Restarting Three Mile Island, a US nuclear power plant that closed for decommissioning

› Edward Kee

Constellation Energy and Microsoft announced a 20-year power purchase agreement that calls for the restart of the Three Mile Island Unit 1 nuclear power plant, which was closed for decommissioning in 2019. This is the second US nuclear power plant attempting a return to operation from decommissioning, following the Palisades plant. This article covers the reasons and conditions for restarting a closed U.S. nuclear power plant and whether this can be considered part of a larger trend.

Fig. 1
Three Mile Island nuclear power plant before the closure of Unit 1[1]

TMI–1 Restart

Microsoft and Constellation Energy announced, on 20 September 2024, a 20-year power purchase agreement (PPA) for the Three Mile Island nuclear power plant to supply power for Microsoft data centers. This PPA would require the restart of the Three Mile Island nuclear power plant unit that was closed for decommissioning.

The Three Mile Island site is located in the U.S. state of Pennsylvania on an island in the Susquehanna River near the state capital in Harrisburg. The site has two nuclear power plant units. Three Mile Island Unit 1 (TMI-1) was in operation until 2019, while Unit 2 (TMI-2) was closed after a core meltdown in 1979. Constellation Energy will restart TMI-1 but not TMI-2.

TMI-1 is an 880 MWe nuclear power plant using the Babcock & Wilcox reactor design that started commercial operation in September 1974. Before the original 40-year operating license expired in 2014, the U.S. Nuclear Regulatory Commission (NRC) issued a 20-year operating license renewal, allowing TMI-1 to operate until 2034. However, Exelon Generation[2] closed TMI-1 in 2019 because it was operating at a financial loss.[3] After closure, TMI-1 was scheduled for decommissioning using the SAFSTOR approach.

Some U.S. states (e.g., Illinois, New Jersey, and New York) implemented Zero-Emission Credit (ZEC) programs to help nuclear power plants that faced economic issues similar to those at TMI-1 to remain in operation.[4] Pennsylvania decided not to implement ZEC payments, and TMI-1 was closed.

Constellation expects that TMI-1 will be returned to commercial operation by 2028 with a 20-year operating license. The TMI-1 restart is a complicated process that will take several years, as outlined in the schedule of activities in **Figure 2** below. The TMI-1 restart is the second in the US, with Palisades announcing a restart in 2022.

1 https://images.saymedia-content.com/.image/t_share/MjEwODY3NzAzNzM5OTE4MTYx/the-three-mile-island-accident-americas-worse-nuclear-crisis.jpg
2 Exelon Generation, the power generation subsidiary of Exelon Corp, was separated from Exelon in February 2022 and renamed Constellation Energy. Constellation Energy is the current owner of TMI-1.
3 https://nuclear-economics.com/29-a-win-for-dirty-electricity/
4 https://nuclear-economics.com/6-u-s-state-action-on-revenue-certainty/

A 20-year PPA supports the TMI-1 restart investment. Constellation and Microsoft have not disclosed the financial terms of the PPA. However, the investment bank Jefferies estimated that Microsoft will be paying $110 to $115 per megawatt-hour, much higher than the current market rate for wholesale electricity.[5] An increase in Constellation's stock closely followed the announcement of this deal.[6]

It is unclear where the Microsoft data centers that use TMI-1 power will be located, but they are not located on the Three Mile Island site. Because the TMI-1 power will be put onto the grid, Microsoft will also have to pay for transmission and other grid charges.

Constellation plans to apply for a U.S. DOE Loan Guarantee, with Constellation providing a corporate repayment guarantee.[7] Constellation has not and will not use any money from the plant decommissioning trust fund to support the plant's restart.[8]

In addition to announcing the TMI-1 restart, Constellation announced that it would rename the plant as the Crane Clean Energy Center (CCEC), honoring Chris Crane, the former CEO of Exelon.

Why restart TMI–1?

The push to restart TMI-1 and other closed nuclear power plants has two main drivers. First, nuclear power is a large source of carbon-free electricity at a time when reducing carbon emissions is important and urgent. Second, electricity demand is increasing, creating a need for reliable, always-on electricity to support grid stability.[9]

The TMI-1 unit closed in 2019 because the wholesale electricity market did not value some important nuclear power plant attributes. Other nuclear power plants in the U.S. have also closed due to the failure to value these attributes.[10]

The TMI-1 restart proposal reflects a new recognition of the value of nuclear power attributes, including clean electricity, reliable operation, important grid services, and long-term asset value.

Clean Electricity

Nuclear power does not emit greenhouse gases during operation, and lifetime greenhouse gas emissions of nuclear power are similar to levels for solar and wind. Unlike intermittent renewable generation, nuclear power offers 24/7 carbon-free electricity generation.

Many companies, including technology companies like Microsoft, have public commitments to be carbon-free in a few years. For example, Microsoft aims to be carbon-negative by 2030, Google aims to have net-zero emissions by 2030, and Amazon aims to have net-zero carbon emissions by 2040. Nuclear electricity can help meet these commitments.

Multiple announcements have been made in recent weeks for tech companies to use nuclear power for data centers.[11] The broader topic of how and why tech companies are looking to nuclear power to meet data center demand will be covered in a future atw publication.[12]

Reliable Operation

Nuclear power is reliable. In most systems, nuclear power plants operate as base-load resources that achieve 90 percent or higher capacity factors. Nuclear power plants can operate as and when needed, so they do not need backup power solutions as are needed for intermittent sun or wind generation.

The base-load operation of nuclear power is well suited to meet the base-load demand of grid systems and data centers.

At the same time, even when operating in a baseload generation role, nuclear power plants can provide critical value for grid stability, with large ramp capability, spinning reserve for frequency control, and rotational inertia.

Scaleable

Nuclear power plants provide a large amount of electricity from a high-energy-density power plant requiring minimal land that can be built almost anywhere in the world.

The capability of nuclear power to provide large amounts of power will be important to meet growing U.S. electricity demand linked to data centers, electric vehicles, electrification of commercial and industrial loads, and higher peak demand due to hotter summers.[13]

5 https://www.nytimes.com/2024/10/30/business/energy-environment/three-mile-island-nuclear-energy.html
6 https://www.reuters.com/markets/deals/microsoft-may-pay-constellation-premium-three-mile-island-power-agreement-2024-09-23/
7 https://www.washingtonpost.com/business/2024/10/03/nuclear-microsoft-ai-constellation/
8 https://www.eia.gov/todayinenergy/detail.php?id=63304
9 https://thebulletin.org/2024/10/what-it-will-take-to-restart-decommissioned-us-nuclear-plants-a-primer/
10 https://nuclear-economics.com/32-market-failure-the-book/
11 https://venturebeat.com/data-infrastructure/why-ai-is-going-nuclear/
12 https://prospectlaw.co.uk/news/article/big-tech-buy-into-smrs-whats-it-all-about/
13 https://www.cnbc.com/2024/10/23/big-tech-is-driving-a-nuclear-power-revival-energy-guru-dan-yergin-says.html

Restarting closed nuclear power plants

Because electricity market designs and conditions did not fully compensate for nuclear power plant attributes, several U.S. merchant nuclear power plants like TMI-1 closed early for economic reasons. At the time, the owners unsuccessfully sought various approaches to increase revenue (e.g., a long-term PPA). Without a way to restore profitability, the owners of these plants had only two realistic options:

- Continue operating at a financial loss for years or decades in hopes that the value of nuclear electricity would eventually increase and return the plant to profitability, or
- Close the plant early to stop financial losses.

Long-term asset value

Nuclear power plant restarts reflect a new recognition of the long-term asset value of nuclear power, with nuclear power plants like TMI-1 capable of operating for decades. The current fleet of operating nuclear power plants can operate reliably and safely for decades past their original 40-year operating life.

Nuclear power plants regularly undertake a level and type of maintenance, repair, and major equipment refurbishment that allows them to operate reliably and safely for a long time. Almost all U.S. operating nuclear reactors, including TMI-1, renewed their original 40-year NRC operating license for an additional 20 years

Background on US electricity reform/restructuring and merchant nuclear power plants

For those outside the U.S. nuclear power industry, a brief recap of the last 25 years will help place the TMI-1 situation in context.

Starting in about 2000, the U.S. embarked on a process of electricity industry reform that included formal electricity markets and industry restructuring.

Before these reforms and restructuring, the traditional electricity industry model had power generation owned by vertically integrated monopoly utilities with oversight by state economic public utility regulators. In this model, the state regulator allowed the costs of building and operating power plants to be recovered from electricity customers.

The resulting electricity markets cover some, but not all, of the country, with some regions (i.e., the Southeast and the West) retaining the traditional regulated utility model. The formal electricity markets (e.g., PJM, CAISO, MISO, SPP, and ERCOT) are similar but not identical. The U.S. Federal Energy Regulatory Commission oversees these formal electricity markets. TMI-1 is in the PJM electricity market.

Each U.S. state has control of the electricity industry and implemented industry restructuring. Some states required all regulated generation plants to be divested, others allowed generation plants to remain in an unregulated affiliate, and others allowed regulated generation plants to participate in wholesale electricity markets. In the U.S. state of Pennsylvania, regulated generation plants, including TMI-1 were divested. TMI-1 and other nuclear power plants in Pennsylvania were sold to unregulated companies and were transformed from regulated assets into so-called merchant plants that relied on wholesale electricity market revenue. In the PJM electricity markets, this includes short-term day-ahead electricity sales and capacity market revenue, supplemented as possible, by power contracts outside the market (i.e., hedge contracts around the day-ahead market).

When nuclear power plants were divested in the early 2000s, the usual transaction was a sale bundled with a power contract with the original owner. These power contracts had a term that typically expired when the original 40-year operating license expired and a price that provided the selling utility with costs of nuclear electricity similar to the costs expected if the plant had not been sold.

The buying companies, typically large nuclear power plant fleet operators, saw this as an opportunity to undertake investments in the newly acquired nuclear power plants to bring the plant's performance and costs in line with fleet performance levels and included an application for license renewal. The additional 20-year operating period, after the expiration of the power contracts with the seller, was expected to provide a return on investment during profitable operation.

In the late 2000s, the U.S. natural gas industry exploited shale gas technology. This resulted in very low natural gas prices, and as wholesale electricity market prices are linked to natural gas prices, electricity market prices were very low. Since then, U.S. natural gas prices have fluctuated but remain relatively low.

Merchant nuclear projects that were expected to be profitable in the period after the end of the original 40-year operating license and any power contracts were not. In the early 2010s, multiple merchant nuclear power plants, including TMI-1, faced financial losses. Local retail utilities had no desire to sign power contracts at prices above prevailing low wholesale electricity market prices, so these merchant nuclear plants relied on sales into the wholesale electricity markets and, depending on the market, some additional compensation from capacity markets.

Some of these merchant nuclear power plants closed when faced with current and expected financial losses. The most vulnerable merchant nuclear power plants were older, smaller, single-unit plants with higher operating costs than newer, larger, multiple-unit plants. Some U.S. states implemented Zero Emissions Credits (e.g., New York, New Jersey, and Illinois) to provide additional revenue for the clean electricity generated by nuclear power plants (i.e., a key nuclear power attribute that is not reflected in wholesale electricity market prices) that would prevent closures. As mentioned in the main article, Pennsylvania declined to implement these Zero Emission Credits, and TMI-1 was closed.

In 2022, the U.S. Inflation Reduction Act implemented production tax credits for new and existing nuclear power, providing a floor for merchant nuclear plant revenue. This revenue floor should preclude additional merchant nuclear power plant closures in states without Zero Emission Credits. However, the financial basis for the TMI-1 restart is the above-market-price PPA with Microsoft

For more information on these topics, see Mr. Kee's 2021 Book: Market Failure – Market-Based Electricity is Killing Nuclear Power (http://mybook.to/Market_Failure).

(i. e., 60 years of commercial operation). Some U.S. reactors have already applied for and received NRC approval to operate for an additional 20 years (i. e., a total of 80 years of operation), and most other U.S. nuclear power plants are expected to apply for such a Subsequent License Renewal.

Most new nuclear power plants are designed to operate for 60 to 100 years.

The value of a nuclear power plant after about 20 years of commercial operation is shown in various Levelized Cost of Electricity (LCOE) calculations, showing that continued operation of an existing operational nuclear power plant is cheaper than most other options.[14]

The long-term operation of existing nuclear capacity will be essential to keep de-carbonization targets within reach over the next decade.[15]

Adding a mothball option

The restart of TMI-1 and Palisades after closure looks like a third option to place the plant in a "*mothball status*" with plans for future restart. The concept of "mothballing" an operating nuclear power plant might have been attractive for these now-closed nuclear power plants, but the cost and requirements were unknown. The lessons learned during the restart of TMI-1, Palisades, and other closed U.S. nuclear power plants may help the NRC and nuclear power plant owners to develop a viable mothball option.

Canada provides an example of this approach. Bruce Power in Canada has eight CANDU pressurized heavy water reactors built between 1970 and 1987 by Ontario Hydro, an Ontario Crown Corporation. In 1995, Bruce 2 was closed, followed in 1998 by Bruce 1, 3, and 4. In 2001, Bruce Power L.P. leased all eight Bruce units. Bruce 4 was restarted in 2003, Bruce 3 in 2004, and Bruce 1 and 2 in 2012.[16]

TMI-1 and Palisades, the first U.S. nuclear power plants being restarted after being permanently closed, will blaze a path for restarting closed nuclear power plants that can be used by other closed nuclear power plants that may be considered for restart. As the detailed requirements for these restarts become clear, owners of operating nuclear power plants might see a viable mothball mode strategy with a planned restart as an alternative to permanently closing a plant.

What is needed to restart

The work needed to restart a closed nuclear power plant (i.e., where the operating license is no longer in place) depends on the plant's decommissioning strategy and other factors. Some U.S. nuclear power plants used the immediate decontamination and deconstruction mode, while others used the SAFSTOR mode. In the SAFSTOR mode, a closed nuclear power plant is maintained and monitored for decades to allow radioactive decay, after which the plant is dismantled. Under the SAFSTOR approach, a closed nuclear power plant remains largely intact for years, so restarting it may involve less work compared to a plant that has started decommissioning activity.[17]

A series of routine nuclear power industry technical and regulatory tasks will be needed to bring a nuclear power plant back online after permanent closure. While nuclear power plants are routinely shut down and restarted as part of their fuel cycle, with inspection and maintenance before returning to operation, de-commissioning differs from regular refueling and maintenance outages.

Before a closed reactor can restart operations, the NRC must formally approve a return to operations. The NRC will thoroughly inspect the nuclear power plant, focusing on reactor pressure vessels and cooling systems as well as operator readiness.

Restarting a closed nuclear power plant will require refurbishment or replacement of components, especially if those components had deferred maintenance near the end of the plant's operation. If the closed nuclear power plant has started decommissioning and dismantlement activities, work will be needed to reverse these activities.

When a nuclear power plant closes, spent nuclear fuel in the spent fuel storage pool will be moved to dry cask storage. A restart will require the spent fuel pool to be returned to full function for use after commercial operation resumes.

A restart will require recruiting and training staff to refurbish and run these plants. Nuclear operators must be highly trained and certified by the NRC for their specific plant, which involves extensive training and simulation exercises. A restart will also require technicians and trades workers.[18]

14 https://www.lazard.com/research-insights/levelized-cost-of-energyplus/
15 NEA LTO report, https://www.oecd-nea.org/jcms/pl_60310/long-term-operation-of-nuclear-power-plants-and-decarbonisation-strategies
16 https://nuclear-economics.com/12-nuclear-flexibility/
17 https://www.utilitydive.com/news/palisades-three-mile-island-duane-arnold-nuclear-reactor-restart-holtec-nextera-constellation-nrc/730393/
18 https://thebulletin.org/2024/10/what-it-will-take-to-restart-decommissioned-us-nuclear-plants-a-primer/

Issues that need to be resolved include:

- What type and level of inspection will be required for key nuclear power plant systems;
- What items of equipment must be replaced;
- Will the nuclear power plant be required to update any procedures, equipment, or other things to reflect NRC requirements that have changed between the time that the NRC approved the plant's original operating license and the date of a restart;
- When will the (new) operating license expire;
- What will be required for the plant operator, especially if the owner of the restarted plant (a) was not the operator before closure or (b) is not a licensed operator at any other U.S. nuclear power plant; and
- What level of upkeep, maintenance, and oversight between closure and restart will be considered adequate (i.e., what cost does this imply during a mothball period)?

Other U.S. Nuclear Power Plant restarts

Palisades

The Palisades nuclear power plant began a restart effort in 2022 before the TMI-1 restart was announced in September 2024.

Palisades is a single-unit plant located on the eastern shore of Lake Michigan about 75 miles from Chicago in the U.S. state of Michigan. The plant has an 805 MWe Combustion Engineering reactor that started commercial operation in 1973. Palisades was originally built and operated by CMS Energy. A CMS 20-year license renewal application for Palisades (i.e., to 2031) was approved by the NRC in 2005.

CMS sold Palisades to Entergy in 2006, along with a 16-year PPA to sell power to Consumers Energy, a CMS subsidiary. This PPA was consistent with other nuclear power plant divestments for electricity industry restructuring.

The prices in the Palisades PPA were, by 2018, higher than the market cost of electricity for Consumers Energy. State regulators rejected a proposed buy-out of the out-of-market PPA and Palisades continued to operate until May 2022, when the PPA expired. Entergy closed the plant, as planned, when the PPA expired. Palisades was sold, along with its decommissioning fund, to Holtec International for decommissioning.[19]

In a turn of events, Holtec in 2022 announced plans to restart Palisades. A $1.52 billion U.S. DOE Loan Guarantee was approved in October 2024 to help fund Holtec's restart effort. The state of Michigan also provided about $300 million to help fund the restart.

Holtec has announced that the plant has signed power contracts with two regional public power companies and that Palisades is on track for restart in October 2025.[20]

Holtec has started obtaining approval from the NRC to restart the plant, with the NRC relying on existing regulations for their review. A petition requiring the NRC to establish a new procedure and regulations was filed and released for public comment in September 2024.[21] The NRC staff will follow existing regulations when reviewing the Palisades and TMI-1 restart applications while this petition is being evaluated.

The Palisades inspections have shown that the condition of Palisades steam generator u-tubes is a concern. Alan Blind, engineering director at the plant from 2006 to 2013, estimated that repairs to the steam generators would cost over $500 million and add two to three years to the restart. Holtec spokesperson Patrick O'Brien said such issues are under evaluation, but the company doesn't expect significant delay or extra costs.[22]

Duane Arnold

Iowa's Duane Arnold nuclear power plant has been mentioned as another potential restart candidate.[23] Duane Arnold is a 601 MWe GE BWR design that started operation in February 1975. The plant was originally owned by several local utilities, with a 70 % share sold to NextEra Energy (formerly FPL Group) in 2006. The NRC approved a 20-year license renewal in 2010, extending the plant's operating license to 2034.

Duane Arnold shut down in 2020 because it was not economically viable, like Palisades and TMI-1. Like TMI-1, a Duane Arnold restart would likely be linked to data center demand.[24]

NextEra is interested in restarting Duane Arnold and is conducting engineering assessments and working with the NRC and local stakeholders to evaluate a possible restart. However, NextEra would only restart Duane Arnold if the restart project were risk-free.[25]

19 This involved an approach to nuclear power plant decommissioning where the sale and transfer of the nuclear power plant included a transfer of the license and the decommissioning fund to a specialist decommissioning firm, see https://www.ans.org/news/article-4095/holtec-completes-acquisition-of-michigans-palisades-and-big-rock-point/

20 https://www.utilitydive.com/news/palisades-nuclear-plant-restart-on-track-for-october-2025-despite-nrc-petit/727780/

21 See U.S. Federal Register Vol. 89, No. 182 19 September 2024, Docket No. PRM-50-125, NRC-2024-0135.

22 https://www.reuters.com/business/energy/us-regulator-says-michigan-nuclear-plant-needs-work-before-restart-2024-09-18/

23 https://www.ans.org/news/article-6248/nextera-energy-considering-duane-arnold-plant-restart/

24 https://www.kcrg.com/2024/09/26/owner-duane-arnold-energy-center-palo-considers-bringing-plant-back-online/

25 https://www.cnbc.com/2024/10/23/nextera-sees-strong-data-center-interest-in-restarting-iowa-nuclear-plant-ceo-says.html

Other potential restarts

A dozen U.S. nuclear power plants closed early because they had trouble profiting in wholesale electricity markets. As the value of nuclear electricity increases, some of these closed nuclear power plants would be candidates for restart.[26]

Nuclear power plants that closed more recently may be more suitable for restart than plants that closed a while ago. Nuclear power plants that elected to use the SAFSTOR decommissioning approach may be more suitable for a restart than plants that used the immediate dismantlement approach.[27] Also, some closed U.S. nuclear power plants were sold to a decommissioning specialist company in an arrangement similar to the Palisades sale to Holtec. Despite the Holtec efforts at Palisades, nuclear power plants that remain in the ownership of the pre-closure operator may be better candidates for restart than plants that were sold to a decommissioning firm.

In addition to Palisades, TMI-1, and Duane Arnold, there might be one or two other U.S. nuclear power plants that are viable restart candidates.[28] This includes nuclear power plants that were not completed and that did not reach commercial operation.

Even the abandoned V.C. Summer 2&3 new build units in South Carolina have been mentioned as potential candidates for completion, with a restart in construction similar to the experience at the Watts Bar nuclear power plant units that were completed and placed into commercial operation after construction was stopped for a long time.[29] Before South Carolina Electric & Gas and Santee Cooper abandoned construction at the V.C. Summer 2&3 units in 2017, the engineering-procurement-construction contractor crews had completed the foundation and other site infrastructure work. Despite the large project cost and overruns, restarting construction should be possible.[30]

Other precedents

While Palisades is the first U.S. nuclear power plant to move toward restart after entering the decommissioning phase, some earlier restarts after long shutdowns may provide some precedents.

Browns Ferry

The Browns Ferry nuclear power plant in Alabama had units that were closed in 1985 and then restarted. These nuclear power plants were returned to operation after shutdowns of six years for BF-2, ten years for BF-3, and 22 years for BF-1. Unlike Palisades and TMI-1, the Browns Ferry units continued to hold an operating license during their prolonged shutdowns and maintained key plant systems in a lay-up condition, anticipating a return to operation. The cost to maintain the Browns Ferry plant as an “operating” plant during its prolonged shutdown was higher than the potential cost of a mothball option where the plant is no longer operational.

Watts Bar

The Watts Bar nuclear power plant in Tennessee has units that suspended construction for a long period, with construction restarted to complete the units. WB-1 was placed into commercial operation in 1996, 23 years after the unit started construction in 1973. WB-2 was placed into commercial operation in 2016, 43 years after the unit started construction in 1973. The Watts bar units, unlike Palisades and TMI-1, involved the start and stop of construction activity before commercial operation, not the closure of operational nuclear power plants for decommissioning.

Onagawa (Japan)

On 29 October 2024, the Onagawa-2 nuclear power plant returned to operation. Onagawa-2 is an 825 MWe BWR located on the east coast of Japan, about 72 miles north of the Fukushima Dai-Ichi nuclear power plants. The Onagawa-2 plant, closed since 2011, was the nuclear power plant closest to the epicenter of the Great East Japan magnitude nine earthquake in 2011.

Onagawa has been in a suspended operation state since 2011, and Tohoku Electric, the owner, has spent about $3.7 billion on safety measures adopted after the 2011 earthquake.[31]

A return to operation from a suspended operation status differs from a restart from a closed status like Palisades and TMI-1. However, some lessons learned about maintaining equipment and staff during 13 years of suspended operation may be useful in returning closed nuclear power plants to operation in other countries. Other Japanese nuclear power plants may provide similar lessons.

26 https://theconversation.com/rising-electricity-demand-could-bring-three-mile-island-and-other-prematurely-shuttered-nuclear-plants-back-to-life-239577
27 https://www.nrc.gov/reading-rm/doc-collections/maps/decommissioning-sites.html
28 https://www.utilitydive.com/news/palisades-three-mile-island-duane-arnold-nuclear-reactor-restart-holtec-nextera-constellation-nrc/730393/
29 https://scdailygazette.com/2024/10/15/7-years-after-sc-nuclear-debacle-advisory-group-suggests-potential-restart-of-failed-project/
30 https://www.utilitydive.com/news/palisades-three-mile-island-duane-arnold-nuclear-reactor-restart-holtec-nextera-constellation-nrc/730393/
31 https://www.reuters.com/world/japan/japans-tohoku-elec-restarts-onagawa-reactor-after-13-year-hiatus-2024-10-29/

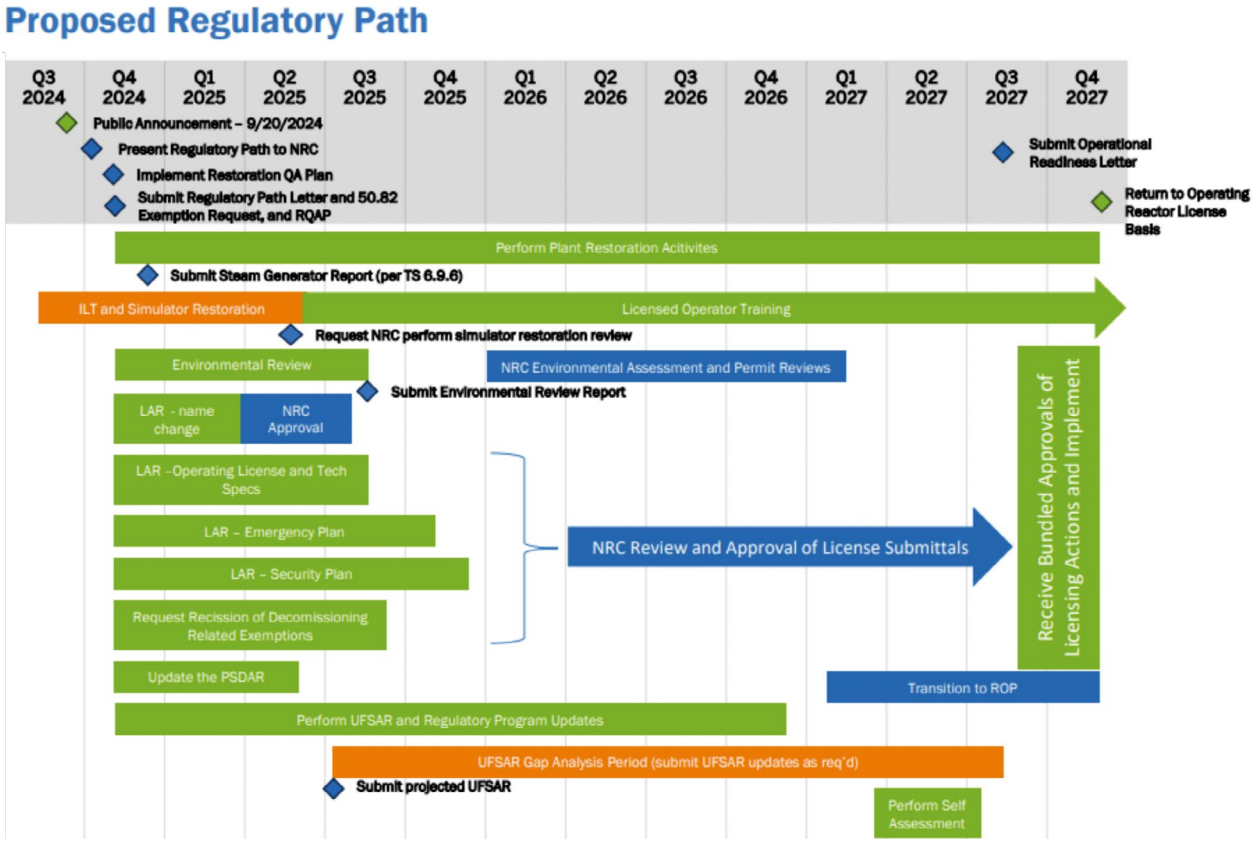

Fig. 2
Constellation Regulatory Path for TMI-1 Restart

Diablo Canyon

Some industry observers have linked recent events at the California Diablo Canyon nuclear power plant with the Palisades and TMI-1 restarts.

However, Diablo Canyon units never closed. The Diablo Canyon units have an original operating license that was to expire in 2024 and 2025. The owner, Pacific Gas & Electric (PG&E), originally filed for a license renewal for both units in 2009. However, PG&E withdrew and terminated these license renewal applications in 2018 and planned to close the two units when the original operating licenses expired in 2024 and 2025.

This decision to close Diablo Canyon in 2024 and 2025 resulted from a California Public Utilities Commission (CPUC) order and a state law. These decisions were reversed in 2022 due to concerns about California's electricity system reliability. PG&E again applied for a license renewal for both units in 2023. The U.S. NRC waived the usual five (5) years timely filing requirement and allowed the PG&E 2023 license renewal applications. The two units will be allowed to continue operating while the license renewal applications are under review at the NRC.

Some of the highlights of the timeline in Figure 2:

- **Nov. 2024:**
  - Submit Restoration Quality Assurance Plan to NRC
  - Request an exemption from restrictions prohibiting reactor operation and fuel placement into the reactor vessel.
- **Dec. 2024:** Submit post-inspection steam generator report (the steam generators are critical equipment for producing electricity).
- **Feb. 2025:** Submit a request to change the name to Crane Clean Energy Center).
- **Mar. 2025:** Submit revised decommissioning report and fuel management plan
- **Apr. through Jun. 2025:**
  - Request that the NRC inspect the simulator used for training.
  - Begin training licensed and non-licensed nuclear operators.
- **Jul. 2025:**
  - Submit an environmental report.
  - Submit operating license and technical specifications amendment, along with an estimated Updated Final Safety Analysis Report.
- **Sep. 2025:** Submit revised emergency plan.
- **Nov. 2025:** Submit revised physical security plan.
- **Jul. 2027:** Submit operational readiness letter.
- **Aug. 2027:** Expect NRC and FEMA to finish the emergency plan evaluation.
- **Oct. – Dec. 2027:** Return to operating reactor license basis.[32]

Constellation is confident that this timeline can be achieved.

32 https://stateimpact.npr.org/pennsylvania/2024/10/25/three-mile-island-owner-lays-out-reopening-timeline-in-public-hearing/

What is ahead for the TMI–1 restart?

The work to restore TMI-1 has started and will cost at least $1.6 billion. The NRC must complete an environmental assessment within a year before a return to operation, and the plant will require other environmental permits for air emissions and water pollutants.[33]

Future activities include additional inspections, testing and restoration work, the plant's main power transformer installation, and workforce development. Constellation has ordered a new main power transformer costing about $100 million for the TMI-1 restart.[34]

The NRC has started a review of the TMI-1 restart application. During a public meeting with the NRC on 25 October 2024, details were sought about:

- The emergency evacuation plans for the restarted plant;
- Information about the commercial deal with Microsoft; and
- How the restart of TMI-1 impact the decommissioning of TMI-2, owned by EnergySolutions?[35]

Constellation laid out the schedule, as shown in **Figure 2**, for restarting TMI-1 at the 25 October 2024 NRC Public Hearing.[36]

Constellation plans to restart the operation of TMI-1, with a new name, in three years. Constellation's plan expects NRC review and approval of a new operating license to take about two years. It hopes to get an operating license by the fourth quarter of 2027 and start generating power in 2028.

Industry implications of closed nuclear power plant restarts

The restart of TMI-1 and Palisades strongly indicates an increasing value for nuclear electricity. Restarting a closed nuclear power plant is a way to get nuclear electricity at a lower risk and cost than building a new one. An even lower-risk and lower-cost way to get more nuclear electricity would have been to prevent the early closure of operating nuclear power plants for economic reasons.

What nuclear power industry developments might follow these restart projects?

The first development is the emerging link between data centers and nuclear power. A key driver of the TMI-1 restart is the PPA with a data center company that provides higher and more certain revenue than sales into the electricity markets.

As discussed above, there has been some mention of restarting construction of the abandoned V.C. Summer 2&3 units in South Carolina.

Another implication of these restarts is that the increased value of nuclear electricity might lead to action to build one or more of the multiple nuclear power plants that applied for and received NRC approval for COL applications.[37] These nuclear power plants could start construction quickly using a banked COL license obtained in the past, avoiding the time, risk, and cost of getting NRC COL approval for new designs and sites.

Under this logic, this increased value of nuclear electricity might lead to building a new nuclear power plant at a site with an approved Early Site Permit using a reactor design with an approved Design Certification. Like building a project that has an approved COL, this should be less risky and lower cost than developing a new site.

Another viable approach may be to build a certified reactor design at a new site.

The most challenging new nuclear power plant projects are those with a new site and a new reactor design (and without experience in building and operating the new reactor design). Such cases would have further complexity if co-located with other industrial activities and closer to residential areas.

Another implication of these restart projects is that the increase in electricity demand, including large data center demand, will support large nuclear power projects. With this demand growth, building new GWe-scale nuclear power plants may be more attractive than building multiple small reactors for grid-based supply. Small or advanced reactor projects may provide extra value[38] in island mode, in providing heat energy, or by burning spent nuclear fuel.

In summary: nuclear power plant restarts, life extension of existing nuclear power plants, and development of new nuclear power plants are viable. But viability requires market designs and conditions that allow nuclear power plants to operate profitably. This will only be possible where and when there is broad and strong, long-term reliable political, public, and administrative/regulatory will, at federal and state levels, to support nuclear power.

33 https://www.insurancejournal.com/news/east/2024/10/28/798778.htm

34 https://www.utilitydive.com/news/palisades-three-mile-island-duane-arnold-nuclear-reactor-restart-holtec-nextera-constellation-nrc/730393/

35 https://www.insurancejournal.com/news/east/2024/10/28/798778.htm

36 https://www.nrc.gov/pmns/mtg?do=details&Code=20241304

37 https://www.nrc.gov/reactors/new-reactors/large-lwr/col.html

38 For further discussion of opportunities and challenges, see our "8 Issues" model at https://nuclear-economics.com/wp-content/uploads/2024/10/2024-08-Navigating-Net-Zero-vgbe-energy-journal.pdf.

Author

Edward Kee

CEO, founder, and Principal Consultant at Nuclear Economics Consulting Group (NECG) in Washington DC, USA

edk@nuclear-economics.com

Edward Kee is an expert on nuclear power economics. Mr. Kee provides strategic and economic advice to companies and governments on nuclear power and electricity issues and has testified as an expert witness in U.S. and international legal and arbitration cases.

As primary author, Edward Kee received helpful input and peer review from his *Nuclear Pathfinders* colleagues Ruediger Koenig and John Warden.