Nuclear Power and ESG: Can They Play Together?

Morningstar and Sustainalytics partner to analyze the pros and cons of nuclear power as an ESG investment.

Morningstar Equity Research
24 July 2017

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Executive Summary

Environmental, social, and governance, or ESG, factors have become important considerations for investors and asset managers. Nuclear power in particular can be a controversial and confusing topic with respect to ESG factors. Sustainalytics, a leading global ESG and corporate governance analytics firm, has joined Morningstar Research Services to present a comprehensive ESG analysis of nuclear power, including a look at carbon emissions intensity, waste management, operational management, public safety, worker safety, and regulatory oversight.

Key Takeaways

- **Market underappreciates nuclear's positive ESG attributes.** Nuclear power holds several important ESG advantages over other energy sources. Its low-carbon emissions profile makes it a critical contributor to meeting state and federal environmental policy goals. And nuclear's strict oversight has helped it become one of the safest methods of baseload power generation for employees and the public. However, nuclear also presents significant ESG risks such as radiation exposure, long-term waste management, and high water usage.
- **Sustainalytics: Sorting nuclear operators by ESG factors.** Sustainalytics identifies three primary ESG issues that can help investors differentiate utilities with nuclear exposure: carbon intensity, waste management, and operational incidents. Its analysis highlights the substantial gap in performance that exists among U.S. utilities on these attributes. We view Exelon, PG&E, and Xcel Energy as best-in-class nuclear operators with strong waste management practices and long records of safe operations. By operating their nuclear fleets in a safe and reliable manner with good oversight, these top-tier utilities enhance their overall ESG profile.

Companies Mentioned

Name/Ticker	Economic Moat	Moat Trend	Currency	Fair Value Estimate	Current Price	Uncertainty Rating	Morningstar Rating	Dividend Yield	Market Cap (Bil)
Exelon EXC	Narrow	Stable	USD	32	37.21	Medium	★★	3.4%	34.7
Entergy ETR	None	Stable	USD	74	76.54	Medium	★★★	4.5%	13.9
PG&E PCG	None	Stable	USD	55	67.90	Low	★★	2.9%	34.9
Xcel Energy XEL	Narrow	Stable	USD	36	46.98	Low	★	3.0%	24.1

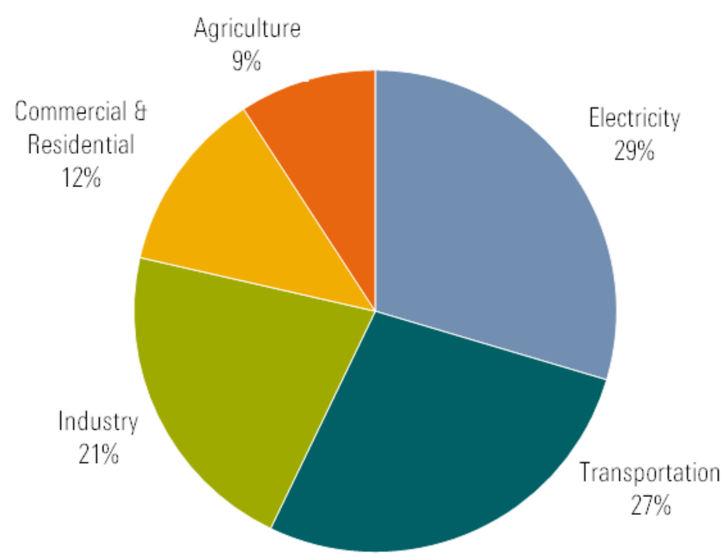
Environmental Analysis

All utilities have a significant environmental impact, both positive and negative. This is particularly true for nuclear energy. Our forecasts show that preserving the existing nuclear fleet is the fastest way to meet U.S. carbon emissions targets, but the country's lack of a long-term waste solution is troubling.

Greenhouse Gas Emissions

The electricity sector is the largest emitter of greenhouse gases, responsible for 29% of total U.S. carbon emissions, followed by the transportation and industry sectors (Exhibit 1).

Exhibit 1 U.S. Greenhouse Gas Emissions by Economic Sector

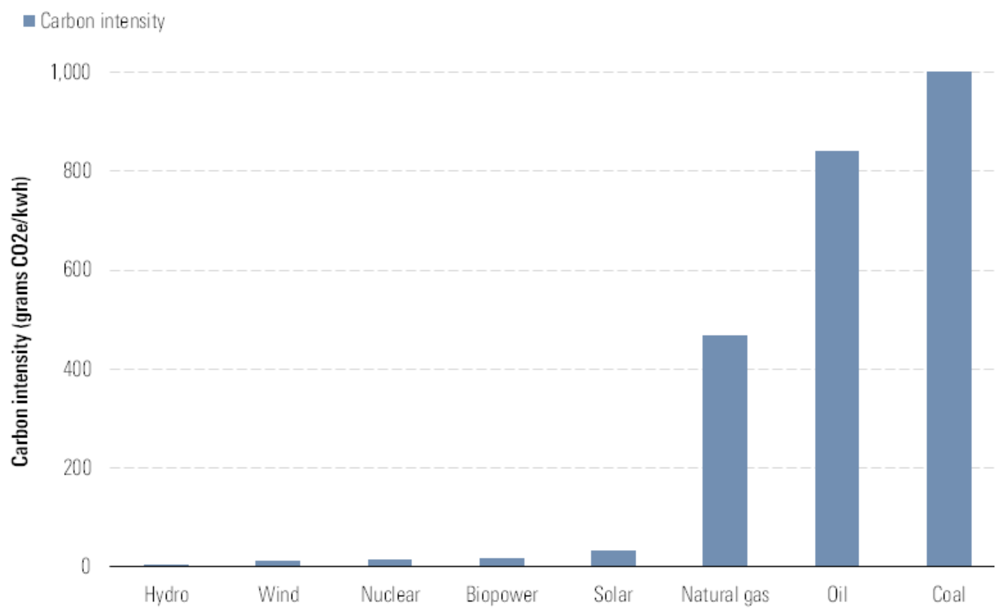


Source: U.S. Energy Information Administration

Increased political pressure—particularly through the U.S. Environmental Protection Agency's 2015 Clean Power Plan and the international Paris Agreement—is pushing utilities to continue reducing their carbon footprint. Nuclear and large-scale hydro are the only baseload generation sources that emit minimal greenhouse gas emissions, helping meet environmental requirements for carbon emissions reductions. Wind and solar are emissions-free but also intermittent resources. To match nuclear as a firm baseload generation source, wind and solar require expensive battery backup or standby natural gas generation, which emits carbon dioxide.

Nuclear power in the United States generates an average of 16 grams of carbon dioxide equivalent per kilowatt-hour, or gCO2e/kWh, according to the U.S. Department of Energy. This output is comparable to that of renewable energy, on average. In fact, nuclear slightly outperforms solar and biopower on a lifecycle basis. Coal (1,001 gCO2e/kWh) and petroleum (840 gCO2e/kWh) are the highest carbon emitters. Natural gas (469 gCO2e/kWh) has a significantly lower carbon-intensity profile but is still well above nuclear and renewable energy (Exhibit 2).

Exhibit 2 Nuclear Power Has a Lifecycle Carbon Emissions Profile Similar to Renewable Energy

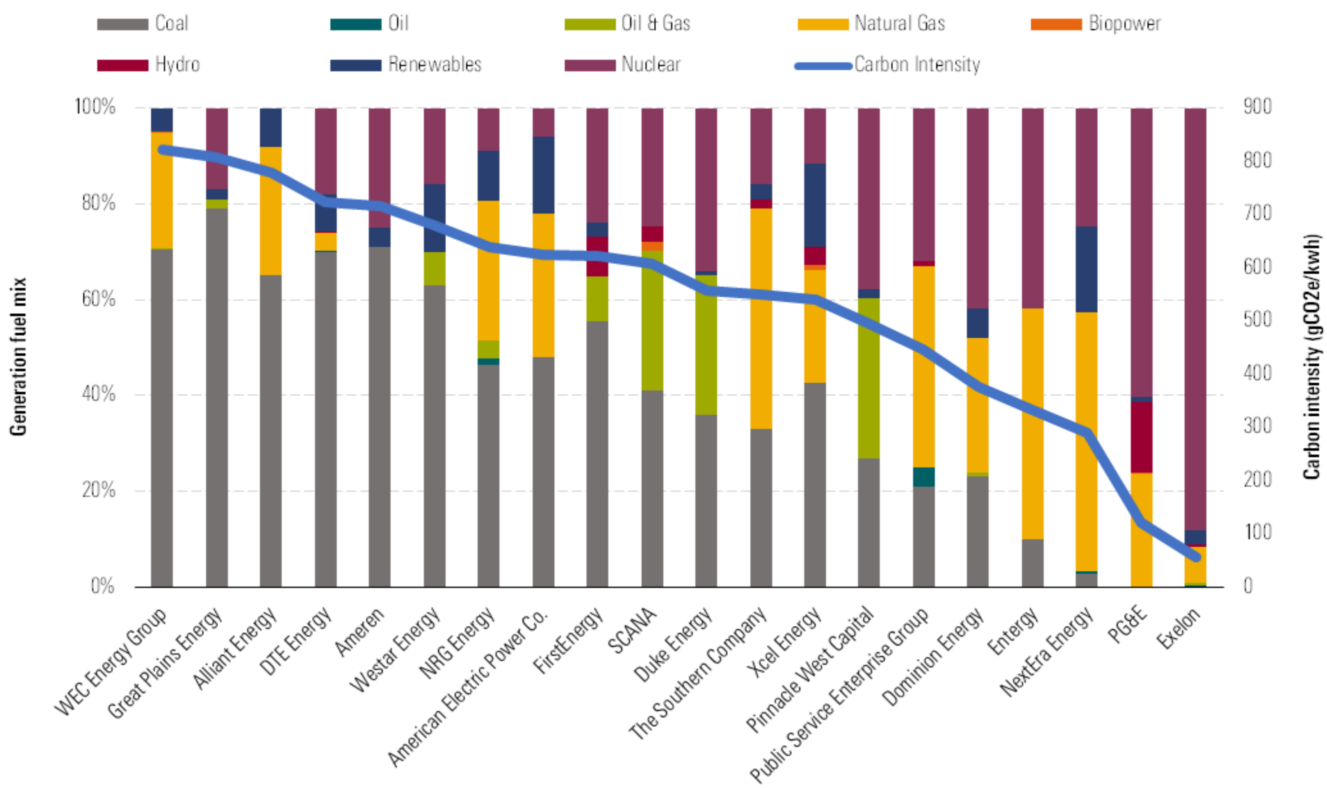


Source: U.S. Department of Energy, IPCC, Sustainalytics

Most U.S. utilities are responding to long-term pressure from regulators and investors to cut emissions. Many of the largest utilities, including Duke Energy and American Electric Power, have made notable reductions in recent years. With new-build nuclear uneconomic, U.S. utilities have achieved the bulk of these reductions by tilting their generation mix toward renewable energy and gas. However, U.S. utilities still trail their European counterparts, such as Spain's Iberdrola, Italy's Enel, and the United Kingdom's SSE, in emissions performance.

U.S. utilities' carbon emissions intensity varies dramatically. Carbon intensity is a function of generation mix. Utilities that are overweight nuclear and renewable energy have a lower carbon intensity, while utilities that are long on fossil generation—especially coal—have a higher carbon intensity (Exhibit 3).

Exhibit 3 Generation Mix and Carbon Intensity of U.S. Utilities



Source: Sustainalytics

WEC Energy Group has the highest carbon intensity (821 gCO2e/kWh) in our joint coverage universe with Sustainalytics. This reflects the absence of nuclear power in WEC Energy Group's generation mix and the company's extensive exposure to coal-fired generation, which accounts for 70% of its generation mix. This proportion of coal is among the highest of all U.S. utilities. WEC Energy has nuclear exposure through its power purchase contract with NextEra Energy's Point Beach nuclear plant, which goes through 2030 for unit 1 and 2033 for unit 2. WEC Energy sold the plant to NextEra's predecessor company, FPL Group, in 2007. Great Plains Energy and Alliant Energy also have minimal nuclear exposure and large coal generation fleets, although both are diversifying into new gas generation and renewable energy.

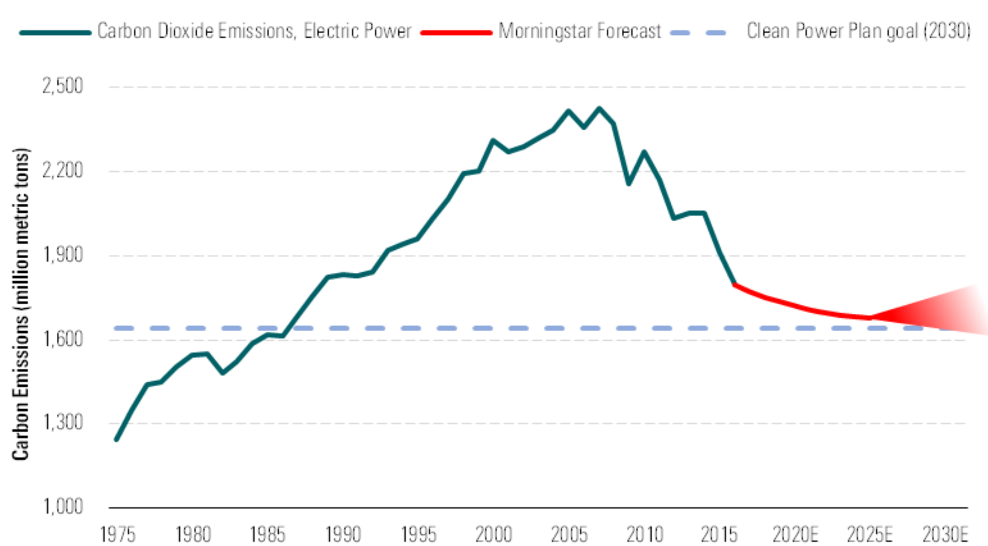
Exelon, which has a generation mix that is 88% from nuclear, has the lowest carbon intensity at 56 gCO2e/kWh. Thus, a kilowatt-hour of electricity generated by WEC Energy Group is 15 times more carbon-intensive than a kilowatt-hour produced by Exelon. The financial materiality of this differential depends to a large degree on uncertain U.S. environmental policies. We think utilities with superior carbon-intensity profiles are best prepared to adapt to rising investor expectations for emissions performance and tightening carbon regulations, which we believe is a given in the U.S. in the long run.

Morningstar's Carbon Emissions Outlook

Utilities have made significant progress in reducing carbon emissions. Carbon emissions from power generators are down 26% since their 2007 peak. We expect decarbonization to continue through 2030 even after considering the Trump administration's decision to suspend the Obama administration's CPP and withdraw from the Paris Agreement.

We think utilities can achieve at least a 31% drop in carbon emissions from 2005 levels by 2025, primarily based on our forecast for state-level renewable portfolio standards, under-construction gas generation capacity, and changes in nuclear generation. Through 2025, we expect utilities to reduce their carbon emissions by 119 million metric tons, from 1,797 million metric tons in 2016. Most of this reduction comes from much higher natural gas and renewable energy generation offsetting a steep drop in coal generation. Our forecasts assume nuclear generation grows slightly as uprates and new-build capacity offset planned and possible retirements. Achieving these carbon emissions reductions would put the U.S. power sector ahead of schedule to meet the CPP's targeted 32% reduction from 2005 levels (Exhibit 4).

Exhibit 4 Morningstar's Base-Case Forecast of Power Sector Carbon Emissions



Source: Morningstar

Scenario Analyses

Our scenario analyses highlight nuclear's role in reducing U.S. carbon emission (Exhibit 5). In these scenarios, we assume nuclear energy operates at a 90% capacity factor. Any lost generation capacity is replaced on a weighted average basis assuming 80% natural gas and 20% renewable energy. We assume any new nuclear capacity offsets the need for new natural gas generation. We also estimate the natural gas fleet emits roughly 500,000 metric tons of carbon per megawatt-hour on average.

Exhibit 5 Morningstar's Power Sector Carbon Emissions Forecast Scenarios

Scenario	Change in Nuclear Capacity (MW)	Generation (GWh)	Change in CO2 Emissions vs. 2016 (mm metric tons)	Increase (Decrease) vs. 2016	Increase (Decrease) vs. Base Case
Base case[1]			(118)	-6.6%	
At-risk nuclear plants retire	(8,550)	(65,377)	(92)	-5.1%	26
All U.S. nuclear plants retire	(91,407)	(698,934)	162	9.0%	280
All proposed new nuclear	9,900	75,699	(148)	-8.3%	(30)

*Assumptions: Replacement generation is 20% met from renewable energy, 80% from natural gas generation; 90% average nuclear capacity factor

*Scenarios are incremental to base case assumptions for plant additions (retirements)

[1] Assumes Illinois and New York ZEC are withdrawn, five Exelon plants close

Source: Morningstar

In our base case, we assume 7,265 MW of planned nuclear retirements by 2025. We also assume the courts and regulators remove nuclear subsidies in Illinois and New York, leading Exelon to close the five plants it owns in those states that currently receive the subsidy payments.

In our first scenario, we assume the at-risk nuclear plants in Ohio, Pennsylvania, and Connecticut close, totaling 8,550 MW of lost nuclear generation capacity (Exhibit 6). This is incremental to closures in our base case. The natural gas generation necessary to replace these at-risk plants' generation would result in an increase of about 26 million tons of carbon emissions relative to our base case.

Exhibit 6 At-Risk Nuclear Plants Not Already Scheduled to Close

Plant	State	Capacity (MW)	Owner
Base Case Closures			
Planned retirements	Many	7,265	Many
Clinton	IL	1,065	Exelon
Quad Cities	IL	1,819	Exelon
Fitzpatrick	NY	837	Exelon
R E Ginna	NY	582	Exelon
Nine Mile Point	NY	1,924	Exelon
Base Case Closures		**13,492**	
At-Risk Scenario Closures			
Davis-Besse	OH	894	FirstEnergy
Perry	OH	1,240	FirstEnergy
Beaver Valley	PA	1,808	FirstEnergy
Susquehanna	PA	2,520	Talen Energy
Millstone	CT	2,088	Dominion Energy
At-Risk Closures		**8,550**	

Source: Morningstar

In our second scenario, we assume all U.S. nuclear plants close, similar to actions taken in Germany. This would result in an increase of about 280 million tons of carbon emissions relative to our base case and an increase of 162 million tons of carbon emissions from 2016, far offsetting the carbon emissions reductions from renewable energy growth.

This scenario could have significant valuation implications for U.S. utilities. We don't expect any fair value estimate cuts would be as severe as the 27% cuts in our RWE and E.ON fair value estimates after Germany's decision in 2011 to shut its nuclear fleet. Germany's deregulated market meant RWE and E.ON had no backstop from rate regulation like most of the U.S. utilities that own nuclear plants. Large merchant nuclear plant owners Exelon and Public Service Enterprise Group could suffer 20%-25% fair value estimate cuts in a forced-retirement scenario. For utilities that own rate-regulated nuclear plants, the valuation implications would depend on how much undepreciated capital the utilities can collect from ratepayers. State regulatory precedents suggest a forced-closure scenario wouldn't have more than a 5% impact on any of our fair value estimates for those rate-regulated utilities. We expect the utilities would be able to recover substantially all of the so-called stranded costs from ratepayers. Federal and company-level insurance might offset any unrecovered costs, leaving investors mostly whole.

Our third scenario assumes new-build nuclear ramps up in the U.S. We include the 9,900 MW of proposed new nuclear projects that the Nuclear Energy Institute has identified. This is incremental to the 4,468 MW of new nuclear capacity under construction in Georgia and South Carolina that we include in our base case. We think it is unlikely that any of these proposed projects will be built, given the challenging economics of new nuclear construction. However, adding those plants would cut an additional 30 million tons of carbon emissions from our base case and reduce carbon emissions by 148 million tons total from 2016.

Waste Management: Avoiding Pitfalls

Waste management is a crucial concern for all power generators, but it is particularly important for nuclear operators because of the long-term health and environmental impacts associated with radioactive waste. Ultimately, we view waste management as an unfavorable ESG issue for nuclear power. Radioactive waste and other hazardous waste produced at nuclear sites are subject to strict regulation. Violations can result in penalties or even the loss of operating licenses.

The Department of Energy is responsible for developing a long-term storage solution for high-level nuclear waste, but those efforts have met social and political roadblocks. In the meantime, utilities remain responsible for managing lower-level radioactive waste as well as storing spent nuclear fuel, which can remain hazardous for well over 10,000 years. While nuclear power plants have safely stored nuclear waste on site since inception, the industry and the U.S. government have failed to come up with a viable long-term solution for spent nuclear fuel. This is critical, given the long decay period and limited on-site storage space.

Waste Management: Nuclear Risks

Nuclear leaves a relatively small footprint of waste volume at 4.4 grams per kilowatt-hour, but this alone does not represent the high level of nuclear waste management risk. About 11% of nuclear waste is radioactive, making nuclear the only generation source with solid waste that has both radioactive and hazardous components (Exhibit 7). Coal produces much higher waste volume, but the U.S. Environmental Protection Agency recently ruled coal combustion residual was nonhazardous despite its heavy metal content, which includes fly ash, bottom ash, boiler slag, and flue gas desulfurization gypsum. Fossil fuel generation upstream and downstream processes also produce much higher waste volume but none that is considered radioactive or hazardous (Exhibit 8).

Exhibit 7 Solid Waste From Operational Processes (Grams/Kilowatt-Hour)

Technology	Grams/Kwh	
Hard coal ash	84	
Lignite ash	172	
Oil ash	0.8	
Natural gas sweetening	4.7	
Nuclear non-radioactive - hazardous	0.022	
Nuclear non-radioactive - other	4.2	**Total Nuclear**
Nuclear radioactive waste	0.2	4.4 Grams/Kwh
of which HLW/spent fuel	0.004	

Source: International Atomic Energy Agency

Exhibit 8 Solid Waste From Upstream and Downstream Processes (Grams/Kilowatt-Hour)

Technology	Grams/Kwh	
Mining coal	3,000	
Nuclear		
Non-Radioactive, Hazardous	0.01	**Total Nuclear**
Non-Radioactive, Other	0.97	1.0 Grams/Kwh
Hydro (reservoir, run of river)	310	
Solar PV - heavy metals		
Low	0.000011	
High	0.000033	

Source: International Atomic Energy Agency

For nuclear generators, radioactive waste can be classified as low-, intermediate-, and high-level risk. Low-level and intermediate-level waste accounts for approximately 98% of radioactive waste from a nuclear plant and consists of items such as protective shoe covers and clothing, reactor water treatment residue, and tools and equipment that have become contaminated with radioactive material. Low-level waste is typically stored on site until large quantities are gathered for disposal at one of four low-level waste facilities in the U.S. Low-level waste poses little public safety hazard.

However, high-level and some intermediate-level radioactive waste poses a material public safety risk if mishandled. High-level radioactive waste is the byproduct of the reaction inside nuclear reactors and comes in two forms: spent nuclear fuel and waste materials remaining after spent fuel is processed. All U.S. nuclear power plants store recent spent fuel rods in water storage pools about 40 feet deep. These pools cool the spent nuclear rods and serve as an additional shield from radiation. The storage container is several feet thick, often with steel liners. Typically, after 5-10 years the spent fuel rods are moved to on-site dry cask storage, where the spent rod is surrounded by inert gas inside a steel cylinder cask.

Nuclear facilities have safely stored nuclear waste on site since the late 1970s. However, the only way for highly radioactive waste to become harmless is through decay, which can take hundreds of thousands of years for high-level wastes. As nuclear waste builds and remains radioactive, nuclear plants will find it challenging to continue storing and managing the waste. Thus, a long-term nuclear waste management solution is needed. The technology to store nuclear waste long-term is available and being tested in Finland. The underground spent nuclear repository Onkalo is 450 meters deep and set for completion in 2023.

Progress on a long-term high-level waste storage facility in the U.S. has been highly politicized with little progress since the 1982 Nuclear Waste Policy Act. In 1987, the U.S. government identified Yucca Mountain, at the southern tip of Nevada, as the permanent underground storage site. It was scheduled to open in 1998. After many years of stalled negotiations, the Obama administration mothballed the project in 2011. The Trump administration has included $120 million of funding in its proposed budget, but we remain skeptical that a long-term storage facility will be completed anytime soon. If the Trump administration's budget is passed, Nevada has filed 218 contentions against the Department of Energy's application for the storage site that must be remediated. This could cost as much as $2 billion. Until the U.S. develops a long-term waste storage solution, we will consider nuclear waste a negative ESG factor.

Sustainalytics shows that some U.S. utilities are better prepared than others to manage environmental risks associated with hazardous waste treatment and disposal for their entire generation fleets, including nuclear (Exhibits 9-10). Sustainalytics scores waste management on three pillars: hazardous waste management, environmental management system, and environmental policy. All scores are out of 100 possible points. Xcel Energy is best positioned with a score of 83 from Sustainalytics. Xcel Energy's 1,594 MW of nuclear capacity accounts for only 12% of its generation mix and only 2% of total U.S. nuclear capacity, limiting its risk relative to other nuclear operators. However, the company is well ahead of its peers with respect to waste management and is well positioned to manage existing risk.

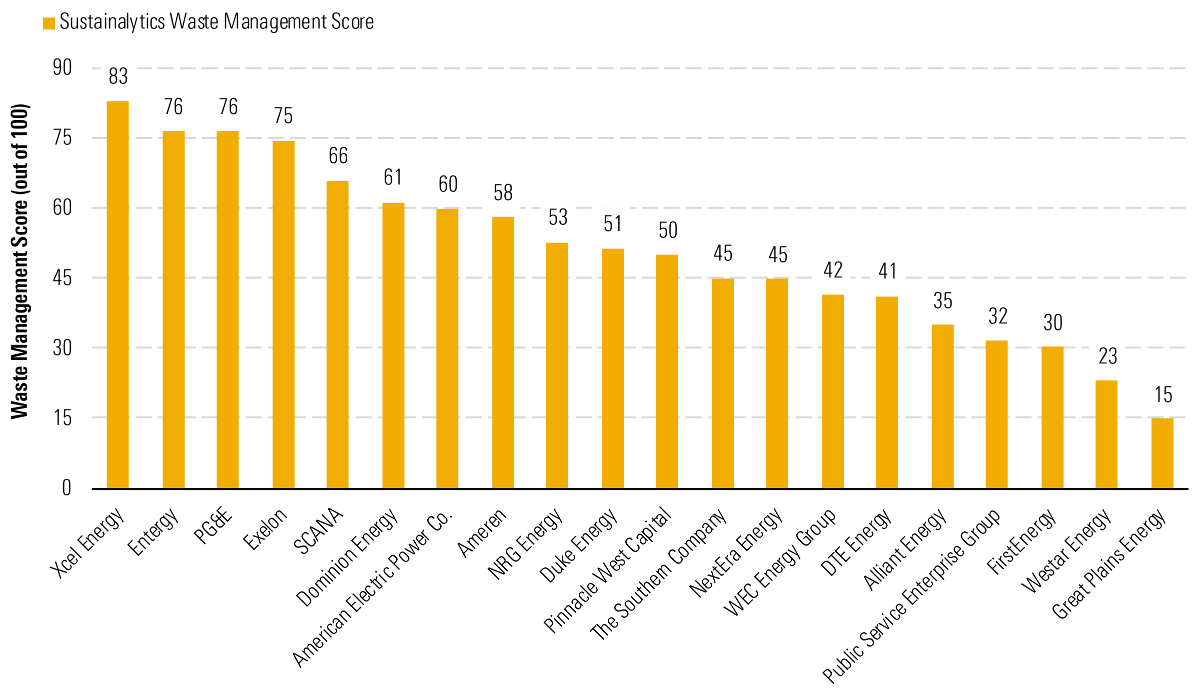
Other top performers in Sustainalytics' waste management rankings include Entergy, PG&E, and Exelon. Exelon and Entergy are the two largest nuclear owners in the U.S. PG&E recently announced plans to exit the nuclear business by closing its Diablo Canyon plant starting in 2024.

Exhibit 9 Sustainalytics' Waste Management Scores of U.S. Utilities

Company Name	Hazardous Waste Management	Environmental Management System	Environmental Policy	Total Score (Weighted)
Xcel Energy	50	100	100	83
Entergy	50	80	100	76
PG&E	50	80	100	76
Exelon	25	100	100	75
SCANA	0	100	100	66
Dominion Energy	25	60	100	61
American Electric Power Co.	50	80	50	60
Ameren	25	100	50	58
NRG Energy	0	60	100	53
Duke Energy	25	80	50	51
Pinnacle West Capital	50	100	0	50
The Southern Company	50	60	25	45
NextEra Energy	25	60	50	45
WEC Energy Group	25	80	20	42
DTE Energy	0	100	25	41
Alliant Energy	25	60	20	35
Public Service Enterprise Group	25	20	50	32
FirstEnergy	50	20	20	30
Westar Energy	0	20	50	23
Great Plains Energy	0	20	25	15

Source: Sustainalytics

Exhibit 10 Sustainalytics Waste Management Capabilities of U.S. Utilities



Source: Sustainalytics

At the other end of the spectrum, Sustainalytics' analysis reveals a dearth of relevant environmental programs at Great Plains Energy (score: 15), Westar Energy (score: 23) and FirstEnergy (score: 30). These firms also have below-average nuclear capacity compared with the U.S. utilities industry as a whole. But their exposure, constituting 17%, 16%, and 24% of their generation mix, respectively, is far from trivial. Great Plains and Westar jointly own the Wolf Creek (Kansas) nuclear plant and plan to merge in the first half of 2018.

The absence of key policies does not guarantee accidents, and robust policies do not always prevent accidents. But the sparse disclosure of waste management and environmental programs at these three low-ranking utilities raises questions about management sophistication and future risk exposure.

Other Environmental Considerations

Water Usage: Negative for Nuclear Power

We consider nuclear power's high water usage another negative ESG factor compared with other generation technologies. Nuclear plants use between 400 and 720 gallons/MWh depending on the plant technology (Exhibit 11). Natural gas generation uses between 100 and 370 gallons/MWh. As an example, a 1,000 MW wet-cooling nuclear power plant running at a 90% capacity factor would use roughly 7.8 million gallons of water annually. A similar natural gas combined-cycle plant with cooling towers would use approximately 2.9 million gallons annually. Utility-scale solar photovoltaic and wind require minimal water usage.

Exhibit 11 Water Consumption By Generation Source

Energy Source for Electricity Generation	Water Consumption (Gallons/MWh)
Natural Gas	
Once-Through Cooling	100
Combined-Cycle with Cooling Towers	370
Coal	
Minimal Pollution Controls & Once-Through Cooling	300
Advanced Pollution Controls & Wet Cooling Towers	714
Nuclear	
Once-Through Cooling	400
Wet Cooling Towers	720
Hydro	4,500
Geothermal	1,800 to 4,000
Solar-Thermal	1,040
Biomass	300 to 480
Solar Photovoltaic	30
Wind	1

Source: Nuclear Energy Institute

Social Analysis

Nuclear power checks many of the boxes for positive social stewardship. Nuclear power plants employee several hundred professionals in high-paying jobs, often in small and midsize towns. Exelon recently estimated its smallest plant, located in Clinton, Illinois (population 7,000), generated $713 million for the state economy and paid $22 million in state and local taxes in 2014. Most of Exelon's other plants produced more than double those numbers.

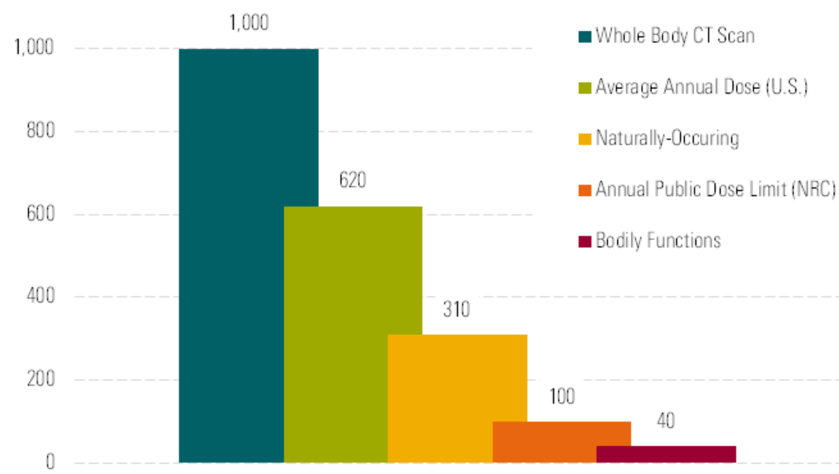
Nuclear safety is a key social concern. New York Gov. Andrew Cuomo cited safety in his opposition to the Indian Point nuclear plant not far from New York City. Nuclear disasters have been dramatized repeatedly, notably in the 1979 movie *The China Syndrome* and the television series *The Simpsons*.

However, we think nuclear power safety is misunderstood. A variety of different measures suggest that nuclear generation is the safest source of baseload power generation in the U.S. We estimate U.S. nuclear plants have been generating power for a cumulative 28 million hours, or almost 3,200 years, since the first unit went into service in 1957. In that time, there has been only one accident in the U.S. with relatively minor radiation leakage and no fatalities. There have been other minor radiation leak incidents but none serious.

Is Radiation Exposure From Nuclear Power Safe?

Americans on average are exposed to about 620 millirems of radiation per year, split evenly between naturally occurring and man-made sources (Exhibit 12). Naturally occurring radiation sources include bodily functions, airborne radon, soil, rock, and certain foods. Man-made sources include diagnostic medical equipment (X-ray, CT scans), nuclear medicine procedures, building and road construction materials, fuels, and electronics.

Exhibit 12 Sources of Man-Made and Natural Radiation



Source: Nuclear Regulatory Commission

Radiation levels from normally operating nuclear plants are a small fraction of normal human radiation exposure and pose no safety risks (Exhibit 13). Studies show:

- Eating one banana exposes a person to more radiation than living for a full year within 50 miles of a nuclear plant.
- Living next to a nuclear plant would result in 1 millirem of additional radiation each year on average, less than living in an all-stone house.
- Living near a coal plant exposes a person to 3 times as much radiation as living near a nuclear plant.
- The U.S. Nuclear Regulatory Commission requires nuclear plants to limit the annual external radiation exposure to the public to 100 millirems, less than 20% of Americans' baseline radiation exposure. Nuclear plant workers are exposed to about 400 millirems of additional radiation each year. Nuclear plant employees cannot be exposed to more than 5,000 millirems of radiation per year based on NRC guidelines.

Exhibit 13 Sources of Man-Made and Natural Radiation

Source	Dose (Millirems)
Severe radiation poisoning	200,000
Limit for lifesaving emergency workers (U.S. EPA)	25,000
Annual NRC-licensed nuclear worker limit	5,000
Whole body CT scan	1,000
Annual average dose (U.S.)	620
Annual natural background dose (U.S.)	310
Annual public dose limit, NRC-licensed activity	100
Cosmic rays	30
Chest X-ray	10
Safe drinking water limit (U.S. EPA)	4
Trans-Atlantic flight (1-way)	2.5
Eating a banana	0.01
Living within 50 miles of nuclear plant	0.009

Source: Nuclear Regulatory Commission, other sources

Nuclear Accidents Rare

Nuclear radiation leaks are rare and typically within a normal range of base radiation exposure. The three worst nuclear power accidents worldwide—Three Mile Island (U.S.), Fukushima Daiichi (Japan), and Chernobyl (Ukraine)—resulted in varying levels of radiation exposure (Exhibit 14).

Exhibit 14 Radiation Exposure From Major Nuclear Accidents

Three Mile Island	Millirems
Average dose for residents within 10 miles	8
Maximum offsite external dose	100
Fukushima Daiichi	
Extra dose to Tokyo in following weeks	4
Total dose at NW edge of exclusion zone	4,000
Maximum received by two plant workers	18,000
Chernobyl	
One hour on grounds in 2010	600
Average nearby public radiation dose	3,100
10 minutes next to reactor core after meltdown	5,000,000

Reference doses	Millirems
Living within 50 miles of nuclear plant	1
Annual average dose (U.S.)	600
Link to increased cancer risk, annual	10,000
Potentially fatal[1]	400,000

[1] Could range from 200,000 to 800,000 depending on time of exposure and other considerations

Source: Various

Three Mile Island, 1979

The only major U.S. nuclear safety breach occurred at the Three Mile Island nuclear plant in Middletown, Pennsylvania, on March 28, 1979. A combination of human error, design deficiencies, and component failures caused the accident. In the nonnuclear section of the plant, an electrical malfunction disabled the main feedwater pumps that provide water to the steam generators to remove heat from the core nuclear reactor. This equipment failure combined with operator error allowed cooling water to leak out, leaving inadequate water supply to cool the reactor core. This caused the reactor to overheat.

During the accident, residents within a 5-mile radius of the nuclear plant were evacuated. Estimates show nearby residents received an average radiation dose of 8 millirems, or about the same as taking a round-trip flight between New York and Los Angeles. Even the most exposed people experienced only about half the radiation as a head CT scan. Still, the Three Mile Island incident led to significant regulatory changes in the U.S. nuclear industry, including enhanced strengthening of structural components, increased personnel training, and greater emergency preparedness.

Fukushima Daiichi, 2011

In 2011, a 9.0 magnitude earthquake struck offshore Japan, creating a 15-meter-high tsunami that hit Tokyo Electric Power's Fukushima Daiichi plant units 1-4. The nuclear reactors and containment structures held up well. However, 12 of the plant's 13 backup power generators failed, causing operators to lose the ability to maintain proper reactor cooling and water circulation. More than 100,000 people were evacuated from the surrounding area. To date, no deaths have been directly attributed to Fukushima. Estimates for the average radiation dose for individuals within the 20-kilometer evacuation area were 20 millirems, or about 3% of normal annual radiation exposure. The highest measured radiation dose among Fukushima workers was well below radiation poisoning levels but still above the annual dose with links to increased cancer risk.

While the human radiation exposure has been less than anticipated, and markedly less than previous accidents such as Chernobyl, the accident did result in a significant dispersion of radioactive material to the surrounding area, necessitating the removal of the top layers of soil. While evacuation orders have been lifted in some of the less affected areas, much of the evacuation zone will probably remain uninhabitable for years to come. The remediation of the reactor site is highly problematic. The core area remains highly radioactive, and engineers have been unable to fully assess the state of the remaining fuel in the core. There have been ongoing issues of radioactive water leaks. The entire project is expected to take several decades and hundreds of billions of dollars.

Chernobyl, 1986

The most damaging nuclear accident occurred in Chernobyl, Ukraine, in 1986. It is the only documented commercial nuclear power accident to cause radiation exposure fatalities. A flawed reactor design that only Eastern Bloc countries used at the time and significant human error caused the disaster. The poorly designed reactor became unstable at low power, accelerating a nuclear chain reaction and causing a heat surge that ruptured fuel pressure tubes. The plant also did not have a nuclear containment structure, which would have prevented most of the radiation leakage. All modern-day plants have containment structures.

Two operators died immediately from the disaster and 28 others died from radiation exposure in the following months. Among the most exposed, 134 people received between 80,000 millirems and 1.6 million millirems. The average radiation dose to the roughly 115,000 individuals evacuated from Chernobyl was roughly 3,100 millirems, or about 5 times the normal annual dose. The radioactive fallout spread throughout Europe and Russia, with Ukraine and neighboring Belarus maintaining long-term exclusion zones in the most highly contaminated areas. There has been a significant increase in incidence of certain cancers among residents who had the greatest exposure. The World Health Organization estimates the number of cancer deaths related to Chernobyl to be about 4,000. Estimates of the cost of the disaster vary greatly, but are in the hundreds of billions of dollars to date.

Employee Safety Record

Nuclear power has a strong record of employee safety, particularly compared with other forms of energy generation. Nuclear energy is safer for workers than coal, natural gas, and hydro generation, based on a study by the Paul Scherrer Institute analyzing power sector accidents in 1969-2000. Coal and natural gas power accidents resulted in the most fatalities (Exhibit 15). Nuclear had no fatalities in developed countries. The Chernobyl accident accounts for the nuclear-related fatalities in non-OECD countries. Many of the hydro-related fatalities were among the public.

Exhibit15 Coal and Natural Gas Far More Dangerous Work Environments Than Nuclear (1969-2000)

	OECD countries		Non-OECD countries	
Energy Chain	**Total**	**Employee Fatality rate***	**Total**	**Employee Fatality rate***
Coal	2,259	157	18,000	597
Natural Gas	1,043	85	1,000	111
Hydro	14	3	30,000	10,285
Nuclear	-	-	31	48

*Employee fatality rate is the number of employee fatalities per terawatt-year of power generation.

Source: Paul Scherrer Institute

Governance Analysis

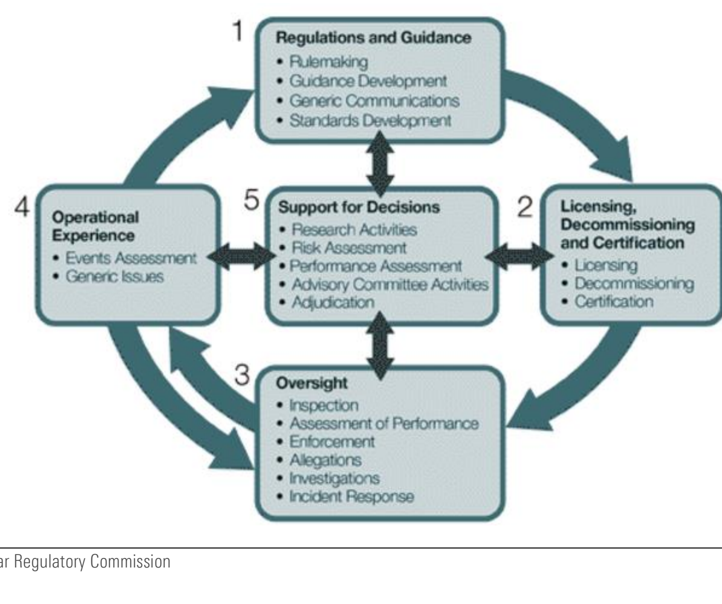
We think the nuclear industry gets high marks for its governance framework. It is the most regulated industry in the U.S. Federal oversight through the Nuclear Regulatory Commission is key, but nuclear plants also are subject to numerous regional, state, and local regulations. This creates a strong governance structure in the industry and an impressive safety record. Additionally, the oversight process is steadily improving. Regulators and plant owners enhanced and strengthened operational requirements after the Fukushima nuclear accident in 2011. In addition, nuclear plants are highly secured and have not had a material security breach in recent years.

Operational Regulation

The NRC routinely visits nuclear facilities to assess compliance with regulations and corrective actions, if ordered. Its activities are based on five core principles (Exhibit 16):

(1) Regulations and guidance
(2) Licensing, decommissioning, and certification
(3) Oversight
(4) Operational experience
(5) Support for decisions

Exhibit 16 NRC Regulatory Process



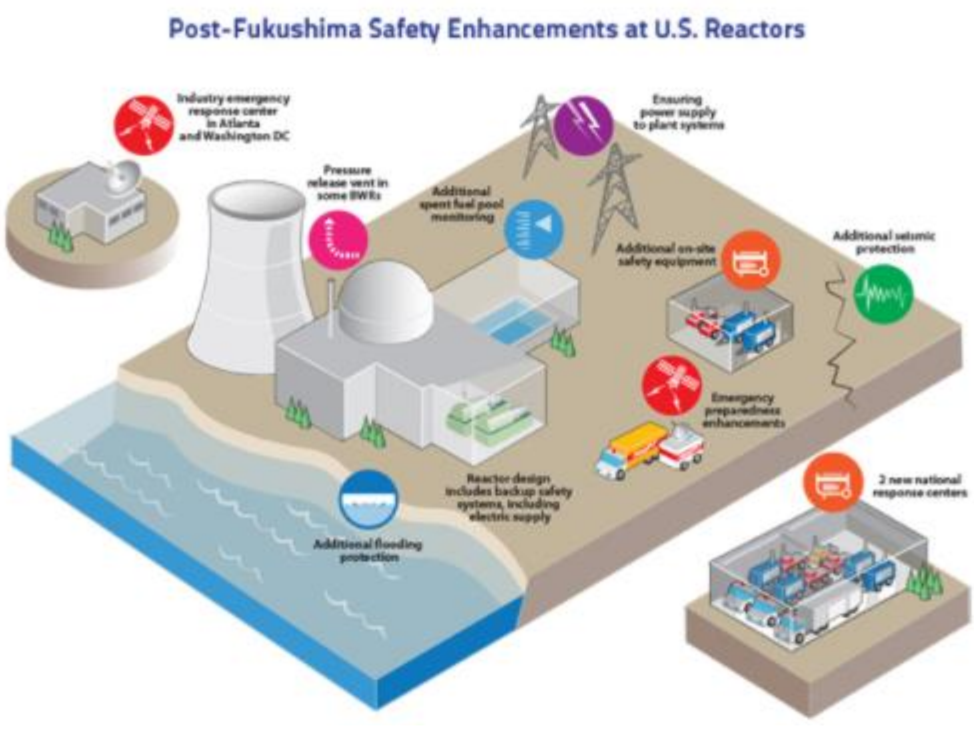
Source: Nuclear Regulatory Commission

The NRC uses enforcement actions to ensure plants are operating safely and in line with current regulations. If the NRC identifies a violation, it assigns a severity level or a risk color code. Risk color codes range from red (highest risk) to green (little risk). Of the 86 enforcement actions the NRC has issued since 2013, there have been only five yellow violations and no red violations.

After Fukushima, the international nuclear generation community implemented additional measures to protect plants from a similar incident. These include (Exhibit 17):

- Development of FLEX capabilities, which are strategies and equipment that will allow a nuclear plant to prevent radiation release if a catastrophic natural event simultaneously affects reactors on a site.
- Establishment of two national response centers (Memphis, Tennessee, and Phoenix) with disaster-response equipment capable of being delivered to any U.S. nuclear site within 24 hours.
- Reverification that current plant designs can withstand severe natural events, including earthquakes and floods.
- Upgraded plant safety equipment.
- Enhanced emergency response capabilities, including improved communication networks and procedural instructions.
- Enhanced plant worker training on new strategies, equipment, and procedures.

Exhibit 17 Post-Fukushima Safety Enhancements at U.S. Reactors



Source: Nuclear Energy Institute

Sustainalytics: Operational Incident Analysis

While the U.S. nuclear industry is highly regulated, operational incidents, including violations of safety standards, small-scale leaks, and chemical releases, happen occasionally. Sustainalytics' incident analysis for the 20 U.S. utilities with nuclear exposure in our coverage universe showed 56 low-risk Category 1 and 2 incidents but no Category 3, 4, or 5 incidents during the last three years (Exhibit 18).

Exhibit 18 Nuclear Incidents Among U.S. Utilities, 2014-Present

Company	Category 1	Category 2	Category 3 Category 4 Category 5	Total	Owned net nuclear capacity (MW)	Incidents per GW
SCANA	1	2		3	647	4.6
Entergy	17	6		23	8,759	2.6
Xcel Energy	3			3	1,594	1.9
PG&E	4			4	2,300	1.7
American Electric Power Co.	2			2	2,069	1.0
NRG Energy	1			1	1,136	0.9
Ameren	1			1	1,193	0.8
FirstEnergy	3			3	3,968	0.8
NextEra Energy	3	1	None	4	5,718	0.7
The Southern Company		2		2	3,690	0.5
Dominion Energy	2			2	5,364	0.4
Exelon	4	2		6	21,585	0.3
Duke Energy	2			2	8,848	0.2
DTE Energy				0	1,124	0.0
Great Plains Energy				0	552	0.0
Pinnacle West Capital				0	1,146	0.0
Public Service Enterprise Group				0	3,635	0.0
Westar Energy				0	552	0.0
Alliant Energy				0	0	NA
WEC Energy Group				0	0	NA

Source: Sustainalytics, Nuclear Energy Institute

Entergy has the second-worst record for incidents when adjusting for its sizable nuclear fleet. Entergy's 8,759 MW nuclear fleet accounts for 10% of total U.S. nuclear capacity, but it is responsible for 23 incidents, or 41% of the national total. Scana has the worst record as a function of the size of its fleet. Scana owns just 67% of one nuclear reactor but has been involved in three incidents during the past three years. By contrast, Exelon, which owns 21,585 MW of nuclear generating capacity, has experienced only six incidents, or 0.3 per gigawatt, and has proved itself to be one of the safest nuclear operators in the world.

Incidents can be the result of many factors, including facility age, but significant gaps in performance can also indicate differences in operational strategy and point to potential weaknesses in management.

In our opinion, Exelon's low number of nuclear-related incidents is in part due to strong nuclear fleet governance. Exelon's board of directors has a generation oversight subcommittee that is responsible for the safe and reliable operation of all its generating facilities. The committee comprises CEO and president Chris Crane and four independent board members who have significant industry expertise. Retired Adm. Richard Mies was a senior commander for the U.S. submarine force and now consults with clients on international security and energy matters. Two other committee members, Nancy Gioia and Nicholas DeBenedictis, have decades of industry experience. Entergy, the second-largest nuclear owner, has a board of directors with vast industry experience, but it has no committee dedicated to the oversight of its nuclear generation fleet. This governance difference might partly explain Exelon's superior performance.

Plant Security

No major physical security breaches have occurred at any U.S. nuclear facility, suggesting the NRC's regulation and the industry's implementation of security requirements has been effective. This gives us confidence that nuclear plant operators can continue managing the safety of their facilities. Security measures at nuclear plants include:

- Physical barriers, electronic detection and assessment systems, and illuminated detection zones
- Electronic surveillance and physical patrols of the plant perimeter and interior structures
- Bullet-resisting protected positions throughout the plant
- Robust barriers to critical areas
- Background checks and access control for employees
- Highly trained, well-armed security guards M

Appendix

Exhibit 1A U.S. Nuclear Fleet, 2016

Plant/Reactor Name	Operating Units	Operator	Capacity (MW)	Owner(s)
Arkansas Nuclear One	2	Entergy	1,812	100% Entergy
Beaver Valley	2	FirstEnergy	1,834	100% FirstEnergy
Braidwood Generation Station	2	Exelon	2,330	100% Exelon
Browns Ferry	3	Tennessee Valley Authority	3,310	100% Tennessee Valley Authority
Brunswick Nuclear	2	Duke Energy	1,870	100% Duke Energy (unit 1); 81.67% Duke Energy (unit 2), 18.33% North Carolina Eastern MPA
Byron Generating Station	2	Exelon	2,300	100% Exelon
Callaway	1	Ameren	1,193	100% Ameren
Calvert Cliffs Nuclear Power Plant	2	Exelon	1,708	100% Exelon
Catawba	2	Duke Energy	2,291	19.25% Duke Energy, 37.5% N.C. Municipal Power Agcy #1, 30.75% N.C. Electric Member Corp, 12.5% Piedmont Municipal Power Agcy
Clinton Power Station	1	Exelon	1,065	100% Exelon
Columbia Generating Station	1	Energy Northwest	1,137	100% Energy Northwest
Comanche Peak	2	Luminant	2,400	100% Luminant
Cooper Nuclear Station	1	Nebraska Public Power District	766	100% Nebraska Public Power District
Davis Besse	1	FirstEnergy	894	100% FirstEnergy
Diablo Canyon	2	Pacific Gas & Electric Co	2,300	100% Pacific Gas & Electric Co
Donald C Cook	2	American Electric Power	2,069	100% American Electric Power
Dresden Generating Station	2	Exelon	1,779	100% Exelon
Duane Arnold Energy Center	1	NextEra Energy	619	70% NextEra Energy, 20% Central Iowa Power Cooperative, 10% Corn Belt Power Coop
Edwin I Hatch	2	Georgia Power Co	1,758	50.1% Southern, 30% Oglethorpe Power Corp, 17.7% Municipal Electric Authority, 2.2% Dalton Utilities
Fermi	1	DTE Energy	1,124	100% DTE Energy
Grand Gulf	1	Entergy	1,409	90% Entergy, 10% South Mississippi Electric Power Association
H B Robinson	1	Duke Energy	741	100% Duke Energy
Harris	1	Duke Energy	928	100% Duke Energy
Hope Creek	1	Public Service Enterprise Group	1,172	100% Public Service Enterprise Group
Indian Point	2	Entergy	2,061	100% Entergy
James A Fitzpatrick	1	Exelon	852	100% Exelon

Continued next page

Source: Nuclear Energy Institute

Exhibit 1A U.S. Nuclear Fleet, 2016 (continued)

Joseph M Farley	2	Southern Co.	1,757	100% Southern Co.
LaSalle Generating Station	2	Exelon	2,271	100% Exelon
Limerick	2	Exelon	2,242	100% Exelon
McGuire	2	Duke Energy	2,316	100% Duke Energy
Millstone	2	Dominion Energy	2,096	93.47% Dominion Energy, 4.8% Massachusetts Municipal Wholesale Electric Co., 1.73% Green Mountain Power Corp
Monticello Nuclear Facility	1	Xcel Energy	554	100% Xcel Energy
Nine Mile Point Nuclear Station	2	Exelon	1,770	Unit 1: 100% Exelon; Unit 2: 82% Exelon, 18% Long Island Power Authority
North Anna	2	Dominion Energy	1,892	88.4% Dominion Energy, 11.6% Old Dominion Electric Coop
Oconee	3	Duke Energy	2,554	100% Duke Energy
Oyster Creek	1	Exelon	608	100% Exelon
Palisades	1	Entergy	789	100% Entergy
Palo Verde	3	Pinnacle West	3,935	29.1% Pinnacle West, 17.49% Salt River Project, 15.8% Edison International, 15.8% El Paso Electric, 10.2% Public Service Co of NM, 5.91% Southern California PPA, 5.7% Los Angeles Department of Water & Power
Peach Bottom	2	Exelon	2,252	50% Exelon, 50% Public Service Enterprise Group
Perry	1	FirstEnergy	1,240	100% FirstEnergy
Pilgrim Nuclear Power Station	1	Entergy	678	100% Entergy
Point Beach Nuclear Plant	2	NextEra Energy	1,193	100% NextEra Energy
Prairie Island	2	Xcel Energy	1,040	100% Xcel Energy
Quad Cities Generating Station	2	Exelon	1,819	75% Exelon, 25% MidAmerican Energy Co
R E Ginna Nuclear Power Plant	1	Exelon	582	100% Exelon
River Bend	1	Entergy	969	100% Entergy
Salem Generating Station	2	Public Service Enterprise Group	2,328	57.41% PSEG, 42.59% Exelon
Seabrook	1	NextEra Energy	1,246	88.23% NextEra Energy, 11.59% Massachusetts Municipal Wholesale Electric Co, 0.1% City of Tauton, 0.08% Town of Hudson (MA)
Sequoyah	2	Tennessee Valley Authority	2,278	100% Tennessee Valley Authority
South Texas Project	2	NRG Energy	2,581	44% NRG Energy, 40% City of San Antonio, 16% Austin Energy
St Lucie	2	NextEra Energy	1,968	85.11% NextEra Energy, 8.81% Florida Municipal Power Agency, 6.08% Orlando Utilities Commission
Surry	2	Dominion Energy	1,676	100% Dominion Energy
TalenEnergy Susquehanna LLC	2	Talen Energy	2,520	90% Talen Energy, 10% Allegheny Electric Coop Inc
Three Mile Island	1	Exelon	803	100% Exelon
Turkey Point	2	NextEra Energy	1,604	100% NextEra Energy
V C Summer	1	Scana	971	66.67% Scana, 33.33% South Carolina Public Service Authority
Vogtle	2	Southern Co.	2,302	45.7% Southern Co., 30% Oglethorpe Power Corp, 22.7% Municipal Electric Authority, 1.6% Dalton Utilities
Waterford 3	1	Entergy	1,164	100% Entergy
Watts Bar Nuclear Plant	2	Tennessee Valley Authority	2,245	100% Tennessee Valley Authority
Wolf Creek Generating Station	1	Westar Energy	1,175	47% Westar Energy, 47% Great Plains Energy, 6% Kansas Electric Power Coop Inc

Source: Nuclear Energy Institute

Research Methodology for Valuing Companies

Overview

At the heart of our valuation system is a detailed projection of a company's future cash flows, resulting from our analysts' research. Analysts create custom industry and company assumptions to feed income statement, balance sheet, and capital investment assumptions into our globally standardized, proprietary discounted cash flow, or DCF, modeling templates. We use scenario analysis, in-depth competitive advantage analysis, and a variety of other analytical tools to augment this process. Moreover, we think analyzing valuation through discounted cash flows presents a better lens for viewing cyclical companies, high-growth firms, businesses with finite lives (e.g., mines), or companies expected to generate negative earnings over the next few years. That said, we don't dismiss multiples altogether but rather use them as supporting cross-checks for our DCF-based fair value estimates. We also acknowledge that DCF models offer their own challenges (including a potential proliferation of estimated inputs and the possibility that the method may miss short-term market price movements), but we believe these negatives are mitigated by deep analysis and our long-term approach.

Morningstar's equity research group ("we," "our") believes that a company's intrinsic worth results from the future cash flows it can generate. The Morningstar Rating for stocks identifies stocks trading at a discount or premium to their intrinsic worth—or fair value estimate, in Morningstar terminology. Five-star stocks sell for the biggest risk-adjusted discount to their fair values, whereas 1-star stocks trade at premiums to their intrinsic worth.

Four key components drive the Morningstar rating: (1) our assessment of the firm's economic moat, (2) our estimate of the stock's fair value, (3) our uncertainty around that fair value estimate, and (4) the current market price. This process ultimately culminates in our single-point star rating.

Economic Moat

The concept of an economic moat plays a vital role not only in our qualitative assessment of a firm's long-term investment potential, but also in the actual calculation of our fair value estimates. An economic moat is a structural feature that allows a firm to sustain excess profits over a long period of time. We define economic profits as returns on invested capital (ROIC) over and above our estimate of a firm's cost of capital, or weighted average cost of capital (WACC). Without a moat, profits are more susceptible to competition. We have identified five sources of economic moats: intangible assets, switching costs, network effect, cost advantage, and efficient scale.

Companies with a narrow moat are those we believe are more likely than not to achieve normalized excess returns for at least the next 10 years. Wide-moat companies are those in which we have very high confidence that excess returns will remain for 10 years, with excess returns more likely than not to remain for at least 20 years. The longer a firm generates economic profits, the higher its intrinsic value. We believe low-quality, no-moat companies will see their normalized returns gravitate toward their cost of capital more quickly than companies with moats.

To assess the sustainability of excess profits, analysts perform ongoing assessments of the moat trend. A firm's moat trend is positive in cases where we think its sources of competitive advantage are growing stronger, stable where we don't anticipate changes to competitive advantages over the next several years, or negative where we see signs of deterioration.

Estimated Fair Value

Combining our analysts' financial forecasts with the firm's economic moat helps us assess how long returns on invested capital are likely to exceed the firm's cost of capital. Returns of firms with a wide economic moat rating are assumed to fade to the perpetuity period over a longer period of time than the returns of narrow-moat firms, and both will fade slower than no-moat firms, increasing our estimate of their intrinsic value.

Our model is divided into three distinct stages:

Stage I: Explicit Forecast

In this stage, which can last 5 to 10 years, analysts make full financial statement forecasts, including items such as revenue, profit margins, tax rates, changes in working capital accounts, and capital spending. Based on these projections, we calculate earnings before interest, after taxes (EBI) and net new investment (NNI) to derive our annual free cash flow forecast.

Stage II: Fade

The second stage of our model is the period it will take the company's return on new invested capital—the return on capital of the next dollar invested (RONIC)—to decline (or rise) to its cost of capital. During the Stage II period, we use a formula to approximate cash flows in lieu of explicitly modeling the income statement, balance sheet, and cash flow statement as we do in Stage I. The length of the second stage depends on the strength of the company's economic moat. We forecast this period to last anywhere from one year (for companies with no economic moat) to 10–15 years or more (for wide-moat companies). During this period, cash flows are forecast using four assumptions: an average growth rate for EBI over the period, a normalized investment rate, average return on new invested capital (RONIC), and the number of years until perpetuity, when excess returns cease. The investment rate and return on new invested capital decline until a perpetuity value is calculated. In the case of firms that do not earn their cost of capital, we assume marginal ROICs rise to the firm's cost of capital (usually attributable to less reinvestment), and we may truncate the second stage.

Stage III: Perpetuity

Once a company's marginal ROIC hits its cost of capital, we calculate a continuing value, using a standard perpetuity formula. At perpetuity, we assume that any growth or decline or investment in the business neither creates nor destroys value and that any new investment provides a return in line with estimated WACC.

Because a dollar earned today is worth more than a dollar earned tomorrow, we discount our projections of cash flows in stages I, II, and III to arrive at a total present value of expected future cash flows.

Because we are modeling free cash flow to the firm—representing cash available to provide a return to all capital providers—we discount future cash flows using the WACC, which is a weighted average of the costs of equity, debt, and preferred stock (and any other funding sources), using expected future proportionate long-term, market value weights.

Uncertainty Around That Fair Value Estimate

Morningstar's uncertainty rating captures a range of likely potential intrinsic values for a company and uses it to assign the margin of safety required before investing, which in turn explicitly drives our stock star rating system. The uncertainty rating represents the analysts' ability to bound the estimated value of the shares in a company around the fair value estimate, based on the characteristics of the business underlying the stock, including operating and financial leverage, sales sensitivity to the overall economy, product concentration, pricing power, and other company-specific factors.

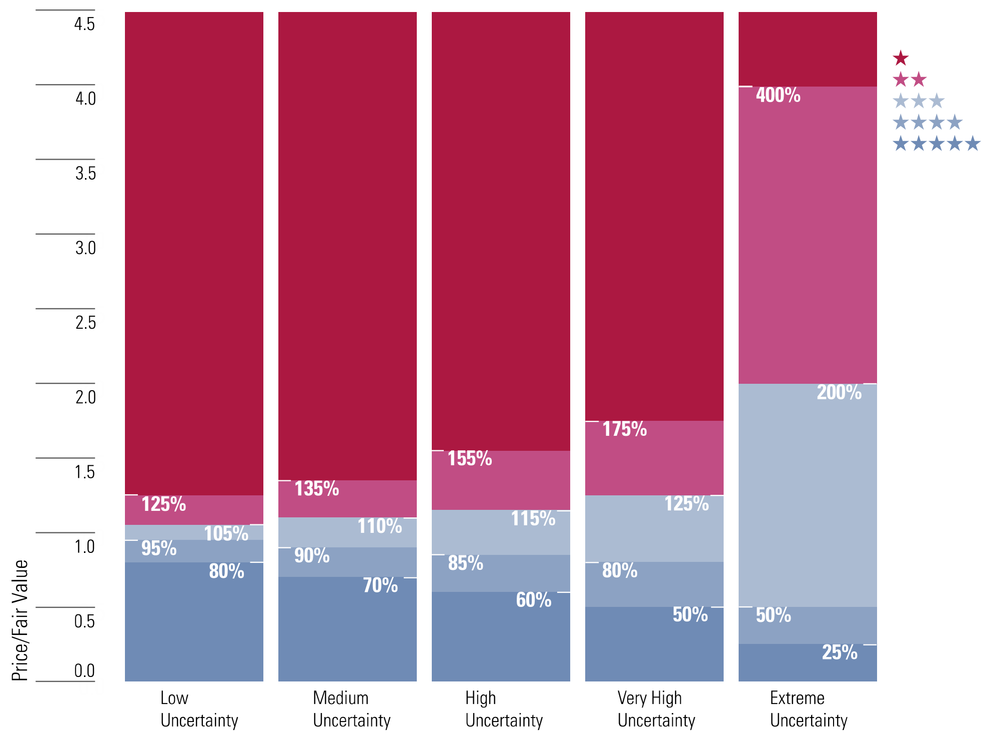
Analysts consider at least two scenarios in addition to their base case: a bull case and a bear case. Assumptions are chosen such that the analyst believes there is a 25% probability that the company will perform better than the bull case and a 25% probability that the company will perform worse than the bear case. The distance between the bull and bear cases is an important indicator of the uncertainty underlying the fair value estimate.

Our recommended margin of safety widens as our uncertainty regarding the estimated value of the equity increases. The more uncertain we are about the estimated value of the equity, the greater the discount we require relative to our estimate of the value of the firm before we would recommend the purchase of the shares. In addition, the uncertainty rating provides guidance in portfolio construction based on risk tolerance.

Our uncertainty ratings for our qualitative analysis are low, medium, high, very high, and extreme.

- Low: Margin of safety for 5-star rating is a 20% discount and for 1-star rating is a 25% premium.
- Medium: Margin of safety for 5-star rating is a 30% discount and for 1-star rating is a 35% premium.
- High: Margin of safety for 5-star rating is a 40% discount and for 1-star rating is a 55% premium.
- Very high: Margin of safety for 5-star rating is a 50% discount and for 1-star rating is a 75% premium.
- Extreme: Margin of safety for 5-star rating is a 75% discount and for 1-star rating is a 300% premium.

Morningstar Equity Research Star Rating Methodology



Market Price

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For more details about our methodology, please go to http://global.morningstar.com/equitydisclosures.

Morningstar Star Rating for Stocks

Once we determine the fair value estimate of a stock, we compare it with the stock's current market price on a daily basis, and the star rating is automatically recalculated at the market close on every day the market on which the stock is listed is open. Our analysts keep close tabs on the companies they follow and, based on thorough and ongoing analysis, raise or lower their fair value estimates as warranted.

Please note, there is no predefined distribution of stars. That is, the percentage of stocks that earn 5 stars can fluctuate daily, so the star ratings, in the aggregate, can serve as a gauge of the broader market's valuation. When there are many 5-star stocks, the stock market as a whole is more undervalued, in our opinion, than when very few companies garner our highest rating.

We expect that if our base-case assumptions are true, the market price will converge on our fair value estimate over time, generally within three years (although it is impossible to predict the exact time frame in which market prices may adjust).

Our star ratings are guideposts to a broad audience, and individuals must consider their own specific investment goals, risk tolerance, tax situation, time horizon, income needs, and complete investment portfolio, among other factors.

The Morningstar Star Ratings for stocks are defined below:

★★★★★ We believe appreciation beyond a fair risk-adjusted return is highly likely over a multiyear time frame. Scenario analysis developed by our analysts indicates that the current market price represents an excessively pessimistic outlook, limiting downside risk and maximizing upside potential.

★★★★ We believe appreciation beyond a fair risk-adjusted return is likely.

★★★ Indicates our belief that investors are likely to receive a fair risk-adjusted return (approximately cost of equity).

★★ We believe investors are likely to receive a less than fair risk-adjusted return.

★ Indicates a high probability of undesirable risk-adjusted returns from the current market price over a multiyear time frame, based on our analysis. Scenario analysis by our analysts indicates that the market is pricing in an excessively optimistic outlook, limiting upside potential and leaving the investor exposed to capital loss.

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