED)

<1 S

<1 Min

<1 Hour

4 Hours

12 Hours

24 Hours

36 Hours

48 Hours

3 Days

7 Days

Education

Elementary &
Secondary Schools

Lights out, technology off	HVAC lacks power, spaces unconditioned	School canceled							
----------------------------	--	-----------------	--	--	--	--	--	--	--

Colleges &
Universities

Lights out, technology off	HVAC lacks power, spaces unconditioned	School canceled				Dorms evacuated due to lack of water pressure/sprinklers			
----------------------------	--	-----------------	--	--	--	--	--	--	--

Tourism

Hotels

Lights out, technology off	HVAC lacks power, spaces unconditioned	Hotels limit occupants				Hotels evacuated due to lack of water pressure/sprinklers			
----------------------------	--	------------------------	--	--	--	---	--	--	--

Entertainment

Lights out, technology off	HVAC lacks power, spaces unconditioned	Event canceled, building evacuated							
----------------------------	--	------------------------------------	--	--	--	--	--	--	--

Casinos

Lights out, technology off	Casino evacuated for security reasons								
----------------------------	---------------------------------------	--	--	--	--	--	--	--	--

Manageable Impacts
Significant, though often localized impacts, dangerous if overlapping
Major, widespread impacts, dangerous everywhere

LONG-TERM : BY 2050

By 2050, the frequency, severity, and duration of outages across the country will begin to grow exponentially. The inability of the reduced electrician workforce to repair, replace, and construct new electrical infrastructure on the grid and in homes and businesses will make outages previously lasting hours now lasting days. As more and more days-long outages emerge, the previous days-long outages begin to overlap and create additional strains on the shrinking workforce. When larger storm-related events occur on the already-fragile electric system, days-long restorations turn into weeks- and months-long outages.

The ability of our country today to rapidly respond to widespread outages depends on a large network of electricians being deployed to areas hit by storms or other contingencies. During Hurricanes Sandy and Florence, thousands of electricians from across the country were dispatched to the east coast from across the country to lend a hand to reduce the duration of the outages and corresponding societal impacts. Without that national assistance network, it would have taken months for utilities, businesses, and homeowners to gain power back.

As outages across the country grow greater in severity and longer in duration, and outages in different regions start to overlap timelines, that sharing and borrowing of an electrician workforce will be unable to support rapid restoration of power. As critical public services, businesses, and residents depend on a shrinking number of electricians for routine maintenance, repair, and replacement of electrical equipment and infrastructure, those electricians will be less able to be deployed for larger impact events.

A business seeking to repair faulty electrical equipment will wait weeks, instead of hours. A utility attempting to replace an aging transformer will delay that work for years, instead of months. As those transformers fail, customers will have to wait weeks, instead of hours for emergency restoration.

This snowball effect on outages will create a new normal for residents, businesses and public officials by 2050. Millions of residents will experience outages of 3 months or longer, and in many locales, permanently, as electricians are prioritized for life-critical facilities and services. This new normal will not be felt all at once, but will be experienced by every region in the country in stages.

Whereas in 2030-2040, communities were experiencing non-weather-related power outages that began to stretch to 3-7 days, by 2050 those outages will begin to rapidly accelerate in duration.

At 14 days, homeowners have rushed to purchase backup generators, gaining all available supply in the region, but still face fuel intermittency due to gasoline and diesel fuel delays and prioritization of critical facilities. While dry goods are able to be restocked at grocery stores, high demand and paranoia create long lines and distribution disparities. Office-based employees must start checking-in with work obligations, but are limited to doing so on mobile devices, which they charge via their vehicle.

On the positive side, at 14 days of an outage, relief support and operations begin to start accommodation. The intermittent fuel delivery starts to normalize, enabling critical facilities to be resume operations in limited capacity. Water treatment and sewage systems begin to be able to manage sewage overflow in spurts of fuel availability. Public transit buses are able to restart both as emergency shelters, as well as in service for a few high-priority transit corridors. Airports are able to gain fuel for limited capacity to allow flights in for emergency operations. Some retail operations re-open with a shift to cash payment with existing stock, but struggle to maintain security. Some product manufacturing re-opens in the region, with a focus on production of necessary goods, but most goods are still imported from other regions. Some hotels are able to purchase and install backup generators, enabling their use as emergency shelters and preferred dwellings for residents unable to gain access to emergency generators at home.

Communities are able to manage this emergency situation for the next two weeks with increasing stress on the population and government actors. At 30 days, telecommunication companies race to install new temporary cell towers connected to facilities with backup generation to replace the failed cell network and restore connectivity. More resourced businesses are able to gain access to backup generators and pursue limited re-openings with employees clustering in few, crowded workspaces for power and connectivity. Banks begin to purchase a limited quantity of backup generators and re-open with limited staff, with customers flocking to banks to withdraw cash to use in the shift to a cash-based economy in the region.

On the industrial side, manufacturing facilities begin to shift production to emergency items, including raw materials for emergency items where possible, with energy-intensive manufacturing operations remaining idle.

By 3 months, the initial re-opening optimism begins to wane, and the compounding effect of multiple regions experiencing overlapping long-term outages begins to minimize any lifelines from outside the region. Public safety issues start to become front and center, as residents desperate for bare necessities seek out resources wherever they can find them, creating unrest and demands on police departments. Abandoned buildings and unsafe space-heating strategies, such as the use of open flames indoors, create a significant increase in fires. The limited ability for communication delays fire response, making fires more severe. Streets go dark as cities are urged to direct any available power generation to emergency shelters and for public use instead of streetlighting.

Backup generation is procured and installed at some hospitals and medical centers, enabling non-emergency procedures and medical visits to resume at a far limited capacity, as patients cannot access doctors' and dentists' offices. Additional fuel storage is installed at water pumping and water treatment facilities to address fuel delivery intermittency. Well-resourced businesses and datacenters pay a premium for limited backup generators on the market, with lead times reaching weeks and months for larger systems.

With vehicles as the power lifeline for cell phone, battery charging, and mobile devices, gas stations become the community destination, as the sole source of fuel for residents and businesses, with electricity access still near-zero and gas-powered appliances lacking electricity to turn on. On the commercial side, with retail stores still primarily shuttered, product delivery sources completely dominate the retail space. The run on banks creates a liquidity crisis, leading the federal government to limit cash withdrawals from banks.

Pressure builds to re-open schools in temperate environments in seasons when HVAC is not required, but at colleges & universities, students abandon campuses as dormitories and students housing remain closed and distance learning is infeasible due to connectivity issues experienced by both students and professors.

During this time period, the entirety of the electrician workforce is being deployed to install new generators and assist in the repair of outages and electrical equipment. No new building construction is taking place, and buildings become abandoned as essential repairs are unable to be addressed.

OUTAGE DURATION - WIDESPREAD OUTAGES THROUGHOUT THE COUNTRY

SOCIETAL NEED	7 Days	14 Days	30 Days	3 Months	1 Year	Permanent Adaptation
Public Safety						
Police	Police charge radios in cars, communications prioritized			Looting and unrest create increased demand on police departments		
Fire	Supplemental water storage tanks accompany trucks to fires			Abandoned buildings and ad-hoc heating attempts produce increase in fires. Limited communication makes fires more severe.		Fire departments forced to purchase water storage trucks
Street Lights	Will intermittently work when power is available			Cities urged to direct available electricity to emergency shelters, public access instead of streetlights		People will adapt to life without streetlights, no repairs performed
Health and Human Services						
Hospital	On-site backup generation, limited to emergencies			Backup generation is procured and installed at some medical centers, enabling non-emergency procedures/visits to resume at far limited capacity		Most hospitals/medical centers have permanent backup generation installed and are prioritized for fuel delivery
Medical Office	Remain closed			Patients shift to hospitals/medical centers with power		
Long-term Care Facilities	Remain closed			Limited facilities able to purchase generators and re-open		More facilities able to purchase generators and re-open vulnerable populations move back in Significant increase in long-term care facilities as vulnerable populations unable to maintain residential backup generation
Other Energy						
Gas				Gas utilities install on-site gas-power generation along pipelines and local distribution to re-establish pressure		
Petroleum				Refineries continue to operate at reduced capacity to match on-site backup generation		
Water						
Water Pumping				Additional fuel storage established to address fuel delivery intermittency for backup generators		
Sewage		Intermittent fuel delivery enables sewage facilities to manage overflow capacity in spurts		Additional fuel storage established to address fuel delivery intermittency for backup generators		
Transportation						
Traffic Lights				Intersection management replaced with 4-way stops instead of traffic management personnel		
Public Transportation (Rail)	Remain closed					
Public Transportation (Bus)		Routes reduced due to reduced fuel availability, priority corridors only		Increased dependence on public transit, as fuel for personal vehicles remains scarce and expensive		
Freight Rail	Slowdown due to manual switching					
Highway Operations	Toll operations remain closed					

Manageable Impacts
Significant, though often localized impacts, dangerous if overlapping
Major, widespread impacts, dangerous everywhere

OUTAGE DURATION - WIDESPREAD OUTAGES THROUGHOUT THE COUNTRY

SOCIETAL NEED (CONTINUED)

7 Days

14 Days

30 Days

3 Months

1 Year

Permanent Adaptation

Gas Stations	Continued intermittent fuel availability		More gas stations get backup generators installed to re-open	Gas stations become primary source of energy for homes/businesses		
Electric Vehicles	Nonfunctional		Limited "recharge" stations open connected to backup generators			
Aviation		Limited backup generation capacity and fuel intermittency allows only emergency operations		Additional backup generator capacity installed to enable limited goods delivery		Air transportation significantly limited, airports scale back operations to existing backup generator capacity
Telecommunications						
Cellular Service			Limited cell service re-established connected to facilities with backup generation		Larger cell towers installed to provide connectivity over larger radius while connected to limited sites	
Broadband Internet	Available at limited capacity				Most wired broadband internet/cable mothballed, infrastructure dedicated to wireless network	
Datacenter				Additional backup generator capacity installed to enable limited operation	New wireless data highways developed for most essential datacenters, others mothballed	
Home						
Lights	Small number of homes purchase limited quantity of backup generators, face fuel intermittency			Some homes shift to rechargeable lamps/flashlights	Most homes shift to combination of rechargeable lamps/flashlights and kerosene lamps	
Appliances	Small number of homes purchase limited quantity of backup generators, face fuel intermittency				Most home shift to combination of kerosene stoves, grills for cooking	No refrigeration for fresh foods
Heating/Cooling	Small number of homes purchase limited quantity of backup generators, face fuel intermittency			Some homes with generators able to use gas for heat.	Most homes turn to wood, oil, or propane-fueled fires for space heating	
Computer/Devices	Small number of homes purchase limited quantity of backup generators, face fuel intermittency			Residents become fully dependent on vehicles for device charging	Some businesses able to support charging of battery-powered laptops for occasional use	Desktop computers are useless outside necessary, powered settings. Productivity/connectivity shifts completely to mobile devices.
Hot Water	No hot water			Some homes with generators able to use gas for heat.	Most homes turn to wood, oil, or propane-fueled fires for water heating	
Food						
Grocery Stores		Dry goods restocking remains intermittent, with high demand at stores		With refrigeration absent, locally-grown produce is available based on season	Some regional grocery stores purchase and install backup generation to support fresh/frozen food	Limited availability of fresh/frozen food storage, shift to same-day consumption
Food Delivery				Food delivery continues to be strained, food varieties become minimal		Delivery mostly continues in limited capacity and with limited options, with some fresh/frozen food
Food Production				As outages are more widespread and overlap, many food production plants go offline, limiting food options		Dry goods food production survives, national meat, dairy, and produce processing shuts down and shifts to local where available

Manageable Impacts
Significant, though often localized impacts, dangerous if overlapping
Major, widespread impacts, dangerous everywhere

OUTAGE DURATION - WIDESPREAD OUTAGES THROUGHOUT THE COUNTRY

**SOCIETAL NEED
(CONTINUED)**

7 Days

14 Days

30 Days

3 Months

1 Year

**Permanent
Adaptation**

Commerce

Retail		Some stores re-open with limited cash payment options		Delivery dominates as retail stores remain without power		Little to no retail stores remain open
Office		Employees shift to working mostly via mobile devices, charging via automobile	Some offices purchase limited quantity of backup generators, employees crowd workspaces for connectivity	More offices purchase backup generators, intermittent fuel availability		Limited office spaces remain open where backup power can be maintained, crowded with workers/tech
Banking/Finance			Banks purchase limited quantity of backup generators, re-open with limited staff. Customers flock to banks to withdraw cash.	Federal Government limits cash withdrawals from banks, fears of liquidity crisis		Financial sectors lose prominence as cash-based economy has resurgence

Industry

Product Manufacturing		Limited manufacturing re-opens, with focus on necessary goods	Most manufacturing facilities shift production to emergency items			
Materials Manufacturing			Energy intensive materials manufacturing remains idle, limited to raw materials for emergency items			
Chemical Manufacturing			Energy intensive materials manufacturing remains idle, limited to raw materials for emergency items			
Agriculture			Supply chain challenges limit agricultural demand at wholesale level	Non-food agricultural product fills storage, remaining product wasted	Farms shift to local markets, dry goods production, as national/global markets are unreachable	Farms shift crop production to more nutrient-rich food items, away from corn and soybean products

Education

Elementary & Secondary Schools			Schools remain closed	Schools able to open in limited capacity in temperate environments	Schools implement alternative heating options to enable winter sessions	Some districts shift schedules to be in session during non-extreme weather months
Colleges & Universities				Schools able to open in limited capacity in temperate environments. Most students leave school, request reimbursement.	Colleges & Universities attempt to re-open without dormitories	

Tourism

Hotels		Limited hotels reopen with backup generation as emergency shelters				
Entertainment	Closed					
Casinos	Closed					

Manageable Impacts
Significant, though often localized impacts, dangerous if overlapping
Major, widespread impacts, dangerous everywhere

OUTAGES AS THE NEW NORMAL

Eventually, as widespread, long-term outages become the new normal in the country, people and businesses begin to adapt and seek alternative structures for survival. Regions that have experienced successive outages are more likely to experience significant out-migration to regions that have seen less impacts. More rural communities that are typically the last communities to see power restoration and food and goods delivery, will lose population to more suburban and urban centers that have greater access to services.

Big cities and commercial centers faced with successive long-duration outages will lose commercial tenants in high-rises and other power-vulnerable buildings. Cities with transportation hubs and more reliable power will continue to support manufacturing, whereas rural or remote industrial facilities will struggle to maintain operations. Traditional vehicle, electronics and appliance manufacturing facilities will be in high demand due to their ability to shift to the production of small-scale power generators.

Families, struggling to maintain power for heating and air conditioning in scattered communities, will gather in reduced locales where outages have been less severe, abandoning homes and consolidating extended family households. Southern and coastal communities will likely see an influx of residents pursuing more temperate climates in the Winter, though reverse migration could happen in the Summer as outages start to spread around the air conditioner-dependent South and Southwest.

This clustering effect will gradually leave more and more regions without power and in disrepair. The limited electrician workforce will shift largely to the clustered regions to support the installation of backup generators, to support their families, and to help maintain electric infrastructure that has not been abandoned.

Across the country, the shift to a permanent expectation of unreliable power forces investment and behavioral changes. In the public sector, without being able to depend on fire hydrant water pressure, fire departments shift to hauling increased water storage with them to fight fires. Communities will grow accustomed to life without streetlights, though some may improvise with a return to gas lamps. Oddly, the invention that first sparked the electrification revolution in 1879 in Menlo Park, New Jersey – streetlights – will now be seen as the least essential public good served by limited electricity capacity.

The clustering continues in the healthcare sector, as vulnerable seniors and people with disabilities are forced into long-term care facilities that have now had time to install backup generation, and where steady power and space heating and cooling can be assured with greater confidence than their own homes.

Gas stations are still the primary source of energy, but new car manufacturing confronts capacity limitations from reduced power certainty and a lack of electricians. Residents seek public transit once again as vehicles fall into disrepair and parts cannot be manufactured for replacement.

Cell phone companies are unable to ensure power to a distributed network of towers and shift instead to locating larger cell towers connected to limited site with power, and providing connectivity over a larger radius. Most wired broadband infrastructure is unusable without power to switches and data connections, with remaining limited infrastructure with backup generation focused on preserving the wireless network. This brings an end to wired cable television and internet as well, but nobody misses it as televisions sets dependent on electricity are unusable. Datacenters processing high-value information largely shift to wireless high-capacity transfers as well, creating point-to-point wireless data express lanes through a much smaller internet infrastructure.

Grocery stores by this point have mostly adapted to the lack of refrigeration and freezer capacity and offer limited (if any) fresh and frozen food items. When available, fresh and frozen items are often limited to same day consumption as residents lack their own refrigeration capacity at home. On a national scale, dry goods food production survives, as its supply chain can survive given the less-perishable nature of the goods. However, national meat, dairy and produce processing shuts down, as there is limited reliability that food stock would survive through to the customer. Local sources of meat, dairy and produce survive, however, though becomes more traditionally seasonal. The traditional retail store becomes a relic of history at this point, with no supply chain capacity, sale processing, or security able to be served reliably, and delivery continues to be the dominant shopping vehicle.

At home, life looks more like it did in the 1840s than the 2040s. Kitchen and work tools shift back to manual, and residents take to kerosene stoves and grills for cooking. Solar-rechargeable lamps that gained prominence in disaster relief and kerosene lamps brighten then night. And most homes turn to wood, oil, or propane-fueled open fires for warmth.

The traditional office disappears as well, with only a limited number of spaces able to access and maintain power, and in which workers crowd to do their work, charge their devices, and conduct face-to-face discussions. Financial sectors lose their prominence as the cash-based economy has a resurgence.

Schools begin to shift their schedules as well, with those not able to implement sufficient alternative heating and cooling options moving to be in session during non-extreme weather months for their climate. While colleges and universities, desperate to regain tuition, attempt to re-open without technology and without dormitories.

These impacts are severe, and widespread, and will likely lead to large-scale readjustment of the expectation residents of the U.S. have developed over easy and inexpensive access to energy.

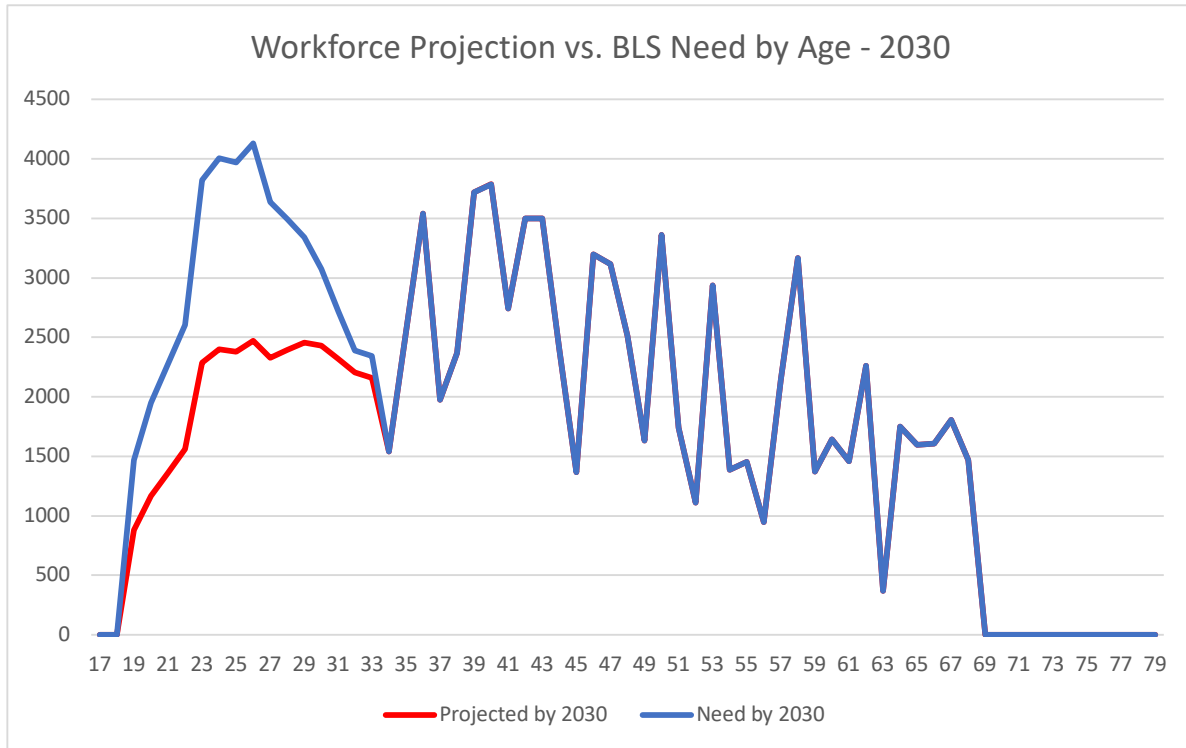
SECTION VI:

CONCLUSION

Without near-term action to recruit, train, and employ hundreds of thousands of new electricians and line workers over the next 10 years, it will be impossible for the country to achieve even the mid-range needs for clean energy growth. Further, the shrinking and aging population of electrical workers threatens to destabilize the country's electrical system, as we become unable to keep up with simple repair and maintenance of electrical equipment and the electric grid. Building-specific and region-wide outages take longer to repair, and they become more frequent as concurrent outages prevent the sharing of electrical workers across the country as we have seen in recent years in response to natural disasters.

To meet the needs of the BLS-projected 10% growth scenario, the country will have to train an additional 107,000 electricians over the next decade, creating a workforce picture as depicted in Chart 6.1.

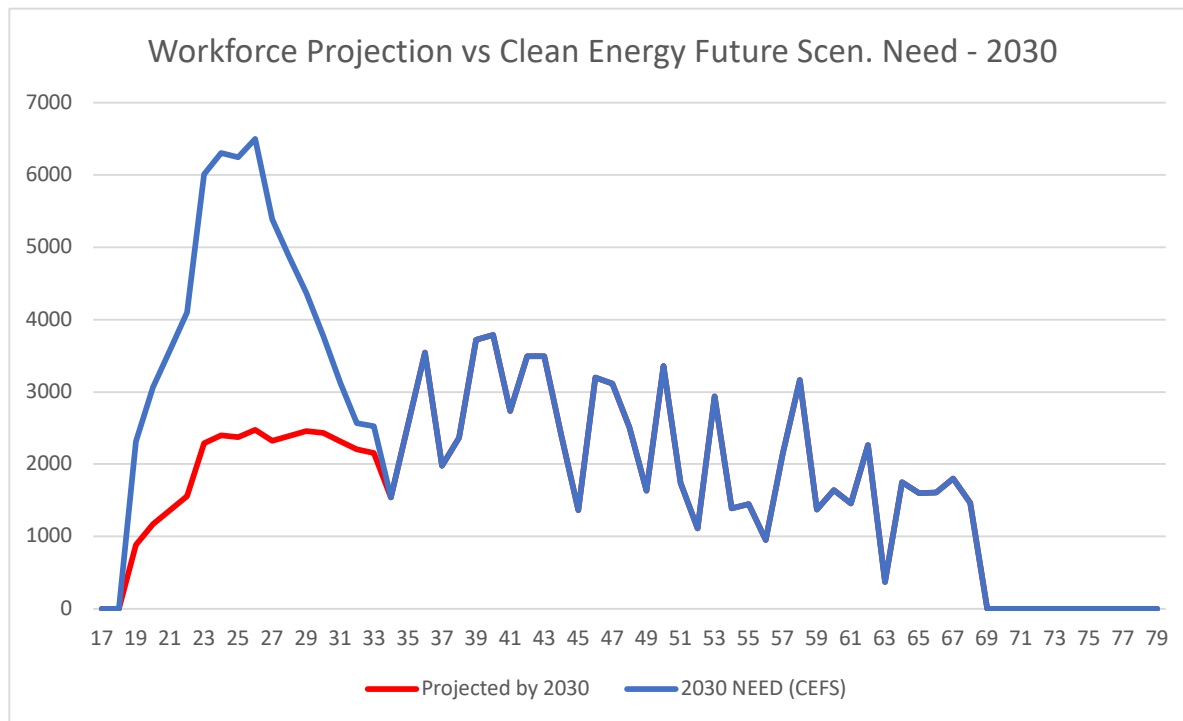
CHART 6.1



Source: The Accelerate Group projection

To meet the needs of the Clean Energy Future Workforce Scenario as described in Section III, the country will have to train an additional 252,000 electricians over the next decade, creating a workforce demographic as depicted in Chart 6.2.

CHART 6.2



Source: The Accelerate Group projection



THE ACCELERATE GROUP | LLC