To: Members of the Nuclear Decommissioning Citizens Advisory Panel

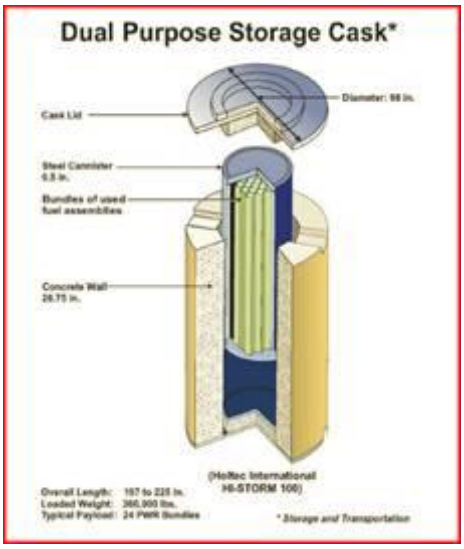
From: James and Mary Lampert

Re: Pilgrim's Spent Fuel Dry Cask Storage Issues

Date: November 15, 2017

Pilgrim's Dry Cask Storage
Spent Fuel Dry Casks

Casks: Entergy is using Holtec Hi-Storm 100, Version B, MPC-68 casks to eventually hold and store 61 dry casks filled with highly radioactive spent fuel assemblies. The cask system is comprised of three primary components: MPC-68, HI-TRAC 100 D, and HI-STORM 100S. The MPC-68 is a metal canister that has a storage capacity of 68 BWR spent fuel assemblies. The HI-TRAC (transfer cask) is a metal transfer cask that provides a means to lift and handle the canister as well as providing radiological shielding of the spent fuel assemblies. The HI-STORM 100-S Version B storage overpack is a steel-encased concrete storage cask that provides physical protection and radiological shielding for the metal canister when in storage. The storage cask is vented for natural convection to dissipate the spent fuel decay heat. The casks are stored in a vertical position outdoors on a storage pad.[11]



Each loaded cask inside the pool weighs **40 tons**, the equivalent of about 7 adult male African elephants. The casks will be placed on a concrete storage pad 52' X 238.5' located about 100 yards from the shore at 25 MSL. Each cask, with its overpack, weighs about 200 tons when placed on the outside pad. The pad is not enclosed or covered in any way.

Pilgrim loaded three dry casks in 2014, and five more in 2016. Each contains 68 spent fuel assemblies.

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[11] Entergy Letter No. 2.13.042, pg., 3 (NRC Electronic Library, ADAMS, Accession Number ML13346A026)

To hold all of the spent fuel that Pilgrim will produce by the time it ceases operations in 2019, a total of about 60 dry casks will be needed. The casks will be onsite for a long-time according to the NRC, perhaps 300 years or more

Transfer of Spent Fuel From Pool To Dry Casks

The following links show the transfer process. Although Pilgrim uses a different cask and stores the casks vertically on the pad, the process is essentially the same as shown on the videos:

- http://www.youtube.com/watch?v=9eFxP0VFdt0_ - NUHOMS Used Nuclear Fuel Loading
- http://www.youtube.com/watch?v=mILvWNgggfU&feature=player_embedded
- http://www.muzikkitabi.com/Video/VIDEOIDrh6FeQWuhCs/Dry-Cask-Storage-For-Spent-Fuel-At-Nuclear-Energy-Plants

Pilgrim's Preparation for Transfer: Pilgrim applied to the NRC for a license amendment in order to begin the transfer process.[12] Prior to transfer, the pool was licensed only for transferring assemblies that themselves weigh about 2,000 lbs; but a loaded cask even when in the pool weighs 40 tons. Pilgrim's license required an energy absorbing pad in the floor of the pool to protect it from a drop. Entergy removed the pad prior to asking for a license amendment. The application justified Pilgrim's readiness for the transfer operation by installing the various changes: upgrading the crane to single failure proof; removing the energy absorbing pad, after the fact; and installing a leveling platform.

Safety Issues Transfer:[13] Entergy remained operating during both a dry run exercise and two actual transfers to dry cask storage. In future cask transfers, Pilgrim will remain operating. NRC's Ray McKinley in response to a question from Pilgrim Watch said:

> The Certificate of Compliance for the spent fuel storage cask requires a dry run training exercise of the activities associated with dry cask loading prior to the first use of the system to load spent fuel assemblies. Pilgrim's dry run is being conducted in four phases which are being observed by the NRC A specially designed simulated MPC will be utilized that approximates the 40 ton weight of an MPC loaded with fuel. The plant will not be shut down during the dry cask loading activities. It is not necessary. The safety features of the crane and the designated heavy loads path in the reactor building protect plant systems

Pilgrim should not operate during transfer: NRC allows Pilgrim to operate during the transfer process because the transfer crane was upgraded to single-failure proof that reduces, but that does not eliminate a possible drop. We believe operations should cease during transfer because although the probability of a drop may be small, the consequences are too great. Accidents can and do happen, even with single-proof cranes, For example at Vermont Yankee (May 2008) the brakes on the crane didn't function properly and it almost dropped a load of high-level radioactive waste during the first removal of spent fuel assemblies from the spent fuel pool into a cask for dry cask storage outside of the plant. According to reports at the time, the brakes on the crane did not respond properly because its electrical relays were

[12] Docket ID NRC-2014-0202, 56608 Federal Register / Vol. 79, No. 183 / Monday, September 22, 2014 / Notices
[13] Email correspondence Raymond McKinley Chief, Division of Reactor Projects Branch 5 U.S. NRC Region and Mary Lampert, Pilgrim Watch/Duxbury Nuclear Advisory Committee-available on request.

"out of adjustment." The cask came to within 1½ inches of the floor, although the operator wanted it to stop four inches above the floor. Another mishap or near-miss with a single-proof crane occurred at Palisades.

Canister Drop in the pool: If a cask is dropped in the pool and the pool floor is breached, there are many safety-related components located on the floors below the spent fuel pool which could be disabled that could simultaneously initiate an accident and disable accident mitigation equipment

Canister Drop on the reactor building floor once removed from the pool and lowered to prepare for transfer outside the building to the storage pad: If a cask is dropped on the reactor building floor once it is removed from the pool, a drop could induce relay chatter or the opening and/or closing of relay contacts. This may result in important equipment being rendered inoperable such as valves erroneously opened or closed, pumps shut off, and loss of indications of the status of safety systems.

NRC Guidance: Entergy, however, was not required to analyze the impact of a canister drop inside the pool or, we presume, analyze the impact of a canister drop, once removed from the pool. onto the reactor building floor. NRC licensing guidelines accept the hypothesis that what it calls a highly-reliable handling system eliminates any need for a load drop analyses. Therefore, going forward, Entergy will credit the handling system rather than a load drop analysis as the basis for safe handling of the canisters, both in the spent fuel pool and when lowering the cask onto the transporter.

Pilgrim Watch believes that there are no guarantees. The operators moving the casks are not failure-proof, neither are the operators or designers and workers at factories manufacturing the crane and its accessory structure's parts. There were problems at Entergy's Palisades NPS[14] and Vermont Yankee NPS,[15] both had failure-proof cranes.

Entergy is not required to have an energy absorbing pad at the floor of the pool. Again the rationale is that they have a single-failure proof crane, and also installed a leveling platform.

David Lochbaum, Union of Concerned Scientists, reported that:[16]:

> In December 1987, an operator at the Wolf Creek nuclear plant near Burlington, Kansas, forgot to close a valve in the pipe connecting the spent fuel pool to the refueling water storage tank. The open valve allowed gravity to drain water from the spent fuel pool to the tank.
>
> The control room operators did not notice the spent fuel pool water level dropping steadily during the next two days. The spent fuel pool water level was not routinely recorded. Operators relied on the spent fuel pool low level alarm to warn them. Unfortunately, the level alarm was not functioning properly and no warning was issued when the level dropped below the alarm point.

[14] http://www.nirs.org/reactorwatch/licensing/caskdanglesummaryreport4406.pdf
[15] http://www.timesargus.com/article/20141104/NEWS03/711049924
[16] http://allthingsnuclear.org/dlochbaum/fission-stories-112-if-i-only-had-a-drain-trouble-at-the-wolf-creek-spent-fuel-pool

> The operators also failed to notice the rising level in the refueling water storage tank during these two days. Luckily, at least 22 feet of water remained over the irradiated fuel assemblies in the spent fuel pool despite the lax monitoring by several consecutive shifts of operators.

Our Takeaway: Had the water level dropped another few feet, high radiation fields in and around the fuel handling building could have made it difficult for workers to recover from the situation once it was finally noticed. Radiation alarms would have ultimately clued operators into the spent fuel pool drainage problem; that is, assuming that the radiation alarms would have worked.

It takes only one equipment failure or worker mistake to cause radioactive materials to be released. Such failures and mistakes happen more often than they should.

Preparations for a seismic event: Entergy analyzed the equipment for a seismic event. The analysis is "proprietary".[17] Pilgrim Watch was informed by NRC's Ray McKinley that the seismic analysis was based on previous expectations, and not on the more severe events that we can now expect in the future.[18] We asked NRC if both the bridge and the trolley were fitted with seismic restraints to maintain the crane on the girder and runway rails. No answer to date.

Vertical Cask Transporter (VCT) to move the cask from the reactor building to the pad: The VCT uses foam filled rubber tires. We understand that rubber tires have advantages in seismic situations (rubber tires have elasticity and a lower center of gravity) and foam fill prevents flat-spotting, loss of pressure, blow-outs and prevents damage to travel surface.

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[17] Holtec Proprietary Report Hl-2104715 Rev. 7 "Seismic Analysis of the Loaded H1-TRAG in the SFP and SFP Slab Qualification" (112 Pages) Entergy Response to NRC Request for Additional Information (RAI), Regarding the Heavy Loads License Amendment Request (TAC NO. MF3237) OCT 3, 2014, NRC Adams Library, ML14280A230

[18] The updated seismic data shows that Pilgrim could feel the effects of earthquakes as far away as 400 miles, double the previously estimated distance. Senators Markey and Warren in a letter to NRC Chair Macfarlane,[18] March 31, 2014 noted that, "The new seismic hazard was found to exceed the safe shutdown earthquake at the ground shaking frequencies that are most likely to threaten the equipment needed to safely shut down the reactor." Further, the Senators expressed special concern about Entergy's March 10 request to the NRC asking for permission to alter some of the numbers used to model the geologic properties of the bedrock on which the Pilgrim nuclear plant sits to "prevent unjustified alarm by stakeholders when GMRS [ground motion response spectrum] results are made public."

On May 2014 Entergy completed a seismic walk-down at Pilgrim. The NRC staff assessment of the walk-down concluded that, "… the licensee, through the implementation of the walk-down guidance activities and, in accordance with plant processes and procedures, verified the plant configuration with the current seismic licensing basis; addressed degraded, nonconforming, or unanalyzed seismic conditions; and verified the adequacy of monitoring and maintenance programs for protective features. Furthermore, the NRC staff notes that no immediate safety concerns were identified."[18] But, <u>significantly NRC failed to say that the seismic walk-downs were based on earlier and outdated understanding of seismic risk here.</u>

Dry Cask Storage Issues[19]

Although dry cask storage is far safer than pool storage, there are problems to consider. According to the Nuclear Regulatory Commission (NRC):

- The thin (0.5") stainless steel canisters may crack within 30 years.
- No current technology exists to inspect, repair or replace cracked canisters.
- With limited monitoring, we will only know after the fact that a casks has leaked radiation.

The Nuclear Regulatory Commission's (NRC), Waste Confidence Final Rule 2014 said that spent fuel can be stored at nuclear plants for 60 years (short-term), 100 years (long-term) and thereafter indefinitely[20]. But the NRC currently only certifies dry cask storage systems for 20 years, so we cannot depend on the NRC for assurances that these cask systems will for even the 60 year short term. The NRC, the Electric Power Research Institute (EPRI), and numerous government and scientific sources report the following problems with the current steel/concrete U.S. spent nuclear fuel dry storage systems:

Canisters may need to be replaced within 30 years or sooner - Stress Corrosion Cracking: The thin 1/2" welded stainless steel canisters may have premature stress corrosion cracking within 30 years, caused by our marine environment. [21] This could result in major radiation releases. Cracks in similar materials at nuclear power plants caused component failures in less than 30 years, including at San Onofre [22]. Other cask systems, such as the German CASTOR V/19 (~20" thick) ductile cast iron casks, do not have this problem. [23] The concrete overpacks also have aging issues that are accelerated in coastal environments.

Our Recommendation: The casks will be stored outside on a pad, perhaps indefinitely**.** Because the Holtec system is susceptible to stress corrosion cracking exacerbated by a salt environment, we believe the ISFSI should be moved to higher ground, away from the Bay, and placed inside a building.

No technology to adequately inspect canisters for stress corrosion cracking. There is no technology to inspect even the outside of the stainless-steel canisters for cracks once they are loaded with nuclear waste (spent nuclear fuel) .[24] The NRC is giving the nuclear industry five years to develop a method to inspect the outside of the canisters. And then the NRC only plans to require inspection of one canister at each nuclear plant, after 25 years of service and then subsequently every year. Cask systems, such as the German CASTOR, can be inspected, since they do not need concrete overpacks for gamma ray and neutron protection.

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[19] San Onofre Dry Cask Storage Issues analyses at:
https://sanonofresafety.files.wordpress.com/2011/11/drycaskstorageissues2014-09-23.pdf

[20] U.S Nuclear Regulatory Commission's (NRC) Nuclear Waste Confidence renamed Continued Storage of Spent Nuclear Fuel Generic Environmental Impact Statement (GEIS) and Rule, 79 Fed. Reg. 56,238-56,263 (Sept. 19, 2014) (Effective October 20, 2014). The decision is under appeal by the NY, MA, Vermont AGO and independent groups.

[24] EPRI Extended Storage: Research Perspective, John Kessler, EPRI Used Fuel and High-Level Waste Management
Program, NWTRB Meeting, September 14, 2011 http://www.nwtrb.gov/meetings/2011/sept/kessler.pdf

- VIDEO **NRC Director of Spent Fuel Management, Mark Lombard, admitted to the Commissioners there is no technology to inspect or repair these systems now and only offered promises they would figure it out in the future.**

Our Recommendation: At the least, more robust aging management program sampling multiple casks, with more frequent inspections. Change to a more robust cask system, as a precautionary measure to the likelihood that casks will remain at Pilgrim far longer than now projected by Entergy and NRC.

No remediation plan to repair failed canisters. Technology used for other stainless-steel components cannot be used to repair canisters containing nuclear fuel waste. [25] The NRC stated that if one of the canisters becomes defective (e.g. 75% through-wall stress corrosion cracks), there is no way to repair or replace the canister.

Before a canister can be transported (inside a transport cask), the canister must not have cracks. The NRC is optimistic there will be a solution before it is needed. However, they do not know what that might be.

Our Recommendation: Store spare overpacks onsite to buy time.

No current method to replace failing canisters. The only fuel-handling method currently available to the commercial nuclear generating industry is to bring a cask [or canister] back into a spent fuel pool for reopening. Dr. Kris Singh, CEO, Holtec International said that,

> ...It is not practical to repair a canister if it were damaged... You will have… millions of curies of radioactivity coming out of canister… A canister that develops a microscopic crack (all it takes is a microscopic crack to get the release), to precisely locate it… And then if you try to repair it (remotely by welding) … the problem with that is you create a rough surface which becomes a new site for corrosion down the road. I don't advocate repairing the canister.

VIDEO The President of Holtec, Kris Singh, says it's not feasible to repair thin steel canisters. He states even a microscopic crack will release millions of curies of radiation into the environment.

However, dry handling of the cask and fuel is important to avoid disturbing the properties of the cask, cladding, fuel, and related hardware that would occur if the materials were rewetted and rapidly cooled. However, there is no dry handling facility available in the nation that is large enough to handle these canisters. …and removal of a welded storage cask lid is problematic [26]. There is also no dry handling (hot cell) mobile facility designed for this purpose and one may not even be feasible. [27]

Our Recommendation: Develop and build the equipment that it needed as quickly as possible. We cannot risk thousands of thousands of casks of spent nuclear fuel, spread throughout the United States, with no way to repair or replace them.

Additionally, there are no monitors installed on each cask to measure heat, helium (to provide early warning) and radiation. The NRC's rationale is unconvincing: The canisters to be used at Pilgrim's are welded closed and therefore do not require the use of instrumentation to assure the safe storage of spent fuel. Prior to being placed on the ISFSI pad, the welds are examined and tested to confirm their integrity, and radiation measurements are taken.

In accordance with the CoC for the HOLTEC HI- STORM 100 system, a surveillance of the passive heat removal system (air inlet and outlet vents) is required daily to ensure system operability. This can be achieved by either monitoring the inlet and outlet vent temperatures or performing a visual inspection daily to ensure that the vents are not blocked. Pilgrim has elected to perform daily visual inspections to ensure the air inlet and outlet vents do not become blocked and the passive heat removal system remains operable.

NRC also says that Thermoluminescent dosimeters (TLDs) will be placed around the ISFSI (cask storage pad). Ray McKinley said that, "The NRC intends to inspect Entergy's plans for radiation monitoring of their independent spent fuel storage installation (ISFSI) at Pilgrim during upcoming inspection activities. Typically we have seen licensees at other sites install thermoluminescent type dosimeters at the ISFSI periphery. The frequency that licensees have performed radiological monitoring from dosimeters has varied from quarterly to yearly based on their specific program requirements. The results of radiological monitoring associated with the ISFSI are included in the licensee's REMP report."

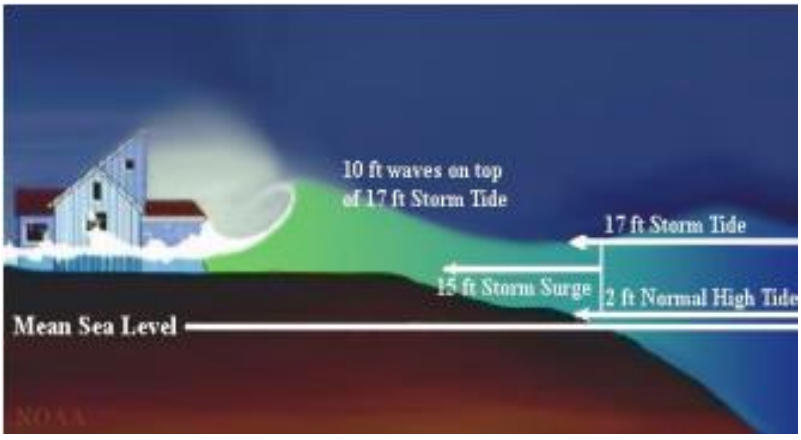
Our Recommendation: The public would be better protected if each cask had heat, helium and radiation monitors, considering that the canisters and concrete outer packs are prone to cracking and, especially in our environment, corrosion. TLDs only provide an average figure, can only read to a maximum threshold, that is, like a film badge they can only read so high, and do not read high or low alpha and beta.

Blocking Air Ventilation Vents: Casks have air holes at bottom and top of casks for ventillation. If the holes are blocked by ice, snow, debris or birds nests cooling will not occur.

Our Recommendation: Provide mitigation to prevent blockage, such as placing casks inside an enclosed building or install an overhead roof, and ensure in the design that there is drainage around each cask.

Vulnerability of Pilgrim's ISFSI to Flooding: Pilgrim's casks are stored on a concrete pad 100 yards from Cape Cod Bay at 25 feet MSL. NRC says that the casks may remain onsite for 300 years; but flooding from sea level rise and storm surges are predicted to increase during the years.

Vulnerability: 15 ft surge on a 2 ft tide + 17ft storm tide + 10 ft waves = 27ft above MSL



Entergy's measurement of water level in the intake canal does not provide useful information about wave height above a storm tide or surge. Why the wave height must be measured is shown in the diagram above.

Casks are vulnerable to attack: Pilgrim's casks will be lined up vertically on a pad, in an arrangement sometimes referred to as "candlepin bowling for terrorists." Casks are vulnerable from an air or land-based attack with weapons readily available today. [28] Yet despite their vulnerability, the NRC commissioners voted to approve a staff proposal submitted on September 11, 2015[29] to postpone the schedule for developing new requirements for protecting spent fuel in dry cask storage from sabotage by five years. There are several good reasons to implement this rule sooner. The most important one is that the current rules do not provide adequate protection of dry casks from certain types of terrorist attack scenarios, as the NRC has acknowledged publicly.

Pilgrim is vulnerable to attack- while operating and after shutdown

The threat against nuclear power plants is real. According to the 9/11 Commission report, the Sept. 11, 2001 terrorists initially considered attacking a nuclear power reactor.[1] According to a new report "Protecting U.S. Nuclear Facilities from Terrorist Attack: Re-assessing the Current 'Design Basis Threat' Approach,"[2] prepared under a contract for the Pentagon by the Nuclear Proliferation Prevention Project (NPPP) at the University of Texas at Austin's LBJ School of Public Affairs, none of the 104 commercial nuclear power reactors in the United States is protected against a maximum credible terrorist attack, such as the one perpetrated on September 11, 2001, nor against airplane attacks, nor even against readily available weapons such as rocket propelled grenades and 50-caliber sniper rifles.

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[28] The Massachusetts Attorney General's Request for a Hearing and Petition for Leave to Intervene With respect to Entergy Nuclear Operations Inc.'s Application for Renewal of the Pilgrim Nuclear Power Plants Operating License and Petition for Backfit Order Requiring New Design features to Protect Against Spent Fuel Pool Accidents, Docket No. 50-293, May 26, 2006 includes a Report to The Massachusetts Attorney General On The Vulnerability of Pilgrim's Spent Fuel Pool - *Risks and Risk-Reducing Options Associated with Pool Storage of Spent Nuclear Fuel at the Pilgrim and Vermont Yankee Nuclear Power Plants,* Gordon Thompson, May 25, 2006; Environmental Impacts of Storing Spent Nuclear Fuel and High-Level Waste from Commercial Nuclear Reactors: A Critique of NRC's Waste Confidence Decision and Environmental Impact Determination, Dr. Gordon Thompson, February 6, 2009, pgs., 29, 47, 50, Tables 7-6, 7-7.

[29] http://allthingsnuclear.org/elyman/ominous-votes-by-the-nrc

[1] http://www.resilience.org/stories/2004-07-25/911-report-reveals-al-qaeda-ringleader-contemplated-ny-area-nuclear-power-plant-p

[2] http://sites.utexas.edu/nppp/files/2013/08/NPPP-working-paper-1-2013-Aug-15.pdf

The following table, prepared by Dr. Gordon Thompson for the Massachusetts Attorney General,[3] summarizes available means of attack. It shows that nuclear power plants are vulnerable.

Mode of Attack	CHARACTERISTICS	PRESENT DEFENSE
Commando-style by land	• Could involve heavy weapons/sophisticated tactics • Attack requiring substantial planning and resources	Alarms, fences, lightly-armed guards, with offsite backup
Commando-style by water	• Could involve heavy weapons/sophisticated tactics • Could target intake canal • Attack may be planned to coordinate with a land attack	500 yard no entry zone – marked by buoys – simply, "no trespassing" signs Periodic Coast Guard surveillance by boat or plane
Land-vehicle bomb	• Readily obtainable • Highly destructive if detonated at target	Vehicle barriers at entry points to Protected Area
Anti-tank missile	• Readily obtainable • Highly destructive at point of impact	None if missile is launched from offsite
Commercial aircraft	• More difficult to obtain than pre-9/11 • Can destroy larger, softer targets	None
Explosive-laden smaller aircraft	• Readily attainable • Can destroy smaller, harder targets	None

Dr. Gordon Thompson also analyzed the impact of a shaped charge as one potential instrument of attack.[30] The analysis shows that the cylindrical wall of the canister is about 1/2 inch (1.3 cm) thick, and could be readily penetrated by available weapons. The spent fuel assemblies inside the canister are composed of long, narrow tubes made of zirconium alloy, inside which uranium oxide fuel pellets are

[3]The Massachusetts Attorney General's Request for a Hearing and Petition for Leave to Intervene With respect to Entergy Nuclear Operations Inc.'s Application for Renewal of the Pilgrim Nuclear Power Plants Operating License and Petition for Backfit Order Requiring New Design features to Protect Against Spent Fuel Pool Accidents, Docket No. 50-293, May 26, 2006 includes a Report to The Massachusetts Attorney General On The Vulnerability of Pilgrim's Spent Fuel Pool - Risks and Risk-Reducing Options Associated with Pool Storage of Spent Nuclear Fuel at the Pilgrim and Vermont Yankee Nuclear Power Plants, Gordon Thompson, May 25, 2006

[30] Gordon R. Thompson, *Environmental Impacts of Storing Spent Nuclear Fuel and High- Level Waste from Commercial Nuclear Reactors: A Critique of NRC's Waste Confidence Decision and Environmental Impact Determination* (Cambridge, Massachusetts: Institute for Resource and Security Studies, 6 February 2009). Tables also in Declaration of 1 August 2013 by Gordon R. Thompson: Comments on the US Nuclear Regulatory Commission's Draft Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a US Mark I Boiling Water Reactor

stacked. The walls of the tubes (the fuel cladding) are about 0.023 inch (0.6 mm) thick. Zirconium is a flammable metal.

Table 7-7: Performance of US Army Shaped Charges, M3 and M2A3

Target Material	Indicator	Type of Shaped Charge	
		M3	M2A3
Reinforced concrete	Maximum wall thickness that can be perforated	60 in	36 in
	Depth of penetration in thick walls	60 in	30 in
	Diameter of hole	• 5 in at entrance • 2 in minimum	• 3.5 in at entrance • 2 in minimum
	Depth of hole with second charge placed over first hole	84 in	45 in
Armor plate	Perforation	At least 20 in	12 in
	Average diameter of hole	2.5 in	1.5 in

Notes: (a) Data are from: Army, 1967, pp 13-15 and page 100. (b) The M2A3 charge has a mass of 12 lb, a maximum diameter of 7 in, and a total length of 15 in including the standoff ring. (c) The M3 charge has a mass of 30 lb, a maximum diameter of 9 in, a charge length of 15.5 in, and a standoff pedestal 15 in long.

Table 7-8: Types of Atmospheric Release from a Spent-Fuel-Storage Module at an ISFSI as a Result of a Potential Attack

Type of Event	Module Behavior	Relevant Instruments and Modes of Attack	Characteristics of Atmospheric Release
Type I: Vaporization	• Entire module is vaporized	• Module is within the fireball of a nuclear-weapon explosion	• Radioactive content of module is lofted into the atmosphere and amplifies fallout from nuc. explosion

Type II: Rupture and Dispersal (Large)	• MPC and overpack are broken open • Fuel is dislodged from MPC and broken apart • Some ignition of zircaloy fuel cladding may occur, without sustained combustion	• Aerial bombing • Artillery, rockets, etc. • Effects of blast etc. outside the fireball of a nuclear weapon explosion	• Solid pieces of various sizes are scattered in vicinity • Gases and small particles form an aerial plume that travels downwind • Some release of volatile species (esp. cesium-137) if incendiary effects occur
Type III: Rupture and Dispersal (Small)	• MPC and overpack are ruptured but retain basic shape • Fuel is damaged but most rods retain basic shape • No combustion inside MPC	• Vehicle bomb • Impact by commercial aircraft • Perforation by shaped charge	• Scattering and plume formation as for Type II event, but involving smaller amounts of material • Little release of volatile species
Type IV: Rupture and Combustion	• MPC is ruptured, allowing air ingress and egress • Zircaloy fuel cladding is ignited and combustion propagates within the MPC	• Missiles with tandem warheads • Close-up use of shaped charges and incendiary devices • Thermic lance • Removal of overpack lid	• Scattering and plume formation as for Type III event • Substantial release of volatile species, exceeding amounts for Type II release

One scenario for an atmospheric release from a dry cask would involve mechanically creating a comparatively small hole in the canister. This could be the result, for example, of the air blast produced by a nearby explosion, or by the impact of an aircraft or missile. If the force was sufficient to puncture the canister, it would also shake the spent fuel assemblies and damage their cladding. A hole with an equivalent diameter of 2.3 mm, radioactive gases and particles released would result in an inhalation dose (CEDE) of 6.3 rem to a person 900 m downwind from the release. Most of that dose would be attributable to release of two-millionths (1.9E-06) of the MPC's inventory of radioisotopes in the "fines" category.

Another scenario for an atmospheric release would involve the creation of one or more holes in a canister, with a size and position that allows ingress and egress of air. In addition, the scenario would involve the ignition of incendiary material inside the canister, causing ignition and sustained burning of the zirconium alloy cladding of the spent fuel. Heat produced by burning of the cladding would release volatile radioactive material to the atmosphere. Heat from combustion of cladding would be ample to raise the temperature of adjacent fuel pellets to well above the boiling point of cesium.

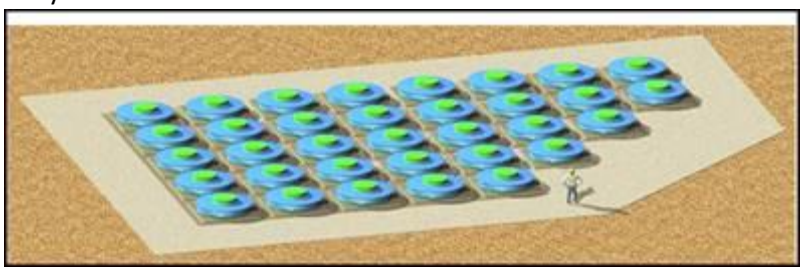
Potential for Release from a Cask and Consequences: Dr. Thompson observes that**:** Casks are not robust in terms of its ability to withstand penetration by weapons available to sub-national groups. A typical

cask would contain 1.3 MCi of cesium-137, about half the total amount of cesium-137 released during the Chernobyl reactor accident of 1986. Most of the offsite radiation exposure from the Chernobyl accident was due to cesium-137. Thus, a fire inside an ISFSI module, as described in the preceding paragraph, could cause significant radiological harm.

Options to reduce risk: Use thick-walled metal casks, dispersal of the casks, and protection of the casks by berms or bunkers in a configuration such that pooling of aircraft fuel would not occur in the event of an aircraft impact.

Holtec has developed a design for a new ISFSI storage module that is said to be more robust against attack than present modules. The new module is the HI-STORM 100U module, which would employ the same canister used in the present Holtec modules. For most of its height, the 100U module would be underground. Holtec has described the robustness of the 100U module as follows[31]:

> "Release of radioactivity from the HI-STORM 100U by any mechanical means (crashing aircraft, missile, etc.) is virtually impossible. The only access path into the cavity for a missile is vertically downward, which is guarded by an arched, concrete-fortified steel lid weighing in excess of 10 tons. The lid design, at present configured to easily thwart a crashing aircraft, can be further buttressed to withstand more severe battlefield weapons, if required in the future for homeland security considerations. The lid is engineered to be conveniently replaceable by a later model, if the potency of threat is deemed to escalate to levels that are considered non-credible today."



http://www.holtecinternational.com/productsandservices/wasteandfuelmanagement/hi-storm/hi-storm-100u/

Liability – Who is responsible if there is a problem - Entergy or Holtec? Casks will remain onsite for decades. Is Holtec just another company, arranged like Entergy, with multi-tiered limited liability companies none of which have the assets to deal with any significant problem? We understand the warranty at SanOnofre, for example, says that Holtec can transfer the warranty to another company at any time. What does Pilgrim's cask warranty say?

National Academies: Congress asked the National Academies to analyze the safety and security of commercial spent nuclear storage in the United States.[32] The report listed additional steps to be taken to make dry casks less vulnerable to reduce the liklihood of releases of radioactive material from dry casks in the event of a terrorist attack. The recommendations included:

[31] Holtec International, "The HI-STORM 100 Storage System.," accessed on 17 June 2007.

[32] Safety and Security of Commercial Spent Nuclear Fuel Storage, Public Report, National Academies of Sciences, April 2005, http://www.nap.edu/books/0309096472/html/

- Additional surveillance could be added to dry cask storage facilities to detect and thwart ground attacks.
- Certain types of cask systems could be protected against aircraft strikes by partial earthen berms. Such berms also would deflect the blasts from vehicle bombs.
- Visual barriers could be placed around storage pads to prevent targeting of individual casks by aircraft or standoff weapons. These would have to be designed so that they would not trap jet fuel in the event of an aircraft attack.
- The spacing of vertical casks on the storage pads can be changed, or spacers (shims) can be placed between the casks, to reduce the likelihood of cask-to-cask interactions in the event of an aircraft attack.
- Relatively minor changes in the design of newly manufactured casks could be made to improve their resistance to certain types of attack scenarios."(Report, pg., 68)

High Burnup Spent Nuclear Fuel - Problems[33]

Pilgrim, like other operating reactors, in recent years is using high burnup fuel. Robert Alvarez (https://www.ips-dc.org/ips-authors/robert-alvarez/) explains the problems in doing so. He said that:

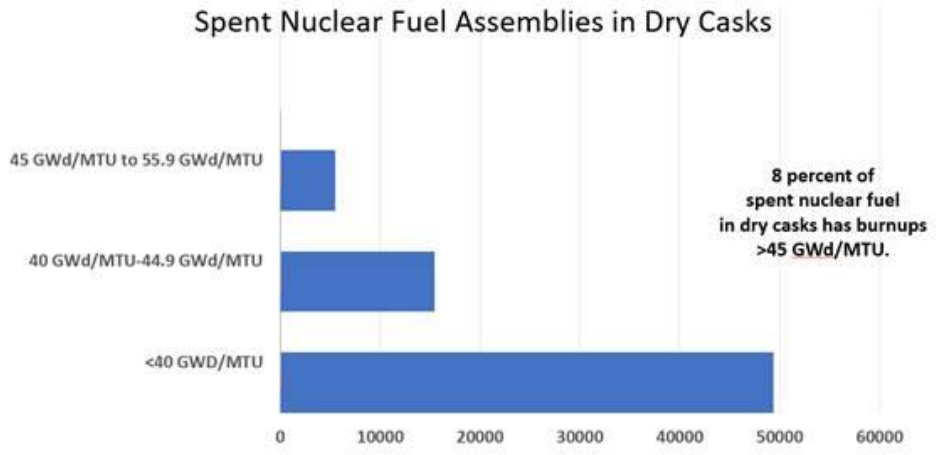
> US commercial nuclear power plants use uranium fuel that has had the percentage of its key fissionable isotope—uranium 235—increased, or enriched, from what is found in most natural uranium ore deposits. In the early decades of commercial operation, the level of enrichment allowed US nuclear power plants to operate for approximately 12 months between refueling. In recent years, however, US utilities have begun using what is called high-burnup fuel. This fuel generally contains a higher percentage of uranium 235, allowing reactor operators to effectively double the amount of time the fuel can be used, reducing the frequency of costly refueling outages.
>
> Research shows that under high-burnup conditions, cladding that of the fuel rods may not be relied upon as a key barrier to prevent the escape of radioactivity, especially during prolonged storage in the "dry casks" that are the preferred method of temporary storage for spent fuel.
>
> High-burnup waste reduces the fuel cladding thickness and a hydrogen-based rust forms on the zirconium metal used for the cladding, which can cause the cladding to become brittle and fail. In addition, under high-burnup conditions, increased pressure between the uranium fuel pellets in a fuel assembly and the inner wall of the cladding that encloses them causes the cladding to thin and elongate. And the same research has shown that high burnup fuel temperatures make the used fuel more vulnerable to damage from handling and transport; cladding can fail when used fuel assemblies are removed from cooling pools, when they are vacuum dried, and when they are placed in storage canisters.

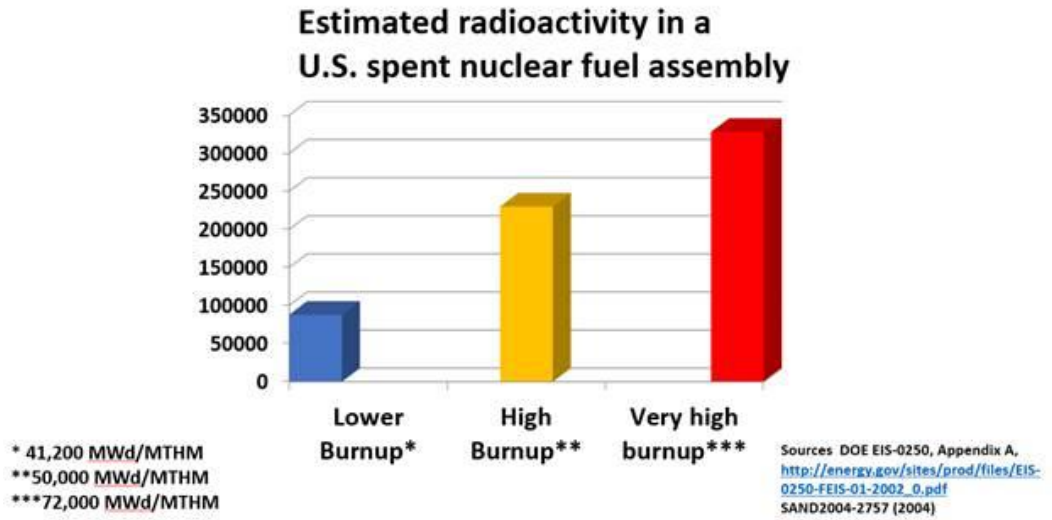
High burnup spent nuclear fuel is proving to be an impediment to the safe storage and disposal of spent nuclear fuel. For more than a decade, evidence of the negative impacts on fuel cladding and

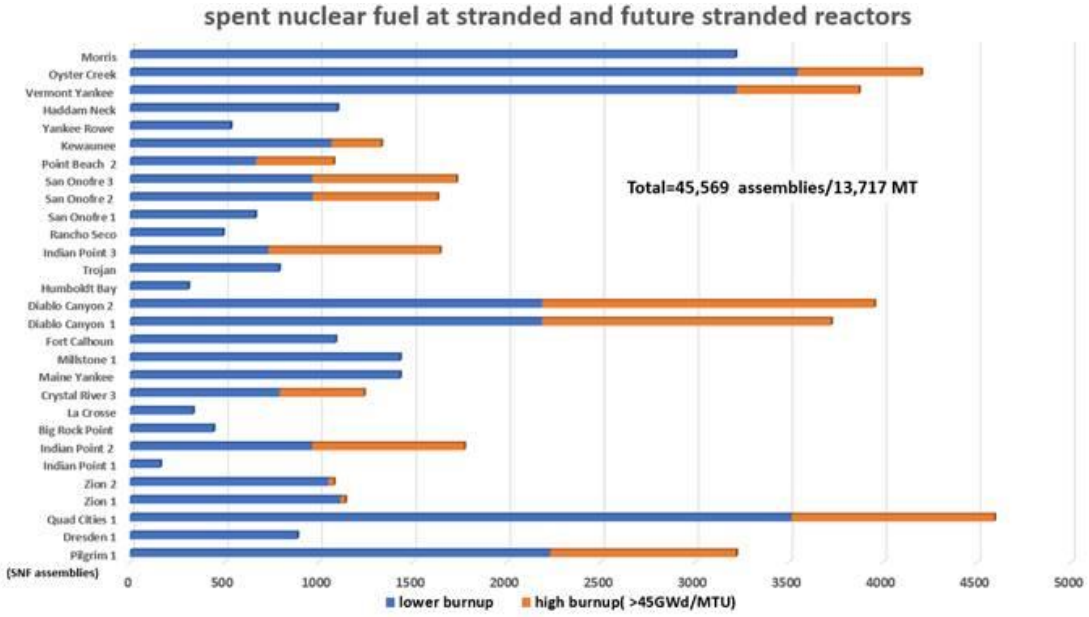
[33] Spent Power Reactor Fuel: Pre-Disposal Issues, Robert Alvarez, Institute for policy Studies, March 3, 2017 at http://www.lasg.org/waste/Alvarez_SNF_closed_reactors_rev3_3Mar2017.pdf

pellets from high burnup has increased, while resolution of these problems remains elusive. For instance, the NRC admits:

- "There is limited data to show that the cladding of spent fuel with burnups greater than 45,000 MWd/MTU will remain undamaged during the licensing period." There is little to no data to support dry storage and transport for spent fuel with burnups greater than 35 gigawatt days per metric ton of uranium.
- "The technical basis for the spent fuel currently being discharged (high utilization, burnup fuels) is not well established,"
- "Insufficient information is available yet on high- burnup fuels to allow reliable predictions of degradation processes during extended dry storage."
- "What can go wrong? For example, what degradation of [high burn-up fuel] cladding might occur, leading to an unsafe condition (e.g. high burn-up fuel] cladding rupture and release of radioactive material)?
- "Experimental data over the last twenty years suggest that fuel utilizations as low as 30,000 MWd/t can present performance issues including cladding embrittlement under accident conditions as well as normal operations.




Estimated radioactivity in a
U.S. spent nuclear fuel assembly
350000
300000
250000
200000
150000
100000
50000
0
Lower Burnup*
High Burnup**
Very high burnup***
* 41,200 MWd/MTHM
**50,000 MWd/MTHM
***72,000 MWd/MTHM
Sources DOE EIS-0250, Appendix A,
http://energy.gov/sites/prod/files/EIS-0250-FEIS-01-2002_0.pdf
SAND2004-2757 (2004)


spent nuclear fuel at stranded and future stranded reactors
Morris
Oyster Creek
Vermont Yankee
Haddam Neck
Yankee Rowe
Kewaunee
Point Beach 2
San Onofre 3
San Onofre 2
San Onofre 1
Rancho Seco
Indian Point 3
Trojan
Humboldt Bay
Diablo Canyon 2
Diablo Canyon 1
Fort Calhoun
Millstone 1
Maine Yankee
Crystal River 3
La Crosse
Big Rock Point
Indian Point 2
Indian Point 1
Zion 2
Zion 1
Quad Cities 1
Dresden 1
Pilgrim 1
(SNF assemblies)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Total=45,569 assemblies/13,717 MT
lower burnup
high burnup(>45GWd/MTU)

Spent Fuel Offsite Storage

America's Hometown, Plymouth - Home for Pilgrim's Spent Fuel for decades

Spent Fuel or so-called High-Level Waste

The long term goal is to move spent fuel to a permanet repository - a storage facility located deep underground and designed for long-term safe disposal so that it will be isolated from the environment for the tens of thousands of years that it will remain toxic. The potential interim goal is consent based consolidated storage.

There is no perfect answer to storing nuclear waste that will be lethal for over 250,000 years - longer than humans have been on this earth. But should efforts to find the perfect solution stand in the way of the good? Pilgrim Watch believes that storing waste in 70 or so separate locations around the country is a bad plan. Reactors are located adjacent to bodies of water, needed to provide cooling to disipate excess heat- exactly the wrong places to store nuclear waste. Reactors are close to often densely populated areas. Reactor sites are tempting terrorst targets.[34]

Nuclear Waste Policy Act: In 1982, the United States Congress passed the Nuclear Waste Policy Act (NWPA), which made the U.S. Department of Energy (DOE) responsible for siting, building, and operating an underground storage facility for nuclear waste, and for taking ownership of the waste on site until it leaves the reactor site and transporting it away from reactors.

The NWPA created a Nuclear Waste Fund to pay for the repository by charging reactor operators a fee on the waste they produced. In 2008, DOE submitted its repository license application for Yucca Mountain but shortly thereafter, in 2010, it shut the Yucca Mountain repository project and dismantled the department's Office of Civilian Radioactive Waste Management. Since then, the federal government has not implemented the used fuel management program established by Congress in the Nuclear Waste Policy Act.

[34] *Containment*, a recent film that we recommend, looks at the problems of storage of nuclear wastes. It is available at http://www.pbs.org/independentlens/films/containment/

More than $11 billion from the Nuclear Waste Fund had been spent on the program. The fund, established by the NWPA to support the nuclear waste management program, collected (with interest) more than $35 billion dollars from electricity customers. They continued to foot the bill for the program at approximately $750 million annually until 2014, when the U.S. Court of Appeals for the D.C. Circuit ruled that DOE could not continue collection because of its 2010 termination of the Yucca Mountain repository program. The court's decision prohibits future collection of the fee until DOE complies with the Nuclear Waste Policy Act or Congress enacts an alternative used fuel management plan.

Yucca Mountain[35]

For several years, the DOE studied a number of locations to determine their suitability, until the Congress amended the NWPA in 1987 directing the DOE to study only Yucca Mountain, located about 80 miles northwest of Las Vegas, Nevada. Years of legal challenges and scientific studies followed.

In 2006 during the George W. Bush administration, the DOE recommended that Yucca should open and begin accepting fuel by 2017. However, opposition continued, and in 2008, presidential candidate Barack Obama promised to abandon the project. After his election, the DOE filed a 2010 motion with the NRC to withdraw its Yucca Mountain license application. It found it technically unsuitable to isolate high-level nuclear waste due to hydrology, earthquakes, and volcanoes to name a few reasons. A number of lawsuits have been filed in response to the DOE's action.

An August 2013 ruling by the U.S. Court of Appeals for the District of Columbia ordered NRC to use available funds and resume work on its safety review of DOE's application and either approve or reject it. President Trump and the new Republican Congress are in favor of funding and moving forward on Yucca. The Trump administration dedicated $120 million of its budget to Yucca. The State of Nevada opposes and promised to mount countless legal challenges.

On August 8, 2017, the NRC voted 2-1 to proceed with the information-gathering stage of approving a license for the contentious nuclear waste storage site at Yucca Mountain in Nevada. But even if Yucca is approved by the NRC, Congress has not appropriated of the needed funds, and may well not do so. Moreover, Yucca could not hold the nation's current and future waste. Yucca has a statutory limit of 77,000 metric tons. Current U.S. commercial reactors already have produced that amount. A second

[35] See State of Nevada Agency for Nuclear Projects http://www.state.nv.us/nucwaste/; and http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/yucca-license-review.html)

geologic repository will be required – reactors are getting relicensed and licenses for new plant construction will increase the total further.[36]

Lawsuits: Because of the federal government's failure to meet its legal obligation under the NWPA, several reactor owners, including Entergy, have successfully sued the federal government for breaching its contracts with the companies by failing to open a facility that could accept fuel by 1998 in exchange for collecting fees for the Nuclear Waste Fund. Because of these lawsuits, the federal government has paid hundreds of millions of dollars in damages to the utilities for costs associated with storing waste at their sites long after the government was supposed to take title to it and ship it off site.

Blue Ribbon Commission: In 2010, the Obama Administration established the Blue Ribbon Commission on America's Nuclear Future (BRC) "to conduct a review of policies for managing radioactive wastes that included all alternatives for the storage, processing, and disposal of civilian and defense used nuclear fuel, high-level waste, and materials derived from nuclear activities." The Commission's final report in 2012 recommended a "consent-based" approach to siting future nuclear waste storage and disposal facilities, the creation of a new agency to manage nuclear waste, and immediate work to begin development of at least one geologic repository and one consolidated storage site. Congress has tried periodically to address the BRC's recommendations, but so far without success.

DOE Consent Based Siting Iniative: In 2016, DOE held eight public hearings to gain the public's perspective on consent based siting so as to be able to design a consent based process. (See http://www.energy.gov/ne/consent-based-siting)

Consolidated or Interim Storage

In addition to pushing to reopen the Yucca Mountain site, members of Congress with closed reactors in their states are seeking to establish a consolidated interim storage site. Energy Department-sponsored research indicates that it may take about 15 years after a license application is filed with the NRC before an interim storage site is opened at an expense of $22.3 billion. During this time, it's likely that more reactors will be shuttered.

Waste Control Specialists (WCS), is seeking to expand its existing radioactive and hazardous waste disposal site in Andrews County, west Texas, to include storage of high-level radioactive waste from nuclear power plants across the country. If approved, 40,000 tons of irradiated fuel rods from nuclear reactors around the country could be routinely transported through major cities and farmlands.

In 2016, WCS and submitted their license application, but during the scoping and licensing process in April 2017, it requested to suspend review of the application due to "limited financial resources." WCS has decided to wait until the company itself is bought out by EnergySolutions, another nuclear waste disposal company based in Utah, but operating at many nuclear processing, disposal, and decommissioning sites in the US and internationally. The US Department of Justice opposed the sale because if the two merged, they would monopolize the nuclear waste disposal industry in most of the US.

[36] Per F. Peterson, Will the United States Need a Second Geologic Repository? https://www.nae.edu/Publications/Bridge/RadioactiveWasteDisposal/WilltheUnitedStatesNeedaSecondGeologicRepository.aspx

Meanwhile, Areva (backed by the French government), one of WCS's original partners, pulled out and its subsidiary, TN Americas (a cask-maker), replaced it as a partner, with apparently less financial backing. NAC International, another cask-maker, is also a partner.

The other proposed consolidated storage site is in southeast New Mexico. Holtec, partnering with the Eddy Lea Energy Alliance (ELEA), applied to the Nuclear Regulatory Commission in March 2017 to store 120,000 tons of irradiated nuclear power fuel.

The proposals face some public opposition and uncertain legal procedures, But, there is support on Capitol Hill. Led by Rep. John Shimkus (R-IL),the Energy and Commerce Committee has passed **HR3053** to amend the **Nuclear Waste Policy Act (NWPA)**.

Roadblocks to Consolidated Storage: Critics say transporting highly radioactive material through densely populated areas will pose risks to residents of Texas and nearby New Mexico, and other regions of the country. Spent nuclear fuel from power plants could be vulnerable in transit to accidents or attacks, exposing people and land to long-term radioactive poisoning, opponents of the Texas and New Mexico projects say. Public interest groups have a national campaign to "Stop Fukushima Freeways" (http://www.nirs.org/) to oppose consolidated sites.

Other challenges for the Texas waste facility or any other consolidated site are legal and Congressional hurdles. For the project to go forward, the Department of Energy would have to assume the title to – and liability for – the spent nuclear fuel stored at the site, but it is unclear whether the DOE can take such action on its own or needs Congressional approval. Legislation introduced last September by Rep. Mike Conaway, R-Texas, of Andrews, and another bill proposed in March by Rep. Mick Mulvaney, R-S.C., would authorize the Department of Energy to enter into fuel storage contracts with private entities that have received a Nuclear Regulatory Commission license. But neither proposall has made it past the initial introductory step.

Prospects: It will likely take decades before either a repository or interim consolidated storage site is sited and constructed. In the meantime, nuclear waste will continue to accumulate at reactor site. Implciations for decommissioning: Until there is the opportunity to ship the spent fuel offsite, Pilgrim cannot decommission and release the entire site. Costs will continue to mount.

Reprocessing- Why it is Not the Answer to Our Spent Fuel Waste Problem

The Yucca Mountain nuclear waste repository may never happen; and Consolidated Storage is not a sure thing by any means. Now we are back to square one on the question: What are we going to do with all the radioactive waste accumulating at U.S. nuclear power reactors? Some are suggesting that we go back to re-processing - a process that takes spent nuclear fuel and dissolves it to separate the uranium and plutonium from the highly radioactive fission products. The plutonium and uranium are then recycled to make new reactor fuel, thereby reducing the amount of fresh uranium required by about 20% but also increasing the supply of weapons grade pluntonium.

Pilgrim Watch does not support reprocessing because it does not solve the waste problem; rather it exacerbates it by creating numerous additional waste streams that have to be managed. It is expensive, polluting and increases nuclear weapons proliferation threats.

Expensive: Based on French and Japanese experience, the cost of producing this recycled fuel produced in reprocessing is several times that of producing fresh uranium reactor fuel. In the past, about half of France's reprocessing capacity was used to process spent fuel from foreign reactors. Because of the high cost, however, virtually all of those foreign customers have decided to follow the U.S. example and simply store their used reactor fuel.

The French reprocessing company AREVA claims that its method reduces the volume and longevity of the radioactive waste produced by nuclear power reactors. But when you take into account the additional radioactive waste streams created by reprocessing and plutonium recycling, the volume of the long-lived radioactive waste is not reduced. And most of the recycled plutonium is neither destroyed nor reused. Its makeup makes it difficult to use in existing reactors, so AREVA simply stores most of it at the reprocessing plant. Reprocessing as practiced in France amounts to an expensive way to shift France's radioactive waste problem from its reactor sites to the reprocessing plant.

Dangerous: Security: Reprocessing is enormously dangerous. The amount of radioactivity in the liquid waste stored at France's reprocessing plant is more than 100 times that released by the Chernobyl accident. That is why France's government set up antiaircraft missile batteries around its reprocessing plant after the 9/11 attacks. Leaks: It is also dangerous due to leaks. The biggest experiment in reprocessing was at Sellafield in Britain. In 2005, after decades of contamination and leaks into the ocean, air, and land around the reprocessing plant, Sellafield was shut down because a bigger-than-usual leak of fuel dissolved in nitric acid —some tens of thousands of gallons — was discovered. It contained enough plutonium to make about 20 nuclear bombs. Radioactive leaks are documented around Areva's reprocessing facilties in France. Nuclear Proliferation: Even more dangerous, however, is the fact that reprocessing provides access to plutonium, a nuclear weapon material. That is why the U.S. turned against it after 1974, the year India used the first plutonium separated with U.S.-provided reprocessing for a nuclear explosion. President Gerald Ford and Henry Kissinger, his secretary of State, managed to intervene before France and Germany sold reprocessing plants to South Korea, Pakistan and Brazil, all of which had secret weapons programs at the time. Japan is the only non-nuclear weapon state that still does today. If the U.S. began to reprocess again, that would legitimize another route to the bomb for nuclear weapon wannabes.

Bob Alvarez, former Department of Energy official and national expert on nuclear issues, summarized in an article he wrote in the Bulletin of Atomic Scientists:

> "Reprocessing plants release about 15,000 times more radioactivity into the environment than nuclear power plants and generate wastes with high decay heat. Other efforts to build what is called a "closed fuel cycle," where waste is recycled and reused in reactors have failed for 50 years. Such failure has left about 250 tons of excess plutonium stored at reprocessing plants around the world--enough for some 30,000 nuclear weapons. It's time to accept that a once-through nuclear fuel cycle, where spent fuel is put into permanent geologic storage, is the only sensible option." - Bulletin of Atomic Scientists, Bob Alvarez, Advice for the Blue Ribbon Commission, March 24, 2010.

Solution: The real solution is to reduce the vulnerability and consequences of a spent fuel pool fire is by thinning the spent fuel pools; moving the spent fuel to hardened dry cask storage; and vigorously looking for a scientifically sound deep geological repository or repositories based on consent-based siting.

Financing Spent Fuel Storage

Entergy said that it then planned partially to "fund the expenditures for license termination and spent fuel management … from proceeds from spent fuel litigation against the Department of Entergy (DOE)." (Pilgrim 2008 Cost Analysis, 1). However, Entergy has not made, and cannot be expected to make, a binding commitment to do so. **The Vermont Attorney General has been very clear that there is no Entergy guarantee that any federal reimbursements would be used for decommissioning.** Beyond that, it is impossible to guess when and how much Entergy might eventually receive as the result of any future litigation, or that any amounts that Entergy receives will be sufficient.

DOE litigation can only reimburse Entergy for what it has already spent. Unless Entergy has first have found other funds, and paid for, "spent fuel management," there will be no "proceeds from spent fuel litigation." Then what?

Spent Fuel - Selected Resources

- Pushing the storage horse with a nuclear waste cart: the spent fuel pool problem, Robert Alvarez, Bulletin of Atomic Scientists, August 2017 (http://thebulletin.org/pushing-storage-horse-nuclear-waste-cart-spent-fuel-pool-problem11002)
- Massachusetts Attorney General Request for Hearing ML061640065 (May 26, 2006);Improvingspent fuel Storage at Nuclear Reactors, Robert Alvarez, Institute Policy Studies, Spent fuel Storage at Nuclear Reactors http://www.ips-dc.org/reports/improving_spent-fuel_storage_at_nuclear_reactors
- DOE Consent Based Siting http://www.energy.gov/ne/consent-based-siting
- Blue Ribbon Commission on America's Nuclear Future in 2010 http://cybercemetery.unt.edu/archive/brc/20120620211605/http:/brc.gov//
- GAO Report (GAO-12-797) Spent Nuclear Fuel Accumulating Quantiies At Commercial Nuclear Reactors Present Storage And Other Challenges, August 2012 http://www.gao.gov/assets/600/593745.pdf
- San Onofre Safety http://sanonofresafety.org/
- EA-12-051 Adjudication Proceeding http://adams.nrc.gov/ehd/ All Power reactors EA-12-050 & EA-12-051

Reprocessing

- **Union of Concerned Scientists**: http://www.ucsusa.org/nuclear_power/nuclear_power_risk/nuclear_proliferation_and_terrorism/nuclear-reprocessing.html
- **Institute of Energy Environment Research** http://ieer.org/?s=reprocessing
- **Institute of Policy Studies**: http://www.ips-dc.org/articles/reprocessing_spent_nuclear_fuel_too_risky