On Path to Success

January 9, 2013

David Lochbaum
Director, Nuclear Safety Project
Union of Concerned Scientists
www.ucsusa.org

First Step – July 12, 2011

RECOMMENDATIONS FOR ENHANCING REACTOR SAFETY IN THE 21ST CENTURY

Enhancing Mitigation

4. The Task Force recommends that the NRC strengthen station blackout mitigation capability at all operating and new reactors for design-basis and beyond-design-basis external events. (Section 4.2.1)

5. The Task Force recommends requiring reliable hardened vent designs in boiling water reactor facilities with Mark I and Mark II containments. (Section 4.2.2)

6. The Task Force recommends, as part of the longer term review, that the NRC identify insights about hydrogen control and mitigation inside containment or in other buildings as additional information is revealed through further study of the Fukushima Dai-ichi accident. (Section 4.2.3)

7. The Task Force recommends enhancing spent fuel pool makeup capability and instrumentation for the spent fuel pool. (Section 4.2.4)

8. The Task Force recommends strengthening and integrating onsite emergency response capabilities such as emergency operating procedures, severe accident management guidelines, and extensive damage mitigation guidelines . (Section 4.2.5)

Second Step

October 3, 2011 SECY-11-0137

FOR: The Commissioners

FROM: R. W. Borchardt
Executive Director for Operations

SUBJECT: PRIORITIZATION OF RECOMMENDED ACTIONS TO BE TAKEN IN RESPONSE TO FUKUSHIMA LESSONS LEARNED

Additional Considerations:

Filtration of containment vents

Instrumentation for seismic monitoring

Basis of emergency planning zone size

Prestaging of potassium iodide beyond 10 miles

Transfer of spent fuel to dry cask storage

Loss of ultimate heat sink

Third Step

December 15, 2011

MEMORANDUM TO: R. W. Borchardt
Executive Director for Operations

J. E. Dyer
Chief Financial Officer

FROM: Annette L. Vietti-Cook, Secretary ***/RA/***

SUBJECT: STAFF REQUIREMENTS – SECY-11-0137 – PRIORITIZATION OF RECOMMENDED ACTIONS TO BE TAKEN IN RESPONSE TO FUKUSHIMA LESSONS LEARNED

The staff should quickly shift the issue of “Filtration of Containment Vents” from the “additional issues” category and merge it with the Tier 1 issue of hardened vents for Mark I and Mark II containments such that the analysis and interaction with stakeholders needed to inform a decision on whether filtered vents should be required can be performed concurrently with the development of the technical bases, acceptance criteria, and design expectations for reliable hardened vents.

Fourth Step

March 9, 2012

MEMORANDUM TO: R. W. Borchardt
Executive Director for Operations

FROM: Annette L. Vietti-Cook, Secretary */RA/*

SUBJECT: STAFF REQUIREMENTS – SECY-12-0025 – PROPOSED ORDERS AND REQUESTS FOR INFORMATION IN RESPONSE TO LESSONS LEARNED FROM JAPAN'S MARCH 11, 2011, GREAT TOHOKU EARTHQUAKE AND TSUNAMI

The Commission has approved the issuance of the proposed Orders subject to the changes and comments below.

The Order on Reliable Hardened Containment Vents (Mark I and II BWRs) provided in Enclosure 5 should be issued as necessary for ensuring continued adequate protection under the 10 C.F.R. § 50.109(a)(4)(ii) exception to the Backfit Rule, as revised in Attachment 2.

Fifth Step

November 26, 2012 SECY-12-0157

FOR: The Commissioners

FROM: R. W. Borchardt
Executive Director for Operations

SUBJECT: CONSIDERATION OF ADDITIONAL REQUIREMENTS FOR CONTAINMENT VENTING SYSTEMS FOR BOILING WATER REACTORS WITH MARK I AND MARK II CONTAINMENTS

RECOMMENDATION

The staff recommends that the Commission approve Option 3 to require the installation of an engineered filtered containment venting system for BWRs with Mark I and Mark II containments.

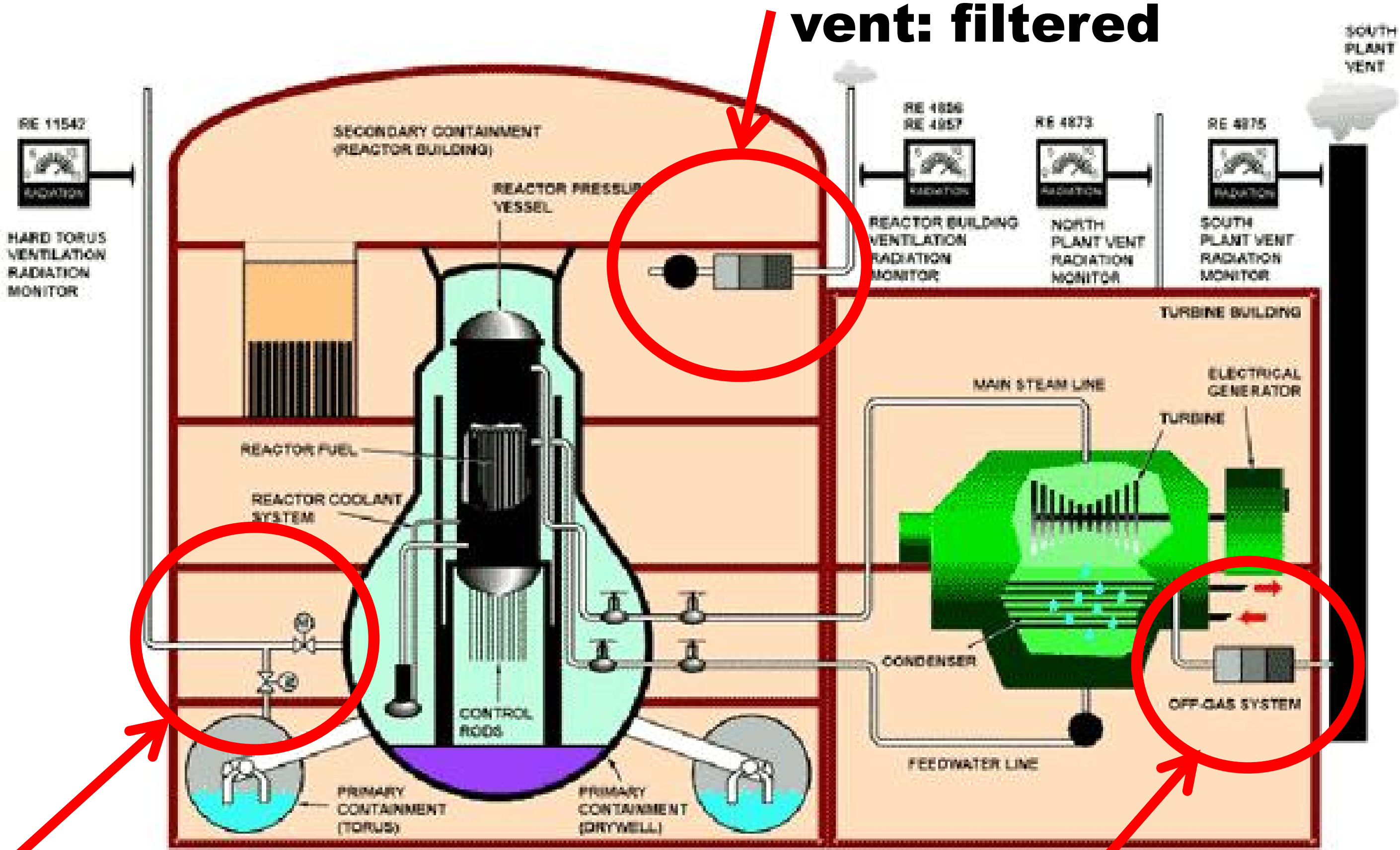
Next Step

The Commission should approve the staff's recommendation to require the installation of an engineered filtered containment venting system for BWRs with Mark I and Mark II containments.

SUCCESS!

Success puts a Filter in All Release Paths

Design basis accident vent: filtered



Beyond design basis accident vent: filtered!

Normal vent: filtered

Staff's Risk Assumption

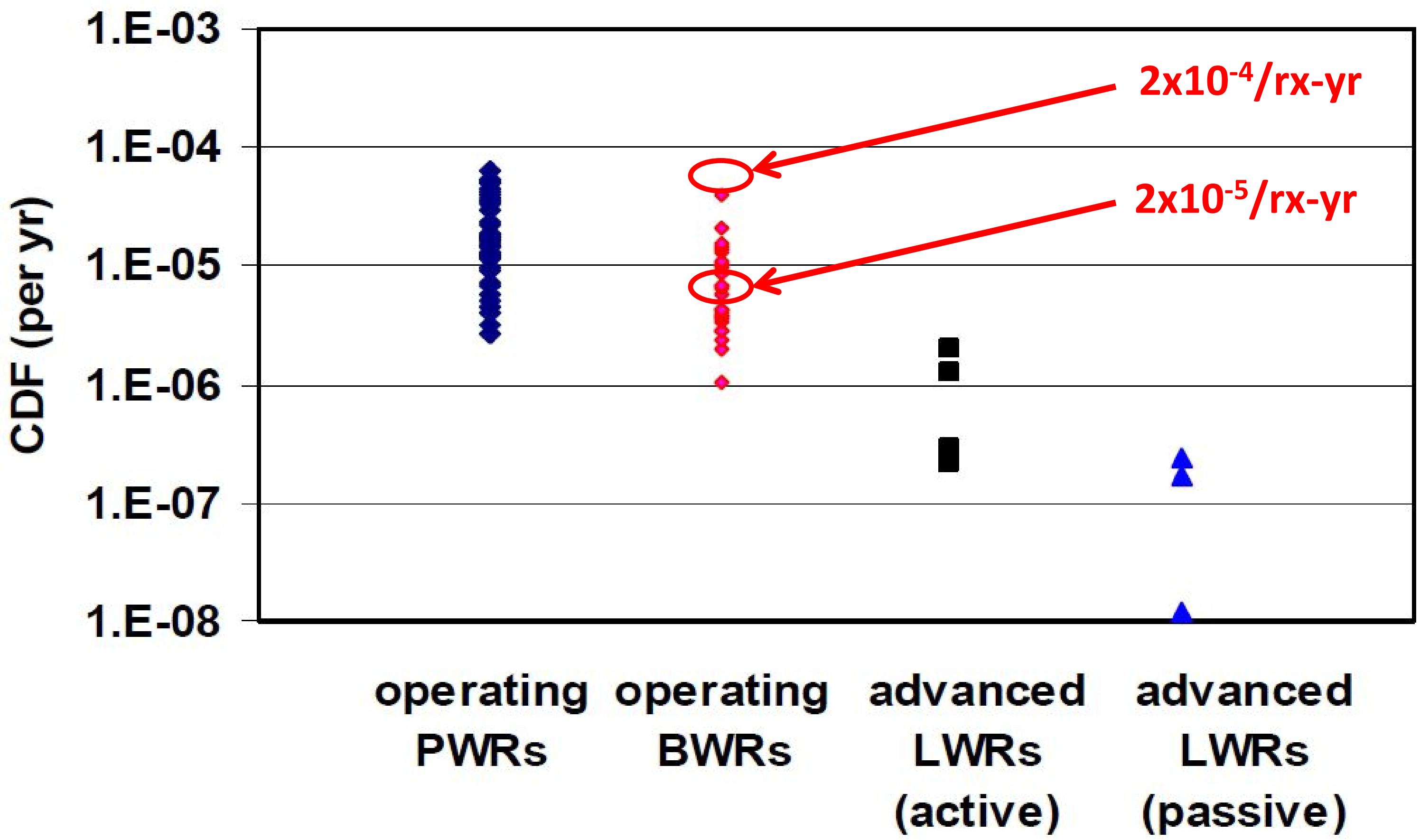
"Base event frequency … is assumed to be $2x10^{-5}$ per reactor-year."

"To address the uncertainties … the assessment is also performed assuming a core damage frequency of $2x10^{-4}$ per reactor-year…."

Source: SECY-0012-0157, Enclosure 1, page 11

Risk Assumption Seems Okay

(internal events at-power for U.S. plants only)



Source: "Comparison of New Light-Water Reactor Risk Profiles," Donald A. Dube, Division of Safety Systems and Risk Assessment, Office of New Reactors, Nuclear Regulatory Commission, Paper Presented at the American Nuclear Society Probabilistic Safety Assessment Conference, September 2008

What are the Odds?

31 BWR Mark I and II reactors

25 years of remaining operation

90% average capacity factor

2×10^{-5} per reactor-year risk

$$1 – (2 \times 10^{-5} \times 31 \times 25 \times .9) = 98.6\%$$

$$1 – (2 \times 10^{-4} \times 31 \times 25 \times .9) = 86.1\%$$

What are the Odds?

98.6 is not just normal body temperature

It’s the chance that the fleet of 31 BWRs with Mark I and II containments can operate for 25 years without experiencing a core damage event.

(Uncertainties reduce the odds to 86.1 percent)

What are the Consequences?

Table 7. Consequences Determined by MELCOR/MACCS2 Calculations							
Case	Core Spray	Drywell Spray	Venting	Location	Population Dose (person-rem/event)	Offsite Cost ($/event)	Land Contamination (km^2/event)
2	no	no	no	n/a	514,000	$1,910,000,000	354
3F	no	no	yes	wetwell	183,000	$274,000,000	8
3NF	no	no	yes	wetwell	397,000	$1,730,000,000	54
6	yes	no	no	n/a	305,000	$847,000,000	91
7F	yes	no	yes	wetwell	37,300	$17,600,000	0.4
7NF	yes	no	yes	wetwell	235,000	$484,000,000	34
12F	no	no	yes	drywell	232,000	$391,000,000	28
12NF	no	no	yes	drywell	3,810,000	$33,300,000,000	9,150
13F	no	yes	yes	drywell	59,990	$37,700,000	2
13NF	no	yes	yes	drywell	3,860,000	$33,000,000,000	8,830
14	no	yes	no	n/a	86,100	$116,000,000	12
15F	no	yes	yes	wetwell	43,300	$20,200,000	0.3
15NF	no	yes	yes	wetwell	280,000	$588,000,000	28

What are the Consequences?

4. CONCLUSIONS

These MACCS consequence analyses show a clear benefit in applying an external filter to either the wetwell or drywell vent path[8]. More specifically:

- The filtered cases with an external filter on either the wetwell or drywell vent path and a DF ≥10 for wetwell venting or a DF ≥1,000 for drywell venting results in a lower conditional latent cancer fatality [LCF] risk (i.e., 40–95 percent reduction) when compared to the unfiltered cases.

- The filtered cases with an external filter on either the wetwell or drywell vent path and a DF ≥10 for wetwell venting or a DF ≥1,000 for drywell venting results in a lower population dose (i.e., 50–95 percent reduction) when compared to the unfiltered cases. Unlike the LCF risk calculations, the population dose includes public doses from the ingestion pathway and doses to offsite decontamination workers.

- All the filtered cases with an external filtered vent path , results in a several order-of-magnitude reduction in Cs-137 land contamination.

- For all cases considered, the conditional prompt fatality risk is either zero or essentially zero.

- For the cases considered, a DF ≥10 for all wetwell venting filtered cases and a DF ≥1,000 for all drywell venting filtered cases results in lower economic costs (i.e., >60 percent to orders of magnitude reduction) than their respective unfiltered cases.

Source: SECY-2012-0157, Enclosure 5b, page 53

What are the Consequences?

An event involving reactor core damage is a very bad day.

Reactor core damage without filtered releases makes that day many times worse.

What is the Company?

Boiling Water Reactors (BWR) by Containment Types

Country	GE Mark I					GE Mark II				
	No. of Rx	FCVS Operational	Committed	Considering	No FCVS	No. of Rx	FCVS Operational	Committed	Considering	No FCVS
Belgium										
Bulgaria										
Canada										
China										
Czech Republic										
Finland										
France										
Germany										
Hungary										
India	2				X					
Japan	4*		X			7		X		
South Korea (ROK)										
Mexico						2				X
Netherlands										
Romania										
Russia										
Slovakia										
Slovenia										
South Africa										
Spain	1			X						
Sweden										
Switzerland	1	X								
Taiwan	2		X							
Ukraine										
United Kingdom										

Country	ABB Mark II					GE Mark III				
	No. of Rx	FCVS Operational	Committed	Considering	No FCVS	No. of Rx	FCVS Operational	Committed	Considering	No FCVS
Belgium										
Bulgaria										
Canada										
China										
Czech Republic										
Finland	2	X								
France										
Germany										
Hungary										
India										
Japan						3		X		
South Korea (ROK)										
Mexico										
Netherlands										
Romania										
Russia										
Slovakia										
Slovenia										
South Africa										
Spain						1			X	
Sweden	4	X								
Switzerland						1	X			
Taiwan						2		X		
Ukraine										
United Kingdom										

Country	Other					ABWR				
	No. of Rx	FCVS Operational	Committed	Considering	No FCVS	No. of Rx	FCVS Operational	Committed	Considering	No FCVS
Belgium										
Bulgaria										
Canada										
China										
Czech Republic										
Finland										
France										
Germany	2	X								
Hungary										
India										
Japan	4		X			3		X		
South Korea (ROK)										
Mexico										
Netherlands										
Romania										
Russia										
Slovakia										
Slovenia										
South Africa										
Spain										
Sweden	3	X								
Switzerland										
Taiwan										
Ukraine										
United Kingdom										

* Does not include the 4 reactors damaged by the earthquake and tsunami at Fukushima Dai-ichi.

Source: SECY-2012-0157, Enclosure 3, page 19

What is the Company?

Country	Other Reactor Designs (non-BWR)																				Notes
	PWR					PHWR/ Candu					VVER					Other					
	No. of Rx	FCVS Operational	Committed	Considering	No FCVS	No. of Rx	FCVS Operational	Committed	Considering	No FCVS	No. of Rx	FCVS Operational	Committed	Considering	No FCVS	No. of Rx	FCVS Operational	Committed	Considering	No FCVS	
Belgium	7			X																	
Bulgaria											2	X									
Canada						18	X	X													
China	10					2					2										Information is unavailable.
Czech Republic	6			X																	
Finland											2	X									
France	58	X																			
Germany	11	X																			
Hungary	4																				Information is unavailable.
India																					
Japan	24		X																		
South Korea (ROK)	17			X		4			X												
Mexico																					
Netherlands	1	X																			
Romania						1		X													
Russia											17										Information is unavailable.
Slovakia											4				X						
Slovenia	1		X																		
South Africa	2																				Information is unavailable.
Spain	6			X																	
Sweden	3	X																			
Switzerland	3	X																			
Taiwan	2		X																		
Ukraine											15			X							
United Kingdom	1		X													18					Other reactor types are gas-cooled.

Source: SECY-2012-0157, Enclosure 3, page 20

What is the Company?

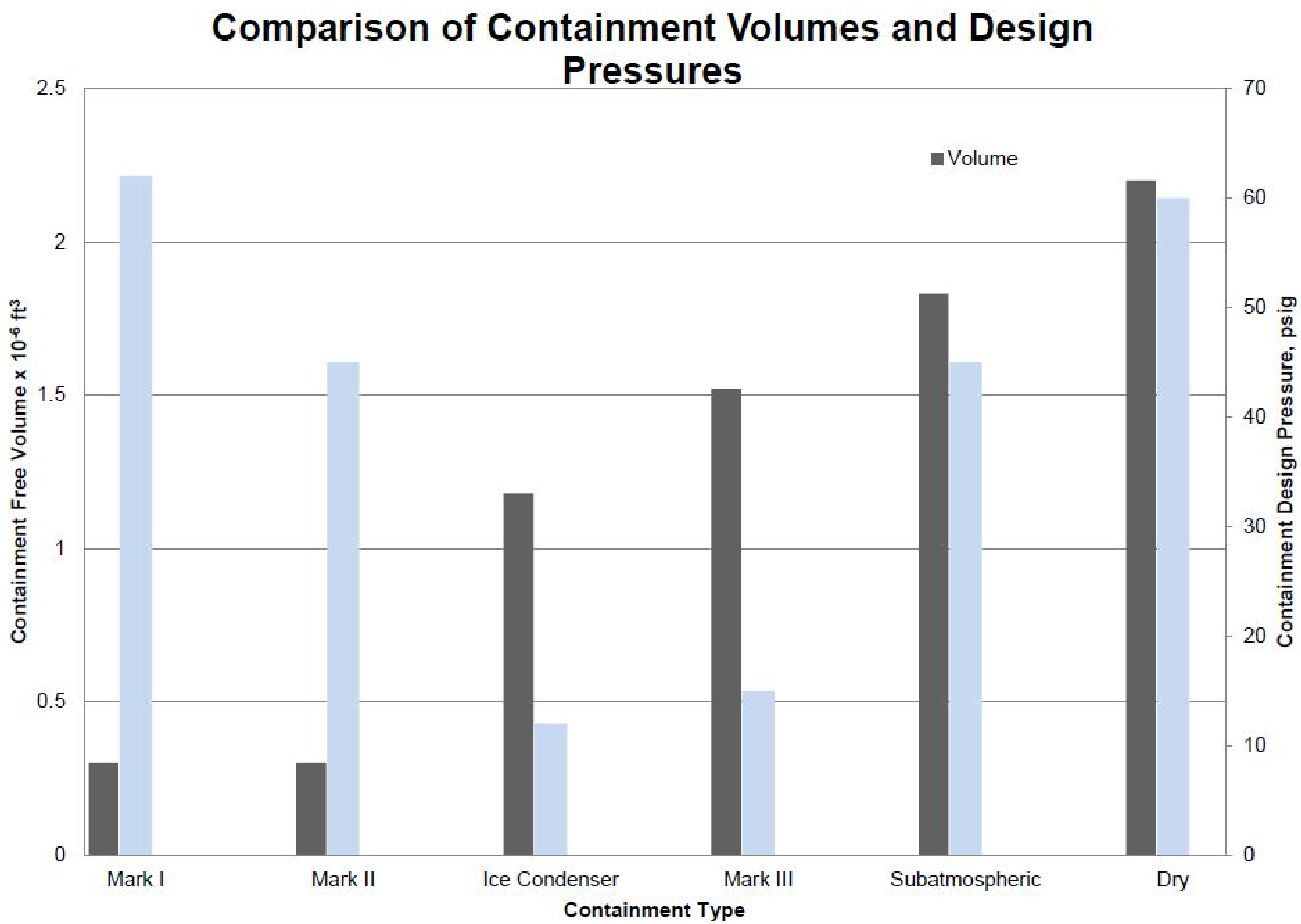


Figure 1. Comparison of containment volumes and design pressures

Source: SECY-2012-0157, Enclosure 2, page 19

What is the Intangible Benefit?

"There were a total of 54 reactors licensed to operate [in Japan] at the time of the Fukushima accidents."

"As of September 2012, there are only two reactors operating in Japan."

Source: SECY-2012-0157, Enclosure 3, page 16

What is the Intangible Benefit?

If filters are <u>not</u> installed on all release paths and an accident at a U.S. reactor results in a large release of radioactivity, the nation's entire fleet of reactors is at jeopardy due to the loss of confidence in the industry and its regulator.

Source: SECY-2012-0157, Enclosure 3, page 16

What About Option 4?

- Venting through the wetwell is preferred as it provides an opportunity for fission product scrubbing in the suppression pool. Pool scrubbing efficiency can be appreciable (decontamination factor in the range between 100 and 300 in the MELCOR analysis). Venting through drywell does not have pool scrubbing benefit. As such, if the drywell vent is used for the purpose, external filtration would be necessary to reduce the amount of fission product release to the environment.

Source: SECY-2012-0157, Enclosure 5a, page 59

Why Option 4 is Not an Option

3.2.1 Mark I Containments

As a potential fission product filter, the wetwell has its greatest value when (1) the core damage is arrested in the reactor vessel, (2) the reactor vessel and attached piping remain intact relieving through the safety relief valves (SRVs), (3) the SRV tailpipes to the T-quenchers (spargers, pipes with many holes approximately 1 centimeter in diameter to spread the discharge and assist with pool mixing to avoid local boiling and containment pressurization above the pool) at the bottom of the wetwell remain intact, and (4) the wetwell water remains substantially subcooled. At Fukushima Units 2 and 3, extended reactor core isolation cooling (RCIC) and high pressure coolant injection (HPCI) operation resulted in SRV discharge pathway transfer of enough decay heat from the RPV to the suppression pools to bring them to saturation conditions.

Source: SECY-2012-0157, Enclosure 4, page 8

Why Option 4 is Not an Option

3.2.1 Mark I Containments

As a potential fission product filter, the wetwell has its greatest value when (1) the core damage is arrested in the reactor vessel, (2) the reactor vessel and attached piping remain intact relieving through the safety relief valves (SRVs), (3) the SRV tailpipes to the T-quenchers (spargers, pipes with many holes approximately 1 centimeter in diameter to spread the discharge and assist with pool mixing to avoid local boiling and containment pressurization above the pool) at the bottom of the wetwell remain intact, and (4) the wetwell water remains substantially subcooled. At Fukushima Units 2 and 3, extended reactor core isolation cooling (RCIC) and high pressure coolant injection (HPCI) operation resulted in SRV discharge pathway transfer of enough decay heat from the RPV to the suppression pools to bring them to saturation conditions.

(1) Wetwell's value drops when core damage is <u>not</u> arrested in the reactor vessel. The wetwell's scrubbing effect has a role in only *some* severe accidents.

Source: SECY-2012-0157, Enclosure 4, page 8

Why Option 4 is Not an Option

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Investigation of Strategies for Mitigating Radiological Releases in Severe Accidents

BWR Mark I and Mark II Studies

1026539
Final Report, September 2012

Unfiltered releases, such as those through the drywell vent, can carry huge consequences in lives, land, and costs.

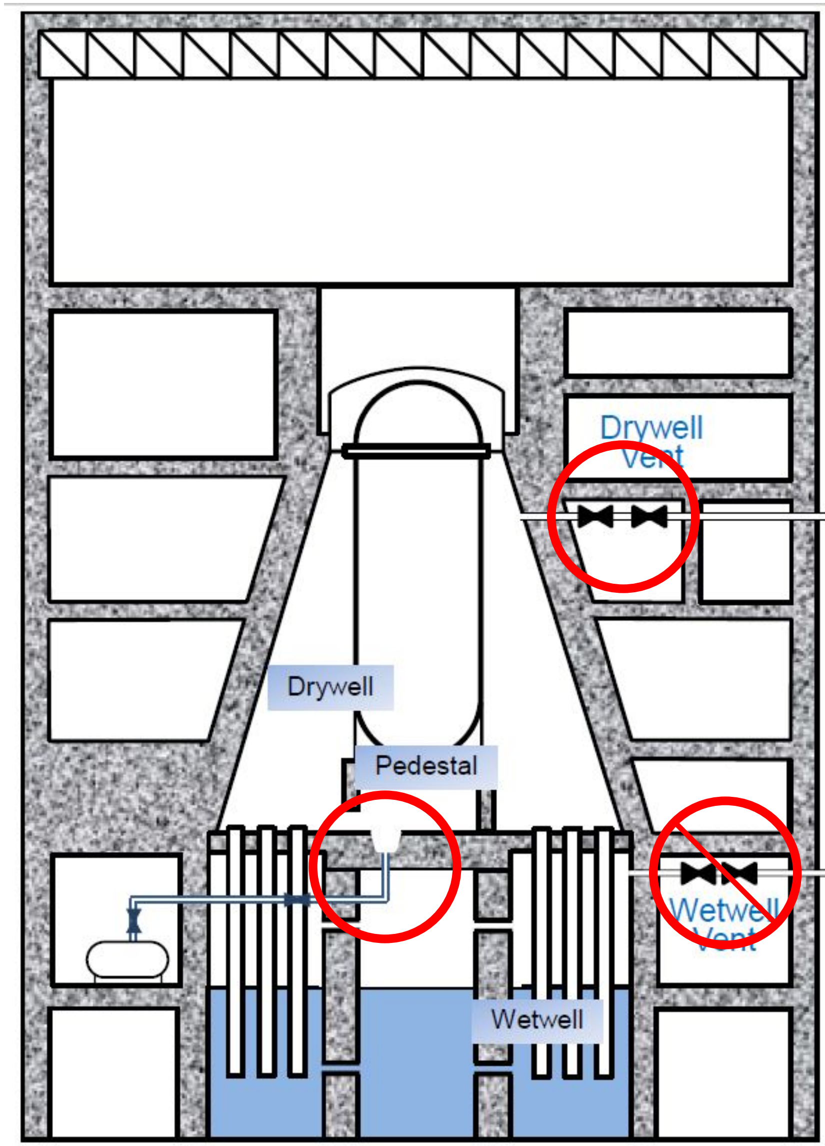


Figure 3-4
Representative Mark II containment layout

Why Option 4 is Not an Option

3.2.1 Mark I Containments

As a potential fission product filter, the wetwell has its greatest value when (1) the core damage is arrested in the reactor vessel, (2) the reactor vessel and attached piping remain intact relieving through the safety relief valves (SRVs), (3) the SRV tailpipes to the T-quenchers (spargers, pipes with many holes approximately 1 centimeter in diameter to spread the discharge and assist with pool mixing to avoid local boiling and containment pressurization above the pool) at the bottom of the wetwell remain intact, and (4) the wetwell water remains substantially subcooled. At Fukushima Units 2 and 3, extended reactor core isolation cooling (RCIC) and high pressure coolant injection (HPCI) operation resulted in SRV discharge pathway transfer of enough decay heat from the RPV to the suppression pools to bring them to saturation conditions.

(2) Wetwell's value drops if there's a loss of coolant accident. The wetwell's scrubbing effect has a role in only *some* severe accidents.

Source: SECY-2012-0157, Enclosure 4, page 8

Why Option 4 is Not an Option

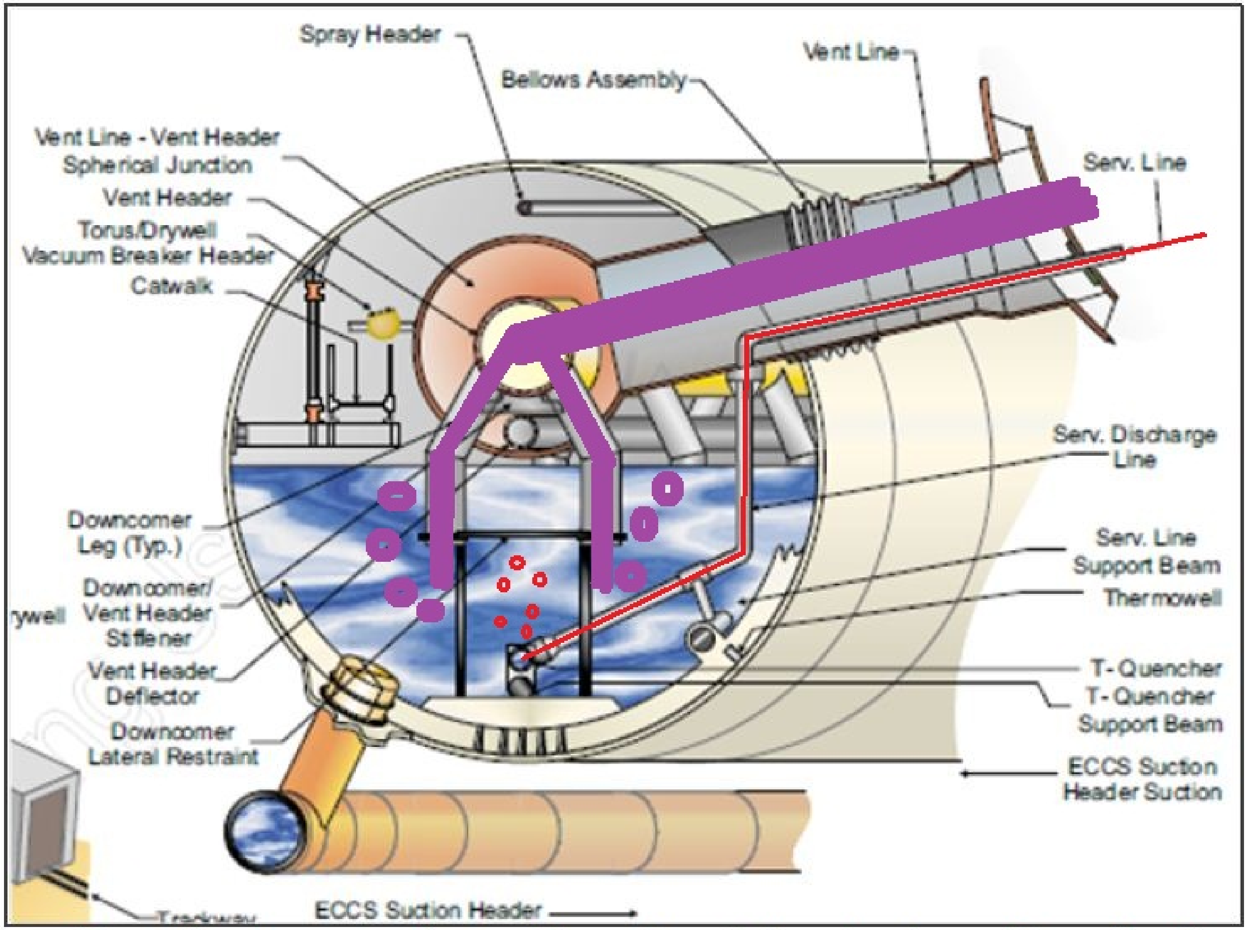
3.2.1 Mark I Containments

As a potential fission product filter, the wetwell has its greatest value when (1) the core damage is arrested in the reactor vessel, (2) the reactor vessel and attached piping remain intact relieving through the safety relief valves (SRVs), (3) the SRV tailpipes to the T-quenchers (spargers, pipes with many holes approximately 1 centimeter in diameter to spread the discharge and assist with pool mixing to avoid local boiling and containment pressurization above the pool) at the bottom of the wetwell remain intact, and (4) the wetwell water remains substantially subcooled. At Fukushima Units 2 and 3, extended reactor core isolation cooling (RCIC) and high pressure coolant injection (HPCI) operation resulted in SRV discharge pathway transfer of enough decay heat from the RPV to the suppression pools to bring them to saturation conditions.

(3) Wetwell's value drops if T-quenchers don't quench enough. The wetwell's scrubbing effect has a role in only *some* severe accidents.

Source: SECY-2012-0157, Enclosure 4, page 8

Why Option 4 is Not an Option



Steam flow to supppresion pool through vents from break from reactor coolant pressure boundary break in drywell

Steam flow from safety relief valve

Source: SECY-2012-0157, Enclosure 4, page 8

Why Option 4 is Not an Option

3.2.1 Mark I Containments

As a potential fission product filter, the wetwell has its greatest value when (1) the core damage is arrested in the reactor vessel, (2) the reactor vessel and attached piping remain intact relieving through the safety relief valves (SRVs), (3) the SRV tailpipes to the T-quenchers (spargers, pipes with many holes approximately 1 centimeter in diameter to spread the discharge and assist with pool mixing to avoid local boiling and containment pressurization above the pool) at the bottom of the wetwell remain intact, and (4) the wetwell water remains substantially subcooled. At Fukushima Units 2 and 3, extended reactor core isolation cooling (RCIC) and high pressure coolant injection (HPCI) operation resulted in SRV discharge pathway transfer of enough decay heat from the RPV to the suppression pools to bring them to saturation conditions.

(4) Wetwell's value drops as the suppression pool's water temperature rises. The wetwell's scrubbing effect has a role in only *some* severe accidents.

Source: SECY-2012-0157, Enclosure 4, page 8

Why Option 4 is Not an Option

"Beyond-design-basis plant conditions are difficult to predict. With increasing plant degradation during a severe accident, the uncertainties regarding relevant phenomena, further development of the accident, and possible containment failure modes increase considerably."

Source: SECY-2012-0157, Enclosure 3, page 11

Why Option 4 is Not an Option

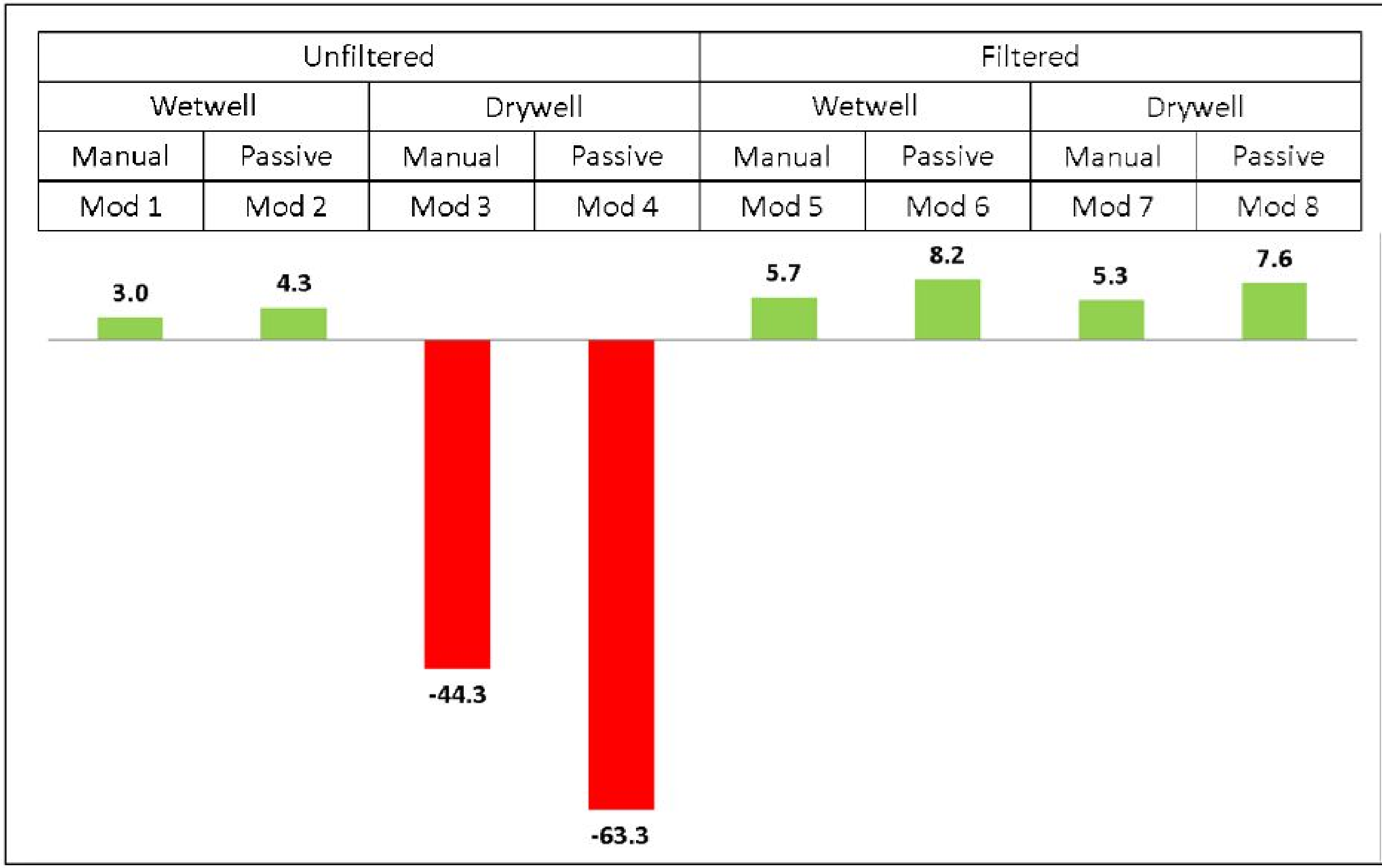


Figure 4. Reduction in population dose risk

Source: SECY-2012-0157, Enclosure 5c

Why Option 4 is Not an Option

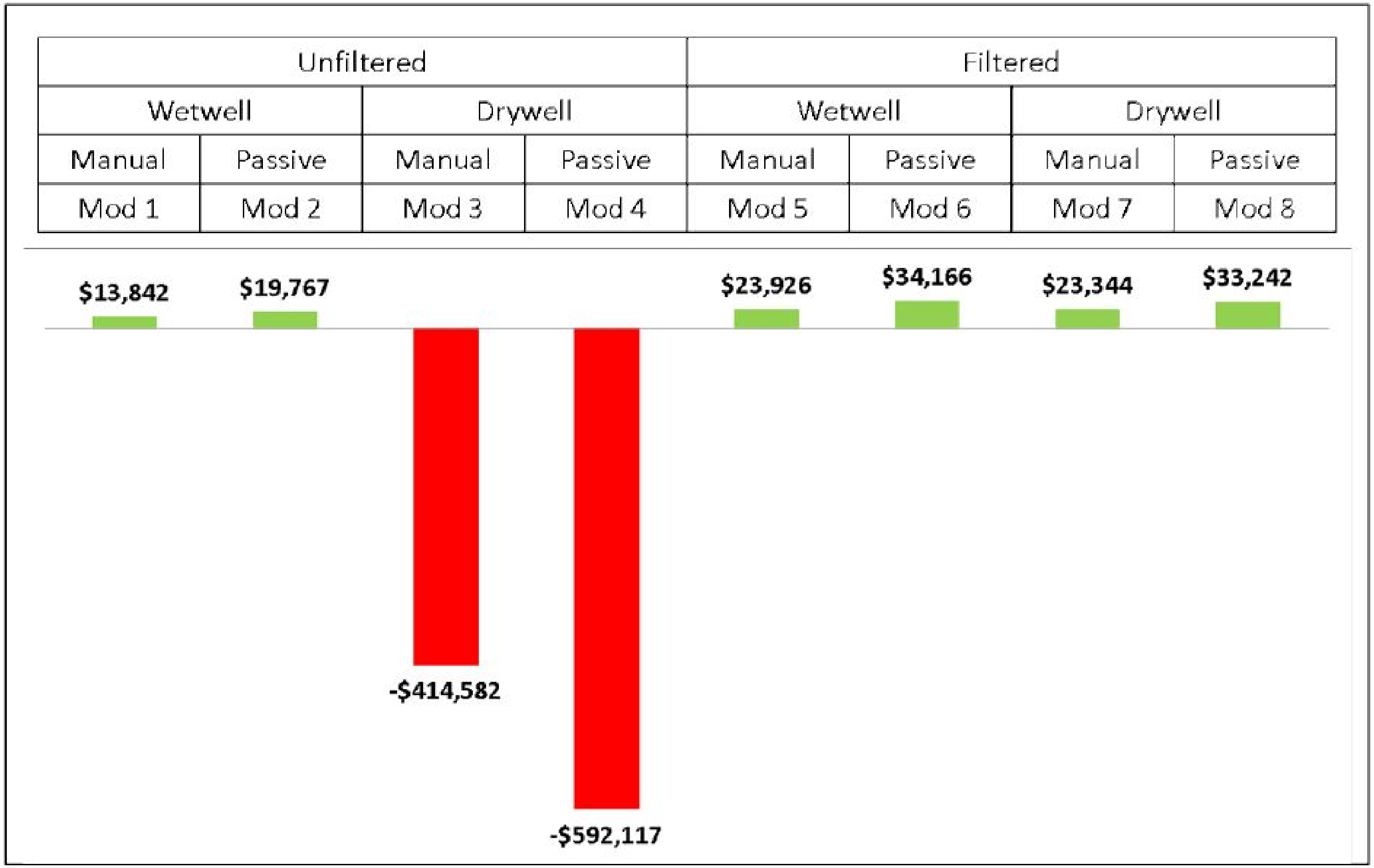


Figure 5. Reduction in offsite cost risk

Source: SECY-2012-0157, Enclosure 5c

Why Option 4 is Not an Option

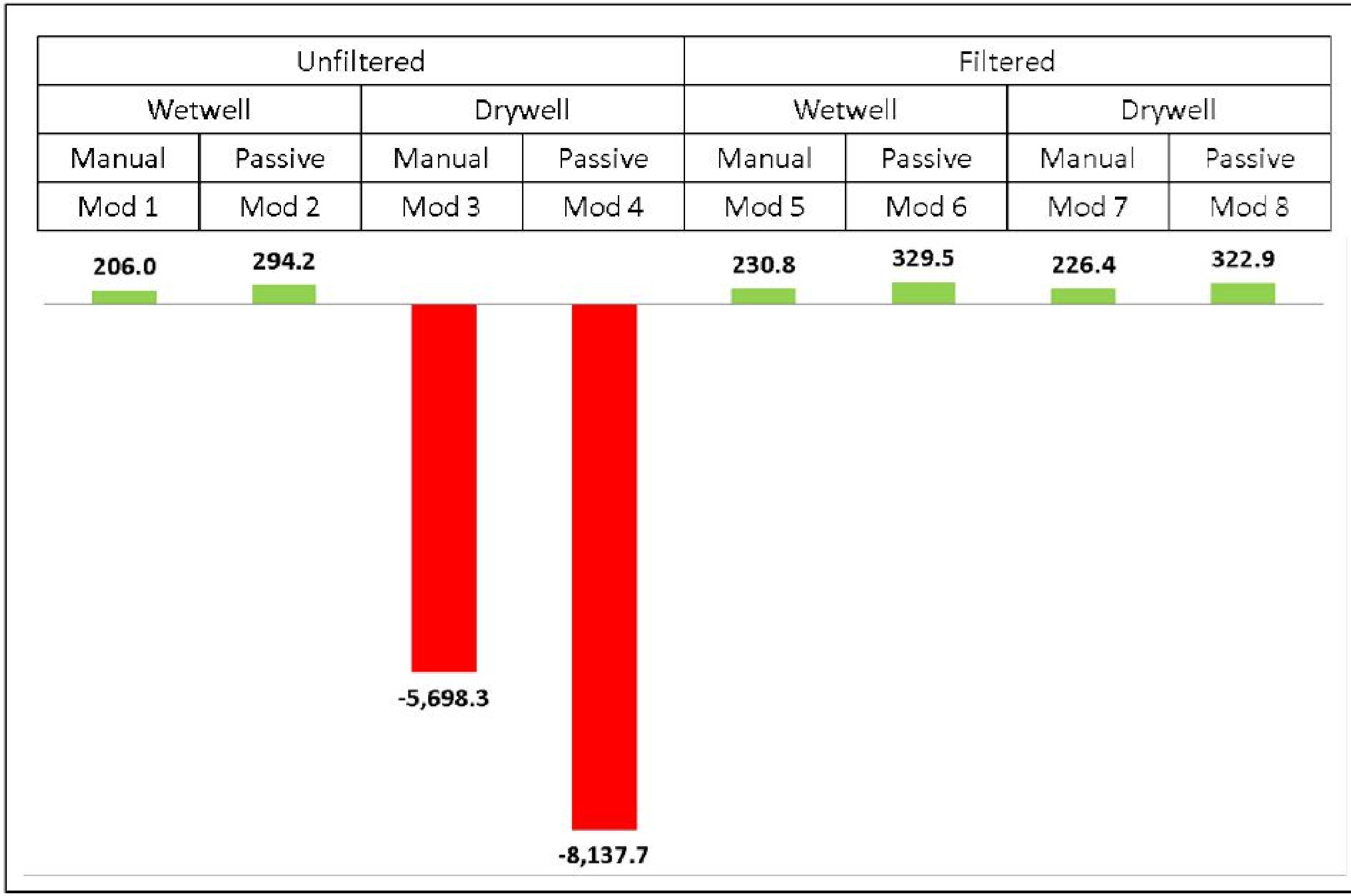


Figure 8. Reduction in conditional contaminated land area

Source: SECY-2012-0157, Enclosure 5c

Next Step

The Commission should approve the staff's recommendation to require the installation of an engineered filtered containment venting system for BWRs with Mark I and Mark II containments.

SUCCESS!