A Beyond Nuclear Decommissioning White Paper

Nuclear power reactors need an autopsy during decommissioning to verify and validate safety of the license extension process

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For many years now, federal nuclear safety officials, national laboratory scientists and safe energy advocates have been requesting that an "autopsy" of sorts be performed on permanently closed and decommissioning nuclear power stations. All agree, if strategically performed, a post-shutdown autopsy of closed reactors is a valuable and justifiable cost of doing business to inform real time safety margins in operating reactors and to project future safety margins in reactors making application to dramatically extend their operations. But industry's contribution is still largely missing.

The U.S. Nuclear Regulatory Commission (NRC) and the federal labs are still seeking the cooperation and collaboration of the nuclear industry.[1] The analysis of samples of actual aged materials (metals, cables, concrete, etc.) taken from decommissioning reactors is critically important to address identified scientific knowledge gaps and safety questions arising out of the review of operating license extensions. Originally licensed to operate for 40-years, the bulk of the U.S. reactors have extended their licenses to 60-years.[2] Nuclear reactor operators are now piloting applications for license extensions through the 60 to 80-year period, known as "*Subsequent License Renewal (SLR)*."[3]

But according to one recent national laboratory report, if the nuclear industry is to extend operating licenses longer and longer, it needs to provide more measurable evidence of the extent of condition of aging safety-related systems, structures and

[1] "*Harvesting of Aged Materials from Nuclear Power Plants,*" U.S. NRC Regulatory Information Conference (RIC), March 13-15, 2018, Poster Session, Rockville, MD, **https://ric.nrc.gov/docs/posters/posterabstract8.htm**

[2] "*Status of Initial License Renewal Applications and Industry Initiatives,"* U.S. NRC, updated May 4, 2018, **https://www.nrc.gov/reactors/operating/licensing/renewal/applications.html**

[3] "*Status of Subsequent License Renewal Applications,*" U.S. NRC, updated April 6, 2018, **https://www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.html#apps**

components with real time aged materials harvested from operating, closed and decommissioning reactors.[4] In view of public safety, the inherent risk in nuclear power and the demonstrated consequences of severe accidents, to approve operating license extensions without peer-reviewed evidentiary science is to "*put the cart before the horse*."

As public safety stakeholders, the U.S. Congress, states and civil society, including independent decommissioning citizen advisory panels established by state authority, have an increasingly important role to play in the laboratory acquisition of real time aged material samples harvested from decommissioning nuclear power stations. Expanding this knowledge base is critically needed to quantify and qualify the aging hazard in nuclear power stations and reasonably inform safety issues potentially emerging in current operating reactors and further NRC license extensions.

The NRC, Oak Ridge National Laboratory (ORNL) and Pacific Northwest National Laboratory (PNNL) have been working on plans to strategically salvage actual aged samples of metal and non-metal materials (principally electrical cable insulation and concrete) from decommissioning reactors for study. The scientific analysis of aged material samples provides an important benchmark measurement of the destructive effects of at least sixteen (16) known age-related degradation mechanisms still attacking critical safety margins in operating nuclear power stations. This is particularly important for the large, irreplaceable safety-related components like the reactor pressure vessel, structures including the concrete containment building and entire systems including the miles of electrical cable embedded throughout the generating stations. The operationally-aged material samples need to be segmented from systems, structures and components that have been affected by decades of high radiation fields, extreme temperature changes, corrosion, vibration and fatigue. According to PNNL,

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[4] "*Criteria and Planning Guidance for Ex-Plant Harvesting to Support Subsequent License Renewal,*" Pacific Northwest National Laboratory (PNNL), prepared for the U.S. Nuclear Regulatory Commission with DOE funding, December 2017, p.30 of 52 **https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-27120.pdf (NOTE: PNNL-27120 has been removed from this government website. To view go to http://www.beyondnuclear.org/storage/aging/slr/autopsy_PNNL-27120_harvesting_Dec2017.pdf)**

laboratory analysis of the effects of actual aging in this harsh operationally environment still needs to build on to the knowledge base as to how attack mechanisms initiate, grow over time, and impact material performance and safety into the future.

Decommissioning, therefore, is not only a process for decontaminating, dismantling and removing radioactive contamination from the site. Decommissioning has an invaluable role at the end-of-reactor-life-cycle to scientifically scrutinize the material condition and safety margins of those irreplaceable systems, structures and components relied upon to extend reactor operating licenses longer and longer.

However, after decades of operation, the nuclear industry and the NRC have done surprisingly little to strategically harvest, archive and scientifically analyze actual aged materials. Much of the industry's harvested samples provided-to-date represent the "*before*" material---taken from cancelled construction projects, supply chain warehouses and never commercially operated reactors like the Shoreham nuclear power station on Long Island, NY. Only a relatively small set of harvested and analyzed aged materials presently makeup the increasingly important "*after*" real time sample set shared with NRC as needed to provide reviewable evidence on the extent of condition of operating reactors and projected future aging impacts on license extensions.

For current licensing purposes, the industry and regulator have focused much more attention and resources on amending their operating licenses with computer models and laboratory accelerated aging of fresh materials. Autopsies of the "*real thing*" are an important check and balance on this present day reliance. A 2015 NRC technical presentation logically recognized that harvesting and analyzing the actual aged material samples taken from post-operational reactors "*offers unique environmental exposures that cannot entirely be replicated by laboratory testing with fresh materials.*"[5] In other words as David Lochbaum, a recognized independent reactor safety engineer with the Union of Concerned Scientist, frames it, "*Nuclear autopsies yield insights that cannot be*

[5] "*Strategic Approach for Obtaining Material and Component Aging Information,*" Matthew Hiser and Amy Hull, U.S. NRC, June 2-4, 2015, Slide 3 of 21, **https://www.nrc.gov/docs/ML1515/ML15155B442.pdf**

obtained by other means."[6] But the real thing is still hard to come by. The NRC attributes the present dearth of actual aged material samples to "*harvesting opportunities have been limited due to few decommissioning plants*."[7] That claim by itself is questionable given at the time, ten (10) U.S. reactors had completed decommissioning and nineteen (19) units in the process. Today, twenty (20) units are decommissioning with more scheduled closures to begin in Fall 2018.

A closer look raises concern that the nuclear industry is reluctant to participate by turning over its bodies to science or pay its fair share to scrutinize projected safety margins as a cost of doing business to extend reactor operating licenses from 40 to 60 years and again from 60 to 80 years. Moreover, the NRC is shying away from taking reasonable regulatory and enforcement action to acquire the requested samples for analysis after prioritizing the need for license extension-related research and validation. In the meantime, the nuclear industry license extension process presses forward.

Burying bodies whole and mothballing others for decades without scrutiny

This is an old story. The industry and regulator's avoidance was first publicly flagged with the 1991 closure and prompt dismantlement of the Yankee Rowe nuclear power station in Western Massachusetts. Yankee Rowe was the nation's pilot applicant for the 40 to 60-year operating license extension process. Instead, the small pressurized water reactor was forced to permanently closed following public-driven disclosure that decades of thermal and radiation-induced embrittlement of the reactor pressure vessel's base metal and weld material had significantly weakened the large, irreplaceable component.[8] The age-related deterioration had rendered the all-important pressure boundary component vulnerable to shattering from pressure thermal shock in the event of initiating the reactor's emergency core cooling system---much like pouring cold water

[6] "*Nuclear Autopsies*," All Things Nuclear [Blog], David Lochbaum, Director, Reactor Safety Project, Union of Concerned Scientists, July 14, 2015, **https://allthingsnuclear.org/dlochbaum/nuclear-autopsies**

[7] Ibid, Hiser and Hull, NRC, 2015, Slide 4 of 21

[8] "*A-Plant to close over safety issue*," New York Times, October 2, 1991, **https://www.nytimes.com/1991/10/02/us/a-plant-to-close-over-safety-issue.html**

into a freshly baked wine glass. Instead, Yankee Atomic Electric Corporation chose prompt dismantlement and decommissioning of the reactor (DECON) and bury critically aged components including the pressure vessel without a requested autopsy of its material condition. A coalition of public interest groups focusing on Yankee Rowe and three other permanently closed reactors (Trojan, Rancho Seco and San Onofre Unit 1) filed an emergency enforcement petition to the NRC requesting the federal agency to modify the decommissioning "*possession only*" license and collaboratively excavate and analyze material samples from the most radiation affected zones of the four reactor pressure vessels. The requested harvesting was to strategically target the pressure vessel wall's beltline base metal and weld material for analysis and archiving to determine the extent of the embrittlement aging phenomenon. The NRC denied the petitioners' request for material scrutiny.[9] The NRC cited in its 1996 denial of the requested enforcement action for sampling that "*the staff concludes that sufficient information is already and will be available to appropriately and timely address the radiation embrittlement phenomenon*."[10]

For another requested site, the NRC's official denial concluded, "*The licensee for the San Onofre 1 reactor has submitted a decommissioning plan to the NRC that proposes SAFSTOR, or long-term storage of the facility, until the licenses for San Onofre Units 2 and 3 expire, sometime after 2013. Therefore, the Unit 1 vessel will remain onsite and in a condition that would allow samples of test material to be obtained for a substantial period of time, should it be determined that such samples would be useful for study."*[11] It is now twenty-two years later and Southern California Edison's San Onofre Unit 1, along with San Onofre Units 2 and 3, permanently closed in 2013, are undergoing decommissioning. The post-closure harvesting of pressure vessel samples from San

[9] "Yankee Atomic Electric Co., Sacramento Municipal Utility District, Portland General Electric Co., and Southern California Edison Co.; Receipt of a Petition for, and Issuance of, a Director's Decision under 10 CFR 2.206," U.S. NRC, Federal Register, Vol. 61, No. 121, June 21, 1996 pp. 31964 to 31966, **https://www.gpo.gov/fdsys/pkg/FR-1996-06-21/pdf/96-15838.pdf**

[10] Ibid, NRC Director's Decision, 1996, Section III, p.31965

[11] Ibid, NRC Director's Decision, 1996, Section III, p.31966

Onofre Unit 1 pressure vessel wall and beltline weld material was considered but without the operator's commitment collect and analyze samples.

Here is an example of a potential opportunity for harvesting of aged metal samples where analyses might be used to scrutinize projected safety margins for another operating reactor of similar design seeking a license extension. Florida Power and Light's Turkey Point Units 3 and 4, two Westinghouse pressurized water reactors operating near Miami, are the first reactors in the U.S. to submit a Subsequent License Renewal (SLR) application for a 60 to 80-year extension. Having started decontamination and preliminary dismantlement in 2016, San Onofre Units 2 and 3, both pressurized water reactors, along with the now long mothballed San Onofre Unit 1, a Westinghouse pressurized water reactor, are prime candidates for the requested strategic harvesting and archiving, though not yet announced. Again, an autopsy can take samples cut from the aged pressurized water reactor vessels to analyze extent of embrittlement for insight into the license extension of Florida's Westinghouse pressurized water reactor complex as well as other potential applications.

At another challenged site, the NRC justified denying the requested enforcement action citing that, "*The Trojan Nuclear Plant is currently* (1996) *undergoing active dismantlement. Portland General Electric, the licensee, is planning to remove the reactor vessel and dispose of it at the Hanford, Washington low-level burial site no earlier than 1998. The staff currently is pursuing the possibility of obtaining samples from the reactor vessel once the reactor vessel reaches the burial site*."[12] In fact, according to a 2001 PNNL planning document for acquiring operational aged materials during decommissioning, the graveside autopsy to assess the condition of the Trojan pressure vessel component never occurred.[13] PNNL additionally reported numerous missed opportunities for post-shutdown harvesting and archiving of strategic materials

[12] Ibid, Federal Register, 1996, p.31966

[13]"*Program Plan for Acquiring and Examining Naturally Aged Materials and Components for Nuclear Reactors*," Pacific Northwest National Laboratory (PNNL), December 2001, p. 16 of 62, **https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-13930.pdf**

including, "*The possibility of obtaining cable samples from Trojan was investigated but was not pursued*."[14]

By and large, the nuclear industry is opting to substantially delay the completion of decommissioning operations (SAFSTOR) as permitted by NRC for as long as 60 years. After promptly defueling the reactor core into onsite irradiated nuclear fuel storage ponds, the reactor complex is mothballed for up to 50 years after which dismantlement and site radiological remediation is to be completed during the last 10 years.[15]

Renewed calls for reactor autopsies during decommissioning

With bodies buried whole and others mothballed for decades to come, the NRC staff hopes that future decommissioning "*provides a unique opportunity to plan harvesting to address the highest priority technical and regulatory issues,"* including reactor pressure vessel embrittlement.*[16]* Without an autopsy, it is arguable that these "*highest priority*" issues cannot be viably evaluated for the industry's first 60 to 80-year extension application now under review by NRC for approval.[17]

To date, the NRC, national laboratories and industry collaboration to gather real time evidence of strategically harvested materials through the decommissioning is limited to relatively small sample sets from U.S. sites and one Spanish reactor site. Samples have been taken from a reactor pressure vessel, neutron absorbing panels in spent fuel pools and electrical cables from two pressurized water reactor sites at the Zion Units 1 & 2 in Illinois (closed in 1996 & 1997) and Crystal River Unit 3 in Florida (closed in 2013). The José Cabrera Nuclear Power Station closed in 2006 (also known as the Zorita nuclear plant), a pressurized water reactor undergoing decommissioning in

[14] Ibid, PNNL 2001, p.44 of 62

[15] "*NRC: $1.4 billion closing of Oyster Creek nuclear plant will take 60 years,"* WHYY Radio, July 2, 2018, **https://whyy.org/segments/nrc-1-4-billion-closing-of-oyster-creek-nuclear-plant-will-take-nearly-60-years/**

[16] Ibid, Hiser and Hull, NRC, 2015, Slide 4 of 21

[17] Turkey Point Units 3 & 4, Subsequent License Renewal Application, U.S. NRC, **https://www.nrc.gov/reactors/operating/licensing/renewal/applications/turkey-point-subsequent.html**

Spain, has harvested a limited number of samples from aged reactor internals and containment concrete.

The NRC and national labs broadly recognize that as nuclear power station operating periods increase, there is a sustained need to selectively acquire and test operationally aged materials to confirm their durability, exam for new aging phenomena and to validate safety margins incorporated into the original 40-year design, the first 20-year license extension and the now proposed "*subsequent*" 20-year extension. However, the reactor licensees' commitments are still missing after decades of ongoing planning.

No boiling water reactor operators, roughly one third of the remaining U.S. operational fleet, are publicly identified in collaboration with the NRC post-shutdown strategic harvesting effort. This is despite the fact that Connecticut's Millstone Unit 1, a GE Mark I boiling water reactor, began decommissioning in 1998. The operator has opted for SAFSTOR to mothball Millstone 1 "*cold and dark*" since 2001.[18] More recently, there is the 2014 closure and commencement of decommissioning at the Vermont Yankee boiling water reactor, another GE Mark I boiling water reactor. Two more GE Mark I boiling water reactors are slated for near-term closure. Oyster Creek (NJ) is scheduled to close in early Fall 2018 followed by the announced closure of Pilgrim (MA) in mid-2019. At an April 10, 2018 public meeting convened by the NRC in New Jersey, Beyond Nuclear with a coalition of New Jersey environmental organizations asked the agency about harvesting and testing material samples from an Oyster Creek autopsy. Neil Sheehan with NRC Office of Public Affairs said the agency and operator, Exelon Nuclear Generating Corporation, had "*no plans*" to autopsy the nation's oldest nuclear power station as it would be "*prohibitively expensive*." [19] [20] Exelon is the first U.S. nuclear utility to submit an 80-year extension application to NRC in July 2018 for two of

[18] "*Decommissioning-Millstone 1,*" The Nuclear Energy Advisory Council Report, State of Connecticut, December 11, 2011, p.4, **http://www.ct.gov/deep/lib/deep/radiation/neac_2011_annual_report.pdf**

[19] "*Oyster Creek needs an autopsy, environmentalists demand,*" Asbury Park Press, April 12, 2018, **https://www.app.com/story/news/local/land-envirosnment/2018/04/12/oyster-creek-nuclear-plant-autopsy-environmentalists-beyond-nuclear/505554002/**

[20] "*NRC has no plans for Oyster Creek 'autopsy,' spokesman says,*" Lacey Patch, April 12, 2018, **https://patch.com/new-jersey/lacey/nrc-has-no-plans-oyster-creek-autopsy-spokesman-says**

its GE Mark I boiling water reactors at Pennsylvania's Peach Bottom nuclear power station. Material samples taken from the owner's Oyster Creek and the other closed boiling water reactors have direct bearing on informing the extent of condition and viability of Exelon's proposed license extension. However, the Turkey Point and Peach Bottom submissions predate commencement of the requested strategic harvesting at any closed GE reactor sites.

The December 2017 PNNL report, funded by the Department of Energy (DOE), identifies that harvesting aged material samples during decommissioning provides the access to important scientific information still needed to validate license extensions reviews for "*reasonable assurance that systems, structures, and components (SSCs) are able to meet their safety functions. Many of the remaining questions regarding degradation of materials will likely require* [emphasis added] *a combination of laboratory studies as well as other research conducted on materials sampled from plants (decommissioned or operating*)."[21] PNNL reiterates, "*Where available, benchmarking can be performed using surveillance specimens. In most cases, however, benchmarking of laboratory tests will require* (emphasis added) *harvesting materials from reactors."*[22] In the absence of such "*reasonable assurance*" it is arguably premature for licensees to be making application for a 60 to 80-year license extension.

Harvesting samples from Cast Austenitic Stainless Steel (CASS) components

One PNNL area of concern focuses on the harvesting and analysis of samples of Cast Austenitic Stainless Steel (CASS) taken from decommissioning reactors. CASS materials are used extensively at nuclear power stations to fabricate safety-significant pressure boundary components that make up light water reactor cooling systems (piping, valves, reactor internals, support structures).[23] PNNL's chief concern for analyzing CASS materials is the dominant and synergistic effects of thermal and

[21] Ibid, PNNL, 2017, p. 5 of 52

[22] Ibid, PNNL, 2017, p. 16 of 52

[23] Ibid, PNNL, 2017, p. 25 of 52

neutron radiation embrittlement and the loss of fracture toughness of the components during the extended operating period. "*It is not known how radiation damage will interact with thermal aging*," cites PNNL as a significant knowledge gap.[24] The autopsy is also necessary to check the calibration of laboratory-accelerated aging and computer simulations. PNNL establishes that, "*At present, accelerated aging of CASS in the laboratory and computer simulations of* microstructural *changes are the main tools used to understand the aging of CASS in service. It would be useful to harvest reactor materials to validate the current accelerated aging program, computer models, and existing regulatory positions*."[25] PNNL rated the "*Harvesting Priority"* for CASS materials as "*Medium to High*" where the "*Availability of materials for harvesting*" is "*To-Be-Determined*" and "*Needs input from industry*."[26]

Harvesting non-metallic material from safety-related electrical cable systems

The 2017 PNNL report focuses significant interest on non-metallic materials from electrical cable insulation and jacketing taken from decommissioning reactors. PNNL rates the "*Harvesting Priority*" as "*High*" where the "*Availability of material for harvesting*" is still "*To-Be-Determined*" that again "*Needs input from utilities*."[27] PNNL identifies, "*As plants consider SLR* [Subsequent License Renewal] *out to 80 years of operation, concerns about non-metallic passive components are increasing. These long-lived components, broadly divided into concrete and electrical cables, are generally difficult to replace and would require a significant investment if across-the-board replacement is considered.*"[28] Destructive examination of electric cable materials at operating reactors has to date largely been reactive and opportunistic. Examinations for the purpose of validating license renewal are complicated by the diversity of the installed vintage cable

[24] Ibid, PNNL, 2017, p. 25 of 52

[25] Ibid, PNNL, 2017, p. 25 of 52

[26] Ibid, PNNL, 2017, p. 27 of 52

[27] Ibid, PNNL, 2017, p. 24 of 52

[28] Ibid, PNNL, 2017, p. 18 of 52

materials and their formulations. PNNL points out that significant knowledge gaps exist for both the dominant effects and synergistic effects of electric cable system aging from heat, radiation, high humidity and submersion. As such, safety-related electrical cable systems still need a larger and broader strategic sampling of real time aged material accessed and harvested during decommissioning to inform the NRC license extension safety review process.

Harvesting concrete samples from irreplaceable structures

In addition to electric cables, the PNNL report identifies concrete as another non-metallic material in structures generally difficult---if not impossible---to replace where decommissioning makes strategic sampling accessible.[29] Another federal laboratory, Oak Ridge National Laboratory (ORNL), in a 2014 report, "*Expanded Materials Degradation Assessment (EMDA),"* recommended building the knowledge base on concrete material degradation as an integral contribution for a viable relicensing review process.[30]

Along with PNNL, ORNL identified concrete as an aging material with significant knowledge gaps in irreplaceable structures that include the reactor containment building, the irradiated nuclear fuel storage pool and below-grade safety-related electrical cable vaults.

Neutron radiation emanating from the operating reactor core intensely bombards concrete structures mainly the reactor cavity and the biological shield. According to ORNL experts, *"The panel also identified the irradiation of concrete as a knowledge gap. This, as mentioned above, is due to a lack of sufficient test data to support a clear*

[29] Ibid, PNNL, 2017, p. 18 of 52

[30] "*Expanded Materials Degradation Assessment (EMDA), Volume 4: Aging of Concrete and Civil Structures,"* Oak Ridge National Laboratory, NUREG/CR-7153, October 2014, **https://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr7153/**

evaluation of the significance of such mechanism for long-term operations."[31]

The ORNL expert panel identifies additional concrete degradation mechanisms that need analysis as part of a license extension review. The expansion and cracking of concrete leading to the loss of strength of aged structures also results from a number of chemical reactions. One particular chemical reaction is "alkali-silica reaction" (ASR). ASR is the chemical combination of reactive silica in concrete aggregate with the alkali from cement paste in the presence of moisture. The chemical reaction generates a gel with an expansive force strong enough over time to cause irreversible micro-cracking of the concrete. As cracking expands, the concrete loses its compressive and tensile strength weakening safety-related structures. "*Alkali-silica reactions were also noted by the expert panel. Though this degradation is well documented by the operating experience (for bridges and dams in particular) and scientific literature, its high ranking in the EMDA analysis describes the need to assess its potential consequences on the structural integrity of the containment, considering the recent operating experience at Davis Besse* [sic] *and other plants*."[32]

The ORNL report is corrected to actually reference the ASR attack discovered in 80% of critical concrete structures at New Hampshire's Seabrook nuclear power station including the reactor containment building, irradiated fuel storage pool and below-grade safety-related electric cable vaults.[33] Seabrook is undergoing a NRC safety review for a license amendment request as part of its 40 to 60-year license extension application review. The operator, NextEra, after an initial sampling of onsite concrete, discovered the loss of over 20% of the concrete's compressive strength after less than 20 years of operation. NextEra suspended harvesting onsite concrete samples. Instead, NextEra is seeking a license amendment from the NRC safety review process that avoids the strength testing of Seabrook contemporaneous concrete samples from either Unit 1 or

[31] Ibid, ORNL, EMDA, 2014, Vol. 4, p. 110 of 137

[32] Ibid, ORNL, EMDA, 2014, Vol. 4, p. 110 of 137

[33] "*Degraded Concrete at Seabrook: An Intro to 'ASR',"* C-10 Research and Education Foundation, **https://irp-cdn.multiscreensite.com/1cc0687d/files/uploaded/C-10%20Fact%20Sheet-%20ASR%20at%20Seabrook%20%282%29.pdf**

the adjacent structures at the cancelled Seabrook Unit 2. The license amendment seeks to validate Seabrook's concrete age management program for the 20-year license extension through computer modeling of laboratory accelerated aging for ASR in virgin concrete test blocks at the University of Texas. As an independent expert on ASR attack who is involved in a public-driven legal intervention into the NRC licensing process has concluded, "*there is no basis to compare compressive strength of the ASR-attacked concrete in the test blocks to that in the actual Seabrook facility.*"[34] The independent expert testimony along with the federal regulator and national laboratory reports again argue that the analysis of contemporaneous aged samples from closed reactors is not adequately substituted by laboratory accelerated aging of fresh materials.

The "Path Forward" and performing the post-shutdown reactor autopsy

The Nuclear Energy Institute (NEI) based in Washington, DC identifies Subsequent License Renewal, extending reactor operations from 60 to 80 years, as the atomic industry's "*Bridge to the Future*."[35] As the nuclear industry's lead advocate, NEI argues "*there are no technical 'show stoppers' to operation beyond 60 years.*"[36] However, given the significant knowledge gaps and the safety importance assigned to gathering evidentiary science to support license extensions, more quantitative data is documented to be needed for such a claim. The NEI "*Second License Renewal Road Map*" is silent on the role of decommissioning as a necessary part of asset recovery from the wrecker ball and grave.[37]

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[34] "Commentary on Seabrook Station License Amendment Request 16-3," on behalf of C-10 Research and Education Foundation, Dr. Paul W. Brown, Testimony, NRC Docket Seabrook 50-443 LA-2, October 30, 2016, p.2, **https://www.nrc.gov/docs/ML1630/ML16306A248.pdf**

[35] "*NRC Commissioner Briefing on Subsequent License Renewal*," S. Jason Remer, Nuclear Energy Institute (NEI), April 26, 2017, slide 2 of 12, **https://www.nrc.gov/reading-rm/doc-collections/commission/slides/2017/20170426/remer-20170426.pdf**

[36] Ibid, Commission Briefing, NEI, slide 7 of 12

[37] "*Second License Renewal Road Map,*" Nuclear Energy Institute, Washington, DC May 2017, **https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/second-license-renewal-road-map-2017.pdf**

At the industrywide NRC Regulatory Information Conference in March 2018, a NRC poster session cites, "*In the NRC's experience, harvesting can yield highly representative and valuable data on material aging, but these efforts will be challenging. Having a clearly defined objective and early engagement with other stakeholders are keys to success. As specific harvesting opportunities are identified through this strategic approach, the NRC welcomes opportunities for cooperation and leveraging of resources with other interested research organizations."*[38] As the critical stakeholder linking reactor decommissioning to material performance benefits during the license renewal period and the historic lack of contemporaneous sampling, the nuclear industry needs to be expressly engaged in the requested cooperation for "early engagement."

In view of the challenges, it is most critical that the U.S. Congress, DOE and the NRC collaborate to redress the current lack of funding for the requested strategic autopsies. As gathering evidentiary science is beneficial to material performance and public safety during the industry requested license renewal period, the nuclear industry is reasonably recognized as not only providing the access to the harvesting of material sample but also collectively obligated to provide their fair share in the funding of the autopsy process through NRC licensing fees.

Civil society is another critical "*stakeholder*" as reactors close and others seek to extend operating licenses. Among these public stakeholders are the site-specific "nuclear decommissioning citizen advisory panels" established by state authority exemplified by the States of Vermont and Massachusetts.[39] [40] The citizen advisory panel's publicly transparent role is charged with educating the public on important decommissioning

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[38]Ibid, NRC, Poster Session, RIC, March 13-15, 2018

[39]Nuclear Decommissioning Citizen Advisory Panel, State of Vermont Department of Public Services, Vermont Yankee Nuclear Power Station, **http://publicservice.vermont.gov/electric/ndcap**

[40]Nuclear Decommissioning Citizen Advisory Panel, State of Massachusetts, Pilgrim Nuclear Power Station, **https://www.mass.gov/orgs/nuclear-decommissioning-citizens-advisory-panel**

issues and opportunities. One such opportunity includes the requested site-specific autopsies as an integral part of the decommissioning process. The autopsy process itself can add to the decommissioning community's economic benefit as well as the general public safety.

Recommendations

1) Congress, DOE and the NRC need to determine the nuclear industry's fair share of autopsy costs collected through licensing fees for strategic sample harvesting and analysis intended to benefit material performance and safety margins of operating reactors seeking license extensions and;

2) NRC and the national laboratories define the autopsy's stated goal as providing "*reasonable assurance that systems, structures, and components (SSCs) are able to meet their safety functions"* for the relicensing period. The NRC approval process for Subsequent License Renewal extensions should therefore be held in abeyance pending completion of strategic harvesting of actual aged materials and conclusive analysis as being requested by the agency and national laboratories and;

3) Civil society can play a more active role in the independent oversight and public transparency of the autopsy at decommissioning reactor sites through state authorized nuclear decommissioning citizen advisory panels as legislated in Vermont, Massachusetts and elsewhere.

An Addendum provided by David Lochbaum, Union of Concerned Scientists, The "Path Forward" without performing post-shutdown reactor autopsies

Researchers, such as those working within DOE's Light Water Reactor Sustainability Program,[41] seek to predict the future aging performance of materials by analyzing the past. But researching how factors like radiation exposure, heat-up and cool-down stresses, and cyclic fatigue (i.e., metal weakening as it bends back and forth) affect materials is complicated by time and variables. Researchers would prefer to know how exposure to radiation for 60 years affects components without waiting six decades for

[41] https://lwrs.inl.gov/SitePages/Home.aspx

the answers. So, they expose materials to “accelerated aging” involving significantly higher radiation levels and more frequent heat-up and cool-down cycles to essentially fast-forward through six decades of time. Researchers compare the results from their time-compression studies with results from tests on materials actually aged for various time periods to calibrate their analytical models.

Material variabilities complicate aging research in that all materials are not the same. Metal parts have different concentrations of nickel and copper and are manufactured via different techniques that affect their properties and performance. Sometimes the property differences are of the “six of one, half dozen of the other” nature having no discernible effect on degradation rates. Other times, the property differences cause pronounced degradation rate changes.

Predicting aging effects is like a connect-the-dots drawing. Insights from materials harvested during reactor decommissioning provide many additional dots to the dots provided from accelerated aging studies. As the number of dots increases, the clearer the true picture can be seen. The fewer the dots, the harder it is to see the true picture.