The Future of the United States Power Grid: The Impact on Nuclear with Increased Renewables and Gas

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Abstract

In recent years there has been a push for clean energy within the United States, and internationally, to combat climate change by lowering emissions. Many efforts include pressing the electricity generation industry to use more renewable energy, such as wind, hydro, and solar, increasing natural gas power plant production, and moving away from coal power plants. While nuclear power is not a renewable energy, it has a high reliability rate with no direct emissions. Even with its benefits, it has not been thought of fondly by the public during the drive towards clean energy. Although nuclear power provides a solid base power for the electric grid, and has benefits over coal and gas regarding emissions levels, it is expensive to run and maintain. Additionally, stigmas against nuclear power have come around since accidents like Fukushima Daiichi, Chernobyl, and Three Mile Island. Given these issues, the nuclear sector, outside of countries like China, has seen more decommissioning than start-ups over the last few decades. Given the trend on decommissioning nuclear, the slow timeline or no timeline on building new nuclear reactors, and the push for more renewable energy, this report will focus on what the future power grid could look like within the United States compared to where it has been, where it currently is, and what the utilities and policies are pushing for.

Sustainability and the Power Grid

The electric power sector has regulated and unregulated markets that vary per state. Some states have regulated markets where generation, transmission, and distribution are provided by a single utility. Other states, have unbundled generation, transmission, and distribution to allow a competitive wholesale and retail power market participate. No single system or market can dominate another. There are a few participates in the power grid: public, private, cooperative utility, and independent power producers. They are connected over three regional synchronized power grids: Western Interconnection, Eastern Interconnection, and Electricity Reliability Council of Texas Interconnection. The interconnected systems move electricity around the lower 48 contiguous states. These systems operate independently with some limited electrical interconnection points. The Eastern Interconnection, specifically, is the largest grid in the US and covers 29 states, DC, and parts of Canada. It also serves 70% of the US population. Electrical transmission system operates can either be Independent System Operators (ISO) or Regional Transmission Operators (RTO). ISO's can operate a single state or multiple states and operates the regions electricity grid. It also administers the region's wholesale electricity markets and provides reliability planning for the region's bulk electricity system. An RTO covers wide areas crossing state lines. They perform the same functions as ISO but have greater responsibility for transmission networks as established by the Federal Energy Regulatory Commission (FERC). RTO's coordinate, control, and monitor the operation of the electric power system within their territories and monitor the operation of the region's transmission network by providing fair transmission access. ISO's and RTO's engage in regional planning to ensure the needs of the system are met with appropriate infrastructure.

Sustainability includes efforts to protect the natural environment, human, and ecological health while driving innovation and without compromising the way of life. It can also be described as including the study of how natural systems function, remain diverse, and produce everything it needs to ecologically remain in balance. There are three pillars of sustainability: economic development, social development, and environmental protection. A sustainable future will require technology towards the improvement of older and cleaner fuel sources as we move into a post-fossil fuel world. Sustainable development requires smart grid technologies, sustainable energy resources, and low carbon emissions in generation systems. It is the main motivator towards the increased interests and implementations of renewable energy and nuclear reactors around the world as we try to prevent further climate change and protect the environment for the future.

Smart grid technologies are identified as self-sufficient systems that can find solutions to problems quickly in any available system which reduces required workforce and targets sustainable, reliable, safe, and quality electricity to all consumers. It is a key element to an efficient use of distributed energy resources that connects electricity networks with intelligently integrated generators and consumers. Difficulties in its implementations include the use of intermittent power and current low utilization efficiency in power systems. However, these technologies will: improve intermittent renewable generation, increase grid-connected clean energy, promote energy saving within the power system, and improve the utilization efficiency of power systems and power consuming. For renewable systems with regards to the smart grid there is potential to have active and reactive power flow control, advanced fault management techniques to improve stability in generating units and access to virtual plant control for integrated renewables, controlled load and energy storage systems on the grid. These technologies can also promote energy saving through the utilization efficiency and optimized scheduling, reduced line loss, improved utilization efficiency by demand response and improve power consumption efficiency by informing the users. A few barriers of the smart grid include justifying the expenditure to consumers and service providers, regulatory constraints, and technology standards.

Accidents in Nuclear

With three major events putting a negative emphasis on nuclear energy, there is a push to show how safe nuclear is today and how these were unpredictable events, rather than events that can occur at any time in any plant. While a number of safety features and regulations for nuclear plants have come from these events, it is difficult to show the public how safe a nuclear plant is. Reviewing the "big three", what their outcomes were, and where we are today, provides a good starting point to why the US has become fearful with building new nuclear, continuing current plant operations, and research for advanced nuclear systems.

Three Mile Island

Located in Pennsylvania, Three Mile Island is a nuclear plant that had two operating pressurized water reactors. After starting service in 1974, and 1978, the two units produced power for a few years before a partial meltdown of Unit 2 occurred in March of 1979.

The plant operators were notified of a failure around 4 AM on March 28, 1979, within the secondary side of the plant regarding one of the main feedwater pumps. The alarm showed that the feedwater pump was unable to send water through to the steam generators that are responsible for removing heat from the reactor core. The plant went into a safe shutdown of the turbine-generator and reactor 2 automatically. To relieve pressure backed up in the primary system, a pilot-operated relief valve at the top of the pressurizer was opened successfully. However, once the pressure dropped back down to a sustainable level, the valve did not auto-close as it should have, even though the control room showed that it was closed. With unaware plant operators, cooling water was pouring from the valve started a loss-of-coolant accident (LOCA) within the reactor. Other instruments provided plant operators misleading or inadequate information showing that the core was covered with water like normal. Further actions by the operators to stabilize the primary system caused the reactor core to become uncovered and ultimately overheat and partially melt. The reactor was stabilized 5 days after the start of the event

Following the accident, the Nuclear Regulatory Commission (NRC), Environmental Protection Agency (EPA), the Department of Health, Education and Welfare, the Department of Energy (DOE), and the Commonwealth of Pennsylvania studied the accident's radiological consequences. Those who were around the accident were estimated to have received average radiation of about 1 millirem, less exposure than a common X-ray scan. While investigating possible adverse effects to humans, wildlife, and the surrounding environment of the plant, none were found to be directly a result of the accident. While low levels of radionuclides in the area can be linked to the accident, it has been concluded that there was not enough radiation leakage to affect the physical health of those near the plant.

Due to the plant's failure, public fear of nuclear and skepticism for NRC regulations increased. While the plant design prevented the meltdown from being entirely catastrophic, the accident was a result of personnel decision errors, design flaws, and component failures and caused the NRC to change and increase their regulations of current and new build plants. With new regulations, nuclear has become inherently safer and further reduced its risk to the public if an accident were to occur and to prevent similar accidents.

Since the accident, reactor 2 has been permanently shut down at the Three Mile Island plant while reactor 1 produced electricity until September of 2019. The coolant system of unit 2 was drained and 99% of the fuel has been removed from the reactor. Radioactive waste from the accident has been stored off site with core debris and fuel being sent to the Idaho National Lab for testing and storage. Both Three Mile Island units will be fully decommissioned together in the coming years as unit 2 has been in monitoring mode with permanent shut down since the accident.

Chernobyl

Chernobyl Nuclear was a power generation plant in Ukraine that operated four RBMK, graphite-moderated, reactors. Unit 1 and 2 were completed in 1977 while Units 3 and 4 were completed in 1983. In 1986 the plant had an accident when undertrained personnel operating the plant during an experiment came across a reactor design flaw. Many of the issues that lead to the accident can be summed up due to a lack of safety awareness within the nuclear community of the Ukraine as a whole.

During routine maintenance on unit 4 in April 1986, an experiment was conducted to determine if the turbine could operate the core cooling water circulating pumps until diesel generators were operating during a loss of plant power. The test was a repeat of a pervious experiment performed where the plant found that the turbine was not able sufficiently continue power until the generators were on. While this experiment was for the secondary side of the plant, information was not properly distributed to the primary side of the plant that was in charge of the reactor and therefore safety precautions were not met to their full requirements.

With the reactor at half power during the shutdown, the electrical grid dispatcher alerted the plant to stop shutdown so that the grid could operate. Additionally, the test required shutting down the emergency core cooling system which was completed while the reactor was at half power. It is noted that while this did not directly affect other events that occurred, it was a primary point of showing the lack of safety considerations within the plant. Just before midnight the grid controller agreed to reducing the power of the reactor. During this power reduction, just after midnight, the power fell to 30 MW due to an operational error causing the operators to quickly increase the power back to 200 MW by manually withdrawing control rods from the core. This activity resulted in the operators removing almost all of the control rods from the reactor and placed it in an unstable state requiring adjustments every few seconds to maintain power. Although the test was meant to be conducted between 700-1000 MWt, the team decided to complete the test at the now seemingly stable 200 MW which included closing the turbine stop valves to power the cooling water pumps. At some point, the feedwater had become warmer than normal and paired with the slow turbine speed, and therefore low flowrate, the reactor starting boiling casing voids at the bottom of the core.

With other things that had occurred within the plant, including a xenon burnout, the voids caused a power spike within the core. As power exceeded 530 MWt, fuel ruptured within the core and the system filled with steam increasing the power further. With fuel ruptures on several fuel channels, the pressure within the reactor exceeded the design limits and detached the support plate. This act additionally prevented more control rods from entering the system to assist in power reduction as they were under the reactor. Along with a steam explosion, a second explosion occurred shortly after due to a hydrogen build-up ejecting fuel and other materials from the reactor. The remaining 3 reactors were shut down shortly after the explosions.

Direct casualty results during the event include two workers who were near the explosions. While debris, smoke, and radioactive products were ejected into the surrounding areas, including radioactivity spread hundreds of thousands of square miles, fires started within the unit 4 building and the turbine hall. The initial fire responders received the highest radiation exposures as they attempted to control the fire that had now spread to unit 3's machine hall room. By the end of July 1986 it was estimated that 6 firemen and 22 plant staff died due to acute radiation poisoning from the accident. Chernobyl is noted as the worst nuclear accident in the world. Being heavily blamed for a lack of safety considerations and poor reactor and containment design, Chernobyl is registered as a level 7 event on the International Nuclear Events Scale.

After the event, eastern Europe adjusted their reactor safety regulations and designs. Lessons learned from the event regarding Soviet-designed reactors have impacted both eastern and western reactor designs, though western designs, like Three Mile Island, were already heavily rooted in the safety of the plant. Collaboration around the culture of nuclear safety has also increased substantially after this event and Soviet-designed reactors have increased their standards.

Operating RBMK reactors have been modified to overcome the initially designed deficiencies regarding how the reactors can increase power. These modifications include changes in the control rods, adding neutron absorbers and increasing fuel enrichment. All modifications have created a more stable reactor at low power operation. Additionally, automatic nut-down mechanisms operator faster, other safeties have been improved and inspection equipment has been automated. It is noted, by a German nuclear safety report (Reaktorsicherheit, 1996), that a repeat event of the Chernobyl accident is virtually impossible with the new standards.

Fukushima Daiichi

Fukushima Daiichi Power Plant, located in Japan, was a six unit, BWR, nuclear plant. Its first reactor began operating in 1971, with the last reactor being fully operational in 1979. In 2013, the final two units were shut down while the other four units were shut down in 2011 due to a tsunami causing a major accident.

On March 11, 2011, a 9.0 magnitude earthquake struck Japan causing all 11 reactors within the area to shut down automatically as a safety precaution. These reactors were located across four sites: Tokyo Electric Power Company, Fukushima Daiichi, Fukushima Daini, Tohoku's Onagawa, and Japco's Tokai. While inspections after the events showed the reactors survived the earthquake with minimal damages, the 15-meter tsunami that followed caused major damage to the Fukushima Daiichi plant.

The Daiichi plant's tsunami walls were rated for protection against 5.7-meter tsunamis, as this was the acceptable height to protect the plant due to average tsunami heights in the area at the time of the plant design in the 1960's. According to some reports in the 1990's, the tsunami walls should have been upgraded to protect against 15.7-meter tsunami due to increased knowledge of the area and the timing of large tsunami's within the past century.

Once the tsunami came over the protective walls, three of the six reactors lost back-up power due to 12 of the 13 back-up generators onsite becoming immobilized and causing a station blackout. The tsunami additionally discharged the reactor waste from the heat exchangers into the water returning to sea. Without backup power and heat exchangers, units 1-3 could not maintain proper reactor cooling, water circulation, or use the electrical switchgear that controls the plant. Without proper cooling, the reactors started losing water through the steam that was created and the cores became uncovered. As steam built up in the containment vessels it was vented through safety valves into the reactor buildings. After being uncovered, the reactor cores began to melt, and the fuel cladding released hydrogen into the venting system. This eventually caused hydrogen explosions within units 1, 3, and 4 damaging the reactor buildings and containment. Units 1-3 had core meltdowns with unit 1 having the most significant damage, including fuel falling to the bottom of the reactor pressure vessel, and units 2 and 3 only partially melting. A sequence of events after the earthquake for units 1-3 can be found in Appendix 1 from (World Nuclear Association, 2020). During these reactor-based incidents, the spent fuel pools were exposed to various levels of heat and damages and were thought to have boiled. However, all spent fuel remained submerged and protected though there was a concern over structural damage to the pools.

After the event, efforts were put towards removing heat from the reactors and dealing with the overheated spent fuel pools. High levels of radiation were reported on site for days after the explosions and evacuations were put in place for 20 km around the plant. Along with the surrounding area receiving radiation, contaminated water was discharged into the Pacific Ocean as an effort to cool and stabilize the reactors. While many lives were taken from the earthquake and tsunami that hit Japan, there were no fatalities reported as a direct result of the nuclear accident that followed the tsunami.

Units 5 and 6 at the plant survived on the one diesel generator that remained after the tsunami until repairs could begin on March 19th, 2011 to restore cooling. The reactors had main power restored by March 22nd, 2011. In 2013, reactor 6 had the fuel removed and the reactors were set up for decommissioning within 2014. It is planned that these reactors will be replaced with two coal burning power plants near the Fukushima Daiichi plant that will include a combined gasification cycle to reduce air pollution.

Current State of Power Generation

US Electricity Generation

Electricity within the United States is generated with a diverse set of energy sources and technologies that have changed over time and range depending on where they are located. The three major categories of electricity generation include fossil fuels like coal, natural gas, and petroleum, nuclear and renewables. Options to turn resources into electricity other than the steam turbine, used by fossil fuels, nuclear, biomass, geothermal, and solar thermal, include gas turbines, hydro turbines, wind turbines, and solar photovoltaics. Additionally, there are two types of generating capacity. The first being utility scale capacity which includes generation and capacity units at power plants with at least 1 MW of total electricity generating capacity. Then, there are small scale generation which are generators with less than 1 MW of generating capacity that are usually at or near consumption. Examples of small-scale capacity includes solar PV systems on rooftops.

In 2019, the United States used approximately 4.1 trillion kWh from utility scale generators and 35 billion kWh from small scale solar PV. Fossil fuels was the largest source of utility electricity generation. In 2019, natural gas made up 38% of all generation, coal was shortly behind at 23% while petroleum made up 1%. The nuclear industry made up 20% of the US generation in 2019 with renewables taking over the remaining 17%. Of the renewables used, the breakdown of total generation was the following: 7% hydroelectric, 7% wind, 1% biomass, 2% solar, 0.5% geothermal.

In order to supply electricity as it is needed, there are different levels of generating units as well. The base load generating station will supply all or part of the minimum or base demand on the grid. These units are ran continuously through most of the day and are normally sources like nuclear, geothermal, and large hydro facility or coal/natural gas plants. Peak load generating units help meet demand over the base load during peak hours like late afternoon when AC or heat increases with the seasons. Peak units are normally turned on and off quickly and consist of natural gas/petroleum generators or pumped storage hydropower. They are not normally efficient and are costly to operate though they provide a high value service during peak demand. Moving forward, we will discuss how different resources are currently performing within the United States and some impactful global markets.

Current Nuclear

Globally, China is known to be the leader in construction of new reactors. With the first Gen 3 reactors from Framatome-Seimens and the AP1000 from Westinghouse, China has actively kept their nuclear fleet growing to create clean energy for their citizens.

On the opposite side, utilities in Japan have been wanting to restart their operational reactors but have faced significant challenges with the public and regulator standards after the Fukushima

Daiichi accident and have been unable to even use majority of their current fleet. After the accident, Japan’s government released new regulations that are costly for the plants to implement but even after being implemented, the public has filed injunctions preventing plants from coming back online. Japan has 28 reactors in long term outage and only nine reactors have been restarted since 2014. An additional seven reactors have been upgraded to the new standards and three reactors are under construction. However, 24 reactors have been planned for decommissioning, including the six at Fukushima Daiichi. A synopsis of the locations of reactors in Japan, and their current status and size can be found in Figure 1 from (Nippon, 2020). Even with the struggles nuclear is facing in Japan, the government’s goal is to have at least 20% of the energy generation come from nuclear by 2030.

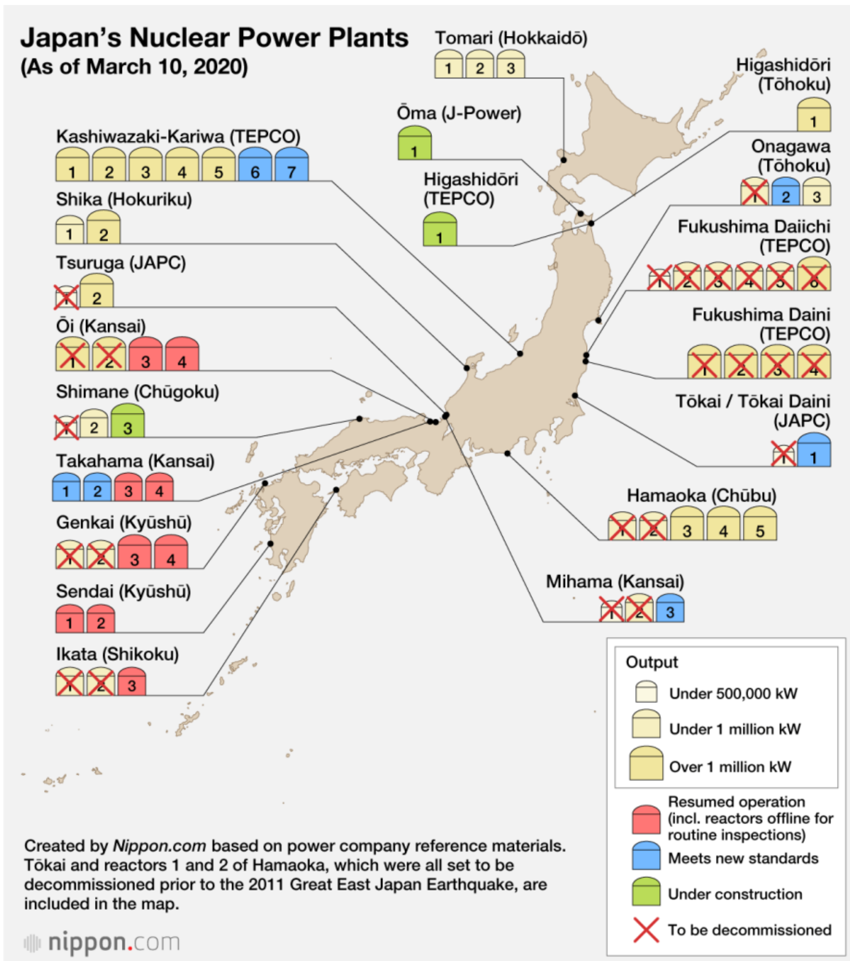

Figure 1 Current Status of Japan's Nuclear Reactors

As for the United Kingdom, where they receive 20% of their generation from nuclear, there is a history of overspending on their new reactor builds. Additionally, about half of their current capacity is planned to retire by 2025. A new build was approved and started in 2018, Hinkely Point, that was planned for two new rectors. However, they had reportedly, (Haas, Mez, & Ajanovic, 2019), spent 3B Euro’s before starting construction and are currently at approximately 21.5B Euros invested and the reactors have not reached operational status yet. They expect the new reactors at Hinkley Point to be fully operational in 2025 and 2026. Additional builds that have been announced within the UK include: Sizewell C which will include two EPR units; Moorside which will potentially contain an EPR power station, small modular reactors and advanced modular reactors including three AP1000's; Wylfa Newydd and Oldbury to hopefully contain up to four AP1000 reactors or three EPR units; Bradwell B to replace the two units that were shut down in 2002 with two Hualong One units; and Sellafield that are planned to have two PRISM units and 2 Candu EC6 units.

Like Europe, overspending on construction is also a common issue with the United States, though they have not had many new builds start over the last 30 years. The United States is also facing man closures before licenses expire due to being unable to compete with the current energy market, politics, and renewable energy movements. The nuclear sector has moved to relying on state efforts and subsidizing schemes to avoid early closures of uneconomic reactors.

Currently, the United States has 95 operating nuclear reactors production 809.4 TWh of electricity annually generating approximately 20% of their required electricity needs. A map of the reactors, and their net summer capacity can be found in Figure 2. A list of all operational plants, their operator, and the type of reactor can be found in Appendix 3.

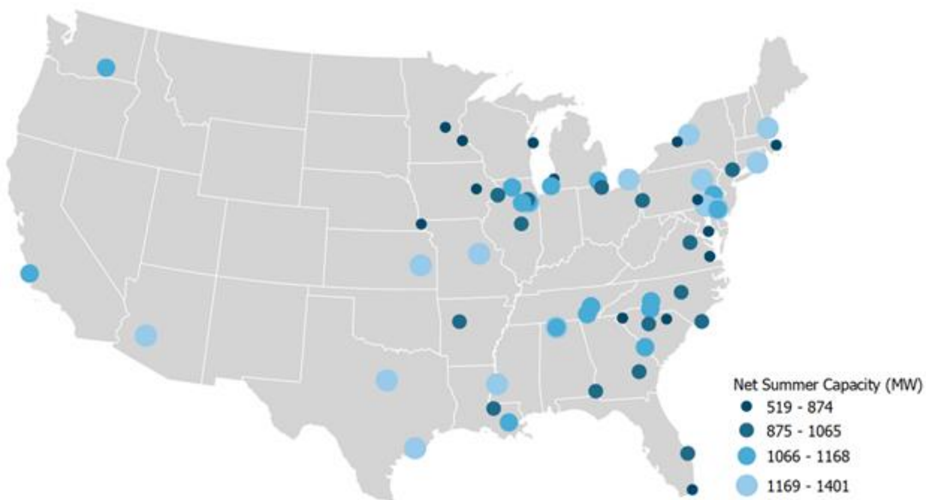

Figure 2 Nuclear Reactors Around the United States

A large reason why new nuclear is not being built in the United States is due to the expansive costs that are assigned to just the construction of the plant and additionally overhead costs once it is built that are expected to be covered by the private industry in full. A recent expansion build, VC Summer, was shut down due to bankruptcy of the company during the build due to overspending and underestimation of true costs. However, a current expansion build, Vogtle, is close to becoming operational and is leading the United State's industry as the only recent successful new build in the last 30 years. Many new builds and expansion projects have been approved within the United States by their regulating body, but have not began construction. It is anticipated that if the Vogtle expansion is completed successfully, it will set the new standards and begin a new generation of builds across the United States.

Overall, new builds in nuclear are not competitive under normal market economy rules. The economic constraints also press the owners of current operating plants to close earlier than necessary as different, cheaper, generation types are available. The largest barrier in the nuclear industry today is the development cost of a reactor and operational costs vs efficiency. Further discussion on this point will be covered in the economics section.

Some federal regulatory agencies that regulate the nuclear safety and security within the United States include the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), the National Nuclear Security Administration, the Energy Information Administration (EIA), and the Nuclear American Electric Reliability Corporation. The NRC regulates the national civilian use of by-product, source, and special nuclear materials to keep the adequate protection of public health and safety as well as promote the common defense, security, and environment. The NRC is also responsible for commercial reactors and non-power reactors, uranium enrichment facilities and nuclear fuel fabrication facilities, the uses of nuclear materials in medical, industrial, or academic settings, and the transportation and disposal of nuclear materials and waste. The DOE serves as a secondary role for supporting the nuclear power industry through promoting civil nuclear technology through research, development, and demonstration. The National Nuclear Security Administration maintains and enhances nuclear safety and security and responds to nuclear and radiological emergencies in the US and abroad. The EIA provides statistical data and analysis for nuclear and uranium products and uses. Finally, the Nuclear American Electric Reliability Corporation works as a non-profit regulatory authority to address the reliability of the US electrical system.

Current Coal

Coal has started to operate less often, earn less revenue, and mostly shut down throughout the US. With their decreasing profitability, and increased pressure for less air emissions, utilities are less inclined to invest in new coal capacity or advance the current production rather than replace it.

Current Gas

The changes in the US electricity market have increased the natural gas use over coal and even some nuclear areas. A few reasons for these changes include a decline in natural gas prices, state requirements for cleaner energy, financial incentives from the government, air pollution regulations, and a slowing demand acceleration. When gas prices are low, and systems have a high efficiency, natural gas-fired combined cycle generations can supply electricity at a lower cost than its coal counterparts. Unlike coal, gas can be added in smaller increments to meet grid generating capacity requirements and can respond quicker to changes in hourly electricity demand. Natural gas options have also proven to have lower compliance costs with environmental regulations than coal.

One state could be part of the Appalachian Basin, the area leading the US in natural gas growth, but has refused to do so and has gone so far as banning natural gas projects. New York has become quite a spotlight for how they are handling their natural gas resources and use. New York contains shale reserves and has a history of oil and gas development. However, the state banned fracking in 2014 and has blocked multiple pipeline projects. Even with these policies in place that seem against natural gas, they have expanded their natural gas use. According to an analysis completed in 2015, New York's power of choice was natural gas, which made up 42% of their generation mix that in 2005 only made up 21% of their generation mix.

Current Renewable

The total generation from non-hydro renewables rising with additional from wind and solar being major contributors. Since 2015, total generation from utility scale non-hydro renewables has been greater than the hydropower generation alone. Wind energy has grown from 0.2% in 1990 to now approximately 9% in 2019 for total utility scale generation in the US. Solar capacity and generation has also increased from 314 MW in 1990 to now being over 37,000 MW in 2019. This increase has brought solar generation's percentage up from 0.1% in 1990 to now 1.8% in 2019. Renewables have a high promise of continued growth within the US.

Economics of Power Generation

The US EIA released a 2020 energy outlook showing different overnight costs, lead time, and operation and management costs for different generating technology (US Energy Information Administration, 2020). This table can be found in Appendix 3. Additionally, construction costs for 2018 have been published through (US Energy Information Administration, 2020). Major findings can be found in Figures 3-5 below.

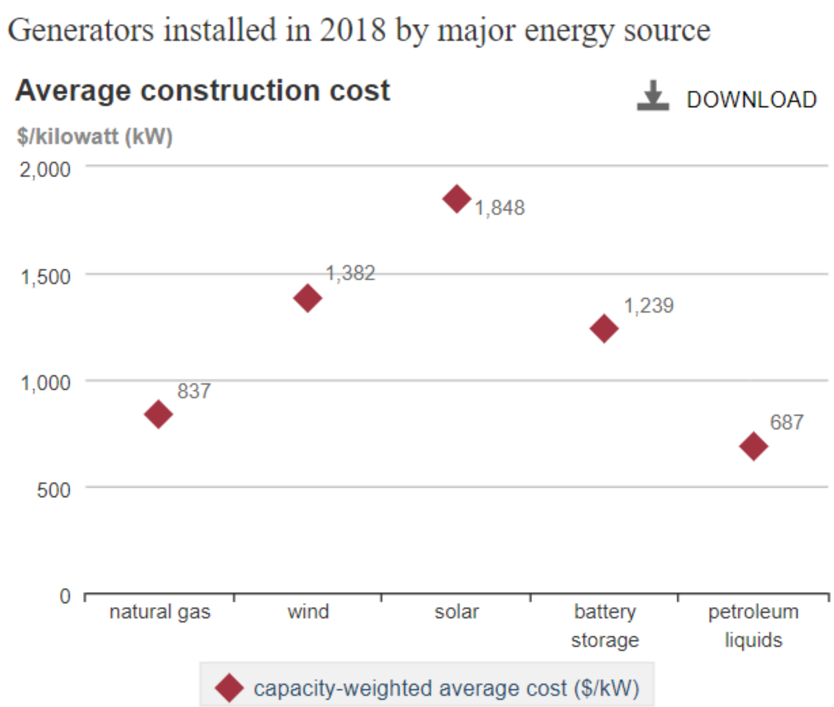

Figure 3 Average Construction Cost of Generators Installed in 2018 by Energy Source

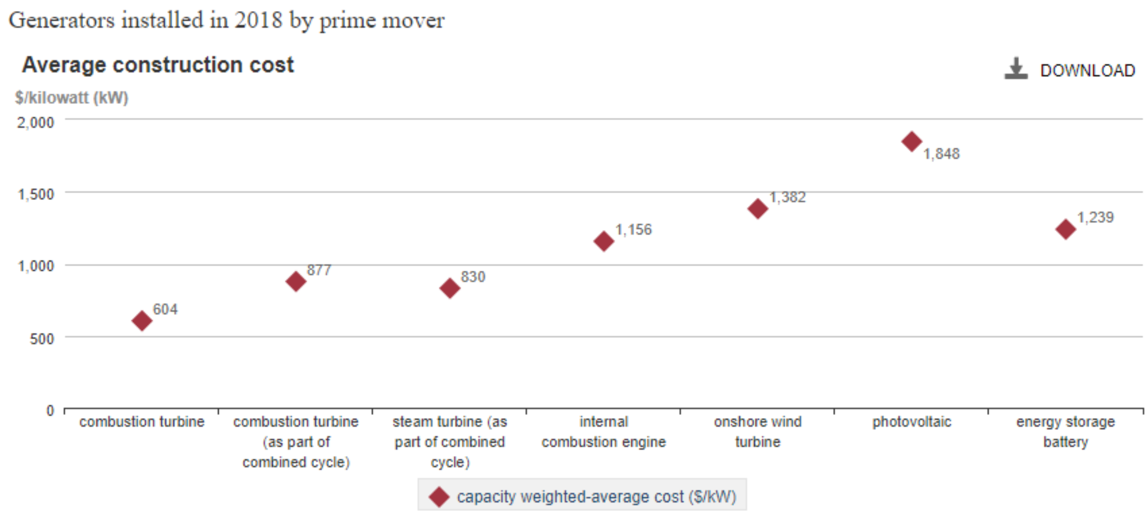

Figure 4 Average Construction Cost of Generators Installed in 2018 by Prime Mover

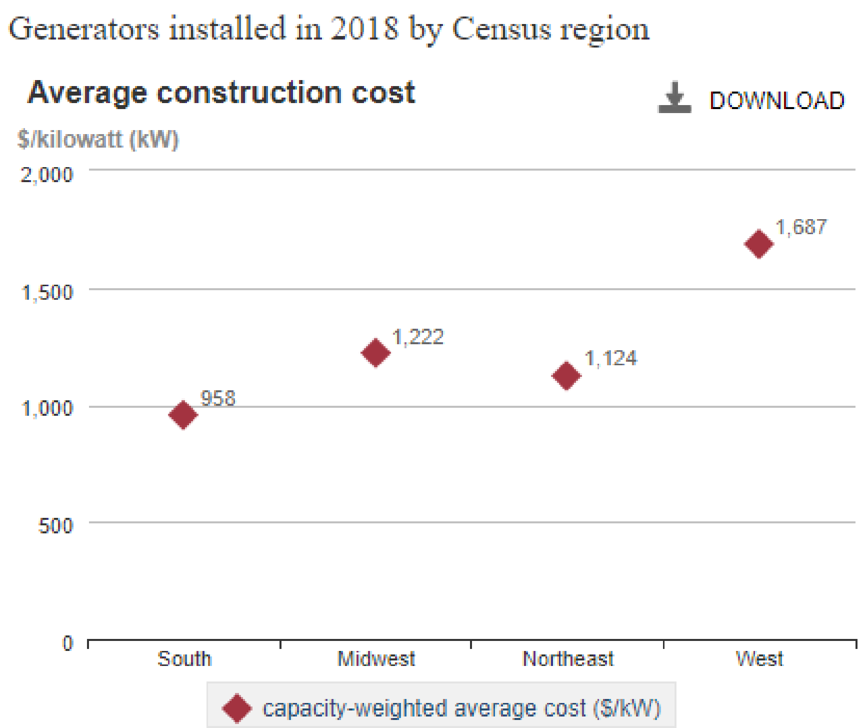

Figure 5 Average Construction Cost in 2018 for Each Census Region

Nuclear Economics

Nuclear plants are funded by stakeholders. These involvements include state and tribal governments, local communities, federal agencies, the industry, and professional organizations.

Historically, the major issue with new plants becoming operational or attempted is the initial construction cost. Over the years, construction costs have escalated and while forecast costs and schedules seem achievable, they have almost never been met within Western countries. In the

1950’s-1960’s nuclear was advertised as too cheap to meter from its low investment costs and short construction times. Nuclear could generate electricity at as low as 2-3 cents per kWh at the time. There is currently no solidified reason the real costs have increased since nuclear power started, though speculations include: additional safety requirements from accidents, the need for higher quality materials, and reactors being prone to cost escalation from the pre-construction forecast. There is also a suggestion that, like any bidding scenario, pre-construction cost estimates are written lower so that contractors can win bids. This situation causes construction projects to go bankrupt due to the overwhelming scale of the nuclear financial structure.

The most recent plant to finish construction as the Watts Bar Unit 2 completed in 2016. It is estimated that plants starting in 2016 would have a baseline overnight cost of $5,148 not accounting for fluctuations.

For decommissioning nuclear plants, this process is paid for through a fund that each plant operator creates during construction and with funds accumulated during the commercial operations. 2/3rd of the total estimated cost of decommissioning all US nuclear reactors has already been collected. The remainder of the money required will be collected as newer plants continue to operate and generate revenue. The utility must report every 2 years on the status of their decommissioning funding until the plant is within 5 years of shutdown, when they start reporting annually. The most recent plant decommissioning that has been completed was finished at a total cost of $893M.

Congress provided the DOE with a $20.5B nuclear power loan to issue out for new nuclear power facilities and front end nuclear fuel cycle work. The first loan was given to Vogtle for the amount of $6.5B in 2014. In March 2018, an additional $3.7B was guaranteed to finance Vogtle. There is now a new budget allowed for reactors entering service after December 31, 2020 to quality for tax credits. This enables the US Secretary of energy to allocate credits for up to 6000 MWe of new nuclear capacity entering service after January 1, 2021. This means that with Vogtle’s extension, they will also be eligible for these tax credits. Other projects such as NuScale Power SMR plant at the Idaho National Lab in 20206 will also quality.

Coal Economics

Ultra supercritical coal has a nominal capacity of 650 MW costing $3,636/KW. Offsite requirements for the plant that must be built for its operation includes coal delivery through rail, truck, or barge, water, water treatment systems, wastewater location sendoff, and electrical interconnections to substations. Other types of coal builds have similar requirements and are cheap to build but expensive to run compared to current natural gas plants.

Even with higher costs to run, the NRC released a report created for Peabody Energy showing the potential economic benefits of building and operating a coal or natural gas plant in the Midwest. This report, (Nuclear Regulatory Commission), shows that for the area being applied it is more favorable to build and operate a coal plant. This is stated due to building the plant and mine increasing busines volume at the state level by $4.5B with over 20K new jobs. The new natural gas plant of the same size would only have 1/3 of the coals impact on the economy and regional employment during construction. The advantages of coal in this area included broader economic benefits, it is a cheaper source of energy to security a low-cost base generation, and the low generation costs will attract new businesses. Therefore, there are some areas, even within the US, that is more economically favorable that natural gas or clean energy sources.

Natural Gas Economics

Oil and gas plants can be large, take years from inception to end point product being sold, almost always involve government, and are subject to specific risks over and above what is generally found in project financing. This industry supports national economies through the following ways: supplying energy to industry and domestic end consumer; exports and imports raw materials and refined products; job creation; revenue generation; furthering inter-governmental connections and trade links; an generating royalties and tax income.

Major companies in the global oil and gas industry include ExxonMobil, BP, Shell, Total, ENI, Resol, Ophir, Tullow, Noble Energy, and Premier Oil. Financing in this industry mostly comes from equity sources and third party financing. These third party financer scan include: corporate loans, acquisition financing, reverse based lending, equity bridge loans, project finance, capital markets, hybrid financing, and hedging.

In 2015, natural gas added almost 7K MW of capacity. Construction costs averaged $812/KW and for 74 generators there was a total const of $5.3B. There are three types of technology utilized that impact the total construction cost: NGCC, combustion turbine, and internal combustion engine. Combined cycle plants have at least one combustion turbine and one steam turbine. They operate at a higher efficiency than other types and have lower operating costs in the long run. However, their construction costs are higher and they are used to meet baseline demands. Combustion turbines are less efficient than NGCC but are built more quickly. They are used in short-term capacity increases needed to meet rising demand. They tend to only run during peak times of demand.

Renewable Economics

Wind is constructed on average at a cost of $1,661/KW in installed nameplate activity. Total construction cost for 66 generators averaged $13B. Construction in this area is reliant on the current regulatory landscape and generation costs. Power plants reliant on wind added less than 900 MW capacity in 2013, they added over 8,000 MW in 2015. This was influenced by the expiration of a federal production tax credit at the end of 2012 to encourage investors to move away from new construction in wind generators until a tax credit was renewed in 2013. The 2015 increase can be seen as a renewed investment due to a favorable regulatory environment due to lag time in construction.

Solar energy is highly dependent on the technology used. The intersection between construction cost and productive capacity is a central consideration for investors. The average construction cost for all types of solar PV plants was around $2,920/KW. For 386 generators, the total construction costs was around $93B. On average these plants yield less capacity increases per generator when compared to natural gas or wind.

Public Policy

The overall direction of the energy sector in the US is determined by market forces rather than formal governmental policies. However, federal policies and regulations influence specific aspects of the generation mix based on how they regulate things like; air and water quality, interstate commerce, mine safety, lending of federal lands, support for research and development, investment incentives, income taxes, tax incentives, nuclear licensing, and nuclear safety oversight. States can also form polices that regulate similar things and include clean energy standards and renewable portfolio standards for utilities within their state. Because utilities are regulated at the federal and state levels, legislations have also been enacted to address national policies, end user needs, and environmental protection.

US Climate Alliance

The US Climate Alliance is a bipartisan coalition among select governors to implement policies to advance the goals of the Paris Agreement that was established June 1, 2017 after President Trump withdrew the United States from the Paris Agreement. The Paris Agreement aims to reduce greenhouse gas emissions by at least 26-28% below 2005 levels by 2025 globally. These states have agreed to track and report the progress to the global community in appropriate settings including when the world convenes on the Paris Agreement and accelerate new and existing policies to reduce carbon pollution and promote clean energy deployment at the state and federal level. Alliance states are said to lead the country in combating climate change through policies encouraging investment in clean energy, energy efficiency and climate resilience. They have reported a 14% reduction in green-house gas emissions between 2005-2016. States involved in the Climate Alliance include, California, Colorado, Connecticut, Delaware, Hawaii, Illinois, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, Nevada, New Jersey, New Mexico, New York, North Carolina, Oregon, Pennsylvania, Puerto Rico, Rhode Island, Vermont, Virginia, Washington, and Wisconsin. Details about these state's involvements and goals is detailed in Appendix 4.

Federal Power Act of 1935

The Federal Power Act of 1935 was passed with PUHCA. It provides federal mechanism, as required by the Commerce Clause of the Constitution, for interstate electricity regulations. Before this, electricity generation, transmission and distribution were typically a series of intrastate transactions.

Atomic Energy Act of 1954

The Atomic Energy Act of 1954 encouraged private enterprise to develop and use nuclear energy for peaceful purposes. It amended the Atomic Energy Act of 1946 to allow non-federal ownership of nuclear production and utilization facilities if an operating license was obtained by the AEC. It enabled the development of the commercial nuclear power industry in the USA

Price-Anderson Nuclear Indemnity Act of 1957

This required each operator of a nuclear power plant to obtain the maximum primary coverage of liability insurance. The annual premium paid by owners of nuclear power plants is

$375M/reactor. Damages exceeding this are funded with a retroactive assessment on all other owners of commercial reactors, based on the number of reactors they own and to not exceed $112M.

Energy Reorganization Act of 1974

The Energy Reorganization Act of 1974 separated the licensing and related functions of the AEC as an independent regulatory authority to ensure the safety and licensing of nuclear reactors and other facilities associated with the processing, transport, and handling of nuclear materials.

Clean Water Act of 1977

This is the primary law governing the discharge of pollutants into all US surface waters. The EPA requires that a National Pollutant Discharge Elimination System permit be obtained before any pollutant is released.

Energy Policy Act of 1992

This act specified the new reactor power plant process and provided an applicant who wanted to build a new reactor to use off-the-shelf designed to have already been approved and certified by the NRC. The NRC may issue a combined construction and license through this bill if an applicant uses a certified design and safety issues have already been resolved. This way they can focus the review on the quality of the reactor construction. This license was valid for 40 years and could be extended in 20 year increments. It was expected that this license type would shorten construction lead times and improve the economics of new nuclear plant licensing and construction. The NRC could also now approve 1+ sites for nuclear power with a n Early Site Permit (ESP) which remained in effect for 10-20 years and could also be renewed. For the COL licenses, the NRC has certified the following designs: Westinghouse AP1000, Westinghouse AP600, System 80++, General Electric Nuclear Energy ABWR, ABWR Design Certification Rule Amendment, GE-Hitachi Economic Simplified BWR. They are also reviewing 4 additional designs for certification.

This act also created a new category of electricity producer – the exempt wholesale generator. This got around the Public Utility Holding Company Act’s impediments on nonutility electricity generation. This also allows the FERC to open a national electricity transmission system to wholesale suppliers.

Nuclear Waste Policy Act of 1982 – Amended

This established the federal responsibility for the development of repositories for the disposal of high-level waste and used nuclear fuel. This was amended in 1987 to require the DOE to begin evaluating the suitability of Yucca Mountain in Nevada as a US permanent high-level waste repository.

Low-Level Radioactive Waste Policy Amendments Act of 1985

This led to the development of new disposal capacity for low level waste. Each state was responsible for providing, by itself or in cooperation with other states, the disposal of low level waste generated with the state. This authorized the states to form compacts to establish and operate regional low level waste disposal facilities subject to NRC licensing approval.

The Public Utility Regulatory Policies Act of 1987

This was established to promote the conservation of electric energy in response to the unstable energy climate of the 1970's. It created a new class of non-utility generator, small power producers, that was qualified co-generators, utilities were required to buy power from.

The Clean Air Act Amendments of 1990

This act established a new emissions reduction program to reduce annual sulfur dioxide emissions by 10 million tons and annual nitrogen oxide emissions by 2 million tons from 1980 levels from all human made sources. Generators of electricity were responsible for large portions of the reductions.

The Energy Policy Act of 2005

This act held provisions affecting nuclear power included in the Price-Anderson Act and incentives for building the first advanced nuclear plant. These incentives include tax credits, loan guarantees, and standby support insurance related to regulatory delays.

American Recovery and Reinvestment Act of 2009

Directed funding for energy efficiency and renewable energy into a loan guaranteeing renewable energy, including nuclear power.

Cross-State Air Pollution Rule (CSAPR)

This ruling limits the NOx and SO2 emissions that create ozone and fine particulate matter. These emissions from upwind states prevent downwind states from achieving air quality standards and covers thousands of sources in the Eastern US. States can employ tradeable air permits to reduce emissions. This rule came into effect in 2015.

Mercury and Air Toxic Standards (MATS)

MATS limits emissions for mercury from coal and oil fired plants while natural gas does not contain mercury and is not included. This standard started in 2015 and has caused some coal plants to retire while most have installed control technology to reduce the emissions. In April of 2020, the EPA issued a revised supplemental cost finding to remove co-benefits from consideration and potentially weakened the legal underpinning for this and future rulings. The EPA revised the rule to allow power plants to burn eastern bituminous coal refuse and emit higher levels of acid gas hazardous air pollutants (sulfur dioxide and hydrochloric acid).

Consolidated Appropriations Act of 2018

This act includes over $1.2B supporting the DOE NE programs and $922M for the NRC. This act allows reactors entering service after December 31, 2020 to quality for tax credits and enables the US Secretary of Energy to allocate credits for up to 6000 MWe of new nuclear capacity entering services after January 2021.

2018 GHG Emissions Regulations

In 2018, the EPA released new emissions regulations for new, modified, or reconstructed plants. This replaced the EPA's 2015 Carbon Pollution Standards for New Power Plants and established

New Performance Source Performance Standards (NSPS) to limit carbon dioxide emissions from fossil fuel power plants. The 2015 rule determined that new natural gas plants should emit no more than 1000 lb of CO2/MWh of electricity produced. This was achievable with the latest combined cycle technology. It also established that new coal plants emit no more than 1400 lb CO2/MWh which requires the use of carbon capture and storage (CCS) technology. The 2018 rule set the best system of emissions reductions for newly constructed large units equivalent to a super-critical coal plant, with an emissions rate of 1900 lb CO2/MWh and would set the best system of emission reductions for small units to 2000 lbs CO2/MWh. This ruling also has separate performance standards for new and reconstructed coal refuse-fired units at emissions rates of 2200 lb CO2.MWh. Additionally, it revised the standards of performance for reconstructed plants to be consistent with emissions rates for new plants. This was adopted in the Clean Air Act and required the EPA to sent numerical performance standards based on the best available technology demonstrated. States will have little flexibility when applying this standard.

Nuclear Energy Innovation and Modernization Act - 2019

The Nuclear Energy Innovation and Modernization Act was enacted into public law in January 2019. The bill revised the budget and fee structure of the NRC and requires them to develop new processes for licensing for advanced nuclear reactors (ANR). The bill amends the Omnibus Budget Reconciliation Act of 1990 which removed the amounts of appropriated for the development of regulations for ANR technologies from the amount the NRC must cover in fees. This additionally excludes the additionally amounts from the NRC fee for R&D at universities. directs the NRC to collect fees equal to the budget authority without excluded amounts and limits the NRC spending on corporate support cost. For commercial ANR's the NRC must establish stages in the licensing process and by the end of 2027 have a technology-inclusive regulatory framework to encourage greater technological innovation. They are also responsible for developing research and test reactor licensing and must report to congress the implementation of stages in the ANR licensing process and the process for accident tolerant fuel. Additionally, this bill requires the NRC to report to congress on the duration of uranium recovery licenses and how to improve the efficiency and transparency of uranium recovery licenses and complete a pilot program to show the feasibility of establishing a flat fee structure for routine licenses regarding uranium recovery.

This act was created to provide the public with greater clarity into the processes the NRC develops and its budget. This law also requires the NRC to establish performance metrics and milestones for licenses and regulatory actions. It also creates a necessity for the NRC to develop a regulatory framework for innovators that seek to deploy ANR technologies in the US and a pilot project for predictable fees and routine licenses regarding uranium production. It is generally accepted among many Senators and industry leaders and is credited to potentially help the US remain the leader in technological innovations to grow the nuclear industry.

State-Level Power Generation Changes

(Popovich, 2018) shows a state-level review of electricity generation changes between 2001-2017. Using data from the United States Energy Information Administration, state-level charts were constructed including a time-lapse of change and the overall United States change. As shown in Figure 6, the United States has shifted from majority coal to a more natural gas-based reliance. This shift includes the number of states relying on coal to decrease from 32 to 18 within the time period analyzed. The shift has assisted with lowering the carbon dioxide emissions and other pollutants across the U.S. Additionally, renewable energy has shown small, but quick, gains throughout many states. Even nuclear power has gained the majority share of some states' electricity generation. The graph of each state's electricity generation between 2001-2017 can be found in Appendix 5.

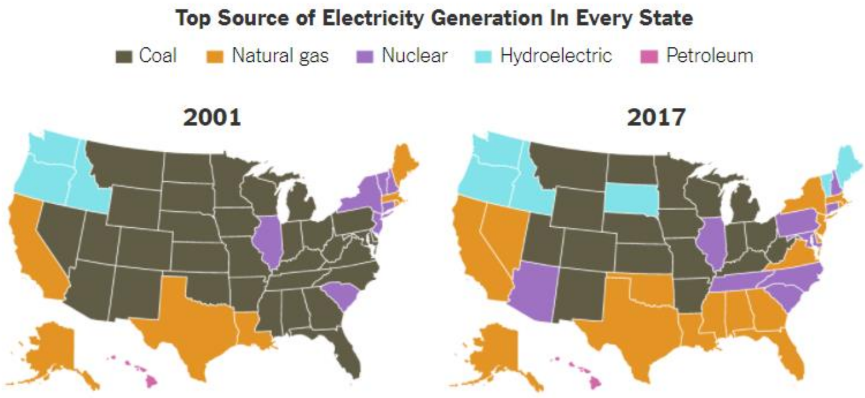

Figure 6 The United States Change In Electricity Generation 2001-2017

The most notable states in regard to their electricity generation metrics from the study include Nevada, Iowa and West Virginia. In Nevada, natural gas production surpassed coal as the top electricity source in 2005 and coal has remained in decline since then. For Iowa, wind power has grown to contribute approximately 37% of their electricity. Unlike many states, West Virginia has become notable by not changing. They have continued with coal as their main electricity generation source, despite the push to decease emissions across the globe. In fact, for West Virginia, coal produces almost all of their electricity.

Along with West Virginia, there are other states that have not substantially decreased their coal usage. These states have done a little better than West Virginia, though not much. Kentucky, for example, is still heavily reliant on coal, which makes up 78% of their generation, and their hydroelectric production has stayed consistent. However, their natural gas production has increased from being essentially nonexistent to now covering approximately 14% of the state's generation needs. Indiana has seen similar growth in their natural gas sector as it has grown into 18% of the state's generation capacity, with coal still having the overwhelming majority at 73%. Other states retaining high coal capacities include: Iowa, even with a growth in the wind sector; Colorado, who has seen major advances in wind generation; New Mexico, who has had growth in their natural gas sector; North Dakota, where wind has grown; Ohio, where natural gas has increased and stagnated in recent years; Utah, who also had an increase in natural gas; Wisconsin, who has had an almost stagnant coal industry but has swapped their nuclear for natural gas; and Wyoming, who has seen minor increases in wind generation since 2008. While some of these states appear to be starting to transition away from coal, it can seem difficult to understand the limited decline when states like Alabama, Delaware, Georgia, Nevada, North Carolina, Oklahoma, Pennsylvania, and Virginia where all capable of essentially eliminating their reliance on coal within short periods of times, some even within one year.

While many states are still hanging on to coal production as their lead electricity source, some states have been coal-free or almost coal-free between 2001-2017. These states include Alaska, California, Idaho, Maine, Oregon, Vermont, and Washington. For the most part, these states are able to rely on hydroelectric power over the years. While this is a resource that not all areas have access to employ entirely, these states have taken advantage of this renewable option. Even Vermont, where their main generation was nuclear power, has moved to use hydroelectric instead starting between 2014 and 2015.

It is not news that nuclear generation within the states has not grown substantially over the last 30 years, due to no new reactors being built, and has decreased through closures. There are some states where it has varied with coal based on how the plants were ran that year and how many short-term closures there were, but for the most part it has stayed relatively consistent in many states. States where nuclear has remained as a key player in the generation market include Alabama, Arizona, Arkansas, Connecticut, Georgia, Illinois, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Nebraska, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, South Carolina, Tennessee, Virginia, and Wisconsin. Alternatively, states where there is a small amount of nuclear that has remained steady or even dropped include California, Iowa, Massachusetts, Missouri, Ohio, Texas, and Washington. As mentioned earlier, Vermont is one that stands out regarding nuclear as it has eliminated all of its nuclear production, which was 76% of its generation capacity in 2001, and replaced it with hydroelectric, biomass, wind, and solar. They have gone fully renewable with their electricity generation.

While Vermont has seemingly been successful in its transition to a fully renewable and clean energy base, they did not need to do this to remove emissions from their generation sector like other states are striving to do. Many states who are have high levels of emissions from their coal use, show a clear change to natural gas even if their renewable fleets are growing. Others have always had a high natural gas use and are either remaining stationary there or working towards higher renewable energy use.

Power Company Standings

Power Companies and Their Influence

Power companies within the United States are regulated by both federal and state level policies. While safety regulations are generally on the federal level, what type of power and what emissions levels are allowed for a whole generation fleet are influenced on a state level. Pressure from political figures and public interest groups can also impact decisions that utility companies make regarding the types of power generation they build and what plants begin decommissioning. The United States has seen a few nuclear and coal plants begin decommissioning solely due to public influence. We have also seen utilities begin to lower their emissions through increased renewables and natural gas due to emission regulations within each state. Figure 7 shows how well each major utility, compared to each other, is doing on decreasing their emissions rates within the United States from (Exelon, 2019). The following section will discuss some of the larger utilities and how their current generation fleets are made up along with their future plans for generation expansion and replacement.

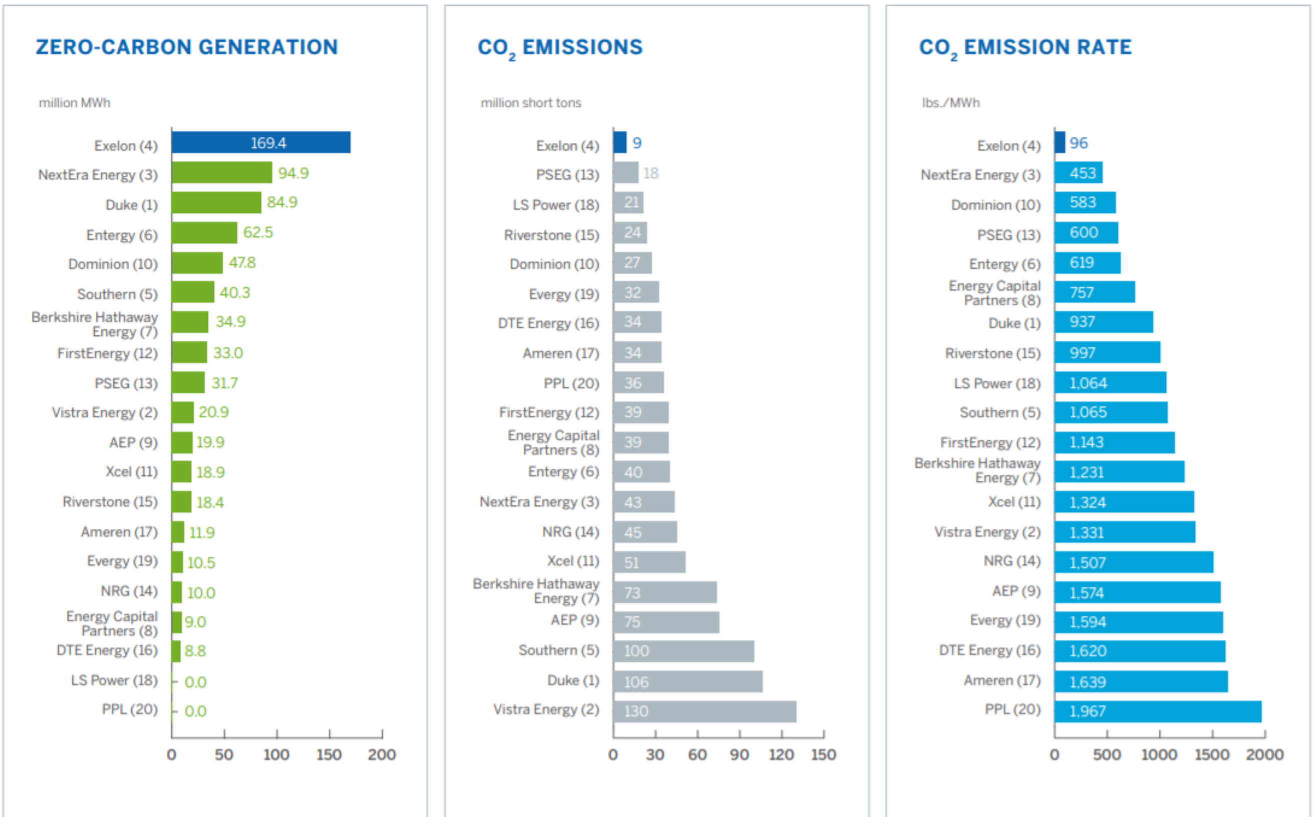

Figure 7 Utility Emissions Level Comparison

American Electric Power

American Electric Power (AEP) has a generation fleet comprised of 45% coal, 28% natural gas, 7% nuclear, and 17% Wind/Hydro/Pumped storage. With a generation capacity of approximately 26,000 MW, American Electric Power serves customers in Arkansas, Indiana, Kentucky, Louisiana, Michigan, Ohio, Oklahoma, Tennessee, Texas, Virginia, and West Virginia.

While coal still comprises a majority of AEP's generation, it has drastically decreased over the last 15 years. In 2005 coal made up 70% of their generation capacity. While moving towards cleaner energy, AEP has reduced their carbon emissions by 65% since 2000, their sulfur dioxide emissions by 97% since 1990, their nitrogen oxide emissions by 94% since 1990, and their mercury emissions by 97% since 2001. Figure 8 from (American Electric Power, 2020) shows AEP's full generation change between 1999-2020 and includes a forecast for upcoming years.

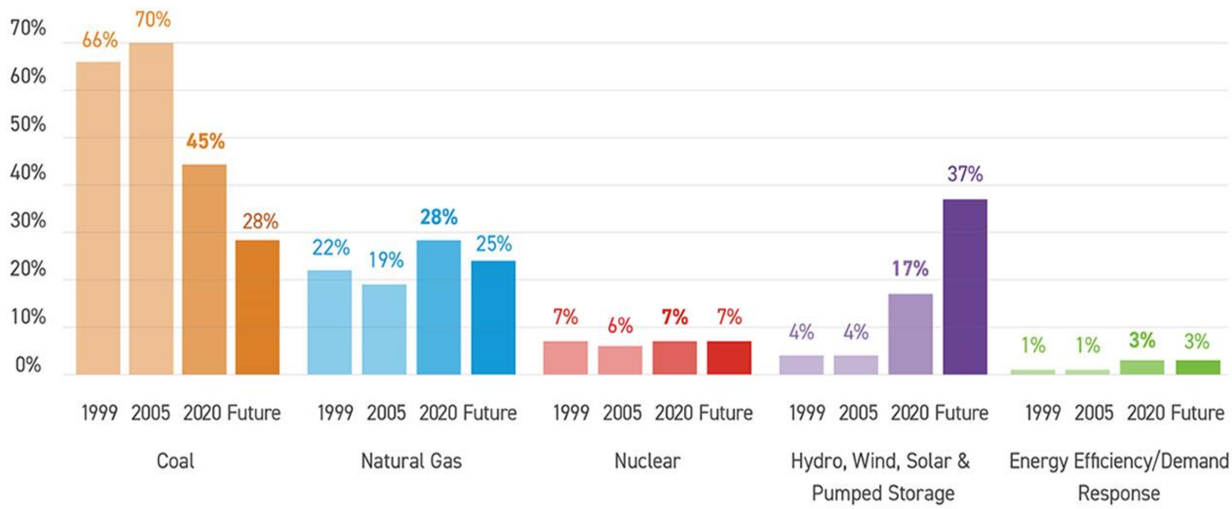

Figure 8 American Electric Power's Generation Over The Years

Developing next-generation sustainability goals is a priority to AEP for a cleaner energy future. They plan on reducing their carbon dioxide emissions by 70% by 2030 and 80% by 2050. To reach this goal, over 8000 MW is planned for regulated wind and solar through 2030 including 4100 MW of solar. AEP recently purchased Sempra Renewables LLC which added approximately 742 MW of wind and battery into their fleet. Other projects include a joint venture with Desert Sky and Trent Mesa, to power 75,000 homes through wind power in West Texas and creating a smarter, modernized power grid.

Dominion Energy

Dominion Energy serves electricity customers in Idaho, North Carolina, Ohio, South Carolina, Utah, Virginia, West Virginia, and Wyoming with 85% of their generation coming from clean energy sources or natural gas. During their expansions for clean energy and increased sustainability within their generation fleet, Dominion Energy has cut back on their own carbon emissions by 57% since 2005 and methane emissions by 25% since 2010. They plan on being net zero by 2050 for emissions.

Part of their renewable generation portfolio includes having the fourth largest solar fleet in the United States, which can be found in Appendix 6. They have also completed reliability testing for a 12 MW offshore wind pilot project, Coastal Virginia Offshore Wind, that should enter commercial service in late 2020 and have announced the largest offshore wind project in the US. Dominion Energy also participates in renewable gas partnerships, has new standards to protect wildlife, and has recycled 41M lbs of material in 3 years. They are continuously working to replace their fossil fuel generation with solar and wind, increased storage capacity, and are looking into renewable natural gas.

Dominion Energy owns 17 natural gas facilities, listed in Appendix 7 and has approximately 16 major projects for pipeline expansions, also in Appendix 7. While they are replacing their coal and oil facilities, listed in Appendix 8, they plan to expand their natural gas resources and renewable energy fleet simultaneously to keep a diversified energy portfolio. They also keep three biomass facilities, Altavista, Hopewell, and Southampton, that were coal conversions started in 2014 and nine hydroelectric plants that were built in the 1900's, found in Appendix 9.

For their nuclear fleet, they have 4 plants: Millstone, North Anna, Surry, and VC Summer. They have started a decommissioning process at VC Summer and have no expansions planned for the remaining three plants.

Duke Energy

Duke Energy serves areas within Indiana, Ohio, Kentucky, North Carolina, South Carolina, and Florida. Their subsidiaries also include Piedmont Natural Gas and Progress Energy. They own 51,144 MW of generation capacity with 36% of that coming from natural gas, 35% from nuclear, 27% from coal and the rest from solar and hydroelectric. Duke Energy plans for new natural gas and renewable generation, stagnant nuclear, and decreased coal over the next decade. They are encouraging a high efficiency modernized natural gas fleet to assist in cost reductions and keep their portfolio diversified.

Through a quick period of closures in their coal plants, Duke Energy intends on cutting carbon emissions by 50% in 2030 and net zero by 2050. To replace of these coal plants, Duke Energy opened three new natural gas plants in the last two years and has one expansion planned in NC. They have also completed 99 renewables projects across 17 states with the majority of their solar power projects taking place in North Carolina and California. Other projects towards renewable generation includes wind power, battery storage options, and third-party customers.

For commercial renewable projects, Duke energy owns 2282 MW coming directly from 22 wind facilities, 126 solar projects, 11 fuel cell locations and 1 battery storage facility. These projects are usually long term power contracts to utilities, electric cooperatives, municipalities, and corporate customers. Future expansions are planned as distributed solar, energy storage systems, and energy management solutions. A current list of Duke Energy's renewables projects can be found in Appendix 10.

Within the battery storage solutions market, Duke Energy has invested over $500 M over the last 15 years through the Carolinas. They have increased the battery storage capacity of the region and helped deliver microgrids of energy to underserved customers. Two main projects involving battery storage solutions include the Hot Springs NC Microgrid, using 2 MW solar and 4 MW lithium battery, and the Phoenix Energy Technologies microgrid serving as an energy management system for commercial customers. Additionally, Duke Energy assists with microgrid solutions for emergency resiliency like Red Cross and schools system. These solutions generally include rooftop solar and microgrid controllers connected to local customers. Duke Energy plans to continue their battery storage, microgrid, and solar expansions while phasing out their coal and natural gas options to become net zero by 2050.

Entergy

Entergy serves customers in Arkansas, Louisiana, Mississippi, New Orleans and Texas. It also serves the wholesale market and includes a separate subsidy that handles their nuclear fleet.

Within their generation fleet from 2019, approximately 40% of their generation was from natural gas, 28% from nuclear, 6% from coal and the rest from purchased power.

For nuclear generation, Entergy owns and operates seven plants totaling 8000 MW of capacity. Their nuclear plants are; Cooper, Arkansas Nuclear, Grand Gulf, Palisades, Indiana Point Energy Center, Waterford 3, and Riverbend. Their wholesale power is completed with three of their plants, Indiana Point, Palisades, and Cooper, paired with two coal plants and a natural gas plant. The remaining four nuclear plants are used as utility generation assets along with natural gas, coal, hydroelectric, and solar plants. A list of Entergy's non-nuclear generation assets, along with additional details provided by (Entergy, 2020) can be found in Appendix 11.

Recent projects and upcoming expansions for Entergy include their natural gas systems and residential rooftop market. Within 2020/2021 Energy should have six new natural gas plants running including combined cycle, reciprocating internal combustion, and simple cycle. They also plant on 5 utility scale solar projects and 2 rooftop solar expansion projects planned in the same time period.

Exelon

Exelon services customers in Delaware, DC, Illinois, Maryland, New Jersey and Pennsylvania through six subsidies; Atlantic City Electric, BGE, ComEd, Delmarva Power, PECO, and Pepco. Their generation capacity is comprised of 62% nuclear, 20% natural gas, 4% hydroelectric, 4% wind, 7% oil and combination, and 1% solar.

Exelon operates the largest nuclear fleet in the United States with 21 reactors. Details regarding their nuclear fleet can be found in Appendix 12. Their sustainability strategy includes continuing their nuclear generation, increasing its efficiencies, and pushing it as a reliable source required for generation needs to be met in a low-carbon future. Along with their nuclear advancements, they plan to expand their solar and wind generation. Their first wind plant went commercial in 2012 and they currently own 40 wind projects across 10 states. Exelon has also built the largest urban solar project in Chicago and have 3 solar locations within the United States. For their hydroelectric fleet they have two plants, one a pumped storage facility and the other running on a river. A list of all renewable sites owned by Exelon can be found in Appendix 13.

While expanding the reach of their renewable and nuclear fleets, Exelon is phasing out their older natural gas and oil facilities and building cleaner natural gas plants to move into a cleaner generation. They currently operate 10 natural gas plants with two combined cycle and one simple cycle plant in construction. They consider oil as a backup operation for their natural gas facilities and own 12 locations that are outfitted with emission control technology. Exelon's fossil fuel generation details can be found in Appendix 14.

Current published goals for Exelon including eliminating 17.5 million metric tons of green-house gas emissions in one year by 2020. They reached over 18 million metric tons in 2013. In 2018 they announced an operational-emissions goal to reduce emissions by 15% by 2022. They are reducing air emissions through a low-emission intensity energy portfolio. They have recently completed 3 green-house gas emissions reduction goals under the EPA Climate Leaders and Exelon 2020 programs. Emission reductions since 2017 can be seen in Figure 9 from (Exelon, 2019). They are evaluating efforts to support their customers through carbon reduction efforts and retiring higher emitting sources while increasing their zero-carbon generation sources. Exelon is also encouraging their customers to specify cleaner generation in their electricity purchases.

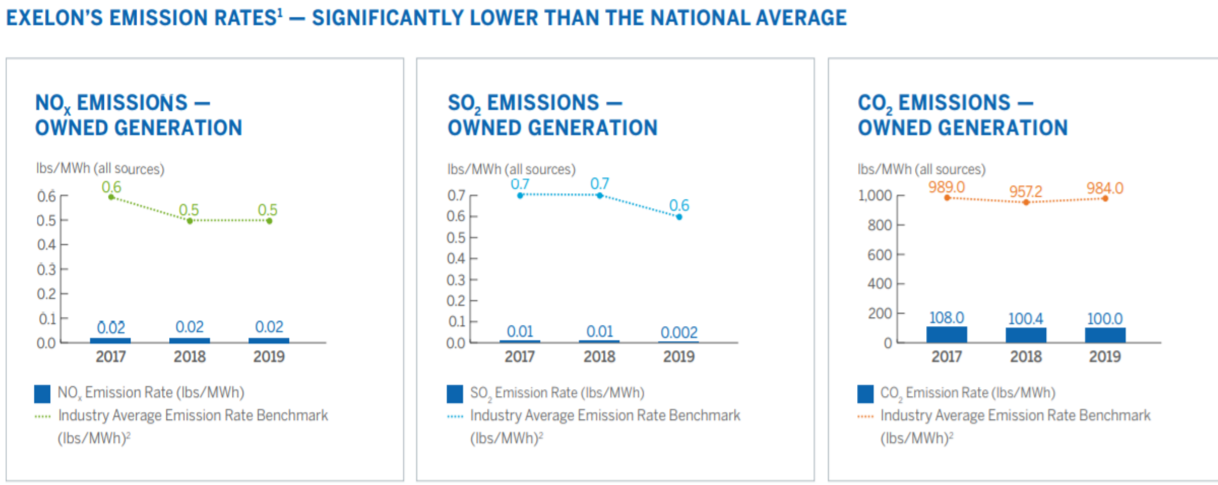

Figure 9 Exelon Corporation's Emission Rate Changes Since 2017

To mitigate climate change, Exelon has published a general plan through 2050. These goals include maximizing zero-carbon generation to the grid, including nuclear, and investing in utility infrastructure through 2025. Between 2025-2030 they plan on installing charging infrastructure and metering options as well as supporting the infrastructure standards changes to connect performance with climate projections. For 2030-205 they intend to drive greenhouse gas emission mitigation and climate change adaptation, transition into a low-carbon climate change resilient economy, and partner with the communities they serve to better meet their needs and desires for clean energy.

First Energy

First Energy operates in Ohio, Pennsylvania, New Jersey, West Virginia and Maryland with nine subsidiaries; Ohio Edison, The Illuminating Company, Toledo Edison, Penelec, Penn Power, West Penn Power, Jersey Central Power and Light, Mon Power, and Potomac Edison. Generation includes two coal stations, Fort Martin Power Station and Harrison Power Station both in West Virginia and two hydropower stations, Bath County Pumped Storage in Virginia and Yards Creek Hydro Station in New Jersey. In total, First Energy owns 3780 MW of generation capacity.

Within the 2019 climate report, First Energy assessed the impacts of reducing carbon dioxide emissions levels. They plan to reduce their emissions by supporting the communities around them rather than changing their generation fleet away from coal. Upgrades planned include supporting the industrial and commercial customers through upgrades with their equipment, energy usage, and transportation methods. They are working with Maryland to have 300K zero-emission vehicles on the road by 2025 and are building the infrastructure for the state through charging station availability. Customers are also being shown ways to reduce their overall energy consumption including natural gas, gasoline, and electricity. First Energy is also looking at the following ways to increase their efficiency with emerging technologies; next-get heat pumps, advanced data center infrastructure, smart thermostats, and advanced building design.

MidAmerican Energy

MidAmerican Energy serves approximately 1.5M customers within Iowa, Illinois, Nebraska and South Dakota. Between 2017 and 2019 their wind generation capacity has grown from 49% to 57% with their coal and natural gas sectors decreasing and nuclear/other remaining steady at 6%. In 2019, MidAmerican Energy reported that coal made up 25% of their generation capacity and natural gas made up the remaining 12%.

The growth in wind can be partially contributed to the Wind XI project that was completed in 2019 adding 2000 MW of capacity to the fleet powering Iowa customers. Iowa customers can also participate in the Green Advantage program where they can claim a verified amount of renewable energy generation to help them reach their sustainability goals. To date, they have invested approximately $11.9B into wind projects. A full list of wind generation plants owned and operated by MidAmerican Energy can be found in Appendix 15. Future growth for their renewable generation includes continuing their wind generation expansion within Iowa, bringing in battery storage, and developing small and utility-scale solar markets where feasible.

NRG Energy

NRG Energy serves retail customers in Texas, Connecticut, Delaware, Illinois, Maryland, Massachusetts, New Jersey, New York, Pennsylvania, Ohio and the District of Columbia with a generation capacity of 23 GW spread around over 30 facilities. 43% of NRG's generating capacity is natural gas coming from 14 plants. Natural gas is the chosen resource for areas it supports due to its reliability, affordability, lower carbon dioxide emissions, and for being produced domestically. NRG is focused on transferring its coal plants to natural gas. With coal covering 34% of the generating capacity through 7 plants, NRG is also looking at carbon capture technology for the current operating plants.

Carbon capture is installed at NRG's Petra Nova plant that in partnership with the Department of Energy, JX Nippon and Hilcorp Energy. Since December of 2016, Petra Nova has captured 92.4% of its carbon dioxide emissions and sent them to the West Ranch oil field. Although this has been a successful venture, in May of 2020 Petra Nova was placed into a reserve shutdown due to the economics of the area leaning towards operating other electricity sources.

For alternative energy sources, NRG has 3 renewable energy plants covering 2% of their generation portfolio. These renewable plants are all solar facilities 100% dedicated to individual businesses who partnered with NRG on the projects and one battery storage facility as a reserve system. Additionally, NRG owns one nuclear plant, the South Texas Project, that represents 5% of the company's generating capacity. The South Texas Project contains two PWR reactors that started generation in 1988 and 1989. There are currently no plans for expanding or decommissioning this plant early, though NRG is working towards a decentralized power market and residential solar expansions.

NextEra

NextEra is the world's largest provider of wind, solar, and a world leader in battery storage solutions. They are also noted as one of America's largest capital investor in infrastructure. Subsidiaries of NextEra include Florida Power and Light, Gulf Power Company, and NextEra Energy Resources LLC. These subsidies provides electricity generation to Washington, Oregon, California, Nevada, Arizona, New Mexico, Colorado, Texas, Oklahoma, Alabama, Georgia, Florida, Virginia, West Virginia, Pennsylvania, Nebraska, Kansas, Missouri, North Dakota, South Dakota, Minnesota, Iowa, Wisconsin, Illinois, Indiana, Michigan, Ohio, New York, New Hampshire, Massachusetts, Maine, Maryland, DC, Delaware, Rhode Island, and parts of Canada.

NextEra Energy owns three natural gas plants; Bellingham, Oleander, and Stanton, five nuclear plants; Duane Arnold Energy Center, Lucie Power, Point Beach Nuclear, Seabrook, and Turkey Point, and three oil facilities; Wyman, Point, and Wyman 4. Data between 2016 and 2019 for NextEra Energy's generation make up can be found in Appendix 16 from (NextEra Energy, 2020). It can be noted that while their solar and wind fleet is large, with wind making up 20% of their generation fleet, their natural gas remains as their main power producer only transitioning from 49% of their generation total in 2016 to approximately 48% of their generation total in 2019. With nuclear power rounding out 24% of their remaining generation, sources like coal, oil and landfill gas are rarely used though coal and landfill gas had a slight increase in the three-year span.

NextEra Energy's solar and wind generation fleets can be found in Appendix 17 and Appendix 18, respectively. With 119 wind projects alone in the US and Canada, NextEra is the leader in implementing this renewable energy source. Since 2016, there have been a number of projects started to continue NextEra Energy's growth in the renewable sector and keep their fleet modernized and producing economic power to their customers. In 2016, Florida Power and Light launched an energy storage pilot project to assist in the scaling of their renewable energy and storage solutions. In 2018, NextEra Energy announced their carbon dioxide emissions goal of 65% reduction by 2021 compared to 2001. This goal was updated in 2019 to reach a 67% reduction by 2025 compared to 2005. In 2019 NextEra Energy acquired Gulf Power and Light to assist with the company's emissions reductions targets, increase clean energy, and lower the cost to Gulf Power and Light customers. Additionally, in 2019 Florida Power and Light announced the projects including installing 30 million solar panels by 2030 and building the world's largest solar-powered battery. For 2020, Florida Power and Light launched Solar Together, the largest community solar program in the US, announced the retirement of their last coal unit, and filed a joint10-year plan with Gulf Power and Light to reach a70% increase in zero-emission energy by 2029 compared to 2019. Overall, NextEra Energy is continuing towards its goals to a cleaner energy future.

Pacific Gas and Electric

Pacific Gas and Electric (PG&E) has a power mix that is approximately 85% green-house gas free serving electricity and natural gas to California. Their generation mix is made up of 39% renewables, 34% nuclear, 13% large hydroelectric, and 15% natural gas and other fuels. Eligible renewables include biomass, geothermal, small hydroelectric, solar and wind projects that have been successfully integrated into the grid. Their fuel resources include coal and natural gas.

Within California, solar has been added through contracts with third-party developers and supporting customers with self-installments. PG&E maintains 380,000 private rooftop solar customers connected to the grid and has a choice program that allows customers to request up to 100% of their electricity to come from solar even if they do not have rooftop solar themselves.

For their hydroelectric operations, PG&E owns and operates the largest investor-owned hydroelectric systems along 16 fiver basins. These systems have a generation capacity of approximately 3900 MW from 66 power houses and include pumped storage solutions with 100 reservoirs.

Moving into the future, PG&E will continue growing their clean energy solutions and investing in cleaner solutions for their natural gas plants to lower the overall emission levels produced.

Southern Company

Southern Company is one of the largest utilities in the United States and supports customers in 19 states: Alabama, California, Delaware, Florida, Georgia, Illinois, Kansas, Louisiana, Maine, Mississippi, New Hampshire, New Mexico, Nevada, North Carolina, Oklahoma, Tennessee, Texas, Virginia, and Washington. They do this through ten subsidiaries: Southern Nuclear, Southern Power, Alabama Power, Georgia Power, Mississippi Power, Southern Company Gas, Southern Telecom, Southern Linc, PowerSecure, and Sequent Energy Management. An overview of their generation fleet types and locations can be seen in Figure 10 from (Southern Company, 2020).

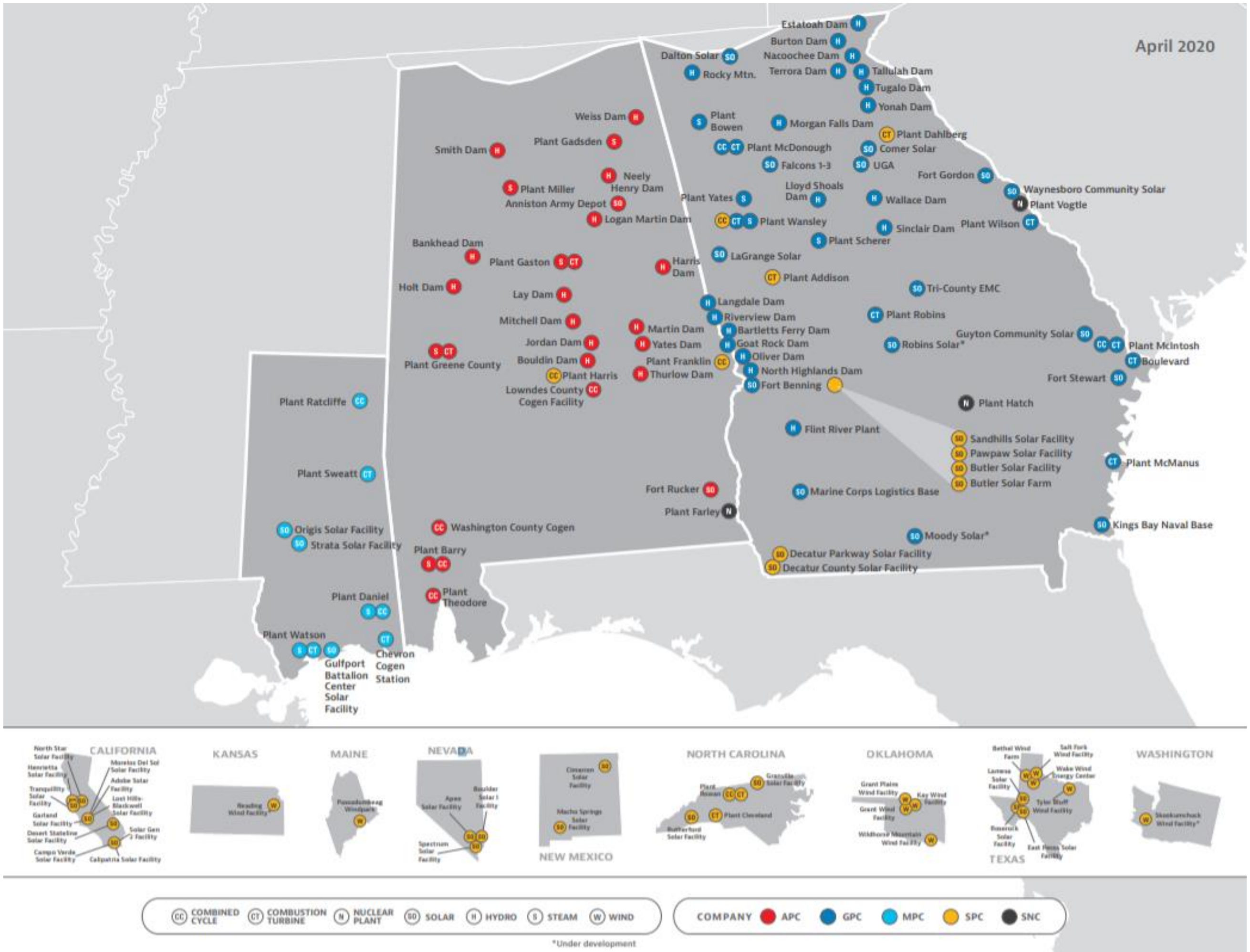

Figure 10 Southern Company's Generation Mix

With approximately 44,000 MW of generating capacity, Southern Company has shifted their generation fleet from being 72% based in coal and 11% in natural gas in 2005 to now having only 22% of their fleet from coal and 52% from natural gas in 2019. Through this progress they have acquired the nation's largest natural gas-only distribution company and a 50% share of Kinder Morgan's Southern Natural Gas Pipeline system. This assists them in keeping fuel costs low and they can control the greenhouse gas emissions within their systems. They are also developing a 21st century coal plant, Kemper County Energy Facility, that should have lower carbon emissions than a similarly sized natural gas plant through coal gasification technology. While committing to lowering their emissions rates through cleaner energy sources, Southern Company is developing two new reactor units at plant Vogtle in Georgia. These units will be the first new nuclear reactors becoming operational in the last 30 years and will both be AP1000's designed by Westinghouse (Georgia Power, 2020). Nuclear makes up approximately 17% of their generation portfolio.

For renewable resources, Southern Company utilizes retail electric subsidiaries for 10% of their generation portfolio and are strategically increasing their renewable bandwidth. They have expanded their resources into solar, wind, biomass, and other alternatives and have achieved the nation's largest voluntary solar portfolio. Furthermore, Southern Company is the only utility in the United States that has partnered with all four branched of the armed forces to develop solar on military bases and they have partnered with companies such as Nest, Tesla and Google to develop energy efficiency and demand response programs. Southern Company is also looking into applications for hydrogen fuel in a collaboration with the International Energy Agency's Hydrogen Implementing Agreement. They have competed short-term steps such as demonstration projects within the automotive and stationary fuel cell uses and are looking at existing system assets, such as idle coal units, to produce hydrogen.

Tennessee Valley Authority

Tennessee Valley Authority (TVA) has a generating capacity that is 60% carbon-free power. Changes in their generation fleet since 2005 show that the majority of their growth has been in nuclear, hydropower, and natural gas to replace coal plants within their fleet. They have also increased their solar and wind, though they are still smaller percentages of the overall generation.

TVA added the 21st century's first nuclear reactor at Watts Bar Nuclear Plant in Tennessee and have increased their efficiencies across their other reactors including Browns Ferry in Alabama and Sequoyah in Tennessee. Browns Ferry is TVA's largest nuclear site and the first site that TVA constructed. Being home to three BWR reactors, it produces 39% of TVA's total generation. The Sequoyah plant contains two PWR units while Watt's Bar was expanded to two PWR units in 2016. By keeping majority of their generation in nuclear power, TVA has kept their generation costs low, being second only to their hydroelectric costs, and reduced their reliance on coal making it easier to decommission those plants.

TVA has 29 hydroelectric plants within the Tennessee River system dating back to the 1930's. Additionally, they have a pumped-storage plant and purchase power from 8 dams owned by the Army Corps or Engineers. Generating 13% of TVA's total capacity, these hydroelectric generation plants provide more than electricity to the area like flood control, river navigation, recreational opportunities while minimizing their effect on the environment. A list of the hydroelectric plants can be found in Appendix 19.

The next area that TVA has expanded in recent years is their natural gas and fuel oil sector which current operates 101 generators at 17 sites within 4 states. Going from 7% to 26% of their total generation between 2005 and 2020, these plants have assisted greatly with replacing the coal generation TVA owns. Natural gas is noted to have a higher operating cost than other generation sources for TVA, although, with their fast start times and flexibility, they are vital to the power mix to meet peak demand and reduce the cost of electricity during peak demand times. Exchanging these plants from the coal generation TVA once had, has improved air quality drastically including a 60% decrease in carbon dioxide emissions. To further increase the ecological effect these plants have, they recycle water and captured methane gas from wastewater treatment plants nearby. A list of TVA's natural gas and fuel oil plants can be found in Appendix 20.

Further growth away from coal and emission-emitting generation can be seen in TVA's renewable energy sector which includes solar, wind, and biogas plants which makes up 3% of their generation mix. In 2016, TVA opened 20 MW of solar capacity mostly including rooftop solar for an integrated consumer. Due to solar being so costly for the utility, TVA has focused efforts into encouraging consumer solar, rather than utility solar to assist with the cost. In 2001, TVA had its first commercial-scale solar farm that was expanded in 2004. TVA also purchases electricity from 9 wind farms throughout the Midwest. This, rather than building new wind farms, was another way that TVA has increased its renewable capacity without investing heavily in infrastructure and construction costs. For biogas, TVA operates a methane gas recovery project in Memphis Tennessee that uses captured methane to produce electricity. This plant contributes 5 MW to the TVA generation fleet.

With expanding gas, increased efficiency in nuclear, and growth in renewables, TVA has successfully decommissioned 5 coal plants: Wilson Steam Plant, Watts Bar Steam Plant, John Sevier Steam Plant, Widows Creek Fossil Plant, and Colbert Fossil Plant. and reduced its generation reliance on coal from 57% in 2005 to 19% in 2020. The Wilson Steam Plant was built solely out of an accelerated increase in demand at the time and was not built for long term use. It was therefore only operational between 1919-1996 and demolished in 1968. Watts Bar Steam Plant was the first TVA built plant, operational from 1942-1982 and demolished in 2011. This plant was replaced by the nuclear and hydroelectric dams that produce power at the same location as the now-nonexistent coal plant. The John Sevier Steam Plant has not yet been demolished and was operational between 1955-2012. It was closed due to the build of the John Sevier Combined Cycle Plant. Otherwise, a direct replacement of coal with a natural gas plant. The Widows Creek Fossil Plant was operational between 1952-2015 and was outpaced in generating capacity and cost during construction of its final unit and therefore decommissioned. Colbert Fossil Plant was operational between 1951-2016, with its last addition being completed in 1965. While this plant was the lowest cost/kW of any plant built during its time, it has since been outpaced by the natural gas and hydroelectric industries. Operating coal plants include Bell Run, Cumberland, Gallatin, Kingston, and Shawnee. These operational plants are either soon to be decommissioned or have introduced higher efficiencies with emission capture systems so that they can be viable longer.

Fleet evolution for TVA shows a future in distributed generation resources, improving current plant performances, new generation within the current fleet, and increasing their reliability on renewables. TVA is also targeting optimization of their transmission systems and fleet flexibility.

Decommissioned Plants

When deciding to retire a plant, owners examine the costs of decommissioning associated with different plants and opportunities for growth elsewhere. Key issues with decommissioning include large costs with environmental remediation, monitoring residuals, and state and local policies as well as economic and fiscal impacts in rural areas. As of 2015, 6,300 electric generating units over 40 years old were operating covering 1/3rd of the nation's total generating capacity. Many older units are expected to retire over the next decade. With this, we can expect the generation fleet to change as they will not be replaced with the same generation type as is being decommissioned. However, there has to be careful consideration when decided which plants to retire as it will affect the local economics and plant owners should work to minimize this negative impact.

Total plant retirements greater than 100MW across the US for all main generation types between 2000-2015 can be seen in Figure 11 from (Raimi, 2017).

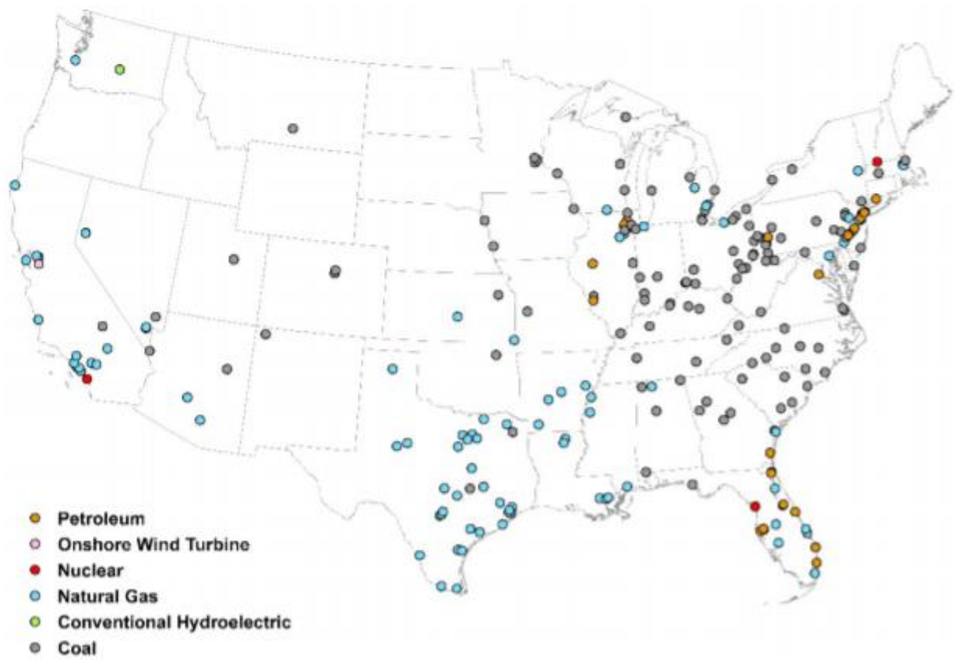

Figure 11 Power Plant Retirements (>100MW), 2000-2015

There is a prevalence of coal-fired retirements in the Midwest and Southeast a significant retirement of petroleum plants in Florida, New Jersey, and New York. The oldest operating plants follow similar geographic and fuel-specific trends. Most of the aging coal is concentrated in the Midwest and Southeast while older petroleum is located in the Northeast. Natural gas is aging out across the US but has concentrations in Texas, California, Oklahoma, and Northeast of the Gulf Coast.

Decommissioning any plant has four major phases: site assessment, project planning, project implementation, and project closure. EPRI has developed reports and guidelines for plant owners by providing established workflows to accomplish decommissioning objectives.

Decommissioned Nuclear

Nuclear plants around the United States have been decommissioned for various reasons, include: politics, special interest groups, public pressure, technology failures, or economics. The list of reactors within the United States that have gone into permanent shutdown and expansion construction projects that were canceled can be found in Appendix 21.

Organizations involved in the decommissioning of nuclear power plants include feral agencies such as the NRC, EPA, OSHA, and DOT. State and local agencies are also regulators of worker and public health and safety. Additionally, EPRI plays a part to develop decontamination techniques.

For nuclear, the retirement process involves disposing nuclear waste and decontaminating equipment and facilities to reduce the residual radioactivity. This causes the process to become more expensive and time consuming than retiring over types of power plants. Since 2013, nine commercial reactors have been shut down and plant have been announced to retire another 8 reactors by 2025. As of 2019, eleven commercial reactors have been successful decommissioned and another 21 are in different stages of the decommissioning process.

Licensees can choose from the following 3 decommissioning strategies: DECON, SAFSTOR, and ENTOMB. DECON refers to an immediate dismantling of the plant starting soon after the facility officially closes. Equipment structures and portions of the facility that contain radioactive containments are removed or decontaminated to levels that permits release of the property and termination of the license. SAFSTOR is referred to as deferred dismantling where the nuclear facility is maintained and monitored in a condition that allows the radioactivity to decay. Once it is at a safe level, the plant is dismantled, and the property is decontaminated. ENTOMB is when the radioactive contaminates are permanently encased on-site in structurally sound material, like concrete. With this the facility is maintained and monitored until the radioactivity decays to a level permitting restricted release of the property. There are currently no NRC licensed facilities that have used this option. Licensees can also choose a combination of DECON and SAFSTOR. The decision are based on factors other than radioactive decay, like the availability of waste disposal sites. Decommissioning must be finished within 60 years of the plant ceasing operations though extensions are considered if it protects the public health and safety under NRC regulations. The most recently decommissioned reactor was the Connecticut Yankee facility that was shut down in 1996 and finished their DECON decommissioning process in 2007 with a total cost of approximately $893M. Locations and statuses of decommissioning plants can be found in Figure 12.

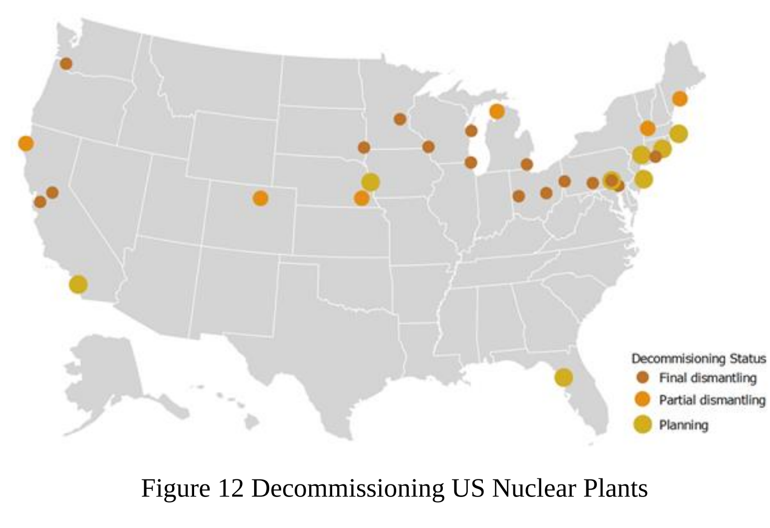

Figure 12 Decommissioning US Nuclear Plants

Decommissioned Coal

Within the United States, 121 coal plants were either converted or replaced within 2011-2019. 103 of these were replaced with natural gas, as it is the quickest and cheapest option to replace the level of production of the coal plant the utility is decommissioning. Figures 13 and 14, from (Aramayo, 2020), depict the various coal plants that were converted to natural gas throughout the United States between 2011 and 2019. Figure 13 represents the size and location of the plants and Figure 14 shows how the coal plants were phased out over time.

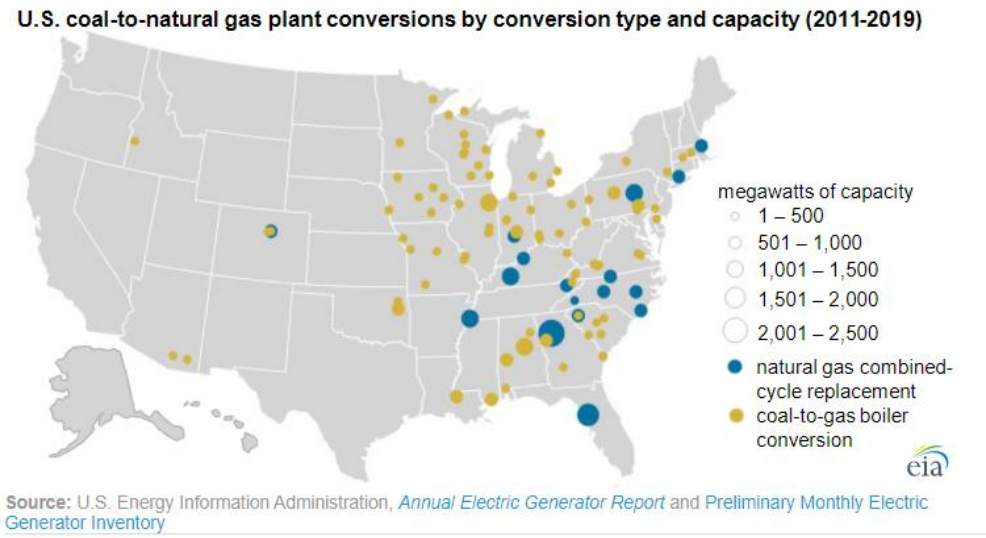

Figure 13 US Coal to Natural Gas Conversion Map

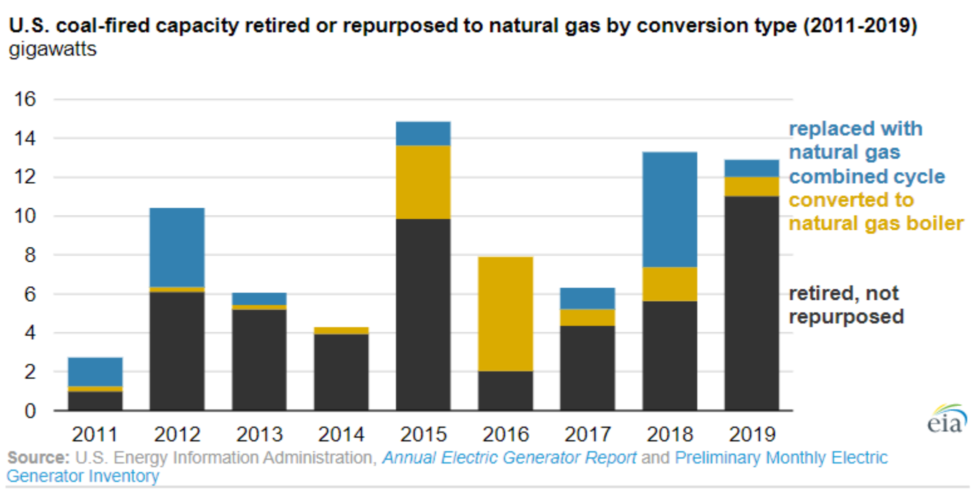

Figure 14 US Coal to Natural Gas Conversion Over Time

The main drivers for these conversions were stricter emissions standards on plants that were costly to implement, low natural gas prices that made swapping the plants a viable option, and efficiency new natural gas turbine technology that was implemented for a more efficient future. There were two methods used for converting coal to natural gas. The first being the retire the plant and replace it with a new natural gas plant. The second includes converting the boiler to burn other fuel, like natural gas, petroleum coke, pulp, or wood waste solids. Majority of the coal plants that were decommissioned used the second method.

Of the utilities that decommissioned coal between 2011-2019, Alabama Power Co completed the most conversions. These were mostly finished between 2015-2016 and were done to comply with the Mercury and Air Toxics Standards (MATS) put in place by the US EPA.

Moving forward, there are 8 natural gas combined cycle coal conversion projects in progress within the United States. For full decommissioning of the coal side of the plants, the process has become more costly due to recent federal regulations. A 2009 study estimated that closing all 155 “wet” ash coal plants in the US will cost roughly $39B over 10 years and billions more for long-term monitoring and remediation. Figure 15, from (Raimi, 2017) shows the costs for coal plant closures in 2016 based on their capacity.

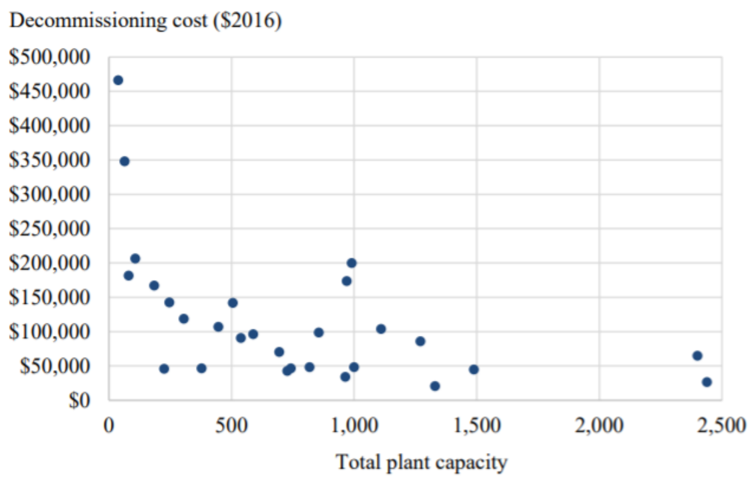

Figure 15 US Coal Decommissioning Costs for 2016 Based on Capacity

Decommissioned Natural Gas

While natural gas has started to increase in its use around the US, there are some states where natural gas has been decommissioned heavily. Texas, for example, has retired 62 natural gas steam turbines which covers approximately 12,000 MW of generating capacity. California followed behind by retiring 6,810 MW of natural gas capacity and then Florida who retired 71 natural gas fired units for a total of 2000 MW. As of 2015, 535 natural gas units were over 50 years old and 133 had announced retirement dates. Decommissioning these plants requires dismantling generation units and removing and managing fuel storage tanks, pipelines, and other equipment. As for costs, decommissioning natural gas has a broad range of estimates that show scaling with plant capacity. Figure 16, from (Raimi, 2017), shows the decommissioning costs per MW from 2016 for select gas and petroleum plants based on their capacity.

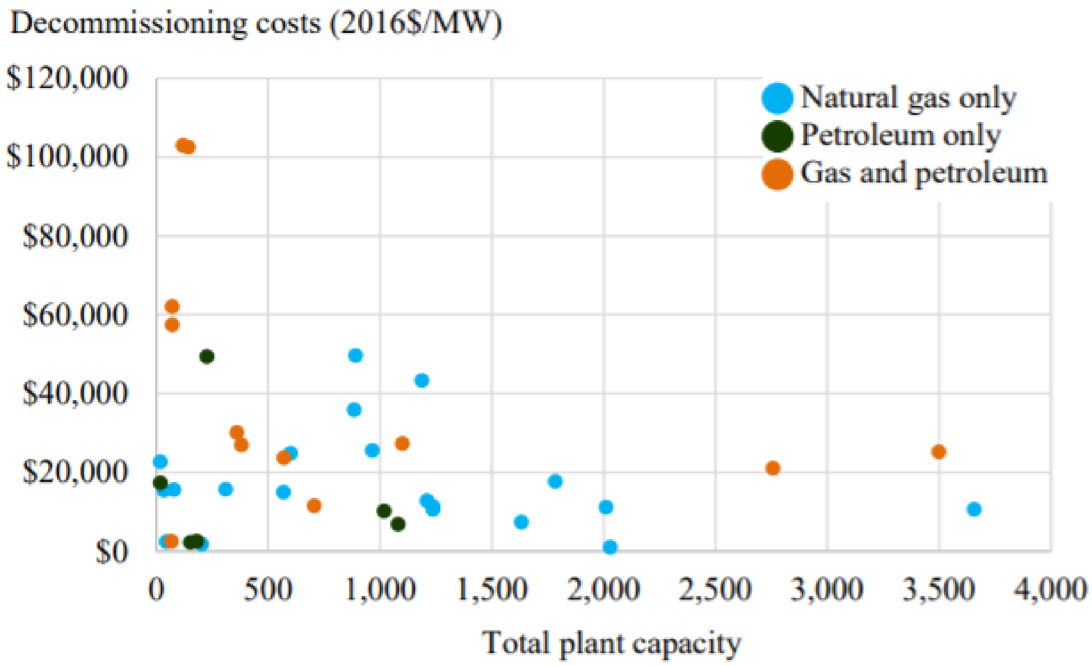

Figure 16 Natural Gas Decommissioning Costs Based on Total Plant Capacity in 2016

New Build Power Generation

Primary drivers for new capacity is the retirement of older, less-efficient fossil fuel units. There is also a near-term availability of renewable energy tax credits and a continued decline in the capital cost of renewables and natural gas prices. With favorable costs for renewables and natural gas it is expected that they will be the primary sources across through 2050. The EIA's history and estimation of the future of renewable generation can be seen in Figure 17 from (US Energy Information Administration, 2020).

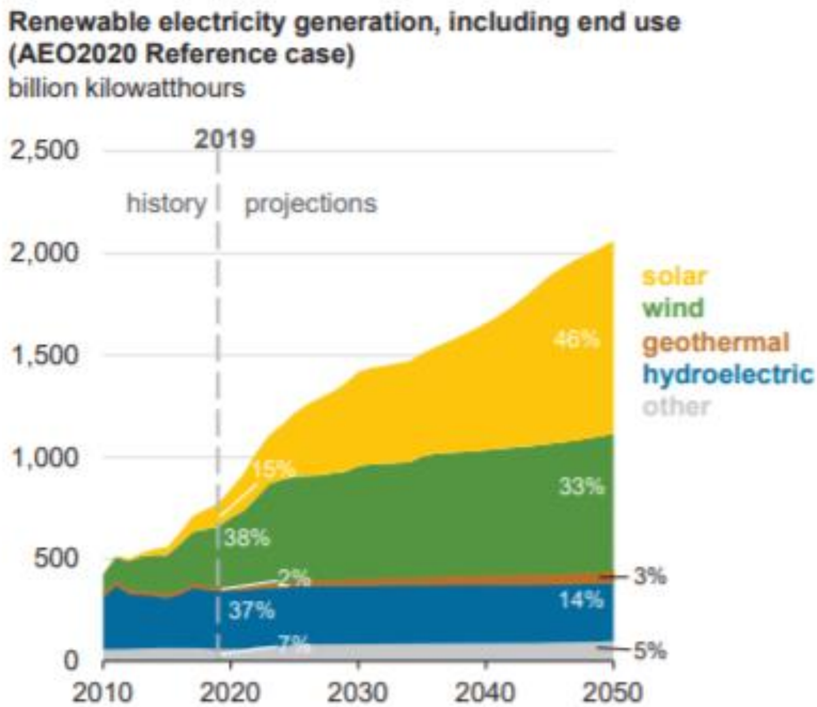

Figure 17 Renewable Generation and End Use

It is noted that results are dependent on the natural gas resource and price assumptions as natural gas will fulfill incremental demand and increase in the later project years. Additionally, combined cycle and solar PV are the most economically competitive generating technologies.

New Build Nuclear

New nuclear builds start with applications submitted through the US Nuclear Regulatory Commission (NRC). After application approval, they can then go through various stages of builds. Many new builds submitted to the NRC have not been started and are often repeal the application before construction starts. Locations of new nuclear power reactor applications can be seen in Figure 18 from (United States Nuclear Regulatory Commission, 2019). A list of these reactor applications and their current status can be found in Appendix 22.

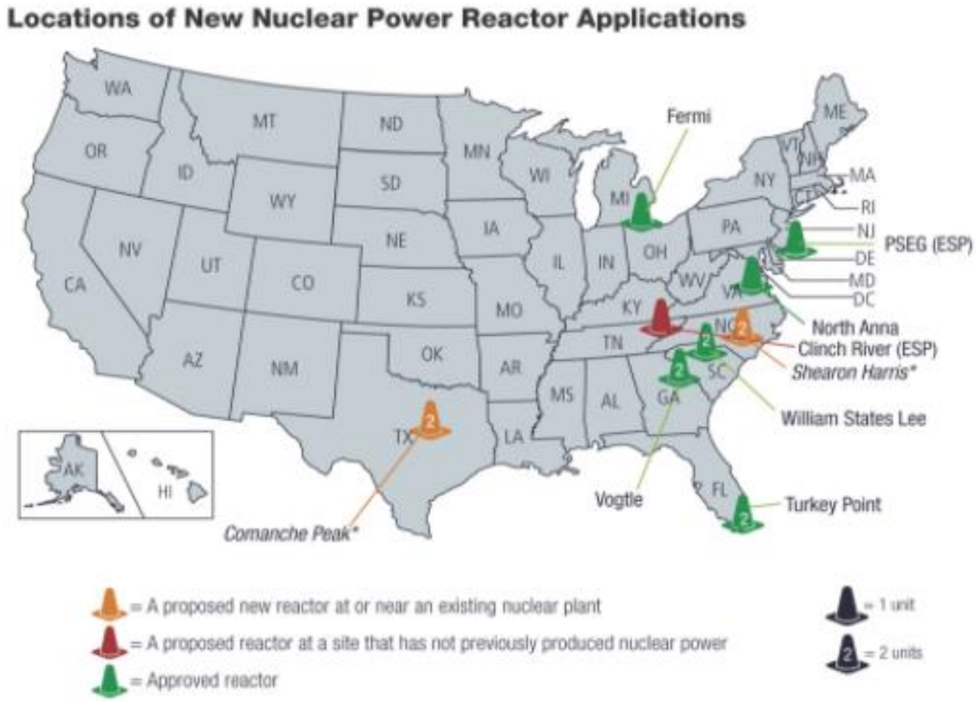

Figure 18 US New Nuclear Power Reactor Applications

Organizations involved in the construction of nuclear power plants includes Westinghouse Corporation, Combustion Engineering, Babcock and Wilcox, General Electric, Brookfield Business Partners, and the ASME for certifications of equipment suppliers.

Watts Bar Unit 2 started construction and was placed on hold in 1985 when it was 60% completed. Then, in 2007 Bechtel started up the construction again and finished the new reactors in 2015. By October 2016, the plant had achieved commercial operation. This was the most recently completed new reactor in the United States and helped replace older, costly, less efficient coal units that were being retired in the area. This reactor was also the first reactor to be built to the NRC's new requirements.

Within the last 10 years there have been two nuclear plants that have started construction on new reactors, V.C. Summer and Vogtle. They have taken different paths and have lead the industry in two ways. V.C. Summer's expansion was started in 2008 as a shared effort between SCANA and Santee Cooper, the two companies who owned the station. They had planned to build reactors 2 and 3, both planned as AP1000's, at the existing plant to support the electricity demand growth in South Carolina. The expansion project, in total, lasted 10 years and cost $9B but was not completed due to delays and cost overruns. SC utility customers were charged for project related fees on their electricity bills through the timeline due to the Base Load Review Act that was passed in 2007 allowing utilities to raise rates to build reactors under construction and plants not completed. In 2017, Westinghouse filed for bankruptcy due to the project cost overruns citing $9B loss from the project. Shortly after, SCANA and Santee Cooper announced they were abandoning the project and ceased construction. After a few lawsuits to get the consumer's their money back and get the appropriate answers about the project, Dominion energy purchased SCANA corp and took over the VC Summer plant and associated projects. As of September 2018, the NRC transferred all licenses to Dominion Energy and left the final transfer up to the state legislators. In November of 2019, Dominion Energy announced they were shutting down reactor 1 at the VC Summer plants after a small leak in the coolant system. In total, this new build is liked to multiple bankruptcy's, a buy-out, customers who financially supported the build that will never see the plant active, and a fully shut down nuclear power plant for South Carolina. On the other end, we have the nuclear power plant Vogtle, in Georgia that is building two AP1000's as an expansion project to the two reactors that are already operational at the site. Construction started in 2013 for both new reactors and was originally awarded to Westinghouse. However, after going bankrupt from VC Summer, Westinghouse had to give the project to Bechtel, an American engineering and construction company. So far, the two reactors are on schedule to become fully operational within 2021, and 2022. Other new builds within the United States are planning to start once Vogtle starts operation so they can use it as an example for their own constructions.

In the US, the DOE leads the effort for ANR's as a resource capable of meeting the nation's energy, environmental, and national security needs by resolving technical, cost, safety, proliferation, resistance, and security barriers through research and development and demonstration as appropriate. The main objectives of the Nuclear Energy R&D roadmap include: light water reactor sustainability project; next generation nuclear plant, advanced reactor concepts, and advanced small modular reactor programs; the office of fuel cycle technologies; and the nuclear energy enabling technologies program.

Internationally, the US cooperates with partners for advancing nuclear through Generation IV International Forum, Nuclear Energy Agency of the Organization for Economic Co-operation and Development, IAEA, and International Framework for Nuclear Energy Cooperation. The DOE collaborates through research and development and related issues with the International Nuclear Energy Research Initiative, negotiated agreements, memoranda of understanding, technical action plants, working groups, and the International Nuclear Cooperation Framework. The Office of International Energy Policy and Cooperation (INEPC) oversees and manages the DOE's international commercial nuclear fuel management initiatives and supports the DOE and government initiatives to foster increases in US exports of nuclear fuel and services. The NRC works with 35 countries and conducts confirmatory regulatory research in partnership with nuclear safety agencies and institutes in over 20 countries.

New Build Natural Gas

Natural gas generation within the United States was increased by 19% in 2015. This started the curve to new natural gas throughout the United States and was prompted by the low price, increased capacity compared to similarly sized coal plants, and coal retirements that were underway. Within the mid-Atlantic states most capacity additions are near the Marcellus and Utica shale regions including Pennsylvania, West Virginia, and Ohio. Ohio has added 10 new plants combining for a total of 9,294 MW of generation capacity and reducing their overall electricity emissions by 50 MMT converting away from coal. They are currently leading the nation in reduced emissions. Pennsylvania was higher in new plants and capacity at 19 new plants and 14,737 MW of new natural gas capacity. However, they only reduced their overall electricity emissions by 36.7 MMT. West Virginia was able to come in third across the US by adding 3 new natural gas plants for 2,055 MW and reducing their electricity emissions by 19.1 MMT. Infrastructure was also added to transport natural gas to population centers along the Atlantic coast. A map of new natural gas construction between 2016 and 2018 can be seen in Figure 19.

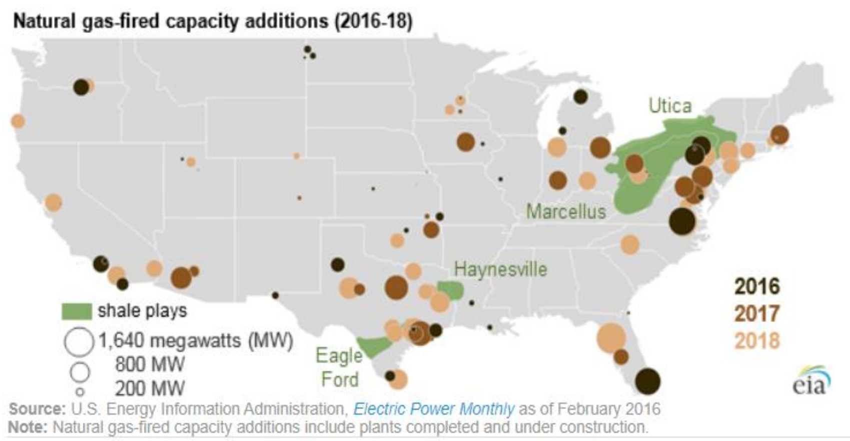

Figure 19 Natural Gas Additions in the US between 2016-2018

The main region driving the growth of US natural gas production is the Appalachian Basin. This area alone has 29 new natural gas plants in various stages of permit, construction, or new operation to add over 26 TW of electricity capacity to the area. With this growth, carbon emissions have also increased within the area. Between 2005-2015 this area accounted for 21.5% of the total US carbon emissions in electricity generation.

New Build Renewable

There are currently 12,000 major solar projects around the US to soon provide an additional 160GW of generation capacity. The locations and capacity sizes of these projects can be seen in Figure 20 from (Solar Energy Industries Association, 2020)

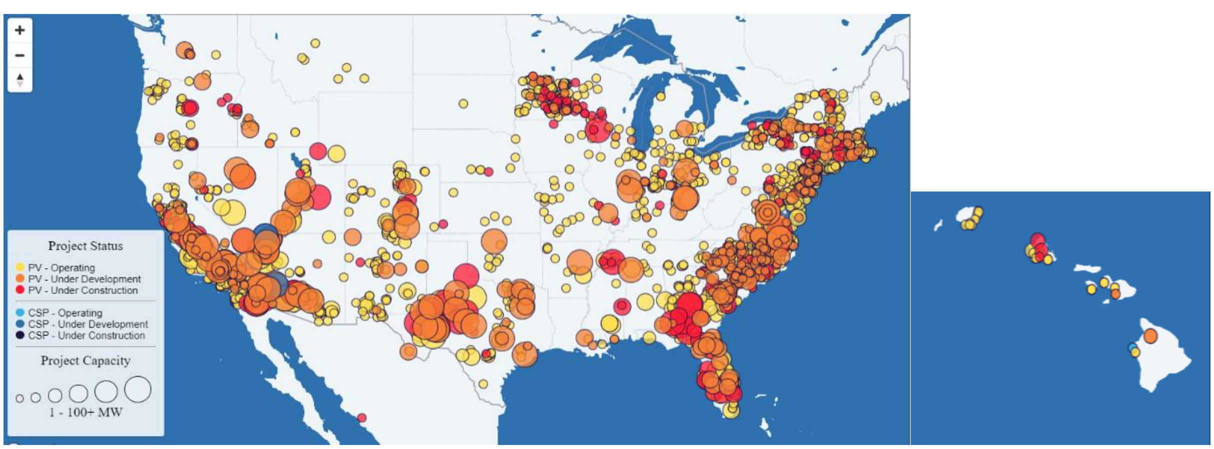

Figure 20 Planned Solar Projects Within the United States

In quarter two of 2020 the US installed 3.5 GW of solar PV. Residential installations were down 23% from quarter one to quarter two due to shelter-in-place. Solar has been 37% of all new electricity generation added in the US this year. There is a forecast of 37% annual growth in 2020 with over 18 GW in installations. The US solar market plans on installing 100 GW between 2021-2025 which comes out to approximately 42% than installed over the last 5 years. By 2025 it is expected that 1/5th of new utility PV systems and 1/3 new residential solar and ¼ new nonresidential will be paired with energy storage solutions.

Utility scale PV had a strong growth recently and reached a new milestone with over 50 GW in operation. In 2011, the US had its first GW of utility solar capacity. The contracted pipeline is at an all-time high of 62.2 GW with strong demand across the US since it is cost-competitive with natural gas. However, major projects cannot access funding causing a risk of cancellation in large projects. As demand grows, and utilities announce solar procurement targets to meet aggressive state renewable targets, smaller projects are likely to be passed over by investors who do not want to work with less-established developers.

Projects with an original target operation dates in 2021 are being pushed out to 2022-2023 due to the funding and procurement pipeline struggles they face. However, there is a decline in estimated solar growth between 2024-2025 as that is when the federal ITC runs out. It is expected that developers will bring 2024 projects forward into 2023 to keep the tax incentives.

Wind is noted as the fastest-growing source of new electricity supply and the largest source of new renewable power generation added in the US since 2000. It is expected that by 2030 wind will contribute as 20% of the US generation capacity and it will be 35% by 2050. Since 2008, wind has scaled in domestic manufacturing which has driven down power costs by approximately a third. Utility scale wind is cost-effective where wind power is capable of being installed. Between 2008 and 2013 there were approximately $13B per year in new investments. With the new domestic manufacturing, imports for this power generation have decreased from 80% in 2006 to now only 30% between 2012 and 2013.

Summary and Conclusions

Specific challenges prevent the US from building up their nuclear energy resources including public awareness of its stability and safety; used fuel transportation, storage, and disposal; construction costs and high capital costs; and high operating costs. However, its benefits show that it is the largest source of clean power. Its thermal energy can be used for decarbonizing other energy sectors. Nuclear is also a reliable source of base power and supports national security. Nuclear plants are actively being decommissioned for a variety of reasons including public influence, economics, and technological or structural failures that are too costly to fix at the time. With these influences in the nuclear market, plant Vogtle is the newest plant to have what is expected to be a successful expansion and is leading the industry on a new build of two AP1000 reactors. Other nuclear development projects that have been announced and approved by the NRC are expected to start construction after Vogtle becomes operational. Additionally, the federal government has released recent legislation to assist with the continued research and advancement in the nuclear industry for things like advanced nuclear reactors and fuel management showing a promise for nuclear growth in the future within the United States.

With the influence of state and federal regulations and an attempt to curb climate change and reduce emissions, large scale growth has occurred in gas, wind, and solar. These developments have changed the nation's electricity mix over the last decade while coal plants have shown high retirement or repurposing during the same period as they are being replaced. It is projected that 1529 GW of generation that is a combination of solar, wind, natural gas, nuclear and hydroelectric could cover the US power needs and reduce carbon dioxide emissions by 78%. This could also keep costs lower than current projections by having a diversified generation fleet. If the market stays as it is today with high-cost renewables and low-cost natural gas, there will still be emissions reductions as the United States will continue their natural gas use and growth to keep costs down for electricity generation. With the current progress of the United States electricity generation sector showing extended growth in natural gas, solar, and wind over the next few decade, it is possible that the natural gas sector will only be put in place to retire coal plants and allow enough time for advanced nuclear reactors designs to be tested and built.

Finally, to support the use of renewable energy generation to fully support electricity demand, battery storage solutions and the smart grid technologies are being explored and implemented. These solutions will assist in the regulation, efficiency, and availability of electricity with the new renewable-heavy generation fleet. The smart grid will also lead to a more sustainable future and allow for the free growth of the consumer and small-scale generation sector.

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Appendices

Appendix 1: Events at Fukushima Daiichi Units 1-3 Following the Earthquake

Event sequence following earthquake (timing from it: 14:46, 11 March)

	Unit 1	Unit 2	Unit 3
Loss of AC power	+ 51 min	+ 54 min	+ 52 min
Loss of cooling	+ 1 hour	+ 70 hours	+ 36 hours
Water level down to top of fuel*	+ 3 hours	+ 74 hours	+ 42 hours
Core damage starts*	+ 4 hours	+ 77 hours	+ 44 hours
Reactor pressure vessel damage*	+11 hours	uncertain	uncertain
Fire pumps with fresh water	+ 15 hours		+ 43 hours
Hydrogen explosion (not confirmed for unit 2)	+ 25 hours service floor	+ 87 hours suppression chamber	+ 68 hours service floor
Fire pumps with seawater	+ 28 hours	+ 77 hours	+ 46 hours
Off-site electrical supply	+ 11-15 days		
Fresh water cooling	+ 14-15 days		

* according to 2012 MAAP analysis

Appendix 2: Active US Nuclear Reactors

Reactor Unit	Type	Operator
ANO-1	PWR	ENTERGY
ANO-2	PWR	ENTERGY
BEAVER VALLEY-1	PWR	FENOC
BEAVER VALLEY-2	PWR	FENOC
BRAIDWOOD-1	PWR	EXELON
BRAIDWOOD-2	PWR	EXELON
BROWNS FERRY-1	BWR	TVA
BROWNS FERRY-2	BWR	TVA
BROWNS FERRY-3	BWR	TVA
BRUNSWICK-1	BWR	PROGRESS
BRUNSWICK-2	BWR	PROGRESS
BYRON-1	PWR	EXELON
BYRON-2	PWR	EXELON
CALLAWAY-1	PWR	AmerenUE
CALVERT CLIFFS-1	PWR	EXELON
CALVERT CLIFFS-2	PWR	EXELON
CATAWBA-1	PWR	DUKEENER
CATAWBA-2	PWR	DUKEENER
CLINTON-1	BWR	EXELON
COLUMBIA	BWR	ENERGYNW
COMANCHE PEAK-1	PWR	LUMINANT
COMANCHE PEAK-2	PWR	LUMINANT
COOK-1	PWR	AEP
COOK-2	PWR	AEP
COOPER	BWR	ENTERGY

DAVIS BESSE-1	PWR	FENOC
DIABLO CANYON-1	PWR	PG&E
DIABLO CANYON-2	PWR	PG&E
DRESDEN-2	BWR	EXELON
DRESDEN-3	BWR	EXELON
DUANE ARNOLD-1	BWR	NEXTERA
FARLEY-1	PWR	SOUTHERN
FARLEY-2	PWR	SOUTHERN
FERMI-2	BWR	DTEDISON
FITZPATRICK	BWR	EXELON
GINNA	PWR	EXELON
GRAND GULF-1	BWR	ENTERGY
HARRIS-1	PWR	PROGRESS
HATCH-1	BWR	SOUTHERN
HATCH-2	BWR	SOUTHERN
HOPE CREEK-1	BWR	PSEG
INDIAN POINT-2	PWR	ENTERGY
INDIAN POINT-3	PWR	ENTERGY
LASALLE-1	BWR	EXELON
LASALLE-2	BWR	EXELON
LIMERICK-1	BWR	EXELON
LIMERICK-2	BWR	EXELON
MCGUIRE-1	PWR	DUKEENER
MCGUIRE-2	PWR	DUKEENER
MILLSTONE-2	PWR	DOMINION
MILLSTONE-3	PWR	DOMINION
MONTICELLO	BWR	NSP

NINE MILE POINT-1	BWR	EXELON
NINE MILE POINT-2	BWR	EXELON
NORTH ANNA-1	PWR	DOMINION
NORTH ANNA-2	PWR	DOMINION
OCONEE-1	PWR	DUKEENER
OCONEE-2	PWR	DUKEENER
OCONEE-3	PWR	DUKEENER
PALISADES	PWR	ENTERGY
PALO VERDE-1	PWR	APS
PALO VERDE-2	PWR	APS
PALO VERDE-3	PWR	APS
PEACH BOTTOM-2	BWR	EXELON
PEACH BOTTOM-3	BWR	EXELON
PERRY-1	BWR	FENOC
POINT BEACH-1	PWR	NEXTERA
POINT BEACH-2	PWR	NEXTERA
PRAIRIE ISLAND-1	PWR	NSP
PRAIRIE ISLAND-2	PWR	NSP
QUAD CITIES-1	BWR	EXELON
QUAD CITIES-2	BWR	EXELON
RIVER BEND-1	BWR	ENTERGY
ROBINSON-2	PWR	PROGRESS
SALEM-1	PWR	PSEG
SALEM-2	PWR	PSEG
SEABROOK-1	PWR	NEXTERA
SEQUOYAH-1	PWR	TVA
SEQUOYAH-2	PWR	TVA

SOUTH TEXAS-1	PWR	STP
SOUTH TEXAS-2	PWR	STP
ST. LUCIE-1	PWR	FPL
ST. LUCIE-2	PWR	FPL
SUMMER-1	PWR	SCE&G
SURRY-1	PWR	DOMINION
SURRY-2	PWR	DOMINION
SUSQUEHANNA-1	BWR	PPL_SUSQ
SUSQUEHANNA-2	BWR	PPL_SUSQ
TURKEY POINT-3	PWR	FPL
TURKEY POINT-4	PWR	FPL
VOGTLE-1	PWR	SOUTHERN
VOGTLE-2	PWR	SOUTHERN
WATERFORD-3	PWR	ENTERGY
WATTS BAR-1	PWR	TVA
WATTS BAR-2	PWR	TVA
WOLF CREEK	PWR	WCNOC

Appendix 3: US Cost and Performance of Generation Technologies.

Technology	First available year[1]	Size (MW)	Lead time (years)	Base overnight cost[2] (2019 $/kW)	Techno-logical optimism factor[3]	Total overnight cost[4,5] (2019 $/kW)	Variable O&M[6] (2019 $/MWh)	Fixed O&M (2019$/ kW-yr)	Heat rate[7] (Btu/kWh)
Ultra-supercritical coal (USC)	2023	650	4	3,661	1.00	3,661	4.48	40.41	8,638
USC with 30% carbon capture and sequestration (CCS)	2023	650	4	4,539	1.03	4,652	7.05	54.07	9,751
USC with 90% CCS	2023	650	4	5,851	1.03	5,997	10.93	59.29	12,507
Combined-cycle—single shaft	2022	418	3	1,079	1.00	1,079	2.54	14.04	6,431
Combined-cycle—multi shaft	2022	1,083	3	954	1.00	954	1.86	12.15	6,370
Combined-cycle with 90% CCS	2022	377	3	2,470	1.04	2,569	5.82	27.48	7,124
Internal combustion engine	2021	21	2	1,802	1.00	1,802	5.67	35.01	8,295
Combustion turbine—aeroderivative[8]	2021	105	2	1,170	1.00	1,170	4.68	16.23	9,124
Combustion turbine—industrial frame	2021	237	2	710	1.00	710	4.48	6.97	9,905
Fuel cells	2022	10	3	6,671	1.10	7,339	0.59	30.65	6,469
Advanced nuclear	2025	2,156	6	6,016	1.05	6,317	2.36	121.13	10,461
Distributed generation—base	2022	2	3	1,555	1.00	1,555	8.57	19.28	8,946
Distributed generation—peak	2021	1	2	1,868	1.00	1,868	8.57	19.28	9,934
Battery storage	2020	50	1	1,383	1.00	1,383	0.00	24.70	NA
Biomass	2023	50	4	4,080	1.01	4,104	4.81	125.19	13,500
Geothermal[9,10]	2023	50	4	2,680	1.00	2,680	1.16	113.29	9,156
Municipal solid waste—landfill gas	2022	36	3	1,557	1.00	1,557	6.17	20.02	8,513
Conventional hydropower[10]	2023	100	4	2,752	1.00	2,752	1.39	41.63	NA
Wind[5]	2022	200	3	1,319	1.00	1,319	0.00	26.22	NA
Wind offshore[9]	2023	400	4	4,356	1.25	5,446	0.00	109.54	NA
Solar thermal[9]	2022	115	3	7,191	1.00	7,191	0.00	85.03	NA
Solar photovoltaic —tracking[5,9,11]	2021	150	2	1,331	1.00	1,331	0.00	15.19	NA

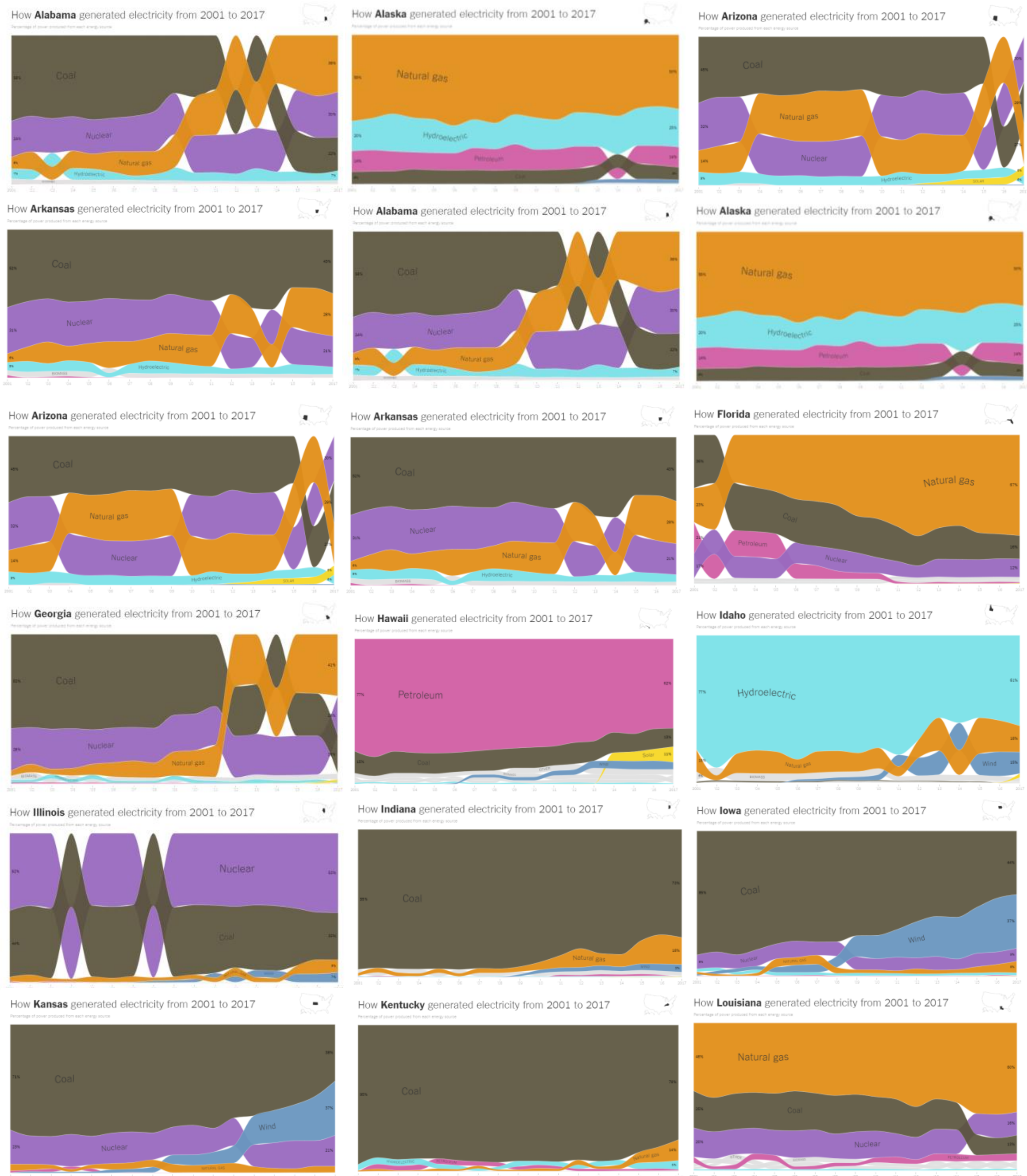
[1] Represents the first year that a new unit could become operational

Appendix 4: US Climate Alliance State Details

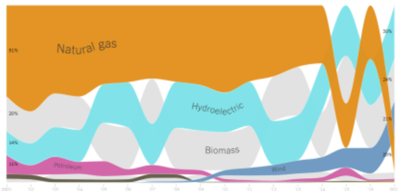
State	Year Joined	Emissions Reduction Target	Renewable Energy Target
California	2018	1990 levels by 2020, 40% below 1990 by 2030, carbon neutral by 2045	100 Renewable for retail sales by 2045
Colorado	2018	36% below 2005 by 2025. 50% by 2030, 90% by 2050	30% by 2020, 10-20% for smaller utilities
Connecticut	2018	10% below 1990 by 2020, 45% below 2001 by 2030, 80% below 2001 by 2050	40% by 2030
Delaware	2018	26-28% below 2005 by 2025	25% by 2025
Hawaii	2018	Carbon neutral by 2045	100% by 2045
Illinois	2019	26-28% below 2005 levels by 2025	25% by 2025
Maine	2018	45% below 1990 levels by 2030, at least 80% by 2050	80% by 2030, 100% by 2050
Maryland	2018	40% below 2006 levels by 2030 80-95% by 2050	50% by 2030
Massachusetts	2018	25% below 1990 levels by 2020 at least 80% by 2050	35% by 2030 with a 1% annual increase each year thereafter
Michigan	2019	20% below 2005 levels by 2020 80% by 2050	15% renewables by 2021 35% combined renewables and energy efficacy by 2025
Minnesota	2018	30% below 2005 by 2025 80% by 2050	25% by 2025 (excel energy 31.5% by 2020 other investor-owned utilities 26.5% by 2025)
Montana	2019	net zero GHG for average annual electric loads by 2035, net neutral GHG emissions economy-wide over the long term	15% by 2015
Nevada	2019	28% below 2005 levels by 2025, 45% by 2030, net zero by 2050	50% renewables by 2030, 100% carbon-free by 2050
New Jersey	2018	80% below 2006 levels by 2050 (reaching 1990 levels by 2020 has been achieved)	50% by 2030, 100% clean energy by 2025
New Mexico	2019	45% below 2005 levels by 2030	40% by 2045 and 50% by 2030 for investor-owned utilities and rural electric cooperatives. 80% by 2040 for investor-owned utilities and by 2050 for rural electric cooperatives

New York	2018	net zero by 2050	70% renewables by 2030 zero carbon by 2040
North Carolina	2018	40% below 2005 levels by 2025	12.5% renewable and/or energy efficiency by 2021
Oregon	2018	10% below 1990 levels by 2020, 75% by 2050	50% by 2040
Pennsylvania	2019	26-28% below 2005 levels by 2025 80% by 2050	8% from tier 1 sources and 10% from tier II sources by 2021
Puerto Rico	2018	50% within the next 5 years	40% by 2025, 60% by 2040, 100% by 2050
Rhode Island	2018	10% below 1990 levels by 2020, 45% by 2035, 80% by 2050	38.5% by 2035
Vermont	2018	40% below 1990 levels by 2030, 80-95% by 2050	55% tier 1 renewables by 2017, 75% by 2032
Virginia	2018	Unreported	30% by 2030, 100% carbon-free by 2050
Washington	2018	return to 1990 levels by 2020, 25% by 2035, and 50% by 2050	100% carbon neutral by 2030, 100% clean energy by 2045
Wisconsin	2019	Unreported	10% renewable by 2015, 100% zero carbon electricity by 2050

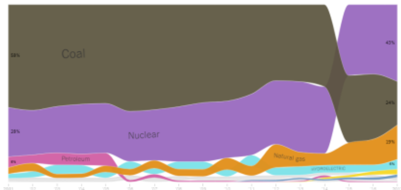
Appendix 5: State-Level Electricity Generation Changes Between 2001-2017



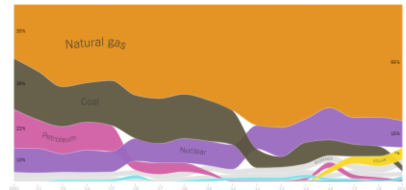
How **Maine** generated electricity from 2001 to 2017



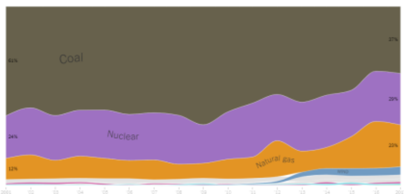
How **Maryland** generated electricity from 2001 to 2017



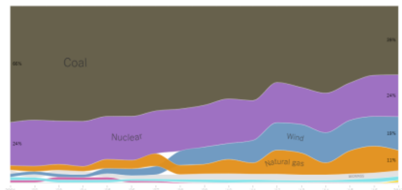
How **Massachusetts** generated electricity from 2001 to 2017



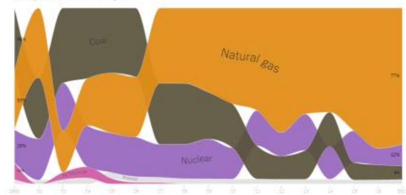
How **Michigan** generated electricity from 2001 to 2017



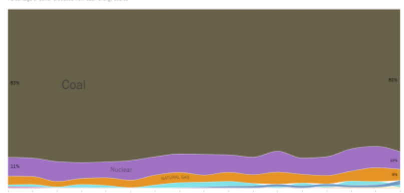
How **Minnesota** generated electricity from 2001 to 2017



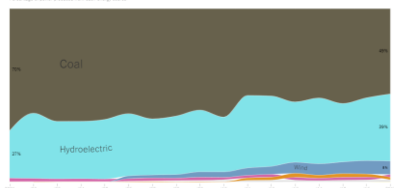
How **Mississippi** generated electricity from 2001 to 2017



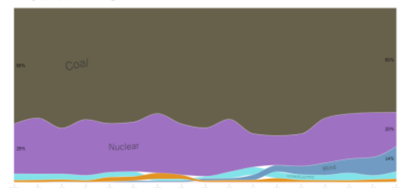
How **Missouri** generated electricity from 2001 to 2017



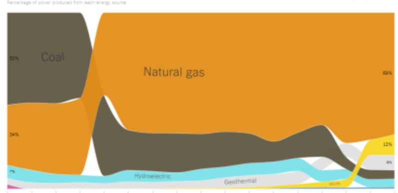
How **Montana** generated electricity from 2001 to 2017



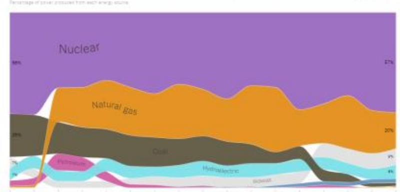
How **Nebraska** generated electricity from 2001 to 2017



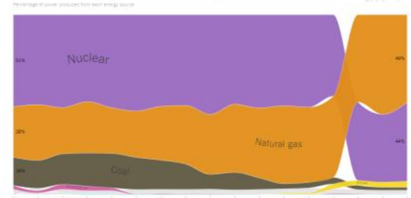
How **Nevada** generated electricity from 2001 to 2017



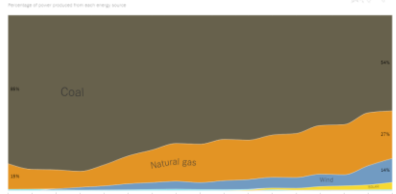
How **New Hampshire** generated electricity from 2001 to 2017



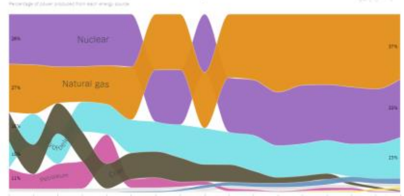
How **New Jersey** generated electricity from 2001 to 2017



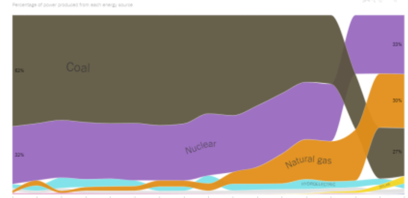
How **New Mexico** generated electricity from 2001 to 2017



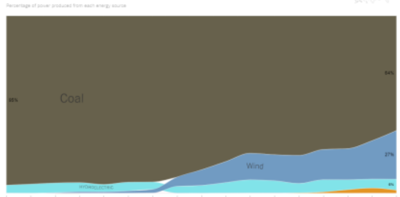
How **New York** generated electricity from 2001 to 2017



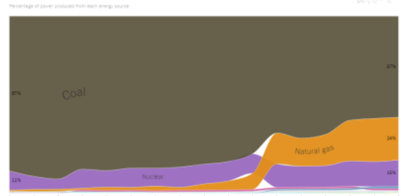
How **North Carolina** generated electricity from 2001 to 2017



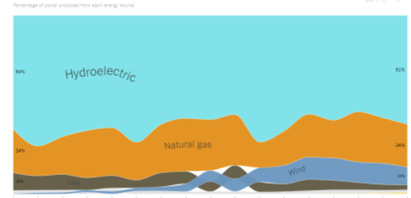
How **North Dakota** generated electricity from 2001 to 2017



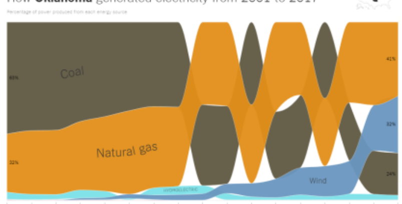
How **Ohio** generated electricity from 2001 to 2017



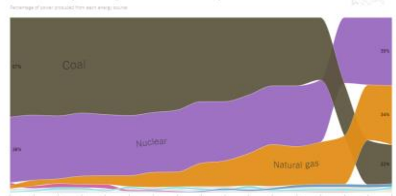
How **Oregon** generated electricity from 2001 to 2017



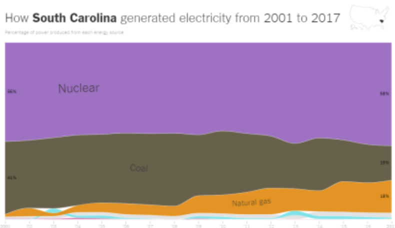
How **Oklahoma** generated electricity from 2001 to 2017

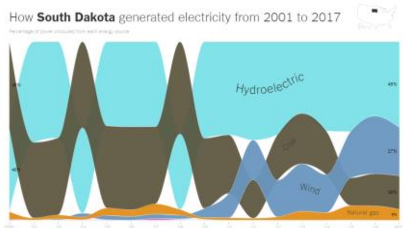


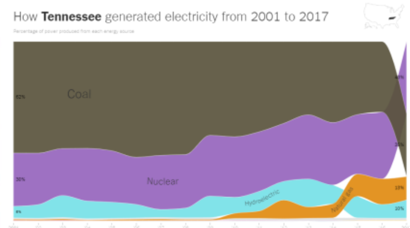
How **Pennsylvania** generated electricity from 2001 to 2017

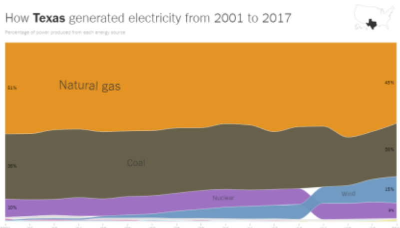


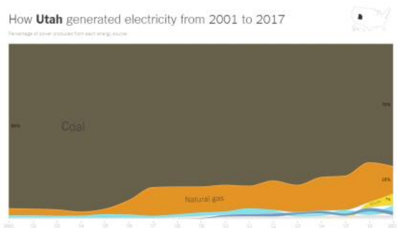
How **Rhode Island** generated electricity from 2001 to 2017

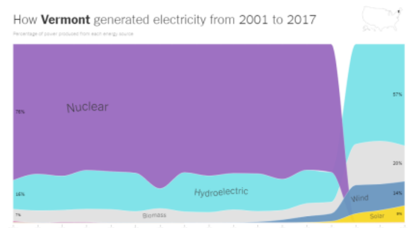

How South Carolina generated electricity from 2001 to 2017
Nuclear
Coal
Natural gas

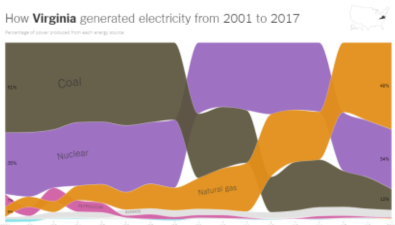

How South Dakota generated electricity from 2001 to 2017
Hydroelectric
Coal
Wind
Natural gas


How Tennessee generated electricity from 2001 to 2017
Coal
Nuclear
Hydroelectric

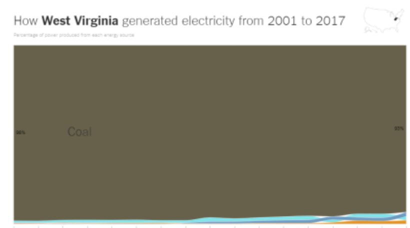

How Texas generated electricity from 2001 to 2017
Natural gas
Coal
Nuclear
Wind

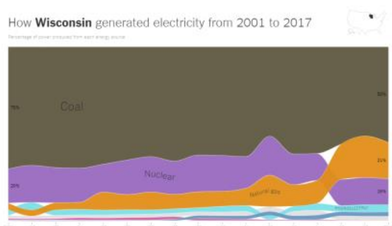

How Utah generated electricity from 2001 to 2017
Coal
Natural gas

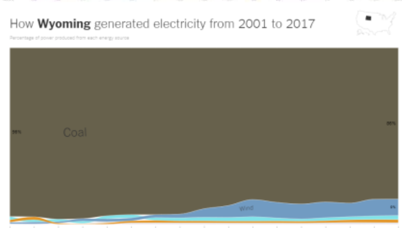

How Vermont generated electricity from 2001 to 2017
Nuclear
Hydroelectric
Biomass
Wind
Solar


How Virginia generated electricity from 2001 to 2017
Coal
Nuclear
Natural gas


How Washington generated electricity from 2001 to 2017
Hydroelectric
Nuclear
Natural gas
Wind


How West Virginia generated electricity from 2001 to 2017
Coal


How Wisconsin generated electricity from 2001 to 2017
Coal
Nuclear
Natural gas


How Wyoming generated electricity from 2001 to 2017
Coal
Wind

Appendix 6: Dominion Energy Solar

California
- Alamo Solar
- West Antelope Solar Park
- Cottonwood
- Catalina Solar 2
- CID Solar Project
- Apallo Solar
- Imperial Valley Solar Company 2
- Maricopa West
- Midway 2

Connecticut
- Somers Solar Center

Georgia
- Azalea Solar Power Facility
- Richland Solar Center

Indiana
- Indy Solar I
- Indy Solar II
- Indy Solar III

North Carolina
- Chestnut Solar
- Clipperton
- Fremont
- Gutenberg Solar
- IS37
- Moorings 2
- Morgans Corner
- Mustang Solar
- Pecan Solar
- Pikeville
- Siler Solar
- Summit Farms
- Wakefield Solar
- Wilkinson Solar

South Carolina
- Blackville
- Denmark
- Ridgeland Solar Project
- Seabrook
- Solvay Solar Energy Facility
- Trask East
- Yemasee

Tennessee
- Mulberry Farm
- Selmer Farm

Utah
- Pavant Solar Project
- Four Brothers
- Three Cedars

Virginia
- Bedford and Belcher
- Cherrydale
- Clarke County
- Colonial Trail West
- Spring Grove 1
- Dulles
- Fort Powhatan
- Greensville
- Myrtle
- Montross
- Gloucester
- Grasshopper
- Oceana
- Pumpkinseed Solar Project
- Remington
- Rochambeau
- Sadler
- Scott
- Whitehouse
- Woodland
- Solar Alliance with Amazon
- Tredegar Solar Canopy
- UVA Hollyfield
- UVA Puller Solar Field

Appendix 7: Dominion Energy Natural Gas

Facilities

- Bear Garden
- Bellemeade
- Bremo
- Brunswick County
- Chesterfield
- Cove Point
- Darbytown
- Elizabeth River
- Gordonsville
- Gravel Neck
- Greensville County
- Hastings Extraction Plant
- Ladysmith
- Remington
- Rosemary
- South Carolina Natural Gas Plants
- Warren County

Projects

- Eureka Project
  - 11 miles of high-pressure pipeline
  - 360 service lines to homes and businesses
  - Utah
- Salt Lake City System Improvement
  - Replacing aging natural gas pipelines under major streets
  - Utah
- Gas Feeder Line 43, 133, 122, 127
  - Relocating/replacing Feeder Line 43, 133, 122, 127
  - Utah
- Magna LNG
  - Alternate source of natural gas to customers
- Augusta Project
  - Meeting the needs of Ohio with Natural Gas
  - 2 gas fired compressor units and equipment
  - Upgrades to add capacity
- East Edisto Pipeline Project
  - New natural gas lines
  - South Carolina
- Buncombe County Pipeline Enhancement Project
  - 11 miles of pipeline upgrading the system to DOT regulations
  - North Carolina
- Wake to Chatham County System Enhancement Project
  - 5.5 mile gas line along roads
  - North Carolina
- Franklin and Wake County Extension Project
  - Extend current lines to reach new customers residential and business
  - North Carolina
- Pipeline Replacement and Expansion
  - Replacing 1000 miles of distribution pipeline
  - West Virginia
- Pipeline Infrastructure Replacement
  - Replacing 5500 miles of pipeline
  - Ohio
- River Neck to Kingsburg Pipeline Project
  - New natural gas line
  - South Carolina
- Short Creek Project
  - Updates to existing pipeline
  - Ohio
- Supply Header Project
  - Transport of natural gas from supply areas in OH PA WV to VA and NC
- Tri-West Project
  - Help serve the Midwest markets
- West Loop Project
  - Improving regional reliability
  - Providing new generation
  - Ohio

Appendix 8: Dominion Energy Coal and Oil

Chesterfield
Clover
Mt. Storm
Virginia City Hybrid Center
Possum Power
Yorktown
Low Moor
Northern Neck
Chesapeake Combustion Turbines
Darbytown
Elizabeth River
Gravel Neck
Remington
Ladysmith

Appendix 9: Dominion Energy Hydroelectric

Bath County Pumped Storage Station
Gaston Hydro Power Station
North Anna Hydro Power Station
Roanoke Rapids Hydro Power Station
Fairfield Pumped Storage
Neal Shoals Hydro
Parr Hydro
Saluda Hydro
Stevens Creek Hydro

Appendix 10: Duke Energy Renewables Projects

Ajo Solar
Bagdad Solar
Battleboro Solar
Bethel Price Solar
Black Mountain Solar
Blue Wing Solar
Campbell Hill Wind Power
Capital Partners, Phase I Solar
Capital Partners, Phase II Solar
Caprock Solar
Cimarron II Wind Power
Conetoe Solar
Creswell Solar
Decatur County Solar I
Decatur County Solar II
Dogwood Solar
Everetts Wildcat Solar
Frontier Wind Power
Garysburg Solar
Gaston Solar
Gato Montes Solar
Halifax Solar
Hancock County Solar
Happy Jack Wind power
Hertford Solar
Highlander Solar
Ironwood Wind Power
Johnson County Solar
Kit Carson Wind Power
Laurel Hill Wind Power
Long Farm Solar
Longboat Solar
Los Vientos I Wind Power
Los Vientos II Wind Power
Los Vientos III Wind Power
Los Vientos VI Wind Power
Los Vientos V Wind Power
Martins Creek Solar
Mesquite Creek Wind Power
Millfield Solar
Murfreesboro Solar
Murphy Farm Solar
North Allenheny Wind Power
Notrees Wind Power
Ocotillo Wind Power
Pumpjack Solar
Rio Bravo I Solar
Rio Bravo II Solar
River Road Solar
Seaboard Solar
Seville I Solar
Seville II Solar
Shawboro Solar
Shelby Solar
Shirley Wind Power
Stanton Solar
Sunbury Solar
Sunset Reservoir Solar
Sweetwater Wind Power
Tarboro Solar
Taylorsville Solar
Top of the World Wind Power
Victory Solar
Ware County Solar
Washington Airport Solar
Washington White Post Solar
Wilcox County Solar
Wildwood II Solar
Wildwood Solar
Windsor Cooper Hill Solar
Wingate Solar
Winton Solar
Woodland Solar

Appendix 11: Entergy's Non-Nuclear Utility Generation Assets

Plant	Unit	Megawatt Capability *	Unit Role	Ownership	Primary Fuel	Generation	Commercial Operation Date	Location
Acadia	2 (CCGT)	534	Intermediate	100% ELL	Natural Gas	Fossil	2002	Eunice, LA
Attala	1 (CCGT)	450	Intermediate	100% EML	Natural Gas	Fossil	2001	Sallis, MS
Baxter Wilson	1	494	Intermediate	100% EML	Natural Gas	Fossil	1967	Vicksburg, MS
Big Cajun 2	3	139	Base	24.15% ELL	Coal	Fossil	1983	New Roads, LA
		103		17.85% ETI				
Calcasieu	1 (CT)	144	Peaking	100% ELL	Natural Gas	Fossil	2000	Sulphur, LA
	2 (CT)	160	Peaking	100% ELL	Natural Gas	Fossil	2001	Sulphur, LA
Carpenter	1	31	Peaking	100% EAL	Hydro	Renewable	1932	Hot Springs, AR
	2	31	Peaking	100% EAL	Hydro	Renewable	1932	Hot Springs, AR
Choctaw	1	796	Intermediate	100% EML	Natural Gas	Fossil	2003	French Camp, MS
Gerald Andrus	1	738	Intermediate	100% EML	Natural Gas	Fossil	1975	Greenville, MS
Hinds	1 (CCGT)	455	Intermediate	100% EML	Natural Gas	Fossil	2001	Jackson, MS
	2(CT)	29	Peaking	100% EML	Natural Gas	Fossil	2020	Jackson, MS
Hot Spring	2 (CCGT)	600	Intermediate	100% EAL	Natural Gas	Fossil	2002	Malvern, AR
Independence	1	260	Base	31.5% EAL	Coal	Fossil	1983	Newark, AR
		206	Base	25% EML	Coal	Fossil	1983	Newark, AR
	2	211	Base	25% EML	Coal	Fossil	1984	Newark, AR
J. Wayne Leonard	1 (CCGT)	926	Intermediate	100% ELL	Natural Gas	Fossil	2019	Montz, LA
Lake Catherine	4	522	Peaking	100% EAL	Natural Gas	Fossil	1970	Malvern, AR
Lake Charles	1	877	Intermediate	100% ELL	Natural Gas	Fossil	2020	West Lake, LA
Lewis Creek	1	249	Intermediate	100% ETI	Natural Gas	Fossil	1970	Willis, TX
	2	254	Intermediate	100% ETI	Natural Gas	Fossil	1971	Willis, TX
Little Gypsy	2	415	Intermediate	100% ELL	Natural Gas	Fossil	1966	Montz, LA
	3	517	Intermediate	100% ELL	Natural Gas	Fossil	1969	Montz, LA
LA Station 2	10	40	Reserve	100% ELL	Natural Gas	Fossil	1950	Baton Rouge, LA
	11	40	Reserve	100% ELL	Natural Gas	Fossil	1950	Baton Rouge, LA
	12	58	Reserve	100% ELL	Natural Gas	Fossil	1953	Baton Rouge, LA
Nelson	4	425	Reserve	100% ELL	Natural Gas	Fossil	1970	Westlake, LA
	6	211	Base	40.25% ELL	Coal	Fossil	1982	Westlake, LA
		156		29.75% ETI				
New Orleans Power Station	1	132	Intermediate	100% ENOI	Natural Gas	Fossil	2020	New Orleans, LA
Ninemile	4	730	Intermediate	100% ELL	Natural Gas	Fossil	1971	Westwego, LA
	5	744	Intermediate	100% ELL	Natural Gas	Fossil	1973	Westwego, LA
	6 (CCGT)	553	Intermediate	100% ELL	Natural Gas	Fossil	2014	Westwego, LA
Ouachita	1 (CCGT)	242	Intermediate	100% EAL	Natural Gas	Fossil	2002	Sterlington, LA
	2 (CCGT)	244	Intermediate	100% EAL	Natural Gas	Fossil	2002	Sterlington, LA
	3 (CCGT)	241	Intermediate	100% ELL	Natural Gas	Fossil	2002	Sterlington, LA
Perryville	1 (CCGT)	526	Intermediate	100% ELL	Natural Gas	Fossil	2002	Sterlington, LA
	2 (CT)	152	Peaking	100% ELL	Natural Gas	Fossil	2001	Sterlington, LA
Remmel	1	4	Peaking	100% EAL	Hydro	Renewable	1925	Malvern, AR
	2	4	Peaking	100% EAL	Hydro	Renewable	1925	Malvern, AR
	3	4	Peaking	100% EAL	Hydro	Renewable	1925	Malvern, AR
Sabine	1	212	Intermediate	100% ETI	Natural Gas	Fossil	1962	Orange, TX
	3	359	Intermediate	100% ETI	Natural Gas	Fossil	1966	Orange, TX
	4	513	Intermediate	100% ETI	Natural Gas	Fossil	1974	Orange, TX
	5	447	Intermediate	100% ETI	Natural Gas	Fossil	1979	Orange, TX
Sterlington	7A (CT)	47	Peaking	100% ELL	Natural Gas	Fossil	1974	Sterlington, LA
Union	1 (CCGT)	507	Intermediate	100% ENOI	Natural Gas	Fossil	2003	El Dorado, AR
	2 (CCGT)	498	Intermediate	100% EAL	Natural Gas	Fossil	2003	El Dorado, AR
	3 (CCGT)	506	Intermediate	100% ELL	Natural Gas	Fossil	2003	El Dorado, AR
	4 (CCGT)	503	Intermediate	100% ELL	Natural Gas	Fossil	2003	El Dorado, AR
Waterford	1	411	Intermediate	100% ELL	Natural Gas	Fossil	1975	Killona, LA
	2	417	Intermediate	100% ELL	Natural Gas	Fossil	1975	Killona, LA
	4 (CT)	33	Peaking	100% ELL	Oil	Fossil	2009	Killona, LA
White Bluff	1	464	Base	57% EAL	Coal	Fossil	1980	Redfield, AR
	2	469	Base	57% EAL	Coal	Fossil	1981	Redfield, AR
Brookhaven Solar	1	0.5		100% EML	Solar	Renewable	2015	Brookhaven, MS
DeSoto Solar	1	0.5		100% EML	Solar	Renewable	2015	Lake Cormorant, MS
Hinds Solar	1	0.5		100% EML	Solar	Renewable	2015	Jackson, MS
New Orleans Solar	1	1		100% ENOI	Solar	Renewable	2015	New Orleans, LA

Appendix 12: Exelon Corporation's Nuclear Fleet

Plant Name, State	Number of Reactors and Type	License Dates
Braidwood, IL	2 PWR	1988-2046 1988-2047
Byron, IL	2 PWR	1985-2044 1987-2046
Calvert Cliffs, MD	2 PWR	1975-2034 1977-2036
Clinton, IL	1 BWR	1987-2027
Dresden, IL	2 BWR	1970-2029 1971-2031
Fitzpatrick, NY	1 BWR	1974-2034
LaSalle, IL	2 BWR	1984-2042 1984-2043
Limerick, PA	2 BWR	1986-2044 1990-2049
Nine Mile Point, NY	2 BWR	1969-2029 1986-2046
Peach Bottom, PA	2 BWR	1974-2053 1974-2054
Quad Cities, IL	2 BWR	1973-2032 1973-2032
R.E. Ginna, NY	1 PWR	1970-2029
Salem, NJ	2 PWR	1977-2036 1981-2040
Three Mile Island, PA	1 PWR	1974-2034

Appendix 13: Exelon Corporation's Renewable Plants

Plant Name, State	Generation Type
Albany Green Energy, GA	Biomass Fuel
Fairless Hills, PA	Landfill Gas
Muddy Run, PA	Pumped Storage
Conowingo, MD	Hydroelectric
Antelope Valley Solar Ranch One, CA	Solar
Exelon City Solar, IL	Solar
Beebe Renewable Energy Wind Project, MI	Wind
Blue Breezes Wind Project, MN	Wind
Bluegrass Ridge Wind Project, MO	Wind
Bluestream Wind Project, OK	Wind
CP Wind Project, MN	Wind
Cassia Wind Project, ID	Wind
Conception Wind Project, MO	Wind
Cow Branch Wind Project, MO	Wind
Criterion Wind Project, MD	Wind
Echo I, II, III, OR	Wind
Ewington Wind Project, MN	Wind
Exelon Wind Project, TX	Wind
Fair Wind Project, MD	Wind
Fourmile Wind Project, MD	Wind
Greensburg Wind Project, KS	Wind
Harvest I, II Wind Project, MI	Wind
High Mesa Wind Project, ID	Wind
High Plains Wind Project, TX	Wind
Loess Hills Wind Project, MO	Wind
Marshall Wind Project, MN	Wind
Michigan Wind Project, MI	Wind
Mountain Home Wind Project, ID	Wind
Sendero Wind Project, TX	Wind
Shooting Star Wind Project, KS	Wind
Three Mile Canyon Wind Project, OR	Wind
Tuana Springs Wind Project, ID	Wind
Whiletail Wind Project, TX	Wind
Wildcat Wind Project, NM	Wind

Appendix 14; Exelon Corporation's Fossil Fuel Plants

Plant Name, State	**Generation Type**
Chester Generating Station, Pa	Oil
Colorado Bend II, TX	Combined Cycle
Croydon Generating Station, PA	Oil
Delaware Generating Station, PA	Oil
Eddystone, PA	Oil/Gas Steam and Combustion
Falls Generating Station, PA	Oil
Framingham Generating Station, MA	Oil
Handley, TX	Gas Steam
Handsome Lake Generating Station, PA	Simple Cycle
Hillabee Energy Center	Combined Cycle
Moser Generating Station, PA	Oil
Mystic & Mystic Jet, MA	Combined Cycle, Conventional Gas, Combustion Oil
Notch Cliff Generating Station, MD	Retired
Perryman Generating Station, MD	Combustion Oil and Natural Gas
Philadelphia Road Generating Station, MD	Oil
Richmond Generating Station, PA	Oil
Riverside Generating Station, MD	Gas Steam, Oil and Gas Turbine
Schuykill Generating Station, PA	Oil
Southeast Chicago Energy Project, IL	Retired
Southwark Generating Station, PA	Oil
West Medway Generating Station II, MA	Simple Cycle Gas and Diesel
Westport Generating Station, MD	Retired
Wolf Hollow II, TX	Combined Cycle

Appendix 15: MidAmerican Energy Company's Wind Generation

<u>Starting Operation in 2020</u>

- Palo Alto II
- Southern Hills
- Diamond Trail
- Contrail

<u>Operational</u>

- Intrepid
- Century
- Victory
- Iowa State Fair Wind Turbine
- Pomeroy
- Charles City
- Adair
- Walnut
- Carroll
- Adams
- Ida Grove
- O'Brien
- Beaver Creek
- Beaver Creek II
- Prairie
- North English
- Arbor Hill
- Orient
- Ivester
- North English II
- Palo Alto
- Ida Grove II
- Pocahontas Prairie
- Rolling Hills
- Laurel
- Eclipse
- Morning Light
- Vienne
- Lundgren
- Wellsburg
- Highland

Appendix 16: NextEra Energy's Owned Generation by Fuel Type

Fuel Type	2016 Net Generation Capacity (MW)	2016 % of Total MWhs	2019 Net Generation Capacity (MW)	2019 % of Total MWhs
Coal	888	2.20%	2554	3.30%
Natural Gas	21730	49.10%	23973	47.80%
Nuclear	6173	26.30%	6202	24.60%
Oil	890	0.30%	944	0.10%
Solar	2442	2.10%	3894	3.40%
Wind	13852	20.00%	14110	20.60%
Landfill Gas	0	0.00%	3	0.01%

Appendix 17: NextEra Solar Generation Fleet

Adelanto I Solar CA
Adelanto II Solar CA
Bluebell Solar TX
Blythe Solar 110 CA
Blythe Solar 125 CA
Blythe Solar III CA
Coolidge Solar VT
Chaves Solar NM
Desert Sunlight 250 CA
Desert Sunlight 300 CA
Dougherty Solar GA
Genesis Solar CA
Grazing Yak Solar CO
Harmony Solar FL
Hatch Solar NM
Live Oak Solar GA
Marshall Solar MN
Mountain View Solar NV
McCoy Solar CA
Paradise Solar NJ
Pinal Central Solar AZ
Quitman Solar GA
River Bend Solar AL
Roswell Solar NM
Shafter Solar CA
Shaw Creek Solar SC
Taylor Creek Solar FL
Silver State South NV
Stuttgart Solar AR
Titan Solar CO
Westside Solar CA
White Oak Solar GA
White Pine Solar GA
Whitney Point Solar CA

Appendix 18: Next Era Wind Generation Fleet

Adelaide Wind
Armadillo Flats Wind OK
Ashtabula Wind ND
Ashtabula Wind ND
Ashtabula Wind ND
Baldwin Wind ND
Blackwell Wind OK
Blue Summit Wind TX
Blue Summit II Wind TX
Blue Summit III Wind TX
Bluff Point Wind IN
Bornish Wind
Brady Wind ND
Brady Wind II ND
Breckinridge Wind OK
Bronco Plains Wind CO
Butler Ridge Wind WI
Callahan Divide TX
Capricorn Ridge TX
Capricorn Ridge TX
Carousel Wind CO
Casa Mesa Wind NM
Cedar Bluff Wind KS
Cedar Point II Wind
Cerro Gordo IA
Cimarron KS
Cottonwood Wind NE
Crowned Ridge Wind SD
Crystal Lake I IA
Crystal Lake II IA
Crystal Lake III IA
Day County Wind SD
East Durham Wind
Elk City Wind OK
Elk City Wind II OK
Emmons-Logan Wind ND
Endeavor Wind IA
Endeavor Wind II IA
Ensign Wind KS
Ghost Pine Wind CA
Golden Hills Wind CA
Golden Hills North Wind CA
Golden West Wind CO
Goshen
Gray County KS
Green Power CA
Hancock County Wind IA
Heartland Divide Wind TX
High Lonesome Mesa Wind NM
High Winds CA
Horse Hollow Wind TX
Horse Hollow Wind II TX
Horse Hollow Wind III TX
Horse Hollow Wind IV TX
Indian Mesa TX
Javelina Wind TX
Javelina Wind II TX
King Mountain TX
Kingman Wind KS
Langdon Wind ND
Langdon Wind II ND
Lee / Dekalb Wind IL
Limon Wind I CO
Limon Wind II CO
Limon Wind III CO
Logan Wind CO
Lorenzo Wind TX
Majestic Wind TX
Majestic Wind II TX
Mammoth Plains OK
Minco Wind OK
Minco Wind II OK
Minco Wind III OK
Minco Wind IV OK
Montezuma Wind CA
Montezuma Wind II CA
Mount Copper
Mount Miller
Mower County Wind MN
New Mexico Wind NM
Ninnescah Wind KS
Northern Colorado CO
North Dakota Wind ND
North Sky River Energy CA
Oklahoma Wind OK
Oliver County Wind ND
Oliver County Wind II ND
Oliver County Wind III ND

Osborn Wind MO
Palo Duro TX
Peetz Table CO
Pegasus Wind MI
Perrin Ranch Wind AZ
Pheasant Run I MI
Pratt Wind KS
Pubnico Point NS
Red Canyon Wind TX
Red Mesa Wind NM
Roundhouse Wind WY
Rush Springs Wind OK
Seiling Wind OK
Seiling Wind II OK
Sholes Wind Energy Center NE
Sky River CA
South Dakota Wind SD
Stateline Umatilla Co., WA
Steele Flats Wind NE
Story County Wind IA
Story County Wind II IA
Torrecillas Wind TX
Tuscola Bay Wind MI
Tuscola Bay Wind II MI
Vansycle OR
Vansycle II OR
Vasco Winds CA
Weatherford Wind OK
Wessington Springs Wind SD
White Oak Wind IL
Wildcat Ranch Wind TX
Wilton Wind Energy Center ND
Wilton Wind II ND
Windpower Ptrs CA
Wolf Ridge Wind TX
Woodward Mountain TX

Appendix 19: TVA's Hydroelectric Plants

Power-Producing Dams

- Apalachia
- Blue Ridge
- Boone
- Chatuge
- Cherokee
- Chickamauga
- Douglas
- Fontana
- Fort Loudoun
- Fort Patrick Henry
- Great Falls
- Guntersville
- Hiwassee
- Kentucky
- Melton Hill
- Nickajack
- Norris
- Nottely
- Ocoee 1
- Ocoee 2
- Ocoee 3
- Pickwick Landing
- Raccoon Mountain
- South Holston
- Tellico
- Tims Ford
- Watauga
- Watts Bar
- Wheeler
- Wilbur
- Wilson

Non-Power Dams - (for flood control and recreation)

- Bear Creek
- Beaver Creek
- Beech
- Cedar
- Cedar Creek
- Clear Creek
- Dogwood
- Little Bear Creek
- Lost Creek
- Nolichucky
- Normandy
- Pin Oak
- Pine
- Redbud
- Sycamore
- Tellico
- Upper Bear Creek

Appendix 20: TVA's Gas Plants

Ackerman Combined Cycle Plant
Allen Combined Cycle Plant
Allen Combustion Turbine Plant
Brownsville Combustion Turbine Plant
Caledonia Combined Cycle Plant
Colbert Combustion Turbine Plant
Gallatin Combustion Turbine Plant
Gleason Combustion Turbine Plant
John Sevier Combined Cycle Plant
Johnsonville Combustion Turbine Plant
Kemper Combustion Turbine Plant
Lagoon Creek Combined Cycle Plant
Lagoon Creek Combustion Turbine Plant
Magnolia Combined Cycle Plant
Marshall Combustion Plant
Paradise Combined Cycle Plant
Southaven Combined Cycle Plant

Appendix 21: Decommissioned Nuclear Reactors in the United States

Reactor Units	Type	Status	Operator
BIG ROCK POINT	BWR	Permanent Shutdown	CPC
BONUS	BWR	Permanent Shutdown	DOE/PRWR
CRYSTAL RIVER-3	PWR	Permanent Shutdown	PROGRESS
CVTR	PHWR	Permanent Shutdown	CVPA
DRESDEN-1	BWR	Permanent Shutdown	EXELON
ELK RIVER	BWR	Permanent Shutdown	RCPA
FERMI-1	FBR	Permanent Shutdown	DTEDISON
FORT CALHOUN-1	PWR	Permanent Shutdown	EXELON
FORT ST. VRAIN	HTGR	Permanent Shutdown	PSCC
GE VALLECITOS	BWR	Permanent Shutdown	GE
HADDAM NECK	PWR	Permanent Shutdown	CYAPC
HALLAM	X	Permanent Shutdown	AEC/NPPD
HUMBOLDT BAY	BWR	Permanent Shutdown	PG&E
INDIAN POINT-1	PWR	Permanent Shutdown	ENTERGY
KEWAUNEE	PWR	Permanent Shutdown	DOMINION
LACROSSE	BWR	Permanent Shutdown	DPC
MAINE YANKEE	PWR	Permanent Shutdown	MYAPC
MILLSTONE-1	BWR	Permanent Shutdown	DOMINION
OYSTER CREEK	BWR	Permanent Shutdown	EXELON
PATHFINDER	BWR	Permanent Shutdown	NMC
PEACH BOTTOM-1	HTGR	Permanent Shutdown	EXELON
PILGRIM-1	BWR	Permanent Shutdown	ENTERGY
PIQUA	X	Permanent Shutdown	CofPiqua
RANCHO SECO-1	PWR	Permanent Shutdown	SMUD
SAN ONOFRE-1	PWR	Permanent Shutdown	SCE
SAN ONOFRE-2	PWR	Permanent Shutdown	SCE
SAN ONOFRE-3	PWR	Permanent Shutdown	SCE
SAXTON	PWR	Permanent Shutdown	SNEC
SHIPPINGPORT	PWR	Permanent Shutdown	DOE DUQU
SHOREHAM	BWR	Permanent Shutdown	LIPA
THREE MILE ISLAND-1	PWR	Permanent Shutdown	EXELON
THREE MILE ISLAND-2	PWR	Permanent Shutdown	GPU
TROJAN	PWR	Permanent Shutdown	PORTGE
VERMONT YANKEE	BWR	Permanent Shutdown	ENTERGY
YANKEE NPS	PWR	Permanent Shutdown	YAEC
ZION-1	PWR	Permanent Shutdown	EXELON
ZION-2	PWR	Permanent Shutdown	EXELON
BELLEFONTE-1	PWR	Suspended Constr.	TVA

BELLEFONTE-2	PWR	Suspended Constr.	TVA
SUMMER-2	PWR	Suspended Constr.	SCE&G
SUMMER-3	PWR	Suspended Constr.	SCE&G
BAILLY	BWR	Cancelled Constr.	NIPS
BLACK FOX-1	BWR	Cancelled Constr.	PSCO
BLACK FOX-2	BWR	Cancelled Constr.	PSCO
CALLAWAY-2C	PWR	Cancelled Constr.	UNION
CHEROKEE-1	PWR	Cancelled Constr.	DUKE
CHEROKEE-2	PWR	Cancelled Constr.	DUKE
CHEROKEE-3	PWR	Cancelled Constr.	DUKE
CLINTON-2	BWR	Cancelled Constr.	IPC
FORKED RIVER	PWR	Cancelled Constr.	JCPL
GRAND GULF-2	BWR	Cancelled Constr.	MP&L
HARRIS-2C	PWR	Cancelled Constr.	CPL
HARRIS-3C	PWR	Cancelled Constr.	CPL
HARRIS-4C	PWR	Cancelled Constr.	CPL
HARTSVILLE A-1	BWR	Cancelled Constr.	TVA
HARTSVILLE A-2	BWR	Cancelled Constr.	TVA
HARTSVILLE B-1	BWR	Cancelled Constr.	TVA
HARTSVILLE B-2	BWR	Cancelled Constr.	TVA
HOPE CREEK-2	BWR	Cancelled Constr.	PSEG
MARBLE HILL-1	PWR	Cancelled Constr.	PSI
MARBLE HILL-2	PWR	Cancelled Constr.	PSI
MIDLAND-1	PWR	Cancelled Constr.	CPC
MIDLAND-2	PWR	Cancelled Constr.	CPC
NORTH ANNA-3C	PWR	Cancelled Constr.	VEPCO
NORTH ANNA-4C	PWR	Cancelled Constr.	VEPCO
PERRY-2	BWR	Cancelled Constr.	CEI
PHIPPS BEND-1	BWR	Cancelled Constr.	TVA
PHIPPS BEND-2	BWR	Cancelled Constr.	TVA
RIVER BEND-2	BWR	Cancelled Constr.	GSU
SEABROOK-2	PWR	Cancelled Constr.	FPL
SURRY-3	PWR	Cancelled Constr.	VEPCO
SURRY-4	PWR	Cancelled Constr.	VEPCO
WNP-1	PWR	Cancelled Constr.	WPPSS
WNP-3	PWR	Cancelled Constr.	WPPSS
WNP-4	PWR	Cancelled Constr.	WPPSS
WNP-5	PWR	Cancelled Constr.	WPPSS
YELLOW CREEK-1	PWR	Cancelled Constr.	TVA
YELLOW CREEK-2	PWR	Cancelled Constr.	TVA
ZIMMER-1	BWR	Cancelled Constr.	CG&E

Appendix 22: New United States Nuclear Reactor Applications

Reactor Name	Location	Status
Aurora – Oklo	California	Current
Bell Bend	Pennsylvania	Withdrawn
Bellefonte, Units 3 & 4	Alabama	Withdrawn
Callaway, Unit 2	Missouri	Withdrawn
Calvert Cliffs, Unit 3	Maryland	Withdrawn
Comanche Peak, Units 3 & 4	Texas	Suspended
Fermi, Unit 3	Michigan	Current
Grand Gulf, Unit 3	Mississippi	Withdrawn
Levy County, Units 1 & 2	Florida	Withdrawn
Nine Mile Point, Unit 3	New York	Withdrawn
North Anna, Unit 3	Virginia	Current
River Bend Station, Unit 3	Louisiana	Withdrawn
Shearon Harris, Units 2 & 3	North Carolina	Suspended
South Texas Project, Units 3 & 4	Texas	Withdrawn
Turkey Point Project, Units 3 & 4	Florida	Current
Victoria County Station, Units 1 & 2	Texas	Withdrawn
Virgil C. Summer, Units 2 & 3	South Carolina	Withdrawn
Vogtle, Units 3 & 4	Georgia	Current
William States Lee III, Uits 1 & 2	South Carolina	Current