

VogtleEISCEmails

From: bredl [bredl@skybest.com]
Sent: Wednesday, November 24, 2010 3:32 AM
To: VogtleCOLAEIS Resource
Cc: Sutton, Mallecia
Subject: NUREG-1947 Vogtle COLA EIS
Attachments: 101124_Vogtle Supplemental EIS comments_LZ w attachment C.pdf

November 24, 2010

Cindy Bladey, Chief
Rules, Announcements and Directives Branch (RAD)
Office of Administration
Mail Stop: TWB-05-B01M
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
VOGTLE.COLAEIS@nrc.gov

Re: Docket ID NRC-2008-0252, THE DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR SOUTHERN NUCLEAR OPERATING COMPANY COMBINED LICENSES (COLs) FOR VOGTLE ELECTRIC GENERATING PLANT UNITS 3 AND 4, Vogtle Draft Supplemental EIS, NUREG-1947, Sept 2010

Dear Ms. Bladey:

Please find attached comments to supplement the remarks made at the public hearing held October 7th at Augusta Technical College in Waynesboro.

Louis A. Zeller

Federal Register Notice: 74FR49407
Comment Number: 35

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Blue Ridge Environmental Defense League

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Dear Ms. Bladey:

I write on behalf of the Blue Ridge Environmental Defense League, our chapter Shell Bluff Concerned Citizens and our member in the affected areas of Georgia and South Carolina. These comments will supplement the remarks we made at the public hearing held October 7th at Augusta Technical College in Waynesboro.

Overview

The September 2010 draft supplemental environmental impact statement by the Nuclear Regulatory Commission recommends that a construction and operating license be granted to Southern Company for two AP1000 nuclear reactors. Approval of the draft SEIS would also allow some backfilling and other site work; modifying the early site permit, the ESP-004 issued in 2009. The document is simultaneously sweeping in scope yet limited in implementation because it seeks to authorize certain things with huge environmental impacts and others of relative insignificance. The draft states:

The purpose of Southern's requested action is to obtain from the NRC a license to construct and operate two new nuclear power units on the VEGP site as well as an LWA to allow early commencement of certain limited construction activities. A license from the NRC to construct and operate nuclear power plants is necessary but not sufficient for construction and operation of the power plant. Southern must obtain and maintain permits from other Federal, State, and local agencies and permitting authorities. Therefore, the purpose of the NRC environmental review of the Southern application is to determine if a nuclear power plant of the proposed design can be constructed and operated at the VEGP site without unacceptable adverse impacts on the human environment.¹

The full environmental impact of two additional nuclear powered electric generating plants must be considered in the final environmental impact statement. In the following pages, we will explain why this is so and the additional issues to be considered.

¹ Draft NUREG-1947, September 2010, page xii

All New and Significant Information Must Be Considered

At the October 7th hearing in Waynesboro, the NRC did a disservice to the members of the public. Despite a pledge to “listen to and gather your comments,” the NRC Staff at the public hearing went to great lengths to explain what they did not want to hear.² For example, in their discussion of the implementing regulations of the National Environmental Policy Act,³ the presenters felt compelled to define the meanings of “significant” and “new.” *New*, according to the NRC, is “not generally known or publicly available during the preparation of the EIS.” *Significant*, as interpreted by the Staff, is to “have the potential to affect the...NRC staff evaluation of the issue.”⁴ The Staff then proceeded to list eleven items for which its conclusions did not change. These included among others land use, air quality, radiological impacts and environmental justice. Incredibly, the sole issues considered were impacts on the Southeastern Pocket Gopher and the Sandhills Milk-vetch. However, the NRC’s definitions of new and significant are either outside the meaning of the statutory definition or wholly absent from NEPA and are, therefore, artificial and improper limitations on the extant NEPA proceeding.

Certainly, new and significant information is allowed under NRC regulations. See Attachment B, Supplemental EIS. In fact, under 10 CFR 51.92(e)(7), a supplemental EIS must:

Include an analysis of the issues related to the impacts of construction and operation of the facility that were resolved in the early site permit proceeding for which new and significant information has been identified, including, but not limited to, new and significant information demonstrating that the design of the facility falls outside the site characteristics and design parameters specified in the early site permit.

A definition of the term “new” is found neither in NEPA nor in NRC regulation 10 CFR 51. Therefore, we may use the dictionary definition: “never existing before; appearing, thought of, developed, made, produced, etc. for the first time.”⁵

The term “significant” is defined at 40 CFR §1508.27, but it does not resemble the one presented by the NRC. See Attachment A, Council on Environmental Quality definition. Under NEPA, significance is determined by considering an action’s *context*—the geographic, physical, and social context in which the impact would occur—and its *intensity*—the severity of the impact. A supplemental EIS is required when an agency makes substantial changes in the proposed action relevant to environmental concerns, or when there are significant new circumstances or information relevant to environmental concerns bearing on the proposed action.

Under NEPA, it is the Nuclear Regulatory Commission’s duty to consider alternatives “as they exist and are likely to exist.” *Monarch Chemical Works, Inc. v. Exxon*, 466 F.Supp. 639, 650 (1979), *Carolina Environmental Study Group v. U.S.*, 510 F.2d 796, 801 (1975). There is both new and significant information—information published after the license application and environmental impact statement—regarding environmental justice which we hereby bring to the Commission’s attention.

² Public meeting presentation for the draft SEIS for COLs for VEGP Units 3 & 4, Gregory P Hatchett, Branch Chief, and Mallecia Sutton, Environmental project Manager, October 7, 2010

³ NEPA Section 102, 42 U.S.C. 4332, codified at 10 CFR 51.92.

⁴ *Ibid*, Environmental Review Process for a COL referencing an ESP, Slide 7, October 7, 2010

⁵ Webster’s New Universal Unabridged Dictionary, Second Edition, ISBN 0-671-41819-X

Environmental Justice

Environmental Justice means seeking to avoid disproportionate adverse environmental impacts on low income populations and minority communities. The relevant regulation for the Nuclear Regulatory Commission is Executive Order 12898 which states:

To the greatest extent practicable and permitted by law, and consistent with the principles set forth in the report on the National Performance Review, each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations. The NRC must avoid disproportionate, adverse environmental impacts on low income and minority populations and impacts on important religious, subsistence, or social practices.⁶

The Final EIS for an early site permit for Plant Vogtle's Units 3 and 4 was completed in July 2008.⁷ The FEIS concluded: "[T]he impacts of plant operations on environmental justice would be SMALL because no environmental pathways, health characteristics, or other preconditions of the minority and low-income population were found that would lead to adverse and disproportionate impacts." Unbelievably, the report attributed the high percentage of minority and low-income people on the "sparseness" of the rural population. The data collection for this report consisted of interviews with just three residents. The application for a Vogtle combined operating license with environmental report was submitted to the NRC on March 31, 2008.

In 2009, subsequent to the Vogtle COLA and ESP-FEIS, a nuclear power siting study was published which suggests that there is a "reactor-related environmental injustice" at Plant Vogtle. Attachment C contains the full article. The study found:

The mining, fuel enrichment-fabrication, and waste-management stages of the US commercial nuclear fuel cycle have been documented as involving environmental injustices affecting, respectively, indigenous uranium miners, nuclear workers, and minorities and poor people living near radioactive-waste storage facilities. After surveying these three environmental-injustice problems, the article asks whether US nuclear-reactor siting also involves environmental injustice. For instance, because high percentages of minorities and poor people live near the proposed Vogtle reactors in Georgia, would siting new reactors at the Vogtle facility involve environmental injustice? If so, would this case be an isolated instance of environmental injustice, or is the apparent Georgia inequity generally representative of environmental injustice associated with nuclear-reactor siting throughout the US? Providing a preliminary answer to these questions, the article uses census data, paired t-tests, and z-tests to compare each state's percentages of minorities and poor people to the percentages living in zip codes and census tracts having commercial reactors. Although further studies are needed to fully evaluate apparent environmental injustices, preliminary results indicate that, while reactor-siting-related environmental injustice is not obvious at the census-tract level (perhaps because census tracts are designed to be demographically homogenous), zipcode-scale data suggest reactor-related environmental injustice may threaten poor people ($p < 0.001$), at least in the southeastern United States.⁸

⁶ Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-income Populations, February 11, 1994

⁷ NUREG-1872, published August 2008

⁸ *Environmental Injustice in Siting Nuclear Plants*, Mary Alldred and Kristin Shrader-Frechette, ENVIRONMENTAL JUSTICE, Volume 2, Number 2, 2009 © Mary Ann Liebert, Inc. DOI: 10.1089/env.2008.0544

The summary conclusions of the ESP Final EIS are plainly wrong or at least premature. The NRC must include this new information in its analysis.

Plant Vogtle's Radioactive Pollution

There are routine releases of airborne radioactive pollution from plant Vogtle, and large increases in radioactivity downstream from the plant. Even without an accident, Vogtle emits radioactive pollution.

Every year, radioactive water in the form of Tritium is emitted by Plant Vogtle into the river. In 2003, Vogtle's pollution was 1,900 curies; in 2004, 1,200 curies and in 2005, 1860 curies.⁹ The discharge of Tritium (Hydrogen-3) in the form of radioactive water pollutes the Savannah River all the way to the ocean.

Downstream drinking water wells are also contaminated. Residents of Beaufort, SC (112 miles downriver) and Port Wentworth, SC (122 miles downriver) have had their public drinking water supplies contaminated with radiation.¹⁰ Other radioactive pollutants, including Cesium-137 and Cobalt-60, have also increased downstream from the Vogtle reactors since they began operation.

The two existing reactors at Plant Vogtle discharge 10,000 gallons of liquid waste per minute into the Savannah River.¹¹ The everyday discharge of hot water includes nuclear fission products and tritium at over 1,400 curies/year. Two new proposed reactors would increase this radioactive pollution by an additional 2,020 curies per year.

The Disproportionate Impacts From Radionuclides in Fish

Section 4-401 of Executive Order 12898 states: "In order to assist in identifying the need for ensuring protection of populations with differential patterns of subsistence consumption of fish and wildlife, Federal agencies, whenever practicable and appropriate, shall collect, maintain, and analyze information on the consumption patterns of populations who principally rely on fish and/or wildlife for subsistence."

Local residents depend on the Savannah River for fish to feed their families. Radiological monitoring reveals that Savanna River fish are contaminated with Cesium-137.¹² Tests in the vicinity of Plant Vogtle routinely find Cesium-137 in the edible parts of fish.

Radioactive Cesium-137 is of particular concern because levels actually increase when fish is cooked.¹³ One study found that cesium levels increase by 32% when fish are fried with breading, and by 62% when fried without breading.¹⁴

⁹ Westinghouse Savannah River Company Environmental Reports: 2003, 2004, 2005, WSRC-TR-2004-00015, WSRC-TR-2005-00005, WSRC-TR-2006-00007

¹⁰ Beaufort/Jasper County Water Treatment Plant and Cherokee Hill Water Treatment Plant recorded 17% increase in beta radiation in finished drinking water and 37% increase in beta radiation in raw water supply.

¹¹ Sources: SNOC Vogtle ESP ER Table 2.9-1; Table 3.0-1; Table 3.5-1

¹² *Vogtle Electric Generating Plant, Annual Radiological Operating Report for 2005*, Southern Company (2006).

¹³ Joanna Burger, et al., *Effects of Cooking on Radiocesium in Fish from the Savannah River: Exposure Differences for the Public*, Arch. Environ. Contam. Toxicol. 46, p. 231, 2004. (Exhibit 2.6).

¹⁴ *Id.* The weight loss during cooking of a breaded fish was 25% and the weight loss of an un-breaded fish was 39%.

African American and low-income individuals are at specific heightened risk from hazardous materials in the Savannah River, and although individuals from all socioeconomic backgrounds engage in fishing in the area, African Americans in particular commonly engage in subsistence fishing along the Savannah River and have a higher than average consumption of fish, frequently surpassing allowable contaminated fish consumption levels.¹⁵

Multiple Exposure Analysis is Required

Section 3–301(b) of Executive Order 12898 states that “Environmental human health analyses, whenever practicable and appropriate, shall identify multiple and cumulative exposures.”

A missing factor in the assessment of Vogtle’s impact is the proximity of the nuclear power station to the Department of Energy’s Savannah River Site. Vogtle and SRS emissions intermingle, making independent assessment challenging. The principal contractor at the Savannah River Site publishes annual reports which contain the following data.

Tritium Transport in Streams¹⁶

Year	SRS emissions	Vogtle emissions	Total curies
2003	4010	1900	5910
2004	2430	1200	3630
2005	2620	1860	4480

The discharge of Tritium in the form of radioactive water pollutes the Savannah River all the way to the ocean. Downstream drinking water wells are contaminated. Does the pollution come from SRS or Vogtle? The answer is “both.” Until a few years ago, the Georgia Department of Natural Resources Environmental Protection Division published reports on its radiation monitoring program. The program tested samples of air, surface water, groundwater, rain, sediments, fish, soil, vegetation, milk and agricultural crops near facilities which are known to emit ionizing radiation and compares these data to background levels. Test results for Vogtle from 1995 to 2002 indicated that the nuclear power plant is the source of a variety of radionuclides which contaminate sediment, river water, fish and drinking water. The state’s test results reveal striking elevations of harmful radionuclides. The test results range from 2 times to 50 times above background level.

A study conducted by the University of South Carolina has shown that there is a higher than average instance of cervical cancer in black women, and a higher rate of esophageal cancer in black men, within a fifty mile radius of Plant Vogtle.¹⁷ Georgia EPD monitoring indicates much of the radioactive pollution comes from the two nuclear reactors at Plant Vogtle.

Studies of U.S. Centers for disease Control and Prevention data indicate that the death rate per 100,000 population from all cancers in Burke County increased by 24.2% and that infant deaths increased by 70.1% in Burke County after the Plant Vogtle reactors went online.¹⁸

¹⁵ Senate Resolution 598, Senator Thomas of the 2nd, 07 LC 25 4926ER,
http://www.legis.ga.gov/legis/2007_08/fulltext/sr598.htm

¹⁶ Westinghouse Savannah River Company Environmental Reports: 2003, 2004, 2005, WSRC-TR-2004-00015, WSRC-TR-2005-00005, WSRC-TR-2006-00007

¹⁷ 1997 FEB 3, Cancer Weekly via NewsRx.com & NewsRx.net (Exhibit 2.7).

¹⁸ U.S. Centers for Disease Control and Prevention ICD-9 codes 000.1-799.9 (<http://wonder.cdc.gov>)

Conclusion

This photo shows the two nuclear reactors now operating at Plant Vogtle. If NRC permits Georgia Power to add two more, it would double the danger of radiation exposure, double the risk of nuclear accidents, and double the impact on future generations.



In view of the fact that the proposed action has not been taken, the Nuclear Regulatory Commission must reassess its environmental justice conclusions in order to prevent disproportionate adverse environmental impacts on low income populations in the Shell Bluff community near Plant Vogtle.

Respectfully,

A handwritten signature in black ink, which appears to read "Louis A. Zeller". The signature is written in a cursive style and is followed by a horizontal line.

Louis A. Zeller

Attachments

Attachment A**40 CFR Sec. 1508.27 Significantly.**

"Significantly" as used in NEPA requires considerations of both context and intensity:

(a) Context. This means that the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of the proposed action. For instance, in the case of a site-specific action, significance would usually depend upon the effects in the locale rather than in the world as a whole. Both short- and long-term effects are relevant.

(b) Intensity. This refers to the severity of impact. Responsible officials must bear in mind that more than one agency may make decisions about partial aspects of a major action. The following should be considered in evaluating intensity:

1. Impacts that may be both beneficial and adverse. A significant effect may exist even if the Federal agency believes that on balance the effect will be beneficial.
2. The degree to which the proposed action affects public health or safety.
3. Unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas.
4. The degree to which the effects on the quality of the human environment are likely to be highly controversial.
5. The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks.
6. The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration.
7. Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts.
8. The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural, or historical resources.
9. The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973.
10. Whether the action threatens a violation of Federal, State, or local law or requirements imposed for the protection of the environment.

[43 FR 56003, Nov. 29, 1978; 44 FR 874, Jan. 3, 1979]

CEQ - Regulations for Implementing NEPA

<http://ceq.hss.doe.gov/nepa/regs/ceq/1508.htm>

Attachment B**10 CFR § 51.92 Supplement to the final environmental impact statement.**

(a) If the proposed action has not been taken, the NRC staff will prepare a supplement to a final environmental impact statement for which a notice of availability has been published in the **Federal Register** as provided in § 51.118, if:

(1) There are substantial changes in the proposed action that are relevant to environmental concerns; or

(2) There are new and significant circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts.

(b) In a proceeding for a combined license application under 10 CFR part 52 referencing an early site permit under part 52, the NRC staff shall prepare a supplement to the final environmental impact statement for the referenced early site permit in accordance with paragraph (e) of this section.

(c) The NRC staff may prepare a supplement to a final environmental impact statement when, in its opinion, preparation of a supplement will further the purposes of NEPA.

(d) The supplement to a final environmental impact statement will be prepared in the same manner as the final environmental impact statement except that a scoping process need not be used.

(e) The supplement to an early site permit final environmental impact statement which is prepared for a combined license application in accordance with § 51.75(c)(1) and paragraph (b) of this section must:

(1) Identify the proposed action as the issuance of a combined license for the construction and operation of a nuclear power plant as described in the combined license application at the site described in the early site permit referenced in the combined license application;

(2) Incorporate by reference the final environmental impact statement prepared for the early site permit;

(3) Contain no separate discussion of alternative sites;

(4) Include an analysis of the economic, technical, and other benefits and costs of the proposed action, to the extent that the final environmental impact statement prepared for the early site permit did not include an assessment of these benefits and costs;

(5) Include an analysis of other energy alternatives, to the extent that the final environmental impact statement prepared for the early site permit did not include an assessment of energy alternatives;

(6) Include an analysis of any environmental issue related to the impacts of construction or operation of the facility that was not resolved in the proceeding on the early site permit; and

(7) Include an analysis of the issues related to the impacts of construction and operation of the facility that were resolved in the early site permit proceeding for which new and significant information has been identified, including, but not limited to, new and significant information demonstrating that the design of the facility falls outside the site characteristics and design parameters specified in the early site permit.

(f)(1) A supplement to a final environmental impact statement will be accompanied by or will include a request for comments as provided in § 51.73 and a notice of availability will be published in the **Federal Register** as provided in § 51.117 if paragraphs (a) or (b) of this section applies.

(2) If comments are not requested, a notice of availability of a supplement to a final environmental impact statement will be published in the **Federal Register** as provided in § 51.118.

[72 FR 49515, Aug. 28, 2007]

<http://www.nrc.gov/reading-rm/doc-collections/cfr/part051/part051-0092.html>

Tuesday, October 26, 2010

Attachment C begins on next page

Environmental Injustice in Siting Nuclear Plants

Mary Alldred and Kristin Shrader-Frechette

ABSTRACT

The mining, fuel enrichment-fabrication, and waste-management stages of the US commercial nuclear-fuel cycle have been documented as involving environmental injustices affecting, respectively, indigenous uranium miners, nuclear workers, and minorities and poor people living near radioactive-waste storage facilities. After surveying these three environmental-injustice problems, the article asks whether US nuclear-reactor siting also involves environmental injustice. For instance, because high percentages of minorities and poor people live near the proposed Vogtle reactors in Georgia, would siting new reactors at the Vogtle facility involve environmental injustice? If so, would this case be an isolated instance of environmental injustice, or is the apparent Georgia inequity generally representative of environmental injustice associated with nuclear-reactor siting throughout the US? Providing a preliminary answer to these questions, the article uses census data, paired t-tests, and z-tests to compare each state's percentages of minorities and poor people to the percentages living in zip codes and census tracts having commercial reactors. Although further studies are needed to fully evaluate apparent environmental injustices, preliminary results indicate that, while reactor-siting-related environmental injustice is not obvious at the census-tract level (perhaps because census tracts are designed to be demographically homogenous), zip-code-scale data suggest reactor-related environmental injustice may threaten poor people ($p < 0.001$), at least in the southeastern United States.

INTRODUCTION

EXAMINING POSSIBLE environmental injustice (EIJ) associated with siting commercial US nuclear reactors is important for at least five reasons.

1. Even when reactors operate normally, statistically significant increases in infant and fetal mortality near US reactors,¹ in childhood leukemia near German reactors,² and in cancer near UK reactors,³ suggest that (even without any accidents) those living near reactors could face higher health risks.^{1,4,5}
2. In the event of a reactor accident, those living nearby also could be most at risk, as suggested by increases in lung cancers and leukemias after the 1979 Three Mile Island, Pennsylvania accident.⁶
3. Minority and poverty-level communities often include higher percentages of women and children, both of whom are more sensitive to ionizing radiation, yet most radiation standards are devised to protect only adult males.^{7,8}
4. Because indigenous uranium miners, nuclear workers, and minorities and poor people living near radioactive-waste dumps have experienced EIJ (see later paragraphs), it is important to ask whether there also is reactor-siting-related EIJ.
5. Few scholars have addressed this question, although some citizens' groups note higher percentages of minorities or poor people living near nuclear plants,⁹ and some scientists suggest children, minorities, and poverty-level people are more sensitive than others to the roughly 100 radioisotopes routinely emitted by reactors.^{1,4,5}

Doctoral student Alldred is in the Department of Ecology and Evolution at the State University of New York at Stony Brook, in Stony Brook, New York. Dr. Shrader-Frechette is O'Neill Family Endowed Professor, Department of Biological Sciences and Department of Philosophy, and Director of the Center for Environmental Justice and Children's Health, all at the University of Notre Dame, Notre Dame, Indiana.

This article first summarizes already-documented cases of nuclear-related EIJ, then briefly surveys the proposed siting of the Vogtle reactors in Georgia, where the utility uses questionable criteria for assessing EIJ. Third, using census data, paired t-tests, and z-tests, the article investi-

gates whether the apparent EIJ at sites like the Grand Gulf, Mississippi reactor is representative of other US nuclear-siting cases. Although further studies are needed to fully evaluate apparent environmental injustices, the article concludes that, while reactor-siting-related EIJ is not obvious at census-tract levels, zip-code data suggest reactor-related EIJ threatens threaten poor people ($p < 0.001$), at least in the southeastern United States.

DISCUSSION

Nuclear generation of electricity involves a complex fuel cycle of at least nine stages: (1) mining uranium; (2) milling it; (3) converting it to uranium hexafluoride, UF_6 ; (4) enriching the UF_6 ; (5) fabricating nuclear fuel; (6) generating electricity; (7) reprocessing spent fuel; (8) interim storing of radioactive waste; and (9) transporting and permanently storing wastes.¹⁰ Because nuclear power has been used for more than half a century, researchers already have documented (see below) many cases of EIJ in nuclear-fuel-cycle stages (1), (2)–(5), and (9).

At stage (1), mining uranium, in most major uranium-producing nations of the world (e.g., Canada, Australia, Kazakhstan, Niger, Russia, Namibia, Uzbekistan, United States), indigenous peoples have been harmed either by working in unregulated uranium mines; by exposure to uncontrolled uranium wastes on native lands; or by risky uranium mining/processing on their lands, although they failed to consent to these operations.¹¹ In Canada, for instance, all uranium mining is on lands claimed by, or directly affecting, indigenous groups.^{12,13} In the United States, Native-American uranium miners, e.g., Navajos, face 14 times the normal lung-cancer risk, “most” of which has been caused by their uranium-mining, not smoking.¹⁴ The US government admits that it failed to require uranium-mine ventilation, failed to disclose radiation risks to Navajo miners, and had “no plausible justification” for allowing massive exploitation of Native-American uranium miners.¹¹ In 2005, Navajo Nation demanded a moratorium on uranium mining/processing on its lands (a moratorium not honored by the US government) until ongoing damages have been assessed and remedied. These damages include inadequate compensation for radiation-induced disease among native miners, no permanent closure/decontamination of hundreds of uranium-mining/processing sites that continue to expose native peoples, and no ongoing medical studies of the health status of Native Americans affected by uranium mining.¹⁵

In stages (2)–(5) of the nuclear fuel cycle, tens of millions of radiation workers, including nearly two million in the United States,¹⁶ also have faced EIJ. US nuclear-facility owners legally may expose workers to annual radiation doses up to 50 times higher than those allowed for members of the public,¹⁷ although there is no safe dose of ionizing radiation.⁷ Yet radiation workers typically receive no hazard pay or compensating wage differential.³ Often they also do not voluntarily accept dangerous nuclear jobs but take them because of economic necessity,³ because government falsification of worker radiation doses has misled them,^{18,19} or because flawed radiation standards, flawed

risk disclosure, and flawed workplace-radiation monitoring cause them to underestimate risks.²⁰ Yet the risks are substantial. The International Agency for Research on Cancer (IARC) shows roughly 1 additional fatal cancer each time 60 people are exposed to the maximum-allowable, annual occupational-radiation dose of 50 mSv.^{20,21}

US nuclear-waste policies in stages (8)–(9), radioactive waste transport/storage, likewise have already caused EIJ (as serious contamination at Hanford, Maxey Flats, Savannah River, and other cases have shown), and EIJ also is likely when future waste-containment canisters fail—long before the million years that (the US National Academy of Sciences says) nuclear wastes must be completely secured.²² Because the US government has falsified and manipulated data on radioactive-waste risk^{22,23,24} (much of which will be borne by Appalachian, Latino, and Native-American populations, who live in higher proportions near existing and proposed nuclear-waste-storage sites),³ United Nations and nuclear-industry studies warn that the US government may underestimate future waste-repository-radiation doses by 9–12 orders of magnitude.²⁵ Yet even if proposed future US nuclear-waste standards are met, their leniency likely will impose EIJ on future generations. After 10,000 years, they would allow exposures of 100 millirems/year (limits 1,000 percent higher than current standards for US Department of Energy facilities). They also use only mean or average dose to assess regulatory compliance. This means that, provided that the average person’s exposure is no more than 100 millirems, many other people would be allowed to receive higher, even fatal, doses.^{8,26}

EIJ and siting the proposed Vogtle nuclear reactors

In addition to EIJ associated with uranium mining, uranium-fuel milling/conversion/enrichment/fabrication, and waste transport/management, commercial reactor siting also may involve EIJ. That is, disproportionate numbers of reactors may be placed in African-American, Hispanic, minority, or poverty-level neighborhoods. Consider the Vogtle nuclear facility in Waynesboro, Georgia. In 2006 Southern Nuclear Operating Company (SNOC) proposed two additional reactors for Waynesboro.²⁷ Currently SNOC’s Early Site Permit Application,²⁸ as well as its Combined Construction Operating License, are under Nuclear Regulatory Commission review.²⁹

Because SNOC uses at least three flawed criteria for assessing EIJ, it likely errs when it denies that the Vogtle facility causes EIJ for minority and poverty-level populations.³⁰ According to these criteria, SNOC considers EIJ to exist only if (1) census blocks within the full, 50-mile radius of the facility include high minority/poverty-level populations; (2) these census blocks have either (a) greater-than-50-percent-minority/poor population, or (b) a minority/poor population that exceeds the averages for Georgia or South Carolina by at least 20 percentage points;^{31,32} and (3) the facility is located amid dense population.³³ Consider (1)–(3) in order.

Criterion (1) arguably dilutes potential EIJ effects by using a 50-mile radius,³¹ instead of assessing closer minor-

ity/poor populations. Obviously the greater the distance from a risky facility, the less likely are risks, therefore EIJ. Besides, the classic National Cancer Institute (NCI) study (of cancer rates near nuclear plants) says areas 30 (not 50) miles from a nuclear plant are those most likely to be affected by emissions.^{1,34} Criterion (1) also ignores wind patterns relative to minority/low-income census tracts; areas downwind of Vogtle would likely experience greater risks.

SNOC use of criteria (2)(a) and (2)(b) likewise are unrealistic and unfair. Regarding (2)(a)—which requires 50 percent minority/low-income population within a 50-mile radius of Vogtle to show EIJ—consider that in the US, average state low-income populations range from 4.3 to 16 percent (Table 1). This means that showing income-related EIJ, under (2)(a), would require showing low-income populations (within 50 miles of Vogtle) that were 3–12 times greater than the state average (Table 1). Even a doubling of low-income groups near Vogtle would not count as EIJ, under criterion (2)(a). Regarding criterion (2)(b)—which requires minority/low-income populations 20 percentage points above Georgia or South Carolina averages, to show EIJ—Georgia and South Carolina already have minority populations of about 30 percent (Table 1). To show EIJ, criterion (2)(b) thus requires nearly doubling (over the state average) the percent-minority population residing near Vogtle.

Using these arguably unrealistic and unfair EIJ criteria (2)(a)–(2)(b), SNOC says 183 census-block groups (37.3 percent within a 50-mile radius of Vogtle) meet criterion (2)(a) for minority populations; 14 census-block groups (2.8 percent) meet criterion (2)(a) for poverty-level populations; 168 census-block groups (34.2 percent) meet criterion (2)(b) for minority populations; and 72 census-block groups (14.7 percent) meet criterion (2)(b) for poverty-level populations.³¹ Using the preceding data and anecdotal evidence collected from two phone interviews, SNOC admits: “some existing communities within the [50-mile-radius] area exhibit disproportionately high percentages of minority (primarily Black races) and low-income populations.”³⁰ Because SNOC says these high-density minority/low-income areas are “scattered,” SNOC concludes that “there were no environmental justice effects to consider with respect to densely populated minority or low-income peoples.”³⁰

As the preceding quotation reveals, EIJ criterion (3) of SNOC likewise is unrealistic and unfair because it recognizes only “densely-populated” minority/low income residents as EIJ victims. Yet whether EIJ victims live in sparsely-populated (rural), or densely-populated (urban) areas is logically irrelevant to whether they are EIJ victims of discrimination. Criterion (3) essentially excludes all rural cases of EIJ. Further bias in assessing EIJ is evident when SNOC uses EIJ criterion (3) and lists Augusta, Georgia (population 195,182)³⁵ as the nearest (26 miles away) population center to Vogtle.³³ It defines “population center” as having greater than 25,000 residents,³³ then claims the Vogtle facility is located in a sparsely populated area.³³ This claim is questionable because Vogtle is directly located in largely-minority, largely low-income Waynesboro, Georgia, whose population is 5,813.³⁶ Thus

although Vogtle satisfies none of SNOC’s three EIJ criteria, because all the criteria are scientifically suspect, siting the Vogtle reactors may well involve EIJ.

Anecdotal evidence for EIJ in US nuclear siting

Apart from questionable EIJ criteria used in the preceding Georgia case, does EIJ typify other US nuclear-siting cases? Consider the Grand Gulf Nuclear station, in Port Gibson, Mississippi. Some Mississippi citizens’ groups claim this reactor was sited under EIJ conditions because its home-county population is 85 percent African-American, and 33 percent poverty-level.^{1,9}

On one hand, as Table 1 reveals, census data (from zip codes in which the 104 US nuclear facilities are located) suggest nuclear plants are often sited in zip codes having higher percentages of African-American/Hispanic/minority/poverty-level residents than is average for their home states. On the other hand, the fact that 42 of 104 zip codes (in which nuclear plants are located) have higher-than-average populations (of these EIJ victims) may not show that US commercial nuclear siting involves EIJ. Even without nuclear-related EIJ, one would expect half of the minority/low-income populations (in zip codes where roughly half (52) of US commercial nuclear reactors are located) to be above the state average, and roughly half below. Also, there is a time-gap in the zip-code demographic data. These data are recent, while many nuclear plants were built 30–35 years ago, when vulnerable populations may not have lived nearby. Moreover, because Table 1 reveals nothing about how far above (or below) average are the percentages of vulnerable populations living near nuclear plants, it provides little reliable evidence regarding EIJ.

Types of, and conditions for, nuclear-siting-related EIJ

To provide a more reliable, preliminary assessment of possible EIJ in commercial nuclear-reactor siting, we first categorized at least four types of EIJ. EIIA, EIJH, EIJM, and EIJP refers to EIJ that impacts, respectively, African-Americans, Hispanics, minorities, and poverty-level residents. (“Minority” refers to any individual who does not self-identify as “white” in the national census.)

We define EIIA, EIJH, EIJM, and EIJP, respectively, as instances in which at least two necessary conditions are met: (1) the percentage of the population that is, respectively, African-American, Hispanic, minority, and poverty-level, in a given nuclear-reactor geographic area (zip code or census tract), is higher than the respective average-percentage for the state in which the reactor is located, and (2) statistical data show that these higher percentages are unlikely to be due purely to chance. Providing a preliminary statistical assessment of nuclear-siting-related EIJ, this article examines (1) and (2).

Zip-code-scale and census-tract-scale statistical evidence regarding nuclear-siting-related EIJ

Each potential instance of EIJ (EIIA, EIJH, EIJM, EIJP) was analyzed using z-tests and/or paired t-tests to compare individual zip-code demographic data (on minor-

TABLE 1. SUMMARY OF ZIP CODE AND STATE AVERAGE DEMOGRAPHICS FOR EACH NUCLEAR PLANT LOCATION

Plant	Number of Reactors	Zip Code	Percent			Percent Families Below Poverty ¹	State	Percent			Percent Families Below Poverty ¹	Potential EIJ Problem ²
			African American ¹	Hispanic ¹	Minority ¹			African American ¹	Hispanic ¹	Minority ¹		
Arkansas Nuclear	2	72801	6.0	3.5	11.6	13.2	Arkansas	15.7	3.2	20.0	12.0	*
Beaver Valley	2	15077	0.0	0.0	0.0	7.0	Pennsylvania	10.0	3.2	14.6	7.8	
Braidwood	2	60407	0.1	3.1	2.1	7.6	Illinois	15.1	12.3	26.5	7.8	
Browns Ferry	3	35602	19.6	5.6	24.5	11.9	Alabama	26.0	1.7	28.9	12.5	*
Brunswick	2	28461	10.2	0.9	12.4	6.1	North Carolina	21.6	4.7	27.9	9.0	
Byron	2	61010	0.3	1.0	2.2	4.5	Illinois	15.1	12.3	26.5	7.8	
Callaway	1	65251	9.4	0.9	12.2	6.9	Missouri	11.2	2.1	15.1	8.6	
Calvert Cliffs	2	20657	15.0	2.3	18.6	4.4	Maryland	27.9	4.3	36.0	6.1	
Catawba	2	29745	18.2	2.8	21.9	10.1	South Carolina	29.5	2.4	32.8	10.7	*
Clinton	1	61727	0.7	1.7	2.7	7.0	Illinois	15.1	12.3	26.5	7.8	
Columbia	1	99352	1.4	4.7	10.4	5.6	Washington	3.2	7.5	18.2	7.3	
Comanche Park	2	76043	0.3	15.1	8.8	7.2	Texas	11.5	32.0	29.0	12.0	
Cooper Station	1	68321	0.0	0.9	0.9	8.9	Nebraska	4.0	5.5	10.4	6.7	*
Crystal River	1	34428	4.0	3.0	7.8	10.9	Florida	14.6	16.8	22.0	9.0	*
Davis-Besse	1	43449	0.2	2.0	1.9	3.6	Ohio	11.5	1.9	15.0	7.8	*
Diablo Canyon	2	93424	0.4	4.3	4.9	5.9	California	6.7	32.4	40.5	10.6	
Donald C. Cook	2	49106	0.6	1.3	2.9	5.4	Michigan	14.2	3.3	19.8	7.4	
Dresden	2	60450	0.2	5.4	3.7	3.8	Illinois	15.1	12.3	26.5	7.8	
Duane Arnold	1	52324	0.6	0.6	1.7	2.0	Iowa	15.1	12.3	26.5	7.8	
Edwin Hatch	2	31513	20.0	4.7	23.8	15.1	Georgia	28.7	5.3	34.9	9.9	*
Enrico Fermi	1	48166	0.9	2.5	3.8	4.8	Michigan	14.2	3.3	19.8	7.4	
Fitzpatrick	1	13093	1.0	2.8	4.7	13.0	New York	15.9	15.1	32.1	11.5	*
Fort Calhoun	1	68023	0.8	1.0	1.8	4.3	Nebraska	4.0	5.5	10.4	6.7	
Grand Gulf	1	39150	79.8	0.9	80.6	27.8	Mississippi	36.3	1.4	38.6	16.0	*
H. B. Robinson	1	29550	30.9	1.2	32.4	16.3	South Carolina	29.5	2.4	32.8	10.7	*
Hope Creek	1	08038	0.7	0.4	1.4	3.3	New Jersey	13.6	13.3	27.4	6.3	
Indian Point	2	10511	0.7	3.5	3.8	2.2	New York	15.9	15.1	32.1	11.5	
Joseph Farley	2	36312	13.4	0.9	14.8	9.2	Alabama	26.0	1.7	28.9	12.5	
Kewaunee	1	54216	0.3	0.5	1.5	7.2	Wisconsin	5.7	3.6	11.1	5.6	*
LaSalle County	2	61341	0.1	1.7	1.9	4.6	Illinois	15.1	12.3	26.5	7.8	
Limerick	2	19464	10.9	3.0	15.0	6.8	Pennsylvania	10.0	3.2	14.6	7.8	*

McGuire	2	28078	8.0	3.7	12.0	1.9	North Carolina	21.6	4.7	27.9	9.0	
Millstone	2	06385	2.1	2.4	7.3	2.4	Connecticut	9.1	9.4	18.4	5.6	
Monticello	1	55362	0.3	1.6	2.7	4.0	Minnesota	3.5	2.9	10.6	5.1	*
Nine Mile Point	2	13093	1.0	2.8	4.7	13.0	New York	15.9	15.1	32.1	11.5	
North Anna	2	23117	18.8	0.9	20.8	4.8	Virginia	19.6	4.7	27.7	7.0	
Oconee	3	68321	0.0	0.9	0.9	8.9	South Carolina	29.5	2.4	32.8	10.7	
Oyster Creek	1	08731	0.4	2.2	2.2	4.1	New Jersey	13.6	13.3	27.4	6.3	*
Palisades	1	49043	36.6	18.9	52.5	21.6	Michigan	14.2	3.3	19.8	7.4	*
Palo Verde	3	85072	5.1	34.1	28.9	11.5	Arizona	3.1	25.3	24.5	9.9	
Peach Bottom	2	17314	1.6	0.5	2.9	4.2	Pennsylvania	10.0	3.2	14.6	7.8	
Perry	1	Ohio	11.5									
Pilgrim	1	02360	1.9	1.6	5.1	4.4	Massachusetts	5.4	6.8	15.5	6.7	
Point Beach	2	54241	0.1	1.3	3.7	3.8	Wisconsin	5.7	3.6	11.1	5.6	
Prairie Island	2	55089	0.3	0.7	12.9	3.1	Minnesota	3.5	2.9	10.6	5.1	*
Quad Cities	2	61242	0.1	1.9	2.5	3.6	Illinois	15.1	12.3	26.5	7.8	
River Bend	1	70775	41.7	0.5	42.8	14.8	Louisiana	32.5	2.4	36.1	15.8	*
Robert E. Ginna	1	14519	1.2	1.2	3.4	2.7	New York	15.9	15.1	32.1	11.5	
Salem	2	08038	0.7	0.4	1.4	3.3	New Jersey	13.6	13.3	27.4	6.3	
San Onofre	2	92674	0.8	15.9	12.1	4.6	California	6.7	32.4	40.5	10.6	
Seabrook	1	03874	0.3	0.8	2.5	6.0	New Hampshire	0.7	1.7	4.0	4.3	*
Sequoyah	2	37379	1.4	0.6	2.6	6.3	Tennessee	16.4	2.2	19.8	10.3	*
Shearon Harris	1	27562	14.2	5.1	19.8	0.8	North Carolina	21.6	4.7	27.9	9.0	
South Texas Project	2	77483	0.5	16.4	14.5	8.3	Texas	11.5	32.0	29.0	12.0	
St. Lucie	2	34954	40.9	15.0	50.5	25.4	Florida	14.6	16.8	22.0	9.0	*
Surry	2	23883	56.0	0.5	57.1	8.8	Virginia	19.6	4.7	27.7	7.0	*
Susquehanna	2	18603	0.7	1.1	2.2	8.5	Pennsylvania	10.0	3.2	14.6	7.8	*
Three Mile Island	1	17057	4.4	2.2	7.7	3.7	Pennsylvania	10.0	3.2	14.6	7.8	
Turkey Point	2	33032	34.7	43.2	47.8	22.1	Florida	14.6	16.8	22.0	9.0	*
Vermont Yankee	1	05354	0.3	0.8	1.4	2.5	Vermont	0.5	0.9	3.2	6.3	
Virgil C. Summer	1	29065	81.5	0.4	81.6	9.2	South Carolina	29.5	2.4	32.8	10.7	*
Vogtle	2	30830	55.6	1.3	57.5	25.1	Georgia	28.7	5.3	34.9	9.9	*
Waterford	1	70066	98.1	0.4	98.5	40.7	Louisiana	32.5	2.4	36.1	15.8	*
Watts Bar	1	37381	1.9	1.1	3.5	11.8	Tennessee	16.4	2.2	19.8	10.3	*
Wolf Creek	1	66839	0.2	1.8	3.9	4.9	Kansas	5.7	7.0	13.9	6.7	

¹US Census 2000. American FactFinder. <http://factfinder.census.gov/saff/main.html?_lang=en> (Last accessed April 13, 2008). Accessing demographics for each zip code and state requires an additional search. Bolded values are those in which the zip code percentages are numerically higher than the state percentages.

Asterisks (*) indicate a potential environmental-injustice (EII) problem, which is defined as a plant located in a zip code that has a numerically greater percentage of African-American, Hispanic, minority, or families in poverty than the state percentage.

ity/low-income populations) to the state-average data (Table 1); each US commercial reactor constituted a replicate ($N = 104$). Based on t-tests and census data, nuclear-related, zip-code-scale EIJ (EIJA/EIJH/EIJM/EIJP) is not obvious, at least not on a national scale (Table 2).

Concerned that geographical dilution could cause the apparent absence of reactor-related, zip-code-scale EIJ (because including more-distant, less-affected population areas often tends to dilute apparent-EIJ effects, as may have occurred with SNOG criterion (1)),³¹ we repeated the same paired t-tests, at a closer-to-facility, census-tract scale (Table 3). These census-tract-scale data likewise showed no obvious national EIJA, EIJH, EIJM, or EIJP (Table 4).

Regional-scale evidence regarding nuclear-siting-related EIJ

Because many more potential nuclear-EIJ sites are located in the southeastern United States (Tables 1, 3), we also analyzed zip-code data by region (Table 5). These regions are defined as follows. The Southeast includes all commercial reactors located in Arkansas, Alabama, North Carolina, South Carolina, Georgia, Florida, Mississippi, Virginia, Louisiana, and Tennessee. The Northeast includes all those located in Pennsylvania, Maryland, New York, New Jersey, Connecticut, Massachusetts, New Hampshire, and Vermont. The Midwest includes all facilities located in Illinois, Ohio, Michigan, Wisconsin, Iowa, and Minnesota. The West (of the Mississippi) includes all facilities located in Missouri, Washington, Texas, Nebraska, California, Arizona, and Kansas.

Paired t-test, zip-code analyses, by regions, show that only the Southeast (with 38 reactors) appears to have potential instances of EIJP (Fig. 1); no EIJA, EIJH, or EIJM are obvious. However, Table 5 shows that, given the caveat that year-2000 census-data demographics accurately represent demographics at the time of reactor siting, at least in southeastern United States, zip-code-scale data and t-tests suggest that commercial, reactor-siting-related EIJP has a 77-percent likelihood of not being due merely to chance ($p = 0.23$). Even more important results are that, given the preceding caveat, more sensitive zip-code and z-test data show that in the Southeast, commercial, reactor-siting-related EIJP has greater-than-99-percent likelihood of not being due merely to chance ($p < 0.001$) (Table 5).

However, statistically significant, reactor-related EIJP does not appear to occur at the census-tract scale in the Southeast, and no instance of EIJ was evident at the census-tract scale within any region (Table 6). Although further research is needed to clarify these census-tract data, their not revealing apparent EIJ may result from the fact that, as the US Census Bureau puts it, census tracts "are designed to be homogenous with respect to population characteristics, economic status and living conditions."³⁷ Drawing census-tract boundaries so as to ensure homogeneity would make EIJ (and its associated racial or economic heterogeneities and inequities) less likely to appear at the census-tract scale. Nevertheless, the census-tract results are interesting because EIJ typically is more evident at a closer-to-facility (census-tract) scale than at a larger scale. In this analysis, EIJP appears only at the larger zip-code scale.

Interestingly, over 36 percent of US nuclear reactors are located in the Southeast, 25 percent in the Northeast, 23 percent in the Midwest, and 15 percent in the West. However, census data show that the Southeast contains only about 26 percent of US population, while the Northeast has 23 percent; the Midwest, 19 percent; and the West, 31 percent. Given the preceding caveat, if the percentage of commercial reactors in each region were proportional to its population, we would expect to find only 26 (not 36) percent of reactors in the Southeast. This means the number of Southeast reactors is 38 percent greater than expected—a disproportionately high percentage of commercial reactors, given the regional population and the preceding caveat. In comparison, reactor numbers are only 7 percent greater than expected in the Northeast and 19 percent greater in the Midwest. Reactor numbers are 52 percent less than expected in the West. The preceding data suggest that the Southeast may be bearing more of a nuclear-reactor burden than the rest of the nation.

CONCLUSIONS

The preceding discussion suggests that although census-tract-scale data indicate no obvious EIJA, EIJH, EIJM, or EIJP associated with US nuclear-reactor siting, perhaps because of the way census-tract boundaries are intentionally drawn, that is not the whole story. Given the preceding caveat that year-2000 census data reasonably estimate demographics at the time of reactor siting, zip-code-scale data and z-tests reveal apparent reactor-

TABLE 2. Z-TESTS AND PAIRED T-TESTS COMPARING PERCENT DEMOGRAPHIC COMPOSITIONS OF ZIP CODES CONTAINING NUCLEAR REACTORS TO THE STATE AVERAGES FOR THE SAME DEMOGRAPHIC COMPOSITIONS

	<i>African American</i>	<i>Hispanic</i>	<i>Minority</i>	<i>Families Below Poverty</i>
t_{103}	-5.932	-9.997	-6.685	-2.558
p	<0.001	<0.001	<0.001	0.012
Z_{104}	-10.777	-7.084	-14.392	-5.531
p	<0.001	<0.001	<0.001	<0.001

Each t_x represents the t-value of a paired t-test with x degrees of freedom.

Each Z_n represents the Z value of a one-sample Z-test with n cases.

Percentage data were arcsine-square-root transformed prior to statistical testing.

TABLE 3. SUMMARY OF CENSUS-TRACT AND STATE-AVERAGE DEMOGRAPHICS FOR EACH NUCLEAR PLANT LOCATION

Plant	Number of Reactors	Census Tract	Percent African American ¹	Percent Hispanic ¹	Percent Minority ¹	Families Below Poverty ²	State	Percent African American ³	Percent Hispanic ³	Percent Minority ³	Percent Families Below Poverty ³	Potential EIJ Problem ⁴
Arkansas Nuclear	2	9508	0.3	0.7	2.3	6.1	Arkansas	15.7	3.2	20.0	12.0	
Beaver Valley	2	6027.01	1.9	1.4	3.1	6.9	Pennsylvania	10.0	3.2	14.6	7.8	
Braidwood	2	8840.01	0.1	2.0	1.4	2.1	Illinois	15.1	12.3	26.5	7.8	
Browns Ferry	3	211	30.1	3.3	33.7	10.6	Alabama	26.0	1.7	28.9	12.5	*
Brunswick	2	203.01	13.8	1.0	15.8	5.3	North Carolina	21.6	4.7	27.9	9.0	
Byron	2	9617	0.4 ¹	1.3	2.2	5.8	Illinois	15.1	12.3	26.5	7.8	
Callaway	1	9702	1.1	1.3	3.2	5.6	Missouri	11.2	2.1	15.1	8.6	
Calvert Cliffs	2	8610.01	7.1	2.6	9.5	0.0	Maryland	27.9	4.3	36.0	6.1	
Catawba	2	617.04	12.3	1.0	24.9	2.3	South Carolina	29.5	2.4	32.8	10.7	
Clinton	1	9715	0.1	0.4	2.2	2.2	Illinois	15.1	12.3	26.5	7.8	
Columbia	1	120	0.0	30.6	5.6	0.0	Washington	3.2	7.5	18.2	7.3	
Comanche Park	2	9901	0.3	12.3	7.0	4.2	Texas	11.5	32.0	29.0	12.0	
Cooper Station	1	9981	0.4	1.1	2.1	9.6	Nebraska	4.0	5.5	10.4	6.7	*
Crystal River	1	9707	0.2	1.3	1.9	12.9	Florida	14.6	16.8	22.0	9.0	*
Davis-Besse	1	508	0.3	2.1	1.8	3.8	Ohio	11.5	1.9	15.0	7.8	*
Diablo Canyon	2	116	0.1	4.9	5.1	3.9	California	6.7	32.4	40.5	10.6	
Donald C. Cook	2	111	0.7	1.3	2.9	5.6	Michigan	14.2	3.3	19.8	7.4	
Dresden	2	7	0.2	2.5	2.1	2.8	Illinois	15.1	12.3	26.5	7.8	
Duane Arnold	1	106	0.6	0.6	2.5	1.1	Iowa	2.1	2.8	2.1	6.0	*
Edwin Hatch	2	9501	3.6	2.1	4.9	9.3	Georgia	28.7	5.3	34.9	9.9	
Enrico Fermi	1	8312	1.0	2.7	3.9	5.6	Michigan	14.2	3.3	19.8	7.4	
Fitzpatrick	1	215.02	0.4	1.8	2.8	10.6	New York	15.9	15.1	32.1	11.5	
Fort Calhoun	1	502.02	0.6	0.9	1.5	4.4	Nebraska	4.0	5.5	10.4	6.7	*
Grand Gulf	1	9501	76.8	0.7	77.6	27.2	Mississippi	36.3	1.4	38.6	16.0	*
H. B. Robinson	1	102	10.9	1.0	12.1	14.0	South Carolina	29.5	2.4	32.8	10.7	*
Hope Creek	1	222.01	2.2	0.5	3.6	4.2	New Jersey	13.6	13.3	27.4	6.3	
Indian Point	2	141	3.2	10.0	11.6	5.1	New York	15.9	15.1	32.1	11.5	
Joseph Farley	2	417	20.2	0.9	21.6	10.1	Alabama	26.0	1.7	28.9	12.5	
Kewaunee	1	9605	0.3	0.4	1.3	6.6	Wisconsin	5.7	3.6	11.1	5.6	*
LaSalle County	2	9637	0.2	1.6	1.7	3.7	Illinois	15.1	12.3	26.5	7.8	
Limerick	2	2087.04	18.3	1.7	22.3	16.8	Pennsylvania	10.0	3.2	14.6	7.8	
McGuire	2	62.07	7.6	3.3	11.5	2.6	North Carolina	21.6	4.7	27.9	9.0	
Millstone	2	6933	1.3	1.9	5.3	3.2	Connecticut	9.1	9.4	18.4	5.6	
Monticello	1	304.02	0.2	1.5	2.8	3.4	Minnesota	3.5	2.9	10.6	5.1	
Nine Mile Point	2	215.02	0.4	1.8	2.8	10.6	New York	15.9	15.1	32.1	11.5	
North Anna	2	9501	19.6	0.7	21.6	4.2	Virginia	19.6	4.7	27.7	7.0	
Oconee	3	112.01	11.9	1.5	23.9	16.4	South Carolina	29.5	2.4	32.8	10.7	*
Oyster Creek	1	7321.02	0.6	2.6	2.4	5.0	New Jersey	13.6	13.3	27.4	6.3	*
Palisades	1	106	35.2	15.2	48.9	26.1	Michigan	14.2	3.3	19.8	7.4	*
Palo Verde	3	506.03	1.9	32.4	25.3	18.3	Arizona	3.1	25.3	24.5	9.9	*

(continued)

TABLE 3. SUMMARY OF CENSUS-TRACT AND STATE-AVERAGE DEMOGRAPHICS FOR EACH NUCLEAR PLANT LOCATION (CONT'D)

<i>Plant</i>	<i>Number of Reactors</i>	<i>Census Tract</i>	<i>Percent African American¹</i>	<i>Percent Hispanic¹</i>	<i>Percent Minority¹</i>	<i>Families Below Poverty²</i>	<i>State</i>	<i>Percent African American³</i>	<i>Percent Hispanic³</i>	<i>Percent Minority³</i>	<i>Percent Families Below Poverty³</i>	<i>Potential EIJ Problem⁴</i>
Peach Bottom	2	240	1.4	0.5	2.7	3.0	Pennsylvania	10.0	3.2	14.6	7.8	
Perry	1	2056	0.2	0.5	1.0	6.1	Ohio	11.5	1.9	15.0	7.8	
Pilgrim	1	5307	1.0	1.3	1.6	4.0	Massachusetts	5.4	6.8	15.5	6.7	
Point Beach	2	101	0.1	0.8	1.4	3.4	Wisconsin	5.7	3.6	11.1	5.6	
Prairie Island	2	9802	1.6	1.3	8.3	4.6	Minnesota	3.5	2.9	10.6	5.1	
Quad Cities	2	8	0.2	2.1	2.2	7.3	Illinois	15.1	12.3	26.5	7.8	
River Bend	1	9518	31.4	0.7	32.6	10.4	Louisiana	32.5	2.4	36.1	15.8	
Robert E. Ginna	1	201.01	0.8	1.2	2.7	0.6	New York	15.9	15.1	32.1	11.5	
Salem	2	222.01	2.2	0.5	3.6	4.2	New Jersey	13.6	13.3	27.4	6.3	
San Onofre	2	187	12.8	22.0	36.3	7.7	California	6.7	32.4	40.5	10.6	*
Seabrook	1	630	0.3	0.9	2.5	6.1	New Hampshire	0.7	1.7	4.0	4.3	*
Sequoyah	2	103.01	0.7	0.9	1.8	5.4	Tennessee	16.4	2.2	19.8	10.3	
Shearon Harris	1	532	17.5	2.6	21.3	2.4	North Carolina	21.6	4.7	27.9	9.0	
South Texas Project	2	7306	4.2	47.1	39.6	18.6	Texas	11.5	32.0	29.0	12.0	*
St. Lucie	2	17.02	0.0	0.4	1.0	4.0	Florida	14.6	16.8	22.0	9.0	*
Surry	2	8601	50.6	0.7	52.2	11.1	Virginia	19.6	4.7	27.7	7.0	*
Susquehanna	2	2161	0.5	0.7	1.4	5.1	Pennsylvania	10.0	3.2	14.6	7.8	
Three Mile Island	1	240.01	0.7	1.0	2.6	4.2	Pennsylvania	10.0	3.2	14.6	7.8	
Turkey Point	2	114.01	11.8	30.9	23.1	10.2	Florida	14.6	16.8	22.0	9.0	*
Vermont Yankee	1	9687	0.2	0.2	2.1	3.7	Vermont	0.5	0.9	3.2	6.3	
Virgil C. Summer	1	9601	84.5	0.9	85.4	18.5	South Carolina	29.5	2.4	32.8	10.7	*
Vogtle	2	9501	40.9	2.3	44.2	17.4	Georgia	28.7	5.3	34.9	9.9	*
Waterford	1	627	59.8	1.0	61.0	23.7	Louisiana	32.5	2.4	36.1	15.8	*
Watts Bar	1	9751	1.6	0.9	3.3	12.6	Tennessee	16.4	2.2	19.8	10.3	*
Wolf Creek	1	9961	0.2	0.8	2.1	5.8	Kansas	5.7	7.0	13.9	6.7	

¹US Census 2000. Census 2000 Summary File 1 (SF 1) 100-Percent Data, Quick Tables.

<http://factfinder.census.gov/servlet/QTGeoSearchByListServlet?ds_name=DEC_2000_SF1_U&lang=en&_ts=234365620-734>. Last accessed April 20, 2008). Accessing Demographics for each census tract requires an additional search using county name and census tract number; data are located in table "DP-1 Profile of General Demographic Characteristics." Bolded values are those in which the census-tract percentages are numerically higher than the state percentages.

²US Census 2000. Census 2000 Summary File 3 (SF 3) —Sample Data.

<http://factfinder.census.gov/servlet/QTGeoSearchByListServlet?ds_name=DEC_2000_SF3_U&lang=en&_ts=234365620-734>. Last accessed April 20, 2008). Accessing Demographics for each census tract requires an additional search using county name and census tract number; data are located in table "DP-3 Profile of General Demographic Characteristics." Bolded values are those in which the census-tract percentages are numerically higher than the state percentages.

³US Census 2000. American FactFinder. <http://factfinder.census.gov/home/saff/main.html?_lang=en> (Last accessed April 13, 2008). Accessing demographics for each state requires an additional search.

⁴Asterisks (*) indicate a potential environmental-injustice (EIJ) problem, which is defined as a plant located in a census tract that has a numerically greater percentage of African-American, Hispanic, minority, or families in poverty than the state percentage.

TABLE 4. Z-TESTS AND PAIRED T-TESTS COMPARING PERCENT DEMOGRAPHIC COMPOSITIONS OF CENSUS TRACTS CONTAINING NUCLEAR REACTORS TO THE STATE AVERAGES FOR THE SAME DEMOGRAPHIC COMPOSITIONS

	<i>African American</i>	<i>Hispanic</i>	<i>Minority</i>	<i>Families Below Poverty</i>
t_{103}	-7.742	-8.572	-8.058	-4.666
p	<0.001	<0.001	<0.001	<0.001
Z_{104}	-12.077	-7.736	-13.394	-10.680
p	<0.001	<0.001	<0.001	<0.001

Each t_x represents the t-value of a paired t-test with x degrees of freedom.

Each Z_n represents the Z value of a one-sample Z-test with n cases.

Percentage data were arcsine-square-root transformed prior to statistical testing.

TABLE 5. Z-TESTS AND PAIRED T-TESTS COMPARING PERCENT DEMOGRAPHIC COMPOSITIONS OF ZIP CODES CONTAINING NUCLEAR REACTORS TO THE STATE AVERAGES FOR THE SAME DEMOGRAPHIC COMPOSITIONS WITHIN EACH GEOGRAPHICAL REGION

<i>Region</i>		<i>African American</i>	<i>Hispanic</i>	<i>Minority</i>	<i>Families Below Poverty</i>
Midwest	t_{23}	-8.788	-4.960	-6.376	-3.406
	p	<0.001	<0.001	<0.001 ²	0.002
Northeast	t_{25}	-9.323	-7.700	-9.205	-4.258
	p	<0.001	<0.001	<0.001	<0.001
Southeast	t_{37}	-0.317	-1.847	-0.471	1.228
	p	0.753	0.073	0.640	0.227
	Z_{38}	-1.269	-2.152	-2.281	3.880
	p	0.205	0.031	0.023	<0.001
West	t_{15}	-3.224	-3.668	-4.397	-3.709
	p	0.005	0.002	0.001	0.002

Each t_x represents the t-value of a paired t-test with x degrees of freedom.

Each Z_n represents the Z value of a one-sample Z-test with n cases.

Percentage data were arcsine-square-root transformed prior to statistical testing.

Significant positive results are shown in bold.

TABLE 6. Z-TESTS AND PAIRED T-TESTS COMPARING PERCENT DEMOGRAPHIC COMPOSITIONS OF CENSUS TRACTS CONTAINING NUCLEAR REACTORS TO THE STATE AVERAGES FOR THE SAME DEMOGRAPHIC COMPOSITIONS WITHIN EACH GEOGRAPHICAL REGION

<i>Region</i>		<i>African American</i>	<i>Hispanic</i>	<i>Minority</i>	<i>Families Below Poverty</i>
Midwest	t_{23}	-8.319	-5.504	-7.258	-3.469
	p	<0.001	<0.001	<0.001 ²	0.002
Northeast	t_{25}	-8.161	-7.394	-8.696	-3.263
	p	<0.001	<0.001	<0.001	0.003
Southeast	t_{37}	-1.468	-4.722	-1.453	-1.687
	p	0.151	<0.001	0.155	0.100
	Z_{38}	-5.187	-5.066	-6.033	-4.315
	p	<0.001	<0.001	<0.001	<0.001
West	t_{15}	-6.289	-1.663	-3.899	-1.258
	p	<0.001	0.117	0.001	0.228

Each t_x represents the t-value of a paired t-test with x degrees of freedom.

Each Z_n represents the Z value of a one-sample Z-test with n cases.

Percentage data were arcsine-square-root transformed prior to statistical testing.

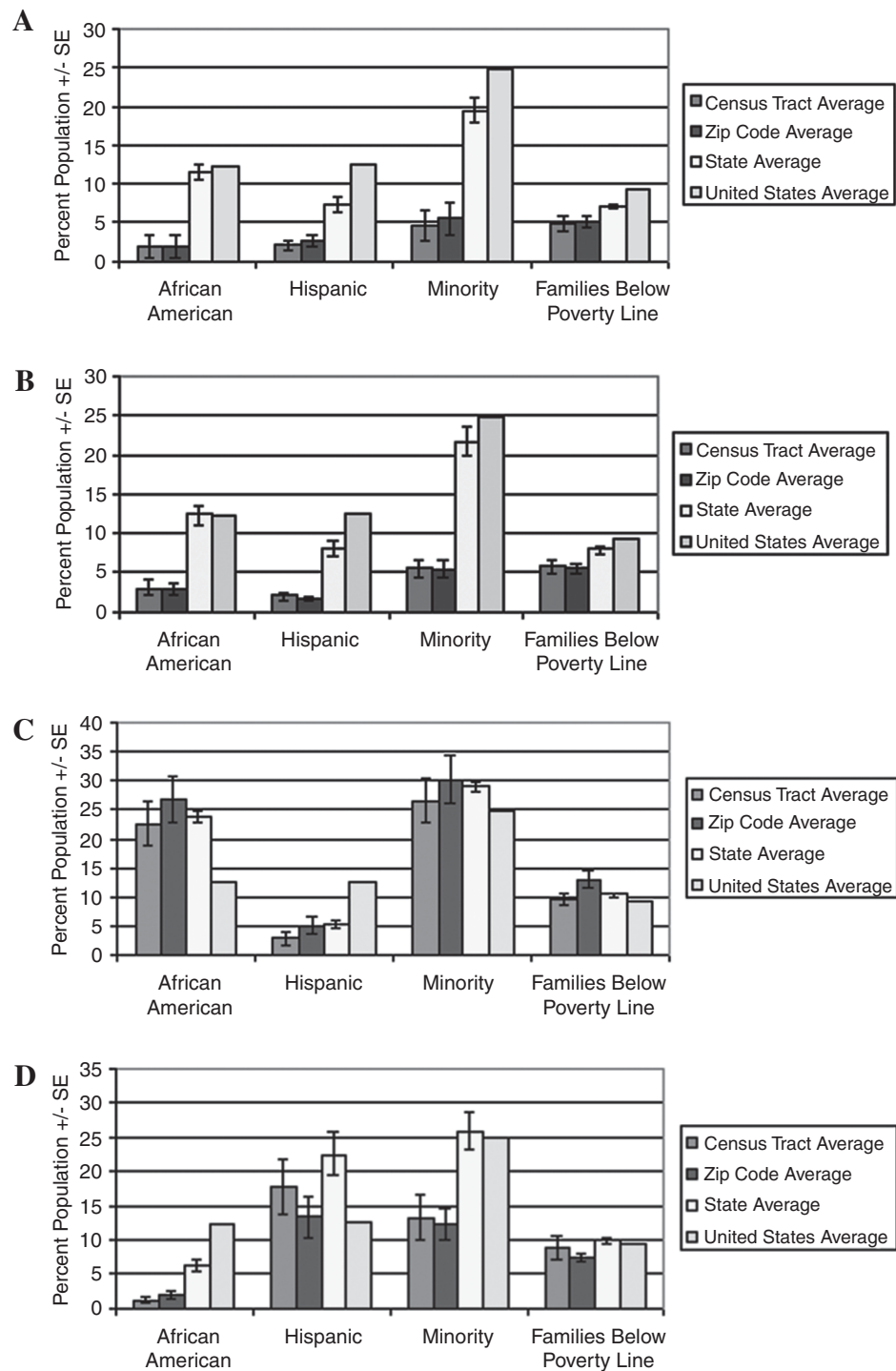


FIG. 1. Demographic data for zip codes and census tracts in which nuclear reactors are located, within each geographical region, compared to both state average demographics and national average demographics. **A.** Midwest communities. **B.** Northeast communities. **C.** Southeast communities. **D.** West communities. Error bars show standard error (SE).

siting-related EIJP, affecting poverty-level people in the Southeast ($p < 0.001$).

These EIJP findings are interesting, given much higher-than-expected numbers of commercial reactors, and a disproportionately higher percentage of both African-American

and poverty-level populations, in the southeastern US than in other regions of the country.³⁸ These considerations suggest that future studies may need to consider both possible commercial-reactor-related, regional (southeastern) EIJP affecting African-American and poverty-level popula-

tions and EIJ that may have occurred at the time of reactor siting, as revealed in year-1960, -1970, -1980, and -1990 census data.

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