Archives of Environmental Health, Feb 2003 v58 i2 p74(9)

Elevated childhood cancer incidence proximate to U.S. nuclear power plants. *Joseph J. Mangano; Janette Sherman; Carolyn Chang; Amie Dave; Elyssa Feinberg; Marina Frimer.*

Author's Abstract: COPYRIGHT 2003 Heldref Publications

Numerous reports document elevated cancer rates among children living near nuclear facilities in various nations. Little research has examined U.S. rates near the nation's 103 operating reactors. This study determined that cancer incidence for children < 10 yr of age who live within 30 mi (48 km) of each of 14 nuclear plants in the eastern United States (49 counties with a population > 16.8 million) exceeds the national average. The excess 12.4% risk suggests that 1 in 9 cancers among children who reside near nuclear reactors is linked to radioactive emissions. If cancer incidence in 5 western states is used as a baseline, the ratio is closer to 1 in 5. Incidence is particularly elevated for leukemia. Childhood cancer mortality exceeds the national average in 7 of the 14 study areas.

<Key words: childhood cancer, ionizing radiation, leukemia, nuclear power plants, radioactive emissions>

IONIZING RADIATION poses a significant health risk to fetuses, infants, and children. Pelvic X-rays delivered to pregnant mothers raise cancer risk during childhood, (1,2) and increased background radiation is associated with elevated cancer levels among exposed children. (3-5) Ingestion of fission products is also linked with elevated childhood cancer levels. Temporal increases in leukemia and other cancers have been documented among children living near sites where large-scale atomic weapons tests were conducted in the 1950s and 1960s. (6-9) Thyroid cancer incidence rose sharply among children living in Belarus (especially the Gomel region) and the Ukraine after the 1986 accident at the Chernobyl plant. (10-12) Elevated thyroid cancer incidence in children in Belgium and northern England after the Chernobyl accident has also been reported. (13,14)

Childhood cancer is the most commonly used measure for evaluating health risks for persons living near nuclear installations. The young are more susceptible to radionuclides than adults because (a) a given dose is proportionally larger for a fetus or child than for an adult, (b) the fetus and young child are undergoing rapid cell growth and division during these life stages, and (c) the child undergoes increasing tissue differentiation in the maturation process.

Reports on childhood cancer near various nuclear plants in the United Kingdom have found higher than expected rates. (15-25) Most studies focus on leukemia, a condition that may be initiated by bone- and bone-marrow-seeking radioisotopes such as strontium-89 and -90, and barium-140. These fission products are not found in natural background radiation, but are exclusively byproducts of nuclear weapons explosions and nuclear reactor operations.

Elevated childhood cancer incidence rates proximate to nuclear facilities have been reported in Canada, (26) France, (27) Germany, (28) and the former Soviet Union. (29) Some of these reports conclude that a causal relationship exists between radiation exposure and childhood cancer risk, whereas others suggest only a statistical association. Still other reports on childhood cancer near nuclear installations have shown no risk from proximity to nuclear sites.

There are few studies of childhood cancer rates near nuclear facilities in the United States--the site of 103 of the world's 435 nuclear power reactors. The nation's 1st nuclear weapons reactor commenced operation in 1943; the 1st nuclear power reactor achieved initial criticality in 1957. The studies that have been conducted have been small in scope, with mixed results. Johnson (30) found an excess of cancer incidence (25 observed vs. 16 expected) in the period 1969 to 1971 among children 0-14 yr living < 13 mi (21 km) from the Rocky Flats weapons processing facility. Data from Hatch et al. (31) show that cancer cases in the area < 10 mi (16 km) from the Three Mile Island complex rose from 34 to 47 cases for children 0-24 yr in the 5 yr after the 1979 accident. Goldsmith reported excess leukemia mortality for children 0-9 yr in the 4 counties closest to the Oak Ridge and Hanford nuclear weapons installations in the 1950s and 1960s, but not in the 1970s. (32) Enstrom (33) found no excess cancer mortality near the San Onofre plant, but Johnson (34) documented that myeloid leukemia deaths among local children increased after the plant began operation.

Jablon et al. (35) reported a significant excess of leukemia incidence in children ages 0-9 yr who lived in 5 counties near 4 nuclear plants in Connecticut and Iowa, but no excess incidence for other childhood cancers, and no excess childhood leukemia/cancer deaths. The Jablon report compared cancer incidence near the Connecticut and Iowa plants with rates for each respective state, and compared cancer mortality with national rates. Cancer incidence and mortality for children < 10 yr in local counties exceeded state and national standards for each of the 4 areas. Moreover, the proportion of excesses for incidence and mortality was very similar (Table 1).

The Surveillance, Epidemiology and End Results (SEER) program of the U.S. Centers for Disease Control and Prevention collects data on 5 states and 4 metropolitan areas with established tumor registries, covering about 1/10 of the U.S. population. The SEER data show that, from 1998 to 2000, cancer incidence in children < 15 yr was 14.83 per 100,000, the highest since SEER was formed in 1973. From 1975 to 2000, cancer rates in children rose 31.7% for all types of cancers, and 39.6% and 49.6%, respectively, for leukemia and brain/other nervous system cancers, which make up over half of childhood malignancies. (36) The increasing trend in childhood cancer incidence has spurred considerable debate on its etiology; the U.S. Environmental Protection Agency has suggested that environmental pollutants are 1 potential cause. (37) Since the completion of the Jablon study, which included data only through 1984, many states have established cancer registries. Our study uses data from some of those registries to determine cancer incidence for children < 10 yr who live within 30 mi (48 km) of a nuclear plant in the eastern United States.

Materials and Method

Childhood cancer incidence and mortality were analyzed for 49 counties situated mostly or completely within 30 mi (48 km) of nuclear reactors in the eastern United States. The analysis focused on cancer in children < 10 yr who resided in the study counties at the time of diagnosis. The age category was selected to match that used by Stewart et al. (1)--who identified it as the period of elevated cancer risk after prenatal irradiation--and that used in the U.S. National Cancer Institute (NCI) study of cancer near nuclear facilities. (38)

The distance of < 30 mi (48 km) was selected because cancer rates at the subcounty level are generally not readily available, or are not reported because of confidentiality rules imposed by various state tumor registries. The NCI examined cancer rates in counties closest to nuclear reactors; some of their locations are duplicated herein (e.g., Dade County, Florida; Westchester/Rockland Counties, New York; Plymouth County, Massachusetts). (38) Examining rates on a smaller scale might be of interest; however, achieving statistical significance would be difficult because only about 1/5 of the population in this study reside within 10 mi (16 km) of the operating reactors.

Establishing significant patterns for rare occurrences like cancers in children often requires multiple years of data. The years 1988 to 1997 were selected because a number of eastern states have comprehensive incidence registries for this period (Connecticut, Delaware, Florida, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island). Childhood cancer mortality data (ICD-9 rubric 140.0-239.9) is available for all states from 1988 to 1997. (39) The population-at-risk estimates we used to compute rates were obtained from the U.S. Centers for Disease Control and Prevention. (39)

Incidence and mortality data for total childhood cancers from 1988 to 1997 were examined for areas near 24 reactors and 14 nuclear plants still in operation at the end of 1997. The Seabrook reactor in New Hampshire was included, even though its initial criticality date was June 1, 1989. All other reactors were in operation for at least 4 yr prior to 1988. (40) The Three Mile Island and Peach Bottom plants are situated about 35 mi (56 km) apart. Because there is overlap of some counties, the 2 sites were combined to avoid double counting. All 24 reactors produce electric power, with the exception of Brookhaven, a government-operated complex of research reactors that also produces radioactive fission products. The nuclear plants and the 49 counties included in the analysis are given in Table 2.

Table 1.—Incidence and Mortality, All Cancers, Persons Age 0-9 Yr, Counties near Nuclear Plants in Connecticut and Iowa, Compared to State (Incidence) and Nation (Mortality)

Plant (start-up)	Location	Years studied	Standardized ratio: Incidence	Standardized ratio: Mortality
[illegible]	Middlesex, CT	[illegible]	[illegible]	[illegible]
[illegible]	New London, CT	[illegible]	[illegible]	[illegible]
[illegible]	Harrison, IA	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			[illegible]	[illegible]

[illegible]

Selected demographic characteristics of residents of the 49 counties were compared with those of the nation (Table 3). The 2000 U.S. Census reported > 16.8 million persons residing in these counties, an increase of 10.1% since 1990. In general, lower proportions of blacks, Hispanics, and poor persons lived in the study counties than in the nation as a whole, with some exceptions. In Miami-Dade County, Florida--the site of the Turkey Point reactors--20.3% and 57.3% of residents were black or Hispanic, respectively, compared with national percentages of 12.3% and 12.5%. In New York's Westchester and Rockland Counties, which flank the Indian Point nuclear installation, the black and Hispanic proportions slightly exceed those for the United States. Some overlap may exist between the 2 categories, as a small proportion of Hispanics are also reported as black. (41)

Leukemia, which accounts for about 1/3 of cancers diagnosed in children < 10 yr, was studied near the 5 nuclear plants in Pennsylvania, because this state's cancer registry makes age- and race-specific incidence data by type of cancer readily available. Pennsylvania makes up 39% of the population in the 14 regions we studied.

Local rates of childhood cancer and leukemia were compared with U.S. rates. The national standard for mortality represents all 50 states plus the District of Columbia. SEER data serve as a proxy for national incidence data. Incidence rates for 1988 to 1997 were calculated using the average rates for 1988 to 1992 and 1993 to 1997, for age groups 0-4 and 5-9 yr. (42,43) Incidence data for 1997 were unavailable for Connecticut, New York, and Rhode Island, so 1988 to 1996 rates were used for the Brookhaven, Indian Point, and Millstone facilities. Data were unavailable for 3 counties < 30 mi (48 km) from 4 nuclear power reactors in the Rochester-Syracuse area in New York.

Of the SEER areas making up the national incidence standard, Hawaii, New Mexico, Utah, Atlanta, San Francisco, and Seattle have no nuclear facilities, and lie at least 100 mi (161 km) from any reactor operating since 1989. The 3 metropolitan Detroit counties are 20 to 40 mi (32 to 64 km) from the Fermi 2 reactor. A small proportion of Connecticut and Iowa residents live within 30 mi (48 km) of a reactor. Thus, the SEER rate suggests a relatively underexposed population to compare with those residing in the 49 counties studied.

Results

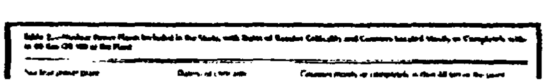
Incidence of all cancers. Incidence for total cancers for children < 5 yr during 1988 to 1997 was higher than the SEER rate near all 14 nuclear plants in our study (Table 4). The rate for all 49 counties combined was 22.51 per 100,000, or 11.4% greater than the SEER rate ($p < 0.0002$). The smallest excess was near the Salem/Hope Creek complex (+0.7%); the largest occurred near both the Turkey Point and St. Lucie facilities in Florida (+29.1%).

Cancer incidence in children 5-9 yr for 1988 to 1997 exceeded the SEER rate for 13 of the 14 areas. The rate for the study counties was 12.15 per 100,000--12.5% higher than the SEER rate of 10.80 ($p < 0.002$). The smallest excess was found near the Millstone reactors in Connecticut (+2.2%), and the largest occurred near St. Lucie (+73.6%). Incidence near the Crystal River facility in Florida was 6.5% below the SEER rate.

Combining the age groups yields an incidence rate of 17.42 per 100,000--12.4% above the SEER rate ($p < 0.00001$). The excess incidence near 3 of the plants (Oyster Creek, St. Lucie, and Turkey Point) was statistically significant; near the Indian Point and Brookhaven facilities it reached borderline significance ($p < 0.08$ and $p < 0.07$, respectively). Although county-specific totals are not shown, considerable variation in rates exists, in part because of the relatively small numbers of cases involved. Still, the incidence rate for those 0-9 yr of age exceeded the U.S. rate in 38 of the 49 study counties.

Childhood cancer incidence < 30 mi (48 km) from nuclear reactors was compared with rates for the remaining counties in the states in which reactors are located. Several adjoining, less-populated states (New Jersey and Delaware, Connecticut and Rhode Island, Massachusetts and New Hampshire) were combined to ensure adequate statistical power. For each of 6 states and combinations of states, cancer incidence for those 0-9 yr in the counties near reactors was higher than in other counties in the state (Table 5). The total excess incidence derived from comparing the counties near reactors with those in the rest of the state, or state combinations, was 5.0% ($p < 0.04$). Elevated rates for the New York and Pennsylvania nuclear counties are of borderline significance ($p < 0.055$ and $p < 0.07$, respectively).

Total cancer incidence by race. U.S. black and Hispanic children < 20 yr of age have cancer incidence rates 23% and 10% below that for whites, respectively. (44) To assess the effect of race on childhood cancer incidence near nuclear plants, incidence data from Pennsylvania counties near nuclear plants were studied (the Pennsylvania registry makes county statistics for whites and blacks more readily available than do registries in other states). Using SEER data, the 1988 to 1997 U.S. cancer incidence rates for white and black children 0-9 yr were calculated at 15.88 and 13.28 per 100,000, respectively. For the 23 Pennsylvania counties located close to reactors, childhood cancer rates exceeded U.S. rates for both whites and blacks (Table 6).



Incidence of leukemia. We

examined the incidence of childhood leukemia in the 23 counties near 5 nuclear plants in Pennsylvania (Table 7). These regions account for slightly more than half the state's population. Leukemia incidence in the state's nuclear counties exceeded the U.S. rate by 10.8%; the rate for the remainder of the state was 11.5% below the U.S. rate ($p < 0.01$). For all other cancers, virtually no difference was seen between nuclear and non-nuclear counties, even though both exceeded the national rate (by 2.6% and 3.2%, respectively).

Mortality. Cancer mortality for U.S. children < 10 yr of age for 1988 to 1997 was 3.49 per 100,000; it was the same for the SEER areas. Cancer mortality for children < 10 yr was higher than the U.S. rate in 7 of the 14 study areas (Table 8). Because cancer mortality represents only 20% of cancer incidence in children, area-specific numbers of deaths are relatively small, and none of the differences achieved statistical significance. A total of 218 leukemia deaths occurred among children < 10 yr in the 49 counties during the 10-yr study period, resulting in a mortality rate of 1.012 per 100,000 (1.6% below the U.S. rate).

Discussion

Few studies of childhood cancer among American children living near nuclear reactors exist. Unlike exposure to external radiation sources such as cosmic rays or X-rays, radioactive nuclides are deposited within the body from food and water. The fetus receives these exposures through the mother's diet during pregnancy. Once in the body, these unstable atoms release alpha, beta, and gamma radiation that damages dividing cells. When a damaged cell is unable to repair itself, an aberrant cell line, or malignancy, may result.

This study found a consistent pattern of increased childhood cancer incidence in all study areas < 30 mi (48 km) from nuclear plants in the eastern United States. Our findings support the biologically plausible concept that susceptibility to carcinogens, such as radioactivity, is greatest in utero and in early childhood. They also support numerous analyses documenting elevated childhood cancer rates near nuclear facilities in the United States and other nations. The finding that cancer incidence for children < 10 yr is 12.4% greater in the study counties than the U.S. as a whole suggests that emissions from nuclear power plants may be linked with 1 of 9 local cases of childhood cancer. These descriptive epidemiological findings suggest a relationship between radioactive nuclides and childhood cancer and should be taken seriously in future research.

In Pennsylvania, childhood leukemia incidence in counties near nuclear plants exceeded U.S. rates by 10.8%; however, rates were 11.5% below the U.S. rate for all other areas of the state. This finding supports the considerable evidence that, although the risk of all forms of childhood cancer is increased by radiation exposure, the risk may be greatest for leukemia.

Childhood cancer incidence in nuclear counties showed significant excess when compared with other parts of the state, although this excess is not as great when the U.S. is used as a comparison group. Although reasons for this are not completely understood, it cannot be assumed that living more than 30 mi (48 km) from a nuclear reactor precludes residents from risk. Airborne emissions are carried by prevailing winds for long distances. Moreover, radioactive particles that are introduced into the diet through precipitation into drinking water, milk, and food may be transported considerable distances before consumption.

Cancer incidence rates for children living near nuclear reactors in Pennsylvania exceed national rates for both whites and blacks. No attempt was made to assess the effect of poverty on cancer rates. However, any elevated cancer rate from lack of access to medical screening does not occur among children, who are not routinely screened for cancer as older persons are. On the basis of SEER data, the 1988 to 1997 U.S. cancer incidence rate for blacks age 0-9 yr was 13.28 per 100,000, or 16% below the 15.88 per 100,000 rate for whites. The fact that Miami-Dade County Florida--with a population that is 77% black and Hispanic--has the 2nd highest childhood cancer incidence rate of the 14 areas studied suggests that racial composition is not the primary factor affecting the elevated rates documented herein.

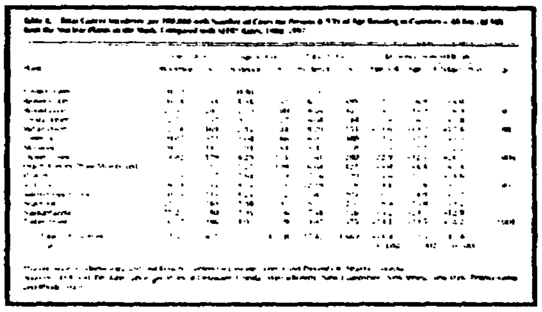
Table 3.—Population in the U.S. and within 48 Km (30 Mi) of the Nuclear Power Plants in the Study, with Percentage of Blacks, Hispanics, and Population below the Poverty Line, 2000

Plant	Population	% black	% Hispanic	% below poverty line
United States	281,421,906	12.3	12.5	[illegible]
Beaver Valley	1,934,701	9.4	0.8	11.0
Brookhaven	1,419,369	6.9	10.7	7.6
Crystal River	542,231	[illegible]	1.9	15.6
Indian Point	1,310,312	11.4	14.3	9.4
Limerick	2,420,190	7.8	4.4	6.8
Millstone	950,250	1.0	3.6	7.0
Oyster Creek	1,126,217	5.8	5.2	7.1
Peach Bottom/Three Mile Island	1,481,310	5.2	[illegible]	7.4
Pilgrim	472,922	4.6	2.4	8.6
St Lucie	319,426	11.4	7.9	11.1
Salem/Hope Creek	945,920	16.9	4.2	8.9
Seabrook	1,113,011	1.9	2.5	9.2
Susquehanna	645,411	1.5	3.3	10.6
Turkey Point	2,251,362	20.3	57.1	21.1
Total 49 counties	16,834,954	9.2	12.4	10.4

Source: U.S. Census of Population, 2000

Incidence rates are taken from multiple state-operated cancer registries, each with its own methods of data collection. Thus, the reliability of interstate comparisons may be compromised. However, because all children with cancer are treated in hospitals (the primary source of cancer incidence data in all states), reporting is likely to approximate completeness. If older, more established registries have more complete reporting, it was not apparent. The Connecticut Tumor Registry was established in 1935, well before any other registry, yet the Connecticut childhood cancer rate is 1 of the lowest in this report.

A precise evaluation of cancer risk for children living near nuclear reactors requires a comparison with an "unexposed control" group, but such a group is difficult to identify. Rates in counties situated > 30 mi (48 km) from reactors in the same state may not prove adequate, because radioactive particles travel considerable distances. The SEER rate for 9 U.S. cities and states may also be an inflated "control" group because these locations contain several nuclear reactors.



Five contiguous states in the western United States that have never had an operating nuclear power reactor and whose borders lie > 100 mi (161 km) from any reactor have a 1988 to 1997 cancer incidence rate for children 0-9 yr (n = 1,550) of 14.27 per 100,000. This figure is 22.1% lower than the rate for the 49 counties near reactors. Residents of these 5 states (Idaho, Nevada, New Mexico, Utah, and Wyoming) may or may not be representative of the U.S., using various criteria. However, they do represent perhaps the segment of the American population least exposed to radioactive emissions from reactors since the late 1980s. Using these 5 states as a control, the excess incidence near nuclear plants is close to 1 in nearly 5 childhood cancer cases (17.42 vs. 14.27 per 100,000). Even this may be a conservative estimate because the food supply in these western states contains some reactor-generated radioactivity from distant imports. Moreover, 3 nuclear weapons laboratories (Idaho National, Sandia, and Los Alamos) that discharged radioactivity in the western areas operated until about 1990.

No difference was seen in mortality rates between nuclear counties and the United States as a whole for cancer and leukemia among children < 10 yr. This finding differs from earlier data for Connecticut and Iowa counties, which showed parallel excesses for both incidence and mortality. (38) It is possible that the considerable enhancements in therapeutic interventions for childhood cancer have altered this prior pattern. From 1973 to 1998, annual mortality from cancer in U.S. children 0-14 yr declined by more than half (from 5.5 to 2.5 per 100,000). Survival from leukemia, especially acute lymphocytic leukemia, has improved most rapidly. (36,42) New treatments are so effective that high-incidence areas may often have below-average death rates.

Limitations. Our study had several limitations. First, the precise national cancer incidence rate is unknown in the United States, which lacks a centralized tumor registry system. We used SEER data--a sample representing < 10% of the U.S. population--to approximate the national incidence rate. Numerous government agencies confidently use these data as the national standard. Moreover, the 1988 to 1997 cancer mortality rate for children < 10 yr of age in the SEER areas equals that for the U.S. as a whole, suggesting that the SEER data are a relatively accurate proxy for the entire nation.

Second, this study examined cancer patterns in only 14 plants, which include 24 (plus the Brookhaven research reactors) of the 103 operating power reactors in U.S. plants. Seven of 16 eastern states did not have 10 yr of cancer incidence data available. These 7 states contain an additional 23 reactors at 13 plants, nearly equal to the 24 reactors at 14 plants analyzed here. (40)

Of the 24 reactors in the study, 13 (54%) achieved initial criticality before 1977. The proportion is 42% (33 of 79) for all other U.S. reactors, making the study reactors slightly older than average. (40) The study reactors are also located in the more industrialized eastern part of the country, which may affect cancer rates. About 1/3 of the 50 million Americans living within 30 mi (48 km) of a nuclear power reactor live near these 14 plants.

A 3rd limitation existed because few of the 50 states compiled cancer incidence statistics prior to the late 1980s, thus it is not possible to analyze data over the entire operating life of the reactors. Information on the birth location of children with cancer living near nuclear plants is not easily available. The effects of in-migration should be addressed in future studies.

Table 5 —Number of Cases, Population, and Incidence per 100,000 for Total Cancers among Persons 0–9 Yr of Age Residing in Counties < 48 Km (30 Mi) from Nuclear Plants in the Eastern United States, Compared with the Remainder of the State, 1988–1997

Area	n	Population	Cases/100,000	% difference	p
Indian Point, Brookhaven	560	3,091,624	18.11	+12.1	<0.055
Other New York	3,222	19,952,023	16.15		
Crystal River, St. Lucie, Turkey Point	715	3,754,244	19.36	+7.9	
Other Florida	2,607	14,362,311	18.15		
Oyster Creek, Salem	485	2,722,573	17.81	+5.7	
Other Delaware, New Jersey	1,553	9,217,923	16.85		
Millstone	178	1,124,275	15.83	+1.0	
Other Connecticut, Rhode Island	647	4,119,792	15.70		
5 Pennsylvania plants	1,341	8,201,264	16.31	+7.4	0.07
Other Pennsylvania	1,178	7,740,218	15.22		
Pilgrim, Seabrook	370	2,166,640	17.10	+4.1	
Other Massachusetts, New Hampshire	1,250	7,569,590	16.42		
Total 49 counties	3,669	21,067,290	17.41	+5.0	0.04
Other counties in 9 states	10,457	62,968,617	16.60		

Note: Data are for 1988 to 1996 for Connecticut, New York, and Rhode Island.
Sources: The state cancer registries of Delaware, Florida, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, and Rhode Island.

Our study leaves a number of points unaddressed. Understanding patterns by type of childhood cancer would enhance knowledge of any radiation-cancer link. Analyzing data for adolescents and young adults would also improve this understanding. Cancer patterns for residents living beyond the 30-mi (48-km) radius from reactors would provide helpful information, as would comparisons of downwind and upwind populations near plants. Comparing interregional childhood cancer patterns by precipitation level might provide useful information, as well. Including areas near other U.S. reactors would make this study part of a more comprehensive analysis.

Perhaps most importantly, the findings from our study should be compared with doses of ionizing radiation. Emissions from nuclear plants can be employed, as well as levels of various radionuclides in the air, water, food, and soil. Comparing childhood cancer risk to in vivo levels of radioactivity offers the most valuable evidence for this type of study. An effort is currently being made to measure radioactive strontium-90 in baby teeth at birth; a link between trends in concentrations of this isotope and childhood cancer incidence in Suffolk County, New York, has recently been reported. (45) Knowing in vivo levels of manmade ionizing radiation will eventually enable case-control and prospective studies to proceed. The strong evidence of high childhood cancer levels near nuclear plants presented in this report indicates that such follow-up studies will be critical.

Table 1.--Incidence and Mortality, All Cancers, Persons Age 0-9 Yr, Counties near Nuclear Plants in Connecticut and Iowa, Compared to State (Incidence) and Nation (Mortality)

			Relative risk (n)	
Plant, yr startup	Location	Yr included	Incidence	Mortality
Haddam Neck, 1967	Middlesex, CT	1968-1984	1.03 (45)	1.04 (18)
Millstone, 1970	New London, CT	1971-1984	1.12 (84)	1.13 (30)
Ft. Calhoun, 1973	Harrison, IA	1974-1984	1.55 (6)	1.94 (5)
Duane Arnold, 1984	Benton, IA, and Linn, IA	1975-1984	1.18 (50)	1.16 (16)
Total			1.12 (185)	1.15 (69)

Source: Jablon S, Hrubec Z, Boice JD, et al. Cancer in Populations Living near Nuclear Facilities. National Cancer Institute. NIH publ. no. 90-874. Washington, DC: U.S. Government Printing Office, 1990.

Table 2.--Nuclear Power Plants Included in the Study, with Dates of Reactor Criticality and Counties Located Mostly or Completely within 48 Km (30 Mi) of the Plant

Nuclear power plant	Date(s) of criticality
Beaver Valley, Shippingport, PA	1976, 1987
Brookhaven, Upton, NY	1950
Crystal River, Red Level, FL	1977
Indian Point, Buchanan, NY	1973, 1976
Limerick, Pottstown, PA	1984, 1989
Millstone, Waterford, CT	1975, 1986
Oyster Creek, Forked River, NJ	1969
Peach Bottom, Delta, PA, and Three Mile Island, Londonderry PA	1973, 1974, and 1974
Pilgrim, Plymouth, MA	1972
St. Lucie, Hutchinson Island, FL	1976, 1983
Salem/Hope Creek, Salem, NJ	1976, 1980, 1986
Seabrook, Seabrook, NH	1989
Susquehanna, Berwick, PA	1982, 1984
Turkey Point, Florida City, FL	1972, 1973

Nuclear power plant	Counties mostly or completely within 48 km of the plant
Beaver Valley, Shippingport, PA	PA: Allegheny, Beaver, Butler, Lawrence, Washington
Brookhaven, Upton, NY	NY: Suffolk
Crystal River, Red Level, FL	FL: Citrus, Hernando, Levy, Marion
Indian Point, Buchanan, NY	NY: Rockland, Westchester
Limerick, Pottstown, PA	PA: Berks, Chester, Delaware, Lehigh, Montgomery
Millstone, Waterford, CT	CT: Middlesex, New London, Tolland, Windham RI: Kent, Washington
Oyster Creek, Forked River, NJ	NJ: Monmouth, Ocean
Peach Bottom, Delta, PA, and Three Mile Island, Londonderry PA	PA: Cumberland, Dauphin, Lancaster, Lebanon, Perry, York
Pilgrim, Plymouth, MA	MA: Plymouth

St. Lucie, Hutchinson Island, FL	FL: Martin, St. Lucie
Salem/Hope Creek, Salem, NJ	DE: Kent, New Castle NJ: Gloucester, Salem
Seabrook, Seabrook, NH	MA: Essex NH: Rockingham, Strafford
Susquehanna, Berwick, PA	PA: Carbon, Columbia, Luzerne, Montour, Schuylkill, Sullivan, Wyoming
Turkey Point, Florida City, FL	FL: Miami-Dade

Table 3.--Population in the U.S. and within 48 Km (30 Mi) of the Nuclear Power Plants in the Study, with Percentage of Blacks, Hispanics, and Population below the Poverty Line, 2000

Plant	Population	% black	% Hispanic	% below poverty line
United States	281,421,906	12.3	12.5	13.3
Beaver Valley	1,934,701	9.4	0.8	11.0
Brookhaven	1,419,369	6.9	10.5	7.6
Crystal River	542,253	7.7	4.9	15.6
Indian Point	1,210,212	13.4	14.3	9.4
Limerick	2,420,190	7.8	4.4	6.8
Millstone	950,250	3.0	3.6	7.0
Oyster Creek	1,126,217	5.8	5.7	7.1
Peach Bottom/Three Mile Island	1,481,810	5.2	3.9	7.4
Pilgrim	472,822	4.6	2.4	8.6
St. Lucie	319,426	11.4	7.9	13.1
Salem/Hope Creek	945,920	16.9	4.2	8.9
Seabrook	1,113,011	1.9	7.5	9.1
Susquehanna	645,411	1.5	1.1	10.6
Turkey Point	2,253,362	20.3	57.3	21.1
Total (49 counties)	16,834,954	9.2	12.4	10.4

Source: U.S. Census of Population, 2000.

Table 4.--Total Cancer Incidence per 100,000 with Number of Cases for Persons 0-9 Yr of Age Residing in Counties < 48 Km (30 Mi) from the Nuclear Plants in the Study, Compared with SEER * Rates, 1988-1997

	Age 0-4 yr		Age 5-9 yr	
Plant	Incidence	n	Incidence	n
United States	20.20		10.80	
Beaver Valley	20.74	253	11.54	142
Brookhaven	23.30	207	12.30	100
Crystal River	22.35	57	10.10	27
Indian Point	22.94	169	12.85	84
Limerick	20.87	322	11.04	166
Millstone	20.71	117	10.93	61
Oyster Creek	24.82	179	14.29	101
Peach Bottom/Three Mile Island	22.01	213	11.27	109
Pilgrim	22.95	77	12.64	43
St. Lucie	26.08	45	18.75	31
Salem/Hope Creek	20.35	133	11.23	72
Seabrook	21.50	163	11.88	87
Susquehanna	21.25	80	13.95	56
Turkey Point	26.07	396	13.01	179
Total (39 counties)	22.51	2,411	12.15	1,258

p

Plant	Total 0-9 yr Incidence	n	% difference from SEER rate Age 0-4	Age 5-9
United States	15.50			
Beaver Valley	16.12	395	+2.7	+6.9
Brookhaven	18.04	307	+15.3	+13.9
Crystal River	16.08	84	+10.6	-6.5
Indian Point	18.20	253	+13.6	+19.0
Limerick	16.02	488	+3.3	+2.2
Millstone	15.85	178	+2.5	+1.2
Oyster Creek	19.61	280	+22.9	+32.3
Peach Bottom/Three Mile Island	16.64	322	+9.0	+4.4
Pilgrim	17.76	120	+13.6	+17.1
St. Lucie	22.49	76	+29.1	+73.6
Salem/Hope Creek	15.83	205	+0.7	+4.0
Seabrook	16.77	250	+6.4	+10.0
Susquehanna	17.48	136	+5.2	+29.1
Turkey Point	19.87	575	+29.1	+20.5
Total (39 counties)	17.42	3,669	+11.4	+12.5
p			< 0.0002	< 0.002

Plant	% difference from SEER rate Total 0-9 yr	p
United States		
Beaver Valley	+4.0	
Brookhaven	+16.4	< 0.07
Crystal River	+3.8	
Indian Point	+17.4	< 0.08
Limerick	+3.3	
Millstone	+2.2	
Oyster Creek	+26.5	< 0.006
Peach Bottom/Three Mile Island	+7.4	
Pilgrim	+14.6	
St. Lucie	+45.1	< 0.03
Salem/Hope Creek	+2.2	
Seabrook	+8.2	
Susquehanna	+12.8	
Turkey Point	+28.2	< 0.001
Total (39 counties)	+12.4	
p	< 0.00001	

* Surveillance, Epidemiology and End Results, Centers for Disease Control and Prevention, Atlanta, Georgia.

Sources: SEER and the state cancer registries of Delaware, Florida, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, and Rhode Island.

Table 5.--Number of Cases, Population, and Incidence per 100,000 for Total Cancers among Persons 0-9 Yr of Age Residing in Counties < 48 Km (30 Mi) from Nuclear Plants in the Eastern United States, Compared with the Remainder of the State, 1988-1997

Area	n	Population	Cases/ 100,000
Indian Point, Brookhaven	560	3,091,824	18.11
Other New York	3,222	19,952,003	16.15
Crystal River, St. Lucie, Turkey Point	735	3,754,294	19.58
Other Florida	2,607	14,362,311	18.15
Oyster Creek, Salem	485	2,722,573	17.81
Other Delaware, New Jersey	1,553	9,217,923	16.85
Millstone	178	1,123,275	15.85
Other Connecticut, Rhode Island	647	4,119,792	15.70
5 Pennsylvania plants	1,341	8,209,264	16.34
Other Pennsylvania	1,178	7,740,218	15.22
Pilgrim, Seabrook	370	2,166,060	17.20
Other Massachusetts, New Hampshire	1,250	7,569,390	16.42
Total 49 counties	3,669	21,067,290	17.43
Other counties in 9 states	10,457	62,988,637	16.60

Area	% difference	p
Indian Point, Brookhaven	+12.1	< 0.055
Other New York		
Crystal River, St. Lucie, Turkey Point	+7.9	
Other Florida		
Oyster Creek, Salem	+5.7	
Other Delaware, New Jersey		
Millstone	+1.0	
Other Connecticut, Rhode Island		
5 Pennsylvania plants	+7.4	< 0.07
Other Pennsylvania		
Pilgrim, Seabrook	+4.8	
Other Massachusetts, New Hampshire		
Total 49 counties	+5.0	< 0.04
Other counties in 9 states		

Note: Data are for 1988 to 1996 for Connecticut, New York, and Rhode Island.

Sources: The state cancer registries of Delaware, Florida, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, and Rhode Island.

Table 6.--Cancer Incidence (per 100,000) for Persons 0-9 Yr of Age, by Race for Counties < 48 Km (30 Mi) from Nuclear Plants vs. Other Counties in Pennsylvania, 1988-1997

			Cases per 100,000		
Race	n	Population	Local	Pennsylvania	% difference
White	1,189	7,319,688	16.24	15.88	+2.3%

Black	105	742,561	14.14	13.28	+6.5%

Source: Pennsylvania State Cancer Registry.

Table 7.--Incidence of Leukemia and All Other Cancers for Persons 0-9 Yr of Age for Counties < 48 Km (30 Mi) from Nuclear Plants, and Other Counties in Pennsylvania, Compared with SEER * Rates, 1988-1997

Area	n	Population	Cases/ 100,000	% difference from SEER rate	p
		Leukemia			
United States			5.30		
Pennsylvania			5.30		
Beaver Valley	144	2,449,693	5.88	+10.9	< 0.06
Limerick	171	3,046,972	5.61	+5.9	
Peach Bottom/ Three Mile Island	112	1,934,559	5.79	+9.2	
Susquehanna	55	778,040	7.07	+33.4	< 0.04
Total	482	8,209,264	5.87	+10.8	< 0.01
Other Pennsylvania	363	7,740,218	4.69	-11.5	
		All other cancers			
United States			10.20		
Pennsylvania			10.50		
Beaver Valley	251	2,449,693	10.25	+0.5	
Limerick	317	3,046,972	10.40	+2.0	
Peach Bottom/ Three Mile Island	210	1,934,559	10.86	+6.4	
Susquehanna	81	778,040	10.41	+2.1	
Total	859	8,209,264	10.46	+2.6	
Other Pennsylvania	815	7,740,218	10.53	+3.2	

* Surveillance, Epidemiology and End Results, Centers for Disease Control and Prevention, Atlanta, Georgia.

Sources: SEER data and the Pennsylvania State Cancer Registry.

Table 8.--Cancer Mortality near Nuclear Plants for Persons 0-9 Yr of Age, Compared with U.S. Rates, 1988-1997

Plant	Deaths	Population	Deaths/ 100,000	% difference from U.S. rate
United States	13,241	378,858,024	3.49	
SEER areas	1,255	35,942,869	3.49	
Beaver Valley	78	2,449,693	3.18	-8.9
Brookhaven	56	1,896,531	2.95	-15.5
Crystal River	11	522,266	2.11	-39.7
Indian Point	55	1,551,301	3.55	+1.4
Limerick	102	3,046,972	3.35	-4.2
Millstone	32	1,249,007	2.56	-26.7
Oyster Creek	65	1,427,943	4.55	+30.2
Peach Bottom/ Three Mile Island	89	1,934,559	4.60	+31.6
Pilgrim	24	675,674	3.55	+1.6
St. Lucie	15	337,853	4.44	+27.0
Salem/Hope Creek	45	1,294,630	3.48	-0.5

Seabrook	65	1,490,386	4.36	+24.8
Susquehanna	28	778,040	3.60	+3.0
Turkey Point	89	2,894,175	3.08	-12.0
Total	754	21,549,030	3.50	+0.1

Source: National Center for Health Statistics, Mortality Data File.

Table 6.—Cancer Incidence (per 100,000) for Persons 0-9 Yr of Age, by Race for Counties < 48 Km (30 Mi) from Nuclear Plants vs. Other Counties in Pennsylvania, 1988-1997

			Cases per 100,000		
Race	n	Population	Local	Pennsylvania	% difference
White	[illegible]	[illegible]	16.24	15.58	[illegible]
Black	105	[illegible]	14.14	[illegible]	+6.7%

Source: Pennsylvania State Cancer Registry

Table 7.—Incidence of Leukemia and All Other Cancers for Persons 0-9 Yr of Age for Counties < 48 Km (30 Mi) from Nuclear Plants, and Other Counties in Pennsylvania, Compared with SEER* Rates, 1988-1997

Area	n	Population	Cases/100,000	% difference from SEER rate	p
Leukemia					
United States			[illegible]		
Pennsylvania			[illegible]		
Beaver Valley	144	2,449,691	5.88	+10.9	[illegible]
Limerick	[illegible]	[illegible]	[illegible]	[illegible]	
Peach Bottom/Three Mile Island	112	[illegible]	[illegible]	[illegible]	
Susquehanna	55	778,040	[illegible]	[illegible]	[illegible]
Total	482	[illegible]	[illegible]	[illegible]	[illegible]
Other Pennsylvania	[illegible]	[illegible]	[illegible]	[illegible]	
All other cancers					
United States			10.20		
Pennsylvania			10.50		
Beaver Valley	251	2,449,691	10.25	+0.5	
Limerick	[illegible]	1,046,972	10.40	+2.0	
Peach Bottom/Three Mile Island	210	1,914,559	10.86	+6.4	
Susquehanna	81	778,040	10.41	+2.1	
Total	859	8,209,264	10.46	+2.6	
Other Pennsylvania	815	7,740,218	10.53	+3.2	

*Surveillance, Epidemiology and End Results, Centers for Disease Control and Prevention, Atlanta, Georgia.
Sources: SEER data and the Pennsylvania State Cancer Registry.

Table 8.—Cancer Mortality near Nuclear Plants for Persons 0-9 Yr of Age, Compared with U.S. Rates, 1988-1997

Plant	Deaths	Population	Deaths/100,000	% difference from U.S. rate
United States	[illegible]	[illegible]	[illegible]	
SEER areas	1,255	[illegible]	3.49	
Beaver Valley	78	2,449,691	3.18	[illegible]
Brookhaven	56	[illegible]	2.95	[illegible]
Crystal River	11	[illegible]	2.11	[illegible]
Indian Point	55	[illegible]	3.55	+1.4
Limerick	102	[illegible]	3.35	-4.2
Millstone	32	[illegible]	2.56	[illegible]
Oyster Creek	65	[illegible]	4.55	+30.2
Peach Bottom/Three Mile Island	89	[illegible]	4.60	+31.6
Pilgrim	24	675,674	3.55	+1.6
St. Lucie	15	337,853	4.44	+27.0
Salem/Hope Creek	45	1,294,610	3.48	[illegible]
Seabrook	65	1,490,386	4.36	+24.8
Susquehanna	28	778,040	3.60	+3.0
Turkey Point	89	2,894,175	3.08	-12.0
Total	754	21,549,030	3.50	+0.1

Source: National Center for Health Statistics, Mortality Data File.

Submitted for publication January 2, 2002; revised; accepted for publication

September 17, 2002.

Requests for reprints should be sent to Joseph Mangano, Radiation and Public Health Project, 786 Carroll Street, #9, Brooklyn, NY 11215.

References

(1.) Stewart A, Webb J, Hewitt D. A survey of childhood malignancies. BMJ 1958; 1:1495-1508.

(2.) MacMahon B. Prenatal x-ray exposure and childhood cancer. J Natl Cancer Inst 1962; 28:1173-92.

(3.) Knox EG, Stewart AM, Gilman EA, et al. Background radiation and childhood cancers. J Radiol Prot 1988; 8:9-18.

(4.) Hatch M, Susser M. Background gamma radiation and childhood cancers within ten miles of a United States nuclear plant. Int J Epidemiol 1990; 19 (3):546-52.

(5.) Petersen NJ, Samuels LD, Lucas HF, et al. An epidemiological approach to low-level radium 226 exposure. Public Health Rep 1966; 81:805-14.

(6.) Stevens W, Thomas DC, Lyon JL, et al. Leukemia in Utah and radioactive fallout from the Nevada tests. JAMA 1990; 264(5):585-91.

(7.) Machado SG, Land CE, McKay FW. Cancer mortality and radioactive fallout in southwestern Utah. Am J Epidemiol 1987; 125(1):44-61.

(8.) Kerber RA, Till JE, Simon SL, et al. A cohort study of thyroid disease in relation to fallout from nuclear weapons testing. JAMA 1993; 270(17):2076-82.

(9.) Weiss ES, Olsen RE, Thompson GD, et al. Surgically treated thyroid disease among young people in Utah, 1948-1962. Am J Public Health 1967; 57 (10):1807-14.

(10.) Tronko MD, Bogdanova TI, Komissarenko IV, et al. Thyroid carcinoma in children and adolescents in Ukraine after the Chernobyl nuclear accident: statistical data and clinicomorphologic characteristics. Cancer 1999; 86(1):149-56.

(11.) Lomat L, Galburt G, Quastel MR, et al. Incidence of childhood disease in Belarus associated with the Chernobyl accident. Environ Health Perspect 1997; 105(Suppl 6):1529-32.

(12.) Antonelli A, Miccoli P, Derzhitski VE, et al. Epidemiologic and clinical evaluation of thyroid cancer in children from the Gomel region (Belarus). World J Surg 1996; 20(7):867-71.

(13.) Blackburn DJ, Michel LA, Rosiere A, et al. Occurrence of thyroid papillary carcinoma in young patients: a Chernobyl connection? J Pediatr Endocrinol Metab 2001; 14(5):503-06.

(14.) Cotterill SJ, Pearce MS, Parker L. Thyroid cancer in children and young adults in the North of England. Is increasing incidence related to the Chernobyl accident? Eur J Cancer 2001; 37(8): 945-47.

(15.) Sharp L, McKinney PA, Black RJ. Incidence of childhood brain and other non-haematopoietic neoplasms near nuclear sites in Scotland, 1975-94. Occup Environ Med 1999; 56(5):308-14.

(16.) Busby C, Cato MS. Death rates from leukaemia are higher than expected in areas around nuclear sites in Berkshire and Oxfordshire. BMJ 1997 (2 Aug); 315(7103):309.

(17.) Black RJ, Sharp L, Harkness EF, et al. Leukaemia and non-Hodgkin's lymphoma: incidence in children and young adults resident in the Dounreay area of Carthness, Scotland in 1968-91. J Epidemiol Community Health 1994; 48 (3):232-36.

(18.) Draper GJ, Stiller CA, Cartwright RA, et al. Cancer in Cumbria and in the vicinity of the Sellafield nuclear installation, 1963-90. BMJ 1993 (9 Jan); 306 (6870):89-94.

(19.) Goldsmith JR. Nuclear installations and childhood cancer in the UK: mortality and incidence for 0-9-year-old children, 1971-1980. Sci Total Environ 1992; 127(1-2):13-35.

(20.) Kinlen LJ, Hudson CM, Stiller CA. Contacts between adults as evidence for an infective origin of childhood leukaemia: an explanation for the excess near nuclear establishments in west Berkshire? Br J Cancer 1991; 64(3):549-54.

(21.) Ewings PD, Bowie C, Phillips MJ, et al. Incidence of leukemia in young people in the vicinity of Hinkley Point nuclear power station, 1959-86. BMJ 1989 (2 Jul); 299(6694):289-93.

(22.) Cook-Mozaffari PJ, Darby SC, Doll R, et al. Geographical variation in mortality from leukemia and other cancers in England and Wales in relation to proximity to nuclear installations, 1969-78. Br J Cancer 1989; 59(3):476-85.

(23.) Roman E, Beral V, Carpenter L, et al. Childhood leukaemia in the West Berkshire and Basingstoke and North Hampshire District Health Authorities in relation to nuclear establishments in the vicinity. BMJ (Clin Res Ed) 1987; 294 (6572):597-602.

(24.) Forman D, Cook-Mozaffari P, Darby S, et al. Cancer near nuclear installations. Nature 1987 (8-14 Oct); 329(6139):499-505.

(25.) Heasman MA, Kemp IW, Urquhart JD, et al. Childhood leukemia in northern Scotland. Lancet 1986 (1 Feb); 1 (8475):266.

(26.) McLaughlin JR, Clarke EA, Nishri ED, et al. Childhood leukemia in the vicinity of Canadian nuclear facilities. Cancer Causes Control 1993; 4(1):51-58.

(27.) Viel JF, Pobel D, Carre A. Incidence of leukaemia in young people around the La Hague nuclear waste reprocessing plant: a sensitivity analysis. Stat Med 1995; 14(21-22):2459-72.

(28.) Hoffmann W, Dieckmann H, Schmitz-Feuerhake I. A cluster of childhood leukemia near a nuclear reactor in northern Germany. Arch Environ Health 1997; 52(4):275-80.

(29.) Zaridze DG, Li N, Men T, et al. Childhood cancer incidence in relation to distance from the former nuclear testing site in Semipalatinsk, Kazakhstan. Int J Cancer 1994; 59(4):471-75.

(30.) Johnson CJ. Cancer incidence in an area contaminated with radionuclides near a nuclear installation. Ambio 1981; 10:176-82.

(31.) Hatch MC, Beyea J, Nieves JW, et al. Cancer near the Three Mile Island nuclear plant: radiation emissions. Am J Epidemiol 1990; 132(3):397-412.

(32.) Goldsmith JR. Childhood leukemia mortality before 1970 among populations near two United States nuclear installations. Lancet 1989 (8 Apr); 1 (8641):793.

(33.) Enstrom JE. Cancer mortality patterns around the San Onofre nuclear power plant, 1960-1978. Am J Public Health 1983; 73(1): 83-92.

(34.) Johnson CJ. Cancer and infant mortality around a nuclear power plant. Am J Public Health 1983; 73(10):1218.

(35.) Jablon S, Hrubec Z, Boice JD. Cancer in populations living near nuclear facilities. A survey of mortality nationwide and incidence in two states. JAMA 1991; 265(11):1403-08.

(36.) Ries LAG, Eisner MP, Kosary CL, et al. (Eds). SEER Cancer Statistics Review, 1975-2000. Bethesda, MD: National Cancer Institute, 2003. Available at <http://www.seer.cancer.gov>.

(37.) Kaiser J. No meeting of minds on childhood cancer. Science 1999 (3 Dec); 286(5446):1832-34.

(38.) Jablon S, Hrubec Z, Boice JD, et al. Cancer in Populations Living Near Nuclear Facilities. National Cancer Institute. NIH Publication No. 90-874. Washington, DC: U.S. Government Printing Office, 1990.

(39.) National Center for Health Statistics. Available at <http://www. cdc.gov>, Data and Statistics, CDC WONDER. Obtained June 2001.

(40.) U.S. Nuclear Regulatory Commission. United States Operating Nuclear Plants. Washington, DC: U.S. Nuclear Regulatory Commission, August 12, 1999.

(41.) U.S. Bureau of the Census. Census of the Population 2000. Available at <http://www.census.gov>, American FactFinder, Census 2000 Gateway, State & County QuickFacts.

(42.) Kosary CL, Ries LAG, Miller BA, et al. (Eds.). SEER Cancer Statistics Review, 1973-1992. Bethesda, MD: National Cancer Institute, 1995. NIH Pub. No. 96-2789.

(43.) Ries LAG, Eisner MP, Kosary CL, et al. (Eds.). SEER Cancer Statistics Review, 1973-1997. Bethesda, MD: National Cancer Institute, 2000.

(44.) Ries LAG, Percy CL, Bunin GR. Introduction. In: Ries LAG, Smith MA, Gurney JG, et al. (Eds). Cancer Incidence and Survival Among Children and Adolescents: United States SEER Program, 1975-1995. Bethesda, MD: National Cancer Institute, SEER Program, 1999. NIH Pub. No. 99-4649.

(45.) Gould JM, Sternglass EJ, Sherman JD, et al. Strontium-90 in deciduous teeth as a factor in early childhood cancer. Int J Health Serv 2000; 30(3):515-39.

JOSEPH J. MANGANO

JANETTE SHERMAN

Radiation and Public Health Project

New York, New York

CAROLYN CHANG

AMIE DAVE

ELYSSA FEINBERG

MARINA FRIMER

Sophie Davie School of Biomedical Education

City University of New York

New York, New York

Radiation and Public Health Project
302 West 86th Street Suite 11B New York NY 10024 Tel 212 496-6787 Fax 212 362-0348 Director: Jay M. Gould

2500 EXCESS CANCER CASES IN NEW LONDON COUNTY SINCE 1970; RADIOACTIVE EMISSIONS FROM MILLSTONE MAY BE CAUSE

Joseph J. Mangano, MPH, MBA, Consultant
Radiation and Public Health Project
New York, NY
February 21, 1998

About 2500 excess cancers have occurred in New London County since the first Millstone nuclear power reactor in Waterford opened in 1970. About 800 of these cases have resulted in deaths, using official figures published by the National Cancer Institute (NCI) and the Connecticut Tumor Registry (CTR).

These figures are pertinent to the Nuclear Regulatory Commission's (NRC) decision whether or not to re-open the three reactors at Millstone, closed due to safety violations for two years. The NRC has held about 30 public meetings on Millstone, but health effects of radioactive emissions from the plant to workers and the local population have been virtually ignored.

A. **New London County.** Major findings governing excess cancer in New London County are:

1. **All Cancers - Cases.** In the 1950s and 1960s, the New London County cancer incidence rate was 8% below the state average, rising to 2% below from 1971-84, and 2.5% above in 1989-91 (CTR). Since 1970, New London has experienced about 2500 cases more than if its rate had remained 8% below the state.

2. **All Cancers - Deaths.** In Millstone's first 14 years, the county cancer mortality rate was 11% above the nation, compared to 5% above in the 1950s and 1960s (NCI). An approximate total of 800 additional cancer deaths occurred in the county since Millstone opened.

3. **Childhood Leukemia.** In Millstone's first 14 years, leukemia cases for New London County children under 10 was 55% higher than the state, and leukemia deaths 45% higher (NCI). The NCI acknowledged these rates to be "significantly elevated" in its 1990 report. All scientists agree that children are most sensitive to low-level radiation's effects, ever since the pioneering work in the 1950s of Dr. Alice Stewart (Xrays) and Dr. Linus Pauling (bomb test fallout).

4. **Thyroid Cancer.** The rate of thyroid cancer in New London County has risen twice as fast as the rest of Connecticut after 1970. Before Millstone, about 3 cases per year were diagnosed in the county; by the early 1990s, the number jumped to 17 (CTR). All scientists agree that exposure to iodine, emitted in large quantities by Millstone, raises the risk of thyroid cancer.

B. **Four Towns Nearest Reactor**. Within New London County, there are several unusual cancer patterns in the four towns closest to Millstone (East Lyme, Groton, New London, and Waterford):

5. **Female Cancers**. In 1989-91, cancer cases in these four towns were 15% higher than the state (CTR). Female-only cancers were especially high including breast cancer (20% greater than the state); cervical cancer (26% greater); ovarian cancer (35% greater); and uterine cancer (29% greater).

6. **Skin Cancer**. Malignant melanoma incidence in the four towns in 1989-91 was 65% greater than for the rest of Connecticut (CTR). It can be argued that persons living in coastal areas are exposed to more sun, and are at higher risk for skin cancer. However, all other coastal towns in the state have melanoma rates only 7% higher than the state.

Information on trends in cancers and other immune-related diseases should be analyzed and discussed with the public by the Nuclear Regulatory Commission, Northeast Utilities, and the Connecticut Department of Health. Trends in these diseases should be fully understood before making any decision on whether or not to re-start the Millstone reactors.

Joseph Mangano is a public health administrator and researcher who has been a consultant with the New York-based Radiation and Public Health Project since 1989. He has published seven articles in medical journals on health effects of low-level radiation exposure, including effects in Connecticut, and his book *An Atomic Era Legacy* will be released in the summer. His work has been presented at four international conferences on radiation. Mr. Mangano received his MPH degree from the University of North Carolina and his MBA degree from Fordham University. He can be reached at 718-857-9825.

OVERSIGHT FINDINGS AND RECOMMENDATIONS OF THE COMMITTEE ON GOVERNMENT OPERATIONS

No findings or recommendations of the Committee on Government Operations were received as referred to in subdivision (d) of clause 2(1)(3) of House Rule XI.

INFLATIONARY IMPACT

In compliance with clause 2(1)(4) of House Rule XI, it is stated that this legislation will have no inflationary impact on prices and costs on the operation of the national economy.

COST

The costs are those outlined in the cost estimate of the Congressional Budget Office included in this report.

COST ESTIMATED OF THE CONGRESSIONAL BUDGET OFFICE

The cost estimate of the Congressional Budget Office, prepared pursuant to section 403 of the Congressional Budget Act of 1974 and received by the Committee on April 11, 1990, is as follows:

U.S. CONGRESS,
CONGRESSIONAL BUDGET OFFICE,
Washington, DC, April 11, 1990.

Hon. JACK BROOKS,
Chairman, Committee on the Judiciary,
House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: The Congressional Budget Office has reviewed S. 1485, an act to grant the consent of Congress to the Quad Cities Interstate Metropolitan Authority Compact entered into between the States of Illinois and Iowa, as ordered reported by the House Committee on the Judiciary, March 28, 1990.

We estimate that no cost to the federal government or to state or local governments would result from enactment of this bill. The compact authorizes the creation of the quad cities interstate authority to provide facilities and to foster cooperative efforts for the development and public benefit of its territory.

If you wish further details on this estimate, we will be pleased to provide them. The CBO staff contact is Mitchell Rosenfeld, who can be reached at 226-2860.

Sincerely,

ROBERT D. REISCHAUER,
Director.

O

101ST CONGRESS
2d Session
HOUSE OF REPRESENTATIVES
REPORT
101-463

RADIATION EXPOSURE COMPENSATION ACT

APRIL 25, 1990.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

Mr. BROOKS, from the Committee on the Judiciary, submitted the following

REPORT

[To accompany H.R. 2372]

[Including cost estimate of the Congressional Budget Office]

The Committee on the Judiciary, to whom was referred the bill (H.R. 2372) to provide jurisdiction and procedures for claims for compassionate payments for injuries due to exposure to radiation from nuclear testing, having considered the same, report favorably thereon with an amendment and recommend that the bill as amended do pass.

The amendment is as follows:

Strike out all after the enacting clause and insert in lieu thereof the following:

SECTION 1. SHORT TITLE.

This Act may be cited as the "Radiation Exposure Compensation Act".

SEC. 2. FINDINGS, PURPOSE, AND APOLOGY.

(a) FINDINGS.—The Congress finds that—

(1) fallout emitted during the Government's above-ground nuclear tests in Nevada exposed individuals who lived in the downwind affected area in Nevada, Utah, and Arizona to radiation that generated an excess of cancers among these individuals;

(2) the health of the individuals who were unwitting participants in these tests was put at risk to serve the national security interests of the United States;

(3) radiation released in underground uranium mines that were providing uranium for the primary use and benefit of the nuclear weapons program of the United States Government exposed miners to massive doses of radiation that produced an increased incidence of lung cancer and respiratory diseases among these miners;

(4) the United States should recognize and assume responsibility for the harm done to these individuals; and

(5) the Congress recognizes that the lives and health of uranium miners and of innocent individuals who lived downwind from the Nevada tests were sacrificed to serve the national security interests of the United States.

(b) PURPOSE.—It is the purpose of this Act to establish a procedure to make partial restitution to the individuals described in subsection (a) for the burdens they have borne for the Nation as a whole.

(c) APOLOGY.—The Congress apologizes on behalf of the Nation to the individuals described in subsection (a) and their families for the hardships they have endured.

SEC. 3. TRUST FUND.

(a) ESTABLISHMENT.—There is established in the Treasury of the United States, a trust fund to be known as the "Radiation Exposure Compensation Trust Fund" (hereinafter in this Act referred to as the "Fund"), which shall be administered by the Secretary of the Treasury.

(b) INVESTMENT OF AMOUNTS IN THE FUND.—Amounts in the Fund shall be invested in accordance with section 9702 of title 31, United States Code, and any interest on, and proceeds from any such investment shall be credited to and become a part of the Fund.

(c) AVAILABILITY OF THE FUND.—Amounts in the Fund shall be available only for disbursement by the Attorney General under section 6.

(d) TERMINATION.—The Fund shall terminate not later than the earlier of the date on which an amount has been expended from the Fund which is equal to the amount authorized to be appropriated to the Fund by subsection (e), and any income earned on such amount, or 10 years after the date of the enactment of this Act. If all of the amounts in the Fund have not been expended by the end of that 10-year period, investments of amounts in the Fund shall be liquidated and receipts thereof deposited in the Fund and all funds remaining in the Fund shall be deposited in the miscellaneous receipts account in the Treasury.

(e) AUTHORIZATION OF APPROPRIATIONS.—There are authorized to be appropriated to the Fund $100,000,000. Any amounts appropriated pursuant to this section are authorized to remain available until expended.

SEC. 4. CLAIMS RELATING TO OPEN AIR NUCLEAR TESTING.

(a) CLAIMS RELATING TO SPECIFIED DISEASES.—Any individual who was physically present in the affected area for a period of at least one year during the period beginning on January 21, 1951, and ending on October 31, 1958, or was physically present in the affected area for the period beginning on June 30, 1962, and ending on July 31, 1962, and who submits written medical documentation that he or she, after such period of physical presence, contracted a specified disease, shall receive $50,000 if—

(1) the claim for such payment is filed with the Attorney General by or on behalf of such individual, and

(2) the Attorney General determines, in accordance with section 6, that the claim meets the requirements of this Act.

Payments under this section may be made only in accordance with section 6.

(b) DEFINITIONS.—For purposes of this section, the term—

(1) "affected area" means—

(A) in the State of Utah, the counties of Washington, Iron, Kane, Garfield, Sevier, Beaver, Millard, and Piute;

(B) in the State of Nevada, the counties of White Pine, Nye, Lander, Lincoln, Eureka, and that portion of Clark County that consists of townships 13 through 16 at ranges 63 through 71; and

(C) that part of Arizona that is north of the Grand Canyon and west of the Colorado River; and

(2) "specified disease" means leukemia (other than chronic lymphocytic leukemia), multiple myeloma, lymphomas (other than Hodgkin's disease), and primary cancer of the thyroid, breast, esophagus, stomach, pharynx, small intestine, pancreas, bile ducts, gall bladder, or liver (except if cirrhosis or hepatitis B is indicated).

SEC. 5. CLAIMS RELATING TO URANIUM MINING.

(a) ELIGIBILITY OF INDIVIDUALS.—Any individual who was employed in a uranium mine located in Colorado, New Mexico, Arizona, or Utah at any time during the period beginning on January 1, 1947, and ending on December 31, 1971, and who, in the course of such employment—

(1) was exposed to 250 or more working level months of radiation, and submits written medical documentation that he or she, after such exposure, devel-

(2) was exposed to 800 or more working level months of radiation, and submits written medical documentation that he or she, after such exposure, developed a radiation-caused respiratory disease,

shall receive $100,000, if—

(A) the claim for such payment is filed with the Attorney General by or on behalf of such individual, and

(B) the Attorney General determines, in accordance with section 6, that the claim meets the requirements of this Act.

Payments under this section may be made only in accordance with section 6.

(b) DEFINITIONS.—For purposes of this section—

(1) the term "working level months of radiation" means radiation exposure at the level of one working level every work day for a month, or an equivalent exposure over a greater or lesser amount of time;

(2) the term "working level" means the concentration of the short half-life daughters of radon that will release (1.3×10^5) million electron volts of alpha energy per liter of air; and

(3) the term "radiation-caused respiratory disease" means fibrosis of the lung, pulmonary fibrosis, and corpulmonale related to fibrosis of the lung.

SEC. 6. DETERMINATION AND PAYMENT OF CLAIMS.

(a) ESTABLISHMENT OF FILING PROCEDURES.—The Attorney General shall establish procedures whereby individuals may submit claims for payment under this Act.

(b) DETERMINATION OF CLAIMS.—

(1) IN GENERAL.—The Attorney General shall, in accordance with this subsection, determine whether each claim filed under this Act meets the requirements of this Act.

(2) CONSULTATION.—The Attorney General shall—

(A) in consultation with the Surgeon General, establish guidelines for determining what constitutes written medical documentation that an individual contracted a specified disease under section 4 or other disease specified in section 5; and

(B) in consultation with the Director of the National Institute for Occupational Safety and Health, establish guidelines for measuring working level months of radiation under section 5.

The Attorney General may consult with the Surgeon General with respect to making determinations pursuant to the guidelines issued under subparagraph (A), and with the Director of the National Institute for Occupational Safety and Health with respect to making determinations pursuant to the guidelines issued under subparagraph (B).

(c) PAYMENT OF CLAIMS.—

(1) IN GENERAL.—The Attorney General shall pay, from amounts available in the Fund, claims filed under this Act which the Attorney General determines meet the requirements of this Act.

(2) OFFSET FOR CERTAIN PAYMENTS.—A payment to an individual, or to a survivor of that individual, under this section on a claim under section 4 or 5 shall be offset by the amount of any payment made pursuant to a final award or settlement on a claim (other than a claim for worker's compensation), against any person, that is based on injuries incurred by that individual on account of—

(A) exposure to radiation, from open air nuclear testing, in the affected area (as defined in section 4(b)(1)) at any time during any period specified in section 4(a), or

(B) exposure to radiation in a uranium mine at any time during the period described in section 5(a).

(3) RIGHT OF SUBROGATION.—Upon payment of a claim under this section, the United States Government is subrogated for the amount of the payment to a right or claim that the individual to whom the payment was made may have against any person on account of injuries referred to in paragraph (2).

(4) PAYMENTS IN THE CASE OF DECEASED PERSONS.—(A) In the case of the individual who is deceased at the time of payment under this section, such payment may be made only as follows:

(i) If the individual is survived by a spouse who is living at the time of payment, such payment shall be made to such surviving spouse.

(ii) If there is no surviving spouse described in clause (i), such payment shall be made in equal shares to all children of the individual who are living at the time of payment.

(iii) If there is no surviving spouse described in clause (i) and if there are no children ...

Cancer Incidence in Connecticut Counties, 1995-99

State of Connecticut
Department of Public Health
Connecticut Tumor Registry
410 Capitol Avenue, MS# 13TMR
P.O. Box 340308
Hartford, CT 06134-0308

Release Date: January, 2004

Table 1
Incidence Rates/100,000 of Invasive Tumors, by County, Sex, with Percent Localized, 1995-99; All Cancer Combined (Site Codes 00.0-80.9)[1]

County	Sex	Tumors	Crude Rate	-----Age-adjusted Rate---- Observed[2]	95% Confidence[3] Lower	Upper	% Localized[4]
Fairfield	M	11332	562.6	488.8	479.7	498.0	50.8
	F	11284	521.9	376.1	368.8	383.5	45.4
Hartford	M	11842	594.1	503.2	494.0	512.6	49.4
	F	11291	525.0	372.2[5]	364.9	379.6	45.7
New Haven	M	10825	567.2	488.9	479.6	498.5	50.5
	F	11584	563.1	403.6[6]	395.8	411.6	49.4
New London	M	3305	527.2	507.1	489.7	525.0	49.4
	F	3344	538.4	417.3[6]	402.5	432.6	47.5
Litchfield	M	2476	556.9	484.5	465.2	504.7	50.2
	F	2376	518.3	377.8	361.7	394.7	47.9
Middlesex	M	1907	522.3	484.6	462.7	507.5	49.8
	F	1997	525.8	389.8	371.7	408.9	47.4
Tolland	M	1535	469.0	508.3	482.7	535.0	52.8
	F	1329	407.6	368.4	347.9	389.9	47.6
Windham	M	1278	497.6	496.4	469.0	525.1	44.8
	F	1243	465.1	372.8	351.0	395.8	44.7
Conn.[7]	M	44511	560.8	493.9	489.2	498.6	50.0
	F	44449	527.7	384.6	380.8	388.5	46.9

1 ICD-O-2 site code shown in parentheses. Includes in situ bladder tumors, excludes epithelial skin tumors for sites other than genital.
2 Age-adjusted directly to the U.S. 1970 standard million.
3 Estimated limits in the range of variation from the observed age-adjusted rate expected at a probability of 95%.
4 Percent localized based on all stages of invasive tumors.
5 The 95% confidence limits are outside those of the Conn. age-adjusted rate.
6 The 99% confidence limits (not shown) are outside those of the Conn. age-adjusted rate.
7 Includes 12 tumors- 11 male and 1 female- for state residents, county not stated.

Good Afternoon:

My name is Richard Brown and I serve as the City Manager of New London, CT. New London is a community of 26,000 persons and six square miles that is adjacent to Waterford, CT and the Millstone Power Station. I support the relicensing of Millstone Units 2&3. Millstone is operated in a safe and efficient manner and not only contributes to the regional economy but is a major supplier to the North East power grid.

Dominion Resources through the Millstone Power Station is a major employer, with over 460 persons employed within southeastern Connecticut. Additionally Millstone supports the local economy by purchasing as many good and services locally as is possible. The total economic impact of Millstone Power station in New London County is estimated to exceed $500 million.

Millstone is a good neighbor. We interact with them in emergency planning exercises and on issues of concern at the plant itself. Communications are excellent. There are regular meetings with community leaders to update us on issues at Millstone. The dissemination of emergency information occurs immediately and there is every attempt to provide information to us an advance of any non- routine activity.

Over the past couple of years Millstone employees on their own initiative cleaned up the City's park at Greens Harbor Beach and constructed a new playground at the Edgerton Elementary School.

To paraphrase a credit card commercial:

Millstone's economic impact - $500 million
Value of their employees and their corporation to the community- priceless.

Comments on Millstone 2 and 3 Relicensing, Appendix E – Environmental Report
By First Selectman Paul B. Eccard

As First Selectman of the Town of Waterford, I believe that the relicensing of these generators is in the best interest of the people of this community. The plants appear to be operating at peak efficiency while maintaining a reliable level of safety for the residents of the region as well as the people who work at the plants.

It is also in the best interest of the people of this community that issues of environmental concern receive full, fair, and thorough review.

I am not an expert on this matter or process and neither are any members of my staff. In fact, it exceeds reasonable expectation and enters the realm of amazement to think that a town of 19,000 with our small town limitations could be expected to understand the information in these application books in the small window of time allotted. **Therefore, my first recommendation is that the NRC consider relicensing as an impact to be mitigated to achieve substantial understanding and acceptance by the host community.**

Now, on to some other specific points:

Many of the issues reviewed are dependent on what occurs within the license period. I am wondering if I understand correctly that there will be no major upgrades to the power plant that constitute "refurbishment". Does this mean major refurbishments are ongoing or will occur prior to 2015? Do improvements made before relicensing approval require the same level of scrutiny as refurbishments anticipated during the extended license period?

The fact that the MPS has not received a renewal of its discharge permit from DEP is of considerable concern. Section 4.2 was all but avoided due to the lack of this extension and reliance on a prior permit. In 1993 and 2001 MPS was required to prepare studies on cooling system alternatives. These were prepared and submitted to the DEP. The conclusions of the 1993 study are included in this environmental report but the results of the 2001 study are not. While the Town is continuously concerned about the plant's impacts on the fisheries of Long Island Sound, the installation of cooling towers on this site has broad aesthetic as well as land use implications. It is essential that the approval by DEP of the NPDES renewal application occur prior to granting the application for relicensing. This concern is further reinforced by the fact that the plant operates in variance with the Clean Water Act as approved by the Commissioner of DEP. I want to know what are the ramifications on the relicensing application if DNC and DEP fail to resolve the outstanding issues.

The outstanding issues on renewal of the discharge permit are not only limited to thermal discharges. Although not described in Section 4, the issue of the impact of the plant on the flounder population is the focus of a disagreement between DNC and DEP. Included in Chapter 2 on page E-2-9, DNC identifies that the issue is with the Marine Fisheries Division of DEP over certain modeling assumptions. More troubling is the statement that these matters will be dealt with as part of the renewal process, with seemingly no connection to the renewal process. I want to know how this disagreement will be addressed.

As the value of MPS continues to decline, taxes on housing will increase at an ever-increasing rate. Page E-2-24 has this concluding statement: "It is also logical to assume the MPS, during the license renewal period, would provide stable, predictable tax revenues for the Town of Waterford". Page E-4-29 indicates that DNC does not anticipate....any related tax increase driven changes to offsite land use and development patterns. The impact of MPS on tax revenue, infrastructure installation, and overall level of service is different in Waterford than any other community in the State of Connecticut. In fact, MPS has been the dominant taxpayer for over a generation bringing real estate taxes to an artificial low and thus attracting retail and commercial development at a breakneck pace straining the ability of the town to provide essential services and ramping up the size and responsibility of this government. Now on the downside, deregulation has suddenly removed 2/3 of the value of MPS and we are left struggling to adjust and maintain a stable community. The point is the applicant's analysis is simplistic and indicative of an outsider's lack of understanding of the profound impacts the nuclear power station has had, continues to have, and will have on Waterford for a long time.

The authors of these conclusions did not talk with this First Selectman and it seems to me that their conclusions are a demonstration of a poor appreciation for this proud New England town. We were incorporated on October 8, 1801. Thomas Jefferson was President then. In the 1814 tax year Millstone was the largest single taxpayer as farmland and a quarry. We know Millstone's tax effect. We have known it for a very long time. I implore the NRC to take the host town seriously and look at these factors in the relicensing review process.

The impact of the implementation of additional security measures is not assessed, nor is the potential for a terrorist attack to result in a severe accident. Will the NRC consider these changes? DNC appears to be saying that if an accident of equal proportion to Three Mile Island occurred they would not intend to do any recovery of the plant and therefore it did not have to be considered in relicensing. I cite page E-4-41. I want to understand this better and I anticipate the NRC will work with us to understand this conclusion.

Issues of current land use of the property include the fill pile on Gardiners Wood Road. This pile was determined to contain materials of concern. What will occur with this pile if licensing is approved? The town should receive information on potential impacts that could occur to children using the adjacent football fields.

Does MPS sample the sediments in Jordan Cove? Are there radioactive deposits identified in these sediments? What are they and in what quantity?

The license renewal process concerns me in that it fails to include a description of changes that have occurred since the initial license was issued. Things like the harvesting of shellfish from Jordan Cove, which has been conditionally opened, and the impact of the installation of a new water line to the site and the resultant change in consumption rates. I anticipate that both of these changes in conditions will be carefully explored.

Hopefully some of the items I have addressed above will be explored in greater detail in the upcoming months. I will work with you to achieve a full, fair, and therefore acceptable level of environmental review. As I said, we have been here a long time and Waterford will be here long after the relicensed plant closes and I want to work to make sure it is a safe and healthful place for a long, long, long time. Thank you.

Economic Impacts on the Connecticut Economy Resulting from the Millstone Station in Waterford, CT

entrepreneurial efficient dynamic versatile responsive trusted creative progressive visionary

PRESENTED BY
Don Klepper-Smith
Chief Economist & Director of Research
DataCore Partners LLC

(860) 349-8221

May 2004

Don Klepper-Smith

- **Chief Economist and Director of Research,** **Scillia Dowling and Natarelli Advisors LLC**
- market research, economic analysis, demographic forecasting, strategic planning (4/2001 to present).

- **President, DataCore Partners, Inc**., a consulting firm specializing in economic & demographic analysis, market research, and customer satisfaction (1996-4/2001)

- **SNET's Corporate Economist**, specializing in economic analysis & forecasting- 1982-1996

- **Over 20 years of experience as a professional economist** involving public utility issues, having been involved with multiple economic impact analyses involving telecommunications, electric utilities and various retail developments, 1979-99

- **Economic Advisor to the Governor of the State of Connecticut**, Weicker Administration

- **Past President of Economic Club of CT, longtime member of NABE,** 1984-86

- **Economics Commentator, WTNH Television, New Haven, CT,** 2001 to present

- **Represented State of CT before multiple Bond Rating agencies on Wall Street**, trying to improve State's bond rating- 1996

- **MPA from S.U.N.Y at Stony Brook** focusing on economics, econometric modeling, statistics & forecasting theory-1978

- **B.S. in Applied Mathematics** from S.U.N.Y at Stony Brook- 1975

- **Clients** now include SNET, CBIA, United Illuminating, People's Bank, CERC, State of CT, and the U.S Small Business Administration

" If we want to have a world-class economy, we first need to have a world-class infrastructure."

- Governor John G. Rowland
State of Connecticut

PRODUCTIVITY AND INFRASTRUCTURE ARE LINKED:

- **THE LACK OF QUALITY INFRASTRUCTURE (I.E. CONGESTION ON OUR ROADS, RAILS AND HIGHWAYS) HAS UNDERMINED BUSINESS PRODUCTIVITY AND ACTED AS AN DISINCENTIVE FOR FIRMS LOOKING TO MIGRATE INTO CONNECTICUT.**

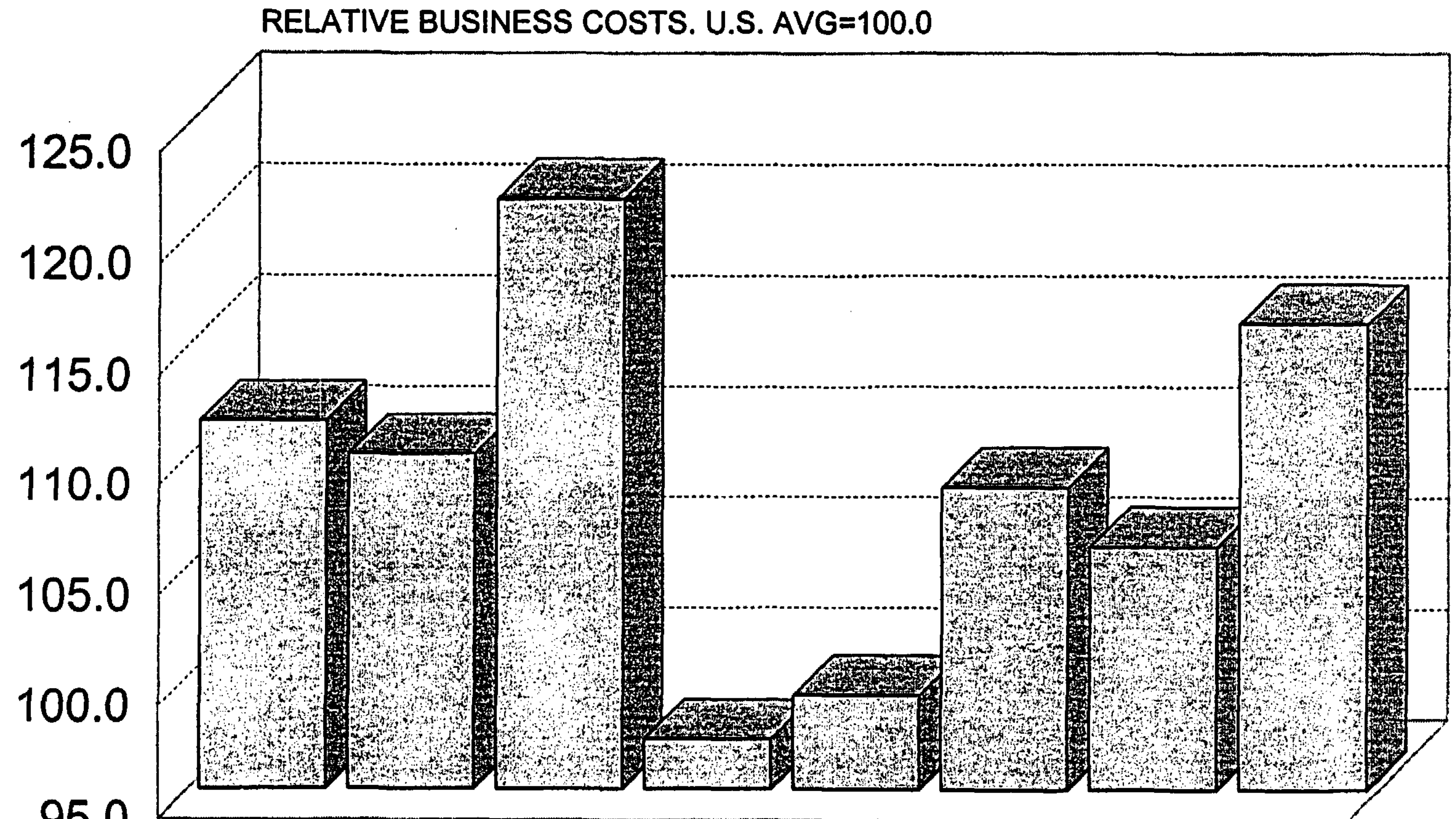
- **THE FALLOUT FROM 9/11 SHOWS MORE JOBS MIGRATING INTO NEW JERSEY AS OPPOSED TO CONNECTICUT, ONE KEY REASON BEING A BETTER-FUNCTIONING INFRASTRUCTURE.**

- **BOTTOM LINE: *STATE-OF-THE-ART INFRASTRUCTURE, IN ALL ITS COMPONENTS, IS NECESSARY FOR FUTURE ECONOMIC DEVELOPMENT AND FACILITATES FUTURE ECONOMIC GROWTH. OUR LONG-TERM ECONOMIC COMPETITIVENESS IS DEPENDENT ON IT*.**

THE COST OF DOING BUSINESS:

- ECONOMIC RESEARCH FROM ECONOMY.COM SHOWS THAT THE RELATIVE COSTS OF DOING BUSINESS IN A REGION HAVE A MAJOR IMPACT ON OVERALL ECONOMIC PERFORMANCE IN THE LONG-RUN. THEREFORE, TO THE DEGREE THAT THE BUSINESS COSTS IN CONNECTICUT CAN BE LOWERED, THE STATE WILL BE ADVANTAGED FROM AN ECONOMIC DEVELOPMENT STANDPOINT.

CURRENT RELATIVE BUSINESS COST RANKINGS FOR NORTHEAST STATES AS OF LATE 2003

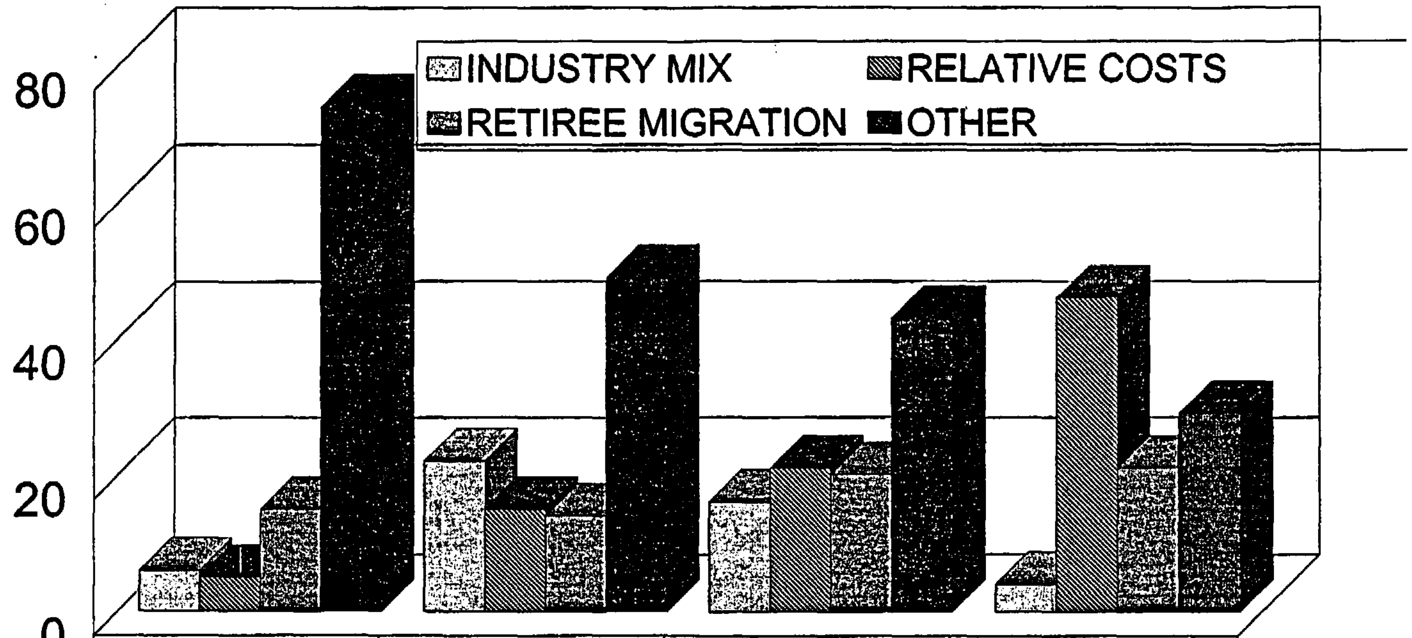


	CT	ME	MA	RI	NH	VT	NY	NJ
RELATIVE BUS. COSTS	111.6	110.1	121.6	97.2	99.2	108.6	105.9	116.0

RELATIVE BUS. COSTS

SOURCE:ECONOMY.COM
CATEGORIES: WAGES, TAXES, ENERGY

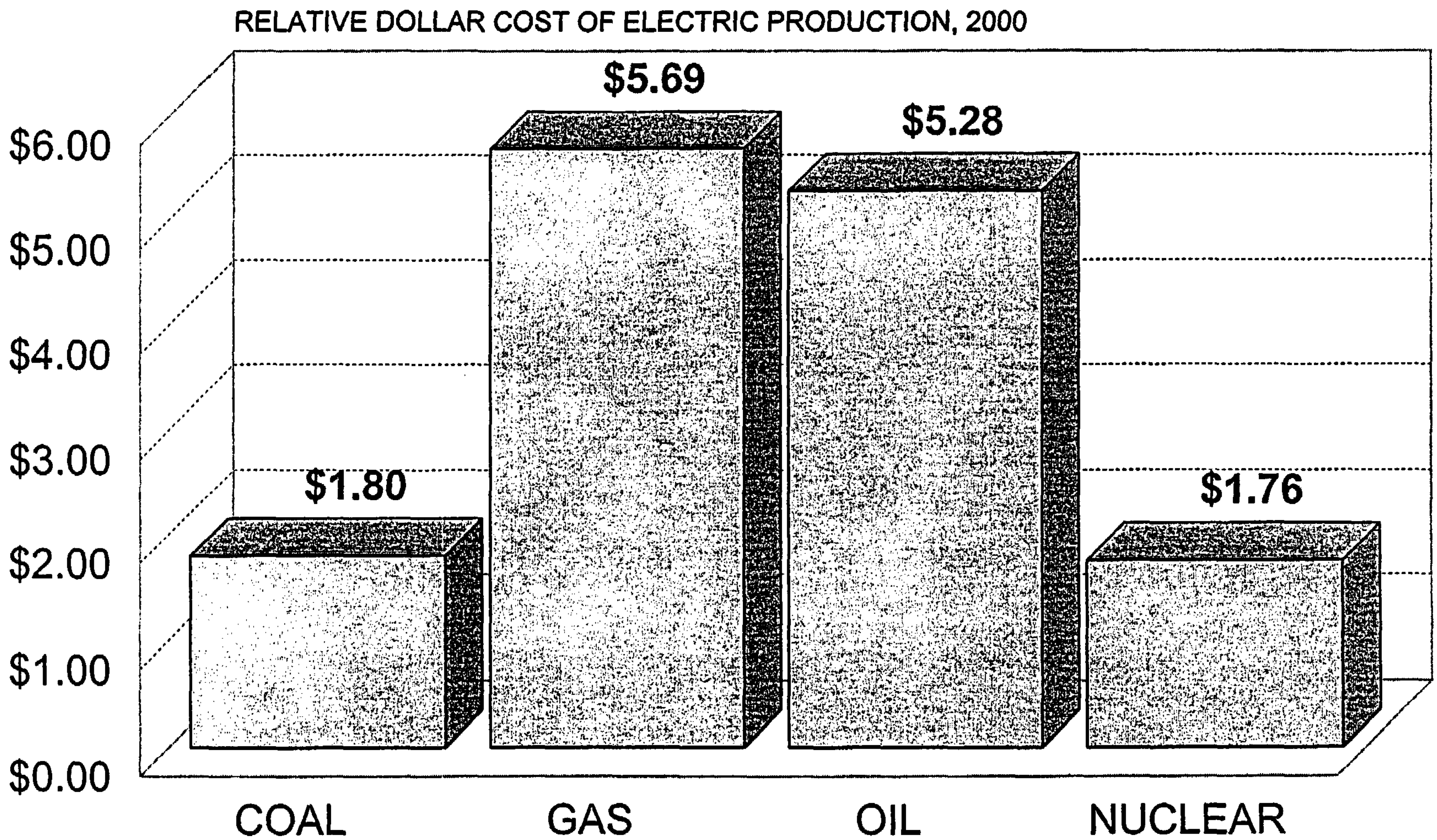
RELATIVE BUSINESS COSTS ARE THE MOST IMPORTANT LONG-TERM DETERMINANTS OF REGIONAL ECONOMIC PERFORMANCE



	1 YEAR	3 YEARS	5 YEARS	10 YEARS
INDUSTRY MIX	6	22	16	4
RELATIVE COSTS	5	15	21	46
RETIREE MIGRATION	15	14	20	21
OTHER	74	49	43	29

SOURCE:ECONOMY.COM

AVERAGE 2000 U.S. PRODUCTION COSTS FOR ELECTRICITY BY FUEL GENERATION TYPE (CENTS PER KILOWATT HOUR)



SOURCE: NEI Production Cost Data

KEY POINT #6: MILLSTONE STATION ECONOMIC IMPACTS: 1,497 DIRECT JOBS & $231.3 MILLION IN ANNUALIZED DIRECT SPENDING

- MILLSTONE STATION PROVIDES COST-EFFECTIVE AND RELIABLE ELECTRICITY TO THE REGION'S COMMERCIAL, INDUSTRIAL, AND RESIDENTIAL USERS, ENHANCING ECONOMIC COMPETITIVENESS.

- MILLSTONE ALSO CONTRIBUTES TO THE STATE'S ECONOMY THROUGH DIRECT JOB CREATION AND SPENDING ON GOODS AND SERVICES, AS WELL AS INDIRECT "MULTIPLIER EFFECTS".

" Energy is a critical concern of the state's business community because Connecticut's power needs are outpacing its ability to deliver it."

- Connecticut Business & Industry Association, March 2002