ENERGY FACTS

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Nuclear Accident at Indian Point:
Consequences and Costs

The catastrophic accident at Japan's Fukushima Daiichi Nuclear Power Plant in March 2011 has resulted in a global re-examination of the safety of nuclear power and teaches us a lot about the risks of continued operation at the Indian Point reactor in New York. Just in the spring and summer of 2011, five nuclear power plants in the United States were damaged and underwent emergency shutdown due to flooding, earthquakes, tornadoes, and hurricanes. A review of the potential radiological consequences of a nuclear accident at Indian Point, the seismic hazards in its location, and cost estimates of a hypothetical accident shows just how dangerous the situation is.

Among the 104 operating U.S. nuclear reactors, the two units at Indian Point, 34 miles north of Central Park, pose heightened risks. Very large populations could be exposed to radiation in a major accident, the reactors are located in a seismically active area, and their owner currently seeks to extend the reactors' lives beyond their engineered 40-year lifespan.

- An accident at Indian Point Unit 3 on the scale of Fukushima Daiichi could require the sheltering or evacuation of as many as 5.6 million people due to a fallout plume blown south to the New York City metropolitan area. People in the path of the plume would be at risk for receiving a whole-body radiation dose greater than 1 rem, which for an average individual results in a 0.3 percent increase in risk of premature death from cancer. An accident of this scale would require the administration of stable iodine to more than six million people (where people would be at risk for receiving a thyroid radiation dose greater than 10 rad).
- An accident at Indian Point Unit 3 involving a full reactor core melt approaching the scale of Chernobyl could put people in New York City at risk for receiving a whole-body radiation dose greater than 25 rem, resulting in a 7 percent increase in risk of premature death from cancer

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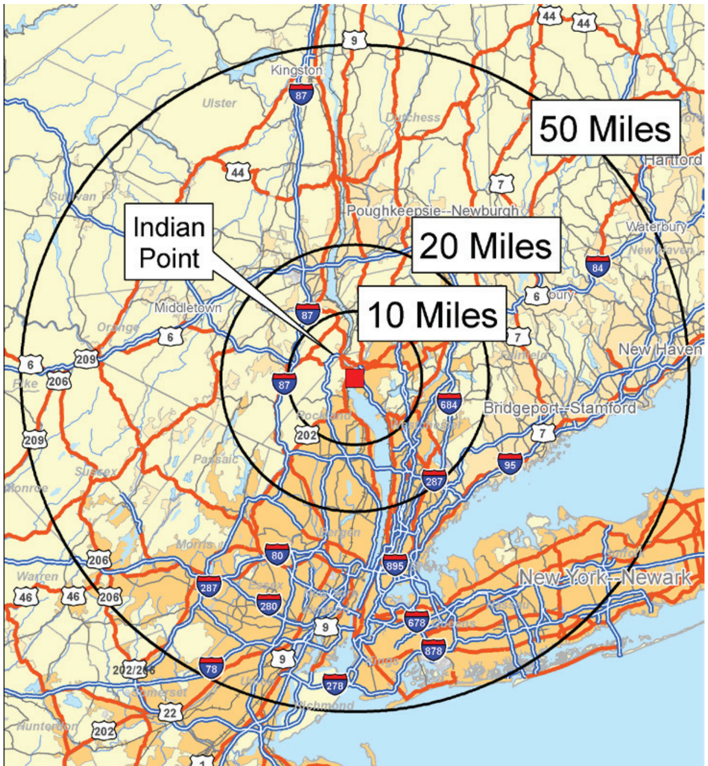

Figure 1: Regional map of the Indian Point Energy Center.

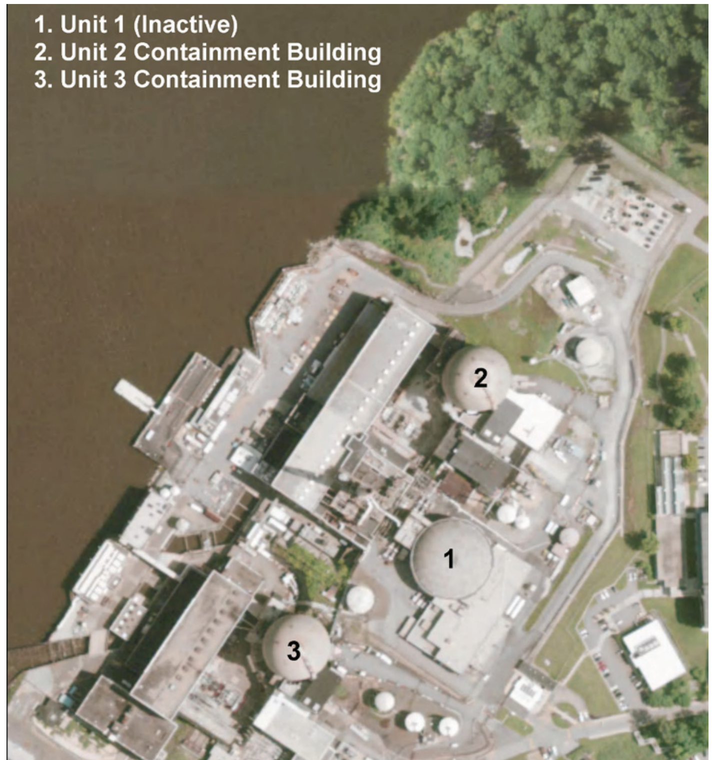

Figure 2: The Indian Point Energy Center reactor containment buildings and other structures.

Image Source: National Agriculture Imagery Program

for an average individual. An accident of this scale would require the administration of stable iodine throughout the New York City metropolitan area, and put thousands at risk for radiation sickness in and near the Hudson Valley.

- An accident at one of Indian Point's reactors on the scale of the recent catastrophe in Japan could cause a swath of land down to the George Washington Bridge to be uninhabitable for generations due to radiation contamination. A release of radiation on the scale of Chernobyl's would make Manhattan too radioactively contaminated to live in if the city fell within the plume.

The Nuclear Regulatory Commission's (NRC's) approach to calculating seismic risk used to oversee Indian Point is outdated, and underestimates the danger of a damaging earthquake that could lead to a radiological release.

NRDC estimates that, if the plume of radiation headed south from Indian Point to New York City, the cost of a severe accident at the plant would be 10 to 100 times higher than for the Fukushima Daiichi accident, where the cost for cleanup and compensation is projected to exceed $60 billion.

RADIOLOGICAL RELEASES IN A SEVERE ACCIDENT

The Indian Point Energy Center is located in the village of Buchanan, New York, on the east bank of the Hudson River in Westchester County, 34 miles directly north of the center of Manhattan Island.[1] Entergy Nuclear Northeast (with headquarters in Jackson, Mississippi), a subsidiary of Entergy Corporation (with headquarters in New Orleans, Louisiana), owns and operates 12 nuclear plants at 10 sites[2], including the two operating Pressurized Water Reactor (PWR) units at Indian Point. Figure 1 shows a regional map of Indian Point with 10, 20, and 50 mile rings around the plant drawn. Figure 2 shows an aerial photograph of Indian Point with labels for the containment building[3] for Unit 1, which was shut down in October 1974, and containment buildings for Unit 2, which began commercial operation in August 1974, and Unit 3, which began commercial operation two years later.

In Entergy's 2010 "Indian Point Energy Center Emergency Plan," the highest category of emergency is termed a "General Emergency" and is described as: "actual or imminent substantial core degradation or melting with potential for loss of containment integrity" with "the potential for a large release of radioactive material."[4] In 1981, Sandia National Laboratory conducted a study for the NRC that predicted a maximum of 50,000 immediate fatalities as far as 17.5 miles downwind and another 14,000 fatal cancers due to radiological releases from a damaged reactor at Indian Point.[5]

The 9-11 attacks have caused additional concern that Indian Point could be the target of a terrorist attack. In 2004, a study by the Union of Concerned Scientists estimated as many as 44,000 near-term deaths from acute radiation syndrome and as many as 518,000 long-term cancer deaths could occur in people within 50 miles of Indian Point in the event of a severe accident.[6]

In order to fully appreciate the implications of a major accident at Indian Point, NRDC used the U.S. Department of Defense (DoD) computer model HPAC (Hazard Prediction and Assessment Capability)[7] to calculate resulting fallout plumes. The DoD software contains specific data on the reactors at Indian Point (as well as at Fukushima Daiichi). Importantly, HPAC computes an inventory of radioactive elements that accumulate in the nuclear fuel rods of these reactors during normal operation. The DoD model captures many other important aspects of the release of radiation due to an accident at a nuclear power plant as well, including the radiological source term, the ambient weather, and data on nearby populations; these terms are defined below.

The source term for an accident at a nuclear plant is the type and quantity of radioactive materials (fission products and transuranic elements) released from the core of a reactor, first into the containment atmosphere and then from within the containment into the surrounding environment. This depends on the design of a reactor, its operating power at the time of the accident, the type of fuel, and the degree of damage to fuel, to containment, and to other reactor components in the accident. The DoD code models three degrees or types of nuclear facility accidents for PWR large and dry containment leakage and failure. In progressing severity these are: gap release; in-vessel severe core damage; and vessel melt-through.

The PWR accident progression[8] begins with loss of reactor coolant and failure of emergency core cooling, as occurred at Fukushima Daiichi due to Station Blackout and earthquake and tsunami damage. As the core heats up, fuel cladding (the metal sheath surrounding the uranium fuel) warps and cracks, resulting in release of the radioactivity located in the gap between nuclear fuel pellets and the cladding: the gap release. If cooling can't be re-established, the core gradually melts and slumps to the bottom of the reactor pressure vessel (the core's sealed steel container), called the in-vessel severe core damage. Finally, if the bottom head of the reactor pressure vessel fails, molten core debris can be ejected from the reactor pressure vessel and will react with the concrete floor below: the vessel melt-through.

Preliminary estimates of the amount of radioactive Iodine-131 and Cesium-137 discharged from the Fukushima Daiichi nuclear power plant in the first intense weeks of its 2011 accident are 4.05E+06 Curies (Ci) and 3.24E+05 Ci, respectively.[9] These values are about one-tenth of the quantities of radioactive material released in the 1987 Chernobyl accident in Ukraine.[10] Similarly, both the land area highly contamination with Cesium-137 and cancer deaths from radiation exposure are estimated to be on the order of 10 times less for Fukushima Daiichi than for Chernobyl.[11] Much of the radiation emitted from Fukushima Daiichi occurred on March 15, 2011, in a plume traveling northwest from the reactors, likely originating from Unit 2. Table 1 below shows the DoD HPAC computer model's source terms for progressively more severe accidents at Fukushima Daiichi Unit 2 and at Indian Point Unit 3.

It is important to note that the thermal power of Indian Point Unit 3 is greater than for Fukushima Daiichi Unit 2, so there is a larger quantity of fuel and radioactive material in the Indian Point reactor. Once the larger power of Indian Point Unit 3 is taken into account, (as shown in Table 1) that the amount of radioactivity calculated by HPAC in the source terms for Fukushima Daiichi and Indian Point are in fact similar. Also note that these calculations were performed for a hypothetical accident at only one of Indian Point's two operating reactors, and the accident scenarios did not involve radiation release from the spent fuel pools, unlike for Fukushima, which was a multi-unit accident with damage to spent nuclear fuel storage.

Table 1: Radiological source terms for DoD HPAC computer models of accidents at Fukushima Daiichi Unit 2 and Indian Point Unit 3.

HPAC Fukushima Daiichi Unit 2 Source Term	**Dry Well Leakage/Failure Boiling Water Reactor Containment**		
	Gap Release	**In-Vessel Severe Core Damage**	**Vessel Melt Through**
Operating Power: 2,280 MWt			
Total Curies	2.80E+07	3.50E+08	5.10E+08
Iodine-131 Curies	2.00E+06	1.20E+07	2.40E+07
Iodine-131 Percent Core	3.8%	23.0%	45.0%
Percent of Estimated Fukushima Release	49.4%	296.3%	592.6%
Cesium-137 Curies	2.10E+05	1.00E+06	2.50E+06
Cesium-137 Percent Core	4.1%	53.0%	67.0%
Percent of Estimated Fukushima Release	64.8%	308.6%	771.6%

HPAC Indian Point Unit 3 Source Term	**Large, Dry, or Subatmospheric Leakage/ Failure Pressurized Water Reactor Containment**		
	Gap Release	**In-Vessel Severe Core Damage**	**Vessel Melt-Through**
Operating Power: 3,025 MWt			
Total Curies	2.6E+07	3.6+08	5.0E+08
Iodine-131 Curies	2.7E+06	2.20E+07	3.5E+07
Iodine-131 Percent Core	3.8%	30.0%	49.0%
Percent of Estimated Fukushima Release	66.7%	543.2%	864.2%
Cesium-137 Curies	2.20E+05	1.30E+06	2.90E+06
Cesium-137 Percent Core	3.8%	55.0%	69.0%
Percent of Estimated Fukushima Release	67.9%	401.2%	895.1%

DoD=Department of Defense
HPAC=Hazard Prediction and Assessment Capability

Given estimates of the amount of radiation actually emitted at Fukushima Daiichi, the severity of this accident would fall in between HPAC's gap release and HPAC's in-vessel severe core damage source terms—a release of about 8 percent of the core inventory calculated by the DoD's HPAC code. The three Indian Point source terms calculated in HPAC bracket the Fukushima Daiichi accident:

- Gap release: About two-thirds of Fukushima Daiichi
- In-vessel severe core damage: Four to five times higher than Fukushima Daiichi
- Vessel melt-through: nine times higher than Fukushima Daiichi.

The size of an accident's source term also depends on the time and duration of a radiation release. For these calculations, it was conservatively assumed that the release of radiation from the Indian Point reactor begins eight hours after an emergency shut-down, or "scram." It is within this eight-hour period in the hypothetical accident that the reactor core loses cooling; damage to the fuel occurs as it is uncovered and overheats and containment is severely damaged. Importantly, during this eight-hour period between scram and the start of the fallout plume, the intensity of radioactivity in the fuel will decrease as shorter-lived radionuclides produced in the fuel during normal operation of the reactor decay. We conservatively modeled the plume resulting from gap release as emitted over one hour, the plume resulting from in-vessel severe core damage as emitted over two hours, and the plume resulting from vessel melt -through as emitted over ten hours.[12]

Ambient weather determines in what direction, how far, and how fast radioactive fallout would travel from Indian Point following a major accident. In NRDC's analysis, we examined wind rose data for the nearby Poughkeepsie/Dutchess County Airport, shown in Figure 3.[13] The length of the petals in the wind rose shows the frequency with which the wind blows from a given direction averaged over a 10 year period, and the relative size of the colored bands in a petal shows with what probability the wind blows at different speeds. Northerly and westerly winds are predominant at Indian Point. Winds in the Hudson Valley are most often channeled by the terrain into a north-south axis.[14] In other words, the predominant northerly winds at Indian Point blow south down the Hudson Valley to New York City. NRDC used the HPAC database of historical weather from a world-wide network of weather stations for the year 1990 as well as terrain data to calculate the likely fallout plumes from an Indian Point reactor accident in October.

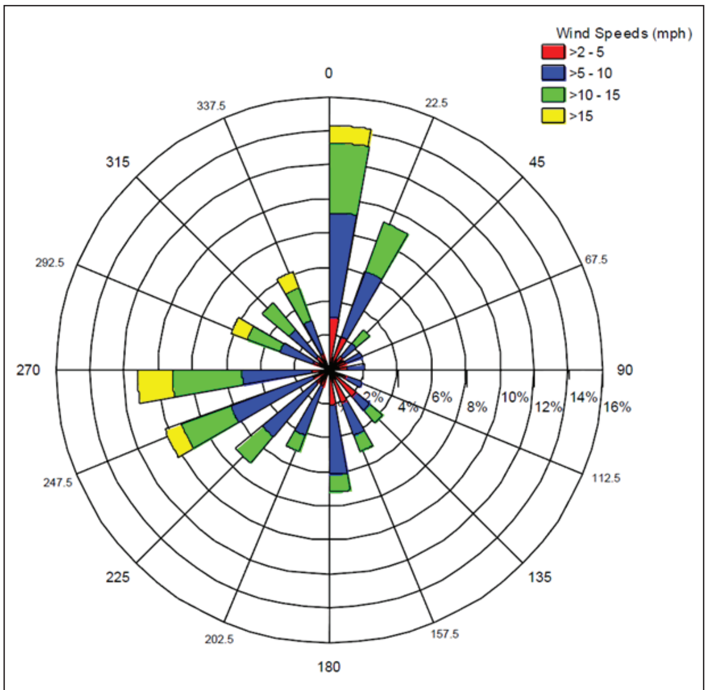

Figure 3: Wind rose for Poughkeepsie/Dutchess County Airport for measurements during the 10-year period 1997-2007. The numbers indicate the direction the wind is blowing from (0 = North, 90 = East, 180 = South, and 270 = West), and the colored bars indicate the percentage of time that the winds blow at a given speed. Northerly and westerly winds dominate in the winter and spring, while slower southerly winds dominate in the summer months.[24]

The population within portions of the fallout plume is given in Table 2, for progressively severe accident scenarios and for different ambient weather.

The first three columns show the number of people expected to receive a given radiation dose from exposure to the plume over 24 hours after the start of the accident, including the radiation given off by inhaled material retained in the human body for a long time after the accident. Here the dose specified is the total effective dose equivalent (TEDE) to the whole body, which is the sum of the inhaled dose, the ground shine dose, and the cloud shine dose. The U.S. EPA publishes protective action guides (PAGs)[15] for public exposure to radiation following a nuclear accident, and for doses 1-5 rem or greater recommends evacuation or sheltering. The EPA PAG for exposure between 5 and 25 rem allows for emergency worker exposure for performing lifesaving actions. The EPA PAG for exposure greater than 25 rem is cautious and voluntary for emergency workers, given the increased risk for cancer from such an exposure.[16]

The Fukushima accident earlier this year increased public familiarity with stable iodine, which inhibits the uptake of radioactive iodine to the thyroid. According to federal guidelines, stable iodine tablets should be taken for adults 18 to 40 years of age receiving a dose greater than 10 rad to the thyroid. The threshold is much higher for older people and lower for children and infants. As can be seen from Table 2 and from Figures 4 through 6, the extent of 10 rad Thryoid dose is greater than for 1 rem whole body dose.

The last column is a calculation of shorter-term (acute) exposure to radiation, where an exposure of 75 rad is the threshold for radiation sickness. For all of these calculations, no sheltering of people downwind of the accident is taken into account in order to estimate an at-risk population. The particular circumstances of an individual following an accident at Indian Point would be uncertain.

NRDC's calculations show that the most widespread effects of a severe accident at Indian Point would be the risk of radiation exposure for people downwind that would increase their risk of cancer, but not be severe enough to cause radiation sickness. We calculated the numbers of people exposed to the plumes that would receive at least 1 rem, 5 rem and 25 rem of radiation exposure within the first 24 hours after an accident began. By comparison, over the course of a year, medical procedures and natural background

Table 2: Hazard Prediction and Assessment Capability calculations of the number of people at risk of receiving radiation doses for exposure during the first 24 hours after the given nuclear accident at Indian Point Unit 3, for different weather conditions and assuming no sheltering.

	EPA PAG Threshold for Public Evacuation or Sheltering (> 1 rem TEDE)	**EPA PAG Threshold for Emergency Lifesaving Worker Exposure** (>5 rem TEDE)	**EPA PAG Threshold for Voluntary Emergency Worker Exposure Due to High Risk** (> 25 rem TEDE)	**Federal Guidelines for Administration of Stable Iodine for Adults 18 to 40 years of age** (> 10 rad thyroid dose)	**Radiation Sickness** (>75 rad acute dose)
	Number of people at risk				
Scenario: Gap Release (two-thirds of Fukushima Daiichi)					
Historical Winds - October Morning (6 a.m.)	102,000	23,000	6,000	162,000	< 10
Historical Winds - October Afternoon (noon)	35,000	4,000	1,000	181,000	< 10
Historical Winds - October Evening (6 p.m.)	101,000	43,000	14,000	115,000	< 10
Historical Winds - October Night (midnight)	86,000	25,000	8,000	105,000	< 10
Westerly Winds (12.5 mph)	87,000	9,000	1,000	293,000	< 10
Northerly Winds (7.5 mph)	2.8 million	24,000	1,000	4.9 million	< 10
Scenario: In-Vessel Severe Core Damage (scaled to Fukushima Daiichi)					
Historical Winds - October Morning (6 a.m.)	216,000	41,000	13,000	314,000	<100
Historical Winds - October Afternoon (noon)	229,000	6,000	1,000	311,000	<100
Historical Winds - October Evening (6 p.m.)	150,000	66,000	20,000	258,000	<100
Historical Winds - October Night (midnight)	118,000	28,000	9,000	228,000	<100
Westerly Winds (12.5 mph)	371,000	20,000	2,000	478,000	<100
Northerly Winds (7.5 mph)	5.6 million	58,000	2,000	6.3 million	<100
Scenario: In-Vessel Severe Core Damage (about four times Fukushima Daiichi)					
Historical Winds - October Morning (6 a.m.)	909,000	147,000	33,000	1.0 million	<100
Historical Winds - October Afternoon (noon)	691,000	219,000	26,000	761,000	400
Historical Winds - October Evening (6 p.m.)	973,000	128,000	55,000	1.4 million	1,300
Historical Winds - October Night (midnight)	1.1 million	128,000	39,000	2.0 million	3,000
Westerly Winds (12.5 mph)	984,000	339,000	17,000	1.1 million	100
Northerly Winds (7.5 mph)	8.5 million	5.1 million	50,000	8.8 million	200
Scenario: Vessel Melt-Through (about nine times Fukushima Daiichi)					
Historical Winds - October Morning (6 a.m.)	1.8 million	616,000	100,000	1.9 million	500
Historical Winds - October Afternoon (noon)	1.9 million	1.1million	300,000	1.9 million	2,500
Historical Winds - October Evening (6 p.m.)	3.5 million	367,000	115,000	3.7 million	1,000
Historical Winds - October Night (midnight)	3.0 million	287,000	73,000	3.1 millioin	500
Westerly Winds (12.5 mph)	1.2 million	796,000	149,000	1.2 million	700
Northerly Winds (7.5 mph)	9.9 million	8.5 million	6.0 million	9.9 million	900

Doses shown with respect to the U.S. Environmental Protection Agency's Protective Action Guides (EPA PAG) are Total Effective Dose Equivalent (TEDE), which is the sum of the inhalation Committed Effective Dose Equivalent, the ground shine dose, and the cloud shine dose for radiation exposures absent sheltering. The fourth column shows calculations of people at risk for greater than 10 rad thyroid dose, and acute doses shown in the last column with respect to radiation sickness are the total acute bone marrow dose.

EPA=Environmental Protection Agency, PAG=Protective action guide, TED=Total effective dose equivalent, MPH=miles per hour radiation result in an average radiation exposure of about 0.6 rem. The added risk of exposure to 1 rem to an average individual would increase a person's chances of getting cancer or dying by about 0.3 percent, 5 rem, by about 1.4 percent, and 25 rem by about 7 percent.

As shown in Table 2, the most extreme accident consequences are for northerly winds carrying the plume to the New York metropolitan area. In the first stage of accident progression, the Gap Release scenario, about three million people would be advised to shelter or evacuate, to reduce the radiation dose and increased risk of cancer and genetic damage. For the next most severe scenario of in-vessel severe core damage, the computer model predicts over five million people could receive the radiation dose allowed for emergency lifesaving workers, which results in elevated 1.4% increased cancer risk for an average individual. Finally, for a vessel melt-through, the model predicts six million people could receive a radiation dose greater than 25 rem, 10 million people could need stable iodine, and potentially thousands would be at risk for radiation sickness in the areas near to the reactor. Figure 4 through Figure 6 illustrate the fallout plumes from the DoD HPAC calculations for progressively severe accidents at Indian Point occurring at different times of the day, using historical weather data for the month of October. Figure 7 shows a plume of radiation impacting New York City for the vessel melt-through accident scenario carried by light northerly winds. As can be seen from these figures, the ambient weather plays a large role in the direction and extent, and therefore the consequences, of fallout from an accident.

SEISMIC RISK

The NRC staff recently recognized that the current state of knowledge related to earthquake threats and accident modeling is not reflected in the regulations at many sites.[16] In general, past attempts by the NRC to reconcile disparities between seismic science and nuclear regulations have not been comprehensive, imposing few or no requirements on previously-licensed reactors. In 1996, the NRC set forth two new seismic regulations, but only applied these new criteria to applications submitted after January 10, 1997.

The NRC's attempts to revise seismic risks at U.S. reactors have suffered from two key flaws: either the scope or methods of the review were limited by scarce

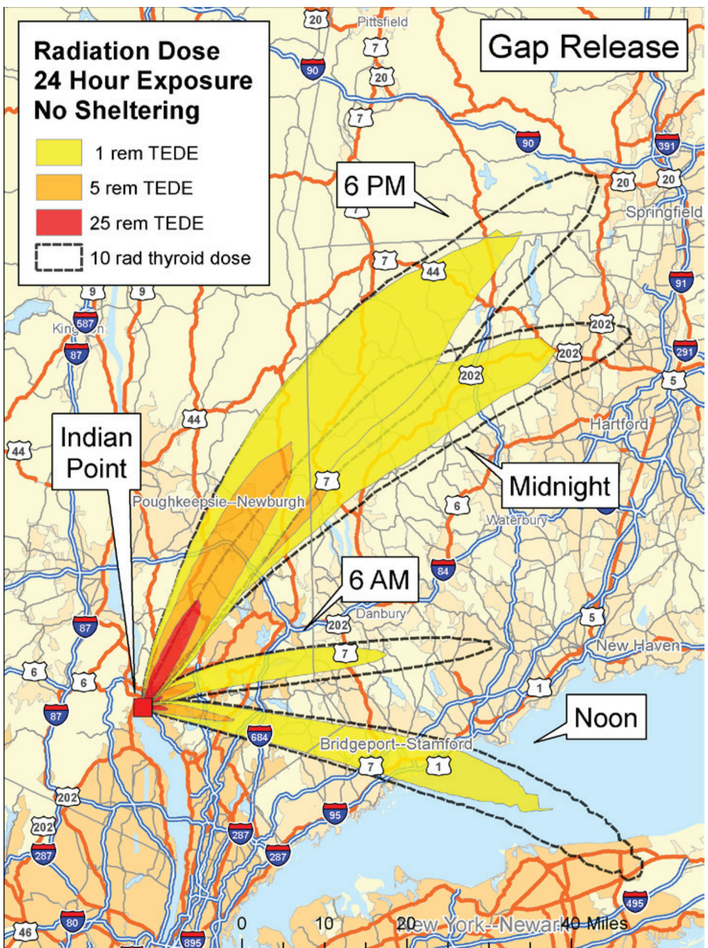

Figure 4: Gap Release calculations using historical weather data for the month of October: Four separate HPAC model runs showing the different plumes resulting from an accident at Indian Point Unit 3 occurring at different times of the day. An accident of this scale would result in approximately two-thirds of the radiation released at the Fukushima Daiichi accident.

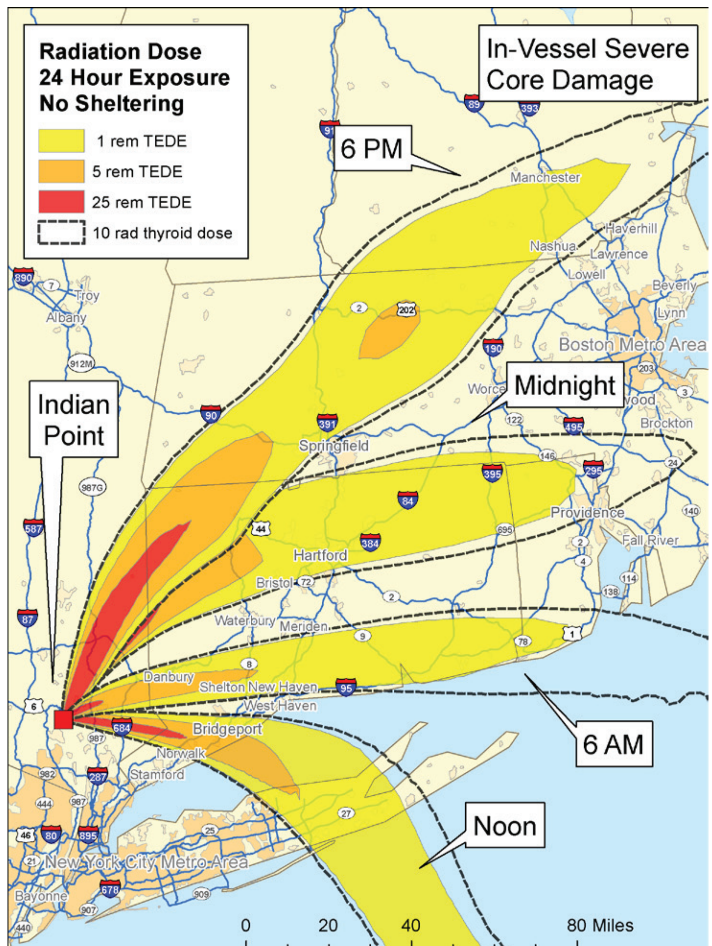

Figure 5: In-vessel severe core damage calculations using historical weather data for the month of October: four separate Hazard Prediction and Assessment Capability model runs showing the different plumes resulting from an accident at Indian Point Unit 3 occurring at different times of the day. An accident of this scale would result in approximately four times the radiation released at the Fukushima Daiichi accident.

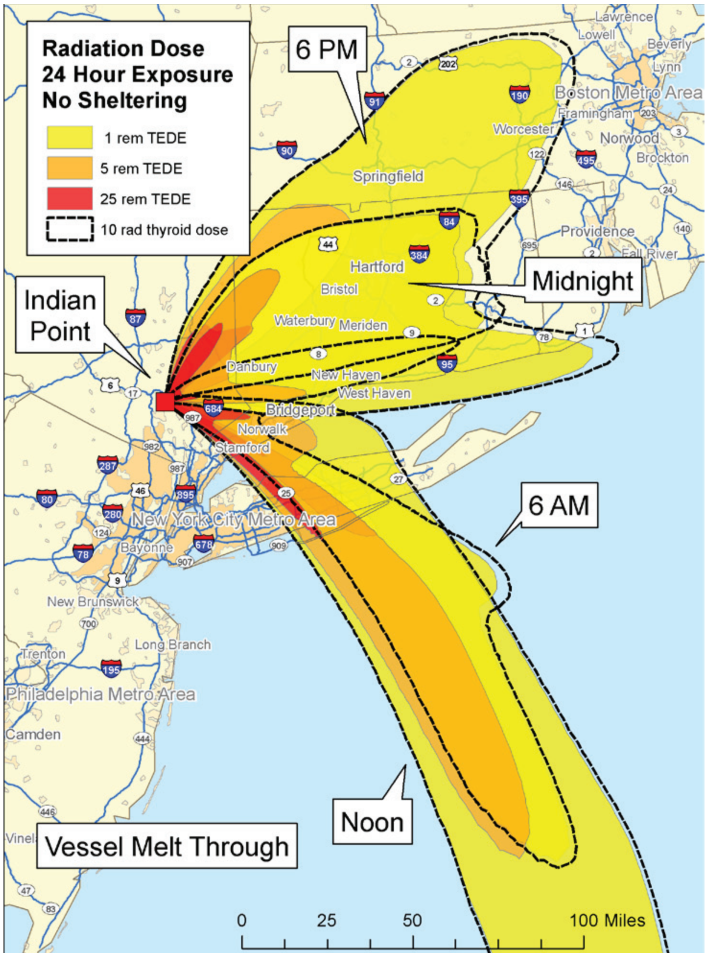

Figure 6: Vessel melt-through calculations using historical weather data for the month of October: Four separate HPAC model runs showing the different plumes resulting from an accident at Indian Point Unit 3 occurring at different times of the day. An accident of this scale would result in approximately nine times the radiation released at the Fukushima Daiichi accident, approaching the scale of the Chernobyl accident.

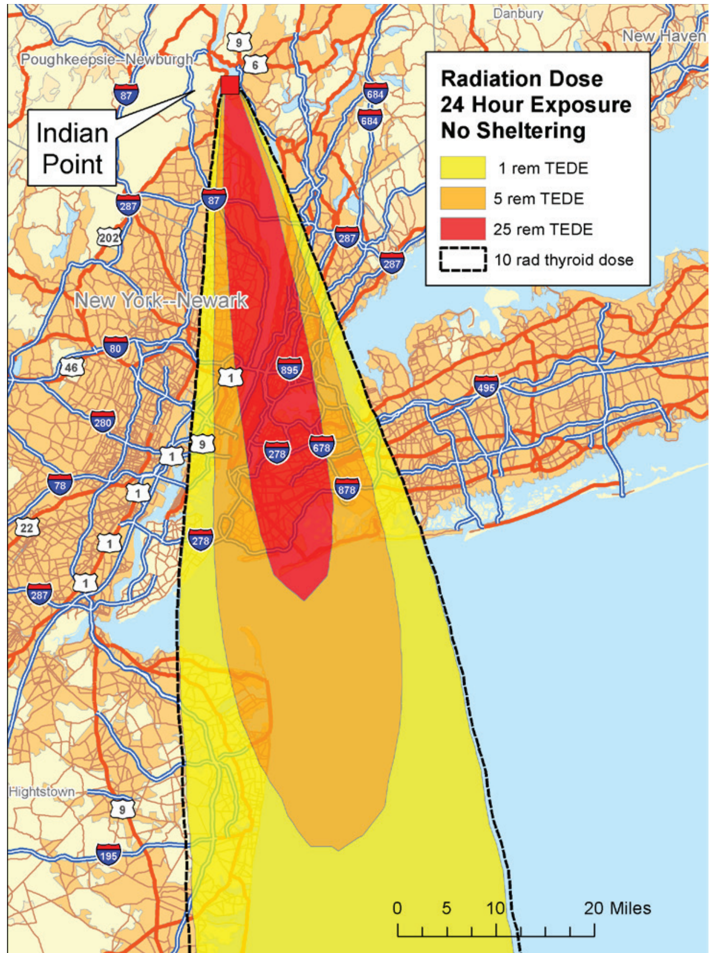

Figure 7: Vessel melt-through calculations for light (7.5 miles per hour) northerly winds blowing radiation south from Indian Point to the New York City metropolitan area. An accident of this scale would result in approximately nine times the radiation released at the Fukushima Daiichi accident, approaching the scale of the Chernobyl accident.

data, or the NRC showed deference to voluntary nuclear industry initiatives. When licensees volunteered to reassess earthquake risk, the NRC did not validate the results or even require licensees to report whether or not the studies were actually completed.[17]

In a 2008 article by seismologists at Columbia University's Lamont-Doherty Earth Observatory,[18] the authors catalogued 383 earthquakes in the New York region and found concrete evidence for a previously unknown active seismic zone that runs from Stamford, Connecticut, to Peekskill, New York, passing less than a mile north of the Indian Point plant (Figure 8). Due to the zone's proximity to other known seismic structures, the authors pointed out the possibility of an earthquake of magnitude 6 or higher along the zone. The authors go as far as to say that the Indian Point site in particular "is clearly one of the least favorable sites in our area study from an earthquake hazard and risk perspective." This study illustrates that new forms of sophisticated analysis, decades of new data on tremors, and improved models together provide valuable insight into the extent to which current NRC regulations may be lacking.

In April 2011, the NRC conducted an inspection at Indian Point Nuclear Generating Unit 2 and reported that the "licensee identified a number of potential vulnerabilities regarding firefighting following a Safe Shutdown Earthquake (SSE). The potential vulnerabilities stem from the fact that the fire protection system in non-safety related buildings, buried/underground fire headers, fire pumps, and the city water makeup supply are not seismically designed which could result in a loss of portions of the fire protection system following a SSE."[19] A SSE is the maximum earthquake potential for which certain structures, systems and components important to safety are designed to remain functional.

Currently, the NRC is conducting a process begun in 2005 to evaluate seismic hazards based on new data for the Central and Eastern United States; this process is called GI-199. A determination of the site-specific seismic hazards and associated plant risk are planned for the next phase of GI-199. However, the overall process appears to be falling short of implementing the already-known seismic criteria established in 1996.On the surface, the results of GI-199 only seem to establish how these new seismic evaluations are considered through a cost-benefit analysis. But if the finding within GI-199 emerges that Indian Point is indeed lacking in its ability protect against earthquakes (an August 2010 NRC report revealed that Indian Point Unit 3 had the highest probability of core damage of any plant in the country)[20] then the implications are compounded by the power plant's proximity to large populations.

FUKUSHIMA AND THE POTENTIAL ECONOMIC COSTS OF AN ACCIDENT AT INDIAN POINT

The cost of the nuclear accident at Fukushima Daiichi is enormous. In August of 2011 Tokyo Electric Power Company (TEPCO), the utility which owns the Fukushima Daiichi reactors and other plants impacted by the Great East Japan Earthquake and tsunami, posted a $7.39 billion loss for its April to June quarter.[21] This loss includes a projection of costs through the final phase of TEPCO's roadmap to achieve cold shutdown of the Fukushima reactors between October 2011 and January 2012.

TEPCO's estimated losses, detailed in the assessment, included:

- **$680 million** operating loss due to suspended operations at nuclear plants and replacement with thermal generating capacity
- **$1.37 billion** cost for resources to bring the crisis at the plant under control
- **$1.15 billion** compensation for mental distress caused by the accident
- **$1.32 billion** compensation to companies that became inoperable due to the evacuation orders and other reasons
- **$1.84 billion** compensation to people who could not work because of the accident
- **$870 million** compensation for losses caused by shipment restrictions on agriculture and marine products due to radiation contamination.

On September 9, 2011, the Japanese government announced that it planned to spend $2.9 billion on cleaning up residential areas contaminated by the Fukushima accident. Japan's Chief Cabinet Secretary Osamu Fujimura described the government's plan to build a facility to store radioactive material in Fukushima Prefecture before it is removed to

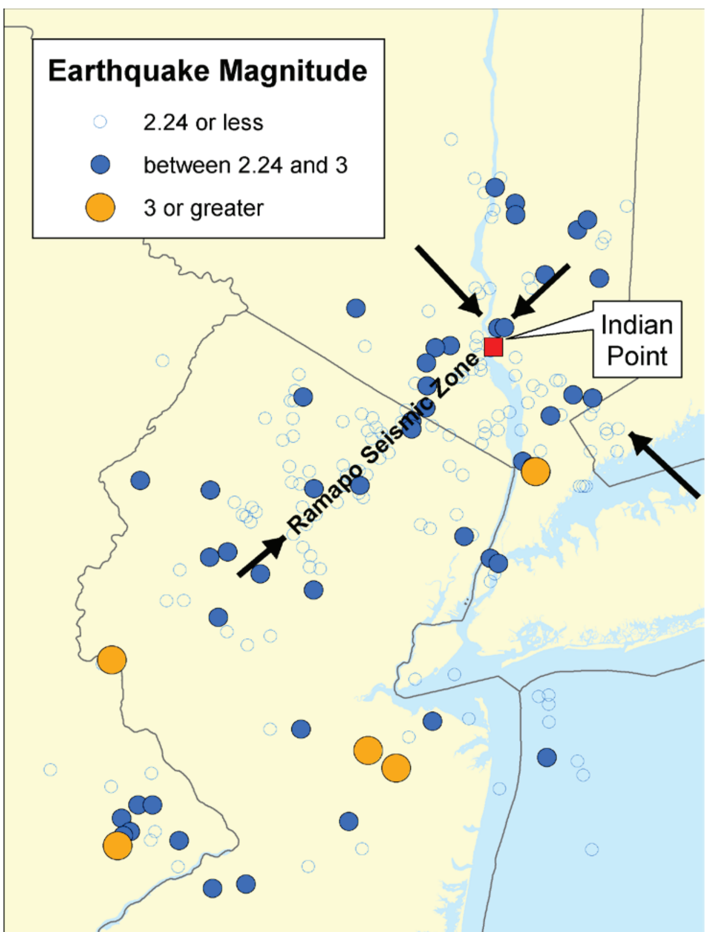

Figure 8: Earthquake locations as measured by seismic instruments between 1974 and 2007. Arrows denote the boundaries of the Ramapo Seismic Zone (map data from Sykes, Armbruster, Kim and Seeber).

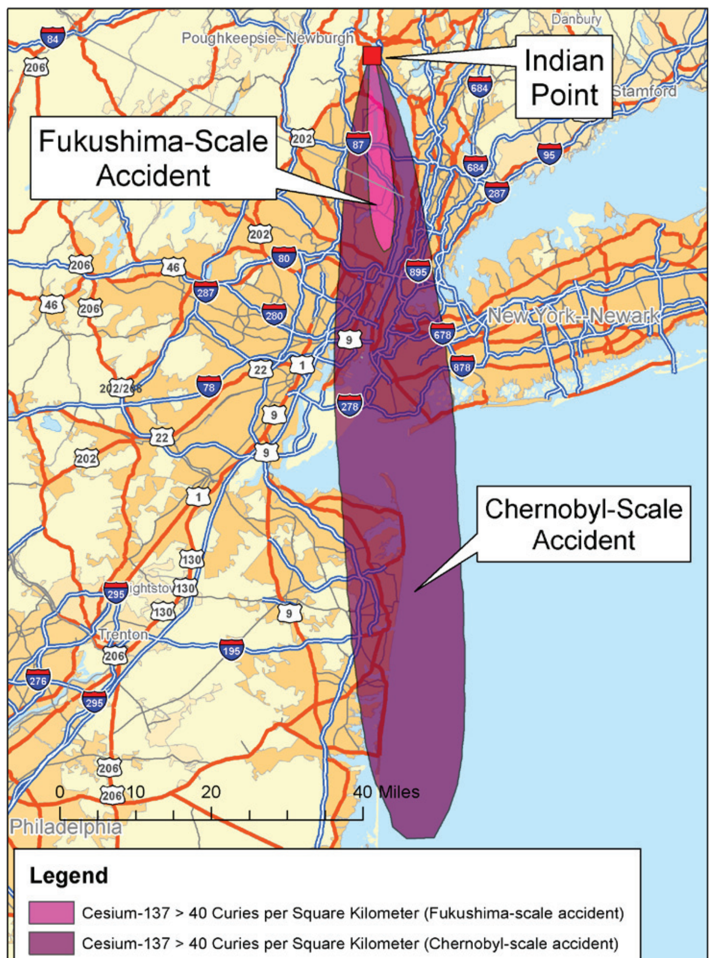

Figure 9: Cesium-137 long-term ground contamination calculated for two accident scenarios at Indian Point Unit 3 and for light (7.5 mph) northerly winds.

a final disposal site.[22] These costs are in addition to multi-billion capital losses from destruction of the reactors themselves and loss of the value of their future generating capacity. And more recently, a Japanese government panel reviewing TEPCO's finances projected that the utility company would eventually face damages of at least $59 billion.[23]

Real estate and economic activity within the New York area is among the most valuable in the world. The damage claims from radioactive contamination of this region would be vast. In the 2004 Union of Concerned Scientists' study, the economic damages within 100 miles of Indian Point were calculated to exceed $1.1 trillion for the worst cases evaluated, using NRC methodologies. Estimating the full cost of a severe accident at Indian Point is difficult, but it can be inferred from two factors that the cost of an accident at the power plant would indeed be one to two orders of magnitude higher than the eventual total cost of the Fukushima Daiichi accident. First, it is likely that winds blew some of the fallout from Fukushima Daiichi eastward out to sea, reducing the radiation dose to nearby populations and diminishing contamination of land. Second, the Fukushima Daiichi accident was located in a predominantly non-urban area. Neither of these considerations would hold for Indian Point.

One factor affecting the cost of an accident at Indian Point would be the extent of the ground concentration of radioactive materials downwind from the reactor. Following the Chernobyl accident, cesium-137, a radionuclide with a half-life of about 30 years, contaminated over 1,000 square kilometers to a level greater than 40 Curies per square kilometer, a level of contamination at which the population was encouraged to leave permanently. The accident at Fukushima Daiichi produced a zone of similar levels of contamination of cesium-137 to the northwest of the plant over about 175 square kilometers. NRDC's calculations for a Fukushima-scale accident and for a Chernobyl-scale accident at Indian Point, on a day with typical, northerly winds, are shown in Figure 9. As can be seen from this figure, an accident at one of Indian Point's reactors on the scale of Chernobyl's would make Manhattan too radioactively contaminated to live in if the city fell within the plume.

Endnotes

1 The Indian Point site measures 239 acres and is centered at 41° 16′ 11″ latitude, 73° 57′ 8″ longitude (41.269722 N, 73.952222 W).

2 In addition to the two units at Indian Point, Entergy Nuclear owns and operates: Arkansas Nuclear (Units 1 and 2) near Russellville, Arkansas; Cooper Nuclear Station near Brownville, Nebraska; FitzPatrick in Oswego, New York; Grand Gulf Nuclear Station near Port Gibson, Mississippi; Pilgrim Nuclear Power Station in Plymouth, Massachusetts; Palisades Power Plant in Covert, Michigan; River Bend Station near St. Francisville, Louisiana; Vermont Yankee in Vernon, Vermont; and Waterford 3 in Taft, Louisiana.

3 Of the three types of containment structures for PWRs – Large Dry, Subatmospheric, and Ice Condenser – Indian Point Unit 2 and Unit 3 have steel-lined reinforced concrete Large Dry containment structures with hemispherical domes and flat bases.

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