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WITNESS: David Lochbaum

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

PREPARED TESTIMONY OF DAVID LOCHBAUM ON BEHALF OF THE ALLIANCE FOR NUCLEAR RESPONSIBILITY (“A4NR”)

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I. INTRODUCTION.

Q01: Please state your name and business address for the record.

A01: My name is David Lochbaum, and my business address is 865 Traditions Drive, Chattanooga, TN 37415.

Q02: Are your professional qualifications included in your testimony?

A02: Yes, my professional qualifications are contained as Appendix A to my testimony.

Q03: Was your testimony prepared by you or under your direction?

A03: Yes, it was.

Q04: Insofar as your testimony contains material that is factual in nature, do you believe it to be correct?

A04: Yes, I do.

Q05: Insofar as your testimony contains matters of opinion or judgment, does it represent your best judgment?

A05: Yes, it does.

Q06: Does this written submittal complete your prepared testimony and professional qualifications?

A06: Yes, it does.

II. SUMMARY OF TESTIMONY.

Q07: What is the purpose of your testimony?

A07: The purpose of my testimony is to provide evidence on the non-financial issues identified in Sections 3.1 and 3.5 of the Scoping Memo in support of A4NR's challenge to the conditions under which PG&E will emerge from bankruptcy proceedings.

Q08: How would you summarize your testimony?

A08: PG&E brought in William D. Johnson as its Chief Executive Officer (CEO). Mr. Johnson had previously served as CEO of Progress Energy and the Tennessee Valley Authority (TVA). During Mr. Johnson's tenure as CEO at both Progress Energy and TVA, the safety performance of their nuclear power reactors as assessed by the U.S. Nuclear Regulatory Commission (NRC) declined. These NRC's assessments were lowest during Mr. Johnson's tenures as CEO than at any time before or after his leadership. Further, the NRC's assessments of safety performance for the Progress Energy and TVA nuclear reactors demonstrated marked underperformance compared to the entire U.S. nuclear industry during Mr. Johnson's tenures. This history raises reasonable doubt as to his ability to lead PG&E out of bankruptcy while sustaining or improving safety performance levels at Diablo Canyon. Compounding the challenge faced by Mr. Johnson and PG&E is the lack of a quantitative tool to aid decision-making about interim spent fuel storage at the Diablo Canyon nuclear plant. The two reactors at Diablo Canyon are supported by extensive safety studies and formal risk analyses that define the hazards as well as the design features and administrative controls intended to manage the risks — providing a solid foundation for sound decisions about allocating resources to ensure the risks continue to be properly managed. But when nuclear fuel is removed from the reactor vessels into spent fuel pools and later into dry storage systems, this interim spent fuel storage is not backed by comparable safety studies and risk analyses. Thus, there is a weaker foundation available for the decision-making needed to manage the inherent risks, and to protect workers and the public. In addition, safeguards against sabotage of nuclear fuel in storage after a nuclear plant permanently shuts down are significantly lessened or eliminated, despite the hazard remaining onsite.

III. MR. JOHNSON'S PRIOR NUCLEAR SAFETY PERFORMANCE RECORD

Q09: Why is Mr. Johnson's prior nuclear safety performance record relevant in this matter?

A09: In his "Prepared Testimony (Non Financial Issues)," Mr. Johnson stated that "During my tenure at TVA, the organization achieved the best safety records in its 85-year history and TVA was a perennial top-decile safety performer in the utility industry."[1] PG&E further notes that "Throughout his career in the energy industry, Mr. Johnson has collaborated closely with elected officials and other community leaders to deliver safe and reliable

[1] I-19-09-016, Pacific Gas & Electric Company Plan of Reorganization OII 2019 (Non-Financial Issues) Prepared Testimony, Chapter 1, Introduction, pg. 1-1, December 13, 2019.

energy."[2] Because PG&E clearly believes that Mr. Johnson's past record explains why he is the right person to now lead the company, a more complete review of this past record is relevant to PG&E's near-term future.

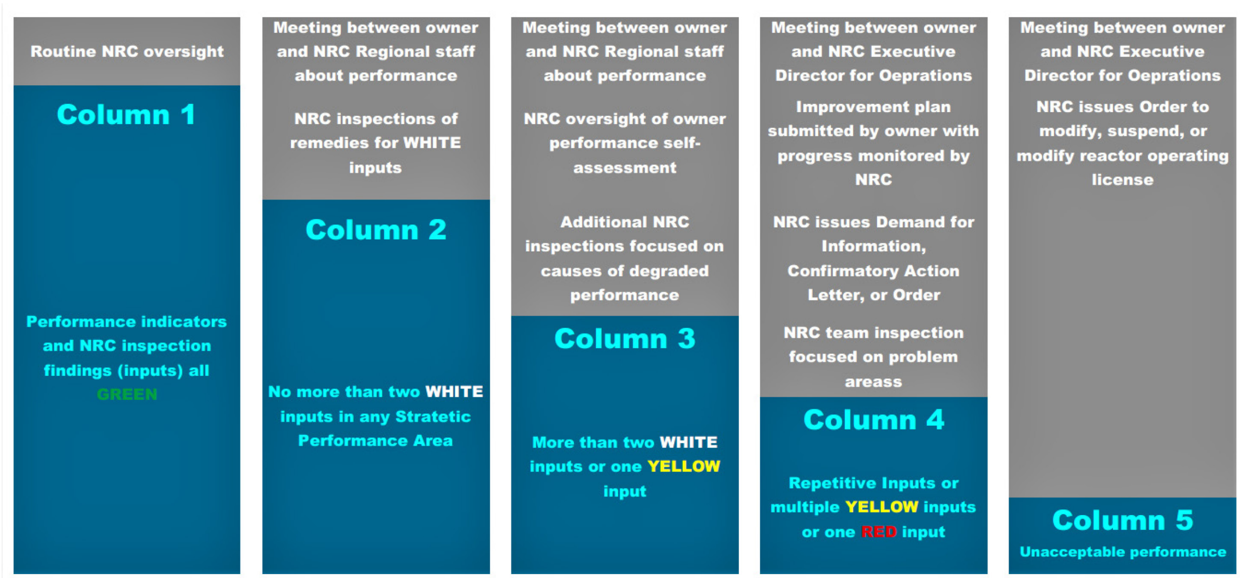
Q10: What did you use to evaluate Mr. Johnson's safety performance record while CEO of Progress Energy and TVA?

A10: The performance assessments by the U.S. Nuclear Regulatory Commission (NRC) were used for this analysis. The NRC is the federal agency with responsibility under federal law for protecting the public and workers from the inherent hazards of nuclear reactor operation. Since the fourth quarter of 2000, the NRC has issued quarterly ratings for all operating nuclear power reactors. The NRC uses inputs from nearly two dozen performance indicators (e.g., number of unplanned reactor shutdowns, number of emergency siren test failures) coupled with findings by NRC inspectors[3] to place each reactor into one of five columns of its "Action Matrix." Performance indicators and NRC inspection findings are color-coded: green, white, yellow, and red in order of increasing safety significance. Column 1 reflects nuclear safety performance meeting or exceeding NRC's expectations. As performance drops, the Action Matrix column placement marches to the right into and through Columns 2, 3, 4 and 5. The following graphic shows the five columns of the NRC's Action Matrix. The upper gray boxes explain the NRC's actions for reactors in the columns. As safety performance ratings decline, the NRC's intervention

[2] PG&E website http://www.pgecorp.com/corp/about-us/corporate-governance/directors/william-johnson.page accessed January 25, 2020.

[3] Each operating nuclear plant has at least two NRC inspectors assigned full-time supplemented by inspectors from the NRC's regional and headquarters offices for specialty areas like security and fire protection. Collectively, the NRC expends about 3,000 hours of inspection effort for each nuclear power plant in Column 1 each year.

activities ramp up with the objective of stemming the decline before it causes or contributes to a serious nuclear event. The lower blue boxes explain the specific performance shortfalls warranting the column placements.



Source: Figure C-1, UCS, 2018[4]

Q11: How did you use the NRC ratings to evaluate Mr. Johnson's record?

A11: Mr. Johnson was the CEO for Progress Energy for 18 full quarters, from the first quarter of 2008 through the second quarter of 2012. I examined the NRC's ratings for the Progress Energy fleet of nuclear reactors[5] and the entire U.S. reactor fleet during the 18-month periods before Mr. Johnson became CEO, while he was CEO, and after he departed. Mr. Johnson was TVA's CEO for 25 full quarters, from the fourth quarter of 2012 through

[4] Clemmer, Steve, Richardson, Jeremy, Sattler, Sandra, and Lochbaum Dave, Union of Concerned Scientists (UCS). "The Nuclear Power Dilemma: Declining Profits, Plant Closures, and the Threat of Rising Carbon Emissions." Cambridge, MA. November 2018. Online at https://www.ucsusa.org/sites/default/files/attach/2018/11/Nuclear-Power-Dilemma-full-report.pdf
[5] The Progress Energy nuclear reactor fleet consists of Brunswick Units 1 and 2 (NC), HB Robinson (SC), and Shearon Harris (NC).

the first quarter of 2019. I examined the NRC's ratings for the TVA fleet of nuclear reactors[6] and the U.S. reactor fleet during the 25-month periods before Mr. Johnson became CEO and while he was CEO. I examined the NRC's ratings for PG&E's nuclear reactors[7] during the period that Mr. Johnson was TVA's CEO. I also examined the NRC's ratings for all U.S. nuclear reactors, for the Progress Energy fleet of reactors, and for the TVA fleet of reactors from 2000 to 2019.

Q12: Why did you use the NRC's ratings?

A12: The NRC's quarterly ratings provide more information than is available from annual assessments, an advantage when looking at a relatively short period of time (i.e., five or six years.). The NRC's ratings are publicly available for all operating reactors since the fourth quarter of 2000. And the quarterly ratings are derived using consistent methods applied by a single entity over the entire period, facilitating apples-to-apples comparisons between reactors across time.

Q13: Is this the first time you have used the NRC's ratings for such an evaluation?

A13: No. For example, there were large cost over-runs during the construction of the Unit 3 and 4 reactors at the Vogtle nuclear plant in Georgia. This begged the question of whether budget restraints and/or management's focus on the new reactors resulted in safety performance declines at the company's four operating reactors [Hatch Units 1 and 2 (GA) and Vogtle Units 1 and 2 (GA)]. I used the NRC's quarterly ratings to show that the nuclear

[6] The TVA nuclear reactor fleet consists of Browns Ferry Units 1, 2 and 3 (AL), Sequoyah Units 1 and 2 (TN), and Watts Bar Units 1 and 2 (TN).
[7] PG&E's nuclear reactor fleet consists of Diablo Canyon Units 1 and 2 (CA).

safety performance of these reactors had not deteriorated.[8] I also used the NRC's ratings to evaluate the performance of the Pilgrim nuclear plant (MA) and other reactors operated by Entergy. In the second quarter of 2011, all eleven of Entergy's nuclear reactors were rated by the NRC as Column 1 performers. By the fourth quarter of 2014, one reactor had permanently shut down due to the high costs of poor performance while the performance of seven of the surviving ten reactors had fallen out of Column 1 — with three Entergy reactors rated as the worst performers among the U.S. reactor fleet.[9]

Q14: When was Mr. Johnson CEO of Progress Energy?

A14: The Progress Energy Board of Directors named Mr. Johnson as CEO in October 2007. Mr. Johnson resigned in July 2012 following the merger of Progress Energy and Duke Power.[10] For this review, I considered Mr. Johnson's CEO tenure at Progress Energy to span the 18 quarters between the first quarter of 2008 and the second quarter of 2012, inclusive.

Q15: What did the NRC's ratings show for the Progress Energy nuclear reactors?

A15: The safety performance ranking of Progress Energy's reactor fleet (1.32)[11] essentially matched that of the average U.S. reactor (1.33) during the 18 quarters prior to Johnson becoming Progress Energy's CEO. The safety performance ranking of Progress

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[8] Dave Lochbaum, All Things Nuclear blog commentary "Vogtle and Hatch; Have Cost Over-Runs Undermined Safety Performance?" September 6, 2018. Online at https://allthingsnuclear.org/dlochbaum/vogtle-and-hatch-safety-performance

[9] Dave Lochbaum, Union of Concerned Scientists. "Nuclear Safety at Pilgrim" presentation at Cape Downwinders public meeting. Plymouth, MA. January 30, 2017.

[10] Wikipedia. "William D. Johnson (CEO)." Accessed December 19, 2019. Online at https://en.wikipedia.org/wiki/William_D._Johnson_(CEO)

[11] The values cited in this testimony (e.q., 1.32) reflect the average NRC rating for the specified reactors over the specific time period similar to how a student receives a grade point average from numerous course grades over multiple semesters.

Energy's reactor fleet improved (1.28 from 1.32)[12] during Johnson's tenure as CEO, but lagged the safety performance improvement achieved by the average U.S. reactor (1.21 from 1.33) during that period. The safety performance ranking of Progress Energy's reactor fleet (1.07) significantly out-performed the average U.S. reactor (1.23) during the 18 quarters after Johnson left Progress Energy. The safety performance ranking of Progress Energy's reactor fleet significantly improved over the 18 quarters after Johnson departed (1.07 from 1.28) whereas the safety performance ranking of the average U.S. reactor declined (1.21 to 1.23) during these two 18-quarter periods.

3rd Quarter 2003 to 4th Quarter 2007, Inclusive - 18 Quarters Prior to William Johnson's as Progress Energy CEO				
	All Reactors	All Reactors	Progress Energy Reactors	Progress Energy Reactors
Quarters Ranked in Column 1	1374	77.1%	64	71.1%
Quarters Ranked in Column 2	291	16.3%	23	25.6%
Quarters Ranked in Column 3	61	3.4%	3	3.3%
Quarters Ranked in Column 4	48	2.7%	0	0.0%
Quarters Ranked in Column 5	8	0.4%	0	0.0%
Average Column Ranking	1.33		1.32	

1st Quarter 2008 to 2nd Quarter 2012, Inclusive - William Johnson's 18 Quarters as CEO of Progress Energy				
	All Reactors	All Reactors	Progress Energy Reactors	Progress Energy Reactors
Quarters Ranked in Column 1	1498	84.1%	66	73.3%
Quarters Ranked in Column 2	212	11.9%	23	25.6%
Quarters Ranked in Column 3	61	3.4%	1	1.1%
Quarters Ranked in Column 4	11	0.6%	0	0.0%
Quarters Ranked in Column 5	0	0.0%	0	0.0%
Average Column Ranking	1.21		1.28	

3rd Quarter 2012 to 4th Quarter 2016, Inclusive - 18 Quarters after William Johnson's Departure as Progress Energy CEO				
	All Reactors	All Reactors	Progress Energy Reactors	Progress Energy Reactors
Quarters Ranked in Column 1	1471	83.0%	71	93.4%
Quarters Ranked in Column 2	226	12.7%	5	6.6%
Quarters Ranked in Column 3	44	2.5%	0	0.0%
Quarters Ranked in Column 4	32	1.8%	0	0.0%
Quarters Ranked in Column 5	0	0.0%	0	0.0%
Average Column Ranking	1.23		1.07	

Q15: Why did the NRC's ratings for the Progress nuclear reactor fleet decline when Mr. Johnson was CEO?

A15: Violations of federal regulations identified by NRC inspectors at all of the Progress Energy nuclear reactors (except Shearon Harris) and classified as White findings caused the NRC to lower its ratings. Specifically, on December 21, 2010, the NRC issued a White

[12] Like golf scorecards, lower numbers on NRC's assessments are better than higher values. 1's on NRC's scorecards are best while 5's are worst.

finding for inadequate emergency planning for Brunswick Units 1 and 2.[13] The emergency plan called for the Operations Support Center, Technical Support Center, and Emergency Operations Facility to be staffed and activated within 75 minutes of declaration of a nuclear emergency. But following an emergency declaration on June 6, 2010, it took nearly 150 minutes to activate these facilities. On January 31, 2011, the NRC issued two White findings for inadequate procedures and training at the HB Robinson nuclear plant.[14] A March 28, 2010, fire at the plant was worsened when operators were unable to prevent the cooldown rate from exceeding safety limits and attempted to re-energize the electrical circuit that started the fire before it had been repaired, causing the start of a second fire. On December 20, 2011, the NRC issued a White finding for deficient emergency response procedures at the Crystal River 3 nuclear plant.[15] The radiation monitoring instruments were not ranged (i.e., not calibrated to measure higher radiation levels) to be able to provide the information needed to make the proper decisions about protective measures.

Q16: When was Mr. Johnson CEO of TVA?

[13] Reyes, Luis A., Regional Administrator, Nuclear Regulatory Commission. "Final Significance Determination of White Finding and Notice of Violation." December 21, 2010. Online at https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML103560553

[14] McCree, Victor M., Regional Administrator, Nuclear Regulatory Commission. "Final Significance Determination of White Findings and Notice of Violation." January 31, 2011. Online at https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML110310469

[15] McCree, Victor M., Regional Administrator, Nuclear Regulatory Commission. "Crystal River Unit 3 – Final Significance Determination of a White Finding, Notice of Violation, and Assessment Follow-up Letter." December 20, 2011. Online at https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML113540744

A16: Mr. Johnson became CEO of TVA in November 2012[16] and left in April 2019.[17] For the purposes of this review, I considered Mr. Johnson's CEO tenure at TVA to span the 25 quarters between the first quarter of 2013 and the first quarter of 2019, inclusive.

Q17: What did the NRC's ratings show for the TVA nuclear reactors?

A17: The safety performance ranking of TVA's reactor fleet (1.35) underperformed that of the average U.S. reactor (1.24) during the 25 quarters prior to Mr. Johnson becoming TVA's CEO. The safety performance ranking of TVA's reactor fleet (1.42) underperformed that of the average U.S. reactor (1.19) during the 25 quarters that Mr. Johnson was TVA's CEO. The safety performance ranking of TVA's reactor fleet worsened during Mr. Johnson's 25-quarter reign as CEO from the 25-quarter period pre-Johnson (1.42 from 1.35). The safety performance of the average U.S. reactor improved during these two 25-quarter periods (1.24 to 1.19). The safety performance ranking of PG&E's reactors (1.19) matched that of the average U.S. reactor (1.19) while Mr. Johnson was TVA's CEO and outperformed the TVA reactor fleet (1.42).

[16] AllGov. "CEO of the Tennessee Valley Authority: Who is Bill Johnson?" June 2, 2013. Accessed December 19, 2019. Online at http://www.allgov.com/news/appointments-and-resignations/ceo-of-the-tennessee-valley-authority-who-is-bill-johnson-130602?news=850184

[17] Wikipedia. "William D. Johnson (CEO)." Accessed December 19, 2019. Online at https://en.wikipedia.org/wiki/William_D._Johnson_(CEO)

4th Quarter 2006 to 4th Quarter 2012, Inclusive - 25 Quarters Prior to William Johnson's as TVA CEO				
	All Reactors	All Reactors	TVA Reactors	TVA Reactors
Quarters Ranked in Column 1	2017	81.5%	123	82.0%
Quarters Ranked in Column 2	334	13.5%	9	6.0%
Quarters Ranked in Column 3	102	4.1%	10	6.7%
Quarters Ranked in Column 4	22	0.9%	8	5.3%
Quarters Ranked in Column 5	0	0.0%	0	0.0%
Average Column Ranking	1.24		1.35	

1st Quarter 2013 to 1st Quarter 2019, Inclusive - William Johnson's 25 Quarters as TVA CEO				
	All Reactors	All Reactors	TVA Reactors	TVA Reactors
Quarters Ranked in Column 1	2119	86.0%	115	70.1%
Quarters Ranked in Column 2	260	10.6%	34	20.7%
Quarters Ranked in Column 3	36	1.5%	10	6.1%
Quarters Ranked in Column 4	48	1.9%	5	3.0%
Quarters Ranked in Column 5	0	0.0%	0	0.0%
Average Column Ranking	1.19		1.42	

1st Quarter 2013 to 1st Quarter 2019, Inclusive - William Johnson's 25 Quarters as TVA CEO				
	All Reactors	All Reactors	PG&E Reactors	PG&E Reactors
Quarters Ranked in Column 1	2119	86.0%	39	78.0%
Quarters Ranked in Column 2	260	10.6%	11	22.0%
Quarters Ranked in Column 3	36	1.5%	0	0.0%
Quarters Ranked in Column 4	48	1.9%	0	0.0%
Quarters Ranked in Column 5	0	0.0%	0	0.0%
Average Column Ranking	1.19		1.19	

Q18: Why did the NRC's ratings for the TVA nuclear reactor fleet decline when Mr. Johnson was CEO?

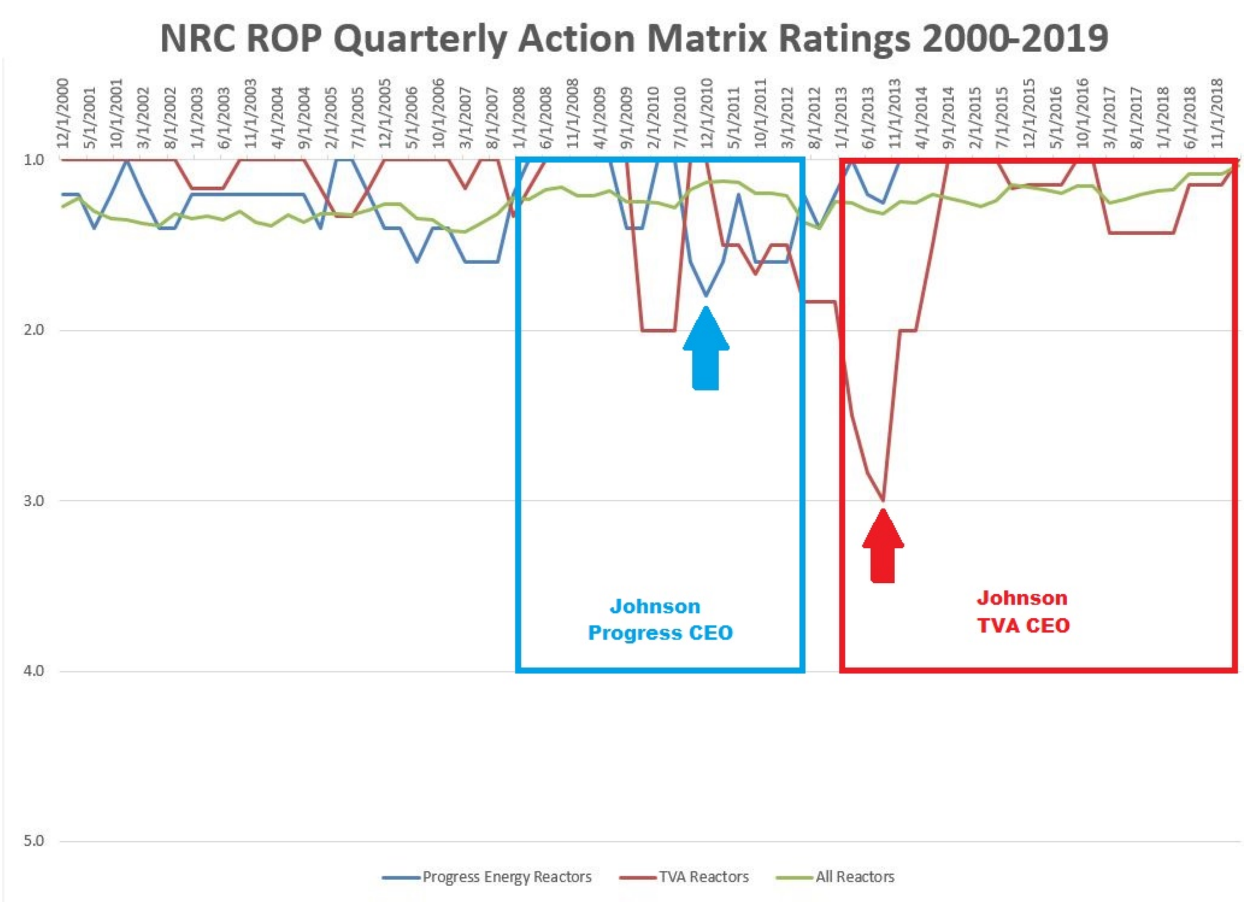
A18: Violations of federal regulations identified by NRC inspectors and classified as White findings coupled with performance indicators reflecting elevated problem occurrence rates caused the NRC to lower its ratings. For example, the NRC issued a White finding on April 30, 2014, for failures to maintain the minimum staffing levels at the Browns Ferry nuclear plant as required by the emergency response plan.[18] On March 23, 2016, the NRC issued a Chilled Work Environment letter to TVA after receiving allegations from operators at the

[18] Croteau, Richard P., Director, Division of Reactor Projects, Nuclear Regulatory Commission. "Browns Ferry Nuclear Plant – NRC Integrated Inspection Report, Final Significance Determination of White Finding and Notice of Violation." April 30, 2014. Online at https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML14120A374

Watts Bar nuclear plant that workers are not free to raise safety concerns due to fear of retaliation and/or harassment.[19]

Q19: What do the NRC's ratings between 2000 and 2019 show?

A19: The lowest average NRC rating for Progress Energy's reactor fleet occurred more than halfway through Johnson's tenure as CEO. The lowest average NRC rating for TVA's reactor fleet also occurred during Johnson's tenure as CEO.



[19] Haney, Catherine, Regional Administrator, Nuclear Regulatory Commission. "Chilled Work Environment for Raising and Addressing Safety Concerns at the Watts Bar Nuclear Plant." Atlanta, GA. March 23, 2016. Online at https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML16083A479

Q20: The NRC's performance ratings for the Progress Energy nuclear reactor fleet achieved the top level (i.e., all reactors in Column 1) shortly after Mr. Johnson departed and remained there for the next five years. Might this reflect the result of improvement reforms/efforts undertaken under Mr. Johnson's leadership belatedly bearing fruit?

A20: It is possible, but a far more likely explanation emerged from my conversations with Brian McCabe and Christopher Nolan. I met both individuals when they worked for the NRC and I worked for the Union of Concerned Scientists. Mr. McCabe left the NRC to work in the Regulatory Affairs department of Progress Energy. Mr. Nolan left the NRC to work in the Regulatory Affairs department of Duke Power. I encountered Mr. McCabe and Mr. Nolan at several NRC public meetings and conferences. Our conversations often addressed recent problems reported for the Progress and Duke nuclear reactors. A recurring theme expressed by both Mr. McCabe and Mr. Nolan was that the problems at the Progress Energy reactors stemmed from budget constraints. Assuming their accounts are reasonably accurate — and I have no reason to suspect otherwise based on numerous interactions with them before and after their NRC careers — the stellar performance of Progress Energy's reactors after Mr. Johnson's tenure as CEO is not the product of an improvement track he blazed but from the resources, financial and managerial, available from Duke Power after the merger of the two companies.

Q21: What insights are suggested by your review of NRC's quarterly performance ratings?

A21: While Mr. Johnson was Progress Energy's CEO, the company's nuclear reactors achieved slightly better performance ratings than they received in the comparable time period before he became CEO. But the performance rating of the average U.S. nuclear reactor improved significantly more over the two periods. In other words, while the safety performance of the Progress Energy reactors improved, it lagged or underperformed the nuclear industry's progress. After Mr. Johnson departed from Progress Energy, the company's reactors achieved and sustained top performance ratings while the performance rating for the average U.S. reactor declined slightly. While Mr. Johnson was TVA's CEO, the agency's nuclear reactors received lowered performance rating than they received in the comparable time period before he became CEO. And the performance rating of the average U.S. nuclear reactor showed marked improvement over the two periods. While Mr. Johnson was CEO of Progress Energy and then TVA, the nuclear reactors under his helm received the lowest safety performance ratings from the NRC they ever received over the two-decade history of the NRC issuing quarterly ratings. The NRC's performance ratings provide little to no reason to believe that the safety performance of PG&E's reactors will be improved, or sustained under Mr. Johnson's guidance.

Q22: What aspect of this review of the past gives you the largest concern about the future of PG&E's nuclear reactors?

A22: The safety performance of the Progress Energy and TVA nuclear reactor fleets under Mr. Johnson's leadership underperformed both nuclear industry and pre-Johnson company performance levels. A reasonable explanation from insiders for the performance shortcomings at the Progress Energy reactors involved budget constraints. PG&E faces budget constraints in seeking to emerge from bankruptcy. Countless decisions must determine what tasks absolutely must be addressed now and what tasks can be properly deferred, or even cancelled. Accurate risk insights are key inputs for proper decision-making. As Answer 17 shows, the performance ratings of PG&E's since 2013 mirror nuclear industry levels and outperform the performance of the Progress Energy and TVA reactor fleets under Mr. Johnson's leadership. Thus, even if the performance of PG&E's nuclear reactors were to decline under Mr. Johnson's leadership, they currently are in a better position to endure performance erosion. As PG&E has announced the pending permanent closure of Diablo Canyon Unit 1 by November 2, 2024, and of Diablo Canyon Unit 2 by August 26, 2025[20], there's not much time for a modest declining performance trend to significantly undermine nuclear safety levels. However, the permanent closure of PG&E nuclear reactors will increase a risk not being properly managed as described in Section IV.

IV. **SPENT FUEL STORAGE RISK MISMANAGEMENT**

Q23: What nuclear safety risk do you believe is being mismanaged?

A23: The interim storage of irradiated spent fuel in pools and in dry storage poses safety and security hazards and risks that are not being properly recognized and managed.

Q24: How much spent fuel will be stored at the Diablo Canyon nuclear plant?

A24: The U.S. Department of Energy (DOE) estimates that there will be 2,357 irradiated fuel assemblies (1,010 metric tons) stored for the Unit 1 nuclear reactor and 2,084 irradiated fuel assemblies (898 metric tons) stored for the Unit 2 nuclear reactor at their

[20] U.S. Department of Energy (DOE). "Spent Nuclear Fuel and High-Level Radioactive Waste Inventory Report: Spent Fuel and Waste Disposition." September 2019. Online at https://sti.srs.gov/fulltext/FCRD-NFST-2013-000263_R6.pdf

announced permanent shut down dates.[21] To put these numbers in context, the reactor core for the Unit 1 and 2 reactors holds 193 fuel assemblies. Thus, there will be approximately 12 core's worth of spent fuel to store for Unit 1 and nearly 11 core's worth of spent fuel to store for Unit 2.

Q25: What is the hazard associated with spent fuel?

A25: The hazard of spent fuel, or irradiated fuel, can be seen from its two end-points: the reactor core and a geological repository. When inside the core of an operating nuclear reactor, irradiated fuel is so hazardous that federal liability protection under the Price-Anderson Act was required to protect nuclear plant owners and reactor vendors from the potentially high financial consequences from a nuclear reactor accident. When inside a geological repository, irradiated fuel is so hazardous that federal law (the Nuclear Waste Policy Act as amended) mandates that its contents be isolated from the environment for at least 10,000 years into the future. Clearly, irradiated fuel in spent fuel pools and onsite dry storage systems between these two highly hazardous endpoints cannot be benign.

Q26: More specifically, what is the nature of the hazard associated with spent fuel?

A26: Spent fuel contains tons of unstable atoms that emit radioactivity in the form of neutrons, gamma rays, and alpha and beta particles. Radioactive emissions can kill or damage living cells as well as damage chromosomes afflicting future generations. The radioactive emissions also generate thermal energy (heat). Spent fuel assemblies are solid components that deter transport of radioactivity. But if the thermal energy produced by

[21] U.S. Department of Energy (DOE). "Spent Nuclear Fuel and High-Level Radioactive Waste Inventory Report: Spent Fuel and Waste Disposition." September 2019. Online at https://sti.srs.gov/fulltext/FCRD-NFST-2013-000263_R6.pdf

radioactive emissions is not removed, the spent fuel assemblies can overheat. In certain configurations, the spent fuel assemblies can even catch on fire. Overheating damage can release radioactive gases and particles to the atmosphere. Likewise, an act of sabotage can breach the integrity of spent fuel assemblies and serve as a catalyst propelling their contents into the atmosphere.

Q27: What could be the consequences from a spent fuel pool accident?

A27: At the request of the NRC to inform decision-making about spent fuel hazards at permanently shut down nuclear reactors, researchers at the Brookhaven National Laboratory examined numerous postulated spent fuel pool accident scenarios (e.g., accidents resulting in damage to the entire inventory of spent fuel pool or just a subset of it, large release of contents from damaged spent fuel or just a small fraction of it, etc.). Table 4.1 from this Brookhaven study[22] compiled the results from the various scenarios for pressurized water reactors (PWRs) like those at Diablo Canyon. The least severe case was estimated to cause 2,300 latent fatalities (defined as persons dying from radiation-induced causes more than a year after exposure to the radioactive plume). More severe cases could claim tens of thousands of lives and contaminate hundreds of square miles of land.

[22] Brookhaven National Laboratory. "A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants." August 1997. Online at https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML082260098

Accident	Inventory	Distance (miles)	Prompt Fatalities	Societal Dose (person-rem $x10^{6}$)	Latent Fatalities	Condemned Land (sq. miles)	Total Cost ($\$x10^{9}$)**
Case 1H	full pool	0-50 0-500	70 95	74 339	31,300 143,000	467 2790	287 566
Case 1L	full pool	0-50 0-500	1.2 1.2	62 130	25,300 53,800	297 869	100 117
Case 2H	last core*	0-50 0-500	29 33	81 226	33,200 94,600	286 776	186 274
Case 2L	last core*	0-50 0-500	0.3 0.3	42 70	16,800 28,800	156 188	56 59
Case 3H	50% pool	0-50 0-500	0 0	32 48	13,200 20,400	25 25	25 25
Case 3L	50% pool	0-50 0-500	0 0	6 8	2,400 3,400	2 2	1.1 1.1
Case 4H	last core*	0-50 0-500	0 0	24 36	10,100 15,400	15 15	15 15
Case 4L	last core*	0-50 0-500	0 0	4 5	1,500 2,300	1 1	0.8 0.8

* The "last core" also includes the last normal refueling discharge.
** excludes health effects

Q28; What could be the consequences from spent fuel sabotage?

A28: At the request of the U.S. House of Representatives Committee on Energy and Commerce, the U.S. General Accounting Office (GAO) examined spent fuel security after 9/11.[23] The GAO obtained information from the NRC about the potential consequences from a successful attack on a spent fuel pool. Even 10 years after permanent shut down of a nuclear reactor, spent fuel pool sabotage was estimated to potentially result in 7,500 deaths from radiation-induced cancers.

[23] U.S. General Accounting Office. "Spent Nuclear Fuel: Options Exist to Further Enhance Security." July 2003. Online at https://www.gao.gov/new.items/d03426.pdf

Table 1: Potential Health Effects of Fire in a Spent Fuel Pool

Time after shutdown of reactor	Lower level of radioactivity[a]		Higher level of radioactivity[a]	
	Number of early fatalities	Number of latent cancer fatalities	Number of early fatalities	Number of latent cancer fatalities
30 days	2	3,500	200	15,000
1 year	1	[b]	80	[b]
5 years	0	[b]	1	[b]
10 years	0	[b]	0	7,500

Source: NRC.

[a]NRC assumed a low level and a high level of ruthenium in the dispersed spent fuel. Ruthenium, found in higher levels in recently discharged fuel, is a particularly lethal isotope when dispersed in small particles.

[b]Information not available.

Q29: The spent fuel hazards seem to be readily recognized and accepted. What makes you believe that spent fuel hazards are not being properly managed?

A29: The risk analyses for irradiated fuel when in the reactor core is significantly different from the analyses of the irradiated fuel storage risk, whether in spent fuel pools or dry storage. Consequently, the information and quality of inputs available for decision-making about managing the risk from reactor operation is significantly different than that available for managing the risk from spent fuel storage.

Q30: What is the risk analyses performed for irradiated fuel in the reactor core?

A30: Two key documents of risk analyses are the Updated Final Safety Analysis Report[24] (UFSAR) and the Probabilistic Risk Assessment (PRA) [25] for Diablo Canyon.

Q31: What is the UFSAR and how is it used?

A31: The UFSAR described the design and operation of components and structures at the plant. The UFSAR also described the analyses performed of postulated accidents. These

[24] Pacific gas & Electric Company. "Revised Updated Final Safety Analysis Report, Revision 23." May 3, 2017. Online at https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML17157B366
[25] Nuclear Regulatory Commission. "Review of the Diablo Canyon Probabilistic Risk Assessment." NUREG/CR-5726. August 1994. Online at https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML16342C677

accident analyses explained how the plant's design features and associated procedures would work together to mitigate the accidents and protect workers and the public. The UFSAR serves many needs, including training workers on the design and operation of the plant and functioning as the safety answer key to questions about replacing equipment or revising operating procedures. For example, the proposed replacement of an emergency makeup pump with a higher capacity pump might seem like a no-brainer — the proposed pump supplies more makeup water. The UFSAR enables workers to check whether the greater power demands of the larger motor on the bigger pump do not overload in-plant electrical circuits to de-energize the new pump and other emergency equipment. The NRC also relies on the UFSAR when reviewing requests by plant owners to amend the reactor operating licenses. The NRC's reviewers confirm that the owners' justifications for the amendments are accurate and complete before they approve them.

Q32: What is the PRA and how is it used?

A32: The PRA covered the same ground of postulated accident scenarios, but with a different objective. The PRA recognized that not all emergency equipment has equal value; certain equipment is relied upon to protect workers and the public during many postulated accident scenarios while other equipment may only need to function in rare events. PRA results serve a "nuclear triage" role in identifying where to best allocate finite resources and how to prioritize repairs. The NRC also relies heavily on PRA results when conducting "smart sample" audits during inspections to focus their examinations on higher risk areas. Both plant owners and the NRC rely on PRA results when determining the safety significance of violations of regulatory requirements.

Q33: How is spent fuel storage handled within the Diablo Canyon UFSAR?

A33: The spent fuel pool and dry storage systems are described in the UFSAR. But there are no postulated scenarios for spent fuel pool or dry storage accidents.[26] Risk is commonly defined as the product of an accident and its consequences. The UFSAR is silent on spent fuel storage risk. Spent fuel storage accidents are neither postulated nor are their potential consequences discussed.

Q34: How is spent fuel storage handled within the Diablo Canyon PRA?

A34: No spent fuel pool or dry storage accidents are covered within the Diablo Canyon PRA. The sole mention of the spent fuel pool in this PRA is the use of a spent fuel pool cooling system pump to provide makeup water to an onsite storage tank for long-term reactor core and containment cooling purposes.

Q35: How does the omission of postulated spent fuel storage accidents from the UFSAR and PRA adversely affect risk management?

A35: It is challenging at best, impossible at worst to connect the dots and properly manage the risks when the dots are non-existent or invisible. If postulated spent fuel storage accidents were described in the UFSAR, plant workers and NRC inspectors would better understand the components and structures relied upon to prevent spent fuel damage and to mitigate the release of radioactivity should spent fuel damage occur. This awareness would help them make proper decisions needed to sustain the available safety

[26] Section 15.4.5 of the Diablo Canyon UFSAR addresses a postulated fuel handling accident. The accident assumed in that analysis involves dropping an irradiated fuel assembly while moving it or dropping something heavy onto irradiated fuel assemblies. No analyses of scenarios such as draining water from the spent fuel pool or disabling the spent fuel pool's cooling system are provided.

margins — in other words, to better manage the risk from spent fuel storage. Similarly, if postulated spent fuel storage accidents were considered in the PRA, plant workers and NRC inspectors would better understand risk factors so as to ensure finite resources are applied where they are most needed — in other words, to better manage the spent fuel storage risk.

Q36: How are the security hazards of spent fuel storage managed?

A36: As with the UFSAR and PRA disparity, the security measures protecting against sabotage of irradiated fuel when in the reactor core are significantly lessened, if not eliminated, when a nuclear reactor permanently shuts down and the only remaining hazard is from spent fuel storage. For example, the NRC oversees force-on-force security tests at all operating nuclear plants. These tests pit a small group of mock attackers against a nuclear plant's gates, guards, and guns. The owners are notified by the NRC many months in advance of the force-on-force tests, allowing ample time to ensure detection and access control equipment is in prime condition and guards are fully trained on their response tactics by the time of the tests. Despite this advance warning and associated preparation, the "bad guys" win at one out of about two dozen plants tested each year.[27] The "good guys" at a permanently shut down nuclear reactor cannot lose a force-on-force test. Not because security is simplified, but because the NRC allows owners to eliminate force-on-force security testing and lessen many other security measures.[28]

[27] Nuclear Regulatory Commission (NRC). "Report to Congress on the Security Inspection Program for Commercial, Power Reactors and Category I Fuel Cycle Facilities: Results and Status Update Annual Report for Calendar Year 2017." Washington DC. July 2018. Online at https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19029A036

[28] Nuclear Regulatory Commission (NRC). "Review of Security Exemptions/License Amendment Requests for Decommissioning Nuclear Power Plants." Washington, DC. September 28, 2015. Online at https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML15106A737

Q37: Are the safety and security hazards from spent fuel storage sufficiently reduced to warrant correspondingly reduced analyses?

A37: The hazards from spent fuel placed within a repository are arguably even lower than the hazards from onsite spent fuel storage prior to transport for the simple reason that longer time onsite affords more decay of unstable radioactive atoms. But the analyses for irradiated fuel to be placed within a geological repository include postulated accidents and sabotage. The postulated accidents include: aircraft crashes, external fires, explosions, human errors, and combinations of events. If the hazards of irradiated fuel require formal analysis and security when in a reactor core and when in a repository, this hazard requires comparable treatment when irradiated fuel is in a spent fuel pool or dry storage system.

Q38: Have others reviewed spent fuel storage security issues?

A38: Yes. For example, the National Academy of Sciences (NAS) established a committee to review the safety and security lessons learned from the March 2011 accident at the Fukushima Daiichi nuclear plant in Japan. This NAS committee reported:

> The committee also finds (Finding 4.7) that the USNRC [U.S. Nuclear Regulatory Commission] has not analyzed the potential vulnerabilities of spent fuel pools to the specific terrorist attack scenarios [29]

Thus, the NRC has allowed security measures to be eliminated and lessened without having first examined the spent fuel pool vulnerabilities to sabotage to ensure the surviving security measures provide sufficient protection.

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[29] National Academies of Sciences, Engineering, and Medicine. 2016. "Lessons Learned from the Fukushima Nuclear Accident for Improving Safety and Security of U.S. Nuclear Plants: Phase 2," page 9.

Q39: Do the NRC's quarterly safety assessments include or cover spent fuel storage?

A39: While there are no direct performance indicators for spent fuel storage, the NRC conducts periodic inspections of spent fuel storage and associated activities (e.g., fuel handling practices.) But the NRC terminates its quarterly safety assessments once all reactors at a nuclear plant have permanently shut down and significantly reduces its inspection efforts.

Q40: Based on your review of Mr. Johnson's record as CEO of companies operating nuclear power plants described in Section III and your assessment of spent fuel storage risk management at permanently shut down nuclear plants described in this section, what are your concerns about PG&E's future under Mr. Johnson's leadership?

A40: During Mr. Johnson's tenures as CEO of Progress Energy and TVA, their nuclear reactor fleets received the lowest safety assessments from the NRC. The NRC's assessments for the Progress Energy fleet significantly improved <u>after</u> Mr. Johnson's departure. Knowledgeable and reliable insiders told me that budget constraints were primarily responsible for the poor performance of the Progress Energy fleet and the company's merger with Duke Power alleviated that factor and facilitated the subsequent performance improvement. PG&E's bankruptcy situation resembles Progress Energy's situation during Mr. Johnson's tenure as CEO. Budget constraints challenge management to decide what work must be done and what other work can be deferred or cancelled. The record does not suggest that Mr. Johnson successfully met these challenges. The pending permanent closure of the Diablo Canyon reactors compounds the challenge. While the reactor safety risk goes to zero, the spent fuel storage risk increases. The dearth of quantitative tools with which to gauge the spent fuel storage risk makes proper decision-making more problematic. And the NRC's cessation of quarterly safety assessments after nuclear reactors permanently shut down means there are fewer checks and balances to flag improper decisions and to correct declining performance trends.

Appendix A

QUALIFICATIONS OF DAVID LOCHBAUM

David Lochbaum worked on nuclear power safety issues for nearly forty years.

Mr. Lochbaum graduated in June 1979 from The University of Tennessee with a Bachelor of Science degree in Nuclear Engineering. He went to work for Georgia Power Company at their Edwin I. Hatch nuclear plant (GA) as a reactor engineer and radwaste system engineer.

Mr. Lochbaum then went to work for the Tennessee Valley Authority at their Browns Ferry nuclear plant (AL) as a reactor engineer. He attained certification as a Shift Technical Advisor, a position mandated by the U.S. Nuclear Regulatory Commission (NRC) following the Three Mile Island (PA) accident.

Mr. Lochbaum joined Enercon Services and worked a series of consulting assignments including:

- supervising the reactor engineers at the Grand Gulf nuclear plant (MS),
- evaluating systems at the Susquehanna nuclear plant (PA) for power uprate capability,
- developing reactor engineer training programs for the Cooper (NE) and Peach Bottom (PA) nuclear plants,
- conducting a vertical slice assessment of the spent fuel pool cooling system at the Salem nuclear plant (NJ),
- compiling a licensing commitment database for the Wolf Creek nuclear plant (KS),

- documenting the design bases for the primary containment and isolation devices for the FitzPatrick nuclear plant (NY),
- developing a topical report on the station blackout licensing basis for the Connecticut Yankee nuclear plant (CT), and
- training engineers and manager at the Perry nuclear plant (OH) on design and licensing bases.

Mr. Lochbaum joined the Union of Concerned Scientists (UCS) in October 1996 and worked for UCS until his retirement in October 2018, except for a one-year period with the NRC discussed below. Mr. Lochbaum directed UCS's nuclear safety project monitoring development in the U.S. nuclear industry and engaging the NRC, the U.S. Congress, the media, and other forums to sustain strong safety performance and resolve safety shortcomings.

Between March 2009 and March 2010, Mr. Lochbaum was a Reactor Technology Instructor for the NRC. He provided initial qualification and requalification training to NRC personnel in classroom and control room simulator sessions.

Mr. Lochbaum authored a book about spent fuel storage issues titled "Nuclear Waste Disposal Crisis" and co-authored a book titled "Fukushima: The Story of a Nuclear Disaster" about the March 2011 tragic accident in Japan. Mr. Lochbaum authored many reports, backgrounders, testimonies to the U.S. Congress, and blog commentaries while working for UCS.

Mr. Lochbaum has testified as an expert witness before the California Public Utilities Commission and made presentations on nuclear safety issues to the California Energy Commission.