The Westchester County Association Inc

The Westchester Public Issues Institute

Independent Minds • Independent Voices
Informed Decisions

JUNE 2002

THE PHYSICAL THREAT AT INDIAN POINT
A Review of the Issues

Introduction

Spurred by the events of 9/11, communities across the United States have re-examined points of possible vulnerability, including the potential risk posed by nuclear power plants. Only 20 miles north of New York City, the two operating nuclear reactors at Indian Point have received particular scrutiny.

The Westchester Public Issues Institute (WPII) has interviewed advocates and stakeholders on both sides of this vigorous debate and consulted sources deemed authoritative by both supporters and opponents of continued power production at Indian Point. The authors of this paper have assumed the role of *interested citizen*, asking questions that will help individuals assess the degree of risk involved in operating these two plants.[1]

Summary & Key Impressions

The arguments supporting or opposing closure of the Indian Point nuclear power plants are complex. The two sides of the debate bring a dramatically different perspective: Supporters of the plants argue that the *likelihood* of a serious event is very small. Opponents focus instead on the possible *consequences* of a major accident. WPII's researchers formed three key impressions:

- The spent fuel pools do not appear to be vulnerable to a 9/11-style attack. Tremendous explosive force, precisely positioned, would be required to expose spent fuel to the air. Even if this goal were achieved, responders would have multiple tools available to effectively protect the community from harm.
- Sudden and massive release of radioactivity can occur only after a powerful and highly sophisticated attack; events that justify evacuation are likely to develop slowly.
- When nuclear power plants malfunction, they cannot explode. There is no risk of a "mushroom cloud" at Indian Point.

Notwithstanding, additional steps can and should be taken to make the site safer than it is right now. Entergy, the community and the public sector must work together to improve both safety and public confidence.

Complicating the debate is the fact that the risk posed by the plant is only mitigated, not eliminated, by closure. Risk from spent fuel storage will remain until the fuel has cooled enough to enable it to be stored off site and another site (e.g., Yucca Mountain in Nevada) is ready to receive the shipment.

Should Indian Point Power Plants Be Closed?

Indian Point, located 20 miles north of New York City on the Hudson River in Westchester County, is home to three nuclear reactors. Indian Point 1, completed in 1962, ceased operation in 1974. Indian Point 2 (IP2) began generating power in 1974, Indian Point 3 (IP3) in 1976. Like all nuclear power plants, these plants were awarded a 40 year operating license by the Nuclear Regulatory Commission (NRC). The license at IP2 expires in September 2013; IP3's license expires in December 2015. This is not to say that the plants are certain to close at the end of the license period. The adjacent map (Figure 1) shows the location and relative age of all nuclear power plants operating in the United States. Nuclear power plants at ten sites are in the process of applying for a 20 year license renewal; some renewal applications have been granted (e.g. Entergy's Arkansas Nuclear One, granted a renewal from 2014 to 2034). The license renewal process includes both a technical review of safety issues and an environmental review.[2]

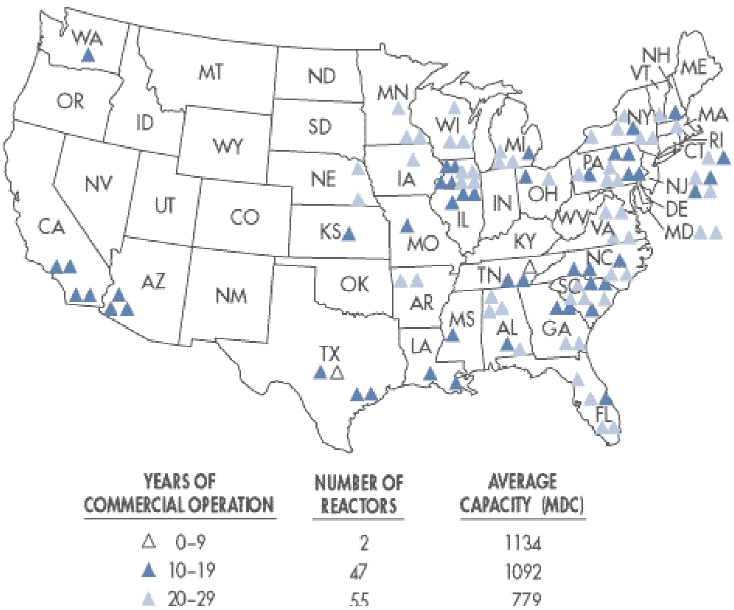

Figure 1: Map of Operating Nuclear Power Plants in U.S.

Source: Nuclear Regulatory Commission (NRC)

The Entergy Corporation purchased IP 3 from the NY Power Authority in November 2000; its purchase of IP 2 from Consolidated Edison was completed only five days before September 11, 2001. With the 9/11 events as context, Westchester and NYC residents have raised questions about the vulnerability of these plants to terrorist attack. Many have called for their closure.

Only the federal government (through the NRC) can close a nuclear power plant. Clearly local and state government officials can recommend certain actions but they do not have the power to force Entergy to cease producing electricity at Indian Point.

This paper considers the vulnerability of these plants to attack and assesses the consequences under several scenarios. The Westchester Public Issues Institute does not take a position on either side of the issue, although this paper does attempt to form impressions of the validity of competing claims. Our goal is to present the arguments developed by both sides of the debate to improve public understanding of the different perspectives.

A Nuclear Power Primer

Nuclear power plants use the heat of a controlled nuclear reaction to produce steam, which drives turbines, creating electricity. Any danger from nuclear power comes from a potential release of radioactivity. ***Nuclear power plants are not bombs and cannot malfunction to behave like bombs.***

Nuclear material is confined primarily to two areas: the reactors and the pools containing spent fuel. An accident causing significant loss of life must involve a release of radioactive material from one of these two sources.

The Reactor

The reactors at Indian Point are pressurized water reactors. Like all plants in the US, they use enriched uranium as fuel, which are produced as "rods" of uranium pellets bundled within a protective casing. These rods are placed in the reactor and bombarded with neutrons, causing some of the uranium atoms to fission, or split, into two lighter atoms, releasing tremendous energy. Each fission releases at least two neutrons, which proceed to bombard other uranium atoms, creating a chain reaction that increases exponentially until the reactor is producing the required amount of energy. Neutron-absorbing control rods are then lowered into the reactor until each fission produces only one other fission, and the plant is producing a constant stream of energy.

This energy heats compressed water passing around the rods, which is then piped through a tank of less-compressed water, turning it into steam. This steam spins the turbines, which generate electricity. (See Figure 2.)

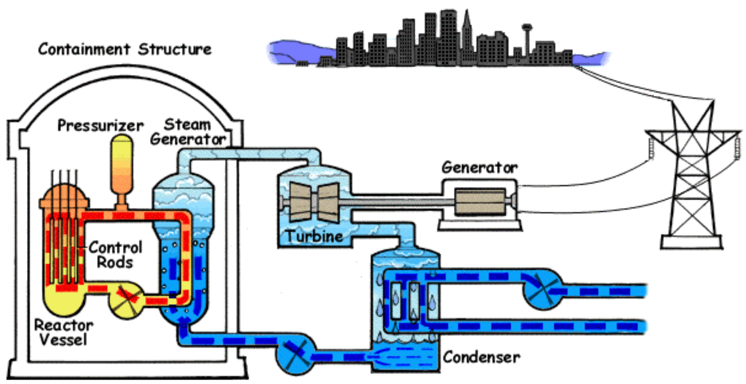

Figure 2: Diagram of a pressurized water reactor

Source: Nuclear Regulatory Commission (NRC) at
http://www.nrc.gov/reading-rm/basic-ref/students/animated-pwr.html

For safety reasons, the nuclear reactor is housed in a containment dome built of steel-reinforced concrete. In the event that an accident occurs at the reactor, the dome is designed to contain the radioactivity. The accidents at Chernobyl and Three Mile Island (TMI), for example, both involved a fuel meltdown. As TMI's reactor is housed in a containment dome, only a small amount of the radioactivity was released as a result of the accident. Without a containment structure, the Chernobyl accident released large amounts of radioactivity with serious and far-reaching consequences.

The containment domes at Indian Point are 3½ feet thick at the top and increase to an average of 4½ feet on the sidewalls. ***The area inside the containment domes is not filled with radioactivity.*** While some of the equipment housed inside the containment structure may be contaminated, a hole in the containment dome, by itself, is not dangerous. Its primary purpose is to contain the effects of an accident involving one of the reactors. Some workers at the plants enter the containment building as a normal part of their responsibilities.

Spent Fuel Pool

After about 18-24 months, the uranium in the rods has mostly split into various smaller, but still highly radioactive atoms, such as cesium and strontium. The reactions caused by continuing radioactive decay still generate a great deal of heat and radioactivity, but are no longer efficient for use in generating electricity. These "spent fuel" rods are removed from the reactor and stored in pools of circulating water. Water keeps the rods from overheating and melting their casings and also shields the area from

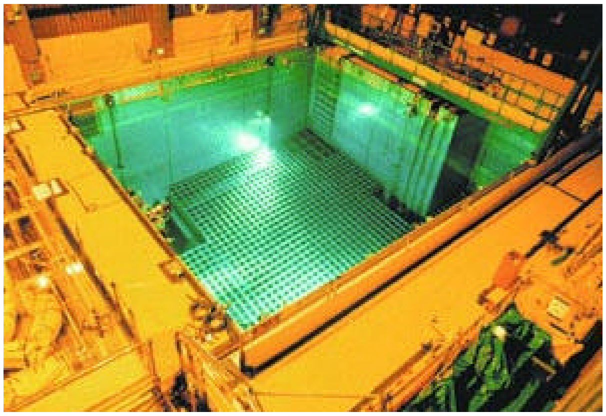

Figure 3: Spent Fuel Pool Source: NRC at http://www.nrc.gov/waste/spent-fuel-storage/pools.html

radioactivity. After five years the rods can be removed from the water and placed in dry casks for long-term storage. As a long-term storage facility has not yet been built, all spent fuel from the Indian Point plants remains in the spent fuel pools (see Figure 3).[3]

The spent fuel pools at Indian Point are housed in masonry buildings with metal roofs. The Indian Point pools are mostly buried (like an in-ground swimming pool, but in some cases with a portion of the wall above grade). The pools are 30 feet wide by 60 feet long and are 40 feet deep. The Nuclear Regulatory Commission requires that more than 20 feet of water cover the rods; Entergy states that fuel rods at Indian Point are covered by 27 feet of water. The walls of the pools are built of 6 ½ feet of reinforced concrete; the pools at IP2 and IP3 are also lined with steel. In the non-buried areas, about half of the pool wall is above grade, leaving the portion of the pool containing the fuel rods below grade.

Assessing the Risk Posed by Operation of Indian Point Plants

An assessment of the risk posed by continued operation must consider both the *likelihood* of possible events causing the release of radioactivity and the *consequences* of these events. Supporters of the plants argue that the *likelihood* of a serious event is very small. Opponents focus instead on the possible *consequences* of a major accident.

The health risked posed by nuclear power plants, then, is that of a concentrated release of radioactive material from the plant. Such a release would require that the fuel (fresh or spent) that is usually contained within the rods be: (a) released from the rod casing, and then (b) propelled into the environment. The most likely way for fuel to escape from a rod is by becoming so hot that it melts through (meltdown), but it could also be released by external damage to the casing. In either case, as the fuel heats up, it can generate its own propulsion out of the plant in the form of a steam plume or even a fire.

What Might Happen?

The remainder of the report is organized around four scenarios posed by those who express concern about the safety of the Indian Point nuclear plants.

- **Scenario #1:** An ***attack on one of the nuclear reactors***, damaging the containment building and the reactor core.
- **Scenario #2:** An ***attack on supporting buildings***, particularly the control room, eliminating the ability of the operators to control the nuclear reactor or provide power or cooling water.
- **Scenario #3**: An ***attack on the spent fuel pools***, exposing the fuel rods to air.
- **Scenario #4**: An ***accident in one of the reactors***, triggering fuel meltdown.

Although there is some information on the likelihood of accidents, the likelihood of terrorism is by its very nature, unpredictable. Yet the events of 9/11 prove that unprecedented and unexpected events can have tragic consequences. Our task is to explore the vulnerability posed by each of these scenarios, asking a layman's questions about the risk.

Scenario #1: Direct Attack on the Reactor

American Airlines flight #11 flew near Indian Point on its deadly mission. What would have been the consequences had its target been one of the containment domes instead of the World Trade Center? This is the question that has spurred the debate over Indian Point.

Effect of a Direct Impact on the Containment Dome

The containment dome is built to withstand a very substantial impact. The plants' owner acknowledges that the containment dome might be damaged by a direct hit from the engine turbine of a heavily loaded commercial jet, although they believe the possibility is extremely remote.

Penetration of the dome would not, by itself, be sufficient to expose the community to radioactivity. The reactor vessel is located at the base of the structure under an additional four feet of reinforced concrete. As the force of the collision would be largely absorbed by the process of penetrating the containment dome, a far more sophisticated attack than that used by the 9/11 terrorists (i.e. involving a secondary explosive device) would be required to damage the reactor directly.

The plant's opponents suggest that damage to other systems within the reactor, e.g. the cooling system, could trigger a serious accident. Although the nuclear reaction would be stopped automatically, the fuel rods would continue to generate heat (as do spent fuel rods) and could eventually melt their casings if not cooled. The fuel melt at Three Mile Island resulted from overheating of the fuel rods after the nuclear reaction had stopped. Unless the reactor vessel was directly damaged, however, the vessel would contain the crisis for a period of time, allowing for a response by plant engineers. The crisis would not cause an immediate and catastrophic release of radioactivity.

Consequences of a Radioactive Release

A chain of unlikely events would all have to occur to trigger a fuel meltdown. The containment building must be damaged; either the reactor core or a critical portion of the cooling or control system must be damaged; both automatic and manual backup systems to stop the reaction and keep the fuel cool would have to fail. Were a meltdown to follow structural damage to the containment building, and the redundant emergency spray systems fail to work, some radioactive material would likely be released. While this could be extremely serious, the magnitude of the consequences—in terms of immediate and long-term health risks to residents—is a matter of much debate. There is a great deal of disagreement about the likely outcome of a fuel-melt induced release of radioactivity. Both sides of the controversy have released reports summarizing the possible outcome of a release. This debate over outcomes is summarized in the Appendix. In brief, plant opponents suggest that the outside limit of casualties in metropolitan New York *could* be extremely high. Plant supporters respond that the chain of events leading to such an outcome is *extremely* improbable.

Scenario #2: Attack on Control Room

Structures outside the containment building are more physically vulnerable to a direct attack. The control room for the reactor is, appropriately, located outside the containment building. In case of a serious problem within the containment structure, operators need to be in a position to take corrective action. The spent fuel pools, facilities providing cooling, and the diesel generators that provide backup power to the plant are also located outside the containment building.

What Could Happen?

Were external controls damaged or disabled in an attack, the reactor is designed to shut down the fission process without operator intervention. The control rods drop down under any sort of emergency, including loss of power. However, as with direct damage to the cooling system, a loss of reactor control could eventually lead to a fuel meltdown. With the containment structure intact, this could lead to a TMI-like event. If the containment structure were also compromised—either by an external attack coinciding with the control room attack, or by the pressure of the fuel melt itself—the consequences could be far greater.

The reactor can be controlled from more than just a single location, however. Remote facilities provide redundant control of the reactor in the event of a problem with the main control room.

Likelihood of a Successful Attack

Unlike the containment dome, the control room is a relatively small target and is not easily identified from the air. A recent flyover by a small plane[4] suggests that some kind of attack from the air may be possible, however, provided that the attacker knows the location of the control room. The control room could also be vulnerable to some form of ground attack, reinforcing the importance of effective ground security at all nuclear power plants. Another potentially vulnerable area might be water intake areas and energy transmission lines.

Entergy, the plant's owner, states that the control room's location is a secret. Plant diagrams to many nuclear plants were readily available prior to 9/11; some were discovered in Afghan caves. It would be prudent to assume that the location of the control room *is* known. As noted above, the reactor can be controlled from remote locations, however. To be successful at eliminating external control, an attack would have to disable both main and remote control locations, thus preventing the operator from taking necessary corrective action.

David Lochbaum, staff member of the Union of Concerned Scientists (UCS) reports that some nuclear plants have auxiliary controls located in the same building as the main control room, as the assumption was that damage to the control room would be accidental and would only affect that one room. He also cautions that main and auxiliary controls occasionally use the same cables to connect with the reactor. Were these cables damaged, both main and remote controls would be disabled. We do not know whether either of these conditions applies to the Indian Point power plants. A 1975 fire below the control room at the Browns Ferry nuclear power plant caused the failure of multiple levels of control. Plant engineers were still able to prevent a core meltdown in this instance.[5]

Scenario #3: Attack on Spent Fuel Pools

The spent fuel pools contain a large amount of highly radioactive material. Entergy has announced its intention to begin moving the fuel to dry cask storage. This will reduce the amount of nuclear material stored in a single location, although planning and implementation will take a couple of years.

Much of the debate over the plant's vulnerability has focused on these pools. The plant's opponents hypothesize that these pools or the system supplying water to the pools could be damaged by an attack and that the consequences of such an attack would be catastrophic.

What Could Happen?

All agree that the consequences of draining cooling water from the pools would be very serious. All the rods are highly radioactive. Rods that have been cooling for less than five years could melt and possibly burn if exposed to the air, causing a fire that might ignite older rods as well and would certainly release large amounts of radioactivity into the atmosphere. Depending on weather patterns, the impact of such an event on human health and the environment could be immense or relatively small.

Likelihood of a Successful Attack

The building housing the spent fuel pools could be attacked from the air or the ground. Vulnerability from the air is unknown, although the small plane incident mentioned above suggests that the site is vulnerable. There are multiple rings of physical security around the perimeter on the ground, including fencing and concrete barriers. The vulnerability of the water supply systems is unknown, however there are multiple means of supplying water to the buildings.

Rupturing the Pool Wall

For an explosive force to drain a pool of the more than 20 feet of water above the rods and prevent its replacement, it would have to fracture the steel liner, create an opening in the pool's 6½ foot thick reinforced concrete walls, and in most places, create a large enough hole in the earth surrounding the pool to cause water to escape quickly. The portion of the pool wall that is below grade would be extremely difficult to rupture. We do not know what level of explosive force would be required to rupture steel-lined walls built of 6 ½ feet of reinforced concrete, although it seems unlikely that an air attack could have the required level of precision or explosive force. A ground attack would require accurate placement of a large quantity of explosive.

David Lochbaum of UCS supports the argument that structural damage to the pools themselves is highly unlikely at Indian Point. He notes that spent fuel pools in other power plants are located in more vulnerable locations.

Cutting Off Supplies of Cooling Water to Pools

Advocates for closure point out the risks posed by the loss of cooling water. Heat given off by the fuel rods could boil off the remaining water, exposing the rods. However, both sides note that this would not occur quickly. A 2001 study commissioned by the Nuclear Regulatory Commission concludes

> In the case of one year old fuel [fuel that was removed from the reactor one year prior], approximately 195 hours is available . . . before the water level drops to within three feet of the spent fuel. If the fuel most recently offloaded is only two months out of the reactor, the time available is still long (100-150 hours).[6]

Lochbaum agrees that even in the case of fuel just removed from the reactor, there would be no less than 12-20 hours available to act before there was risk of exposing the fuel rods to the air.

Although the water's radiation shielding properties are reduced with its level, the exposure would be limited to those within the spent fuel storage building. Risk to the public can only occur if the fuel rods are exposed to the air. External sources of water (e.g. water pumped from the Hudson, emergency tanks or fire department tanker/pumpers) would be able to keep the risk of fuel meltdown very low until the supply system is repaired.

In sum, a chain of unlikely events would all have to occur to create a threat to public health. A powerful explosive device would be necessary to breach the walls of the spent fuel pool. Only if the force were sufficient to breach the pool walls *below ground* and enable substantial quantities of water to leak would there be risk of immediate exposure of the fuel rods. In any event, a constant supply of water should be able to keep the site safe.

Many have recommended that the roofs of the spent fuel storage buildings be reinforced, to reduce the likelihood of an air attack. Entergy has indicated to WPII that it is studying the possibility.

Finally, it has been noted by many that the risk posed by the fuel pools does not disappear if the plants are closed, although the risk diminishes as the fuel cools. Riverkeeper has suggested on-site, dry cask storage for old fuel.

Scenario #4: Reactor Meltdown Due to Internal Accident

Opposition to nuclear power at the Indian Point site is long-standing; plant opponents point to the risk of an accidental TMI-like fuel meltdown caused by a wholly-internal chain of events. Both the Three Mile Island and Chernobyl accidents demonstrate that human error and mechanical breakdowns can occur. The proximity of New York City to Indian Point raises the possibility, however remote, of very significant harm.

Nuclear advocates, in turn, point to the overall safety record of the nuclear industry in the U.S. and in Europe. The Uranium Information Centre noted that, "The situation to date is that in over 9,500 reactor-years of civil operation there has been only one accident to a commercial reactor [Chernobyl] which was not substantially contained within the design and structure of the reactor."[7] They point out that Three Mile Island was the worst accident in the United States, and caused no significant release of radioactivity. Furthermore, they note, it was the reactor design—similar to the design used at Indian Point—that prevented the melted fuel from escaping. Chernobyl used a more hazardous reactor design and was not protected with a containment structure.

Indian Point 2's safety history is not in dispute. The Nuclear Regulatory Commission (NRC) has given it the lowest rating a plant can have and still remain operating. The March 2002 letter to Entergy from the NRC cites two incidents—an August 1999 problem with the electrical system and a February 2000 steam generator tube rupture—for the low rating.[8] What *is* in dispute is whether Entergy will be able to make sufficient changes to the physical plant and improve the competence of the operating staff. Entergy is very aware of the problems with the plant and has invested $150 million in capital improvements since purchasing the plant. The company has made a major commitment to staff training since assuming control of the plant last September.

What Could Happen?

Assuming a sequence of system failures and/or operator errors, a fuel meltdown could occur if the system either loses coolant and backup cooling, or if the reactor fails to shut down in response to a major failure. Even so, the radioactive materials would stay within the containment area, unless it is ruptured by overpressure, or the containment isolation systems do not operate correctly.

Likelihood of Significant Accident

Studies consistently show that the likelihood of a serious accident is very low. And, although closure advocates sometimes dispute the numbers, their main argument is that *any* chance of an accident—given the magnitude of the possible worst-case consequences—is too great.

Certainly Con Ed's operation and maintenance record at the plant were poor. Many have welcomed the transfer of operating responsibility to Entergy. The plant's new owner is working to bring the physical plant and staff of Indian Point 2 up to the same level of safety compliance as IP3, which receives the NRC's best rating.

Conclusion

WPII's review of the most likely impacts of either a terrorist attack or an accident at Indian Point's two operating nuclear power plants suggests three findings:

- The risk of a radioactive release as a result of either a terrorist attack or an accident is real, but small; it would be very difficult for a 9/11-style attack to create a public health crisis.
- A sudden and massive release of radioactivity can only occur after a powerful and highly sophisticated attack; in scenarios posed by closure advocates, a serious risk to public health will develop slowly, allowing the operator and the authorities time to respond.
- The risk to public health posed by the plants would not be eliminated by closing the plants. The spent fuel is likely to remain at Indian Point for many years to come.
- Additional steps can and should be taken to make the site safer than it is right now; the community and the public sector must work together to improve both safety and public confidence.

A Terrorist Attack Must Be Powerful and Highly Sophisticated to Succeed

There does not appear to be a single point of vulnerability that would cause a sudden and massive release of radioactivity. Nuclear power plants do prepare for terrorist attacks. The NRC requires plants to be prepared for attacks, and historically ran each power plant's security personnel through "force-on-force" drills approximately once every eight years, although plant operators conduct their own drills more frequently. These simulated attacks involve outside attackers with one person assisting from inside the plant, and have targeted a number of areas, such as the control room and containment domes. The results were used to discover and correct any problems. After September 11th, the NRC postponed these simulations, partly to reconsider their model, and partly due to heightened security, which both increased the likelihood of confusion and reduced the likelihood that such a test could provide information to plant operators about holes in their regular security.

Power plants have been the targets of terrorist attacks in the past, mostly overseas. A report presented to the International Atomic Energy Agency (IAEA) in the wake of September 11th noted that the type of terrorist most likely to engineer such an attack would be one looking for a high-profile target, rather than a high death toll. This is due to the inherent difficulty of ensuring a radiological release.[9]

- A successful attack on the containment structure would need to be accompanied either by a secondary explosion within the dome or by the simultaneous destruction of external controls, both primary and secondary.

- An attack on external controls would have to eliminate both primary and secondary controls; the containment structure would still protect the environment from the most likely consequences.
- An attack on the spent fuel pools would likely have to exceed the force delivered by the crash of a commercial airliner to cause an immediate release of radioactivity; the loss of water supply systems would become a threat only if left unaddressed.

A Threat To Public Health Would Develop Slowly

The emergency response plan has been widely criticized as inadequate. In the wake of 9/11 the plan is being substantially revised under the direction of the Westchester County Office of Emergency Services. One criticism leveled at the plan has been its assumption that a threat to public safety would evolve slowly, allowing authorities to respond according to an orderly and measured plan.

Supporters of closure have argued that an immediate and massive threat does not allow for such a plan to be put into effect—in fact, that no plan would be workable in such a populous area in the face of an immediate and massive release of radioactivity.

WPII's review of the assertions of the plants' opponents and the response of Entergy and other stakeholders suggests that a sudden and massive threat to public safety would require a large and sophisticated assault on more than a single point of vulnerability. Although 9/11 has shown that this is not outside the realm of possibility, it is not the sort of act traditionally associated with terrorist organizations. The operating record of 440 nuclear power plants strongly supports the claim that accidents in similar plants tend to develop slowly (at least to the extent that external releases are involved), allowing the operator and public authorities to respond to the threat.

Risk is Mitigated, not Eliminated by Plant Closure

A portion of the risk posed by the site is a consequence of fuel stored in the spent fuel pools adjacent to the reactors. After closure the pools would no longer receive new, thermally hot, fuel from the reactors, thus reducing the risk of fuel melt, even if water were removed from the pool. Nonetheless, the risk of a fuel melt will persist until all fuel in the pools has been cooling for a period of five years.

The process of removing and transporting the spent fuel raises additional concerns. Nor is there yet a place to deposit the spent fuel. The Yucca Mountain nuclear waste repository will not be ready to receive nuclear materials until 2010 at the earliest.[10]

More Can Be Done

Whether the nuclear power plants at Indian Point continue operating or not, actions can and should be taken to improve the safety of the public. The events of 9/11 demonstrate that the standard for security at vulnerable facilities like nuclear power plants must be set higher.

The federal, state and local governments and the plant owner have taken steps to limit access to the Indian Point site and protect against hazards from land, air and water. Entergy reports that it has spent several million dollars on new perimeter security. The New York State Office of Public Security has conducted a thorough assessment of the measures put in place at the site and has declared itself satisfied. The NRC also issued orders regarding security procedures to all nuclear power plants following 9/11. These include "additional personnel access controls; enhanced requirements for guard forces; increased stand-off distances for searches of vehicles approaching nuclear facilities" and other steps.[11] As the details of these actions are, of necessity, secret, it is impossible to judge whether they are adequate.

Many individuals have recommended changes that would improve the safety of these plants. We summarize the more common below. None of the steps suggested below are novel and we expect that many are in the process of being implemented.

- The NRC should put more focus on "force-on-force" terrorism drills for security personnel. These should be restructured to encompass attacks on more points of vulnerability, including spent fuel pools and water intake areas. These drills should resume as soon as possible, and should be far more frequent. In WPII's opinion, they should continue to be conducted by the NRC, rather than being conducted by plant operators, as had been considered prior to September 11th.
- Vulnerability to attack from air, land and water should be continually assessed; additional steps should be taken as deemed necessary.
- The NRC and Entergy should assume that the location of both the control room and auxiliary control sites are known and establish new auxiliary control sites that do not appear on any plans that may have been available prior to 9/11.
- If communication links with the reactor are shared between primary and secondary controls, this should be changed. Truly redundant control requires duplicate cabling.
- The buildings housing the spent fuel pools should be reinforced.
- Spent fuel that has cooled sufficiently should be moved to dry casks and stored in a secure location.
- Re-training of IP2 personnel should proceed as quickly as possible, coupled with additional capital improvements.
- The Nuclear Regulatory Commission should be particularly vigilant in its enforcement of safety standards at both plants, recognizing that the plants' proximity to New York City places a special burden of safe operation on Entergy as the operator and the NRC as its overseer.

The consequences of shutting down the Indian Point plants are not insignificant. WPII's companion paper on the impact of closure on New York's power grid demonstrates that the loss of Indian Point power will have a substantial impact on system reliability and would increase prices in a region already facing the highest prices in the nation. However, financial impacts are insignificant in the face of a tangible threat to human life. The challenge of public health policy involves balancing the cost of action against the benefit of reduced risk.

NOTE: Full text of report plus endnotes and appendix can be downloaded from the Westchester Public Issues Institute website at http://www.westchester.org/wpii_frame.htm.

APPENDIX

The Consequences of a Nuclear Accident

Fuel that is encased in rods is highly radioactive, but contained. A person standing near an exposed rod would be killed almost instantaneously. However, as long as the fuel remains in the rods, it cannot spread. It is only when fuel escapes from the rods that it can travel – via wind, water, and eventual absorption into the food chain – to cause great short and long-term damage.

A Release of Radiation From Fuel Rods

Fuel rod casings could melt due to the thermal heat of the radioactive fuel, either during fission or when the fuel is still hot following removal from the reactor vessel. Under particular circumstances this could cause a fire, although this has never happened in a power reactor. Melting has occurred—in Chernobyl, from an uncontrolled chain reaction, and in Three Mile Island, from rods that had been stopped from fissioning but were nonetheless extremely hot. Both of these incidents happened inside reactors. In theory, if still-hot spent fuel rods in the spent fuel pool were not properly covered with water, they could also melt. The casing of a fuel rod could also be ruptured by some kind of explosive force.

In either event, the radioactivity would then have to be propelled into the atmosphere to cause widespread harm. This would likely occur as part of a steam plume generated by the overheating event combining with the water that is usually present in the reactor and pools, or possibly as smoke rising from a fire. There would be immediate short-term deaths and injuries in the area immediately beneath a steam plume, especially closer in to the plant. Longer-term "latent" health effects, however—such as increased cancers and genetic mutations—would be spread over a much larger area, through exposure to radiation on the ground and in the food chain.

Concentration of Harm

A recent Entergy-commissioned study states that a steam plume is *either* concentrated by prevailing winds, thus causing deadly harm to a small radius around the source *or* is spread over a larger territory in a more diffused, thus less dangerous, form. The study concludes that even if a serious accident were to occur, it is misleading to assert that everyone in the 10-mile area surrounding the plant could be killed or seriously injured.

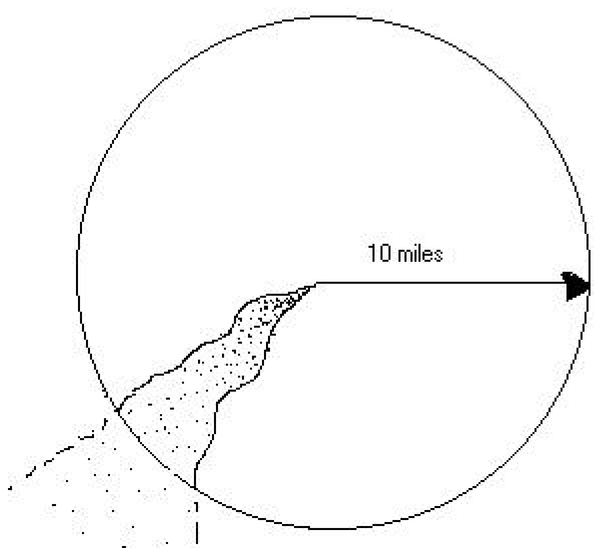

Figure 3: Typical Daytime Plume Within 10 Mile EPZ
Source: Specter, 2002, 6

Typically, prevailing winds blow a plume of steam or smoke over only a small portion of the radius surrounding the source. While still concentrated (as it would likely be close to the source), a radioactive plume would be extremely dangerous. As it traveled with the wind, it would become more diffuse. The greater the spread of the radiation, the lower the damage, since radiation causes many fewer early injuries at lower doses than at high ones.

A single plume that resulted in 400

rads of exposure to an individual would produce a 50% chance of that person becoming an early fatality assuming minimal medial treatment. Two plumes, each causing 200 rads of exposure to two individuals, would result in 2 x 0.15% or 0.30% chance of an early fatality. In this example two half-strength plumes would result in early fatality health risks…over 150 times smaller than…one full strength plume.

How Many Deaths?

If there were a meltdown combined with structural damage to the containment building—whether by accident or due to terrorism—radioactive material would be released. While no one disputes that this would be extremely serious, the magnitude of the consequences—in terms of immediate and long-term health risks to residents—is a matter of much debate.

The Challenge of Estimating Nuclear Hazards & Consequences

A statistical assessment of risk is determined by extrapolating from known past events to unknown future events. Some probabilities can be estimated with great precision: The outcomes from rolling dice or flipping coins are very predictable, for example. Circumstance—time of day, age of the participants, atmospheric pressure, wind direction—has no systematic effect on the number of "heads" in 1,000 tosses. It is also easy to use experimentation to verify estimates of likelihood.

Fortunately, the world has witnessed very few serious accidents at nuclear power plants. The record of the nuclear power industry provides some evidence for the low probability of serious accident. While this is encouraging, the number of power plants in operation and the number of operating years of experience is still relatively small, compared with other methods of power generation.

Few accidents and the nature of the hazard make it even more difficult to forecast the extent of harm caused by an accident. The range of factors influencing the consequences of a nuclear accident is wide—from the quantity and nature of the release to wind patterns to the type and speed of emergency response.

Finally, the broadest impact of a radioactive release is in the form of so-called "latent" deaths, a result of a changed susceptibility to disease. Radiation exposure is known to increase the risk of certain life-threatening conditions, particularly cancer. The vast majority of deaths predicted from a release of radiation are expected to occur at some time in the future—deaths that would have been delayed for some unknown period of time if the radiation had not been released. Thus exposure to unusual quantities of radiation will shorten the sum of years lived by the entire group of persons exposed. These latent deaths are not the same as immediate fatalities caused by radiation or gunshot wounds. No sane individual would be indifferent to a choice between dying today or accepting an increased risk of a life-threatening disease later in life.

For all these reasons, nuclear accident risk estimates are both highly speculative and difficult to interpret. We do not suggest that they are irrelevant. But they should be used cautiously. Small differences in assumption or approach can change estimates by several orders of magnitude.

Other Forms of Power Generation Also Have Health Consequences

Many proponents of nuclear power have also pointed out that one cannot assess this sort of risk in a vacuum. For example, one might compare this with the long-term health risks of other methods of power generation – such as burning coal, for example, which is estimated to cause thousands or even tens of thousands of deaths per year from diseases caused by air pollution, and many more from deaths to coal miners.[12]

Individuals Do Balance Risk & Benefit

Closure advocates assert that no increased risk is acceptable. Were there no benefit to be gained from nuclear power, then this position would be consistent and valid. Yet the benefit of low cost power in a high cost state is not insignificant (see WPII's study of the supply impacts of closing Indian Point). If saving lives at any cost is the standard, then there are a number of policies that would have a more demonstrable impact, e.g. robust enforcement of reduced speed limits on highways.

Conflicting Claims

Assemblyman Richard Brodsky, in his *Interim Report on the Evacuation Plan for the Indian Point Nuclear Facility*, asserts that a reactor-based release could cause up to 50,000 deaths, and make the whole NYC-metropolitan area uninhabitable. If a terrorist attack could, indeed, be reasonably expected to have these consequences, the answer seems obvious: close Indian Point.

These numbers are often cited as being from Sandia National Laboratories, one of several independent scientific institutes that often conduct research for the NRC and other US government entities. However, the "CRAC-2 study," as the report they came from is often called, was actually published by a Congressional committee chaired by long-time nuclear power opponent, Edward J. Markey of Massachusetts. That report did use data runs from Sandia's CRAC-2 (Calculation of Reactor Accident Consequences, Version 2) computer model, but in ways that the Laboratory repudiated at the time.[13] Sandia itself, however, did publish a study using CRAC-2 that showed a worst possible outcome of 830 early fatalities with 8,100 latent cancer fatalities, still a large number.

Entergy, on the other hand, puts the likely risk from such a disaster much lower, and it also draws a distinction between early fatalities (such as would be suffered by those exposed to the steam plume as it passes overhead) and latent fatalities (cancer deaths).

Entergy points out that early fatalities would probably be lower than assumed in either report, above, for several reasons. For one thing, even the Sandia published study assumes little evacuation or sheltering. This is because that study was trying to assess the absolute worst possible scenario for release, not what would probably happen. In addition, Entergy claims that more is known about dispersal and absorption of radiation into the environment now than when the study was done, and that the new knowledge indicates substantially lower amounts of radiation emitted from even a catastrophic unbounded accident. In the end, Entergy's commissioned report seems to indicate that there would likely be very few early fatalities, even from a large accident. David Lochbaum of UCS counters that the Entergy-sponsored study assumes relatively favorable weather conditions and evacuation behaviors.

Entergy's report also draws a sharp distinction between early fatalities and latent cancer deaths, noting that the latter sound far more alarming in terms of absolute numbers than after one considers them in context. In a recent New York Times Magazine article, Bill Keller illustrated a similar point by noting that a "dirty bomb" detonated in Manhattan would cause anyone living anywhere even as far away as the Hudson Valley to have at least a 1-in-100 chance of dying from cancer caused by the resulting radiation. Yet, he went on to quote Princeton physicist Frank von Hippel who noted that people already have about a 20 percent chance of dying from cancer during their lifetime and that the increase in risk from such a bomb would actually only bring that risk to 21 percent, not a huge jump. Even an increase of 50,000 latent fatalities on a base population of 20 million (the estimated population of the area that might be affected, according to plant opponents) would be more on the order of 1-in-400 chance, so it would have presumably even less noticeable effects.

Outcomes: Releases From Spent Fuel

Closure advocates suggest that the radioactive material in the spent fuel rods is in some ways even more dangerous to human health than those in the reactor core. If they were damaged, either by melting due to a lack of cooling water, or by a direct hit, they could release radioactive material into the vicinity, including cesium-137, which is easily absorbed into the food chain. Riverkeeper quotes a 1997 Brookhaven study on safety issues around decommissioned plants as predicting between 1,500 and 143,000 latent cancer fatalities from a spent fuel fire incident, as well as making between 1 and 2,790 square miles uninhabitable. (The study also notes between 0 and 95 early fatalities.)

Entergy claims this study has been misinterpreted, as it depends upon the assumption that nothing is done to mitigate the situation, and that nobody shelters or evacuates the immediate area. They claim that there would be no short-term deaths from a release from the spent fuel pools, and about 4,250 latent fatalities, according to their own report's calculations. As noted above, the number of early fatalities in NUREG-6451 could be as high as 95, but in most scenarios appears to be zero to about one death. Only if they assumed a fire with most or all of the fuel pool involved did the death tolls grow.

In addition, the number of latent cancer fatalities from radiation in the food chain would be mitigated by interdiction. At Chernobyl, the choice for many was between eating contaminated food and having sufficient quantities of food. This is unlikely in the United States. However, such an interdiction would cause great economic disruption in the region.

U.S. is Less Dependent on Nuclear Power Than Many Other Countries

Although the US has more nuclear power plants than any other country (104 of the 440 current plants around the world), it only provides 20 percent of the nation's electricity. Other nations have a far greater dependence on nuclear power, including France (77%) and Japan (34%), both of which have plants similar designs to US plants. The United Kingdom relies on gas-cooled reactors, which cool the fuel with carbon dioxide moderated with graphite, rather than with water. Russia has an assortment of light water and gas-cooled reactors of their own distinctive designs, including the now infamous RBMK (water-cooled graphite moderated) reactors, of which Chernobyl was one. Chernobyl's RBMK reactor not only had no containment dome, it also had a design feature that could cause overheating when the reactor was running at low power – a deadly combination. All RBMK reactors are currently being retrofitted with better safety equipment.

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The website of the **Canadian Coalition for Nuclear Responsibility** has information on CANDU heavy-water reactors and radioactive waste issues: http://www.ccnr.org. It includes a detailed description of the fire at Browns Ferry nuclear power plant.

The **Environmental Protection Agency** has information on radioactive waste storage, including the proposed Yucca Mountain storage facility for long-term waste from nuclear power plants: http://www.epa.gov/radiation/index.html.

The **Nuclear Regulatory Commission** Home Page, www.nrc.gov, has excellent descriptions of nuclear power reactors and spent fuel storage, as well as diagrams and photographs. It also has lots of documents about specific power plants, although many have been removed from the page post-September 11th, due to security concerns.

The **Nuclear Tourist** website has a lot of general information about nuclear power and specific power plants. www.nucleartourist.org

The **Union of Concerned Scientists** has information on nuclear safety concerns, at: http://www.ucsusa.org/index.html

Pro-Indian Point

Entergy has a website devoted to the Indian Point issues: www.safesecurevital.org.

Anti-Indian Point Websites

For arguments made by the coalition calling for the closure of Indian Point, see: www.closeindianpoint.org.

Riverkeeper, a local environmental organization, has been very vocal against Indian Point, at: www.riverkeeper.org

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ENDNOTES

[1] WPII has also completed a study of the impact of closure on the system supplying power to the NYC Metro area.
[2] See http://www.nrc.gov/reactors/operating/licensing/renewal/process.html.
[3] The federal government has recently decided to establish a nuclear fuel storage facility at Yucca Mountain in Nevada, although the State of Nevada is still attempting to block final approval.
[4] "Flyover Shows Indian Point's A Sitting Duck," Marsha Kranes, New York Post, Thursday, April 18, 2002.
[5] Website of Canadian Coalition for Nuclear Responsibility, http://www.ccnr.org/browns_ferry.html; NRC website (including http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/fire-protection.html); and Dept of Energy website (http://www.eia.doe.gov/cneaf/nuclear/page/at_a_glance/reactors/brownsferry.html).
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[10] http://www.epa.gov/radiation/yucca/about.htm#yucca_repository
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[12] Sierra Club at http://sierraclub.org/cleanair/factsheets/power.asp.
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June 2002