**A Cost-Benefit Analysis of Restarting the Kashiwazaki-Kariwa Unit 7 Nuclear Power Plant**

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**Corey Alt**
**Nhi Nguyen**
**Ashley Tiscareno**
**Alexander Rumbino**

## Executive Summary:

The Fukushima Daiichi nuclear disaster has had long-lasting impacts on not only the people affected and displaced, but on the energy policy of Japan. After the disaster, every nuclear plant in the country was quickly taken offline while the government established new safety standards that required substantial retrofitting before plants could reopen.

15 years later, less than half of the nuclear fleet is back on the grid, cost projections have escalated dramatically, and reconnections are routinely pushed off by construction delays and regulatory changes. The Kashiwazaki-Kariwa Nuclear plant is in the middle of such a reconnection process. One reactor at the plant, Unit 6, has already been reconnected. Unit 7, the other advanced boiling water reactor at the facility, has not. Here we perform a simplified cost-benefit analysis of the decision whether or not to invest in reconnecting Unit 7 to the grid.

The cost-benefit model presented here takes 3 structural parameters—discount rate, remaining operating life, and construction time. A discount rate of 3% reflects existing practice for nuclear restart projects in Japan and the financing structure these projects face. A likely remaining operating life of 45 years is based on the current projected life of Japan's oldest generation of nuclear plants. An 11 year construction time reflects the average timeline that nuclear plants have faced to make the required retrofits and obtain regulatory approval to restart.

The costs included in this model are those of restarting the Kashiwazaki-Kariwa Unit 7 reactor, operating the unit, and the mental health costs to the people living near the plant. Expected restart costs are $2.25B; operating costs are estimated at $580m per year; and mental health costs are estimated at $152m per year.

The benefits modeled here of restarting the unit are avoided costs of building and operating natural gas power plants that the restart would displace, the avoided costs of imported LNG to fuel those facilities, and the benefit of avoiding the emissions that those facilities would produce. Those operation and capitalized construction costs are estimated at $327m per year; the avoided fuel costs are estimated at $735m per year; and the avoided emissions, using a social cost of carbon of $191/ton, are estimated at $453m per year.

A net present value analysis with those parameters and cost and benefit estimates yields a base case expected NPV of $12.3B. Based on this result, we recommend that TEPCO pursue the restart of the Kashiwazaki-Kariwa Unit 7 reactor.

To test the robustness of this result, we modeled expected uncertainty for each of the parameters, costs, and benefits estimated using plausible alternative estimates. A simple best/worst analysis yields a worst-case scenario NPV of -$18.8B, indicating a risk of substantial losses in deciding to restart the reactor. Seeking to quantify that risk, we performed a Monte Carlo analysis using uniform, normal, and triangular distributions to model the expected distribution of possible outcomes for each input, depending on available data, over 100,000 simulations. In 96% of simulations, the NPV was positive. The average NPV across all scenarios was $10.9B, somewhat lower than the base-case for distributional reasons.

## Introduction:

On March 11, 2011, a magnitude 9 earthquake struck off the east coast of Japan, producing a powerful tsunami that washed ashore a few minutes later. In addition to nearly 20,000 dead and hundreds of thousands of people displaced, the tsunami prompted meltdowns in the three active reactor units at the Fukushima Daiichi Nuclear Plant after cooling systems failed (Nuclear Energy Agency (NEA), 2012).

On March 12, following the failure of diesel generators and fire suppression systems, plant staff began a controlled venting of steam contaminated with radioactive isotopes from the containment vessel to the atmosphere, producing nuclear fallout. Thereafter, a series of hydrogen gas explosions between March 12 and 14 damaged the superstructures of the reactors and forced the evacuation of most workers. In addition, plant staff injected seawater into compromised reactor containment vessels, which was contaminated with radioactive material and subsequently leaked into the ocean. (NEA, 2012)

Although there were no immediate fatalities caused by the meltdown, the disaster exposed serious safety vulnerabilities in Japan's nuclear fleet. Responding to the disaster, Japan created a new safety agency, the Nuclear Regulation Authority (NRA) in 2012 to provide independent nuclear safety regulation. In 2011 and 2012, nuclear plants in Japan were gradually cycled off as regulators ordered new testing before reactors could restart following regular refueling or maintenance (World Nuclear News, 2012). Most have stayed offline ever since.

In 2013, the NRA published new operational standards for Japanese nuclear plants which, unlike previous updates to regulations, were applied to all nuclear plants, not just new construction, requiring extensive retrofitting of any plant seeking to come back online (TEPCO, n.d.-a). Initial estimates of the total costs of these retrofits across all plants in 2013 were roughly 1 trillion yen ($11.4b at 1/2013 exchange rates) (Asahi Shimbun, 2025; Federal Reserve Bank of St. Louis, 2026b). By 2025, that number had ballooned to $44.3b (6.5t yen at 9/25 exchange rates) (Asahi Shimbun, 2025, Federal Reserve Bank of St. Louis, 2026b), raising concerns that bringing these plants back online may no longer be the most safe or cost effective way to provide carbon-free, reliable energy for Japanese consumers.

The Kashiwazaki-Kariwa nuclear plant was once the largest nuclear power plant in the world by nameplate capacity at nearly 8GW (International Atomic Energy Agency, 2026). Like every other nuclear plant in Japan, it was cycled offline following the 2011 quake. Following extensive upgrades, the first of its seven reactors (unit 6) was brought back online in February, 2026 (U.S. Energy Information Administration (EIA), 2026). The remainder of this piece will provide a simplified cost-benefit analysis of reopening Kashiwazaki-Kariwa Unit 7, a 1356MW (1315MW net capacity) advanced boiling water reactor (World Nuclear Association (WNA), 2026).

The following sections articulate the expected case and uncertainty bounds for each parameter, cost, and benefit, present results of the resulting net present value analysis, perform robustness checks, and discuss the policy implications of the results.

## Parameters

**Discount rate -** 3%
We are using a 3% discount rate for this analysis. Japanese plants have used a 3% discount rate when assessing nuclear power generation cost both before and after the Fukushima accident. (Matsuo & Nei, 2014; World Nuclear Association, 2026). The restart of Kashiwazaki-Kariwa nuclear plant is expected to yield beneficial energy returns to consumers consistently for ~45 years after their restart opening date and have long term $CO_2$ emissions impact on the environment. Since this project is focused on long term impact, sustainability, and stability in the region, we deemed 3% is the appropriate discount amount.

The discount rate of restarting a new nuclear power plant reflects the economic risk and uncertainties of the project (International Energy Agency, 2020). A low discount rate of 3% is used for nuclear power plant projects with a stable economic environment (such as government support financing (International Energy Agency, 2020)), and high discount rate of 7% reflects a more unstable, riskier economic environment. In the case of restarting Kashiwazaki-Kariwa, a 3% discount rate is appropriate because the restarting operation is overseen by the Tokyo Electric Power Company (TEPCO), which is funded by the Japanese government through Japan's Ministry of Economy, Trade and Industry (METI) (International Trade Administration, 2025). Other countries also have their discount rate based on whether a nuclear plant project cost is private or government-backed. The U.S. nuclear power plant construction projects have a high discount rate of about 12.5% (Lurshina et al., 2019) due to lack of government cost recovery in retail-choice electricity markets (Ohio, Illinois, Texas, New Jersey, and New York) (Morey, 2019). France, on the other hand, has a 4% discount rate (Gaster, 2019), due to heavy government interventions such as government subsidized construction loans and guaranteed pricing in the first 40 years of operation (Gaster, 2019).

**Construction Time -** 11 years (8-14 years)
Once a final decision to restart the plant is taken, the plan approval, safety retrofit and inspection processes take time before a plant can be reconnected to the grid. Plants that have already restarted have followed a wide range of timetables. However, there have only been three reactors that have restarted that are of comparable design to the Kashiwazaki-Kariwa #7 reactor. Two—Onagawa #2 and Shimane #2—took 11 years (Yomiuri Shimbun, 2024; Reuters, 2024). The other—Kashiwazaki-Kariwa #6—took 12 (TEPCO, 2017; EIA, 2026). Based on these examples, this analysis will use 11 years as the baseline estimate of construction length.

The Onagawa #2 reactor, which took 11 years from application to the NRA to reconnection, sustained significant structural damage in the 2011 Fukushima earthquake that needed to be repaired (Nakajima, 2024). The Kashiwazaki-Kariwa #7 reactor did not suffer such damage, and thus may be able to achieve a shorter time to restart. This analysis will use 8 years as a low-end estimate. A high-end estimate of 14 years reflects the pattern of utilities' plans for facility restarts being delayed by new safety regulations (Reuters, 2024b; Taguchi, 2025), and the potential for the NRA to issue additional mandates going forward.

**Time horizon -** 45 years (25-65 years)
Japan initially licenses nuclear plants to operate for 40 years, after which approval for license extension is required every 10 years thereafter (World Nuclear Association, 2026). In 2023, Japan enacted a tolling arrangement for nuclear plants under which their idle period between 2011 and their restart would not be counted against their license term.

The Kashiwazaki-Kariwa nuclear power plant was connected to the grid for 15 years before being halted in 2011 (World Nuclear Association, 2026). Thus, once the plant is restarted, it will have 25 years of additional life before it reaches the end of its initial license. It's possible that the authorities would deny a license extension, so this will serve as our low-end estimate. The Takehama nuclear plant is the oldest operating nuclear facility in Japan. Its current license renewal is valid until its 60th year in operation 2034 (World Nuclear News, 2024). This will serve as our baseline estimate, meaning 45 years of additional life for Kashiwazaki-Kariwa reactor 7.

The nuclear fleet in the United States is somewhat older than in Japan, and has already licensed ten facilities to operate for up to 80 years (U.S. Nuclear Regulatory Commission, 2026). Although no Japanese plant is currently licensed to operate beyond 60 years, legal frameworks exist for them to do so (World Nuclear News, 2024). In light of these facts, a high-end estimate of 65 additional years for Kashiwazaki-Kariwa #7—for a total of 80 years of operational life—seems appropriate.

## Cost and Benefits Estimates

**Costs:**

**Plant Restart Costs** - $2.25B ($1.72-$6.10B)
Early estimates of the cost to retrofit and restart nuclear plants in Japan were relatively contained, with the World Nuclear Association estimating $700m-$1b in retrofit costs per reactor based on a 2011-2017 study (World Nuclear Association, 2026). However, as the process of retrofitting plants has proceeded, cost estimates have ballooned. A 2025 survey of all 11 Japanese electric utilities showed a total estimated costs for safety improvements at all of their nuclear reactors of ¥6.556T (Asahi Shimbun, 2025)—$1.639B per reactor in dollar terms. Scaling that cost from the size of an average reactor to the size of the Kashiwazaki-Kariwa Unit 7 gives an estimated safety retrofit cost of $2.25B—the primary estimate for this analysis. (Richards, 2025).

METI's Power Generation Cost Verification Working Group (PGCVWG) (2025) reports an expected cost was ¥266.2B per reactor in June 2024. Scaling this per-reactor cost to the capacity of the Kashiwazaki-Kariwa #7 reactor gives an expected cost of $1.727B, but this estimate is almost certainly too low, as there are other costs associated with restarting beyond the cost of the safety retrofits themselves, including community benefit agreements, planning and inspection costs, and equipment recommissioning that aren't cleanly separated out in the PGCVWG's methodology in the way that the retrofit costs are. Given these limitations, that $1.7B seems appropriate as a low-end estimate.

On the other hand, a few power plants covered in English language press have faced dramatically higher costs. Hokkaido Electric Power Co, which recently restarted its Tomari #3 reactor, spent nearly $4B on safety upgrades before the restart was allowed (Dalton, 2025). Similarly, Tohoku Electric's Onagawa #2 cost $3.7B (Reuters, 2024). Taking an average per-kW cost between these two plants, adjusting for inflation and converting to dollars gives an estimated restart cost of $6.1B to restart the Kashiwazaki-Kariwa plant, a suitable high-end estimate.

**Nuclear Operating Costs -** $579,553,000/year (SD = $180m)
This category will include some additional costs that are not strictly speaking operational, but are ongoing costs associated with running a nuclear plant, including fuel cycle costs, recurring regulatory costs and community benefit arrangement payments costs. 2023 data from the PGCVWG indicate that all of these ongoing costs come to 7.1¥/kWh (PGCVWG, 2025). Inflating that figure to the present, converting to dollars, and scaling to the capacity of the Kashiwazaki-Kariwa plant gives an estimated annual operating cost of roughly $580m per year (Federal Reserve Bank of St. Louis, 2026b).

Uncertainty around the ongoing cost of operating a nuclear power plant is significant. English-language data on Japanese plants is limited, but the Nuclear Energy Institute publishes data about the US nuclear fleet showing the median and quartiles in operating, fuel, and capital costs (McCallum, 2025). The median total ongoing generating costs (fuel + operating cost + ongoing capital investment) across the US nuclear fleet is $32.14/MWh. The first quartile is $26.17MWh, 19.1% below the median, and the third is $38.27/MWh, 22.8% above the median (McCallum, 2025). Assuming that Japanese plans see similar cost variation and that the costs of operating nuclear plants are normally distributed, we can use these figures as a 50% confidence interval and derive a standard deviation. Using the first quartile to do so yields a standard deviation of $164m, using the third yields $195m. The average of the two is $180m.

**Mental Health Costs -** $152,212,000 per year ($0 - $304m)
The restart of the Kashiwazaki-Kariwa Nuclear Power Plant generates significant mental health costs. To establish the affected population, the Niigata government identifies the primary impact area to be 30 km zone around the Kashiwazaki-Kariwa nuclear plant, the zone's population is around 420,000 living within the 30km radius and would have to evacuate in a Fukushima-style incident (McCurry, 2026).

The best available evidence for monetizing the effect on mental health outcomes of living in proximity to a nuclear plant comes from two studies in the wake of the Fukushima disaster. The first in 2013 measured the impact of proximity to the disaster site on life satisfaction scores, as well as the effect on well-being of living in proximity to an operational nuclear plant (Rehdanz et al., 2013). The second study—by one of the coauthors on the 2013 paper—investigated the impact on life satisfaction scores of German-speaking Swiss from living in proximity to an operating nuclear plant (Welsch & Biermann, 2015). Although the 2013 study found very large effects on life satisfaction of living close to the Fukushima Daiichi site, its regression analysis relating to operating plants found no impact on life satisfaction from the proximity of the closest nuclear power plant or the number of plants nearby (Rehdanz et al., 2013). Using this finding, we determined that the lower bound for mental health cost of living within a nuclear power plant impact zone is zero.

The upper bound for this analysis comes from a follow-on study of the effect of living near an operating nuclear plant in Switzerland (Welsch & Biermann, 2015). The paper found that for their sample of German-speaking Swiss, "living 1km farther away from the nearest nuclear power plant is worth 0.5% of equivalized disposable income" (Welsch & Biermann, 2015). Applying this figure to Japanese disposable incomes in Niigata Prefecture, we find that the monetized mental health benefit of moving 1km further from the plant is about ¥10,841 per year (E-Stat, 2026; Statistics Bureau of Japan, 2026; Federal Reserve Bank of St. Louis, 2026a; Federal Reserve Bank of St. Louis, 2026b). The following calculation will assume that the 420,000 people within the 30km evacuation radius are evenly distributed—making the average person 20km from the plant—and that people living beyond the impact radius face no mental health costs. The mental health costs for any individual would be their projected benefit of living outside the evacuation zone, which on average is 10km away, yielding a per-person cost of ¥108,411 per year. Multiplying the 420,000 people in the impact radius and converting to dollars yields a total annualized mental health cost of $304,424,000 (E-Stat, 2026; Federal Reserve Bank of St. Louis, 2026b). This will serve as the high-end estimate for our analysis.

For our baseline estimate, we will use the midpoint between these high and low estimates. Although the 2013 study is more directly relevant to the Japanese context, the comparison isn't quite clean. The study measures the effect of proximity to a nuclear plant on life satisfaction scores before and after the 2011 disaster, but the salience of the accident risk was likely lower in that time period, and all Japanese nuclear plants closed in the wake of the disaster, so the post-disaster effect measures the impact of proximity to a shuttered nuclear plant, which could have a different effect than an operating one (Rehdanz et al, 2013). In addition, the sustained public opposition that the plant's restart has faced indicates that residents expect to face some amount of disutility from the plant opening (Hannany & Pratama, 2025). While the Swiss comparison is methodologically cleaner, their context is very different as a higher-income country with no history of nuclear accidents. With these considerations in mind, taking the average—$152 million—seems like an appropriate balancing of the available evidence.

**<u>Benefits</u>**

**Avoided Cost of LNG Fuel -** $734,646,000/yr ($401m-$1.59B/ yr)

One major benefit of restarting nuclear power plant operations in Japan is to lessen Japan's dependency on relatively expensive imported fossil fuels. In 2015, the Institute of Energy Economics, Japan stated that the country spent around 30 to 40 billion dollars on importing fuel each year to compensate for idle reactors (World Nuclear Association, 2026).

The PGCVWG report models the component costs of a typical combined cycle gas turbine facility, estimating that the long-term average fuel costs of ¥9.0/kWh (PGCVWG, 2025). This figure will serve as our baseline estimate.

That figure is based on a 2024 report from the International Energy Agency (IEA), which also estimates Japanese gas costs under alternative demand scenarios. Under a scenario in which the globe reaches net zero emissions by 2050, IEA estimates that gas costs would be 46% lower by 2040 than one in which current policy persists (IEA, 2024). Applying this difference to our baseline estimate gives a low-end barrier of ¥4.9/kWh. On the other hand, unexpected supply shortages have caused extreme price increases twice in recent years—due to the ongoing war in the Middle East, and the 2022 Russian invasion of Ukraine. These conflict-inflated prices represent a defensible high-end boundary if conflict continues to regularly disrupt global LNG supply. The Russians invaded Ukraine in late February 2022. The average wholesale gas cost in Japan in the 12 months following was $19.00/mmbtu (World Bank, 2026), equivalent to 19.4¥/kWh when applied to METI's model gas plant used to derive the baseline estimate.

Scaling each of these figures to the size of the Kashiwazaki-Kariwa #7 reactor gives the savings associated with not having to fuel that generation capacity with LNG. A long-term average unit price of ¥4.9/kWh would be $401m per year, ¥9.0 would be $735m per year, and ¥19.4 would be $1.59B per year in avoided fuel costs.

**Avoided Cost of Gas Plant Operations -** $326,509,000 ($261m-$392m)
The same PGCVWG report that models a combined cycle gas turbine plant's fuel costs also models its other ongoing costs, which we will refer to broadly as operational costs even though they include things like maintenance and compliance costs. The PGCVWG estimates that these costs will average ¥4.0/kWh over the life of the plant (PGCVWG, 2025).

The US National Renewable Energy Laboratory publishes forecasts of capitalized construction and operations and maintenance costs for US plants. From the high end of their range of estimates to the low end—depending on the type of plant and different parameters—annualized capital costs vary by 55% and operating costs vary by 36% between plants. It's implausible that a plant at the very low-end of the capital cost range would also be at the low-end of the operating range, so instead of applying each of these ranges to the values of their corresponding components in the PGCVWG composite model, this analysis will take a weighted average between them and apply that range to the total annualized non-fuel costs estimated by the PGCVWG. Doing so produces an estimate that the lowest cost gas plants might have total operating and annualized capital costs 40% lower than the highest-cost ones. Situating the METI baseline estimate of 4.0¥/kWh at the center of this interval gives a range of possible operations costs from 3.2-4.8¥/kWh. Scaling these unit costs to the size of the Kashiwazaki-Kariwa #7 reactor gives a low-end estimate of $261m in annual operations costs, a baseline estimate of $327m, and a high-end estimate of $392m.

**Emissions Reduction -** 1.8 Mt$CO_2$/ year - $439 million/year ($3m-$584m/year)
Restarting the Kashiwazaki-Kariwa Unit 7 reactor could significantly reduce greenhouse gas emissions, relative to a counterfactual where that power is produced by other sources, because nuclear energy produces almost zero CO2 emissions. At a global level, nuclear energy has

prevented over 60 gigatonnes of CO2 emissions, making it a major low carbon energy source (International Energy Agency, 2019).

In 2012, after the Fukushima disaster, Japan's nuclear energy reduced from 300 TWh/year (in 2010) to ~20 TWh/year (in 2012) due to the halting operations of nuclear power plants, while fossil fuel electricity sources increased from ~420 TWh/year (in 2010) to ~960 TWh/ year (in 2012) (Kharecha & Sato, 2019). This increase in fossil fuel electricity use in the Japan energy mix resulted in an increase of ~1770 $MtCO_2$/year, or 0.2 $MtCO_2$/TWh.

Kashiwazaki Kariwa Unit 7 before the shutdown produced ~11878 GWh/year in its maximum capacity (WNA, 2026). With the restarting of the nuclear power plant, we can assume that the Kashiwazaki Kariwa Unit 7 will contribute the same amount of energy into Japan's energy mix while producing no $CO_2$ emission. Using dimensional analysis to convert the amount of $CO_2$ emission from 11878 GWh, we find that using Kashiwazaki Kariwa Unit 7 to generate power that would otherwise have come from other sources would prevent 2.375 Mt/year of $CO_2$ emissions.

The social cost of carbon (SCC) in Japan has not been set by the government. While we can calculate the social cost of carbon by using Japan's carbon tax of ¥289/$tCO_2$ (resulting in ~$3.25 million/year), research has shown that Japan's carbon tax is low compared to other countries with carbon tax (Gokhale, 2021). This number can be our lower bound estimate.

The social cost of carbon in the United States, determined by the Environmental Protection Agency, varies widely based on the administration (Asdourian and Wessel, 2023). At the time of this paper, there is no published social cost of carbon on the U.S. Environmental Protection Agency website, as the President directed federal agencies to stop factoring in climate change-related economic damages into their regulations (Environmental and Energy Law Program, 2026). Therefore, we are using the last social cost of carbon published by the EPA under the Biden administration, which is $191/$tCO_2$ (Brookings, 2023). This cost will equal 2.375 $MtCO_2$/year to ~$439 million/year. By restarting Kashiwazaki Kariwa Unit 7, Japan can reduce the social cost of carbon up to $453 million/year.

The social cost of carbon can increase even further when equity is taken into account (Prest et al., 2024). When using an equity weighted SCC of $246/$tCO_2$ (UC Santa Cruz Sustainability Office, 2022), we found that restarting the nuclear power plant can benefit Japan up to $584 million/year. This will serve as our upper bound value for SCC.

## Results

Using a 3% discount rate, an 11-year construction period, and a 45 year remaining operation life, a discounted cash flow analysis of the costs and benefits enumerated above yields a total net present value of $12.3B—our base case estimate. However, given the uncertainty about our parameters and the values assigned to the costs and benefits, a sensitivity analysis was performed to check the robustness of this result.

## Sensitivity Analysis

**Best/Worst**

In order to accurately assess how the net present value will change based on uncertainties, sensitivity analysis for best and worst possible outcome was performed. The upper and lower bound estimates for each variable are presented in Table 1.

| Table 1 | | | | |
|---|---|---|---|---|
| | **Parameters** | | | |
| | | **Baseline** | **Lower Bound** | **Upper Bound** |
| | Discount Rate | 3% | - | - |
| | Time Horizon (years) | 45 | 25 | 65 |
| | Construction time (years) | 11 | 8 | 14 |
| Cost | Restart Cost | $2,250,000,000 | $1,729,000,000 | $6,100,000,000 |
| | Nuclear Operating Cost +/- 2SDs (per year) | $579,553,930 | $219,553,930 | $939,553,930 |
| | Nuclear Operating SD | $180,000,000 | | |
| | Mental Health Cost | $0 | $0.0 | $0 |
| Benefit | Avoided cost of LNG Imported Fuel (per year) | $734,646,000 | $400,716,000 | $1,586,167,000 |
| | Avoided Cost of Gas Plant Operations (per year) | $326,509,000 | $261,207,000 | $391,811,000 |
| | Emission Reduction (tCO2/year) | 2375000 | - | - |
| | Social Cost of Carbon ($/tCO2) | $191 | $2.65 | $246 |
| | Emission Reduction Value | $453,625,000 | | |

Both best and worst-case scenarios were calculated using the baseline discount rate of 3%.

The best-case scenario was calculated using the upper bound estimates for benefits and lower bound for cost, leading to the plant producing a profit every year. Therefore, we are choosing the time horizon for the best-case scenario as 65 years, to maximize the potential profit that the plant can generate. We found that the best-case scenario net present value is $52,634,661,869.

The worst-case scenario was calculated using lower bounds for benefits and upper bounds for costs, leading to the plant not making a profit every year. Since the plant is losing money, we also chose the time horizon for the worst-case scenario as 65 years, resulting in the most loss the plant can have. The worst-case scenario net present value is -$18,833,218,195.

Because the best and worst-case analysis did not provide clarity on whether we should move forward with the project, we conducted a Monte Carlo sensitivity analysis.

| Table 2 | |
|---|---|
| Projected NPV | $ 12,336,123,048.49 |
| Best Case NPV | $ 52,634,661,869.37 |
| Worst Case NPV | $ (18,833,218,195.28) |

**Monte Carlo**

To provide a sense of the distribution of possible outcomes, we performed a Monte Carlo analysis. For each of 100,000 simulations, random values were selected for each of eight parameters within their ranges of uncertainty. For the parameters where no evidence was found to justify the shape of the applicable probability distribution, a uniform distribution was assumed.

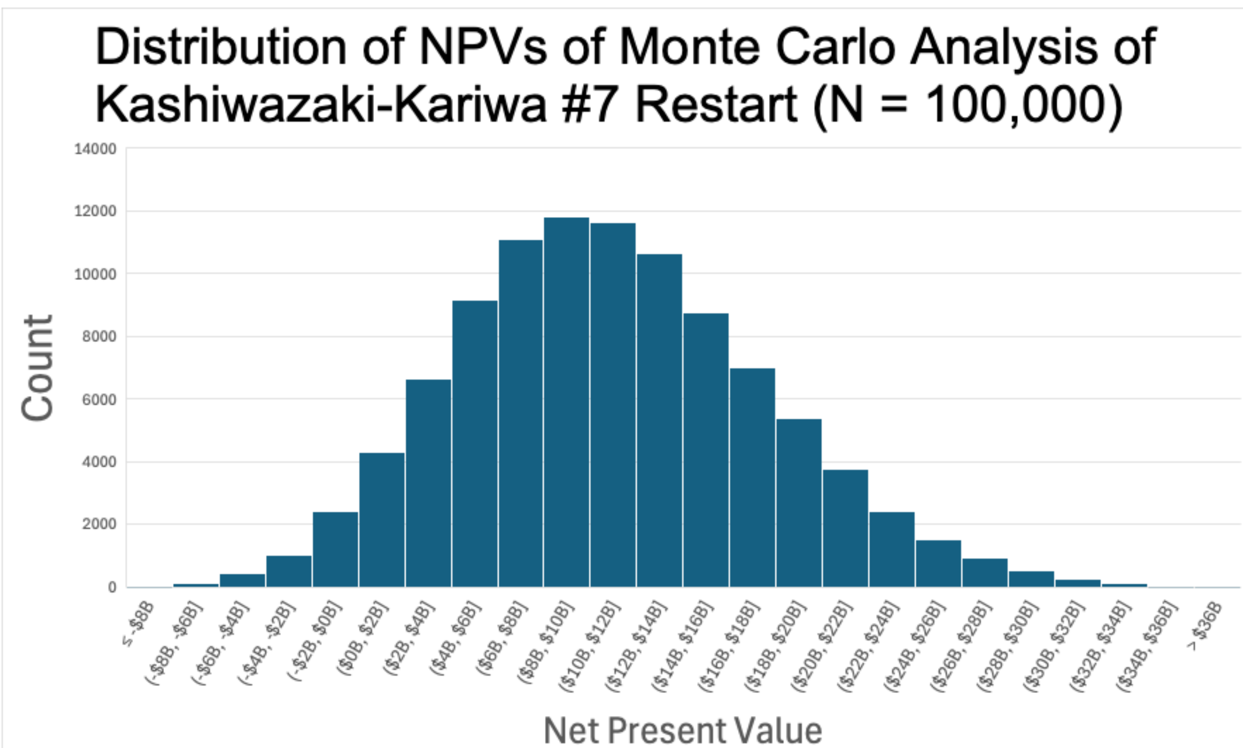
Where justified by available data, triangular (Wright, 2018) and normal distributions were used to model uncertainty. Table 3 shows the type of distribution used to model each parameter.

The results of the Monte Carlo analysis indicate that the potential worst and best-case scenarios modeled above are dramatically unlikely. The mean net present value across the 100,000 simulations was \$10.9B, with 96% of simulations returning a positive NPV. A 95% confidence interval about the mean is -\$2.5B to \$23.9B. A histogram of the simulation outcomes (Figure 1) indicates a slight rightward skew.

**Table 3**

| Parameter | Distribution |
|---|---|
| Time Horizon | Uniform |
| Construction Time | Uniform |
| Restart Cost | Triangular |
| Nuclear Operating Cost | Normal |
| Mental Health Cost | Uniform |
| Avoided Cost of LNG Fuel | Triangular |
| Avoided Cost of Gas Operations | Uniform |
| Social Cost of Carbon | Uniform |

The average result of this analysis is somewhat lower than the base-case projected NPV. This discrepancy has two primary causes. First, a triangular distribution with a rightward skew will have a mean higher than the mode, as seen in the distribution of restart costs modeled here. Second, the uniform distribution applied to the social cost of carbon produces an average random draw well below our base case estimate. In a given simulation, these effects increase




the costs and understate the benefits on average relative to our base case.

## Limitations

### <u>Scope</u>

This analysis is limited in scope by the assignment instructions. By excluding costs other than those assigned—such as accident risk, non-$CO_2$ pollution reduction, and carrying costs—this analysis is inherently limited in its ability to capture the actual costs and benefits TEPCO faces in its decision to restart the Kashiwazaki-Kariwa Nuclear plant.

In the interest of clarity, this analysis treats TEPCO's decision to restart Kashiwazaki-Kariwa #7 as if it were yet to be made. In fact, TEPCO applied for approval for its plan to retrofit and restart Kashiwazaki-Kariwa #6 and #7 in 2013, and the 15m seawall that protects both units has already been built (World Nuclear News, 2020; TEPCO, n.d.). Due the impracticality of separating which costs are attributable to each unit and what costs are already sunk, this analysis will treat the #7 reactor as a separate facility deciding whether or not to embark on the retrofitting and inspection process needed to obtain restart authorization.

**Estimates**

One major limitation in calculating the restart cost for Kashiwazaki-Kariwa nuclear power plant is the ballooned estimates due to lengthy safety assessment, added safeguards against earthquakes, tsunami, and terrorism attacks (Asahi Shimbun, 2025). In 2025, the safety cost for 11 reactors to restart in Japan is estimated to be 6.5 trillion yen, 6.5 times more than the 2013 estimates, with no determined opening date (Asahi Shimbun, 2025). While our calculations did take into account the potential ballooning safety retrofit cost, including the higher restart cost of Hokkaido Electric's Tomari #3 and Tohoku Electric's Onagawa #2, the high-end estimate does not account for potential continued escalation in retrofit costs beyond what's been seen at other plants to date.

Our calculation of mental health impact also has its own limitations. First, our paper uses the 30 km impact radius that the Japanese government uses in its disaster planning. However, the figure excludes impacts on people living outside that 30km radius, and our estimation for how much someone would pay to move outside the 30km radius circle assumes that people living outside the 30km radius face no mental health impact. However, Ohtake (2016) found that people thousands of miles away from the event still experience mental distress due to media coverage. We did not take this cost into account. Additionally, our mental health cost calculation is based on an estimate of individuals' willingness to pay to move 1km away from a nuclear plant in Switzerland. The external validity of this estimate in the Japanese context is questionable, due to differences in income and its effects on the marginal utility of money and the Japanese population's recent experience with a nuclear disaster.

Lastly, our emission reductions are calculated using the social cost of carbon. Japan has not set its own social cost of carbon, therefore we used the U.S. Environmental Protection Agency's published social cost of carbon. However, the social cost of carbon changes drastically based on the discount rates (Lesser, 2025), requires numerous assumptions and different models (Lesser, 2025), and fluctuates based on the U.S.'s current administration (Environmental & Energy Law Program at Harvard Law School, 2021). That dramatic uncertainty and potential for future change in carbon pricing policy in Japan and around the world are not captured by the static cost of carbon modeled here.

## Conclusion

We recommend that TEPCO move forward with restarting the Kashiwazaki-Kariwa #7 reactor. We project a base-case net present value of $12.3B in choosing to embark on the estimated 11-year, $2.25B restart process.

This result is remarkably robust. Although worst-case scenarios exist in which the net present value of restarting the plant is negative, these scenarios are highly unlikely. A Monte Carlo analysis of 100,000 simulations shows a 96% probability of a positive NPV investment, indicating that this investment is likely to produce a positive NPV even under conditions much closer to our worst-case than the base-case. Subject to the limitations discussed above, these results demonstrate the strong viability of restarted nuclear power to meet the growing demand for power in Japan.

In the aftermath of Fukushima, Japan halted its nuclear power plant fleet, leading the country to be dependent on gas energy, both through importing fuels from foreign countries and capital investment in new gas operations. Only 15 of Japan’s 33 viable nuclear reactors have been restarted, indicating significant additional capacity to add zero-carbon generation supply at lower cost than the primary competing source. These projects have economic development benefits as well—the restart of the Kashiwazaki-Kariwa plant and others like it provide an opportunity for Japanese utilities to keep more money in the Japanese economy as less money would go to foreign fuel sellers. For these reasons—affordability, climate, and economic—we recommend that TEPCO and the Nuclear Regulatory Authority move forward with the restart of the Kashiwazaki-Kariwa Unit 7 reactor and explore opportunities to bring online additional reactors that remain offline.

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