Written Testimony before the

U.S. House of Representatives
Committee on Science, Space, and Technology
Energy & Environment and Investigations & Oversight Subcommittees

by
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For nearly four decades, the Union of Concerned Scientists has been a nuclear power safety and security advocate. Neither anti- nor pro-nuclear power, UCS strives to ensure that the technology's inherent risks are minimized to the extent that is practically achievable.

The tragic events at the Fukushima Dai-Ichi nuclear plant in Japan have already revealed areas of elevated risk that should be rectified. Over the ensuing months and years, additional lessons will undoubtedly surface as workers conduct CSI Nuclear to assess what failed due to various causes, including the earthquake, the tsunami, the extended power outage, the hydrogen explosions, the torrents of water dropped from above and sprayed from below, and the submersion of equipment in water. Today, UCS would like to share six of the lessons already evident from Fukushima Dai-Ichi that are applicable to ensuring safer nuclear power plants in the United States:

- Better protection against extended power outages
- Adequate severe accident management guidance
- Safer storage of spent fuel
- Upgraded guidance for spent fuel pool events
- Additional regulatory requirements for defueled reactors

BETTER PROTECTION AGAINST EXTENDED POWER OUTAGES

Some may argue that what happened at Fukushima Dai-Ichi cannot happen here—that our nuclear power plants are not vulnerable to extended power outages caused by the one-two punch of an earthquake and tsunami. In June 1998, a tornado disabled the normal power supply for the Davis-Besse nuclear plant in Ohio, just as the earthquake had done for Fukushima Dai-Ichi. Outside air temperatures exceeding 90°F caused the backup power supply to overheat and fail, just as the tsunami had done at Fukushima Dai-Ichi. The difference was that workers restored the normal power supply for Davis-Besse an hour before the backup power supply failed while more extensive damage prevented workers at Fukushima Dai-Ichi from restoring its normal power supply for nearly a week, days too late to prevent fuel damage.

Enclosure 1 provides Tables B-1 and B-2 from a 2003 report issued by the NRC on power outages at U.S. nuclear power plants. When both the normal and backup power supplies are lost, a condition called station blackout occurs. As at Fukushima Dai-Ichi, the only source of power during a station blackout is a bank of batteries. The fourth column of data in Tables B-1 and B-2 provides the percentage of overall risk of reactor core damage (called core damage frequency or CDF) due to station blackouts as calculated by the plant owners themselves. For example, station blackouts constitute 80.6 percent of the overall core damage risk at the LaSalle nuclear plant in Illinois. In other words, the risk from station blackouts is roughly four times the risk from all other causes combined. And LaSalle is located far away from the earthquake faults of California and the tsunami risks of both coasts, so clearly an earthquake and tsunami is not the only path to a station blackout disaster.

The three reactors at Fukushima Dai-Ichi operating at the time of the earthquake were each equipped with banks of batteries having 8-hour capacities. As reflected by the data in the fifth column of Tables B-1 and B-2, the majority of U.S. reactors have equal or shorter station blackout coping durations. This means that workers at a U.S. reactor experiencing a station blackout would essentially be playing a very high stakes version of "Beat the Clock." If they restore normal or backup power within a few hours, they win. If not, many may lose.

Requiring nuclear plants to have 16 hours of battery capacity would give workers a greater chance of bearing the clock. But what if, as at Fukushima Dai-Ichi, it takes longer than 16 hours to restore the normal and backup power supplies? The world has been watching what happens, and it isn't pretty or worth emulating.

UCS believes a better way to ensure victory in station blackout "Beat the Clock" is to evaluate how long it will likely take for replacement batteries and/or portable generators to be delivered to each nuclear power plant site. For some plant sites, the current situation is fine because nearby reinforcements exist and it will be possible to supply replacement batteries or portable generators within the existing 4-hour or 8-hour station blackout coping duration. However, for other plants reinforcements are not likely to arrive in time, and reactor owners should increase the battery capacity and/or pre-stage battery replacements and portable generators closer to the site.

ADEQUATE SEVERE ACCIDENT MANAGEMENT GUIDANCE

In NRC terminology, a severe accident is one in which at least some of the fuel melts. In testimony at Congressional hearings, NRC and nuclear industry representatives have claimed that the severe accident management guidelines (SAMGs) developed in the wake of reactor meltdown at Three Mile Island would provide reliable protection against the problems faced at Fukushima Dai-Ichi. They have not been telling the whole story. As newscaster Paul Harvey used to say, here's the rest of the story.

Enclosure 2 provides part of Table 2 from NRC Manual Chapter 0308 on its reactor oversight process (ROP). The fourth column for the severe accident management guidelines entry states:

> *The [NRC] staff concluded that regular inspection of SAMG was not appropriate because the guidelines are voluntary and have no regulatory basis.*

The NRC never checks—repeat, never checks—the guidelines to see if they would be effective under severe accident conditions.

From March 2009 until March 2010, I worked for the NRC as a Boiling Water Reactor technology instructor at their Technical Training Center. My duties included teaching the severe accident management guidelines to NRC employees for their initial qualifications and re-qualifications. I and the other instructors emphasized that NRC inspectors were not authorized to evaluate the adequacy of the guidelines. Plant owners are required to have the guidelines while NRC inspectors are required <u>not</u> to assess their effectiveness. It's like maritime inspectors ensuring that passenger liners have lifeboats, but not checking to see that there's sufficient capacity for all passengers and crew members.

If NRC continues to rely on these guidelines to protect public health, it must evaluate their effectiveness.. It would be too late and too costly to find out after a U.S. nuclear plant disaster that the plant's severe accident management guideline was missing a few key steps or contained a handful of missteps.

SAFER STORAGE OF SPENT FUEL

Much has been reported about the problems with the fuel in the spent fuel pools at Fukushima Dai-Ichi Units 3 and 4. Helicopters dropped tons of water from above while water cannons on fire trucks sprayed water from below. And yet it appears that fuel in at least two spent fuel pools has been damaged.

Virtually nothing has been reported about the fuel stored in dry casks at Fukushima Dai-Ichi. It experienced the earthquake. It experienced the tsunami. It experienced the prolonged power outage. It did not overheat. It was not damaged. It did not produce hydrogen that later exploded. It did not cause the evacuation of a single member of the public. It did not cause a single worker to receive radiation over-exposure.

The spent fuel pools at nuclear plants in the United States are significantly fuller than those in Japan. As a result, the chances of a spent fuel accident are higher and the consequences would be greater.

For the first five years after being taken out of the reactor core, spent fuel generates too much heat to be placed into dry casks. After five years, the heat generation rates have dropped low enough to permit dry cask storage.

It takes no pumps, no power, no switches, and no forced circulation of water to protect spent fuel in dry casks from damage. Instead, air enters an inlet in the bottom of the dry cask, gets warmed by the heat from the spent fuel, and flows out an outlet in the top of the dry cask via the chimney effect. It’s the “passive” safety system that worked at Fukushima Dai-Ichi and would work here, if we bothered to use it.

Instead, spent fuel pools in America are filled nearly to capacity. Then and only then is spent fuel transferred into dry casks. But the amount of spent fuel transferred is just enough to free up the space needed for the next fuel discharged from the reactor core. This practice maintains the spent fuel pool risk at a level about as high as can be achieved, and exposes millions of Americans to elevated and undue risk.

The safer way to store spent fuel is to transfer it into dry casks as soon as possible following the five year cooling off period in a spent fuel pool. That’s the “passive” safety system Americans need most.

UPGRADED GUIDANCE FOR SPENT FUEL POOL EVENTS

Following the March 1979 accident at Three Mile Island Unit 2 in Pennsylvania, the NRC and the nuclear industry significantly upgraded the procedures used by operators during reactor core accidents. The upgraded procedures provide the operators with the full array of options available to deal with a reactor core accident, not just those relying on emergency equipment. In addition, the upgraded procedures would help the operators handle problems like unavailable or misleading instrument readings.

No such procedures, and associated training, are available to help operators deal with spent fuel pool accidents. After the water level in the Unit 4 spent fuel pool at Fukushima Dai-Ichi dropped below the top of the fuel assemblies, the fuel rods heated up, producing large amounts of hydrogen gas. That hydrogen exploded, destroying the reactor buildings walls and roof and creating a pathway for radioactivity to freely escape to the environment. To lessen the likelihood of similar explosions, workers cut openings in the roofs and walls of the reactor buildings on Units 2, 5, and 6. Their efforts were ad hoc and reactive.

The NRC should require robust procedures for spent fuel pool problems, comparable to those for reactor core problems, to help operators either prevent fuel damage or mitigate its consequences should such damage occur.

ADDITIONAL REGULATORY REQUIREMENTS FOR DEFUELED REACTORS

When the earthquake and tsunami happened, the reactor core on Fukushima Dai-Ichi Unit 4 was empty of fuel, with the fuel having been transferred to its spent fuel pool. That configuration is termed a defueled operating condition. There’s a gaping hole in the regulatory safety net when reactors are defueled.

Enclosure 3 contains pages excerpted from the NRC’s Standard Technical Specifications for boiling water reactors. When the NRC issues, or renews, licenses to operate nuclear power reactors, Appendix A to these licenses are the technical specifications. These specifications establish “the lowest functional capability or performance levels of equipment required for safe operation of the facility"[1] along with the scope and frequency of testing required to verify that capability. The operational condition of the reactor (also called its MODE and defined by the Reactor Mode Switch Position and the temperature of the reactor cooling water) determines which requirements are applicable when. However, technical specification requirements only apply when one or more fuel assemblies are located in the reactor core. When the entire reactor core inventory has been offloaded to the spent fuel pool, almost no technical specification requirements still apply.

For example, technical specification 3.6.4.1 no longer requires secondary containment to be intact. Secondary containment, which is the reactor building, houses the spent fuel pool and acts as a barrier to prevent any radioactivity released from fuel in the spent fuel pool from reaching the environment—but only when it is intact. Likewise, technical specification 3.8.2 does not require normal or backup power supplies to be available. And technical specification 3.8.5 does not even require battery power to be available.

When one or more fuel assemblies is in the reactor core, the technical specifications mandate safety measures to protect Americans from that hazard. But when that hazard is entirely relocated to the spent fuel pool, the technical specifications allow all of those safety measures to be taken away. Technical specification 3.7.8 would even allow all the water to be drained from the spent fuel pool with all the irradiated fuel in it.

The NRC must fix this technical specification deficiency to provide adequate protection of public health when reactor cores are defueled.

CONCLUSION

The measures we have recommended will lessen the chance of a disaster at a U.S. nuclear power plant. But if it happens anyway, the federal government would be able to look Americans in the eye and say, "we took every reasonable measure to protect you." Americans expect that protection. We urge the Congress to ensure the NRC provides Americans the protection they deserve.

Enclosures:

1. Pages from NRC NUREG-1776, "Regulatory Effectiveness of the Station Blackout Rule, August 2003.
2. Pages from NRC Inspection Manual Chapter 0308, "Reactor Oversight Process (ROP) Basis Document," October 16, 2006.
3. Pages from NRC NUREG-1433, Volume 1, Rev. 3, "Standard Technical Specifications General Electric Plants, BWR/4," December 2005.
4. Executive Summary from UCS's report "Nuclear Power: Still Not Viable without Subsidies," February 2011.

[1] 10 CFR 50.36, Technical Specifications. Available online at http://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0036.html

Enclosure 1

NUREG-1776

Regulatory Effectiveness of the Station Blackout Rule

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Plant-Specific Station Blackout Information by Reactor Type and Operating Status

Table B-1 Operating pressurized-water reactors

Plant	Plant CDF	SBO CDF	Percent SBO CDF of Plant CDF	Coping time in hours/EDG reliability/Aac access time in minutes/ extremely severe weather	Modification summary including dc load shed procedural modifications	SBO factors					
						PRA LOOP initiating event frequency	Number of LOOP events at power since commercial operation			LOOP event recovery times ≥ 240 minutes	
							Plant	Weather	Grid	Power	Shutdown
Arkansas Nuclear One Unit 1	4.67E-05	1.58E-05	33.8	4/.95/10/1	Added 1 DG and crosstie	3.58E-02	2	1			
Arkansas Nuclear One Unit 2	3.40E-05	1.23E-06	3.6	4/.95/10/1	Added crosstie	5.84E-02	1	1			
Beaver Valley Unit 1	2.14E-04	6.51E-05	30.4	4/.975/60/1	Added crosstie	6.64E-02	2				
Beaver Valley Unit 2	1.92E-04	4.86E-05	25.3	4/.975/60/1	Added crosstie	7.44E-02	1				
Braidwood Units 1&2	2.74E-05	6.20E-06	22.6	4/.95/10/1		4.53E-02	2				
Bryon Units 1&2	3.09E-05	4.30E-06	13.9	4/.95/10/1		4.43E-02					
Callaway	5.85E-05	1.80E-05	30.8	4/.975/-/1		4.60E-02					
Calvert Cliffs Units 1&2	2.40E-04	8.32E-06	3.4	4/.975/60/4	Added 1 EDG and one 1 DG	1.36E-01	3				
Catawba Units 1&2	5.80E-05	6.0E-07	10.3	4/.95/10/1		2.0E-03	1			330	
Comanche Peak Units 1&2	5.72E-05	1.5E-05	26.2	4/.95/-/1							

The battery capacity for each reactor is the first number provided in the 5th column of this table. For Arkansas Nuclear One Unit 1, the battery capacity is 4 hours. The fourth column shows fraction of overall risk from reactor core damage that station blackout represents. For example, station blackout represents 33.8% of the risk of reactor core damage at Arkansas Nuclear One Unit 1. NOTE: These risk values only consider the hazard of reactor core damage. The hazard of spent fuel pool accidents is neglected here.

Plant-Specific Station Blackout Information by Reactor Type and Operating Status

Table B-1 Operating pressurized-water reactors (Cont.)

Plant	Plant CDF	SBO CDF	Percent SBO CDF of Plant CDF	Coping time in hours/EDG reliability/Aac access time in minutes/ extremely severe weather	Modification summary including dc load shed procedural modifications	SBO factors					
						PRA LOOP initiating event frequency	Number of LOOP events at power since commercial operation			LOOP event recovery times ≥ 240 minutes	
							Plant	Weather	Grid	Power	Shutdown
Crystal River Unit 3	1.53E-05	3.28E-06	21.5	4/.975/-/4	dc load shed. Added nonclass 1E battery	4.35E-01	3				
Davis-Besse	6.6E-05	3.50E-05	53	4/.95/10/2	Added 1 DG	3.50E-02	2	1		1680	
DC Cook Units 1&2	6.2E-05	1.13E-05	18.1	4/.975/-/2	dc load shed	4.0E-02	1				
Diablo Canyon Units 1&2	8.8E-05	5.0E-06	5.68	4/.95/-/1	Added 1 DG	9.1E-02	1				261 917
Farley Units 1&2	1.3E-04	1.22E-05	9.4	4/.95/10/3	Service water to Aac, auto load shedding	4.70E-02	2				
Fort Calhoun	1.36E-05	NA	–	4/.95/-/2	DC load shed	2.17E-01	2				
Ginna	8.74E-05	1.0E-06	1.14	4/.975/-/1		3.50E-03	4				
Harris	7.0E-05	1.71E-05	24.4	4/.95/-/3	Lighting in several areas, ladder to isolation valve						
Indian Point Unit 2	3.13E-05	4.47E-06	14.3	8/.95/60/2	Added a DG for gas turbine auxiliaries	6.91E-02	2		3	390	

Plant-Specific Station Blackout Information by Reactor Type and Operating Status

Table B-2 Operating boiling-water reactors

Plant	Plant CDF	SBO CDF	Percent SBO CDF of Plant CDF	Coping time in hours/EDG reliability/Aac access time in minutes/ extremely severe weather	Modification summary including dc load shed procedural modifications	SBO factors					
						PRA LOOP initiating event frequency	Number of LOOP events at power since commercial operation			LOOP event recovery times ≥ 240 minutes	
							Plant	Weather	Grid	Power	Shutdown
Browns Ferry Units 2&3	4.80E-05	1.30E-05	27	4/.95/-/1	dc load shed	1.12E-01					
Brunswick Units 1&2	2.70E-05	1.80E-05	66.7	4/.975/60/5	Modified controls for existing crosstie	7.40E-02	3				1508 814
Clinton	2.66E-05	9.8E-06	36.8	4/.95/10/1	Added gas fans for selected room cooling	8.40E-02					
Cooper	7.97E-05	2.77E-05	34.8	4/.95/-/2		3.50E-02					
Dresden Units 2&3	1.8E-05	9.30E-07	5.03	4/.95/60/2	Added 2 DGs	1.12E-01	3	1		240	
Duane Arnold	7.84E-06	1.90E-06	24.2	4/.975/-/2	dc load shed, RCIC insulation & main control room lighting	1.17E-01			1		
Fermi	5.70E-06	1.3E-07	NMN	4/.95/60/1		1.88E-01					
FitzPatrick	1.92E-06	1.75E-06	NMN	4/.95/-/1	dc load shed, instrumentation and power supply mods	5.70E-02					
Grand Gulf	1.77E-05	7.46E-06	36.8	4/.95/-/2	dc load shed	6.80E-02					

Plant-Specific Station Blackout Information by Reactor Type and Operating Status

Table B-2 Operating boiling-water reactors (Cont.)

Plant	Plant CDF	SBO CDF	Percent SBO CDF of Plant CDF	Coping time in hours/EDG reliability/Aac access time in minutes/ extremely severe weather	Modification summary including dc load shed procedural modifications	SBO factors					
						PRA LOOP initiating event frequency	Number of LOOP events at power since commercial operation			LOOP event recovery times ≥ 240 minutes	
							Plant	Weather	Grid	Power	Shutdown
Hatch Unit 1	2.23E-05	3.30E-06	14.8	4/.95/60/2	Replaced battery chargers	2.20E-02					
Hatch Unit 2	2.36E-05	3.23E-06	13.7	4/.95/60/2	Replaced battery chargers	2.20E-02					
Hope Creek	4.63E-05	3.38E-05	73	4/.95/-/2	Valve modifications	3.4E-02					
LaSalle Units 1&2	4.74E-05	3.82E-05	80.6	4/.975/-/1	dc load shed, New batteries	9.60E-02	1				
Limerick Units 1&2	4.30E-06	1.0E-07	NMN	4/.95/60/3	Upgraded cross-ties	5.9E-02					
Monticello	2.60E-05	1.20E-05	46.2	4/.95/-/1	dc load shed	7.90E-02					
Nine Mile Point Unit 1	5.50E-06	3.50E-06	NMN	4/.975/-/1	dc load shed, added two safety related batteries	5.00E-02	4			595	
Nine Mile Point Unit 2	3.10E-05	5.50E-06	17.7	4/.975/-/1	dc load shed	1.20E-01					

Plant-Specific Station Blackout Information by Reactor Type and Operating Status

Table B-2 Operating boiling-water reactors (Cont.)

Plant	Plant CDF	SBO CDF	Percent SBO CDF of Plant CDF	Coping time in hours/EDG reliability/Aac access time in minutes/ extremely severe weather	Modification summary including dc load shed procedural modifications	SBO factors					
						PRA LOOP initiating event frequency	Number of LOOP events at power since commercial operation			LOOP event recovery times ≥ 240 minutes	
							Plant	Weather	Grid	Power	Shutdown
Oyster Creek	3.90E-06	2.30E-06	NMN	4/.975/60/1	Added crosstie & reactor pressure indication	3.26E-02	3				240
Peach Bottom Units 2 & 3	5.53E-06	4.81E-07	8.7	8/.975/60/3	Cross-tie to hydro unit	5.9E-02					
Perry	1.30E-05	2.25E-06	43.4	4/.95/10/1	Replaced selected cables	6.09E-02					
Pilgrim	5.80E-05	1.0E-10	NMN	8/.975/10/4	Alarms to line-up Aac	6.17E-01	1	5			1263 534
Quad Cities Units 1&2	1.2E-06	5.72E-07	NMN	4/.95/60/1	Added 2 DGs	4.81E-02	2				
River Bend	1.55E-05	1.35E-05	87.5	4/.95/-/2	Minor structural mod	3.50E-02	1				
Susquehanna Units 1&2	1.7E-05	4.2E-11	NMN	4/.975/-/2	dc load shed	-	1				
Vermont Yankee	4.30E-06	9.17E-07	21.3	8/.975/10/4	Modified incoming line and controls	1.0E-01	2			277	
Washington Nuclear Plant Unit 2	1.73E-05	1.07E-05	61.1	4/.95/-/1	dc load shed, replaced inverters	2.46E-02					

NRC INSPECTION MANUAL

IPAB

MANUAL CHAPTER 0308

REACTOR OVERSIGHT PROCESS (ROP)
BASIS DOCUMENT

0308-01 PURPOSE

To describe the basis for the significant decisions reached by the U.S. Nuclear Regulatory Commission (NRC) staff during the development and implementation of the Reactor Oversight Process (ROP) for operating commercial nuclear power plants. This document shall serve as the source information for all applicable program documents such as manual chapters, performance indicator guidance, and assessment guidance.

0308-02 OBJECTIVES

02.01 To discuss significant developmental steps and decisions reached.

02.02 To describe in general how the processes work and why they are setup the way they are.

02.03 To summarize the history of, and reasons for, significant changes made to the oversight processes.

02.04 To explain those significant attributes that were considered but not used in the ROP, and the basis for the decision not to include them in the process.

0308-03 DEFINITIONS

None stated.

0308-04 RESPONSIBILITIES AND AUTHORITIES

None stated.

0308-05 GENERAL REQUIREMENTS

05.01 Introduction

On April 2, 2000, the NRC implemented a new ROP at all operating commercial nuclear power plants. The objectives of the staff in developing the various components of this new

Table 2 Other Inspection Program Elements Considered But Not Included (continued)			
Inspectable Area or Program Attribute	**Cornerstone**	**Scope**	**Basis for Not Including in Baseline Inspection Program**
Severe Accident Management Guidelines (SAMG)	Emergency Preparedness	SAMGs include strategies for dealing with accidents that impact RCS integrity. SAMGs are sometimes implemented during EP drills and must be written is such a manner as to not impede implementation of the Plan.	The staff concluded that regular inspection of SAMG was not appropriate because the guidelines are voluntary and have no regulatory basis. The emergency response organization that would implement SAMGs is inspected through EP baseline inspection and performance is covered by two PIs.
Radiation Worker Performance	Occupational and Public Rad Safety	The objective of this area is to verify that workers understand the radiological hazards associated with nuclear plant operation, effectively identify and control these hazards, identify and resolve adverse trends or deficiencies, and maintain proper oversight of work.	Worker performance is a cross cutting area. Since the PIs are performance based, problems in this area should result in an operational occurrence that meets the definition of a PI.

Standard Technical Specifications General Electric Plants, BWR/4

Specifications

This electronic text represents the Commission's current Standard Technical Specifications. This document is updated periodically to incorporate NRC approved generic changes to the Standard Technical Specifications.

The last Standard Technical Specification NUREGs were published as Revision 3 of NUREG-1430, NUREG-1431, NUREG-1432, NUREG-1433, and NUREG-1434 in June 2004.

1.1 Definitions

LEAKAGE (continued)

b. Unidentified LEAKAGE

All LEAKAGE into the drywell that is not identified LEAKAGE,

c. Total LEAKAGE

Sum of the identified and unidentified LEAKAGE, and

d. Pressure Boundary LEAKAGE

LEAKAGE through a nonisolable fault in a Reactor Coolant System (RCS) component body, pipe wall, or vessel wall.

[LINEAR HEAT GENERATION RATE (LHGR)	The LHGR shall be the heat generation rate per unit length of fuel rod. It is the integral of the heat flux over the heat transfer area associated with the unit length.]
LOGIC SYSTEM FUNCTIONAL TEST	A LOGIC SYSTEM FUNCTIONAL TEST shall be a test of all logic components required for OPERABILITY of a logic circuit, from as close to the sensor as practicable up to, but not including, the actuated device, to verify OPERABILITY. The LOGIC SYSTEM FUNCTIONAL TEST may be performed by means of any series of sequential, overlapping, or total system steps so that the entire logic system is tested.
[MAXIMUM FRACTION OF LIMITING POWER DENSITY (MFLPD)	The MFLPD shall be the largest value of the fraction of limiting power density in the core. The fraction of limiting power density shall be the LHGR existing at a given location divided by the specified LHGR limit for that bundle type.]
MINIMUM CRITICAL POWER RATIO (MCPR)	The MCPR shall be the smallest critical power ratio (CPR) that exists in the core [for each class of fuel]. The CPR is that power in the assembly that is calculated by application of the appropriate correlation(s) to cause some point in the assembly to experience boiling transition, divided by the actual assembly operating power.
MODE	A MODE shall correspond to any one inclusive combination of mode switch position, average reactor coolant temperature, and reactor vessel head closure bolt tensioning specified in Table 1.1-1 with fuel in the reactor vessel.

3.6 CONTAINMENT SYSTEMS

3.6.4.1 [Secondary] Containment

LCO 3.6.4.1 The [secondary] containment shall be OPERABLE.

APPLICABILITY: MODES 1, 2, and 3,
During movement of [recently] irradiated fuel assemblies in the [secondary] containment,
During operations with a potential for draining the reactor vessel (OPDRVs).

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. [Secondary] containment inoperable in MODE 1, 2, or 3.	A.1 Restore [secondary] containment to OPERABLE status.	4 hours
B. Required Action and associated Completion Time of Condition A not met.	B.1 Be in MODE 3. AND B.2 Be in MODE 4.	12 hours 36 hours
C. [Secondary] containment inoperable during movement of [recently] irradiated fuel assemblies in the [secondary] containment or during OPDRVs.	C.1 ---------------NOTE-------------- LCO 3.0.3 is not applicable. ------------------------------------- Suspend movement of [recently] irradiated fuel assemblies in the [secondary] containment. AND C.2 Initiate action to suspend OPDRVs.	 Immediately Immediately

3.7 PLANT SYSTEMS

3.7.8 Spent Fuel Storage Pool Water Level

LCO 3.7.8 The spent fuel storage pool water level shall be ≥ [23] ft over the top of irradiated fuel assemblies seated in the spent fuel storage pool racks.

APPLICABILITY: During movement of irradiated fuel assemblies in the spent fuel storage pool.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. Spent fuel storage pool water level not within limit.	A.1 ---------------NOTE-------------- LCO 3.0.3 is not applicable. ------------------------------------- Suspend movement of irradiated fuel assemblies in the spent fuel storage pool.	 Immediately

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.7.8.1	Verify the spent fuel storage pool water level is ≥ [23] ft over the top of irradiated fuel assemblies seated in the spent fuel storage pool racks.	7 days

3.8 ELECTRICAL POWER SYSTEMS

3.8.2 AC Sources - Shutdown

LCO 3.8.2 The following AC electrical power sources shall be OPERABLE:

a. One qualified circuit between the offsite transmission network and the onsite Class 1E AC electrical power distribution subsystem(s) required by LCO 3.8.10, "Distribution Systems - Shutdown" and

b. One diesel generator (DG) capable of supplying one division of the onsite Class 1E AC electrical power distribution subsystem(s) required by LCO 3.8.10.

APPLICABILITY: MODES 4 and 5,
During movement of [recently] irradiated fuel assemblies in the [secondary] containment.

ACTIONS

---NOTE---
LCO 3.0.3 is not applicable.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One required offsite circuit inoperable.	--------------------NOTE------------------- Enter applicable Condition and Required Actions of LCO 3.8.10, with one required division de-energized as a result of Condition A. --- A.1 Declare affected required feature(s), with no offsite power available, inoperable. <u>OR</u>	 Immediately

3.8 ELECTRICAL POWER SYSTEMS

3.8.5 DC Sources - Shutdown

LCO 3.8.5 [DC electrical power subsystems shall be OPERABLE to support the DC electrical power distribution subsystem(s) required by LCO 3.8.10, "Distribution Systems - Shutdown."]

[One DC electrical power subsystem shall be OPERABLE.]

-----------------------------------REVIEWER'S NOTE---------------------------------
This second option above applies for plants having a pre-ITS licensing basis (CTS) for electrical power requirements during shutdown conditions that required only one DC electrical power subsystem to be OPERABLE. Action A and the bracketed optional wording in Condition B are also eliminated for this case. The first option above is adopted for plants that have a CTS requiring the same level of DC electrical power subsystem support as is required for power operating conditions.

APPLICABILITY: MODES 4 and 5,
During movement of [recently] irradiated fuel assemblies in the [secondary] containment.

ACTIONS

---NOTE---
LCO 3.0.3 is not applicable.

CONDITION	REQUIRED ACTION	COMPLETION TIME
[A. One [or two] battery charger[s on one division] inoperable. AND The redundant division battery and charger[s] OPERABLE.	A.1 Restore battery terminal voltage to greater than or equal to the minimum established float voltage. AND	2 hours

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

NUCLEAR POWER:

Still Not Viable without Subsidies

Executive Summary

February 2011

Conspicuously absent from industry press releases and briefing memos touting nuclear power's potential as a solution to global warming is any mention of the industry's long and expensive history of taxpayer subsidies and excessive charges to utility ratepayers. These subsidies not only enabled the nation's existing reactors to be built in the first place, but have also supported their operation for decades.

The industry and its allies are now pressuring all levels of government for large new subsidies to support the construction and operation of a new generation of reactors and fuel-cycle facilities. The substantial political support the industry has attracted thus far rests largely on an uncritical acceptance of the industry's economic claims and an incomplete understanding of the subsidies that made—and continue to make—the existing nuclear fleet possible.

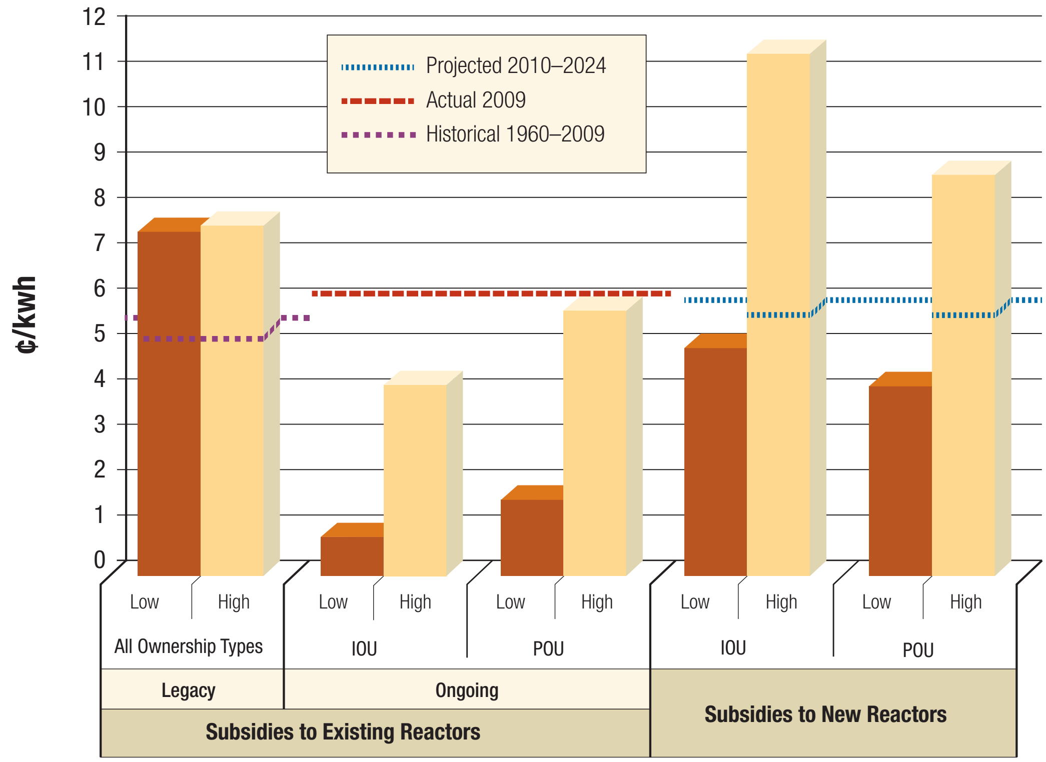
Such blind acceptance is an unwarranted, expensive leap of faith that could set back more cost-effective efforts to combat climate change. A fair comparison of the available options for reducing heat-trapping carbon emissions while generating electricity requires consideration not only of the private costs of building plants and their associated infrastructure but also of the public subsidies given to the industry. Moreover, nuclear power brings with it important economic, waste disposal, safety, and security risks unique among low-carbon energy sources. Shifting these risks and their associated costs onto the public is the major goal of the new subsidies sought by the industry (just as it was in the past), and by not incorporating these costs into its estimates, the industry presents a skewed economic picture of nuclear power's value compared with other low-carbon power sources.

SUBSIDIES OFTEN EXCEED THE VALUE OF THE ENERGY PRODUCED

This report catalogues in one place and for the first time the full range of subsidies that benefit the nuclear power sector. The findings are striking: since its inception more than 50 years ago, the nuclear power industry has benefited—and continues to benefit—from a vast array of preferential government subsidies. Indeed, as Figure ES-1 (p. 2) shows, subsidies to the nuclear fuel cycle have often exceeded the value of the power produced. This means that buying power on the open market and giving it away for free would have been less costly than subsidizing the construction and operation of nuclear power plants. Subsidies to new reactors are on a similar path.

Since its inception more than 50 years ago, the nuclear power industry has benefited—and continues to benefit—from a vast array of preferential government subsidies.

Figure ES-1. Nuclear Subsidies Compared to EIA Power Prices



Note: Legacy subsidies are compared to the Energy Information Administration (EIA) average 1960–2009 industrial power price (5.4 ¢/kWh). Ongoing subsidies are compared to EIA 2009 actual power prices for comparable busbar plant generation costs (5.9 ¢/kWh). Subsidies to new reactors are compared to EIA 2009 reference-case power prices for comparable busbar plant generation costs (5.7 ¢/kWh).

Throughout its history, the industry has argued that subsidies were only temporary, a short-term stimulus so the industry could work through early technical hurdles that prevented economical reactor operation. A 1954 advertisement from General Electric stated that, "In five years—certainly within ten," civilian reactors would be "privately financed, built without government subsidy." That day never arrived and, despite industry claims to the contrary, remains as elusive as ever.

The most important subsidies to the industry do not involve cash payments. Rather, they shift construction-cost and operating risks from investors to taxpayers and ratepayers, burdening taxpayers with an array of risks ranging from cost overruns and defaults to accidents and nuclear waste management. This approach, which has remained remarkably consistent throughout the industry's history, distorts market choices that would otherwise favor less risky investments. Although it may not involve direct cash payments, such favored treatment is nevertheless a subsidy, with a profound effect on the bottom line for the industry and taxpayers alike.

Reactor owners, therefore, have never been economically responsible for the full costs and risks of their operations. Instead, the public faces the prospect of severe losses in the event of any number of potential adverse scenarios, while private investors reap the rewards if nuclear plants are economically successful. For all practical purposes, nuclear power's economic gains are privatized, while its risks are socialized.

Recent experiences in the housing and financial markets amply demonstrate the folly of arrangements that separate investor risk from reward. Indeed, massive new subsidies to nuclear power could encourage utilities to make similarly speculative, expensive investments in nuclear plants—investments that would never be tolerated if the actual risks were properly accounted for and allocated.

While the purpose of this report is to quantify the extent of past and existing subsidies, we are not blind to the context: the industry is calling for even more support from Congress. Though the value of these new subsidies is not quantified in this report, it is clear that they would only further increase the taxpayers' tab for nuclear power while shifting even more of the risks onto the public.

LOW-COST CLAIMS FOR EXISTING REACTORS IGNORE HISTORICAL SUBSIDIES

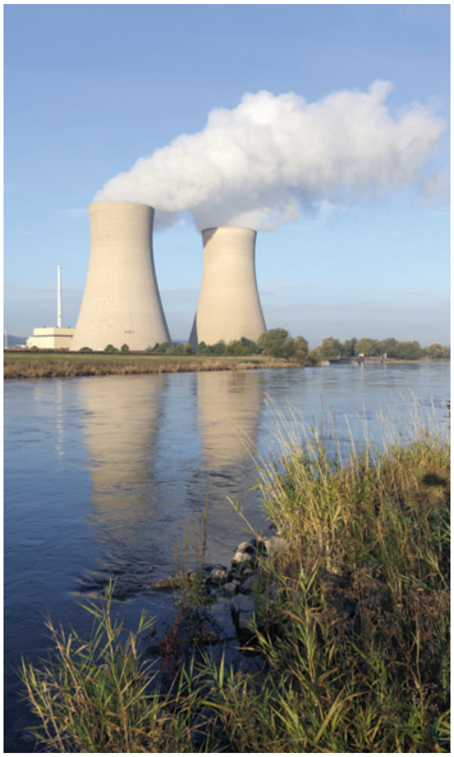
The nuclear industry is only able to portray itself as a low-cost power supplier today because of past government subsidies and write-offs. First, the industry received massive subsidies at its inception, reducing both the capital costs it needed to recover from ratepayers (the "legacy" subsidies that underwrote reactor construction through the 1980s) and its operating costs (through ongoing subsidies to inputs, waste management, and accident risks). Second, the industry wrote down tens of billions of dollars in capital costs after its first generation of reactors experienced large cost overruns, cancellations, and plant abandonments, further reducing the industry's capital-recovery requirements. Finally, when industry restructuring revealed that nuclear power costs were still too high to be competitive, so-called stranded costs were shifted to utility ratepayers, allowing the reactors to continue operating.

These legacy subsidies are estimated to exceed seven cents per kilowatt-hour (¢/kWh)—an amount equal to about 140 percent of the average wholesale price of power from 1960 to 2008, making the subsidies more valuable than the power produced by nuclear plants over that period. Without these subsidies, the industry would have faced a very different market reality—one in which many reactors would never have been built, and utilities that did build reactors would have been forced to charge consumers even higher rates.

ONGOING SUBSIDIES CONTRIBUTE TO NUCLEAR POWER'S PERCEIVED COST ADVANTAGE

In addition to legacy subsidies, the industry continues to benefit from subsidies that offset the costs of uranium, insurance and liability, plant security, cooling water, waste disposal, and plant decommissioning. The value of these subsidies is harder to pin down with specificity, with estimates ranging from a low of 13 percent of the value of the power produced to a high of 98 percent. The breadth of this range largely reflects three main factors: uncertainty over the dollar value of accident liability caps; the value to publicly owned utilities (POUs) of ongoing subsidies such as tax breaks and low return-on-investment requirements; and generous capital

Massive new subsidies to nuclear power could encourage speculative, expensive investments in nuclear plants that would never be tolerated if the actual risks were properly accounted for and allocated.



Legacy and ongoing subsidies to existing reactors are not sufficient to attract new investment in nuclear infrastructure. Thus an array of new subsidies was rolled out during the past decade, targeting not only reactors but also other fuel-cycle facilities.

subsidies to investor-owned utilities (IOUs) that have declined as the aging, installed capacity base is fully written off.

Our low-end estimate for subsidies to existing reactors (in this case, investor-owned facilities) is 0.7 ¢/kWh, a figure that may seem relatively small at only 13 percent of the value of the power produced. However, it represents more than 35 percent of the nuclear production costs (operation and maintenance costs plus fuel costs, without capital recovery) often cited by the industry's main trade association as a core indicator of nuclear power's competitiveness; it also represents nearly 80 percent of the production-cost advantage of nuclear relative to coal. With ongoing subsidies to POUs nearly double those to IOUs, the impact on competitive viability is proportionally higher for publicly owned plants.

SUBSIDIES TO NEW REACTORS REPEAT PAST PATTERNS

Legacy and ongoing subsidies to existing reactors may be important factors in keeping facilities operating, but they are not sufficient to attract new investment in nuclear infrastructure. Thus an array of new subsidies was rolled out during the past decade, targeting not only reactors but also other fuel-cycle facilities. Despite the profoundly poor investment experience with taxpayer subsidies to nuclear plants over the past 50 years, the objectives of these new subsidies are precisely the same as the earlier subsidies: to reduce the private cost of capital for new nuclear reactors and to shift the long-term, often multi-generational risks of the nuclear fuel cycle away from investors. And once again, these subsidies to new reactors—whether publicly or privately owned—could end up exceeding the value of the power produced (4.2 to 11.4 ¢/kWh, or 70 to 200 percent of the projected value of the power).

It should be noted that certain subsidies to new reactors are currently capped at a specific dollar amount, limited to a specific number of reactors, or available only in specific states or localities. Therefore, although all the subsidies may not be available to each new reactor, the values shown in Figure ES-1 are reasonably representative of the subsidies that will be available to the first new plants to be built. Furthermore, it is far from clear whether existing caps will be binding. Recent legislative initiatives would expand eligibility for these subsidies to even more reactors and extend the period of eligibility during which these subsidies would be available.

KEY SUBSIDY FINDINGS

Government subsidies have been directed to every part of the nuclear fuel cycle. The most significant forms of support have had four main goals: reducing the cost of

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Methodology: How We Estimated Nuclear Subsidies

Identifying and valuing subsidies to the nuclear fuel cycle for this report involved a broad review of dozens of historical studies and program assessments, industry statements and presentations, and government documents. The result is an in-depth and comprehensive evaluation that groups nuclear subsidies by type of plant ownership (public or private), time frame of support (whether the subsidy is ongoing or has expired), and the specific attribute of nuclear power production the subsidy is intended to support.

Plant ownership

Subsidies available to investor-owned and publicly owned utilities are not identical, so were tracked separately.

Time frame of support

The data were organized into:

- **Legacy subsidies**, which were critical in helping nuclear power gain a solid foothold in the U.S. energy sector but no longer significantly affect pricing
- **Ongoing subsidies to existing reactors**, which continue to affect the cost of electricity produced by the 104 U.S. nuclear reactors operating today
- **Subsidies to new reactors**, which are generally provided in addition to the ongoing subsidies available to existing reactors

A further set of subsidies proposed for the nuclear sector but not presently in U.S. statutes is discussed qualitatively but not quantified.

Attribute of production

The following subcategories were modeled on the structure commonly used internationally (as by the Organisation for Economic Cooperation and Development):

- **Factors of production**—subsidies intended to offset the cost of capital, labor, and land
- **Intermediate inputs**—subsidies that alter the economics of key inputs such as uranium, enrichment services, and cooling water
- **Output-linked support**—subsidies commensurate with the quantity of power produced
- **Security and risk management**—subsidies that address the unique and substantial safety risks inherent in nuclear power
- **Decommissioning and waste management**—subsidies that offset the environmental or plant-closure costs unique to nuclear power

To enable appropriate comparisons with other energy options, the results are presented in terms of levelized cents per kilowatt-hour and as a share of the wholesale value of the power produced. Inclusion of industry and historical data sources for some component estimates means that some of the levelization inputs were not transparent. Where appropriate, a range of estimates was used to reflect variation in the available data or plausible assumptions.

capital, labor, and land (i.e., factors of production), masking the true costs of producing nuclear energy ("intermediate inputs"), shifting security and accident risks to the public, and shifting long-term operating risks (decommissioning and waste management) to the public. A new category of subsidy, "output-linked support," is directed at reducing the price of power produced. Table ES-1 (p. 6) shows the estimated value of these subsidies to existing and new reactors. The subsequent sections discuss each type of subsidy in more detail.

A. Reducing the Cost of Capital, Labor, and Land (Factors of Production)

Nuclear power is a capital-intensive industry with long and often uncertain build times that exacerbate both the cost of financing during construction and the market risks of misjudging demand. Historically, investment tax credits, accelerated depreciation, and other capital subsidies have been the dominant type of government support for the industry, while subsidies associated with labor and land costs have provided lesser (though still relevant) support.

Legacy subsidies that reduced the costs of these inputs were high, estimated at 7.2 ¢/kWh. Ongoing subsidies to existing reactors are much lower but still significant, ranging from 0.06 to 1.94 ¢/kWh depending on ownership structure. For new reactors, accelerated depreciation has been supplemented with a variety of other capital subsidies to bring plant costs down by shifting a large portion of the capital risk from investors to taxpayers.

The total value of subsidies available to new reactors in this category is significant for both POUs and IOUs, ranging from 3.51 to 6.58 ¢/kWh. These include:

- **Federal loan guarantees.** Authorized under Title 17 of the Energy Policy Act (EPACT) of 2005, federal loan guarantees are the largest construction subsidy for new, investor-owned reactors, effectively shifting the costs and risks of financing and building a nuclear plant from investors to taxpayers. The industry's own estimates, which we have used despite large subsequent increases in expected plant costs, place the value of this program between 2.5 and 3.7 ¢/kWh. Total loan guarantees are currently limited to $22.5 billion for new plants and enrichment facilities, but the industry has been lobbying for much higher levels.

Federal loan guarantees are the largest construction subsidy for new, investor-owned reactors, effectively shifting the costs and risks of financing and building a nuclear plant from investors to taxpayers.

Loan guarantees not only allow firms to obtain lower-cost debt, but enable them to use much more of it—up to 80 percent of the project's cost. For a

Table ES-1. Subsidies to Existing and New Reactors

	Subsidies to Existing Reactors (¢/kWh)			Subsidies to New Reactors (¢/kWh)	
	Legacy	Ongoing			
Subsidy Type	All Ownership Types	IOU	POU	IOU	POU
Factors of production	7.20	0.06	0.96–1.94	3.51–6.58	3.73–5.22
Intermediate inputs	0.10–0.24	0.29–0.51	0.16–0.18	0.21–0.42	0.21–0.42
Output-linked support	0.00	0.00	0.00	1.05–1.45	0.00
Security and risk management	0.21–0.22	0.10–2.50	0.10–2.50	0.10–2.50	0.10–2.50
Decommissioning and waste management	No data available	0.29–1.09	0.31–1.15	0.13–0.48	0.16–0.54
Total	**7.50–7.66**	**0.74–4.16**	**1.53–5.77**	**5.01–11.42**	**4.20–8.68**
Share of power price	139%–142%	13%–70%	26%–98%	84%–190% (high)	70%–145% (high)
				88%–200% (reference)	74%–152% (reference)

Note: A range of subsidy values is used where there was a variance in available subsidy estimates. To determine the subsidy's share of the market value of the power produced, legacy subsidies are compared to the Energy Information Administration (EIA) average 1960–2009 industrial power price (5.4 ¢/kWh). Ongoing subsidies are compared to EIA 2009 power prices for comparable busbar plant generation costs (5.9 ¢/kWh). Subsidies to new reactors are compared to EIA 2009 high- and reference-case power prices for comparable busbar plant generation costs (6.0 and 5.7 ¢/kWh, respectively); using the low case would have resulted in even higher numbers.

single 1,600-megawatt (MW) reactor, the loan guarantee alone would generate subsidies of $495 million per year, or roughly $15 billion over the 30-year life of the guarantee.

- **Accelerated depreciation.** Allowing utilities to depreciate new reactors over 15 years instead of their typical asset life (between 40 and 60 years) will provide the typical plant with a tax break of approximately $40 million to $80 million per year at current construction cost estimates. Rising plant costs, longer service lives, and lower capacity factors would all increase the value of current accelerated depreciation rules to IOUs. This subsidy is not available to POUs because they pay no taxes.
- **Subsidized borrowing costs to POUs.** The most significant subsidy available to new publicly owned reactors is the reduced cost of borrowing made possible by municipal bonds and new Build America Bonds, which could be worth more than 3 ¢/kWh.

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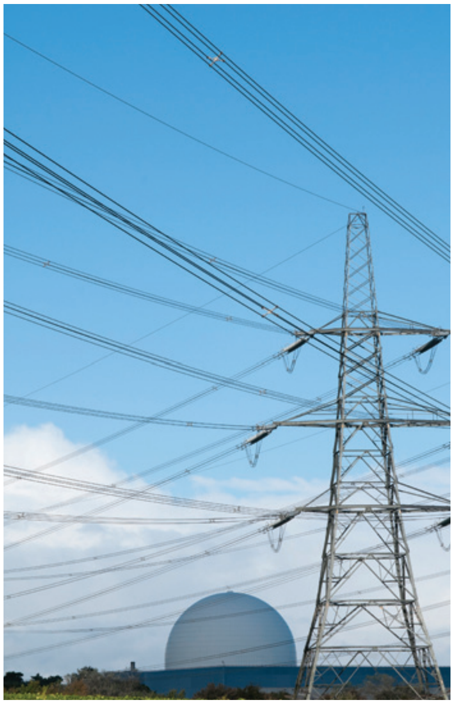
- **Construction work in progress.** Many states allow utilities to charge ratepayers for construction work in progress (CWIP) by adding a surcharge to customers' bills. This shifts financing and construction risks (including the risk of cost escalations and/or plants being abandoned during construction) from investors to customers. CWIP benefits both POUs and IOUs and is estimated to be worth between 0.41 and 0.97 ¢/kWh for new reactors.
- **Property-tax abatements.** Support for new plants is also available through state and local governments, which provide a variety of plant-specific subsidies that vary by project.

B. Masking the True Costs of Producing Nuclear Energy (Intermediate Inputs)

A variety of subsidies masks the costs of the inputs used to produce nuclear power. Uranium fuel costs, for example, are not a major element in nuclear economics, but subsidies to mining and enrichment operations contribute to the perception of nuclear power as a low-cost energy source. In addition, the under-pricing of water used in bulk by nuclear reactors has significant cost implications. The value of such legacy subsidies to existing reactors is estimated between 0.10 and 0.24 ¢/kWh, and the value of ongoing subsidies is estimated between 0.16 and 0.51 ¢/kWh. The value of



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such subsidies to new reactors is estimated between 0.21 and 0.42 ¢/kWh. Subsidized inputs include:

- **Fuel.** The industry continues to receive a special depletion allowance for uranium mining equal to 22 percent of the ore's market value, and its deductions are allowed to exceed the gross investment in a given mine. In addition, uranium mining on public lands is governed by the antiquated Mining Law of 1872, which allows valuable ore to be taken with no royalties paid to taxpayers. Although no relevant data have been collected on the approximately 4,000 mines from which uranium has been extracted in the past, environmental remediation costs at some U.S. uranium milling sites actually exceeded the market value of the ore extracted.

- **Uranium enrichment.** Uranium enrichment, which turns mined ore into reactor fuel, has benefited from substantial legacy subsidies. New plants that add enrichment capacity will receive subsidies as well, in the form of federal loan guarantees. Congress has already authorized $2 billion in loan guarantees for a new U.S. enrichment facility, and the Department of Energy has allocated an additional $2 billion for this purpose. While we could not estimate the per-kilowatt-hour cost of this subsidy because it depends on how much enrichment capacity is built, the $4 billion represents a significant new subsidy to this stage of the fuel cycle.
- **Cooling water.** Under-priced cooling water is an often-ignored subsidy to nuclear power, which is the most water-intensive large-scale thermal energy technology in use. Even when the water is returned to its source, the large withdrawals alter stream flow and thermal patterns, causing environmental damage. Available data suggest that reactor owners pay little or nothing for the water consumed, and are often given priority access to water resources—including exemption from drought restrictions that affect other users. While we provide a low estimate of water subsidies (between $600 million and $700 million per year for existing reactors), more work is needed to accurately quantify this subsidy—particularly as water resources become more constrained in a warming climate.

Nuclear power is the most water-intensive large-scale thermal energy technology in use. The large withdrawals alter stream flow and thermal patterns, causing environmental damage.

C. Reducing the Price of Power Produced (Output-Linked Support)

Until recently, subsidies linked to plant output were not a factor for nuclear power. That changed with the passage of EPACT in 2005, which granted new reactors an important subsidy in the form of:

- **Production tax credits (PTCs).** A PTC will be granted for each kilowatt-hour generated during a new reactor's first eight years of operation; at present, this credit is available only to the first plants to be built, up to a combined total capacity of six gigawatts. While EPACT provides a nominal PTC of 1.8 ¢/kWh, payments are time-limited. Over the full life of the plant, the PTC is worth between 1.05 and 1.45 ¢/kWh. Under current law, PTCs are not available to POUs (since POUs do not pay taxes), but there have been legislative efforts to enable POUs to capture the value of the tax credits by selling or transferring them to other project investors that do pay taxes.

D. Shifting Security and Accident Risks to the Public (Security and Risk Management)

Subsidies that shift long-term risks to the public have been in place for many years. The Price-Anderson Act, which caps the nuclear industry's liability for third-party damage to people and property, has been a central subsidy to the industry for more than half a century.

Plant security concerns have increased significantly since 9/11, and proliferation risks will increase in proportion to any expansion of the civilian nuclear sector (both in the United States and abroad). The complexity and lack of data in these areas made it impossible to quantify the magnitude of security subsidies for this analysis. But it is clear that as the magnitude of the threat increases, taxpayers will be forced to bear a greater share of the risk. Subsidies that shift these risks are associated with:

- **The Price-Anderson Act.** This law requires utilities to carry a pre-set amount of insurance for off-site damages caused by a nuclear plant accident, and to contribute to an additional

The Industry's Shopping List: New Subsidies Under Consideration

The following nuclear subsidies, as proposed in the American Power Act (APA) and the American Clean Energy Leadership Act (ACELA), would not necessarily be available to every new reactor, but their collective value to the industry would be significant:

- A clean-energy bank that could promote nuclear power through much larger loans, letters of credit, loan guarantees, and other credit instruments than is currently possible
- Tripling federal loan guarantees available to nuclear reactors through the Department of Energy, from $18.5 billion to $54 billion
- Reducing the depreciation period for new reactors from 15 years to five
- A 10 percent investment tax credit for private investors or federal grants in lieu of tax payments to publicly owned and cooperative utilities
- Expanding the existing production tax credit from 6,000 to 8,000 megawatts, and permitting tax-exempt entities to allocate their available credits to private partners
- Permitting tax-exempt bonds to be used for public-private partnerships, which would allow POUs to issue tax-free, low-cost bonds for nuclear plants developed jointly with private interests
- Expanding federal regulatory risk insurance coverage from $2 billion to $6 billion (up to $500 million per reactor), which would further shield plant developers from costs associated with regulatory or legal delays

pool of funds meant to cover a pre-set portion of the damages. However, the law limits total industry liability to a level much lower than would be needed in a variety of plausible accident scenarios. This constitutes a subsidy when compared with other energy sources that are required to carry full private liability insurance, and benefits both existing and new reactors.

Only a few analysts have attempted to determine the value of this subsidy over its existence, with widely divergent results: between 0.1 and 2.5 ¢/kWh. More work is therefore needed to determine how the liability cap affects plant economics, risk-control decisions, and risks to the adjacent population.

- **Plant security.** Reactor operators must provide security against terrorist attacks or other threats of a certain magnitude, referred to as the "design basis threat." For threats of a greater magnitude (a larger number of attackers, for example), the government assumes all financial responsibility, which constitutes another type of subsidy. It is difficult to quantify the value of this taxpayer-provided benefit because competing forms of energy do not carry similar risks. But it is important that plant security costs be reflected in the cost of power delivered to consumers, rather than supported by taxpayers in general.
- **Proliferation.** The link between an expanded civilian nuclear sector and proliferation of nuclear weapons or weapons technology is fairly widely accepted. It is also consistently ignored when assessing plant costs—much as investors in coal plants ignored the cost of carbon controls until recently. Though quantifying proliferation costs may be difficult, assuming they are zero is clearly wrong. These ancillary impacts should be fully assessed and integrated into the cost of nuclear power going forward.

E. Shifting Long-Term Operating Risks to the Public (Decommissioning and Waste Management)

The nuclear fuel cycle is unique in the types of long-term liabilities it creates. Reactors and fuel-cycle facilities have significant end-of-life liabilities associated with the proper closure, decommissioning, and decontamination of facilities, as well as the safe management of nuclear waste over thousands of years. The industry has little operational experience with such large and complex undertakings, greatly increasing the likelihood of dramatic cost overruns. In total, the subsidies that shift these long-term operating risks to the public amount to between 0.29 and 1.09 ¢/kWh for existing reactors and between 0.13 and 0.54 ¢/kWh for new reactors. The specific subsidies that do the shifting are associated with:

- **Nuclear waste management.** The federal Nuclear Waste Repository for spent fuel is expected to cost nearly $100 billion over its projected operating life, 80 percent of which is attributed to the power sector. A congressionally mandated fee on nuclear power consumers, earmarked for the repository, has collected roughly $31 billion in waste-disposal fees through 2009. There is no mechanism other than investment returns on collections to fully fund the repository once reactors close.

  The repository confers a variety of subsidies to the nuclear sector. First, despite its complexity and sizable investment, the repository is structured to operate on a break-even basis at best, with no required return on investment. Second, utilities do not have to pay any fee to secure repository capacity; in fact, they are allowed to defer payments for waste generated prior to the repository program's creation, at interest rates well below their cost of capital. Third, the significant risk of delays and cost overruns will be borne by taxpayers rather than the program's beneficiaries. Delays in the repository's opening have already triggered a rash of lawsuits and taxpayer-funded waste storage at reactor sites, at a cost between $12 billion and $50 billion.

- **Plant decommissioning.** While funds are collected during plant operation for decommissioning once the plant's life span has ended, reduced tax rates on nuclear decommissioning trust funds provide an annual subsidy to existing reactors of between $450 million and $1.1 billion per year. Meanwhile, concerns persist about whether the funds accrued will be sufficient to cover the costs; in 2009, the Nuclear Regulatory Commission (NRC) notified the operators of roughly one-quarter of the nation's reactor fleet about the potential for insufficient funding. We did not quantify the cost of this potential shortfall.

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CONCLUSIONS AND POLICY RECOMMENDATIONS

Historical subsidies to nuclear power have already resulted in hundreds of billions of dollars in costs paid by taxpayers and ratepayers. With escalating plant costs and more competitive power markets, the cost of repeating these failed policies will likely be even higher this time around. Of equal importance, however, is the fact that subsidies to nuclear power also carry significant opportunity costs for reducing global warming emissions because reactors are so expensive and require such long lead times to construct. In other words, massive subsidies designed to help underwrite the large-scale expansion of the nuclear industry will delay or diminish investments in less expensive abatement options.

Other energy technologies would be able to compete with nuclear power far more effectively if the government focused on creating an energy-neutral playing field rather than picking technology winners and losers. The policy choice to invest in nuclear also carries with it a risk unique to the nuclear fuel cycle: greatly exacerbating already thorny proliferation challenges as reactors and ancillary fuel-cycle facilities expand throughout the world.

As this report amply demonstrates, taxpayer subsidies to nuclear power have provided an indispensable foundation for the industry's existence, growth, and survival. But instead of reworking its business model to more effectively manage and internalize its operational and construction risks, the industry is pinning its hopes on a new wave of taxpayer subsidies to prop up a new generation of reactors.

Future choices about U.S. energy policy should be made with a full understanding of the hidden taxpayer costs now embedded in nuclear power. To accomplish this goal, we offer the following recommendations:

- **Reduce, not expand, subsidies to the nuclear power industry**. Federal involvement in energy markets should instead focus on encouraging firms involved in nuclear power—some of the largest corporations in the world—to create new models for internal risk pooling and to develop advanced power contracts that enable high-risk projects to move forward without additional taxpayer risk.
- **Award subsidies to low-carbon energy sources on the basis of a competitive bidding process across all competing technologies.** Subsidies should be awarded to those approaches able to achieve emissions reductions at the lowest possible cost per unit of abatement—not on the basis of congressional earmarks for specific types of energy.
- **Modernize liability systems for nuclear power.** Liability systems should reflect current options in risk syndication, more robust requirements for the private sector, and more extensive testing of the current rules for excess risk concentration and counterparty risks. These steps are necessary to ensure coverage will actually be available when needed, and to send more accurate risk-related price signals to investors and power consumers.
- **Establish proper regulation and fee structures for uranium mining.** Policy reforms are needed to eliminate outdated tax subsidies, adopt market-level royalties for uranium mines on public lands, and establish more appropriate bonding regimes for land reclamation.
- **Adopt a more market-oriented approach to financing the Nuclear Waste Repository.** The government should require sizeable waste management deposits by the industry, a repository fee structure that earns a return on investment at least comparable to other large utility projects,

Other energy technologies would be able to compete with nuclear power far more effectively if the government focused on creating an energy-neutral playing field rather than picking technology winners and losers.

and more equitable sharing of financial risks if additional delays occur.

- **Incorporate water pricing to allocate limited resources among competing demands, and integrate associated damages from large withdrawals.** The government should establish appropriate benchmarks for setting water prices that will be paid by utilities and other consumers, using a strategy that incorporates ecosystem damage as well as consumption-based charges.
- **Repeal decommissioning tax breaks and ensure greater transparency of nuclear decommissioning trusts (NDTs).** Eliminating existing tax breaks for NDTs would put nuclear power on a similar footing with other energy sources. More detailed and timely information on NDT funding and performance should be collected and publicized by the NRC.
- **Ensure that publicly owned utilities adopt appropriate risk assessment and asset management procedures.** POUs and relevant state regulatory agencies should review their internal procedures to be sure the financial and delivery risks of nuclear investments are appropriately compared with other options.
- **Roll back state construction-work-in-progress allowances and protect ratepayers against cost overruns by establishing clear limits on customer exposure.** States should also establish a refund mechanism for instances in which plant construction is cancelled after it has already begun.
- **Nuclear power should not be eligible for inclusion in a renewable portfolio standard.** Nuclear power is an established, mature technology with a long history of government support. Furthermore, nuclear plants are unique in their potential to cause catastrophic damage (due to accidents, sabotage, or terrorism); to produce very long-lived radioactive wastes; and to exacerbate nuclear proliferation.
- **Evaluate proliferation and terrorism as an externality of nuclear power.** The costs of preventing nuclear proliferation and terrorism should be recognized as negative externalities of civilian nuclear power, thoroughly evaluated, and integrated into economic assessments—just as global warming emissions are increasingly identified as a cost in the economics of coal-fired electricity.
- **Credit support for the nuclear fuel cycle via export credit agencies should explicitly integrate proliferation risks and require project-based credit screening.** Such support should require higher interest rates than those extended to other, less risky power projects, and include conditions on fuel-cycle investments to ensure the lending does not contribute to proliferation risks in the recipient country.

The full text of this report is available on the UCS website at *www.ucsusa.org/nuclear_power*.

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