Recent scientific work suggests that avoiding the worst aspects of climate change will require a near-zero emissions energy system by mid-century. The electric grid will be a critical link in achieving that decarbonization because it directly represents 40% of global carbon dioxide emissions from energy, and is also expected to displace fossil fuels in transport and industry over the coming decades. Multiple analyses, including by the Intergovernmental Panel on Climate Change, envision nuclear energy as an important component of a zero carbon grid, as well as potentially a source of energy to produce industrial process heat and zero carbon fuels such as hydrogen. Achieving a zero grid emissions solely by renewable energy such as wind and solar is technically possible, but has been found by multiple analyses to be prohibitively expensive, due to the large overbuild of peak demand required, and very large quantities of storage needed to capture and utilize large seasonal surpluses for use in deficit periods. Nuclear energy, while recently expensive in first of kind projects in the United States and Europe, is being built competitively around the world where the same designs are repeated, under cost-conscious management. Nuclear waste has proven challenging to address politically, but safe options are available and being adopted by other countries. While nuclear energy, like all industrial activity, carries risks, those risks must be compared to the risks to human health and the environment from having an incomplete climate change solution set.

New Mexico's Experience With Nuclear Generation

The New Mexico Public Regulation Commission (NMPRC) regulates El Paso Electric Co. and Public Service Company of New Mexico (PNM), the wholly owned electric utility subsidiary of PNM Resources. El Paso Electric Co. and PNM Resources, have a combined 26% interest in the approximately 4,000 MW Palo Verde Nuclear Generation Station (PVNGS), located some 50 miles to the west of Phoenix, Arizona. PVNGS is the largest nuclear generating plant by net generation in the US.

Over the years, many cases addressing PVNGS issues have been decided by the NMPRC. What has been learned about nuclear generation in general and PVNGS in particular includes:

1. In NMPRC Case No. 13-00390-UT, it was shown that power produced at the PVNGS costs more than what it is worth in a market driven by gas fired generation prices. This has been true for over a decade and will continue for as long as gas prices continue to be low-cost.

2. When the cost of nuclear power is determined, all expenses to produce the power must be included in order to make a valid comparison of the cost of power produced by different types of generators. Total cost of power produced at PVNGS include expenses for:

   a. Operations and maintenance
   b. Capital improvements

c. Fuel
d. Water
e. Lack of flexibility
f. Economic risk
g. Decommissioning

3. PVNGS became fully operational in the late 1980s. It has maintained a high capacity factor for the past several years. This helps offset expenses for: maintenance, capital expenditures and decommissioning that continue to increase as the plant ages.

4. PVNGS evaporates some 20 billion gallons of treated wastewater annually to meet its cooling needs. PNM stated in its 2017 Integrated Resource Plan that PVNG uses 768 gallons of water per MWh. It's not only arid sites that could have cooling water problems. Due to climate change, it can be anticipated that there may be future water shortages at some nuclear plants, including PVNGS, due to heat waves and droughts.

Ironically, nuclear plants not only face lack of cooling water risks, they also face storm risks. Nuclear plants do not produce the power needed to operate water pumps, heavy equipment and control rooms. If the grid goes out, these plants have nowhere to send power output and no source of energy needed to operate. In past years nuclear units have been shutdown due to external grid problems caused by storms.

5. It is difficult to quantify economic risks inherent with nuclear power plants but they do exist. One of the units at PVNGS shutdown for several months due to a mechanical problem. Several US nuclear plants, shutdown due to mechanical problems, never restarted due to cost considerations.

6. Although not readily apparent, the operating characteristics of a nuclear generating plant can impose costs as renewable resources are added to a utility's electrical system. PVNGS' output (like all existing nuclear plants) is not flexible. That is, its output can't be quickly ramped up or down to load follow. PVNGS's output isn't dispatchable since it operates at full output at all times that it isn't shut down for a mechanical problem or refueling.

New Mexico's legislature recently enacted an Energy Transition Act. This act requires that no less than 40% of the energy provided by regulated utilities to its retail customers must come from renewable sources by 2025. Due to PVNGS' lack of ability to load follow; El Paso Electric Co. and PNM must add peaking gas-fired plants and/or batteries to their systems to support increased amounts of intermittent renewable generation mandated by the new legislation. In the near future cases will be filed at the NMPRC to determine what resources must be added to the systems of regulated utilities in order to comply with the new act.

7. PVNGS decommissioning was an issue in NMPRC Case No. 15-00261-UT. In this case, the Commission determined that PNM was imprudent in: a)

buying interests in PVNGS that it had previously sold than leased back; and, b) extending some sale leaseback leases. As its remedy for PNM's imprudent transactions, the NMPRC ordered PNM to bear all future decommissioning expenses for its PVNGS interests that exceed the current amount included in the facilities decommissioning trust. This is not a small matter. Based on recent decommissioning expenses, PVNGS' trust fund is probably underfunded. The decommissioning expense portion of the commission's Case No. 15-00261-UT final order is one of the rulings in the final order that was appealed.

6. On April 22, 2019, a large coalition led by New Energy Economy filed a joint petition in NMPRC Case No. 19-00102-UT. This petition asks for an investigation of PNM's intended purchase of 114 MW interest in PVNGS Units 1 and 2 that the company is leasing and that the commission ruled in Case No. 15-00261-UT was imprudently extended. The reason for many in the coalition to join the petition are the hundreds of deaths that have occurred in New Mexico due to uranium mining and milling activities that contaminated land surfaces and ground water aquifers.

7. Another issue that will likely be the subject of future litigation at the NMPRC is the cost of nuclear waste storage and/or disposal once PVNGS is decommissioned. The distinction between storage and disposal is that storage is temporary while disposal is permanent. If no disposal site(s) exist when PVNGS is

decommissioned, nuclear waste from the plant will probably be stored on site, as is currently done at nuclear plants around the county.

Nuclear Generation's Future

There is no certainty regarding the future of nuclear generating plants. What is certain is that all operating large capacity nuclear plants will be retired over the next few decades. When addressing the issue of replacement capacity for retiring plants, one question is whether large capacity nuclear plants will be built to replace retired plants. This seems to be unlikely for a variety of reasons. Construction costs for nuclear plants have greatly exceeded initial projections. Lender risk caused by long-term, high-capital investment in deregulated (or regulated) markets driven by short-term price signals makes financing multibillion-dollar construction projects difficult. Finally, because of their inability to load follow; these plants are incompatible with large amounts of power produced by intermittent renewable resources. If new large capacity nuclear plants don't replace retiring nuclear plants, is there a viable nuclear plant alternative. Perhaps. It may be that small nuclear units (50 MW) currently being developed could be part of the replacement capacity mix.

When it comes time to replace retiring units capacity, replacement decisions will be based on a multitude of location specific factors such as: politics, jobs, replacement cost, amount of intermittent renewable resources in the local grids and

cost for storage/disposal of accumulating nuclear waste. Another factor will be the rapidly decreasing cost of renewable resources backed up with long-term energy storage that can quickly adjust to renewable resource output variability.

Although there is no certainty about what resources will replace retiring nuclear plants, what is certain is that the country faces a huge nuclear waste disposal problem. Nuclear waste disposal will become increasingly important because it presents serious problems related to cost, security and long-term safety. As reported by Stanford University, some 80,000 tons of highly radioactive spent fuel from commercial nuclear power and millions of gallons of high-level nuclear waste from defense programs are presently stored in pools, dry casks and large tanks at more than 75 sites through out the country.

In 2009 there was an In-depth report in Scientific American. One of the sections of this report is entitled: Spent Nuclear Fuel: A Trash Heap Deadly For 250,000 Years Or A Renewable Energy Source. Although nuclear energy is not a renewable energy source, it's clear that spent nuclear fuel is a national problem that needs to be solved. One of the things making its difficult to solve this problem is the not in my backyard syndrome. The great bulk of nuclear units are located in the eastern interconnect. The states where these units are located often want to send the waste to western states that don’t want it.